



Department of Physics,
Shivaji University, Kolhapur

M. Sc. – I [Physics] Course Structure

With effect from June, 2008

(Under Academic Flexibility Scheme)

CREDIT SYSTEM

M. Sc. - I [Physics] Semester I

Code No.	Title of the course	
Course PH	Mathematical Methods in Physics	(C1)
Course PH	Classical Mechanics	(C2)
Course PH	Quantum Mechanics 1	(C3)
Course PH	Electronic Devices	(C4)
Course PH	Laboratory/ Practical Course 1	(CL1)
Course PH	Laboratory/ Practical Course 2	(CL2)

M. Sc. - I [Physics] Semester II

Code No.	Title of the course	
Course PH	Quantum Mechanics 2	(C5)
Course PH	Statistical Mechanics	(C6)
Course PH	Electrodynamics	(C7)
Course PH	Atomic and Molecular Physics	(C8)
Course PH	Laboratory/ Practical Course 3	(CL3)
Course PH	Laboratory/ Practical Course 4	(CL4)

Semester I

M. Sc.-I [Physics] Semester-I
Academic Flexibility
(4-credits)

Course – PH **Mathematical Methods in Physics** [C1]

Unit 1- Matrix Algebra and Eigenvalue Problems (15)

Matrix multiplication – Inner product, direct product, Diagonal matrices, trace, matrix Inversion, Example of Gauss-Jordan Inversion, problems (Rajput 735 – 45, Iyengar 1.1 – 1.26).

Eigenvalues and Eigenvectors, Properties of Eigenvalues and Eigenvectors, Cayly-Hamilton Theorem and applications, similar matrices and diagonalizable Matrices, Eigenvalues of some Special Complex Matrices, Quadratics forms, problems. (Iyengar 2.1 to 2.35).

Unit 2- Complex Variables (15)

Definition of Complex Numbers, Equality of Complex Number, Complex Algebra, Conjugate Complex Numbers, Geometrical representation of Complex Number, Geometrical representations of the sum, difference, product and quotient of Complex Number, Cauchy-Rieman Conditions, Analytic functions, Multiply connected regions, Cauchy Theorem, Cauchy Integration formula, Derivatives, problems (Rajput – 283 – 314).

Unit 3-Calculus of Residues (15)

Singularities- Poles, Branch Points, Calculus of Residues-Residues Theorem, Cauchy Principle value, Pole Expansion of Meromorphic Functions, Product expansion of entire Functions, problems (Rajput 326 – 384).

Unit 4- Fourier- Series, Integral, and Transform (15)

Definition, Evaluation of Coefficients of Fourier Series (Cosine and Sine Series), Dirichelet's Theorem, Graphical representation of a square wave function, Extension of interval, Complex form of Fourier Series, Properties of Fourier Series (Conversions, Integration, Differentiation, Parseval's Theorem).

Fourier Integral- exponential form, Applications of Fourier Series analysis in Physics (Square wave, Full wave rectifier, Expansion of Raman Zeta function) (Rajput 527 – 561).

Fourier transform, Inversion theorem, exponential transform Example: Full wavetrain, Uncertainty principle [Arfken 931-946].

Text Books:

- Rajput B S, Mathematical Physics, Pragati Prakashan (Meerat) 1999
- Iyengar S R K, Jain R K , Mathematical Methods, Narosa, 2006
- Arfken And Weber, Mathematical Methods For Physicists 6th Edition, Academic Press, 2005

Reference Book:

1. Riley K F, Hobson M P and Bence S J, Mathematical Methods for Physics and Engineering, Cup, 1997

M. Sc. – I [Physics] Semester I
(Academic Flexibility)
(4-credits)

Course - PH **Classical Mechanics** [C2]

Unit I: Central Force Problem: (15)

Two body problem, the equation of motion and first integral, Equation of orbit, Kepler's laws, Kepler's problem, General analysis of orbits, Stability of orbits, Artificial satellites, Rutherford Scattering: Differential scattering cross – section, Rutherford Formulae for scattering.

Unit II: Variational principle and Hamiltonian formulation: (15)

Hamilton's principle, Hamiltonian, Generalized momentum, Constant of motion, Hamilton's canonical equations of motion, Deduction of canonical equations from Variational principle, Applications of Hamilton's equations of motion. Principle of least action, Proof of principle of least action.

Unit III: Canonical Transformations and Hamiltons - Jacobi Theory: (15)

Generating Functions, Illustrations of Canonical transformations, Condition for Transformation to be Canonical, examples.
Poisson's Brackets, Poisson's theorem, Properties of Poisson's Brackets, Hamiltons Canonical equations in terms of Poisson's Brackets,
Hamiltons – Jacobi Theory, Solution of harmonic oscillator problem by HJ Method. Problems.

Unit IV: Special Relativity in Classical Mechanics: (15)

Special theory of relativity, Lorentz transformations and its consequences, 4-Vectors, 4-Momentum, Lorentz Tensor, Minkowski Space, Elastic Scattering, Addition of velocities, Mass- Energy relation, Lagrangian formulation of relativistic mechanics, Particle accelerating under constant force, Hamiltonian formulation of relativistic mechanics, particle in an EM field.

Text and Reference Books:

1. Classical Mechanics, by H Goldstein (Addison Wesley 1980).
2. Classical Mechanics, by N C Rana and P S Joag (Tata McGraw Hill 1991).
3. Introduction to Classical Mechanics, by R G Takwale and P S Puranik (Tata McGraw Hill 1999).
4. Classical Mechanics, by Gupta, Kumar and Sharma (Pragati Prakashan 2000).

M. Sc. – I [Physics] Semester I
(Academic Flexibility)
(4-credits)

Course - PH

Quantum Mechanics-1

[C3]

Unit 1: Fundamental Concepts and Formalism (15)

Why QM? Revision; Inadequacy of classical mechanics; Sequential Stern-Gerlach Experiment, Analogy with polarization of light, Ket and Bra spaces and inner products, Operators, the associative axiom Base kets and Matrix Representations, Measurements, Observables and the uncertainty relations, Change of basis, Position, momentum and translation; Wave function in Position and Momentum space

Unit 2: Quantum Dynamics (15)

Time evolution and Schrödinger equation; The Schrödinger versus the Heisenberg picture, Simple Harmonic Oscillation, Schrödinger Wave Equation, One-dimensional problems, wells and barriers; Harmonic oscillator by Schrödinger equation and by operator method. Uncertainty relation of x and p , States with minimum uncertainty product; General formalism of wave mechanics; Commutation relations

Unit 3: Angular Momentum (15)

Rotations and Angular momentum commutation relations, Spin $\frac{1}{2}$ systems and Finite Rotations; SO(3), SU(2) and Euler Rotations, Eigenvalues and Eigenstates of Angular Momentum, Orbital Angular momentum, Addition of angular momenta

Unit 4: Approximation Methods for Stationary States (15)

Time-independent perturbation theory: Non-degenerate and degenerate case, first and second order perturbations, Applications: Stark Effect, Anharmonic oscillator, Hydrogenlike atoms: Fine Structure and Zeeman effects

Text and Reference Books

1. J J Sakurai, Modern Quantum Mechanics (Addison Wesley)
2. L I Schiff, Quantum Mechanics (McGraw-Hill)
3. Mathews and Venkatesan Quantum Mechanics
4. S Gasiorowicz, Quantum Physics (Wiley)
5. B Craseman and J D Powell, Quantum Mechanics (Addison Wesley)
6. A P Messiah, Quantum Mechanics

Tutorials

Black body radiation and Planck's hypothesis; Insignificance of de Broglie hypothesis in macro-physics; Hamilton's and Fermat's principles.

One-dimensional step, barrier, well; Particle energy below and above barrier height; Similarly for well; Plotting of harmonic oscillator wave functions; problems involving matrix representations of an operator.

Commutation relations; uncertainty; Transformations.

Angular momentum states; Addition of angular momenta: L, S, J values for various atoms in the periodic table.

Anharmonic perturbations of the form x^3 and x^4 , various other time-independent perturbations. In addition to above, the tutorial will also consist of solving problems given in the Text and Reference books.

M. Sc. – I [Physics] Semester I
(Academic Flexibility)
(4-credits)

Course - PH

Electronic Devices

[C4]

Unit 1 Transistors and Microwave Devices: (15)

Bipolar junction transistor (BJT), frequency response and switching of BJT, Field effect transistor (JFET), MOSFET and related devices, MESFET device structure and its operation, Tunnel diode, Transferred electron devices and Gunn diode, Avalanche transit time diode and IMPATT diode.

Unit 2 Photonic Devices: (15)

Radiative transitions and optical absorption, Light emitting Diodes, OLED, Infrared LED, Photodetector, Photoconductor, Photodiode, p-n junction Solar cells, Conversion efficiency, Semiconductor Lasers, Laser operation, population inversion, carrier and optical confinement, optical cavity.

Unit 3 Memory Devices : (15)

Semiconducting memories, memory organization and operation, Read and Write operation, Expanding memory size, Classification and characteristics of memories, Static and dynamic RAM, SRAM and DRAM, Charge couple memory (CCD) Devices, Magnetic, optical and ferroelectric memory devices,

Unit 4 Other electronic Devices: (15)

Magneto-optic and acousto-optic effects, Material's properties related to get these effects, Piezoelectric, Electrostrictive and magnetostrictive effects, important materials exhibiting these properties and their applications in sensors and actuator devices.

Reference Books:

1. Semiconductor devices: Physics and Technology 2nd Edition, S. M. Sze
2. Modern Digital Electronics, R. P. Jain
3. Introduction to Semiconductor devices by M. S. Tyagi
4. Optical electronics by Ajoy Ghatak and K. Thyagrajan, Cambridge University Press.

M. Sc. – I [Physics] Semester I
Academic Flexibility

Course PH	Laboratory/ Practical Course 1 (2-credits)	(CL1)
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- [1] Design of regulated power supply
- [2] Stair case ramp generator
- [3] Negative feedback Amplifier
- [4] Astable Mutivibrator
- [5] Monostable Mutivibrator
- [6] Characteristics of Silicon Controlled Rectifier
- [7] Fabry Parot Etalon
- [8] LVDT
- [9] Strain Gauge
- [10] Lattice Dynamics
- [11] Microprocessor – Two digit decimal counter
- [12] Microprocessor – Flashing display
- [13] Computer – Applications of MS office
- [14] Computer – Programming in C – Real roots of quadratic Equations
- [15] Computer – Programming in C – Solution of Differential Equations
- [16] Hall effect
- [17] Neutron Diffraction
- [18] Crystal Structure – B.C.C.

M. Sc. – I [Physics] Semester I
Academic Flexibility

Course PH	Laboratory/ Practical Course 2 (2-credits)	(CL2)
	Seminar	1 credit
	Tutorials on practicals	1 credit

Semester II

M. Sc. – I [Physics] Semester II
(Academic Flexibility)
(4-credits)

Course - PH

Quantum Mechanics-2

[C5]

Unit 1: Variational Methods; Perturbation theory for time evolution problem (15)

Variational methods, Time-dependent potentials: the Interaction picture, Time dependent perturbation theory, Applications to Interactions with classical radiation field

Unit 2: Scattering Theory (15)

The Lippmann-Schwinger Equation, the Born Approximation, Optical Theorem, Method of Partial Waves, Low-Energy Scattering and Bound States, Resonance Scattering , Scattering by Hard sphere, Coulomb Scattering,

Unit 3: Theory of Spin Angular Momentum (15)

Identical particles; Symmetric and antisymmetric wave functions; Collision of identical particles; Spin angular momentum; Spin functions for a many-electron system.

Unit 4: Theory of Radiation (15)

Semiclassical theory of radiation; Transition probability for absorption and induced emission; Electric dipole and forbidden transitions; Selection rules.

Text and Reference Books

1. J J Sakurai, Modern Quantum Mechanics
2. L I Schiff, Quantum Mechanics (McGraw-Hill)
3. S Gasiorowicz, Quantum Physics (Wiley)
4. B Craseman and J D Powell, Quantum Mechanics (Addison Wesley)
5. A P Messiah, Quantum Mechanics
6. Mathews and Venkatesan Quantum Mechanics

Tutorial:

1. Helium atom and hydrogen molecule; Various time-dependent perturbations; Density of continuum states; Transition probabilities.
2. Partial wave analysis of scattering from standard simple potentials; Scattering cross section; Optical theorem.
3. Slater determinants; spin and statistics; Difference in collision process between classical and quantum identical particles.
4. Magnetic dipole transitions; Stimulated emission; Higher order transitions.

In addition to above, the tutorial will also consist of solving problems given in the Text and Reference books.

M. Sc.-I [Physics] Semester II
Academic Flexibility
(4-credits)

Course-PH

Statistical Mechanics

[C6]

Unit I: Statistical Mechanics and Thermodynamics: (15)

Basic concepts – Phase space, ensemble, a priori probability, Liouville's theorem (Revision). Fluctuations of physical quantities, Statistical Equilibrium, Thermodynamics – Thermodynamic Laws and Functions – Entropy, Free energy, Internal Energy, Enthalpy (definitions), Contact between statistics and thermodynamics – Entropy in terms of microstates, change in entropy with volume and temperature.

Unit II: Statistical Ensembles Theory: (15)

Micro canonical Ensemble– Micro canonical distribution, Entropy and specific heat of a perfect gas, Entropy and probability distribution.
Canonical Ensemble– Canonical Distribution, partition function, Calculation of free energy of an ideal gas, Thermodynamic Functions, Energy fluctuations.
Grand Canonical Ensemble– Grand Canonical distribution, Thermodynamic Functions, Number and Energy fluctuations.

Unit III: Formulation of Quantum Statistics: (15)

Distinction between MB, BE and FD distributions, Quantum distribution functions – Boson and Fermion gas and their Boltzmann limit, Partition function.
Ideal Bose gas, Bose Einstein Condensation, Phonon gas, Liquid He4: Second Sound.
Ideal Fermi gas: Weakly and strongly degenerate, Electron gas: Free electron theory of metals, Pauli paramagnetism

Unit IV: Phase Transitions and Critical Phenomenon: (15)

Phase Transitions, Conditions for phase equilibrium, First order Phase Transition: Clausius - Clayperon equation, Second order phase transition, The critical indices

Text and Reference books:

1. Statistical Mechanics Theory and Applications, S K Sinha, Tata McGraw-Hill, (1990).
2. Introduction to Statistical mechanics, B B Laud, Macmillan, N Delhi, (1981).
3. Statistical Mechanics by R K Pathria, Pergamon press (1972).
4. Statistical and thermal Physics F Reif, McGraw-Hill (1965).
5. Statistical Physics, L D Landau and E M Lifshitz, Pergamon press (1958).

M. Sc.-I [Physics] Semester II
Academic Flexibility
(4-credits)

Course – PH

Electrodynamics

[C7]

Unit I: Maxwell's Equations and E.M. Waves: (15)

Maxwell's Equations: microscopic and macroscopic forms (revision), conservation of the bound charge and current densities, E.M. wave equations in waveguide of the arbitrary cross section: TE and TM modes; Rectangular and circular waveguides, hybrid modes, concept of LP modes

Unit II: Time –Dependent Potentials and Fields: (15)

Scalar and vector potentials: coupled differential equations, Gauge transformations: Lorentz and Coulomb Gauges, Retarded Potentials, Lienard –Wiechert Potentials, Fields due to a charge in the arbitrary motion.

Unit III: Radiation from Accelerated Charges and Radiation Reaction: (15)

Fields of charge in uniform motion, applications to linear and circular motions: cyclotron and synchrotron radiations, Power radiated by point charge – Larmor's formula, Angular distribution of radiated power, Cerenkov radiation and Bremsstrahlung (qualitative treatments).

Radiation Reaction: criteria for validity, Abraham –Lorentz formula, Physical basis of radiation reaction – self force.

Unit IV: Formulation of Covariant Electrodynamics: (15)

Contravariant and co-variant four-vectors and their products, tensors of rank two and their differentiation, Co-variant form of Maxwell's equations: Four –potential and Fourcurrent, E.M. field tensor – its curl and divergence.

Text and Reference books:

1. Introduction to Electrodynamics – D.J. Griffiths (Prentices- Hall 2002 (3rd edn))
2. Foundation of E.M. Theory- J.R. Reitz, F.J. Milford & R.W. Christy (Narosa Publication House 3rd edition 1993)
3. Classical Electrodynamics – J.D.Jackson (Wiley Eastern 2nd edition)
4. Classical Electrodynamics –S.P. Puri (Tata McGraw Hill 1990)

M. Sc.-I [Physics] Semester II
Academic Flexibility
(4-credits)

Course-PH **Atomic and Molecular Physics** [C8]

Unit I: The Atom Model for Two Valence Electrons (15)

Coupling Schemes : l-l coupling, s-s coupling, LS or Russell - Saunder's coupling; the Pauli exclusion principle, Coupling schemes for two electrons, Tau-factors for LS coupling, Lande interval rule, jj-coupling, branching rules, selection rules.

Unit II: Zeeman Effect, Paschen-Back Effect and Stark Effect (15)

The magnetic moment of the atom, Zeeman effect for two-electrons, Intensity rules for Zeeman effect, Paschen-Back effect for two electrons, Stark effect of hydrogen, weak field Stark effect in hydrogen, strong field Stark effect in hydrogen, origin of hyperfine structure.

Unit III: Microwave Spectroscopy (15)

Classification of molecules: linear, symmetric tops, spherical tops, asymmetric tops; rotational spectra: the rigid diatomic molecule, the non-rigid rotator, spectrum of a non-rigid rotator, chemical analysis by microwave spectroscopy, techniques and instrumentation of microwave spectroscopy.

Unit IV: Infra-Red Spectroscopy (15)

The energy of a diatomic molecule, the simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating-rotator, analysis by infra-red spectroscopy, techniques and instrumentation of infra-red spectroscopy.

Text books

- 1) Introduction to Atomic Spectra – H.E. White, Mac-Graw Hill (1934).
- 2) Fundamentals of Molecular Spectroscopy, Edn. 3 – C.N. Banwell, Tata MacGraw Hill (1983).

Reference books

- 1) Spectra of Diatomic Molecules, Vol. I – G. Herzberg, N.J.D. van Nostrand (1950).
- 2) Spectroscopy, Vol. I, II and III – B.P. Straughan and S. Walker, Chapman and Hall (1976).
- 3) Introduction to Molecular Spectroscopy – G.M. Barrow, MacGraw Hill (1962).
- 4) Molecular Spectroscopy – J.M. Brown, Oxford University Press (1998).

M. Sc. – I [Physics] Semester II
Academic Flexibility

Course PH	Laboratory/ Practical Course 4 (2-credits)	(CL4)
	Seminar	1 credit
	Tutorials on practicals	1 credit

Semester – III

Course Code	Subject
PH	CONDENSED MATTER PHYSICS
PH	NUCLEAR AND PARTICLE PHYSICS
PH	ENERGY SCIENCE – I Renewable Energy Resources
PH	MATERIALS SCIENCE – I Imperfection in crystals
PH	SOLID STATE PHYSICS– I Physical Properties of Solids
PH	MODERN OPTICS – I Laser Physics
PH	SPACE SCIENCE – I Windows to the Universe, Solar System, Planetary Atmospheres
PH	THEORETICAL PHYSICS Relativistic Quantum Mechanics
PH	ENERGY SCIENCE – II Energy Conversion Devices
PH	MATERIALS SCIENCE – II Physics of Metals and Alloys
PH	SOLID STATE PHYSICS–II Semiconductor Physics
PH	MODERN OPTICS – II Nonlinear Optics and Fiber Optics
PH	SPACE SCIENCE–II Astrophysics of the Sun
PH	THEORETICAL PHYSICS Quantum Field Theory-1

PH	ENERGY SCIENCE LAB-I
PH	MATERIALS SCIENCE LAB-I
PH	SOLID STATE PHYSICS LAB -I
PH	MODERN OPTICS LAB-I
PH	SPACE SCIENCE LAB-I
PH	THEORETICAL PHYSICS LAB-I
PH	ENERGY SCIENCE PROJECT WORK-I
PH	MATERIALS SCIENCE PROJECT WORK-I
PH	SOLID STATE PHYSICS PROJECT WORK-I
PH	MODERN OPTICS PROJECT WORK-I
PH	SPACE SCIENCE PROJECT WORK-I
PH	THEORETICAL PHYSICS PROJECT WORK-I

	Elective Papers
PH	General Relativity
PH	Special Relativity

Semester III

M.Sc.-II [Physics] (Sem. III)
(Under Academic Flexibility Scheme)
(4-credits)

PH CONDENSED MATTER PHYSICS

- Unit I *Crystal Physics*
Crystalline state of solids, simple crystal structures, Bragg condition, Brillouin zones, reciprocal lattice, structure factor; comparison of X-ray, electron and neutron diffraction methods; types of bonding. (15)
- Unit II *Crystal Defects*
Point defects (Schottky and Frenkel defects, equilibrium concentration of vacancies, color centers); line defects (screw and edge dislocations, Berger's vector and circuit, role of dislocations in plastic deformation and crystal growth); planar defects (stacking faults), observation of imperfections in the crystals. (15)
- Unit III *Semiconducting and Superconducting Properties*
Semiconductors : Energy band gap, effective mass, intrinsic carrier concentration, conductivity of semiconductors, impurity levels in doped semiconductors.
Superconductors: Critical temperature, Meissner effect, type-I and type-II superconductors, BCS theory of superconductivity, flux quantisation, Josephson effect, SQUID, high-T_c superconductivity. (15)
- Unit IV *Dielectric and Magnetic Properties*
Dielectrics: Polarization mechanism, dielectric constant, Lorenz cavity field, Clausius-Mossotti relation, ferroelectricity, polarization catastrophe, types of ferroelectrics, piezoelectrics.
Magnetics : Theory of diamagnetism, classical and quantum theories of paramagnetism, exchange interactions, magnetic order (ferro-, anti-ferro- and ferrimagnetism), Weiss theory of ferromagnetism, ferromagnetic domains. (15)

Reference Books :

- 1.Introduction to solid state physics - C. Kittel, 5th edn., John Wiley & Sons. Inc., New York (1976).
- 2.Solid state physics by A. J. Dekker, MacMillan India Ltd. (1986).
- 3.Solid state physics - N. W. Ashcroft and N. D. Mermin, HRW International edn.(1976).
- 4.Electronic properties of materials - R. E. Hummel, 2nd edn., Springer International (1994).
- 5.Solid state physics - J. S. Blakemore, 2nd edn., Cambridge University Press (1985).

M. Sc.-II [Physics] (Sem-III)
(Under Academic Flexibility Scheme)
(4-credits)

PH NUCLEAR AND PARTICLE PHYSICS

Unit I Nucleon -Nucleon Interaction:

- A. N-N interaction in the bound state :** The theory of ground state of deuteron, excited states of deuteron;
- B. N-N interaction in the unbound state:** n-p scattering at low energies (cross-section, phase shift analysis, scattering length, n-p scattering for square well potential, effective range theory); p-p scattering at low energies (cross-section, experiment , and results) ; symmetry and charge independence of nuclear forces, exchange forces, tensor forces; high energy N-N scattering (qualitative discussion only of n-p and p-p scatterings).

(15)

Unit II Nuclear Decay:

- A. Beta decay:** Beta energy spectrum, detection and properties of neutrino, Fermi theory of beta decay, shape of the beta spectrum, Kurie plot, total decay rate, comparative half- lives, allowed and forbidden transitions, selection rules, parity violation in the beta decay, and measurement of neutrino helicity.
- B. Gamma decay:** Multipole transitions in nuclei, selection rules, multipole transition probability, internal conversion, nuclear isomerism.

(15)

Unit III Nuclear Models and Nuclear Reactions:

- A. Nuclear Models:** Evidence for nuclear shell structure, single particle shell model-its validity and limitations, collective model (collective vibration and collective rotation).
- B. Nuclear Reactions:** Compound nucleus reaction (origin of the compound nucleus hypothesis, discrete resonances, continuum states), direct reactions (experimental characteristics, direct inelastic scattering and transfer reactions).

(15)

Unit IV Particle Physics:

Classification of fundamental forces and elementary particles, isospin, strangeness, Gell-Mann-Nishijima formula, quark model [SU (3)], CPT invariance, parity-non-conservation in weak interaction, K-meson complex, time reversal invariance.

(15)

Reference Books:

1. The Atomic Nucleus- Robley D.Evans (McGraw-Hill, New York, 1955).
2. Introduction to Nuclear Physics-Harald A.Enge (Addision -Wesly, Massachusetts, 1966).
3. Physics of Nuclei and Particles (Vol. I & II) - Pierre Mermier and Eric Sheldon (Academic, New York, 1969 & 1970).
4. Nuclei and Particles -Emilio Segre' (W.A. Benjamin, Massachusetts, 1977).
5. Nuclear Physics- Iriving Kaplan (Narosa, Madras, 1989).
6. Nuclear Physics -R.R.Roy and B.P. Nigam (Wiley Eastern, New Delhi, 1967).
7. Introduction to High Energy Physics- Donald H.Perkins (Addison Wesley, Massachusetts, 1982).
8. Nuclear and Particle Physics- W.E. Burcham and M.Jobes, (Addison Wesley, Longman, England, 1995).
9. Introdotion to Quantum Electrodynamics & Partical Physics – D.C.Joshi (I.K.International Publishing House Pvt. Ltd.,New Delhi, 2006).
10. Fundamentals in Nuclear Physics - Jean-Louis Basdevant, James Rich and Michel Spiro (Springer, 2005).
11. Introduction to Particle Physics- M.P. Khanna (Prentice Hall, India, 1999).

• **Topics for tutorials:**

1. Nuclear size and shape
2. Nuclear charge distribution
3. Nuclear spin and parity
4. Importance of binding energy curve
5. Empirical mass formula
6. Liquid drop model

M.Sc.-II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
(4-credits)

PH

ENERGY SCIENCE - I
Renewable Energy Resources

- Unit I Energy and Thermodynamics (15)**
Forms of Energy, Conservation of Energy, Entropy, Heat capacity, Thermodynamic cycles: Brayton, Carnot Diesel, Otto and Rankin cycle; Fossil fuels, time scale of fossil fuels and solar energy as an option.
- Unit II Solar Energy for Clean Environment (15)**
Sun as the source of energy and its energy transport to the earth, Extraterrestrial and terrestrial solar radiations, solar spectral irradiance, solar radiation geometry, Measurement techniques of solar radiations, Estimation of average solar radiation.
- Unit III Wind Energy (15)**
Origin and classification of winds, Aerodynamics of windmill: Maximum power, and Forces on the Blades and thrust on turbines; Wind data collection and field estimation of wind energy, Site selection, Basic components of wind mill, Types of wind mill, Wind energy farm, Hybrid wind energy systems: wind + PV; The present Indian Scenario.
- Unit IV Biomass Energy and Biogas Technology (15)**
Nature of Biomass as a fuel, Biomass energy conversion processes, Direct combustion: heat of combustion, combustion with improved Chulha and cyclone furnace; Dry chemical conversion processes: pyrolysis, gasification, types of gasification, Importance of biogas technology, anaerobic decomposition of biodegradable materials, Factors affecting Bio-digestion, Types of biogas plants, Applications of biogas.

Reference Books

- 1 Biomass, Energy and Environment- N.H. Ravindranath and D.O Hall, Oxford University Press.
- 2 Solar Energy and Rural development- S.H. Pawar, C.D. Lokhande and R.N. Patil.
- 3 Biomass Energy- S.H. Pawar, L.J. Bhosale, A.B. Sabale and S.K. Goel.
- 4 Solid State Energy Conversion-S.H. Pawar, C.H. Bhosale, and R.N. Patil
- 5 Solar Energy Conversion-A.E. Dixon and J.D. Leslie.
- 6 Advances in Energy systems and technology- Peter Auer.

M. Sc.-II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
(4-credits)

PH

MATERIALS SCIENCE - I
Imperfections in crystals

- Unit I Point defects (15)**
Classification of defects, fundamental properties of point defects, lattice distortion, migration energy, point defects in thermal equilibrium, point defects in ionic crystals, equilibrium concentration of Frenkel and Schottky defects, ionic conductivity, determination of physical quantities associated with point defects, point defects in non-thermal equilibrium.
- Unit II Dislocations (15)**
Strength of an ideal crystal, concept of dislocation, geometrical aspects of dislocations, movement of dislocations, dislocations in periodic crystal structures, interaction of dislocations with point defects, Cottrell atmosphere, imperfect or partial dislocations, stacking faults, Lomer Cottrell locks, Thomson tetrahedron, partial dislocations in other crystal structures, multiplication of dislocations, Jogs and their formation, motion of a vacancy jog, measurement of stacking fault energy, origin of dislocations.
- Unit III Techniques for observation of defects (15)**
Techniques for observation of point defects and dislocations, electron microscopy, field ion microscopy, surface methods, x-ray topography, moiré technique.
- Unit IV Mechanical testing of materials (15)**
Mechanical testing of materials, tensile testing, tests of hardness, creep, fatigue and impact testing.

Reference Books :

1. Physical metallurgy - R.W. Cahn, II Edition, North Holland, Amsterdam (1970)
2. Introduction to dislocations - D. Hull, ELBS (1971)
3. Dislocations and plastic flow in crystals - A.H. Cottrell, Oxford Univ. Press (1965)
4. Imperfections in crystals - Van Burren, North Holland (1960)
5. Theory of crystal dislocations - F.R.N. Nabarro, Clarendon Press (1968)
6. Dislocations in crystals - W.T. Read, McGraw Hill (1953)
7. Modern physical metallurgy - R.E. Smallman, Butterworths (1970)
8. Techniques of metal research - R.F. Bunshaw, Interscience (1968)
9. Experimental methods in materials research - Herbert Herman, Interscience (1967)
10. Modern techniques in metallography - D.G. Brandon, Butterworths (1966)
11. Introduction to properties of engineering materials - K.J. Pascoe, Blackie and Sons, London (1968).

M.Sc.-II (Physics) [Sem III]
(Academic Flexibility)
(4-credits)

PH

SOLID STATE PHYSICS- I
(Physical Properties of Solids)

Unit 1 : The Drude Theory of metals (15)

Basic assumptions of Model, Collision or relaxation times, DC electrical conductivity, Failures of the free electron model

The tight-binding method

Linear combinations of atomic orbitals, Application to bands from s-Levels, General features of Tight-binding levels, Wannier functions

Other methods for calculating band structure

Independent electron approximation, general features of valence band wave functions, Cellular method, Muffin-Tin potentials, Augmented plane wave (APW) method, Pseudopotentials

Unit 2: Transport Properties of Metals (15)

Drift velocity and relaxation time, The Boltzmann transport relation, The Sommerfeld theory of metals of electrical conductivity, The mean free path in metals, Thermal scattering, The electrical conductivity at low temperature, The thermal conductivity of metals,

Dielectric Properties of insulators

Macroscopic electrostatic Maxwell equations, Theory of Local Field, Theory of polarizability, Clausius- Mossotti relation, Long- wavelength optical modes in Ionic crystals.

Unit 3: Phonons, Plasmons, Polaritons, and Polarons (15)

Vibrations of monatomic lattices: first Brillouin zone, group velocity, Long wavelength limit, Lattice with two atoms per primitive cell. Quantization of lattice vibrations, Phonon momentum

Dielectric function of the electron gas, Plasma optics, Dispersion relation for

Electromagnetic waves, Transverse optical modes in a plasma, Longitudinal

Plasma oscillations, Plasmons, Polaritons, LST relations, Electron- electron interaction, Electron- phonon interaction: Polarons,

Unit 4: Point defects and Luminescence (15)

Lattice vacancies, diffusion, colour centres: F centres, other centres in alkali halides

Types of luminescence, The Frank–Condon principle, mechanism of Photoluminescence, Thermoluminescence, and Electroluminescence

Reference Books :

1. Solid State Physics by N W Ashcroft and N D Mermin, HRW, International editions (1996) (Units 1 and 2)
2. Introduction to Solid State Physics by C Kittel (4th edition) John Willey Publication (1979) (Units 3 and 4)

3. Solid State Physics by A J Dekker ((1986) Macmillan India Ltd

Tutorials:

1. Comparison between free electron theory and tight binding approximation
2. Transport properties of semiconductors
3. Fundamentals of magnetism
4. Thermal properties and heat capacity.

M. Sc.-II [Physics] (Sem. – III)

Academic flexibility

(4-credits)

PH

MODERN OPTICS – I

SPC – I

(Laser Physics)

Unit – I: Laser Fundamentals and Pumping Processes: (15)

Properties of laser beams, Higher order coherence
Attainment of population inversion, Line shape function, Laser modes.
Optical pumping efficiency, pump energy distribution within active
material, electrical pumping, Pumping rate equations, excitation by resonant
energy transfer.

Unit – II: Optical Resonators: (15)

Plane – parallel resonator, concentric resonator, confocal resonator, resonators using a
combination of plane and spherical mirrors, Fox and Li treatment, confocal resonator.

Unit – III: Continuous Wave Laser behavior: (15)

Rate equations in 3 level and 4 level laser systems, CW behavior,
Optimum out put coupling, limit to monochromaticity and frequency pulling

Unit – IV : Transient Laser Behavior: (15)

Step– pump pulse, single mode oscillation, multimode oscillation,
Q – Switching, methods of Q – switching, Mode locking, method's
Of Mode locking. Multi-mode verses Single mode oscillations.

Text and Reference Books:

1. B.A. Lengyl, Introduction to Laser Physics.
2. Svelto, Principle of Lasers.
3. J. Wilson and J.F.B. Hawkes. Laser Principles and Applications, Prentice Hall International, NY, (1987).
4. Siegman, An Introduction to Laser and Masers, Mc Graww Hill Book Co., (1971).

Tutorial: Laser Physics

The tutorials will consist of solving problems given in the text and reference books.

M.Sc.-II [Physics] (Sem. – III)
Under Academic Flexibility Scheme
(4-credits)

PH

SPACE SCIENCE – I
Windows to the Universe, Solar System, Planetary Atmospheres

Unit I Astronomy Fundamentals, Telescopes for Astronomy (15)
Radiation from space, radiation laws, Basic terminology used in astronomy, Introduction to the various types of astronomy: optical, radio, IR, UV, X-ray, γ ray, Gravitational etc. Introduction to Optical, IR, X ray, γ ray telescopes, brief description of the various instruments.

Unit II Radio Telescopes and Receivers (15)
Antennas, Types of interferometers, array, Radio telescopes of the world including GMRT, OOTY, PRL, Radio telescope receivers, total power receiver, Dicke receiver, correlation receiver, noise temperature. Noise sources.

Unit III The Solar System, Terrestrial and Jovian planets, (15)
Origin of solar system, occurrence of planetary systems, celestial mechanics, properties of the sun. Orbital and physical characteristics, atmosphere, Studies of Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and their moons. Recent explorations of various planets

Unit IV Scintillation, near earth and interplanetary plasma, ionization process of planetary atmosphere (15)
Interplanetary scintillation, interstellar scintillation, methods for probing solar wind, use of IPS in measurement of solar wind, study of irregularities in the interplanetary medium, properties of plasma at different distances from earth, photoionisation, cosmic ray ionization, meteoric ionization, various resonances in plasma, various waves in plasma, measurement procedures.

Reference Books

- 1 Source book on space science: S.Glasstone
- 2 Radio Astronomy : J.Kraus
- 3 Radio Telescopes: Christensen, Hogbom
- 4 Fundamental Astronomy: H.Karttunem, P.Kroger, H.Oja, M.Poutanen, K.J.Donner.
- 5 The new Astronomy: N.Henbest, M.Marten.
- 6 Solar and Interplanetary Disturbances: S.K.Alurkar.
7. Various web sites using internet.

Other Books

- 1 The New Cosmos: A.Unsold, B.Baschek, New York: Springer Verlag
- 2 The problems/exercise/short answer questions given in the text and reference books will form tutorial course.

M.Sc. –II (Physics) Semester-III

Academic Flexibility

4-Credits

Theoretical Physics

PH

RELATIVISTIC QUANTUM MECHANICS

UNIT 1 THE THEORY OF SPECIAL RELATIVITY (15)

The Lorentz transformations, Relativistic velocities, Mass, momentum and Energy, Four-vectors, Relativity and Electromagnetism (p. 1 – 18)

UNIT 2 ASPECTS OF ANGULAR MOMENTUM (15)

Various Angular Momenta, Angular momentum and Rotations, Operators and Eigenvectors for spin $\frac{1}{2}$, Operators for Higher Spins, Orbital Magnetic moments, Spin without relativity, Thomas precession, Dirac Notation, Clebsch-Gordon and Racah coefficients, Relativistic quantum numbers and spin-angular momentum functions, Energy levels of one-Electron atom (p. 23 – 40, 50-62)

UNIT 3 PARTICLES OF SPIN ZERO AND THE DIRAC EQUATION (15)

The Klein-Gordon Equation, Relativistic wave functions, Probabilities and Currents, The fine structure constants, Two component KG equation, Free KG particles-antiparticles, Klein paradox, Spinless Electron atom (p. 64-88, 91-97)

Origin of Dirac equation, Dirac matrices, Lorentz invariance of the Dirac equation, Non-relativistic limit of Dirac equation, Probabilities and currents, Forces and fields, Gauge invariance and Dirac equation (p. 99-118, 121-23, 125-28)

UNIT 4 FREE PARTICLES, CPT AND SECOND QUANTIZATION (15)

Wave functions, Densities, currents, Free particle solutions, Free particle spin, A generalized spin operators, Negative energy states, Antiparticles, Non-Relativistic Spin Projection Operators, Relativistic Energy and spin projection operators, Charge conjugation, Time reversal, Parity, CPT, Angular momentum , non-relativistic limits, Second quantization, field operators, Second quantization (p. 130-138, 142-150, 157-197)

TEXT AND REFERENCE BOOKS

Paul Strange, Relativistic Quantum Mechanics, Cambridge University, 1998

The problems given in the Text and Reference books will form tutorial course.

M.Sc.II [Physics] (Sem. – III)
Academic Flexibility
(4-credits)

PH

ENERGY SCIENCE - II
(*Energy Conversion Devices*)

Unit 1. Photovoltaic converters
(15)

Interaction of solar radiations with semiconductors, photovoltaic effect, types of solar cell, equivalent circuit diagram of a solar cell, determination of series resistance (R_s) and shunt resistance (R_{sh}), ideal properties of semiconductor for use in solar cell, carrier generation and recombination, dark and illuminated characteristics of solar cell, solar cell output parameters: R_L , V_{oc} , I_{sc} , P_m , FF , efficiency, performance dependence of a solar cell on band gap energy, diffusion length and carrier life time, Types of heterojunction, construction of energy band diagram of heterojunctions, origin of capacitance in a heterojunction, expression for junction capacitance, Mott – Schottky relation, problems.

Unit 2: Materials and Solar cell Technology (15)

Single, poly – and amorphous silicon, GaAs, CdS, Cu_2S , $CuInSe_2$, CdTe etc. technologies for fabrication of single and polycrystalline silicon solar cells, amorphous silicon solar cells and tandem cells, solar cell modules, photovoltaic systems, space quality solar cells, problems.

Unit 3: Photochemical Converters
(15)

Semiconductor – electrolyte interface, photoelectrochemical solar cells, conversion efficiency in relation to material properties, photoelectrolysis cell, driving force of photoelectrolysis, alkaline fuel cell, semiconductor-septum storage cell, problems.

Unit 4: Thermoelectric Converters (15)

Thermoelectric effects, solid state description of thermoelectric effect, Kelvin's thermodynamic relations, analysis of thermoelectric generators, basic assumptions, temperature distribution and thermal energy transfer for generator, co-efficient of performance for thermoelectric cooling, problems.

Reference Books:

1. Solar energy conversion: The solar cell, by Richard C. Neville.
2. Photoelectrochemical solar cells – Suresh Chandra
3. Solar energy conversion – A. E. Dixon and J. D. Leslie.
4. Solar cells – Martin A.Green
5. Heterojunction and metal – semiconductor junctions – A.G. Milnes and D. L. Feucht.
6. Solid state electronic devices - B.G. Streetman.

7. Principles of solar engineering – Frank Kreith and Janf Kreider.
8. Direct energy conversion (4th edition) – Stanley W Angrist.
9. Handbook of batteries and fuel cells – Lindsey. David

Topics for tutorials:

1. Construction of energy band diagram- examples
2. Examples on photovoltaic converters
3. Maintenance of photovoltaic systems
4. Energy bands diagrams for photoelectrochemical and photoelectrolysis cells
5. Design of thermoelectric cooler
6. Solar energy storage in the form of chemical energy

M.Sc.-II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
4-Credits

PH

MATERIALS SCIENCE - II
(Physics of Metals and Alloys)

SPC-II

Unit-1 Metallurgical thermodynamics (15)

Thermodynamic conditions for equilibrium, chemical potential, Gibb's phase rule, entropy of mixing, applications of entropy of mixing (equilibrium concentration of vacancies in a crystal and entropy of mixing in metals), surface effects.

Unit-2 Solid solutions (15)

Solid solubility, types of solid solutions, Hume-Rothery rules, electron concentration, atomic size in solid solution , deviation from Vegard's law , intermediate phases (electrochemical compounds, size factor compounds, and electron compounds), Laves phases , semiconducting intermediate phases , defect structures, order in solid solutions (types of super lattices , long and short – range order).

(15)

Unit-3 Binary phase diagrams

Isomorphous alloy system , lever rule , derivation of phase diagrams from free energy principles (complete solubility , partial solid solubility, systems having intermediate phases), determination of liquid-solid equilibria (thermal analysis, and annealing & quenching methods), determination of solid state equilibrium by annealing and quenching method, study of equilibrium diagrams using X-ray technique.

Unit-4 Diffusion and Solidification (15)

Diffusion : Fick's laws of diffusion, solutions to the diffusion equation, calculation of jump frequency, mechanisms of diffusion, Kirkendal effect and Darken's equations , self-diffusion , diffusion - along grain boundaries.

Solidification: Homogeneous nucleation, heterogeneous nucleation, atomic kinetics, solute manipulation (normal freezing, zone melting & zone refining).

Reference books

1. Physical metallurgy. – R. W. Cahn, II Edition, North Holland, Amsterdam (1970)
2. Physical metallurgy. – R. W. Cahn and P. Haasen, III Edition, North Holland, Amsterdam, (1983)
3. Physical metallurgy principles – R.E. Read-Hill, Affiliated East West Press Ltd., New Delhi, (1970)
4. Modern physical metallurgy – R.E. Smallman, Butterworths, London (1970)
5. An introduction to metallurgy – A.H. Cottrell, Edward Arnold, London (1967)

Tutorials: Physics of Metals and Alloys:

The tutorials will consist of solving problems given in the text and reference books.

M.Sc.-II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
(4-credits)

PH

SOLID STATE PHYSICS-II
Semiconductor Physics

Unit I Energy bands and charge carriers in semiconductors (15)

Bonding forces and energy bands, direct and indirect band gap semiconductors, variation of energy bands with alloy composition, effective mass, electrons and holes in quantum wells, the Fermi level, electron and hole concentrations at equilibrium, temperature dependence of carrier concentrations, electrical conductivity and mobility, high field effects.

Unit II Excess carriers in semiconductors (15)

Optical absorption, direct recombination of electrons and holes, indirect recombination, trapping, steady state carrier generation, quasi Fermi levels, diffusion process of carriers, diffusion and drift of carriers, diffusion and recombination: the continuity equation, steady state carrier injection, diffusion length, the Haynes-Shockley experiment.

Unit III Dynamics of charge carriers and lattice, and Semiconductor Interfaces (15)

Electrons in a periodic potential, group velocity of electrons, inverse effective mass tensor, force equation, dynamics of electrons and holes, effective mass theory of impurities, the vibrational specific heat, thermal expansion, thermal conductivity. Schottky barriers, rectifying contacts, ohmic contacts, surface and interface states and their effects on barrier height, acceptor and donor surface states, Fermi level pinning

Unit IV Semiconductor crystal growth process (15)

Nucleation and growth theory, atomic bonding, formation energy of clusters, supersaturation, supercooling and volume energy, stability of small nuclei, the formation energies of liquid nuclei and crystalline nuclei, nucleation rates, the growth of crystal surfaces, growth of bulk semiconductors by zone melting and zone refining, Czochralski and liquid encapsulation techniques, growth of epitaxial layers by LPE, VPE and MBE techniques.

Reference Books

1. Physics of Semiconductor Devices by Dilip K. Roy, Univ. Press (India) Pvt. Ltd., 1992.
2. Physics of Semiconductor Devices by S.M. Sze
3. Solid state electronic devices by B. G. Streetman.
4. Semiconductors by R. A. Smith, Cambridge Univ. Press.
5. Solid state electronics by Wang, Mc. Graw Hill.
6. Crystal Growth by B. R. Pamplin (ed.)
7. Growth of Single Crystal by R. A. Laudise.
8. Growth of crystals from solutions by J. C. Brices
9. Solid State and Semiconductor Physics by M.C. Kelvey.
10. Modern techniques in metallography – D.G. Brandon, Butterworths (1966)

M.Sc.-II [Physics] (Sem. – III)
Academic Flexibility
(4-credits)

PH

MODERN OPTICS – II
(*Nonlinear Optics and Fiber Optics*)

SPC – II

Unit – I: Nonlinear Medium: (15)

Maxwell's equations in Nonlinear media, Nonlinear polarization and susceptibilities, classical model of nonlinearity: anharmonic oscillator and free electron gas. Electrooptical and magneto-optical effects.

Unit – II: Nonlinear Phenomena and Applications: (15)

Second Harmonic Generations – Polarization waves, phase matching conditions, coherence length, Coupled wave equations, Parametric amplification and oscillation, Optical phase conjugation, Self – Self focusing of laser beam – physical description, elementary analysis, Parabolic wave equation and solution for slowly converging/diverging beam.

Tunable coherence radiation source, spectroscopy tools.

Unit – III: Optical fibers: (15)

Physical description, step index and graded index fibers, material and fabrication, light propagation (ray theory), numerical aperture, Transmission losses.

Unit – IV: Optical Fiber Waveguide and Applications: (15)

E.M. theory of propagation, Modes of fiber, Modes cut-off, Single and multimode fibers, Modal analysis of step index and graded index fibers, Signal distortion – inter modal, material and wave guide dispersion, Nonlinear Optical effects in fiber. Detectors for optical fibre, communication, Optical fibers in Telecommunications and Sensor systems.

Text and Reference Books:

5. Y.R. Shen, The Principles of Nonlinear Optics, Wiley Inter Science, (1984).
6. A.K. Ghatak and K. Thyagarajan, Optical Electronics, Cambridge University Press, (1991).
7. A.N. Matveev, Optics, Mir Publisher, (1988).
8. M.S. Sodha, A.K. Ghatak & V.K. Tripathi, Self-Focusing of Laser beams, Tata McGraw Hill, (1974).
9. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press (1999).
10. J. Wilson and J.F.B. Hawkes, Optoelectronics, Prentice Hall, (1989).
11. L. Tarasov, Laser Physics and Applications, Mir Publisher, (1983).
12. L. Tarasov, Laser Age in Optics, Mir Publisher, (1981).

Tutorial: Nonlinear Optics and Fiber Optics:

The tutorials will consist of solving problems given in the text and reference books.

M. Sc.-II [Physics] (Sem. – III)
Academic Flexibility
(4-credits)

PH

SPACE SCIENCE-II
(Astrophysics of the Sun)

Unit 1: Stellar Studies (15)

Formation of the Stars, Interstellar Medium, Birth of Stars, Sources of Stellar Energy, Main Sequence Stars, H-R Diagram, Main Sequence Evolution, Variable Stars, Star Cluster, Lower Main Sequence, Upper Main Sequence, Evolution of Binary Stars, Chandrasekhar Limit and White Dwarfs, Neutron Stars, Black Holes.

Unit 2: The Sun and solar activity (15)

Internal Structure, atmosphere-Photosphere, Chromosphere, Corona, Sunspots, Sunspot Cycle, Butterfly Diagram, Magnetic Cycle, Prominence, Solar Flares and there Classification, Coronal activities- Coronal Mass Ejection (CMEs), Solar Constants.

Unit 3: Electromagnetic and Corpuscular Emissions from the Sun (15)

Solar UV, X-Ray and Radio Emissions, Particle Emissions e.g. Electron and Protons, Solar Visible Radiation, Solar Radio Emission, 10.7-Cm Radio Noise Flux, Solar Proton Events, Solar Cosmic Rays

Unit 4: Methods for Solar Observations (15)

Space Borne; Solar and Heliospheric Observatory (SOHO), YOHKOHO, Stereographic Observations (NASA's Stereo-Mission), Observations by NOAA's GOES Satellites, Ground Based; H -alpha, K-Line and White Light Observations from Big Bear and Udaipur Solar Observatory, Magnetograms, □Radio Observation at 10.7-cm

Text Books:

1. Unit No.- 6,8,11,12,13,14 from Fundamentals of astronomy by Michael a. Seeds
2. Unit No.- 3, from Introduction to Space Physics, by M. G. Kivelson, C. T. Russell
3. Unit No.- 11,12,13 from Fundamental of astronomy, Editors; H. Karttunen, P. Kroger H. Oja, M. Poutanen, K. J. Donner
4. Unit No.-9 from Survey of the Universe, D.H. Menzel
5. Unit No.-8; Section 8.7 from Introduction to Statistical Mechanics, B. B. Laud

References Books:

1. Astrophysics of the solar System, by K .D. Abhyankar
2. Sourcebook on the Space Science, by S. Glasstone
3. Astrophysics Ed. By L.W. Fredrick
4. Planets, Stars and Galaxies, by S.J. Inglis
5. Astrophysics of the Sun , by H. Zirin

Other Books

1. Modern Astrophysics, B. W. Carroll, D. A. Ostlie
2. Stars and Galaxies, K. D. Abhyankar

Topics for tutorials:

The problems/ exercise/ short answer questions given in the Text and Reference Books will form Tutorial Course.

M. Sc. –II (Physics) Semester-III
Academic Flexibility
4-Credits

PH

Theoretical Physics
Introductory Quantum Field Theory-I
(Second Quantization, QED and Renormalization)

Unit 1 Klein Gordon and Dirac Fields (15)

Elements of Classical Field Theory – Lagrangian and Hamiltonian Field Theory, Noether's Theorem, KG Field as Harmonic Oscillators, KG Field in space-time, Causality, KG Propagator, particle creation by a classical source, Lorentz invariance in wave equations, The Dirac equation, Free particle solutions of the Dirac equation, Dirac matrices and Dirac field bilinears, Quantization of Dirac Field – spin and statistics, the Dirac propagator, Discrete symmetries of the Dirac Theory, Parity, Time Reversal, Charge conjugation (PeskinSchroeder 13-70:58)

Unit 2 Interacting Fields and Feynman Diagrams (15)

Perturbation Expansion of Correlation Functions, Wick's theorem, Feynman Diagrams, Cross-sections and the S-matrix, Computing S-matrix elements from Feynman Diagrams, Feynman rules for fermions, *Yukawa Theory*, Feynman rules for QED, *The Coulomb potential* (PeskinSchroeder 77-125:52)

Unit 3 Elementary Processes of QED (15)

$e^+e^- \rightarrow \mu^+\mu^-$: Trace technology, unpolarized cross section, $e^+e^- \rightarrow \text{hadrons}$; $e^+e^- \rightarrow \mu^+\mu^-$:helicity structure, non-relativistic limit, bound states, vector meson production and decay, crossing symmetry, Compton scattering, Soft Bremsstrahlung : Classical and Quantum computations, Electron Vertex function: formal structure, evaluation, infra red divergence, Field strength renormalization, *Electron self energy*, LSZ Reduction formula, (PeskinSchroeder 176-201, 211-230:56)

Unit 4 Functional Methods (15)

Ward Takahashi identity, Renormalization of Electric charge, Dimensional regularization, Path Integrals in QM, Functional quantization of Scalar Field - correlation functions, Feynman rules, Functional derivatives and the Generating Functional, Quantization of the EM field, Functional quantization of the Spinor fields – Anticommutation numbers, The Dirac propagator, Generating Functional for the Dirac Field; QED; Functional determinants (PeskinSchroeder 238-256,275-291, 294-305:45)

Text and Reference Books

Michael E Peskin and Daniel V Schroeder, *An Introduction to Quantum Field Theory*, **Perseus Books**, 1995

M . Kaku, *Quantum Field Theory: A Modern Introduction*, OUP, 1993

The problems given in the Text and Reference books will form tutorial course.

M.Sc. –II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)

2-credits

PH

ENERGY SCIENCE LAB-I

List of Experiments

1. Oxygen bomb Calorimeter
2. Wood Pyrolysis-I
3. Wood Pyrolysis-II
4. Powdery Biomass Gasifier
5. Microsoft Excel
6. Current Density
7. Solar Cell Characteristics
8. Sunshine Recorder
9. Pyranometer
10. Wind Data analysis
11. Air mass Ratio
12. Underground Resistivity measurement
13. Heat pipe
14. Biogas Plant
15. Vacuum Deposition System
16. Spray Pyrolysis System

M.Sc. –II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
2-credits

PH

MATERIALS SCIENCE LAB-I

List of Experiments

- 1 Jominy end test
- 2 Cooling curves
- 3 Stress-Strain curves
- 4 Average grain diameter
- 5 Laue diffraction
- 6 Crystal structure
- 7 Preparation of ferrite
- 8 Spectrometry of colored solutions
- 9 Crystal structure of thin film
- 10 Crystal growth from solution
- 11 Ionic conductivity

Tutorials

- 1 Tutorials will consist of 3-4 experiments based upon syllabi of theory paper of Materials Science.

M.Sc. –II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
2-credits

PH

SOLID STATE PHYSICS LAB -I

List of Experiments

- 1 Resistivity of thin film by two point probe method
- 2 Flat band potential
- 3 Ionic conductivity
- 4 Crystal structure of ferrite
- 5 Intensity calculations
- 6 Unijunction Transistor
- 7 Band gap energy of thin film
- 8 Growth of single crystal
- 9 Phase diagram
- 10 Metal semiconductor diode
- 11 Laue diffraction
- 12 Spectra of ions

M.Sc. –II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
2-credits

PH

MODERN OPTICS LAB-I

List of Experiments

- 1 Michelson's Interferometer
- 2 Talbot's Bands.
- 3 Calibration of Spectrograph.
- 4 Laser beam parameter.
- 5 Iron arc spectra
- 6 Copper arc spectra
- 7 Setting of C.D. spectrograph.
- 8 Mixture analysis.
- 9 Zeeman effect
- 10 Recording of Hologram
- 11 Mathematica-I
- 12 Recording of FT-NMR Spectra
- 13 UV-Visible spectra of organic material

Tutorials

- 1 Concerning above list of experiments, it is possible to arrange some expt. With the availability of new experimental kits.

M.Sc. –II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
2-credits

PH

SPACE SCIENCE LAB-I

List of Experiments

- 1 Proton precession magnetometer
- 2 Amplitude Modulation
- 3 Variable Attenuator
- 4 Total electron content by GPS
- 5 Solar Data Analysis
- 6 Mesospheric Temperature Measurement from night airglow study
- 7 Frequency characteristic of Ku-band
- 8 Beam width of parabolic dish antenna
- 9 Mounting of Telescope
- 10 PR Radar
- 11 Designing of Yagi Antenna
- 12 Study of Leafy Vegetation
- 13 Beam width of Yagi Antenna & field strength
- 14 X-band characteristics of patch antenna

M.Sc. –II [Physics] (Sem. – III)
(Under Academic Flexibility Scheme)
2-credits

PH

THEORETICAL PHYSICS LAB-I

List of Experiments

Introduction to Mathematica for Scientists and Engineers (Notebook form in Mathematica Tutorials) (IMSE)

1. IMSE Ch1: Introduction
2. IMSE Ch2: Functions
3. IMSE Ch3: Symbolic Manipulations
4. IMSE Ch4: Plots
5. IMSE Ch5: Lists, Arrays
6. Frequency characteristic of Ku-band

Tutorials

Tutorials from Schaum's Outlines: Mathematica (Eugene Don)

1. Getting Acquainted
2. Basic Concepts
3. Lists
4. Two-dimensional Graphics
5. Three-dimensional Graphics

M. Sc. –II (Physics) Semester-III
Academic Flexibility
4-Credits

Elective Paper
General Relativity

PH

Unit 1 Theory of Gravitation

15 Lectures

Review of the special theory of relativity and the Newtonian theory of gravitation. Distinction between Newtonian space and relativistic space. The conflict between Newtonian Theory of gravitation and special Relativity. Non-Euclidean space time. General Relativity and gravitation, desirable features of gravitational theory. Principle of equivalence and principle of covariance.

Unit 2 Tensor Analysis

15 Lectures

Transformation of co-ordinates, Summation convention, Symmetric and skew-symmetric tensors, contraction of tensor and quotient laws, Laws of transformation of contravariant, covariant and mixed tensors of different ranks, Cartesian tensor, Metric tensor, Algebra of tensors, associate tensors, Physical components of tensors
Christoffel symbols, covariant derivative of tensors, Intrinsic derivative, covariant derivative of second order, Curvature tensor and its symmetric properties, Riemann Christoffel tensor, Ricci Theorem, Ricci tensor, Einstein tensor, Local inertial co-ordinate system, Bianchi identities, contracted Bianchi identities

Unit 3 Geodesic and Field Equations

15 Lectures

Riemannian metric. The Levi-Civita tensor, Dual tensor. Parallel transport and Lie derivative. Geodesic: i) geodesic as a curve of unchanging direction ii) geodesic as the curve of shortest distance and iii) geodesic through variational principle. The first integral of geodesic and types of geodesics. Geodesic deviation and geodesic deviation equation. Einstein field equation and its Newtonian approximation, Energy momentum tensor of perfect fluid, Electromagnetic field, Einstein Maxwell equation

Unit 4 Crucial Tests of General Relativity, Schwarzschild Solution

15 Lectures

Planetary orbits, general relativistic Kepler problem, Advance of perihelion of Mercury, Bending of light rays in a gravitational field, gravitational red shift in spectral lines, Schwarzschild interior solution

Spherical symmetry, Einstein field equations under spherical symmetry, Schwarzschild space time, Isotopic coordinates, retarded time, Schwarzschild exterior solution and its isotropic form,

Text and Reference Books

J V Narlikar, *Lectures on General Relativity and Cosmology*, McMillan, 1978
R Adler, M. Bazin and M Schiffer, *Introduction to General Relativity*, McGraw-Hill, 1975

The problems given in the Text and Reference books will form tutorial course.

Special Relativity

Unit 1 Relativistic Kinematics

15 Lectures

Galilean transformations, Newtonian Relativity, Electromagnetism and Newtonian Relativity, Inertial frames, postulates of special Relativity, Derivation of the Lorentz transformation equations, Consequences of the Lorentz transformation equations viz. Lorentz-Fitzgerald contraction, time dilation, simultaneity and co-locality of events, Invariance of electromagnetic wave equation, the relativistic addition of velocities (Einstein's formula), Lorentz velocity and acceleration transformation equations, relativistic aberration formula and Doppler effect. [1]

Unit 2 Relativistic Dynamics

15 Lectures

Variation of mass of a moving particle, relativistic momentum, force, work and energy, The equivalence of mass and energy, The transformation properties of momentum, energy, mass and force, Minkowski spacetime, four velocity vector, four momentum, Light cone, Relativistic Lagrangian and Hamiltonian

Unit 3 Electromagnetism

15 Lectures

The interdependences of electric and magnetic fields, the transformation for electric and magnetic fields, the field of a uniformly moving point charge, the invariance of Maxwell's equations [1]

Unit 4 Tensor Analysis

15 Lectures

Transformation of co-ordinates, Summation convention, Symmetric and skew-symmetric tensors, contraction of tensor and quotient laws, Laws of transformation of contravariant, covariant and mixed tensors of different ranks, Cartesian tensor, Metric tensor, Algebra of tensors, associate tensors, raising and lowering of Indices, Physical components of tensors, Maxwell's equations in tensor form [2]

Text and Reference Books

1. **Robert Resnik**, Introduction to Special Relativity, Wiley (Eastern) :td. 1968
 2. **Synje J L**, *Relativity: The Special Theory*, North Holland Publication, 1972
 3. **Landau L D and Lifshitz E M**, *The Classical Theory of Fields*, Pergman Press, 1978
 3. **Benjamin P G**, *Introduction to Theory of Relativity*, Prentice Hall of India, 1969
 4. **Soni V S**, *Mechanics of Relativity Chap. 9*, PHI Learning Pvt Ltd, New Delhi, 2009
- The problems given in the Text and Reference books will form tutorial course.*

Semester IV

Semester – IV

Course Code	Subject
PH	COMPUTATIONAL METHODS AND PROGRAMMING
PH	EXPERIMENTAL TECHNIQUES
PH	ENERGY SCIENCE–III The New Energy Technologies
PH	MATERIALS SCIENCE–III Mechanical Properties and Liquid Crystals
PH	SOLID STATE PHYSICS– III

	Thin Solid Films: Deposition and properties
PH	MODERN OPTICS – III Laser and its Applications
PH	SPACE SCIENCE–III Solar Wind and its Interaction with Planets and Satellites
PH	THEORETICAL PHYSICS Interaction of Electromagnetic Waves with Electron Beams and Plasmas
PH	ENERGY SCIENCE – IV Solar Thermal Devices
PH	MATERIALS SCIENCE – IV Special Materials
PH	SOLID STATE PHYSICS– IV Semiconductor Devices
PH	MODERN OPTICS – IV Holography
PH	SPACE SCIENCE–IV Solar terrestrial Physics & Space Applications
PH	THEORETICAL PHYSICS Quantum Field Theory 2
PH	ENERGY SCIENCE LAB–II
PH	MATERIALS SCIENCE LAB–II
PH	SOLID STATE PHYSICS LAB–II

PH	MODERN OPTICS LAB-II
PH	SPACE SCIENCE LAB-II
PH	THEORETICAL PHYSICS LAB-II
PH	ENERGY SCIENCE PROJECT WORK-II
PH	MATERIALS SCIENCE PROJECT WORK-II
PH	SOLID STATE PHYSICS PROJECT WORK-II
PH	MODERN OPTICS PROJECT WORK-II
PH	SPACE SCIENCE PROJECTWORK-II
PH	THEORETICAL PHYSICS PROJECT WORK-II

	Elective Papers
PH	Cosmology General Relativity

M.Sc.-II [Physics] (Sem. – IV)

(Under Academic Flexibility Scheme)

(4-credits)

PH

COMPUTATIONAL METHODS AND PROGRAMMING

Unit I Ordinary Differential Equations (15)

Types of Differential Equations, Euler Method, Applications to non-linear and vector equations, The Leap -Frog method, Runge-Kutta method, The Predictor-Corrector method, The Intrinsic Method

Unit II Partial Differential Equations (15)

Types of Equations, Elliptic equations- Laplace's equation, Hyperbolic equations- Wave equation, Eulerian and Lagrangian methods, Parabolic equations - Diffusion, Conservative Methods - The equation of continuity, Maxwell's equations, Dispersion

Unit III Matrix Algebra (15)

Types of Matrices, Simple matrix problems, Elliptic equations- Poisson's equation, Systems of equation and Matrix inversion, Iterative methods- The Jacobi Method, Matrix Eigenvalue Problems-Schrödinger's equation,

Unit IV Monte Carlo Methods and Simulation (15)

Random number generators, Monte Carlo integration, the metropolis algorithm, The Ising model, Quantum Monte Carlo

Reference Books

1. Potter D, Computational Physics, Wiley, Chichester, 1973
2. Press W H et. al., Numerical Recipes: The Art of Scientific Computing, CUP, Cambridge, 1992
3. Wolfram S, Mathematica- A System For Doing Mathematics By Computer, Addison Wesley, 1991
4. Angus McKinnon, Computational Physics - 3rd/4th Year Option, Notes in .pdf format

Tutorials

- 1 The problems given in the Text and Reference books will form tutorial course.

M. Sc. - II [Physics] (Sem - IV)
(Academic Flexibility)
(4-credits)

PH- EXPERIMENTAL TECHNIQUES

Unit I Vacuum Techniques (B 1 & 2)

Production of low pressures: rotary, diffusion, and sputter ion pumps; measurement of low pressure: McLeod, Pirani, thermocouple & Penning gauges; leak detection : simple methods of LD, palladium barrier and halogen leak detectors.

(15)

Unit II Low Temperature and Microscopy Techniques (B 3 – 8)

Production of low temperatures: Adiabatic cooling, the Joule-Kelvin expansion, adiabatic demagnetization, ³He cryostat, the dilution refrigerator, principle of Pomeranchuk cooling, principle of nuclear demagnetization; measurement of low temperatures.

Optical microscopy, scanning electron microscopy, electron microprobe analysis, low energy electron diffraction.

(15)

Unit III Atomic Absorption Spectrometry (B 9 – 11)

Fundamentals : principle, basic equipment, operation, monochromator action, modulation; apparatus : double beam instrument, radiation sources, aspiration and atomization; interferences, control of AAS parameters, reciprocal sensitivity and detection limit; techniques of measurement : routine procedure, matrix matching method, and method of additions.

(15)

Unit IV X-Ray Fluorescence Spectrometry and Mössbauer Spectroscopy (B 11–16)

Introduction to wavelength-dispersive X-ray fluorescence spectrometry (WDXRF) and energy-dispersive X-ray fluorescence spectrometry (EDXRF), dispersive systems, detectors, instruments, matrix effects, XRF with synchrotron radiation.

Elementary theory of recoil free emission and resonant absorption of gamma rays, Mössbauer experiment, hyperfine interactions: chemical isomer shift, magnetic dipole hf splitting, and electric quadrupole hf splitting; line broadening.

(15)

Reference Books:

1. High vacuum techniques- J.Yarwood (Chapman & Hall) 1967
2. Vacuum technology- A.Roth (North-Holland Publishing Company, Amsterdam) 1982
3. Experimental techniques in low temperature physics – G.K.White (Oxford) 1968
4. Low temperature physics – L.C. Jackson
5. Experimental principles & methods below 1K – O.V.Lounasmaa (Academic press, New York) 1974
6. Modern metallography - R.E.Smallman & K.H.G.Ashbee(Peramon press, Oxford)
7. Microscopy of materials - D.K.Bowen & C.R.Hall (the MacMillan press Ltd. (London) 1975; Chap.1-3.

8. Electron optical applications in materials science- L.E. Murr, (McGraw Hill, New York) 1970.
9. Atomic absorption spectroscopy - B.Welz (Verlag Chemie, New York) 1976.
10. Atomic absorption spectroscopy- R.J. Reynolds,K.Aldous & K.C. Thompson (Charles Griffin and company Ltd. London) 1970.
11. Modern methods for trace element determination- C.Vandecasteele & C.B.Block (John Wiley & Sons, New York) 1993.
12. Principles of instrumental analysis- D.A. Skoog & J.J.Leary (Saunders College publishing) 1992.
13. Mössbauer spectroscopy- N.N.Greenwood & T.C. Gibb (Chapman & Hall, London) 1971.
14. Spectroscopy, vol.1 – Straughan & Walker (Chapman& Hall, London) 1976; Chap.5.
15. Mössbauer effect: principles and applications- G.K.Wertheim (Academicpress, New York) 1964.
16. An introduction to Mössbauer spectroscopy - Leopold May, Edr. (Plenumpress, New York) 1971.

Topics for tutorial:

1. Hot cathode gauges
2. Gas-probe technique of leak detection
3. Simple cryostat designs
4. Etching techniques
5. Importance of Mössbauer spectroscopy technique.

M.Sc.-II [Physics] (Sem. – IV)
(Under Academic Flexibility Scheme)
(4-credits)

PH

ENERGY SCIENCE-III
The New Energy Technologies

Unit I Environmental Impacts of Renewable Energy Sources (15)

Energy flow diagram to the earth, Carbon cycle, Ecological Niche, Green house effect. Energy Consumption in India, Environmental degradation due to conventional energy production and utilization: Asian Brown Cloud Effect, Environmental impacts of Biomass energy, solar energy systems, wind energy and ocean thermal energy. Power co-generation.

Unit II Hydrogen as clean source of Energy (15)

Sources of hydrogen, Thermodynamics of water splitting, Hydrogen production methods, Photoelectrolysis of water, Direct decomposition of water, Thermochemical production of hydrogen; Hydrogen storage methods: Conventional, Liquid Hydrogen storage, Metal Hydrides, and Cryo-adsorbing storage.

Unit III Superconductors and Fuel Cell Technology (15)

Cuprates and MgB_2 superconductors and their properties, superconducting wires, Role of superconductor in Electric generator, Magnetic energy storage devices and power transmission. Working principle of fuel cell, Components of fuel cell, EMF of fuel cell and polarization in fuel cells, Types of fuel cells, Advantages and disadvantages of fuel cell, Power generation with fuel cells.

Unit IV Batteries and Supercapacitors (15)

Energy storage systems, Faradaic and non-Faradaic processes, Types of capacitors and batteries, Comparison of capacitor and battery, Charge-discharge cycles, experimental evaluation using Cyclic voltammetry, and other techniques, Energy and entropy stored by capacitor, Electrochemical behaviour of RuO_2 , IrO_2 , and mixed oxides, Energy density and power density, Applications for electric vehicle drive systems.

Reference Books

- 1) Biological paths to self reliance- Russell E. Anderson.
- 2) Encyclopedia of Environmental Energy Resources- G.R. Chhatwal Vol. 1 & 2.
- 3) Renewable Energy Sources and their Environmental Impacts- S.A. Abbasi & N. Abbasi.
- 4) Electrochemical supercapacitors by B. E. Conway, Kluwer Academic Press.
- 5) Hydrogen as an Energy Carrier- T. Carl-Jochen Winter, Joachim Nitsch (eds.)
- 6) Advances in Renewable Energy Technologies- S.H. Pawar, and L. A. Ekal (eds.)
- 7) Handbook of Batteries and Fuel Cells- David Linden.

M. Sc.-II [Physics] (Sem. – IV)
(Under Academic Flexibility Scheme)
(4-credits)

PH	MATERIALS SCIENCE-III Mechanical Properties and Liquid Crystals	
Unit I	Stress strain curves General theory of stress and strain, glide elements, independent slip systems, general theory of glide, von Mises criterion, stress strain curves, Luders bands, temperature dependence of stress strain curves, dependence of lower yield point on grain size, strain ageing, work hardening, theories of work hardening, microstructure of deformed metals, solid solution hardening and precipitation hardening, Bauschinger effect.	(15)
Unit II	Recovery , recrystallization , and creep Recovery of mechanical and other properties, polygonization, recrystallization, grain growth, secondary recrystallization. Creep in metals, creep curve, types and mechanisms of creep, creep resistant alloys.	(15)
Unit III	Fracture and fatigue Modes of fracture, ductile and brittle fracture, fracture behaviour of semi-brittle materials, fracture under creep and fatigue conditions, ductile to brittle transition, microscopical examination of fracture, Griffith theory, nucleation and propagation of fracture cracks, blue brittleness. S-N curves, mechanism of fatigue, theory of fatigue, fatigue resistant structures.	(15)
Unit IV	Liquid crystals a. <i>Liquid crystal mesophases</i> : Mesomorphic behaviour, mesogenic compounds, classification of mesophases, nematics proper, chiral nematics, smectics with liquid layers, bond orientational order and ordered layers, cubic thermotropic mesophases of disc like molecules, liquid crystalline polymers, lyotropic liquid crystals. b. <i>Physical properties of liquid crystals</i> : Physical properties of liquid crystals	(15)
Reference Books :		
1. Mechanical properties of materials - Mclintock and Argon, Addison Wesley		
2. Mechanical properties of metals - D. McLean, Wiley, (1962)		
3. Mechanical properties of matter - A.H. Cottrell, John Wiley and Sons (1964)		
4. Physical metallurgy - R.W. Cahn, II Edition, North Holland, Amsterdam (1965)		
5. Physical metallurgy principles - R.E. Reed-Hill, Van Nostrand (1966)		
6. Crystallography and crystal defects - A. Kelly and G.W. Groves, Longman (1970)		
7. Modern techniques in metallography - D.G. Brandon, Butterworth (1966)		
8. Techniques of metal research - R.F. Bunshaw, Interscience (1968)		
9. Liquid crystals - S. Chandrasekhar, Cambridge University Press (1977)		
Tutorials		
1. Yield point phenomenon		
2. Effect of grain growth on properties		
3. Fracture in semi-brittle materials		

**M. Sc.-II (Physics) [Sem IV]
(Academic Flexibility)
(4-credits)**

PH

**SOLID STATE PHYSICS- III
(Thin Solid Films: Deposition and properties)**

Unit 1: Physical methods: Vacuum evaporation and sputtering (15)

Vacuum system, experimental technique, Thermal evaporation methods: Resistive heating, Flash evaporation, Laser evaporation, Electron bombardment heating, Arc evaporation, Radio frequency heating, Sputtering process, Glow discharge DC sputtering, Triode sputtering, Getter Sputtering, Radio frequency sputtering, Magnetron sputtering, Ion beam sputtering.

Unit 2: Chemical Methods (15)

Chemical vapor deposition: Common CVD reactions, Methods of film preparation, laser CVD, Photochemical CVD, Plasma enhanced CVD, Chemical bath deposition: ionic and solubility products, preparation of binary semiconductors,
Electrodeposition,: Deposition mechanism and preparation of compound thin film
Spray pyrolysis :Deposition mechanism and preparation of compound thin films

Unit 3: Nucleation, growth and structure of films (15)

Nucleation: Condensation process, Langmuir- Frenkel theory, other theories of condensation and experimental results

Growth: Liquid like coalescence, influence of deposition parameters, physical structure of films

Crystallographic structure of films: lattice constant, Size effect, Disordered and amorphous structures, Abnormal metastable crystalline structures, two-dimensional superstructures. Epitaxial growth of thin films: Influence of substrate and deposition conditions, theories of Epitaxy

Unit 4: Properties of thin films (15)

Mechanical properties: Stresses in thin films, Mechanical constants of thin films,

Electrical and magnetic properties: Electrical conduction in thin metallic discontinuous films, Electrical conduction in thin metallic films,,

Optical properties: Optical constants of thin films, experimental methods as Reflection, Interferometric, and Critical angle method.

Reference books

1. Thin Film Phenomena by K L Chopra McGraw -Hill Book Company, NY 1969
2. Thin Film Technology by O S Heavens (1970)
3. Properties of Thin Films by Joy George, Marcel and Decker, (1992) (Units 1-3)
4. Physics of Thin Films L Eckertova, Plenum Press NY (1980) (Unit 4)

Tutorials

1. Deposition of copper film using thermal evaporation
2. Chemical bath deposition of semiconductor thin films
3. Epitaxial growth of silicon
4. Electrical properties of metallic and semiconducting thin films
5. Quantum size effect

M. Sc.-II [Physics] (Sem. – IV):
Under Academic Flexibility Scheme
(4-credits)

PH **MODERN OPTICS – III** SPC – III
(*Laser and its Applications*)

Unit – I: Crystalline Solid State Lasers: (15)

The Ruby laser, Nd: YAG laser, Nd: Glass lasers.

Characteristics of Dye lasers, Rate equations for Dye lasers Chemical lasers:

H₂, F₂ mixture and DF, CO₂ mixture lasers. Characteristics of

Semiconductor laser, CW – Room temperature lasers

Unit – II: Gas Lasers: (15)

Process of excitation and de-excitation in gas lasers, Neutral-Atom gas laser, Lamb-Dip phenomenon and construction. Ion lasers: Working of A – laser, Metal Vapour laser: Energy levels and penning/ ionization in He-Cd and He-Se lasers, construction of metal vapour lasers,. Molecular gas lasers: Energy levels of molecules, Vibrational – Rotational lasers: CO₂ – laser system, construction and working of CO₂ laser, Different types of CO₂ lasers,. Vibronic lasers: Construction and working of N₂ laser, Excimer laser.

Unit –III: Applications of Lasers: (15)

Applications in pure science, Applications in applied science, Industrial Applications, optical communication. optical data processing.

Unit-IV : Advances in Laser physics: (15)

The semi classical approach, material equation, field equation,

Travelling waves, Standing waves.

Text and Reference Books:

13. B.A. Lengyl, Introduction to Laser Physics.
14. Svelto, Principles of Lasers.
15. Willate, Introduction to Gas Lasers.
16. R.J. Collier, Optial Holography.
17. L. Taroso, Laser Physics and Applications.
18. J.F.B. Hawkes and J. Wilson, Lasers – Principles and Applications, Prentice Hall, NY, (1987).

Tutorial: Laser and its Applications:

The tutorials will consist of solving problems given in the text and reference books

M. Sc.-II [Physics] (Sem. – IV)
(Academic Flexibility)
(4 credits)

PH

SPACE SCIENCE-III

SPC – III

(Solar Wind and its Interaction with Planets and Satellites)

Unit 1: Study of Solar Wind and Interaction with Magnetized Planets: (15)

Introduction, a Quick Survey of the Solar Wind Properties, Basic Concepts of S.W. formation In the Solar Corona, the Magnetic Structure of the Corona and S.W. the Major Time Dependent Disturbances of the S.W., Planetary Magnetic Fields, Size and Shape of the Magnetospheric Cavity, Self-Consistent Models, Flow around the Magnetospheres.

Unit 2: S. W. Interaction with Earth's Magnetosphere: (15)

Magnetic Field of the Earth- Magnetosphere, Earth's Variable Magnetic Field, Solar activities and Earth's Magnetic Weather, S.W. Interaction, the Chapman-Ferraro model of Closed Magnetosphere, Dungey's Open Magnetosphere, Van-Allen Radiation Belt, Disturbed S.W. Interaction, Magnetic Storms, Magnetic Reconnection and Magnetic Storms, International Programs.

Unit 3: Magnetosphere in the solar system and Effects of Solar activities on Technological Earth Systems: (15)

Magnetospheres of Inner and Outer Planets, Comets, Helio-magnetosphere, Long Conductors, Power Systems, Radio Communication, Space Systems, Space Weather forecast, Schematic Illustration of Present Day Technological Systems.

Unit 4: Physics of space plasma and interaction with unmagnetized celestial bodies (15)

Introduction, Single Particle Motion, Collection of Particles, Plasma State, Fluid Description of Plasma, Magnetohydrodynamics(MHD) and its applications, Plasma Interaction with Moonlike Bodies, Plasma Interaction with Bodies with Atmospheres.

References Books:

1. Astrophysics of the solar System, by K. D. Abhyankar
2. Sourcebook on the Space Science, by S. Glasstone
3. Astrophysics Ed. By L.W. Fredrick
4. Solar wind and Interplanetary Disturbances S. K. Alurkar
5. Planets, Stars and Galaxies, by S.J. Inglis

Topics for tutorials:

The problems/ exercise/ short questions answers given in the Text and Reference Books will form Tutorial Course.

M.Sc. II (Physics) Semester-IV
Academic Flexibility
4-Credits

PH Theoretical Physics
INTERACTION OF ELECTROMAGNETIC WAVES WITH ELECTRON BEAMS
AND PLASMAS

UNIT 1 BASIC EQUATIONS AND PROPERTIES OF LINEAR WAVES **(15)**
Introduction, Maxwell Equations, Dispersion Relation, Energy Density and Energy flow, The Kinetic equation, Fluid equations, Plasma response to an electromagnetic wave, Diffraction divergence, Dispersion broadening, Electromagnetic wave propagation in an Inhomogeneous plasma, Surface waves, Duct propagation, Thomson scattering of Radiation, Anomalous resistivity (LiuTripathi 1-44:44)

UNIT 2 RESONANCE ABSORPTION, PLASMA WAVE EXCITATION, COHERENT EMISSION OF RADIATION **(15)**
Current Density, Coupled Mode Equations, Mode conversion
Excitation of a Langmuir wave, Electron Acceleration in a Langmuir wave
Phase coherence and Bunching, Cerenkov FEL, Free Electron Laser (LiuTripathi 45-87:43)

UNIT 3 SELF-FOCUSING AND FILAMENTATION, PARAMETRIC INSTABILITIES IN A HOMOGENEOUS PLASMA **(15)**
Nonlinear Permittivity, Self-focussing, Filamentation Instability
A Harmonic oscillator, Parametric oscillator with two degrees of freedom, Parametric coupling in a Plasma, Nonlinear dispersion relation, Stimulated Raman scattering, Stimulated Compton scattering, Stimulated Brillouin scattering, Non-linear ion Landau damping, Modulational Instability, Filamentation Instability, Decay instability, Oscillating two-stream instability, Two-Plasmon decay, Parametric instability of a Random Pump (LiuTripathi 88-133:46)

UNIT 4 A NONLINEAR SCHRÖDINGER EQUATION AND PARAMETRIC INSTABILITIES IN AN INHOMOGENEOUS PLASMA **(15)**
Basic equation, Stationary solution, Instability of an Envelope Soliton, Criterion for Collapse WKB Solution, Raman Side scattering, Brillouin Side scattering, Scattering off a Heavily damped Ion Acoustic Mode, Decay Instability, Oscillating two-stream Instability, Two-Plasmon decay (LiuTripathi 134-166:43)

TEXT AND REFERENCE BOOKS

C S Liu and V S Tripathi, Interaction of Electromagnetic waves with electron beams and Plasmas, World Scientific, 1994

The problems given in the Text and Reference books will form tutorial course.

M.Sc.-II [Physics] (Sem. – IV)
Under Academic Flexibility Scheme
(4-credits)

PH

ENERGY SCIENCE - IV
(Solar Thermal Devices)

Unit 1: Principles of heat transfer (15)

Conduction: plane wall, multiplayer wall, cylinders and spheres, thermal conductivity of solid, liquid and gas, convection: free and forced convections, heat transfer through plane wall, radiation: characteristics of radiation, secular and diffuse reflections, gray surfaces, radiation function table, radiation exchange between two parallel gray surfaces, radiation characteristics and properties of materials, heat exchangers, double pipe heat exchangers, expression for effectiveness, methods to obtain rate of heat transfer in heat exchangers: LMTD and ENTU, flow and convection heat transfer in forced beds, problems.

Unit 2: Flat Plate Collectors (15)

Selective surfaces its characteristics and examples, energy balance equation for flat plate collector, thermal analysis of a flat plate collector, efficiency of flat plate collector, solar cookers, solar thermal systems for various applications, solar dryers and industrial products, problems.

Unit 3: Concentrating solar energy collectors (15)

Reasons for using concentrating collectors, thermodynamic limits to concentration, optical limits to concentration, various types of concentrators, compound parabolic concentrators (CPC) and its thermal analysis, tracking of the sun, continuously tracking solar concentrators.

Unit 4: Solar pond (15)

Basic principle of operation of solar pond, theoretical analysis of solar pond, extraction of heat from solar pond, types of solar pond ,applications of solar ponds, problems.

Reference Books:

1. Principles of solar engineering by Frank Kreith and Janf Kreider.
2. Solar energy conversion, A. E. Dixon & J. D. Leslie
3. Solar Energy Engineering, A. A. M. Sayigh
4. Solar energy by Sukhatme
5. Solar energy utilization by G.D.Rai
6. Selective surfaces by O.P. Agnihotri

Topics for tutorials:

1. Methods to obtain selective surfaces
2. Examples on determination of rate flow of heat
3. Maintenance of flat plate collector based devices
4. Derivation of efficiency of CPC
5. Maintenance of solar ponds

M.Sc.-II [Physics] (Sem. – IV)
(Under Academic Flexibility Scheme)
(4-credits)

PH MATERIALS SCIENCE – IV
Special Materials

Unit I *Iron carbon system*

Phase diagram of iron carbon system, pearlite transformation,, effect of (15)
temperature on pearlite transformation, TTT diagrams, hardening of
steels, hardenability, variables influencing the hardenability, martensite
transformation, quench cracks, tempering, cast irons.

Unit II *Alloys*

Alloy steels, tool steels, brasses and bronzes, lead alloys, magnetic alloys (15)
and super alloys.

Unit III *Composite materials*

Introduction, properties of component materials, particulate composites, (15)
fiber reinforced composites, planar composites, fabrication and
applications of composites, theories of hardening of composites
(dispersion strengthening and fibrous reinforcement)

Unit IV *Glasses*

Types of glasses, role of oxides in glasses, glass transition temperature, (15)
optical properties of glasses, electrical properties of glasses,
electronically conducting glasses, special glasses, metallic glasses.

Reference Books

1. Physical metallurgy principles - R. E. Reed-Hill, Affiliated East-west press Pvt. Ltd., New Delhi (1973)
2. Metallurgy theory and practice - D. K. Allen, American technical society, Chicago (1969)
3. Structure and principle of engineering materials - R. M. Brick, A. W. Pense and R. B. Gordon, McGraw-Hill Kogakusha, Ltd., Tokyo (1977)
4. Engineering metallurgy, part 1 - R. A. Higgins, ELBS, London (1973)
5. Superalloys - C. T. Sims and W. C. Hagel, John Wiley and sons, N.Y. (1972))
6. Physical metallurgy for engineers - A. G. Guy, Addison- Wesley Pub. Co. Massachusetts (1962)
7. Introduction to materials science for engineers - J.F. Shackelford McMillan, N. Y. (1985)
8. Materials and technology, metals and ores, Vol. 3 - T. J. W. van Thoor, (Edr.) Longmans, London (1970), Chapter 12
9. Glass science - R H Doremus, John Wiley and sons, N. Y. (1973)
10. Physical properties of glass - D. G. Holloway Wykeham publications, London (1973)
11. Modern composite materials - L. J. Broutman and R H Krock Addition-Wesley Pub. Co., Massachusetts (1967)

12. Materials science, testing, and properties for technicians - W. O. Fellers
Prentice Hall, N. J. (1990)
13. Elements of materials science -L. H. van Vlack Addition-Wesley, Massachusetts
(1959)
14. Introduction to ceramics - W. D. Kingery, John Wiley and sons, N. Y. (1960)

Topics for Tutorials

1. Heat treatment of steels
2. Effect of alloying elements on properties
3. Modern developments in glasses

M. Sc.-II [Physics] (Sem. – IV)
(Under Academic Flexibility Scheme)
(4-credits)

PH SOLID STATE PHYSICS – IV
Semiconductor Devices

- Unit I Semiconductor abrupt junctions (15)**
Equilibrium conditions, the contact potential, space charge at a semiconductor junction, qualitative description of current flow at a junction, minority and majority carrier currents, carrier injection, minority carrier distributions, variation of the quasi Fermi levels with the position, junction current from excess minority carriers, junction breakdown mechanisms, capacitance of p-n junctions.
- Unit II Semiconductor heterojunctions (15)**
Types of heterojunctions, energy band diagrams of heterostructures, current-voltage and capacitance-voltage characteristics of anisotype heterojunctions, heterojunction bipolar transistors, electrical and optical characteristics of LEDs, laser gain semiconductor band system, high electron mobility transistor, hot electron heterojunction transistor.
- Unit III 2D electron gas and Quantum wells (15)**
2D electron gas in Si and GaAs MOS structures, effect of applied bias on energy bands of the MOS capacitors, bias dependence of capacitance, free charge carrier transfer, triangular quantum wells (both finite and infinite), coupled quantum wells and super lattices, double-heterostructure lasers, single quantum well lasers, multiple quantum well lasers. Optical absorption due to electronic transitions in quantum wells
- Unit IV Transport properties of heterostructures and quantum devices (15)**
Effect of electric field parallel and perpendicular to the interfaces, effects of constant magnetic field, Landau levels, magneto conductivity in a 2D heterostructure. One-D and Zero-D quantum structures, density of states in 3D, 2D, 1D and 0D structures, 1D and 0D optical phenomena and optical devices, quantum confined stark effect, quantum well modulators, self-electro-optic effect devices, resonant tunneling devices, the coulomb blockade, single electron transistor

Reference Books

1. Semiconductor heterojunctions by B. L. Sharma and R. K. Purohit, Pergamon press.
2. Heterojunction and metal-semiconductor junctions by A. R. Milnes and D. L. Hench, Academic press.
3. Solar cells by H. J. Hovel.
4. Solid-state electronic devices by B. G. Streetman.

5. Luminescence and LED by E. W. Williams and R. Hall.
6. Semiconductor physics and applications by M. Balkanski and R. F. Wallis, Oxford University Press.
7. Physics of semiconductor devices by S. M. Sze.
8. Physics of semiconductor devices by D. K. Roy, Univ. Press, 2000.
9. Introduction to mesoscopic physics-second edition by Yoseph Imry, Oxford Univ. Press, 2002.

Tutorials

1. Photonics and optical storage devices
2. Optical modulators/switches and electro-optical wave guides
3. Coupling and device integration and energy losses

M. Sc.-II [Physics] (Sem. – IV)
Academic Flexibility
(4-credits)

PH

MODERN OPTICS – IV
(Holography)

SPC – IV

Unit – I: Introduction to Basic Concepts: (15)

Optical holography, Light waves, hologram formation, wavefront reconstruction, Plane and Volume hologram formation geometries, Basic holography equations.

Beginning of Optical Holography, in - line (Gabor) hologram, The off-axis hologram, Image hologram, Fraunhofer hologram, Thin hologram and Volume hologram, Properties of holograms. Critical assessment of Holograms.

Unit – II: The Reconstructed Image: (15)

Image of a point, Image magnification, orthoscopic and pseudoscopic images, Image aberrations, effect of source size and spectral bandwidth.

Unit – III: Optical system and Light Sources (15)

Mechanical Stability in Hologram Formation, Fringe visibility, Optical components, Coherence requirements. Temporal coherence of laser light.

Hologram Recording Materials:

Optical changes in Photosensitive materials, Exposure & sensitivity, Recording resolution, Noise and Recording Linearity and Ideal recording material, Silver halide photographic Photoconductor-Thermoplastic films, emulsions, Dichromated gelatine films, Thermoplastic films, Photocromic materials.

Unit – IV: Applications of Holography: (15)

Information storage and processing.

Holographic Interferometry: Time average holographic Interferometry,

Real time & Double exposure holographic interferometry. Acoustical Holography.

Text and Reference Books:

19. R. J. Collier, C.B. Burukhardt, L. Lan, Optical Holography, Academic Press (1971).
20. H.M. Smith, Principles of Holography, Wiley Interscience Inc., (1969).
21. L. M. Soroko, Holography & Coherent optics, Plenum Press, (1980).
22. G.W. Stroke, An Introduction to Coherent optics & Holography, Academic Press, New York (1969)
23. P. Hariharan, Optical Holography, Cambridge University Press, (1984)

Tutorial: Holography

The tutorials will consist of solving problems given in the text and reference books.

M. Sc.-II [Physics] (Sem. – IV)
(Under Academic Flexibility Scheme)
(4-credits)

PH

SPACE SCIENCE-IV
Solar terrestrial Physics & Space Applications

Unit I Wave Propagation in ionosphere, (15)

Radio wave propagation in absence and presence of magnetic field, Formation of Chapman layer, Appleton Hartree equation and its explanation, propagation of radio waves at different frequencies.

Unit II Diagnostic techniques for probing ionosphere (15)

Ground based, balloon based, space based techniques, Ionosonde, air glow, P.R.Radar, radio scintillation, magnetometer, Langmuir probe, electrostatic analyzer, mass spectrometer, radiosonde.

Unit III Fundamentals of antennas, microstrip antennas, Remote Sensing (15)

Types of antennas, radiation pattern, arrays, microstrip antennas, radiation pattern, Physical basis of remote sensing, signatures, sensors, air borne and space borne techniques, multispectral scanner, IR scanner, mechanical scanner, microwave radiometry.

Unit IV Satellite Communication, propulsion and power for space, materials for space, microwaves in space (15)

Orbital mechanics of satellite, attitude of satellite, transmission process, power, systems for communication. Rocket propulsion, power for rockets, Materials processing in space, design of space vehicles, methods of gravity simulation, space lab payloads. Microwave technology for space power beaming

Reference Books

1. An introductory course on space science and earth environment: S.S. Degaonkar
2. An introduction to ionosphere and magnetosphere: J.A.Ratcliffe.
3. Ionosphere techniques and phenomena: A.Giraud, M.Petit
4. Antennas: J.D. Kraus.
5. Antenna Engineering: T.K.Bandhopadhyay.
6. Antenna Theory Analysis and design: C.A.Balanis
7. Remote sensing principles and interpretations: F.F.Sabins
8. Introduction to remote sensing: J.B.Campbell
9. Electronic communications: D.Roddy, J.Coolen
10. Microwave radiometer: N.Skou
11. Microwave propagation and techniques: D.C.Sarkar
12. Materials processing in space: S.Ramaseshan, M.K.Tiwari.
13. Recent information from internet

Tutorial

- 1 The problems/exercise/short answer questions given in the text and reference books will form tutorial course.

M.Sc.-II (Physics) Semester-IV
Academic Flexibility
4-Credits

PH Theoretical Physics
INTRODUCTORY QUANTUM FIELD THEORY2
(Renormalization and Non-Abelian Gauge Theories)

UNIT 1 RENORMALIZATION AND SYMMETRY (15)

Counting of ultra-violet divergences, Renormalized Perturbation theory: one loop structure of ϕ^4 -theory, Renormalization of QED: one loop structure of QED, Spontaneous symmetry breaking, : The linear sigma model, Goldstone's theorem, Renormalization and symmetry : An explicit example, , The effective action, Computation of the effective action, The effective action as a Generating Functional (PeskinSchroeder 315-334, 348-382:55)

UNIT 2 NON-ABELIAN GAUGE INVARIANCE AND QUANTIZATION OF NON-ABELIAN GAUGE THEORIES (15)

Geometry of Gauge Invariance, The Yang-Mills Lagrangian, Basic facts about Lie Algebras: Classification of Lie Algebras, Representations, The Casimir Operator, Interactions of Non-Abelian Gauge bosons, The Fadeev-Popov Lagrangian, Ghosts and Unitarity, BRST Symmetry, Asymptotic Freedom: A qualitative Explanation (PeskinSchroeder 481-490, 495-501, 505-520, 541-544:35)

UNIT 3 QUANTUM CHROMODYNAMICS (15)

From quarks to QCD, e^+e^- Annihilation into hadrons: Total cross-section, The running of α_s , Gluon emission, Deep Inelastic scattering: Deep inelastic neutrino scattering, The distribution functions, Hard scattering processes in Hadron Collisions: Lepton pair production, Kinematics, Jet Pair production, Parton Evolution: The equivalent photon Approximation, Measurement of α_s (PeskinSchroeder 545-579, 593-595:37)

UNIT 4 GAUGE THEORIES WITH SPONTANEOUS SYMMETRY BREAKING AND FRONTIERS OF QFT (15)

The Higgs Mechanism : An Abelian Example, Systematics of Higgs Mechanism, Non-Abelian Examples; Formal Description, The Glashow-Weinberg-Salam Theory of Weak Interactions – Gauge Boson Masses; Coupling to Fermions; Experimental consequences of GWS Theory, Fermion Mass Terms, The Higgs Boson, A Higgs sector?, Symmetries of the Theory of Quarks and Leptons, Strong strong interactions, Grand Unification and its paradoxes, Exact solutions in QFT, Supersymmetry, Towards ultimate theory of nature (PeskinSchroeder 690-727, 781-800:58)

TEXT AND REFERENCE BOOKS

Michael E Peskin and Daniel V Schroeder, An Introduction to Quantum Field Theory, Perseus Books, 1995

M . Kaku, Quantum Field Theory: A Modern Introduction, OUP, 1993

The problems given in the Text and Reference books will form tutorial course.

M.Sc.-II Physics (Sem. - IV)
(Under Academic Flexibility Scheme)
(2-credits)

PH

ENERGY SCIENCE LAB--II

List of Experiments

1. Solar Line Concentrator (I)
2. Solar Line Concentrator (II)
3. Solar Point Concentrator
4. Solar Still
5. Solar Dryer
6. Solar Cooker
7. Flat Plate Collector
8. PV – IV Characteristics
9. PV-Water Pumping System
10. PV-Spray System
11. Flue Gas Analyser
12. Wind Energy Conversion
13. Partical Size Measurement
14. Close Cycle Cryogenic System
15. Hot Water Bumb
16. 3kW Aerogenerator

M.Sc.-II Physics (Sem. - IV)
(Under Academic Flexibility Scheme)
(2-credits)

PH

MATERIALS SCIENCE LAB-II

List of Experiments

- 1 Brinell hardness
- 2 Crystal structure
- 3 Hysteresis loop tracer
- 4 Band gap of semiconducting thin films
- 5 Work hardening
- 6 Intensity calculations
- 7 Phase diagram of Pb-Sn alloy
- 8 Phase diagram of Pb-Sn alloy
- 9 Microstructure of steels
- 10 Microstructure of brasses
- 11 Crystal growth by gel technique

Tutorials

- 1 Tutorials will consist of 3-4 experiments based upon syllabi of theory paper of Materials Science.

M.Sc.-II Physics (Sem. - IV)
(Under Academic Flexibility Scheme)
(2-credits)

PH

SOLID STATE PHYSICS LAB-II

List of Experiments

- 1 Mathematica 5.1
- 2 Thermoelectric power
- 3 Chemical bath deposition
- 4 Flat band potential – II
- 5 Successive Ionic Layer Absorption and Reaction (SILAR)
- 6 Work function
- 7 Phosphorescence decay
- 8 Magnetic susceptibility
- 9 van der pauw method
- 10 Vacuum deposition
- 11 Crystal growth by gel technique
- 12 Photovoltaic cell
- 13 Electrodeposition

M.Sc.-II Physics (Sem. - IV)
(Under Academic Flexibility Scheme)
(2-credits)

PH

MODERN OPTICS LAB--II

List of Experiments

- 1 Vibrational analysis of CN
 - 2 Vibrational analysis of AIO
 - 3 Vibrational analysis of C₂
 - 4 Mixture analysis
 - 5 Solar Spectrum
 - 6 Temperature of flame
 - 7 Measurement of Brewster angle and R.I. of materials like glass
 - 8 Determination of wavelength of light by grating
 - 9 Production and analysis of polarized light with the help of He-Ne laser
 - 10 Fabry-Parot etalon – Exact fraction method
 - 11 Mathematica- II
 - 12 Recording of IR spectra
- Depending on availability of new experimental kits, few new experiments will be added to this list

M.Sc.-II Physics (Sem. - IV)
(Under Academic Flexibility Scheme)
(2-credits)

PH

SPACE SCIENCE LAB–II

List of Experiments

- 1 Brightness of sky using photometer
- 2 Study of atmospheric disturbance using He-Ne laser
- 3 Ionospheric Scintillation
- 4 Moisture content in soil by Resistively meter
- 5 Solar spectrum
- 6 Study of ionosphere using GPS
- 7 Study of effect of rain & cloud on Satellite signal
- 8 Analysis of solar data in C-Band
- 9 Study of earth's seismicity using seismograph
- 10 Computer programming
- 11 Lemi data analysis using Matlab
- 12 Accelerograph
- 13 Sunspot recording using C+5 telescope

M.Sc.-II Physics (Sem. - IV)
(Under Academic Flexibility Scheme)
(2-credits)

PH

THEORETICAL PHYSICS LAB–II

ADVANCED MATHEMATICA

TUTORIALS:

1. Tutorials From Schaum's Outlines: Mathematica (Eugene Don)

Chapter 7: Algebra and Trigonometry
Chapter 7: Differential Calculus
Chapter 9: Integral Calculus
Chapter 10: Multivariate Calculus
Chapter 11: Ordinary Differential Equations
Chapter 12: Linear Algebra

2. Introduction to Mathematica for Scientists and Engineers (Notebook form in Mathematica Tutorials)

IMSE Ch7: Complex
IMSE Ch8: Fourier
IMSE Ch9: Programming
IMSE Ch10: Statistics
IMSE Ch5: Input-Output
IMSE Ch6: Solve – Numerical Solutions

3. Assignments

M. Sc. –II (Physics) Semester-IV
Academic Flexibility
4-Credits

PH Elective Paper
Cosmology

Unit 1 Physics of Black Holes, Gravitational wave 15 Lectures

Schwarzschild Black Holes, Potential Energy, The Extendability of Schwarzschild spacetime, The uniformly accelerated lattice, Kruskal space, Black Hole Thermodynamics

Plane wave metric, Interaction of Gravitational wave with dust and radiation, The Penrose topology, solving the field Equation (Rindler 258-295)

Unit 2 Curved spacetime, de-Sitter space, Linearized General Relativity 15 Lectures

Laws of Physics in curved spacetime, Full field equations, Cosmological constant, Modified Schwarzschild space, de Sitter and anti-de Sitter spaces

The basic equation, Gravitational waves, some physics of plane waves, generation and detection of gravitational waves, The EM analogy in linearized GR (Rindler 296-341)

Unit 3 Cosmological Spacetimes, FRW universes 15 Lectures

Basic facts, Cosmological models, Milne's model, FRW Metric, Robertson and Walker's theorem, Representation of FRW universes by subuniverses, cosmological frequency shift, cosmological horizons, The apparent horizon, Observables

Applying the field equations, The Friedman models, comparison with observation, Inflation (Rindler 347-415)

Unit 4 Modern Developments in Cosmology 15 Lectures

Text and Reference Books

Wolfgang Rindler, *Relativity –Special General and Cosmological*, Oxford University Press, 2001

The problems given in the Text and Reference books will form tutorial course.

General Relativity

Unit 1 Theory of Gravitation

15 Lectures

Review of the special theory of relativity and the Newtonian theory of gravitation, Distinction between Newtonian space and relativistic space, the conflict between Newtonian Theory of gravitation and special Relativity, Non-Euclidean space time, General Relativity and gravitation, desirable features of gravitational theory, Principle of equivalence and principle of covariance

Unit 2 Tensor Analysis

15 LECTURES

Christoffel symbols, covariant derivative of tensors, Intrinsic derivative, covariant derivative of second order, Curvature tensor and its symmetric properties, Riemann Christoffel tensor, Ricci Theorem, Ricci tensor, Einstein tensor, Local inertial co-ordinate system, Bianchi identities, contracted Bianchi identities

Unit 3 Geodesic and Field Equations

15 Lectures

Riemannian metric, The Levi-Civita tensor, Dual tensor, Parallel transport and Lie derivative, Geodesic: i) geodesic as a curve of unchanging direction, ii) geodesic as the curve of shortest distance and iii) geodesic through variational principle. The first integral of geodesic and types of geodesics, Geodesic deviation and geodesic deviation equation, Einstein field equation and its Newtonian approximation, Energy momentum tensor of perfect fluid, Electromagnetic field, Einstein Maxwell equation

Unit 4 Crucial Tests of General Relativity, Schwarzschild Solution

15 Lectures

Planetary orbits, general relativistic Kepler problem, Advance of perihelion of Mercury, Bending of light rays in a gravitational field, gravitational red shift in spectral lines, Schwarzschild interior solution

Spherical symmetry, Einstein field equations under spherical symmetry, Schwarzschild spacetime, isotopic coordinates, retarded time, Schwarzschild exterior solution and its isotropic form

Text and Reference Books

1. J V Narlikar, *Lectures on General Relativity and Cosmology*, McMillan, 1978
2. R Adler, M. Bazin and M Schiffer, *Introduction to General Relativity*, McGraw-Hill, 1975

The problems given in the Text and Reference books will form tutorial course.