ENGINEERING PHYSICS

Programme Code: ENGG18

Programme Outcome:

The courses in engineering sciences aim to provide the research scholars a broad overview of the subjects which are relevant for their research programs in beam technology. The students are equipped with in-depth knowledge of skill set required for research work. The courses cover advanced topics in the areas of Fuel Cycle, Nuclear Power Plant Technology, Radiation Safety, Health Physics, Material Science, Reactor Systems, Reactor Physics, Computation and Simulation which are useful for the students to understand their research areas and carry out their experimental and theoretical work. Th courses are deigned to help students understand the various aspects of their field of research, foster a sense of enquiry, independent thinking about the solutions to the problems that define their areas of research.

DETAILED COURSE STRUCTURE

Foundation Courses				
Sr. No	**Course Code**	**Subject Title**	**Hours (T)**	**Credits**
1	03ENGG01-001-F	Physics Courses for Engineering Graduates • Introduction to Mechanical Engineering • Power Devices & Circuit Theory • Electronics & Instrumentation • RF & Microwave Systems including RF cavities • Quantum Mechanics • Optics • Atomic Molecular Physics • Relativity • Solid State Physics	45	3
2	03ENGG01-002-F	Engineering Courses for Physics Post-Graduates • Introduction to Mechanical Engineering • Design and manufacturing • Power Devices and Circuits • Electronics and Instrumentation	45	3
		FOUNDATION TOTAL	**90**	**6**

Core Courses					
Sr. No	**Course Code**	**Subject Title**	**Hours**		**Credits**
			(T)	**(L)**	
1	03ENGG01-002-C	Mathematical Methods in Science & Engineering	30		2
2	03ENGG01-005-C	Accelerator Physics & Beam Diagnostics	40		2
3	03ENGG01-003-C	Laser Physics & Technology	40		2
4	03ENGG01-004-C	Electromagnetic Theory	40		2
5	03ENGG01-011-C	Vacuum Physics & Technology	25		1
6	03ENGG01-007-C	Numerical Methods and Computing Methodologies	35	15	3
7	03ENGG01-006-C	Radiological Safety and Reactor Physics	30		2

8	03ENGG01-008-C	Basic Solid-State Physics & Materials Science	30		2
		CORE TOTAL	**270**	**15**	**16**

Electives (any four)					
Sr. No	**Course Code**	**Subject Title**	**Hours**		**Credits**
			(T)	**(L)**	
1	03PHYS04-001-E	Advanced Optics	30		2
2	03PHYS04-002-E	Advanced Accelerator Physics	30		2
3	03PHYS04-005-E	Instrumentation for Material Characterization	30		2
4	03PHYS04-006-E	Advanced Beam Dynamics	30		2
5	03PHYS04-007-E	Course on Bio-Photonics	30		2
6	03PHYS04-009-E	Concepts in X-Ray Physics	30		2
7	03PHYS04-004-E	Plasma Physics & Technology	30		2
9	03PHYS04-011-E	Fibre Optics & Fibre Sensors	30		2
10	03PHYS04-010-E	Physics of semiconductor Quantum Structures	30		2
11	03PHYS04-002-E	Magnet Physics & Technology	30		2
12	03PHYS04-008-E	Advanced Course on Atom-Photon Interactions	30		2
13	03PHYS04-003-E	Statistical Physics	30		2
14	03ENGG01-001-E	Power Supplies	30		2
15	03ENGG01-007-E	Digital Signal, Image Processing & Applications	30		2
16	03ENGG01-005-E	Reliability Engineering	30		2
17	03ENGG01-002-E	Advanced Power Electronics	30		2
18	03ENGG01-003-E	Advanced Course on RF and Microwaves	30		2
19	03ENGG01-004-E	Real Time Embedded System	30		2
20	03ENGG01-006-E	Advanced Course in High Voltage Engineering	30		2
21	03ENGG01-007-E	Digital Control Systems	30		2
		ELECTIVES TOTAL	**120**		**8**

FOUNDATION COURSES COORDINATOR

Chief Coordinators:

Dr. Ajit Upadhyay, Extn.: 2396 , E-Mail: ajitup@rrcat.gov.in

Course	Coordinators	Contact
Introduction to Mechanical Engineering	Dr. Vikas Jain	vikas@rrcat.gov.in
Power Devices & Circuit Theory	Shri Yashpal Singh	ysp@rrcat.gov.in
Electronics and Instrumentation	Dr. M.B.Borage	mbb@rrcat.gov.in
RF & Microwave Systems including RF cavities	Dr. Akhilesh Jain	ajain@rrcat.gov.in
Quantum Mechanics	Dr. T.K.Sharma	tarun@rrcat.gov.in
Optics	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Atomic & Molecular Physics	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Relativity	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Solid State Physics	Dr. M.K.Chattopadhyay	maulindu@rrcat.gov.in

CORE COURSES COORDINATOR

Chief Coordinators:

Dr. Ajit Upadhyay, Extn.: 2396 , E-Mail: ajitup@rrcat.gov.in

Course	Coordinators	Contact
Mathematical Methods in Science and Engineering	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Accelerator Physics & Beam Diagnostics	Dr. K.K.Pant	kkpant@rrcat.gov.in
Laser Physics and Technology	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Electromagnetic Theory	Dr. Anand Moorti	moorti@rrcat.gov.in
Vacuum Physics and Technology	Shri D. P. Yadav	dpyadav@rrcat.gov.in
Numerical Methods and Computing Methodologies	Dr. Ajit Upadhyay Dr. Jitendra Patil	ajitup@rrcat.gov.in jkmadaan@rrcat.gov.in
Radiological Safety and Reactor Physics	Dr. Haridas G.	haridas@rrcat.gov.in
Basic Solid State Physics and Materials Science	Dr. Indranil Bhaumik	neel@rrcat.gov.in

ELECTIVES COURSES COORDINATOR

Chief Coordinators:

Dr. Ajit Upadhyay, Extn.: 2396, E-Mail: ajitup@rrcat.gov.in

Course	Coordinators	Contact
Course on Bio-photonics	Dr. S.K.Majumder	shkm@rrcat.gov.in
Advanced Beam Dynamics	Dr. Vinit Kumar	vinit@rrcat.gov.in
Instrumentation for Material Characterization	Dr. S. Verma	sverma@rrcat.gov.in
Advanced Accelerator Physics	Dr. Vinit Kumar	vinit@rrcat.gov.in
Advanced Optics	Dr. S. Verma	sverma@rrcat.gov.in
Concept in X-Ray Physics	Dr. Gurvinderjit Singh	gjit@rrcat.gov.in
Plasma Physics & Technology	Dr.Anand Moorti	moorti@rrcat.gov.in
Fibre Optics & Fibre Sensors	Dr. Om Prakash	oprakash@rrcat.gov.in
Physics of semiconductor Quantum Structures	Dr. Pankaj Misra	pmisra@rrcat.gov.in
Magnet Physics & Technology	Shri S.N. Singh	snsingh@rrcat.gov.in
Advanced Course on Atom-Photon Interactions	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Statistical Physics	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Course on Bio-Photonics	Dr. S.K.Majumder	shkm@rrcat.gov.in
Power Supplies	Shri M.L. Gandhi	mlg@rrcat.gov.in
Digital Signal, Image Processing & Applications	Shri Viraj Bhanage	viraj@rrcat.gov.in
Digital Control Systems	Dr. Rishi Pal Yadav	rpyadav@rrcat.gov.in
Reliability Engineering	Dr. Mangesh B. Borage	mbb@rrcat.gov.in
Advanced Power Electronics	Dr. Mangesh B. Borage	mbb@rrcat.gov.in
Advanced Course on RF and Microwave	Dr. Akhilesh Jain	ajain@rrcat.gov.in
Real Time Embedded Systems	Dr. R. P. Yadav	rpyadav@rrcat.gov.in
Advanced Course in High Voltage Engineering	Sh. Yashpal Singh	ysp@rrcat.gov.in
Digital Control Systems	Dr. R. P. Yadav	rpyadav@rrcat.gov.in

FOUNDATION COURSES

03ENGG01-001-F: Physics Courses for Engineering Graduates (Lectures: 45, Credit: 3)

Course Details:

- **Quantum Physics**
  Wave-particle dualism. Wave function, operators, expectation values, Schrodinger equation, Some applications: particle in a box, harmonic oscillator and hydrogen atom.Atomic and Molecular Physics: Hydrogen spectrum, selection rules. Fine and hyperfine structure. Many electron atoms, energy levels structure, angular momentum coupling like LS & JJ; molecular structure, chemical bonding; electronic, vibration and rotational levels of molecules, Frank-Condon principle, radiative and non-radiative processes in atoms and molecules e.g. fluorescence, phosphorescence, energy transfer, and Raman effect. Special Theory of Relativity: Galilean transformation, Lorentz transformation, relativistic dynamics - length contraction and time dilation, mass-energy relation..

- **Solid-state physics:**
  Bonding in solids. Bloch theorem, band structure in periodic systems. Fermi levels, semiconductors, metals and insulators. Normal modes of vibrations and phonons. Specific heat of solids.Nuclear Physics: Binding energy, nuclear structure and models. Alpha, beta and gamma decay. Fission and fusion processes

- **Optics:**
  General concepts, Equipments/materials required with few typical examples, Scope and limitations of Concepts of wave front amplitude, phase and coherence, Basic ideas of interference, diffraction and polarization. Michelson interferometer.

Course Outcomes:

To familiarize the engineering background students with basics of physics and update their knowledge in physics aspects of engineering.

03ENGG01-002-F:Engineering Courses for Physics Post-Graduates(Lectures: 45, Credit: 3)

Course Details:

- **Introduction to Mechanical Engineering:**
  Basics, dimensional management and tolerance analysis. Surface texture; standard machine elements, their specifications and usage.

- **Design and manufacturing:**
  Evolution of product, process of design, parameter determination based on numerical calculations; Material properties and selection; Introduction to material joining & machining processes.

- **Power Devices and Circuits:**
  Rectifier diode, Zener diode ,Bipolar junction transistor, MOSFET, IGBT, SCR, Triac & GTO: Principle of operation, characteristics, Specifications, Ratings, Protections, Series/Parallel operation, Thermal considerations.Transformers, Inductors, Saturable reactors: Principle of operation, Parameters, Different types, Specifications, Ratings.Circuit theory and applications and High voltage Switches: Thyratron, Spark gap: Principle of operation, Characteristics, Specifications, Ratings, ProtectionsSwitching circuit analysis: R-L, R-C, R-L-C circuits. Power amplifiers: Types, Biasing, Load line, Circuit configuration, preliminary design aspects.

- **Electronics and Instrumentation:**
  Basics of operational amplifiers, linear and nonlinear circuits based on opamps; Principles and types of ADC and DAC, specifications; Digital circuits- combinational and sequential; Logic families; Introduction to microprocessors and PCs, interfacing with PC with serial and parallel modes; Transducers: Temperature, pressure etc; Oscilloscope, logic analyzer, multimeter etc.
  RF and Microwave system Fundamentals: Basic concepts: frequency band designations, units of RF power measurements Transmission modes TEM, TE, TM, co-axial lines, microstriplines, waveguides, VSWR, insertion loss, reflection coefficients RF cavities: Physics of RF cavities, shunt impedance, quality factor, coupling: modes, HOMs, multipactoring, transit time factor; superconducting cavities RF and microwave passive devices: Microwave diodes, isolators, circulators, directional couplers, power dividers/combiners, RF Load.
  RF amplifier systems and active devices: RF transistors, FETS, klystrons, magnetrons, tetrodes, triodes. Measurements: Fundamentals of RF and microwave measurements, S-parameters, measuring RF instruments, VNA, spectrum Analyzers, RF power meter, Smith chart and applications.
  Typical RF & Microwave systems for accelerators: Pulsed microwave systems, CW RF systems for SRS and proton accelerators

Course Outcomes:

To familiarize the physics background students with various essential engineering skills so that they are able to take up inter-disciplinary projects.

CORE COURSES

03ENGG01-007-C: Numerical Methods and Computing Methodologies (Lectures: 35Hrs, Lab: 15 Hrs, Credit: 3)

Coordinators: Dr. Ajit Upadhyay(ajitup@rrcat.gov.in),
Dr. Jitendra Patil(jkmadaan@rrcat.gov.in)

Course Details:

- ***Numerical Methods : (Lectures 25, Lab: 5Hrs)***

  - **System of Linear Algebraic Equations:**
  Direct methods - Gauss elimination and Gauss Jordan methods. Iterative methods - Jacobi, Gauss-Seidel and Successive over relaxation (SOR) methods. Eigenvalue problem .

  - **System of Nonlinear Equations:**
  Newton-Raphson and Secant methods. Roots of polynomials, synthetic division of polynomials, and Baristow method.

  - **Interpolation, Extrapolation, Error and Regression Analysis:**
  Types of errors their analysis.

  - **Numerical Integration:**
  Newton-Cotes, Gauss quadratures, trapezoidal, Simpson's 1/3 and 3/8 rule. Numerical differentiation - forward, backward and central difference quotient..

  - **Differential Equation:**
  Solution of ordinary differential equations. Solution of partial differential equations. Fast Fourier transformation.

  - **Statistical Distributions:**
  Poisson and Gaussian distributions. Monte Carlo simulation, pseudo random numbers, and central limit theorem.

  - **Interpolation, Extrapolation, Error and Regression Analysis:**
  Types of errors their analysis.

- ***Finite Element Method (FEM)***

  - **Introduction:**
  Basic concepts of finite element method, application of finite element method, finite element method versus classical methods, finite element method versus finite difference method, and advantage of finite element method.

  - **Integral Formulations for Numerical Solutions:**
  Variational method, collocation method; subdomain method, weighted residual methods, Rayleigh-Ritz method, Galarkin's method, and least square method.

- **Elements, Nodes, and Co-ordinate Systems:**
  Introduction, element shapes, nodes, nodal unknowns, and coordinate systems

- **Shape Functions:**
  Introduction, polynomial shape functions, convergence requirement of shape function, and derivation of shape functions.

- **Introduction to Stiffness (Displacement) Method:**
  Definition of the stiffness matrix, derivation of the stiffness, matrix, assembly of the total stiffness matrix, properties of the global stiffness matrix.

- **Application of Finite Element Method in Heat Transfer Problem:**
  Fundamentals, one dimensional finite element formulation, and problems.

▪ ***Computing Methodologies : (Lectures 10, Lab: 10Hrs)***

- **Operating System Basic:**
  Linux, windows, shell programming, and CLI, vi, multithreading, multiuser, multitasking, hyper threading, file permissions, and ssh.

- **Networking Basic:**
  TCP/IP, DNS, Internet, and Intranet.

- **Introduction to C Programming Language:**
  Program structure, header files, basic data types, variables, and declarations.

- **Operators and Declarations in C:**
  Relational, logical, increment, and decrement operators. Expressions and precedence of operators. Input and output operations, control statements, iterative loops, arrays, and pointers.

- **Overview of Scientific Computing:**
  Languages and compilers and scientific libraries.

- **Overview of Trends and Techniques:**
  Sequential, parallel computing, cluster and grid computing.

- **Architecture Taxonomy:**
  Traditional architecture, Flynn's classical taxonomy, SISD, SIMD, MISD, and MIMD Models.

- **Steps for Creating a Parallel Program:**
  Decomposition of the program, communication, computations, and composing the results. Parallel example-array processing.

Course Outcomes:

Imparting knowledge on advances in numerical methods and computing methodologies.

Reference books:

1. "Numerical Methods for Engineers with Personal Computer", S.C Chapra and R. P. Canale
2. "Numerical Analysis", R. L. Burden and J. Douglas Faires
3. "An Introduction to Numerical Analysis", K.E. Atkinson

4. "Numerical Method", E. Balagurusamy
5. "Numerical Methods for Engineers", D. V. Griffiths and I. M. Smith

6. "Data Reduction and Error Analysis for the Physical Sciences", P. R. Bevington and D. K. Robinson
7. "Finite Element Analysis", S. Krishnamurthy
8. "Introduction to the Finite Element Method", Desai and Abel 4
9. "An Introduction to the Finite Element Method", J. N. Reddy
10. "Concepts and Applications of Finite Element Analysis", R. D. Cook 11. "Finite Element Modeling for Stress Analysis", R. D. Cook 12. "Finite Elements and Approximation", O. C. Zienkiewicz and K. Morgan

03ENGG01-001-C: Mathematical Methods in Science and Engineering (Lectures: 30, Credit: 2)

Coordinators: Dr. Ajit Upadhyay
(ajitup@rrcat.gov.in)

Course Details:

- **Complex Analysis:**
  Analytic functions, Cauchy-Reimann conditions, Cauchy integral theorem, Laurent expansion, conformal mapping, singularities, calculus of residues, evaluation of definite integrals. Principal value of integrals, Analytic continuation, Dispersion relation, The Method of Steepest Descent.

- **Linear Vector Spaces, Matrices and Tensors:**
  Real and complex linear vector spaces, Scalar product, Dual Vectors, Cauchy-Schwartz Inequality, Metric Spaces, Linear Operators and their algebra, Linear independence of Vectors, Eigen values and Eigen vectors, Representation of Linear Operators, Matrix algebra, Symmetric, Skew-symmetric, Orthogonal, Hermitian, Skew-Hermitian and Unitary matrices, Change of basis, Tensors in real vector space, Tensor functions, Rotations, Invariant subspaces

- **Function Space, Orthogonal Polynomials and Integral Transform:**
  Metric properties of the space of continuous functions, Lebesgue integral, The Reisz-Fisher Theorem, Expansions in orthogonal functions, Hilbert space, The Weistrass theorem, Classical orthogonal polynomials, Laplace and Fourier Transforms.

- **Ordinary and Partial Differential Equations:**
  Review of ordinary differential equations, Introductions to partial differential equations, classification of partial differential equations, boundary and types of partial differential equations, Green's function technique for solving differential equation, Introduction to difference equations., Introduction of Geometric methods for analysis of nonlinear differential equations.

- **Group Theory:**
  Basic introduction, Representations of groups, Symmetry and degeneracy, Lie groups and Lie algebras, The orthogonal group in three dimensions, A few representative applications in classical and quantum physics.

Course Outcomes:

- Imparting / updating knowledge on the subject

References:

1. Mathematics for Physicists, P. Dennery and A. Krzywicki
2. Mathematical Methods in Classical and Quantum Physics, T. Dass and S. K. Sharma
3. Mathematical Methods for Physicist, G. Arfken
4. Mathematical Methods for Scientists and Engineers, Donald A. McQuarrie
5. Ordinary Differential Equations, V.I. Arnold
6. Advance Engineering Mathematics, Erwin Kreyszig

03ENGG01-004-C: Electromagnetic Theory (Lecture: 40, Credit: 2)

Coordinators: Dr. Anand Moorti
(moorti@rrcat.gov.in)

Course Details:

- **Electrostatics:**
  Electrostatic field in matter. Laplace equation and the uniqueness theorems, variational approach to solutions of the Laplace and Poisson equations. Formal solutions of electrostatic boundary value problems with Green function. Method of relaxation for 2D electrostatic problems, method of images, separation of 5 variables and special functions, Application of finite element method in solving electromagnetic problems.

- **Magnetostatics:**
  Maxwell equations of magnetostatic, macroscopic Maxwell equations in magnetic material and boundary conditions on B and H, and solution of boundary value problems in magnetostatics.

- **Electromagnetic Wave:**
  Wave equation and its solutions, plane waves, Gaussian beams, pulse propagation in material media, dispersion relations, Fresnel's laws of reflection and refraction, total internal reflection and evanescent waves. Negative refractive index.

- **Wave-guides, Resonant Cavities and Optical Fibers:**
  Hollow metallic waveguides, dielectric waveguides, optical fibers, resonant cavities, and elements of microwave transport line.

- **Radiation by Moving Charges:**
  Lienard-Wiechert potentials and fields, power radiated by an accelerated charge, Larmor's formula, and angular distribution of emitted radiation, Characterization of synchrotron radiation. Lorentz transformation of electromagnetic fields.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Electromagnetic Theory", D. J. Griffith
2. "Classical Electrodynamics", J. D. Jackson
3. "Soft X-rays and Extreme Ultraviolet Radiation: Principle and Applications", D. T. Atwood
4. "Microwave Devices and Circuits", S. Y. Liao

03ENGG01-003-C: Laser Physics and Technology (Lectures: 40, Credit: 2)

Coordinators: Dr. Ajit Upadhyay
(ajitup@rrcat.gov.in)

Course Details:

- **Basic Formalism:**

  Spontaneous and induced transitions, Einstein's approach, A and B coefficients, conditions for light amplification and oscillations, and characteristics of laser light. Homogeneous and inhomogeneous broadening of the transitions, spectral narrowing in a laser, gain saturation, spatial and spectral hole burning and their consequences, Lamb dip spectroscopy and its applications.

  Propagation of optical beams in free space and in dielectric slab waveguides, Hermite-Gaussian beam modes, and ABCD law for Gaussian beam propagation.

  Optical resonators, concept of cavity modes, resonators with spherical mirrors, resonance frequencies of optical resonators, losses in optical resonators, stable/ unstable resonators, Kirchoff's diffraction treatment for transverse modes.

- **Methods For Obtaining Population Inversion:**

  Optical pumping, coherent and incoherent pumping, one- and two-photon processes, pumping geometries, pump sources, electrical pumping by discharge in gases, excitation mechanisms, self sustained and e-beam sustained operation, chemical pumping, and gas dynamic pumping.

- **Laser Dynamics:**

  Laser oscillation, three and four level lasers, rate equation modeling, power in laser oscillators, optimum output coupling low- and high-loss regimes, multimode laser oscillation and mode locking. Different techniques of mode locking. Relaxation oscillations, cavity dumping and Q-switching. Techniques of Qswitching. Pulse compression techniques for ultrashort pulse generation. Spectral 6 control of laser output, tunability of output frequency, single frequency operation, and frequency stabilization.

- **Physics and Technology of Specific Laser Systems:**

  Solid state lasers, vibronic lasers, semiconductor diode lasers, diode pumped solid state lasers, fiber lasers, dye lasers, atomic and molecular gas lasers, chemical lasers, excimer lasers, free electron lasers. Measurement of parameters of a laser system.

- **Nonlinear Optics:**

  Crystal optics, electro-optic effect, wave propagation in nonlinear media, phase matched second harmonic generation, optical parametric oscillator, two-photon absorption, stimulated Raman scattering, frequency mixing in gases and vapours, self-focusing, optical bistability and optical phase conjugation. Quantum optics: second quantization, non-classical effects.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Laser Fundamentals", W. T. Silfvast
2. "Laser Electronics", J. T. Verdeyen
3. "Lasers", A. E. Siegman
4. "Quantum Electronics", A. Yariv
5. "Laser Physics and Technology, Proc. of the school on Laser Physics and Tech." Eds. P. K Gupta, R. Khare
6. "Nonlinear Optics", R. W. Boyd
7. "Elements of Nonlinear optics", P. N Butcher and D Cotter

03ENGG01-005-C: Accelerator Physics and Beam Diagnostics (Lectures: 40, Credit: 2)

Coordinators: Dr. K. K. Pant
(kkpant@rrcat.gov.in)

Course Details:

- **Introduction:**
  Motion under electric and magnetic fields. DC and RF acceleration. Relativistic kinematics, Brief history and review of particle accelerators.

- **Synchrotron/Storage Rings:**
  Accelerator magnets - dipole, quadrupole and sextupole magnets. Multipole expansion method. Equation of motion, betatron oscillations, weak and strong focusing, transfer matrices, beam stability, twiss parameters, motion of particles with momentum deviation, momentum compaction, and chromaticity. Magnetic field errors, closed orbit distortion and its correction, resonances - integer and half integer, beam acceleration, synchrotron oscillations, phase stability, transition energy, beam emittance, Liouville's theorem, single turn injection, H-injection, and fast extraction.

- **Beam Transfer Lines:**
  FODO cells, quadrupole triplet, phase space matching, emittance dilution.

- **Synchrotron Radiation Sources:**
  Synchrotron radiation, Radiation damping, quantum excitations, equilibrium beam emittance, and beam lifetime.

- **Linear Accelerators:**
  DC accelerators, various types of RF accelerators, EM mode in a simple structure, Q-factor, shunt impedance, transit time factor, filling time, energy gain, dispersion curve, TW and SW accelerators, and beam dynamics in LINACS.

- **Cyclotrons:**
  Basic principle of cyclotron, resonance condition, orbit stability, limitations of classical cyclotrons, AVF cyclotrons, injection, central region, extraction, time structure, energy resolution, and beam emittance.

- **Microtrons:**
  Classical microtrons, basic equations, and Racetrack microtrons.

- **Beam Diagnostics:**
  Physical principles, charge collection, secondary emission, Ionization, fluorescence, scintillation, capacitive pick up, magnetic pick up, wall current, synchrotron radiation detection, and optical transition radiation.

- **Instrumentation:**
  Faraday cup, secondary emission wire monitor, beam loss monitor, beam profile monitor, beam position monitor, DC beam current transformer, fast current transformer, wall current monitor, photomultiplier, photo diode, image dissector, and streak camera.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Particle Accelerator Physics", Helmut Wiedemann, Springer

2. "Introduction to Accelerator Physics", Arvind Jain, Macmillan India

3. "CERN Accelerator School Proceedings, Fifth General Accelerator Physics Course, 1992 (Available online)"

4. "The principles of circular accelerators and storage rings", P. J. Bryant and K. Johnsen, Cambridge University Press

5. "Principles of RF linear accelerators", T. Wangler, John Wiley and Sons

6. "Collective phenomenon in synchrotron radiation sources", S. Khan, springer

7. "Physics of collective beam instabilities in high energy accelerators", A. Chao, John Wiley and Sons

03ENGG01-006-C: Radiological Safety and Reactor Physics (Lectures: 30, Credit: 2)

Coordinators: Dr. Haridas G.
(haridas@rrcat.gov.in)

Course Details:

- **Health Physics:**
  Radiation sources - radioisotopes, natural and manmade sources, radioactive series, reactors, accelerators, radiation facilities, solid, liquid and gaseous activity. Control measures - time, distance, decay, shielding, administrative control, radioactive discharge, waste disposal, and exposure control.

- **Interaction of Radiation with Matter:**
  Interaction of light and heavy charged particles, photons, and neutrons. Interaction of high energy charged particles, electromagnetic cascade, and Hardronic cascade.

- **Radiation Quantities, Units, and Regulatory Recommendations:**
  Dosimetric quantities, exposure, absorbed dose, equivalent and effective dose, committed dose, ALI, DAC, ICRP, AERB, and dose limits.

- **Biological Effects of Radiation:**
  Somatic and genetic effects, stochastic and deterministic effects, and LD30/50.

- **Detection of Radiation:**
  Ionisation chamber, proportional counters, GM tubes, scintillation detectors, semiconductor detectors, thermoluminiscent dosimeters, direct reading dosimeters neutron detectors, BF3 and He3 tubes, Rem-meters, CR-39-foils, pulsed radiation detection. Low and high energy radiation detection.

- **Reactor Physics:**
  Introduction to nuclear energy – fission and fusion, interaction of neutrons with matter; fission process and energy release, fission cross-section, fissile and fertile materials. Chain reaction, neutron cycle and lifetime, criticality and classical four-factor formula. Thermal and fast systems, slowing down of neutrons, conversion and breeding of fissile materials, concept of neutron flux and current, neutron diffusion theory, critical size and mass, reflected systems and reflector saving, heterogeneous systems. Reactor kinetics, reactivity and importance of delayed neutrons, reactivity changes and coefficients, fission product poisoning, control devices, uranium and thorium fuel cycles and enrichment processes.

- **Accelerator Safety:**
  Types of accelerators, prompt and residual radiation, source terms, radiation hazards, radiation safety systems, shielding, radiation monitoring, non-ionizing radiation safety, RF and MW safety, magnetic field safety; ozone safety, safety at synchrotron radiation beam lines, spallation neutron sources, and accelerator driven sub-critical systems.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Nuclear Reactor Engineering Vol-1", Samuel Glasstone and Sesonske
2. "Health Physics", Herman Cember

3. "Radiation Detection & Measurement", G. F. Knoll
4. "Atoms, Radiation & Radiation Protection", James Turner
5. "Physics for Radiation Protection", James Martin
6. "Radiological Safety Aspects of the Operation of Electron Accelerators, IAEA Technical Report Series. 188", W. P. Swanson
7. "Radiation Protection for Particle Accelerator Facilities NCRP Report No.144"
8. "Radiological Safety Aspects of the Operation of Proton Accelerators. IAEA Technical Report Series. 283", R. H.Thomas.
9. "A Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators Nuclear Technology", A. Sullivan

03ENGG01-011-C: Vacuum Physics and Technology (Lectures: 25, Credit: 1)

Coordinators: Shri D. P. Yadav
(dpyadav@rrcat.gov.in)

Course Details:

- **Vacuum Theory:**
  Definitions - throughput, conductance, pumping speed etc. Pressure equations, mean free path. Units of vacuum, pressure regions in vacuum, Gas load calculation and ultimate pressure, estimation of gas loads.

- **Vacuum Systems and Components:**
  Vacuum pumps - rotary pumps, dry pumps, turbomolecular pump, sorption and getter pumps, sputter ion pump, Pump characteristics and controllers, Vacuum gauges - capacitance gauge, Pirani, thermocouple gauges, BA gauge and controllers, penning gauge, partial pressure gauge, Inverted magnetron gauge, extractor gauge, flanges and seals, vacuum valves and feed throughs.

- **Vacuum System Design and Development:**
  Design considerations, sources of gas load (vaporization, thermal desorption, diffusion, permeation, electron and ion stimulated desorption etc). Materials, fabrication techniques and leak detection. Processing to achieve ultra high vacuum.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Handbook of Vacuum Science and Technology", Ed. Dorothy M. Hoffman, Bawa Singh, John H. Thomas III and John H. Thomas III
2. "Vacuum Technology -3rd edition", A. Roth
3. "A User's Guide to Vacuum Technology - July 4, 2003", John F. O'Hanlon
4. "Vacuum Engineering Calculations, Formulas", Armand Berman 5. "Vacuum Technology-CERN Accelerator School", CERN

03ENGG01-008-C: Basic Solid-State Physics and Material Sciences (Lectures: 30, Credit: 2)

Coordinators: Dr. Indranil Bhaumik
(neel@rrcat.gov.in)

Course Details:

- **Atomic Structures of Crystals:**
  Crystal systems, Choice of unit cell and symmetry consideration, Bravais lattice: 2D, 3D and Symmetry operations; Reciprocal lattice; Structure determination by scattering: structure factor, concept of Ewald sphere; Types of bonding in solid.

- **Lattice dynamics and thermal properties:**
  Classical vibration in one and three dimensions, Quantum theory of harmonic crystal: Quantization, energy and momentum conservation; Specific heat: Einstein, Debye model and beyond (correction from actual phonon dispersion curve); Thermal conductivity: Effect of Phonon scattering and mean free path, Graphene, carbon nanotube and polymer; Thermal expansion: Effect of anharmonic oscillator model; Negative thermal expansion, Grüneisen parameter.

- **Free electron model:**
  Drude model, Relaxation time approximation, Electrical conductivity of metal, Wiedemann-Franz law, Hall effect, Seebeck effect, Thermoelectric effect. Quantum theory of free electron gas (Sommerfeld model of metal), Density of states, Specific heat and Thermal conductivity of metal.

- **Electronic band structure of solids:**
  Bloch theorem, free electron and tight binding electron approximations for band structure, Concept of holes and effective mass, Electronic properties of selected crystals, Optical properties.

- **Electron-electron interaction:**
  Hartree and Hartree-Fock equations, Density Functional theory, Electronic properties and phase diagram of homogeneous electron gas, and Fermi liquid theory. (5)

- **Electronic states at the surface:**
  Work function, Contact potential, Thermoionic emission, Electronic surface levels, Topological insulator. (3)

- **Magnetism:**
  Quantum Theory of diamagnetism and paramagnetism, Magnetism of free electron gas, Pauli paramagnetism and Landau diamagnetism. Quantum mechanics of interacting magnetic movements. Origin of ferromagnetism and antiferromagnetism; Stoners model of ferromagnetism. Direct indirect, and super exchange. Order-disorder transition in magnetism.

- **Dielectric properties of materials:**
  Polarization mechanisms in dielectrics, Dispersion in dielectric material; Principles of piezoelectricity, transducers and energy harvesting materials; Pyroelectricity and Ferroelectricity. (4)

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. Solid State Physics, N. W. Ashcroft and N. D. Mermin
2. Condensed Matter Physics, M. P. Marder
3. Solid State Physics, An introduction to the Principles of Materials Science, H. Ibach and H. Luth
4. Atomic and Electronic Structure of Solids, E. Kaxiras
5. Dielectric Phenomena in Solids: With Emphasis on Physical Concepts of Electronic Processes: Kwan-Chi Kao

Engineering Based Elective Courses for Engineering TSOs

03ENGG01-001-E: Power Supplies (Lectures :30, Credit: 2)

Coordinators: Shri M. L. Gandhi
(mlg@rrcat.gov.in)

Course Details:

- **AC-DC Converters:**
  Single phase and three phase diode and controlled rectifiers, effect of source inductance, ripple and harmonic analysis, 12-pulse rectifier, firing angle control schemes, THD and power factor, filters - passive and active, passive and active damping of filters.

- **Power factor Correction:**
  Effects and limiting standards for line current harmonics, Passive PFC techniques, Active PFC. 10

- **DC-DC Converters:**
  Principle of operation, steady-state analysis of buck, boost, buck-boost converters, Isolated dc-dc converters- forward, flyback and bridge converters, pulse width modulator and control of dc-dc converters.

- **Principles of Feedback Control System:**
  Negative feedback, Stability criteria- gain and phase margin, steady state errors, transient response, current loop and voltage loop acting together.

- **Magnet power supplies in Accelerators:**
  Requirements, Load characterisation, DC and ramping type power supplies, Pulsed power supplies.

- **High current magnet power supplies:**
  Stability requirements, current cycling, Field stabilization.

- **Power supplies for superconducting magnets :**
  Load requirements, quench detection, protection and training.

- **Laser and Plasma power supplies:**
  Load characterisation, Gas discharge, Ballast requirements, CW/Pulsed operation, Current stabilisation, Power coupling schemes to gas discharges.

- **Thermal Management:**
  Heat transfer, Heat sink design, Water- cooled heat sinks.

Course Outcomes:

Imparting / updating knowledge on the subject

03ENGG01-002-E: Advanced Power Electronics (Lectures :30, Credit: 2)

Coordinators: Dr. Mangesh B. Borage
(mbb@rrcat.gov.in)

Course Details:

- **Power Semiconductor Devices:**
  Diode, SCR, MOSFET, IGBT, Static and switching characteristics, Safe operating areas, Drive requirements and circuits, Introduction to the properties of emerging materials and devices, High voltage switches, Turn-on and turn-off snubbers.

- **Modelling and Analysis :**
  Introduction to modelling and analysis techniques for dcdc converters, Averaged equivalent circuit modelling and analysis, small-signal analysis with an illustrative converter, Feedback control of power converters: Feedback controller design, voltage- mode control and current-mode control, reliability, production of power converters.

- **Soft-switching Converters:**
  Concept of soft-switching, Load resonant converters: concept and definition, ac analysis of converters and modes of operation, Full bridge zero voltage switching converter: Phase shifted PWM, Operation and analysis of converter in steady state.

- **High frequency Magnetics:**
  Ferrites- characteristics and types, skin effect, proximity effect, parasitic components- origin, minimisation and characterisation, design of high frequency magnetic components, introduction to planar magnetics.

- **Electromagnetic Interference:**
  Measurement techniques, LISN, separation of common mode and differential mode noise, limiting standards and mitigation techniques, design of high frequency filters.

Course Outcomes:

Imparting / updating knowledge on the subject

03ENGG01-003-E: Advanced Course on RF and Microwaves (Lectures: 30, Credit: 2)

Coordinators: Dr. Akhilesh Jain
(ajain@rrcat.gov.in)

Course Details:

- **Microwave Networks:**
  S-parameters, Matrix representation of Microwave networks and its properties, cascade networks, periodic network system and application, mixed mode S parameters and their applications, Smith chart and applications.

- **Generation of RF power for accelerators:**
  Design requirements, RF power amplifiers using tetrode & triodes and solid state devices, klystrons, IOT, Gyrotron, Cooling and protection, Grounding and shielding.

- **High Power RF transmission:**
  design aspect of high power RF transmission, directional couplers, dividers, combiners, high power waveguide and coaxial transmission lines, circulators, bends, magic-T, microwave windows, dummy loads, RF couplers.

- **Accelerator cavities:**
  Characterizing RF cavity, determination of important cavity parameters, Fundamentals of beam-cavity interactions. RF power coupling to cavity, superconducting cavities.

- **Low level RF components and systems:**
  Planar circuits, microstrips, substrate materials, lumped and distributed circuits, mixer circuits, phase shifters, filters, switches, couplers, dividers/combiners, Low level RF signal processing and RF feedback systems.

- **RF systems for accelerators:**
  Design and configuration of typical RF system, Safety interlocks and operation of RF system.

- **RF/Microwave measurements:**
  Specialty of high frequency measurements, Measurement of RF power, impedance, VSWR, frequency and phase. Measuring instruments used in RF/microwaves, passive and active detectors, spectrum analyzer, VNA calibration systems, Vector measurement with VNA, peak and average power meters, impedance analyzer, frequency counter.

Course Outcomes:

Imparting / updating knowledge on the subject

03ENGG01-004-E Real Time Embedded Systems (Lectures :30, Credit: 2)

Coordinators: Dr. R. P. Yadav
(rpyadav@rrcat.gov.in)

Course Details:

- Introduction to embedded system, Prototyping and emulation techniques, Hardware components, System-on-Chip, Finite state machines, Networks for embedded systems.

- Introduction to real time systems, Real time programming and operating system, Operating system evaluation, scheduling, Multi-tasking and resource sharing, Concurrent programming, Multi-rate systems, Inter-process communication, Real Time Interfacing, Software reliability.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. Embedded system design: A unified hardware/Software introduction, Frank Vahid, Wiley, 2002.
2. A Practical introduction to hardware/software co-design, Patrick Schaumont, Springer, 2012.
3. Real-Time Systems Development, Rob Williams, Elsevier, 2006.
4. Real-Time systems, scheduling, analysis and verification, Albert M K Cheng, John Wiley and sons, 2002.

03ENGG01-005-E: Reliability Engineering (Lectures: 30, Credit: 2)

Coordinators: Dr. Mangesh B. Borage
(mbb@rrcat.gov.in)

Course Details:

- **Basic engineering statistics:**

  Basic probability, random variables, probability density and cumulative distribution functions of engineering importance such as the binomial, poisson, normal, exponential, weibull, etc.

  Random sampling and sampling statistics and distribution of sampling statistics, such as the Chi-Square and Students test, point and interval parameter estimation, test of hypothesis, examples to solve on continuous and discrete distributions, mathematical equations relating to hazard rate, reliability, cumulative failure probability and failure probability (density) function, Bath-tub curve - explanation of different parts of the life characteristic curve and corresponding failure distributions.

  Quality and reliability, QA/QC concepts – Acceptance sampling plans, quality measurement, quality improvement and control methods with applications in design, development, and manufacturing, modern quality management philosophies, engineering/statistical methods including process control, control charts, process capability studies, loss functions, design of experiments, and total quality management (TQM) topics.

  Reliability, availability and maintainability concepts and principles, reliability statistical analysis concept overview and application, accelerated life testing concepts, principles and application, qualitative and quantitative accelerated life testing principles, life-stress relationships and application to electronic components and semiconductor devices, software reliability issues, reliability prediction for electronic systems, system reliability concepts and case studies, role of redundancy in system reliability, design for reliability concepts and case studies, degradation analysis and case studies, reliability or life characteristics of hardware electronic circuit components, and comparison with the characteristics of mechanical/electromechanical components and computer software, hardware reliability analysis of electronic and computer based C&I systems based on MIL-STD-217, methods of measuring the reliability effectiveness of complex engineering systems, optimization theory, preventive maintenance models, and statistical analysis.

Course Outcomes:

Imparting / updating knowledge on the subject

03ENGG01-006-E: Advanced Course in High Voltage Engineering (Lectures: 30, Credit: 2)

Coordinators: Shri. Yashpal Singh
(ysp@rrcat.gov.in)

Course Details:

- **High Voltage Technology:**
  Introduction, classification of voltage levels, high voltage in electric supply network, major components of a high voltage network.

- **Electrostatic Fields and their Control:**
  Electric field intensity, electric strength, classification of electric fields, degree of uniformity of electric fields, control of electric field intensity.

  - **Dielectric Materials and their Behavior in Electric Fields:**
    - **Insulating Behavior of Air and other Gaseous Dielectrics:**
      Generation of charge carriers: impact ionization, thermal ionization and photo-ionization, Negative ion formation, Breakdown by avalanche discharge (Townsend

      Mechanism); Breakdown voltage characteristics in uniform fields (Paschen's Law) Practical factors affecting the breakdown voltage: Corona, Fields non-uniform, high pressure and vacuum.

    - **Liquid Dielectrics in High Voltage applications:**
      Mineral insulating oils, Dielectric properties of insulating liquids, Dielectric power losses in insulating materials, Breakdown in liquid dielectrics, Aging of mineral insulating oils.

    - **Solid Dielectrics and their Behavior in Electric Fields:**
      Classification of solid insulating materials, Breakdown and pre-breakdown phenomena in solid dielectrics, Partial discharge and its effects on dielectrics.

- **Generation of High Voltages:**
  - **Alternating voltages:**
    single step-up transformer, Transformers in cascade, Voltage control of testing transformers, Series resonant circuits.
  - **Direct Voltages:**
    Half wave and full wave rectification, Voltage doublers and cascade circuits.
  - **Impulse Voltages:**
    Single stage impulse generator, Multistage Marx generator, Practical Impulse Generators.

- **High Voltage Test & Measurement:**
  Types of tests, Power frequency tests, DC voltage test and Impulse withstand test, Peak voltage measurements by spark gaps, Sphere gaps and uniform field gaps, Voltage measurement using ammeter in series with high impedance, Voltage measurement using potential dividers, Generating voltmeter, Voltage and current transformers.

- **High Voltage Design and Applications:**
  Design considerations of high voltage bushings, power cables, transformers and switchgears; high voltage applications and electrostatic hazards. High Voltage Safety and Protection.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "High Voltage Engineering", E. Kuffel and W S Zaengl.
2. "High Voltage Measurement, Testing and Design", T J Gallagher and A J Pearmain
3. "High Voltage Insulation Engineering", Prof. Ravindra Arora and Prof. Wolfgang Mosch
4. "High Voltage Technology", L. L. Alston

03ENGG01-007-E: Digital Signal, Image Processing and Applications (Lectures: 30, Credit: 2)

Coordinators: Shri. Viraj Bhanage
(viraj@rrcat.gov.in)

Course Details:

- **Introduction:**
  Digital image, steps of digital image processing systems, elements of visual perception, connectivity and relations between pixels. Image acquisition: Frame grabber, optics and illumination Simple Operations - Arithmetic, Logical, geometric operations.

- **Mathematical Preliminaries:**
  2D LTI systems, 2D convolution, correlation, 2D random sequence, 2D spectrum.

- **Image Transforms:**
  2D orthogonal and unitary transforms- properties and examples. 2D DFT, histogram, image smoothening, image filtering, Sharpening, thresholding.

- **Image Segmentation and Analysis:**
  Edge detection, line detection, curve detection, Edge linking and boundary extraction, boundary representation, region representation and segmentation, morphology-dilation, erosion, opening and closing. Image understanding and recognition: Matching by templates, classifiers models, statistical, matching shapes by contour and texture.

- **Review of LTI systems:**
  Fourier transform for discrete-time signals and its properties, comparison with continuous-time Fourier transform. Discrete time signals, sequences, representation of signals on orthogonal basis, sampling and reconstruction of signals.
  Signal analysis using the Fourier transform, impulse function and complex exponential signal, modulation and frequency translation, duality, Fourier transform of periodic signals, correlation, energy and power spectral density, Hilbert transform, Fourier transform of finite-duration discrete - time sequences.
  Z-transform, Discrete Fourier Transform (DFT), Fast Fourier Transform algorithm and applications. Design of FIR & IIR digital filters, effect of finite register length in FIR filter design. Overview of DSP processors, FPGAs, Signal processing tool based system design. Typical applications in Lasers and Accelerators.

Course Outcomes:

Imparting / updating knowledge on the subject

Reference:

1. “Digital Image Processing”, Rafel C Gonzalez, and Richard E Woods.
2. “Fundamental of Digital image processing”, A K Jain.
3. “Fundamentals of Electronic Image Processing”, A R Weeks Jr.

4. “Practical Image Processing in C; Wiley professional Computing”, Dr. Craig A Lindsey.
5. “Digital image processing: concepts, algorithms, and scientific applications”, Jaehne, Bernd.
6. “Digital Imaging: Theory and applications”, Burdick Howard E.
7. “Two dimensional signal and Image processing”, Lim Jae S, V Oppenheim Allan.
8. "Discrete-Time Signal Processing", A. Oppenheim, R. Schafer and J. Buck.
9. "Signals and Systems", Oppenheim, Willsky and Nawab.
10. “Discrete Time Signal Processing”, A.V. Oppenheim and Schafer.
11. “Digital Signal Processing: Principle, Algorithms and Applications”, John G. Proakis and D.G. Manolakis.
12. “Theory and Application of Digital Signal Processing”, L.R. Rabiner and B. Gold.
13. “Introduction to Digital Signal Processing”, J.R. Johnson.
14. “Digital Signal Processing”, D. J. DeFatta, J. G. Lucas and W. S. Hodgkiss.

03ENGG01-007-E: Digital control systems (Lectures :30, Credit: 2)

Coordinators: Dr. R. P. Yadav
(rpyadav@rrcat.gov.in)

Course Details:

- **Introduction**
  Discrete time systems, Difference equation, Z-transform, bilinear transformation, Jury criterion for system stability, Introduction to control system tools for System Identification, Observer and Controller design.

- **State models for discrete systems**
  Introduction to state-space, State transition matrix, Eigenvalues and singularity, Transfer function and Impulse response matrices, State-space analysis of multi-variable and multi-loop systems.

- **Optimal and adaptive Control**
  Formulation of optimal control problems, Linear quadratic regulator, Optimal estimation, Introduction to adaptive control system, Recursive parameter estimation.

- **Applications of modern control system**
  Discrete form of PID controllers, Realization of Deadbeat and Dahlin's algorithms, Control techniques for power electronics circuits, Control systems for particle accelerators.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. Modern Control Systems, K. Ogata, , Prentice Hall (India)
2. Digital Control and State Variable Methods, M. Gopal, Tata McGraw Hill, 3rd Edition, 2009.
3. Digital Control Systems - Theory, Hardware, Software, C.M. Houpis and G. B. Lamount, International Student Edition, McGraw Hill Book Co., 1985.
4. Adaptive Control Tutorial, Petros Ioannou and Baris Fidan, SIAM, 2006.

Physics Based Elective Courses for Physics TSOs

03PHYS04-003-E: Statistical Physics (Lectures: 30, Credit: 2)

Coordinators: Dr. Ajit Upadhyay
(ajitup@rrcat.gov.in)

Course Details:

- **Classical and Quantum Statistical Mechanics:**
  Introduction, postulates, microcanonical, canonical and grand canonical ensembles, partition and grand partition functions and their properties.

- **Ideal Bose Gas:**
  Introduction, chemical potential, equation of state and thermodynamic properties, system of phonons, system of photons, Bose-Einstein condensation, Bose-Einstein condensation in dilute atomic gases, and superfluidity.

- **Ideal Fermi Gas:**
  Introduction, equation of state and thermodynamic properties of degenerate Fermi gas. Neutron stars, conduction electrons in metals, and cold Fermi atomic gases.

- **Phase Transition:**
  Mean-field theories, symmetry, order parameters, break-down of mean-field theories, critical phenomena and renormalization group.

- **Non-equilibrium Phenomena:**
  Elementary ideas, irreversibility, study of Brownian motion, random walk model, Langevin force equation, fluctuation-dissipation theorem, Fokker-Planck equation, Glauber dynamics.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Fundamental of Statistical and Thermal Physics", F. Reif
2. "Statistical Mechanics", R. Pathria
3. "Statistical Mechanics", K. Huang 16

03PHYS04-001-E: Advanced Optics (Lectures: 30, Credit: 2)

Coordinators: Dr. S. Verma
(sverma@rrcat.gov.in)

Course Details:

- **Fundamentals of geometric and wave Optics:**
  Concepts of Wave front and phase, complex representation of electromagnetic wave, image formation and spatial resolution, optical path and spatial coherence, monochromaticity and temporal coherence, optics design and wave front aberrations, basics of interference and diffraction, Intensity due to two beam interference, contrast/visibility of fringes.

- **Fourier Optics:**
  Concept of Fourier Transform and far field diffraction, concept of spatial filtering, amplitude and phase filters in spatial frequency domain, image processing, optical correlations in spatial and temporal domains, principles of phase shifting techniques and phase un-wrapping.

- **Modern Optical Instruments:**
  Basics of Michelson, Fabry-Perrot, Mach-Zender Fizeau, Twyman-Green, and lateral shear interferometer, concept of coherence and white light interferometry, scanning white light interferometer(SWLI), Sagnac (cyclic) interferometer, Shack-Hartman wave-front sensor, Nomarsky Microscope, basics of diffraction gratings and spectrometers, modern optical instrumentation like electronoptics (photo-cathodes) and introduction to streak cameras, Dopler velocimetry and Velocity Interferometer System for Any Reflector (VISAR), use of spatial light modulators for amplitude and phase modulation, phase correcting mirrors.

- **Surface imperfections and ISO 1011 standard:**
  Definitions of surface form, parallelism, scratch and Dig and RMS roughness their measurements using surface profilometers, white light confocal microscopy, Nomarsky microscopy and scatterometers.

- **Super resolution and measurements for overcoming diffraction limits:**
  Introduction to Scanning near field optical microscope (SNOM).

- **Optical coatings:**
  Introduction, electromagnetic theory of dielectric coating, antireflection coating, beam splitters, neutral density filters, high-reflection mirror coatings, edge filters, bandpass interference filters, deposition of optical thin film multilayer coatings, infrared optical coatings, characterization of coatings.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. Introduction to Fourier Optics, Joseph W. Goodman

2. Handbook of Optical Design (Optical Science and Engineering), Daniel Malacara

3. Encyclopedia of Optical Engineering, Ronald G. Driggers (Editor)

4. Laser Resonators and Beam Propagation, Norman Hodgson and Horst Weber

5. The Physics and Technology of Laser Resonators, Denis Hall
6. Optical Interferometry, P. Hariharan
7. Theory and Practice of Scanning Optical Microscopy, Colin Sheppard
8. Wave Optics and its Applications, R.S. Sirohi
9. Optical Thin Films and Coatings-From Materials to Applications, Ed. Angela Piegari and François Flory

03PHYS04-002-E: Advanced Accelerator Physics (Lectures: 30, Credit: 2)

Coordinators: Dr. Vinit Kumar
(vinit@rrcat.gov.in)

Course Details:

- **Ion Sources:**
  Emission processes and Child Langmuir Law, positive and negative ion sources, atomic and molecular phenomena in ion sources, beam extraction and transport.
- **Proton and Heavy Ion Accelerators:**
  Introduction to acceleration of protons and heavy ions, RFQ, different type of cavities/accelerating structures, including SCRF, and introductory beam transport.
- **Instabilities in Linear Accelerators:**
  Basics of beam instabilities, short and long range instabilities.
- **Other topics:**
  FEL, Linac based synchrotron sources, laser plasma acceleration, and ADS.

Course Outcomes:

Imparting / updating knowledge on the subject

03PHYS04-004-E: Plasma Physics and Technology (Lectures: 30, Credit: 2)

Coordinators: Dr. Anand Moorti
(moorti@rrcat.gov.in)

Course Details:

- **Basic Plasma Physics:**
  Definition of plasma, concept of temperature, Debye shielding, plasma parameter, criterion for plasma, variety of plasmas.

- **Plasma Behaviour:**
  Single particle motion in electric and magnetic fields, collisions, plasma as fluid, kinetic approach.

- **Waves in Plasmas:**
  Dielectric function, plasma oscillations, electromagnetic equations, dispersion relations.

- **Methods of Plasma Production:**
  Electrical discharge, ohmic heating, RF heating, plasma production by lasers and particle beams, Tokamak plasma, Z-pinch, Theta pinch

- **Plasma Processes:**
  Ionization, recombination, plasma equilibrium. Radiation from Plasmas: Emission processes, spectral characteristics.

- **Plasma Diagnostic Methods:**
  Density and temperature diagnostics using plasma radiation

- **Plasma Heating by Laser Beams:**
  Propagation of laser beam in plasmas, inverse Bremsstrahlung, resonance absorption, parametric processes, second harmonic generation, filamentation, self-focusing.

- **Laser Plasma Interaction at Ultrahigh Intensities:**
  Ultrahigh intensity parameters, multi-photon ionization, tunnel ionization, above threshold ionization, high harmonic generation. Applications of Laser-plasma: Electron acceleration, x-ray lasing, inertial confinement fusion and fast ignition.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Introduction to Plasma Physics and Controlled Fusion Volume 1: Plasma Physics", Francis F. Chen
2. "Fundamentals of Plasma Physics, 3rd Ed.", J. A. Bittencourt Springer
3. "Principles of Plasma Spectroscopy", Hans R. Griem
4. "Principles of Plasma Diagnostics", I H Hutchinson
5. "The Physics of Laser Plasma Interactions", W. L. Kruer
6. "Short Pulse Laser Interaction with Matters: An Introduction", P. Gibbon 18

03PHYS04-005-E: Instrumentation for Material Characterization (Lectures: 30, Credit: 2)

Coordinators: Dr. S. Verma
(sverma@rrcat.gov.in)

Course Details:

- Concept of noise in electrical measurements, sources of noise, noise spectrum. Low signal DC voltage and current measurements, measurement system designing, problems in low signal measurements: ground loops, noise pickup, thermo-electric EMF, electromagnetic interference etc.

- **Resistance and impedance measurement techniques.**

    - **Lock-in detection:**
      principles with mathematical derivation; Analog vs. digital lock-in amplifiers.

    - Measurement of pulsed (nano seconds) electrical signals, RC and LR delays in circuits.

    - High frequency (RF) electrical signal detection and resonant perturbation techniques for studying material properties.

    - **Time dependent measurement (nano seconds):**
      boxcar, Detection of ultrafast optical signals (pico seconds, femto seconds): pump-probe techniques, Streak camera and its working principle.

    - Accurate temperature measurement (cryogenic to high temperature, radiation environment, high magnetic field environment).

    - **Magnetic measurement:**
      Vibrating sample magnetometer, SQUID.

    - **Basics of spectroscopy:**
      Monochromators, spectrographs.

    - Energy and wavelength dispersion techniques in spectroscopy (specifically in the xray region). Spectroscopy in the IR region, FTIR.

    - Introduction to photon detectors: Photodiodes, Photomultiplier tubes, Proportional counters, CCD.

    - Uncertainties in measurements, with specific cases.

    - **Software related aspects:**
      Fourier transform, windowing and software based noise reduction in signal. Sampling theorem and its effect on the data: aliasing.

    - **Computer based data acquisition**
      Interface buses (LAN, LXI, USB, GPIB, RS-485, 232), PC based data acquisition (IPC, PCI, Compact PCI, PCI Express, PXI), Introduction to LabVIEW, Image acquisition hardware (GigE Vision, Cameralink, CoaXpress).

Course Outcomes:

Imparting / updating knowledge on the subject

03PHYS04-008-E: Advanced Course on Atom-Photon Interactions (Lectures: 30, Credit: 2)

Coordinators: Dr. Ajit Upadhyay
(ajitup@rrcat.gov.in)

Course Details:

- **Interaction of Light with Matter:**
  Hamiltonian description, multipolar approximation, review of the time dependent perturbation theory, concept of transition amplitude, semiclassical theory of a two level atom coupled to a single mode radiation field, density matrix, optical Bloch equations, semi-classical laser theory.

- **Coherent Effects:**
  Coherent population trapping (CPT), electromagnetically induced transparency, laser without population inversion, mechanical effects of light and its application in laser cooling and trapping.

- **Quantum Field:**
  Quantization of electromagnetic field, interaction of quantized radiation with matter, Jaynes-Cummings model, quantum dissipative processes, atom in the vacuum field and spontaneous emission, resonance fluorescence.

- **Elementary of Theory of Coherence:**
  Quasi-probability distribution functions, classical light and Non-classical light, coherent state, squeezed state and its experimental realization, atom-photon and atom-atom entanglement, multiparticle Entanglement, Entanglement in Quantum Information Processing.

- **Interaction of Atom with Intense Light Field:**
  Virtual absorption and multiphoton ionization, generalized Fermi-Golden Rule, above threshold ionization, Volkov state and KFR theory, high harmonic generation, Floquet theory, many-body correlation effects and non-perturbative field effects, and S-Matrix theory.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Quantum Optics", M. O. Scully and M Suhail Zubairy
2. "Elements of Quantum Optics", Pierre Meystre and Murray Sargent
3. "Laser Physics", Murray Sargent, Marlan O Scully and Willis E Lamb
4. "Photon and Atoms: Introduction to Quantum Electrodynamics", C. CohenTannoudji, J. Dupont-Roc, G. Grynberg

03PHYS04-006-E: Advanced Beam Dynamics (Lectures: 30, Credit: 2)

Coordinators: Dr. Vinit Kumar
(vinit@rrcat.gov.in)

Course Details:

- RMS envelope equation, beam matrix approach, concept of stationary states for beam distribution functions.
- Transverse beam dynamics in a solenoid, Busch emittance, transverse and longitudinal beam dynamics in RF field, Panofsky-Wenzel theorem and its applications, wakefields and impedances in linear accelerators.
- Emittance growth mechanisms and approximate techniques to estimate the emittance growth, beam halo. Bunch compressors and coherent synchrotron radiation (CSR), emittance growth due to CSR.
- Beam dynamics with ion trapping and electron clouds
- Coupling of electromagnetic power to RF cavities, beam loading and its implications, Slater perturbation theorem and its applications.
-
- Computational methods in accelerator physics, symplectic integration, Lie Algebraic methods.

Course Outcomes:

Imparting / updating knowledge on the subject.

References:

1. "Theory and Design of Charged Particle Beams", Martin Reiser.
2. "RF Linear Accelerators", Thomas P. Wangler.
3. "Advanced Beam Dynamics", Bruce Carlsten and Steve Russell, a course offered at US Particle Accelerator School, Univ. of California, 2005.
4. "Computational Methods in Beam Dynamics", Robert Ryne, a course offered at US Particle Accelerator School, Univ. of California, 2005. 20
5. "Advanced Accelerator Physics Course", CERN Accelerator School Proceedings", CERN-95-06-V1-V2.
6. "Neutralization of Accelerator Beam by Ionization of the Residual Gas", Y. Baconneir, A. Poncet and P. F. Tavares, Lecture notes, CERN.

03PHYS04-007-E: Course on Bio-Photonics (Lectures: 30, Credit: 2)

Coordinators: Dr. S. K. Mazumder (shkm@rrcat.gov.in)

Course Details:

- **Introduction:**
  Scope of bio-photonics, interaction of light with cells and tissues: absorption, scattering and depolarization of light . Basics of Biology: Cell structure and organization, structure and function of biomolecules, metabolism and energetics. General methods for biophysical and biochemical analysis, mechanism of cell death.

- **Light Propagation in Tissues:**
  Rayleigh and Mie scattering, multiple scattering and propagation of light in tissues, Radiative transport and diffusion approximation, effect of boundary conditions, numerical approaches for determining irradiance at surface and interior of scattering objects, techniques for determination of optical properties of biological samples.

- **Optical Imaging Through Turbid Medium:**
  Trade-off between resolution and depth of imaging, use of spatial filtering, polarization gating and time-gating for optical imaging, high resolution imaging using coherence gating, Optical coherence tomography (OCT) and diffuse optical tomography.

- **Optical Spectroscopy for Biomedical Diagnosis:**
  Elastic scattering spectroscopy for disease diagnosis, Fluorescence and Raman spectroscopy for diagnosis.

- **Optical Techniques for Micro-manipulation:**
  Optical tweezers and micro-beams, radiation pressure and force on microscopic objects, gradient and scattering force, applications of optical tweezer.

- **Optical Microscopy: Recent Developments:**
  Contrast methods in optical microscopy, techniques for single molecule imaging, scanning laser microscopy, multi-photon microscopy and near-field techniques.

- **Optical Methods for Bio-sensing Applications:**
  Surface plasmon resonance based sensors, quantum dots and functionalized nanoparticles as biosensors approaches for label-free sensing, opto fluidics and lab-on-a-chip approach.

- **Effect of Light on Biological Tissue:**
  Basic principals of photobiology, photoacceptors, action spectra and light induced signaling mechanism, Ligh effect based on endogenous photosensitizers, use of exogenous photosensitizers for photodynamic therapy and photo anti-microbial therapy, biological effects of narrow bandwidth light.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Biomedical Photonics Handbook", Editor-in-Chief Tuan Vo-Dinh
2. "Optical Tweezers: Methods and Applications", Ed. Miles J. Padgett, Justin Molloy, David McGloin
3. "Introduction to Biophotonics", Paras N. Prasad

03PHYS04-009-E: Concepts in X-Ray Physics (Lectures: 30, Credit: 2)

Coordinators: Dr. Gurivinderjit Singh
(gjit@rrcat.gov.in)

Course Details:

- **X-ray and Their Interaction With Matter:**
  X-ray waves and photons, sources of Xrays, X-ray scattering from an electron and atom, refractive index including absorption, coherence, Kramer-Kroning relationship.

- **Refraction and Reflection of X-rays:**
  Refraction and phase shifting in scattering, Snell's law and Fresnel equation in X-ray region, reflection from homogeneous slab and multilayers, rough interfaces and surfaces, examples of refractive and reflective X-ray optics and curved mirrors.

- **Kinematical Diffraction and Resonant Scattering:**
  Laue condition and reciprocal space, Ewald sphere, lattice vibration, the Debye-Waller factor, Lorenz factor, application of kinematical diffraction, structure factor and basics of structure solving, phase problem in crystallography, anomalous diffraction and some examples, introduction to Rietveld refinement method.

- **Diffraction by Perfect Crystals:**
  Kinematical reflection from few layers, basics of dynamical theory, Darwin's theory of extinction depth, integrated intensity, standing waves, higher order reflection, effect of absorption, asymmetric Bragg geometry, DuMond diagrams, applications in synchrotron X-ray monochromators, X-ray Topography.

- **X-Ray Absorption:**
  X-ray absorption from isolated atoms, extended X-ray absorption fine structure (EXAFS), near edge X-ray absorption (XANES), EXAFS equation, basics of EXAFS data acquisition and sample preparation, Transmission versus fluorescence modes of EXAFS.

- **X-Ray Fluorescence:**
  Theoretical details and data analysis, details of the experimental technique, sample preparation, trace element quantification and related issues.

- **Photo Emission Spectroscopy and X-Ray Magnetic Circular Dichroism:**
  Basics of photoemission and inverse photoemission, experimental setup, photoelectron and Auger electrons, core level binding energies, chemical shifts, line shapes and background, valence band structure determination, resonant photoemission, angle resolved photoemission and band structure determination, spin polarized photoemission, basics of XMCD

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Elements of Modern Optics", Jens Als-Nielsen & Des McMorrow
2. "Dynamical Theory of X-ray Diffraction", Andre Authier
3. "Soft X-Rays and Extreme Ultraviolet Radiation", David Attwood

03PHYS04-011-E: Fiber Optics and Fiber Sensors (Lectures: 30, Credit: 2)

Coordinators: Dr. Om Prakash
(oprakash@rrcat.gov.in)

Course Details:

- **Fiber Optics:**
  Optical fiber basics, single mode fiber, multi-mode fiber, step index fiber, graded index fiber, double-cladded fiber, microstructured fiber, modes in optical fiber, dielectric slab wave guide, propagating modes of the symmetric slab waveguide, odd even TE modes, characterization of modes, TE, TM hybrid modes, characteristic equations, mode cutoff conditions, ray optics explanation of modes in a dielectric slab waveguide, Basic equations, physical constraints in round optical fibers, the fields in the core cladding, boundary conditions, linearly polarized modes, power distribution in optical fiber.

- **Characteristics of Optical Fiber:**
  Losses in optical fiber: intrinsic impurity absorption loss, waveguide scattering loss, macrobending loss, coupling splicing loss; dispersion in optical fiber, group velocity dispersion, material dispersion, waveguide dispersion, polarization mode dispersion, dispersion management in optical fiber.

- **Fiber Optic Components and Devices:**
  Directional couplers, coupled mode equations, power transfer characteristics, transfer matrix of a coupler, super modes of a coupler, effect of fiber dispersion, optical isolator, and optical circulators.

- **Nonlinear Fiber Optics:**
  Nonlinearities in optical fiber, Kerr nonlinearity, self-phase modulation, self-focusing, cross phase modulation, four wave mixing, stimulated Brillouin scattering, stimulated Raman scattering. Ultra short pulse propagation, derivation of nonlinear Schrödinger equation (NLSE), ultra-short pulse propagation through fiber, soliton, similariton Gaussian pulse. Effect of gain loss on pulse propagation, interplay of dispersion, nonlinearity gain

- **Optical Fiber Gratings:**
  Photosensitivity, defects in the optical fiber, photosensitivity of doped fibers, photosensitization methods for optical fiber, refractive index modulation in the optical fiber, methods of fiber grating writings e.g. phase mask based, Interferometry, point by point; Types of fiber gratings such as uniform Bragg grating, long period grating, tilted fiber Bragg grating, chirped fiber grating, Type-IIa fiber grating, Type-II fiber grating, Type-Ia fiber grating etc., properties of lasers sources used for fabrication of fiber gratings, Optical theory of fiber Bragg, titled and long period gratings, mode coupling, reflection and transmission spectra.

- **Optical Fiber Sensors:**
  Principle of fiber optic sensor, classification of fiber optic sensor, sensing region, optical modulation mechanism, fiber grating sensors, principle of sensing, fiber designs for sensing, single point sensing, multipoint/distributed sensing, measurement of temperature with FBG, measurement of strain with FBG, measurement of pressure with FBG, FBG wavelength temperature compensation techniques, chirped grating sensor, long period grating sensor, evanescent field refractive index sensor, FBG based refractive index sensors, tilted FBG based

refractive index sensors, LPG based refractive index sensors, sensors based on surface plasmon resonance (SPR), Raman, Brillouin and Rayleigh scattering based fiber sensors.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. Introduction to Fiber Optics, Ghatak and Tyagrajan
2. Applications of Nonlinear Fiber Optics by G. P. Agrawal
3. Fiber Optics, Physics and Technology, Fedor Mitschke
4. Fiber Bragg Gratings by Raman Kashyap
5. Fiber optics sensors: Fundamental and applications, D. A. Krohn
6. Fiber Optic Sensors, Shizhuo Yin, Paul B. Ruffin, Francis T. S. Yu

03PHYS04-002-E: Magnet Physics and Technology (Lectures: 30, Credit: 2)

Coordinators: Shri. S. N. Singh
(snsingh@rrcat.gov.in)

Course Details:

- **Origin of Magnetism:**
  Classical and quantum concepts, magnetic moments, angular momentum and quantization of angular momentum.

- **Classification of Magnetism:**
  Diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, and ferrimagnetism.

- **Role of Magnets in Accelerators:**
  Dipole, quadrupole, sextupole, and combined function magnets, DC and fast cyclic magnets, Slow and fast pulsed magnets.

- **Fundamentals of Magnet Design:**
  Magnetic circuit, dipole, quadrupole, sextupole and higher order multipole magnets and coil design, B-H curve, Numerical methods for magnet simulation: computer code and related mathematical formalism, methods of optimization, multipole expansion, Fourier representation of magnetic field.

- **Magnetic materials for accelerator magnets:**
  Materials for DC magnets: low field magnets, high field magnets, permanent magnets, pulsed magnets, electromagnetic absorbers and shielding. Magnet Technology: Magnet core and coil fabrication techniques, coil impregnation, tolerances, and economic issues. Methods of magnetic field measurements: magnetic induction, point and integral coil, stretched wire, Helmholtz coil, Hall probe, and nuclear magnetic resonance.

- **Superconducting Magnets:**
  Basic concept of superconducting magnets, magnet geometries for dipole magnets, superconducting materials, need for twisted composite conductors, hot spot temperature, current densities, quench, training of magnets and persistent switch, High Tc superconducting magnets, insertion devices.

- **Geodesy and Alignment of Accelerators:**
  Introduction, survey and alignment as applicable to accelerators and its requirement. Position sensitive elements and their typical tolerances for alignment, fiducial references and adjustment system, fiducial posts and targets, and techniques of fiducialsation. Features of support elements and their adjustments during alignment.

- **Network and Alignment Procedure:**
  Defining coordinate systems, control networkstypes, survey procedure, data adjustment and error analysis.

- **Survey and Alignment Instruments and Toolings:**
  Electronic theodolite, optical level, laser Interferometer, distinvar, inclinometer, offset meter etc. Different types of targets and sensors.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Iron Dominated Magnets", Jack T. Tanabe
2. "Synchrotron Radiation Sources - A Primer," Herman Winick
3. "Iron Dominated Electromagnets, Design, Fabrication, Assembly Measurements", Jack T. Tanabe
4. "Conventional Magnets,Proceedings of CAT- CERN Accelerator School, Nov. 1993, Page 23," Neil Marks
5. "Classical Electrodynamics," J. D. Jackson
6. "Superconducting Magnet Systems," H. Brechna
7. "Physics of Magnetism," S. Chikazumi
8. "Soft Ferrite its Applications", E.C Snelling
9. "Permanent Magnet Materials Their Applications," Peter
10. "Modern Ferrite Technology", Alex Goldman

03PHYS04-010-E: Physics of Semiconductor Quantum Structures (Lectures: 30, Credit: 2)

Coordinators: Dr. Pankaj Misra
(pmisra@rrcat.gov.in)

Course Details:

- **Introduction to Semiconductor Nanostructures:**
  Review of condensed matter and semiconductor physics, scientific and technological significance of nanostructures 24 and mesoscopic structures, characteristic length scales for quantum phenomena, energy states of carriers in free space of different dimensionality, effect of quantum confinement on carrier energy states, density of states for semiconductors of reduced dimensionality, key ideas on effect of quantum confinement in electronic properties, transport phenomenon and interaction of photons with materials, and applications of nanostructured semiconductors.

- **Growth of Semiconductor Nanostructures:**
  Homo and hetero epitaxial growth, nucleation and nucleation kinetics, strain in lattice mismatched systems, psudomorphic growth and critical thickness, growth modes: Volmer–Weber (VW) or planer growth, Frank–van der Merwe (FM) or island growth and Stranski–Krastinov (SK) nucleation and growth, fundamental and principle of physical and chemical vapor deposition methods: Pulsed laser deposition, molecular beam epitaxy, chemical vapor deposition, atomic layer deposition, sputtering. Bandgap engineering and growth of quantum well structures, key issues in growth of quantum wires, quantum dots and super lattices, Fundamental characteristics of semiconductor nanostructures.

- **Properties and Characterizations of Semiconductor nanostructures:**
  Optical processes in low dimensional semiconductors: Excitons, free carriers and defect level induced optical transitions, optical phonons and polaritrons, Basic principles and key issues of optical spectroscopy techniques for nanostructured semiconductors; absorption, reflection, photoluminescence, photoluminescence excitation and surface photovoltage spectroscopy. Transport in semiconductor nanostructures: conductance, resonant tunneling, hot electrons; transport in magnetic field, semi-classical and quantum approach, Aharonov-Bohm effect, Shubnikov-de Haas effect, introduction to quantum Hall effect. Principles of application of devices based on Semiconductor nanostructures: photodetectors, lasers, resonant tunneling diodes and solar cells etc.

Course Outcomes:

Imparting / updating knowledge on the subject

References:

1. "Material Science of Thin Films: Deposition Structures", Milton Ohring
2. "Solid State Electronic Devices", Jaspreet Singh
3. "Physics of Low-Dimensional Semiconductors", Davies John H
4. "Semiconductor Devices Design", Jaspreet Singh and Umesh K Mishra
5. "Semiconductor Materials", B. G. Yacobi
6. "Semiconductor Nanostructures", Ed. D. Bimberg
7. "Semiconductor Optoelectronics: Physics Technology", J. Singh

Short Term Project

- A short Term Project of typically 270 hours is to be completed by the trainees during their Training period.

Research Methodology

- **Research Methodology:**
  Definition and characteristics of research, objectives and importance of research, planning of research, types and stages of research, scientific methods, searching for scientific information, accessing scientific literature, reading scientific papers.

- **Documentation:**
  Preparing scientific papers/reports, scientific presentations. Laboratory safety: Safe practices in laboratory.

- **Research ethics:**
  Ethical conduct in science, ethical issues in scientific publication, awareness of plagiarism and other scientific misconducts.

- **Probability and Statistics:**
  Bayes formula, random variable, expected value and variance, discrete and continuous distributions, joint distributions, conditional distributions, covariance and correlation, normal distribution, Poisson process, central limit theorem and its applications, definition of precision, accuracy, systematic and random errors, propagation of errors in experimental data and their estimation, estimation of variance and confidence intervals.

- **Mathematical modeling:**
  Measurement of functional relationships, order of magnitude analysis, dimensional analysis, goodness of a fit, linear regression and data fitting.

- **Data Security:**
  Introduction to Data Security, Data security requirements, Different Cyber threats to Data & possible Solutions, Basic concepts of Cryptography & Data encryption algorithms, Research opportunities in Data Security.

- **Data management:**
  Data planning, handling, modelling, analysis, visualization, Different Data Models, Data Management Software, Data Backup & Storage

References:

1. Research Methods for Science, M. P. Marder (Cambridge University Press
2. The Ethics of Science, An Introduction, David Resnick (Taylor and Francis, 2005)
3. Avoiding plagiarism, self-plagiarism, and other questionable writing practices: A guide to ethical writing, Miguel Roig 4) Advance Engineering Mathematics, E. Kreyzwig (Wiley, 2006)
4. An Introduction to Probability: Theory and Applications Vol. 1 and 2, W. Feller (Wiley)