INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-503** Course Title: **Quantum Mechanics-I**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 4 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**: PH-303**

9. Objective: To apply quantum mechanics to the dynamics of single particle in one-, two- and three- dimensional potential fields.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Postulates of Quantum Mechanics and meaning of measurement, Operators and their expectation values, Schrodinger equation, Particle in a box, Orthogonality of eigen functions, Dirac rotations, Hilbert space.	6
2.	**Matrix Formulation:** Matrix formulation of 1-dimensional harmonic oscillator problem; creation and annihilation operators; Equation of motion and classical correspondence, Heisenberg equation of motion, Schrodinger, Heisenberg and Interaction picture, Motion in a one-dimensional periodic potential, Kroning-penny model.	8
3.	**Motion in a Central Potential:** Angular momentum operator, expressions of L^2 and L_z, eigen values and eigen functions of L^2 and L_z, hydrogen atom, solution of radial equation, energy eigen values, eigen functions of H atom, orthogonality of eigen functions, rigid rotator, matrix representation L^2, L_x, L_y, L_z, generalized angular momentum, generator of rotation and their commutation relations, spin – ½ matrices, coupling of angular momenta, Clebsch-Gordon Coefficients.	10

4.	**Scattering Theory:** Scattering amplitude, differential and total cross-section, scattering by a central potential, method of partial waves, phase-shift analysis, optical theorem, scattering by a square-well potential, integral equation, the Born approximation.	10
5.	**Approximate Methods:** WKB approximation, WKB expansion, connecting formulas, variational principle and its application to Helium atom and hydrogen molecule	8
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books/Publishers**	**Year of Publication/Reprint**
1.	Schiff L.I., "Quantum Mechanics", 3rd Ed, McGraw Hill Book Co.	**1990**
2.	Merzbacher E, "Quantum Mechanics", 2nd Ed., John Wiley & Sons	**1996**
3.	Gasiorowicz S, "Quantum Physics", John Wiley	**2000**
4.	Mathews P. M. and Venkatesan K, "A Text Book of Quantum Mechanics", Tata McGraw Hill	**2000**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-505** Course Title: **Mathematical Physics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**:** **Nil**

9. Objective: **To familiarize the students with the standard techniques in modern mathematical physics**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Complex variables and applications**,** analytic functions, contour integration, residue calculus, conformal mapping and its applications. Fourier and Laplace transforms, evaluation of integral transforms and their inverses using contour integrals.	6
2.	Special equations of Mathematical Physics; Legendre and associated Legendre equations; Hermite equation; Laguerre and associated Laguerre equations; Bessel's equation; Hypergeometric equation; Beta and gamma functions.	8
3.	Green's functions and solutions to inhomogeneous differential equations and applications.	8
4.	Covariant and Contravariant tensors, covariant derivatives, affine connections Christoffel symbols, Curvature tensor.	6
5.	Classification and examples of (finite) groups, homomorphisms, isomorphisms, representation theory for finite groups, reducible and irreducible representations, Schur's Lemma and orthogonality theorem,	8
6.	Characters; Lie Groups and Lie algebra; Vector Spaces; Hilbert Space and operators	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Arfken G. B. and Weber H. J., "Mathematical Methods for Physicists" , 5th Ed. Academic Press.	**2005**
2.	Whittaker E.T.and Watson E.W., "A Course of Modern Analysis", Cambridge University Press	**2008**
3.	Hammermesh M., "Group Theory and Applications to Physical Problems", Dover publications, NY.	**1989**
4.	Akhiezer N. I. and Glazman I. M., " Theory of Linear Operator in Hilbert Space", Dover Publications	**1993**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-507** Course Title: **Classical Electrodynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 4 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **PH-202**

9. Objective: To emphasize electric and magnetic phenomena and introduce the covariant formulation of Maxwell's theory of electromagnetism

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Maxwell's Equation:** Maxwell's equation, vector and scalar potentials, Gauge transformation, Poynting theorem., plane electro-magnetic waves, waves in non-conducting and conducting medium; Linear and Circular polarization, reflection and refraction.	12
2.	**Covariant Formulation of Vacuum Electrodynamics:** Space-Time symmetry of the field equations; Covariant formulation; Four-vector potential; Electromagnetic field tensor and its invariants; Lorentz-Force equation in a covariant form.	12
3.	**Radiation from Accelerated Charges:** Retarded potentials; Lienard-Wiechert potentials; Fields produced by a charge in uniform and arbitrary motion, radiated power; Angular and frequency distribution of radiation, radiation from charged particle with co-linear velocity and acceleration; Synchrotron radiation; Thomson scattering; Cherenkov radiation.	14
4.	**Multipole Fields:** Inhomogeneous wave equation, multipole expansion of electromagnetic fields, angular distribution, multipole moments.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Jakson J D, “Classical Electrodynamics”, John Wiley	**2002**
2.	Griffiths D J, “Introduction to Electrodynamics”, Prentice Hall	**1999**
3.	Capri A.Z. and Panat P.V., “Introduction to Electrodynamics” Narosa Publication House	**2002**
4.	Franklin J., “Classical Electromagnetism”, Pearson Education	**2007**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-509** Course Title: **Classical Mechanics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **PH-203**

9. Objective: To familiarize students with the various methods of solving problems in classical mechanics using the techniques of Lagrange, Hamilton, Hamilton-Jacobi and Poisson Brackets.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Lagrange's Equation: C**onstraints; D'Alembert's principle and Lagrange's equation of motion, dissipation function, Hamilton's principle, calculus of variations, nonholonomic systems, conservation laws, relativistic and covariant formulation.	10
2.	**Hamilton's Equations:** Hamilton's equation of motion, cyclic co-ordinates, Routh's procedure, relativistic formation, variational principle, principle of least action.	8
3.	**Canonical Transformations:** Equations of canonical transformations and examples, sympletic approach, Poisson brackets and equation of motion, conservation laws, angular momentum, symmetry groups & Louville's theorem.	8
4.	**Hamilton-Jacobi Theory:** Hamilton-Jacobi equation's of motion, harmonic oscillations, separation of variables, action-angle variables, Kepler problem, geometrical optics and wave mechanics.	8
5.	**Canonical Perturbation Theory:** Time-dependent perturbation, examples, time-independent theory in first order and higher orders, applications to celestial and space mechanics, Adiabatic invariants.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Goldstein H, “Classical Mechanics”, Narosa	**2001**
2.	Rana W.C. and Jog P.S, “Classical Mechanics” , Tata McGraw Hill	**1991**
3.	Gupta K.C., “Classical Mechanics of particles and Rigid Bodies”, Wiley Eastern	**2001**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-513** Course Title: **Semiconductor Devices and Applications**

2. Contact Hours: **L: 3** **T: 0** **P: 3**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 3

4. Relative Weightage**:** **CWS** 15 **PRS** 15 **MTE** 15 **ETE** 40 **PRE** 15

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**:** **PH-110**

9. Objective: To introduce the physics of semiconductors, p-n junction, bipolar junction transistors, FET and MOSFET.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Semiconductors:** Energy bands, direct and indirect semiconductors, charge carriers, mobility, drift of carriers in field, Diamond and Zinc-Blende structure, bonds and bands in semiconductors, intrinsic and extrinsic semiconductors, law of mass action, Hall effect and cyclotron resonance in semiconductors.	12
2.	**Optical Injection:** Carrier life time, direct and indirect recombination of electron and holes, steady state carrier generation, diffusion and drift of carriers, the continuity equation, steady state carrier injection, The Haynes-Shockley experiment.	8
3.	**Junctions:** Metal-Semiconductor contact: under equilibrium, and non-equilibrium conditions, the junction diode theory, tunnel diode, photodiode, LED, solar cell, Hetro-junctions and Laser diode.	10
4.	**Bipolar Junction Transistors:** Charge transport and amplification, minority carrier distribution and terminal currents switching behaviour in bipolar transistor.	4
5.	**FET and MOSFET:** Ideal MOS capacitor, effect of work function and interface charge on threshold voltage.	6
6.	**Gunn Diode:** Transferred electron mechanism and drift of space charge	2

	domain.	
	Total	**42**

List of Practical

S. No.	Particulars	Contact Hours
1.	To draw the I-V characteristics of a p-n junction diode in forward and reverse bias and to determine its DC and AC resistance for a given current.	
2.	To study the temperature dependence of the reverse saturation current of a p-n junction diode and to determine the band gap of semiconductor.	
3.	To study half wave, full wave and bridge rectifiers and to determine ripple factor.	
4.	To design a regulated power supply using Zener diode and fixed voltage regulator.	
5.	(a)To draw input and output characteristic of a bipolar transistor. (b)To design a CE amplifier and study its frequency response.	
6.	To draw input and output characteristic of a JFET and determine g_m, r_d and verify square law.	
7.	To design inverting and non-inverting amplifiers of different gain using operational amplifier and study their frequency response.	
8	To verify truth tables of various logic gates.	
9	To verify Boolean theorems using logic gates	
10	To design and study of astable, monostable multivibrators using Timer 555	

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Streetman B G and Banerjee S "Solid State Electronic Devices", 6th Ed. Prentice Hall	**2005**
2.	Sze S M, "Semiconductor Devices Physics and Technology" 2nd Ed. John Wiley & Sons	**2003**
3.	Tyagi M S, "Semiconductor Materials and Devices", John Wiley & Sons	**2000**
4.	Chattopadhyay D. and Rakshit P. C. , "An advanced course in Practical Physics" 7th Edition; New Central Book Agency (P) Ltd.	**2005**
5.	Gupta S. L. and Kumar V., "Practical Physics" 25th Ed. Pragati Prakashan	**2002**
6.	Paul P., Malvino A. and Miller M., " Basic Electronics: A Text-Lab Manual, Tata McGraw Hill	**1999**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-502** Course Title: **Laboratory Work**

2. Contact Hours: **L: 0** **T: 0** **P: 6**

3. Examination Duration (Hrs.): **Theory** 0 **Practical** 4

4. Relative Weightage: **CWS** 0 **PRS** 50 **MTE** 0 **ETE** 0 **PRE** 50

5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To familiarize with the basic experiments in Solid State Physics, Nuclear Physics, Laser Physics and Atmospheric Physics.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Study of Hall effect and to determine the Hall coefficient	14 x 6
2	To measure resistivity of semiconductor by Four Probe method and determination of band gap.	
3	To determine reverse saturation current, material constant and band gap of PN Junction	
4	To ascertain of the Random nature of nuclear radiation	
5	To study G.M. tube characteristics and to calculate the dead time,	
6	To determine the relative beta counting of two strong β-sources of nuclear radiation and to determine the absorption coefficients,	
7	To determine the distribution of the size of Aerosol.	
8	To measure the attenuation of laser radiation in varying atmospheric condition.	
9	The measurement of precipitation rate of water using rain gauge.	
10	To determine the numerical aperture of a given multimode fiber using the far field measurements.	

11	To measure the spot size and the angle of divergence of a laser beam, to produce the elliptically and circularly polarized light from an unpolarized laser beam and study their angular intensity profiles.	
12	Design of counter using JK flip flop and a relaxation oscillator with given frequency and duty cycle	
13.	Design a Schmitt trigger with given UTP LTP and hysteresis	
14.	To design a binary/BCD up-down counter using IC 74190/74191	
	Total	**84**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Nakra B.C. &. Chaudhery K.K , " Instrumentation Measurements & Analysis**",** Tata McGraw Hill	**2002**
2.	Sayer M. & Mansingh A., "Measurement, Instrumentation & Experiment Design in Physics and Engineering", Prentice Hall India	**2000**
3.	Melissinos A.C. and Napolitano J, "Experiments in Modern Physics", Academic Press	**2000**
4.	W.R. Runyan , **"**Semiconductor Measurements and Instrumentation**",** McGraw Hill	**2002**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-504** Course Title: **Condensed Matter Physics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage: **CWS** **15** **PRS** **0** **MTE** **35** **ETE** **50** **PRE** **0**

5. Credits: **3** 6. Semester: **Spring** 7. Subject Area: **PCC**

8. Pre-requisite: **PH-304**

9. Objective: To familiarize with the structural and electronic properties of crystalline and non-crystalline materials and their dynamical properties.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Crystalline Materials:** Scattering of x-ray, neutrons and electrons from solids; Atomic scattering factor; Lattice planes and Miller indices.	6
2.	**Lattice Dynamics:** Harmonic and adiabatic approximations; Lattice vibrations of three dimensional crystals; Periodic boundary conditions; Normal modes. Quantization of lattice vibrations; Lattice heat capacity (Einstein and Debye theories) anharmonicity of thermal expansion.	9
3.	**Electronic Energy Bands:** Resume of free-electron model; Fermi energy; Fermi surface and electronic heat capacity, electrical and thermal conductivity, nearly free electron model; Periodic potential and Bloch theorem, extended and reduced zone scheme, tight binding model.	9
4.	**Superconductivity:** Experimental evidence (Meissner effect, heat capacity, energy gap, microwave properties and isotope effect), Thermodynamics of superconductors; London equation; Elementary BCS theory.	9

5.	**Non-crystalline Materials:** Non-crystalline solids – diffraction pattern and radial distribution function, Elementary idea of glass transition, Quasi crystals, Liquid crystals – idea of orientational order and Landau theory of isotropic-nematic phase transition, Physics of Polymers.	**9**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books/Publishers**	**Year of Publication/Reprint**
1.	Taylor P. L. and Heinonen O., "A Quantum Approach to Condensed Matter Physics", Cambridge University Press	**2004**
2.	Ashcroft N W and Mermin N D, "Solid State Physics", Holt-Saunders	**2000**
3.	Chaikin P M and Lubensky T C, "Principles of Condensed Matter Physics", Cambridge University Press	**2000**
4.	Hamley I. W., "An Introduction to Soft Matter: Polymers, Colloids, Amphiphiles and Liquids" John Wiley	**2000**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-506** Course Title: **Statistical Mechanics**
2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PCC**

8. Pre-requisite: **PH-503 & PH-509**

9. Objective: To understand the macroscopic behaviour of the classical and quantum thermodynamic systems.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Classical Statistical Mechanics:** Macro and microstates, connection between statistics and thermodynamics, phase space; Liouville's Theorem. Microcanonical, canonical and grand canonical ensembles; Energy and Density fluctuations; equivalence of various ensembles. Equipartition and virial theorem, partition function; Derivation of thermodynamic properties; some examples including (i) classical ideal gas (ii) system of classical harmonic oscillators, (iii) system of magnetic dipoles in magnetic field.	10
2.	**Quantum Statistical Mechanics:** Quantum mechanical ensembles theory, the density matrix and partition function with examples including (i) an electron in a magnetic field (ii) a free particle in a box (iii) a linear harmonic oscillator. Symmetric and Antisymmetric Wavefunctions. Microcanonical ensemble of ideal Bose, Fermi and Boltzmann gases, derivation of Bose, Fermi and Boltzmann statistics; Grand Partition function of ideal Bose and Fermi gases; Statistics of the occupation.	12
3.	**Ideal Bose and Fermi Systems:** Thermodynamic behaviour of an ideal Bose gas; Bose condensation; Liquid Helium; Blackbody radiation and Planck's law of radiation; Thermodynamic behaviour of an ideal Fermi gas; Electrons in metals, specific heat and Pauli susceptibility of electron gas.	10

4.	**Phase Transitions and Critical Phenomenon :** Order parameter, Ist and IInd order phase transitions. Ising model in zeroth and first approximation. Critical exponents, thermodynamic inequalities, Landau theory of phase transitions.	10
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication/ Reprint
1.	Patharia R K "Statistical Mechanics" (2nd Ed.), Pergaman press	**2001**
2.	Huang K "Statistical Mechanics" (2nd Ed., 2nd reprint), John Wiley & Sons	**2003**
3.	Landau L.D. and Lifshitz E M "Statistical Mechanics", Butteworth-Heinemaun	**1998**
4.	McQuarrie D A "Statistical Mechanics", Harper & Row	**2003**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-508** Course Title: **Quantum Mechanics-II**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0
5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PCC**
8. Pre-requisite: **PH-503**
9. Objective: To introduce various approximation methods for stationary and time-dependent problems; two-particle systems, basic ideas of self-consistent field theoriesand relativistic quantum mechanics.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Time-independent Perturbation Theory:** Non-degenerate and degenerate perturbation theory, its application to Stark effect, Zeeman effect, spin-orbit coupling, fine structure and to anharmonic oscillator.	10
2.	**Time-dependent Perturbation Theory:** Transition probability, harmonic perturbation, Fermi-golden rule, semi-classical theory of radiation, stimulated emission cross-section.	10
3.	**Identical Particles:** Indistinguishability, permutation symmetry, two-particle system; Helium atoms, simple idea of Hartee self-consistent field method, Hartee-Fock method.	10
4.	**Relativistic Quantum Mechanics:** Klein-Gordon equation and its applications, Dirac theory of electron, spin of the electron, solution of Dirac equation for free particles, hole (positron)-Dirac equation for Hydrogen atom.	12
	Total	**42**

1. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Schiff L I, "Quantum Mechanics", 3rd Ed, McGraw Hill Book Co.	**1990**
2.	Griffiths D J, "Introduction to Quantum Mechanics", 2nd Ed, Pearson Eduction	**2005**
3.	Bransden B H and Joachain C J, "Quantum Mechanics", 2nd Ed, Pearson Eduction	**2000**
4.	Zettili N, "Quantum Mechanics: Concepts and Applications", 2nd Ed, John Wiley	**2009**
5.	Bjorken J D and Drell S D, "Relativistic Quantum Mechanics", McGraw Hill Book Co.	**1998**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-512** Course Title: **Physics of Earth's Atmosphere**

2. Contact Hours: **L: 2** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 2 **Practical** 0

4. Relative Weightage**:** **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits**:** 2 6. Semester**: Spring** 7. Subject Area**: PCC**

8. Pre-requisite**:** **None**

9. Objective: To introduce the basics of atmospheric physics.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Atmospheric Evolution:** Solar radiation, present atmospheric constituents, evolution of the atmosphere, formation of ozone.	6
2.	**Lower Atmosphere:** Variation of temperature, density, ionization and pressure with altitude, hydrostatic equation, green house effect, lapse rate and stability criteria, cloud formation and precipitation.	8
3.	**Upper Atmosphere:** Chapman theory of layer production, formation of ionosphere, photochemistry of the thermosphere, electron, ion and neutral temperatures in the thermosphere, airglow and auroral emissions.	8
4.	**Weather:** weather and climate, weather modification, artificial rain making, cloud suppression, storms.	6
	Total	**28**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Seeds M.A., "Solar System", Brooks/Cole Thomson Learning	**2007**
2.	Houghton J.T. "Physics of Atmosphere**",** Cambridge Univ. Press	**2002**
3.	Rogers R R, **"**A Short Course in Cloud Physics**"**, Pergamon Press	**1989**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Physics Department**

1. Subject Code: **PH-516** Course Title: **Elements of Nuclear and Particle Physics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** -

4. Relative Weightage: **CWS** 25 **PRS** - **MTE** 25 **ETE** 50 **PRE** -

5. Credits: 4 6. Semester: **- Spring** 7.Subject Area: **PCC**

8. Pre-requisite: **PH-505**

9. Objective: **To introduce the elements of introductory nuclear and particle physics**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Two nucleon problem: General symmetry properties of two nucleon Hamiltonian and two nucleon states, General forms of two nucleon interaction; Nuclear global properties: the N-Z chart, nuclear masses, densities, radii, spin, parities, electric and magnetic moments.	10
2.	Semi empirical (liquid drop) model, Fermi-gas model, nuclear shell model (with the harmonic oscillator potential), spin-orbit coupling and magic numbers.	6
3.	Introduction to nuclear reactions: Kinematics, conservation laws, angular distributions and cross sections, simple models of direct and compound reactions.	5
4.	Concept of elementary particles and their classification. Conservation of the different quantum numbers viz. baryon number strangeness etc. in particle physics. Concept of color and quark model. Deep inelastic scattering of lepton-hadron scattering: discovery of quarks and gluons	5
5.	Representation theory of SU(2) and SU(3) and its generators, preliminary idea of lie algebra, SU(3) flavour symmetry and construction of meson octet, baryon octet & decuplet and calculation of magnetic moments using their wave functions.	5
6.	Fermi theory and V-A theory of β-decay, concept of parity, helicity, non-conservation of parity in β-decay and its experimental verifications. **, Klein-Gordon equation, Dirac equation (derivation not required), Concept of anti-particle. Qualitative descriptions of Feynman diagram and the cross sections for processes *e.g.* Compton scattering, Moller scattering etc.**	8
7.	A brief introduction to the electromagnetic, weak and strong interactions Gauge theory: Abelian gauge theory (QED) and its extension to non-abelian gauge theory. Spontaneous symmetry breaking and electroweak unification	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Heyde, K., "Basic Ideas and concepts in Nuclear physics, An introductory approach", Institute of Physics Publishing	2004
2.	Bertulani, C.A. and Danielewicz, P, "Introduction to Nuclear reactions", Institute of Physics Publishing	2004
3.	Ghoshal, S.N., "Nuclear Physics", S. Chand and Company	2000
4.	Griffith D, "Introduction of Elementary Particles", John Wiley	2000
5.	Halzen, F. and Martin, A.D. "Quarks and Leptons" John Wiley	2011
6.	T.-P. Cheng and L.-F.Li, "Gauge theory of Elementary Particle Physics''Oxford University Press	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-518** Course Title: **Atomic, Molecular and Laser Physics**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory 3** **Practical 0**
4. Relative Weightage**:** **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0
5. Credits**:** 4 6. Semester**: Spring** 7. Subject Area**: PCC**
8. Pre-requisite**:** **Nil**
9. Objective: To introduce basics of Atomic, Molecular and Laser Physics

10. Details of Course:

Sl.No	Contents	Contact Hours
1.	**Atomic Spectroscopy-I:** Spectra of one and two electron system, Alkali spectra, Electron spin and magnetic moment, Fine structure splitting: spin-orbit interaction and relativistic corrections; Lamb shift, hyperfine structure and isotope shifts; Excited states of atoms, exotic atoms.	10
2.	**Atomic Spectroscopy-II:** Many-electron atoms, Pauli exclusion principle, Angular momentum coupling schemes: L-S and j-j coupling, equivalent and non-equivalent electrons, Hund's rules, ground state configurations of elements in periodic table; atoms in electric and magnetic fields, X-ray spectra.	10
3.	**Molecular structure and properties:** The Born-Oppenheimer Approximation, Application to H_2^+, Molecular orbital theory, LCAO approach, homonuclear and heteronuclear diatomic molecules, orbitals of polyatomic molecules; Ionic and Covalent bonds; Mechanical properties: sizes, shapes, masses, specific heat, kinetic energy - of molecules; electric and magnetic properties of molecules.	10
4.	**Laser Physics:** Characteristics of laser light, directionality, intensity, monochromaticity, spatial and temporal coherence, interaction of radiation with matter. Spontaneous and Stimulated emission and Absorption processes and their transition rates. Optical amplification, Population inversion, Basic concepts of 2-, 3- and 4- level systems, optical resonator, characteristics of semiconductor lasers and He-Ne lasers, CO_2 lasers, basic concepts of holography.	12
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication/ Reprint
1.	Haken H and Wolf H. C, "The Physics of Atoms and Quanta**",** 6th Ed., Springer	2007
2.	Demtroder W., "Atoms, Molecules and Photons", 2nd edition, Springer-Verlag	2010
3.	Bransden B. H. and Joachian C. J., "Physics of Atoms and Molecules" 2nd Edition, Prentice Hall	2012
4.	Eisberg R. and Resnick R., "Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles", 2nd Edition, Wiley Student Edition	2003
5.	Atkins P. and Friedman R., "Molecular Quantum Mechanics", 5th edition, Oxford University Press	2010
6.	Laud, B. B., "Lasers and Non-linear Optics", 3rd edition, New Age International	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-601** Course Title: **Advanced Condensed Matter Physics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite**:** **PH-504**

9. Objective: To introduce the general aspects of phase transition, electronic transport phenomena, superconductivity, dielectric, optical and magnetic properties of solids.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Surface and Interfaces:** Work function and contact potential; Thermoionic emission; Low-energy electron diffraction; Electronic surface levels; Super lattices; Quantum wells; Quantum wires, Quantum dots and carbon Nanotubes.	**9**
2.	**Magnetism:** Magnetic properties of insulators, Langevin diamagnetism and Van Vleck paramagnetism, Curie paramagnets and Curie-Weiss ferromagnets, Neel Antiferromagnets, Heisenberg model; Spin Waves, Ising model; Elements of magnetic properties of metals, Landau diamagnetism, Pauli paramagnetism, Stoner ferromagnetism; Magnetic resonance; NMR and EPR.	**9**
3.	**Transport Properties:** Boltzmann equation; Relaxation time approximation; General transport coefficients; Electronic conduction in metals; Thermoelectric effects; Transport phenomena in magnetic field; Magnetoresistance; Hall effect and Quantum Hall effect.	**8**
4.	**Phase Transitions:** Order parameter; Critical points; First and second order phase transitions; Mean field theory; Properties near critical point; Landau theory; Bragg-Williams theory; Liquid-gas transition and Isotropic-mematic transition.	**8**

5.	**Superconductivity:** Cooper pairing and BCS theory; Ginzburg-Landau theory; Flux quantization; Supercurrent tunneling; DC and AC Josephson effects; High-Tc superconductors.	**8**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books/Publishers**	**Year of Publication/Reprint**
1.	Kittel C, "Introduction to Solid State Physics", 6th Ed. Wiley eastern Ltd	**2004**
2.	Ashcroft N W and Mermin N D, "Solid State Physics", Holt-Saunders	**2000**
3.	Chaikin P M and Lubensky T C, "Principles of Condensed Matter Physics", Cambridge University Press	**1995**
4.	Harrison P, "Quantum Wells, Wires and Dots", Wiley & Sons Ltd.	**2005**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-603** Course Title: **Advanced Atmospheric Physics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite**:** **PH-512**

9. Objective: To provide the knowledge of advances in atmospheric physics.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Atmospheric Dynamics:** Apparent forces, effective gravity, coriolis force, pressure gradient force, gradient wind, thermal wind, continuity equation, perturbation theory and atmospheric waves, sound waves, gravity waves and Rossby waves, Momentum and energy transports by waves in the horizontal and the vertical.	**12**
2.	**Atmospheric Instabilities** Atmospheric instabilities, dynamical instabilities, barotropic instability, baroclinic inertial instability, Necessary condition of barotropic and baroclinic instability. Combined barotropic andbaroclinic instability. Kelvin-Helmholtz instability	**10**
3.	**Ionosphere:** Formation of Ionosphere,Chemical processes, Ionospheric conductivity, Planetary ionospheres, Ionospheric exploration using rockets and satellites, langmuir probe, temperature measurements, airglow and aurora, radio wave propagation in the ionosphere.	**10**
4.	**Magnetosphere:** Earth as a magnet, solar wind, types and theory of solar wind, frozen-in magnetic field, interaction of solar wind with Earth's magnetic field and formation of magnetosphere, inter planetary magnetic field (IMF), geomagnetic storms, van-allen	**10**

	radiation belts, plasmasphere,coronal holes, CMEs, satellite observations of various plasma domains and plasma instabilities.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Vallace J and Hobbs, P V, "Atmospheric Science", Academic Press	**1997**
2.	Rees M H, "Physics & Chemistry of Upper Atmosphere", Cambridge Univ. Press	**1989**
3.	Ratcliffe J A, "An Introduction to the Ionosphere & Magnetosphere, Cambridge Univ. Press	**1972**
4.	Smithson P, "Fundamentals of Physical Environment", Ken Addison and Attrinson,	**2008**
5.	Rogers R R, " A short course in Cloud Physics", Pergamon Press	**1989**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-605** Course Title: **Advanced Laser Physics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: **4** 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite: **PH-518**

9. Objective: To introduce the concept of laser physics and its applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Quantum theory for the evaluation of the transition rates and Einstein's coefficients, interaction of matter with radiation having broad spectrum, interaction of near monochromatic radiation with an atom having broad frequency response.	6
2.	Line broadening mechanisms, homogeneous and inhomogeneous broadening, natural collision and Doppler broadening mechanisms and line shape functions.	4
3.	Laser rate equations, the three levels and four levels system, variation of power around threshold, optimum output coupling, quality factor, the ultimate line width of the laser.	5
4.	Optical resonators, modes of a rectangular cavity and open planar resonators, confocal resonator system, modes of a confocal resonator using Huygen's principle, planar resonators, Fox and Li theory.	6
5.	Pulsed lasers, Q-switching techniques, active and passive shutters, mode-locking, various techniques for mode-locking of a laser.	5
6.	Mechanism and applications of Ar-ion, CO_2, Nd:YAG, Ti:Sapphire, Dye, Excimer and free electron lasers.	5
7.	Semiconductor lasers, p-n junction diode lasers, hetrojunction lasers.	5
8.	Modulation techniques for laser light, electro-optic and acousto-optic modulation, electro-optic effect in KDP crystal, longitudinal and transverse modes, acousto-optic effect, Raman-Nath and Bragg diffraction, small and large angle Bragg diffraction.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Laud B B, "Lasers and Nonlinear Optics", Wiley Eastern Ltd.	**1992**
2.	Ghatak A K and Thyagarajan K., "Optical Electronics", Cambridge University Press	**2003**
3.	Yariv A, "Quantum Electronics", John Wiley & Sons	**1989**
4.	Thyagarajan K. and Ghatak A. "Lasers: Theory and Applications", Macmillan	**1997**
5.	Yariv A, "optical Electronics", Oxford University Press	**1997**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-607** Course Title: **Advanced Nuclear Physics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 4 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite**: PH 516**

9. Objective: To introduce the advanced concepts of nuclear physics.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Yukawa theory of nuclear forces, Deuteron problem and tensor forces, n-p, p-p scattering and partial wave theory, effective range theory.	6
2.	Shell Model and its predictions: magnetic moments of nuclei and Schmidt lines, quadrupole moments; Even-even, odd-even, odd-odd nuclei, pairing interaction; Many-body basis states, Hartree-Fock single-particle Hamiltonian, selection of shell model space and effective Hamiltonian.	8
3.	Deformed nuclei and their shapes; Colletive model Hamiltonian, vibrational and rotational spectra, Nilsson model. High spin phenomena (back bending), superdeformation, octopole deformation Giant dipole resonances.	7
4.	Kinematics of nuclear reaction, reciprocity theorem, compound nuclear reaction, direct reaction and derivation of the crossections in these processes; Statistical theory of nuclear reaction and concept of nuclear temperature and entropy	7
5.	Shape-elastic, compound elastic scattering and dispersion relations, Electromagnetic transitions in nuclei, multipole expansion of the electromagnetic field; Transition probability in semiclassical treatment, Weisskopf estimate.	7
6.	Angular correlation studies; Lifetime measurements; Detection of gamma rays; Hp-Ge and other detectors; Gamma arrays.	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Roy R R and Nigam B P, “Nuclear Physics”, John Wiley	**2002**
2.	Srivastava B B, “Fundamentals of Nuclear Physics”, Rastogi Publications	**2006**
3.	Eisenberg J M and Greiner W, “Nuclear Theory”, Vols. 1, North Holland	**2002**
4.	Eisenberg J M and Greiner W, “Nuclear Theory”, Vols. 2, North Holland	**2002**
5.	Eisenberg J M and Greiner W, “Nuclear Theory”, Vols. 3, North Holland	**2002**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-609** Course Title: **Experiments in Condensed Matter Physics**

2. Contact Hours: **L: 0** **T: 0** **P: 6**

3. Examination Duration (Hrs.): **Theory** 0 **Practical** 6

4. Relative Weightage: **CWS** 0 **PRS** 50 **MTE** 0 **ETE** 0 **PRE** 50

5. Credits: 3 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite**:** **PH-502**

9. Objective: To familiarize the students with the advanced experiments in Condensed Matter Physics.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Study of variation of resistivity of metal and highly resistive materials with temperature by Four Probe Technique.	14 x 6
2	Mapping and analysis of the resistivity of large samples (thin films, superconductors. etc) by Four probe Technique.	
3	To study the temperature dependence of Hall coefficient of N and P type semiconductors	
4	(a) To measure the dielectric constant and Curie temperature of given ferroelectric samples. (b) To measure the coercive field (E_c), Remanent Polarization (P_r), Curie Temperature (T_c) and Spontaneous Polarization (P_s) of Barium Titanate ($BaTiO_3$).	
5	Thermoluminescence in alkali halides crystals. (a) To produce F centers in the crystal exposing to X-ray /UV source. (b) To determine activation energy of the F-centers from initial rise method.	
6	Verification of Bragg's law and determination of wavelength/energy spectrum of X-rays.	
7	Study of Solar Cell characteristics and to determine (i) Open circuit voltage 'V_{oc}' (ii) Short circuit current 'I_{sc}', (iii)Efficiency 'η',(iv) Fill factor, (v) Spectral characteristics and (vi) Chopper characteristics.	
8	To measure the magnetoresistance of semiconductor and analyze the plots of $\Delta R/R$ and log-log plot of $\Delta R/R$ Vs magnetic field.	

9	To determine the coercivity, saturation magnetization and retentivity of ferromagnetic samples using Magnetic Hysteresis Loop Tracer	
10	To study the temperature dependence of Laser diode characteristics	
11	To determine transition temperature of given superconducting material and study Meissner effect.	
12	To measure critical current density of given superconductor and study its field dependence.	
13	To determine the value of Lande's 'g' factor using ESR spectrometer.	
14	To study C-V characteristics of various solid state devices & materials. (like p-n junctions and ferroelectric capacitors	
	Total	**84**

11. Suggested Books:

S. No.	**Name of Authors/ Books/Publishers**	**Year of Publication/Reprint**
1.	Melissinos A.C. and Napolitano J, "Experiments in Modern Physics", Academic Press	2003
2.	S.M. Sze, "Semiconductor devices Physics & Tech.", Wiley	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-611** Course Title: **Experiments in Atmospheric Physics**
2. Contact Hours: **L: 0** **T: 0** **P: 6**
3. Examination Duration (Hrs.): **Theory** **0** **Practical** **6**
4. Relative Weightage: **CWS** **0** **PRS** **50** **MTE** **0** **ETE** **0** **PRE** **50**
5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **PEC**
8. Pre-requisite: **PH-502**
9. **Objective of Course:** The lab work aims to familiarizing students with the basic experiments in Atmospheric Physics.
10. **Details of Course:**

Sl.No.	**Contents**	**Contact Hours**
1	To measure fair weather electric field and do atmospheric electric field simulation	14 x 6
2	To measure the concentration of salts in the ground water and rain water using Flame Photometer	
3	To measure the rain water precipitation rate and to find rain drop size distribution using Rain Gauge:	
4	To measure attenuation coefficient of a gas for a given wave length of electromagnetic radiation.	
5	To measure the size distribution of aerosol particles.	
6	To measure solar constant using Solarimeter and study the diuranal variation of solar flux in the visible spectrum.	
7	To measure the diuranal variation of sound noise: A case study.	
8	To study and analysis of VLF generated by lightning.	
9	Study and assessment of ambient air quality using spectrophotometer.	
10	To analyze Ionosonds data and obtain electron density is the ionosphere.	
	Total	84

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	McCartney E J, “Optics of the Atmosphere”, Wiley	**1976**
2.	Hulst H C, “Light Scattering by Small Particle”, Courier Dover Pub	**1964**
3.	Lab Manual for Flame Photometer, Elico Ltd.	
4.	Lab Manual for Aerosol Size distribution, Scientific India	
5.	Lab Manual for Attenuation Constant, Spectra Laser	
6.	Lab Manual for Rain Gauge, Weather Measure Corp.	
7.	Lab Manual for Electric Field Simulation, Atmospheric Lab, IITR	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Physics**

1. Subject Code: **PH-613** Course Title: **Experiments in Laser Physics**
2. Contact Hours: **L: 0** **T: 0** **P: 6**
3. Examination Duration (Hrs.): **Theory** 0 **Practical** 6
4. Relative Weightage: **CWS** 0 **PRS** 50 **MTE** 0 **ETE** 0 **PRE** 50
5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PEC**
8. Pre-requisite: **PH-502**
9. Objective: The lab work aims to familiarize the students with the advanced experiments in Laser Physics Lab.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	To determine the mode field diameter (MFD) of the fundamental mode of a given single-mode fiber using the far field technique.	14 x 6
2.	To measure the near field intensity profile of a multimode fiber and thereby its refractive index profile.	
3.	To measure the propagation constants of a given optical waveguide using the prism coupling technique.	
4.	To study electrical and optical characteristics of LED and LD.	
5.	To measure power loss at a splice between two multimode fibers and study the variation of splice loss with transverse, longitudinal and angular offsets.	
6.	To study bend-induced loss in a single mode fiber.	
7.	To study faraday effect and to measure the angle of rotation as a function of mean flux density at different wavelengths thereby evaluate Verdet's constant as a function of wavelength.	
8.	To study Kerr effect and to determine Kerr constant of a given material.	
9.	To study fiber grating based pressure sensor.	
10.	To construct EDF ring laser and characterize it in terms of slope efficiency, lasing threshold and intra-cavity loss.	
11.	To record and reconstruct holograms.	
12.	To characterizes a WDM based optical communication system in terms of insertion/return loss, isolation/extinction ratio, narrowband wavelength response of WDM components and chromatic dispersion.	
13.	To construct and characterize a diode pumped Nd:YVO_4/Nd:YAG laser and to do second harmonic generation.	

14.	To study the acousto-optic effect and determine the velocity of acoustic waves in a given medium using a laser beam	
	Total	**84**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Ghatak and Shenoy, "Fiber Optics through experiments", Viva Books	**1994**
2.	Laud B B, "Lasers and Nonlinear Optics", Wiley Eastern Ltd.	**1992**
3.	Ghatak A.K., Pal, B.P., Shenoy M. R. and Khijwania S.K, " Fiber Optics through Experiment", Viva Books	**2009**
4.	Ghatak A. K. and Thyagrajan K., " Optical Electronics", Cambridge University Press	**2003**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-615** Course Title: **Experiments in Nuclear Physics**
2. Contact Hours: **L: 0** **T: 0** **P: 6**
3. Examination Duration (Hrs.): **Theory** **0** **Practical** **6**
4. Relative Weightage**:** **CWS** **0** **PRS** **50** **MTE** **0** **ETE** **0** **PRE** **50**
5. Credits**:** **3** 6. Semester**: Autumn** 7. Subject Area**: PEC**
8. Pre-requisite**:** **PH-502**
9. Objective: The lab work aims to familiarizing students with the advanced experiments in Nuclear Physics.
10. Details of Course:

S. No.	Particulars	Contact Hours
1.	To do the energy analysis of an Unknown Gamma Source by Gamma Ray Spectroscopy using NaI(Tl) - Single Channel Analyzer (i) Energy Calibration (ii) Energy Analysis of an Unknown Gamma Source. (iii) Energy Resolution.	**14 x 6**
2.	To do Spectrum Analysis of ^{60}Co and ^{137}Cs by Gamma Ray Spectroscopy using NaI(Tl) - Multi Channel Analyzer and study the Energy resolution dependence on detector size.	
3.	To find the Mass Absorption Coefficient of lead for 662 KeV gamma ray	
4.	Alpha Spectroscopy with surface barrier detectors (i) Alpha spectrum and energy calibration. (ii) Energy determination of an Unknown alpha source of alpha particles.	
5.	Spectrum expansion with Multi-channel Analyzer and decay ratios of ^{241}Am.	
6.	Beta spectroscopy (i) Calibration with a pulser (ii) Beta end point determination for ^{204}Tl (iii) Conversion electron ratio.	
7.	Compton Scattering (i) Simple Compton Scattering (Energy Determination) (ii) Simple Compton Scattering (Cross-section Determination)	

8. **9.** **10.**	To study Rutherford Scattering of alpha particles from thin gold foil and Al foil. To determine Half-Lives of Radioactive sources prepared by neutron activation – In and Ag isotopes To study Gamma-gamma coincidence by (i) Overlap coincidence method – ^{22}Na (ii) Time to pulse height converter method – ^{22}Na	
	Total	**84**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Leo W R, "**Techniques for Nuclear & Particle Physics Experiments**", Narosa	**2000**
2.	Kapoor S S and Ramamurthy V "**Nuclear Radiation Detectors**", New Age Publishers	**1986**
3.	ORTEC Lab Manual, "**Experiments in Nuclear Science**", ORTEC	**1992**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-617** Course Title: **Advanced Characterization Techniques**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PEC**

8. Pre-requisite: **PH-201, PH-202**

9. Objective: To introduce the various methods of characterization of materials for their structural, electrical, magnetic and optical properties.

10. Details of Course:

S.No.	Contents	Contact Hours
1	**Crystal Structure Determination:** Brief description of Crystal Lattices; X-ray diffractometer; Determination of Crystal Structure using X-ray diffraction	12
2	**Electron Microscopes:** Brief description of different microscopes like TEM, SEM, AFM; Different modes of operation of microscopes, sample preparation, Interpretation of electron diffraction and determination of Crystal Structure; Morphology of the Crystals.	11
3	**Thermal Analysis:** Thermogravimetric analysis, Differential thermal analysis and Differential scanning calorimetry and methodology; Determination of phase transitions using these methods.	05
4	**Electrical and Magnetic Property:** Measurement of Electrical conductivity in different materials, e.g. insulators, metals and semiconductors. Using Four Probe and Hall Effect method. Vibrating Sample Magnetometer (VSM), Superconducting Quantum interference Devices (SQUID), Magnetodielectric effect	8
5	**Optical Characterization:** Optical characterization of materials using Photoluminescence and UV-visible spectroscopy.	03

6	**Chemical Analysis:** Brief description to X-ray fluorescence, Atomic absorption and electronic spin resonance spectroscopy.	**03**
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication /Reprint
1.	Culity B D, “Elements of X-ray Diffraction”, Addison-Wesley.	**2001**
2.	Grundy P J and Jones G A, “Electron Microscopy in the Study of Materials”, Edward Arnold	**1976**
3.	Egerton R F, “Physical Principles of Electron Microscopy”, Springer	**2008**
4.	Willard, Merritt, Dean and Settle, “Instrumental Methods of Analysis”, CBS publications	**1991**
5.	Fultz B and Howe J M, “Transmission Electron Microscopy and Diffractometry of Materials”, Springer.	**2007**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-619** Course Title: **A Primer in Quantum Field Theory**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0
5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PEC**
8. Pre-requisite: **PH-503**
9. Objective: To familiarize students with applications of relativistic quantum mechanics.
10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Basics:** Action principle; Euler-Lagrange equations of motion, second quantization; Symmetry (space-time and internal) Conserved Nöther charges.	4
2.	**Tensors:** Definitions of contravariant, covariant and mixed tensors, need to use tensors in relativistic quantum mechanics.	2
3.	**Spin-0 (Klein Gordon Field Theory):** Real scalar field theory and its canonical quantization; Normal Ordering; Charged scalar field theory and its canonical quantization, conserved Nöther current and charge, Propagator (also as vacuum expectation value of a time-ordered product), interpretation of negative-energy solutions as anti-matter; Recasting Klein-Gordon equation as a Schrödinger equation, Zitterbewegung.	7
4.	**Spin-1/2 (Dirac Field Theory):** Dirac Lagrangian for spinor fields, Feynman Gamma matrices and related identities; Covariance of the Dirac equation; Canonical quantization of the spinor fields, positive- and negative-energy spinors, positive- and negative-energy projectors, Lorentz transformations to boost from rest frame to lab frame; Propagator (also as vacuum expectation value of a time-ordered product), Discrete symmetries: Charge conjugation, Parity and Time reversal symmetries.	9
5.	**Spin-1 (Gauge Field Theory):** Covariant formulation of Maxwell's equations, (transverse) canonical quantization of the gauge field (in the Coulomb gauge),	5
6.	**Scattering**: LSZ reduction (for bosons and fermions), Wick's theorem, S-matrix, cross sections.	6

7.	**Quantum Electrodynamics**: Quantization of abelian gauge theories with fermions; Feynman Rules; Compton effect; Møller Scattering, radiative corrections; Anomalous Magnetic Moment; Infrared Divergence; Lamb shift.	9
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication/ Reprint
1.	Michio K, Quantum Field Theory: A Modern Introduction, Oxford University Press.	1993
2.	Claude I and Jean B. Z., "Quantum Field Theory, McGraw Hill College Div.	2006
3.	Lewis H R, "Quantum Field Theory", Cambridge University Press	2001
4.	Michael E. P, "An Introduction to Quantum Field Theory, Perseus Books Publishing	2002
5.	Lahiri A, Pal P B., A First Book of Quantum Field Theory, Narosa Publishing House	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-621** Course Title: **Astrophysics**
2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**: CWS** **15** **PRS** **0** **MTE** **35** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite**: PH-202 and PH-303**

9. Objective: The course exposes the students to a broad field of astrophysics and cosmology at the introductory level.

10. Details of Course:

S.No.	Particulars	Contact Hours
1	**Introduction:** Celestial sphere, elliptical orbits, Newtonian mechanics, Kepler's laws, Virial theorem, magnitude scales, color index, stellar parallax, distance measurements, astronomical instruments.	8
2	**Physics of Sun:**Spectralclassification of stars,structure of the Sun, solar cycle, sun spots, properties and structure of our solar system, extrasolar planets.	6
3	**Physics of Stars:** Star formation, stellar evolution from pre-main sequence throughthe main sequence,binaries, clusters.Final stages of stellar evolution and stellar remnant:giants, white dwarfs, supernovae, neutron stars, pulsars, blackholes.	10
4	**Physics of Galaxies:** Galactic structure and classification, our galaxy, active galactic nuclei, quasars, galactic rotation curves and dark matter, galaxy clusters and large-scale structure.	10
5.	**Cosmology:**Big bang cosmology, redshift and expansion of the universe,the cosmic microwave background,physics of the early universe.	8
	Total	42

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication
1.	Carroll B W &Ostlie D A, "An introduction to modern astrophysics", 2nd ed., Pearson Education	**2007**
2.	Basu B,Tanuka C, &Nath B S, "An introduction to astrophysics", 2nd ed., Prentice Hall of India,	**2010**
3.	Abhyankar K D, "Astrophysics: Stars and Galaxies", 1st ed., Universities Press (India) Limited.	**2000**
4.	Shu Frank, "The Physical Universe: An Introduction to Astronomy",1st ed., University Science Books	**1982**
5.	Padmanabhan T, "Theoretical Astrophysics: vol.1,2,3", Cambridge University Press	**2010**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-623** Course Title: **General Relativity**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage**:** **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0
5. Credits**:** 3 6. Semester**: Autumn** 7. Subject Area**: PEC**
8. Pre-requisite**:** **PH-505**
9. Objective: To introduce the basics of non-Euclidean Geometry and Einstein's theory of general relativity and its applications.
10. Details of Course:

S.No.	Contents	Contact Hours
1.	Inertial mass and gravitational mass, gravitational redshift, action in relativity	3
2.	Principle of equivalence, metric tensor and the affine connection, geodesics.	5
3.	Covariant differentiation, analogy with electromagnetism, p-forms, generalized Stokes theorem.	5
4.	Curvature tensor, parallel transport, algebraic properties of the curvature tensor, Bianchi identities.	7
5	Lorentz transformation, representation of Lorentz group, conserved currents and energy momentum tensor	5
6	Einstein's field equations and some of their solutions: Robertson-Walker metric, Schwarzschild metric, black holes, deflection of light by Sun, precession of perihelia of planets. Expanding universe	8
7.	Expanding universe, Tetrad formalism, Killing vectors, maximally symmetric spaces.	5
8.	Kaluza-Klein theories an approach towards unification of, e.g., electromagnetism and gravity.	4
	Total	**42**

11.	Suggested Books:	
S.No.	**Name of Authors/ Books/Publishers**	**Year of Publication/ Reprint**
1.	Landau L D and Lifshitz E M, “The Classical Theory of Fields”, 4th Ed. Elsevier.	**2005**
2.	Weinberg S, “Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity”, Wiley	**1972**
3.	Kaku M, “Quantum Field Theory: A Modern Introduction”, Oxford University Press.	**1993**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-625** Course Title: **Particle Physics**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**
4. Relative Weightage: **CWS** **15** **PRS** **0** **MTE** **35** **ETE** **50** **PRE** **0**
5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **PEC**
8. Pre-requisite: **PH-516**
9. Objective: To introduce the basics of elementary particle physics.
10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Qualitative preview**: A preview of particle physics**,** basic ideas of the four interactions – gravitational, electromagnetic, strong and weak.	2
2.	**Tools** (i) **Tensors:** Definitions of contravariant, covariant and mixed tensors, need to use tensors in relativistic quantum mechanics and particle physics; (ii) **Relativistic Kinematics**: Lorentz transformations, 4-Vectors, energy and momentum, collisions; (iii) **Scattering**: Lifetimes and Cross Sections, Fermi's Golden Rule, Feynman Rules, evaluation of scattering amplitudes and cross sections using Feynman Rules.	8
3.	**Symmetries**: Symmetries, Groups and Conservation Laws; Spin and Orbital Angular Momentum, Addition of Angular Momentum; Flavor symmetries; Parity; Charge Conjugation; CP violation; Time reversal symmetry; CPT Theorem; Noether's Theorem: Symmetry and conservation laws.	6
4.	**Electromagnetic Interaction**: (i) **Gauge Field Theory**: Covariant formulation of Maxwell's equations, (transverse) canonical quantization of the gauge field (in the Coulomb gauge); (ii) **QED** (quantization of abelian gauge theories with fermions): Feynman Rules, Compton effect, Møller Scattering, radiative corrections, Anomalous Magnetic Moment, Lamb shift.	8

5.	**Strong Interaction**: (i) **Pre-QCD**: The structure of Hadrons, Probing a charge distribution with electrons: Inelastic electron -proton scattering, Partons and Bjorken scaling; (ii) **QCD** (quantization of non-abelian gauge theories with fermions): Yang-Mills theory, Parton model revisited, Feynman rules, Asymptotic freedom.	8
6.	**Weak Interaction**: (i) **Phenomenology**: Parity violation and the V-A form of the weak current, Muon decay, Pion decay, charged current, neutral currents, Cabibbo angle, weak mixing angle, CP Invariance, CP violation; (ii) **Electroweak Unification (Glashow-Salam-Weinberg model)**: The basic electroweak interaction, effective current-current Interaction, Spontaneous symmetry breaking, Higgs mechanism and choice of the Higgs field, masses of gauge bosons and fermions, the complete Lagrangian.	10
	Total	**42**

11. Suggested Books:

S.No.	**Name of Authors/ Books/Publishers**	**Year of Publication/ Reprint**
1	Halzen F and Martin A D, "Quarks and Leptons: Introductory Course in Modern Particle Physics", John Wiley and Sons, Inc	1990
2	Griffiths D, "Introduction to Elementary Particles", John Wiley and Sons Inc.	1987
3	Perkins D H, "Introduction to High Energy Physics", Cambridge University Press	2000
4	Georgi H, "Weak Interactions and Modern Particle Theory", Benjamin-Cummings Pub Co	1984
5	Kane G L and Kane G, "Modern Elementary Particle Physics", Westview Press	1993

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-627** Course Title: **Quantum Theory of Solids**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0
5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PEC**
8. Pre-requisite: **PH-504 and PH-508**
9. Objective: To provide deeper understanding of cooperative phenomenon in solids using the many body technique.
10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Many Body Techniques and the Electron Gas:** Creation and annihilation operators, many particle wave function in occupation number representation, commutation relations, N-electron Hamiltonian in creation- annihilation operators form; One electron and two-electron, parts. Hartree-Fock ground state energy, free electron gas; Ground State energy in Ist order. Elementary idea of Greens functions.	12
2.	**Plasma Oscillations in Free Electron Gas:** Resume of plasma theory, quantum mechanical plasma theory, Energy of the ground state; Correlation Energy; Short range and long range correlation energy.	10
3.	**Magnetism:** Magnetism in Insulators; Heisenberg model; Spin waves; quantization of spin waves; Acoustic and optical magnons; Magnon specific heat; Antiferromagnitic Magnons; Magnetism in metals; Itinerant Ferromagnetism.	10
4.	**Superconductivity:** Electron-phonon interactions; Bound electron-pairs in a Fermi gas; Superconducting ground state; Hamiltonian solution of BCS equation for the energy-gas; Electrodynamics of superconductors, coherence length.	10
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication /Reprint
1.	Raimes S, "Many Electron Systems", North Holland Publishing Co.	**2000**
2.	Kittel C, "Quantum Theory of Solids", John Wiley and Sons	**1987**
3.	Ziamn J M, "Principles of Theory of Solids", Cambridge Univ. Press	**2000**
4.	Chaikin P M and Lubensky T C, "Principles of Condensed Matter", Cambridge Univ. Press	**2000**
5.	Kantorovich L, "Quantum Theory of the Solid State:An Introduction", Kluwer Academic Publishers	**2004**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-629** Course Title: **Weather Forecasting**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0
5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PEC**
8. Pre-requisite: **None**
9. Objective: To familiarize with the dynamic meteorology of earth's atmosphere
10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Atmospheric Dynamics:** Equation of motion, the geostrophic approximation, cyclostrophic motion; The thermal wind equation; The equation of continuity.	8
2.	**The General Circulation:** A symmetric circulation, Inertial instability, Barotropic instability; Baroclinic instability; Sloping convection; The general circulation of the middle atmosphere.	8
3.	**Numerical Modelling of Weather:** A barotropic model; Baroclinic models; Primitive equation models; Moist processes; Radiation transfer; Forecasting models.	10
4.	**Global Observations:** Conventional observations; Remote sounding from satellites; Remote sounding of atmospheric temperature; Remote measurements of composition.	8
5.	**Atmospheric Predictability and Climate change:** Short term predictability; Variations of climate; Atmospheric feedback processes; Different kind of predictability	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication/ Reprint
1.	Houghton J T, “The physics of atmospheres”, Cambridge University Press	**1997**
2.	Holton J R, “Introduction to dynamic meteorology”, Academic Press,	**1992**
3.	Zdunkowski W and Boot A, “Dynamics of the Atmosphere”, Cambridge University Press,	**2003**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Physics Department**

1. Subject Code: **PH-631** Course Title: **Nuclear Instrumentation**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**

4. Relative Weightage: **CWS** 15 **PRS** 00 **MTE** 35 **ETE** 50 **PRE** 00

5. Credits: **03** 6. Semester: **Autumn**

7. Pre-requisite: **None** 8. Subject Area: **PEC**

9. **Objective of Course:** To provide comprehensive knowledge on instrumentation related to nuclear physics.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Radioactive decay, Source of charged and uncharged radiation, Interaction of radiation with matter: heavy charged particle, electron, gamma-rays and neutrons, stopping power, Bragg curve, Radiation exposure, absorbed dose, equivalent dose, Counting statistics, Error analysis	**9**
2.	Properties of radiation detectors: operation mode, pulse height spectra, energy resolution, detection efficiency and dead time. Ionization chambers, Proportional counters, Geiger Mueller counters Scintillation detectors: Inorganic and Organic scintillators, photomultiplier tube, Response of scintillation detectors to gamma-rays and neutrons. Application of scintillation detectors	**11**
3.	Semiconductor diode detector and its use in alpha spectrometry, fission fragment spectroscopy, particle identification, X-ray spectroscopy. Gamma spectroscopy with Silicon(Si(Li)) and Germanium (Ge(Li), HPGe) detectors, Fast and slow neutron detection Pulse processing electronics: NIM: Amplifier, SCA, CFD, CAMAC: ADC, TDC, Timing and coincidence measurements.	**12**
4.	Linear and circular accelerators, Nuclear reactor: neutron source and power generator. Applications in tracing, material modification, sterilization, material modification; neutron activation analysis, medicine: CT, PET, SPECT, MRI, therapy	**10**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Glenn F. Knoll, "**Radiation Detection and Measurement" 4th Ed.**	**2010**
2.	W.R. Leo, "**Techniques for Nuclear and Particle Physics experiments**", Springer-Verlag	**1994**
3.	S Ahmed**, "Physics and Engineering of Radiation Detection"** Academic press	**2007**
4.	S.S. Kapoor, V. Ramamurthy, "**Nuclear Radiation Detectors**" New Age International (P) Ltd.	**2005**
5.	John R. Lamarsh, Anthony J. Baratta, "**Introduction To Nuclear Engineering"**, Prentice Hall.	**2011**
6.	Gordon R. Gilmore, "**Practical Gamma-ray Spectrometry**", John Wiley & Sons (2nd Ed.)	**2008**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **DEPARTMENT OF PHYSICS**

1. Subject Code: **PH-633** Course Title: **Physics and Technology of Thin Films**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0
5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PEC**
8. Pre-requisite: **None**
9. **Objective: To familiarize students with basic understanding of science and technology of thin films and their potential device applications**.
10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Vacuum Technology:** Role of Thin films in Technology and Devices; Introduction to Vacuum, Gas impingement on surfaces, Gas transport and pumping, Vacuum Pumps: Rotary pump, Diffusion Pump, Turbomolecular and Cryopumps.Vacuum systems, Vacuum gauges: Pirani gauge, Pennning gauge.	10
2.	**Thin Film Deposition:** PVD & CVD, Evaporation: Thermal & Electron beam evaporation , Glow discharge and plasmas-Plasma structure, Sputtering processes-Mechanism and sputtering yield, DC, RF & Reactive Sputtering, Pulsed laser deposition, Molecular beam epitaxy, Atomic layer deposition, CVD film growth, Thermal CVD Processes: Atmospheric Pressure CVD, Low Pressure CVD, Metalorganic CVD, Plasma enhanced CVD	12
3.	**Nucleation & Growth Kinetics**: Adsorption, Surface diffusion, Film growth modes, models for 3D and 2D nucleation, coalescence and depletion, grain structure and microstructure and its dependence on deposition parameters. Role of energy enhancement in nucleation; Characterization methods: XRD, SEM, AES, STM & thickness measurement. Epitaxy, homo- and hetero-epitaxy, lattice misfit and imperfections, superlattice structures	12

4.	**Applications & Emerging Technologies:** Semiconductor thin films for Micro and Nanoelectronics, Superconducting thin films for Josephson devices, Magnetic Multilayers for GMR & Spintronics, Quantum Well devices, Thin film solar cells, Sensor & Actuators.	08
	Total	**42**

11. Suggested Books:

Sl. No.	Authors/Name of Books/ Publisher	Year of Publications/ Reprint
1	J.L. Vassen, W. Kem, Thin Film Process, Academic Press	1990
2	R.K. Waits, Thin film deposition and patterning, American Vacuum Society	1998
3	J.A. Venables, Introduction to Surface and thin film processes, Academic Press	2000
4	M. Ohring, Materials science of thin films, Academic Press	2006
5	W.R. Fahrner, Nanotechnology and Nanoelectronics, Springer	2005
6	Thin Film Phenomena by K. L. Chopra, McGraw Hill	1979
7	H. Luth, Solid Surfaces, Interfaces and Thin Films, Springer	2010
8	V. Agranovich, Thin Films & Nanostructures, Elsevier	2012
9	G.Decher, J.B.Schlenoff, Multilayer Thin Films, Wiley-VCH Verlag GmbH & Co. KGaA	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Physics Department**

1. Subject Code: **PH-635** Course Title: **Advanced Nuclear Reactions**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** -

4. Relative Weightage: **CWS** 15 **PRS** - **MTE** 35 **ETE** 50 **PRE** -

5. Credits: **3** 6. Semester: **- Autumn** 7. Subject Area: **- PEC**

8. Pre-requisite: **None**

9. Objective: The course is designed to provide the advance knowledge of nuclear reactions and its applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Formal Scattering theory: introduction, Lipmann-Schwinger equation, operator algebra, Born series, Analytic properties of the S-matrix: Jost-function, Analytic continuation in the complex plane, bound states, resonances, Kinematics (non relativistic) of two- and three bodies, 2 body and 3-body phase space of scattering processes	**8**
2.	Direct reaction theory: Two-potential formula, DWBA, various applications: rearrangement reactions, inelastic scattering, breakup reactions: post, prior and alternate prior form. Various models of breakup reactions, Coupled channel formalism, Introduction to transfer reactions: angular momentum transfer and single particle structure information, Introduction to the theory of Coulomb excitation.	**10**
3.	Intermediate energy collisions: Relativistic Kinematics: Use of invariants in calculations of energy momentum and velocity relations among various frame of references, Transformation of differential cross sections, variables and coordinates systems of elastic scattering (s-, u- and t-channel variables), Eikonal approximation, Coulomb corrected eikonal approximation	**8**
4.	Compound reaction theory: Compound reaction formation, R-matrix, Compound nucleus decay, Reciprocity theorem, Hauser-Feshbach theory	**6**
5.	Nuclear physics at the extremes of stability: weakly bound quantum systems and exotic nuclei, nuclear halos, neutron skins, proton rich nuclei, Radioactive ion beams as a new experimental technique, ISOL and in-flight fragment separation	**7**
4.	Nuclei in the Cosmos: thermonuclear cross sections and nuclear reaction rates in non-degenerate stars, Gamow peak, nuclear burning stages in stars.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Bertulani, C.A. and Danielewicz, P, "Introduction to Nuclear reactions", Institute of Physics Publishing	2004
2.	Glendenning, N.K., Direct Nuclear Reactions, World-Scientific	2004
3.	Thompson, I.J., Nunes F.M., "Nuclear Reactions for Astrophysics", Cambridge	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Physics Department**

1. Subject Code: **PH-637** Course Title: **Semiconductor Photonics**
2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Autumn** 7.Subject Area: **PEC**

8. Pre-requisite: **None**

9. Objective: **The course is aimed at introducing to students the concepts of semiconductor photonic devices and various devices based on these.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Interaction of photons with atoms, spontaneous emission, stimulated emission and absorption, semiconductors, energy bands and charge carriers, semiconductor materials, elemental, binary, ternary and quaternary semiconductors, interaction of photons with semiconductors, generation, recombination and injection processes, junctions, hetrojunctions, quantum wells, superlattices, interaction of photons with electrons and holes, band-to-band absotption and emission, rates of absorption and emission, refractive index.	**8**
2.	Light emitting diode (LED), operation of LED, carrier injection and spontaneous emission, internal quantum efficiency, external quantum efficiency, P-I characteristics, slope efficiency, output spectrum, radiation pattern, temperature dependence, modulation of LED, temporal response, advanced LED structures, heterojunction LED, edge and surface emitting LEDs, applications of LEDs as light sources, displays, and in communication.	**10**
3.	Semiconductor optical amplifier (SOA), basic configuration , stimulated emission in a semiconductor, optical gain, effect of optical reflections, limitations of SOA	**3**
4.	Laser diode (LD), semiconductor laser basics, optical gain in forward	**7**

	biased p-n junction, laser oscillations and threshold current, P-I characteristics, slope efficiency, differential external quantum efficiency, temperature dependence, output spectrum, longitudinal modes, single frequency operation, DFB laser, DBR laser, radiation pattern, modulation, heterojunction LD, quantum well laser	
5.	Properties of semiconductor photodetectors, quantum efficiency, responsivity, response time, photoconductors, photodiodes, p-n photodiode, p-i-n photodiode, hetrostructure photodiodes, array detectors, avalanche photodiodes, noise in photodetectors.	**7**
6.	Solar photovoltaic, solar energy spectrum, photovoltaic device principle, p-n junction photovoltaic, I-V characteristics, series resistance and equivalent circuit, temperature effects, solar cell materials, devices and efficiencies.#	**7**
	Total	**42**

11. Suggested Books:

S. No.	Authors/Name of Books/Publisher	Year of Publication
1.	Saleh B E A and Teich M C, "**Fundamentals of Photonics**", John Wiley & Sons, Inc.	**1991**
2.	Jaspreet Singh, " **Optoelectronics: An Introduction to Materials and Devices**". McGraw Hill International Edition	**1996**
3.	Safa O. Kasap, "**Optoelectronics and Photonics**", Pearson.	**2009**
4.	Streetman B G and Banerjee S K, **"Solid State Electronic Devices,"** Pearson Prentice Hall	**2008**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-639** Course Title: **Advanced Atomic and Molecular Physics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weightage: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 4 6. Semester: **Autumn** 7. Subject Area: **PEC**

8. Pre-requisite: PH-503, PH-518

9. Objective: To introduce the mean-field methods necessary for studying the physics of many electron systems, to study interaction of atoms with electromagnetic radiation, molecular spectroscopy and the applications of group theory.

10. Details of Course:

Sl.No	Contents	Contact Hours
1.	**Many-electron Atoms :** The central field approximation, Thomas-Fermi potential, Hartree- and Hartree-Fock approximation, self-consistent field procedure, Dirac-Hartree-Fock method, Breit interaction, electron correlation effects, basic concepts of post-mean field methods, Qualitative ideas of density functional theory.	**12**
2.	**Interaction of atoms with radiation :** Transition rates, Einstein coefficients, electric dipole (E1) approximation, E1 selection rules, oscillator strengths, line intensities, line shapes and line widths; retardation effects, magnetic dipole and electric quadrupole transitions, lifetimes of excited states; photoelectric effect, Bremsstrahlung.	**08**
3.	**Molecular rotations and vibrations:** Spectroscopic transitions, rotational spectra of molecules, rotational selection rules; vibrational spectra of diatomic molecules, vibrational selection rules, vibration-rotation spectra of diatomic molecules.	**08**
4.	**Molecular electronic transitions :** Vibronic transitions, Franck-Condon principle, rotational structure of vibronic transitions, Fortrat diagram, dissociation energy of molecules, continuous spectra, Raman transitions and Raman spectra.	**08**
5.	**Molecular Symmetry and Symmetry Groups :** Symmetry elements and symmetry operations, symmetry classification of molecules, point groups; reducible and irreducible representations; character tables for point groups; normal modes of molecular vibrations; applications of group theory to molecular vibrations.	**06**
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication/ Reprint
1.	Bransden B. H. and Joachain C. J., "Physics of Atoms and Molecules", 2nd edition, Pearson Education	2004
2.	Atkins P. and Friedman R., "Molecular Quantum Mechanics", 5th edition, Oxford University Press	2011
3.	Haken H and Wolf H. C., "Molecular Physics and Elements of Quantum Chemistry", 2nd edition Springer-Verlag	2004
4.	Hollas J. M., "Modern Spectoscopy", 4th edition, Wiley	2004
5.	Atkins P. and Paula J. D., "Physical Chemistry", 9th edition, Oxford University Press	2010
6.	Cotton F. A., "Chemical Applications of Group Theory", 3rd edition, Wiley 1990	1990

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Physics**

1. Subject Code: **PH-602** Course Title: **Nuclear Astrophysics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** **CWS** **15** **PRS** **0** **MTE** **35** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** **PH-503**

9. Objective: To introduce the emerging field of nuclear astrophysics which attempts to understand how nuclear processes generate the energy of stars over their lifetimes and synthesize heavier elements.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	**Introduction :** Astronomy-Observing the universe**,** Astrophysics-'Explaining' the universe; General characteristics of Thermonuclear reactions; Sources of nuclear energy; Cross sections, stellar reaction rates, mean lifetime; Maxwell-Boltzmann velocity distribution, Astrophysical *S* – factor,	10
2.	**Determination of reaction rates :** Neutron and charged particle induced non-resonant reactions**;** Reactions through narrow and broad resonances	8
3.	**Hydrogen and Helium burning :** p-p chain, CNO cycles, other cycles like NeNa, MgAl; Creation and survival of ^{12}C	9
4.	**Explosive Burning and Nucleosynthesis beyond Iron :** Silicon burning**;** Nucleosynthesis in massive stars**,** *s* – process, *r* - process	9
5.	**Indirect methods in Nuclear Astrophysics :** Coulomb dissociation, Trojan Horse and ANC methods; Neutron stars; Radioactive Ion	6

	Beams	
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Rolfs C E and Rodney W S, “Cauldrons in the Cosmos : Nuclear Astrophysics”, The University of Chicago Press	**2005**
2.	Clayton D D, “Principles of Stellar Evolution and Nucleosynthesis”, The University of Chicago Press	**1984**
3.	Glendenning N K, “Compact Stars”, Springer	**2000**
4.	Boyd R, “An Introduction to Nuclear Astrophysics”, The University of Chicago Press	**2008**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-604** Course Title: **Physics of Nanosystems**
2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits**:** 3 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** **PH-303**

9. Objective: This course on physics of nanosystems is designed to introduce the emerging area of nanotechnology.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	***Introduction*** - An overview of quantum mechanical concepts related to low-dimensional systems.	2
2.	***Hetrostructures*** **–** Heterojunctions, Type I and Type II heterostructures, Classification of Quantum confined systems, Electrons and holes in Quantum wells, Electronic wavefunctions, energy subbands and density of electronic states in Quantum wells, Quantum wires, and Quantum dots, Effective mass mismatch in heterostructures, Coupling between Quantum wells, Superlattices	5
3.	***Electron states*** - Wavefunctions and Density of States for superlattices, Excitons in bulk, in Quantum structures and in heterostructures, The unit cell for quantum well, for quantum wire and for quantum dot	6
4.	***Nanoclusters and Nanoparticles*** **–** introduction, Metal nanoclusters- Magic numbers, Geometric structures, Electronic structure, Bulk to nanotransition, Magnetic clusters; Semiconducting nanoparticles; Rare-gas and Molecular clusters.	4
5.	***Carbon Nanostructures*** **–** Introduction, Carbon molecules, Carbon clusters, Structure of C60 and its crystal, Small and Large Fullerenes and Other Buckyballs, Carbon nanotubes and their Electronic structure	3

6.	**Properties of Nano Materials:** Size dependence of properties, Phenomena and Properties at nanoscale, Mechanical/Frictional, Optical, Electrical Transport, Magnetic properties.	4
7.	**Nanomaterial Characterization:** Electron Microscopy, Scanning Probe Microscopies, near field microscopy, Micro- and near field Raman spectroscopy, Surface-enhanced Raman, Spectroscopy, X-ray photoelectron spectroscopy.	7
8.	**Synthesis of nanomaterials:** Fabrication techniques: Self-Assembly, Self-Replication, Sol-Gels. Langmuir-Blodgett thin films, Nanolithograph, Bio-inspired syntheses, Microfluidic processes, Chemical Vapor Deposition, Pulse laser deposition.	8
9.	**Applications of Nanomaterials:** Nanoelectronics, Nanosensors, Environmental, Biological, Energy Storage and fuel cells.	3
	Total	**42**

11. Suggested Books:

S.No.	**Name of Authors/ Books/Publishers**	**Year of Publication /Reprint**
1.	Edelstein A. A. and Cammarata R .C., "Nanomaterials- Synthesis, Properties and Applications", Institute of Physics Publishing, London	1998
2.	Shik, A, "Quantum Wells: Physics and Electronics of two-dimensional systems", World Scientific	1999
3.	Benedek et al G., "Nanostructured Carbon for advanced Applications", Kluwer Academic Publishers	2001
4.	Harrison, P, "Quantum Wells, Wires, and Dots: Theoretical and Computational Physics", John Wiley	2000
5.	Mitin, VV, Kochelap, VA and Stroscio, MA "Quantum Heterostructures: Microelectronics and Optoelectronics", Cambridge University Press	1999
6.	Poole, Jr. CP and Owens, FJ, "Introduction to Nanotechnology", Wiley India.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-606** Course Title: **Superfluidity and Superconductivity**

2. Contact Hours: L: **3** T: **0** P: 0

3. Examination Duration (Hrs.): Theory **3** Practical **0**

4. Relative Weightage: **CWS** **15** **PRS** **0** **MTE** **35** **ETE** **50** **PRE** **0**

5. Credits: **3** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **PH-504**

9. Objective: It introduces advanced concepts of superfluidity and superconductivity and their interrelationship.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Superfluidity:** Basic properties of superfluid ^{4}He and ^{3}He; Bose-Einstein condensation in an Ideal Bose Gas; Bose-Einstein Condensation in Interacting Gases, Condensate Wave Function.	8
2.	**Theory of Bose Fluids:** Landau Criterion for Superfluidity. Excitations in a uniform Gas – Bogoliubov Transformation; Excitations in a Trapped Gas – Weak Coupling, Excitations in Non-uniform Gases.	9
3.	**Vortex States:** Quantization of Circulation, Quantized Vortices in He-II; Quantized Vortices in Superconductors; Comparison of He-II and Superconducting Vortices; Dynamics of Vortex States.	9
4.	**Ginzburg-Landau Theory:** Ginzburg Landau equations, second order critical fields; Abrikosov vortex lattice; Relation of GL theory with BCS theory; Ginzburg-Pitaevskii equations for He-II; Broken symmetry.	8
5.	**High-Tc Superconductivity:** Nature and various mechanisms of High Tc superconductivity; Equation for the critical temperature and strong electron-phonon coupling; SDW and CDW.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Chaikin P M and Lubensky T C, “Principles of Condensed Matter Physics”, Cambridge University Press	**1995**
2.	Tilley D R and Tilley J, “Superfluidity and Superconductivity” (3^{rd} Ed), Overseas Press	**2005**
3.	Suneto T and Nakahara M,“Superconductivity and Superfluidity”, Cambridge University Press	**2005**
4.	Pethick C J and Smith H, “Bose-Einstein Condensation in Dilute Gases”, Cambridge University Press	**2002**
5.	Pitaevskii L and Stringari S, “Bose-Einstein Condensation”, Clarendon Press	**2003**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-608** Course Title: **Fiber and Nonlinear Optics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **PH-201 and PH-202**

9. Objective: To introduce applications of lasers in nonlinear optics, optical fiber communication and sensors.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Fiber optics:** Rectangular waveguides: optical waveguides, planar mirror waveguides, electromagnetic analysis of planar optical waveguides, TE and TM modes of a symmetric and asymmetric planar waveguide, power associated with a mode.	12
2.	Optical fiber: optical fiber waveguide, the numerical aperture, pulse dispersion in a step-index fiber, scalar wave equation and modes of a fiber, LP modes, single-mode fibers, material and waveguide dispersion for a communication link, attenuation, splice loss, methods of fabrication of optical fibers, optical fiber components, directional coupler, multiplexer, demultiplexer, fiber Bragg gratings, long-period fiber gratings, optical fibers in sensors, photonic crystal fibers.	12

3.	**Nonlinear optics:** Nonlinear optical media, nonlinear polarization and susceptibility 2nd order nonlinear optics: optical second harmonic generation, sum frequency generation, difference frequency generation, optical parametric amplification and oscillation, three wave mixing.	10
4.	3rd order nonlinear optics: third harmonic generation, optical Kerr effect, self phase modulation, self focusing, spatial solitons, Raman gain, four wave mixing, optical phase conjugation, Raman and Brillouin scattering.	8
	Total	**42**

11. Suggested Books:

S.No.	**Name of Authors/ Books/Publishers**	**Year of Publication/ Reprint**
1.	Ghatak A K and Thyagarajan K, "Optical Electronics", Cambridge University Press	**2003**
2.	Ghatak A K and Thyagarajan K, "Introduction to Fiber Optics", Cambridge University Press	**1998**
3.	Laud B B, "Lasers and Nonlinear Optics", Wiley Eastern	**1992**
4.	Saleh B E A and Teich M C, "Fundamantals of Photonics", Wiley Interscience	**2007**
5.	Snyder A and Love J, "Optical Waveguide Theory", Chapmann and Hall	**1983**
6.	Keiser G, "Optical Fiber Communications", McGraw Hill	**2000**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-610** Course Title: **Quantum Optics**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0
5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **PH-201 and PH-202**
9. Objective: The course provides an understanding of the physical principles of quantum optics and its use in laser cooling trapping of atoms.
10. Details of Course:

S.No.	Contents	Contact Hours
1	Two-level atom and classical electric field. Rabi solutions. Comparison to Lorentz atom. Multi-level atoms, selection rules for electric dipole transitions, Raman coupling in 3-level systems, optical pumping.	6
2	Density-matrix formalism: Application to two-level atom , optical Bloch equations, the Bloch vector, Ramsey fringes, photon echoes, adiabatic following, optical Bloch equations with dissipation (Relaxation. Spontaneous emission and collisions).	10
3	Dressed states: ac Stark effect, the Mollow triplet, Electromagnetically Induced Transparency (EIT), “slow light”, Coherent Pouplation Trapping (CPT), cavity QED, Jaynes-Cummings model.	10
4	Laser cooling and trapping: scattering force (Light forces on two-level atoms), Doppler cooling limit, magneto-optic trap (MOT), Optical lattices, Polarization gradient cooling overview, Raman transitions,	10
5	Magnetic trapping, evaporative cooling and Bose–Einstein condensation	6
	Total	42

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication / Reprint
1	Foot C. J.,"Atomic Physics", Oxford University Press	2005
2	Loudon R., "The Quantum Theory of Light", Oxford University Press	2001
3	Metcalf H. J. and Straten P. der , "Laser Cooling and Trapping", Springer-Verlag New York, Inc.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-612** Course Title: **Advanced Topics in Mathematical Physics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **PH-505**

9. Objective: The objective of this course is to familiarize the students with techniques that are part and parcel in a variety of fields in theoretical physics, specially, theoretical high energy physics, cosmology, etc.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Topology**: topological spaces, connectedness and compactness of spaces, continuous functions, homeomorphisms	8
2.	**Real Manifolds**: definition, vector fields, differential forms, frames, connection, curvature, torsion, integration of differential forms, Stokes theorem, Laplacian on forms.	8
3.	**Homology And Cohomology**: Simplicial Homology and De-Rham Cohomology	6
4.	**Homotopy:** Loops and homotopies, fundamental and higher homotopy groups.	6
5.	**Fibre Bundles**: the concept, tangent and cotangent bundles, vector and principal bundles.	6
6.	**Complex Manifolds And Cohomology**: Definition, Dolbeault Cohomology of complex forms, harmonic analysis, basic ideas about Kähler and Calabi-yau manifolds.	8
	Total	42

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication / Reprint
1.	Brian R. Greene, " String Theory on Calabi-Yau Manifolds", Lectures given at Theoretical Advanced Study Institute in Elementary Particle Physics (TASI 96) Published in *Boulder 1996, Fields, strings and duality* 543-726	1996
2.	Mukhi S. and Mukunda N., " Introduction to Topology, Differential Geometry and Group Theory for Physicists", Wiley Eastern, New Delhi.	1990

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-614** Course Title: **Introduction to Superstring Theory**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** **CWS** **15** **PRS** **0** **MTE** **35** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite: PH-505, PH-619

9. Objective: The main objective of this course is to prepare the student with the basics of superstring theory.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	Bosonic String Theory: Perturbative: free bosonic string in Minkowski space, commutation relation and mode expansion, Virasoro algebra, Light-cone gauge Quantization and no-ghost theorem, analysis of spectrum.	8
2.	Superstring Theory: World-sheet supersymmetry, boundary conditions and mode expansions, light-cone gauge quantization, [no-ghost theorem, GSO condition], extended world-sheet supersymmetry [N=2, 4], super Yang-Mills theory.	14
	Space-time supersymmetry, superparticle and superstring, type I and II superstrings, Light-cone quantization and analysis of open and closed-string spectra.	
	SO(32) and E_8 x E_8 heterotic string theories.	
3.	Basic Mathematics of String Theory: Topological Spaces, Continuous Functions, real (differentiable) manifolds, vector fields, differential forms, Riemannian Geometry, integrals of forms and Stokes theorem, Laplacian on forms, Simplicial Homology, de Rham Cohomology, Fiber Bundles, Homotopy theory, Complex Manifolds, Kählerian	8

	geometry, Dolbeault Cohomology, Calabi-Yau manifolds and their Moduli Spaces	
4.	Nonperturbative: dualities, basic ideas of M- and F -theories, compactifications, dualities, examples and their tests and interrelation between different duality conjectures, M-theory in 11 dimensions and its compactification, F-theory in 12 dimensions and its compactifications, nonperturbative D-branes and open strings in closed string theories.	12
	Total	42

11. Suggested Books:

S.No.	**Name of Books/Authors**	**Year of Publication**
1.	Superstring Theory: Volume 1, Introduction by Michael B. Green, John H. Schwarz, Edward Witten Cambridge University Press	1988
2.	String Theory (Cambridge Monographs on Mathematical Physics) (Volumes 1,2), J.Polchinksi	1998
3.	An Introduction to Nonperturbative String Theory, By Ashoke Sen, In *Cambridge 1997, Duality and supersymmetric theories* 297-413	1997
4.	*String theory on Calabi-Yau manifolds*, Brian R. Greene, (Columbia U.) : Lectures given at Theoretical Advanced Study Institute in Elementary Particle Physics (TASI 96): Fields, Strings, and Duality, Boulder, CO, 2-28 Jun 1996, Published in Boulder 1996, Fields, *Strings and* Duality, World Scientific Singapore	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **DEPARTMENT OF PHYSICS**

1. Subject Code: **PH-616** Course Title: **Advanced Electroceramics Technology**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: This course will introduce the students to modern day electoceramic materials and their applications and will enable the students to learn about modern applications of electroceramic materials and the underlying physical principles.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	INTRODUCTION: Oxide and non-oxide ceramics, their chemical formulae, crystal and defect structures, non-stoichiometry and typical properties.	4
2.	POWDER PREPARATION: Physical methods (different techniques of grinding), chemical routes - co-precipitation, sol-gel, hydrothermal, combustion synthesis, high temperature reaction (solid state reaction).	6
3.	BASIC PRINCIPLES AND TECHNIQUES OF CONSOLIDATION AND SHAPING OF CERAMICS: powder pressing- uniaxial, biaxial and cold isostatic and hot isostatic, injection moulding, slip casting, tape-casting, calendaring, multilayering.	5
4.	Sintering: different mechanisms and development of microstructure (including microwave sintering) Preparation of single crystal, thick and thin film ceramics Problems of sintering: Inhomogeneties and their effects on sintering, constrained sintering; rigid inclusion, thin film, solid solution additives and the sintering, sintering with chemical reaction, viscous sintering with crystallization.	5
5.	EXOTIC CERAMICS: functionally graded, smart/ Intelligent, bio-mimetic and nano-ceramics - basic principles, preparation and applications, Ceramic Sensors, Transparent ceramics, coatings and films: preparation and applications	8

6	Ceramic Capacitors: Historical Background, Ferro Electricity in Capacitors Technology, Dielectric Properties of Multi-Phase systems, Basic Dielectric Materials, Varieties of Ceramic capacitor, Capacitor performance Parameters, Typical Ceramic Dielectric Compositions, fuel cells and batteries	8
7.	Magnetic Ceramics: Spinal ferrites, Hexagonal ferrites, Rare earth-Garnet, Processing & application in various fields.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1.	Michel W. Barsoum, M. W., "Fundamental of Ceramics", McGraw Hill International edition	1997
2.	Richerson, D.W., " Modern Ceramic Engineering", Mercel Dekker NY	1992
3.	Rahman, M. N., "Ceramic Processing and Sintering", Mercel Dekker	2003
4.	Somiya, S., "Handbook of Advanced Ceramics", Academic Press	2003
5.	Somiya, S., "Handbook of Advanced Ceramics, Parts 1 and 2, Academic Press	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

1. Subject Code: **PH-618** Course Title: Atomic and Molecular Collision Physics

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Autumn** 7. Subject Area: **PEC**

8. Pre-requisite: **PH-516**

9. Objective: The course aims at introducing the formal scattering theory, and its applications to scattering of projectiles from atoms and molecules.

10. Details of Course:

Sl.No	Contents	Contact Hours
1.	**Potential scattering-I:** General features, partial wave analysis, Optical theorem and unitarity relation, the phase shifts, Absorption processes, Scattering by a complex potential, Coulomb potential in parabolic coordinates, partial wave decomposition, Scattering by a modified Coulomb field	12
2.	**Potential scattering-II:** Schrödinger equation as an integral equation, Green's function, Lippmann-Schwinger equation, Compact solutions of Lippmann-Schwinger equation, Integral representations of scattering amplitude, Partial wave analysis of Lippmann-Schwinger equation, Born expansion as a perturbation series, the first born approximation, Born Series.	10
3.	**Electron – atom collisions:** Electron scattering: general principles, elastic scattering, excitation of atoms to discrete levels, ionization, resonance phenomena	6
4.	**Atom-atom collisions:** Long range interactions between atoms, the classical approximation, the elastic scattering of atoms at low velocities, electronic excitation and charge exchange	8
5.	**Electron - molecule collisions:** Theory of electron-molecule collisions, calculation of differential and integrated cross sections and illustrative results	6
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/Publishers	Year of Publication / Reprint
1.	Joachain C. J., "Quantum Collision Theroy", North Holland, 3rd Edition, Amsterdam	1983
2.	Bransden B. H. and Joachain C. J., "Physics of Atoms and Molecules" 2nd Edition, Prentice Hall	2003
3.	Gianturco F. A., "Atomic and Molecular Collision Theory", Plenum Press, New York and London	1982
4.	Burke P. G. and Joachain C. J., "Theory of electron- Atom Collisions: Potential Scattering", Springer	1995
5.	Bransden B. H., "**Atomic Collision Theory**", 2d Ed., Benjamin, New. York	1983
6.	Zettili N, "Quantum Mechanics: Concepts and Applications", 2^{nd} Ed, John Wiley	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **PHYSICS**

Subject Code: **PH-620** Course Title: **Advanced Quantum Field Theory**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **PH-619, PH-505**

9. Objective: The main objective of this course is to prepare the student in terms of techniques extremely useful in a variety of areas in theoretical physics

10. Details of Course:

S.No.	Particulars	Contact Hours
1.	**Path Integrals:** (a) Nonrelativistic QM: Multi-dimensional path integral, time-ordered product, n-point functions, generating functional (b) Field Theory: Generating functional and Green's function, Generating functional for interacting fields, 1 PI graphs, Effective actions, Path integrals for scalar quantum fields, Path integrals for fermion fields	6 8
2.	Non-abelian gauge theories, canonical quantization, path integral quantization and Fadeev-Popov ghost fields, BRST invariance	10
3.	Supersymmetry, superspace formalism: supersymmetry and supersymmetric actions, superspace formalism, supersymmetric Feynman rules, Nonrenormalization theorems, N=1 Supergravity.	10
4.	Conformal field theory: Operator product expansion, Ward identities, Noether's theorem, conformal invariance, free CFT's, Virasaro algebra, vertex operators, operator-state correspondence.	8

11. Suggested Books:

S.No.	Name of Books/Authors	Year of Publication
1.	W. Greiner, J. Reinhardt and D.A.Bromley, "Field Quantization", Springer, 2nd edition	1997
2.	Ashok Das, "Lectures on Quantum Field Theory", World Scientific	2008
3.	H.J.W.Muller- Kirsten, A. Wiedemann and H. Muller-Kirsten "Supersymmetry: An Introduction with Conceptual and Calculational Details", World Scientific Publishing Co Pte Ltd	1987
4.	J.Polchinnksi, "String Theory" (Cambridge Monographs on Mathematical Physics) (Volume 1),	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **DEPARTMENT OF PHYSICS**

1. Subject Code: **PH-622** Course Title: **Solar Terrestrial Physics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** **CWS** **15** **PRS** **0** **MTE** **35** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** **PH-603**

9. Objective: **Aspects of solar interaction with Earth's upper atmosphere**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**The sun and interplanetary space:** The sun as a star, solar atmosphere, solar electromagnetic radiations, variance in the solar spectra, solar wind, solar and interplanetary magnetic field, solar cycle variations, cosmic rays in the interplanetary space, interaction of solar wind and other planets.	**6**
2.	**The Physics of Geospace:** Properties of gases, Magnetoplasma, Gyrofrequency, plasma frequency, waves, radio wave propagation in ionized medium, waves propagation in plasma, Langmuir wave, ion-acoustic wave, electromagnetic wave in unmagnetized plasma, plasma instabilities.	10
3.	**Dynamo action:** Equations of motion of terrestrial atmosphere, the atmospheric circulation, heating of upper atmosphere, tidal oscillations of the atmosphere, the lunar tide, the solar tides, tides at the ionospheric level, motion of charged particles, conductivities, Layer conductivity	10
4.	**Ionosphere:** Physical aeronomy, chemical aeronomy, formation of D, E, F1 and F2 regions in low and mid latitudes, Ionospheric electric currents, F-region drifts, ion drag effects, storms, geomagnetic indices, irregularities in ionosphere, travelling ionospheric disturbances.	10
5.	**Whistlers:** Whistlers and VLF emissions, Emission theories, dispersion relation for whistler mode wave, growth rate calculation, nonlinear effects, quasilinear theory, diffusion into loss cone.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	Seeds M.A., “Solar System”, Brooks/Cole Thomson Learning	**2007**
2.	A. C. Das, “Space Plasma Physics”, Narosa Publishing House.	**2004**
3.	J. K. Hargreaves, “The solar-terrestrial environment”, Cambridge Atmospheric and Space Science Series.	**2003**
4.	Syun-Ichi Akasofu, Sydney Chapman, Solar-Terrestrial Physics, Oxford Press	**1972**
5.	M.C. Kelley, “The Earth’s Ionosphere”, Academic Press	**2009**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **DEPARTMENT OF PHYSICS**

1. Subject Code: **PH-624** Course Title: **Computational Nuclear Physics**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 15 **PRS** 0 **MTE** 35 **ETE** 50 **PRE** 0

5. Credits: 3 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: Introductory course in nuclear physics and in computer programming

9. Objective: To understand the concepts of nuclear physics through numerical solutions obtained by writing computer programs

10. Details of the Course:

S. No.	Contents	Contact Hours
1.	Harmonic oscillator, wave functions, evaluation of special functions using recurrence relations and optimization, spherical harmonics, shapes of atomic orbitals, Coupling of angular momenta.	**5**
2.	Simulation of Rutherford scattering, Semi empirical mass formula, estimation of the constants in mass formulae using atomic mass evaluations, mapping of drip lines. Quantum tunneling: application of WKB approach to alpha and proton decays.	**5**
3.	Numerical evaluation of Eigen states for different potentials by solving coupled differential equations with boundary conditions, harmonic oscillator, square-well and Woods-Saxon potentials. Complex Eigen values and resonances	**5**
4.	Independent particle models, Eigen states, Solutions for Nilsson model. Single-j shell approximation and Cranking model. Effective interaction: Simple estimates, Evaluation of matrix elements in sd shell. Superconductivity: Solution for BCS equations at $T = 0$. Hot nuclei: Application of Fermi-Dirac distribution. Quantum Hadrodynamics: Walecka model, Equation of State for symmetric, asymmetric and neutron star matter	**10**
5.	Setting up large codes, parallel and distributed computing, open access codes, libraries	**3**
	Total	**28**

11. Suggested Books:

S. No.	Name of Books/Authors	Year of Publication
1.	Greiner W and Maruhn J A, “Nuclear models”, Springer-Verlag	1997
2.	Arfken G B, Weber H J and Harris F E, “Mathematical Methods for Physicists 7ed”, Academic Press	2013
3.	Abramowitz M and Stegun I A, “Handbook of mathematical functions with formulas, graphs and mathematical tables”, Dover Publications	1972
4.	Giordano N and Nakanishi H “Computational Physics, 2ed”, Pearson/Prentice Hall	2006
5.	Pang T, “An Introduction to Computational Physics”, Cambridge Univ. Press	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. / CENTRE: DEPARTMENT OF PHYSICS

1. Subject Code: **PHN-643** Course Title: **Numerical Analysis and Computer Programming**

2. Contact Hours: **L: 2** **T: 0** **P: 2**

3. Examination Duration (Hrs.): Theory | 0 | 3 | Practical | 0 | 2 |

4. Relative Weightage: **CWS** | 1 | 5 | **PRS** | 2 | 5 | **MTE** | 2 | 0 | **ETE** | 4 | 0 | **PRE** | 0 | 0 |

5. Credits: | 0 | 4 | 6. Semester: | Autumn | | |

7. Pre-requisite: None 8. Subject Area: PCC

9. **Objective of Course:** The course is designed to provide the basic knowledge of Numerical Analysis, Computer Programming and its applications to solve the problems in Physics.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	**Programming:** Constants and Variables, Operators and Expressions, Intrinsic Functions, I/O Statements, File I/O, Conditional Statements and Loops, Subprograms, Matrix and array operations: sorting, transpose; modular programming, sharing of variables between modules	14
2.	**Visualization:** 2D plots, 3D plots, mesh and surface plots, contour plots.	06
3.	**Numerical Analysis:** Errors and Their Propagation, Least-Squares fitting, Solution of simultaneous linear equations, Interpolation and Extrapolation, Integration: Trapezoidal and Simpsons rules, Gauss quadrature, Numerical derivatives, Bisection and Newton-Raphson methods, Runge-Kutta method.	14
4.	**Applications:** Use of standard libraries/subroutines, Evaluation of Eigen values and eigen vectors, Evaluation of special functions	08
	Total	**42**

List of Experiments

1. Black body radiation (computation and graphical representation)
2. Reflection and transmission of an electromagnetic wave
3. Statistical distributions at different temperatures
4. Binding energy curve for nuclei using liquid drop model
5. Eigen-value problem: 1-D square potential well
6. Eigen-values and wave-functions of a simple harmonic oscillator
7. Monte-Carlo simulation
8. Linear/Projectile motion (simulation and solutions)

11. Suggested Books:

S. No.	Name of Books/Authors	Year of Publication
1.	Rajaraman V, **"Computer Oriented Numerical Methods, 3rd ed"**, Prentice-Hall	2006
2.	Hildebrand F B, **"Introduction to numerical analysis"**, Dover	1974
3.	Press W H, Flannery B P, Teukolsky S A, Vetterling W T, **"Numerical Recipes in Fortran 77: The Art of Scientific Computing 2nd ed"**, Cambridge University Press	1992
4.	Mayo W, Cwiakala M, **"Schaum's Outline of Programming With Fortran 77"**, McGraw-Hill	1994
5.	Hamming R W, **"Numerical Methods for Scientists and Engineers 2nd ed"**, Dover	1987
6	Chapman, S.J., **"Fortran 95/2003 For Scientists and Engineers 3rd ed."**, McGraw-Hill	2008