Syllabus: Ph. D. Course Work

Integrated Science Education & Research Centre

Siksha Bhavana, Visva-Bharati

STRUCTURE

Paper-1: Marks = 100

Group-A: Research Methodology (Marks = 75)
Group-B: Basic Computer Applications (Marks = 25)

Paper-2: Marks = 100

Optional:
Group-A: Nanomaterials (Marks = 25)
Group-B: Renewable Energy (Marks = 25)
Group-C: Energy Storage Systems (Marks = 25)
Group-D: Water Pollution (Marks = 25)
Group-E: Soil and Rock (Marks = 25)
Group-F: General Techniques in Life Science (Marks = 25)
Group-G: Mathematics I (Marks = 25)
Group-H: Mathematics II (Marks = 25)
Group-I: Mathematics III (Marks = 25)
Group-J: Dynamical Systems (Marks = 25)
Group-K: Fundamentals of UV-visible Spectroscopy (Marks = 25)
Group-L: Basic Instruments in UV-visible Spectroscopy (Marks = 25)
(Students will opt for any four of the above topics)

Paper-3: Review Work (Marks = 100)

SYLLABI

Paper-1: Marks = 100

Group-A: Research Methodology (Marks = 75)

Research: Meaning, characteristics, types, importance.

Defining research problem.

Literature survey of previous works.

Methods of data collection, qualitative and quantitative data, data interpretation, graphical representation of data, error analysis.

Technical aspects of scientific article and thesis writing: organization of materials, style, drawing figures, graphs, tables, footnotes, references, etc.

Scientific paper presentation: one seminar paper preparation (oral or poster) which includes text, figures, pictures, tables, references, etc., question and answer session.

Patent laws, process of patenting a research finding, copyright, cyber laws, scientific ethics, plagiarism.

Differences between theory, principle, law, hypothesis, postulate, proposition. Empirical basis of hypothesis formulation. Types of errors in formulation of hypothesis.

Operating systems & computing languages: Compatibility with Windows, Linux. C language, Matlab, Mathematica, Tecplot, Gnuplot, Xfig.

Testing of hypothesis, t-test, F-test, Z-test, correlation, regression, goodness of fit test, ANOVA, dispersion.

Analytical techniques, spectral techniques, purification techniques, synthetic methodologies.

Toxicity of chemicals, storage and handling of chemicals and solvents in laboratory and their disposal.

Environmental sampling design, planning and sampling protocols. Standard sampling methods for air, surface water, groundwater, soil and sediment.

Group-B: Basic Computer Applications (Marks = 25)

The syllabus is framed and taught by the Department of Computer and System Studies.

Paper-2: Marks = 100

(Students will opt for any four of the following topics)

Group-A: Nanomaterials (Marks = 25)

Nanostructured materials: their syntheses, characterization and applications. Physical property measurements. Basic principles and instrumentation of electron microscopic and X-ray diffraction studies, Atomic absorption, X-ray photoelectron and Inductively coupled plasma-atomic emission spectroscopy, thermogravimetric studies, chromatographic techniques. Study of gas adsorption and catalysis. Magnetic properties of solids and modern methods of determination.

Group-B: Renewable Energy (Marks = 25)

Energy Alternatives: The Solar Option, Solar Radiation, availability, measurement and estimation. Fundamentals of Solar Energy**:** Basics of photovoltaic energy conversion, Optical properties of solids, direct and indirect transition semiconductors, Fermi energy, band diagram, intrinsic and extrinsic semiconductors, p-n junction. Interrelationship between absorption coefficients and band gap, recombination of the carriers. High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, III-V, II-VI thin-film solar cells (GaAs, Cu(In,Ga)Se2, CdTe) Nano-, micro- and poly-crystalline Si for solar cells. Conjugated polymers, organic/plastic/flexible solar cells, polymer composites for solar cells, device fabrication, Characterization: Current density, Open circuit voltage and short circuit current, efficiency calculation, fill factor, etc.

Group-C: Energy Storage Systems (Marks = 25)

Materials and devices for energy storage; Materials for electrochemical devices, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNTs for hydrogen storage, Batteries and fuel cells: Thermodynamic analysis, design and analysis of batteries and fuel cells. Types of batteries: primary and secondary both aqueous and non-aqueous systems, and their characterictics: components, electrolytes and operating voltage. Types of Fuel Cells: PEM fuel cell, Acid/alkaline fuel cells, Solid oxide fule cell, their characterization and operating condition. Polymer membranes for fuel cells.

Hydrogen Energy: Relevance in relation to depletion of fossil fuels and environmental considerations, solar thermal generation of hydrogen fuel through photoelectrolysis, Catalyst for solar thermal photo-electrolysis. Solid state hydrogen storage materials, Various factors relevant to its safety, Use of hydrogen as fuel in vehicular transport and electricity generation and hydrogen fuel cell.

Group-D: Water Pollution (Marks = 25)

Hydrological cycle, Properties of water, Different water resources, Eutrophication, Nature and type of water pollutants, Heavy metals, Metalloids, Persistent organic pollutants, Pesticides in water, Radioactive and thermal pollution, Water quality parameters and its standards (DO, BOD, COD, Acidity, Alkalinity, Hardness), Ground water pollution, Waste water treatment.

Group-E: Soil and Rock (Marks = 25)

Introduction to lithosphere and its interaction with living system, Surface features and Internal structure of earth; Weathering and Erosion; Mass wasting; Erosion, transportation and deposition by water, ice and wind; Plate tectonics as an unifying theory, Plate boundaries, Earthquake, volcanoes. Types of minerals and their use, Environmental problems associated with mining industries. Sources, behaviour and fate of soil pollutants; Effects of soil pollutants on living systems. Soil micro-organisms and their functions; Role of microorganisms in the biochemical cycles. Sources and generation of solid wastes, management of solid & other hazardous and toxic wastes.

Group-F: General Techniques in Life Science (Marks = 25)

Microscopy (Light - normal, confocal, etc.).
PCR (uses and types).
Blotting techniques (Southern, Northern, etc.).
Electrophoresis (1D, 2D, etc.).
Chromatography (TLC, GLC, HPLC, etc.).
Immunotechniques (ELISA, RIA, etc).
Genomics (microarray, NGS, etc.).
Mass spectrometry.

Group-G: Mathematics I (Marks = 25)

Using C/Matlab language:

- Solve AX=B by Gauss Siedel, BICG, BiCGStab, Thomas Algorithm.
- Integrate by Simpson's Quadrature Rule.
- Solve ODE by Runge-Kutta Method.

Texts/References:

- Let Us C by Kanetkar.
- The Mathematica Book, Fifth Edition, Wolfram Media, 2003.
- Magrab, Azarm, Balachandran, Duncan, Herold, Walsh, An Engineer's Guide to MATLAB.

Group-H: Mathematics II (Marks = 25)

Integral Transforms: Fundamentals of Integral Transform.
Integral Equations: Overview of Integral equations.
Legendre functions: Legendre polynomials and their zeros, Rodrigues' formula, generating function, Legendre coefficients, Recurrence relations, Orthogonality.

Bessel's functions: Bessel's function of first kind and of second kind of integer order, Generating function, Identities, Recurrence relations, Orthogonality, Bessel's integral formula.
Green's functions: Construction of a solution of first and second order linear differential equations by Green's function.
Topology: Basics of Topology.
Differential geometry: Basics of differential geometry.
Functional Analysis**:** Introduction to functional analysis.

Texts/References:

1. J. A. Thorpe, Introduction to Differential Geometry, Springer-Verlag.
2. S. G. Mikhlin - Linear Integral Equations (Transl. from Russian) (Hindustan Book 1960).
3. I. N. Sneddon - Fourier Transforms (McGraw -Hill).
4. Petrovsky - Integral Equations.
5. Ordinary Differential Equations- Birkoff and Rota.
6. J. L. Kelley, General Topology, East-West Press Pvt. Ltd.
7. B. V. Limaye, Functional Analysis, Wiley Eastern Limited.

Group-I: Mathematics III (Marks = 25)

- Finite difference schemes for partial differential equations - explicit and implicit schemes; Consistency, stability and convergence - stability analysis by matrix method and von Neumann method, Lax's equivalence theorem.
- Finite difference schemes for initial and boundary value problems - FTCS, backward Euler and Crank-Nicolson schemes, ADI methods, Lax Wendroff method, upwind scheme; CFL conditions.
- Multigrid methods, Higher Order methods, Lattice Boltzman method.
- Applications: Fundamental equations of the flow of viscous compressible fluids, Navier-Stokes equations, The energy equation, Fundamental equations in cylindrical and spherical coordinates. Euler's dynamical equations, Bernoulli's theorem, Potential flows, Some exact solutions of Navier-Stokes equations.

Texts/References:

1. G. D. Smith, Numerical Solutions to Partial Differential Equations, Oxford University Press, 3rd Edn., 1986.
2. J. C. Strikwerda, Finite Difference Schemes and Partial Differential Equations, SIAM, 2004.
3. L. Lapidus and G. F. Pinder, Numerical Solution of Partial Differential Equations in Science and Engineering, John Wiley, 1982.
4. Frank M White, Viscous Fluid Flow, McGraw-Hill, 1991.

Group-J: Dynamical Systems (Marks = 25)
Basic concepts of phase space trajectories; Dynamical systems; Examples from harmonic oscillators with damping/forcing; Differentiating between dissipative systems; conservative systems and growing Systems.

One dimensional dynamical systems: Fixed points, Stability analysis; Bifurcations: Transcritical, Pitchfork (Super/Sub-critical), Saddle Node, Examples.

Two dimensional dynamical systems: Spirals, Saddles, Centres; Bifurcations; Supercritical and Subcritical Hopf Bifurcations; Predator-Prey model.

Group-K: Fundamentals of UV-visible Spectroscopy (Marks = 25)
Beer-Lambert law, Fluorescence, Phosphorescence, Kasha's rule, Stokes shift, Fluorescence lifetime and quantum yield, Concept of non-radiative transitions in molecules, Jablonski diagram, Fluorescence quenching, Static and dynamic quenching, Radiative and non-radiative energy transfer, Photoinduced electron transfer, Marcus theory.

Group-L: Basic Instruments in UV-visible Spectroscopy (Marks = 25)
Steady state absorption spectrophotometer and emission spectrofluorimeter, Time correlated single photon counting (TCSPC) technique, Pump-probe transient absorption technique.

Paper-3: Review Work (Marks = 100)

Review work in the relevant field of research.