

CHOICE BASED CREDIT SYSTEM

Syllabus

For

B.Sc. BOTANY HONOURS



**DEPARTMENT OF BOTANY
GAUHATI UNIVERSITY
GUWAHATI-781014**

Effective from Academic Session 2019-2020

Preamble

Today plant science is a fusion of the traditional components with the modern aspects of biochemistry, molecular biology and biotechnology. Over the years, plant science (Botany) has shown enormous gain in information and applications owing to tremendous inputs from research in all its aspects. With global recognition of the need for conservation, field plant biologists have contributed significantly in assessing plant diversity. Taxonomists have explored newer dimensions for the classification of plants. New insights have been gained in functional and structural aspects of plant development by utilizing novel tools and techniques for botanical research. Challenging areas of teaching and research have emerged in ecology and reproductive biology. Concern for ever increasing pollution and climate change is at its highest than ever before. Keeping these advancements in view, a revision of the curriculum at the undergraduate level is perfectly timed as sought by UGC from the beginning of 2019 session, the Botany students of Gauhati Universities shall have the benefit of a balanced, carefully-crafted course structure taking care of different aspects of plant science, namely plant diversity, physiology, genetics, biochemistry, molecular biology, reproduction, anatomy, taxonomy, ecology, economic botany and the impact of environment on the growth and development of plants. All these aspects have been given due weightage over the six semesters. Keeping the employment entrepreneurship in mind, applied courses have also been introduced. These courses shall provide the botany students hands on experience and professional inputs. On the whole, the curriculum is a source of lot of information and is supported by rich resource materials. It is hoped that a student graduating in Botany with the new curriculum will be a complete botanist at Honours level.

Students should opt for atleast 1 or 2 Generic Electives from other life sciences like Zoology/Microbiology/Biotechnology / Biochemistry and Chemistry. They should, however, opt atleast one generic elective from Chemistry Course besides life Sciences.

Scheme for Choice Based Credit System in B. Sc. Botany Honours

Semester		CORE COURSE(14)	Ability Enhancement Compulsory Course(AEC)(2)	Skill Enhancement Course (SEC) (2)	Discipline Specific Elective (DSE) (4)	Generic Elective: (GE) (4)
I	Core Course I	Phycology and Microbiology	English Communication			GE-1
	Core Course II	Biomolecules and Cell Biology				
II	Core Course III	Mycology and Phytopathology	Environmental Studies			GE-2
	Core Course IV	Archegoniate				
III	Core Course V	Morphology and Anatomy of Angiosperm		SEC -1		GE-3
	Core Course VI	Economic Botany				
	Core Course VII	Genetics				
IV	Core Course VIII	Molecular Biology		SEC -2		GE-4
	Core Course IX	Plant Ecology and Phytogeography				
	Core Course X	Plant Systematics				
V	Core Course XI	Reproductive Biology of Angiosperms			DSE-1	
	Core Course XII	Plant Physiology			DSE-2	
VI	Core Course XIII	Plant Metabolism			DSE -3	
	Core Course XIV	Plant Biotechnology			DSE-4	

Course Structure for CBCS in B. Sc. Botany Hounours as per requirement of UGC

SEMESTER	COURSE OPTED	COURSE NAME	Credits
I	ENG-AE-1014	English communications	4
	BOT-HC-1016	Phycology and Microbiology	4
	BOT-HC-1016 (Practical)	Phycology and Microbiology	2
	BOT-HC-1026	Biomolecules and Cell Biology	4
	BOT-HC-1026 (Practical)	Biomolecules and Cell Biology- Practical	2
II	ENV-AE-2014	Environmental Studies	4
	BOT-HC-2016	Mycology and Phytopathology	4
	BOT-HC-2016 (Practical)	Mycology and Phytopathology- Practical	2
	BOT-HC-2026	Archegoniate	4
	BOT-HC-2026 (Practical)	Archegoniate- Practical	2
III	BOT-HC-3016	Morphology Anatomy and of Angiosperm	4
	BOT-HC-3016 (Practical)	Morphology Anatomy and of Angiosperm –Practical	2
	BOT-HC-3026	Economic Botany	4
	BOT-HC-3026 (Practical)	Economic Botany-Practical	2
	BOT-HC-3036	Genetics	4
	BOT-HC-3036 (Practical)	Genetics- Practical	2
	1. BOT-SE-3014 2. BOT-SE-3024	SEC-1 (any one) 1. Biofertilizers 2. Herbal Technology	4

IV	BOT-HC-4016	Molecular Biology	4
	BOT-HC-4016 (Practical)	Molecular Biology- Practical	2
	BOT-HC-4026	Plant Ecology and Phytogeography	4
	BOT-HC-4026 (Practical)	Plant Ecology and Phytogeography – Practical	2
	BOT-HC-4036	Plant Systematics	4
	BOT-HC-4036 (Practical)	Plant Systematics Practical	2
	1. BOT-SE-4014 2. BOT-SE-4024 3. BOT-SE-4034	SEC-II (any one) 1. Nursery and Gardening 2. Floriculture 3. Intellectual Property Rights	4
V	BOT-HC-5016	Reproductive Biology of Angiosperms	4
	BOT-HC-5016 (Practical)	Reproductive Biology of Angiosperm – Practical	2
	BOT-HC-5026	Plant Physiology	4
	BOT-HC-5026 (Practical)	Plant Physiology- Practical	2
	BOT-HE-5016	DSE-1 Natural Resource Management	4
	BOT-HE-5016 (Practical)	DSE-1 Practical Natural Resource Management – Practical	2
	BOT-HE-5026	DSE-2 Horticultural Practices and Post-Harvest Technology	4
	BOT-HE-5026 (Practical)	DSE-2 Practical Horticultural Practices and Post-Harvest Technology-Practical	2

VI	BOT-HC-6016	Plant Metabolism	4	
	BOT-HC-6016 (Practical)	Plant Metabolism- Practical	2	
	BOT-HC-6026	Plant Biotechnology	4	
	BOT-HC-6026 (Practical)	Plant Biotechnology- Practical	2	
	BOT-HE-6016	DSE-3 Industrial and Environmental Microbiology	4	
	BOT-HE-6016 (Practical)	DSE-3 Industrial and Environmental Microbiology-Practical	2	
	Discipline Centric Elective-4 (Theory & practical / Project Work)	Either 1 or 2 below		
	1.BOT-HE-6026	DSE-4 1.Analytical Techniques in Plant Sciences	4	6
	1.BOT-HE-6026 (Practical)	DSE-4 1.Analytical Techniques in Plant Sciences-Practical	2	
	2.BOT-HE-6036	DSE-4 2. Project Work/ Dissertation	6	
Total Credits in B. Sc. Botany Honours: 116				

List of Papers

B. Sc Honours Botany Under CBCS

Core Papers

1	BOT-HC-1016	: Phycology and Microbiology
2	BOT-HC-1026	: Biomolecules and Cell Biology
3	BOT-HC-2016	: Mycology and Phytopathology
4	BOT-HC-2026	: Archegoniate
5	BOT-HC-3016	: Morphology and Anatomy of Angiosperm
6	BOT-HC-3026	: Economic Botany
7	BOT-HC-3036	: Genetics
8	BOT-HC-4016	: Molecular Biology
9	BOT-HC-4026	: Plant Ecology and Phytogeography
10	BOT-HC-4036	: Plant Systematics
11	BOT-HC-5016	: Reproductive Biology of Angiosperms
12	BOT-HC-5026	: Plant Physiology
13	BOT-HC-6016	: Plant Metabolism
14	BOT-HC-6026	: Plant Biotechnology

Discipline Specific Elective (DSE) Papers

1	BOT-HE-5016	: Natural Resource Management
2	BOT-HE-5026	: Horticultural Practices and Post-Harvest Technology
3	BOT-HE-6016	: Industrial and Environmental Microbiology
4	BOT-HE-6026	: Analytical Techniques in Plant Sciences
5	BOT-HE-6036	: Project work/Dissertation

Generic Elective (GE)

1	BOT-HG-1016	: Biodiversity (Microbes, Algae, Fungi and Archegoniate)
2	BOT-HG-2016	: Plant Ecology and Taxonomy
3	BOT-HG-3016	: Plant Physiology and Metabolism
4	BOT-HG-3026	: Environmental Biotechnology
5	BOT-HG-4016	: Plant Anatomy and Embryology
6	BOT-HG-4026	: Economic Botany and Plant Biotechnology

Ability Enhancement Course Compulsory

- 1 ENG-AE-1014 : English/MIL communication
- 2 ENV-AE-2014: Environmental Studies

Skill Enhancement Paper

- 1 BOT-SE-3014 : Biofertilizers (SEC-I)
- 2 BOT-SE-3024 : Herbal Technology (SEC-I)
- 3 BOT-SE-4014 : Nursery and Gardening (SEC-II)
- 4 BOT-SE-4024 : Floriculture (SEC-II)
- 5 BOT-SE-4034 : Intellectual Property Rights (SEC-II)

Core Courses

1

BOT-HC-1016

Phycology and Microbiology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

1.1 THEORY

Unit 1 : *Introduction to microbial world*

(10 lectures)

Scope of microbes in industry and environment; Microbial nutrition, growth and metabolism [Only an overview of microbial metabolism- the concept of anabolism (Biosynthesis) and catabolism (ATP-generating Pathways-Respiration and Fermentation)].

Unit 2 : *Viruses*

(7 lectures)

Discovery, physiochemical and biological characteristics; classification (Baltimore), general structure with special reference to viroids and prions; replication (general account), DNA virus (T-phage), lytic and lysogenic cycle; RNA virus (TMV). Economic importance of viruses with reference to vaccine production, role in research, medicine and diagnostics, as causal organisms of plant diseases.

Unit 3 : *Bacteria*

(7 lectures)

Discovery, general characteristics; Types-archaeobacteria, eubacteria, actinomycetes, mycoplasma, rickettsia, chlamydiae and sphaeroplasts); Cell structure; Nutritional types; Reproduction-vegetative, asexual and recombination (conjugation, transformation and transduction). Economic importance of bacteria with reference to their role in agriculture and industry (Alcohol and Antibiotic production).

Unit 4 : Algae**(10 lectures)**

General characteristics; Ecology and distribution; range of thallus organization; Cell structure and components; cell wall, pigment system, reserve food (of only groups represented in the syllabus), flagella; methods of reproduction; Classification; Evolutionary significance of *Prochloron*; criteria, system of Fritsch, and evolutionary classification of Lee (only upto groups); Role of algae in the environment, agriculture, biotechnology and industry, Economic importance of Diatoms.

Unit 5 : Cyanophyta and Xanthophyta**(8 lectures)**

Ecology and occurrence; Range of thallus organization; Cell structure; Reproduction, Morphology and life-cycle of *Nostoc* and *Vaucheria*.

Unit 6 : Chlorophyta, Charophyta and Bacillariophyta**(10 lectures)**

General characteristics; Occurrence; Range of thallus organization; Cell structure; Reproduction. Morphology and life-cycles of *Volvox*, *Oedogonium*, *Coleochaete*, *Chara*. General Account of Bacillariophyta.

Unit 7 : Phaeophyta and Rhodophyta**(8 lectures)**

Characteristics; Occurrence; Range of thallus organization; Cell structure; Reproduction. Morphology and life-cycles of *Ectocarpus*, *Fucus* and *Polysiphonia*.

1.2 PRACTICAL

Microbiology

1. Electron micrographs/Models of viruses – T-Phage and TMV/ Line drawings/ Photographs of Lytic and Lysogenic Cycle.
2. Types of Bacteria to be observed from temporary/permanent slides/photographs. Electron micrographs of bacteria, binary fission, endospore, conjugation, root Nodule.
3. Gram staining.

4. Isolation of soil microflora.
5. Endospore staining with malachite green using the (endospores taken from soil bacteria).

Phycology

1. Study of vegetative and reproductive structures of *Nostoc*, *Volvox*, *Oedogonium*, *Chara*, *Vaucheria*, *Ectocarpus*, *Fucus* and *Polysiphonia*, *Prochloron* through electron micrographs, permanent slides.

Suggested Readings

1. Lee, R.E. (2008). Phycology, Cambridge University Press, Cambridge. 4th edition.
2. Wiley JM, Sherwood LM and Woolverton CJ. (2013) Prescott's Microbiology. 9th Edition. McGraw Hill International.
3. Kumar, H.D. (1999). Introductory Phycology. Affiliated East-West Press, Delhi.
4. Sahoo, D. (2000). Farming the ocean: seaweeds cultivation and utilization. Aravali International, New Delhi.
5. Campbell, N.A., Reece J.B., Urry L.A., Cain M.L., Wasserman S.A. Minorsky P.V., Jackson R.B. (2008). Biology, Pearson Benjamin Cummings, USA. 8th edition.
6. Pelczar, M.J. (2001). Microbiology, 5th edition, Tata McGraw-Hill Co, New Delhi.
7. Sharma, P.D. (2009). Microbiology, latest edition, Rastogi Publication, Meerut.

2

BOT-HC-1026 Biomolecules and Cell Biology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

2.1 THEORY

Unit 1 : Biomolecules (20 lectures)

Types and significance of chemical bonds; Structure and properties of water; pH and buffers.

Carbohydrates : Nomenclature and classification; Monosaccharides; Disaccharides; Oligosaccharides and polysaccharides.

Lipids : Definition and major classes of storage and structural lipids; Fatty acids structure and functions; Essential fatty acids; Triacyl glycerols structure, functions and properties; Phosphoglycerides.

Proteins : Structure of amino acids; Levels of protein structure-primary, secondary, tertiary and quaternary; Protein denaturation and biological roles of proteins.

Nucleic acids : Structure of nitrogenous bases; Structure and function of nucleotides; Types of nucleic acids; Structure of A, B, C, D, Z types of DNA; Types of RNA.

Unit 2 : Bioenergetics (4 lectures)

Laws of thermodynamics, concept of free energy, endergonic and exergonic reactions, coupled reactions, redox reactions. ATP: structure, its role as an energy currency molecule.

Unit 3 : Enzymes (6 lectures)

Structure of enzyme: holoenzyme, apoenzyme, cofactors, coenzymes and prosthetic group; Classification of enzymes; Features of active site, substrate specificity, mechanism of action (activation energy, lock and key hypothesis, induced-fit theory), Michaelis – Menten equation, enzyme inhibition and factors affecting enzyme activity.

Unit 4 : *The cell*

(4 lectures)

Cell as a unit of structure and function; Characteristics of prokaryotic and eukaryotic cells; Origin of eukaryotic cell (Endosymbiotic theory).

Unit 5 : *Cell wall and plasma membrane*

(4 lectures)

Chemistry, structure and function of Plant cell wall. Overview of membrane function; fluid mosaic model; Chemical composition of membranes; Membrane transport – Passive, active and facilitated transport, endocytosis and exocytosis.

Unit 6 : *Cell organelles*

(16 lectures)

Nucleus: Structure-nuclear envelope, nuclear pore complex, nuclear lamina, molecular organization of chromatin; nucleolus.

Cytoskeleton: Role and structure of microtubules, microfilaments and intermediary filament.

Chloroplast, mitochondria and peroxisomes: Structural organization; Function; Semiautonomous nature of mitochondria and chloroplast.

Endomembrane system: Endoplasmic Reticulum – Structure, targeting and insertion of proteins in the ER, protein folding, processing; Smooth ER and lipid synthesis, export of proteins and lipids; Golgi Apparatus – organization, protein glycosylation, protein sorting and export from Golgi Apparatus; Lysosomes

Unit 7 : *Cell division*

(6 lectures)

Phases of eukaryotic cell cycle, mitosis and meiosis; Regulation of cell cycle-checkpoints, role of protein kinases.

2.2 PRACTICAL

1. Qualitative tests for carbohydrates, reducing sugars, non-reducing sugars, lipids and proteins.
2. Study of plant cell structure with the help of epidermal peel mount of Onion/*Rhoeo*/*Crinum*.
3. Demonstration of the phenomenon of protoplasmic streaming in *Hydrilla* and *Vallisneria* leaf.
4. Counting the cells per unit volume with the help of haemocytometer. (Yeast/pollen grains).
5. Cytochemical staining of : DNA- Feulgen and cell wall in the epidermal peel of onion using Periodic Schiff's (PAS) staining technique.
6. Study the phenomenon of plasmolysis and deplasmolysis.
7. Study different stages of mitosis and meiosis (Demonstration).

Suggested Readings

1. Campbell, MK (2012) Biochemistry, 7th ed., Published by Cengage Learning
2. Campbell, PN and Smith AD (2011) Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone
3. Tymoczko JL, Berg JM and Stryer L (2012) Biochemistry: A short course, 2nd ed., W.H.Freeman
4. Berg JM, Tymoczko JL and Stryer L (2011) Biochemistry, W.H.Freeman and Company
5. Nelson DL and Cox MM (2008) Lehninger Principles of Biochemistry, 5th Edition., W.H. Freeman and Company.
6. Karp, G. (2010). Cell Biology, John Wiley & Sons, U.S.A. 6th edition.
7. Hardin, J., Becker, G., Skliensmith, L.J. (2012). Becker's World of the Cell, Pearson Education Inc. U.S.A. 8th edition.
8. Cooper, G.M. and Hausman, R.E. (2009) The Cell: A Molecular Approach. 5th edition. ASM Press & Sunderland, Washington, D.C.; Sinauer Associates, MA.
9. Becker, W.M., Kleinsmith, L.J., Hardin. J. and Bertoni, G. P. (2009) The World of the Cell. 7th edition. Pearson Benjamin Cummings Publishing, San Francisco

3

BOT-HC-2016 Mycology and Phytopathology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

3.1 THEORY

Unit 1 : *Introduction to Fungi* (10 lectures)

General characteristics; Status of Fungi in living system; Thallus organization, modification of hyphae; Cell and Cell wall composition; Nutrition, flagella, septum, homothallism and heterothallism, cell division.

History of Classification (Hidetta *et al.* 2007); Classification of Fungi (Ainsworth, 1973, Webster 1977) up to sub-division with diagnostic characters and examples.

General characteristics of Myxomycota, Oomycota, Zygomycota, Ascomycota, Basidiomycota and Deuteromycota.

Unit 2 : *Mastigomycotina (Chytridiomycetes and Oomycetes)* (6 lecture)

Characteristic features; Reproduction; Life cycle with reference to *Synchytrium*, *Phytophthora* and *Albugo*.

Unit 3 : *Zygomycotina* (2 lecture)

Characteristic features; Reproduction; Life cycle with reference to *Rhizopus*.

Unit 4 : *Ascomycotina* (10 lectures)

General characteristics (asexual and sexual fruiting bodies); Life cycle, Heterokaryosis and parasexuality; Life cycle and classification with reference to *Saccharomyces*, *Aspergillus*, *Penicillium*, *Neurospora* and *Peziza*.

Unit 5 : Basidiomycotina (8 lectures)

General characteristics; Life cycle and Classification with reference to black stem rust on wheat *Puccinia* (Physiological Specialization), loose and covered smut (symptoms only), *Agaricus*; Bioluminescence, Fairy Rings and Mushroom Cultivation.

Unit 6 : Deuteromycotina (Fungi Imperfecti) (3 lectures)

General characteristics; Thallus organization; Reproduction; Classification with special reference to *Alternaria* and *Colletotrichum*.

Unit 7 : Allied Fungi- Myxomycota (3 lectures)

General characteristics; Status of Slime molds, Classification; Occurrence; Types of plasmodia; Types of fruiting bodies.

Unit 8 : Symbiotic associations (3 lectures)

Lichen – Occurrence; General characteristics; Range of thallus organization; Internal structure and nature of associations of algal and fungal partners; Reproduction.

Mycorrhiza- Ectomycorrhiza, Endomycorrhiza and their significance.

Unit 9 : Applied Mycology (5 Lectures)

Role of fungi in biotechnology; food industry (Flavour & texture, Fermentation, Baking, Organic acids, Enzymes, Mycoproteins); Pharmaceutical (Secondary metabolites); Agriculture (Biofertilizers); Mycotoxins; Biological control (Mycofungicides, Mycoherbicides, Mycoinsecticides, Myconematicides); Medical mycology.

Unit 10 : Phytopathology (10 lectures)

Terms and concepts; General symptoms; Geographical distribution of diseases; Etiology; Symptomology; Host-Pathogen relationships; Disease cycle and environmental relation; prevention and control of plant diseases, and role of quarantine.

Bacterial diseases – Citrus canker and angular leaf spot of cotton. Viral diseases – Tobacco Mosaic viruses, vein clearing. Fungal diseases – Early blight of potato, Black stem rust of wheat, White rust of crucifers.

3.2 PRACTICAL

1. *Rhizopus*: study of asexual stage from temporary mounts and sexual structures through permanent slides.
2. *Aspergillus* and *Penicillium*: study of asexual stage from temporary mounts. Study of

- Sexual stage from permanent slides/photographs.
3. *Peziza*: sectioning through ascocarp.
 4. *Alternaria*: Specimens/photographs and temporary mounts.
 5. *Puccinia*: Herbarium specimens of Black Stem Rust of Wheat and infected Barberry leaves; sections/ mounts of spores on wheat and permanent slides of both the hosts.
 6. *Agaricus*: Specimens of button stage and full grown mushroom; sectioning of gills of *Agaricus*, fairy rings and bioluminescent mushrooms to be shown.
 7. Study of phaneroplasmodium from actual specimens and /or photograph. Study of *Stemonitis* sporangia.
 8. *Albugo*: Study of symptoms of plants infected with *Albugo*; asexual phase study through section/ temporary mounts and sexual structures through permanent slides.
 9. Lichens: Study of growth forms of lichens (crustose, foliose and fruticose) on different substrates. Study of thallus and reproductive structures (soredia and apothecium) through permanent slides. Mycorrhizae: ectomycorrhiza and endomycorrhiza (Photographs)
 10. Phytopathology: Bottle specimens, Herbarium specimens should be made of bacterial diseases, Viral diseases, Fungal diseases (Locally available).
 11. Applied mycology: Photographs of Mycorrhizae, Fungi used in medicine (Cylindriocarpon, Tolyposporium, Ganoderma, Cephalosporium – any one), fungi used as biological control agents (fungi used in control of seedling, soil borne, post-harvest diseases and in control of nematodes, insects and weeds – any one), photographs/mounts of spores of fungi causing human infections (*Aspergillus*, *Candida*, *Cryptococcus*, *Histoplasma*, *Microsporium*, *Trichophyton* – any one).

Suggested Readings

1. Agrios, G.N. (1997) Plant Pathology, 4th edition, Academic Press, U.K.
2. Alexopoulos, C.J., Mims, C.W., Blackwell, M. (1996). Introductory Mycology, John Wiley & Sons (Asia) Singapore. 4th edition.
3. Webster, J. and Weber, R. (2007). Introduction to Fungi, Cambridge University Press, Cambridge. 3rd edition.
4. Sethi, I.K. and Walia, S.K. (2011). Text book of Fungi and Their Allies, Macmillan Publishers India Ltd.
5. Sharma, P.D. (2011). Plant Pathology, Rastogi Publication, Meerut, India.
6. College Botany, Vol. II. – Gangulee and Kar, New Central Book Agency, Kolkata.
7. Studies in Botany, Vol. I. – Mitra, Mitra, Choudhury. Moulik Library, Kolkata.
8. Text Book of Botany, Vol. I & II. – Hait, Ghosh and Bhattacharya, New Central Book Agency, Kolkata.

4

BOT-HC-2026

Archegoniate

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

4.1 THEORY

Unit 1: *Introduction* (4 lectures)

Unifying features of archegoniates; Transition to land habit; Alternation of generations.

Unit 2: *Bryophytes* (6 lectures)

General characteristics; Adaptations to land habit; Classification; Range of thallus organization.

Unit 3: *Type Studies- Bryophytes* (12 lectures)

Classification, morphology, anatomy and reproduction of *Riccia*, *Marchantia*, *Anthoceros*, *Sphagnum* and *Polytrichum*; Reproduction and evolutionary trends in *Riccia*, *Marchantia*, *Anthoceros*, *Sphagnum* and *Polytrichum*. Ecological and economic importance of bryophytes.

Unit 4: *Pteridophytes* (6 lectures)

General characteristics; Classification; Early land plants (*Cooksonia* and *Rhynia*).

Unit 5: *Type Studies- Pteridophytes* (14 lectures)

Classification, morphology, anatomy and reproduction of *Psilotum*, *Lycopodium*, *Selaginella*, *Equisetum*, *Pteris* and *Marsilea*. Apogamy and apospory, heterospory and seed habit, telome theory, stelar evolution; Ecological and economic importance.

Unit 6: *Gymnosperms*

(18 lectures)

General characteristics, classification (up to family), morphology, anatomy and reproduction of *Cycas*, *Pinus*, *Ginkgo* and *Gnetum*; Ecological and economic importance.

4.2 PRACTICAL

1. **Riccia** – Morphology of thallus.
2. **Marchantia**- Morphology of thallus and reproductive parts; vertical and transverse section of thallus; vertical section of Gemma cup, Antheridiophore and Archegoniophore. **Sphagnum**- Morphology of plant, whole mount of leaf.
3. **Sphagnum**- Morphology of plant; whole mount of leaf.
4. **Polytrichum**- Morphology of vegetative and reproductive parts; Transverse Section of rhizome, whole mount of leaf; Longitudinal Section through antheridial and archegonial heads; L.S. of capsule.
5. **Lycopodium**- Morphology of plant, whole mount of leaf; transverse section of stem; Longitudinal Section of strobilus; morphology of sporophyll.
6. **Selaginella**- Morphology of plant, whole mount of leaf with ligule, transverse section of stem and rhizophore; longitudinal section of strobilus; morphology of sporophyll.
7. **Equisetum**- Morphology of plant, transverse section of internode, longitudinal and transverse section of strobilus, whole mount of sporangiophore and spore.
8. **Pteris**- Morphology of plant, transverse section of rachis, vertical section of leaflets through sorus; whole mount of prothallus with sex (permanent slide).
9. **Marsilea**- Morphology of plant, transverse section of rhizome and petiole; vertical transverse and vertical longitudinal section of sporocarp.
10. **Cycas**- Morphology of plant; morphology and transverse section of coralloid roots; transverse section of leaflets; Longitudinal Section of male and female cone; morphology of microsporophyll and megasporophyll; Longitudinal section of ovule (permanent slide).
11. **Pinus**- Morphology of plant; transverse section of Needle; longitudinal section of male cone and female cone; whole mount of Microspores.
12. **Ginkgo**- Morphology of plants and reproductive structures (only photographs).
13. **Gnetum**- Morphology of plant; Morphology of male and female strobilus; vertical section of ovule (permanent slide).

Suggested Readings

1. Vashistha, P.C., Sinha, A.K., Kumar, A. (2010). Pteridophyta. S. Chand. Delhi, India.
2. Bhatnagar, S.P. & Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi, India.
3. Parihar, N.S. (1991). An introduction to Embryophyta: Vol. I. Bryophyta. Central Book Depot. Allahabad.
4. Raven, P.H., Johnson, G.B., Losos, J.B., Singer, S.R. (2005). Biology. Tata McGraw Hill, Delhi.
5. Vanderpoorten, A. & Goffinet, B. (2009) Introduction to Bryophytes. Cambridge University Press.
6. Vashistha, B. R., Sinha, A.K. and Kumar, A. (Latest edition). Botany for Degree Students: Bryophyta. S. Chand Publishing 7361, Ram Nagar, Qutab Road, New Delhi-110055.
7. Vashistha, B. R., Sinha, A.K. and Kumar, A. (Latest edition). Botany for Degree Students: Gymnosperm. S. Chand Publishing 7361, Ram Nagar, Qutab Road, New Delhi-110055.
8. Vashistha, B. R., Sinha, A.K. and Kumar, A. (Latest edition). Botany for Degree Students: Pteridophytes. S. Chand Publishing 7361, Ram Nagar, Qutab Road, New Delhi-110055.

5

BOT-HC-3016

Morphology and Anatomy of Angiosperms

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

5.1 THEORY

Unit 1: *Morphology* (4 Lectures)

Morphology of inflorescence, stamens and carpel, fruit; Telome theory, phyllode theory; Role of morphology in plant classification.

Unit 2: *Introduction and scope of plant Anatomy* (4 Lectures)

Application in systematics, forensics and pharmacognosy.

Unit 3: *Structure and Development of Plant Body* (6 Lectures)

Internal organization of plant body: The three tissue systems, types of cells and tissues. Development of plant body: Polarity, Cytodifferentiation and organogenesis during embryogenic development.

Unit 4: *Tissues* (11 Lectures)

Classification of tissues; Simple and complex tissues (no phylogeny); cytodifferentiation of tracheary elements and sieve elements; Pits and plasmodesmata; Wall ingrowths and transfer cells, adcrustation and incrustation, Ergastic substances. Hydathodes, cavities, lithocysts and laticifers.

Unit 5: Apical meristems**(14 Lectures)**

Evolution of concept of organization of shoot apex (Apical cell theory, Histogen theory, Tunica Corpus theory, continuing meristematic residue, cytohistological zonation); Types of vascular bundles; Structure of dicot and monocot stem. Origin, development, arrangement and diversity in size and shape of leaves; Structure of dicot and monocot leaf, Kranz anatomy. Organization of root apex (Apical cell theory, Histogen theory, Korper-Kappe theory); Quiescent centre; Root cap; Structure of dicot and monocot root; Endodermis, exodermis and origin of lateral root.

Unit 6: Vascular Cambium and Wood**(14 Lectures)**

Structure, function and seasonal activity of cambium; Secondary growth in root and stem. Axially and radially oriented elements; Types of rays and axial parenchyma; Cyclic aspects and reaction wood; Sapwood and heartwood; Ring and diffuse porous wood; Early and late wood, tyloses; Dendrochronology. Development and composition of periderm, rhytidome and lenticels.

Unit 7: Adaptive and Protective Systems**(7 Lectures)**

Epidermal tissue system, cuticle, epicuticular waxes, trichomes(uni- and multicellular, glandular and nonglandular, two examples of each), stomata (classification); Adcrustation and incrustation; Anatomical adaptations of xerophytes and hydrophytes.

5.2 PRACTICAL

1. Study of special types of inflorescence – Cyathium, Hypanthodium, Verticillaster, Hypanthium.
2. Study of special types of fruits- Superior fruits (*Dillenia*); Aggregate fruits (Custard apple, *Michelia*, Periwinkles, *Polyalthia*); Multiple fruits (Pine apple, Jack fruits).
3. Study of anatomical details through permanent slides/temporary stain mounts / macerations / museum specimens with the help of suitable examples.
4. Apical meristem of root, shoot and vascular cambium.
5. Epidermal system: cell types, stomata types; trichomes: non-glandular and glandular.
6. Root: monocot, dicot, secondary growth.
7. Stem: monocot, dicot - primary and secondary growth; periderm; lenticels.
8. Leaf: isobilateral, dorsiventral, C4 leaves (Kranz anatomy).
9. Adaptive Anatomy: xerophytes, hydrophytes.
10. Secretory tissues: cavities, lithocysts and laticifers.

Suggested Readings

1. Dickison, W.C. (2000). Integrative Plant Anatomy. Harcourt Academic Press, USA.
2. Fahn, A. (1974). Plant Anatomy. Pergmon Press, USA.
3. Mauseth, J.D. (1988). Plant Anatomy. The Benjammin/Cummings Publisher, USA.
4. Evert, R.F. (2006) Esau's Plant Anatomy: Meristems, Cells, and Tissues of the Plant Body: Their Structure, Function and Development. John Wiley and Sons, Inc.

6

BOT-HC-3026 Economic Botany

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

6.1 THEORY

Unit 1: *Origin of Cultivated Plants* (6 lectures)

Centres of Origin, their importance with reference to Vavilov's work. Introductions, domestication and loss of crop genetic diversity; evolution of new crops/varieties, importance of germplasm diversity.

Unit 2: *Cereals* (6 lectures)

Wheat and Rice (origin, morphology, processing & uses); Brief account of millets.

Unit 3: *Legumes* (6 lectures)

Origin, morphology and uses of Chick pea, Pigeon pea and fodder legumes. Importance to man and ecosystem.

Unit 4: *Sources of sugars and starches* (4 lectures)

Morphology and processing of sugarcane, products and by-products of sugarcane industry. Potato – morphology, propagation & uses.

Unit 5: *Spices* (6 lectures)

Listing of important spices, their family and part used. Economic importance with special reference to fennel, saffron, clove and black pepper.

Unit 6: Beverages (4 lectures)

Tea, Coffee (morphology, processing & uses).

Unit 7: Sources of oils and fats (10 lectures)

General description, classification, extraction, their uses and health implications groundnut, coconut, linseed, soybean, mustard and coconut (Botanical name, family & uses). Essential Oils: General account, extraction methods, comparison with fatty oils & their uses.

Unit 8: Natural Rubber (3 lectures)

Para-rubber: tapping, processing and uses.

Unit 9: Drug-yielding plants (8 lectures)

Therapeutic and habit-forming drugs with special reference to *Cinchona*, *Digitalis*, *Papaver* and *Cannabis*; Tobacco (Morphology, processing, uses and health hazards).

Unit 10: Timber plants (3 Lectures)

General account with special reference to teak and pine.

Unit 11: Fibers (4 lectures)

Classification based on the origin of fibers; Cotton, Coir and Jute (morphology, extraction and uses).

6.2 PRACTICAL

1. **Cereals:** Study of useful parts: Rice/Bean (habit sketch, study of paddy and grain, starch grain, micro-chemical test).
2. **Legumes:** Bean, Groundnut, (habit, fruit, seed structure, micro-chemical tests).
3. **Beverages:** Tea (plant specimen, tea leaves), Coffee (plant specimen, beans).
4. **Sources of oils and fats:** Coconut and Mustard.
5. **Rubber:** Specimen, photograph/model of tapping, samples of rubber products.
6. **Test for alkaloids:** Neem, *Vinca rosea*.
7. **Fiber-yielding plants:** Cotton (specimen, whole mount of seed to show lint and fuzz; whole mount of fiber and test for cellulose), Jute (specimen, transverse section of stem, test for lignin).

Suggested Readings

1. Kochhar, S.L. (2012). *Economic Botany in Tropics*, MacMillan & Co. New Delhi, India.
2. Wickens, G.E. (2001). *Economic Botany: Principles & Practices*. Kluwer Academic Publishers, The Netherlands.
3. Chrispeels, M.J. and Sadava, D.E. 1994 *Plants, Genes and Agriculture*. Jones & Bartlett Publishers.

7

BOT-HC-3036

Genetics

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

7.1 THEORY

Unit 1: Mendelian genetics and its extension (16 lectures)

Mendelism: History; Principles of inheritance; Chromosome theory of inheritance; Autosomes and sex chromosomes; Probability and pedigree analysis; Incomplete dominance and codominance; Multiple alleles, Lethal alleles, Epistasis, Pleiotropy, Recessive and Dominant traits, Penetrance and Expressivity, Numericals; Polygenic inheritance.

Unit 2: Extrachromosomal Inheritance (7 lectures)

Chloroplast inheritance: Variegation in Four o'clock plant; Mitochondrial inheritance in yeast; Maternal effects-shell coiling in snail; Kappa particles in *Paramecium*.

Unit 3: Linkage, crossing over and chromosome mapping (12 lectures)

Linkage and crossing over-Cytological basis of crossing over; Recombination frequency, two factor and three factor crosses; Interference and coincidence; Numericals based on gene mapping; Sex Linkage.

Unit 4: Variation in chromosome number and structure (8 lectures)

Deletion, Duplication, Inversion, Translocation, Position effect, Euploidy and Aneuploidy

Unit 5: Gene mutations (7 lectures)

Types of mutations; Molecular basis of Mutations; Mutagens – physical and chemical (Base analogs, deaminating, alkylating and intercalating agents); Detection of mutations: CIB method. Role of Transposons in mutation. DNA repair mechanisms.

Unit 6: *Fine structure of gene*

(4 lectures)

Classical vs molecular concepts of gene; Ciston, Racon, Muton, rII locus

Unit 7. *Population and Evolutionary Genetics*

(6 lectures)

Allele frequencies, Genotype frequencies, Hardy-Weinberg Law, role of natural selection, mutation, genetic drift. Genetic variation and Speciation.

7.2 PRACTICAL

1. Meiosis through temporary squash preparation.
2. Mendel's laws through seed ratios.
3. Chromosome mapping using point test cross data.
4. Incomplete dominance and gene interaction through seed ratios (9:7, 9:6:1, 13:3, 15:1, 12:3:1, 9:3:4).
5. Permanent Slides showing Translocation Ring, Photograph showing Laggards and Inversion Bridge.

Suggested Readings

1. Gardner, E.J., Simmons, M.J., Snustad, D.P. (1991). Principles of Genetics, John Wiley & sons, India. 8th edition.
2. Snustad, D.P. and Simmons, M.J. (2010). Principles of Genetics, John Wiley & Sons Inc., India. 5th edition.
3. Klug, W.S., Cummings, M.R., Spencer, C.A. (2009). Concepts of Genetics. Benjamin Cummings, U.S.A. 9th edition.
4. Griffiths, A.J.F., Wessler, S.R., Carroll, S.B., Doebley, J. (2010). Introduction to Genetic Analysis. W. H. Freeman and Co., U.S.A. 10th edition.

8

BOT-HC-4016 Molecular Biology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

8.1 THEORY

Unit 1: *Nucleic acids : Carriers of genetic information* (4 lectures)

Historical perspective; DNA as the carrier of genetic information (Griffith's, Hershey & Chase, Avery, McLeod & McCarty, Fraenkel-Conrat's experiment.

Unit 2: *The Structures of DNA and RNA / Genetic Material* (10 lectures)

DNA Structure: Miescher to Watson and Crick- historic perspective, DNA structure, Salient features of double helix, denaturation and renaturation, cot curves; Organization of DNA- Prokaryotes, Viruses, Eukaryotes. Organelle DNA -- mitochondria and chloroplast DNA. The Nucleosome Chromatin structure- Euchromatin, Heterochromatin- Constitutive and Facultative heterochromatin.

Unit 3: *The replication of DNA* (10 lectures)

Chemistry of DNA synthesis (Kornberg's discovery); General principles – bidirectional, semi-conservative and semi discontinuous replication, RNA priming; Various models of DNA replication, including rolling circle, θ (theta) mode of replication, replication of linear ds-DNA; Enzymes involved in DNA replication.

Unit 4: *Central dogma and genetic code* (2 lectures)

Key experiments establishing-The Central Dogma (Adaptor hypothesis and discovery of mRNA template), Genetic code (deciphering & salient features)

Unit 5: Transcription**(18 lectures)**

Transcription in prokaryotes and eukaryotes. Principles of transcriptional regulation; Prokaryotes: Regulation of lactose metabolism and tryptophan synthesis in *E.coli*. Eukaryotes: transcription factors, heat shock proteins, steroids and peptide hormones; Gene silencing.

Unit 6: Processing and modification of RNA**(8 lectures)**

Split genes-concept of introns and exons, removal of introns, spliceosome machinery, splicing pathways, group I and group II intron splicing, alternative splicing eukaryotic mRNA processing(5' cap, 3' poly A tail); Ribozymes; RNA editing and mRNA transport.

Unit 7: Translation**(8 lectures)**

Ribosome structure and assembly, mRNA; Charging of tRNA, aminoacyl tRNA synthetases; Various steps in protein synthesis, proteins involved in initiation, elongation and termination of polypeptides; Fidelity of translation; Inhibitors of protein synthesis; Post-translational modifications of proteins.

8.2 PRACTICAL

1. DNA isolation from any plant material.
2. DNA estimation by diphenylamine reagent/UV Spectrophotometry (Demonstration).
3. Study of DNA replication mechanisms through photographs (Rolling circle, Theta replication and semi-discontinuous replication).
4. Study of structures of prokaryotic RNA polymerase and eukaryotic RNA polymerase II through photographs.
5. Study of the following through photographs: Assembly of Spliceosome machinery; Splicing mechanism in group I & group II introns; Ribozyme and Alternative splicing.

Suggested Readings

1. Watson J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M., Losick, R. (2007). Molecular Biology of the Gene, Pearson Benjamin Cummings, CSHL Press, New York, U.S.A. 6th edition.
2. Snustad, D.P. and Simmons, M.J. (2010). Principles of Genetics. John Wiley and Sons Inc., U.S.A. 5th edition.
3. Klug, W.S., Cummings, M.R., Spencer, C.A. (2009). Concepts of Genetics. Benjamin Cummings. U.S.A. 9th edition.
4. Russell, P. J. (2010). i-Genetics- A Molecular Approach. Benjamin Cummings, U.S.A. 3rd edition.
5. Griffiths, A.J.F., Wessler, S.R., Carroll, S.B., Doebley, J. (2010). Introduction to Genetic Analysis. W. H. Freeman and Co., U.S.A. 10th edition.

9

BOT-HC-4026

Plant Ecology and Phytogeography

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

9.1 THEORY

Unit 1 : *Introduction* (4 lectures)

Basic concepts; Levels of organization. Inter-relationships between the living world and the environment, the components and dynamism, homeostasis.

Unit 2 : *Soil* (8 lectures)

Importance; Origin; Formation; Composition; Physical; Chemical and Biological components; Soil profile; Role of climate in soil development.

Unit 3 : *Water* (4 lectures)

Importance: States of water in the environment; Atmospheric moisture; Precipitation types (rain, fog, snow, hail, dew); Hydrological Cycle; Water in soil; Water table.

Unit 4 : *Adaptation of plants to various environmental factors* (6 lectures)

Light, temperature, wind and fire

Unit 5 : *Biotic interactions* (2 lectures)

Trophic organization, basic source of energy, autotrophy, heterotrophy; symbiosis, commensalism, parasitism; food chains and webs; ecological pyramids; biomass, standing crop.

Unit 6 : *Population ecology* (4 lectures)

Population characteristics, Growth curve, population regulation, r and k selection.
Ecological speciation: Allopatric/ Sympatric and Parapatric speciation.

Unit 7 : *Plant communities* (8 lectures)

Concept of ecological amplitude; Habitat and niche; Characters: analytical and synthetic;
Ecotone and edge effect; Dynamics: succession – processes, types; climax concepts.

Unit 8 : *Ecosystems* (4 lectures)

Structure; Processes; Trophic organisation; Food chains and Food webs; Ecological pyramids.

Unit 9 : *Functional aspects of ecosystem* (8 lectures)

Principles and models of energy flow; Production and productivity; Ecological efficiencies;
Biogeochemical cycles; Cycling of Carbon, Nitrogen and Phosphorus.

Unit 10 : *Phytogeography* (12 lectures)

Principles; Continental drift; Theory of tolerance; Endemism; Brief description of major terrestrial biomes (one each from tropical, temperate & tundra); Phytogeographical division of India; Vegetation types of NE India with special reference to Assam.

9.2 PRACTICAL

1. Study of instruments used to measure microclimatic variables: Soil thermometer, maximum and minimum thermometer, anemometer, psychrometer/hygrometer, rain gauge and lux meter.
2. Determination of pH of various soil and water samples using pH meter.
3. Analysis for carbonates, chlorides, nitrates, sulphates, organic matter and base deficiency from two soil samples by rapid field tests.
4. Determination of organic matter of different soil samples by Walkley & Black rapid titration method.
5. Determination of dissolved oxygen of water samples from polluted and unpolluted sources.
6. (a). Study of morphological adaptations of hydrophytes and xerophytes (four each).

- (b). Study of biotic interactions of the following: Stem parasite (*Cuscuta*), Root parasite (*Orobancha*) Epiphytes, Predation (Insectivorous plants).
7. Determination of minimal quadrat size for the study of herbaceous vegetation in the college campus, by species area curve method (species to be listed).
 8. Quantitative analysis of herbaceous vegetation in the college campus for frequency and comparison with Raunkiaer's frequency distribution law.
 9. Quantitative analysis of herbaceous vegetation for density and abundance in the college campus.
 10. Field visit to familiarise students with ecology of different sites.

Suggested Readings

1. Odum, E.P. (2005). Fundamentals of ecology. Cengage Learning India Pvt. Ltd., New Delhi. 5th edition.
2. Singh, J.S., Singh, S.P., Gupta, S. (2006). Ecology Environment and Resource Conservation. Anamaya Publications, New Delhi, India.
3. Sharma, P.D. (2010). Ecology and Environment. Rastogi Publications, Meerut, India. 8th edition.
4. Wilkinson, D.M. (2007). Fundamental Processes in Ecology: An Earth Systems Approach. Oxford University Press. U.S.A.
5. Kormondy, E.J. (1996). Concepts of ecology. PHI Learning Pvt. Ltd., Delhi, India. 4th edition.
6. Smith and Smith(2012): Elements of Ecology. Pearson Publisher (Sixth edition).
7. Bhattacharya, K., Ghosh, A.K. and Hait, G. (2017). A text Book of Botany (Ecology, Environmental Biology, Economic Botany and Pharmacognosy). New Central Book Agency (P) Ltd.
8. Ambasht and Ambasht (2002): A text book of Plant Ecology. CBS publisher and Distributors.
9. Agarwal, A.K. and Deo, P.P. (2006). Plant Ecology. Agrobios (India)
10. William D Bowmen, Sally D Hacker and Michael L. Cain (2018) Ecology, Oxford University Press
11. Verma, P.S. and Agarwal V. K.(2003) Environmental Biology-Principles of Ecology. S Chand & Company Ltd, Ramnagar, New Delhi-110055.

10

BOT-HC-4036 Plant Systematics

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

10.1 THEORY

Unit 1 : *Significance of Plant systematics* (8 lectures)

Introduction to systematics; Plant identification, Classification, Nomenclature. Evidences from palynology, cytology, phytochemistry and molecular data. Functions and importance of Herbarium; Important herbaria and botanical gardens of the world and India; Virtual herbarium; E-flora; Concept of taxa (family, genus, species); Categories and taxonomic hierarchy.

Unit 2 : *Botanical nomenclature* (10 lectures)

Principles and rules (ICN); Ranks and names; Typification, author citation, Effective and valid publication, rejection of names, principle of priority and its limitations; Names of hybrids.

Unit 3 : *Systems of classification* (12 lectures)

Major contributions of Theophrastus, Bauhin, Tournefort, Linnaeus, Adanson, de Candolle, Bessey, Hutchinson, Takhtajan and Cronquist; Classification systems of Bentham and Hooker (upto series) and Engler and Prantl (upto series); Brief reference of Angiosperm Phylogeny Group (APG) classification.

Unit 4 : *Numerical taxonomy and cladistics* (10 lectures)

Characters; Variations; OTUs, character weighting and coding; Cluster analysis; Phenograms, cladograms (definitions and differences).

Unit 5 : Phylogeny of Angiosperms**(12 lectures)**

Terms and concepts (primitive and advanced, homology and analogy, parallelism and convergence, monophyly, Paraphyly, polyphyly and clades). Origin and evolution of angiosperms; Co-evolution of angiosperms and animals; Methods of illustrating evolutionary relationship (phylogenetic tree, cladogram).

Unit 6 : Angiospermic Families**(8 lectures)**

Detail study of the following families:

Magnoliaceae, Fabaceae, Asteraceae, Solanaceae, Acanthaceae, Lamiaceae, Euphorbiaceae, Orchidaceae, Musaceae, Zingiberaceae, Poaceae.

10.2 PRACTICAL

1. Study of vegetative and floral characters of locally available angiospermic plants belonging to the following families (Description, V.S. flower, section of ovary, floral diagram/s, floral formula/e and systematic position according to Bentham & Hooker's system of classification): Fabaceae, Solanaceae, Acanthaceae, Lamiaceae, Euphorbiaceae, Musaceae, Orchidaceae.
2. Field visit to familiarise students with vegetation of an area and identification of plant species / Visit to Academic or Research Institutions.
3. Mounting of a properly dried and pressed specimen of any wild plant with herbarium label (to be submitted in the record book).

Suggested Readings

1. Singh, (2012). *Plant Systematics: Theory and Practice* Oxford & IBH Pvt. Ltd., New Delhi. 3rd edition.
2. Jeffrey, C. (1982). *An Introduction to Plant Taxonomy*. Cambridge University Press, Cambridge.
3. Judd, W.S., Campbell, C.S., Kellogg, E.A., Stevens, P.F. (2002). *Plant Systematics-A Phylogenetic Approach*. Sinauer Associates Inc., U.S.A. 2nd edition.
4. Maheshwari, J.K. (1963). *Flora of Delhi*. CSIR, New Delhi.
5. Radford, A.E. (1986). *Fundamentals of Plant Systematics*. Harper and Row, New York.
6. Pandey, B.P. (2018). *A Textbook of Botany: Angiosperm*. S. Chand Publishing, 7361, Ram Nagar, Qutab Road, New Delhi-110055.

11

BOT-HC-5016

Reproductive Biology of Angiosperms

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

11.1 THEORY

Unit 1 : *Introduction* (4 lectures)

History (contributions of G.B. Amici, W. Hofmeister, E. Strasburger, S.G. Nawaschin, P. Maheshwari, B.M. Johri, W.A. Jensen, J. Heslop-Harrison) and scope.

Unit 2 : *Reproductive development* (6 lectures)

Induction of flowering; flower as a modified determinate shoot. Flower development: genetic and molecular aspects.

Unit 3 : *Anther and pollen biology* (10 lectures)

Anther wall: Structure and functions, microsporogenesis, callose deposition and its significance. Microgametogenesis; Pollen wall structure, MGU (male germ unit) structure, NPC system; Palynology and scope (a brief account); Pollen wall proteins; Pollen viability, storage and germination; Abnormal features: Pseudomonads, polyads, massulae, pollinia.

Unit 4 : *Ovule* (10 lectures)

Structure; Types; Special structures—endothelium, obturator, aril, caruncle and hypostase; Female gametophyte— megasporogenesis (monosporic, bisporic and tetrasporic) and megagametogenesis (details of *Polygonum* type); Organization and ultrastructure of mature embryo sac.

Unit 4 : Pollination and fertilization (6 lectures)

Pollination types and significance; adaptations; structure of stigma and style; path of pollen tube in pistil; double fertilization.

Unit 5 : Self incompatibility (10 lectures)

Basic concepts (interspecific, intraspecific, homomorphic, heteromorphic, GSI and SSD); Methods to overcome self- incompatibility: mixed pollination, bud pollination, stub pollination; Intra-ovarian and *in vitro* pollination; Modification of stigma surface, parasexual hybridization; Cybrids, *in vitro* fertilization.

Unit 6 : Embryo, Endosperm and Seed (8 lectures)

Structure and types; General pattern of development of dicot and monocot embryo and endosperm; Suspensor: structure and functions; Embryo-endosperm relationship; Nutrition of embryo; Unusual features; Embryo development in *Paeonia*. Seed structure, importance and dispersal mechanisms

Units 7 : Polyembryony and apomixis (6 lectures)

Introduction; Classification; Causes and applications.

11.2 PRACTICAL

1. **Anther:** Wall and its ontogeny; Tapetum (amoeboid and glandular); MMC, spore tetrads, uninucleate, bicelled and dehisced anther stages through slides/micrographs, male germ unit (MGU) through photographs and schematic representation.
3. **Pollen grains:** Fresh and acetolyzed showing ornamentation and aperture, pseudomonads, polyads, pollinia (slides/photographs, fresh material), ultrastructure of pollen wall (micrograph); Pollen viability: Tetrazolium test. germination: Calculation of percentage germination in different media using hanging drop method.
4. **Ovule:** Types-anatropous, orthotropous, amphitropous/campylotropous, circinotropous, unitegmic, bitegmic; Tenuinucellate and crassinucellate; Special structures: Endothelium, obturator, hypostase, caruncle and aril (permanent slides/specimens/photographs).
5. **Female gametophyte through permanent slides/ photographs:** Types, ultrastructure of mature egg apparatus.
6. Intra-ovarian pollination; Test tube pollination through photographs.
7. **Endosperm:** Dissections of developing seeds for endosperm with free-nuclear haustoria.
8. **Embryogenesis:** Study of development of dicot embryo through permanent slides; dissection of developing seeds for embryos at various developmental stages.

Suggested Readings

1. Bhojwani, S.S. and Bhatnagar, S.P. (2011). The Embryology of Angiosperms, Vikas Publishing House. Delhi. 5th edition.
2. Shivanna, K.R. (2003). Pollen Biology and Biotechnology. Oxford and IBH Publishing Co. Pvt. Ltd. Delhi.
3. Raghavan, V. (2000). Developmental Biology of Flowering plants, Springer, Netherlands.
4. Johri, B.M. 1 (1984). Embryology of Angiosperms, Springer-Verlag, Netherlands.
5. Bhattacharya, Majimdar and Bhattacharya. (2012). A Textbook of Palynology: Basic and Applied. New Central Book Agency (P) Ltd. Guwahati.

12

BOT-HC-5026 Plant Physiology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

12.1 THEORY

Unit 1 : *Plant-water relations* (10 lectures)

Water Potential and its components, water absorption by roots, aquaporins, pathway of water movement, symplast, apoplast, transmembrane pathways, root pressure, guttation. Ascent of sap– cohesion-tension theory. Transpiration and factors affecting transpiration, antitranspirants, mechanism of stomatal movement. Plant response to water stress.

Unit 2 : *Mineral nutrition* (8 lectures)

Essential and beneficial elements, macro and micronutrients, methods of study and use of nutrient solutions, criteria for essentiality, mineral deficiency symptoms, roles of essential elements, chelating agents, Ion antagonism and toxicity.

Unit 3 : *Nutrient Uptake* (8 lectures)

Soil as a nutrient reservoir, transport of ions across cell membrane, passive absorption, electrochemical gradient, facilitated diffusion, active absorption, role of ATP, carrier systems, proton ATPase pump and ion flux, uniport, co-transport, symport, antiport.

Unit 4 : *Translocation in the phloem* (8 lectures)

Experimental evidence in support of phloem as the site of sugar translocation. Pressure–Flow Model; Phloem loading and unloading; Source–sink relationship.

Unit 5 : *Plant growth regulators* (14 lectures)

Discovery, chemical nature (basic structure), bioassay and physiological roles of Auxin, Gibberellins, Cytokinin, Abscisic acid, Ethylene, Brassinosteroids and Jasmonic acid.

Unit 6 : *Physiology of flowering* (6 lectures)

Photoperiodism, flowering stimulus, florigen concept, vernalization, seed dormancy.

Unit 7 : *Phytochrome, cryptochromes and phototropins* (6 lectures)

Discovery, chemical nature, role in photomorphogenesis, low energy responses (LER) and high irradiance responses (HIR), mode of action.

12.2 PRACTICAL

1. Determination of osmotic potential of plant cell sap by plasmolytic method.
2. Determination of water potential of given tissue (potato tuber) by weight method.
3. Study of the effect of light on the rate of transpiration in excised twig/leaf.
4. Calculation of stomatal index and stomatal frequency from the two surfaces of leaves of a mesophyte and xerophyte.
5. To study the effect of different concentrations of IAA on Gram/Pea/Moong root (IAA Bioassay).
6. To study the induction of amylase activity in germinating Maize/Bean grains.
7. Effect of carbon dioxide concentration on the rate of photosynthesis.

Demonstration experiments

1. To demonstrate suction due to transpiration.
2. Fruit ripening/Rooting from cuttings (Demonstration).

Suggested Readings

1. Hopkins, W.G. and Huner, A. (2008). Introduction to Plant Physiology. John Wiley and Sons. U.S.A. 4th edition.
2. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A (2015). Plant Physiology and Development. Sinauer Associates Inc. USA. 6th edition.
3. Bajracharya D. (1999). Experiments in Plant Physiology-A Laboratory Manual. Narosa Publishing House, New Delhi.

Semester-VI

13

BOT-HC-6016 Plant Metabolism

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

13.1 THEORY

Unit 1 : *Concept of metabolism* (8 lectures)

Introduction, anabolic and catabolic pathways, regulation of metabolism, role of regulatory enzymes; classification, nomenclature and importance of enzyme; concept of coenzyme, apoenzyme and prosthetic group; enzyme inhibition (allosteric, covalent modulation and Isozymes).

Unit 2 : *Carbon assimilation* (12 lectures)

Historical background, photosynthetic pigments, role of photosynthetic pigments (chlorophylls and accessory pigments), antenna molecules and reaction centres, photochemical reactions, photosynthetic electron transport, PSI, PSII, Q cycle, CO₂ reduction, photorespiration, C₄-pathways; Crassulacean acid metabolism; Factors affecting CO₂ reduction.

Unit 3 : *Carbohydrate metabolism* (2 lectures)

Synthesis and catabolism of sucrose and starch.

Unit 4 : *Carbon Oxidation* (10 lectures)

Glycolysis, fate of pyruvate, regulation of glycolysis, oxidative pentose phosphate pathway, oxidative decarboxylation of pyruvate, regulation of PDH, NADH shuttle; TCA cycle, amphibolic role, anaplerotic reactions, regulation of the cycle, mitochondrial electron transport, oxidative phosphorylation, cyanide-resistant respiration, factors affecting respiration.

Unit 5 : *ATP-Synthesis* (8 lectures)

Mechanism of ATP synthesis, substrate level phosphorylation, chemiosmotic mechanism

(oxidative and photophosphorylation), ATP synthase, Boyers conformational model, Racker's experiment, Jagendorf's experiment; role of uncouplers.

Unit 6 : *Lipid metabolism* (8 lectures)

Synthesis and breakdown of triglycerides, β -oxidation, glyoxylate cycle, gluconeogenesis and its role in mobilisation of lipids during seed germination, α oxidation.

Unit 7: *Nitrogen metabolism* (8 lectures)

Nitrate assimilation, biological nitrogen fixation (examples of legumes and non-legumes); Physiology and biochemistry of nitrogen fixation; Ammonia assimilation and transamination.

Unit 8 : *Mechanisms of signal transduction* (4 lectures)

Receptor-ligand interactions; Second messenger concept, Calcium calmodulin, MAP kinase cascade.

13.2 PRACTICAL

1. Chemical separation of photosynthetic pigments.
2. Estimation of sugar content by Somogyi method.
3. Determination of TAN in plant materials.
4. To compare the rate of respiration in different parts of a plant (Demonstration).
5. Estimation of protein in a sample by Biuret method.
6. Separation of amino acids by paper chromatography.
7. Demonstration of Thin layer chromatography (TLC).
8. Quantitative analysis of absorption spectrum of photosynthetic pigments.

Suggested Readings

1. Hopkins, W.G. and Huner, A. (2008). Introduction to Plant Physiology. John Wiley and Sons. U.S.A. 4th edition.
2. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A (2015). Plant Physiology and Development. Sinauer Associates Inc. USA. 6th edition.
3. Harborne, J.B. (1973). Phytochemical Methods. John Wiley & Sons. New York.

14

BOT-HC-6026 Plant Biotechnology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

14.1 THEORY

Unit 1 : *Plant Tissue Culture*

(16 lectures)

Historical perspective; Composition of media; Nutrient and hormone requirements (role of vitamins and hormones); Totipotency; Organogenesis; Embryogenesis (somatic and zygotic); Protoplast isolation, culture and fusion; Tissue culture applications (micropropagation, androgenesis, virus elimination, secondary metabolite production, haploids, triploids and hybrids; Cryopreservation; Germplasm Conservation).

Unit 2 : *Recombinant DNA technology*

(12 lectures)

Restriction Endonucleases (History, Types I-IV, biological role and application); Restriction Mapping (Linear and Circular); Cloning Vectors: Prokaryotic (pUC 18 and pUC19, pBR322, Ti plasmid, BAC); Lambda phage, M13 phagemid, Cosmid, Shuttle vector; Eukaryotic Vectors (YAC).

Unit 3 : *Gene Cloning*

(10 lectures)

Recombinant DNA, Bacterial Transformation and selection of recombinant clones, PCR-mediated gene cloning; Gene Construct; construction of genomic and cDNA libraries, screening DNA libraries to obtain gene of interest by genetic selection; complementation, colony hybridization; PCR

Unit 4 : Methods of gene transfer**(8 lectures)**

Agrobacterium-mediated, Direct gene transfer by Electroporation, Microinjection, Microprojectile bombardment; Selection of transgenics– selectable marker and reporter genes (Luciferase, GUS, GFP).

Unit 5 : Applications of Biotechnology**(14 lectures)**

Pest resistant (Bt-cotton); herbicide resistant plants (RoundUp Ready soybean); Transgenic crops with improved quality traits (Flavr Savr tomato, Golden rice); Improved horticultural varieties (Moondust carnations); Role of transgenics in bioremediation (Superbug); edible vaccines; Industrial enzymes (Aspergillase, Protease, Lipase); Genetically Engineered Products– Human Growth Hormone; Humulin; Biosafety concerns.

14.2 PRACTICAL

1. (a) Preparation of MS medium.
(b) Demonstration of *in vitro* sterilization and inoculation methods using leaf and nodal explants of tobacco, *Datura*, *Brassica* etc.
2. Study of anther, embryo and endosperm culture, micropropagation, somatic embryogenesis & artificial seeds through photographs.
3. Isolation of protoplasts.
4. Construction of restriction map of circular and linear DNA from the data provided.
5. Study of methods of gene transfer through photographs: *Agrobacterium*-mediated, direct gene transfer by electroporation, microinjection, microprojectile bombardment.
6. Study of steps of genetic engineering for production of Bt cotton, Golden rice, Flavr Savr tomato through photographs.
7. Isolation of plasmid DNA.
8. Restriction digestion and gel electrophoresis of plasmid DNA.

Suggested Readings

1. Bhojwani, S.S. and Razdan, M.K., (1996). Plant Tissue Culture: Theory and Practice. Elsevier Science Amsterdam. The Netherlands.
2. Glick, B.R., Pasternak, J.J. (2003). Molecular Biotechnology- Principles and Applications of recombinant DNA. ASM Press, Washington.
3. Bhojwani, S.S. and Bhatnagar, S.P. (2011). The Embryology of Angiosperms. Vikas Publication House Pvt. Ltd., New Delhi. 5th edition.
4. Snustad, D.P. and Simmons, M.J. (2010). Principles of Genetics. John Wiley and Sons, U.K. 5th edition.
5. Stewart, C.N. Jr. (2008). Plant Biotechnology & Genetics: Principles, Techniques and Applications. John Wiley & Sons Inc. U.S.A.

Discipline Specific Elective

1

BOT-HE-5016 Natural Resource Management

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

1.1 THEORY

Unit 1 : *Natural resources*

Definition and types.

(2 lectures)

Unit 2 : *Sustainable utilization*

Concept, approaches (economic, ecological and socio-cultural).

(8 lectures)

Unit 3 : *Land*

Utilization (agricultural, pastoral, horticultural, silvicultural); Soil degradation and management.

(8 lectures)

Unit 4 : *Water*

Fresh water (rivers, lakes, groundwater, aquifers, watershed); Marine; Estuarine; Wetlands; Threats and management strategies.

(8 lectures)

Unit 5 : *Biological Resources*

Biodiversity-definition and types; Significance; Threats; Management strategies; Bio-prospecting; IPR; CBD; National Biodiversity Action Plan).

(10 lectures)

Unit 6 : *Forests*

Definition, Cover and its significance (with special reference to India); Major and minor forestproducts; Depletion; Management.

(6 lectures)

Unit 7 : *Energy*

Renewable and non-renewable sources of energy.

(6 lectures)

Unit 8 : *Contemporary practices in resource management*

(8 lectures)

EIA, GIS, Participatory Resource Appraisal, Ecological Footprint with emphasis on carbon footprint, Resource Accounting; Waste management.

Unit 9 : *National and international efforts in resource management and conservation*

(4 lectures)

1.2 PRACTICAL

1. Estimation of solid waste generated by a domestic system (biodegradable and non-biodegradable) and its impact on land degradation.
2. Collection of data on forest cover of specific area.
3. Measurement of dominance of woody species by DBH (diameter at breast height) method.
4. Calculation and analysis of ecological footprint.
5. Uses of GPS and GIS (Mapping of an area).

Suggested Readings

1. Vasudevan, N. (2006). Essentials of Environmental Science. Narosa Publishing House, New Delhi.
2. Singh, J. S., Singh, S.P. and Gupta, S. (2006). Ecology, Environment and Resource Conservation. Anamaya Publications, New Delhi.
3. Rogers, P.P., Jalal, K.F. and Boyd, J.A. (2008). An Introduction to Sustainable Development. Prentice Hall of India Private Limited, New Delhi.

2

BOT-HE-5026

Horticultural Practices and Post-Harvest Technology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

2.1 THEORY

Unit 1 : *Introduction*

(4 lectures)

Scope and importance, Branches of horticulture; Role in rural economy and employment generation; Importance in food and nutritional security; Urban horticulture and ecotourism.

Unit 2 : *Ornamental plants*

(4 lectures)

Types, classification (annuals, perennials, climbers and trees); Identification and salient features of some ornamental plants [rose, marigold, gladiolus, carnations, orchids, poppies, gerberas, tuberose, sages, cacti and succulents (opuntia, agave and spurges)] Ornamental flowering trees (Indian laburnum, gulmohar, Jacaranda, Lagerstroemia, fishtail and areca palms, semul, coraltree).

Unit 3 : *Fruit and vegetable crops*

(4 lectures)

Production, origin and distribution; Description of plants and their economic products; Management and marketing of vegetable and fruit crops; Identification of some fruits and vegetable varieties (citrus, banana, mango, chillies and cucurbits).

Unit 4 : *Horticultural techniques*

(8 lectures)

Application of manure, fertilizers, nutrients and PGRs; Weed control; Biofertilizers, biopesticides; Irrigation methods (drip irrigation, surface irrigation, furrow and border irrigation); Hydroponics; Propagation Methods: asexual (grafting, cutting, layering, budding), sexual (seed propagation), Scope and limitations.

Unit 5 : *Landscaping and garden design*

(6 lectures)

Planning and layout (parks and avenues); gardening traditions - Ancient Indian, European, Mughal and Japanese Gardens; Urban forestry; policies and practices.

Unit 6 : Floriculture**(6 lectures)**

Cut flowers, bonsai, commerce (market demand and supply); Importance of flower shows and exhibitions.

Unit 7 : Post-harvest technology**(10 lectures)**

Importance of post harvest technology in horticultural crops; Evaluation of quality traits; Harvesting and handling of fruits, vegetables and cut flowers; Principles, methods of preservation and processing; Methods of minimizing losses during storage and transportation; Food irradiation - advantages and disadvantages; food safety.

Unit 8 : Disease control and management**(8 lectures)**

Field and post-harvest diseases; Identification of deficiency symptoms; remedial measures and nutritional management practices; Crop sanitation; IPM strategies (genetic, biological and chemical methods for pest control); Quarantine practices; Identification of common diseases and pests of ornamentals, fruits and vegetable crops.

Unit 9 : Horticultural crops - conservation and management**(10 lectures)**

Documentation and conservation of germplasm; Role of micropropagation and tissue culture techniques; Varieties and cultivars of various horticultural crops; IPR issues; National, international and professional societies and sources of information on horticulture.

Unit 10 : Field trip

Field visits to gardens, standing crop sites, nurseries, vegetable gardens and horticultural fields at suitable locations.

Suggested Readings

1. Singh, D. & Manivannan, S. (2009). Genetic Resources of Horticultural Crops. Ridhi International, Delhi, India.
2. Swaminathan, M.S. and Kochhar, S.L. (2007). Groves of Beauty and Plenty: An Atlas of Major Flowering Trees in India. Macmillan Publishers, India.
3. NIIR Board (2005). Cultivation of Fruits, Vegetables and Floriculture. National Institute of Industrial Research Board, Delhi.
4. Kader, A.A. (2002). Post-Harvest Technology of Horticultural Crops. UCANR Publications, USA.
5. Capon, B. (2010). Botany for Gardeners. 3rd Edition. Timber Press, Portland, Oregon.

3

BOT-HE-6016

Industrial and Environmental Microbiology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

3.1 THEORY

Unit 1 : *Scope of microbes in industry and environment* (6 lectures)

Unit 2 : *Bioreactors/Fermenters and fermentation processes* (12 lectures)

Solid-state and liquid-state (stationary and submerged) fermentations; Batch and continuous fermentations. Components of a typical bioreactor, Types of bioreactors-laboratory, pilotscale and production fermenters; Constantly stirred tank fermenter, tower fermenter, fixed bed and fluidized bed bioreactors and air-lift fermenter.

A visit to any educational institute/ industry to see an industrial fermenter, and other downstream processing operations.

Unit 3: *Microbial production of industrial products* (12 lectures)

Microorganisms involved, media, fermentation conditions, downstream processing and uses; Filtration, centrifugation, cell disruption, solvent extraction, precipitation and ultrafiltration, lyophilization, spray drying; Hands on microbial fermentations for the production and estimation (qualitative and quantitative) of Enzyme: amylase or lipase activity, Organic acid (citric acid or glutamic acid), alcohol (Ethanol) and antibiotic (Penicillin)

Unit 4: *Microbial enzymes of industrial interest and enzyme immobilization* (8 lectures)

Microorganisms for industrial applications and hands on screening microorganisms for casein hydrolysis; starch hydrolysis; cellulose hydrolysis. Methods of immobilization, advantages and applications of immobilization, large scale applications of immobilized enzymes (glucose isomerase and penicillin acylase).

Unit 5: Microbes and quality of environment. (6 lectures)

Distribution of microbes in air; Isolation of microorganisms from soil, air and water.

Unit 6: Microbial flora of water. (8 lectures)

Water pollution, role of microbes in sewage and domestic waste water treatment systems. Determination of BOD, COD, TDS and TOC of water samples; Microorganisms as indicators of water quality, check coliform and fecal coliform in water samples.

Unit 7: Microbes in agriculture and remediation of contaminated soils. (8 lectures)

Biological fixation; Mycorrhizae; Bioremediation of contaminated soils. Isolation of root nodulating bacteria, arbuscular mycorrhizal colonization in plant roots.

3.2 PRACTICAL

1. Principles and functioning of instruments in microbiology laboratory
2. Hands on sterilization techniques and preparation of culture media.
3. Pure culture techniques.

Suggested Readings

1. Pelzar, M.J. Jr., Chen E.C. S., Krieg, N.R. (2010). Microbiology: An application based approach. Tata McGraw Hill Education Pvt. Ltd., Delhi.
2. Tortora, G.J., Funke, B.R., Case. C.L. (2007). Microbiology. Pearson Benjamin Cummings, San Francisco, U.S.A. 9th edition.

4

BOT-HE-6026

Analytical Techniques in Plant Sciences

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

4.1 THEORY

Unit 1 : *Imaging and related techniques* (15 lectures)

Principles of microscopy; Light microscopy; Fluorescence microscopy; Confocal microscopy; Use of fluorochromes: (a) Flow cytometry (FACS); (b) Applications of fluorescence microscopy: Chromosome banding, FISH, chromosome painting; Transmission and Scanning electron microscopy – sample preparation for electron microscopy, cryofixation, negative staining, shadow casting, freeze fracture, freeze etching.

Unit 2 : *Cell fractionation* (8 lectures)

Centrifugation: Differential and density gradient centrifugation, sucrose density gradient, CsCl₂ gradient, analytical centrifugation, ultracentrifugation, marker enzymes.

Unit 3 : *Radioisotopes* (4 lectures)

Use in biological research, auto-radiography, pulse chase experiment.

Unit 4 : *Spectrophotometry* (4 lectures)

Principle and its application in biological research.

Unit 5 : *Chromatography* (8 lectures)

Principle; Paper chromatography; Column chromatography, TLC, GLC, HPLC, Ion-exchange chromatography; Molecular sieve chromatography; Affinity chromatography.

Unit 6 : *Characterization of proteins and nucleic acids* (6 lectures)

Mass spectrometry; X-ray diffraction; X-ray crystallography; Characterization of proteins and nucleic acids; Electrophoresis: AGE, PAGE, SDS-PAGE

Unit 7 : *Biostatistics* (15 lectures)

Statistics, data, population, samples, parameters; Representation of Data: Tabular, Graphical; Measures of central tendency: Arithmetic mean, mode, median; Measures of dispersion: Range, mean deviation, variation, standard deviation; Chi-square test for goodness of fit.

4.2 PRACTICAL

1. Study of Blotting techniques: Southern, Northern and Western, DNA fingerprinting, DNA sequencing, PCR through photographs.
2. Demonstration of ELISA.
3. To separate sugars by thin layer chromatography.
4. Isolation of chloroplasts by differential centrifugation.
5. To separate chloroplast pigments by column chromatography.
6. To estimate protein concentration through Lowry's methods.
7. To separate proteins using PAGE.
8. To separation DNA (marker) using AGE.
9. Study of different microscopic techniques using photographs/micrographs (freeze fracture, freeze etching, negative staining, positive staining, fluorescence and FISH).

Suggested Readings

1. Plummer, D.T. (1996). An Introduction to Practical Biochemistry. Tata McGraw-Hill Publishing Co. Ltd. New Delhi. 3rd edition.
2. Ruzin, S.E. (1999). Plant Microtechnique and Microscopy, Oxford University Press, New York. U.S.A.
3. Ausubel, F., Brent, R., Kingston, R. E., Moore, D.D., Seidman, J.G., Smith, J.A., Struhl, K. (1995). Short Protocols in Molecular Biology. John Wiley & Sons. 3rd edition.
4. Zar, J.H. (2012). Biostatistical Analysis. Pearson Publication. U.S.A. 4th edition.

5

BOT-HE-6036
Project Work/Dissertation

Credits : 6

Generic Elective Courses

1

BOT-HG-1016

Biodiversity (Microbes, Algae, Fungi and Archegoniate)

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

1.1 THEORY

Unit 1 : *Microbes* (10 lectures)

Viruses – Discovery, general structure, replication (general account), DNA virus (T-phage); Lytic and lysogenic cycle, RNA virus (TMV); Economic importance; Bacteria – Discovery, General characteristics and cell structure; Reproduction – vegetative, asexual and recombination (conjugation, transformation and transduction); Economic importance.

Unit 2 : *Algae* (12 lectures)

General characteristics; Ecology and distribution; Range of thallus organization and reproduction; Classification of algae; Morphology and life-cycles of the following: *Nostoc*, *Chlamydomonas*, *Oedogonium*, *Vaucheria*, *Fucus*, *Polysiphonia*. Economic importance of algae.

Unit 3 : *Fungi* (12 lectures)

Introduction- General characteristics, ecology and significance, range of thallus organization, cell wall composition, nutrition, reproduction and classification; True Fungi- General characteristics, ecology and significance, life cycle of *Rhizopus* (Zygomycota) *Penicillium*, *Alternaria* (Ascomycota), *Puccinia*, *Agaricus* (Basidiomycota); Symbiotic Associations-Lichens:

General account, reproduction and significance; Mycorrhiza: ectomycorrhiza and endomycorrhiza and their significance.

Unit 4 : Introduction to Archegoniate (2 lectures)

Unifying features of archegoniate, Transition to land habit, Alternation of generations.

Unit 5 : *Bryophytes*

(10 lectures)

General characteristics, adaptations to land habit, Classification, Range of thallus organization. Classification (up to family), morphology, anatomy and reproduction of *Marchantia* and *Funaria*. (Developmental details not to be included). Ecology and economic importance of bryophytes with special mention of *Sphagnum*.

Unit 6 : *Pteridophytes*

(8 lectures)

General characteristics, classification, Early land plants (*Cooksonia* and *Rhynia*). Classification (up to family), morphology, anatomy and reproduction of *Selaginella*, *Equisetum* and *Pteris*. (Developmental details not to be included). Heterospory and seed habit, stellar evolution. Ecological and economical importance of Pteridophytes.

Unit 7: *Gymnosperms*

(6 lectures)

General characteristics; Classification (up to family), morphology, anatomy and reproduction of *Cycas* and *Pinus* (Developmental details not to be included). Ecological and economical importance.

1.2 PRACTICAL

1. EMs/Models of viruses – T-Phage and TMV, Line drawing/Photograph of Lytic and Lysogenic Cycle.
2. Types of Bacteria from temporary/permanent slides/photographs; Binary Fission; Conjugation; Structure of root nodule.
3. Gram staining
4. Study of vegetative and reproductive structures of *Nostoc*, *Chlamydomonas* (electron micrographs), *Oedogonium*, *Vaucheria*, *Fucus** and *Polysiphonia* through temporary preparations and permanent slides.
5. ***Rhizopus* and *Penicillium***: Asexual stage from temporary mounts and sexual structures through permanent slides.
6. ***Puccinia***: Herbarium specimens of Black Stem Rust of Wheat and infected Barberry leaves; section/tease mounts of spores on Wheat and permanent slides of both the hosts.
7. ***Agaricus***: Specimens of button stage and full grown mushroom; Sectioning of gills of *Agaricus*.
8. **Lichens**: Study of growth forms of lichens (crustose, foliose and fruticose)
9. **Mycorrhiza**: ecto mycorrhiza and endo mycorrhiza (Photographs)
10. ***Marchantia***- morphology of thallus, w.m. rhizoids and scales, v.s. thallus through gemma cup,

w.m.
gemmae
(all
temporar

y slides),

ophore,
sporophyte (all permanent slides).

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archegoni

l.s.60

11. *Funaria*- morphology, w.m. leaf, rhizoids, operculum, peristome, annulus, spores (temporary slides); permanent slides showing antheridial and archegonial heads, l.s. capsule and protonema.
12. *Selaginella*- morphology, w.m. leaf with ligule, t.s. stem, w.m. strobilus, w.m. microsporophyll and megasporophyll (temporary slides), l.s. strobilus (permanent slide).
13. *Equisetum*- morphology, t.s. internode, l.s. strobilus, t.s. strobilus, w.m. sporangiophore, w.m. spores (wet and dry)(temporary slides); t.s rhizome (permanent slide).
14. *Pteris*- morphology, t.s. rachis, v.s. sporophyll, w.m. sporangium, w.m. spores (temporary slides), t.s. rhizome, w.m. prothallus with sex organs and young sporophyte (permanent slide).
15. *Cycas*- morphology (coralloid roots, bulbil, leaf), t.s. coralloid root, t.s. rachis, v.s. leaflet, v.s. microsporophyll, w.m. spores (temporary slides), l.s. ovule, t.s. root (permanent slide).
16. *Pinus*- morphology (long and dwarf shoots, w.m. dwarf shoot, male and female), w.m. dwarf shoot, t.s. needle, t.s. stem, , l.s./t.s. male cone, w.m. microsporophyll, w.m. microspores (temporary slides), l.s. female cone, t.l.s. & r.l.s. stem (permanent slide).

Suggested Readings

1. Kumar, H.D. (1999). Introductory Phycology. Affiliated East-West. Press Pvt. Ltd. Delhi. 2nd edition.
Tortora, G.J., Funke, B.R., Case, C.L. (2010). Microbiology: An Introduction, Pearson th Benjamin Cummings, U.S.A. 10th edition.
3. Sethi, I.K. and Walia, S.K. (2011). Text book of Fungi & Their Allies, MacMillan Publishers Pvt. Ltd., Delhi.
4. Alexopoulos, C.J., Mims, C.W., Blackwell, M. (1996). Introductory Mycology, John Wiley and Sons (Asia), Singapore. 4th edition.
5. Raven, P.H., Johnson, G.B., Losos, J.B., Singer, S.R., (2005). Biology. Tata McGraw Hill, Delhi, India.
6. Vashishta, P.C., Sinha, A.K., Kumar, A., (2010). Pteridophyta, S. Chand. Delhi, India.
7. Bhatnagar, S.P. and Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi, India.
8. Parihar, N.S. (1991). An introduction to Embryophyta. Vol. I. Bryophyta. Central Book Depot, Allahabad.

2

BOT-HG-2016 Plant Ecology and Taxonomy

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

2.1 THEORY

Unit 1 : *Introduction* (2 lectures)

Unit 2 : *Ecological factors* (10 lectures)

Soil: Origin, formation, composition, soil profile. Water: States of water in the environment, precipitation types. Light and temperature: Variation Optimal and limiting factors; Shelford law of tolerance. Adaptation of hydrophytes and xerophytes

Unit 3 : *Plant communities* (6 lectures)

Characters; Ecotone and edge effect; Succession; Processes and types

Unit 4 : *Ecosystem* (8 lectures)

Structure; energy flow trophic organisation; Food chains and food webs, Ecological pyramids production and productivity; Biogeochemical cycling; Cycling of carbon, nitrogen and Phosphorous

Unit 5 : *Phytogeography* (4 Lectures)

Principle biogeographical zones; Endemism.

Unit 6 : *Introduction to plant taxonomy* (2 Lectures)

Identification, Classification, Nomenclature.

Unit : 7 *Identification* (4 Lectures)

Functions of Herbarium, important herbaria and botanical gardens of the world and India; Documentation: Flora, Keys: single access and multi-access

Unit : 8 *Taxonomic evidences from palynology, cytology, phytochemistry and molecular data.*
(6 lectures)

Unit 9 : Taxonomic hierarchy (2 lectures)

Ranks, categories and taxonomic groups

Unit 10 : Botanical nomenclature (6 lectures)

Principles and rules (ICN); ranks and names; binominal system, typification, author citation, valid publication, rejection of names, principle of priority and its limitations.

Unit 11 : Classification (6 lectures)

Types of classification-artificial, natural and phylogenetic. Bentham and Hooker (upto series), Engler and Prantl (upto series).

Unit 12 : Biometrics, numerical taxonomy and cladistics (4 lectures)

Characters; variations; OTUs, character weighting and coding; cluster analysis; phenograms, cladograms (definitions and differences).

2.1 PRACTICAL

1. Study of instruments used to measure microclimatic variables: Soil thermometer, maximum and minimum thermometer, anemometer, psychrometer/hygrometer, rain gauge and lux meter.
2. Study of morphological adaptations of hydrophytes and xerophytes (four each).
3. Determination of minimal quadrat size for the study of herbaceous vegetation in the college campus by species area curve method. (species to be listed)
4. Quantitative analysis of herbaceous vegetation in the college campus for frequency and comparison with Raunkiaer's frequency distribution law.
5. Study of vegetative and floral characters of the following families (Description, V.S. flower, section of ovary, floral diagram/s, floral formula/e and systematic position according to Bentham & Hooker's system of classification): Brassicaceae, Solanaceae, Lamiaceae.
6. Mounting of a properly dried and pressed specimen of any wild plant with herbarium label (to be submitted in the record book).

Suggested Readings

1. Kormondy, E.J. (1996). Concepts of Ecology. Prentice Hall, U.S.A. 4th edition.
2. Sharma, P.D. (2010) Ecology and Environment. Rastogi Publications, Meerut, India. 8th edition.
3. Simpson, M.G. (2006). *Plant Systematics*. Elsevier Academic Press, San Diego, CA, U.S.A.
4. Singh, G. (2012). *Plant Systematics: Theory and Practice*. Oxford & IBH Pvt. Ltd., New Delhi. 3rd edition.

3

BOT-HG--3016

Plant Physiology and Metabolism

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

3.1 THEORY

Unit 1 : *Plant-water relations*

(8 lectures)

Importance of water, water potential and its components; Transpiration and its significance; Factors affecting transpiration; Root pressure and guttation.

Unit 2 : *Mineral nutrition*

(8 lectures)

Essential elements, macro and micronutrients; Criteria of essentiality of elements; Role of essential elements; Transport of ions across cell membrane, active and passive transport, carriers, channels and pumps.

Unit 3 : *Translocation in phloem*

(6 lectures)

Composition of phloem sap, girdling experiment; Pressure flow model; Phloem loading and unloading

Unit 4 : *Photosynthesis*

(12 lectures)

Photosynthetic Pigments (Chl a, b, xanthophylls, carotene); Photosystem I and II, reaction center, antenna molecules; Electron transport and mechanism of ATP synthesis; C₃, C₄ and CAM pathways of carbon fixation; Photorespiration.

Unit 5 : *Respiration*

(6 lectures)

Glycolysis, anaerobic respiration, TCA cycle; Oxidative phosphorylation, Glyoxylate, Oxidative Pentose Phosphate Pathway.

Unit 6 : *Enzymes*

(4 lectures)

Structure and properties; Mechanism of enzyme catalysis and enzyme inhibition.

Unit 7 : Nitrogen metabolism**(4 lectures)**

Biological nitrogen fixation; Nitrate and ammonia assimilation.

Unit 8 : Plant growth regulators**(6 lectures)**

Discovery and physiological roles of auxins, gibberellins, cytokinins, ABA, ethylene.

Unit 9 : Plant response to light and temperature**(6 lectures)**

Photoperiodism (SDP, LDP, Day neutral plants); Phytochrome (discovery and structure), red and far red light responses on photomorphogenesis; Vernalization.

3.2 PRACTICAL

1. Determination of osmotic potential of plant cell sap by plasmolytic method.
2. To study the effect of light on transpiration by excised twig.
3. Calculation of stomatal index and stomatal frequency.
4. Demonstrate the activity of catalase and study the effect of pH and enzyme concentration.
5. To study the effect of bicarbonate concentration on O₂ evolution in photosynthesis.

Demonstration experiments

1. Bolting.
2. Effect of auxins on rooting.
3. Suction due to transpiration.
4. R.Q.
5. Respiration in roots.

Suggested Readings

1. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A (2015). Plant Physiology and Development. Sinauer Associates Inc. USA. 6th edition.
2. Hopkins, W.G., Huner, N.P., (2009). Introduction to Plant Physiology. John Wiley & Sons, U.S.A. 4th Edition.
3. Bajracharya, D., (1999). Experiments in Plant Physiology- A Laboratory Manual. Narosa Publishing House, New Delhi.

4

BOT-HG-3026 Environmental Biotechnology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

4.1 THEORY

Unit 1 : *Environment* (4 lectures)

Basic concepts and issues, global environmental problems - ozone depletion, UV-B, greenhouse effect and acid rain due to anthropogenic activities, their impact and biotechnological approaches for management.

Unit 2 : *Environmental problems* (6 lectures)

Environmental pollution - types of pollution, sources of pollution, measurement of pollution, methods of measurement of pollution, fate of pollutants in the environment, Bioconcentration, bio/geomagnification.

Unit 3 : *Microbiology of waste water treatment* (8 lectures)

Aerobic process - activated sludge, oxidation ponds, trickling filter, towers, rotating discs, rotating drums, oxidation ditch. Anaerobic process - anaerobic digestion, anaerobic filters, up-flow anaerobic sludge blanket reactors. Treatment schemes for waste waters of dairy, distillery, tannery, sugar and antibiotic industries.

Unit 4 : *Xenobiotic compounds* (10 lectures)

Organic (chlorinated hydrocarbons, substituted simple aromatic compounds, polyaromatic hydrocarbons, pesticides, surfactants) and inorganic (metals, radionuclides, phosphates, nitrates). Bioremediation of xenobiotics in environment - ecological consideration, decay behavior and degradative plasmids, molecular techniques in bioremediation.

Unit 5 : *Role of immobilized cells/enzymes in treatment of toxic compounds* (6 lectures)

Biopesticides, bioreactors, bioleaching, biomining, biosensors, biotechniques for air pollution abatement and odour control.

Unit 6 : *Sustainable Development* (8 lectures)

Economics and Environment: Economic growth, Gross National Productivity and the quality of life, Tragedy of Commons, Economics of Pollution control, Cost-benefit and cost effectiveness analysis, WTO and Environment, Corporate Social Responsibility, Environmental awareness and Education; Environmental Ethics.

Unit 7 : *International Legislations, Policies for Environmental Protection* (6 lectures)

Stockholm Conference (1972) and its declaration, WCED (1983) and Brundtland Report (1987), Rio Earth Summit-UNCED (1992) and its declaration, Montreal Protocol - 1987, Basel Convention (1989), Kyoto Protocol- 1997, Ramsar Convention 1971.

Unit 8 : *National Legislations, Policies for Pollution Management* (6 lectures)

Salient features of Wild life protection act 1972, Water Pollution (Prevention and Control) Act-1974, Forest conservation act 1980, Air Pollution (Prevention and Control) Act-1981, National Environmental Policy -2006, Central and State Pollution Control Boards: Constitution and power.

Unit 9 : *Public Participation for Environmental Protection* (6 lectures)

Environmental movement and people's participation with special references to Gandhamardan, Chilika and Narmada Bachao Andolan, Chipko and Silent valley Movement; Women and Environmental Protection, Role of NGO in bringing environmental awareness and education in the society.

4.2 PRACTICAL

1. Water/Soil analysis - DO, salinity, pH, chloride, total hardness, alkalinity, acidity, nitrate, calcium, Magnesium and phosphorus.
2. Gravimetric analysis-Total solid, dissolved solid, suspended solid in an effluent
3. Microbial assessment of air (open plate and air sample) and water

Suggested Readings

1. Waste water engineering - treatment, disposal and reuse, Metcalf and Eddy Inc., Tata McGraw Hill, New Delhi.
2. Environmental Chemistry, AK. De, Wiley Eastern Ltd, New Delhi.
3. Introduction to Biodeterioration, D.Allsopp and K.J. Seal, ELBS / Edward Arnold.
4. Bioremediation, Baaker, KH and Herson D.S., 1994. Mc.GrawHill Inc, NewYork.
5. Industrial and Environmental Biotechnology - Nuzhat Ahmed, Fouad M. Qureshi and Obaid Y. Khan, 2006. Horizon Press.
6. Environmental Molecular Biology, Paul. A, Rochelle, 2001.Horizon Press.
7. Environmental Protection and Laws by Jadhav and Bhosale, V.M.Himalaya publ. House
13. Biodiversity Assessment and Conservation by PC Trivedi, Agrobios publ.

5

BOT-HG-4016

Plant Anatomy and Embryology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

5.1 THEORY

Unit 1: *Meristematic and permanent tissues*

(8 lectures)

Root and shoot apical meristems; Simple and complex tissues

Unit 2: *Organs*

(4 lectures)

Structure of dicot and monocot root stem and leaf.

Unit 3: *Secondary Growth*

(8 lectures)

Vascular cambium – structure and function, seasonal activity. Secondary growth in root and stem, Wood (heartwood and sapwood)

Unit 4: *Adaptive and protective systems*

(8 lectures)

Epidermis, cuticle, stomata; General account of adaptations in xerophytes and hydrophytes.

Unit 5: *Structural organization of flower*

(8 lectures)

Structure of anther and pollen; Structure and types of ovules; Types of embryo sacs, organization and ultrastructure of mature embryo sac.

Unit 6: *Pollination and fertilization*

(8 lectures)

Pollination mechanisms and adaptations; Double fertilization; Seed-structure appendages and dispersal mechanisms.

Unit 7: *Embryo and endosperm*

(8 lectures)

Endosperm types, structure and functions; Dicot and monocot embryo; Embryo-endosperm relationship

5.2 PRACTICAL

1. Study of meristems through permanent slides and photographs.
2. Tissues (parenchyma, collenchyma and sclerenchyma); Macerated xylary elements, Phloem (Permanent slides, photographs)
3. Stem: Monocot: *Zea mays*; Dicot: *Helianthus*; Secondary: *Helianthus* (only Permanent slides).
4. Root: Monocot: *Zea mays*; Dicot: *Helianthus*; Secondary: *Helianthus* (only Permanent slides).
5. Leaf: Dicot and Monocot leaf (only Permanent slides).
6. Adaptive anatomy: Xerophyte (*Nerium* leaf); Hydrophyte (*Hydrillastem*).
7. Structure of anther (young and mature), tapetum (amoeboid and secretory) (Permanent slides).
8. Types of ovules: anatropous, orthotropous, circinotropous, amphitropous / campylotropous (permanent slides)
9. Female gametophyte: *Polygonum* (monosporic) type of Embryo sac Development (Permanent slides/photographs).
10. Ultrastructure of mature egg apparatus cells through electron micrographs.
11. Pollination types and seed dispersal mechanisms (including appendages, aril, caruncle) (Photographs and specimens).
12. Dissection of embryo/endosperm from developing seeds.

Suggested Readings

1. Bhojwani, S.S. & Bhatnagar, S.P. (2011). Embryology of Angiosperms. Vikas Publication House Pvt. Ltd. New Delhi. 5th edition.
2. Mauseth, J.D. (1988). Plant Anatomy. The Benjamin/Cummings Publisher, USA.

6

BOT-HG- 4026

Economic Botany and Plant Biotechnology

Total Lectures : 60 Credits : 6 (Theory - 4, Practical - 2)

6.1 THEORY

Unit 1 : *Origin of Cultivated Plants*

(4 lectures)

Concept of centres of origin, their importance with reference to Vavilov's work.

Unit 2 : *Cereals*

(4 lectures)

Wheat -Origin, morphology, uses

Unit 3 : *Legumes*

(4 lectures)

General account with special reference to Gram and soybean

Unit 4 : *Spices*

(4 lectures)

General account with special reference to clove and black pepper (Botanical name, family, part used, morphology and uses)

Unit 5 : *Beverages*

(2 lectures)

Tea (morphology, processing, uses)

Unit 6 : *Oils and Fats*

(2 lectures)

General description with special reference to groundnut

Unit 7 : *Fiber Yielding Plants*

(2 lectures)

General description with special reference to Cotton (Botanical name, family, part used, morphology and uses)

Unit 8 : Introduction to biotechnology (2 lecture)

Unit 9 : Plant tissue culture (8 lectures)

Micropropagation ; haploid production through androgenesis and gynogenesis; brief account of embryo and endosperm culture with their applications

Unit 10 : Recombinant DNA Techniques (18 lectures)

Blotting techniques: Northern, Southern and Western Blotting, DNA Fingerprinting; Molecular DNA markers i.e. RAPD, RFLP, SNPs; DNA sequencing, PCR and Reverse Transcriptase-PCR. Hybridoma and monoclonal antibodies, ELISA and Immunodetection. Molecular diagnosis of human disease, Human gene Therapy.

Unit 11 : Bioinformatics (5 Lectures)

Introduction, branches, Aim, Scope and research areas, Biological data base and the retrieval system.

Unit 12 :Applications of Bioinformatics (5 Lectures)

Molecular Phylogeny; Basics in Proteomics and Genomics and their applications in crop improvement, Drug Discovery.

6.2 PRACTICAL

1. Study of economically important plants : Wheat, Gram, Rice, Soybean, Black pepper, Curcuma, Clove, Tea, Cotton, Groundnut through specimens, sections and microchemical tests
2. Familiarization with basic equipment in tissue culture.
3. Study through photographs: Anther culture, somatic embryogenesis, endosperm and embryo culture; micropropagation.
4. Study of molecular techniques: PCR, Blotting techniques, AGE and PAGE.
5. Data base searching, and retrieval of Sequence from databases.
6. Sequence alignment, Homology and construction of Phylogenetic tree.

Suggested Readings

1. Kochhar, S.L. (2011). Economic Botany in the Tropics, MacMillan Publishers India Ltd., New Delhi. 4th edition.
2. Bhojwani, S.S. and Razdan, M.K., (1996). Plant Tissue Culture: Theory and Practice. Elsevier Science Amsterdam. The Netherlands.
3. Glick, B.R., Pasternak, J.J. (2003). Molecular Biotechnology- Principles and Applications of recombinant DNA. ASM Press, Washington.

4. Ghosh Z. and Bibekanand M. (2008) *Bioinformatics: Principles and Applications*. Oxford University Press.
5. Pevsner J. (2009) *Bioinformatics and Functional Genomics*. II Edition. Wiley Blackwell.
6. Campbell A. M., Heyer L. J. (2006) *Discovering Genomics, Proteomics and Bioinformatics*. II Edition. Benjamin Cummings.

Skill Enhancement Courses

1

BOT-SE-3014 Biofertilizers

Total Lectures : 60 Credits : 4

Unit 1 : General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, mass multiplication, carrier based inoculants, Actinorrhizal symbiosis.

(8 lectures)

Unit 2 : *Azospirillum*: isolation and mass multiplication – carrier based inoculant, associative effect of different microorganisms. *Azotobacter*: classification, characteristics – crop response to *Azotobacter* inoculum, maintenance and mass multiplication.

(16 lectures)

Unit 3 : Cyanobacteria (blue green algae), *Azolla* and *Anabaena azollae* association, nitrogen fixation, factors affecting growth, blue green algae and *Azolla* in rice cultivation.

(8 lectures)

Unit 4 : Mycorrhizal association, types of mycorrhizal association, taxonomy, occurrence and distribution, phosphorus nutrition, growth and yield – colonization of VAM – isolation and inoculum production of VAM, and its influence on growth and yield of crop plants.

(16 lectures)

Unit 5 : Organic farming – Green manuring and organic fertilizers, Recycling of bio-degradable municipal, agricultural and Industrial wastes – biocompost making methods, types and method of vermicomposting – field Application.

(12 lectures)

Suggested Readings

1. Dubey, R.C., 2005 A Text book of Biotechnology S.Chand & Co, New Delhi.
2. Kumaresan, V. 2005, Biotechnology, Saras Publications, New Delhi.
3. John Jothi Prakash, E. 2004. Outlines of Plant Biotechnology. Emkay Publication, New Delhi.
4. Sathe, T.V. 2004 Vermiculture and Organic Farming. Daya publishers.
5. Subha Rao, N.S. 2000, Soil Microbiology, Oxford & IBH Publishers, New Delhi.
6. Vayas, S.C, Vayas, S. and Modi, H.A. 1998 Bio-fertilizers and organic Farming Akta Prakashan, Nadiad

2

BOT-SE-3024 Herbal Technology

Total Lectures : 60 Credits : 4

Unit 1: Herbal medicines: history and scope - definition of medical terms - role of medicinal plants in Siddha systems of medicine; cultivation - harvesting - processing - storage - marketing and utilization of medicinal plants. **(12 Lectures)**

Unit 2: Pharmacognosy - systematic position m edicinal uses of the following herbs in curing various ailments; Tulsi, Ginger, Fenugreek, Indian Goose berry and Ashoka. **(12 Lectures)**

Unit 3: Phytochemistry - active principles and methods of their testing - identification and utilization of the medicinal herbs; *Catharanthus roseus* (cardiotonic), *Withania somnifera* (drugs acting on nervous system), *Clerodendron phlomoides* (anti-rheumatic) and *Centella asiatica* (memory booster). **(12 Lectures)**

Unit 4: Analytical pharmacognosy: Drug adulteration - types, methods of drug evaluation - Biological testing of herbal drugs - Phytochemical screening tests for secondary metabolites (alkaloids, flavonoids, steroids, triterpenoids, phenolic compounds) **(16 Lectures)**

Unit 5: Medicinal plant banks micro propagation of important species (*Withania somnifera*, neem and tulsi- Herbal foods-future of pharmacognosy) **(8 Lectures)**

Suggested Readings

1. Glossary of Indian medicinal plants, R.N.Chopra, S.L.Nayar and I.C.Chopra, 1956. C.S.I.R, New Delhi.
2. The indigenous drugs of India, Kanny, Lall, Dey and Raj Bahadur, 1984. International Book Distributors.
3. Herbal plants and Drugs Agnes Arber, 1999. Mangal Deep Publications.
4. Ayurvedic drugs and their plant source. V.V. Sivarajan and Balachandran Indra 1994. Oxford IBH publishing Co.
5. Ayurveda and Aromatherapy. Miller, Light and Miller, Bryan, 1998. Banarsidass, Delhi.
6. Principles of Ayurveda, Anne Green, 2000. Thomsons, London.
7. Pharmacognosy, Dr.C.K.Kokate et al. 1999. Nirali Prakashan.

3

BOT-SE-4014 Nursery and Gardening

Total Lectures : 60 Credits : 4

Unit 1: Nursery: definition, objectives and scope and building up of infrastructure for nursery, planning and seasonal activities - Planting - direct seeding and transplants. **(8 Lectures)**

Unit 2: Seed: Structure and types - Seed dormancy; causes and methods of breaking dormancy - Seed storage: Seed banks, factors affecting seed viability, genetic erosion – Seed production technology - seed testing and certification. **(12 Lectures)**

Unit 3: Vegetative propagation: air-layering, cutting, selection of cutting, collecting season, treatment of cutting, rooting medium and planting of cuttings - Hardening of plants – green house - mist chamber, shed root, shade house and glass house. **(12 Lectures)**

Unit 4: Gardening: definition, objectives and scope - different types of gardening - landscape and home gardening - parks and its components - plant materials and design - computer applications in landscaping - Gardening operations: soil laying, manuring, watering, management of pests and diseases and harvesting. **(16 Lectures)**

Unit 5: Sowing/raising of seeds and seedlings - Transplanting of seedlings - Study of cultivation of different vegetables: cabbage, brinjal, lady's finger, onion, garlic, tomatoes, and carrots - Storage and marketing procedures. **(12 Lectures)**

Suggested Readings

1. Bose T.K. & Mukherjee, D., 1972, Gardening in India, Oxford & IBH Publishing Co., New Delhi.
2. Sandhu, M.K., 1989, Plant Propagation, Wile Eastern Ltd., Bangalore, Madras.
3. Kumar, N., 1997, Introduction to Horticulture, Rajalakshmi Publications, Nagercoil.
4. Edmond Musser & Andres, Fundamentals of Horticulture, McGraw Hill Book Co., New Delhi.
5. Agrawal, P.K. 1993, Hand Book of Seed Technology, Dept. of Agriculture and Cooperation, National Seed Corporation Ltd., New Delhi.
6. Janick Jules. 1979. Horticultural Science. (3rd Ed.), W.H. Freeman and Co., San Francisco, USA.

4

BOT-SE-4024

Floriculture

Total Lectures : 60 Credits : 4

Unit 1: Introduction: History of gardening; Importance and scope of floriculture and landscape gardening. **(4 Lectures)**

Unit 2: Nursery Management and Routine Garden Operations: Sexual and vegetative methods of propagation; Soil sterilization; Seed sowing; Pricking; Planting and transplanting; Shading; Stopping or pinching; Defoliation; Wintering; Mulching; Topiary; Role of plant growth regulators. **(16 lectures)**

Unit 3: Ornamental Plants: Flowering annuals; Herbaceous perennials; Divine vines; Shade and ornamental trees; Ornamental bulbous and foliage plants; Cacti and succulents; Palms and Cycads; Ferns and Selaginellas; Cultivation of plants in pots; Indoor gardening; Bonsai. **(8 lectures)**

Unit 4: Principles of Garden Designs: English, Italian, French, Persian, Mughal and Japanese gardens; Features of a garden (Garden wall, Fencing, Steps, Hedge, Edging, Lawn, Flower beds, Shrubbery, Borders, Water garden. Some Famous gardens of India. **(8 lectures)**

Unit 5: Landscaping Places of Public Importance: Landscaping highways and Educational institutions. **(8 lectures)**

Unit 6: Commercial Floriculture: Factors affecting flower production; Production and packaging of cut flowers; Flower arrangements; Methods to prolong vase life; Cultivation of Important cut flowers (Carnation, Aster, Chrysanthemum, Dahlia, Gerbera, Gladiolous, Marigold, Rose, Liliun, Orchids). **(12 lectures)**

Unit 7: Diseases and Pests of Ornamental Plants. **(4 lectures)**

Suggested Readings

1. Randhawa, G.S. and Mukhopadhyay, A. 1986. Floriculture in India. Allied Publishers.

5

BOT-SE-4034

Intellectual Property Rights

Total Lectures : 60 Credits : 4

Unit 1: Introduction to intellectual property right (IPR) (4 lectures)

Concept and kinds. Economic importance. IPR in India and world: Genesis and scope, some important examples. IPR and WTO (TRIPS, WIPO).

Unit 2 : Patents (6 Lectures)

Objectives, Rights, Patent Act 1970 and its amendments. Procedure of obtaining patents, Working of patents. Infringement.

Unit 3: Copyrights (6 Lectures)

Introduction, Works protected under copyright law, Rights, Transfer of Copyright, Infringement.

Unit 4: Trademarks (6 Lectures)

Objectives, Types, Rights, Protection of goodwill, Infringement, Passing off, Defences, Domain name.

Unit 5: Geographical Indications (6 Lectures)

Objectives, Justification, International Position, Multilateral Treaties, National Level, Indian Position.

Unit 6: Protection of Traditional Knowledge (8 Lectures)

Objective, Concept of Traditional Knowledge, Holders, Issues concerning, Bio-Prospecting and Bio-Piracy, Alternative ways, Protectability, need for a Sui-Generis regime, Traditional Knowledge on the International Arena, at WTO, at National level, Traditional Knowledge Digital Library.

Unit 7: Industrial Designs (4 Lectures)

Objectives, Rights, Assignments, Infringements, Defences of Design Infringement

Unit 8 : Protection of Plant Varieties**(4 Lectures)**

Plant Varieties Protection-Objectives, Justification, International Position, Plant varieties protection in India. Rights of farmers, Breeders and Researchers. National gene bank, Benefit sharing. Protection of Plant Varieties and Farmers' Rights Act, 2001.

Unit 9 : Information Technology Related Intellectual Property Rights**(8 Lectures)**

Computer Software and Intellectual Property, Database and Data Protection, Protection of Semi-conductor chips, Domain Name Protection

Unit 10 : Biotechnology and Intellectual Property Rights.**(8 Lectures)**

Patenting Biotech Inventions: Objective, Applications, Concept of Novelty, Concept of inventive step, Microorganisms, Moral Issues in Patenting Biotechnological inventions.

Suggested Readings

1. N.S. Gopalakrishnan & T.G. Agitha, (2009) Principles of Intellectual Property Eastern Book Company, Lucknow.
2. Kerly's Law of Trade Marks and Trade Names (14th Edition) Thomson, Sweet & Maxweel.
3. Ajit Parulekar and Sarita D' Souza, (2006) Indian Patents Law – Legal & Business Implications; Macmillan India Ltd.
4. B.L.Wadehra (2000) Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India.
5. P. Narayanan (2010) Law of Copyright and Industrial Designs; Eastern law House, Delhi.

APPENDIX I

SEMESTER	COURSE OPTED	COURSE NAME	Credits
I	Ability Enhancement Compulsory Course-I	English communications	2
	Core course-I	Phycology and Microbiology	4
	Core Course-I Practical	Phycology and Microbiology	2
	Core course-II	Biomolecules and Cell Biology	4
	Core Course-II Practical	Biomolecules and Cell Biology- Practical	2
	Generic Elective -1	GE-1	4
	Generic Elective -1 Practical/ Tutorial	GE-1 Practical	2
II	Ability Enhancement Compulsory Course-II	Environmental Studies	2
	Core course-III	Mycology and Phytopathology	4
	Core Course-III Practical	Mycology and Phytopathology- Practical	2
	Core course-IV	Archegoniate	4
	Core Course-IV Practical	Archegoniate- Practical	2

	Generic Elective -2	GE-2	4
	Generic Elective -2 -- Practical	GE-2 Practical	2
III	Core course-V	Morphology and Anatomy of Angiosperm	4
	Core Course-V Practical	Morphology and Anatomy of Angiosperm- Practical	2
	Core course-VI	Economic Botany	4
	Core Course-VI Practical	Economic Botany-Practical	2
	Core course-VII	Genetics	4
	Core Course-VII Practical	Genetics- Practical	2
	Skill Enhancement Course-1	SEC-1	4
	Generic Elective -3	GE-3	4
	Generic Elective -3 Practical	GE-3 Practical	2
IV	Core course-VIII	Molecular Biology	4
	Course-VIII Practical	Molecular Biology- Practical	2
	Core course-IX	Plant Ecology and Phytogeography	4
	Course-IX Practical	Plant Ecology and Phytogeography - practical	2
	Core course-X	Plant Systematics	4
	Core Course- X Practical	Plant Systematics	2

		Practical	
	Skill Enhancement Course-2	SEC-2	4
	Generic Elective -4	GE-4	4
	Generic Elective – 4 Practical	GE-4 Practical	2
V	Core course-XI	Reproductive Biology of Angiosperms	4
	Core Course-XI Practical	Reproductive Biology of Angiosperms - Practical	2
	Core course-XII	Plant Physiology	4
	Core Course-XII Practical	Plant Physiology-Practical	2
	Discipline Specific Elective -1	DSE-1	4
	Discipline Specific Elective -1 Practical	DSE-1 Practical	2
	Discipline Specific Elective -2	DSE-2	4
	Discipline Specific Elective-2 -Practical /Tutorial	DSE-2 Practical	2
VI	Core course-XIII	Plant Metabolism	4
	Core Course-XIII -Practical /Tutorial	Plant Metabolism-Practical	2
	Core course-XIV	Plant	4

		Biotechnology	
	Core Course-XIV - Practical /Tutorial	Plant Biotechnology-Practical	2
	Discipline Centric Elective -3	DSE-3	4
	Discipline Centric Elective -3 Practical /Tutorial	DSE-3 Practical	2
	Project Work	DSE-4 Practical	6
			Total: 144

Course outcomes

B.Sc. Botany Honours

Core Papers

BOT-HC-1016: Phycology and Microbiology

- CO1. Detailed knowledge on microbes, viruses and bacteria, and their importance in agriculture and medicine
- CO2. Knowledge on Algal classification, Economic and ecological importance of Algae
- CO3. Practical knowledge on structure of T-Phage and TMV, lytic and lysogenic life cycle
- CO4. Practical knowledge on microscopy of bacteria and algae

BOT-HC-1026: Biomolecules and Cell Biology

- CO1. Knowledge on structure, classification and physicochemical properties of biomolecules and enzymes
- CO2. Detailed knowledge on structure, properties and functions of cell and its components
- CO3. Practical knowledge on properties of cell and cell membrane, DNA staining techniques and microscopy of plant cell
- CO4. Knowledge on qualitative tests of biomolecules

BOT-HC-2016: Mycology and Phytopathology

- CO1. Detailed knowledge on different classes of fungi, their structure, classification, life cycle and reproduction
- CO2. Knowledge on diseases in plants caused by viruses, bacteria and fungi and biotechnological applications of fungi
- CO3. Structural analysis of different classes of fungi and their reproductive stages
- CO4. Knowledge on structures of symbiotic associations (Lichens, Mycorrhiza)

BOT-HC-2026: Archegoniate

CO1. Detailed knowledge on morphology, anatomy, classification and properties of bryophytes, pteridophytes and gymnosperms

CO2. Knowledge on reproduction and economic importance and ecological significance of bryophytes, pteridophytes and gymnosperms

CO3. Practical knowledge on morphology and reproductive structures of archegoniates

CO4. Spore morphology analysis and detailed knowledge on male and female reproductive structures in gymnosperms

BOT-HC-3016: Morphology and Anatomy of Angiosperms

CO1. Knowledge on morphology of angiosperms and developmental biology of plant body

CO2. Knowledge on structural and anatomical organization of tissue system in plants and their classification

CO3. Practical knowledge on inflorescences and fruits of angiosperms

CO4. Practical knowledge on anatomical features of plant body parts

BOT-HC-3026: Economic Botany

CO1. Knowledge on morphology, uses and economic importance of crop plants

CO2. Knowledge on uses of industrially important plants

CO3. Practical knowledge on economically important plant parts and their products

BOT-HC-3036: Genetics

CO1. Knowledge on Mendelian concepts in genetics; structure, functions and properties of chromosome; chromosomal aberration

CO2. Knowledge on gene structures and gene mutations, population genetics

CO3. Practical knowledge on chromosomal mapping and gene interaction studies

CO4. Practical visualization of chromosomal anomalies

BOT-HC-4016: Molecular Biology

CO1. Detailed knowledge on architecture of nucleic acids, organization of DNA in organisms, models of replication and the factors associated with it

CO2. Detailed knowledge on transcriptional and post transcriptional events in a cell, translation of proteins

CO3. Practical acquaintance of isolation and quantification of DNA from plants

CO4. Knowledge on photographic study of RNA polymerases and RNA modification machinery

BOT-HC-4026: Plant Ecology and Phytogeography

CO1. Knowledge on origin, formation and properties of abiotic components of the ecosystem, interactions and adaptation of plants with biotic and abiotic factors

CO2. Knowledge on properties of communities in a population and tropical and habitat organization in an ecosystem

CO3. Practical knowledge on property analysis of abiotic components of the ecosystem

CO4. Practical knowledge on vegetation study and different ecological sites

BOT-HC-4036: Plant Systematics

CO1. Knowledge on plant identification and classification systems, plant nomenclature

CO2. Knowledge on phylogenetic and evolutionary relationships of angiosperms

CO3. Practical knowledge on foliar morphology and taxonomical study of angiosperms

BOT-HC-5016: Reproductive Biology of Angiosperms

- CO1. Knowledge on detailed morphological and anatomical study of reproductive structures of angiospermic plants
- CO2. Knowledge on embryology and embryological abnormalities in angiosperms
- CO3. Structural documentation of reproductive structures of angiosperms
- CO4. Practical knowledge on developmental biology of embryo and endosperms

BOT-HC-5026: Plant Physiology

- CO1. Knowledge on mechanisms of water, minerals and nutrient absorption of plants
- CO2. Knowledge on roles of plant hormones and mechanism of flowering in plants
- CO3. Practical knowledge on effects of growth regulators on plant parts
- CO4. Practical knowledge on determination of osmotic and water potential

BOT-HC-6016: Plant Metabolism

- CO1. Detailed knowledge of metabolic events of photosynthesis and nutrient metabolism
- CO2. Knowledge of signalling molecules and pathways in the plant cell
- CO3. Practical knowledge on different types of chromatographic techniques
- CO4. Estimation of TAN, sugar and protein contents in plant sample

BOT-HC-6026: Plant Biotechnology

- CO1. Knowledge on applications of tissue culture techniques, construction of recombinant DNA and transformation into hosts, construction of DNA libraries
- CO2. Knowledge on development of transgenic plants for agricultural or industrial use
- CO3. Practical utility on isolation of plasmid DNA, its digestion and separation of fragments through gel electrophoresis
- CO4. Preparation of media for tissue culture techniques and photographic study of plant tissue culture
- CO5. Photographic study of generating transgenic plants for agriculture

Discipline Specific Elective (DSE) Papers

BOT-HE-5016: Natural Resource Management

- CO1. Comprehensive knowledge on different types of natural resources and their ecological, economical and socio-cultural values
- CO2. Basic understandings of land, water and forest resources
- CO3. Overall knowledge on resource degradation, their judicious use and management for sustainability
- CO4. Knowledge on biodiversity - its importance, management and Bioprospecting
- CO5. Knowledge on IPR, and global arena on resource management, conservation and benefit sharing
- CO6. Hands on experience on the domestic solid waste estimation and determining its impact on land degradation
- CO7. Hands on experience on forest study using tools like GPS/GIS, and understanding of ecological importance of forest resources

BOT-HE-5026: Horticultural Practices and Post-Harvest Technology

- CO1. Basic understandings on Horticultural science and its importance in employment generation and socio-economic development

- CO2. Classification of horticultural crops, identification of potential horticultural crops – their cultivation, production, management and commercialization
- CO3. Knowledge on horticultural techniques, landscaping and gardening
- CO4. Overall knowledge on post-harvest technology, disease management, and germplasm management for horticulture
- CO5. Field knowledge of gardening, nurseries, standing crops of horticultural importance

BOT-HE-6016: Industrial and Environmental Microbiology

- CO1. Understanding the roles of microbes in industries and environment
- CO2. Basic knowledge of different kinds of bioreactors and fermentation processes
- CO3. Knowledge on production processes of some microbial products in industries through site visits
- CO4. Knowledge on application of enzymes in industries
- CO5. Diversity and distribution of microbes in air, water and soil
- CO6. Basic understandings on water microbiology and water analysis methods
- CO7. Usefulness of microbes in agriculture and bioremediation of contaminated soils
- CO8. Practical experiences on basic microbiological techniques and handlings

BOT-HE-6026: Analytical Techniques in Plant Sciences

- CO1. Knowledge on microscopy and imaging in plant science
- CO2. Principles and application of centrifuge, spectroscopy and chromatography in biology
- CO3. Basic knowledge on biostatistics including measures of central tendency and dispersions, statistical data analysis and representations
- CO4. Practical knowledge on microscopy, chromatography, centrifugation and spectroscopy

BOT-HE-6036: Project Work/Dissertation

- CO1. Practical knowledge on addressing relevant scientific questions through experimentation

Generic Elective Courses

BOT-HG-1016: Biodiversity (Microbes, Algae, Fungi and Archegoniate)

- CO1. Knowledge on structure and reproduction of viruses and bacteria, and their economic importance
- CO2. Describe general characteristics, morphological diversity, thallus organization, life cycles, ecological and economic importance of algae
- CO3. Describe general characteristics, morphological diversity, thallus organization, life cycles, ecological and economic importance of fungi
- CO4. General characteristics, classification, morphological diversity and evolutionary significance of bryophytes
- CO5. General characteristics and classification of pteridophytes; evolution of stele, heterospory and seed habit in pteridophytes
- CO6. Classify gymnosperms, and describe their general characteristics and economic importance
- CO7. Practical knowledge on staining and slide preparation to study bacteria, algae and fungi under the microscope
- CO8. Practical knowledge on vegetative and reproductive structures of some representative bryophytes, pteridophytes and gymnosperms

BOT-HG-2016: Plant Ecology and Taxonomy

- CO1. Understanding soil, water, light and temperature as ecological factors

- CO2. Knowledge on adaptive characters of hydrophytes and xerophytes
- CO3. Knowledge on plant community types and their succession
- CO4. Knowledge on ecosystem, trophic levels and energy flow in ecosystems
- CO5. Knowledge on biogeochemical cycling with an emphasis on carbon, nitrogen and phosphorus cycles
- CO6. General idea on phytogeography and endemism
- CO7. Knowledge on plant taxonomy, principles, ICN rules, ranks and hierarchy
- CO8. Knowledge on different systems of plant classification and cluster analysis
- CO9. Practical knowledge on soil temperature measurement, humidity measurement, rainfall estimation and light intensity measurement
- CO10. Adaptive morphological characterization of hydrophytes and xerophytes
- CO11. Quadrature size determination for herbaceous plant studies in ecology
- CO12. Estimation of frequency distribution of herbaceous plants using quadrature method
- CO13. Practical knowledge on plant identification upto the family level that belongs to Brassicaceae, Solanaceae and Lamiaceae; Preparation of herbarium specimens

BOT-HG-3016: Plant Physiology and Metabolism

- CO1. Understanding the roles of water in plant physiology, transpiration, and guttation
- CO2. Knowing of macro- and micro-nutrients and mineral uptakes in plants
- CO3. Understanding the transportations of minerals and foods in plants
- CO4. Knowledge on photosynthetic pigments, photosynthetic reactions and photorespiration
- CO5. Understanding of respiration processes – glycolysis, TCA and PPP pathways
- CO6. Knowledge on enzyme properties, actions and inhibitions
- CO7. Knowledge on biological nitrogen fixation
- CO8. Knowledge on plant hormones, and plant responses to light and temperature
- CO9. Determine osmotic potentials of plant cells and effect of light on transpiration
- CO10. Calculate stomatal index and frequency
- CO11. Demonstrate the effect of pH and concentrations in catalase activity
- CO12. Demonstrate the effect of bicarbonate concentration on O₂ evolution in photosynthesis

BOT-HG-3026: Environmental Biotechnology

- CO1. Knowledge on environment and the cause of environmental pollutions
- CO2. Knowledge on the methods of pollution measurement and bioremediation
- CO3. Knowledge on waste water treatment processes
- CO4. Knowledge on xenobiotics – their types and bioremediation
- CO5. Knowledge on application of immobilized cells/enzymes in industries
- CO6. Knowledge on national legislations and international treaties for environmental protection and pollution management
- CO7. Practical knowledge on determining basic properties of soil and water like DO, salinity, pH, total hardness, etc
- CO8. Practical knowledge on gravimetric analysis of effluents
- CO9. Practical knowledge on the assessment of microorganisms in air and water samples

BOT-HG-4016: Plant Anatomy and Embryology

- CO1. Knowledge on different types of tissues and their organizations in plants
- CO2. Knowledge on secondary growth and anomalous structures in plants
- CO3. Knowledge on adaptive and protective characters of plants
- CO4. Understanding the reproductive units of a flower; ovule types, ovary types, pollination and fertilization mechanisms; embryo and endosperm developments and functions
- CO5. Hands on experiences on slide preparation for anatomical studies of leaf, stem and root
- CO6. Flower dissection and study of flower reproductive parts and events

BOT-HG-4026: Economic Botany and Plant Biotechnology

- CO1. Understanding the concept of 'centre of origin of crop plants' and their distribution with a special emphasis on wheat
- CO2. Overall knowledge on economically important crops with their botanical characters and parts used
- CO3. Knowledge on plant tissue culture and the basic molecular techniques used in biotechnology
- CO4. Basic concept of bioinformatics and its application

Skill Enhancement Paper

BOT-SE-3014: Biofertilizers

- CO1. Basic knowledge on the microbes used as biofertilizer and understand the process of their isolation, identification, mass multiplication, carrier based inoculants and knowledge on Actinorrhizal symbiosis
- CO2. Concept on the general characteristics, isolation, mass multiplication carrier based inoculants of *Azospirillum* and *Azotobacter* also the knowledge on the crop response to *Azotobacter*
- CO3. Basic knowledge on Cyanobacteria including factors affecting growth of Cyanobacteria, concept on the nitrogen fixation and use of blue green algae in rice cultivation
- CO4. Brief knowledge on the Mycorrhizal association and understand the details of various types, taxonomy, occurrence, distribution and growth parameters of Mycorrhiza
- CO5. Details about the organic farming, maintenance and recycling of biodegradable waste material and understand the methods of making biocompost and vermicompost with application

BOT-SE-3024: Herbal Technology

- CO1. Concept on the plants used as traditional medicine, and understanding the process of cultivation, harvesting, processing, storage, marketing and utilization of medicinal plants

CO2. Brief knowledge on medicinal drugs obtained from plants and comprehensive idea about systematic position, medicinal uses of Tulsi, Ginger, Fenu greek, Indian goose berry and Ashoka

CO3. Concept on the phytochemistry of medicinal herbs and identification, utilization of medicinal plants

CO4. Basic knowledge on quality control, owing the medicinal properties of herbal drugs including the secondary metabolites and concept of drug adulteration, types, methods of drug evaluation

CO5. Understand the process of micro propagation of important medicinal plant species

BOT-SE-4014: Nursery and Gardening

CO1. Brief idea about objectives, scope, infrastructure and maintenance of Nursery

CO2. Concept on structure, types and dormancy of seeds and brief idea about seed storage including types and process and knowledge on seed production technology

CO3. Knowledge on various modes of vegetative propagation and maintenance of plants in green house

CO4. Brief idea about development and maintenance of gardening including scope and types and understand the various gardening operations including management of pests and diseases

CO5. Detail knowledge on managements of seeds and seedlings and concept about cultivation, storage and marketing of important vegetables

BOT-SE-4024: Floriculture

CO1. Basic knowledge including history, importance and scope of floriculture

CO2. Brief idea about Nursery management and garden operations and knowledge on the terms related to gardening and concept about role of plant growth regulators

CO3. Covers the knowledge of various ornamental plants and concept of cultivations of plants in pots and knowledge about Bonsai

CO4. Idea about various garden designs and features of such gardens and knowledge about some famous gardens of India

CO5. Knowledge about the process of making garden more attractive by altering the existing design in places of public importance, highways and educational institute

BOT-SE-4034: Intellectual Property Rights

CO1. Knowledge on IPR, their types and infringement

CO2. Understanding about traditional knowledge and their protection, bio-prospecting and bio-piracy.

CO3. Knowledge on protection of plant varieties, farmer rights

CO4. Knowledge on Information technology related IPR; data, database, chips and domain name protection

CO5. Knowledge on novelty, bio-based patenting, and moral issues associated with biotechnological inventions

Gauhati University

**Syllabus for
B.Sc.(Honors)
Chemistry**

Choice Based Credit System (CBCS)

Course effective from academic year 2019-20

*This is approved in the Academic Council held
on 08/11/2019*



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Gauhati University

Guwahati::Assam

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Preamble

The choice based credit system is naturally the next logical step in a credit based semester system. This makes the system the more learner-centric. A CBCS offers the student a diversity of courses to choose from and the autonomy to decide on the place, pace and the time of learning.

The Gauhati University has decided to introduce the CBCS system at the under graduate level from the session 2019-20. The CBCS syllabus for the B.Sc. (Honours) is prepared in the model of syllabus prepared by the UGC.

A student opting for honours course in chemistry must have and passed the Mathematics as a subject in the Senior Secondary level examination.

Course Structure	
Course	*Credits
	Theory+ Practical
I. Core Course (14 Papers)	14×4= 56
Core Course Practical / Tutorial* (14 Papers)	14×2= 28
II. Elective Course (8 Papers)	4×4=16
A.1. Discipline Specific Elective (4 Papers)	
A.2. Discipline Specific Elective Practical/Tutorial*(4 Papers)	4×2=8
B.1. Generic Elective/ Interdisciplinary (4 Papers)	4×4=16
B.2. Generic Elective Practical/ Tutorial* (4 Papers)	4×2=8
III. Ability Enhancement Courses	2×4=8
1. Ability Enhancement Compulsory (2 Papers of 2 credit each)	
Environmental Studies	
English/MIL Communication	
2. Ability Enhancement Elective (Skill Based) (Minimum 2)	
(2 Papers of 2 credit each)	2×4=8
Total	148

***Core and DSE courses without practicals will have tutorial and have credit distribution of : 5 credits for theory and 1 credit for tutorial, total 6 credits, same as the papers with practical**

Structure of BSc Honours(Chemistry) Programme

Semester	Type	Core	AECC	SEC	DSE	GEN
	Credits	14 × 6 = 84	2 × 4 = 8	2 × 4 = 8	4 × 6 = 24	4 × 6 = 24
I	CHE-HC-1016	ENG-AE-1014				XXX-HG-1XX6
	CHE-HC-1026					
II	CHE-HC-2016	ENV-AE-2014				XXX-HG-2XX6
	CHE-HC-2026					
III	CHE-HC-3016			CHE-SE-3YY4†		XXX-HG-3XX6
	CHE-HC-3026					
	CHE-HC-3036					
IV	CHE-HC-4016			CHE-SE-4YY4†		XXX-HG-4XX6
	CHE-HC-4026					
	CHE-HC-4036					
V	CHE-HC-5016				CHE-HE-5YY6‡	
	CHE-HC-5026				CHE-HE-5YY6‡	
VI	CHE-HC-6016				CHE-HE-6YY6‡	
	CHE-HC-6016				CHE-HE-6YY6‡	

**SCHEME FOR CHOICE BASED CREDIT SYSTEM IN B. Sc.
Honours (Chemistry)**

SEMESTER	COURSE CODE	COURSE NAME	Credits
I	ENG-AE-1014	English Communications	4
	CHE-HC-1016	Inorganic Chemistry-I	4+2=6
		Inorganic Chemistry-I Lab	
	CHE-HC-1026	Physical Chemistry-I	4+2=6
		Physical Chemistry-I Lab	
AAA-HG-1YY6*	GE-1	4+2/5+1=6	
	Generic Elective -1 Practical/Tutorial		
Total Credits in Semester I			22
II	Ability Enhancement Compulsory Course-II**	Environmental Studies	4
	CHE-HC-2016	Organic Chemistry-I	4+2=6
		Organic Chemistry-I Lab	
	CHE-HC-2026	Physical Chemistry-II	4+2=6
		Physical Chemistry-II Lab	
AAA-HG-2YY6*	GE-2	4+2/5+1=6	
	Generic Elective -2 Practical/Tutorial		
Total Credits in Semester II			22
III	CHE-HC-3016	Inorganic Chemistry-II	4+2=6
		Inorganic Chemistry-II Lab	
	CHE-HC-3026	Organic Chemistry-II	4+2=6
		Organic Chemistry-II Lab	
	CHE-HC-3036	Physical Chemistry-III	4+2=6
		Physical Chemistry-III Lab	
CHE-SE-3YY4†	SEC-1	4	
AAA-HG-3YY6*	GE-3	4+2/5+1=6	
	Generic Elective -3 Practical/Tutorial		
Total Credits in Semester III			28
IV	CHE-HC-4016	Inorganic Chemistry-III	4+2=6
		Inorganic Chemistry-III Lab	
	CHE-HC-4026	Organic Chemistry-III	4+2=6
		Organic Chemistry-III Lab	
	CHE-HC-4036	Physical Chemistry-IV	4+2=6
		Physical Chemistry-IV Lab	
CHE-SE-4YY4†	SEC -2	4	
AAA-HG-4YY6*	GE-4	4+2/5+1=6	
	Generic Elective -4 Practical		
Total Credits in Semester IV			28
V	CHE-HC-5016	Organic Chemistry-IV	4+2=6

		Organic Chemistry-IV Lab	
	CHE-HC-5026	Physical Chemistry-V Physical Chemistry-V Lab	4+2=6
	CHE-HE-5YY6‡	DSE-1 DSE-1 Lab	4+2=6
	CHE-HE-5YY6‡	DSE-2 DSE-2 Lab	4+2=6
Total Credits in Semester V			24
VI	CHE-HC-6016	Inorganic Chemistry-IV Inorganic Chemistry-IV Lab	4+2=6
	CHE-HC-6026	Organic Chemistry-V Organic Chemistry-V Lab	4+2=6
	CHE-HE-6YY6‡	DSE-3 DSE-3 Lab	4+2=6
	CHE-HE-6YY6‡	DSE-4 DSE-3 Lab/tutorial	4+2=6
Total Credits in Semester VI			24
Grand Total Credits			148

***Generic Electives (Other Discipline) - GE 1 to GE 4**

1. Mathematics
2. Physics
3. Economics
4. Computer Science
5. Zoology
6. Botany
7. Statistics
8. Geology
9. Biotechnology
10. Anthropology

*** a) Generic Electives (GE) are to be taken preferably from Physics and Mathematics disciplines.**

b) Students can choose minimum of two GE papers from two different disciplines or four papers from one discipline.

c) Some Universities in India require at least two mathematics papers to be studied by the student for admission into M. Sc. (Chemistry).

‡ Discipline Specific Elective Papers: (Credit: 06 each) (4 papers to be selected)-

DSE for Semester V

DSE-1(Any One from the following)

1. CHE-HE-5016: Applications of Computers in Chemistry (4) + Lab (2)
2. CHE-HE-5026: Analytical Methods in Chemistry (4) + Lab (2)
3. CHE-HE-5036: Molecular Modelling & Drug Design (4) + Lab (2)

DSE-2(Any One from the following)

4. CHE-HE-5046: Novel Inorganic Solids (4) + Lab (2)
5. CHE-HE-5056: Polymer Chemistry (4) + Lab (2)
6. CHE-HE-5066: Instrumental Methods of Analysis (4) + Lab (2)

DSE for Semester VI

DSE-3(Any One from the following)

7. CHE-HE-6016: Green Chemistry (4) + Lab (2)
8. CHE-HE-6026: Industrial Chemicals & Environment (4) + Lab (2)
9. CHE-HE-6036: Inorganic Materials of Industrial Importance (4) + Lab (2)

DSE-4(Any One from the following)

10. CHE-HE-6046: Research Methodology for Chemistry (5) + Tutorials (1)
11. CHE-HE-6056: Dissertation

† **Skill Enhancement Courses (04 papers) (Credit: 04 each)**

SEC for Semester III

Any One from the following

1. AAA-SE-3014 : English (Syllabus will be available on the GU website)
2. CHE-SE-3024: IT Skills for Chemists
3. CHE-SE-3034: Basic Analytical Chemistry
4. CHE-SE-3044: Chemical Technology & Society
5. CHE-SE-3054: Chemoinformatics
6. CHE-SE-3064: Business Skills for Chemists
7. CHE-SE-3074: Intellectual Property Rights

SEC for Semester IV

Any One from the following

8. CHE-SE-4014: Analytical Clinical Biochemistry
9. CHE-SE-4024: Green Methods in Chemistry
10. CHE-SE-4034: Pharmaceutical Chemistry
11. CHE-SE-4044: Chemistry of Cosmetics & Perfumes
12. CHE-SE-4054: Pesticide Chemistry
13. CHE-SE-4064: Fuel Chemistry

****Ability Enhancement Compulsory Courses (02 papers) (Credit: 04 each)**

AECC for Semester I

1. ENG-AE-1014: English Communications (<https://sites.google.com/a/gauhati.ac.in/syllabus-ug-cbcs/aecc/english-a>)

AECC for Semester II

2. ENV-AE-2014: Environmental Studies (Syllabus will be available on the GU website)
-

CORE COURSE (HONOURS IN CHEMISTRY)

Semester I

CHE-HC-1016: INORGANIC CHEMISTRY-I

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objectives: This course aims at giving students theoretical understanding about the basic constituents of matter – atoms, ions and molecules in terms of their electronic structure and reactivity. Structure and bonding in/of these are to be dealt with basic quantum chemistry treatment. Reactivity of chemical species based on their electron transfer affinity is introduced. Further, periodic classification of elements in the periodic table and changes in properties along the periods and groups to be studied in detail. Accompanying laboratory course is designed for students to have hands-on experience of basic quantitative analytical techniques related to volumetric titrations.

Learning Outcome: On successful completion, students would have clear understanding of the concepts related to atomic and molecular structure, chemical bonding, periodic properties and redox behaviour of chemical species. Students will also have hands on experience of standard solution preparation in different concentration units and learn volumetric estimation through acid-base and redox reactions.

Atomic Structure:

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2 . Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Contour boundary and probability diagrams. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.

(14 Lectures)

Periodicity of Elements:

s, *p*, *d*, *f* block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to *s* & *p*-block.

- Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
- Atomic radii (van der Waals)
- Ionic and crystal radii.
- Covalent radii (octahedral and tetrahedral)
- Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
- Electron gain enthalpy, trends of electron gain enthalpy.
- Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

(16 Lectures)

Chemical Bonding:

(i) *Ionic bond*: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) *Covalent bond*: Lewis structure, Valence Bond theory (Heitler-London approach). Energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N₂, O₂, C₂, B₂, F₂, CO, NO, and their ions; HCl, BeF₂, CO₂, (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths.

Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization.

Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

(iii) *Metallic Bond*: Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

(iv) *Weak Chemical Forces*: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment) Effects of chemical force, melting and boiling points, solubility energetics of dissolution process.

(26 Lectures)

Oxidation-Reduction:

Redox equations, Standard Electrode Potential and its application to inorganic reactions. Principles involved in volumetric analysis to be carried out in class.

(4 Lectures)

Recommended Books:

1. Lee, J. D. Concise Inorganic Chemistry, 5th Ed., Oxford University Press, 2008.
2. Douglas, B.E. and Mc Daniel, D.H., Concepts and Models of Inorganic Chemistry, 3rd Ed. Wiley India, 2006.
3. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
5. Atkins, P.W. & Paula, J. Physical Chemistry, 11th Ed., Oxford University Press, 2018.
6. Housecroft, C. E. and Sharpe, A. G. Inorganic Chemistry, 5th Ed., Pearson, 2018.
7. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, Literary Licensing, LLC, 2012.

LAB

60 Lectures

(A) Titrimetric Analysis

- (i) Calibration and use of common laboratory apparatus
- (ii) Preparation of solutions of different Molarity/Normality of titrants

(B) Acid-Base Titrations

- (i) Estimation of carbonate and hydroxide present together in mixture.
- (ii) Estimation of carbonate and bicarbonate present together in a mixture.
- (iii) Estimation of free alkali present in different soaps/detergents

(C) Oxidation-Reduction Titrimetry

- (i) Estimation of Fe(II) and oxalic acid using standardized KMnO_4 solution.
- (ii) Estimation of oxalic acid and sodium oxalate in a given mixture.
- (ii) Estimation of Fe(II) with $\text{K}_2\text{Cr}_2\text{O}_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis; 6th Ed. Pearson Education, 2009.

CHE-HC-1026: PHYSICAL CHEMISTRY I

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course objective: This course contains states of matter- gaseous, liquid and solid states along with ionic equilibria. A small unit of molecular and crystal symmetry is also there in the course.

Learning outcome: In gaseous state unit the students will learn the kinetic theory of gases, ideal gas and real gases. In liquid state unit, the students are expected to learn the qualitative treatment of the structure of liquid along with the physical properties of liquid, viz, vapour pressure, surface tension and viscosity. In the molecular and crystal symmetry unit they will be introduced to the elementary idea of symmetry which will be useful to understand solid state chemistry and group theory in some higher courses. In solid state unit the students will learn the basic solid state chemistry application of x-ray crystallography for the determination of some very simple crystal structures. The students will also learn another important topic "ionic equilibria" in this course.

Gaseous state:

Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η ; variation of viscosity with temperature and pressure.

Maxwell distribution and its use in evaluating molecular velocities (average, root meansquare and most probable) and average kinetic energy.

Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, Z , and its variation with pressure for different gases. Causes of deviation from ideal behaviour. Van der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dieterici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states.

(18 Lectures)

Liquid state:

Qualitative treatment of the structure of the liquid state; Radial distribution function; physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases.

Qualitative discussion of structure of water.

(6 Lectures)

Molecular and Crystal Symmetry

Elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices.

(6 Lectures)

Solid state:

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices,; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Defects in crystals. Liquid crystals (Introductory idea)

(10 Lectures)

Ionic equilibria:

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di- and triprotic acids (exact treatment).

Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body.

Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations.

Multistage equilibria in polyelectrolyte systems; hydrolysis and hydrolysis constants.

(20 Lectures)

Recommended Books:

1. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry Ed., Oxford University Press (2006).
2. Ball, D. W. Physical Chemistry Thomson Press, India (2007).
3. Castellan, G. W. Physical Chemistry 4th Ed. Narosa (2004).
4. Mortimer, R. G. Physical Chemistry 3rd Ed. Elsevier: NOIDA, UP (2009).
5. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co. (2017)
6. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 1) McGraw Hill Education; Sixth edition (2019)

LAB

60 Lectures

1. Surface tension measurements.

- a. Determine the surface tension by (i) drop number (ii) drop weight method.
- b. Study the variation of surface tension of detergent solutions with concentration.

2. Viscosity measurement using Ostwald's viscometer.

- a. Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
- b. Study the variation of viscosity of sucrose solution with the concentration of solute.

3. Indexing of a given powder diffraction pattern of a cubic crystalline system.

4. pH metry

- a. Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
- b. Preparation of buffer solutions of different pH
 - i. Sodium acetate-acetic acid
 - ii. Ammonium chloride-ammonium hydroxide
- c. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.
- d. Determination of dissociation constant of a weak acid.

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).

Semester II

CHE-HC-2016: ORGANIC CHEMISTRY I

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objectives: This course is inducted to apprise students with introduction to organic compounds, electron displacement, type of reagents and reaction intermediates. The chemistry of aliphatic and aromatic hydrocarbon, conformational analysis of cycloalkanes and basic stereochemical phenomena are included.

Students are expected to learn different classes learn, explain, describe and analyze different classes of organic compounds, their reactivities and mechanisms along with stereo chemical considerations.

Learning Outcome: Students will be able to identify different classes of organic compounds, describe their reactivity and explain/analyze their chemical and stereo chemical aspects.

Basics of Organic Chemistry

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties.

Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength.

Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophilicity and basicity; Types, shape and their relative stability of Carbocations, Carbanions, Free radicals and Carbenes.

Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

(8 Lectures)

Stereochemistry:

Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: cis-trans and, syn-anti isomerism E/Z notations with C.I.P rules.

Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations.

(16 Lectures)

Chemistry of Aliphatic Hydrocarbons

A. Carbon-Carbon sigma bonds

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation -relative reactivity and selectivity.

B. Carbon-Carbon pi bonds:

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations.

Reactions of alkenes: Electrophilic additions and their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroborationoxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation). 1,2-and 1,4-addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene.

Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

C. Cycloalkanes and Conformational Analysis

Types of cycloalkanes and their relative stability, Baeyer strain theory, Conformation analysis of alkanes: Relative stability: Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms; Relative stability with energy diagrams.

(24 Lectures)

Aromatic Hydrocarbons

Aromaticity: Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups.

(12 Lectures)

Recommended Books:

1. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry* (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Eliel, E. L. & Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
4. Nasipuri, D. *Stereochemistry of Organic Compounds*, Wiley Eastern Limited.
5. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
6. Subrata Sen Gupta, *Basic Stereochemistry of Organic Molecules*, Oxford Higher Education.
7. Dhillon, R. S.; Singh, I. P. & Baskar, C. *Stereochemistry*, Narosa.
8. Loudon, G. M. *Organic Chemistry*, Oxford.

9. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003.
 10. Clayden, J., Greeves, N. & Warren, S. *Organic Chemistry*, Second edition, Oxford University Press, 2012.
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LAB

60 Lectures

1. Checking the calibration of the thermometer
2. Purification of organic compounds by crystallization using the following solvents:
 - a. Water
 - b. Alcohol
 - c. Alcohol-Water
3. Determination of the melting points of above compounds and unknown organic Compounds.
4. Effect of impurities on the melting point – mixed melting point of two unknown organic Compounds.
5. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and use of thiele tube method)
6. Chromatography
 - a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography
 - b. Separation of a mixture of two sugars by ascending paper chromatography
 - c. Separation of a mixture of o- and p-nitrophenol or o- and p-aminophenol by thin layer chromatography (TLC)

Recommended Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009).
 2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)
 3. Vogel, A. I. *Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis*, CBS Publishers and Distributors.
 4. Bhattacharyya, R. C, *A Manual of Practical Chemistry*.
 5. Dutta, S, *B. Sc. Honours Practical Chemistry*, Bharati Book Stall.
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CHE-HC-2026: PHYSICAL CHEMISTRY II

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: In this course the chemical thermodynamics, chemical equilibrium, solutions and colligative properties will be taught to the students. Another unit of this course is systems of variable compositions.

Learning Outcome: In this course the students are expected to learn laws of thermodynamics, thermochemistry, thermodynamic functions, relations between thermodynamic properties, Gibbs Helmholtz equation, Maxwell relations etc. Moreover the students are expected to learn partial molar quantities, chemical equilibrium, solutions and colligative properties. After completion of this course, the students will be able to understand the chemical systems from thermodynamic point of view.

Chemical Thermodynamics:

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics.

First law: Concept of heat, q , work, w , internal energy, U , and statement of first law; enthalpy, H , relation between heat capacities, calculations of q , w , U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Thermochemistry: Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations) and pressure on enthalpy of reactions. Adiabatic flame temperature, explosion temperature.

Second Law: Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Third Law: Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules.

Free Energy Functions: Gibbs and Helmholtz energy; variation of S , G , A with T , V , P ; spontaneous process-enthalpy change, entropy change and free energy change considerations. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

(36 Lectures)

Systems of Variable Composition:

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

(8 Lectures)

Chemical Equilibrium:

Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Coupling of exoergic and endoergic reactions. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants K_p , K_c and K_x . Le Chatelier principle (quantitative treatment); equilibrium between ideal gases and a pure condensed phase.

(8 Lectures)

Solutions and Colligative Properties:

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions.

Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

(8 Lectures)

Recommended Books

1. Peter, A. & Paula, J. de. *Physical Chemistry 9th Ed.*, Oxford University Press (2011).
2. Castellan, G. W. *Physical Chemistry 4th Ed.*, Narosa (2004).
3. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
4. McQuarrie, D. A. & Simon, J. D. *Molecular Thermodynamics* Viva Books Pvt. Ltd.: New Delhi (2004).
5. Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. *Commonly Asked Questions in Thermodynamics*. CRC Press: NY (2011).
6. Levine, I. N. *Physical Chemistry 6th Ed.*, Tata Mc Graw Hill (2010).
7. Metz, C.R. *2000 solved problems in chemistry*, Schaum Series (2006)
8. Puri, B. R.; Sharma, L. R.; Pathania, M. S. *Principles of Physical Chemistry*, Vishal Publishing Co.; 47th Ed. (2017)
9. Kapoor, K. L. *A Textbook of Physical Chemistry (Volume 2)* McGraw Hill Education; Sixth edition (2019)

LAB

60 Lectures

Thermochemistry

(a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).

(b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

(c) Calculation of the enthalpy of ionization of ethanoic acid.

(d) Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.

(e) Determination of basicity/proticity of a polyprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculate the enthalpy of neutralization of the first step.

(f) Determination of enthalpy of hydration of copper sulphate.

(g) Study of the solubility of benzoic acid in water and determination of ΔH .

Any other experiment carried out in the class.

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Athawale, V. D. & Mathur, P. *Experimental Physical Chemistry* New Age International: New Delhi (2001).

Semester III

CHE-HC-3016: INORGANIC CHEMISTRY-II

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: *This course starts with the basic principles of metallurgy so as to acquaint the students with the application of the redox chemistry they have learnt in the earlier course on inorganic chemistry. Concepts of protonic and non-protonic acids and bases are introduced for students to appreciate different types of chemical reactions. Periodic behavior of s and p block elements related to their electronic structure and their reactivity is included to acquaint students with the principles governing their reactivity. This course further intend to apprise students about the variety of compounds of the main group elements including oxides, hydrides, nitrides, interhalogens, noble gases and inorganic polymers. As part of the accompanying lab course, experiments involving iodo- and iodi-metric titrations are included for the students to explore other varieties of redox titration. Preparation of simple inorganic compounds is introduced to give hands-on experience of inorganic synthesis.*

Learning Outcome: *On successful completion of this course students would be able to apply theoretical principles of redox chemistry in the understanding of metallurgical processes.*

Students will be able to identify the variety of s and p block compounds and comprehend their preparation, structure, bonding, properties and uses. Experiments in this course will boost their quantitative estimation skills and introduce the students to preparative methods in inorganic chemistry.

General Principles of Metallurgy

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining.

(6 Lectures)

Acids and Bases

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB) Application of HSAB principle.

(8 Lectures)

Chemistry of s and p Block Elements:

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Complex formation tendency of s and p block elements.

Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrogen compounds, boranes, carboranes and graphitic compounds, silanes, oxides and oxoacids of nitrogen, phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogens and basic properties of halogens.

(30 Lectures)

Noble Gases:

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF₂, XeF₄ and XeF₆; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF₂). Molecular shapes of noble gas compounds (VSEPR theory).

(8 Lectures)

Inorganic Polymers:

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Silicates – clays and zeolites, polyphosphazenes, metal-organic framework compounds (MOFs).

(8 Lectures)

Recommended Books:

1. Lee, J. D., Concise Inorganic Chemistry, 5th Ed., Oxford University Press, 2008.
2. Douglas, B.E. and Mc Daniel, D.H., Concepts and Models of Inorganic Chemistry, 3rd Ed. Wiley India, 2006.
3. Greenwood, N.N. & Earnshaw, A., Chemistry of the Elements, 2nd Ed., Elsevier India, 2010.

4. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
 5. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
 6. Miessler, G. L. & Tarr, D. A., Inorganic Chemistry 4th Ed., Pearson, 2010.
 7. Weller, M., Armstrong, F., Rourke, J. & Overton, T., Inorganic Chemistry 6th Ed. 2015.
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LAB

60 Lectures

(A) Iodo / Iodimetric Titrations

- (i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).
- (ii) Estimation of (i) arsenite and (ii) antimony in tartar-emetic iodimetrically
- (iii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic preparations

- (i) Cuprous Chloride, CuCl
- (ii) Preparation of manganese(III) phosphate, $MnPO_4 \cdot H_2O$
- (iii) Preparation of aluminium potassium sulphate $KAl(SO_4)_2 \cdot 12H_2O$ (Potash alum) or Chrome alum.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
 2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.
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CHE-HC-3026: ORGANIC CHEMISTRY-II

(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

Course Objectives: This course is intended to apprise students about different classes of organic compounds, including halogenated hydrocarbons, alcohols, phenols, epoxides, carbonyl compounds and carboxylic and sulfonic acids.

Students are expected to learn and differentiate between various organic functional groups; explain, analyze and design transformations between different functional groups.

Learning Outcome: Students will be able to describe and classify organic compounds in terms of their functional groups and reactivity.

Chemistry of Halogenated Hydrocarbons:

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_Ni mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

Aryl halides: Preparation, including preparation from diazonium salts. nucleophilic aromatic substitution; S_NAr, Benzyne mechanism. Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

(16 Lectures)

Alcohols, Phenols, Ethers and Epoxides:

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouveault-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement;

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer-Tiemann and Kolbe's-Schmidt Reactions, Fries and Claisen rearrangements with mechanism;

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and LiAlH₄

(16 Lectures)

Carbonyl Compounds:

Preparation, properties, structure and reactivity;

Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisan-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α -substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, LiAlH₄, NaBH₄, MPV, PDC and PGC);

Addition reactions of unsaturated carbonyl compounds: Michael addition.

Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

(14 Lectures)

Carboxylic Acids and their Derivatives:

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids;

Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmannbromamide degradation and Curtius rearrangement.

(10 Lectures)

Sulphur containing compounds:

Preparation and reactions of thiols, thioethers and sulphonic acids.

(4 Lectures)

Recommended Books:

1. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
4. Clayden, J., Greeves, N. & Warren, S. *Organic Chemistry*, Second edition, Oxford University Press, 2012.
5. Keeler, J., Wothers, P. *Chemical Structure and Reactivity – An Integrated approach*, Oxford University Press.
6. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
7. Carey, F. A.; Sundberg, R. J. *Advanced Organic Chemistry: Reactions and Synthesis (Part B)*, Springer.

LAB

60 Lectures

1. Test of functional groups like alcohols, phenols, carbonyl and carboxylic acid group.
2. Organic preparations:
 - i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines *o*-, *m*-, *p*-anisidine) and phenols (β -naphthol, vanillin, salicylic acid) by any one method:
 - a. Using conventional method.
 - b. Using green approach
 - ii. Benzoylation of one of the following amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine) and one of the following phenols (β -naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.
 - iii. Oxidation of ethanol/ isopropanol (Iodoform reaction).
 - iv. Bromination of any one of the following:
 - a. Acetanilide by conventional methods
 - b. Acetanilide using green approach (Bromate-bromide method)
 - v. Nitration of any one of the following:
 - a. Acetanilide/nitrobenzene by conventional method
 - b. Salicylic acid by green approach (using ceric ammonium nitrate).

- vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.
- vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.
- viii. Hydrolysis of amides and esters.
- ix. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.
- x. *S*-Benzylisothiuronium salt of one each of water soluble and water insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).
- xi. Aldol condensation using either conventional or green method.
- xii. Benzil-Benzilic acid rearrangement.

The above preparations should be done using 0.5-1g of the organic compound. The solid samples must be collected and may be used for recrystallization, melting point and TLC.

Recommended Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)
3. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, University Press (2000).
4. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).
5. Vogel, A. I. *Elementary Practical Organic Chemistry, Part 1: Small scale Preparations*, CBS Publishers and Distributors.

CHE-HC-3036: PHYSICAL CHEMISTRY-III

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: The aim of this course is to teach students four important topics of physical chemistry- phase equilibria, chemical kinetics, surface chemistry and catalysis. Phase equilibria and chemical kinetics will be discussed in detail but surface chemistry and catalysis will be introduced to the students.

Learning Outcome: The students are expected to learn phase rule and its application in some specific systems. They will also learn rate laws of chemical transformation, experimental methods of rate law determination, steady state approximation etc. in chemical kinetics unit. After attending this course the students will be able to understand different types of surface adsorption processes and basics of catalysis including enzyme catalysis, acid base catalysis and particle size effect on catalysis.

Phase Equilibria:

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications.

Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions.

Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and nonideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation.

Nernst distribution law: its derivation and applications.

(28 Lectures)

Chemical Kinetics

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (iv) chain reactions.

Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates.

Reaction mechanism- steady-state approximation and rate determining step approximation methods.

(18 Lectures)

Catalysis:

Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis.

(8 Lectures)

Surface chemistry:

Physical adsorption, chemisorption, adsorption isotherms, nature of adsorbed state.

(6 Lectures)

Recommended Books:

1. Peter Atkins & Julio De Paula, *Physical Chemistry 9th Ed.*, Oxford University Press(2010).
2. Castellan, G. W. *Physical Chemistry*, 4th Ed., Narosa (2004).
3. McQuarrie, D. A. & Simon, J. D., *Molecular Thermodynamics*, Viva Books Pvt. Ltd.:New Delhi (2004).
4. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
5. Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. *Commonly Asked Questions in Thermodynamics*. CRC Press: NY (2011).
6. Zundhal, S.S. *Chemistry concepts and applications* Cengage India (2011).
7. Ball, D. W. *Physical Chemistry* Cengage India (2012).
8. Mortimer, R. G. *Physical Chemistry 3rd Ed.*, Elsevier: NOIDA, UP (2009).
9. Levine, I. N. *Physical Chemistry 6th Ed.*, Tata McGraw-Hill (2011).
10. Metz, C. R. *Physical Chemistry 2nd Ed.*, Tata McGraw-Hill (2009).

11. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co.; 47th Ed. (2017)
 12. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 5) McGraw Hill Education; 5th edition (2017)
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LAB

60 Lectures

- I. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.
- II. Phase equilibria: Construction of the phase diagram using cooling curves or ignition tube method:
 - a. simple eutectic and
 - b. congruently melting systems.
- III. Distribution of acetic/ benzoic acid between water and cyclohexane.
- IV. Study the equilibrium of at least one of the following reactions by the distribution method:
 - (i) $I_2(aq) + I^- \rightarrow I_3(aq)$
 - (ii) $Cu^{2+}(aq) + nNH_3 \rightarrow Cu(NH_3)_n$
- V. Study the kinetics of the following reactions.
 1. Initial rate method: Iodide-persulphate reaction
 2. Integrated rate method:
 - a. Acid hydrolysis of methyl acetate with hydrochloric acid.
 - b. Saponification of ethyl acetate.
 3. Compare the strengths of HCl and H₂SO₄ by studying kinetics of hydrolysis of methyl acetate.
- VI. Adsorption
 - I. Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
 2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
 3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).
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Semester IV

CHE-HC-4016: INORGANIC CHEMISTRY-III

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: This course introduces students to coordination chemistry. Various aspects like nomenclature, structure, bonding, variety and reactivity of the coordination compounds are included for the students to appreciate.

Bioinorganic chemistry is included in this course to acquaint students on the useful and harmful aspects of metals in biological systems.

Through the accompanying lab course, experiments related to gravimetric analysis, synthesis of coordination compounds and separation of metal ions using chromatography is included. This will broaden the experimental skills of the students where students will learn about various aspects of experiment design depending upon the requirements like synthesis, estimation or separation.

Learning Outcome: On successful completion, students will be able name coordination compounds according to IUPAC, explain bonding in this class of compounds, understand their various properties in terms of CFSE and predict reactivity. Students will be able to appreciate the general trends in the properties of transition elements in the periodic table and identify differences among the rows.

Through the experiments students not only will be able to prepare, estimate or separate metal complexes/compounds but also will be able to design experiments independently which they should be able to apply if and when required.

Coordination Chemistry:

Coordination compounds, types of ligands, Werner's theory, IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers.

Valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of $10 Dq$ (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of $10 Dq$ (Δ_o , Δ_t). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspects of ligand field and MO Theory. Chelate effect, polynuclear complexes, labile and inert complexes.

(26 Lectures)

Transition Elements:

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Frost diagrams). Difference between the first, second and third transition series.

Chemistry of Ti, V, Cr Mn, Fe and Co (Chemistry of first -row transition elements) in various oxidation states as halides, oxides, hydroxides.

(18 Lectures)

Lanthanoids and Actinoids:

Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction, separation of lanthanides (ion-exchange method only).

(6 Lectures)

Bioinorganic Chemistry:

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on the distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd and As), reasons for toxicity, Use of chelating agents in medicine.

Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

(10 Lectures)

Recommended Books:

1. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
2. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed., Pearson Education India, 2006.
3. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry, Panima Publishing Company, 1994.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
5. Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
6. Greenwood, N.N. & Earnshaw, A., Chemistry of the Elements, 2nd Ed., Elsevier India, 2010.

LAB

60 Lectures

Gravimetric Analysis:

- i. Estimation of nickel(II) using dimethylglyoxime (DMG).
- ii. Estimation of copper as CuSCN
- iii. Estimation of iron as Fe₂O₃ by precipitating iron as Fe(OH)₃.
- iv. Estimation of Al (III) by precipitating with oxine and weighing as Al(oxine)₃ (aluminium oxinate).

Inorganic Preparations:

- i. Tetraamminecopper(II) sulphate, [Cu(NH₃)₄]SO₄.H₂O
- ii. *Cis* and *trans* K[Cr(C₂O₄)₂.(H₂O)₂] Potassium dioxalatoaquachromate (III)
- iii. Tetraamminecarbonatocobalt (III) ion
- iv. Potassium tris(oxalato)ferrate(III)

Chromatography of metal ions

Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:

- i. Ni(II) and Co(II)
- ii. Fe(III) and Al(III)

Recommended Book:

1. Mendham, J. et al.: Vogel's Textbook of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.

2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.
 3. *Inorganic Syntheses*, Vol. 1-10.
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CHE-HC-4026: ORGANIC CHEMISTRY-III

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objectives: The course intrudes students to different classes of N-based compounds, including alkaloids and terpenoids and their potential application.

Students are expected to learn about different classes of N-based compounds; their structures, synthesis and reactivity.

Learning Outcome: Students shall demonstrate the ability to identify and classify different types of N-based derivatives, alkaloids and hetrocyclic compounds/explain their structure mechanism and reactivity/critically examine their synthesis and reactions mechanism.

Nitrogen Containing Functional Groups

Preparation and important reactions of nitro and compounds, nitriles and isonitriles

Amines: Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid.

Diazonium Salts: Preparation and their synthetic applications.

(18 Lectures)

Polynuclear Hydrocarbons

Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

(8 Lectures)

Heterocyclic Compounds

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom;

Synthesis, reactions and mechanism of substitution reactions of:

Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine.

Indole: Fischer indole synthesis and Madelung synthesis).

Quinoline and isoquinoline: Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner- Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction

(22 Lectures)

Alkaloids

Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

(6 Lectures)

Terpenes

Occurrence, classification, isoprene rule; Elucidation of structure and synthesis of Citral, Neral and α -terpineol.

(6 Lectures)

Recommended Books:

1. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
 2. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
 3. Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
 4. Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
 5. Kalsi, P. S. *Textbook of Organic Chemistry 1st Ed.*, New Age International (P) Ltd. Pub.
 6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
 7. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Parakashan (2010). (2010).
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LAB

60 Lectures

1. Detection N, S, halogens in organic compounds.
2. Functional group test for nitro, amine and amide groups.
3. Qualitative analysis of unknown organic compounds containing simple functional groups (alcohols, carboxylic acids, phenols and carbonyl compounds)

Recommended Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic*

- Chemistry, 5th Ed.*, Pearson (2012)
3. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, University Press (2000).
 4. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).
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CHE-HC-4036: PHYSICAL CHEMISTRY-IV

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: The aim of this course is to introduce students with primarily two areas of physical chemistry- electrochemistry and electrical and magnetic properties of atoms and molecules. It contains three units- conductance, electrochemistry and electrical & magnetic properties of atoms and molecules.

Learning Outcome: In this course the students will learn theories of conductance and electrochemistry. Students will also understand some very important topics such as solubility and solubility products, ionic products of water, conductometric titrations etc. The students are also expected to understand the various parts of electrochemical cells along with Faraday's Laws of electrolysis. The students will also gain basic theoretical idea of electrical & magnetic properties of atoms and molecules.

Conductance

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules.

Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

(20 Lectures)

Electrochemistry

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials.

Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb₂O₃ electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric

titrations (acid-base, redox, precipitation). Applications of electrolysis in metallurgy and industry.

(28 Lectures)

Electrical & Magnetic Properties of Atoms and Molecules

Basic ideas of electrostatics, Electrostatics of dielectric media, Clausius-Mosotti equation, Lorenz-Laurentz equation, Dipole moment and molecular polarizabilities and their measurements. Diamagnetism, paramagnetism, magnetic susceptibility and its measurement, molecular interpretation.

(12 Lectures)

Recommended Books:

1. Atkins, P.W & Paula, J.D. *Physical Chemistry*, 9th Ed., Oxford University Press (2011).
2. Castellan, G. W. *Physical Chemistry 4th Ed.*, Narosa (2004).
3. Mortimer, R. G. *Physical Chemistry 3rd Ed.*, Elsevier: NOIDA, UP (2009).
4. Barrow, G. M., *Physical Chemistry 5th Ed.*, Tata McGraw Hill: New Delhi (2006).
5. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
6. Rogers, D. W. *Concise Physical Chemistry* Wiley (2010).
7. Silbey, R. J.; Alberty, R. A. & Bawendi, M. G. *Physical Chemistry 4th Ed.*, John Wiley & Sons, Inc. (2005).
8. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co.; 47th Ed. (2017)
9. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 1) McGraw Hill Education; Sixth edition (2019)

LAB

60 Lectures

Conductometry

- I. Determination of cell constant
- II. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
- III. Perform the following conductometric titrations:
 - i. Strong acid vs. strong base
 - ii. Weak acid vs. strong base
 - iii. Mixture of strong acid and weak acid vs. strong base
 - iv. Strong acid vs. weak base

Potentiometry

- I Perform the following potentiometric titrations:
 - i. Strong acid vs. strong base
 - ii. Weak acid vs. strong base
 - iii. Dibasic acid vs. strong base
 - iv. Potassium dichromate vs. Mohr's salt

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R.

- Chand & Co.: New Delhi (2011).
- Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
 - Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).
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Semester V

CHE-HC-5016: ORGANIC CHEMISTRY-IV

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objectives: This course introduces students to nucleic acids, amino acids and pharmaceutical compounds.

Students will be familiarized with the importance of nucleic acids, amino acids and develop basic understanding of enzymes, bioenergetics and pharmaceutical compounds.

Learning Outcome: Students will be able to explain/describe the important features of nucleic acids, amino acids and enzymes and develop their ability to examine their properties and applications.

Nucleic Acids

Components of nucleic acids; Nucleosides and nucleotides;

Synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine;
Polynucleotides: DNA and RNA

(9 Lectures)

Amino Acids, Peptides and Proteins

Amino acids, Peptides and their classification.

α -Amino Acids - Synthesis, ionic properties and reactions. Zwitterions, pK_a values, isoelectric point and electrophoresis;

Study of peptides: determination of their primary structures-end group analysis, methods of peptide synthesis. Synthesis of peptides using N-protecting, C-protecting and C-activating groups -Solid-phase synthesis

(16 Lectures)

Enzymes

Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes.

Mechanism of enzyme action (taking trypsin as example), factors affecting enzyme action, coenzymes and cofactors and their role in biological reactions, specificity of enzyme action

(including stereospecificity), enzyme inhibitors and their importance, phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition).

(8 Lectures)

Lipids

Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, saponification value, acid value, iodine number, rancidity.

(6 Lectures)

Concept of Energy in Biosystems

Cells obtain energy by the oxidation of foodstuff (organic molecules).

Introduction to metabolism (catabolism, anabolism).

ATP: The universal currency of cellular energy, ATP hydrolysis and free energy change.

Agents for transfer of electrons in biological redox systems: NAD⁺, FAD.

Conversion of food to energy: Outline of catabolic pathways of carbohydrate- glycolysis, fermentation, Krebs cycle.

Overview of catabolic pathways of fat and protein.

Interrelationship in the metabolic pathways of protein, fat and carbohydrate.

Calorific value of food, standard calorie content of food types.

(9 Lectures)

Pharmaceutical Compounds: Structure and Importance

Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis), Antimalarials: Chloroquine (with synthesis). An elementary treatment of Antibiotics and detailed study of chloramphenicol, Medicinal values of curcumin (turmeric), azadirachtin (neem), vitamin C and antacid (ranitidine).

(12 Lectures)

Recommended Books:

1. Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. VIth Edition. W.H. Freeman and Co.
2. Nelson, D.L., Cox, M.M. and Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.
3. Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.

LAB

60 Lectures

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.
3. Estimation of proteins by Lowry's method.
4. Study of the action of salivary amylase on starch at optimum conditions.
5. Effect of temperature on the action of salivary amylase.
6. Saponification value of an oil or a fat.
7. Determination of Iodine number of an oil/ fat.
8. Isolation and characterization of DNA from onion/ cauliflower/peas.

Recommended Books:

1. Arthur, I. V. *Quantitative Organic Analysis*, Pearson.
2. Plummer, D. T. *An Introduction to Practical Biochemistry*, 3rd Edition, McGraw Hill.

CHE-HC-5026: PHYSICAL CHEMISTRY V**(Credits: Theory-04, Lab-02)****Theory: 60 Lectures**

Course Objective: The aim of this course is to introduce the students with three important areas- quantum chemistry, molecular spectroscopy and photochemistry. In quantum chemistry unit the students will be taught the postulates of quantum mechanics and the application of quantum mechanical ideas in some simple systems such as particle in a box, rigid rotor, simple harmonic oscillator etc. In spectroscopy unit, rotational, vibrational, Raman, electronic, spin resonance, and electronic spectroscopy will be introduced.

Learning Outcome: After completion of this course the students are expected to understand the application of quantum mechanics in some simple chemical systems such as hydrogen atom or hydrogen like ions. The students will also learn chemical bonding in some simple molecular systems. They will be able to understand the basics of various kinds of spectroscopic techniques and photochemistry.

Quantum Chemistry:

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and “particle-in-a-box” (rigorous treatment), quantization of energy levels, zero-point energy Extension to two and three dimensional boxes, separation of variables, degeneracy.

Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wavefunctions. Vibrational energy of diatomic molecules and zero-point energy.

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component.

Rigid rotator model of rotation of diatomic molecule. Schrödinger equation, transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution.

Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus.

Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom).

Chemical bonding: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+ . Bonding and antibonding orbitals. Qualitative extension to H_2 . Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, detailed solution not required) and their limitations. Refinements of the two approaches (Configuration Interaction for MO, ionic terms in VB). Qualitative description of LCAO-MO treatment of homonuclear and heteronuclear diatomic molecules (HF, LiH). Localised and non-localised molecular orbitals treatment of triatomic (BeH_2 , H_2O) molecules. Qualitative MO theory and its application to AH_2 type molecules.

(24 Lectures)

Molecular Spectroscopy:

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation.

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.

(24 Lectures)

Photochemistry

Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws, of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, photochemical equilibrium and the differential rate of photochemical reactions, photosensitised reactions, quenching. Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence.

(12 Lectures)

Recommended Books:

1. Banwell, C. N. & McCash, E. M. Fundamentals of Molecular Spectroscopy 4th Ed. Tata McGraw-Hill: New Delhi (2006).
2. Chandra, A. K. Introductory Quantum Chemistry Tata McGraw-Hill (2001).
3. House, J. E. Fundamentals of Quantum Chemistry 2nd Ed. Elsevier: USA (2004).
4. Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).
5. Kakkar, R. Atomic & Molecular Spectroscopy, Cambridge University Press (2015).

6. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 4) McGraw Hill Education; 5th edition (2017)
 7. Sen, B. K. Quantum Chemistry- Including Spectroscopy, Kalyani Publishers; 4th edition (2011)
 8. McQuarrie, D. A. Quantum Chemistry, Viva Books (2016)
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LAB

60 Lectures

UV/Visible spectroscopy

- I. Study the 200-500 nm absorbance spectra of KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule⁻¹, kJ mol⁻¹, cm⁻¹, eV).
- II. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $\text{K}_2\text{Cr}_2\text{O}_7$.
- III. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.

Colourimetry

- I. Verify Lambert-Beer's law and determine the concentration of $\text{CuSO}_4/\text{KMnO}_4/\text{K}_2\text{Cr}_2\text{O}_7$ in a solution of unknown concentration
- II. Determine the concentrations of KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ in a mixture.
- III. Study the kinetics of iodination of propanone in acidic medium.
- IV. Determine the amount of iron present in a sample using 1,10-phenanthroline.
- V. Determine the dissociation constant of an indicator (phenolphthalein).
- VI. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.
- VII. Analysis of the given vibration-rotation spectrum of $\text{HCl}(\text{g})$

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
 2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
 3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).
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Semester VI

CHE-HC-6016: INORGANIC CHEMISTRY-IV

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: The unit on reaction mechanism is included for the students to get acquainted with the kinetic and thermodynamic factors governing the reaction path and stability of inorganic compounds.

Organometallic compounds are introduced so as to apprise students about the importance of metal carbon bond to form complexes and their application as catalysts. Students are expected to learn factors leading to stability of organometallic compounds, their synthesis, reactivity and uses.

Qualitative inorganic analysis is included to give students an idea and hands on experience of application of inorganic chemistry. Students should learn how differential reactivity under different conditions of pH can be used to identify variety of ions in a complex mixture.

Experiments related to synthesis and characterization of coordination compounds are included to supplement their theoretical knowledge.

Learning Outcome: By studying this course the students will be expected to learn about how ligand substitution and redox reactions take place in coordination complexes.

Students will also learn about organometallic compounds, comprehend their bonding, stability, reactivity and uses. They will be familiar with the variety of catalysts based on transition metals and their application in industry.

On successful completion, students in general will be able to appreciate the use of concepts like solubility product, common ion effect, pH etc. in analysis of ions and how a clever design of reactions, it is possible to identify the components in a mixture.

With the experiments related to coordination compound synthesis, calculation of $10Dq$, controlling factors etc. will make the students appreciate the concepts of theory in experiments.

Mechanism of Inorganic Reactions

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans-effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes. Electron transfer reactions.

(18 Lectures)

Organometallic Compounds

Definition and classification of organometallic compounds on the basis of bond type.

Concept of hapticity of organic ligands.

Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π -acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls.

Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.

Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich

condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

(22 Lectures)

Transition Metals in Catalysis

Study of the following industrial processes and their mechanism:

1. Alkene hydrogenation (Wilkinson's Catalyst)
2. Hydroformylation (Co catalysts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes

(10 Lectures)

Theoretical Principles in Qualitative Inorganic Analysis (H₂S Scheme)

Basic principles involved in analysis of cations and anions and solubility products, common ion effect. Principles involved in separation of cations into groups and choice of group reagents. Interfering anions (fluoride, borate, oxalate and phosphate) and need to remove them after Group II.

(10 Lectures)

Recommended Books:

1. Vogel, A.I. *Qualitative Inorganic Analysis*, Longman, 1972.
2. Svehla, G. & Sivasankar, B., *Vogel's Qualitative Inorganic Analysis*, 7th Ed., Prentice Hall, 2012.
3. Cotton, F.A., Wilkinson, G. and Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley, 2007.
4. Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry*. 6th Ed., Wiley-VCH, 2007.
5. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., *Inorganic Chemistry: Principles of Structure and Reactivity*, 4th Ed., Pearson Education India, 2006.
6. Sharpe, A.G. *Inorganic Chemistry*, 4th Indian Reprint (Pearson Education) 2005
7. Douglas, B.E. and Mc Daniel, D.H., *Concepts and Models of Inorganic Chemistry*, 3rd Ed. Wiley India, 2006.
8. Greenwood, N.N. & Earnshaw, A., *Chemistry of the Elements*, 2nd Ed., Elsevier India, 2010.
9. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Oxford University Press, 2008.
10. Powell, P. *Principles of Organometallic Chemistry*, Chapman and Hall, 1988.
11. Shriver, D.D. & Atkins, P., *Inorganic Chemistry 2nd Ed.*, Oxford University Press, 1994.
12. Basolo, F. & Person, R. *Mechanisms of Inorganic Reactions: Study of Metal Complexes in Solution* 2nd Ed., John Wiley & Sons Inc; NY.
13. Purcell, K.F. & Kotz, J.C., *Inorganic Chemistry*, W.B. Saunders Co. 1977
14. Miessler, G. L. & Tarr, D. A., *Inorganic Chemistry* 4th Ed., Pearson, 2010.
15. Crabtree, Robert H. *The Organometallic Chemistry of the Transition Metals. j* New York, NY: John Wiley, 2000.
16. Spessard, Gary O., & Gary L. Miessler. *Organometallic Chemistry*. Upper Saddle River, NJ: Prentice-Hall, 1996.

LAB

60 Lectures

- Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested: CO_3^{2-} , NO_2^- , S^{2-} , SO_3^{2-} , $\text{S}_2\text{O}_3^{2-}$, CH_3COO^- , F^- , Cl^- , Br^- , I^- , NO_3^- , BO_3^{3-} , $\text{C}_2\text{O}_4^{2-}$, PO_4^{3-} , NH_4^+ , K^+ , Pb^{2+} , Cu^{2+} , Cd^{2+} , Bi^{3+} , Sn^{2+} , Sb^{3+} , Fe^{3+} , Al^{3+} , Cr^{3+} , Zn^{2+} , Mn^{2+} , Co^{2+} , Ni^{2+} , Ba^{2+} , Sr^{2+} , Ca^{2+} , Mg^{2+}
- Mixtures should preferably contain one interfering anion, **or** insoluble component (BaSO_4 , SrSO_4 , PbSO_4 , CaF_2 or Al_2O_3) **or** combination of anions e.g. CO_3^{2-} and SO_3^{2-} , NO_2^- and NO_3^- , Cl^- and Br^- , Cl^- and I^- , Br^- and I^- , NO_3^- and Br^- , NO_3^- and I^- .
- Spot tests should be done whenever possible.
- Synthesis of ammine complexes of Ni(II) and their ligand exchange reactions involving bidentate ligands like acetylacetonate, dimethylglyoxime, glycine, etc.
- Preparation of acetylacetonate complexes of $\text{Cu}^{2+}/\text{Fe}^{3+}$.
- Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs. thermodynamic factors.
- Determination of ϵ_{max} value from UV-visible spectra of complexes.
- Measurement of 10 Dq by spectrophotometric method, verification of spectrochemical series.

Recommended Books

1. Vogel's *Qualitative Inorganic Analysis*, Revised by G. Svehla.
2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.

CHE-HC-6026: ORGANIC CHEMISTRY-V

(Credits: Theory-04, Lab -02)

Theory: 60 Lectures

(24 Lectures)

Course Objectives: This is a basic course in organic spectroscopy and provides introduction to carbohydrate chemistry, dyes and polymers.

Students are expected to learn about the different spectroscopic techniques and their applications in organic chemistry. Students shall be apprised with carbohydrate chemistry, dyes and polymers and their structure, reactivity and chemical properties.

Learning Outcome: Students will be able to explain/describe basic principles of different spectroscopic techniques and their importance in chemical/organic analysis. Students shall be able to classify/identify/critically examine carbohydrates, polymers and dye materials.

Spectroscopy

Introduction to absorption and emission spectroscopy.

UV Spectroscopy: Types of electronic transitions, λ_{max} , Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Application of Woodward

Rules for calculation of λ_{\max} for the following systems: α,β unsaturated aldehydes, ketones, carboxylic acids and esters; Conjugated dienes: alicyclic, homoannular and heteroannular; Extended conjugated systems (aldehydes, ketones and dienes); distinction between cis and trans isomers.

IR Spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O, N and S containing functional groups; Effect of H-bonding, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis.

NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin – Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds.

Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals.

Applications of IR, UV and NMR for identification of simple organic and inorganic molecules.

(24 Lectures)

Carbohydrates

Occurrence, classification and their biological importance.

Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, determination of ring size of glucose and fructose, Haworth projections and conformational structures; Interconversions of aldoses and ketoses; Killiani-Fischer synthesis and Ruff degradation;

Disaccharides – Structure elucidation of maltose, lactose and sucrose.

Polysaccharides – Elementary treatment of starch, cellulose and glycogen.

(16 Lectures)

Dyes

Classification, Colour and constitution; Mordant and Vat Dyes; Synthesis and applications of: Azo dyes – Methyl Orange and Congo Red (mechanism of Diazo Coupling); Triphenyl Methane Dyes -Malachite Green, Rosaniline and Crystal Violet; Phthalein Dyes – Phenolphthalein and Fluorescein; Natural dyes synthesis of Alizarin and Indigotin; Edible Dyes with examples.

(8 Lectures)

Polymers

Introduction and classification.

Number average molecular weight, Weight average molecular weight, Degree of polymerization, Polydispersity Index.

Polymerisation reactions -Addition and condensation -Mechanism of cationic, anionic and free radical addition polymerization; Preparation and applications of plastics – thermosetting (phenol-formaldehyde, Polyurethanes) and thermosoftening (PVC, polythene);

Fabrics – natural and synthetic (acrylic, polyamido, polyester); Rubbers – natural and synthetic: Buna-S, Chloroprene and Neoprene; Vulcanization; Polymer additives;

Introduction to liquid crystal polymers; Biodegradable and conducting polymers with examples.

(12 Lectures)

Recommended Books:

1. Banwell, C. N. & Mc.Cash, E. M. *Fundamentals of Molecular Spectroscopy*, 4th Edition, McGraw Hill.
 2. Pavia, Lampman, Kriz & Vyvyan, *Introduction to Spectroscopy*, 5th Edition, CENGAGE Learning.
 3. Silverstein, R. M.; Webster, F. X.; Kiemle, D. J. & Bryce, D. L. *Spectrometric Identification of Organic Compounds*, 8th Edition, Wiley.
 4. Kemp, W. *Organic Spectroscopy*, Palgrave.
 5. Kalsi, P. S. *Textbook of Organic Chemistry 1st Ed.*, New Age International (P) Ltd. Pub.
 6. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
 7. Billmeyer, F. W. *Textbook of Polymer Science*, John Wiley & Sons, Inc.
 8. Gowariker, V. R.; Viswanathan, N. V. & Sreedhar, J. *Polymer Science*, New Age International (P) Ltd. Pub.
 9. Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
 10. Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
 11. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
 12. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Prakashan (2010).
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LAB

60 Lectures

1. Extraction of caffeine from tea leaves.
2. Preparation of sodium polyacrylate.
3. Preparation of urea formaldehyde.
4. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars
5. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, for e.g. salicylic acid, cinnamic acid, nitrophenols etc.
6. Identification of simple organic compounds by IR spectroscopy and NMR spectroscopy (Spectra to be provided).
7. Preparation of methyl orange.

Recommended Books:

1. Vogel, A.I. *Quantitative Organic Analysis*, Part 3, Pearson (2012).

2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)
 3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)
 4. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, University Press (2000).
 5. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).
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CHEMISTRY-Discipline Specific Electives (DSE)

CHE-HE-5016: APPLICATIONS OF COMPUTERS IN CHEMISTRY

(Credits: Theory-04, Lab -02)

Theory: 60 Lectures

Course Objective: This course intends to make learners familiar with basics of computer language, computer programming, handling of experimental data, curve fitting etc to analyze experimental results. This basic knowledge will help the students to perform and interpret results of various chemistry practicals.

Learning Outcome: After the completion of this course it will help the student to interpret laboratory data, curve fitting of experimental work, also perform quantum mechanical calculations for various molecular models.

Basics:

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

Numerical methods:

Roots of equations: Numerical methods for roots of equations: Quadratic formula, iterative method, Newton-Raphson method, Binary bisection and Regula-Falsi.

Differential calculus: Numerical differentiation.

Integral calculus: Numerical integration (Trapezoidal and Simpson's rule), probability distributions and mean values.

Simultaneous equations: Matrix manipulation: addition, multiplication. Gauss-Siedal method.

Interpolation, extrapolation and curve fitting: Handling of experimental data.

Conceptual background of molecular modelling: Potential energy surfaces. Elementary ideas of molecular mechanics and practical MO methods.

Recommended Books:

1. Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
 2. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
 3. Noggle, J. H. *Physical chemistry on a Microcomputer*. Little Brown & Co. (1985).
 4. Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).
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LAB

60 Lectures

Computer programs based on numerical methods for

1. Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).
2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).
3. Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values.
4. Matrix operations. Application of Gauss-Siedel method in colourimetry.
5. Simple exercises using molecular visualization software.

Recommended Books:

1. McQuarrie, D. A. *Mathematics for Physical Chemistry* University Science Books (2008).
 2. Mortimer, R. *Mathematics for Physical Chemistry*. 3rd Ed. Elsevier (2005).
 3. Steiner, E. *The Chemical Maths Book* Oxford University Press (1996).
 4. Yates, P. *Chemical Calculations*. 2nd Ed. CRC Press (2007).
 5. Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
 6. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
 7. Noggle, J. H. *Physical Chemistry on a Microcomputer*. Little Brown & Co. (1985).
 8. Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).
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CHE-HE-5026: ANALYTICAL METHODS IN CHEMISTRY

(Credits: Theory-04, Lab -02)

Theory: 60 Lectures

Course Objective: This is an elective course designed to complement the needs of students who wish to learn more about the qualitative/quantitative characterization and separation techniques. The content of this course aims to cover some of the widely used instrumental techniques for characterization of samples. Experiments included aim at giving students hands on experience using different instrumental techniques and chemical analysis.

Learning outcome: On successful completion students will be have theoretical understanding about choice of various analytical techniques used for qualitative and quantitative characterization of samples. At the same time through the experiments students will gain hands on experience of the discussed techniques. This will enable students to take judicious decisions while analyzing different samples.

Qualitative and quantitative aspects of analysis:

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

(5 Lectures)

Optical methods of analysis:

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of metal complex composition using Job's method of continuous variation and mole ratio method.

Infrared Spectroscopy: Basic principles of instrumentation (choice of source, monochromator & detector) for continuous wave and Fourier transform spectrometers; sampling techniques.

Structure elucidation through interpretation of data. Effect and importance of isotope substitution.

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and detector, choice of flame and Burner designs. Techniques of atomization and sample introduction. Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

(25 Lectures)

Thermal methods of analysis:

Theory of thermogravimetry (TG), basic principle of instrumentation.
Techniques for quantitative estimation of Ca and Mg from their mixture.

(5 Lectures)

Electroanalytical methods:

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

(10 Lectures)

Separation techniques:

Solvent extraction: Classification, principle and efficiency of the technique.

Mechanism of extraction: extraction by solvation and chelation.

Technique of extraction: batch, continuous and counter current extractions.

Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

Chromatography: Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange.

Development of chromatograms: frontal, elution and displacement methods.

Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral chromatographic techniques using chiral columns (GC and HPLC).

Role of computers in instrumental methods of analysis.

(15 Lectures)

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. CBS Publishers & Distributors, 2004.
3. Christian, Gary D: Analytical Chemistry, 6th Ed. Wiley India (P) Ltd., 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, 4th Ed. W. H. Freeman, 2008.

5. Khopkar, S.M.: Basic Concepts of Analytical Chemistry, 3rd Ed. New Age, International Publisher, 2009.
 6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, 6th Ed. Thomson Asia Pvt. Ltd. Singapore.
 7. Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.1979
 8. Ditts, R.V. *Analytical Chemistry: Methods of separation*. Van Nostrand, New York, 1974.
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LAB

60 Lectures

1. Separation Techniques

I. Chromatography:

(a) Separation of mixtures

(i) Paper chromatographic separation of Fe^{3+} , Al^{3+} , and Cr^{3+} .

(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.

(b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their R_f values.

(c) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:

(i) To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+} - DMG complex in chloroform, and determine its concentration by spectrophotometry.

(ii) Solvent extraction of zirconium with amberliti LA-1, separation from a mixture of irons and gallium.

3. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

4. Determination of Na, Ca, Li in cola drinks and fruit juices using fame photometric techniques.

5. Analysis of soil:

(i) Determination of pH of soil.

(ii) Total soluble salt

(iii) Estimation of calcium, magnesium, phosphate, nitrate

6. Ion exchange:

(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

- (ii) Separation of metal ions from their binary mixture.
- (iii) Separation of amino acids from organic acids by ion exchange chromatography.

7. Spectrophotometry

- (i) Determination of pKa values of indicator using spectrophotometry.
- (ii) Structural characterization of compounds by infrared spectroscopy.
- (iii) Determination of dissolved oxygen in water.
- (iv) Determination of chemical oxygen demand (COD).
- (v) Determination of Biological oxygen demand (BOD).
- (vi) Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job's method.

Recommended Books:

1. Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5th Ed. The English Language Book Society of Longman .
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, Gary D; Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
9. Ditts, R.V. *Analytical Chemistry: Methods of separation*. Van Nostrand, New York, 1974.

CHE-HE-5036: MOLECULAR MODELLING & DRUG DESIGN

(Credits: Theory-04, Lab -02)

Theory: 60 Lectures

Course Objective: The course introduces students to the basic principles of computer assisted drug design, modelling and the important theoretical concepts and programming.

Learning Outcome: Students will be able to identify basic components of computer and programming as applied to computer assisted design and modelling of molecules.

Introduction to Molecular Modelling:

Introduction. Useful Concepts in Molecular Modelling: Coordinate Systems. Potential Energy Surfaces. Molecular Graphics. Surfaces. Computer Hardware and Software. The Molecular Modelling Literature.

(10 Lectures)

Force Fields:

Fields. Bond Stretching. Angle Bending. Introduction to nonbonded interactions. Electrostatic interactions. van der Waals Interactions. Hydrogen bonding in Molecular Mechanics. Force Field Models for the Simulation of Liquid Water.

(14 Lectures)

Energy Minimization and Computer Simulation:

Minimization and related methods for exploring the energy surface. Non-derivative method, First and second order minimization methods. Computer simulation methods. Simple thermodynamic properties and Phase Space. Boundaries. Analyzing the results of a simulation and estimating Errors.

(12 Lectures)

Molecular Dynamics & Monte Carlo Simulation:

Molecular Dynamics Simulation Methods. Molecular Dynamics using simple models. Molecular Dynamics with continuous potentials. Molecular Dynamics at constant temperature and pressure. Metropolis method. Monte Carlo simulation of molecules. Models used in Monte Carlo simulations of polymers.

(12 Lectures)

Structure Prediction and Drug Design:

Structure prediction - Introduction to comparative Modeling. Sequence alignment. Constructing and evaluating a comparative model. Predicting protein structures by 'Threading', Molecular docking. Structure based de novo ligand design,

Drug Discovery – Chemoinformatics – QSAR.

(12 Lectures)

Recommended Books:

1. A.R. Leach, Molecular Modelling Principles and Application, Longman, 2001.
 2. J.M. Haile, Molecular Dynamics Simulation Elementary Methods, John Wiley and Sons, 1997.
 3. Satya Prakash Gupta, QSAR and Molecular Modeling, Springer - Anamaya Publishers, 2008.
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LAB

60 Lectures

i. Compare the optimized C-C bond lengths in ethane, ethene, ethyne and benzene. Visualize the molecular orbitals of the ethane σ bonds and ethene, ethyne, benzene and pyridine π bonds.

- ii. (a) Perform a conformational analysis of butane. (b) Determine the enthalpy of isomerization of *cis* and *trans* 2-butene.
- iii. Visualize the electron density and electrostatic potential maps for LiH, HF, N₂, NO and CO and comment. Relate to the dipole moments. Animate the vibrations of these molecules.
- iv. (a) Relate the charge on the hydrogen atom in hydrogen halides with their acid character. (b) Compare the basicities of the nitrogen atoms in ammonia, methylamine, dimethylamine and trimethylamine.
- v. (a) Compare the shapes of the molecules: 1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2-propanol. Note the dipole moment of each molecule. (b) Show how the shapes affect the trend in boiling points: (118 °C, 100 °C, 108 °C, 82 °C, respectively).
- vi. Build and minimize organic compounds of your choice containing the following functional groups. Note the dipole moment of each compound: (a) alkyl halide (b) aldehyde (c) ketone (d) amine (e) ether (f) nitrile (g) thiol (h) carboxylic acid (i) ester (j) amide.
- vii. (a) Determine the heat of hydration of ethylene. (b) Compute the resonance energy of benzene by comparison of its enthalpy of hydrogenation with that of cyclohexene.
- viii. Arrange 1-hexene, 2-methyl-2-pentene, (*E*)-3-methyl-2-pentene, (*Z*)-3-methyl-2-pentene, and 2,3-dimethyl-2-butene in order of increasing stability.
- ix. (a) Compare the optimized bond angles H₂O, H₂S, H₂Se. (b) Compare the HAH bond angles for the second row dihydrides and compare with the results from qualitative MO theory.

Note: Software: ChemSketch, ArgusLab (www.planaria-software.com), TINKER 6.2 (dasher.wustl.edu/ffe), WebLab Viewer, Hyperchem, or any similar software.

Recommended Books:

1. A.R. Leach, Molecular Modelling Principles and Application, Longman, 2001.
2. J.M. Haile, Molecular Dynamics Simulation Elementary Methods, John Wiley and Sons, 1997.
3. Satya Prakash Gupta, QSAR and Molecular Modeling, Springer - Anamaya Publishers, 2008.

CHE-HE-5046: NOVEL INORGANIC SOLIDS

(Credits: Theory-04, Lab -02)

Theory: 60 Lectures

Course Objective: This introductory course intends to make learners familiar with a wide variety of technologically important and emerging materials. It will prepare the learners for studying materials further at the master's level. Prior completion of one introductory UG level course on inorganic and physical chemistry will be essential.

Learning outcome: After the completion of this course it will also be possible for the students to opt for studying an interdisciplinary master's programme with an emphasis on the synthesis and applications of various materials or take up a job in the materials production and/or processing industry.

Synthesis and modification of inorganic solids:

Conventional heat and beat methods, Co-precipitation method, Sol-gel methods, Hydrothermal method, Ion-exchange and Intercalation methods.

(10 Lectures)

Inorganic solids of technological importance:

Solid electrolytes – Cationic, anionic, mixed Inorganic pigments – coloured solids, white and black pigments.

Molecular material and fullerides, molecular materials & chemistry – one-dimensional metals, molecular magnets, metal containing liquid crystals.

(10 Lectures)

Nanomaterials:

Overview of nanostructures and nanomaterials: classification.

Preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-control of nanoarchitecture-one dimensional control. Carbon nanotubes and inorganic nanowires. Bio-inorganic nanomaterials, DNA and nanomaterials, natural and artificial nanomaterials, bionano composites.

(10 Lectures)

Introduction to engineering materials for mechanical construction:

Composition, mechanical and fabricating characteristics and applications of various types of cast irons, plain carbon and alloy steels, copper, aluminium and their alloys like duralumin, brasses and bronzes cutting tool materials, super alloys thermoplastics, thermosets and composite materials.

(10 Lectures)

Composite materials:

Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

(10 Lectures)

Speciality polymers:

Ceramics & Refractory: Introduction, classification, properties, raw materials, manufacturing and applications.

(10 Lectures)

Recommended Books:

1. Shriver & Atkins. Inorganic Chemistry, Peter Atkins, Tina Overton, Jonathan Rourke, Mark Weller and Fraser Armstrong, 5th Edition, Oxford University Press (2011-2012)
2. Smart, L. E., Moore, E. A., Solid State Chemistry: An Introduction, 4th Ed., CRC Press, 2012.
3. Poole, C. P., Ovens, F. J., Introduction to Nanotechnology, Wiley India, 2009.

4. Murty, B. S., Shankar, P., Raj, B., Rath, B. B., Murday, J. Textbook of Nanoscience and Nanotechnology, Springer, 2013.
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LAB

60 Lectures

1. Determination of cation exchange capacity.
2. Synthesis of oxides by ceramic method.
3. Synthesis of hydrogel by co-precipitation method.
4. Synthesis of silver and gold metal nanoparticles.

Recommended Book:

1. Fahlman, B. D., Materials Chemistry, Springer (2011).
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CHE-HE-5056: POLYMER CHEMISTRY

(Credits: Theory-06, Lab -02)

Theory: 60 Lectures

Course objective: This is an introductory level course in polymer chemistry. The aim of the course is to introduce the theory and applications of polymer chemistry to the students. Some industrially important polymers and conducting polymers, a promising class of polymeric materials for next generation devices will also be introduced in this course.

Learning outcome: After completion of this course the students will learn the definition and classifications of polymers, kinetics of polymerization, molecular weight of polymers, glass transition temperature, and polymer solutions etc. They also learn the brief introduction of preparation, structure and properties of some industrially important and technologically promising polymers.

Introduction and history of polymeric materials:

Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.

(4 Lectures)

Functionality and its importance:

Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems.

(8 Lectures)

Kinetics of Polymerization:

Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques.

(8 lectures)

Crystallization and crystallinity:

Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.

(4 Lectures)

Nature and structure of polymers-Structure Property relationships.

(2 Lectures)

Determination of molecular weight of polymers (M_n , M_w , etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

(8 Lectures)

Glass transition temperature (T_g) and determination of T_g, Free volume theory,

WLF equation, Factors affecting glass transition temperature (T_g).

(8 Lectures)

Polymer Solution – Criteria for polymer solubility, Solubility parameter,

Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

(8 Lectures)

Properties of Polymers (Physical, thermal, Flow & Mechanical Properties).

Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphide polypyrrole, polythiophene)].

(10 Lectures)

Recommended Books:

1. *Seymour's Polymer Chemistry*, Marcel Dekker, Inc.
 2. G. Odian: *Principles of Polymerization*, John Wiley.
 3. F.W. Billmeyer: *Text Book of Polymer Science*, John Wiley.
 4. P. Ghosh: *Polymer Science & Technology*, Tata McGraw-Hill.
 5. R.W. Lenz: *Organic Chemistry of Synthetic High Polymers*.
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LAB

60 Lectures

1. Polymer synthesis

1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).
 - a. Purification of monomer
 - b. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bis-isobutyronitrile (AIBN)
2. Preparation of nylon 66/6
 1. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
 - a. Preparation of IPC
 - b. Purification of IPC
 - c. Interfacial polymerization
 3. Redox polymerization of acrylamide
 4. Precipitation polymerization of acrylonitrile
 5. Preparation of urea-formaldehyde resin
 6. Preparations of novalac resin/resold resin.
 7. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry:
 - (a) Polyacrylamide-aq. NaNO₂ solution
 - (b) (Poly vinyl propylidene (PVP) in water
2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).
4. Testing of mechanical properties of polymers.
5. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer analysis

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method
2. Instrumental Techniques
3. IR studies of polymers
4. DSC analysis of polymers
5. Preparation of polyacrylamide and its electrophoresis

*at least 7 experiments to be carried out.

Recommended Books:

1. Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed.
2. Harry R. Allcock, Frederick W. Lampe and James E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003)
3. Fred W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984)
4. Joel R. Fried, Polymer Science and Technology, 2nd ed. Prentice-Hall (2003)

5. Petr Munk and Tejraj M. Aminabhavi, Introduction to Macromolecular Science, 2nd ed. John Wiley & Sons (2002)
 6. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005)
 7. Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd ed. Oxford University Press (2005)
 8. Seymour/ Carraher's Polymer Chemistry, 9th ed. by Charles E. Carraher, Jr. (2013).
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CHE-HE-5066: INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: Students shall be introduced to the fundamental concepts/theory and application of different analytical techniques, as applied to chemistry.

Learning Outcome: Students shall be able to explain the theoretical basis of different analytical techniques, identify the experimental requirements and compare/analyze the data/results thereof.

Introduction to spectroscopic methods of analysis:

Recap of the spectroscopic methods covered in detail in the core chemistry syllabus: Treatment of analytical data, including error analysis. Classification of analytical methods and the types of instrumental methods. Consideration of electromagnetic radiation.

(4 Lectures)

Molecular spectroscopy:

Infrared spectroscopy:

Interactions with molecules: absorption and scattering. Means of excitation (light sources), separation of spectrum (wavelength dispersion, time resolution), detection of the signal (heat, differential detection), interpretation of spectrum (qualitative, mixtures, resolution), advantages of Fourier Transform (FTIR). Samples and results expected. Applications: Issues of quality assurance and quality control, Special problems for portable instrumentation and rapid detection.

UV-Visible/ Near IR – emission, absorption, fluorescence and photoacoustic. Excitation sources (lasers, time resolution), wavelength dispersion (gratings, prisms, interference filters, laser, placement of sample relative to dispersion, resolution), Detection of signal (photocells, photomultipliers, diode arrays, sensitivity and S/N), Single and Double Beam instruments, Interpretation (quantification, mixtures, absorption vs. fluorescence and the use of time, photoacoustic, fluorescent tags).

(16 Lectures)

Separation techniques

Chromatography: Gas chromatography, liquid chromatography, supercritical fluids, Importance of column technology (packing, capillaries), Separation based on increasing number of factors (volatility, solubility, interactions with stationary phase, size, electrical field), Detection: simple vs. specific (gas and liquid), Detection as a means of further analysis (use of tags and coupling to IR and MS), Electrophoresis (plates and capillary) and use with DNA analysis.

Immunoassays and DNA techniques

Mass spectroscopy: Making the gaseous molecule into an ion (electron impact, chemical ionization), Making liquids and solids into ions (electrospray, electrical discharge, laser desorption, fast atom bombardment), Separation of ions on basis of mass to charge ratio, Magnetic, Time of flight, Electric quadrupole. Resolution, time and multiple separations, Detection and interpretation (how this is linked to excitation).

(16 Lectures)

Elemental analysis:

Mass spectrometry (electrical discharges).

Atomic spectroscopy: Atomic absorption, Atomic emission, and Atomic fluorescence
Excitation and getting sample into gas phase (flames, electrical discharges, plasmas),
Wavelength separation and resolution (dependence on technique), Detection of radiation
(simultaneous/scanning, signal noise), Interpretation (errors due to molecular and ionic
species, matrix effects, other interferences).

(8 Lectures)

NMR spectroscopy: Principle, Instrumentation, Factors affecting chemical shift, Spincoupling, Applications.

(4 Lectures)

Electroanalytical Methods: Potentiometry & Voltammetry

(4 Lectures)

Radiochemical Methods

(4 Lectures)

X-ray analysis and electron spectroscopy (surface analysis)

(4 Lectures)

Recommended books:

1. Principles of Instrumental Analysis - 6th Edition by Douglas A. Skoog, F. James Holler, and Stanley Crouch (ISBN 0-495-01201-7).
2. Instrumental Methods of Analysis, 7th ed, Willard, Merritt, Dean, Settle.
3. P.W. Atkins: Physical Chemistry.
4. G.W. Castellan: Physical Chemistry.
5. C.N. Banwell: Fundamentals of Molecular Spectroscopy.
6. Brian Smith: Infrared Spectral Interpretations: A Systematic Approach.
7. W.J. Moore: Physical Chemistry.

LAB

60 Lectures

1. Safety Practices in the Chemistry Laboratory
2. Determination of the isoelectric pH of a protein.
3. Titration curve of an amino acid.
4. Determination of the void volume of a gel filtration column.

5. Determination of a Mixture of Cobalt and Nickel (UV/Vis spec.)
6. Study of Electronic Transitions in Organic Molecules (i.e., acetone in water)
7. IR Absorption Spectra (Study of Aldehydes and Ketones)
8. Determination of Calcium, Iron, and Copper in Food by Atomic Absorption
9. Quantitative Analysis of Mixtures by Gas Chromatography (i.e., chloroform and carbon tetrachloride)
10. Separation of Carbohydrates by HPLC
11. Determination of Caffeine in Beverages by HPLC
12. Potentiometric Titration of a Chloride-Iodide Mixture
13. Cyclic Voltammetry of the Ferrocyanide/Ferricyanide Couple
14. Nuclear Magnetic Resonance
15. Use of fluorescence to do “presumptive tests” to identify blood or other body fluids.
16. Use of “presumptive tests” for anthrax or cocaine
17. Collection, preservation, and control of blood evidence being used for DNA testing
18. Use of capillary electrophoresis with laser fluorescence detection for nuclear DNA (Y-chromosome only or multiple chromosome)
19. Use of sequencing for the analysis of mitochondrial DNA
20. Laboratory analysis to confirm anthrax or cocaine
21. Detection in the field and confirmation in the laboratory of flammable accelerants or explosives
22. Detection of illegal drugs or steroids in athletes
23. Detection of pollutants or illegal dumping
24. Fibre analysis

At least 10 experiments to be performed.

Recommended Books:

1. Principles of Instrumental Analysis - 6th Edition by Douglas A. Skoog, F. James Holler and Stanley Crouch (ISBN 0-495-01201-7).
2. Instrumental Methods of Analysis, 7th ed, Willard, Merritt, Dean, Settle.

CHE-HE-6016 : GREEN CHEMISTRY

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objective: The learners will be taught about the emerging discipline of green chemistry particularly to differentiate as to how the principles of green chemistry may be applied to organic synthesis.

Learning Outcome: Apart from introducing learners to the principles of green chemistry, this course will make them conversant with applications of green chemistry to organic synthesis. Students will be prepared for taking up entry level jobs in the chemical industry. They also will have the option of studying further in the area.

Introduction to Green Chemistry

What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.

(4 Lectures)

Principles of Green Chemistry and Designing a Chemical synthesis

Twelve principles of Green Chemistry with their explanations and examples; Designing a Green Synthesis using these principles; Prevention of Waste/ byproducts; maximum incorporation of the materials used in the process into the final products (Atom Economy); prevention/ minimization of hazardous/ toxic products; designing safer chemicals – different basic approaches to do so; selection of appropriate auxiliary substances (solvents, separation agents), green solvents, solventless processes, immobilized solvents and ionic liquids; energy requirements for reactions - use of microwaves, ultrasonic energy; selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups; use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; designing of biodegradable products; prevention of chemical accidents; strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

(24 Lectures)

Examples of Green Synthesis/ Reactions

1. Green Synthesis of the following compounds: adipic acid, catechol, BHT, methyl methacrylate, urethane, citral, ibuprofen, paracetamol, furfural.
2. Microwave assisted reactions in water: Oxidation of toluene, alcohols. Microwave assisted reactions in organic solvents: Esterification, Fries rearrangement, Diels-Alder Reaction. Microwave assisted solid state reactions: Deacetylation, Deprotection. Saponification of esters, Alkylation of reactive methylene compounds, reductions, benzimidazoles.
3. Selective methylation of active methylene group using dimethylcarbonate: Solid-state polymerization of amorphous polymers using diphenylcarbonate; Use of “Clayan”, a nonmetallic oxidative reagent for various reactions; Free Radical Bromination; Role of Tellurium in organic syntheses; Biocatalysis in organic syntheses.

(24 Lectures)

Future Trends in Green Chemistry

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Solventless reactions; Green chemistry in sustainable development.

(8 Lectures)

Recommended Books:

1. V.K. Ahluwalia & M.R. Kidwai: New Trends in Green Chemistry, Anamalaya Publishers (2005).
2. P.T. Anastas & J.K. Warner: Oxford Green Chemistry- Theory and Practical, University Press (1998).
3. A.S. Matlack: Introduction to Green Chemistry, Marcel Dekker (2001).
4. M.C. Cann & M.E. Connely: Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).
5. M.A. Ryan & M. Tinnesand, Introduction to Green Chemistry, American Chemical Society, Washington (2002).

LAB

60 Lectures

1. Safer starting materials

The Vitamin C clock reaction using Vitamin C tablets, tincture of iodine, hydrogen peroxide and liquid laundry starch.

- (i) Effect of concentration on clock reaction
- (ii) Effect of temperature on clock reaction.

2. Using renewable resources

Preparation of biodiesel from vegetable oil.

3. Avoiding waste

Principle of atom economy.

Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.

Preparation of propene by two methods can be studied

(I) Triethylamine ion + OH⁻ → propene + trimethylpropene + water

(II) 1-propanol $\xrightarrow{\text{H}_2\text{SO}_4/\Delta}$ propene + water

The other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.

4. Use of enzymes as catalysts

Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide

Alternative Green solvents

5. Diels Alder reaction in water

Reaction between furan and maleic acid in water and at room temperature rather than in benzene and reflux.

6. Extraction of D-limonene from orange peel using liquid CO₂ prepared from dry ice.

7. Mechanochemical solvent free synthesis of azomethines

8. Co-crystal controlled solid state synthesis (C₂S₃) of N-organophthalimide using phthalic anhydride and 3-aminobenzoic acid.

Alternative sources of energy

9. Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).

10. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Recommended Books:

1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).
3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnensand; (Ed), American Chemical Society, Washington DC (2002).
4. Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. *Green Chemistry Experiment:*

A monograph, I.K International Publishing House Pvt Ltd. New Delhi. Bangalore
CISBN 978-93-81141-55-7 (2013).

5. Cann, M.C. & Connelly, M. E. *Real world cases in Green Chemistry*, American Chemical Society (2008).
6. Cann, M. C. & Thomas, P. *Real world cases in Green Chemistry*, American Chemical Society (2008).
7. Pavia, D. L. Lampman, G. H. & Kriz, G.S. *W B Introduction to Organic Laboratory Techniques: A Microscale Approach*, 4th Ed., Brooks/Cole; 2007.

CHE-HE-6026: INDUSTRIAL CHEMICALS AND ENVIRONMENT

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

***Course Objectives:** This course provides an introduction to the various industrial gases and inorganic chemicals, their manufacturing processes, applications, storage and the hazards of handling them. Contribution of these industrial chemicals towards air and water pollution and their effects on living organisms and the environment has also been covered. Students are also expected to learn about metallurgy, energy generation industry and the pollution threat they pose. This course also discusses about management of the different kinds of wastes, their safe disposal and the importance of practicing green chemistry in chemical industry.*

***Learning Outcomes:** After successful completion of the course, students would have learnt about the manufacture, applications and safe ways of storage and handling gaseous and inorganic industrial chemicals. Students will get to know about industrial metallurgy and the energy generation industry. Students will also learn about environmental pollution by various gaseous, liquid wastes and nuclear wastes and their effects on living beings. Finally, the students will learn about industrial waste management, their safe disposal and the importance of environment friendly “green chemistry” in chemical industry.*

Industrial Gases and Inorganic Chemicals

***Industrial Gases:** Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.*

***Inorganic Chemicals:** Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.*

(10 Lectures)

Industrial Metallurgy

Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

(4 Lectures)

Environment and its segments

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur.

Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution.

Pollution by SO₂, CO₂, CO, NO_x, H₂S and other foul smelling gases. Methods of estimation of CO, NO_x, SO_x and control procedures.

Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.

Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems.

Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal.

Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

(30 Lectures)

Energy & Environment

Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.

Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

(10 Lectures)

Biocatalysis

Introduction to biocatalysis: Importance in “Green Chemistry” and Chemical Industry.

(6 Lectures)

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
4. S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.
5. K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.
6. S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.
7. S.E. Manahan, *Environmental Chemistry*, CRC Press (2005).

8. G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).
 9. A. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).
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LAB

60 Lectures

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Determination of Biological Oxygen Demand (BOD)
4. Percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by simple titration method (AgNO_3 and potassium chromate).
6. Estimation of total alkalinity of water samples (CO_3^{2-} , HCO_3^-) using double titration method.
7. Measurement of dissolved CO_2 .
8. Study of some of the common bio-indicators of pollution.
9. Estimation of SPM in air samples.
10. Preparation of borax/ boric acid.

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
 2. R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
 3. J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
 4. S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.
 5. K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.
 6. S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.
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CHE-HE-6036: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

(Credits: Theory-04, Lab-02)

Theory: 60 Lectures

Course Objectives: To learn the synthetic process, properties and the utility of the industrially important inorganic materials (such as silicates, ceramics, cements, fertilizers, paints, batteries, alloys and explosives).

To provide opportunity to learn some of the industrial process such as surface coating and catalysis in relevant to industry where heterogeneous catalysis dominates.

Experiments are aimed at helping learners acquire hands on experience in qualitative and quantitative analysis of the inorganic materials which are basically manufactured in chemical industries.

To learn some industrial techniques such as surface coating etc..

Learning Outcome: This course will establish the basic foundation of industrial inorganic chemistry among the students. This will be helpful for pursuing further studies of industrial chemistry in future. Experiments will help the Students to gather the experience of qualitative and quantitative chemical analysis. Students will be capable of doing analysis of the inorganic materials which are used in our daily life. They will have insight of the industrial processes.

Silicate Industries

Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

Ceramics: Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fibre.

Cements: Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cements.

(16 Lectures)

Fertilizers:

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

(8 Lectures)

Surface Coatings:

Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings (electrolytic and electroless), metal spraying and anodizing.

(10 Lectures)

Batteries:

Primary and secondary batteries, battery components and their role, Characteristics of battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

(6 Lectures)

Alloys:

Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (argon treatment, heat treatment, nitriding, carburizing). Composition and properties of different types of steels.

(10 Lectures)

Catalysis:

General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrial applications, Deactivation or regeneration of catalysts.

Phase transfer catalysts, application of zeolites as catalysts.

(6 Lectures)

Chemical explosives:

Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX). Introduction to rocket propellants.

(4 Lectures)

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
 2. R. M. Felder, R. W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
 3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: *Introduction to Ceramics*, Wiley Publishers, New Delhi.
 4. Karl Heinz Büchel, Hans-Heinrich Moretto Peter, Woditsch; *Industrial Inorganic Chemistry*, Wiley-VCH.
 5. J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
 6. P. C. Jain, M. Jain: *Engineering Chemistry*, Dhanpat Rai & Sons, Delhi.
 7. R. Gopalan, D. Venkappayya, S. Nagarajan: *Engineering Chemistry*, Vikas Publications, New Delhi.
 8. B. K. Sharma: *Engineering Chemistry*, Goel Publishing House, Meerut
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LAB

60 Lectures

1. Determination of free acidity in ammonium sulphate fertilizer.
2. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
3. Estimation of phosphoric acid in superphosphate fertilizer.
4. Electroless metallic coatings on ceramic and plastic material.
5. Determination of composition of dolomite (by complexometric titration).
6. Analysis of (Cu, Ni); (Cu, Zn) in alloy or synthetic samples.
7. Analysis of Cement.
8. Preparation of pigment (zinc oxide).

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R. M. Felder, R. W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: *Introduction to Ceramics*, Wiley Publishers, New Delhi.
4. J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
5. P. C. Jain, M. Jain: *Engineering Chemistry*, Dhanpat Rai & Sons, Delhi.
6. R. Gopalan, D. Venkappayya, S. Nagarajan: *Engineering Chemistry*, Vikas Publications, New Delhi.

CHE-HE-6046: RESEARCH METHODOLOGY FOR CHEMISTRY

(Credits: Theory-05, Tutorials-01)

Theory: 75 Lectures

Course Objectives:

This course is introduced to impart knowledge about the basic concepts of research and to provide a road map for conducting research

Students are expected to identify, explain and apply basic concepts of research; acquire information, recognize various issues related to research and to learn instrumental methods required for research in chemistry.

Learning Outcome:

After completing this course, students should be able to construct a rational research proposal to generate fruitful output in terms of publications and patents in the field of chemical sciences.

Literature Survey:

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples.

Digital: Web resources, E-journals, Journal access, TOC alerts, Hot articles, Citation index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and

communities, Blogs, Preprint servers, Search engines, Scirus, Google Scholar, ChemIndustry, Wiki- Databases, ChemSpider, Science Direct, SciFinder, Scopus.

Information Technology and Library Resources: The Internet and World Wide Web. Internet resources for chemistry. Finding and citing published information.

(20 Lectures)

Methods of Scientific Research and Writing Scientific Papers:

Reporting practical and project work. Writing literature surveys and reviews. Organizing a poster display. Giving an oral presentation.

Writing scientific papers – justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work. Writing ethics. Avoiding plagiarism.

(20 Lectures)

Chemical Safety and Ethical Handling of Chemicals:

Safe working procedure and protective environment, protective apparel, emergency procedure and first aid, laboratory ventilation. Safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric – safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of

laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals.

(12 Lectures)

Data Analysis

The Investigative Approach: Making and Recording Measurements. SI Units and their use. Scientific method and design of experiments.

Analysis and Presentation of Data: Descriptive statistics. Choosing and using statistical tests. Chemometrics. Analysis of variance (ANOVA), Correlation and regression, Curve fitting, fitting of linear equations, simple linear cases, weighted linear case, analysis of residuals, General polynomial fitting, linearizing transformations, exponential function fit, r and its abuse. Basic aspects of multiple linear regression analysis.

(13 Lectures)

Electronics

Basic fundamentals of electronic circuits and their components used in circuits of common instruments like spectrophotometers, typical circuits involving operational amplifiers for electrochemical instruments. Elementary aspects of digital electronics.

(10 Lectures)

Recommended Books

1. Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J. & Jones, A. (2011) *Practical skills in chemistry*. 2nd Ed. Prentice-Hall, Harlow.
2. Hibbert, D. B. & Gooding, J. J. (2006) *Data analysis for chemistry*. Oxford University Press.
3. Topping, J. (1984) *Errors of observation and their treatment*. Fourth Ed., Chapman Hall, London.
4. Harris, D. C. *Quantitative chemical analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
5. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*. Cambridge Univ. Press (2001) 487 pages.
6. Chemical safety matters – IUPAC – IPCS, Cambridge University Press, 1992.
7. OSU safety manual 1.01.

CHE-HE-6056: DISSERTATION

Student will complete a project work and then prepare a report on that.

Skill Enhancement Courses

CHE-SE-3024: IT SKILLS FOR CHEMISTS

(Credits: 04)

60 Lectures

Course Objective: *The objectives of the proposed course are:*

- 1) *To provide the basic knowledge of mathematics which are needed to pursue chemistry as major subject.*
- 2) *To provide the necessary training for the basic programming knowledge.*
- 3) *The course provides information technology literacy and basic skills training for learners with limited experience.*
- 4) *To familiarize with the Introductory writing activities and Handling numeric data.*

Learning Outcome: *Course learning outcomes focus on skill development related to basic computer operations and information technology. After completing the course the incumbent is able to use the computer for basic purposes of preparing his personnel/business letters, viewing information on Internet (the web), sending mails, using internet banking services etc. After opting this course the students are expected to accumulate the skills in writing activities and Handling numeric data.*

Mathematics

Fundamentals, mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs.

Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities.

Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).

Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms). Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

Computer programming:

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Errors (Syntax and Logical), Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

BASIC programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

HANDS ON

Introductory writing activities: Introduction to word processor and structure drawing (ChemSketch) software. Incorporating chemical structures, chemical equations, expressions from chemistry (e.g. Maxwell-Boltzmann distribution law, Bragg's law, van der Waals equation, etc.) into word processing documents/Latex.

Handling numeric data: Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a spreadsheet (Planck's distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory- Maxwell-Boltzmann distribution curves as function of temperature and molecular weight), spectral data, pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

Numeric modelling: Simulation of pH metric titration curves. Excel functions LINEST and Least Squares. Numerical curve fitting, linear regression (rate constants from concentrationtime data, molar extinction coefficients from absorbance data), numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pK_a of weak acid), integration (e.g. entropy/enthalpy change from heat capacity data).

Statistical analysis: Gaussian distribution and Errors in measurements and their effect on data sets. Descriptive statistics using Excel. Statistical significance testing: The t test. The F test.

Presentation: Presentation graphics

Recommended Books:

1. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).
2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).
3. Steiner, E. The Chemical Maths Book Oxford University Press (1996).
4. Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007).
5. Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
6. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
7. Noggle, J. H. *Physical chemistry on a Microcomputer*. Little Brown & Co. (1985).
8. Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).

CHE-SE-3034: BASIC ANALYTICAL CHEMISTRY

(Credits: 04)

60 Lectures

Course Objective: To familiarize students with different micro and semimicro analytical techniques and help develop the ability to use modern instrumental methods for chemical analysis of food, soil, air and water.

Learning Outcome: Upon completion of this course, students shall be able to explain the basic principles of chemical analysis, design/implement microscale and semimicro experiments, record, interpret and analyze data following scientific methodology.

Introduction: Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results, from the point of view of significant figures.

Analysis of soil: Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators

- Determination of pH of soil samples.
- Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

Analysis of water: Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

- Determination of pH, acidity and alkalinity of a water sample.
- Determination of dissolved oxygen (DO) of a water sample.

Analysis of food products: Nutritional value of foods, idea about food processing and food preservations and adulteration.

- Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.
- Analysis of preservatives and colouring matter.

Chromatography: Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

- Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).
- To compare paint samples by TLC method.

Ion-exchange: Column, ion-exchange chromatography etc.
Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

Analysis of cosmetics: Major and minor constituents and their function

- Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.
- Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration.

Suggested Applications (Any one):

- To study the use of phenolphthalein in trap cases.
- To analyze arson accelerants.
- To carry out analysis of gasoline.

Suggested Instrumental demonstrations:

- a. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.
- b. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.
- c. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drink.

Recommended Books:

1. Willard, H. H. *Instrumental Methods of Analysis*, CBS Publishers.
2. Skoog & Lerry. *Instrumental Methods of Analysis*, Saunders College Publications, New York.
3. Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6th Ed.*, Saunders College Publishing, Fort Worth (1992).
4. Harris, D. C. *Quantitative Chemical Analysis*, W. H. Freeman.
5. Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
6. Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India.
7. Freifelder, D. *Physical Biochemistry 2nd Ed.*, W.H. Freeman and Co., N.Y. USA(1982).
8. Cooper, T.G. *The Tools of Biochemistry*, John Wiley and Sons, N.Y. USA. 16(1977).
9. Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7th Ed.*, Prentice Hall.
10. Vogel, A. I. *Vogel's Quantitative Chemical Analysis 6th Ed.*, Prentice Hall.
11. Robinson, J.W. *Undergraduate Instrumental Analysis 5th Ed.*, Marcel Dekker, Inc., New York (1995).

CHE-SE-3044: CHEMICAL TECHNOLOGY & SOCIETY

(Credits: 04)

Theory: 60 Lectures

***Course Objective:** The objective of the course is to enable students to have a firsthand understanding of different types of equipments needed in chemical technology and offer them concepts regarding some important parameters. The syllabus also emphasizes the dynamic nature of the relations between society on one hand and technological achievement from chemical industries on the other hand. In other words, it tries to explore societal and technological issues from a chemical perspective.*

***Learning Outcome:** Students shall be familiarized with processes and terminologies in chemical industry, like mass balance, energy balance etc... Learners will be able to use chemical and scientific literacy as a means to better understand the topics related to the society.*

Chemical Technology

Different types of equipments needed in chemical technology, including reactors, distillation columns, extruders, pumps, mills, emulgators. Scaling up operations in chemical industry. Introduction to clean technology.

Concept of relative humidity, molal humidity, dew point, partial saturation.

Material Balance: Recycle, bypass in batch, stage wise and continuous operations in systems with and without chemical reactions.

Energy balance: Energy balance of systems with and without chemical reactions.

Society

Social issues related to soil, air and water pollution.

Energy crisis of modern society and search for alternatives such as energy from natural sources (i.e. solar and renewable forms), and from nuclear fission, biofuel etc.

Pros and cons of use of materials like plastics and polymers and their natural analogues, Genetic engineering and the manufacture of drugs (proteins and nucleic acids, and molecular reactivity and interconversions)

Recommended Book:

1. John W. Hill, Terry W. McCreary & Doris K. Kolb, *Chemistry for changing times* 13th Ed.
2. E.J. Hackett, O. Amsterdamska, M. Lynch and J. Wajcman (eds.), *The Handbook of Science and Technology Studies*, The MIT Press, 2008.
3. D. MacKenzie and J. Wajcman (eds.), *The Social Shaping of Technology*, The Open University Press, 1999.

CHE-SE-3054: CHEMOINFORMATICS

(Credits: 04)

Theory: 60 Lectures

***Learning Objectives:** The primary objective of this course is to familiarize the students with the use of various computer software and information technology. The students are expected to learn different chemical search engines and utilize them for molecular modelling and structure elucidation with a final goal to compute NMR, IR, mass and other spectra that can be later compared with the experimental data. The course also provides sufficient information and hands on exercises on the use of cheminformatics, with a special emphasis on its application in modern drug discovery.*

***Learning Outcomes:** On the successful completion of the course, the students should be able to explain, interpret and critically examine the utility of computers and software tools to solving chemistry related problems. Recognize, apply, compare and predict chemical structures, properties, and reactivity and; solve chemistry related problems.*

Employ critical thinking and scientific reasoning to design and safely implement laboratory experiments and keep the records of the same.

Compile, interpret and analyze the qualitative/quantitative data and communicate the same in a scientific literature

Introduction to Chemoinformatics: History and evolution of chemoinformatics, Use of chemoinformatics, Prospects of chemoinformatics, Molecular Modelling and Structure elucidation.

Representation of molecules and chemical reactions: Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification.

Searching chemical structures: Full structure search, sub-structure search, basic ideas, similarity search, three dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.

Applications: Prediction of Properties of Compounds; Linear Free Energy Relations; Quantitative Structure-Property Relations; Descriptor Analysis; Model Building; Modeling Toxicity; Structure-Spectra correlations; Prediction of NMR, IR and Mass spectra; Computer Assisted Structure elucidations; Computer Assisted Synthesis Design, Introduction to drug design; Target Identification and Validation; Lead Finding and Optimization; Analysis of HTS data; Virtual Screening; Design of Combinatorial Libraries; Ligand-Based and Structure Based Drug design; Application of Chemoinformatics in Drug Design.

Hands-on Exercises

Recommended Books:

1. Andrew R. Leach & Valerie, J. Gillet (2007) *An introduction to Chemoinformatics*. Springer: The Netherlands.
 2. Gasteiger, J. & Engel, T. (2003) *Chemoinformatics: A text-book*. Wiley-VCH.
 3. Gupta, S. P. (2011) *QSAR & Molecular Modeling*. Anamaya Pub.: New Delhi.
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CHE-SE-3064: BUSINESS SKILLS FOR CHEMISTS

(Credits: 04)

Theory: 60 Lectures

Course Objective: To familiarize students with important concepts of business operations and intellectual rights as applied to chemical industry.

Learning outcome: students shall be able to explain and/or analyze the important steps of business operations, finance and intellectual property as applied to chemical industry.

Chemistry in Industry

Current challenges and opportunities for the chemistry-using industries, role of chemistry in India and global economies.

Basics of Business and Management

Key business concepts: Business plans, market need, project management and routes to market.

Management Functions and skills, principles of motivation, forms of business organization including partnerships and companies.

Marketing Skills

Understanding basics of marketing and marketing mix strategies with cases.

Human Resource Management (HRM) Skills

Managerial HRM functions viz. recruitment, training and development and compensation.

Financial Management Skills

An overview of financial and cost accounting with cases, managerial finance functions.

Intellectual Property Rights

Concept of intellectual property rights, patents.

Recommended books

1. <http://www.rsc.org/learn-chemistry/resources/business-skills-for-chemists/OnlineCourse/>
2. Philip Kotler, Keven Lane Keller Marketing Management 15th Ed., Pearson Education; Fifteenth edition (10 August 2017)
- 3.

CHE-SE-3074: INTELLECTUAL PROPERTY RIGHTS (IPR)

(Credits: 04)

Theory: 60 Lectures

Course Objective: In this era of liberalization and globalization, the perception about science and its practices has undergone dramatic change. The importance of protecting the scientific discoveries, with commercial potential or the intellectual property rights is being discussed at all levels – statutory, administrative, and judicial. With India ratifying the WTO agreement, it has become obligatory on its part to follow a minimum acceptable standard for protection and enforcement of intellectual property rights. The purpose of this course is to apprise the students about the multifaceted dimensions of this issue.

Learning Outcome: After completing this course, students will have in-depth understanding about the importance and types of IPR. This course will also provide the clarity on the legal and economic aspects of the IP system.

Introduction to Intellectual Property:

Historical Perspective, Different Types of IP, Importance of protecting IP.

Copyrights

Introduction, How to obtain, Differences from Patents.

Trade Marks

Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, Trade names, etc.

Differences from Designs.

Patents

Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Healthcare – balancing promoting innovation with public health, Software patents and their importance for India.

Geographical Indications

Definition, rules for registration, prevention of illegal exploitation, importance to India.

Industrial Designs

Definition, How to obtain, features, International design registration.

Layout design of integrated circuits

Circuit Boards, Integrated Chips, Importance for electronic industry.

Trade Secrets

Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.

Different International agreements

(a) World Trade Organization (WTO):

- (i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement
- (ii) General Agreement on Trade related Services (GATS)
- (iii) Madrid Protocol
- (iv) Berne Convention
- (v) Budapest Treaty

(b) Paris Convention

WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity

IP Infringement issue and enforcement – Role of Judiciary, Role of law enforcement agencies – Police, Customs etc. Economic Value of Intellectual Property – Intangible assets and their valuation, Intellectual Property in the Indian Context – Various laws in India Licensing and technology transfer.

Recommended Books:

1. N.K. Acharya: *Textbook on intellectual property rights*, Asia Law House (2001).
2. Manjula Guru & M.B. Rao, *Understanding Trips: Managing Knowledge in Developing Countries*, Sage Publications (2003).
3. P. Ganguli, *Intellectual Property Rights: Unleashing the Knowledge Economy*, Tata McGraw-Hill (2001).
4. Arthur Raphael Miller, Micheal H.Davis; *Intellectual Property: Patents, Trademarks and Copyright in a Nutshell*, West Group Publishers (2000).
5. Jayashree Watal, *Intellectual property rights in the WTO and developing countries*, Oxford University Press, Oxford.

CHE-SE-4014: ANALYTICAL CLINICAL BIOCHEMISTRY

(Credits: 04)

THEORY: 60 Lectures

Course objective: This course is intended to apprise students with various clinically relevant biomolecules, their structures and physiological roles. Students are also expected to learn the basics of analysis of pathological samples (blood and urine).

Learning outcome: Students will be able to identify various molecules relevant to a particular pathological condition and their estimation protocols.

Basic understanding of the structures, properties and functions of carbohydrates, lipids and proteins:

Review of concepts studied in the core course.

Carbohydrates: Biological importance of carbohydrates, metabolism, cellular currency of energy (ATP), glycolysis, alcoholic and lactic acid fermentations, Krebs cycle, Isolation and characterization of polysachharides.

Proteins: Classification, biological importance, primary and secondary, tertiary and quaternary structures of proteins: α -helix and β -pleated sheets, isolation, characterization, denaturation of proteins.

Enzymes: Nomenclature, characteristics, classification, active site, mechanism of enzyme action, stereospecificity of enzymes, effect of pH, temperature on enzyme activity, , enzyme inhibitors, coenzymes and cofactors introduction to biocatalysis: importance in “Green Chemistry” and chemical industry.

Lipids: Classification, biological importance of triglycerides and phosphoglycerides and cholesterol, lipid membrane, liposomes and their biological functions and underlying applications.

Lipoproteins.

Properties, functions and biochemical functions of steroid hormones.

Biochemistry of peptide hormones.

Structure of DNA (Watson-Crick model) and RNA, genetic code, biological roles of DNA and RNA: replication, transcription and translation, introduction to gene therapy.

Biochemistry of disease: A diagnostic approach by blood/ urine analysis:

Blood: Composition and functions of blood, blood coagulation, blood collection and preservation of samples, anemia, regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

Urine: Collection and preservation of samples, formation of urine, composition and estimation of constituents of normal and pathological urine.

Practicals:

Identification and estimation of the following:

1. Carbohydrates - qualitative and quantitative analysis.
2. Lipids - qualitative and quantitative analysis.
3. Determination of the iodine number of oil.
4. Determination of the saponification number of oil.
5. Detection of cholesterol using Liebermann- Burchard reaction.
6. Isolation of protein.
7. Determination of concentration of protein by the Biuret reaction.
8. Determination of nucleic acid concentration.
9. Separation of nucleic acids.

Recommended Books:

1. David L. Nelson and Michael M. Cox: Lehninger Principles of Biochemistry
 2. T.G. Cooper: Tool of Biochemistry.
 3. Keith Wilson and John Walker: Practical Biochemistry.
 4. Alan H Gowenlock: Varley's Practical Clinical Biochemistry.
 5. Thomas M. Devlin: Textbook of Biochemistry.
 6. Jeremy M. Berg, John L Tymoczko, Lubert Stryer: Biochemistry.
 7. G. P. Talwar and M Srivastava: Textbook of Biochemistry and Human Biology.
 8. O. Mikes, R.A. Chalmers: Laboratory Handbook of Chromatographic Methods.
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CHE-SE-4024: GREEN METHODS IN CHEMISTRY

(Credits: 04)

Theory: 60 Lectures

Course Objectives: This course introduces students to the utilization of green chemistry from industrial perspective and provides exposure to methods by which environmental problems are evaluated and designing of sustainable solutions.

Learning Outcome: Students shall be able to describe and evaluate chemical products and processes from environmental perspective, define and propose sustainable solutions and critically assess the methods for waste reduction and recycling.

Tools of Green chemistry, Twelve principles of Green Chemistry, with examples.

The following Real world Cases in Green Chemistry should be discussed:

- 1 A green synthesis of ibuprofen which creates less waste and fewer byproducts (Atom economy).
- 2 Surfactants for Carbon Dioxide – replacing smog producing and ozone depleting solvents with CO₂ for precision cleaning and dry cleaning of garments.
- 3 Environmentally safe antifoulant.
- 4 CO₂ as an environmentally friendly blowing agent for the polystyrene foam sheet packaging market.
- 5 Using a catalyst to improve the delignifying (bleaching) activity of hydrogen peroxide.

- 6 A new generation of environmentally advanced preservative: getting the chromium and arsenic out of pressure treated wood.
7. Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.
- 8 Development of a fully recyclable carpet: cradle to cradle carpeting.

Recommended Books:

1. Manahan S.E. (2005) Environmental Chemistry, CRC Press
 2. Miller, G.T. (2006) Environmental Science 11th edition. Brooks/Cole
 3. Mishra, A. (2005) Environmental Studies. Selective and Scientific Books, New
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CHE-SE-4034: PHARMACEUTICAL CHEMISTRY

(Credits: 04)

Theory: 60 Lectures

Course Objective: This primary objective of this course is to introduce students to the fundamentals of drug design and development process, drugs for various diseases available in market, their mode of action and side effects. Students are expected to learn the biosynthetic procedures of various bio-relevant small molecules.

Learning Outcome: Students will be able to appreciate the drug development process, identify various small molecules used for treatments different ailments and other physiological processes.

Drugs & Pharmaceuticals:

Drug discovery, design and development; basic retrosynthetic approach, synthesis of the representative drugs of the following classes: analgesics, antipyretic, anti-inflammatory (aspirin, paracetamol, ibuprofen), antibiotics (chloramphenicol), antibacterial and antifungal (sulphonamides, sulphanethoxazol, sulphacetamide, trimethoprim), antiviral (acyclovir), drugs effecting central nervous system (phenobarbital, diazepam), cardiovascular (glyceryl trinitrate), antilaprosy (dapson), HIV-AIDS related drugs (AZT- Zidovudine).

Fermentation:

Aerobic and anaerobic fermentation, production of (i) ethanol and citric acid, (ii) antibiotics (penicillin, cephalosporin, chloromycetin and streptomycin), (iii) lysine, glutamic acid, vitamin B2, vitamin B12 and vitamin C.

Practicals:

1. Preparation of Aspirin and its analysis.
2. Preparation of magnesium bisilicate (antacid).

Recommended Books:

1. Graham L. Patrick: *An Introduction to Medicinal Chemistry*, Oxford University Press, UK.
2. Gareth Thomas: *Fundamentals of Medicinal Chemistry*, Wiley.

3. Hakishan, V.K. Kapoor: *Medicinal and Pharmaceutical Chemistry*, Vallabh Prakashan, Pitampura, New Delhi.

4. William O. Foye, Thomas L., Lemke, David A. William: *Principles of Medicinal Chemistry*, B.I. Waverly Pvt. Ltd. New Delhi.

CHE-SE-4044: CHEMISTRY OF COSMETICS & PERFUMES

(Credits: 04)

60 Lectures

Course Objective: This course intends to apprise students about the chemical knowledge related to some of the commonly used cosmetics. Laboratory experiments for preparation of talcum powder, shampoo etc. are included to give hands on experience.

Learning Outcome: Students will learn about the preparation and chemistry involved with the production different cosmetic. This may encourage students to take up entry level jobs at cosmetics industry or venture into commercial production of cosmetics as an entrepreneur.

A general study including preparation and uses of the following: Hair dye, hair spray, shampoo, suntan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavours. Essential oils and their importance in cosmetic industries with reference to Eugenol, Geraniol, sandalwood oil, eucalyptus, rose oil, 2-phenyl ethyl alcohol, Jasmone, Civetone, Muscone.

Practicals

1. Preparation of talcum powder.
2. Preparation of shampoo.
3. Preparation of enamels.
4. Preparation of hair remover.
5. Preparation of face cream.
6. Preparation of nail polish and nail polish remover.

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol -I, Ellis Horwood Ltd. UK.
 2. P.C. Jain, M. Jain: *Engineering Chemistry*, Dhanpat Rai & Sons, Delhi.
 3. B.K. Sharma: *Industrial Chemistry*, Goel Publishing House, Meerut.
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CHE-SE-4054: PESTICIDE CHEMISTRY

(Credits: 04)

60 Lectures

Course Objective: This is a brief and introductory course on pesticides, through which the students will be introduced to various classes of pesticides, their synthesis, applications and possible hazards of their uses.

Learning Outcome: Students will be able to explain or describe and critically examine different types of pesticides, their activity/toxicity and their applications and the need for the search of an alternative based on natural products.

Definition of pesticides, general introduction to pesticides (natural and synthetic), benefits and adverse effects of pesticides. Classification, mode of action, toxicity and methods of pesticides residue analysis. Synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene); organophosphate (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor)

Practicals:

1. To calculate acidity/alkalinity in given sample of pesticides formulations as per BIS specifications.
2. Preparation of simple organophosphates, phosphonates and thiophosphates.

Recommended Book:

1. R. Cremlyn: Pesticides, Preparation and Mode of Action, John Wiley & Sons, New York, 1978
2. RPBateman, Pesticide Applications, AAB Press, 2004
3. Principles of Pesticide chemistry: S K Handa, Ed. by Agrobios (India), 2008
4. Pesticide Science & Biotechnology: R Greenhalgh and T R Robers, IUPAC, Blackwell Scientific Publications, 1987
5. The Chemical Process Industries: D N Shreve
6. Pesticide Chemistry : G Matolesy, M. Nadasy, V. Andriska, Elsevier Sc. Publisher, USA, 1988

CHE-SE-4064: FUEL CHEMISTRY

(Credits: 04)

60 Lectures

Course Objectives: This course discusses about the chemistry of various sources of energy. Students are expected to learn about the composition of coal and petroleum products, their extraction, purification methods and usage. A section also covers classification and applications of natural and synthetic lubricants. Students will also learn about the determination and significance of various industrially relevant physical parameters for different fuels and lubricants.

Learning Outcomes: At the end of this course students will learn about the classes of renewable and non-renewable energy sources. Students will learn about the composition of coal and crude petroleum, their classification, isolation of coal and petroleum products and their usage in various industries. They will also learn to determine industrially significant physical parameters for fuels and lubricants.

Fuel Chemistry

Review of energy sources (renewable and non-renewable). Classification of fuels and their calorific value.

Coal: Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas—composition and uses. Fractionation of coal tar, uses of coal tar bases chemicals, requisites of a good metallurgical coke, Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining.

Petroleum and Petrochemical Industry: Composition of crude petroleum, Refining and different types of petroleum products and their applications.

Fractional Distillation (Principle and process), Cracking (Thermal and catalytic cracking), Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels. Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives Xylene.

Lubricants: Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semisolid lubricants, synthetic lubricants.

Properties of lubricants (viscosity index, cloud point, pour point) and their determination.

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol -I, Ellis Horwood Ltd. UK.
 2. P.C. Jain, M. Jain: *Engineering Chemistry*, Dhanpat Rai & Sons, Delhi.
 3. B.K. Sharma: *Industrial Chemistry*, Goel Publishing House, Meerut.
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Syllabus
Mathematics (Honours)

Version 2 submitted to



Gauhati University
under the
Choice Based Credit System

By
Department of Mathematics
Gauhati University

Credit and Marks distribution of the courses

Sl. No.	Stream	Subject	Paper code	Paper name	Credit	Total marks	Theory/External marks/End sem	Internal marks	Practical Marks	Regular/Honours
1257	B.Sc.	Mathematics	MAT-HC-1016	Calculus (including practical)	6	100	60	20	20	Honours
1258	B.Sc.	Mathematics	MAT-HC-1026	Algebra	6	100	80	20		Honours
1259	B.Sc.	Mathematics	MAT-HC-2016	Real Analysis	6	100	80	20		Honours
1260	B.Sc.	Mathematics	MAT-HC-2026	Differential Equations (including practical)	6	100	60	20	20	Honours
1261	B.Sc.	Mathematics	MAT-HC-3016	Theory of Real Functions	6	100	80	20		Honours
1262	B.Sc.	Mathematics	MAT-HC-3026	Group Theory-I	6	100	80	20		Honours
1263	B.Sc.	Mathematics	MAT-HC-3036	Analytical Geometry	6	100	80	20		Honours
1264	B.Sc.	Mathematics	MAT-HC-4016	Multivariate Calculus	6	100	80	20		Honours
1265	B.Sc.	Mathematics	MAT-HC-4026	Numerical Methods (including practical)	6	100	60	20	20	Honours
1266	B.Sc.	Mathematics	MAT-HC-4036	Ring Theory	6	100	80	20		Honours
1267	B.Sc.	Mathematics	MAT-HC-5016	Complex Analysis	6	100	80	20		Honours
1268	B.Sc.	Mathematics	MAT-HC-5026	Linear Algebra	6	100	80	20		Honours
1269	B.Sc.	Mathematics	MAT-HC-6016	Riemann Integration and Matric Space	6	100	60	20	20	Honours
1270	B.Sc.	Mathematics	MAT-HC-6026	Partial Differential Equations (including practical)	6	100	60	20	20	Honours
1271	B.Sc.	Mathematics	MAT-HE-5016	Number Theory	6	100	80	20		Honours
1272	B.Sc.	Mathematics	MAT-HE-5026	Mechanics	6	100	80	20		Honours
1273	B.Sc.	Mathematics	MAT-HE-5036	Probability and Statistics	6	100	80	20		Honours
1274	B.Sc.	Mathematics	MAT-HE-5046	Linear Programming	6	100	80	20		Honours
1275	B.Sc.	Mathematics	MAT-HE-5056	Spherical Trigonometry and Astronomy	6	100	80	20		Honours
1276	B.Sc.	Mathematics	MAT-HE-5066	Programming in C	6	100	60	20	20	Honours
1277	B.Sc.	Mathematics	MAT-HE-6016	Boolean Algebra and Automata Theory	6	100	80	20		Honours
1278	B.Sc.	Mathematics	MAT-HE-	Bio-Mathematics	6	100	80	20		Honours

		s	6026							
1279	B.Sc.	Mathematics	MAT-HE-6036	Mathematical Modeling	6	100	60	20	20	Honours
1280	B.Sc.	Mathematics	MAT-HE-6046	Hydromechanics	6	100	80	20		Honours
1281	B.Sc.	Mathematics	MAT-HE-6056	Rigid Dynamics	6	100	80	20		Honours
1282	B.Sc.	Mathematics	MAT-HE-6066	Group Theory II	6	100	80	20		Honours
1283	B.Sc.	Mathematics	MAT-HE-6076	Mathematical Finance	6	100	80	20		Honours
1284	B.Sc.	Mathematics	MAT-HG-1016/MAT-RC-1016	Calculus	6	100	80	20		Honours
1285	B.Sc.	Mathematics	MAT-HG-1026	Analytical Geometry	6	100	80	20		Honours
1286	B.Sc.	Mathematics	MAT-HG-2016/MAT-RC-2016	Algebra	6	100	80	20		Honours
1287	B.Sc.	Mathematics	MAT-HG-2026	Discrete Mathematics	6	100	80	20		Honours
1288	B.Sc.	Mathematics	MAT-HG-3016/MAT-RC-3016	Differential Equations	6	100	80	20		Honours
1289	B.Sc.	Mathematics	MAT-HG-3026	Linear Programming	6	100	80	20		Honours
1290	B.Sc.	Mathematics	MAT-HG-4016/MAT-RC-4016	Real Analysis	6	100	80	20		Honours
1291	B.Sc.	Mathematics	MAT-HG-4026	Numerical Analysis	6	100	80	20		Honours
1292	B.Sc.	Mathematics	MAT-RC-1016	Calculus	6	100	80	20		Regular
1293	B.Sc.	Mathematics	MAT-RC-2016	Algebra	6	100	80	20		Regular
1294	B.Sc.	Mathematics	MAT-RC-3016	Differential Equations	6	100	80	20		Regular
1295	B.Sc.	Mathematics	MAT-RC-4016	Real Analysis	6	100	80	20		Regular
1296	B.Sc.	Mathematics	MAT-RE-5016	Number Theory	6	100	80	20		Regular
1297	B.Sc.	Mathematics	MAT-RE-5026	Discrete Mathematics	6	100	80	20		Regular
1298	B.Sc.	Mathematics	MAT-RE-6016	Numerical Analysis	6	100	80	20		Regular
1299	B.Sc.	Mathematics	MAT-RE-6026	Programming in C	6	100	80	20		Regular
1300	B.Sc.	Mathematics	MAT-SE-3014	Computer Algebra Systems and Related Software	4	100	60	20	20	Honours
1301	B.Sc.	Mathematics	MAT-SE-3014	Computer Algebra Systems and Related Software	4	100	60	20	20	Regular
1302	B.Sc.	Mathematics	MAT-SE-3024	Combinatorics and Graph Theory	4	100	60	20	20	Honours

1303	B.Sc.	Mathematics	MAT-SE-4014	R-Programming	4	100	60	20	20	Honours
1304	B.Sc.	Mathematics	MAT-SE-4014	R-Programming	4	100	60	20	20	Regular
1305	B.Sc.	Mathematics	MAT-SE-4024	LATEX and HTML	4	100	60	20	20	Honours
1306	B.Sc.	Mathematics	MAT-SE-4034	Boolean Algebra	4	100	80	20		Honours
1307	B.Sc.	Mathematics	MAT-SE-5014	Combinatorics and Graph Theory	4	100	80	20		Regular
1308	B.Sc.	Mathematics	MAT-SE-6014	LATEX and HTML	4	100	60	20	20	Regular

1. Introduction to CHOICE BASED CREDIT SYSTEM (CBCS):

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill-based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Therefore, it is necessary to introduce uniform grading system in the entire higher education in India. This will benefit the students to move across institutions within India to be given with and across countries. The uniform grading system will also enable potential employers in assessing the performance of the candidates. In order to bring uniformity in evaluation system and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations, the UGC has formulated the guidelines to be followed.

2. Outline of Choice Based Credit System:

2.1 Core Course: A course, which should compulsorily be studied by a candidate as a core requirement is termed as a Core course.

2.2 Elective Course: Generally, a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course.

2.2.1 Discipline Specific Elective (DSE) Course: Elective courses may be offered by them an indiscipline/subject of study is referred to as Discipline Specific Elective. The University/Institute may also offer discipline related Elective courses of inter disciplinary nature (to be offered by main discipline/subject of study).

2.2.2 Dissertation/Project: An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project.

2.2.3 Generic Elective (GE) Course: An elective course chosen generally from an unrelated discipline/subject, with an intention to seek exposure is called a Generic Elective. P.S.: A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective.

3. Ability Enhancement Courses (AEC)/Competency Improvement Courses/Skill Development Courses /Foundation Course: The Ability Enhancement (AE) Courses may be of two kinds: AE Compulsory Course (AECC) and AE Elective Course (AEEC). "AECC" courses are the courses based upon the content that leads to Knowledge enhancement. They are

((i) Environmental Science(ii) English/MIL Communication) are mandatory for all disciplines. AEEC courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc.

3.1 AE Compulsory Course (AECC): Environmental Science, English Communication /MIL Communication.

3.2 AE Elective Course (AEEC): These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based instruction.

Project work/Dissertation is considered as a special course involving application of knowledge in solving /analyzing /exploring a real life's situation/difficult problem. A Project/Dissertation work would be of 6 credits. A Project/Dissertation work may be given in lieu of a discipline specific elective paper.

4. BACHELOR OF MATHEMATICS(Hons.) Program Details:

4.1. Program Objectives:

Students who choose BMATH(H) Program, develop the ability to think critically, logically and analytically and hence use mathematical reasoning in everyday life.

Pursuing a degree in mathematics will introduce the students to a number of interesting and useful ideas in preparations for a number of mathematics careers in education, research, government sector, business sector and industry.

The program covers the full range of mathematics. The course lays a structured foundation of Calculus, Real and Complex analysis, Algebra, Differential equations and Mathematical modelling, Number theory, Graph theory, Mechanics and C-programming.

An exceptionally broad range of topics covering Pure and Applied Mathematics: Linear Algebra, Metric spaces, Statistics, Linear Programming and Applications, Mathematical Finance, and Bio-Mathematics cater to varied interests and ambitions. Also, to carry out the hand on sessions in Computer lab using various CAS software to have a deep conceptual understanding of the above tools to widen the horizon of students' self-experience.

4.2. Program Learning Outcomes: The completion of the BMATH(H) Program shall enable a student to:

- i) Communicate mathematics effectively by oral, written, computational and graphic means.
- ii) Create mathematical ideas from basic axioms.
- iii) Gauge the hypothesis, theories, techniques and proofs provisionally.
- iv) Utilize mathematics to solve theoretical and applied problems by critical understanding, analysis and synthesis.
- v) Identify applications of mathematics in other disciplines and in the real world, leading to enhancement of career prospects in a plethora of fields.
- vi) Appreciate the requirement of lifelong learning through continued education and research.

4.3. Program Structure: The BMATH(H) program is a three-year course divided into six-semester. A student is required to complete 148creditsforthe completion of course and the award of degree.

		<i>Semester</i>	<i>Semester</i>
Part-I	First Year	Semester I: 22	Semester II:22
Part-II	Second Year	Semester III:28	Semester IV:28
Part-III	Third Year	Semester V:24	Semester VI:24

4.4. Program Implementation Requirement:

The B.MATH(H) program is a three-year course divided into six-semester. For proper implementation of the UG CBCS program the following infrastructure are necessary:

- (a) Sufficient lab facilities with computers and software
- (b) At least 7 faculties for Honours and 5 faculties without Honours.

4.5. Instruction for questions paper setter: Question Paper setter should set from the prescribed text books, mentioned in the syllabus.

5. Credit allocation (B.Sc. Honours):

Course	*Credits	
	Theory +Practical	Theory +Tutorial
I Core Course (6credits)		
(14papers)	14X4=56	14x5=70
Core Course Practical/Tutorial*(14Papers)	14x2=28	14x1=14
I. Elective Course(6credits) (8Papers)		
A.1.Discipline Specific Elective(4Papers)	4x4=16	4x5=20
A.2.Discipline Specific Elective Practical/Tutorial* (4Papers)	4x2=8	4x1=4
B.1.Generic Elective/Interdisciplinary (4Papers)	4x4=16	4x5=20
B.2.Generic Elective Practical/ Tutorial*(4Papers)	4x2=8	4x1=4
Optional dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 6 th semester		
1.Ability Enhancement Compulsory Courses (AECC) (2 Papers of 4credit each)	2x4=4	2x4=8
Environmental Science		
English Communication		
2.Skill Enhancement Courses (SEC)(Minimum2) (2 Papers of 4credit each)	2x4=8	2x4=8
Total credit	148	148

*Wherever there is practical, there will be no tutorial and vice-versa

CBCS Course Structure for B.Sc. (Hons.) Mathematics Program SEMESTER WISE PLACEMENT OF THE COURSES

Sem	Core Course (14)	Ability Enhancement Compulsory Course (AECC) (2)	Skill Enhancement Course (SEC) (2)	Discipline Specific Elective (DSE) (4)	Generic Elective (GE) (4) (Other than Mathematics Honours)
I	MAT-HC-1016: Calculus (including practical)	ENG-AE-1014			MAT-HG-1016 / MAT-RC-
	MAT-HC-1026: Algebra				1016 MAT-HG-1026
II	MAT-HC-2016: Real Analysis	ENV-AE-2014			MAT-HG-2016 / MAT-RC-2016
	MAT-HC-2026: Differential Equations (including practical)				MAT-HG-2026
III	MAT-HC-3016: Theory of Real Functions		MAT-SE-3014		MAT-HG-3016 / MAT-RC-
	MAT-HC-3026: Group Theory-I		MAT-SE-3024		3016 MAT-HG-
	MAT-HC-3036: Analytical Geometry				3026
IV	MAT-HC-4016: Multivariate Calculus		MAT-SE-4014		MAT-HG-4016 / MAT-RC-
	MAT-HC-4026: Numerical Methods (including practical)		MAT-SE-4024		4016 MAT-HG-
	MAT-HC-4036: Ring Theory		MAT-SE-4034		4026
V	MAT-HC-5016: Complex Analysis			DSE-1 MAT-HE-5016 MAT-HE-5026 MAT-HE-5036	
	MAT-HC-5026: Linear Algebra			DSE-2 MAT-HE-5046 MAT-HE-5056 MAT-HE-5066	
VI	MAT-HC-6016: Riemann Integration and Metric spaces			DSE-3 MAT-HE-6016 MAT-HE-6026 MAT-HE-6036 MAT-HE-6046	
	MAT-HC-6026: Partial Differential Equations (including practical)			DSE-4 MAT-HE-6056 MAT-HE-6066 MAT-HE-6076	
				Project In lieu of DSE-3 or DSE-4	

Legends: HC: Core Papers HE: Discipline Specific Elective Papers SE: Skill

Enhancement Papers HG: Generic Elective Papers

Core Papers:

- MAT-HC-1016: Calculus (including practical)
- MAT-HC-1026: Algebra
- MAT-HC-2016: Real Analysis
- MAT-HC-2026: Differential Equations (including practical)
- MAT-HC-3016: Theory of Real Functions
- MAT-HC-3026: Group Theory-I
- MAT-HC-3036: Analytical Geometry
- MAT-HC-4016: Multivariate Calculus
- MAT-HC-4026: Numerical Methods (including practical)
- MAT-HC-4036: Ring Theory
- MAT-HC-5016: Complex Analysis
- MAT-HC-5026: Linear Algebra
- MAT-HC-6016: Riemann Integration and Metric spaces
- MAT-HC-6026: Partial Differential Equations (including practical)

Skill Enhancement Course (SEC)

papers SEC1(choose one)

- (i) MAT-SE-3014: Computer Algebra Systems and Related Software
- (ii) MAT-SE-3024: Combinatorics and Graph Theory

SEC2(choose one)

- (i) MAT-SE-4014: R-Programming
- (ii) MAT-SE-4024: LATEX and HTML
- (iii) MAT-SE-4034: Boolean Algebra

Discipline Specific Electives (DSE) papers

DSE1(choose one)

- (i) MAT-HE-5016: Number Theory
- (ii) MAT-HE-5026: Mechanics
- (iii) MAT-HE-5036: Probability and Statistics

DSE2(choose one)

- (i) MAT-HE-5046: Linear Programming
- (ii) MAT-HE-5056: Spherical Trigonometry and Astronomy
- (iii) MAT-HE-5066: Programming in C

DSE-3(choose one)

- (i) MAT-HE-6016: Boolean Algebra and Automata Theory
- (ii) MAT-HE-6026: Bio-Mathematics
- (iii) MAT-HE-6036: Mathematical Modeling
- (iv) MAT-HE-6046: Hydromechanics

DSE4(choose one)

- (i) MAT-HE-6056: Rigid Dynamics

- (ii) MAT-HE-6066: Group Theory II
- (iii) MAT-HE-6076: Mathematical Finance

Project (in lieu of DSE3 or DSE4)

Generic Elective (GE) papers

GE1(choose one)

- (i). MAT-HG-1016/MAT-RC-1016: Calculus
- (ii). MAT-HG-1026: Analytical Geometry

GE2(Choose one)

- (i). MAT-HG-2016/MAT-RC-2016: Algebra
- (ii). MAT-HG-2026: Discrete Mathematics

GE3(choose one)

- (i). MAT-HG-3016/MAT-RC-3016: Differential Equations
- (ii). MAT-HG-3026: Linear Programming

GE4(choose one)

- (i). MAT-HG-4016/MAT-RC-4016: Real Analysis
- (ii). MAT-HG-4026: Numerical Analysis

Detailed Syllabus

SEMESTER-I

SEMESTER-I

MAT-HC-1016: Calculus (including practical)

Total marks: 100 (Theory: 60, Practical 20, Internal Assessment: 20)

Lectures 2 Practical, Credits 6 (4+2) *Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of calculus and geometric properties of different conic sections which are helpful in understanding their applications in planetary motion, design of telescope and to the real-world problems. Also, to carry out the hand on sessions in computer lab to have a deep conceptual understanding of the above tools to widen the horizon of students' self-experience.

Course Learning Outcomes: This course will enable the students to:

- Learn first and second derivative tests for relative extrema and apply the knowledge in problems in business, economics and life sciences.
- Sketch curves in a plane using its mathematical properties in the different coordinate systems of reference.
- Compute area of surfaces of revolution and the volume of solids by integrating over cross-sectional areas.
- Understand the calculus of vector functions and its use to develop the basic principles of planetary motion.

UNIT 1: (a) Higher order derivatives, Leibnitz rule and its applications to problems of type $e^{ax+b} \sin x$, $e^{ax+b} \cos x$, $(ax+b)^n \sin x$, $(ax+b)^n \cos x$,

(b) Concavity and inflection points, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L-Hopital's rule, applications in business, economics and life sciences.

[1] Chapter 4 (Sections 4.3-4.5,4.7) (for part (b))

[2] Chapter 10 (Section 10.1-10.6) (for part (b)).

[3] Chapter 5 (only for part (a))

UNIT 2: (a) Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x \, dx$, $\int \cos^n x \, dx$, $\int \tan^n x \, dx$, $\int \sec^n x \, dx$, $\int (\log x)^n \, dx$, $\int \sin^n x \cos^m x \, dx$.

(b) Volumes by slicing, disks and washers' methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution.

[1] Chapter 6 (Section 6.2,6.4), Chapter 9 (Section 9.4) (for part (b))

[2] Chapter 6 (Section 6.1-6.5), (for part (b))

[4] Chapter 4 (4.1-4.6) (only for part (a))

UNIT 3: Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law.

[1] Chapter 9 (Section 9.3), Chapter 10

[2] Chapter 11 (11.3, 11.4) Chapter 12

Practical / Lab work to be performed on a computer:

List of the practical to be done using MATLAB / Mathematica / Maple / Scilab / Maxima etc.

- Plotting the graphs of the following functions: ax , $[x]$ (greatest integer function),

$$\sqrt{ax+b}, |ax+b|, c \pm |ax+b|, x^{\pm n}, x^{1/n}, n \in \mathbb{Z}$$

$$|x|/x, \sin(1/x), x \sin(1/x), \text{ and } e^{\pm 1/x} \text{ for } x \neq 0.$$

$$e^{ax+b}, \log(ax+b), 1/(ax+b), \sin(ax+b), \cos(ax+b), |\sin(ax+b)|, |\cos(ax+b)|.$$

Observe and discuss the effect of changes in the real constants a , b and c on the graphs.

- Plotting the graphs of polynomial of degree 4 and 5, the graphs of their first and second derivatives, and analysis of these graphs in context of the concepts covered in Unit 1.

- (iii). Sketching parametric curves, e.g., Trochoid, Cycloid, Epicycloid and Hypocycloid.
- (iv). Tracing of conic in cartesian coordinates.
- (v). Obtaining surface of revolution of curves.
- (vi). Graph of hyperbolic functions.
- (vii). Computation of limit, Differentiation, Integration and sketching of vector-valued functions.
- (viii). Complex numbers and their representations, Operations like addition, Multiplication, Division, Modulus. Graphical representation of polar form.
- (ix). Find numbers between two real numbers and plotting of finite and infinite subset of R

Text Books:

1. M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus (3rd Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
2. H. Anton, I. Bivens and S. Davis, Calculus (10th Edition), John Wiley and sons (Asia), Pt Ltd., Singapore, 2011.
3. Shanti Narayan and P.K. Mittal, Differential Calculus, S. Chand, 2005.
4. Shanti Narayan and P.K. Mittal, Integral Calculus, S. Chand, 2007.

Reference Book:

1. G. L. Bradley and K. J. Smith, Calculus, Prentice Hall Inc, (1st Edition) 1995.

MAT-HC-1026: Algebra

Totalmarks:100(Theory:80 InternalAssessment:20)

Perweek:5Lectures1Tutorial, Credits6, *each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of set theory, functions, induction principle, theory of equations, complex numbers, number theory, matrices and determinant understand their connection with the real-world problems.

Course Learning Out comes: This course will enable the students to:

- i) Employ DeMoivre’s theorem in a number of applications to solve numerical problems.
- ii) Learn about equivalent classes and cardinality of a set.
- iii) Use modular arithmetic and basic properties of congruences.
- iv) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix.
- v) Learn about the solution sets of linear systems using matrix method and Cramer’s rule

UNIT-1: Polar representation of complex numbers, nth roots of unity, De Moivre’s theorem for rational indices and its applications.

[1]: Chapter2

UNIT-2: Statements and logic, statements with quantifier, compound statements, implications, proofs in Mathematics; Sets, operations on sets, family of sets, power sets, Cartesian product; Functions, one-one, onto functions and bijections, Composition of functions, Inverse of a function, Image and Inverse image of subsets

[2] Chapters1– 3

UNIT-3: Relation, Equivalence relations, Equivalence classes and partitions of a set, congruence modulo n in integers; Induction Principles, the well-ordering principle, greatest common divisor of integers.

[3] Chapters 4– 5.

UNIT 4: Systems of Linear Equations, row reduction and echelon forms, vector equations, the matrix equation $Ax = b$, solution sets of linear systems, linear independence, introduction to linear transformations, the matrix of

a linear transformation; Matrix operations, inverse of a matrix, characterizations of invertible matrices; Determinants, Cramer's rule

[4]: Chapter1(Sections1.1–1.9); Chapter2(Sections,2.1–1.3); Chapter3(Sections3.1–3.3)

Text Books:

1. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser,2006.
2. A Kumar, S. Kumaresan and B.K.Sarma, A Foundation Course in Mathematics,Narosa,2018.
3. David C. Lay, Linear Algebra and its Applications(3rdEdition), Pearson Education Asia, Indian print,2007.

Reference Books:

1. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory (3rd Edition), Pearson Education (Singapore) Pvt. Ltd., Indian Reprint, 2005.
2. Gilbert Strang, Linear Algebra and its Applications, Thomson,2007.

GENERIC ELECTIVE

MAT-HG-1016/ MAT-RC-1016: Calculus

Total Marks: 100(Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial **Credits: 6**, Each unit carry equal credit

Course Objectives: Calculus is referred as 'Mathematics of change' and is concerned with describing the precise way in which changes in one variable relate to the changes in another. Through this course, students can understand the quantitative change in the behaviour of the variables and apply them on the problems related to the environment.

Course Learning Outcomes: The students who take this course will be able to:

- i) Understand continuity and differentiability in terms of limits.
- ii) Describe asymptotic behavior in terms of limits involving infinity.
- iii) Use derivatives to explore the behavior of a given function, locating and classifying its extrema, and graphing the function.
- iv) Understand the importance of mean value theorems.

Unit 1: Graphs of simple concrete functions such as polynomial, Trigonometric, Inverse trigonometric, Exponential and logarithmic functions

[1] Chapter 1 (Sections 1.1 to 1.3), and Chapter 7 (Sections 7.2, 7.3, and 7.6)

Unit 2: Limits and continuity of a function including approach, Properties of continuous functions including Intermediate value theorem.

[2] Chapter 1

Unit 3: Differentiability, Successive differentiation, Leibnitz theorem, Recursion formulae for higher derivatives.

[3] Chapter 5.

Unit 4: Rolle's theorem, Lagrange's mean value theorem with geometrical interpretations and simple applications, Taylor's theorem, Taylor's series and Maclaurin's series, Maclaurin's series expansion of functions such as their use in polynomial approximation and error estimation.

[1] Chapter 4 (Sections 4.2, and 4.3), [2] Chapter 9 (Sections 9.8, and 9.9)

Unit 5: Functions of two or more variables, Graphs and level curves of functions of two variables, Partial differentiation up to second order.

[2] Chapter 13 (Sections 13.1, and 13.3)

Text books:

1. Thomas, Jr. George B., Weir, Maurice D., & Hass, Joel (2014). *Thomas' Calculus* (13thed). Pearson Education, Delhi. Indian Reprint 2017.
2. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd.

Reprint (2016) by Wiley India Pvt. Ltd. Delhi

3. Shanti Narayan and P.K. Mittal, Differential Calculus, S. Chand, 2005

MAT-HG-1026: Analytical Geometry

Total Marks: 100 (Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial Credits: 6, *Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of two-dimensional coordinate systems, general conics, and three-dimensional coordinate systems. Also, introduces the vectors in coordinate systems with geometrical properties

Course Learning Out comes: This course will enable the students to:

- i) Transform coordinate systems, conic sections
- ii) Learn polar equation of a conic, tangent, normal and related properties
- iii) Have a rigorous understanding of the concept of three-dimensional coordinate systems
- iv) Understand geometrical properties of dot product, cross product of vectors

UNIT 1: Transformation of coordinates, pair of straight lines. Parabola, parametric coordinates, tangent and normal, ellipse and its conjugate diameters with properties, hyperbola and its asymptotes, general conics: tangent, condition of tangency, pole and polar, center of a conic, equation of pair of tangents, reduction to standard forms, central conics, equation of the axes, and length of the axes, polar equation of a conic, tangent and normal and properties.

[1] Chapter 3, 4, 10

UNIT 2: Three-Dimensional Space: Vectors

Rectangular coordinates in 3-space, Spheres and Cylindrical surfaces, Vector viewed geometrically, Vectors in coordinate system, Vectors determine by length and angle, Dot product, Cross product and their geometrical properties, Parametric equations of lines in 2-space and 3-space.

[1] Chapter 11 (11.1, 11.2, 11.3 to 11.5)

Text Books:

1. R.M. Khan, Analytical Geometry of two and three dimension and vector analysis. New Central Book agency 2012.
2. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Reprint (2016) by Wiley India Pvt. Ltd. Delhi.

Reference Book:

1. E.H. Askwith, The Analytical Geometry of the Conic Sections, Nabu Press (27 February 2012)
2. R.J.T. Bell, Coordinate Solid Geometry, Macmillan, 1983.
3. B. Das, Analytical Geometry and Vector Analysis, Orient Book Company, Kolkata - 700007

SEMESTER-II

MAT-HC-2016: Real Analysis

Total marks: 100 (Theory: 80 Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The course will develop a deep and rigorous understanding of real line R and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. These concepts have wide range of applications in real life scenario.

Course Learning Out comes: This course will enable the students to:

- i) Understand many properties of the real line R , including completeness and Archimedean properties.

- ii) Learn to define sequences in terms of functions from N to a subset of R .
- iii) Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence. Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

UNIT 1: Algebraic and order properties of R , absolute value and real line, bounded sets, supremum and infimum, completeness property of R , the Archimedean property, the density theorem, intervals, nested interval theorem.

[1] Chapter2

UNIT-2: Real sequences, limit of a sequence, convergent sequence, bounded sequence, limit theorems, monotone sequences, monotone convergence theorem, subsequences, monotone subsequence theorem, Bolzano Weierstrass theorem for sequences, Cauchy sequences, Cauchy's convergence criterion, properly divergence sequences.

[1] Chapter3

UNIT 3: Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: comparison test, limit comparison test, ratio test, root test, integral test, Absolute convergence, rearrangement theorem, alternating series, Leibniz test, conditional (non-absolute) convergence.

[1] Chapter9Sections9.1-3.

Text Book:

1. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, 3rdEd., John Wiley and Sons,2002.

Reference Books:

1. Gerald G. Bilodeau, Paul R. Thie, G.E. Keough, *An Introduction to Analysis*, Jones & Bartlett, Second Edition, 2010.
2. A. Kumar and S. Kumaresan, *Basic Course in Real Analysis*, CRC Press,2014.
3. K.A. Ross, Elementary Analysis: The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

MAT-HC-2026: Differential Equations (including practical)

Total Marks:100: (Theory60, Practical20, Internal assessment 20)

Per week: 4 Lectures, 2 Practical, Credits 6 (4+2) *Each unit carry equal credit*

Course Objectives: The main objective of this course is to introduce the students to the exciting world of differential equations, mathematical modeling and their applications.

Course Learning Outcomes: The course will enable the students to:

- i) Learn basics of differential equations and mathematical modeling.
- ii) Formulate differential equations for various mathematical models.
- iii) Solve first order non-linear differential equations and linear differential equations of higher order using various techniques.
- iv) Apply these techniques to solve and analyze various mathematical models.

UNIT 1: Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

[2] Chapter 1 (Sections 1.1, and 1.6), [3] Chapter 2, [2] Chapter 1 (Section 1.4, pages 35 to 38), and Chapter 2(Section 2.3). [3] Chapter3 (Section 3.3, A and B with Examples 3.8, 3.9)

UNIT 2: Introduction to compartmental model, exponential decay model, exponential growth of population, limited growth of population, limited growth with harvesting.

[1] Chapter 2 (Sections 2.1, 2.5, and 2.6), [1] Chapter 2 (Sections 2.7, and 2.8), [1] Chapter 3 (Sections 3.1 to 3.3)

UNIT3: General solution of homogeneous equation of second order, principle of superposition for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

[2] Chapter 3 (Sections 3.1 to 3.3, Sections 3.4 (pages 172 to 177), and 3.5)

List of Practical (using any software)

1. Plotting of second order solution family of differential equation.
2. Plotting of third order solution family of differential equation.
3. Growth model (exponential case only).
4. Decay model (exponential case only).
5. Lake pollution model (with constant/seasonal flow and pollution concentration).
6. Case of single cold pill and a course of cold pills.
7. Limited growth of population (with and without harvesting).

Text Books:

1. Barnes, Belinda & Fulford, Glenn R. (2015). *Mathematical Modelling with Case Studies, Using Maple and MATLAB* (3rd ed.). CRC Press, Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). *Differential Equation and Boundary Value Problems: Computing and Modeling* (5th ed.). Pearson Education.
3. Ross, Shepley L. (2004). *Differential Equations* (3rded.). John Wiley & Sons. India

Reference Books:

1. Martha L Abell, James P Braselton, *Differential Equations with MATHEMATICA*, 3rdEd., Elsevier Academic Press, 2004.
2. Ross, Clay C. (2004). *Differential Equations: An Introduction with Mathematica* (2nded.). Springer.

GENERIC ELECTIVE

PAPERSMAT-HG-2016/MAT-RC-2016:

Algebra

Total Marks: 100 (Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits: 6, *Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of theory of equations, complex numbers, number theory, matrices, determinant, along with algebraic structures like group, ring and vector space to understand their connection with the real-world problems.

Course Learning Outcomes: This course will enable the students to:

- i) Learn how to solve the cubic and biquadratic equations, also learn about symmetric functions of the roots for cubic and biquadratic
- ii) Employ De Moivre's theorem in a number of applications to solve numerical problems.
- iii) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix. Finding inverse of a matrix.
- iv) Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, ring etc.

Unit 1: Theory of Equations, De Moivre's Theorem and Roots of complex Numbers:

General properties of equations, Theorems related to real roots of equations, Existence of a root in the general equation, Imaginary roots, Equal roots, Theorems determining the number of roots of an equation. Relation between roots and coefficients of n th degree equation, Solutions of cubic and biquadratic equations, when some conditions on roots of the equation are given, Depression of an equation when a relation exists between two of its roots, Symmetric functions of the roots for cubic and biquadratic.

[2] Chapter II (12- 18) Chapter III (23-25, 27)

De Moivre's theorem (both integral and rational index), Roots of complex numbers, Solutions of equations using trigonometry and De Moivre's theorem.

[1] Chapter 7 (Sections 7.3)

Unit 2: Matrices:

Matrix Algebra, Addition, Transposition, Symmetry, Multiplication of matrices and their properties, Matrix inversion and properties, Row Echelon form and Rank of a matrix, Reduced row Echelon form, Consistency of linear systems, Solutions of system of homogeneous and non-homogeneous linear equations with number of equations and unknowns up to four. Invariance of rank under elementary transformations, Reduction to normal form.

[3] Chapter 3 (Sections 3.2, 3.5, and 3.7) Chapter 2 (Sections 2.1 to 2.5) Chapter 3 (section 3.9)

Unit 3: Groups and Rings:

Permutations. Congruence of Integers. Groups, Properties of group elements. Subgroups. Cyclic groups, Permutation groups, Cosets of a subgroup. Definition of Ring, Subring, Ring with unity, Commutative Ring (Up to definition 5.5)

[1] Chapter 1 (Section 1.5), Chapter 2 (Section 2.5), Chapter 3 (Sections 3.1- 3.4)

Chapter 4 (Sections 4.1 and 4.4) and Chapter 5 (Section 5.1)

Text Books:

1. Gilbert, Linda & Gilbert, Jimmie. *Elements of Modern Algebra*, (8th Edition) 2013, Cengage Learning
2. Burnside, William Snow & Panton, Arthur William. *The Theory of Equations*, Vol. 1 (8th Edition), Dublin University Press Series.
3. Meyer, Carl D. (2000). *Matrix Analysis and Applied Linear Algebra*. Society for Industrial and Applied Mathematics (Siam).

Reference Books:

1. Dickson, Leonard Eugene (2009). *First Course in The Theory of Equations*. The Project Gutenberg eBook (<http://www.gutenberg.org/ebooks/29785>)
2. Gilbert, William J. (2004). *Modern Algebra with Applications* (2nd ed.). John Wiley & Sons.
3. Gilbert, William J., & Vanstone, Scott A. (1993). *Classical Algebra* (3rd ed.). Waterloo Mathematics Foundation, Canada.
4. Beachy, John A., & Blair, William D. (2006). *Abstract Algebra* (3rd ed.). Wavel and Press, Inc.

MAT-HG-2026: Discrete Mathematics

TotalMarks:100(Theory:80InternalAssessment:20)

Per week: 5 Lectures, 1 Tutorial, Credits:6, *Each unit carry equal credit*

Course Objectives: The course aims at introducing the concepts of ordered sets, lattices, sublattices and homomorphisms between lattices. It also includes introduction to modular and distributive lattices along with complemented lattices and Boolean algebra. Then some important applications of Boolean algebra are discussed in switching circuits.

Course Learning outcomes: After the course, the student will be able to:

- i) Understand the notion of ordered sets and maps between ordered sets.
- ii) Learn about lattices, modular and distributive lattices, sub lattices and homomorphisms between lattices.
- iii) Become familiar with Boolean algebra, Boolean homomorphism, Karnaugh diagrams, switching circuits and their applications.

Unit1: Ordered Sets:

Definitions, Examples and basic properties of ordered sets, Order isomorphism, Hasse diagrams, Dual of an ordered set, Duality principle, Maximal and minimal elements, Building new ordered sets, Maps between ordered sets.

[1] Chapter 1(Sections 1.1 to 1.5 and 1.14 to 1.26, and 1.34 to 1.36)

[3] Chapter 1[Section1(1.1to1.3)]

Unit2: Lattices

Lattices as ordered sets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, Examples and properties of modular and distributive lattices, The $M_3 - N_5$ Theorem with applications, Complemented lattice, Relatively complemented lattice, Sectionally complemented lattice. homomorphisms.

[1] Chapter2(Sections2.1to2.19) Chapter4(Sections4.1to4.11)

[3] Chapter1[Section1(1.5to1.20)] Chapter2[Section2(2.1to2.14)]

Unit3: Boolean Algebras and Switching Circuits

Boolean Algebras, De Morgan's laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive normal form and conjunctive normal form, Minimal forms of Boolean polynomial, Quinn-McCluskey method, Karnaugh diagrams, switching circuits and applications of switching circuits.

[3] Chapter 1 (Sections 3,4 and 6) Chapter 2 (Sections 7 and 8).

Text Books:

1. Davey, B.A., & Priestley, H.A. (2002). *Introduction to Lattices and Order* (2nd ed.). Cambridge University press, Cambridge.
2. Goodaire, Edgar G., & Parmenter, Michael M. (2011). *Discrete Mathematics with Graph Theory* (3rd ed.). Pearson Education (Singapore) Pvt. Ltd. Indian Reprint.
3. Lidl, Rudolf & Pilz, Gunter. (2004). *Applied Abstract Algebra* (2nd ed.), Undergraduate Texts in Mathematics. Springer (SIE). Indian Reprint.

SEMESTER-III

MAT-HC-3016: Theory of Real Functions

TotalMarks:100(Theory 80, Internal assessment 20)

Per week: 5 Lectures, 1Tutorial, Credits (6) *Each unit carry equal credit*

Course Objectives: It is a basic course on the study of real valued functions that would develop an analytical ability to have a more matured perspective of the key concepts of calculus, namely; limits, continuity, differentiability and their applications

Course Learning Outcomes: This course will enable the students to:

- i) Have a rigorous understanding of the concept of limit of a function.
- ii) Learn about continuity and uniform continuity of functions defined on intervals.
- iii) Understand geometrical properties of continuous functions on closed and bounded intervals.
- iv) Learn extensively about the concept of differentiability using limits, leading to a better understanding for applications.
- v) Know about applications of mean value theorems and Taylor's theorem

UNIT 1: Cluster point or limit point of a set, limits of a function (ϵ - δ approach), sequential criterion for limits, divergence criteria, limit theorems, one sided limits, infinite limits and limits at infinity.

[1] Chapter4

UNIT 2: Continuous functions, sequential criterion for continuity and discontinuity, algebra of continuous functions, continuous functions on intervals, maximum-minimum theorem, intermediate value theorem, location of roots theorem, preservation of intervals theorem, uniform continuity, uniform continuity theorem.

[1] Chapter5 (5.1 to 5.5)

UNIT 3: Differentiability of a function at a point and in an interval, Caratheodory's theorem, chain rule, derivative of inverse function, Rolle's theorem, mean value theorem, Darboux's theorem, Cauchy mean value

theorem, Taylor's theorem and applications to inequalities, Taylor's series expansions of exponential and trigonometric functions, $\ln(1+x)$, $1/(ax+b)$ and $(1+x)^n$.

[1] Chapter 6, and Taylor series as in Section 6.4.

Text Book:

1. R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2015.

Reference Books:

1. Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Indian Edn. 2014.
2. K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
3. A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.
4. S.R. Ghorpade and B.V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006.

MAT-HC-3026: Group Theory-I

Total Marks: 100 (Theory 80 Internal assessment 20)

Per week: 5 Lectures, 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The objective of the course is to introduce the fundamental theory of groups and their homomorphisms. Symmetric groups and group of symmetries are also studied in detail. Fermat's Little theorem is studied as a consequence of the Lagrange's theorem on finite groups.

Course Learning Outcomes: The course will enable the students to:

- i) Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.
- ii) Link the fundamental concepts of groups and symmetrical figures.
- iii) Analyze the subgroups of cyclic groups and classify subgroups of cyclic groups.
- iv) Explain the significance of the notion of cosets, normal subgroups and factor groups.
- v) Learn about Lagrange's theorem and Fermat's Little theorem.
- vi) Know about group homomorphisms and group isomorphisms.

UNIT 1: Symmetries of a square, Dihedral groups, definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), elementary properties of groups. Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups. Properties of cyclic groups, classification of subgroups of cyclic groups.

[1]: Chapters 1, Chapter 2, Chapter 3 (including Exercise 20 on page 66 and Exercise 2 on page 86), Chapter 4.

UNIT 2: Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem. External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.

[1]: Chapter 5 (till end of Theorem 5.7), Chapter 7 (till end of Theorem 7.2, including Exercises 6 and 7 on Page 168), Chapter 8 (till the end of Example 2), Chapter 9 (till end of Example 10, Theorem 9.3 and 9.5).

UNIT 3: Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems.

[1]: Chapter 6 (till end of Theorem 6.2), Chapter 10.

Text Book:

1. Gallian, Joseph. A. (2013). *Contemporary Abstract Algebra* (8th ed.). Cengage Learning India Private Limited, Delhi. Fourth impression, 2015.

Reference Books:

1. John B. Fraleigh, A First Course in Abstract Algebra, 7thEd., Pearson, 2002.
2. G. Santhanam, Algebra, Narosa Publishing House, 2017.
3. Joseph J. Rotman, An Introduction to the Theory of Groups, 4thEd., Springer Verlag, 1995.
4. David S. Dummit and Richard M. Foote, Abstract Algebra (2nd Edition), John Wiley and Sons (Asia) Pvt. Ltd, Singapore, 2003.

MAT-HC-3036: Analytical Geometry

Total Marks:100:(Theory 80, Internal assessment 20)

Per week:5 Lectures, 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of two-dimensional coordinates systems, general conics, and three-dimensional coordinate systems.

Course Learning Outcomes: This course will enable the students to:

- i) Learn conic sections and transform co-ordinate systems
- ii) Learn polar equation of a conic, tangent, normal and properties
- iii) Have a rigorous understanding of the concept of three-dimensional coordinates systems

UNIT 1: Transformation of coordinates, pair of straight lines. Parabola, parametric coordinates, tangent and normal, ellipse and its conjugate diameters with properties, hyperbola and its asymptotes, general conics: tangent, condition of tangency, pole and polar, center of a conic, equation of pair of tangents, reduction to standard forms, central conics, equation of the axes, and length of the axes, polar equation of a conic, tangent and normal and properties.

[1] Chapter 1(1.30-1.34),2, 3,4,5,6,7, 9 (up to 9.43)

UNIT 2: Plane, straight lines and shortest distance. Sphere, cone and cylinder, central conicoid, ellipsoid, hyperboloid of one and two sheets, diametral planes, tangent lines, director sphere, polar plane, section with a given center.

[1] Chapter 6 (Part-II) (B &C)

[2] Chapters4,5,6,7(uptopage125)

Text Books:

1. R. M. Khan, Analytical Geometry of two and three-dimension and vector analysis. New Central Book agency 2012.
2. R.J.T. Bell, Coordinate Solid Geometry, Macmillan,1983.

Reference Book:

1. E.H. Askwith, The Analytical Geometry of the Conic Sections, Nabu Press (27 February 2012)
2. B. Das, Analytical Geometry and Vector Analysis, Orient Book Company, Calcutta-7

SKILL ENHANCEMENT COURSES**EC-1****MAT-SE-3014: Computer Algebra Systems and Related Software**

Total marks:100(Theory 50, Practical 50)

Per week;2 Lectures, 2 Practical, Credits 4(2+2) *Each unit carry equal credit.*

Course Objectives: This course aims at familiarizing students with the usage of mathematical software (Mathematica/MATLAB/Maxima/Maple) and the statistical software **R**. The basic emphasis is on plotting and working with matrices using CAS. Data entry and summary commands will be studied in **R**. Graphical representation of data shall also be explored.

Course Learning Outcomes: This course will enable the students to:

- i) Use of software; Mathematica/MATLAB/Maxima/Maple, etc. as a calculator, for plotting functions and animations.
- ii) Use of CAS for various applications of matrices such as solving system of equations and finding eigenvalues

and eigen vectors.

iii) Understand the use of the statistical software **R** as calculator and learn to read and get data into **R**.

iv) Learn the use of **R** in summary calculation, pictorial representation of data and exploring relationship between data.

v) Analyze, test, and interpret technical arguments on the basis of geometry

Unit1: Introduction to CAS and Applications:

Computer Algebra System (CAS), Use of a CAS as a calculator, Computing and plotting functions in 2D, plotting functions of two variables using Plot 3 D and Contour Plot, plotting parametric curves surfaces, customizing plots, animating plots, producing tables of values, working with piecewise defined functions, Combining graphics.

[1] Chapter 12 (Sections 12.1 to 12.5)

[2] Chapter 1, and Chapter 3 (Sections 3.1 to 3.6, and 3.8) Chapter 6 (Sections 6.2, and 6.3)

Unit2: Working with Matrices:

Simple programming in a CAS, working with matrices, Performing Gauss elimination, operations (transpose, determinant, inverse), Minors and cofactors, working with large matrices, Solving system of linear equations, Rank and nullity of a matrix, Eigenvalue, eigen vector and diagonalization.

[2] Chapter 7 (Sections 7.1 to 7.8)

Practical:

Six practicals should be done by each student. The teacher can assign practical from the exercises from [1,2].

Text Books:

1. Bindner, Donald & Erickson, Martin. (2011). *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*. CRC Press, Taylor & Francis Group, LLC.
2. Torrence, Bruce F., & Torrence, Eve A. (2009). *The Student's Introduction to Mathematica: A Handbook for Precalculus, Calculus and Linear Algebra* (2nd ed.). Cambridge University Press

MAT-SE-3024: Combinatorics and Graph Theory

Total marks: 100 (Theory 80, Internal Assessment 20)

Per week : 4 Lectures, Credits 4, *Each unit carry equal credit.*

Course Objectives: This course aims to provide the basic tools of counting principles, pigeonhole principle. Also introduce the basic concepts of graphs, Eulerian and Hamiltonian graphs, and applications to dominoes, Diagram tracing puzzles, Knight's tour problem and Gray codes.

Course Learning Outcomes: This course will enable the students to:

- i) Learn about the counting principles, permutations and combinations, Pigeon hole principle
- ii) Understand the basics of graph theory and learn about social networks, Eulerian and Hamiltonian graphs, diagram tracing puzzles and Knight's tour problem.

Unit1: Basic counting principles, Permutations and combinations, the inclusion-exclusion principle, Pigeon hole principle.

[2] Chapter 1 (Sections 1.1, 1.2, 1.3), Chapter 2 (Sections 2.1, 2.2) Chapter 4 (Section 4.1) Chapter 8 (Section 8.1).

Unit2: Graphs, Diagraphs, Networks and sub graphs, Vertex degree, Paths and cycles, Regular and bipartite graphs, Four cube problem, Social networks, Exploring and travelling, Eulerian and Hamiltonian graphs, Applications to dominoes, Diagram tracing puzzles, Knight's tour problem, Gray codes.

[1] Chapter 1 (Section 1.1), and Chapter 2

Text Books:

1. Aldous, Joan M., & Wilson, Robin J. (2007). *Graphs and Applications: An Introductory Approach*. Springer. Indian Reprint.
2. Sharad S. Sane, *Combinatorial Techniques*, Hindustan Book Agency, 2013.

Reference Books:

1. Michael Towusend, *Discrete Mathematics; Applied Combinatorics and Graph Theory*, Benjamin-Cummings Pub Co (March 1, 1987)
2. K.R. Parthasarathi, *Basic Graph Theory*, Tata McGraw-Hill, 1994.
3. C.L. Liu and D. Mohapatra *Elements of discrete mathematics*, McGraw Hill, Computer Science Series. 2017

GENERIC ELECTIVE PAPERS**MAT-HG-3016/MAT-RC-3016: Differential Equations**

Total Marks: 100 (Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits: 6, *Each unit carry equal credit*

Course Objectives: The main objective of this course is to introduce the students to the exciting world of ordinary differential equations, mathematical modeling and their applications.

Course Learning Outcomes: The course will enable the students to:

- i) Learn basics of differential equations and mathematical modelling.
- ii) Solve first order non-linear differential equations and linear differential equations of higher order using various techniques.

Unit 1: First Order Ordinary Differential Equations

First order exact differential equations, integrating factors, Rules to find an integrating factor

[1] Chapter 1 (Section 1.1, 1.2, 1.4),

[2] [2] Chapter 1 (Sections 1.1, and 1.2) Chapter 2 (Sections 2.1, and 2.2)

Linear equations and Bernoulli equations, Orthogonal trajectories and oblique trajectories; Basic theory of higher order linear differential equations, Wronskian, and its properties; Solving differential equation by reducing its order.

[3] Chapter 2 (Sections 2.3, and 2.4), Chapter 3 (Section 3.1), and Chapter 4 (Section 4.1)

Unit 2: Second Order Linear Differential Equations

Linear homogenous equations with constant coefficients, Linear non-homogenous equations, The method of variation of parameters, The Cauchy-Euler equation; Simultaneous differential equations.

[1] Chapter 2 (Section 2.2), [2] Chapter 4 (Sections 4.2, 4.3, 4.4, 4.5, 4.6) Chapter 7 (Sections 7.1, 7.3)

Text Books:

1. Kreyszig, Erwin (2011). *Advanced Engineering Mathematics* (10th ed.). John Wiley & Sons, Inc. Wiley India Edition 2015.
2. Ross, Shepley L. (1984). *Differential Equations* (3rd ed.). John Wiley & Sons, Inc

MAT-HG-3026: Linear Programming

Total Marks: 100 (Theory: 80 Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial Credits: 6, *Each unit carry equal credit*

Course Objectives: This course develops the ideas underlying the Simplex method. The course covers Linear programming problems with applications to transportation, assignment and game problem. Such problems arise

in manufacturing resource planning and financial sectors.

Course Learning Outcomes: This course will enable the students to:

- i) Learn about the graphical solution of linear programming problem with two variables.
- ii) Learn about the relation between basic feasible solutions and extreme points.
- iii) Understand the theory of the simplex method used to solve linear programming problems.
- iv) Learn about two-phase and big-M methods to deal with problems involving artificial variables.
- v) Learn about the relationships between the primal and dual problems.
- vi) Solve transportation and assignment problems.
- vii) Apply linear programming method to solve two-person zero-sum game problems.

Unit1: The Linear Programming Problem: Standard, Canonical and matrix forms, Graphical solution. Hyper planes, Extreme points, Convex and polyhedral sets. Basic solutions; Basic Feasible Solutions; Reduction of any feasible solution to a basic feasible solution; Correspondence between basic feasible solutions and extreme points.

[1] Chapter1(Section1.1,1.4and1.6)

[2] Chapter2(Sections2.16,2.19and2.20), Chapter 3(Sections3,2,3.4and3.10)

Unit2: Simplex Method: Optimal solution, Termination criteria for optimal solution of the Linear Programming Problem, Unique and alternate optimal solutions, Unboundedness; Simplex Algorithm and its Tableau Format; Artificial variables, Two-phase method, Big-M method.

[1] Chapter 3(Sections 3.3, 3.6,3.7 and 3.8)

Unit3: Motivation and Formulation of Dual problem; Primal-Dual relationships; Fundamental Theorem of Duality; Complimentary Slackness.

[1] Chapter 4(Sections4.1to4.3)

[1] Chapter 6(Section 6.1 and 6.2, up to Example6.4)

Unit4: Applications

Transportation Problem: Definition and formulation; Methods of finding initial basic feasible solutions; North West corner rule. Least cost method; Vogel's Approximation method; Algorithm for solving Transportation Problem.

Assignment Problem: Mathematical formulation and Hungarian method of solving.

Game Theory: Basic concept, Formulation and solution of two-person zero-sum games, Games with mixed strategies, Linear Programming method of solving a game.

[3] Chapter 5(Sections 5.1, 5.3 and 5.4)

[2] Chapter 11(Sections 11.12 and 11.13)

Text Books:

1. Bazaraa, Mokhtar S., Jarvis, John J. and Sherali, Hanif D. (2010). *Linear Programming and Network Flows* (4th ed.). John Wiley and Sons.
2. Hadley, G. (1997). *Linear Programming*. Narosa Publishing House. New Delhi.
3. Taha, Hamdy A. (2010). *Operations Research: An Introduction* (9th ed.). Pearson.

Reference Books:

1. Hillier, Frederick S. & Lieberman, Gerald J. (2015). *Introduction to Operations Research* (10th ed.). McGraw-Hill Education (India) Pvt. Ltd.
2. Thie, Paul R., & Keough, G. E. (2014). *An Introduction to Linear Programming and Game Theory*. (3rd ed.). Wiley India Pvt. Ltd.

SEMESTER-IV

MAT-HC-4016: Multivariate Calculus

Total Marks: 100 (Theory 80, Internal assessment 20)

Per week: 5 lectures 1 Tutorial, Credits 6, *Each unit carry equal credit*

(Use of Scientific calculator is allowed)

Course Objectives: To understand the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables. Also, the emphasis will be on the use of Computer Algebra Systems by which these concepts may be analyzed and visualized to have a better understanding. This course will facilitate to become aware of applications of multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

Course Learning Outcomes: This course will enable the students to:

- i) Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
- ii) Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.
- iii) Learn about inter-relationship amongst the line integral, double and triple integral formulations.
- iv) Familiarize with Green's, Stokes' and Gauss divergence theorems

UNIT 1: Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Higher order partial derivative, Tangent planes, Total differential and differentiability, Chain rule, Directional derivatives, The gradient, Maximal and normal property of the gradient, Tangent planes and normal lines.

[1] Chapter 11 (Sections 11.1 and 11.2, 11.3 and 11.4, 11.5, 11.6)

UNIT 2: Extrema of functions of two variables, Method of Lagrange multipliers, Constrained optimization problems; Definition of vector field, Divergence and curl.

[1] Chapter 11 [Section 11.7 (up to page 605)], Section 11.8 (pages 610-614)], Chapter 13 (Section 13.1)

UNIT 3: Double integration over rectangular and nonrectangular regions, Double integrals in polar coordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals.

[1] Chapter 12 (Sections 12.1-12.4)

UNIT 4: Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral; Surface integrals, Stokes' theorem, The Gauss divergence theorem.

[1] Chapter 12 (Sections 12.5 and 12.6) Chapter 13 (Section 13.2, 13.3), [Sections 13.4 (pages 712 to 716), 13.5 (pages 723 to 726)]

Text book:

[1] Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). *Calculus* (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011

Reference Books:

1. Marsden, J. E., Tromba, A., & Weinstein, A. (2004). *Basic Multivariable Calculus*. Springer (SIE). First Indian Reprint.
2. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
3. M. J. Strauss, G. L. Bradley and K. J. Smith, *Calculus* (3 Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
4. James Stewart, *Multivariable Calculus, Concepts and Contexts*, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001.

MAT-HC-4026: Numerical Methods (including practical)

Total marks: 100: (Theory: 60, Practical 20, Internal Assessment: 20)

Per week: 4 Lectures, 2 Practical, Credits 6(4+2), *Each unit carry equal credit*

Course Objectives: To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations, to find the approximate solutions of system of linear equations and ordinary differential equations.

Also, the use of Computer Algebra System (CAS) by which the numerical problems can be solved both numerically and analytically, and to enhance the problem solving skills.

Course Learning Outcomes: The course will enable the students to:

- i) Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
- ii) Know about methods to solve system of linear equations, such as False position method, Fixed point iteration method, Newton's method, Secant method, LU decomposition.
- iii) Interpolation techniques to compute the values for a tabulated function at points not in the table.
- iv) Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

UNIT 1: Algorithms, Convergence, Bisection method, False position method, Fixed point iteration method, Newton's method, Secant method, LU decomposition.

[1] Chapter 1 (Sections 1.1-1.2), Chapter 2 (Sections 2.1-2.5), Chapter 3 (Section 3.5, 3.8).

UNIT 2: Lagrange and Newton interpolation: linear and higher order, finite difference operators.

[1] Chapter 5 (Sections 5.1, 5.3) [2] Chapter 4 (Section 4.3).

UNIT 3: Numerical differentiation: forward difference, backward difference and central difference. Integration: trapezoidal rule, Simpson's rule, Euler's method.

[1]: Chapter 6 (Sections 6.2, 6.4), Chapter 7 (Section 7.2)

Note: Emphasis is to be laid on the algorithms of the above numerical methods.

Practical / Lab work to be performed on a computer:

Use of computer aided software (CAS), for example *Matlab/Mathematica/Maple/Maxima* etc., for developing the following Numerical programs:

- (i) Calculate the sum $1/1 + 1/2 + 1/3 + 1/4 + \dots + 1/N$.
- (ii) To find the absolute value of an integer.
- (iii) Enter 100 integers into an array and sort them in an ascending order.
- (iv) Any two of the following
 - (a) Bisection Method
 - (b) Newton Raphson Method
 - (c) Secant Method
 - (d) Regula Falsi Method
 - (v) LU decomposition Method
 - (vi) Gauss-Jacobi Method
 - (vii) SOR Method or Gauss-Seidel Method
 - (viii) Lagrange Interpolation or Newton Interpolation
 - (ix) Simpson's rule.

Note: For any of the CAS *Matlab/Mathematica/Maple/Maxima* etc., Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

Text Books:

1. B. Bradie, *A Friendly Introduction to Numerical Analysis*, Pearson Education, India, 2007.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New age International Publisher, India, 5th edition, 2007.

Reference Book:

1. C. F. Gerald and P. O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India, 7th edition, 2008

MAT-HC-4036: Ring Theory

Total Marks: 100: (Theory 80 Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The objective of this course is to introduce the fundamental theory of rings and their corresponding

homomorphisms. Also introduces the basic concepts of ring of polynomials and irreducibility tests for polynomials over ring of integers.

Courses Learning Outcomes: On completion of this course, the student will be able to:

- i) Appreciate the significance of unique factorization in rings and integral domains.
- ii) Learn about the fundamental concept of rings, integral domains and fields.
- iii) Know about ring homomorphisms and isomorphisms theorems of rings.
- iv) learn about the polynomial rings over commutative rings, integral domains, Euclidean domains, and UFD

UNIT 1: Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideals, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals. Ring homomorphisms, properties of ring homomorphisms, Isomorphism theorems I, II and III, field of quotients.

[1]: Chapter 12, Chapter 13, Chapter 14, Chapter 15.

UNIT 2: Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion, unique factorization in $Z[x]$. Divisibility in integral domains, irreducibles, primes, unique factorization domains, Euclidean domains.

[1]: Chapter 16, Chapter 17, Chapter 18.

Text Books:

1. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.

Reference Books:

1. John B. Fraleigh (2002), A First Course in Abstract Algebra, 7th Ed., Pearson.
2. M. Artin (2011), Abstract Algebra, 2nd Ed., Pearson.
3. D.A.R. Wallace (1998), Groups, Rings and Fields, Springer Verlag London Ltd.
4. G. Santhanam (2017), Algebra, Narosa Publishing House.

SKILLENHANCEMENTCOURSES

EC-2

MAT-SE-4014: R Programming

Total marks: 100 (Theory 60, Internal assessment 20, Practical 20)

Per week: 2 Lectures 2 Practical, Credits 4(2+2)

Course Objectives: The purpose of this course is to help you begin using **R**, a powerful free software program for doing statistical computing and graphics. It can be used for exploring and plotting data, as well as performing statistical tests.

Course Learning Outcomes: This course will enable the students to:

- i) Be familiar with **R** syntax and use **R** as a calculator.
- ii) Understand the concepts of objects, vectors and data types.
- iii) Know about summary commands and summary table in **R**.
- iv) Visualize distribution of data in **R** and learn about normality test.
- v) Plot various graphs and charts using **R**.

Unit 1: Getting Started with R - The Statistical Programming Language

Introducing **R**, using **R** as a calculator; Explore data and relationships in **R**; Reading and getting data into **R**: combine and scan commands, viewing named objects and removing objects from **R**, Types and structures of data items with their properties, Working with history commands, Saving work in **R**; Manipulating vectors, Data frames, Matrices and lists; Viewing objects within objects, Constructing data objects and their conversions.

[1] Chapter 14 (Sections 14.1 to 14.4), [2] Chapter 2, Chapter 3

Unit 2: Descriptive Statistics and Tabulation

Summary commands: Summary statistics for vectors, Data frames, Matrices and lists; Summary tables.

[2] Chapter 4

Unit 3: Distribution of Data

Stem and leaf plot, Histograms, Density function and its plotting, The Shapiro-Wilk test for normality, The Kolmogorov-Smirnov test.

[2] Chapter 5

Unit 4: Graphical Analysis with R

Plotting in R: Box-whisker plots, Scatter plots, Pairs plots, Line charts, Pie charts, Cleveland dot charts, Bar charts; Copy and save graphics to other applications.

[1] Chapter 14 (Section 14.7) [2] Chapter 7

Practical to be done in the Computer Lab using Statistical Software R:

[1] Chapter 14 (Exercises 1 to 3)

[2] Relevant exercises of Chapters 2 to 5, and 7

Note: The practical may be done on the database to be downloaded from <https://data.gov.in/>

Text books:

1. Bindner, Donald & Erickson, Martin. (2011). *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*. CRC Press, Taylor & Francis Group, LLC.
2. Gardener, M. (2012). *Beginning R: The Statistical Programming Language*, Wiley Publications.

MAT-SE-4024: LaTeX and HTML (practical)

Total marks: 100 (Theory 60, Internal assessment 20, Practical 20)

Per week: 2 Lectures 2 Practical, Credits 4(2+2)

Course Objectives: The purpose of this course is to acquaint students with the latest type setting skills, which shall enable them to prepare high quality typesetting, beamer presentation and webpages

Course Learning Outcomes: After studying this course the student will be able to:

- i) Create and typeset a LaTeX document.
- ii) Typeset a mathematical document using LaTeX.
- iii) Learn about pictures and graphics in LaTeX.
- iv) Create beamer presentations.
- v) Create web page using HTML.

Unit 1: Elements of LaTeX; Hands-on-training of LaTeX; graphics in LaTeX; PS Tricks; Beamer presentation

[1] Chapters 9,10, 11.

Unit 2: HTML, creating simple web pages, images and links, design of web pages.

[1] Chapter 9-11, 15

Practical: Six practical should be done by each student. The teacher can assign practical from the exercises from [1].

Text Book:

1. Martin J. Erickson and Donald Bindner, *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*, CRC Press, Boca Raton, FL, 2011.

Reference Book:

1. L. Lamport, *LATEX: A Document Preparation System, User's Guide and Reference Manual*. Addison-Wesley, New York, second edition, 1994.

MAT-SE-4034: Boolean Algebra

Total Marks: 100 (Theory 80 Internal Assessment 20)

Per week 3 Lectures, Tutorial 1, Credits 4, *Each unit carry equal credit*

Course Objectives: This course aims to introduce the basic ideas and properties of ordered sets, Lattices, Boolean algebra and automata theory.

Course Learning Outcomes: The course will enable the students to:

- i) learn about the order isomorphism, Hasse diagrams, building new ordered set.
- ii) learn about the algebraic structure lattices, properties of modular and distributive lattices.
- iii) get ideas about the Boolean algebra, Switching circuits and applications of switching circuits.

Unit 1: Ordered Sets

Definitions, Examples and basic properties of ordered sets, Order isomorphism, Hasse diagrams, Dual of an ordered set, Duality principle, Maximal and minimal elements, Building new ordered sets, Maps between ordered sets.

[1] Chapter 1

Unit 2: Lattices

Lattices as ordered sets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, Examples and properties of modular and distributive lattices, The M3 – N5 Theorem with applications, Complemented lattice, Relatively complemented lattice, Sectionally complemented lattice homomorphisms.

[1] Chapter 2 and 4

[2] Chapter 1

Unit 3: Boolean Algebras and Switching Circuits

Boolean Algebras, De Morgan's laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive normal form and conjunctive normal form, Minimal forms of Boolean polynomial, Quinn-McCluskey method, Karnaugh diagrams, Switching circuits and applications of switching circuits.

[2] Chapter 1 (Section 2) and Chapter 2

Text Books:

1. Davey, B. A., & Priestley, H. A. (2002). *Introduction to Lattices and Order* (2nd ed.). Cambridge University press, Cambridge
2. Lidl, Rudolf and Pilz, Gunter. (2004). *Applied Abstract Algebra* (2nd ed.), Undergraduate Texts in Mathematics. Springer (SIE). Indian Reprint.

Reference Books:

1. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, *Elements of the Theory of Computation*, 2nd Ed., Prentice-Hall, NJ, 1997.
2. Goodaire, Edgar G. and Parmenter, Michael M. (2011). *Discrete Mathematics with Graph Theory* (3rd ed.) Pearson Education (Singapore) Pvt. Ltd. Indian Reprint.

GENERIC ELECTIVE PAPERS

GENERIC ELECTIVE PAPERS

MAT-HG-4016/ MAT-RC-4016: Real Analysis

Total Marks: 100(Theory: 80 Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits: 6, *Each unit carry equal credit*

Course Objectives: The course will develop a deep and rigorous understanding of real line \mathbb{R} and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. These concepts have wide range of applications in real life scenario.

Course Learning Outcomes: This course will enable the students to:

- i) Understand many properties of the real line \mathbb{R} , including completeness and Archimedean properties.
- ii) Learn to define sequences in terms of functions from \mathbb{R} to a subset of \mathbb{R} .
- iii) Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.
- iv) Apply the ratio, root and limit comparison tests for convergence and absolute convergence of an

infinite series of real numbers.

Unit 1: Algebraic and order properties of Real numbers, Order completeness of Real numbers, Open and closed sets, Limit of functions, Sequential criterion for limits, Algebra of limits, Properties of continuous functions, Uniform continuity.

[1] Chapter 2 (Sections 2.1 and 2.2, Sections 2.3, and 2.4) Chapter 11 (Section 11.1, Definition and Examples only) Chapter 4 (Sections 4.1 to 4.3). Chapter 5 (Sections 5.1, 5.3, 5.4.1, 5.4.3 up to Uniform Continuity theorem excluding continuous extension and approximation)

Unit 2: Sequences, Convergent and Cauchy sequences, Sub sequences, Limit superior and limit inferior of a bounded sequence, Monotonically increasing and decreasing sequences, Infinite series and their convergences, Positive term series, Absolute convergence, Comparison tests, Cauchy's nth root test, D'Alembert's ratio test, Raabe's test.

[1] Chapter 3, (Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.7), Chapter 9 [Section 9.1 (excluding grouping of series)] Sections 9.2 (Statements of related tests only)

Text Book:

1. Bartle, Robert G., & Sherbert, Donald R. (2015). *Introduction to Real Analysis* (4th ed.) Wiley India Edition.

Reference Book:

1. Ross, Kenneth A. (2013). *Elementary Analysis: The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint
2. Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). *An Introduction to Analysis* (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

MAT-HG-4026: Numerical Analysis

Total Marks:100 (Theory:80 Internal Assessment:20)

Per week: 5 Lectures, 1 Tutorial, Credits: 6, *Each unit carry equal credit*

Course Objectives: To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations, to find the approximate solutions of system of linear equations and Quadratic equations.

Course Learning Outcomes: The course will enable the students to:

- i) Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
- ii) Know about methods to solve system of linear equations, such as Gauss–Jacobi, Gauss–Seidel and SOR methods.
- iii) Interpolation techniques to compute the values for a tabulated function at points not in the table.
- iv) Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

Unit 1: Gaussian elimination method (with row pivoting), Gauss-Jordan method; Iterative methods: Jacobi method, Gauss-Seidel method; Interpolation: Lagrange form, Newton form, Finite difference operators, Gregory-Newton forward and backward difference interpolations, Piecewise polynomial interpolation (Linear and Quadratic).

[2] Chapter 3 (Sections 3.1 and 3.2), Chapter 6 (Sections 6.1 and 6.2) Chapter 8 (Section 8.1 Section 8.3 (8.3.1 and 8.3.2)

[3] Chapter 3 (Sections 3.2 and 3.4) Chapter 4 (Section 4.2) Chapter 4 (Sections 4.3, and 4.4)

[1] Chapter 18 (Sections 18.1 to 18.3).

Unit 2: Numerical differentiation: First and second order derivatives; Numerical integration: Trapezoid rule, Simpson's

rule; Extrapolation methods: Richardson extrapolation, Romberg integration; Ordinary differential equation: Euler's method, Modified Euler's methods (Heun and Mid-point).

[2] Chapter 11 [Sections 11.1 (11.1.1, 11.1.2, 11.1.4) and 11.2 (11.2.1, 11.2.2, 11.2.4)]

[1] Chapter 22 (Sections 22.1, 22.2, 22.3)

Text Books:

1. Chapra, Steven C. (2018). *Applied Numerical Methods with MATLAB for Engineers and Scientists* (4th ed.). McGraw-Hill Education.
2. Fausett, Laurene V. (2009). *Applied Numerical Analysis Using MATLAB*. Pearson. India
3. Jain, M. K., Iyengar, S. R. K., & Jain R. K. (2012). *Numerical Methods for Scientific and Engineering Computation* (6th ed.). New Age International Publishers. Delhi.

SEMESTER-V

MAT-HC-5016: Complex Analysis (including practical)

Total marks: 100 (Theory: 60, Practical 20, Internal Assessment: 20)

Per week: 4 Lectures, Practical 2, Credits 6 (4+2) *Each unit carry equal credit*

Course Learning Outcomes: The completion of the course will enable the students to:

- i) Learn the significance of differentiability of complex functions leading to the understanding of Cauchy–Riemann equations.
- ii) Learn some elementary functions and evaluate the contour integrals.
- iii) Understand the role of Cauchy–Goursat theorem and the Cauchy integral formula.
- iv) Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities, find residues and apply Cauchy Residue theorem to evaluate integrals.

UNIT 1: Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability. Limits, Limits involving the point at infinity, continuity.

[1]: Chapter 1 (Section 11), Chapter 2 (Section 12, 13) Chapter 2 (Sections 15, 16, 17, 18, 19, 20, 21, 22)

UNIT 2: Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, definite integrals of functions.

[1]: Chapter 2 (Sections 24, 25), Chapter 3 (Sections 29, 30, 34), Chapter 4 (Section 37, 38)

UNIT 3: Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals.

[1]: Chapter 4 (Section 39, 40, 41, 43)

UNIT 4: Antiderivatives, proof of antiderivative theorem, Cauchy-Goursat theorem, Cauchy integral formula. Liouville's theorem and the fundamental theorem of algebra.

[1]: Chapter 4 (Sections 44, 45, 46, 50), Chapter 4 (Sections 51, 52, 53)

LAB WORK TO BE PERFORMED ON A COMPUTER

(MODELING OF THE FOLLOWING PROBLEMS USING MATLAB/ MATHEMATICA/ MAPLE ETC.)

1. Declaring a complex number and graphical representation. e.g. $Z_1 = 3 + 4i$, $Z_2 = 4 - 7i$
2. Program to discuss the algebra of complex numbers, e.g.,
 $Z_1 = 3 + 4i$, $Z_2 = 4 - 7i$, then find $Z_1 + Z_2$, $Z_1 - Z_2$, $Z_1 * Z_2$ and Z_1 / Z_2
3. To find conjugate, modulus and phase angle of an array of complex numbers. e.g.
 $Z = [2+ 3i, 4-2i, 6+11i, 2-5i]$
4. To compute the integral over a straight line path between the two specified end points.
e. g., $\oint \text{Sin}z \, dz$, along the contour C which is a straight line path from $-1+ i$ to $2 - i$.

5. To perform contour integration., e.g.,
 - (i) $\oint (z^2 - 2z + 1)dz$ along the Contour C given by $x = y^2 + 1; -2 \leq y \leq 2$.
 - (ii) $\oint (z^3 + 2z^2 + 1)dz$ along the contour C given by $x^2 + y^2 = 1$, which can be parameterized by $x = \cos(t), y = \sin(t)$ for $0 \leq t \leq 2\pi$.
6. To plot the complex functions and analyze the graph. e.g.,
 - (i) $f(z) = z, iz, z^2, z^3, e^z$ and $(z^4-1)^{1/4}$, etc.
7. To perform the Taylor series expansion of a given function $f(z)$ around a given point z . The number of terms that should be used in the Taylor series expansion is given for each function. Hence plot the magnitude of the function and magnitude of its Taylor series expansion, e.g.,
 - (i) $f(z) = \exp(z)$ around $z = 0, n = 40$ and
 - (i) $f(z) = \exp(z^2)$ around $z = 0, n = 160$.
8. To determine how many terms should be used in the Taylor series expansion of a given function $f(z)$ around $z = 0$ for a specific value of z to get a percentage error of less than 5%. e.g., for $f(z) = \exp(z)$ around $z = 0$, execute and determine the number of necessary terms to get a percentage error of less than 5 % for the following values of z :
 - (i) $z = 30 + 30i$ (ii) $z = 10 + 103i$
9. To perform Laurents series expansion of a given function $f(z)$ around a given point z . e.g.,
 - (i) $f(z) = (\sin z - 1)/z^4$ around $z = 0$ (ii) $f(z) = \cot(z)/z^4$ around $z = 0$.

Text Book:

1. James Ward Brown and Ruel V. Churchill, *Complex Variables and Applications* (Eighth Edition), McGraw – Hill International Edition, 2009.

Reference Book:

1. Joseph Bak and Donald J. Newman, *Complex analysis* (2nd Edition), Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.
2. M.R. Spiegel, *Complex Variables*, Schaum series, **Year**

MAT-HC-5026: Linear Algebra

Total Marks: 100: (Theory 80 Internal Assessment: 20)

Per week: 5 Lectures 1 Tutorial. Credits 6, *Each unit carry equal credit*

Course Objectives: The objective of this course is to introduce the fundamental theory of vector spaces, also emphasizes the application of techniques using the adjoint of a linear operator and their properties to least squares approximation and minimal solutions to systems of linear equations.

Course Learning Outcomes: The course will enable the students to:

- i) Learn about the concept of linear independence of vectors over a field, and the dimension of a vector space.
- ii) Basic concepts of linear transformations, dimension theorem, matrix representation of a linear transformation, and the change of coordinate matrix.
- iii) Compute the characteristic polynomial, eigenvalues, eigenvectors, and eigenspaces, as well as the geometric and the algebraic multiplicities of an eigenvalue and apply the basic diagonalization result.
- iv) Compute inner products and determine orthogonality on vector spaces, including Gram–Schmidt orthogonalization to obtain orthonormal basis.
- v) Find the adjoint, normal, unitary and orthogonal operators.

Unit 1: Vector spaces and subspaces, null space and column space of a matrix, linear transformations, kernel and range, linearly independent sets, bases, coordinate systems, dimension of a vector space, rank, change of basis.

[1]: Chapter 4 (Sections 4.1 – 4.7)

Unit 2: Eigenvectors and eigenvalues of a matrix, the characteristic equation, diagonalization, eigenvectors of a linear transformation, complex eigenvalues,

[1]: Chapter 4 (Sections 5.1 – 5.5)

Invariant subspaces and Cayley-Hamilton theorem.

[2]: Chapter 5 (Section 5.4)

Unit 3: Inner product, length, and orthogonality, orthogonal sets, orthogonal projections, the Gram–Schmidt process, inner product spaces; Diagonalization of symmetric matrices, the Spectral Theorem.

[1]: Chapter 6 (Sections 6.1 – 6.4, 6.7); Chapter 7 (Section 7.1)

Text Books:

1. David C. Lay, *Linear Algebra and its Applications* (3rd Edition), Pearson Education Asia, Indian Reprint, 2007.
2. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra* (4th Edition), Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.

Reference Books:

1. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
2. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
3. Kenneth Hoffman, Ray Alden Kunze, *Linear Algebra*, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
4. G. Schay, *Introduction to Linear Algebra*, Narosa, 1997.

DISCIPLINESPECIFICSELECTIVEPAPERS

DSE-1

MAT-HE-5016: Number Theory

Total Marks: 100 (Theory 80 Internal assessment 20)

Per week: 5 lectures 1 Tutorial Credits 6, *Each unit carry equal credit*

Course Objectives: In number theory there are challenging open problems which are comprehensible at undergraduate level, this course is intended to build a micro aptitude of understanding aesthetic aspect of mathematical instructions and gear young minds to ponder upon such problems.

Course Learning Outcomes: This course will enable the students to:

- i) Learn about some fascinating discoveries related to the properties of prime numbers, and some of the open problems in number theory, viz., Goldbach conjecture etc.
- ii) Know about number theoretic functions and modular arithmetic.
- iii) Solve linear, quadratic and system of linear congruence equations.

Unit 1: Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat's Little theorem, Wilson's theorem.

[1] Chapter 2 (Section 2.5), [2] Chapter 2 (Section 2.2, 2.3), [3] Chapter 4 (Sections 4.2, 4.4), Chapter 5: Section 5.2

Unit 2: Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.

[1] Chapter 6 (Sections 6.1 to 6.2, 7.2, 7.3, and 7.4)

Text Books:

1. David M. Burton, *Elementary Number Theory*, 6th Ed., Tata McGraw Hill, Indian reprint, 2007.
2. G. A. Jones and J. Mary Jones, *Elementary Number Theory*. Undergraduate Mathematics Series (SUMS). First Indian Print. 2005

Reference Books:

1. Neville Robinns, *Beginning Number Theory*, 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007.
2. K. C. Chowdhury, *A First Course in Number Theory*, Asian Books Publications 2012

MAT-HE-5026: Mechanics

Total Marks: 100: (Theory 80, Internal assessment 20)

Per week: 5 Lectures 1 Tutorial, Credits 6 (5+1) *Each unit carry equal credit*

Course Objectives: The course aims at understanding the various concepts of physical quantities and their late defects on different bodies using mathematical techniques. It emphasizes knowledge building for applying mathematics in physical world.

Course Learning Outcomes: The course will enable the students to:

- i) Know about the concepts in statics such as moments, couples, equilibrium in both two and three dimensions.
- ii) Understand the theory behind friction and center of gravity.
- iii) Know about conservation of mechanical energy and work-energy equations.
- iv) Learn about translational and rotational motion of rigid bodies.

UNIT1: Composition and resolution of forces, Parallelogram of forces, Triangle of forces, Converse of triangle of forces, Lami's Theorem, Parallel forces, Moment of a force about a point and an axis. Couple, Resultant of a system of forces. Equilibrium of coplanar forces. Friction, C.G of an arc, plane area, surface of revolution, solid of revolution.

[3] Chapter I-X

UNIT 2: Velocities and acceleration along radial and transverse directions and along tangential and normal directions, motion in a straight line under variable acceleration, simple harmonic motion and elastic string. Newton's law of motion. Work, Energy and momentum, Conservative forces-Potential energy, Impulsive forces, Motion in resisting medium.

[1] Chapter I Sections 1.1, 1.2,1.3, Chapter –2 Sections 2.1,2.2, Chapter 3 Sections 3.1.3.2, Chapter 4 Sections 4.1, Chapter 5 Sections 5.1, 5.3, Chapter 6 Sections6.1,6.3.

[2]Chapter3(Sections:3.1,3.2,3.3,3.4).

Text Book:

1. S.L. Loney, An elementary treatise on the dynamics of a particle and of rigid bodies, Surjeet publications
2. F. Chorlton, Textbook of Dynamics, CBS, Publications 2nd Edition,1985
3. B.C. Das & B. N. Mukherjee, Statics, U. N. Dhur & Sons Pvt. Ltd.

Reference books:

1. M.R. Spiegel, Theoretical Mechanics, Schaum Series 2010.

MAT-HE-5036: Probability and Statistics

Total Marks: 100 (Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial, **Credits 6**, *Each unit carry equal credit*

Course Objectives: To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness. The course intends to render the students to several examples and exercises that blend their everyday experiences with their scientific interests.

Course Learning Outcomes: This course will enable the students to:

- i) Learn about probability density and moment generating functions.
- ii) Know about various univariate distributions such as Bernoulli, Binomial, Poisson, gamma and exponential distributions.
- iii) Learn about distributions to study the joint behavior of two random variables.
- iv) Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.
- v) Understand central limit theorem, which helps to understand the remarkable fact that: the empirical frequencies of so many natural populations, exhibit a bell-shaped curve, i.e., a normal distribution

UNIT-1: Sample space, Probability set function, Real random variables - Discrete and continuous, Cumulative distribution

function, Probability mass/density functions, Transformations, Mathematical expectation, Moments, Moment generating function, Characteristic function.

[1] Chapter 1 (Sections 1.1, 1.3, 1.5, 1.6 to 1.9)

UNIT-2: Discrete distributions: Uniform, Bernoulli, Binomial, Negative binomial, Geometric and Poisson; Continuous distributions: Uniform, Gamma, Exponential, Chi-square, Beta and normal; Normal approximation to the binomial distribution.

[1] Chapter 5 (Sections 5.2 to 5.4, Sections 5.5, and 5.7)

[2] Chapter 6 (Sections 6.2 to 6.4, Sections 6.5, and 6.6)

UNIT-3: Joint cumulative distribution function and its properties, Joint probability density function, Marginal distributions, Expectation of function of two random variables, Joint moment generating function, Conditional distributions and expectations.

[1] Chapter 2 (Sections 2.1, and 2.3)

UNIT-4: The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Independent random variables, Linear regression for two variables, The method of least squares, Bivariate normal distribution, Chebyshev's theorem, Strong law of large numbers, Central limit theorem and weak law of large numbers.

[1] Chapter 2 (Section 2.4, and Section 2.5), [2] Chapter 14 (Sections 14.1 to 14.3)

[2] Chapter 6 (Section 6.7), and Chapter 4 (Section 4.4), [3] Chapter 2 (Section 2.8, and Exercise 76, page 89)

Text Books:

1. Hogg, Robert V., McKean, Joseph W., & Craig, Allen T. (2013). *Introduction to Mathematical Statistics* (7th ed.). Pearson Education, Inc.
2. Miller, Irwin & Miller, Marylees. (2014). John E. Freund's *Mathematical Statistics with Applications* (8th ed.). Pearson. Dorling Kindersley (India).
3. Ross, Sheldon M. (2014). *Introduction to Probability Models* (11th ed.). Elsevier Inc.

Reference Books:

1. Mood, A. M., Graybill, F. A. & Boes, D. C. (1974). *Introduction to the Theory of Statistics* (3rd ed.). McGraw-Hill Education Pvt. Ltd. Indian Edition (2017)

DSE-2

MAT-HE-5046: Linear Programming

Total Marks: 100 (Theory: 80 Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial Credits: 6, *Each unit carry equal credit*

Course Objectives: This course develops the ideas underlying the Simplex Method for Linear Programming Problem, as an important branch of Operations Research. The course covers Linear programming with applications to transportation, assignment and game problem. Such problems arise in manufacturing resource planning and financial sectors.

Course Learning Outcomes: This course will enable the students to:

- i) Learn about the graphical solution of linear programming problem with two variables.
- ii) Learn about the relation between basic feasible solutions and extreme points.
- iii) Understand the theory of the simplex method used to solve linear programming problems.
- iv) Learn about two-phase and big-M methods to deal with problems involving artificial variables.
- v) Learn about the relationships between the primal and dual problems.
- vi) Solve transportation and assignment problems.
- vii) Apply linear programming method to solve two-person zero-sum game problems.

Unit 1: The Linear Programming Problem: Standard, Canonical and matrix forms, Graphical solution. Hyperplanes, Extreme points, Convex and polyhedral sets. Basic solutions; Basic Feasible Solutions; Reduction of any feasible solution to a basic feasible solution; Correspondence between basic feasible solutions and extreme points.

[1] Chapter 1 (Section 1.1, 1.4, and 1.6)

[2] Chapter 2 (Sections 2.16, 2.19, and 2.20), and Chapter 3 (Sections 3.2, 3.4, and 3.10)

Unit 2: Simplex Method: Optimal solution, Termination criteria for optimal solution of the Linear Programming Problem, Unique and alternate optimal solutions, Unboundedness; Simplex Algorithm and its Tableau Format; Artificial variables, Two-phase method, Big-M method.

[1] Chapter 3 (Sections 3.3, and 3.6, 3.7, and 3.8)

Unit 3: Motivation and Formulation of Dual problem; Primal-Dual relationships; Fundamental Theorem of Duality; Complimentary Slackness.

[1] Chapter 4 (Sections 4.1 to 4.3)

[1] Chapter 6 (Section 6.1, and 6.2, up to Example 6.4)

Unit 4: Applications *Transportation Problem:* Definition and formulation; Methods of finding initial basic feasible solutions; North West corner rule. Least cost method; Vogel's Approximation method; Algorithm for solving Transportation Problem.

Assignment Problem: Mathematical formulation and Hungarian method of solving.

Game Theory: Basic concept, Formulation and solution of two-person zero-sum games, Games with mixed strategies, Linear Programming method of solving a game.

[3] Chapter 5 (Sections 5.1, 5.3, and 5.4)

[2] Chapter 11 (Sections 11.12, and 11.13)

Text Books:

1. Bazaraa, Mokhtar S., Jarvis, John J. and Sherali, Hanif D. (2010). *Linear Programming and Network Flows* (4th ed.). John Wiley and Sons.
2. Hadley, G. (1997). *Linear Programming*. Narosa Publishing House. New Delhi.
3. Taha, Hamdy A. (2010). *Operations Research: An Introduction* (9th ed.). Pearson.

Reference Books:

1. Hillier, Frederick S. & Lieberman, Gerald J. (2015). *Introduction to Operations Research* (10th ed.). McGraw-Hill Education (India) Pvt. Ltd.
2. Thie, Paul R., &Keough, G. E. (2014). *An Introduction to Linear Programming and Game Theory*. (3rd ed.). Wiley India Pvt. Ltd.

MAT-HE-5056: Spherical Trigonometry and Astronomy

Total Marks:100 (Theory 80, Internal Assessment 20)

Per week: 5 Lecture Tutorial 1, *Each unit carry equal credit*

Course Objectives: This main objective of this course is to provide the spherical triangles, Napier's rule of circular parts and Planetary motion

Course Learning Outcomes: This course will enable the students to:

- i) Learn about the properties of spherical and polar triangles
- ii) Know about fundamental formulae of spherical triangles
- iii) Learn about the celestial sphere, circumpolar star, rate of change of zenith distance and azimuth
- iv) Learn about Kepler's law of planetary motion, Cassini's hypothesis, differential equations or fraction

Unit1: Section of a sphere by a plane, spherical triangles, properties of spherical and polar triangles, fundamental formulae of spherical triangles, sine formula, cosine formula, sine-cosine formula, cot formula, Napier's rule of circular parts.

[1] Chapter1: Sections:1-8,16

Unit2: The standard (or geometric) celestial sphere, system of coordinates, conversion of one coordinate system to another system, diurnal motion of heavenly bodies, sidereal time, solar time(mean), rising and setting of stars, circumpolar star, dip of the horizon, rate of change of zenith distance and azimuth, examples.

[1] Chapter2Sections18,19,22,27

Unit3: Planetary motion: annual motion of the sun, planetary motion, synodic period, orbital period, Kepler's law of planetary motion, deduction of Kepler's law from Newton's law of gravitation, the equation of the orbit, velocity of a planet in its orbit, components of linear velocity perpendicular to the radius vector and to the major axis, direct and retrograde motion in a plane, laws of refraction: refraction for small zenith distance, general formula for refraction, Cassini's hypothesis, differential equation for refraction, effect of refraction on sunrise, sunset, right ascension and declination, shape of the disc of the sun.
[1] Chapter 5 Sections 57-59, 64-69, 74, 81-83

Text Book:

1. W.M. Smart and R.M. Green Spherical Astronomy. Cambridge University Press; 6 edition, 1977.

Reference Books:

1. Sir Robert Ball, Spherical Astronomy, Publisher: Forgotten Books 2018
2. Brunnow Franz, Spherical Astronomy Publisher: Biblio Life, Aug 2009.

MAT-HE-5066: Programming in C (including practical)

Total Marks: 100 (Theory 60, Practical 20, Internal Assessment 20)

Per week: 4 Lectures 2 Tutorial, Credits 6(4+2) *Each unit carry equal credit*

Course Objectives: This course introduces C programming in the idiom and context of mathematics and imparts a starting orientation using available mathematical libraries, and their applications.

Course Learning Outcomes: After completion of this paper, student will be able to:

- i) Understand and apply the programming concepts of C which is important to mathematical investigation and problem solving.
- ii) Learn about structured data-types in C and learn about applications in factorization of an integer and understanding Cartesian geometry and Pythagorean triples.
- iii) Use of containers and templates in various applications in algebra.
- iv) Use mathematical libraries for computational objectives.
- v) Represent the outputs of programs visually in terms of well formatted text and plots.
- vi) In practical students learn about the roots of a quadratic equation, solution of an equation using N-R algorithm, $\sin(x)$, $\cos(x)$ with the help of functions

Unit 1: Variables, constants, reserved words, variable declaration, initialization, basic data types, operators and expression (arithmetic, relational, logical, assignment, conditional, increment and decrement), hierarchy of operations for arithmetic operators, size of and comma operator, mixed mode operation and automatic (implicit) conversion, cast (explicit) conversion, library functions, structure of a C program, input/output functions and statements.

Unit 2: Control Statements: if-else statement (including nested if-else statement), switch statement. Loop control Structures (for and nested for, while and do-while). Break, continue, go to statements, exit function.

Unit 3: Arrays and subscripted variables: One and Two-dimensional array declaration, accessing values in an array, initializing values in an array, sorting of numbers in an array, addition and multiplication of matrices with the help of array. Functions: function declaration, actual and formal arguments, function prototype, calling a function by value, recursive function.

Programs for practical:

To find roots of a quadratic equation, value of a piecewise defined function (single variable), factorial of a given positive integer, Fibonacci numbers, square root of a number, cube root of a number, sum of different algebraic and trigonometric series, a given number to be prime or not, sum of the digits of any given positive integer, solution of an equation using N-R algorithm, reversing digits of an integer. Sorting of numbers in an array, to find addition, subtraction and multiplication of matrices. To find $\sin(x)$, $\cos(x)$ with the help of functions.

[1] Chapters 3, 4, 5, 6, 7 and 9

Text Book:

1. T. Jeyapoovan, A First Course in Programming with C T. Jeyapoovan, Vikash Publishing House Pvt. Ltd.

Reference books:

1. E. Balaguruswamy, Programming with C, Schaum Series.
2. Y. Kanetkar, *Let us C*, B.P. Publication.

SEMESTER-VI**MAT-HC-6016: Riemann Integration and Metric spaces**

Total Marks: 100: (Theory 80, Internal assessment 20)

Per week: 5 Lectures 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: To understand the integration of bounded functions on a closed and bounded interval and its extension to the cases where either the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration. Up to this stage, students do study the concepts of analysis which evidently rely on the notion of distance. In this course, the objective is to develop the usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.

Course Learning Outcomes: The course will enable the students to:

- i) Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Fundamental theorems of integration.
- ii) Know about improper integrals including, beta and gamma functions.
- iii) Learn various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces.
- iv) Analyse how a theory advances from a particular frame to a general frame.
- v) Appreciate the mathematical understanding of various geometrical concepts, viz. Balls or connected sets etc. in an abstract setting.
- vi) Know about Banach fixed point theorem, whose far-reaching consequences have resulted into an independent branch of study in analysis, known as fixed point theory.
- vii) Learn about the two important topological properties, namely connectedness and compactness of metric spaces.

UNIT 1: Riemann integration: upper and lower sums; Darboux integrability, properties of integral, Fundamental theorem of calculus, mean value theorems for integrals, Riemann sum and Riemann integrability, Riemann integrability of monotone and continuous functions on intervals, sum of infinite series as Riemann integrals, logarithm and exponential functions through Riemann integrals, improper integrals, Gamma functions.

[1] Chapter 6

UNIT 2: Metric spaces: definition and examples, sequences in metric spaces, Cauchy sequences, complete metric spaces. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, Cantor's theorem. Subspaces, dense sets, separable spaces.

[2] Chapter 1, Sections: 1.1-1.4, Chapter 2, Sections: 2.1.2.2, 2.3.12-2.3.16

UNIT 3: Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Homeomorphism, Contraction mappings, Banach contraction mapping principle. Connectedness, connected subsets of \mathbf{R} , connectedness and continuous mappings.

[2] Chapter 3, Sections 3.1, 3.4, 3.5, 3.7 (up to 3.7.7), Chapter 4 Sections 4.1.

Text Books:

1. Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Indian Edn. 2014.
2. Satish Shirali & Harikishan L. Vasudeva, Metric Spaces, Springer Verlag London (2006) (First Indian Reprint 2009)

Reference Books:

1. R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.

2. Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
3. S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
4. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
5. Micheal O. Searcoid, Metric Spaces, Springer Publication, 2007

MAT-HC-6026: Partial Differential Equations (including practical)

Total marks: 100: (Theory: 60, Practical 20, Internal Assessment: 20)

Per week: 4 Lectures, 2 Practical, Credits 6(4+2), *Each unit carry equal credit*

Course Objectives: The main objectives of this course are to teach students to form and solve partial differential equations and use them in solving some physical problems.

Course Learning Outcomes: The course will enable the students to:

- i) Formulate, classify and transform first order PDEs into canonical form.
- ii) Learn about method of characteristics and separation of variables to solve first order PDE's.
- iii) Classify and solve second order linear PDEs.
- iv) Learn about Cauchy problem for second order PDE and homogeneous and non-homogeneous wave equations.
- v) Apply the method of separation of variables for solving many well-known second order PDEs.

Unit 1: Introduction, Classification, Construction of first order partial differential equations (PDE). Cauchy's problem for first order equations, linear equations of the first order, Integral surfaces passing through a given curve, Nonlinear partial differential equations of the first order, Cauchy's method of characteristics, Charpit's method. Solutions satisfying given conditions, Jacobi's method.

[1] Chapter 2 (Sections 2.1 to 2.3), [2] Chapter 2 (Section 3, 4,5, 7,8,10,12, 13)

Unit 2: Canonical form of first order PDE, Method of separation of variables for first order PDE.

[1] Chapter 2 (Sections 2.6 and 2.7)

Unit 3: Reduction to canonical forms, Equations with constant coefficients, General solution.

[1] Chapter 4 (Sections 4.1 to 4.5), [2] Chapter 3 (Sections 4, 5)

Practical /Lab work to be performed in a Computer Lab:

Modelling of the following similar problems using Mathematica /MATLAB/ Maple/ Maxima/ Scilab etc.

1. Solution of Cauchy problem for first order PDE.
2. Plotting the characteristics for the first order PDE.
3. Plot the integral surfaces of a given first order PDE with initial data.
4. Solution of wave equation $\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$ for any two of the following associated conditions:
 - (a) $u(x,0) = \phi(x); u_t(x,0) = \psi(x), x \in R; t > 0$
 - (b) $u(x,0) = \phi(x); u_t(x,0) = \psi(x); u(0,t) = 0, x > 0; t > 0$
 - (c) $u(x,0) = \phi(x); u_t(x,0) = \psi(x); u_x(0,t) = 0, x > 0; t > 0$
 - (d) $u(x,0) = \phi(x); u_t(x,0) = \psi(x); u(0,t) = 0, u(l,t) = 0; x > 0; t > 0$
5. Solving systems of ordinary differential equations.
6. Solution of one-Dimensional heat equation $u_t = k u_{xx}$, for a homogeneous rod of length l .

That is - solve the IBVP:

$$\begin{aligned}
 u_t &= k u_{xx}, & 0 < x < l, & & t > 0 \\
 u(0, t) &= 0, & u(l, t) &= 0, & t \geq 0 \\
 u(0, t) &= f(x), & 0 \leq x \leq l & &
 \end{aligned}$$

Text Book:

1. Tyn Myint-U and Lokenath Debnath, *Linear Partial Differential Equation for Scientists and Engineers*, Springer, Indian reprint, 2006.
2. Sneddon, I. N. (2006). *Elements of Partial Differential Equations*, Dover Publications. Indian Reprint.

Reference Book:

1. Stavroulakis, Ioannis P & Tersian, Stepan A. (2004). *Partial Differential Equations: An Introduction with Mathematica and MAPLE* (2nd ed.). World Scientific.
2. M. D. Raisinghania, *Advanced Differential Equations*, S. Chand & Company LTD.

DISCIPLINE SPECIFIC PAPERS

DSE-3

MAT-HE-6016: Boolean Algebra and Automata Theory

Total Marks: 100 (Theory 80 Internal Assessment 20)

Per week 5 Lectures, Tutorial 1, Credits 6, *Each unit carry equal credit*

Course Objectives: This course aims to introduce the basic ideas and properties of ordered sets, Lattices, Boolean algebra and automata theory.

Course Learning Outcomes: The course will enable the students to:

- i) learn about the order isomorphism, Hasse diagrams, building new ordered set.
- ii) learn about the algebraic structure lattices, properties of modular and distributive lattices.
- iii) get ideas about the Boolean algebra, Switching circuits and applications of switching circuits.
- iv) Appreciate the theory of automata and its applications

Unit 1: Ordered Sets

Definitions, Examples and basic properties of ordered sets, Order isomorphism, Hasse diagrams, Dual of an ordered set, Duality principle, Maximal and minimal elements, Building new ordered sets, Maps between ordered sets.

[1] Chapter 1 (Sections 1.1 to 1.5 and 1.14 to 1.26, and 1.34 to 1.36), [3] Chapter 1 [Section 1 (1.1 to 1.3)]

Unit 2: Lattices

Lattices as ordered sets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, Examples and properties of modular and distributive lattices, The M3 – N5 Theorem with applications, Complemented lattice, Relatively complemented lattice, Sectionally complemented lattice homomorphisms.

[1] Chapter 2 (Sections 2.1 to 2.19) Chapter 4 (Sections 4.1 to 4.9) (Sections 4.10, and 4.11)

[3] Chapter 1 [Section 1 (1.5 to 1.20)] Chapter 1 [Section 2 (2.1 to 2.6) Chapter 1 [Section 2 (2.7 to 2.14)]

Unit 3: Boolean Algebras and Switching Circuits

Boolean Algebras, De Morgan’s laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive normal form and conjunctive normal form, Minimal forms of Boolean polynomial, Quinn-McCluskey method, Karnaugh diagrams, Switching circuits and applications of switching circuits.

[3] Chapter 1 (Sections 3, and 4) Chapter 1 (Section 6) Chapter 2 (Sections 7, and 8).

Unit 4: Introduction: Alphabets, strings, and languages. Finite Automata and Regular Languages: deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.

[4] Chapter 1, 2,3,4

Context Free Grammars and Pushdown Automata: Context free grammars (CFG), parse trees, ambiguities in grammars and languages, pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non- deterministic PDA, properties of context free languages; normal forms, pumping lemma, closure properties, decision properties.

[4] Chapter 5

Text Books:

3. Davey, B. A., & Priestley, H. A. (2002). *Introduction to Lattices and Order* (2nd ed.). Cambridge University press, Cambridge
4. Goodaire, Edgar G. and Parmenter, Michael M. (2011). *Discrete Mathematics with Graph Theory* (3rd ed.). Pearson Education (Singapore) Pvt. Ltd. Indian Reprint.
5. Lidl, Rudolf and Pilz, Gunter. (2004). *Applied Abstract Algebra* (2nd ed.), Undergraduate Texts in Mathematics. Springer (SIE). Indian Reprint.
6. J.E. Hopcroft, R. Motwani and J. D. Ullman, *Introduction to Automata Theory, Languages, and Computation*, 2nd Ed., Addison-Wesley, 2001.

Reference Books:

3. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, *Elements of the Theory of Computation*, 2nd Ed., Prentice-Hall, NJ, 1997.
4. J.A. Anderson, *Automata Theory with Modern Applications*, Cambridge University Press, 2006.

MAT-HE-6026: Bio-Mathematics

Total Marks: 100 (Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial Credits: 6, *Each unit carry equal credit*

Course Objectives: The focus of the course is on scientific study of normal functions related to living systems. It is intended to provide basic knowledge of different mathematical models and techniques for studying biomathematics in real life problems.

Course Learning outcomes: Towards the end of the course the student would be able to

- i) Learn the development, analysis and interpretation of bio-mathematical models.
- ii) Learn about the mathematics behind different bio-mathematical models
- iii) Solve basic application-oriented mathematical problems in real life situation. Students also would be able to develop problem solving skills useful in future study.

Unit 1: Discussions on some discrete models

Linear difference equations: Basic Definitions and Notation, Linear difference equations of first and second order, First-Order Linear Systems and Leslie's Age-Structured Model, Properties of the Leslie Matrix (Theorem 1.5, Example 1.17, Example 1.18).

[1] Chapter1 (1.2-1.7)

Nonlinear difference equations: Basic Definitions and Notation, Local Stability in First-order Equations, The Approximate Logistic Equation (excluding bifurcations), Stability in First- Order Systems, Jury Conditions, An Example: Epidemic Model.

[1] Chapter 2 (2.2, 2.3, 2.6, 2.8,2.9, 2.10)

Some applications of difference equations: Predator-Prey Models (excluding bifurcations), Measles Model with Vaccination.

[1] Chapter 3(3.6, 3.9)

Unit 2: Discussions on some continuous models

Linear differential equations: Basic Definitions and Notation, Linear differential equations of first and higher order, Routh-Hurwitz Criteria, First-Order Linear Systems, Phase Plane Analysis, An Example: Pharmacokinetics Model.

[1] Chapter 4(4.1-4.5,4.7-4.8, 4.10)

Nonlinear differential equations: Basic Definitions and Notation, Local Stability in First-order Equations, Application to Population Growth Models (excluding bifurcations), Phase line diagram, Local Stability in First-Order Systems, Phase Plane Analysis.

[1] Chapter5 (5.1-5.6)

Some applications of differential equations: Epidemic Models, The Simple Kermack–McKendrick Epidemic Model

[1] Chapter 6 (6.8.1)

[2] Chapter9 (9.2)

Text Books:

1. Linda J. S. Allen, Introduction to Mathematical Biology, Pearson; 1st edition (17 August 2006).
2. Jones, D. S., & Sleeman B. D. (2003). Differential Equations and Mathematical Biology, Chapman & Hall, CRC Press, London, UK.

MAT-HE-6036: Mathematical Modelling (including practical)

TotalMarks:100(Theory:60, Practical20, Internal Assessment:20)

Per week: 4 Lectures, 2 practical, Credits 6 *Each unit carry equal credits*

Course Objectives: The main objective of this course is to teach students how to model physical problem using differential equations and solve them. Also, the use of Computer Algebra Systems (CAS) by which the listed problems can be solved both numerically and analytically.

Course Learning Outcomes: The course will enable the students to:

- i) Know about power series solution of a differential equation and learn about Legendre's and Bessel's equations.
- ii) Use of Laplace transform and inverse transform for solving initial value problems.
- iii) Learn about various models such as Monte Carlo simulation models, queuing models, and linear programming models.

Unit 1: Power series solution of a differential equation about an ordinary point, solution about a regular singular point, The method of Frobenius; Legendre's and Bessel's equation.

[1] Chapter 8 (Sections 8.1 to 8.3, Section 8.5 up to Equation (19), page 551).

Unit2: Laplace transform and inverse transform, application to initial value problem up to second order.

[1] Chapter 7 (Sections 7.1 to 7.3).

Unit 3: Monte Carlo Simulation Modelling: Simulating deterministic behaviour (area under a curve, volume under a surface); Generating Random Numbers: Middle square method, Linear congruence; Queuing Models: Harbor system, Morning rush hour.

[2] Chapter 5 (Sections 5.1 to 5.2, and 5.5), Chapter 7.

Practical/Lab work to be performed in Computer Lab:

Modelling of the following problems using Mathematica/MATLAB/Maple/Maxima/Sci lab etc.

- (i) Plotting of Legendre polynomial for $n = 1$ to 5 in the interval $[0, 1]$. Verifying graphically that all the roots of $P_n(x)$ lie in the interval $[0, 1]$.
- (ii) Automatic computation of coefficients in the series solution near ordinary points.
- (iii) Plotting of the Bessel's function of first kind of order 0 to 3.
- (iv) Automating the Frobenius Series Method.

- (v) Random number generation and then use it for one of the following:
 - (a) Simulate area under a curve. (b) Simulate volume under a surface.
- (vi) Programming of either one of the queuing model:
 - (a) Single server queue (e.g. Harbor system). (b) Multiple server queue (e.g. Rush hour).
- (vii) Programming of the Simplex method for 2/3 variables

Text Books:

1. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). *Differential Equation and Boundary Value Problems: Computing and Modeling* (5th ed.). Pearson.
2. Giordano, Frank R., Fox, William P., & Horton, Steven B. (2014). *A First Course in Mathematical Modeling* (5th ed.). Brooks/Cole, Cengage Learning.

MAT-HE-6046: Hydromechanics

Total Marks: 100: (Theory 80 Internal assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The main objectives of this course are to teach students about fluid pressure on plane surfaces, curved surfaces and Gas law. Also introduce velocity of a fluid at a point, Eulerian and Lagrangian method, velocity potential and acceleration of a fluid at a point.

Course Learning Outcomes: The course will enable the students to:

- i) Know about Pressure equation, rotating fluids.
- ii) learn about Fluid pressure on plane surfaces, resultant pressure on curved surfaces, Gas law, mixture of gases
- iii) learn about the Eulerian and Lagrangian method.
- iv) learn about equation of continuity, examples, acceleration of a fluid at a point

Unit 1: Hydrostatics

Pressure equation, condition of equilibrium, lines of force, homogeneous and heterogeneous fluids, elastic fluids, surface of equal pressure, fluid at rest under action of gravity, rotating fluids. Fluid pressure on plane surfaces, center of pressure, resultant pressure on curved surfaces. Gas law, mixture of gases, internal energy, adiabatic expansion.

[1] Part I Chapter 1 – IV (related sections only), Chapter VI

Unit 2 Hydrodynamics

Real and ideal fluid, velocity of a fluid at a point, Eulerian and Lagrangian method, stream lines and path lines, steady and unsteady flows, velocity potential, rotational and irrotational motions, material local, convective derivatives, local and particle rate of change, equation of continuity, examples, acceleration of a fluid at a point. Equation of motion (For non-viscous fluid)

[1] Part II Chapter I, Chapter II (Sections 2.1, 2.2)

Text Book:

1. Besant, W. H., Ramsey, A. S., *A Treatise on Hydromechanics*. (part I & part II), G. Bell and Sons Limited. CBS Publication 1988 (Indian print).

Reference:

1. Raisinghania, M.D., *Fluid Dynamics*, S. Chand
2. Kar, J.M., *Hydrostatics*,

DSE-4

MAT-HE-6056: Rigid Dynamics

Total Marks 100 (Theory 80 Internal assessment 20)

Per week: 5 Lectures 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The main objectives of this course to introduce moments and products of inertia, theorem of six constants, D'Alembert's principle, Motion of a body in two dimension and Lagrange's equations.

Course Learning Outcomes: The course will enable the students to:

- i) Know about find the moments and products of inertia.
- ii) learn about the motion of the center of inertia.
- iii) learn about the D'Alembert's principle and Lagrange's equations.
- iv) learn about motion of a body in 2-dimension.

Unit1: Moments and products of inertia, parallel axes theorem, theorem of six constants, the momental ellipsoid, equimomental systems, principle axes.

Unit2: D'Alembert's principle, the general equation of motion of a rigid body, motion of the centre of inertia and motion relative to the center of inertia.

Unit3: Motion about a fixed axis, the compound pendulum, centre of percussion. Motion of a body in two dimension under finite and impulsive forces.

Unit4: Conservation of momentum and energy, generalized coordinates, Lagrange's equations, initial motions.

[1] Chapter -11-18 (related sections only)

Text Book:

1. S.L. Loney, An elementary treatise on the Dynamics of a particle and of Rigid bodies, Cambridge University Press Kindle Edition August 2018.

Reference Book:

1. A.S. Ramsey, Dynamics Part I, Cambridge University Press; 1 edition, 1952.
2. Spiegel, M. *Theoretical Mechanics*, Schaum Series

MAT-HE-6066: Group Theory II

Total Marks: 100 (Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits: 6, *Each unit carry equal credit*

Course Objectives: The course will develop an in-depth understanding of one of the most important branch of the abstract algebra with applications to practical real-world problems. Classification of all finite abelian groups (up to isomorphism) can be done.

Course Learning Outcomes: The course shall enable students to:

- i) Learn about automorphisms for constructing new groups from the given group.
- ii) Learn about the fact that external direct product applies to data security and electric circuits.
- iii) Understand fundamental theorem of finite abelian groups.
- iv) Be familiar with group actions and conjugacy in S_n .
- v) Understand Sylow's theorems and their applications.

Unit 1: Isomorphisms, automorphisms, inner automorphisms, Automorphisms groups; External direct products of groups and their properties; the group of units modulo n as an external direct product

[1] Chapter 6 Chapter 8.

Unit 2: Normal subgroups, factor groups and their applications, Internal direct products, of subgroups, Fundamental theorem of finite Abelian groups, isomorphism classes of finite abelian groups.

[1] Chapter 9 Chapter 11 (with proof of Fundamental theorem)

Unit 3: Conjugacy classes, the class equation, Conjugacy classes in the symmetric group S_n , p -groups, The Sylow's theorems and their applications.

[1] Chapter 24, [2] Chapter 4 [Section 4.3(Pages 125-126, Ex 2-12)]

Text Books:

1. Gallian, Joseph. A. (2013). *Contemporary Abstract Algebra* (8th ed.). Cengage Learning India Private Limited. Delhi. Fourth impression, 2015.
2. Dummit, David S., & Foote, Richard M. (2016). *Abstract Algebra* (3rd ed.). Student Edition. Wiley India.

Reference Book:

1. Joseph J. Rotman, (1995). *An Introduction to The Theory of Groups* (4th ed.). Springer Verlag, New York.
2. John B. Fraleigh (2002), *A First Course in Abstract Algebra*, 7th Ed., Pearson.
3. G. Santhanam (2017), *Algebra*, Narosa Publishing House.

MAT-HE-6076: Mathematical Finance

Total Marks: 100 (Theory: 80, Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial Credits: 6, *Each unit carry equal credit*

Course Objectives: This course is an introduction to the application of mathematics in financial world, that enables the student to understand some computational and quantitative techniques required for working in the financial markets and actuarial mathematics.

Course Learning outcomes: On completion of this course, the student will be able to:

- i) Know the basics of financial markets and derivatives including options and futures.
- ii) Learn about pricing and hedging of options, as well as interest rate swaps.
- iii) Learn about no-arbitrage pricing concept and types of options.
- iv) Learn stochastic analysis (Ito formula, Ito integration) and the Black–Scholes model.
- v) Understand the concepts of trading strategies and valuation of currency swaps.

Unit 1: Interest Rates: Types of rates, Measuring interest rates, Zero rates, Bond pricing, Forward rate, Duration, Convexity, Exchange traded markets and OTC markets, Derivatives--Forward contracts, Futures contract, Options, Types of traders, Hedging, Speculation, Arbitrage.

[1] Chapter 4 (Section 4.1 to 4.4, 4.6, 4.8, and 4.9) Chapter 1 (Sections 1.1 to 1.9)

Unit 2: Mechanics and Properties of Options: No Arbitrage principle, Short selling, Forward price for an investment asset, Types of Options, Option positions, Underlying assets, Factors affecting option prices, Bounds on option prices, Put-call parity, Early exercise, Effect of dividends.

[1] Chapter 5 (Sections 5.2 to 5.4), Chapter 8 (Sections 8.1 to 8.3), Chapter 9 (Section 9.1, Sections 9.2 to 9.7)

Unit 3: Stochastic Analysis of Stock Prices and Black-Scholes Model

Binomial option pricing model, Risk neutral valuation (for European and American options on assets following binomial tree model), Lognormal property of stock prices, Distribution of rate of return, expected return, Volatility, estimating volatility from historical data, Extension of risk neutral valuation to assets following GBM, Black-Scholes formula for European options.

[1] Chapter 11 (Sections 11.1 to 11.5) Chapter 13 (Sections 13.1 to 13.4, 13.7, and 13.8)

Unit 4: Hedging Parameters, Trading Strategies and Swaps

Hedging parameters (the Greeks: Delta, Gamma, Theta, Rho and Vega), Trading strategies involving options, Swaps, Mechanics of interest rate swaps, Comparative advantage argument, Valuation of interest rate swaps, Currency swaps, Valuation of currency swaps.

[1] Chapter 17 (Sections 17.1 to 17.9) Chapter 10 (except box spreads, calendar spreads and diagonal spreads) Chapter 7 (Sections 7.1 to 7.4, and 7.7 to 7.9)

Text Book:

1. Hull, J. C., & Basu, S. (2010). *Options, Futures and Other Derivatives* (7th ed.). Pearson Education. New Delhi.

Reference Books:

1. Luenberger, David G. (1998). *Investment Science*, Oxford University Press. Delhi.
2. Ross, Sheldon M. (2011). *An elementary Introduction to Mathematical Finance* (3rd ed.). Cambridge University Press. USA.

Reference Books

- [1] Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002,Pearson Education.
- [2] Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
- [3] Classical Electrodynamics, J.D. Jackson, 3rd Edn., 1998, Wiley.
- [4] The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4th Edn., 2003, Elsevier.
- [5] Introduction to Electrodynamics, D.J. Griffiths, 2012, Pearson Education.
- [6] Classical Mechanics, P.S. Joag, N.C. Rana, 1st Edn., McGraw Hall.
- [7] Classical Mechanics, R. Douglas Gregory, 2015, Cambridge University Press.
- [8] Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
- [9] Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press

Choice Based Credit System (CBCS)

UNIVERSITY OF GAUHATI

DEPARTMENT OF STATISTICS

UNDERGRADUATE PROGRAMME

(Courses effective from Academic Year 2019 - 20)



SYLLABUS OF COURSES TO BE OFFERED

Core Courses, Elective Courses & Ability Enhancement Courses

Declaration of Conformity

I / We certify that the syllabus for the stream **B.Sc. (Honours)** in the subject **Statistics** is as per guidelines laid down in the UG-CBCS Regulations of GU and the Sequence and Nomenclature of the Core Papers are maintained as per model syllabus published by the UGC, which is also a mandate of the UG-CBCS Regulations of GU.

Signature of the Head of the Department/Chairperson of UG-CCS

Department of **Statistics**, Gauhati University

Date 17-05-2019

Course Structure for B.Sc. in Statistics (Honours) under CBCS

May 2019

Semester	Type	Core	AECC	SEC	DSE	GE
	Credits	14×6 = 84	2×4 = 8	2×4 = 8	4×6 = 24	4×6 = 24
I	STA – HC – 1016	ENG – AE – 1014				STA – HG – 1016
	STA – HC – 1026					
II	STA – HC – 2016	ENV – AE – 2014				STA – HG – 2016
	STA – HC – 2026					
III	STA – HC – 3016			STA - SE – 3YY4		STA – HG – 3016
	STA – HC – 3026					
	STA – HC – 3036					
IV	STA – HC – 4016			STA - SE – 4YY4		STA – HG – 4016
	STA – HC – 4026					
	STA – HC – 4036					
V	STT – HC – 5016				STA - HE – 5YY6	
	STA – HC – 5026					
VI	STA – HC – 6016				STA - HE – 6YY6	
	STA – HC – 6026					

Total Credit: 148

Legends

HC: Core Papers for **Honours**

HE: Discipline Specific Elective Papers for **Honours**

AE: Ability Enhancement Compulsory Course

RE: Discipline Specific Elective Papers for **Regular**

YY: Serial No. of Paper: Two-digit numerical number (within the Semester)

SE: Skill Enhancement Papers

HG: Generic Elective Papers for **Honours**

RC: Core Papers for **Regular**

RG: Generic Elective for Regular

Directives & Advisory

- A student majoring (honours) in Statistics MAY take **HG** papers from any available discipline in the college, except Statistics.
- It is also advisable that a student majoring (honours) in Statistics take at least one **HG** paper from Mathematics.
- A student majoring (honours) in Statistics MAY choose any four papers out of eight papers mentioned in **HE**.
- A student majoring (honours) in Statistics MAY choose any two papers out of four papers mentioned in **SE**.
- The Generic Elective Papers prepared HERE for other disciplines/Departments.
- Red FONTS stands for Regular Courses

List of Papers

Core Papers

Total Lectures for each Theory papers: 60

Credits: 6 (Theory: 04, Practical/Lab: 02)

Semeste	Paper Code	Course name	Paper code for DSE for Regular
I	STA–HC–1016	Descriptive Statistics	
	STA–HC–1026	Calculus	
II	STA–HC–2016	Probability and Probability Distributions	
	STA–HC–2026	Algebra	
III	STA–HC–3016	Sampling Distributions	
	STA–HC–3026	Survey Sampling & Indian Official Statistics	STA-RE-5046
	STA–HC–3036	Mathematical Analysis	
IV	STA–HC–4016	Statistical Inference	
	STA–HC–4026	Linear Models	
	STA–HC–4036	Statistical Quality Control	
V	STA–HC–5016	Stochastic Processes and Queuing Theory	
	STA–HC–5026	Statistical Computing Using C/C++ Programming	
VI	STA–HC–6016	Design of Experiments	STA-RE-6036
	STA–HC-- 6026	Multivariate Analysis and Nonparametric Methods	

Discipline Specific Elective (DSE) Papers for Honours

Total Lectures for each Theory papers: 60

Credits: 6 (Theory: 04, Practical/Lab: 02)

(Any **TWO** papers **MUST** be chosen from given **FOUR** options papers in each Semester)

Semester	Paper Code	Course name	Paper code for DSE for Regular
V	STA – HE – 5016	Operations Research	STA – RE – 5016
	STA – HE – 5026	Time Series Analysis	STA – RE – 5026
	STA – HE – 5036	Survival Analysis and Biostatistics	STA – RE – 5036
	STA – HE – 5046	Financial Statistics	
VI	STA – HE – 6016	Econometrics	STA – RE – 6016
	STA – HE – 6026	Demography and Vital Statistics	STA – RE – 6026
	STA – HE – 6036	Actuarial Statistics	STA – RE – 6046
	STA – HE – 6046	Project Work	

Skill Based (SEC) Papers for Honours

Total Lectures for each Theory papers: 30

Credits: 4 (Theory: 02, Practical/Lab: 02)

(Any **ONE** paper **MUST** be chosen from given **TWO** options papers in each Semester)

Semester	Paper Code	Course name	Paper code for SEC for Regular
III	STA – SE – 3014	Statistical-Data Analysis Using Software Packages	STA – SE – 3014
	STA – SE – 3024	Data Base Management Systems	STA – SE – 4014
IV	STA – SE – 4014	Statistical Data Analysis Using R	STA – SE – 5014
	STA – SE – 4024	Statistical Techniques for Research Methods	STA – SE – 6014

Generic Elective (GE) Papers for Honours

Total Lectures for each Theory papers: 60

Credits: 6 (Theory: 04, Practical/Lab: 02)

Semester	Paper Code	Course name	Paper code for Regular Core (RC) for Regular
I	STA – HG – 1016	Statistical Methods	STA – RC – 1016
II	STA – HG – 2016	Introductory Probability	STA – RC – 2016
III	STA – HG – 3016	Basics of Statistical Inference	STA – RC – 3016
IV	STA – HG – 4016	Applied Statistics	STA – RC – 4016

Regular Core (RC) Papers for Regular

Total Lectures for each Theory papers: 60

Credits: 6 (Theory: 04, Practical/Lab: 02)

Semester	Paper Code	Course name
I	STA – RC – 1016	Statistical Methods
II	STA – RC – 2016	Introductory Probability
III	STA – RC – 3016	Basics of Statistical Inference
IV	STA – RC – 4016	Applied Statistics

Discipline Specific Elective (DSE) Papers for Regular

Total Lectures for each Theory papers: 60

Credits: 6 (Theory: 04, Practical/Lab: 02)

Semester	Paper Code	Course name
V	STA – RE – 5016	Operations Research
	STA – RE – 5026	Time Series Analysis
	STA – RE – 5036	Survival Analysis and Biostatistics
	STA – RE – 5046	Survey Sampling & Indian Official Statistics
VI	STA – RE – 6016	Econometrics
	STA – RE – 6026	Demography and Vital Statistics
	STA – RE – 6036	Design of Experiments
	STA – RE – 6046	Actuarial Statistics

Skill Based (SEC) Papers for Regular

Total Lectures for each Theory papers: 30

Credits: 4 (Theory: 02, Practical/Lab: 02)

Semester	Paper Code	Course name
III	STA – SE – 3014	Statistical-Data Analysis Using Software Packages
IV	STA – SE – 4014	Data Base Management Systems
V	STA – SE – 5014	Statistical Data Analysis Using R
VI	STA – SE – 6014	Statistical Techniques for Research Methods

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STA-HC-1016

Descriptive Statistics

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

1.1 Theory

1.1.1 Unit I: *Statistical Methods*: (Lectures: 10)

Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement- nominal, ordinal, interval and ratio. Presentation: tabular and graphical, including histogram and ogives, box plot, consistency and independence of data with special reference to attributes.

1.1.2 Unit 2: *Measures of Central Tendency*: (Lectures: 20)

Mathematical and positional. Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, Moments, absolute moments, factorial moments, skewness and kurtosis, Sheppard's corrections.

Collection and Scrutiny of Data: Primary data-designing a questionnaire and a schedule; checking their consistency; Secondary data-their major sources including some government publications. Complete enumeration, controlled experiments, observational studies and sample surveys. Scrutiny of data for internal consistency and detection of errors of recording. Ideas of cross-validation.

1.1.3 Unit 3: *Bivariate data*: (Lectures: 15)

Definition, scatter diagram, simple, partial and multiple correlation (3 variables only), rank correlation. Simple linear regression, principle of least squares and fitting of polynomials and exponential curves.

1.1.4 Unit 4: *Index Numbers*: (Lectures: 15)

Definition, construction of index numbers and problems thereof for weighted and unweighted index numbers including Laspeyre's, Paasche's, Edgeworth-Marshall and Fisher's. Chain index numbers, conversion of fixed based to chain based index numbers and vice-versa. Consumer price index numbers.

1.2 Practical/Lab

List of Practical

1. Graphical representation of data.
2. Problems based on measures of central tendency.
3. Problems based on measures of dispersion.
4. Problems based on combined mean and variance and coefficient of variation.
5. Problems based on moments, skewness and kurtosis.
6. Fitting of polynomials, exponential curves.

7. Karl Pearson correlation coefficient.
8. Correlation coefficient for a bivariate frequency distribution.
9. Lines of regression, angle between lines and estimated values of variables.
10. Spearman rank correlation with and without ties.
11. Partial and multiple Correlations.
12. Planes of regression and variances of residuals for given simple correlations.
13. Planes of regression and variances of residuals for raw data.
14. Calculate price and quantity index numbers using simple and weighted average of price relatives.
15. To calculate the Chain Base index numbers.
16. To calculate consumer price index number.

SUGGESTED READING:

1. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, 8th Edn. The World Press, Kolkata.
2. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
3. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn., (Reprint), Tata McGraw-Hill Pub. Co.Ltd.

STA-HC-1026

Calculus

Total Lectures: 60 Credits: 6 (Theory: 04, Tutorial: 02)

2.1 Theory

2.1.1 Unit 1: *Differential Calculus*: (Lectures: 18)

Limits of function, continuous functions, properties of continuous functions, partial differentiation and total differentiation. Indeterminate forms: L - Hospital's rule, Leibnitz rule for successive differentiation. Euler's theorem on homogeneous functions. Maxima and minima of functions of one and two variables, constrained optimization techniques (with Lagrange multiplier) along with some problems. Jacobian.

2.1.2 Unit 2: *Integral Calculus*: (Lectures: 12)

Review of integration and definite integral. Differentiation under integral sign, double integral, change of order of integration, transformation of variables. Beta and Gamma functions: properties and relationship between them.

2.1.3 Unit 3: *Differential Equations*: (Lectures: 25)

Exact differential equations, Integrating factors, change of variables, Total differential equations, Differential equations of first order and first degree, Differential equations of first order but not of first degree, Equations solvable for x , y , q , Equations of the first degree in x and y , Clairaut's equations. Higher Order Differential Equations: Linear differential equations of order n , Homogeneous and non-homogeneous linear differential equations of order n with constant coefficients, Different forms of particular integrals.

2.1.4 Unit 4: *Partial Differential Equations*: (Lectures: 5)

Formation and solution of a partial differential equations. Equations easily integrable. Linear partial differential equations of first order.

2.2 Tutorial

SUGGESTED READINGS:

1. Gorakh Prasad: Differential Calculus, Pothishala Pvt. Ltd., Allahabad (14th Edition - 1997).
2. Gorakh Prasad: Integral Calculus, Pothishala Pvt. Ltd., Allahabad (14th Edition -2000).
3. Zafar Ahsan: Differential Equations and their Applications, Prentice-Hall of India Pvt. Ltd., New Delhi (2nd Edition -2004).
4. Piskunov, N: Differential and Integral Calculus, Peace Publishers, Moscow.

STA-HC-2016

Probability and Probability Distributions

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

3.1 Theory

3.1.1 Unit 1: *Probability*: (Lectures: 12)

Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.

3.1.2 Unit 2: *Random variables*: (Lectures: 18)

Discrete and continuous random variables, p.m.f., p.d.f. and c.d.f., illustrations and properties of random variables, univariate transformations with illustrations. Two dimensional random variables: discrete and continuous type, joint, marginal and conditional p.m.f, p.d.f., and c.d.f., independence of variables, bivariate transformations with illustrations.

3.1.3 Unit 3: *Mathematical Expectation and Generating Functions*: (Lectures: 12)

Expectation of single and bivariate random variables and its properties. Moments and Cumulants, moment generating function, cumulant generating function and characteristic function. Conditional expectations.

3.1.4 Unit 4: *Mathematical Expectation and Generating Functions*: (Lectures: 18)

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform, normal, exponential, Cauchy, beta and gamma along with their properties and limiting/approximation cases, Log normal, Laplace, Weibull.

3.2 Practical/Lab

List of Practical

1. Fitting of binomial distributions for n and $p = q = \frac{1}{2}$.
2. Fitting of binomial distributions for given n and p .
3. Fitting of binomial distributions after computing mean and variance.
4. Fitting of Poisson distributions for given value of λ .
5. Fitting of Poisson distributions after computing mean.
6. Fitting of negative binomial.
7. Fitting of suitable distribution.
8. Application problems based on binomial distribution.
9. Application problems based on Poisson distribution.
10. Application problems based on negative binomial distribution.
11. Problems based on area property of normal distribution.
12. To find the ordinate for a given area for normal distribution.
13. Application based problems using normal distribution.

14. Fitting of normal distribution when parameters are given.
15. Fitting of normal distribution when parameters are not given.

SUGGESTED READING:

1. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
2. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
3. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi

STA-HC-2026

Algebra

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

4.1 Theory

4.1.1 Unit 1: *Theory of equations*: (Lectures: 15)

Statement of the fundamental theorem of algebra and its consequences. Relation between roots and coefficients or any polynomial equations. Solutions of cubic and biquadratic equations when some conditions on roots of equations are given. Evaluation of the symmetric polynomials and roots of cubic and biquadratic equations. Vector spaces, Subspaces, sum of subspaces, Span of a set, Linear dependence and independence, dimension and basis, dimension theorem.

4.1.2 Unit 2: *Algebra of matrices*: (Lectures: 17)

A review, theorems related to triangular, symmetric and skew symmetric matrices, idempotent matrices, Hermitian and skew Hermitian matrices, orthogonal matrices, singular and non-singular matrices and their properties. Trace of a matrix, unitary, involutory and nilpotent matrices. Adjoint and inverse of a matrix and related properties.

4.1.3 Unit 3: *Determinants of Matrices*: (Lectures: 18)

Definition, properties and applications of determinants for 3rd and higher orders, evaluation of determinants of order 3 and more using transformations. Symmetric and Skew symmetric determinants, Circulant determinants and Vandermonde determinants for n^{th} order, Jacobi's Theorem, product of determinants. Use of determinants in solution to the system of linear equations, row reduction and echelon forms, the matrix equations $AX=B$, solution sets of linear equations, linear independence, Applications of linear equations, inverse of a matrix.

4.1.4 Unit 4: *Matrices*: (Lectures: 10)

Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum and the product of two matrices. Partitioning of matrices and simple properties. Characteristic roots and Characteristic vector, Properties of characteristic roots, Cayley Hamilton theorem, Quadratic forms, Linear orthogonal transformation and their diagonalization.

3.2 Practical/Lab

List of Practical

Practical will done from the Unit 1 to Unit 4.

SUGGESTED READINGS:

1. Lay David C.: Linear Algebra and its Applications, Addison Wesley, 2000.
2. Schaum's Outlines : Linear Algebra, Tata McGraw-Hill Edition, 3rd Edition, 2006.
3. Krishnamurthy, V., Mainra, V.P. and Arora J.L.: An Introduction to Linear Algebra (II, III, IV, V).
4. Jain, P.K. and Khalil Ahmad: Metric Spaces, Narosa Publishing House, New Delhi, 1973
5. Biswas, S. (1997): A Textbook of Matrix Algebra, New Age International, 1997.
6. Gupta, S.C.: An Introduction to Matrices (Reprint). Sultan Chand & Sons, 2008.

7. Artin, M.: Algebra. Prentice Hall of India, 1994.
8. Datta, K.B.: Matrix and Linear Algebra. Prentice Hall of India Pvt. Ltd., 2002.
9. Hadley, G.: Linear Algebra, Narosa Publishing House (Reprint), 2002.
10. Searle, S.R.: Matrix Algebra Useful for Statistics. John Wiley & Sons., 1982.

STA-HC-3016

Sampling Distributions

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

5.1 Theory

5.1.1 Unit 1: *Order Statistics*: (Lectures: 8)

Introduction, distribution of the r th order statistic, smallest and largest order statistics. Joint distribution of r th and s th order statistics, distribution of sample median and sample range.

5.1.2 Unit 2: *Sampling Distributions*: (Lectures: 20)

Definitions of random sample, parameter and statistic, sampling distribution of a statistic, sampling distribution of sample mean, standard errors of sample mean, sample variance and sample proportion. Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region. Large sample tests, testing single proportion, difference of two proportions, single mean, difference of two means, standard deviation and difference of standard deviations by classical and p -value approaches.

5.1.3 Unit 3: *Exact sampling distributions*: (Lectures: 12)

Definition and derivation of p.d.f. of χ^2 with n degrees of freedom (d.f.) using m.g.f., nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., cumulant generating function, mode, additive property and limiting form of χ^2 distribution. Tests of significance and confidence intervals based on χ^2 distribution.

5.1.4 Unit 4: *Sampling distribution*: (Lectures: 20)

Student's and Fishers t -distribution, Derivation of its p.d.f., nature of probability curve with different degrees of freedom, mean, variance, moments and limiting form of t distribution.

Snedecore's F -distribution: Derivation of p.d.f., nature of p.d.f. curve with different degrees of freedom, mean, variance and mode. Distribution of $1/F(n_1, n_2)$. Relationship between t , F and χ^2 distributions. Test of significance and confidence Intervals based on t and F distributions.

5.2 Practical/Lab

List of Practical

1. Testing of significance and confidence intervals for single proportion and difference of two proportions
2. Testing of significance and confidence intervals for single mean and difference of two means and paired tests.
3. Testing of significance and confidence intervals for difference of two standard deviations.
4. Exact Sample Tests based on Chi-Square Distribution.

5. Testing if the population variance has a specific value and its confidence intervals.
6. Testing of goodness of fit.
7. Testing of independence of attributes.
8. Testing based on 2 X 2 contingency table without and with Yates' corrections.
9. Testing of significance and confidence intervals of an observed sample correlation coefficient.
10. Testing and confidence intervals of equality of two population variances

SUGGESTED READING:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2003): *An Outline of Statistical Theory*, Vol. I, 4th Edn. World Press, Kolkata.
2. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): *An Introduction to Probability and Statistics*. 2nd Edn. (Reprint) John Wiley and Sons.
3. Hogg, R.V. and Tanis, E.A. (2009): *A Brief Course in Mathematical Statistics*. Pearson Education.
4. Johnson, R.A. and Bhattacharya, G.K. (2001): *Statistics-Principles and Methods*, 4th Edn. John Wiley and Sons.
5. Mood, A.M., Graybill, F.A. and Boes, D.C. (2007): *Introduction to the Theory of Statistics*, 3rd Edn. (Reprint). Tata McGraw-Hill Pub. Co. Ltd.

STA-HC-3026

Survey Sampling and Indian Official Statistics

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

6.1 Theory

6.1.1 Unit 1: *Survey Sampling*: (Lectures: 8)

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion.

6.1.2 Unit 2: *Stratified random sampling*: (Lectures: 26)

Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision. Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates ($N=n \times k$). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections, introduction to PPS sampling and two stage sampling.

6.1.3 Unit 3: *Ratio and Regression Method of Sampling*: (Lectures: 20)

Introduction to Ratio and regression methods of estimation, first approximation to the population mean and total (for SRS of large size). Cluster sampling (equal clusters only) estimation of population mean and its variance, Concept of sub sampling.

6.1.4 Unit 4: *Official Statistics*: (Lectures: 6)

Present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications containing data on the topics such as population, industry and finance.

6.2 Practical/Lab

List of Practical

1. To select a SRS with and without replacement.
2. For a population of size 5, estimate population mean, population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
3. For SRSWOR, estimate mean, standard error, the sample size
4. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods
Compare the efficiencies of above two methods relative to SRS
5. Estimation of gain in precision in stratified sampling.
6. Comparison of systematic sampling with stratified sampling and SRS in the presence of a

linear trend.

7. Ratio and Regression estimation: Calculate the population mean or total of the population. Calculate mean squares. Compare the efficiencies of ratio and regression estimators relative to SRS.
8. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS.

SUGGESTED READING

1. Cochran, W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern.
2. Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. Asok,C.(1984). Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics
3. Murthy, M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
4. Des Raj and Chandhok, P. (1998): Sample Survey Theory, Narosa Publishing House.
5. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2001): Fundamentals of Statistics (Vol.2), World Press.
6. Guide to current Indian Official Statistics, Central Statistical Office, GOI, New Delhi.
7. <http://mospi.nic.in/>

STA-HC-3036

Mathematical Analysis

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

7.1 Theory

7.1.1 Unit 1: *Real Analysis*: (Lectures: 12)

Representation of real numbers as points on the line. Bounded and unbounded sets, neighborhoods and limit points, Supremum and infimum, derived sets, open and closed sets, sequences and their convergence, limits of some special sequences such as r^n , $\left(1 + \frac{1}{n}\right)^n$, and $\frac{1}{n^n}$ and Cauchy's general principle of convergence, Cauchy's first theorem on limits, monotonic sequences, limit superior and limit inferior of a bounded sequence.

7.1.2 Unit 2: *Infinite Series*: (Lectures: 12)

Infinite series, positive term series and their convergence; Comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test, Raabe's test (For all the tests, statement only is required, without proof and applications). Absolute convergence of series, Leibnitz's test for the convergence of alternating series, Conditional convergence. Indeterminate form, L' Hospital's rule.

7.1.3 Unit 3: *Limits, Continuity and Differentiability*: (Lectures: 16)

Review of limit, continuity and differentiability, uniform Continuity and boundedness of a function. Rolle's and Lagrange's Mean Value theorems. Taylor's theorem with Lagrange's and Cauchy's form of remainder (without proof). Taylor's and Maclaurin's series expansions of $\sin(x)$, $\cos(x)$, e^x , $(1+x)^n$, $\log(1+x)$.

7.1.4 Unit 4: *Numerical Analysis*: (Lectures: 20)

Factorial, finite differences and interpolation. Operators, E and divided difference. Newton's forward, backward and divided differences interpolation formulae. Lagrange's interpolation formulae. Central differences, Gauss and Stirling interpolation formulae. Numerical integration. Trapezoidal rule, Simpson's one-third rule, three-eighths rule, Weddle's rule with error terms. Stirling's approximation to factorial n . Solution of difference equations of first order.

7.2 Practical/Lab

Practical to be done from topics contained in Unit 4 only.

SUGGESTED READINGS

1. Malik, S.C. and Savita Arora: Mathematical Analysis, Second Edition, Wiley Eastern Limited, New Age International Limited, New Delhi, 1994.
2. Somasundram, D. and Chaudhary, B.: A First Course in Mathematical Analysis, Narosa Publishing House, New Delhi, 1987.
3. Gupta, S.L. and Nisha Rani: Principles of Real Analysis, Vikas Publ. House Pvt. Ltd., New Delhi, 1995.
4. Appostol, T.M.: Mathematical Analysis, Second Edition, Narosa Publishing House, New Delhi, 1987.
5. Shanti Narayan: A course of Mathematical Analysis, 12th revised Edition, S. Chand & Co. (Pvt.) Ltd., New Delhi, 1987.
6. Singal, M.K. and Singal, A.R.: A First Course in Real Analysis, 24th Edition, R. Chand & Co., New Delhi, 2003.
7. Bartle, R. G. and Sherbert, D. R. (2002): Introduction to Real Analysis (3rd Edition), John Wiley and Sons (Asia) Pte. Ltd., Singapore.
8. Ghorpade, Sudhir R. and Limaye, Balmohan V. (2006): A Course in Calculus and Real Analysis, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint.
9. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. (2003): Numerical methods for scientific and engineering computation, New age International Publisher, India.
10. Mukherjee, Kr. Kalyan (1990): Numerical Analysis. New Central Book Agency.
11. Sastry, S.S. (2000): Introductory Methods of Numerical Analysis, 3rd edition, Prentice Hall of India Pvt. Ltd., New Del.

STA-HC-4016

Statistical Inference

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

8.1 Theory

8.1.1 Unit 1: *Estimation*: (Lectures: 20)

Concepts of estimation, unbiasedness, sufficiency, consistency and efficiency. Factorization theorem. Complete statistic, Minimum variance unbiased estimator (MVUE), Rao-Blackwell and Lehmann-Scheffe theorems (statement only). Cramer-Rao inequality and MVB estimators.

8.1.2 Unit 2: *Methods of Estimation*: (Lectures: 19)

Method of moments, method of maximum likelihood estimation, method of minimum Chi-square.

8.1.3 Unit 3: *Principles of test of significance*: (Lectures: 18)

Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power, best critical region, most powerful test, uniformly most powerful test, Neyman Pearson Lemma (statement and applications to construct most powerful test). Likelihood ratio test, properties of likelihood ratio tests (without proof).

8.1.4 Unit 4: *Principles of test of significance*: (Lectures: 3)

Sequential Analysis: Introduction to Sequential probability ratio test (SPRT).

8.2 Practical/Lab

List of Practical

1. Unbiased estimators (including unbiased but absurd estimators)
2. Consistent estimators, efficient estimators and relative efficiency of estimators.
3. Cramer-Rao inequality and MVB estimators
4. Sufficient Estimators – Factorization Theorem, Rao-Blackwell theorem, Complete Sufficient estimators
5. Lehman-Scheffe theorem and UMVUE
6. Maximum Likelihood Estimation
7. Estimation by the method of moments, minimum Chi-square
8. Type I and Type II errors
9. Most powerful critical region (NP Lemma)
10. Uniformly most powerful critical region
11. Unbiased critical region
12. Power curves
13. Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis
14. Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis
15. Asymptotic properties of LR tests

SUGGESTED READINGS:

1. Goon, A.M., Gupta, M.K.: Das Gupta, B. (2005), Fundamentals of Statistics, Vol.I, World Press, Calcutta.
2. Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.
3. Miller, I. and Miller, M. (2002) : John E. Freund's Mathematical Statistics (6th addition, low price edition), Prentice Hall of India.
4. Dudewicz, E. J., and Mishra, S. N. (1988): Modern Mathematical Statistics. John Wiley & Sons.
5. Mood, A.M, Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, McGraw Hill.
6. Bhat, B.R, Srivenkatramana, Tand Rao Madhava, K.S. (1997) Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.
7. Snedecor, G.W and Cochran, W.G.(1967) Statistical Methods. Iowa State University Press.

STA-HC-4026

Linear Models

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

9.1 Theory

9.1.1 Unit 1: *Gauss-Markov Set-up*: (Lectures: 12)

Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance.

9.1.2 Unit 2: *Regression Analysis*: (Lectures: 15)

Simple regression analysis, Estimation and hypothesis testing in case of simple regression models.

9.1.3 Unit 3: *Analysis of Variance*: (Lectures: 18)

Definitions of fixed, random and mixed effect models, analysis of variance and covariance in one-way classified data for fixed effect models, analysis of variance and covariance in two-way classified data with one observation per cell for fixed effect models.

9.1.4 Unit 4: *Model Checking*: (Lectures: 15)

Prediction from a fitted model, Violation of assumptions of AOV and their remedies by transformation.

9.2 Practical/Lab

List of Practical

1. Estimability when X is a full rank matrix and not a full rank matrix
2. Distribution of Quadratic forms
3. Simple Linear Regression
4. Multiple Regression
5. Tests for Linear Hypothesis
6. Bias in regression estimates
7. Lack of fit
8. Orthogonal Polynomials
9. Analysis of Variance of a one way classified data
10. Analysis of Variance of a two way classified data with one observation per cell
11. Analysis of Covariance of a one way classified data
12. Analysis of Covariance of a two way classified data

SUGGESTED READINGS:

1. Weisberg, S. (2005). Applied Linear Regression (Third edition). Wiley.
2. Wu, C. F. J. And Hamada, M. (2009). Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
3. Renchner, A. C. And Schaalje, G. B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons.

STA-HC-4036

Statistical Quality Control

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

10.1 Theory

10.1.1 Unit 1: *Statistical Process Control*: (Lectures: 18)

Quality: Definition, dimensions of quality, historical perspective of quality control and improvements starting from World War II, historical perspective of Quality Gurus and Quality Hall of Fame. Quality system and standards: Introduction to ISO quality standards, Quality registration. Statistical Process Control - Seven tools of SPC, chance and assignable Causes of quality variation. Statistical Control Charts- Construction and Statistical basis of 3- σ Control charts, Rational Sub-grouping.

10.1.2 Unit 2: *Control Charts for Variables*: (Lectures: 18)

\bar{X} -bar & R -chart, \bar{X} -bar & s -chart. Control charts for attributes: np -chart, p -chart, c -chart and u -chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart, estimation of process capability.

10.1.3 Unit 3: *Acceptance Sampling Plan*: (Lectures: 20)

Principle of acceptance sampling plans. Single and Double sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables.

10.1.4 Unit 4: *Six-Sigma*: (Lectures: 4)

Introduction to Six-Sigma: Overview of Six Sigma.

10.2 Practical/Lab

List of Practical

1. Construction and interpretation of statistical control charts \bar{X} -bar & R -chart
 - \bar{X} -bar & s -chart
 - np -chart
 - p -chart
 - c -chart
 - u -chart
2. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves
3. Calculation of process capability and comparison of 3-sigma control limits with specification limits.

SUGGESTED READING:

1. Montgomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.
2. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, 8th Edn. The World Press, Kolkata.
3. Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd.
4. Montgomery, D. C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, 3rd Edition reprint, Wiley India Pvt. Ltd.
5. Ehrlich, B. Harris (2002): Transactional Six Sigma and Lean Servicing, 2nd Edition, St. Lucie Press.
6. Hoyle, David (1995): ISO Quality Systems Handbook, 2nd Edition, Butterworth Heinemann Publication.

STA-HC- 5016

Stochastic Processes and Queuing Theory

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

11.1 Theory

11.1.1 Unit 1: *Probability Distributions*: (Lectures: 8)

Generating functions, Bivariate probability generating function. Stochastic Process: Introduction, Stationary Process.

11.1.2 Unit 2: *Markov Chains*: (Lectures: 18)

Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains.

11.1.3 Unit 3: *Poisson Process*: (Lectures: 18)

Postulates of Poisson process, properties of Poisson process, inter-arrival time.

11.1.4 Unit 4: *Queuing System*: (Lectures: 16)

General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).

11.2 Practical/Lab

List of Practical

1. Calculation of transition probability matrix
2. Identification of characteristics of reducible and irreducible chains.
3. Identification of types of classes
4. Identification of ergodic transition probability matrix
5. Stationarity of Markov chain and graphical representation of Markov chain
6. Computation of probabilities in case of generalizations of independent Bernoulli trials.
7. Computation of inter-arrival time for a Poisson process.
8. Calculation of Probability and parameters for (M/M/1) model and change in behaviour of queue as N tends to infinity.
9. Calculation of generating function and expected duration for different amounts of stake.

SUGGESTED READING:

1. Medhi, J. (2009): Stochastic Processes, New Age International Publishers.
2. Basu, A.K. (2005): Introduction to Stochastic Processes, Narosa Publishing.
3. Bhat, B.R.(2000): Stochastic Models: Analysis and Applications, New Age International Publishers.
4. Taha, H. (1995): Operations Research: An Introduction, Prentice- Hall India.
5. Feller, William (1968): Introduction to probability Theory and Its Applications, Vol I, 3rd Edition, Wiley International.

STA-HC- 5026

Statistical Computing Using C/C++ Programming

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

12.1 Theory

12.1.1 Unit 1: *C Programming*: (Lectures: 30)

History and importance of C. Components, basic structure programming, character set, C tokens, Keywords and Identifiers and execution of a C program. Data types: Basic data types, Enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, Symbolic Constants, overflow and underflow of data.

Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement, operators, precedence of operators in arithmetic, relational and logical expression. Implicit and explicit type conversions in expressions, library functions. Managing input and output operations: reading and printing formatted and unformatted data

12.1.2 Unit 2: *Decision making and Arrays*: (Lectures: 30)

Decision making and branching - if...else, nesting of if...else, else if ladder, switch, conditional (?) operator. Looping in C: for, nested for, while, do...while, jumps in and out of loops.

Arrays: Declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: Declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only).

12.2 Practical/Lab

List of Practical

1. Plot of a graph $y = f(x)$
2. Roots of a quadratic equation (with imaginary roots also)
3. Sorting of an array and hence finding median
4. Mean, Median and Mode of a Grouped Frequency Data
5. Variance and coefficient of variation of a Grouped Frequency Data
6. Preparing a frequency table
7. Value of $n!$ using recursion
8. Random number generation from uniform, exponential, normal (using CLT) and gamma distribution, calculate sample mean and variance and compare with population parameters.
9. Matrix addition, subtraction, multiplication Transpose and Trace
10. Fitting of Binomial, Poisson distribution and apply Chi-square test for goodness of fit
11. Chi-square contingency table
12. t-test for difference of means
13. Paired t-test
14. F-ratio test
15. Multiple and Partial correlation.

16. Compute ranks and then calculate rank correlation (without tied ranks)
17. Fitting of lines of regression

SUGGESTED READING:

1. Kernighan, B.W. and Ritchie, D. (1988): C Programming Language, 2nd Edition, Prentice Hall.
2. Balagurusamy, E. (2011): Programming in ANSI C, 6th Edition, Tata McGraw Hill.
3. Gottfried, B.S. (1998): Schaum's Outlines: Programming with C, 2nd Edition, Tata McGraw Hill.

STA-HC- 6016

Design of Experiments

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

13.1 Theory

13.1.1 Unit 1: *Design of Experiments*: (Lectures: 25)

Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, choice of size and shape of plots and blocks.

Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model and statistical analysis, relative efficiency, analysis with missing observations, Greaco Latin Square Design.

13.1.2 Unit 2: *Design of Experiments*: (Lectures: 15)

Split Plot Design, Strip Plot Design, Incomplete Block Designs, Introduction to Balanced Incomplete Block Design (BIBD).

13.1.3 Unit 3: *Factorial Experiments*: (Lectures: 20)

Factorial experiments: advantages, notations and concepts, 2^2 , $2^3 \dots 2^n$ and 3^2 factorial experiments, design and analysis, Total and Partial confounding for 2^n ($n \leq 5$), idea of 3^2 experiment.

13.2 Practical/Lab

List of Practical

1. Analysis of a CRD
2. Analysis of an RBD
3. Analysis of an LSD
4. Analysis of an RBD with one missing observation
5. Analysis of an LSD with one missing observation
6. Analysis of 2^2 and 2^3 factorial in CRD and RBD
7. Analysis of a completely confounded two level factorial design in 2 blocks
8. Analysis of a completely confounded two level factorial design in 4 blocks
9. Analysis of a partially confounded two level factorial design.

SUGGESTED READINGS:

1. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
2. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
3. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8th Edn. World Press, Kolkata.
4. Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
5. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.

STA-HC- 6026

Multivariate Analysis and Nonparametric Methods

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

14.1 Theory

14.1.1 Unit 1: *Bivariate and Multivariate Distributions: (Lectures: 20)*

Bivariate Normal Distribution (BVN): p.d.f. of BVN, properties of BVN, marginal and conditional p.d.f. of BVN.

Multivariate Data: Random Vector: Probability mass/density functions, Distribution function, Mean vector & Dispersion matrix, Marginal & Conditional distributions.

14.1.2 Unit 2: *Multivariate Normal Distributions: (Lectures: 20)*

Multivariate Normal distribution and its properties. Sampling distribution for mean vector and variance- covariance matrix. Multiple and partial correlation coefficient and their properties, Basic idea of Principal Component Analysis, Hotelling T^2 – concept and applications.

14.1.3 Unit 3: *Non-parametric Tests: (Lectures: 20)*

Nonparametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function, Kolmogorov Smirnov test for one sample, Sign tests- one sample and two samples, Wilcoxon-Mann-Whitney test, Kruskal-Wallis test.

14.2 Practical/Lab

List of Practical

1. Multiple Correlation
2. Partial Correlation
3. Bivariate Normal Distribution,
4. Multivariate Normal Distribution
5. Principal Components Analysis
6. Test for randomness based on total number of runs,
7. Kolmogorov Smirnov test for one sample.
8. Sign test: one sample, two samples, large samples.
9. Wilcoxon-Mann-Whitney U-test,
10. Kruskal-Wallis test.

SUGGESTED READING:

1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rdEdn., John Wiley
2. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.
3. Kshirsagar, A.M. (1972) :Multivariate Analysis, 1stEdn. Marcel Dekker.
4. Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Analysis, 6thEdn., Pearson & Prentice Hall.
5. Mukhopadhyay, P. : Mathematical Statistics.
6. Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Edition. Marcel Dekker, CRC.

STA-HE- 5016

Operations Research

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

15.1 Theory

15.1.1 Unit 1: *Operations Research: (Lectures: 20)*

Introduction to Operations Research, phases of O.R., model building, various types of O.R. problems. Linear Programming Problem, Mathematical formulation of the L.P.P, graphical solutions of a L.P.P. Simplex method for solving L.P.P.

15.1.2 Unit 2: *Transportation Problem: (Lectures: 15)*

Transportation Problem: Initial solution by North West corner rule, Least cost method and Vogel's approximation method (VAM).

15.1.3 Unit 3: *Game theory: (Lectures: 10)*

Game theory: Rectangular game, minimax-maximax principle.

15.1.4 Unit 4: *Inventory Management: (Lectures: 15)*

Inventory Management: ABC inventory system, characteristics of inventory system. EOQ Model and its variations, with and without shortages, Quantity Discount Model with price breaks.

15.2 Practical/Lab (Using TORA/WINQSB/LINGO)

List of Practical

1. Mathematical formulation of L.P.P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables.
2. Identifying Special cases by Graphical and Simplex method and interpretation
 - a. Degenerate solution
 - b. Unbounded solution
 - c. Alternate solution
 - d. Infeasible solution
3. Allocation problem using Transportation model
4. Networking problem
 - a. Minimal spanning tree problem
 - b. Shortest route problem
5. Problems based on game matrix
 - a. Graphical solution to $m \times 2 / 2 \times n$ rectangular game
 - b. Mixed strategy
6. Mathematical formulation of L.P.P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables.
7. Networking problem
 - a. minimal spanning tree problem
 - b. Shortest route problem
8. Problems based on game matrix
 - a. Graphical solution to $m \times 2 / 2 \times n$ rectangular game
 - b. Mixed strategy

9. To find optimal inventory policy for EOQ models and its variations
10. To solve all-units quantity discounts model

SUGGESTED READING:

1. Taha, H. A. (2007): Operations Research: An Introduction, 8th Edition, Prentice Hall of India.
2. KantiSwarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons.
3. Hadley, G: (2002) : Linear Programming, Narosa Publications
4. Hillier, F.A and Lieberman, G.J. (2010): Introduction to Operations Research- Concepts and cases, 9th Edition, Tata McGraw Hill.

STA-HE- 5026

Time Series Analysis

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

16.1 Theory

16.1.1 Unit 1: *Introduction to Time Series*: (Lectures: 15)

Introduction to times series data, application of time series from various fields, Components of a times series, Decomposition of time series. Trend: Estimation of trend by free hand curve method, method of semi averages, fitting a various mathematical curve, and growth curves.

16.1.2 Unit 2: *Introduction to Time Series*: (Lectures: 18)

Trend Cont.: Method of moving averages. Detrending. Effect of elimination of trend on other components of the time series. Seasonal Component: Estimation of seasonal component by Method of simple averages, Ratio to Trend.

16.1.3 Unit 3: *Moving averages*: (Lectures: 15)

Seasonal Component continued: Ratio to Moving Averages and Link Relative method, Deseasonalization.

16.1.4 Unit 4: *Forecasting and smoothing to Time Series*: (Lectures: 12)

Random Component: Variate component method. Forecasting: Exponential smoothing methods.

SUGGESTED READING:

1. Kendall M.G. (1976): Time Series, Charles Griffin.
2. Chatfield C. (1980): The Analysis of Time Series –An Introduction, Chapman & Hall.
3. Mukhopadhyay P. (2011): Applied Statistics, 2nd ed. Revised reprint, Books and Allied

PRACTICAL / LAB WORK

List of Practical

1. Fitting and plotting of modified exponential curve
2. Fitting and plotting of Gompertz curve
3. Fitting and plotting of logistic curve
4. Fitting of trend by Moving Average Method
5. Measurement of Seasonal indices Ratio-to-Trend method
6. Measurement of Seasonal indices Ratio-to-Moving Average method
7. Measurement of seasonal indices Link Relative method
8. Calculation of variance of random component by variate difference method
9. Forecasting by exponential smoothing
10. Forecasting by short term forecasting methods.

STA-HE- 5036

Survival Analysis and Biostatistics

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

17.1 Theory

17.1.1 Unit 1: *Survival Analysis*: (Lectures: 18)

Survival Analysis: Functions of survival times, survival distributions and their applications- exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function.

Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples.

17.1.2 Unit 2: *Independent and dependent Risk*: (Lectures: 12)

Theory of independent and dependent risks. Bivariate normal dependent risk model.

17.1.3 Unit 3: *Epidemic Model*: (Lectures: 15)

Stochastic Epidemic Models: Simple epidemic models, general epidemic model definition and concept (without derivation). Duration of an epidemic.

17.1.4 Unit 4: *Statistical Genetics*: (Lectures: 15)

Statistical Genetics: Introduction, concepts-Genotype, Phenotype, Dominance, Recessiveness, Linkage and Recombination, Introduction to Clinical Trials.

SUGGESTED READING:

1. Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Edition, John Wiley and Sons.
2. Biswas, S. (2007): Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2nd Central Edition, New Central Book Agency.
3. Kleinbaum, D.G. (1996): Survival Analysis, Springer.
4. Chiang, C.L. (1968): Introduction to Stochastic Processes in Bio Statistics, John Wiley and Sons.
5. Indrayan, A. (2008): Medical Biostatistics, 2nd Edition Chapman and Hall/CRC.

PRACTICAL / LAB WORK

List of Practical

1. To estimate survival function
2. To determine death density function and hazard function
3. To identify type of censoring and to estimate survival time for type I censored data
4. To identify type of censoring and to estimate survival time for type II censored data
5. To identify type of censoring and to estimate survival time for progressively type I censored data
6. Estimation of mean survival time and variance of the estimator for type I censored data
7. Estimation of mean survival time and variance of the estimator for type II censored data
8. Estimation of mean survival time and variance of the estimator for progressively type I censored data
9. To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods
10. To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method
11. To estimate Crude probability of death
12. To estimate Net-type I probability of death
13. To estimate Net-type II probability of death
14. To estimate partially crude probability of death
15. To estimate gene frequencies

STA-HE- 5046

Financial Statistics

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

18.1 Theory

18.1.1 Unit 1: *Probability Review*: (Lectures: 15)

Probability review: Real valued random variables, expectation and variance, skewness and kurtosis, conditional probabilities and expectations. Discrete Stochastic Processes, Binomial processes, General random walks.

18.1.2 Unit 2: *Tools for Pricing*: (Lectures: 15)

Tools Needed For Option Pricing: Wiener process, stochastic integration, and stochastic differential equations. Introduction to derivatives: Forward contracts, spot price, forward price, future price. Call and put options, zero-coupon bonds and discount bonds

18.1.3 Unit 3: *Pricing Derivatives*: (Lectures: 15)

Pricing Derivatives: Arbitrage relations and perfect financial markets, pricing futures, put-call parity for European options, relationship between strike price and option price.

18.1.4 Unit 4: *Hedging Portfolios*: (Lectures: 15)

Hedging portfolios: Delta, Gamma and Theta hedging. Binomial Model for European options: Cox-Ross-Rubinstein approach to option pricing. Discrete dividends

SUGGESTED READING:

1. Franke, J., Hardle, W.K. and Hafner, C.M. (2011): *Statistics of Financial Markets: An Introduction*, 3rd Edition, Springer Publications.
2. Stanley L. S. (2012): *A Course on Statistics for Finance*, Chapman and Hall/CRC.

PRACTICAL / LAB WORK (Using spreadsheet/ R)

List of Practical

1. To verify “no arbitrage” principle
2. To verify relationship between spot price, forward price, future price
3. To price future contracts
4. To verify put-call parity for European options
5. To construct binomial trees and to evaluate options using these trees
6. To price options using black – Scholes formula
7. To hedge portfolios using delta and gamma hedging

8. To hedge portfolios theta hedging
9. Pricing of call options using binomial model
10. Computation of dividends on call options as a percentage of stock price.
11. Computation of dividends on call options as a fixed amount of money.
12. Pricing of put options using binomial model
13. Call-put parity for options following binomial models.
14. Effect of dividends on put options.

STA-HE- 6016

Econometrics

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

19.1 Theory

19.1.1 Unit 1: *Economic Models*: (Lectures: 15)

Introduction: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, linear models: two or more variables.

19.1.2 Unit 2: *Estimation*: (Lectures: 18)

Least square assumptions, estimation of regression parameters, tests of significance and confidence intervals.

19.1.3 Unit 3: *Regression*: (Lectures: 15)

Multiple Regression analysis, estimation and inference.

19.1.4 Unit 4: *Collinearity*: (Lectures: 12)

Violations of Least Square assumptions: multicollinearity, autocorrelation and heteroscedasticity.

SUGGESTED READING:

1. Gujarati, D. and Sangeetha, S. (2007): Basic Econometrics, 4th Edition, McGraw Hill Companies.
2. Johnston, J. (1972): Econometric Methods, 2nd Edition, McGraw Hill International.
3. Koutsoyiannis, A. (2004): Theory of Econometrics, 2nd Edition, Palgrave Macmillan Limited,
4. Maddala, G.S. and Lahiri, K. (2009): Introduction to Econometrics, 4th Edition, John Wiley & Sons.

PRACTICAL /LAB WORK

List of Practical

1. Problems based on estimation of General linear model
2. Testing of parameters of General linear model
3. Forecasting of General linear model
4. Problems concerning specification errors
5. Problems related to consequences of Multicollinearity
6. Diagnostics of Multicollinearity
7. Problems related to consequences of Autocorrelation (AR(I))
8. Diagnostics of Autocorrelation
9. Estimation of problems of General linear model under Autocorrelation

10. Problems related to consequences Heteroscedasticity
11. Diagnostics of Heteroscedasticity
12. Estimation of problems of General linear model under Heteroscedastic distance terms
13. Problems related to General linear model under(Aitken Estimation).

STA-HE- 6026**Demography and Vital Statistics**

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

20.1 Theory**20.1.1 Unit 1: *Population Theory*: (Lectures: 10)**

Population Theories: Coverage and content errors in demographic data, use of balancing equations, Population composition, dependency ratio.

20.1.2 Unit 2: *Measurement of Mortality*: (Lectures: 15)

Introduction and sources of collecting data on vital statistics, errors in census and registration data. Measurement of population, rate and ratio of vital events. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality, Rate (IMR) and Standardized Death Rates.

20.1.3 Unit 3: *Life Table*: (Lectures: 18)

Stationary and Stable population, Central Mortality Rates and Force of Mortality. Life (Mortality) Tables: Assumption, description.

20.1.4 Unit 4: *Measurement of Fertility*: (Lectures: 17)

Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR). Measurement of Population Growth: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR).

SUGGESTED READING:

1. Mukhopadhyay, P. (1999): Applied Statistics, Books and Allied (P) Ltd.
2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition, World Press.
3. Biswas, S. (1988): Stochastic Processes in Demography & Application, Wiley Eastern Ltd.
4. Croxton, Fredrick E., Cowden, Dudley J. and Klein, S. (1973): Applied General Statistics, 3rd Edition. Prentice Hall of India Pvt. Ltd.
5. Keyfitz N., Beckman John A.: Demography through Problems S-Verlag New York.

PRACTICAL/LAB. WORK:

List of Practical

1. To calculate CDR and Age Specific death rate for a given set of data
2. To find Standardized death rate by:- (i) Direct method (ii) Indirect method
3. To construct a complete life table
4. To fill in the missing entries in a life table
5. To calculate probabilities of death at pivotal ages and use it construct abridged life table using (i) Reed-Merrell Method, (ii) Greville's Method and (iii) King's Method
6. To calculate CBR, GFR, SFR, TFR for a given set of data
7. To calculate Crude rate of Natural Increase and Pearle's Vital Index for a given set of data
8. Calculate GRR and NRR for a given set of data and compare them

STA-HE- 6036

Actuarial Statistics

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

21.1 Theory

21.1.1 Unit 1: *Probability Distributions*: (Lectures: 15)

Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory.

21.1.2 Unit 2: *Premium Calculation*: (Lectures: 15)

Principles of Premium Calculation: Properties of premium principles, examples of premium principles. Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.

21.1.3 Unit 3: *Survival Distribution*: (Lectures: 18)

Survival Distribution and Life Tables: Uncertainty of age at death, survival function, time- until-death for a person, curate future lifetime, force of mortality, life tables with examples, deterministic survivorship group, life table characteristics.

21.1.4 Unit 4: *Life Insurance*: (Lectures: 12)

Life Insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death.

SUGGESTED READING:

1. Dickson, C. M. D. (2005): Insurance Risk And Ruin (International Series On Actuarial Science), Cambridge University Press.
2. Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A. And Nesbitt, C. J. (1997): Actuarial Mathematics, Society of Actuaries, Itasca, Illinois, U.S.A.

PRACTICAL / LAB WORK (Using Spreadsheet/R)

List of Practical

- 1 Risk computation for different utility models
2. Discrete and continuous risk calculations
3. Calculation of aggregate claims for collective risks
4. Calculation of aggregate claim for individual risks
5. Computing Ruin probabilities and aggregate losses
6. Annuity and present value of contract
7. Computing premium for different insurance schemes
8. Practical based on life models and tables

STA-HE- 6046

Project Work

Total Lectures: 60 Credits: 6

Objective: The aim of the course is to initiate students to write and present a statistical report, under the supervision of a faculty, on some area of human interest. The project work will provide hands on training to the students to deal with data emanating from some real life situation and propel them to dwell on some theory or relate it to some theoretical concepts.

STA-HG- 1016

Statistical Methods

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

23.1 Theory

23.1.1 Unit 1: *Statistical Data*: (Lectures: 12)

Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Data: Univariate Data: quantitative and qualitative, attributes, variables, scales of measurement - nominal, ordinal, interval and ratio. Presentation: tabular and graphic, including histogram and ogives.

23.1.2 Unit 2: *Measures of Central Tendency*: (Lectures: 12)

Measures of Central Tendency: mathematical and positional. Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, skewness and kurtosis.

23.1.3 Unit 3: *Calculus of Finite Difference*: (Lectures: 12)

Finite Difference: Definition, Operators Δ & E , their properties, Difference table, missing terms, Interpolation: Definition, Newton's Forward and Backward interpolation formula. Divided Difference (DD): Definition, DD table, Newton's DD formula. Lagrange's interpolation formula. Numerical Integration: Introduction, General quadrature formula, Trapezoidal, Simpson's 1/3rd & 3/8th rules, Newton-Raphson method.

23.1.4 Unit 4: *Bivariate Data*: (Lectures: 12)

Bivariate data: Definition, scatter diagram, simple, partial and multiple correlation (3 variables only), rank correlation. Simple linear regression, principle of least squares.

23.1.5 Unit 5: *Theory of Attributes*: (Lectures: 12)

Theory of attributes, consistency of data, independence and association of attributes, measures of association and contingency.

SUGGESTED READING:

1. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, 8th Edn. The World Press, Kolkata.
2. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
3. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn., (Reprint), Tata McGraw-Hill Pub. Co.Ltd.

PRACTICAL/ LAB WORK

List of Practical

1. Graphical representation of data
2. Problems based on measures of central tendency
3. Problems based on measures of dispersion
4. Problems based on combined mean and variance and coefficient of variation
5. Problems based on moments, skewness and kurtosis
6. Fitting of polynomials, exponential curves
7. Karl Pearson correlation coefficient
8. Partial and multiple correlations
9. Spearman rank correlation with and without ties.
10. Correlation coefficient for a bivariate frequency distribution
11. Lines of regression, angle between lines and estimated values of variables.
12. Checking consistency of data and finding association among attributes.

STA-HG- 2016

Introductory Probability

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

24.1 Theory

24.1.1 Unit 1: *Probability*: (Lectures: 15)

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.

24.1.2 Unit 2: *Random Variables*: (Lectures: 15)

Random Variables: Discrete and continuous random variables, p.m.f., p.d.f., c.d.f. Illustrations of random variables and its properties. Expectation, variance, moments and moment generating function.

24.1.3 Unit 3: *Convergence in Probability*: (Lectures: 12)

Idea of convergence in probability, Chebyshev's inequality, weak law of large numbers, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorem (C.L.T.) (statement only without proof).

24.1.4 Unit 4: *Standard Distributions*: (Lectures: 18)

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform, normal, exponential, beta, gamma.

SUGGESTED READING:

1. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
2. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
3. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi

PRACTICAL/LAB. WORK:

List of Practical

1. Fitting of binomial distributions for n and $p = q = \frac{1}{2}$ given
2. Fitting of binomial distributions for n and p given
3. Fitting of binomial distributions computing mean and variance
4. Fitting of Poisson distributions for given value of λ
5. Fitting of Poisson distributions after computing mean

6. Application problems based on binomial distribution
7. Application problems based on Poisson distribution
8. Problems based on area property of normal distribution
9. To find the ordinate for a given area for normal distribution
10. Application based problems using normal distribution
11. Fitting of normal distribution when parameters are given
12. Fitting of normal distribution when parameters are not given.

STA-HG- 3016

Basics of Statistical Inference

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

25.1 Theory

25.1.1 Unit 1: *Tests of Hypothesis: (Lectures: 20)*

Estimation of population mean, confidence intervals for the parameters of a normal distribution (one sample).

The basic idea of significance test. Null and alternative hypothesis. Type I & Type II errors, level of significance, concept of p-value. Tests of hypotheses for the parameters of a normal distribution (one sample), Non-parametric tests: Sign test for median, Sign test for symmetry, Wilcoxon two-sample test.

25.1.2 Unit 2: *Categorical Data Analysis: (Lectures: 18)*

Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction.

25.1.3 Unit 3: *Analysis of Variance: (Lectures: 22)*

Analysis of variance, one-way and two-way classification. Brief exposure of three basic principles of design of experiments, treatment, plot and block. Analysis of completely randomized design, randomized complete block design. Bioassay.

SUGGESTED READING:

1. Daniel, Wayne W., Bio-statistics: A Foundation for Analysis in the Health Sciences. John Wiley (2005).
2. Goon, A.M., Gupta M.K. & Das Gupta, Fundamentals of statistics, Vol.-I & II (2005).
3. Dass, M. N. & Giri, N. C.: Design and analysis of experiments. John Wiley.
4. Dunn, O.J Basic Statistics: A primer for the Biomedical Sciences. (1964, 1977) by John Wiley.
5. Bancroft, Holdon Introduction to Bio-Statistics (1962) P.B. Hoebar New York.
6. Goldstein, A Biostatistics-An introductory text (1971). The Macmillan New York.

PRACTICAL/LAB WORK

List of Practical

1. Estimators of population mean.
2. Confidence interval for the parameters of a normal distribution (one sample).
3. Tests of hypotheses for the parameters of a normal distribution (one sample).
4. Chi-square test of proportions.
5. Chi-square tests of association.
6. Chi-square test of goodness-of-fit.
7. Test for correlation coefficient.

8. Sign test for median.
9. Sign test for symmetry.
10. Wilcoxon two-sample test.
11. Analysis of Variance of a one way classified data
12. Analysis of Variance of a two way classified data.
13. Analysis of a CRD.
14. Analysis of an RBD.

STA-HG- 4016

Applied Statistics

Total Lectures: 60 Credits: 6 (Theory: 04, Practical/Lab: 02)

26.1 Theory

26.1.1 Unit 1: *Time Series*: (Lectures: 12)

Economic Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear, quadratic and modified exponential). Measurement of seasonal variations by method of ratio to trend.

26.1.2 Unit 2: *Index Numbers*: (Lectures: 12)

Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price index number. Uses and limitations of index numbers.

26.1.3 Unit 3: *Statistical Quality Control*: (Lectures: 12)

Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: chance and assignable. General theory of control charts, process & product control, Control charts for variables: X- bar and R-charts. Control charts for attributes: p and c-charts

26.1.4 Unit 4: *Demography*: (Lectures: 12)

Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized death rates. Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR.

26.1.5 Unit 5: *Demand Analysis*: (Lectures: 12)

Demand Analysis: Theory of consumption and demand, demand function, elasticity of demand, determination of elasticity of demand by family budget method, Lorentz curve and Gini's coefficient, Engel's law and Engel's curve, Pareto's law of income distribution.

SUGGESTED READING:

- 1 Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta.
- 2 Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition World Press, Kolkata.
- 3 Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4th Edition (Reprint), Sultan Chand & Sons
- 4 Montgomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.

PRACTICAL/LAB WORK

List of Practical

1. Measurement of trend: Fitting of linear, quadratic trend, exponential curve and plotting of trend values and comparing with given data graphically.
2. Measurement of seasonal indices by Ratio-to-trend method and plotting of trend values and comparing with given data graphically.
3. Construction of price and quantity index numbers by Laspeyre's formula, Paasche's formula, Marshall-Edgeworth's formula, Fisher's Formula. Comparison and interpretation.
4. Construction of wholesale price index number, fixed base index number and consumer price index number with interpretation
5. Construction and interpretation of \bar{X} & R-chart
6. Construction and interpretation p-chart (fixed sample size) and c-chart
7. Computation of measures of mortality
8. Completion of life table
9. Computation of measures of fertility and population growth

STA – SE - 3014

Statistical Data Analysis Using Software Packages

Total Lectures: 30 Credits: 4 (Theory: 02, Practical/Lab: 02)

27.1 Theory/Practical/Lab

This course will review and expand upon core topics in statistics and probability, particularly by initiating the beneficiaries of the course to at least one of the software packages viz., Microsoft Excel, SPSS, Minitab, Matlab, for statistical computing.

27.1.1 Unit 1: *Graphical Representation*: (Lectures: 8)

Learn how to load data, plot a graph viz. histograms (equal class intervals and unequal class intervals), box plot, stem-leaf, frequency polygon, pie chart, ogives with graphical summaries of data

27.1.2 Unit 2: *Report Generation*: (Lectures: 6)

Generate automated reports giving detailed descriptive statistics, correlation and lines of regression.

27.1.3 Unit 3: *Fitting Curves*: (Lectures: 8)

Random number generation and sampling procedures. Fitting of polynomials and exponential curves. Application Problems based on fitting of suitable distribution, Normal probability plot.

27.1.4 Unit 4: *Analysis*: (Lectures: 8)

Simple analysis and create and manage statistical analysis projects, import data, code editing, Basics of statistical inference in order to understand hypothesis testing and compute p-values and confidence intervals.

SUGGESTED READING:

1. Moore, D.S. and McCabe, G.P. and Craig, B.A. (2014): Introduction to the Practice of Statistics, W.H. Freeman
2. Cunningham, B.J (2012): Using SPSS: An Interactive Hands-on approach
3. Cho, M,J., Martinez, W.L. (2014) Statistics in MATLAB: A Primer, Chapman and Hall/CRC

STA – SE - 3024

Data Base Management Systems

Total Lectures: 20 Credits: 4 (Theory: 02, Practical/Lab: 02)

28.1 Theory/Practical/Lab

This skill based course is structured to enhance database handling, data manipulation and data processing skills through SQL. The course will enable its beneficiaries develop data centric computer applications.

28.1.1 Unit 1: *Overview of DBMS*: (Lectures: 8)

Introduction: Overview of Database Management System, Introduction to Database Languages, advantages of DBMS over file processing systems.

28.1.2 Unit 2: *RDBMS*: (Lectures: 8)

Relational Database Management System: The Relational Model, Introduction to SQL: Basic Data Types, Working with relations of RDBMS: Creating relations e.g. Bank, College Database (create table statement)

28.1.3 Unit 3: *RDBMS Continued*: (Lectures: 6)

Modifying relations (alter table statement), Integrity constraints over the relation like Primary Key, Foreign key, NOT NULL to the tables, advantages and disadvantages of relational Database System

28.1.4 Unit 4: *Data Base Structure*: (Lectures: 8)

Database Structure: Introduction, Levels of abstraction in DBMS, View of data, Role of Database users and administrators, Database Structure: DDL, DML, Data Manager (Database Control System). Types of Data Models Hierarchical databases, Network databases, Relational databases, Object oriented databases

SUGGESTED READING:

1. Gruber, M. (1990): Understanding SQL, BPB publication
2. Silberschatz, A, Korth, H and Sudarshan, S (2011) "Database System and Concepts", 6th Edition McGraw-Hill.
3. Desai, B. (1991): Introduction to Database Management system, Galgotia Publications.

STA – SE - 4014

Statistical Data Analysis using R

Total Lectures: 20 Credits: 4 (Theory: 02, Practical/Lab: 02)

29.1 Theory/Practical/Lab

This course will review and expand upon core topics in probability and statistics through the study and practice of data analysis and graphical interpretation using 'R'.

29.1.1 Unit 1: *Plotting Graphs*: (Lectures: 8)

Learn how to load data, plot a graph viz. histograms (equal class intervals and unequal class intervals), box plot, stem-leaf, frequency polygon, pie chart, ogives with graphical summaries of data

29.1.2 Unit 2: *Report Generation*: (Lectures: 6)

Generate automated reports giving detailed descriptive statistics, correlation and lines of regression.

29.1.3 Unit 3: *Generation of Random Numbers*: (Lectures: 8)

Random number generation and sampling procedures. Fitting of polynomials and exponential curves. Application Problems based on fitting of suitable distribution, Normal probability plot.

29.1.4 Unit 4: *Statistical Analysis*: (Lectures: 8)

Simple analysis and create and manage statistical analysis projects, import data, code editing, Basics of statistical inference in order to understand hypothesis testing and compute p-values and confidence intervals.

SUGGESTED READING:

1. Gardener, M (2012) Beginning R: The Statistical Programming Language, Wiley Publications.
2. Braun W J, Murdoch D J (2007): A First Course in Statistical Programming with R. Cambridge University Press. New York

STA – SE - 4024

Statistical Techniques for Research Methods

Total Lectures: 20 Credits: 4 (Theory: 02, Practical/Lab: 02)

30.1 Theory/Practical/Lab

Statistical Techniques provide scientific approaches to develop the domain of human knowledge largely through empirical studies. The course aims at enabling students understand basic concepts and aspects related to research, data collection, analyses and interpretation.

30.1.1 Unit 1: *Research problems*: (Lectures: 7)

Introduction: Meaning, objection and motivation in research, types of research, research approach, significance of research. Research problems: definition, selection and necessity of research problems.

30.1.2 Unit 2: *Survey Methodology*: (Lectures: 7)

Survey Methodology and Data Collection, inference and error in surveys, the target populations, sampling frames and coverage error, methods of data collection, non-response, questions and answers in surveys.

30.1.3 Unit 3: *Data Analysis and Interpretation*: (Lectures: 7)

Processing, Data Analysis and Interpretation: Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation.

30.1.4 Unit 4: *Questionnaire Preparation*: (Lectures: 9)

Develop a questionnaire, collect survey data pertaining to a research problem (such as gender discriminations in private v/s government sector, unemployment rates, removal of subsidy, impact on service class v/s unorganized sectors), interpret the results and draw inferences.

SUGGESTED READING:

1. Kothari, C.R. (2009): *Research Methodology: Methods and Techniques*, 2nd Revised Edition reprint, New Age International Publishers.
2. Kumar, R (2011): *Research Methodology: A Step - by - Step Guide for Beginners*, SAGE publications.

Gauhati University
Syllabus for B.Sc.(Honors)
ZOOLOGY
Choice Based Credit System (CBCS)

Course effective from academic year 2019-20

Syllabus for B.Sc.(Honors) Zoology

Choice Based Credit System (CBCS)

Course effective from academic year 2019-20

This is approved in the Academic Council on 08//11/2019



Gauhati University

Guwahati::Assam

Mapping of Subjects 1st Semester

Type	Core	AEC	SEC	DSE	GEN
Credits	14 × 6 = 84	2 × 4 = 8	2 × 4 = 8	4 × 6 = 24	4 × 6 = 24
Honours Sem I	ZOO-HC-1016	ENG-AE-1014			XXX-HG-1XX6
	ZOO-HC-1026				ZOO-HG-1XX6
					XXX-HG-1XX6
					...
					...

Type	Core	AECC	SEC	DSE
Credits	12 × 6 = 72	2 × 4 = 8	4 × 4 = 16	6 × 6 = 36
Regular Sem I	ZOO-RC-1016	ENG-AE-1014		
	YYY-RC-1016			
	ZZZ-RC-1016			

2nd Semester

Type	Core	AEC	SEC	DSE	GEN
Credits	14 × 6 = 84	2 × 4 = 8	2 × 4 = 8	4 × 6 = 24	4 × 6 = 24
Honours Sem II	ZOO-HC-2016	ENV-AE-2014			XXX-HG-2XX6
	ZOO-HC-2026				ZOO-HG-2XX6
					XXX-HG-2XX6
					...
					...

Type	Core	AECC	SEC	DSE
Credits	12 × 6 = 72	2 × 4 = 8	4 × 4 = 16	6 × 6 = 36
Regular Sem II	ZOO-RC-2016	ENV-AE-2014		
	YYY-RC-2016			
	ZZZ-RC-2016			

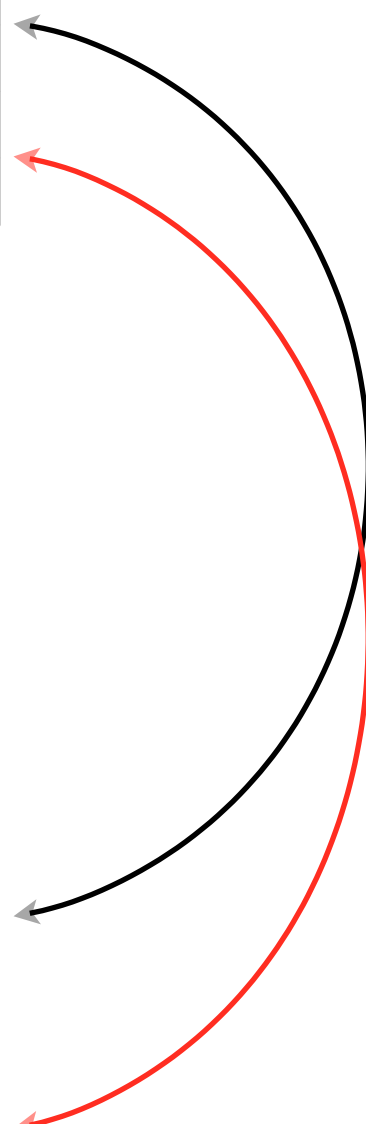
BSc Courses
3rd - 6th Semesters

Honours

Type	Core	AEC	SEC	DSE	GEN
Credits	14 × 6 = 84	2 × 4 = 8	2 × 4 = 8	4 × 6 = 24	4 × 6 = 24
Sem III	ZOO-HC-		ZOO-SE- 3XX4		ZOO-HC- 3XX6
	ZOO-HC-				
	ZOO-HC-				
Sem IV	ZOO-HC-		ZOO-SE- 4XX4		ZOO-HG- 4XX6
	ZOO-HC-				
	ZOO-HC-				
Sem V	ZOO-HC-			ZOO-HE-	
	ZOO-HC-			ZOO-HE-	
Sem VI	ZOO-HC-			ZOO-HE-	
	ZOO-HC-			ZOO-HE-	

Regular

Type	Core	AECC	SEC	DSE
Credits	12 × 6 = 72	2 × 4 = 8	4 × 4 = 16	6 × 6 = 36
Sem III	ZOO-RC-3016		ZOO-SE-3XX4	
	YYY-RC-3016			
	ZZZ-RC-3016			
Sem IV	ZOO-RC-4016		ZOO-SE-4XX4	
	YYY-RC-4016			
	ZZZ-RC-4016			
Sem V			ZOO-SE-5XX4	ZOO-RE-5XX6
				ZOO-RE-5XX6
				ZOO-RE-5XX6
Sem VI			ZOO-SE-6XX4	ZOO-RE-6XX6
				ZOO-RE-6XX6
				ZOO-RE-6XX6



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ZOO-HC-2026: Cell Biology.....	
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ZOO-HE-6056 DISSERTATION-----

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ZOO-SE-3024: APICULTURE
ZOO-SE-4014: Non-Mulberry Sericulture.....
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Preamble

The choice based credit system is naturally the next logical step in a credit based semester system. This makes the system the more learner-centric. A CBCS offers the student a diversity of courses to choose from and the autonomy to decide on the place, pace and the time of learning.

The Gauhati University has decided to introduce the CBCS system at the under graduate level from the session 2019-20. The CBCS syllabus for the B.Sc. (Honours) is prepared in the model of syllabus prepared by theUGC.

A student opting for honors course in ZOOLOGY must have and passed the BIOLOGY as a subject in the Senior Secondary level examination.

Course Structure	
Course	*Credits
	Theory+ Practical
I. Core Course (14 Papers) Core Course Practical / Tutorial* (14 Papers)	14×4= 56 14×2= 28
II. Elective Course (8 Papers) A.1. Discipline Specific Elective (4Papers) A.2. Discipline Specific Elective Practical/Tutorial*(4Papers)	4×4=16 4×2=8
B.1. Generic Elective/ Interdisciplinary (4 Papers) B.2. Generic Elective Practical/ Tutorial* (4 Papers)	4×4=16 4×2=8
III. Ability Enhancement Courses 1. Ability Enhancement Compulsory (2 Papers of 2 credit each) Environmental Studies English/MIL Communication 2. Ability Enhancement Elective(SkillBased) (Minimum2) (2 Papers of 2 credit each)	2×4=8 2×4=8
Total	148

***Core and DSE courses without practicals will have tutorial and have credit distribution of: 5credits for theory and 1credit for tutorial, total6credits,sameasthe papers with practical**

Structure of BSc Honours(ZOOLOGY) Programme

Semester	Type Credits	Core 14 × 6 = 84	AECC 2 × 4 = 8	SEC 2 × 4 = 8	DSE 4 × 6 = 24	GEN 4 × 6 = 24
I	ZOO- HC- 1 016	ENG- AE- 10 14				XXX- HG- 1XX6
	ZOO- HC- 1 026					
II	ZOO- HC- 2 016	ENV- AE- 20 14				XXX- HG- 2XX6
	ZOO- HC- 2 026					
III	ZOO- HC- 3 016			ZOO- SE- 3YY4†		XXX- H G- 3XX6
	ZOO- HC- 3 026					
	ZOO- HC- 3 036					
IV	ZOO- HC- 4 016			ZOO- SE- 4YY4†		XXX- H G- 4XX6
	ZOO- HC- 4 026					
	ZOO- HC- 4 036					
V	ZOO- HC- 5 016				ZOO- HE- 5YY6‡	
	ZOO- HC- 5 026				ZOO- HE- 5YY6‡	
VI	ZOO- HC- 6 016				ZOO- HE- 6YY6‡	
	ZOO- HC- 6 016				ZOO- HE- 6YY6‡	

SCHEME FOR CHOICE BASED CREDIT SYSTEM IN B. Sc.

Honours (ZOOLOGY)

SEMESTER	COURSE CODE	COURSE NAME	Credits
I	ENG-AE-1014	English Communications	4
	ZOO-HC-1016	Non Chordates I: Protista to Pseudocoelomates	4+2=6
		NON Chordates-I Lab	
	ZOO-HC-1026	Principles of Ecology	4+2=6
		Principles of Ecology Lab	
	AAA-HG-1YY6	GE-1	4/5
		Generic Elective 1 Practical/Tutorial	2/1
Total Credits in Semester I			22
II	Ability Enhancement Compulsory Course-II**	Environmental Studies	4
	ZOO-HC-2016	Non Chordates-II: Coelomate	4+2=6
		NON Chordates-II Lab	
	ZOO-HC-2026	Cell Biology	4+2=6
		Cell Biology Lab	
	AAA-HG-2YY6*	GE-2	4/5
		Generic Elective 2 Practical/Tutorial	2/1
Total Credits in Semester II			22
III	ZOO-HC-3016	Diversity of Chordates	4+2=6
		Diversity of Chordates Lab	
	ZOO-HC-3026	Physiology: Controlling and Coordinating Systems	4+2=6
		Physiology Controlling and Coordinating Systems Lab	
	ZOO-HC-3036	Fundamental of Biochemistry	4+2=6
		Fundamental of Biochemistry Lab	
	ZOO-SE-3YY4†	SEC-1	4
	AAA-HG-3YY6*	GE-3	4/5

		Generic Elective Practical/Tutorial 3	2/1
Total Credits in Semester III			28
IV	ZOO-HC-4016	Comparative anatomy of Vertebrate	4+2=6
		Comparative Anatomy of Vertebrate Lab	
	ZOO-HC-4026	Physiology Life Sustaining systems	4+2=6
		Physiology Life Sustaining systems Lab	
	ZOO-HC-4036	Biochemistry of Metabolic process	4+2=6
		Biochemistry of Metabolic Process Lab	
	ZOO-SE-4YY4†	SEC -2	4
	AAA-HG-4YY 6*	GE-4	4/5
		Generic Elective Practical/tutorial	2/1
Total Credits in Semester IV			28
V	ZOO-HC-5016	Molecular Biology	4+2=6
		Molecular Biology Lab	
	ZOO-HC-5026	Principles of Genetics	4+2=6
		Principles of genetics Lab	
	ZOO-HE-5YY6‡	DSE-1	4+2=6
		DSE-1 Lab	
	ZOO-HE-5YY6‡	DSE-2	4+2=6
	DSE-2 Lab		
Total Credits in Semester V			24
VI	ZOO-HC-6016	Developmental Biology	4+2=6
		Developmental Biology Lab	
	ZOO-HC-6026	Evolutionary Biology	4+2=6
		Evolutionary Biology Lab	
	ZOO-HE-6YY6‡	DSE-3	4+2=6
		DSE-3 Lab	
	ZOO-HE-6YY6‡	DSE-4	4+2=6

	DSE-4 Lab	
Total Credits in Semester VI		24
Grand Total Credits		148

***Generic Electives (Other Discipline) - GE 1 to GE 4**

1. Botany (4) + Lab(4)
2. Chemistry (4)+ Lab (4)
3. Anthropology (4)+ Lab (4)
4. Geography (4)+ Lab (4)
5. Geology (4)+ Lab (4)
6. Biotechnology (4)+ Lab (4)
7. Computer Science (4)+Lab (4)
8. STATISTICS (4)+ Lab (2)
9. MATHEMATICS
10. MICROBIOLOGY (4)+ Lab (2)
11. PHYSICS (4)+ Lab (2)

***a)Generic Electives(GE) are to be taken preferably from Botany and Chemistry disciplines.**

b) Students can choose minimum of two GE papers from different disciplines.

‡ Discipline Specific Elective Papers: (Credit: 06 each) (4 papers to be selected)-

DSE for Semester V DSE-1 (Any One from the following)

1. **ZOO-HE-5016:** Computational Biology and Biostatistics (4) + Lab(2) (Compulsory)

DSE-2(Any One from the following)

2. **ZOO-HE-5026:** Animal biotechnology (4) + Lab(2)
3. **ZOO-HE-5036:** Endocrinology (4) + Lab(2)
4. **ZOO-HE-5046:** Parasitology (4) + Lab(2)

DSE for Semester VI

DSE-3(Any One from the following)

5. **ZOO-HE-6016:** Biology of Insect (4) + Lab(2)
6. **ZOO-HE-6026:** FISH and Fisheries (4) + Lab(2)

DSE-4 (Any One from the following)

7. **ZOO-HE-6046:** Reproductive Biology (4) + Lab(2)
8. **ZOO-HE-6056:**Wildlife Conservation and Management (4)+ Lab (2)
9. **ZOO-HE-6066:** Dissertation in any Zoology Specific Subject (6)

†Skill Enhancement Courses (04papers)(Credit:04each)

SEC for Semester III

Any One from the following

1. **ZOO-SE-3014:** Ornamental fish and Fischeies
2. **ZOO-SE-3024:** Apiculture

SEC for Semester IV

Any One from the following

3. **ZOO-SE-4014:** Non Mulberry sericulture
4. **ZOO-SE-4024:** Wildlife Photography and Ecotourism
5. **ZOO-SE-4034:** Research Methodology

****Ability Enhancement Compulsory Courses (02 papers) (Credit: 04 each)**

AECC for Semester I

1. **ENG-AE-1014: English Communications**

AECC for Semester II

2. **ENV-AE-2014: Environmental Science**
-

CORE COURSE I
CODE: ZOO-HC-1016

NON-CHORDATES I: PROTISTS TO PSEUDOCOELOMATES

THEORY	(Credits 4)
Unit 1: Protista, Parazoa and Metazoa	19
General characteristics and Classification upto classes Study of <i>Euglena</i> , <i>Amoeba</i> and <i>Paramecium</i>	
Life cycle and pathogenicity of <i>Plasmodium vivax</i> and <i>Entamoeba histolytica</i>	
Locomotion and Reproduction in Protista	
Evolution of symmetry and segmentation of Metazoa	
Unit 2: Porifera	7
General characteristics and Classification upto classes Canal system and spicules in sponges	
Unit 3: Cnidaria	12
General characteristics and Classification upto classes Metagenesis in <i>Obelia</i>	
Polymorphism in Cnidaria Corals and coral reefs	
Unit 4: Ctenophora	4
General characteristics and Evolutionary significance	
Unit 5: Platyhelminthes	10
General characteristics and Classification up to classes	
Life cycle and pathogenicity of <i>Fasciola hepatica</i> and <i>Taeniasolium</i>	
Unit 6: Nemathelminthes	8
General characteristics and Classification up to classes	
Lifecycle, and pathogenicity of <i>Ascaris lumbricoides</i> and <i>Wuchereri abancrofti</i>	
Parasitic adaptations in helminthes	

Note: Classification to be followed from “Barnes, R.D. (1982). *Invertebrate Zoology*, V Edition”

NON-CHORDATES I: PROTISTS TO PSEUDOCOELOMATES

PRACTICALS

(Credits 2)

1. Study of whole mount of *Euglena*, *Amoeba* and *Paramecium*, Binary fission and Conjugation in *Paramecium*
2. Examination of pond water collected from different places for diversity in protista
3. Study of *Sycon* (T.S. and L.S.), *Hyalonema*, *Euplectella*, *Spongilla*
4. Study of *Obelia*, *Physalia*, *Millepora*, *Aurelia*, *Tubipora*, *Corallium*, *Alcyonium*, *Gorgonia*, *Metridium*, *Pennatulula*, *Fungia*, *Meandrina*, *Madrepora*
5. One specimen/slide of any ctenophore
6. Study of adult *Fasciola hepatica*, *Taenia solium* and their life cycles (Slides/micro- photographs)
7. Study of adult *Ascaris lumbricoides* and its life stages (Slides/micro-photographs)
8. To submit a Project Report on any related topic on life cycles.

Note: Classification to be followed from “Ruppert and Barnes (2006) *Invertebrate Zoology*, 8th edition, Holt Saunders International Edition”

SUGGESTED READINGS

- Ruppert and Barnes, R.D. (2006). *Invertebrate Zoology*, VIII Edition. Holt Saunders International Edition.
- Barnes, R.S.K., Calow, P., Olive, P.J.W., Golding, D.W. and Spicer, J.I. (2002). *The Invertebrates: A New Synthesis*, III Edition, Blackwell Science
- Barrington, E.J.W. (1979). *Invertebrate Structure and Functions*. II Edition, E.L.B.S. and Nelson

CORE COURSE II
CODE: ZOO-HC-1026
PRINCIPLES OF
ECOLOGY

THEORY **(Credits 4)**

Unit 1: Introduction to Ecology **6**

History of ecology, Autecology and synecology, Levels of organization, Laws of limiting factors, Study of physical factors

Unit2:Population **24**

Unitary and Modular populations
Unique and group attributes of population: Density, natality, mortality, life tables, fecundity tables, survivorship curves, age ratio, sex ratio, dispersal and dispersion Exponential and logistic growth, equation and patterns, r and K strategies Population regulation - density-dependent and independent factors

Population interactions, Gause's Principle with laboratory and field examples, Lotka-Volterra equation for competition and Predation, functional and numerical responses

Unit3:Community **12**

Community characteristics: species richness, dominance, diversity, abundance, vertical stratification, Ecotone and edge effect; Ecological succession with one example

Theories pertaining to climax community

Unit4:Ecosystem **14**

Types of ecosystems with one example in detail, Food chain: Detritus and grazing food chains, Linear and Y-shaped food chains, Food web, Energy flow through the ecosystem, Ecological pyramids and Ecological efficiencies

Nutrient and biogeochemical cycle with one example of Nitrogen cycle Human modified ecosystem

Unit 5:Applied Ecology **4**

Ecology in Wildlife Conservation and Management

PRINCIPLES OF ECOLOGY

PRACTICALS

(Credits 2)

1. Study of life tables and plotting of survivorship curves of different types from the hypothetical/real data provided
2. Determination of population density in a natural/hypothetical community by quadrat method and calculation of Shannon-Weiner diversity index for the same community
3. Study of an aquatic ecosystem: Phytoplankton and zooplankton, Measurement of area, temperature, turbidity/penetration of light, determination of pH, and Dissolved Oxygen content (Winkler's method).
4. Report on a visit to National Park/Biodiversity Park/Wild life sanctuary

SUGGESTED READINGS

- Colinvaux, P.A. (1993). Ecology. II Edition. Wiley, John and Sons, Inc.
- Krebs, C. J. (2001). Ecology. VI Edition. Benjamin Cummings.
- Odum, E.P., (2008). Fundamentals of Ecology. Indian Edition. Brooks/Cole
- Robert Leo Smith Ecology and field biology Harper and Row publisher
- Ricklefs, R.E., (2000). Ecology. V Edition. Chiron Press

CORE COURSE III
CODE: ZOO-HC-2016
NON-CHORDATES II: COELOMATES

THEORY	(Credits 4)
Unit 1: Introduction to Coelomates	2
Evolution of coelom and metamerism	
Unit 2: Annelida	10
General characteristics and Classification upto classes Excretion in Annelida	
Unit 3: Arthropoda	17
General characteristics and Classification upto classes Vision and Respiration in Arthropoda Metamorphosis in Insects Social life in bees and termites	
Unit 4: Onychophora	4
General characteristics and Evolutionary significance	
Unit 5: Mollusca	
General characteristics and Classification upto classes Respiration in Mollusca Torsion and detorsion in Gastropoda Pearl formation in bivalves Evolutionary significance of trochophore larva	
Unit 6: Echinodermata	12
General characteristics and Classification upto classes Water-vascular system in Asteroidea Larval forms in Echinodermata Affinities with Chordates	

Note: Classification to be followed from “Ruppert and Barnes (2006)
Invertebrate Zoology, 8th edition, Holt Saunders International Edition”

NON-CHORDATES II: COELOMATES

PRACTICAL

(Credits 2)

1. Study of following specimens:
Annelids - *Aphrodite*, *Nereis*, *Heteronereis*, *Sabella*, *Serpula*, *Chaetopterus*, *Pheretima*, *Hirudinaria*
Arthropods - *Limulus*, *Palaemon*, *Daphnia*, *Balanus*, *Sacculina*, *Cancer*, *Eupagurus*, *Scolopendra*, *Julus*, *Bombyx*, *Periplaneta*, termites and honey bees
Onychophora - *Peripatus*
Molluscs - *Chiton*, *Dentalium*, *Pila*, *Doris*, *Helix*, *Unio*, *Ostrea*, *Pinctada*, *Sepia*, *Octopus*, *Nautilus*
Echinodermates - *Pentaceros*/*Asterias*, *Ophiura*, *Clypeaster*, *Echinus*, *Cucumaria* and *Antedon*
2. Study of digestive system, septal nephridia and pharyngeal nephridia of earthworm
3. T.S. through pharynx, gizzard, and typhlosolar intestine of earthworm
4. Mount of mouth parts and dissection of digestive system and nervous system of *Periplaneta**
5. To submit a Project Report on any related topic to larval forms (crustacean, mollusc and echinoderm)

Note: Classification to be followed from “Ruppert and Barnes (2006) *Invertebrate Zoology*, 8th edition, Holt Saunders International Edition”

SUGGESTED READINGS

- Ruppert and Barnes, R.D. (2006). *Invertebrate Zoology*, VIII Edition. Holt Saunders International Edition
- Barnes, R.S.K., Calow, P., Olive, P.J.W., Golding, D.W. and Spicer, J.I. (2002). *The Invertebrates: A New Synthesis*, III Edition, Blackwell Science
- Barrington, E.J.W. (1979). *Invertebrate Structure and Functions*. II Edition, E.L.B.S. and Nelson

CORE COURSE IV
CODE: ZOO-HC-2026
CELL BIOLOGY

THEORY	(Credits4)
Unit 1: Over view of Cells	3
Prokaryotic and Eukaryotic cells, Virus, Viroids, Mycoplasma, Prions	
Unit 2:Plasma Membrane	7
Various models of plasma membrane structure Transportacrossmembranes:ActiveandPassivetransport,Facilitatedtransport Cell junctions: Tight junctions, Desmosomes, Gapjunctions	
Unit 3:Endomembrane System	10
Structure and Functions: Endoplasmic Reticulum, Golgi Apparatus, Lysosomes	
Unit 4: Mitochondria and Peroxisomes	8
Mitochondria:Structure,Semi-autonomousnature,Endosymbiotichypothesis Mitochondrial Respiratory Chain, Chemi-osmotichypothesis Peroxisomes	
Unit5:Cytoskeleton	8
Structure and Functions: Microtubules, Microfilaments and Intermediate filaments	
Unit6:Nucleus	12
Structure of Nucleus: Nuclearenvelope, Nuclear pore complex, Nucleolus Chromatin: Euchromatin and Hetrochromatin and packaging(nucleosome)	
Unit 7:Cell Division	8
Mitosis, Meiosis, Cell cycle and its regulation	
Unit 8:Cell Signaling	4
GPCR and Role of second messenger (cAMP)	

CELL BIOLOGY

PRACTICAL

(Credits 2)

1. Preparation of temporary stained squash of onion root tip to study various stages of mitosis
2. Study of various stages of meiosis.
3. Preparation of permanent slide to show the presence of Barrbody in human female blood cells/cheek cells.
4. Preparation of permanent slide to demonstrate:
 - i DNA by Feulgen reaction
 - ii Mucopolysaccharides by PAS reaction
 - iii Proteins by Mercurio bromophenol blue/FastGreen

SUGGESTED READINGS

- Karp, G. (2010). *Cell and Molecular Biology: Concepts and Experiments*. VI Edition. John Wiley and Sons.Inc.
- De Robertis, E.D.P. and De Robertis, E.M.F. (2006). *Cell and Molecular Biology*. VIII Edition. Lippincott Williams and Wilkins,Philadelphia.
- Cooper, G.M. and Hausman, R.E. (2009). *The Cell: A Molecular Approach*. V Edition. ASM Press and Sunderland, Washington, D.C.; Sinauer Associates, MA.
- Becker, W.M., Kleinsmith, L.J., Hardin. J. and Bertoni, G. P. (2009). *The World of the Cell*. VII Edition. Pearson Benjamin Cummings Publishing, San Francisco.
- Bruce Albert, Bray Dennis, Levis Julian, Raff Martin, Roberts Keith and Watson James (2008). *Molecular Biology of the Cell*, V Edition, Garland publishing Inc., New York and London.

CORE COURSE V

DIVERSITY OF

CHORDATA

CODE: ZOO-HC-3016

THEORY	(Credits 4)
Unit 1: Introduction to Chordates	2
General characteristics and outline classification	
Unit2:Protochordata	8
General characteristics of Hemichordata, Urochordata and Cephalochordata; Study of larval forms in protochordates; Retrogressive metamorphosis in Urochordata	
Unit 3: Origin of Chordata	3
Dipleurula concept and the Echinoderm theory of origin of chordates Advanced features of vertebrates over Protochordata	
Unit4:Agnatha	2
General characteristics and classification of cyclostomes up to class	
Unit5:Pisces	8
General characteristics of Chondrichthyes and Osteichthyes, classification up to order Migration, Osmoregulation and Parental care in fishes	
Unit6:Amphibia	6
Origin of <i>Tetrapoda</i> (Evolution of terrestrial ectotherms); General characteristics and classification up to order; Parental care in Amphibians	
Unit7:Reptilia	7
General characteristics and classification up to order; Affinities of <i>Sphenodon</i> ; Poison apparatus and Biting mechanism in snakes	
Unit8:Aves	8
General characteristics and classification up to order <i>Archaeopteryx</i> -- a connecting link; Principles and aerodynamics of flight, Flight adaptations and Migration in birds	
Unit9:Mammals	8
General characters and classification up to order; Affinities of Prototheria; Adaptive radiation with reference to locomotory appendages	

Unit10:Zoogeography

8

Zoo geographical realms, Theories pertaining to distribution of animals, Plate tectonic and Continental drift theory, distribution of vertebrates in different realms

DIVERSITY OF CHORDATA

PRACTICAL

(Credits 2)

1. Protochordata

Balanoglossus, *Herdmania*, *Branchiostoma*, Colonial Urochordata
Sections of *Balanoglossus* through proboscis and branchio genital regions, Sections of *Amphioxus* through pharyngeal, intestinal and caudal regions. Permanent slide of *Herdmania* spicules

2. Agnatha

Petromyzon, *Myxine*

3. Fishes

Scoliodon, *Sphyrna*, *Pristis*, *Torpedo*, *Chimaera*, *Mystus*,
Heteropneustes, *Labeo*, *Exocoetus*, *Echeneis*, *Anguilla*, *Hippocampus*,
Tetrodon/Diodon, *Anabas*, Flat fish

4. Amphibia

Ichthyophis/Ureotyphlus, *Necturus*, *Bufo*, *Hyla*, *Alytes*, *Salamandra*

5. Reptilia

Chelone, *Trionyx*, *Hemidactylus*, *Varanus*,
Uromastix, *Chamaeleon*, *Ophiosaurus*, *Draco*,
Bungarus, *Vipera*, *Naja*, *Hydrophis*, *Zamenis*, *Crocodylus* Key for
Identification of poisonous and non-poisonous snakes

6. Aves

Study of six common birds from different orders. Types of beaks and claws

7. Mammalia

Sorex, Bat (Insectivorous and Frugivorous), *Funambulus*, *Loris*,
Herpestes, *Erinaceous*.

Mount of weberian ossicles of fish

Power point presentation on study of any two animals from two different classes by students (may be included if dissections not given permission)

Classification from Young, J. Z. (2004) to be followed

SUGGESTED READINGS

18

- Young, J. Z. (2004). *The Life of Vertebrates*. III Edition. Oxford university press.
- Pough H. *Vertebrate life*, VIII Edition, Pearson International.

- Darlington P.J. *The Geographical Distribution of Animals*, R.E. Krieger Pub Co.
- Hall B.K. and Hallgrímsson B. (2008). *Strickberger's Evolution*.
IV Edition. Jones and Bartlett Publishers Inc.

CORE COURSE VI
ANIMAL PHYSIOLOGY: CONTROLLING AND COORDINATING
SYSTEMS
CODE: ZOO-HC-3026

THEORY	(Credits 4)
Unit 1: Tissues	6
Structure, location, classification and functions of epithelial tissue, connective tissue, muscular tissue and nervous tissue	
Unit 2: Bone and Cartilage	4
Structure and types of bones and cartilages, Ossification, bone growth and resorption	
Unit 3: Nervous System	10
Structure of neuron, resting membrane potential, Origin of action potential and its propagation across the myelinated and unmyelinated nerve fibers; Types of synapse, Synaptic transmission and, Neuromuscular junction; Reflex action and its types - reflex arc; Physiology of hearing and vision.	
Unit 4: Muscle	12
Histology of different types of muscle; Ultra structure of skeletal muscle; Molecular and chemical basis of muscle contraction; Characteristics of muscle twitch; Motor unit, summation and tetanus	
Unit 5: Reproductive System	10
Histology of testis and ovary; Physiology of male and female reproduction; Puberty, Methods of contraception in male and female	
Unit 6: Endocrine System	18
Histology of endocrine glands - pineal, pituitary, thyroid, parathyroid, pancreas, adrenal; hormones secreted by them and their mechanism of action; Classification of hormones; Regulation of their secretion; Mode of hormone action, Signal transduction pathways for steroid and non-steroidal hormones; Hypothalamus (neuroendocrine gland)- principal nuclei involved in neuro endocrine control of anterior pituitary and endocrines system; Placental hormones	

ANIMAL PHYSIOLOGY: CONTROLLING AND COORDINATING SYSTEMS

PRACTICALS

(Credits 2)

- *1. Demonstration of the unconditioned reflex action (Deep tendon reflex such as knee jerk reflex)
2. Preparation of temporary mounts: Squamous epithelium, Striated muscle fibres and nerve cells
3. Study of permanent slides of Mammalian skin, Cartilage, Bone, Spinal cord, Nerve cell, Pituitary, Pancreas, Testis, Ovary, Adrenal, Thyroid and Parathyroid
4. Microtomy: Preparation of permanent slide of any five mammalian (Goat/ rat/ mice) tissues

(*Subject to UGC guidelines)

SUGGESTED BOOKS

- Guyton, A.C. & Hall, J.E. (2006). Textbook of Medical Physiology. XI Edition. Harcourt Asia PTE Ltd. /W.B. Saunders Company.
- Tortora, G.J. & Grabowski, S. (2006). Principles of Anatomy & Physiology. XI Edition John Wiley & sons
- Victor P. Eroschenko. (2008). diFiore's Atlas of Histology with Functional correlations. XII Edition. Lippincott W. & Wilkins.

CORE COURSE VII
FUNDAMENTALS OF BIOCHEMISTRY

CODE: ZOO-HC-3036

THEORY	(CREDITS 4)
Unit1:Carbohydrates	8
Structure and Biological importance: Monosaccharides, Disaccharides, Polysaccharides and Glycoconjugates	
Unit2:Lipids	8
Structure and Significance: Physiologically important saturated and unsaturated fatty acids, Tri-acylglycerols, Phospholipids, Glycolipids, Steroids	
Unit3:Proteins	14
Amino acids: Structure, Classification and General properties of α -amino acids; Physiological importance of essential and non-essential α -amino acids	
Proteins: Bonds stabilizing protein structure; Levels of organization in proteins; Denaturation; Introduction to simple and conjugate proteins	
Immunoglobulins: Basic Structure, Classes and Function, Antigenic Determinants	
Unit 4:NucleicAcids	12
Structure:Purines and pyrimidines,Nucleosides,Nucleotides,Nucleicacids CotCurves: Base pairing, Denaturation and Renaturation of DNA Types of DNA and RNA, Complementarity of DNA, Hpyo- Hyperchromaticity of DNA	
Unit5:Enzymes	18
Nomenclature and classification; Cofactors; Specificity of enzyme action; Isozymes; Mechanism of enzyme action; Enzyme kinetics; Factors affecting rate of enzyme-catalyzed reactions; Derivation of Michaelis-Menten equation, Concept of K_m and V_{max} , Lineweaver-Burk plot; Multi-substrate reactions; Enzyme inhibition; Allosteric enzymes and their kinetics; Regulation of enzyme action	

FUNDAMENTALS OF BIOCHEMISTRY

PRACTICAL

(CREDITS2)

1. Qualitative tests of functional groups in carbohydrates, proteins and lipids.
2. Paper chromatography of amino acids.
3. Action of salivary amylase under optimum conditions.
4. Effect of pH, temperature on the action of salivary amylase.
5. Demonstration of proteins separation by SDS-PAGE.

SUGGESTED READING

- Cox, M.M and Nelson, D.L. (2008). *Lehninger's Principles of Biochemistry*, V Edition, W.H. Freeman and Co., New York.
- Berg, J.M., Tymoczko, J.L. and Stryer, L. (2007). *Biochemistry*, VI Edition, W.H. Freeman and Co., New York.
- Murray, R.K., Bender, D.A., Botham, K.M., Kennelly, P.J., Rodwell, V.W. and Well, P.A. (2009). *Harper's Illustrated Biochemistry*, XXVIII Edition, International Edition, The McGraw-Hill Companies Inc.
- Hames, B.D. and Hooper, N.M. (2000). *Instant Notes in Biochemistry*, II Edition, BIOS Scientific Publishers Ltd., U.K.
- Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M. and Losick, R. (2008). *Molecular Biology of the Gene*, VI Edition, Cold Spring Harbor Lab. Press, Pearson Pub.

**CORE COURSE VIII COMPARATIVE
ANATOMY OF VERTEBRATES**

CODE: ZOO-HC-4016

THEORY	(CREDITS 4)
Unit 1: Integumentary System	8
Structure, functions and derivatives of integument	
Unit 2: Skeletal System	8
Overview of axial and appendicular skeleton, Jaw suspensorium, Visceral arches	
Unit 3: Digestive System	8
Alimentary canal and associated glands, dentition	
Unit 4: Respiratory System	8
Skin, gills, lungs and air sacs; Accessory respiratory organs	
Unit 5: Circulatory System	8
General plan of circulation, evolution of heart and aortic arches	
Unit 6: Urinogenital System	6
Succession of kidney, Evolution of urinogenital ducts, Types of mammalian uteri	
Unit 7: Nervous System	8
Comparative account of brain Autonomic nervous system, Spinal cord, Cranial nerves in mammals	
Unit 8: Sense Organs	6
Classification of receptors Brief account of visual and auditory receptors in man	

COMPARATIVE ANATOMY OF VERTEBRATES

PRACTICAL

(CREDITS 2)

1. Study of placoid, cycloid and ctenoid scales through permanent slides/photographs
2. Disarticulated skeleton of Frog, Fowl, Rabbit
3. Carapace and plastron of turtle/tortoise
4. Mammalian skulls: One herbivorous and one carnivorous animal
5. Study of structure of any two organs (heart, lung, kidney, eye and ear) from video recording (may be included if dissection not permitted)
6. Project on skeletal modifications in vertebrates (may be included if dissection not permitted)

SUGGESTED READINGS

- Kardong, K.V. (2005) *Vertebrates' Comparative Anatomy, Function and Evolution*. IV Edition. McGraw-Hill Higher Education
- Kent, G.C. and Carr R.K. (2000). *Comparative Anatomy of the Vertebrates*. IX Edition. The McGraw-Hill Companies
- Hilderbrand, M and Gaslow G.E. *Analysis of Vertebrate Structure*, John Wiley and Sons
- Walter, H.E. and Sayles, L.P.; *Biology of Vertebrates*, Khosla Publishing House

CORE COURSE IX
ANIMAL PHYSIOLOGY: LIFE SUSTAINING SYSTEMS
CODE: ZOO-HC-4026

THEORY

(Credits 4)

Unit 1: Physiology of Digestion

14

Structural organization and functions of gastrointestinal tract and associated glands; Mechanical and chemical digestion of food; Absorptions of carbohydrates, lipids, proteins, water, minerals and vitamins; Hormonal control of secretion of enzymes in Gastrointestinal tract.

Unit 2: Physiology of Respiration

12

Histology of trachea and lung; Mechanism of respiration, Pulmonary ventilation; Respiratory volumes and capacities; Transport of oxygen and carbon dioxide in blood; Respiratory pigments, Dissociation curves and the factors influencing it; Carbon monoxide poisoning; Control of respiration

Unit 3: Renal Physiology

8

Structure of kidney and its functional unit; Mechanism of urine formation; Regulation of water balance; Regulation of acid-base balance

Unit 4: Blood

14

Components of blood and their functions; Structure and functions of haemoglobin

Haemostasis: Blood clotting system,
Kallikrein-Kininogen system, Complement system & Fibrinolytic system, Haemopoiesis
Blood groups: Rh factor, ABO and MN

Unit 5: Physiology of Heart

12

Structure of mammalian heart; Coronary circulation; Structure and working of conducting myocardial fibers. Origin and conduction of cardiac impulses Cardiac cycle; Cardiac output and its regulation, Frank-Starling Law of the heart, nervous and chemical regulation of heart rate. Electrocardiogram, Blood pressure and its regulation

ANIMAL PHYSIOLOGY: LIFE SUSTAINING SYSTEMS

PRACTICALS

(CREDITS 2)

1. Determination of ABO Blood group
2. Enumeration of red blood cells and white blood cells using haemocytometer
3. Estimation of haemoglobin using Sahli's haemoglobinometer
4. Preparation of haemin crystals
5. Recording of blood pressure using a sphygmomanometer
6. Examination of sections of mammalian oesophagus, stomach, duodenum, ileum, rectum, liver, trachea, lung, kidney

(*Subject to UGC guidelines)

SUGGESTED READINGS

- Guyton, A.C. & Hall, J.E. (2006). Textbook of Medical Physiology. X Edition. Harcourt Asia PTE Ltd. W.B. Saunders Company.
- Tortora, G.J. & Grabowski, S. (2006). Principles of Anatomy & Physiology. XI Edition John Wiley & sons,
- Victor P. Eroschenko. (2008). diFiore's Atlas of Histology with Functional correlations. XII Edition. Lippincott W. & Wilkins.
- Vander A, Sherman J. and Luciano D. (2014). Vander's Human Physiology: The Mechanism of Body Function. XIII Edition, McGrawHills

**CORE COURSE X BIOCHEMISTRY OF
METABOLIC PROCESSES**

CODE: ZOO-HC-4036

THEORY	(CREDITS 4)
Unit 1: Overview of Metabolism	10
Catabolism vs Anabolism, Stages of catabolism, Compartmentalization of metabolic pathways, Shuttle systems and membrane transporters; ATP as "Energy Currency of cell"; coupled reactions; Use of reducing equivalents and cofactors; Intermediary metabolism and regulatory mechanisms	
Unit 2: Carbohydrate Metabolism	16
Sequence of reactions and regulation of glycolysis, Citric acid cycle, Phosphate pentose pathway, Gluconeogenesis, Glycogenolysis and Glycogenesis	
Unit 3: Lipid Metabolism	14
β -oxidation and omega-oxidation of saturated fatty acids with even and odd number of carbon atoms; Biosynthesis of palmitic acid; Ketogenesis	
Unit 4: Protein Metabolism	10
Catabolism of amino acids: Transamination, Deamination, Urea cycle; Fate of C-skeleton of Glucogenic and Ketogenic amino acids	
Unit 5: Oxidative Phosphorylation	10
Redox systems; Review of mitochondrial respiratory chain, Inhibitors and un-couplers of Electron Transport System	

BIOCHEMISTRY OF METABOLIC PROCESS

PRACTICALS

(CREDITS 2)

1. Estimation of total protein in given solutions by Lowry's method.
2. Detection of SGOT and SGPT in serum/tissue
3. To study the enzymatic activity of Trypsin and Lipase.
4. Study of biological oxidation (SDH) [goat liver]
5. To perform the Acid and Alkaline phosphatase assay from serum/tissue.

SUGGESTED READINGS

- Cox, M.M and Nelson, D.L. (2008). *Lehninger Principles of Biochemistry*, V Edition, W.H. Freeman and Co., New York.
- Berg, J.M., Tymoczko, J.L. and Stryer, L. (2007). *Biochemistry*, VI Edition, W.H. Freeman and Co., New York.
- Murray, R.K., Bender, D.A., Botham, K.M., Kennelly, P.J., Rodwell, V.W. and Well, P.A. (2009). *Harper's Illustrated Biochemistry*, XXVIII Edition, International Edition, The McGraw-Hill Companies Inc.
- Hames, B.D. and Hooper, N.M. (2000). *Instant Notes in Biochemistry*, II Edition, BIOS Scientific Publishers Ltd., U.K.

CORE COURSE XI

MOLECULAR

BIOLOGY

CODE: ZOO-HC-5016

THEORY

(CREDITS 4)

Unit 1:NucleicAcids

4

Salient features of DNA and RNA Watson and Crick model of DNA

Unit 2:DNAReplication

12

DNA Replication in prokaryotes and eukaryotes, mechanism of DNA replication, Semi-conservative, bidirectional and semi-discontinuous replication, RNA priming, Replication of circular and linear *ds*-DNA, replication of telomeres

Unit3:Transcription

10

RNA polymerase and transcription Unit, mechanism of transcription in prokaryotes and eukaryotes, synthesis of rRNA and mRNA, transcription factors

Unit4:Translation

12

Geneticcode, DegeneracyofthegeneticcodeandWobbleHypothesis; Process of protein synthesis in prokaryotes: Ribosome structure and assembly in prokaryotes, fidelity of protein synthesis, aminoacyl tRNA synthetases and charging of tRNA; Proteins involved in initiation, elongation and termination of polypeptidechain; Inhibitors of proteinsynthesis; Differencebetweenprokaryotic and eukaryotic translation

Unit 5: Post Transcriptional Modifications and Processing of Eukaryotic RNA

6

Structure of globin mRNA; Split genes: concept of introns and exons, splicing mechanism, alternative splicing, exon shuffling, and RNA editing, Processing of tRNA

Unit 6:GeneRegulation

10

Transcription regulation in prokaryotes: Principles of transcriptional regulation with examples from *lac* operon and *trp* operon; Transcription regulation in eukaryotes: enhance silencer elements; Activators, repressors, rs, elements; Gene silencing, Genetic imprinting

Unit 7: DNA Repair Mechanisms

3

Pyrimidine dimerization and mismatch repair

Unit 8: Regulatory RNAs

3

Ribo-switches, RNA interference, miRNA,
siRNA

MOLECULAR BIOLOGY

PRACTICAL

(CREDITS 2)

1. Study of Polytene chromosomes from Chironomous / Drosophilalarvae
2. Preparation of liquid culture medium(LB)andraisecultureof*E.coli*
3. Estimation of the growth kinetics of *E. coli* by turbidity method
4. Quantitative estimation DNA using colorimeter (Diphenylamine reagent)
5. Quantitative estimation of RNA using Orcinolreaction
6. Study and interpretation of electron micrographs/ photographshowing
 - (a) DNA replication
 - (b) Transcription
 - (c) Splitgenes

SUGGESTED READINGS

- Becker, W.M., Kleinsmith, L.J., Hardin, J. and Bertoni, G.P. (2009). *The World of the Cell*. VII Edition. Pearson Benjamin Cummings Publishing, San Francisco.
- Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter: *Molecular Biology of the Cell*, IV Edition.
- Cooper G.M. and Robert E. Hausman R.E. *The Cell: A Molecular Approach*, V Edition, ASM Press and Sinauer Associates.
- De Robertis, E.D.P. and De Robertis, E.M.F. (2006). *Cell and Molecular Biology*. VIII Edition. Lippincott Williams and Wilkins, Philadelphia.
- Karp, G. (2010) *Cell and Molecular Biology: Concepts and Experiments*. VI Edition. John Wiley and Sons. Inc.
- Lewin B. (2008). *Gene XI*, Jones and Bartlett
- McLennan A., Bates A., Turner, P. and White M. (2015). *Molecular Biology* IV Edition. GS, Taylor and Francis Group, New York and London.

CORE COURSE XII
PRINCIPLES OF
GENETICS

CODE: ZOO-HC-5026

THEORY	(CREDITS 4)
Unit 1: Mendelian Genetics and its Extension	8
Principles of inheritance, Incomplete dominance and co-dominance, Multiple alleles, Lethal alleles, Epistasis, Pleiotropy, Sex-linked, sex- influenced and sex-limited characters inheritance.	
Unit 2: Linkage, Crossing Over and Chromosomal Mapping	12
Linkage and crossing over, Cytological basis of crossing over, Molecular mechanisms of crossing over including models of recombination, Recombination frequency as a measure of linkage intensity, Two factor and three factor crosses, Interference and coincidence, Somatic cell hybridization.	
Unit3:Mutations	10
Typesofgenemutations(Classification),Typesofchromosomalaberrations (Classification, figures and with one suitable example of each), Molecular basisofmutationsinrelationtoUVlightandchemicalmutagens;Detection of mutations: CLB method, attached X method.	
Unit 4:SexDetermination	4
Chromosomal mechanisms of sex determination in Drosophila and Man	
Unit 5:Extra-chromosomalInheritance	6
Criteria for extra-chromosomal inheritance, Antibiotic resistance in <i>Chlamydomonas</i> , Mitochondrial mutations in <i>Saccharomyces</i> , Infective heredity in <i>Paramecium</i> and Maternal effects	
Unit 6:PolygenicInheritance	3
Polygenic inheritance with suitable examples; simple numericals based on it.	
Unit 7: Recombination in BacteriaandViruses	9
Conjugation, Transformation, Transduction, Complementation test in Bacteriophage	
Unit 8: TransposableGeneticElements	8
Transposons in bacteria, Ac-Ds elements ³³ in maize and P elements in <i>Drosophila</i> , Transposons in humans	

PRINCIPLES OF GENETICS

PRACTICALS

(CREDITS 2)

1. To study the Mendelian laws and gene interactions.
2. Chi-square analyses using seeds/beads/*Drosophila*.
3. Linkage maps based on data from conjugation ,transformation and transduction.
4. Linkage maps based on data from *Drosophila* crosses.
5. Study of human karyotype (normal and abnormal).
6. Pedigree analysis of some human inherited traits.

SUGGESTED READINGS

- Gardner, E.J., Simmons, M.J., Snustad, D.P. (2008). *Principles of Genetics*. VIII Edition. WileyIndia
- Snustad, D.P., Simmons, M.J. (2009). *Principles of Genetics*. V Edition. John Wiley and SonsInc
- Klug, W.S., Cummings, M.R., Spencer, C.A. (2012). *Concepts of Genetics*. X Edition. BenjaminCummings
- Russell, P. J. (2009). *Genetics- A Molecular Approach*.III Edition. BenjaminCummings
- Griffiths, A.J.F., Wessler, S.R., Lewontin, R.C. and Carroll,S.B. *Introduction to Genetic Analysis*.IX Edition. W. H. Freeman and Co
- Fletcher H. and Hickey I. (2015). *Genetics*. IV Edition. GS, Taylor and Francis Group, New York andLondon.

**CORE COURSE XIII
DEVELOPMENTAL
BIOLOGY**

CODE: ZOO-HC-6016

THEORY

(CREDITS 4)

Unit1:Introduction

4

Historical perspective and basic concepts: Phases of development, Cell-Cell interaction, Pattern formation, Differentiation and growth, Differential gene expression, Cytoplasmic determinants and asymmetric cell division

Unit 2: Early Embryonic Development

28

Gametogenesis, Spermatogenesis, Oogenesis; Types of eggs, Egg membranes; Fertilization (External and Internal): Changes in gametes, Blocks to polyspermy; Planes and patterns of cleavage; Types of Blastula; Fate maps (including Techniques); Early development of frog and chick up to gastrulation; Embryonic induction and organizers

Unit 3: Late Embryonic Development

8

Fate of Germ Layers; Extra-embryonic membranes in birds; Implantation of embryo in humans, Placenta (Structure, types and functions of placenta)

Unit 4: PostEmbryonicDevelopment

12

Metamorphosis: Changes, hormonal regulations in amphibians and insects; Regeneration: Modes of regeneration, epimorphosis, morphallaxis and compensatory regeneration (with one example each); Ageing: Concepts and Theories

Unit 5: Implications ofDevelopmentalBiology

8

Teratogenesis: Teratogenic agents and their effects on embryonic development; *In vitro* fertilization, Stem cell (ESC), Amniocentesis

DEVELOPMENTAL BIOLOGY

PRACTICALS

(CREDITS 2)

1. Study of whole mounts and sections of developmental stages of frog through permanent slides: Cleavage stages, blastula, gastrula, neurula, tail-bud stage, tadpole (external and internal gillstages)
2. Study of whole mounts of developmental stages of chick through permanent slides: Primitive streak (13 and 18 hours), 21, 24, 28, 33, 36, 48, 72, and 96 hours of incubation (Hamilton and Hamburgerstages)
3. Study of the developmental stages and life cycle of *Drosophila* from stock culture
4. Study of different sections of placenta (photomicrograph/slides)
5. Project report on *Drosophila* culture/chick embryodevelopment

SUGGESTED READINGS

- Gilbert, S. F. (2010). Developmental Biology, IX Edition, Sinauer Associates, Inc., Publishers, Sunderland, Massachusetts, USA
- Balinsky B. I. and Fabian B. C. (1981). An Introduction to Embryology, V Edition, International Thompson Computer Press
- Carlson, R. F. Patten's Foundations of Embryology
- Kalthoff (2008). Analysis of Biological Development, II Edition, McGraw-Hill Publishers
- Lewis Wolpert (2002). Principles of Development, II Edition, Oxford University Press

CORE COURSE XIV

EVOLUTIONARY

BIOLOGY

CODE: ZOO-HC-6026

THEORY	(CREDITS 4)
Unit1: Life's Beginnings: Chemogeny, RNA world, Biogeny, Origin of photosynthesis, Evolution of eukaryotes	7
Unit2: Historical review of evolutionary concept: Lamarckism, Darwinism, Neo-Darwinism	4
Unit3: Evidences of Evolution: Fossil record (types of fossils, transitional forms, geological time scale, evolution of horse, Molecular (universality of genetic code and protein synthesising machinery, three domains of life, neutral theory of molecular evolution, molecular clock ,example of globin gene family, rRNA/cyt c	10
Unit4: Sources of variations: Heritable variations and their role in evolution	8
Unit5: Population genetics: Hardy-Weinberg Law (statement and derivation of equation, application of law to human Population); Evolutionary forces upsetting H-W equilibrium; Natural selection (concept of fitness, selection coefficient, derivation of one unit of selection for a dominant allele, genetic load, mechanism of working, types of selection, density-dependent selection, heterozygous superiority, kin selection, adaptive resemblances, sexual selection. Genetic Drift (mechanism, founder's effect, bottleneck phenomenon; Role of Migration and Mutation in changing allele frequencies	13
Unit6: Product of evolution: Micro evolutionary changes (inter-population variations, clines, races, Species concept, Isolating mechanisms, modes of speciation—allopatric, sympatric, Adaptive radiation / macroevolution (exemplified by Galapagos finches	7
Unit7: Extinctions, Background and mass extinctions (causes and effects), detailed example of K-T extinction	2
Unit8: Origin and evolution of man, Unique hominin characteristics contrasted with primate characteristics, primate phylogeny from <i>Dryopithecus</i> leading to <i>Homo</i>	6

sapiens, molecular analysis of human origin

Unit9:

Phylogenetic trees, Multiple sequence alignment, construction of phylogenetic trees, interpretation of trees

2

EVOLUTIONARY BIOLOGY

PRACTICALS

(CREDITS2)

1. Study of fossils from models/pictures
2. Study of homology and analogy from suitable specimens
3. Study and verification of Hardy-Weinberg Law by chi square analysis
4. Graphical representation and interpretation of data of height/weight of a sample of 100 humans in relation to their age and sex.
5. Construction of phylogenetic trees with the help of bioinformatics tools (Clustal X, Phylip, NJ) and its interpretation.

SUGGESTED READINGS

- Ridley, M (2004) Evolution III Edition Blackwell publishing
- Hall, B.K. and Hallgrimson, B (2008). Evolution IV Edition. Jones and Barlett Publishers.
- Campbell, N.A. and Reece J.B (2011). Biology. IX Edition. Pearson, Benjamin, Cummings.
- Douglas, J. Futuyma (1997). Evolutionary Biology. Sinauer Associates.
- Snustad. S Principles of Genetics.
- Pevsner, J (2009). Bioinformatics and Functional Genomics. II Edition Wiley- Blackwell

DISCIPLINE CENTRIC ELECTIVE COURSES
CODE: ZOO-HE-5016
COMPUTATIONAL BIOLOGY and BIOSTATICS

THEORY **(Credits 4)**

Unit 1: Introduction to Bioinformatics **5**

Importance, Goal, Scope; Genomics, Transcriptomics, Systems Biology, Functional Genomics, Metabolomics, Molecular Phylogeny; Applications and Limitations of Bioinformatics

Unit 2: Biological Databases **10**

Introduction to biological databases; Primary, secondary and composite databases; Nucleic acid databases (GenBank, DDBJ, EMBL and NDB); Protein databases (PIR, SWISS-PROT, TrEMBL, PDB); Metabolic pathway database (KEGG, EcoCyc, and MetaCyc); Small molecule databases (PubChem, Drug Bank, ZINC, CSD)

Unit 3: Data Generation and Data Retrieval **14**

Generation of data (Gene sequencing, Protein sequencing, Mass spectrometry, Microarray), Sequence submission tools (BankIt, Sequin, Webin); Sequence file format (flat file, FASTA, GCG, EMBL, Clustal, Phylip, Swiss-Prot); Sequence annotation; Data retrieval systems (SRS, Entrez)

Unit 3: Basic Concepts of Sequence Alignment **14**

Scoring Matrices (PAM, BLOSUM), Methods of Alignment (Dot matrix, Dynamic Programming, BLAST and FASTA); Local and global alignment, pair wise and multiple sequence alignments; Similarity, identity and homology of sequences.

Unit 4: Applications of Bioinformatics **7**

Structural Bioinformatics (3-D protein, PDB), Functional genomics (genome-wide and high throughput approaches to gene and protein function), Drug discovery method (Basic concepts)

Unit 5: Biostatistics **10**

Introduction, calculation of standard deviation, standard error, Coefficient of Variance, Chi-square test, Z test, t-Test

COMPUTATIONAL BIOLOGY

PRACTICAL

(Credits 2)

1. Accessing biological databases
2. Retrieval of nucleotide and protein sequences from the databases.
3. To perform pair-wise alignment of sequences (BLAST) and interpret the output
4. Predict the structure of protein from its amino acid sequence.
5. To perform a “two-sample t- test” for a given set of data
6. To learn graphical representations of statistical data with the help of computers (e.g. MS Excel).

SUGGESTED READINGS

- Ghosh Z and Mallick B. (2008). *Bioinformatics: Principles and Applications*, Oxford University Press.
- Pevsner J. (2009). *Bioinformatics and Functional Genomics*, II Edition, Wiley Blackwell.
- Zvelebil, Marketa and Baum O. Jeremy (2008). *Understanding Bioinformatics*, Garland Science, Taylor and Francis Group, USA.
- Zar, Jerrold H. (1999). *Biostatistical Analysis*, IV Edition, Pearson Education Inc and Dorling Kindersley Publishing Inc. USA
- Antonisamy, B., Christopher S. and Samuel, P. P. (2010). *Biostatistics: Principles and Practice*. Tata McGraw Hill Education Private Limited, India.
- Pagana, M. and Gavreau, K. (2000). *Principles of Biostatistics*, Duxbury Press, USA

CODE: ZOO-HC-5026

ANIMAL BIOTECHNOLOGY

THEORY

(Credits
4)

Unit 1. Introduction	8
Concept and scope of biotechnology	
Unit 2. Molecular Techniques in Gene manipulation	24
Cloning vectors: Plasmids, Cosmids, Phagemids, Lambda Bacteriophage, M13, BAC, YAC, MAC and Expression vectors (characteristics).	
Restriction enzymes: Nomenclature, detailed study of Type II.	
Transformation techniques: Calcium chloride method and electroporation.	
Construction of genomic and cDNA libraries and screening by colony and plaque hybridization	
Southern, Northern and Western blotting	
DNA sequencing: Sanger method	
Polymerase Chain Reaction, DNA Finger Printing and DNA micro array	
Unit 3. Genetically Modified Organisms	18
Production of cloned and transgenic animals: Nuclear Transplantation, Retroviral Method, DNA microinjection	
Applications of transgenic animals: Production of pharmaceuticals, production of donor organs, knock out mice.	
Production of transgenic plants: <i>Agrobacterium</i> mediated transformation.	
Applications of transgenic plants: insect and herbicide resistant plants.	
Unit 4. Culture Techniques and Applications	10
Animal cell culture, Expressing cloned genes in mammalian cells, Molecular diagnosis of genetic diseases (Cystic fibrosis, Sickle cell anemia)	
Recombinant DNA in medicines: Recombinant insulin and human growth hormone, Gene therapy	

ANIMAL BIOTECHNOLOGY

PRACTICAL

(Credits 2)

1. Genomic DNA isolation from *E.coli*
42
2. Plasmid DNA isolation (pUC 18/19) from *E.coli*

3. Restriction digestion of plasmid DNA.
4. Construction of circular and linear restriction map from the data provided.
5. Calculation of transformation efficiency from the data provided..
6. To study following techniques through photographs
 - a. Southern Blotting
 - b. Northern Blotting
 - c. Western Blotting
 - d. DNA Sequencing (Sanger's Method)
 - e. PCR
 - f. DNA fingerprinting
7. Project report on animal cell culture

SUGGESTED READINGS

- Brown, T.A. (1998). *Molecular Biology Labfax II: Gene Cloning and DNA Analysis*. II Edition, Academic Press, California, USA.
- Glick, B.R. and Pasternak, J.J. (2009). *Molecular Biotechnology- Principles and Applications of Recombinant DNA*. IV Edition, ASM press, Washington, USA.
- Griffiths, A.J.F., J.H. Miller, Suzuki, D.T., Lewontin, R.C. and Gelbart, W.M. (2009). *An Introduction to Genetic Analysis*. IX Edition. Freeman and Co., N.Y., USA.
- Snustad, D.P. and Simmons, M.J. (2009). *Principles of Genetics*. V Edition, John Wiley and Sons Inc.
- Watson, J.D., Myers, R.M., Caudy, A. and Witkowski, J.K. (2007). *Recombinant DNA- Genes and Genomes- A Short Course*. III Edition, Freeman and Co., N.Y., USA.
- Beauchamp, T.I. and Childress, J.F. (2008). *Principles of Biomedical Ethics*. VI Edition, Oxford University Press.

CODE: ZOO-HE-5036

ENDOCRINOLOGY

THEORY

(Credits 4)

Unit 1: Introduction to Endocrinology

12

History of endocrinology, Classification, Characteristic and Transport of Hormones, Neuro secretions and Neuro hormones

Unit 2: Epiphysis, Hypothalamo-hypophysial Axis

15

Structure of pineal gland, Secretions and their functions in biological rhythm sand reproduction.

Structure of hypothalamus, Hypothalamic nuclei and their functions, Regulation of neuroendocrine glands, Feed back mechanisms

Structure of pituitary gland, Hormones and their functions, Hypothalamo- hypophysial portal system, Disorders of pituitary gland.

Unit3:Peripheral Endocrine Glands

18

Structure, Hormones, Functions and Regulation of Thyroid gland, Parathyroid, Adrenal, Pancreas, Ovary and Testis

Hormones in homeostasis, Disorders of endocrine glands

Unit4: Regulation of Hormone Action

15

Hormone action at Cellular level: Hormone receptors, transduction and regulation Hormone action at Molecular level: Molecular mediators, Genetic control of hormone action

ENDOCRINOLOGY

PRACTICAL

(Credits 2)

1. Dissect and display of Endocrine glands in laboratory bred rat*
2. Study of the permanent slides of all the endocrine glands
3. Demonstration of Castration/ovariectomy in laboratory bred rat*
4. Designing of primers of any hormone

SUGGESTED READINGS

- General Endocrinology C. Donnell Turner Pub- Saunders Toppan
- Endocrinology: An Integrated Approach; Stephen Nussey and Saffron Whitehead.
- Oxford: BIOS Scientific Publishers; 2001.
- Hadley, M.E. and Levine J.E. 2007. Endocrinology, 6th Edition. Pearson Prentice-Hall, Pearson Education Inc., New Jersey.
- Vertebrate Endocrinology by David O. Norris,

CODE: ZOO-HE-5046

PARASITOLOGY

THEORY

(CREDITS 4)

Unit I: Introduction to Parasitology

3

Brief introduction of Parasitism, Parasite, Parasitoid and Vectors (mechanical and biological vector) Host parasite relationship

Unit II: Parasitic Protists

15

Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Entamoeba histolytica*, *Giardia intestinalis*, *Trypanosoma magambiense*, *Leishmania donovani*, *Plasmodium vivax*

Unit III: Parasitic Platyhelminthes

15

Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Fasciolopsis buski*, *Schistosoma haematobium*, *Taenia solium* and *Hymenolepis nana*

Unit IV: Parasitic Nematodes

15

Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Ascaris lumbricoides*, *Ancylostoma duodenale*, *Wuchereria bancrofti* and *Trichinella spiralis*. Study of structure, life cycle and importance of *Meloidogyne* (root knot nematode), *Pratylenchus* (lesion nematode)

Unit IV: Parasitic Arthropoda

10

Biology, importance and control of ticks, mites, *Pediculus humanus* (head and body louse), *Xenopsyllacheopsis* and *Cimex lectularius*

Unit V: Parasitic Vertebrates

2

A brief account of parasitic vertebrates; Cookicutter Shark, Candiru, Hood Mockingbird and Vampire bat

PARASITOLOGY

PRACTICAL

(Credits 2)

- Study of life stages of *Entamoeba histolytica*, *Giardia intestinalis*, *Trypanosoma gambiense*, *Leishmania donovani* and *Plasmodium vivax* through permanent slides/microphotographs
- Study of adult and life stages of *Fasciolopsis buski*, *Schistosoma mahaematobium*, *Taenia solium* and *Hymenolepis nana* through permanent slides/microphotographs
- Study of adult and life stages of *Ascaris lumbricoides*, *Ancylostomaduodenale*, *Wuchereria bancrofti* and *Trichinella spiralis* through permanent slides/microphotographs
- Study of plant parasitic root knot nematode, *Meloidogyne* from the soil sample
- Study of *Pediculus humanus* (Head louse and Body louse), *Xenopsyllacheopis* and *Cimex lectularius* through permanent slides/photographs
- Study of monogenea from the gills of fresh/marine fish [Gills can be procured from fish market as by product of the industry]
- Study of nematode/cestode parasites from the intestines of Poultry bird [Intestine can be procured from poultry/market as a byproduct]

Submission of a brief report on parasitic

vertebrates SUGGESTED READINGS

- Arora, D. R. and Arora, B. (2001) *Medical Parasitology*. II Edition. CBS Publications and Distributors
- E.R. Noble and G.A. Noble (1982) *Parasitology: The biology of animal parasites*. V Edition, Lea & Febiger
- Ahmed, N., Dawson, M., Smith, C. and Wood, Ed. (2007) *Biology of Disease*. Taylor and Francis Group
- Parija, S. C. *Textbook of medical parasitology, protozoology & helminthology (Text and colour Atlas)*, II Edition, All India Publishers & Distributors, Medical Books Publishers, Chennai, Delhi
- Rattan Lal Chhpujani and Rajesh Bhatia. *Medical Parasitology*, III Edition, Jaypee Brothers Medical Publishers (P) Ltd., New Delhi

□ Meyer, Olsen & Schmidt's Essentials of Parasitology,
Murray, D. Dailey, W.C. Brown Publishers

K. D. Chatterjee (2009). Parasitology: Protozoology and Helminthology. XIII Edition, CBS *Publishers & Distributors* (P)Lt

CODE: ZOO-HE-6016
BIOLOGY OF INSECTA

THEORY	(Credits 4)
Unit I: Introduction	4
General Features of Insects	
Distribution and Success of Insects on the Earth	
Unit II: Insect Taxonomy	4
Basis of insect classification; Classification of insects up to orders	
Unit III: General Morphology of Insects	8
External Features; Head – Eyes, Types of antennae, Mouth parts w.r.t. feeding habits	
Thorax: Wings and wing articulation, Types of Legs adapted to diverse habitat Abdominal appendages and genitalia	
Unit IV: Physiology of Insects	28
Structure and physiology of Insect body systems - Integumentary, digestive, excretory, circulatory, respiratory, endocrine, reproductive, and nervous system	
Sensory receptors	
Growth and metamorphosis	
Unit IV: Insect Society	6
Group of social insects and their social life	
Social organization and social behaviour (w.r.t. any one example)	
Unit V: Insect Plant Interaction	4
Theory of co-evolution, role of allelochemicals in host plant mediation Host-plant selection by phytophagous insects, Insects as plant pests	
Unit VI: Insects as Vectors	6
Insects as mechanical and Biological vectors, Brief discussion on houseflies and mosquitoes as important insect vectors	

BIOLOGY OF INSECTA

PRACTICAL

(CREDITS 2)

1. Study of one specimen from each insect order
2. Study of different kinds of antennae, legs and mouth parts of insects
3. Study of head and sclerites of any one insect
4. Study of insect wings and their venation.
5. Study of insect spiracles
6. Methodology of collection, preservation and identification of insects.
7. Morphological studies of various castes of *Apis*, *Camponotus* and *Odontotermes*
8. Study of any three insect pests and their damages
9. Study of any three beneficial insects and their products

Field study of insects and submission of a project report on the insect diversity

SUGGESTED READINGS

- A general text book of entomology, Imms, A. D., Chapman & Hall, UK
- The Insects: Structure and function, Chapman, R. F., Cambridge University Press, UK
- Principles of Insect Morphology, Snodgrass, R. E., Cornell Univ. Press, USA
- Introduction to the study of insects, Borror, D. J., Triplehorn, C. A., and Johnson, N. F., M Saunders College Publication, USA
- The Insect Societies, Wilson, E. O., Harvard Univ. Press, UK
- Host Selection by Phytophagous Insects, Bernays, E. A., and Chapman, R. F., Chapman and Hall, New York, USA
- Physiological system in Insects, Klowden, M. J., Academic Press, USA
- The Insects, An outline of Entomology, Gullan, P. J., and Cranston, P. S., Wiley Blackwell, UK

Insect Physiology and Biochemistry, Nation, J. L., CRC Press, USA

CODE: ZOO-HE-6026

FISH AND FISHERIES

THEORY (Credits 4)

UNIT 1: Introduction and Classification: 6

General description of fish; Account of systematic classification of fishes (upto classes); Classification based on feeding habit, habitat and manner of reproduction.

UNIT 2: Morphology and Physiology: 18

Types of fins and their modifications; Locomotion in fishes; Hydrodynamics; Types of Scales, Use of scales in Classification and determination of age of fish; Gills and gas exchange; Swim Bladder: Types and role in Respiration, buoyancy; Osmoregulation in Elasmobranchs; Reproductive strategies (special reference to Indian fishes); Electric organs; Bioluminescence; Mechanoreceptors; Schooling; Parental care; Migration

UNIT3: Fisheries 12

Inland Fisheries; Marine Fisheries; Environmental factors influencing the seasonal variations in fish catches in the Arabian Sea and the Bay of Bengal; Fishing crafts and Gears; Depletion of fisheries resources; Application of remote sensing and GIS in fisheries; Fisheries law and regulations

Unit4: Aquaculture 20

Sustainable Aquaculture; Extensive, semi-intensive and intensive culture of fish; Pen and cage culture; Polyculture; Composite fish culture; Brood stock management; Induced breeding of fish; Management of finfish hatcheries; Preparation and maintenance of fish aquarium; Preparation of compound diets for fish; Role of water quality in aquaculture; Fish diseases: Bacterial, viral and parasitic; Preservation and processing of harvested fish, Fishery by-products

UNIT 5: Fish in research 53 4

Transgenic fish, Zebra fish as a model organism in research

FISH AND FISHERIES

PRACTICAL

(Credits 2)

1. Morphometric and meristic characters of fishes
2. Study of *Petromyzon*, *Myxine*, *Pristis*, *Chimaera*, *Exocoetus*, *Hippocampus*, *Gambusia*, *Labeo*, *Heteropneustes*, *Anabas*
3. Study of different types of scales (through permanent slides/photographs).
4. Study of crafts and gears used in Fisheries
5. Water quality criteria for Aquaculture: Assessment of pH, conductivity, Total solids, Total dissolved solids
6. Study of air breathing organs in *Channa*, *Heteropneustes*, *Anabas* and *Clarias*
7. Demonstration of induced breeding in Fishes (video)
8. Demonstration of parental care in fishes (video)
9. Project Report on a visit to any fish farm/pisciculture unit/Zebra fish rearing Lab.

SUGGESTED READINGS

- Q Bone and R Moore, Biology of Fishes, Talyor and Francis Group, CRC Press, U.K.
- D. H. Evans and J. D. Claiborne, The Physiology of Fishes, Taylor and Francis Group, CRC Press, UK von der Emde, R. J. Mogdans and B. G. Kapoor. The Senses of Fish: Adaptations for the Reception of Natural Stimuli, Springer, Netherlands
- C.B.L. Srivastava, Fish Biology, Narendra Publishing House
- J.R. Norman, A history of Fishes, Hill and Wang Publishers
- S.S. Khanna and H.R. Singh, A text book of Fish Biology and Fisheries, Narendra Publishing House

CODE: ZOO-HE-6036

REPRODUCTIVE BIOLOGY

THEORY

(CREDITS 4)

Unit 1: Reproductive Endocrinology

Gonadal hormones and mechanism of hormone action, steroids, glycoprotein hormones, and prostaglandins, hypothalamo – hypophyseal – gonadal axis, regulation of gonadotrophin secretion in male and female; Reproductive System: Development and differentiation of gonads, genital ducts, external genitalia, mechanism of sex differentiation.

Unit 2: Functional anatomy of male reproduction

Outline and histological of male reproductive system in rat and human; Testis: Cellular functions, germ cell, stem cell renewal; Spermatogenesis: kinetics and hormonal regulation; Androgen synthesis and metabolism; Epididymal function and sperm maturation; Accessory glands functions; Sperm transportation in male tract

Unit 3: Functional anatomy of female reproduction

Outline and histological of female reproductive system in rat and human; Ovary: folliculogenesis, ovulation, corpus luteum formation and regression; Steroidogenesis and secretion of ovarian hormones; Reproductive cycles (rat and human) and their regulation, changes in the female tract; Ovum transport in the fallopian tubes; Sperm transport in the female tract, fertilization; Hormonal control of implantation; Hormonal regulation of gestation, pregnancy diagnosis, foeto – maternal relationship; Mechanism of parturition and its hormonal regulation; Lactation and its regulation

Unit 4: Reproductive Health

Infertility in male and female: causes, diagnosis and management; Assisted Reproductive Technology: sex selection, sperm banks, frozen embryos, in vitro fertilization, ET, EFT, IUT, ZIFT, GIFT, ICSI, PROST; Modern contraceptive technologies; Demographic terminology used in family planning

REPRODUCTIVE BIOLOGY

PRACTICAL

(CREDITS 2)

1. Study of animal house: set up and maintenance of animal house, breeding techniques, care of normal and experimental animals.
2. Examination of vaginal smear rats from live animals.
3. Examination of histological sections from photomicrographs/ permanent slides of rat/human: testis, epididymis and accessory glands of male reproductive systems; Sections of ovary, fallopian tube, uterus (proliferative and secretory stages), cervix and vagina.
4. Sperm count and sperm motility in rat
5. Study of modern contraceptive devices

SUGGESTED READINGS

- Austin, C.R. and Short, R.V. reproduction in Mammals. Cambridge University Press.
- Degroot, L.J. and Jameson, J.L. (eds). Endocrinology. W.B. Saunders and Company.
- Knobil, E. et al. (eds). The Physiology of Reproduction. Raven Press Ltd.
- Hatcher, R.A. et al. The Essentials of Contraceptive Technology. Population Information Programme.

CODE: ZOO-HE-6046

WILD LIFE CONSERVATION AND MANAGEMENT

THEORY

(CREDITS 4)

Unit 1: Introduction to Wild Life

Values of wildlife-positive and negative; Conservation ethics; Importance of conservation; Causes of depletion; World conservation strategies.

Unit 2: Evaluation and management of wild life

Habitat analysis, Physical parameters : Topography, Geology, Soil and water; Biological Parameters: food, cover, forage, browse and cover estimation; Standard evaluation procedures: remote sensing and GIS.

Unit 3: Management of habitats

Setting back succession; Grazing logging; Mechanical treatment; Advancing the successional process; Cover construction; Preservation of general genetic diversity; Restoration of degraded habitats

Unit 4: Population estimation

Population density, Natality, Birth rate, Mortality, fertility schedules and sex ratio computation; Faecal analysis of ungulates and carnivores: Faecal samples, slide preparation, Hair identification, Pug marks and census method.

Unit 5: Management planning of wild life in protected areas

Estimation of carrying capacity; Ecotourism/wildlife tourism in forests; Concept of climax persistence; Ecology of perturbation.

Unit 7: Management of excess population

Bio-telemetry; Care of injured and diseased animal; Quarantine; Common diseases of wild animal

Unit 8: Protected areas

National parks & sanctuaries, Community reserve; Important features of protected areas in India; Tiger conservation - Tiger reserves in India; Management challenges in Tiger reserve.

WILD LIFE CONSERVATION AND MANAGEMENT

PRACTICALS

(CREDITS 2)

1. Identification of flora, mammalian fauna, avian fauna, herpeto-fauna
2. Demonstration of basic equipment needed in wildlife studies use, care and maintenance (Compass, Binoculars, Spotting scope, Range Finders, Global Positioning System, Various types of Cameras and lenses)
3. Familiarization and study of animal evidences in the field; Identification of animals through pugmarks, hoofmarks, scats, pellet groups, nest, antlers etc.
4. Demonstration of different field techniques for flora and fauna
5. PCQ, Tentree method, Circular, Square & rectangular plots, Parker's 2 Step and other methods for ground cover assessment, Tree canopy cover assessment, Shrub cover assessment.
6. Trail/transect monitoring for abundance and diversity estimation of mammals and bird (direct and indirect evidences)

SUGGESTED READINGS

- Caughley, G., and Sinclair, A.R.E. (1994). *Wildlife Ecology and Management*. Blackwell Science.
- Woodroffe R., Thirgood, S. and Rabinowitz, A. (2005). *People and Wildlife, Conflict or Co-existence?* Cambridge University.
- Bookhout, T.A. (1996). *Research and Management Techniques for Wildlife and Habitats*, 5 th edition. The Wildlife Society, Allen Press.
- Sutherland, W.J. (2000). *The Conservation Handbook: Research, Management and Policy*. Blackwell Sciences
- Hunter M.L., Gibbs, J.B. and Sterling, E.J. (2008). *Problem-Solving in Conservation Biology and Wildlife Management: Exercises for Class, Field, and Laboratory*. Blackwell Publishing.

ZOO-HE-6056

DISSERTATION

Dissertation of Zoology Specific subject

□ .

GENERIC ELECTIVE COURSES

CODE: ZOO-HG-1016

ANIMAL DIVERSITY

THEORY

(CREDITS 4)

Unit 1: Kingdom Protista

4

General characters and classification up to classes; Locomotory Organelles and locomotion in Protozoa

Unit 2: Phylum Porifera

3

General characters and classification up to classes; Canal System in *Sycon*

Unit 3: Phylum Cnidaria

3

General characters and classification up to classes; Polymorphism in Hydrozoa

Unit 4: Phylum Platyhelminthes

3

General characters and classification up to classes; Life history of *Taenia solium*

Unit 5: Phylum Nematelminthes

5

General characters and classification up to classes; Life history of *Ascaris lumbricoides* and its parasitic adaptations

Unit 6: Phylum Annelida

3

General characters and classification up to classes; Metamerism in Annelida

Unit 7: Phylum Arthropoda

5

General characters and classification up to classes; Vision in Arthropoda, Metamorphosis in Insects

Unit 8: Phylum Mollusca	4
General characters and classification up to classes; Torsion in gastropods	
Unit 9: Phylum Echinodermata	4
General characters and classification up to classes; Water-vascular system in Asterozoa	
Unit 10: Protochordates	2
General features and Phylogeny of Protochordata	
Unit 11: Agnatha	2
General features of Agnatha and classification of cyclostomes up to classes	
Unit 12: Pisces	4
General features and Classification up to orders; Osmoregulation in Fishes	

Unit13: Amphibia	4
General features and Classification up to orders; Parental care	
Unit14: Reptiles	4
General features and Classification up to orders; Poisonous and non-poisonous snakes, Biting mechanism in snakes	
Unit15: Aves	5
General features and Classification up to orders; Flight adaptations in birds	
Unit17: Mammals	5
Classification up to orders; Origin of mammals	

Note: Classification of Unit 1-9 to be followed from “Barnes, R.D. (1982). *Invertebrate Zoology*, V Edition”

ANIMAL DIVERSITY

PRACTICAL

(CREDITS2)

1. Study of the following specimens:

Amoeba, Euglena, Plasmodium, Paramecium, Sycon, Hyalonema, and Euplectella, Obelia, Physalia, Aurelia, Tubipora, Metridium, Taeniasolium, Male and female Ascarislumbricoides, Aphrodite, Nereis, Pheretima, Hirudinaria, Palaemon, Cancer, Limulus, Palamnaeus, Scolopendra, Julus, Periplaneta, Apis, Chiton, Dentalium, Pila, Unio, Loligo, Sepia, Octopus, Pentaceros, Ophiura, Echinus, Cucumaria and Antedon, Balanoglossus, Herdmania, Branchiostoma, Petromyzon, Sphyrna, Pristis, Torpedo, Labeo, Exocoetus, Anguilla, Ichthyophis/Ureotyphlus, Salamandra, Bufo, Hyla, Chelone, Hemidactylus, Chamaeleon, Draco, Vipera, Naja, Crocodylus, Gavialis, Any six common birds from different orders, Sorex, Bat, Funambulus, Loris

2. Study of the following permanent slides:

T.S. and L.S. of *Sycon*, Study of life history stages of *Taenia*, T.S. of Male and female *Ascaris*

3. Key for Identification of poisonous and non-poisonous snakes

An “**animal album**” containing photographs, cut outs, with appropriate write up about the above mentioned taxa. Different taxa/ topics may be given to different sets of students for this purpose.

SUGGESTED READINGS

- Ruppert and Barnes, R.D. (2006). *Invertebrate Zoology*, VIII Edition. Holt Saunders International Edition.
- Barnes, R.S.K., Calow, P., Olive, P.J.W., Golding, D.W. and Spicer, J.I. (2002). *The Invertebrates: A New Synthesis*, III Edition, Blackwell Science
- Young, J. Z. (2004). *The Life of Vertebrates*. III Edition. Oxford university press.
- Pough H. *Vertebrate life*, VIII Edition, Pearson International.
- Hall B.K. and Hallgrimsson B. (2008). *Strickberger's Evolution*. IV Edition. Jones and Bartlett Publishers Inc.

**COMPARATIVE ANATOMY AND DEVELOPMENTAL BIOLOGY OF
VERTEBRATES**
CODE: ZOO-HG-2016

THEORY	(CREDITS 4)
Unit 1: Integumentary System	4
Derivatives of integument w.r.t. glands and digital tips	
Unit 2: Skeletal System	3
Evolution of visceral arches	
Unit 3: Digestive System	4
Brief account of alimentary canal and digestive glands	
Unit 4: Respiratory System	5
Brief account of Gills, lungs, air sacs and swim bladder	
Unit 5: Circulatory System	4
Evolution of heart and aortic arches	
Unit 6: Urinogenital System	4
Succession of kidney, Evolution of urinogenital ducts	
Unit 7: Nervous System	3
Comparative account of brain	
Unit 8: Sense Organs	3
Types of receptors	
Unit 9: Early Embryonic Development	12
Gametogenesis: Spermatogenesis and oogenesis w.r.t. mammals, vitellogenesis in birds; Fertilization: external (amphibians), internal (mammals), blocks to polyspermy; Early development of frog and humans (structure of mature egg and its membranes, patterns of cleavage, fate map, up to formation of gastrula); types of morphogenetic movements; Fate of germ layers; Neurulation in frog embryo.	
Unit 10: Late Embryonic Development	10
Implantation of embryo in humans, Formation of human placenta and functions, other types of placenta on the basis of histology; Metamorphic events in frog life cycle and its hormonal regulation.	
Unit 11: Control of Development	8

Fundamental processes in development (brief idea) – Gene activation, determination, induction, Differentiation, morphogenesis, intercellular communication, cell movements and cell death

COMPARATIVE ANATOMY AND DEVELOPMENTAL BIOLOGY OF VERTEBRATES

PRACTICAL

(CREDITS 2)

1. Osteology:

- a) Disarticulated skeleton of fowl and rabbit
- b) Carapace and plastron of turtle/tortoise
- c) Mammalian skulls: One herbivorous and one carnivorous animal.

2. Frog - Study of developmental stages - whole mounts and sections through permanent slides – cleavage stages, blastula, gastrula, neurula, tail bud stage, tadpole external and internal gill stages.

3. Study of the different types of placenta- histological sections through permanent slides or photomicrographs.

4. Examination of gametes - frog/rat - sperm and ova through permanent slides or photomicrographs.

SUGGESTED READINGS

- Kardong, K.V. (2005) *Vertebrates' Comparative Anatomy, Function and Evolution*. IV Edition. McGraw-Hill Higher Education.
- Kent, G.C. and Carr R.K. (2000). *Comparative Anatomy of the Vertebrates*. IX Edition. The McGraw-Hill Companies.
- Hilderbrand, M and Gaslow G.E. *Analysis of Vertebrate Structure*, John Wiley and Sons.
- Walter, H.E. and Sayles, L.P; *Biology of Vertebrates*, Khosla Publishing House.
- Gilbert, S. F. (2006). *Developmental Biology*, VIII Edition, Sinauer Associates, Inc., Publishers, Sunderland, Massachusetts, USA.
- Balinsky, B.I. (2008). *An introduction to Embryology*, International Thomson Computer Press.
- Carlson, Bruce M (1996). *Patten's Foundations of Embryology*, McGraw Hill, Inc.

CORE COURSE III
PHYSIOLOGY AND BIOCHEMISTRY
CODE: ZOO-HG-3016

THEORY

(CREDITS 4)

Unit 1: Nerve and muscle	8
Structure of a neuron, Resting membrane potential, Graded potential, Origin of Action potential and its propagation in myelinated and non-myelinated nerve fibres, Ultra-structure of skeletal muscle, Molecular and chemical basis of muscle contraction	
Unit 2: Digestion	5
Physiology of digestion in the alimentary canal; Absorption of carbohydrates, proteins, lipids	
Unit 3: Respiration	5
Pulmonary ventilation, Respiratory volumes and capacities, Transport of Oxygen and carbon dioxide in blood	
Unit 4: Excretion	5
Structure of nephron, Mechanism of Urine formation, Counter-current Mechanism	
Unit 5: Cardiovascular system	6
Composition of blood, Hemostasis, Structure of Heart, Origin and conduction of the cardiac impulse, Cardiac cycle	
Unit 6: Reproduction and Endocrine Glands	7
Physiology of male reproduction: hormonal control of spermatogenesis; Physiology of female reproduction: hormonal control of menstrual cycle Structure and function of pituitary, thyroid, Parathyroid, pancreas and adrenal	
Unit 7: Carbohydrate Metabolism	8
Glycolysis, Krebs Cycle, Pentose phosphate pathway, Gluconeogenesis, Glycogen metabolism, Review of electron transport chain	
Unit 8: Lipid Metabolism	5
Biosynthesis and β oxidation of palmitic acid	
Unit 9: Protein metabolism	5
Transamination, Deamination and Urea Cycle	
Unit 10: Enzymes	6
Introduction, Mechanism of action, Enzyme Kinetics, Inhibition and Regulation	

PHYSIOLOGY AND BIOCHEMISTRY

PRACTICAL

(CREDITS2)

1. Preparation of hemin crystals
2. Study of permanent histological sections of mammalian pituitary, thyroid, pancreas, adrenal gland
3. Study of permanent slides of spinal cord, duodenum, liver, lung, kidney, bone, cartilage
4. Qualitative tests to identify functional groups of carbohydrates in given solutions (Glucose, Fructose, Sucrose, Lactose)
2. Estimation of total protein in given solutions by Lowry's method.
3. Study of activity of salivary amylase under optimum conditions

SUGGESTED READINGS

- Tortora, G.J. and Derrickson, B.H. (2009). *Principles of Anatomy and Physiology*, XII Edition, John Wiley & Sons, Inc.
- Widmaier, E.P., Raff, H. and Strang, K.T. (2008) *Vander's Human Physiology*, XI Edition., McGrawHill
- Guyton, A.C. and Hall, J.E. (2011). *Textbook of Medical Physiology*, XII Edition, Harcourt Asia Pvt. Ltd/ W.B. Saunders Company
- Berg, J. M., Tymoczko, J. L. and Stryer, L. (2006). *Biochemistry*. VI Edition. W.H Freeman and Co.
- Nelson, D. L., Cox, M. M. and Lehninger, A.L. (2009). *Principles of Biochemistry*. IV Edition. W.H. Freeman and Co.
- Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2009). *Harper's Illustrated Biochemistry*. XXVIII Edition. Lange Medical Books/McGraw3Hill.

GENETICS AND EVOLUTIONARY BIOLOGY

CODE: ZOO-HG-4016

THEORY

(CREDITS 4)

Unit 1: Introduction to Genetics **3**

Mendel's work on transmission of traits, Genetic Variation, Molecular basis of Genetic Information

Unit 2: Mendelian Genetics and its Extension **8**

Principles of Inheritance, Chromosome theory of inheritance, Incomplete dominance and co-dominance, Multiple alleles, Lethal alleles, Epistasis, Pleiotropy, sex linked inheritance, extra-chromosomal inheritance

Unit 3: Linkage, Crossing Over and Chromosomal Mapping **9**

Linkage and crossing over, Recombination frequency as a measure of linkage intensity, two factor and three factor crosses, Interference and coincidence, Somatic cell genetics - an alternative approach to gene mapping

Unit 4: Mutations **7**

Chromosomal Mutations: Deletion, Duplication, Inversion, Translocation, Aneuploidy and Polyploidy; Gene mutations: Induced versus Spontaneous mutations, Back versus Suppressor mutations,

Unit 5: Sex Determination **4**

Chromosomal mechanisms, dosage compensation

Unit 6: History of Life **2**

Major Events in History of Life

Unit 7: Introduction to Evolutionary Theories **5**

Lamarckism, Darwinism, Neo-Darwinism

Unit 8: Direct Evidences of Evolution **5**

Types of fossils, Incompleteness of fossil record, Dating of fossils, Phylogeny of horse

Unit 9: Processes of Evolutionary Change **9**

Organic variations; Isolating Mechanisms; Natural selection (Example: Industrial melanism); Types of natural selection (Directional, Stabilizing, Disruptive), Artificial selection

Unit 10: Species Concept **6**

Biological species concept (Advantages and Limitations); Modes of speciation (Allopatric, Sympatric)

Unit11:Macro-evolution

5

Macro-evolutionary Principles (example: Darwin's Finches)

Unit 12: Extinction

6

Mass extinction (Causes, Names of five major extinctions, K-T extinction in detail), Role of extinction in evolution

GENETICS AND EVOLUTIONARY BIOLOGY

PRACTICAL

(CREDITS 2)

1. Study of Mendelian Inheritance and gene interactions (Non Mendelian Inheritance) using suitable examples. Verify the results using Chi-square test.
2. Study of Linkage, recombination, gene mapping using the data.
3. Study of Human Karyotypes (normal and abnormal).
4. Study of fossil evidences from plaster cast models and pictures
5. Study of homology and analogy from suitable specimens/pictures
6. Charts:
 - a) Phylogeny of horse with diagrams/ cut outs of limbs and teeth of horse ancestors
 - b) Darwin's Finches with diagrams/ cut outs of beaks of different species
7. Visit to Natural History Museum and submission of report

SUGGESTED READINGS

- Gardner, E.J., Simmons, M.J., Snustad, D.P. (2008). *Principles of Genetics*. VIII Edition. WileyIndia.
- Snustad, D.P., Simmons, M.J. (2009). *Principles of Genetics*. V Edition. John Wiley and SonsInc.
- Klug, W.S., Cummings, M.R., Spencer, C.A. (2012). *Concepts of Genetics*. X Edition. BenjaminCummings.
- Russell, P. J. (2009). *Genetics- A Molecular Approach*. III Edition. Benjamin Cummings.
- Griffiths, A.J.F., Wessler, S.R., Lewontin, R.C. and Carroll, S.B. *Introduction to Genetic Analysis*. IX Edition. W. H. Freeman andCo.
- Ridley, M. (2004). *Evolution*. III Edition. BlackwellPublishing
- Barton, N. H., Briggs, D. E. G., Eisen, J. A., Goldstein, D. B. and Patel, N. H.(2007). *Evolution*. Spring, Harbour Laboratory Press.
- Hall, B. K. and Hall grimsson, B. (2008). *Evolution*. IV Edition. Jones and Bartlett Publishers
- Campbell, N. A. and Reece J. B. (2011). *Biology*. IX Edition, Pearson, Benjamin, Cummings.
- Douglas, J. Futuyma (1997). *Evolutionary Biology*. Sinauer Associates.

SKILL ENHANCEMENT COURSES

CODE: ZOO-SE-3014

Credit-4

Ornamental Fish & Fisheries

1. Ornamental Fish Diversity of North East India.
2. Aquarium plant diversity in the wetland of Assam.
3. Construction and management of Home Aquarium.
4. Natural feed of Ornamental Fish
5. Strategies for maintenance of natural colour of Ornamental Fish
6. Natural Breeding of Tricogaster species
7. Health management of Ornamental Fish
8. Feed formulation of Ornamental Fish
9. Development of Biological filtration in Aquarium
10. Pure culture of planktons

Practical's

11. Identification of Ornamental Fish
12. Culture of Indigenous ornamental fish in Aquarium
13. Estimation of Physico-chemical characteristics of Aquarium water
14. Biological filter for removal of Ammonia from Aquarium
15. Culture of Planktons

APICULTURE

CODE: ZOO-SE-3024

(CREDITS4)

Unit 1: Biology of Bees

History, Classification and Biology of Honey
Bees Social Organization of Bee Colony

Unit 2: Rearing of Bees

Artificial Bee rearing(Apiary),Beehives–Newton and
Langstroth Bee Pasturage
Selection of Bee Species for
Apiculture Bee Keeping Equipment
Methods of Extraction of Honey (Indigenous and Modern)

Unit 3: Diseases and Enemies

Bee Diseases and Enemies

Control and Preventive
measures

Unit 4: Bee Economy

Products of Apiculture Industry and its Uses (Honey, Bees Wax, Propolis), Pollen etc

Unit 5: Entrepreneurship in Apiculture

Bee Keeping Industry—Recent Efforts, Modern Methods in employing artificial Beehives for cross pollination in horticultural gardens

SUGGESTED READINGS

- Prost, P. J. (1962). *Apiculture*. Oxford and IBH, New Delhi.
- Bisht D.S., *Apiculture*, ICAR Publication.
- Singh S., *Bee keeping in India*, Indian council of Agricultural Research, New Delhi.

CODE: ZOO-SE-4014

SEC 2 NON-

MULBERRY

SERICULTURE

(CREDITS 4)

Unit 1: Introduction

Sericulture: Definition, history and present status of Mulberry and Non-Mulberry Sericulture; Silk route Varieties of Silk; Types and distribution of non-mulberry or wild or vanya sericigenous insects in N-E India

Unit 2: Biology of Non-mulberry Silkworm:

Life cycle of silkworm- Eri and Muga
Structure of silk gland and Nature of Silk

Unit 3: Rearing of Silkworms (Eri and Muga Silkworm):

Food plants of Eri and Muga Silkworm

Rearing Operation:

Rearing house/Site and rearing appliances
Disinfectants: Formalin, bleaching powder
Rearing technology: Early age and Late age rearing
Environmental conditions in rearing-Temperature, Humidity, Light and Air
Types of mountages
Harvesting and storage of cocoons
Spinning and Reeling of silk

Unit 4: Pests and Diseases:

Pests of eri and muga silkworm
Pathogenesis of eri and muga silkworm diseases: Protozoan, viral, fungal and bacterial
Prevention and control measures of pests and diseases

Unit 5: Entrepreneurship in Non-Mulberry Sericulture:

Varieties of Non-Mulberry Silk products and economics in India

Prospectus of Non-Mulberry Sericulture in India: Non-Mulberry Sericulture industry in different states, employment generation and potential

Visit to various sericulture Govt. /Private Farm/ Centers.

SUGGESTED READINGS

- Jolly, M. S., S. K. Sen, T.N. Sonwalkar and G.K. Prashad 1979. *Non-Mulberry Sericulture. In: Manual of Sericulture, Rome, FAO, 4 (29)*
- Chowdhury, S.N. 1981. *Muga Silk Industry*. Directorate of Sericulture, Govt. of Assam, Guwahati-781005, Assam.
- Chowdhury, S.N. 1982. *Eri Silk Industry*. Directorate of Sericulture, Govt. of Assam, Guwahati-781005, Assam.
- Chowdhury, S.N. 1992. *Silk and Sericulture*. Directorate of Sericulture and Weaving, Govt. of Assam, Guwahati-781005, Assam.

**Wildlife Photography and
Ecotourism**

**CREDITS 4
Credit-1**

Unit-I Tools and Technique of Photography

- Introduction to Photography
- Still && Video Photography
- To develop expertise in Photography
- Field trips for photography in different periods (Light and Dark), seasons and places (Wetlands, Wildlife sanctuaries, National parks, Industrial sites)
- Methods of documentation

Practical

- Submission of Photography
- Preparation of Poster and Calendar

Unit-2 Eco-tourism

- Introduction of Eco-tourism
- Scope of Eco-tourism with special reference to North East region of India
- Management of Eco-tourism & hospitality
- Development of Eco-tourism with innovative Eco-restoration ideas.

Practical

- Field visit to Wildlife sanctuaries, Eco-park, Historical and religious places, Cultural museum etc.
- Preparation of report and seminar presentation

CODE: ZOO-SE-4034
RESEARCH METHODOLOGY
Credit:4

Unit 1:

Foundations of Research:

Meaning, Objectives, Motivation: Research Methods vs Methodology, Types of Research: Analytical vs Descriptive, Quantitative vs Qualitative, Basic vs Applied

Unit 2:

Research Design Need for research design:

Features of good design, Important concepts related to good design- Observation and Facts, Prediction and Explanation, Development of Models. Developing a research plan: Problem identification, Experimentation, Determining experimental and sample designs

Unit 3:

Data Collection, Analysis and Report Writing

Observation and Collection of Data-Methods of data collection- Sampling Methods, Data Processing and Analysis Strategies, Technical Reports and Thesis writing, Preparation of Tables and Bibliography. Data Presentation using digital technology

Unit 4:

Ethical Issues

Intellectual property Rights, Commercialization, Copy Right, Royalty, Patent law, Plagiarism, Citation, Acknowledgement

SUGGESTED READINGS

- Anthony, M, Graziano, A.M. and Raulin, M.L. 2009. Research Methods: A Process of Inquiry, Allyn and Bacon.
- Walliman, N. 2011. Research Methods- The Basics. Taylor and Francis, London, New York.
- Wadhera, B.L.: Law Relating to Patents, Trade Marks, Copyright Designs and Geographical Indications, 2002, Universal Law publishing
- C.R.Kothari: Research Methodology, New Age International, 2009
- Coley, S.M. and Scheinberg, C.A. 1990, "Proposal writing". Stage Publications.