M.Sc. in Physics

Under the Framework of Honours School System

CHOICE BASED CREDIT SYSTEM (CBCS)

Syllabus for Semester III and IV

Academic Session 2025-26

PANJAB UNIVERSITY, CHANDIGARH

OUTLINES OF TESTS, SYLLABI AND COURSES OF READING FOR

CHOICE BASED CREDIT SYSTEM (CBCS) M.Sc. IN PHYSICS

UNDER THE FRAMEWORK OF HONOURS SCHOOL SYSTEM EXAMINATION,

SYLLABUS FOR ACADEMIC SESSION 2025-2026

SEMESTER III and IV

Choice Based Credit System (CBCS) is one of the important measures recommended by the University Grants Commission (UGC) to enhance academic standards and quality in higher education include innovation and improvements in curriculum, teaching-learning process, examination and evaluation systems. CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising Core, and Discipline Specific and Generic Elective courses. The performance of students in examinations will be evaluated following the Grading system, which provides uniformity in the evaluation and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations. The grading system will facilitate student mobility across institutions within and across countries and also enable potential employers to assess the performance of students.

OBJECTIVES OF THE COURSE

The objectives of the M.Sc. Physics programme are manifold and start with understanding diverse phenomena observed in nature through the fundamental concepts of Physics using logical and mathematical reasoning. It imparts students with an in-depth knowledge and understanding through the Core courses, which form the basis of Physics, namely, Classical Mechanics, Quantum Mechanics, Mathematical Physics, Statistical Mechanics and Thermodynamics, Electromagnetic Theory, Solid State Physics, Electronics, Nuclear Physics, Particle Physics and Atomic and Molecular Physics. The syllabus will provide comprehensive knowledge, and improve theoretical and practical skills of Physics subject. The Discipline Specific elective courses are designed for more specialized Physics content to equip students with experimental and theoretical techniques. The Generic elective courses are designed for interdisciplinary content to equip students with a broader knowledge base.

Creative thinking and problem solving capabilities are also aimed to be encouraged through tutorials. The laboratory-based courses are designed to develop an appreciation for the fundamental concepts and their applications, Instrumentation, Scientific methods/tools of Physics and Electronics skills. Computational physics course is aimed to equip the students to use computers as a tool for scientific investigations/understanding. The Project work in theory and experimental stream are expected to give a flavor of how research leads to new findings. Exposure to the Advanced instruments in the Experimental Physics will promote the research skills of students.

The M.Sc. course lays a solid foundation for a doctorate in Physics and its Allied subjects later. Major portions of the National Entrance Test (NET for Research Fellowship and Teaching Posts) syllabi are covered in the first two semesters of the course. Thorough grounding in the subject will also enable students to teach Physics at the college and school levels. The Course content also covers Industrial visit of the students on individual or small group basis to inculcate the enprenuership character in students.

PREAMBLE

Physics is the science that involves the study of matter and its motion through space and time, along with related concepts. One of the most fundamental scientific disciplines, the main goal of physics is to understand how the universe evolved and behaves. New ideas in physics often explain the fundamental mechanisms of other sciences and the boundaries of physics are not rigidly defined. Physics also makes significant contributions through advances in new technologies that arise from theoretical breakthroughs.

After partition of India, the Department of Physics was re-established in 1947, in Govt. College, Hoshiarpur (Punjab) and later, shifted to the present campus in August 1958. With the modest beginning of research in high-energy particle physics (nuclear emulsion) and optical UV spectroscopy, the research activities got a major fillip with installation of cyclotron accelerator in late sixties. The department strengthened its research activities through UGC Special Assistance Programme (SAP) from 1980 to 1988 and College Science Improvement Programme from 1984 to 1991. In 1988, the department was accorded the status of Center of Advanced Study (CAS) by UGC with three major thrust areas, Particle physics, Nuclear physics and Solid-state physics, which is a unique feature in itself. The department is now in CAS fifth phase. The department participates in various national and international research initiatives in Accelerator-based research in High Energy Physics, Nuclear Physics and Solid-State Physics. The department houses Cyclotron lab, EDXRF lab., Detector development lab., Experimental Solid-state Physics laboratories, Molecular Physics lab. and Advanced computation facilities for analyses of data from High Energy Physics, and Nuclear Spectroscopy and Reaction experiments. High Performance Computation facility is available for Condensed matter Physics and Nuclear Physics simulation calculations.

The Physics department is running undergraduate and postgraduate courses in Physics, and Physics (Specialization in Electronics) under the Honours School System. At present the department has strength of about 30 faculty members and Post-doctoral fellows, 50 non-teaching/administrative staff, 130 research students and 450 graduate and undergraduate students. The department has well equipped Practical and computing laboratories, Workshops and Library. The department has an 11-inch telescope to encourage/inculcate the scientific temper among public and with particular emphasis on college and school students. The department houses Indian Association of Physics Teachers (IAPT) office and actively leads in IAPT and Indian Physics Association (IPA) activities.

COURSE STRUCTURE

M.Sc. IN PHYSICS UNDER THE FRAMEWORK OF HONOURS SCHOOL SYSTEM

'The M. Sc. programme under the framework of Honours School System is a two-year course divided into four-semesters with a total of 80 credits. A student is required to complete 80 credits for the completion of the course and the award of degree. In general, one-hour lecture per week equals 1 Credit, 2 hours practical class per week equals 1 credit.

Subjects offered in the M.Sc. Course is divided into three categories:

(i) 'Core Course' means a course that is Compulsory for a particular programme and offered by the Department, where the student is admitted.

(ii) 'Discipline Specific Elective (DSE) Course' means an optional course to be selected by a student out of such courses offered by the Department, where the student is admitted.

(iii) 'Generic Elective (GE)' means an elective course which is taken by the students in the department other than where the student is admitted.

Syllabus (Teaching and Examination)

The details related to admissions, teaching, and conduct & evaluation of the examinations of students are given in a separate document "Regulations of the M.Sc. under the framework of Honours School System". The teaching hours and credits allocation, and the question paper pattern for the Mid Term and End-semester examinations and their evaluations for various courses of M.Sc. are given in syllabus of each Course, which is supplemented by the procedures given below:

1. **TEACHING :** The number of Lectures mentioned for each Course is 50 (40 + 10) hours, which includes 45 contact hours of teaching to be delivered exclusively by the Teacher as per the scheduled time table and 15 contact hours are for interaction, discussion, tutorials, assignments and seminars (attended/ delivered) by the student.

2. **EXAMINATION**: There shall be Mid-term Examination (75 min duration) of 20% Marks for theory papers in each semester. End-semester examinations (3 hours duration) shall be of 80% of total marks. The question paper for the Mid-term examinations should be such that more emphasis is given to the problems related to the subject. The student will be given 70% choice in attempt. Only in special cases, where the student misses the mid-term examination, retest for the mid-term examinations will be held. For a student who has used first mid term examination chance, teacher may allow him/her to take another midterm test but the maximum score 80% of the first chance of the mid-term test.

   The End-semester question paper will consist of seven questions in all with equal weightage. It will include one Compulsory question (consisting of short answer type questions) covering whole syllabus. There will be no choice in this question. The candidate will be asked to attempt five questions including the compulsory question. The question paper should consists of 30%problem related, 10% thought provoking questions and 60% descriptive questions.

3. **EVALUATION** :

Evaluation of Practicals Subjects –

There shall be internal assessment component for practical courses having weightage of 20% of the allocated marks. It will be based on practical performance of the students in the laboratory, number of experiments performed, written report/record of the experiments and regularity (attendance) in the class.

The final end-semester Practical examination will be of 80% of the total marks and 4 (3+1) hours duration. The evaluation will be based on the following components:

(i) There will be written comprehensive test of 1 hour duration containing short answer questions and covering all the experiments. The test will have a weightage of 20% of the total allocated marks and will be jointly set by the teachers involved in the examination.
(ii) Performance in the allotted experiments done during the End-semester Practical examination (weightage - 25 %)
(iii) Viva voce by the external examiner (weightage - 20%) related to the practicals.
(iv) Continuous evaluation by the internal examiners based on the Viva Voce of the checked practicals (weightage - 15%).

4. **PASSING CRITERION** : The student has to obtain minimum of 40% marks to qualify a Course. The failing candidate has to reappear in end-semester examination. The grading system is detailed in a separate document “Regulations of the M.Sc. under the framework of Honours School System”.

Semester I (Credits = 20, Marks = 500)

Course	Subject	Marks	Credits	Teaching hrs./week
Core Courses (Compulsory)				
Core Course-1	PHY-MC1: Mathematical Physics-I	75	3	4 hrs.
Core Course-2	PHY-MC2: Classical Mechanics	75	3	4 hrs.
Core Course-3	PHY-MC3: Quantum Mechanics	75	3	4 hrs.
Core Course-4	PHY-MC4: Electronics-I	75	3	4 hrs.
Core Course-5	PHY-MC5 : Physics Laboratory PHY-MC5A: Practical Laboratory-I	200 150	8 6	 9 hrs.

Semester II (Credits = 20, Marks = 500)

Course	Subject	Marks	Credits	Teaching hrs./week
Core Courses (Compulsory)				
Core Course-6	PHY-MC6: Mathematical Physics	75	3	4 hrs.
Core Course-7	PHY-MC7: Statistical Mechanics	75	3	4 hrs.
Core Course-8	PHY-MC8: Relativistic Quantum Mechanics and Quantum Field Theory	75	3	4 hrs.
Core Course-9	PHY-MC9: Classical Electrodynamics	75	3	4 hrs.
Core Course-10	PHY-MC10 : Physics Laboratory PHY-MC10A:Practical Laboratory-II PHY-MC10B: Computer Laboratory-II	200 150 50	8 6 2	 9 hrs. 4 hrs.

Semester III (Credits = 20, Marks = 500)

Course	Subject	Marks	Credits	Teaching hrs./week
Core Courses				
Core Course-11	PHY-MC11: Condensed Matter Physics – I	75	3	4 hrs.
Core Course-12	PHY-MC12: Nuclear Physics - I	75	3	4 hrs.
Core Course-13	PHY-MC13: Particle Physics - I	75	3	4 hrs.
Core Course-14	PHY-MC14: Physics Laboratory-III	125	5	9 hrs.
Elective Courses - Choose any Two of the listed Discipline Specific Elective Courses*. Candidate may choose one of the Generic Elective Course** in place of one of the Discipline Specific Elective Courses.				
Discipline Specific Elective Course-1		75	3	4 hrs.
Discipline Specific Elective Course-2		75	3	4 hrs.
Generic-Elective Courses**				
Generic-Elective Course-1		75	3	4 hrs.

Semester IV (Credits = 20, Marks = 500)

Course	Subject	Marks	Credits	Teaching hrs./week
Core Course -				
Core Course-15	PHY-MC15: Nuclear Physics-II	100	4	4 hrs.
Core Course-16	PHY-MC16:Particle Physics-II	100	4	4 hrs.
Core Course-16	PHY-MC17: Condensed Matter Physics-II	100	4	4 hrs.
Elective Courses - Choose any two of the listed Discipline Specific Elective Courses*. Candidate may choose one of the Generic Elective Course**(if available) in place of one of the Discipline Specific Elective Courses.				
Discipline Specific Elective Course-3		100	4	4 hrs.

Discipline Specific Elective Course-4		100	4	9 hrs.
Generic-Elective Courses*				
Generic-Elective Course-2		100	4	4 hrs.

*** DISCIPLINE SPECIFIC ELECTIVE (DSE) COURSES (Semesters III and IV)**
Choose any two DSE courses in semester III and IV. A DSE Course will be offered only if a minimum of 10 students opt for the same and depending of the Faculty available.

A. Choose any two of the following in each of semesters III and IV: (teaching: 4hrs)

1. PHY-MDS1 Electrodynamics and General theory of Relativity
2. PHY-MDS2 Exp. Tech. in Nuclear & Particle Physics
3. PHY-MDS3 Exp. Tech. In Physics
4. PHY-MDS4 Space Science and Technology
5. PHY-MDS5 Astrophysics
6. PHY-MDS6 Electronics II
7. PHY-MDS7 Fiber Optics and Non-linear Optics
8. PHY-MDS8 Informatics
9. PHY-MDS9 Nonlinear Dynamics
10. PHY-MDS10 Particle Accelerator Physics
11. PHY-MDS11 Physics of Nano-materials
12. PHY-MDS12 Science of Renewable Energy Sources
13. PHY-MDS13 Advanced Statistical Mechanics

B. One of the following will be offered in each of semester IV. Allotment will be on merit of results of Semesters I and II: (teaching 9hrs)

1. PHY-MDS14 Physics Laboratory-IV
2. PHY-MDS15 (i) Project work (Nuclear Physics) Experimental
3. PHY-MDS15 (ii) Project work (Particle Physics) Experimental
4. PHY-MDS15 (iii) Project work (Condensed Matter Physics) Experimental
5. PHY-MDS15 (iv) Project work (Atomic and Molecular Physics) Experimental
6. PHY-MDS15 (iv) Project work Electronics) Experimental
7. PHY-MDS15 (v) Project work (Nuclear Physics) Theory
8. PHY-MDS15 (vi) Project work (Particle Physics) Theory
9. PHY-MDS15 (vii) Project work (Condensed Matter Physics) Theory
10. PHY-MDS15 (viii) Project work (Atomic and Molecular Physics) Theory
11. PHY-MDS15 (ix) Project work (Astrophysics) Theory
12. PHY-MDS15 (x) Project work (Non-linear Physics) Theory
13. PHY-MDS16 (xi) Quantum Computations

14.

THIRD SEMESTER

PHY- MC11: CONDENSED MATTER PHYSICS-I

Max. Marks :15+60=75

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Elastic constants :
Binding in solids; Stress components, stiffness constant, elastic constants, elastic waves in crystals.

II Lattice Dynamics and Thermal Properties :
Rigorous treatment of lattice vibrations, normal modes; Density of states, thermodynamic properties of crystal, anharmonic effects, thermal expansion.

III Energy Band Theory :
Electrons in a periodic potential: Bloch theorem, Nearly free electron model; tight binding method; Semiconductor Crystals, Band theory of pure and doped semiconductors; elementary idea of semiconductor superlattices.

IV Transport Theory :
Electronic transport from classical kinetic theory; Introduction to Boltzmann transport equation; electrical and thermal conductivity of metals; thermoelectric effects; Hall effect and magnetoresistance.

V Dielectric Properties of Materials :
Polarization mechanisms, Dielectric function from oscillator strength, Clausius-Mosotti relation; piezo, pyro- and ferro-electricity.

VI Liquid Crystals :

Thermotropic liquid crystals, Lyotropic liquid crystals, long range order and order parameter, Various phases of liquid crystals, Effects of electric and magnetic field and applications, Physics of liquid crystal devices.

TUTORIALS : Relevant problems given in the books listed below.

Books :

1. Introduction to Solid State Physics: C. Kittel (Wiley, New York), 8th ed. 2005.
2. Quantum Theory of Solids : C. Kittel (Wiley, New York) 1987.
3. Principles of the Theory of Solids : J. Ziman (Cambridge University Press) 1972.
4. Solid State Physics : H. Ibach and H. Luth (Springer Berlin) 3rd. ed. 2002.
5. Solid State Theory : Walter A. Harrison (Tata McGraw-Hill, New Delhi) 1970.
6. Liquid Crystals : S. Chandrasekhar (Cambridge University), 2nd ed. 1992.

7.The Liquid Crystal Phases : Physics & Technology : T.J. Sluckin, Contemporary Physics (Taylor & Francis), 2000.

PHY-MC12 NUCLEAR PHYSICS- I

Max. Marks: 15+60 = 75

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Static properties of nuclei : Nuclear radii and measurements, nuclear binding energy (review), nuclear moments and systematic, wave-mechanical properties of nuclei, hyperfine structure, effect of external magnetic field, Nuclear magnetic resonance.

II Radioactive decays : Review of barrier penetration of alpha decay & Geiger-Nuttal law. Beta decays, Fermi theory, Kurie plots and comparative half-lives, Allowed and forbidden transitions, Experimental evidence for Parity-violation in beta decay, Electron capture probabilities, Double beta decay, Neutrino, detection of neutrinos, measurement of the neutrino helicity.

Multipolarity of gamma transitions, internal conversion process, transition rates, Production of nuclear orientation, angular distribution of gamma rays from oriented nuclei.

III Nuclear forces : Evidence for saturation of nuclear density and binding energies (review), types of nuclear potential, Ground and excited states of deuteron, dipole and quadruple moment of deuteron, n-p scattering at low energies, partial wave analysis, scattering length, spin-dependence of n-p scattering, effective-range theory, coherent and incoherent scattering, central and tensor forces, p-p scattering, exchange forces & single and triplet potentials, meson theory of nuclear forces.

IV Neutron physics : Neutron production, slowing down power and moderating ratio, neutron detection.

V Nuclear reactions: Nuclear reactions and cross-sections, Resonance, Breit–Wigner dispersion formula for l=0 and higher values, compound nucleus, Coulomb excitation, nuclear kinematics and radioactive nuclear beams.

TUTORIALS : Relevant problems given in the books listed below:

Books:

1. Nuclear Physics : Irving Kaplan (Narosa), 2002.
2. Basic Ideas and Concepts in Nuclear Physics : K. Hyde (Institute of Physics) 2004.
3. Introduction to Nuclear Physics ; Herald Enge (Addison-Wesley) 1971.
4. Nuclei and Particles : E. Segre (W.A. Benjamin Inc), 1965.
5. Theory of Nuclear Structure : R.R. Roy and B.P. Nigam (New Age, New Delhi) 2005.
6. Nuclear physics: Experimental and Theoretical, H.S. Hans (New Academic Science) 2nd ed (2011).

PHY-MC13: PARTICLE PHYSICS - I

Max. Marks: 15+60= 75

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Introduction : Fermions and bosons, particles and antiparticles, quarks and leptons, interactions and fields in particle physics, classical and quantum pictures, Yukawa picture, types of interactions - electromagnetic, weak, strong and gravitational, units.

II Invariance Principles and Conservation Laws : Invariance in classical mechanics and in quantum mechanics, Parity, Pion parity, Charge conjugation, Positronium decay. Time reversal invariance, CPT theorem.

III Hadron-Hadron Interactions : Cross section and decay rates, Pion spin, Isospin, Two-nucleon system, Pion-nucleon system, Strangeness and Isospin, G-parity, Particle production at high energy.

IV Relativistic Kinematics and Phase Space : Introduction to relativistic kinematics, particle reactions, Lorentz invariant phase space, two-body and three-body phase space, recursion relation, effective mass, dalitz, K-3π-decay, τ-θ puzzle, Dalitz plots for dissimilar particles, Breit-Wigner resonance formula, Mandelstem variables.

V Static Quark Model of Hadrons : The Baryon decuplet, quark spin and color, baryon octet, quark-antiquark combination.

VI Electrodynamics and Chromo dynamics of Quarks: Hadron production in e^+e^- collisions, Elastic electron-proton scattering, Feynman rules for Chromo-dynamics, color factors, quark and antiquark, quark and quark, Asymptotic freedom.

VII Weak Interactions : Classification of weak interactions, Charged Leptonic Weak Interactions, Decay of the muon, Decay of the pion, Charged Weak Interactions of quarks, neutral weak interactions, helicity of neutrino, K-decay, CP violation in K- decay and its experimental determination.

VIII Cosmic rays, origin and composition, energy spectrum, acceleration and propagation of UHE ($>10^{14}$ eV) particles, Cosmic ray shower, Measurements of UHE cosmic rays on earth (GRAPES experiment).

TUTORIALS : Relevant problems given at the end of each chapter in the books listed below.

Books :

1. Introduction to High Energy Physics : D.H. Perkins (Cambridge University Press), 4th ed. 2000.
2. Elementary Particles : I.S. Hughes (Cambridge University Press), 3rd ed. 1991.
3. Introduction to Quarks and Partons : F.E. Close (Academic Press, London), 1979.
4. Introduction to Particle Physics : M.P. Khanna (Prentice Hall of India, New Delhi), 2004.

PHY-MC14: Physics Laboratory III

Max. Marks: 20+80=100

Note:

(i) Students are expected to perform at least 10 experiments in each semester. The experiments performed in first semester cannot be repeated in second Semester.

(ii) Each student will complete a project work and give seminar on one of the topics on Advances in Electronics during first year. Project work will consist of understanding, handling and repair of Audio-Video and communication Electronics Equipment.

(iii) The evaluation procedure for the Practical examination is given in the beginning of the syllabus.

List of Experiments :

1. To determine the g-factor of free electron using ESR.
2. To measure dielectric constant of barium titanate as function of temperature and frequency and hence study its phase transition.
3. To study structural and melting transition in KNo_3 using Differential Thermal Analyzer.
4. To study Martensite to Austenite phase transition in Shape memory alloy Nitinol.
5. To study Metal-Insulator transition in a thin film of strontium doped lanthanum mangenite
6. To study thermoluminescence of F-centres in alkali halide crystals.
7. To study Raman scattering in CCl_4 .
8. To study Zeeman effect by using Na lamp.
9. Determination of velocity of light using modulated Laser method
10. Hands on experience on X-ray diffractometer for studying (i) Crytal structure (ii) Phase identification and (iii) size of nanoparticles.
11. Experiments with microwave (Gunn diode): Young's double slit experiment, Michelson interferometer, Febry-Perot interferometer, Brewester angle, Bragg's law, refractive index of a prism.
12. To measure (i) dielectric constant of solid/liquid; (ii) Q of a cavity. Use of Klystron-based microwave generator.
13. To plot polar pattern and gain characteristics of Pyramidal horn antenna and parabolic dish for microwaves.
14. Scanning tunneling microscope – hardware and software familiarization, Atomic lattice image of graphite, Study of thin film and nanogrid .
15. Energy calibration of a gamma-ray spectrometer and determination of the energy resolution by using multi-channel analyzer.
16. To study time resolution of a gamma-gamma ray coincidence set-up.
17. To study anisotropy of gamma-ray cascade emission in ^{60}Ni (^{60}Co source) using a coincidence set-up.
18. Time calibration and determination of the time resolution of a coincidence set-up using a multi- channel analyzer.
19. To study calibration of a beta-ray spectrometer.
20. To study scattering of gamma rays from different elements.
21. To determine range of Alpha-particles in air at different pressure and energy loss in thin foils.

22. To determine strength of alpha particles using SSNTD.
23. To measure p(of a particle using emulsion track.
24. To study p-p interaction and find the cross-section of a reaction using a bubble chamber.
25. To study n-p interaction and find the cross-section using a bubble chamber.
26. To study k-d interaction and find its multiplicity and moments using a bubble chamber.
27. To study a ((event using emulsion track.
28. To design (i) Low pass filter (ii) High pass filter (iii) All-pass filter (iv) Band pass filter (v) Band-reject filter using 741 OPAMP.
29. To study of Switched-mode power supply.
30. To study Phase Locked Loop (PLL) – (i) adjust the free running frequency (ii) determination of lock range and capture range (iii) determine the dc output from Frequency modulated wave.
31. Measurement of (i) low resistance (ii) Mutual inductance using Lock- In-Amplifier
32. Frequency modulation using Varactor and Reactance modulator and Frequency demodulation using Quadrature detector and Phased Locked Loop detector.
33. Dynamics of non-linear systems – (i) Feigenbaum Circuit and (ii) Chua Circuit.
34. Computer controlled experiments and measurements (Phoenix kit and Python language) – Digital and analog measurements based experiments.
35. Control of devices and data logger using parallel port of PC – programming using Turbo C.
36. Programming of parallel port of PC using C-language and control of devices connected.
37. Microprocessor kit: (a) hardware familiarization
(b) programming for (i) addition and subtraction of numbers using direct and indirect addressing modes (ii) Handling of 16 bit numbers (iii) use of CALL and RETURN instructions and block data handling.
38. (a) Selection of port for I & O and generation of different waveforms (b) control of stepper motor.
39. Microcontroller kit: hardware familiarization of (Controller and universal programmer and programming for four digit seven segment multiplexed up-conter upto 9999.
40. (a) EEPROM based 8 to 3 encoder using microcontroller (b) interfacing with ADC (temperature sensor) and DAC (variable voltage source).

Project Work : Develop a new experiment or perform open-ended thorough investigations using the available set-up. Weightage of the project work equal to few experiments to be decided by the teachers.

FOURTH SEMESTER

PHY-MC15 NUCLEAR PHYSICS-II

Max. Marks: 20+80 = 100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

Review of Fermi gas model, liquid drop model and Nuclear fission

I Shell model : Coupling of angular momenta, C.G. & Racah coefficients, Wigner's 3j,6j and 9j symbols and properties, Extreme particle model with square-well & harmonic oscillator potentials, spin-orbit coupling, shell model predictions, static electromagnetic moments of nuclei, LS & jj coupling, seniority wave function, magnetic moment-Schmidt lines, Single particle model, Total spin 'J' for various configurations, electric quadrupole moment, configuration mixing, independent particle model, coefficient of fractional parentage, Two nucleon wavefunction, Matrix elements of one and two body operators, Correlation in nuclear matter.

II Collective model : Rotation-D matrices and properties, Collective modes of motion, nuclear vibrations, iso-scalar vibrations, Giant resonance, derivation of collective Hamiltonian and applications, Rotation and vibration of even-even nuclei, β and γ-vibrations, Rotational-vibrational coupling, odd-mass nuclei -coupling of particle to even-even core, Nilsson model, Rotational motion at high spin, Kinematic and dynamic moment of inertia, Routhian and alignment plots, backbending behaviour.

III Nuclear reactions : Review of Statistical model for compound nucleus, Review of optical Model. Direct reactions : Kinematics and theory of stripping, pick up and reverse reactions. Fusion-evaporation & transfer reactions and various models, Heavy-ion induced nuclear reactions and various phenomena at low, intermediate and high energies.

TUTORIALS : Relevant problems given at the end of each chapter in the books listed below.

Books :

1 Theory of Nuclear Structure : M.K. Pal (East-West Press, New Delhi) 1982.
2 Nuclear Physics : R.R. Roy and B.P. Nigam (New Age, New Delhi) 2005.
3 Basic Ideas and Concepts in Nuclear Physics by K. Hyde (Institute of Physics) 2004.
4 Elementary theory of Angular Momentum by M.E. Rose (Dover) 2011.
5 Quantum Mechanics, V.K.Thankappan (New Age Publications), 2012.

6 Concepts of Nuclear Physics by B.L. Cohen (Tata McGraw Hill), 2004.
7 Nuclear physics: Experimental and Theoretical, H.S. Hans (New Academic Science) 2^{nd} ed 2011.
8 Angular Momentum Techniques in Quantum mechanics, V. Debanathan (Kluwar Academic), 1999.
9 Introduction to Nuclear Reactions, C.A. Bertulani and P. Danielwicz (CRC Press) 2004.

PHY-MC16 PARTICLE PHYSICS – II

Max. Marks: 20+80 = 100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Review of fundamental particles and their interactions: Present day fundamental particles and their characteristics. Constituent and current quark masses. Generations and quark-lepton symmetry. Present picture of QED, QCD, weak interactions and gravitational interactions.

II Hadron symmetries: Introduction to continuous groups and O(3). Unitary symmetries: SU(2), SU(3), SU(6) and their simple applications.

III Quark model and its applications: Going from SU(3) to quark model. Valence quark contents of hadrons. Construction of hadron wave functions in terms of quarks. Simple calculations of hadronic properties in terms of quark wave functions.

IV Electromagnetic interactions: Form factors of nucleons. Charge radii of nucleons. Deep inelastic scattering, structure and scaling. Introduction to Parton Model.

V Weak interactions: Four fermion Fermi theory. Fermi and Gamow-Teller transitions. Dirac bilinear covariants. V─A theory. Intermediate Vector Boson Model. GIM Model.

VI Gauge Theories and Standard Model: Global gauge invariance and its consequences. Local gauge invariance-QED as an example. Local Non-Abelian gauge theories (Yang-Mills theory). QCD Lagrangian. Spontaneous Symmetry Breaking. Brief introduction to SM.

VII Recent Developments: Introduction to GUTs, Neutrino oscillations, Dark matter, Dark energy. Brief introduction to Neutrino Oscillations and Collider experiments.

TUTORIALS: Relevant problems given at the end of each chapter in the books listed.

Books :

1. An Introduction to High Energy Physics, D.H. Perkins (Cambridge Press) 4th ed. 2000.
2. An Introduction to Elementary Particles : D. Griffiths (Wiley-Vch), 2008.
3. Unitary Symmetry and Elementary Particles : Litchtenberg (Academic, NY) 1978.
4. Introduction to Quarks and Partons : F.E. Close (Academic Press, London), 1979.
5. Introduction to Particle Physics : M.P. Khanna (Prentice-Hall of India, New Delhi), 2004.

6. Gauge Theories of Weak, Strong and Electromagnetic Interactions: C. Quigg (Addison-Wesley), 1994.
7. Gauge Theory of Elementary Particle Physics: T.P Cheng, L.F. Li (Oxford University Press, Oxford), 2000.
8. Particle Physics and introduction to Field Theory: T.D. Lee, (Harwood Academic), 1988.

PHY-MC17 CONDENSED MATTER PHYSICS-II

Max. Marks: 20+80=100

Note:
(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.
(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Optical Properties : Macroscopic theory – generalized susceptibility, Kramers-Kronig relations, Brillouin scattering, Raman effect; interband transitions.

II Magnetism : Dia- and para-magnetism in materials, Pauli paramagnetism, Exchange interaction. Heisenberg Hamiltonian – mean field theory; Ferro-, ferri- and antiferro-magnetism; spin waves, Bloch T3/2 law.

III Principles of Magnetic Resonance : ESR and NMR – equations of motion, line width, motional narrowing, Knight shift.

IV Superconductivity: Experimental Survey; Basic phenomenology; BCS pairing mechanism and nature of BCS ground state; Flux quantization; Vortex state of a Type II superconductors; Tunneling Experiments; High T_c superconductors.

V Nano Structures in Solids: Nanostructures – short expose; Quasicrystals. Zero-, one, two and three dimensional nanostructures – Naorods, Nanowires Qquantum dots, Nanocomposites, Concept of Top Down and Bottom Up Fabrication approach, Self-assembly, Origin of plasmon band, Influence of various factors on the plasmon absorption. Quantum confinement in semiconductors – particle in a box like model for quantum dots .

TUTORIALS : Relevant problems given at the end of each chapter in the books listed below.

Books :

1. Introduction to Solid State Physics : C. Kittel (Wiley, New York) 2005.
2. Quantum Theory of Solids : C. Kittel (Wiley, New York) 1987.
3. Principles of the Theory of Solids : J. Ziman (Cambridge University Press) 1972.
4. Solid State Physics : H. Ibach and H. Luth (Springer, Berlin), 3rd. ed. 2002.
5. A Quantum Approach to Solids : P.L. Taylor (Prentice-Hall, Englewood Cliffs), 1970.

6. Intermediate Quantum Theory of Solids : A.O.E. Animalu (East-West Press, New Delhi), 1991.
7. Solid State Physics : Ashcroft and Mermin (Reinhert & Winston, Berlin), 1976.

*** DISCIPLINE SPECIFIC ELECTIVE (DSE) COURSES (Semesters III and IV)**

Choose any two DSE courses in semester III and IV. A DSE Course will be offered only if a minimum of 10 students opt for the same and depending of the Faculty available.

PHY-MDS1: CLASSICAL ELECTRODYNAMICS AND GENERAL THEORY OF RELATIVITY

Max. Marks : 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Special Theory of Relativity : Lorentz transformation as orthogonal transformation in 4-dimension, relativistic equation of motion, applications of energy momentum conservation, Disintegration of a particle, C.M. System and reaction thresholds.

II Covariant Formulation of Electrodynamics in Vacuum : Four vectors in Electrodynamics, 4-current density, 4-potential, covariant continuity equation, wave equation, covariance of Maxwell equations. Electromagnetic field tensor, transformation of EM fields. Invariants of the EM fields. Energy momentum tensor of the EM fields and the conservation laws. Lagrangian and Hamiltonian of a charged particle in an EM field.

III Radiation From Accelerated Charges : Lienard-Wiechert Potentials, Field of a charge in arbitrary motion and uniform motion, Radiated power from an accelerated charge at low velocities-Larmor-Power formula. Radiation from a charged particle with collinear velocity and acceleration. Radiation from a charged particle in a circular orbit, Radiation from an ultra-relativistic particle, Radiation reaction. Line-width and level shift of an oscillator.

IV Scattering : Thomson scattering, Rayleigh scattering, absorption of radiation by bound electron.

V General Theory of Relativity : Introduction of Arbitrary point transformation, Elements of general tensor and covariant differentiation, Motion of free particle in curvilinear coordinates : Variational Principle, Principle of equivalence, motion of mass point in gravitational field : Newtonian approximation, Basic tensor of gravitational field (Riemann curvature tensor, Bianchi identities, Ricci tensor), Einstein field equations and Poisson approximation, Electromagnetic field in Riemann space time.

Experimental tests: The Schwarzchild metric, precession of planetary orbits. Deflection of ray of light.

TUTORIALS : Relevant problems given at the end of each chapter in the listed books.

Books :

1. Classical Electrodynamics : S.P. Puri (Narosa Publishing House), 2011.
2. Classical Electrodynamics : J.D. Jackson (New Age, New Delhi), 2009.
3. Theory of Relativity : R.K. Patharia (Hindustan Pub., Delhi) 2nd ed., 1974.
4. General Relativity : I.R. Kenyon (Oxford Univ. Press) 2001.
5. Classical Electromagnetic Radiation : J.B. Marion and M.A. Heald (Saunders college Publishing House), 3rd ed. 1995.
6. Introduction to Electrodynamics : D.J. Griffiths (Prentice-Hall Learning), 2009.
7. An Introduction to General Relativity : S.K. Bose (Wiley Eastern Limited, New Delhi), 1980.
8. Principles of Cosmology and Gravitation: M. Berry (Overseas Press, New Delhi), 2005.

PHY-MDS2 EXPERIMENTAL TECHNIQUES IN NUCLEAR PHYSICS AND PARTICLE PHYSICS

Max. Marks: 20+80 = 100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Detection of radiations: Interaction of gamma-rays, electrons, heavy charged particles, neutrons, neutrinos and other particles with matter.

General properties of Radiation detectors, energy resolution, detection efficiency and dead time. Statistics and treatment of experimental data.

Gas-filled detectors, Proportional counters, space charge effects, energy resolution, time characteristics of signal pulse, position-sensitive proportional counters, Multiwire proportional chambers, Drift chamber, Time projection chamber.

Organic and inorganic scintillators and their characteristics, light collection and coupling to photomultiplier tubes and photodiodes, description of electron and gamma ray spectrum from detector, phoswich detectors, Cherenkov detector.

Semiconductor detectors, Ge and Si(Li) detectors, Charge production and collection processes, detector structures and fabrication aspects, semiconductor detectors in X- and gamma-ray spectroscopy, Pulse height spectrum, Compton-suppressed Ge detectors, Semiconductor detectors for charged particle spectroscopy and particle identification, Silicon strip detectors, Radiation damage.

Electromagnetic and Hadron calorimeters.

Motion of charged particles in magnetic field, Magnetic dipole and quadrupole lenses, beta ray spectrometer.

Detection of fast and slow neutrons - nuclear reactions for neutron detection. General Background and detector shielding.

II Electronics associated with detectors : Electronics for pulse signal processing, CR-$(RC)^n$ and delay-line pulse shaping, pole-zero cancellation, baseline shift and restoration, preamplifiers (voltage and charge-sensitive configurations), overload recovery and pileup, Linear amplifiers, single-channel analyzer, anolog-to-digital converters, multichannel analyzer.

Basic considerations in time measurements, Walk and jitter, Time pickoff methods, time-to-amplitude converters, Systems for fast timing, fast-slow coincidence, and particle identification, NIM and CAMAC instrumentation standards and data acquisition system.

III Experimental methods : Detector systems for heavy-ion reactions : Large gamma and charge particle detector arrays, multiplicity filters, electron spectrometer, heavy-ion reaction analyzers, nuclear lifetime measurements (DSAM and RDM techniques), production of radioactive ion beams.

Detector systems for high energy experiments : Collider physics (brief account), Particle Accelerators (brief account), Secondary beams, Beam transport, Modern Hybrid experiments- CMS and ALICE.

Tutorials: Relevant problems pertaining to the topics covered in the course.

Books :

1. Introduction to Experimental Particle Physics by Richard Fernow (Cambridge University Press), 2001.
2. Radiation detection and measurement by Glenn F. Knoll (Wiley), 2010.
3. Techniques in Nuclear and particle Experiments by W.R. Leo (Springer), 1994.
4. Detectors for particle radiation by Konrad Kleinknecht(Cambridge University P

PHY-MDS3 EXPPERIMENAL TECHNIQUES IN PHYSICS

Max. Marks: 20+80 = 100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

Unit-I

I. Revisit to Atomic and Molecular Physics:

Atomic Physics : Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS & JJ couplings.

Zeeman, Paschen-Bach & Stark effects.

Inner-shell ionization and vacancy decay mechanisms, Selection rules, X-ray spectra.

Lasers: Temporal and spatial coherence, Spontaneous and stimulated emission, line broadening mechanisms, rate equation, He-Ne laser, Nitrogen laser, CO_2 laser, Ruby laser, Holography.

Molecular Physics : Molecular spectra, symmetric structures, Frank-Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules.

II. Analytical techniques : (Brief account) Atomic Absorption and emission Spectrometers, UV-Vis Spectrometer, FTIR Spectrometer, Raman Spectrometer.

Electron spin resonance, Nuclear magnetic resonance.

TEM, AFM, STM, X-ray fluorescence, XRD.

III. Vacuum Techniques : Production and Measurements of vacuum**.**

Unit – II

IV. Detection of radiations: Interaction of gamma-rays, electrons, heavy charged particles, neutrons, neutrinos and other particles with matter.
Radiation detectors - energy resolution, detection efficiency and dead time. Statistics and treatment of experimental data.
Gas-filled detectors, Proportional counters, space charge effects, position-sensitive proportional counters.
Organic and inorganic scintillators and their characteristics, light collection and coupling to photomultiplier tubes and photodiodes, description of electron and gamma ray spectra from scintillation detector, Cherenkov detector.
Semiconductor detectors in X- and gamma-ray spectroscopy, Charge production and collection processes, Pulse height spectrum, Compton suppressed Ge detectors, Semiconductor detectors for charged particle spectroscopy. Detection of fast and slow neutrons - nuclear reactions for neutron detection. General Background and detector shielding. Beta ray spectrometer.

V. Electronics associated with detectors : Pulse height analysis - Electronics for pulse signal processing, Pulse shaping, pole-zero cancellation, preamplifiers (voltage and charge-sensitive configurations), Linear amplifiers, Single-channel analyser, multichannel analyzer.
Basic considerations in time measurements, Walk and jitter, Time pickoff methods, time-to-amplitude converters, Systems for fast timing, fast-slow coincidence set up.

VI. Experimental methods for nuclear and high energy experiments (Brief account) : Large gamma and charge particle detector arrays, multiplicity filters, electron spectrometer, heavy-ion reaction analysers, nuclear lifetime measurements (DSAM and RDM techniques). Mossbauer Spectroscopy. Collider physics and Particle Accelerators, Secondary beams, Modern Hybrid experiments- CMS and ALICE.

Tutorials: Relevant problems pertaining to the topics covered in the course.

Books :

1. Atomic and Molecular Spectra: Rajkumar (Kedarnath Ramnath Prakashan, Meerut).
2. Undergraduate Instrumental Analysis: James W. Robinson (Marcel Dekker, New York) (1970).
3. Fundamentals of Molecular spectroscopy: Banwell and McCash (Tata McGraw Hill) (1994).
4. Molecular Structure and Molecular Spectroscopy G. Aruldhas (PHI Learning) (2009)
5. Lasers and Non-linear Optics: B.B. Laud. (Wiley Eastern) (1991).
6. Vacuum Technology: A. Roth (North Holland) (1990).
7. Introduction to Experimental Particle Physics by Richard Fernow (Cambridge University Press), 2001.
8. Radiation detection and measurement by Glenn F. Knoll (Wiley), 2010.
9. Techniques in Nuclear and particle Experiments by W.R. Leo (Springer), 1994.
10. Detectors for particle radiation by Konrad Kleinknecht (Cambridge University Press), 1999.

PHY-MDS4 SPACE SCIENCES AND TECHNOLOGY

Max. Marks 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed

I Astronomy & Astrophysics: Stellar properties and associated astronomy; Interstellar medium; Galaxy structure and dynamics; Structure of star; Star formation and evolution; Red-giant stage, Supernovae, Black hole; Nucleosynthesis; Origin and the evolution of the Universe; Big-bang cosmology.

II Planetary Science: An introduction to the planets, satellites, asteroids, etc. and the associated planetary processes; Origin and the early evolution of the solar system; Formation & evolution of planets and satellites.

III Atmospheric Science: Physical and chemical characteristics of the Earth's atmosphere; Major regions of the atmosphere; Comparison with the atmosphere of other planets and satellites e.g., Venus, Mars, Titan; Evolution of planetary atmosphere; Sun-Earth interaction; Radiation balance; Concepts of climatic studies & global warming.

IV Space technology: Overview of the planetary missions by various space agencies e.g., NASA, ESA, ISRO, etc.; Science and technology related with the designing, launch, landing and orbit insertion of planetary spacecrafts/mission and satellites; Designing of planetary spacecrafts and missions; Elements of hyper-spectral imaging, SAR (Synthetic Aperture Radar), onboard optical, IR, UV, X-ray, γ-ray spectrometers and particle detectors.

Tutorials: Relevant problems pertaining to the topics covered in the course.

Books:

1. Physics of stellar evolution and cosmology: H.S. Goldberg and M.D. Scadron (Gordon and Breach), 1986.

2. Theoretical Astrophysics (Vol. I, II, III): T. Padmanabhan (Cambridge University Press), 2005.

3. Moons and Planets: W. K. Hartmann (Wadsworth Publishing Company), 1999.

4. Basics of Atmospheric science: A. Chandrasekhar (PHI Learning Private Limited), 2011.

5. Space Technology: J. A. Angelo (Greenwood Press), 2003.

PHY-MDS5 ASTROPHYSICS

Max. Marks: 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Introduction: Basic concepts of celestial sphere, Co-ordinate systems; Alt-azimuth, Equatorial, Right Ascension, Ecliptic, Basic stellar properties; Luminosity, apparent and absolute magnitude, photo visual and photographic magnitude system, estimation of distance using parallax method and Cepheid variables, stellar masses in binary system. Spectral classification of stars, Origin of emission and absorption spectra, Doppler effect and its applications, Mass-Luminosity relation; free electron scattering and bound-free scattering, HR diagram. Basic concepts of astronomical observations in γ-rays, X-rays, UV,
visible, infra-red, radio waves.

II Interstellar medium and molecular clouds: Structure of our galaxy, Globular clusters, velocity distribution of stars, origin of 21-cm radiation and interstellar gas, fine structure of Carbon, Origin of spiral arms and its basic features, Interstellar dust and theory of extinction of stellar light, molecules and molecular clouds, the galactic magnetic field, the active star forming molecular clouds.

III Stellar evolution and nucleosynthesis: Pre-main sequence collapse, origin of the solar system, Jean's criteria, Shedding excess of angular momentum and magnetic field, T Tauri phase, Quasi-hydrostatic equilibrium, Virial theorem, Radiative and convective heat transfer, the sun on the main sequence, rates of nuclear energy generation, the standard solar model, evolution of low, intermediate and high mass stars on HR diagram, late stage evolution of stars, red giant phase, white dwarf, supernova (type Ia, Ib/c, II), neutron star, black hole, stellar nucleosynthesis, hydrostatic and explosive nucleosynthesis, sprocess, r- process, the galactic chemical evolution.

IV Cosmology: Simple extragalactic observations, Olber's paradox, Hubble's constant and its implications, the steady state universe, Evolution of the Big Bang, hadron era, lepton era, primordial nucleosynthesis, the radiation era, the matter era, time evolution of the future universe.

Tutorials: Relevant problems pertaining to the topics covered in the course.

Books:

1. Physics of stellar evolution and cosmology: H.S. Goldberg and M.D. Scadron (Gordon and Breach), 1986.
2. Astronomy: Principles and Practice : A.E. Roy and D. Clarke (Adam Hilger), 2003.
3. Theoretical Astrophysics (Vol. I, II, III) : T. Padmanabhan (Cambridge University Press), 2005.

PHY-MDS6 ELECTRONICS-II

Max. Marks: 20+80 = 100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed..

I **Digital circuits :** Boolean algebra, de Morgans theorem, Karnaugh maps.
Data processing circuits : Multiplexers, Demultiplexers, Arithmetic building blocks, Encoders, Decoders, Parity generators, PLA.
Sequential circuits : Flip-Flops – RS, JK, D, clocked, preset and clear operation, race-around conditions in JK Flip-flops, master-slave JK flip-flops, Switch contact bounce circuit.
Shift registers, Asynchronous and Synchronous counters, Counter design and applications.
A/D Converters : Successive approximation, Counter-type, Dual slope, voltage to frequency and voltage to time conversion techniques, accuracy and resolution.
D/A converter using resistive network, accuracy and resolution.
Applications: Multiplexed displays, Frequency Counters, Time Measurement, Digital Voltmeters, ADC 0804

II **Digital logic families :** RTL, DTL, TTL, ECL, CMOS, MOS, Tri-state logic - switching and propagation delay, fan out and fan in, TTL-CMOS and CMOS-TTL interfaces.

III **Basic concepts of Integrated Circuits :** IC technology, Fabrication of monolithic IC's - epitaxial growth, diffusion of impurities, masking and etching; Active and Passive components, MSI, LSI and VLSI chips, FPGA.

IV **Microprocessor :** Buffer registers, Bus oraganised computers, SAP-I, Microprocessor (μP) 8085 Architecture, memory interfacing, interfacing I/O devices. Assembly language programming : Instruction classification, addressing modes, timing diagram, Data transfer, Logic and Branch operations- Programming examples.

V **Semiconductor Memories :** ROM, PROM and EPROM, RAM, Static and Dynamic Random Access Memories (SRAM and DRAM), content addressable memory, Other advanced memories.

TUTORIALS : Relevant problems given at the end of each chapter in the books listed below.

Books :

1. Digital Principles and Applications : Malvino and Leach (Tata McGraw Hill), 2010.
2. Microelectronics : Millman and Grabel (Tata McGraw Hill), 1999.
3. A text book of digital electronics, R.S. Sedha (S. Chand Publishers), 2004.
4. Integrated Electronics : Millman and Halkias (Tata McGraw Hill) 2010.
5. Semiconductor Devices : Physics and Technology : S.M. Sze (John Wiley), 2007.

6. Digital Computer Electronics : Albert P. Malvino, Jerald A Brown (Tata-McGraw Hill) 3rd ed.
7. Microprocessor Architecture, Programming and Applications with 8085 : R.S. Gaonkar (Prentice Hall) 2002.

PHY-MDS7: FIBRE OPTICS AND NON-LINEAR OPTICS

Max. Marks: 20+80 = 100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I. Optical fibre and its properties: Introduction, basic fibre construction, propagation of light, modes and the fibre, refractive index profile, types of fibre, dispersion, data rate and band width, attenuation, leaky modes, bending losses, cut-off wavelength, mode field diameter, other fibre types.

II. Fiber fabrication and cable design: Fibre fabrication, mass production of fiber, comparison of the processes, fiber drawing process, coatings, cable design requirements, typical cable design, testing.

III. Optics of anisotropic media: Introduction, the dielectric tensor, stored electromagnetic energy in anisotropic media, propagation of monochromatic plane waves in anisotropic media, directions of D for a given wave vector, angular relationships between D, E, H, k and Poynting vector S, the indicatrix, uniaxial crystals, index surfaces, other surfaces related to the uniaxial indicatrix, Huygenian constructions, retardation, biaxial crystals, intensity through polarizer/waveplate/ polarizer combinations.

IV. Electro-optic and acousto-otpic effects and modulation of light beams: Introduction to the electro-optic effects, linear electro-optic effect, quadratic electro-optic effects, longitudinal electro-optic modulation, transverse electrooptic modulation, electro-optic amplitude modulation, electro-optic phase modulation, high frequency wave guide, electro-optic modulator, strain optic tensor, calculation of LM for a logitudinal acoustic wave in isotropic medium, calculation of LM for a shear wave in lithium niobate, Raman-Nath diffraction, Raman-Nath acousto-optic modulator.

V. Non-linear optics/processes: Introduction, anharmonic potentials and nonlinear polarization, non-linear susceptibilities and mixing coefficients, parametric and other non-linear processes, macroscopic and microscopic susceptibilities.

TUTORIALS: Relevant problems pertaining to the topics covered in the course.

Books

1. The Elements of Fibre Optics: S.L.Wymer and Meardon (Regents/Prentice Hall), 1993.
2. Lasers and Electro-Optics: C.C. Davis (Cambridge University Press), 1996.
3. Optical Electronics : Gathak & Thyagarajan (Cambridge Univ. Press), 1989.
4. The Elements of Non-linear Optics: P.N. Butcher & D. Cotter (Cambridge University Press), 1991.

PHY-MDS8 INFORMATICS

Max. Marks: 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I **Introduction :** Computer hardware, software, programming languages, Fortran 77, classification of data, variables, dimension and data statement, input/output, format, branching, IF statements, DO statements, subprogrammes, operations with files.

II **Operating Systems :** Introduction to Unix/Linux and shell scripting, graphics and plotting, tools: internet, e-mail, etc. Conceptual framework of computer languages.

III **Introduction to C++ :** Basics of C++, Data types and operators, statements and control flow, functions and programme structure, classes in C++, strings, the preprocessor, pointers, C++ memory allocation, Input/output, subprogramme, recursion, file access.

IV **Object Oriented Programming :** Classes, objects, inheritence and encapsulation, interface and implementation, reuse and extension of classes, inheritence and polymorphism; analysis and design, notations for object – oriented analysis and design. Some applications using object oriented programming languages.

TUTORIALS : Solving problems pertaining to the topics covered in the course, using computers.

Books :

1. Fortran Programming : V. Rajaraman (Prentice-Hall of India, New Delhi), 2004.
2. Teach Yourself C++ : A. Stevens (BPB Pub., New Delhi), 2003.
3. Let us C++ : Y.P. Kanetkar (BPB Pub., New Delhi), 2008.
4. Object Oriented Systems Development using Unified Modeling Language : A Bahrami (McGraw-Hill, New York), 1999.

PHY-MDS9 NONLINEAR DYNAMICS

Max. Marks: 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I **Phenomenology of Chaos :** Linear and nonlinear systems, A nonlinear electrical system, Biological population growth model, Lorenz model; determinism, unpredictability and divergence of trajectories, Feigenbaum numbers and size scaling, self similarity, models and universality of chaos.

II **Dynamics in State Space:** State space, autonomous and nonautonomous systems, dissipative systems, one dimensional state space, Linearization near fixed points, two dimensional state space, dissipation and divergence theorem. Limit cycles and their stability, Bifurcation theory, Heuristics, Routes to chaos. Three-dimensional dynamical systems, fixed points and limit cycles in three dimensions, Lyapunov exponents and chaos. Three dimensional iterated maps, U-sequence.

III Hamiltonian System : Non-integrable systems, KAM theorem and period doubling, standard map. Applications of Hamiltonian Dynamics, chaos and stochasticity.

IV Quantifying Chaos : Time series, Lyapunov exponents. Invariant measure, Kolmogorov - Sinai entropy. Fractal dimension, Statistical mechanics and thermodynamic formalism.

V Quantum Chaos : Quantum Mechanical analogies of chaotic behaviour. Distribution of energy eigenvalue spacing, chaos and semi-classical approach to quantum mechanics.

TUTORIALS : Relevant problems pertaining to the topics covered in the course.

Books

1. Chaos and Non Linear Dynamics : R.C. Hilborn (Oxford Univ. Press), 2001.
2. Chaos in Dynamical Systems : E. Ott (Cambridge Univ. Press), 2002.
3. Applied Nonlinear Dynamics : A.H. Nayfeh and B. Balachandran (Wiley), 1995.
4. Chaos in Classical and Quantum Mechanics : M.C. Gutzwiller (Springer-Verlag), 1990.

PHY-MDS10 PARTICLE ACCELERATOR PHYSICS

Max. Marks: 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Charged Particle Dynamics : Particle motion in electric and magnetic fields, Beam transport system, Beam pulsing and bunching techniques, microbeams, Particle and ion sources, secondary beams, Measurement of beam parameters.

II Radiofrequency Accelerators : Linear accelerators - Resonance acceleration and phase stability, electron and proton Linacs. Circular accelerators- Cyclotron, Frequency Modulated Synchrocyclotron, AVF Cyclotron, Alternating-gradient accelerators.

III Electrostatic and Heavy Ion Accelerators : Van de Graaff voltage generator, Cockcroft-Walton voltage generator, insulating column, voltage measurement, Acceleration of heavy ions, Tandem electrostatic accelerator, Production of heavy negative ions, Pelletron and Tandetron, Cluster beams, Superconducting Heavy Ion Linear Accelerators.

IV Synchrotron Radiation Sources : Electromagnetic radiation from relativistic electron beams, Electron synchrotron, dipole magnet, multipole wiggler, noncoherent and coherent, Undulator, Characteristics of synchrotron radiation.

V Radioactive ion beams : Production of Radioactive ion beams, Polarized beams, Proton synchrotron, Colliding accelerators.

VI Applications : Use of accelerators for AMS and Ion-beam Analysis Techniques.

TUTORIALS : Relevant problems given in the books listed below.

Books :

1. Particle Accelerator Physics, Vol I and II, H.J. Wiedman, (Springer Verlag), 1998.
2. Particle Accelerators, M.S. Livingston and J.P. Blewel, (McGraw-Hill Book Press), 1962.
3. Nuclear Spectroscopy and Reactions Part-A, Ed. J. Cerny, (Academic Press), 1974.
4. Theory of Resonance Linear Accelerators by I.M. Kapchenkey, (Harwood Academic Publishers).

PHY-MDS11 PHYSICS OF NANOMATERIALS (Special paper)

Max. Marks: 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Introductory Aspects : Free electron theory and its features, Idea of band structure—metals, insulators and semiconductors. Density of state in one, two and three dimensional bands and its variation with energy, Effect of crystal size on density of states and band gap. Examples of nanomaterials.

II Preparation of Nanomaterials : Bottom up: Cluster beam evaporation, ion beam deposition, chemical bath deposition with capping techniques and Top down: Ball Milling.

III General Characterization Techniques : Determination of particle size, study of texture and microstructure, Increase in x-ray diffraction peaks of nanoparticles, shift in photo luminescence peaks, variation in Raman spectra of nanomaterials, photoemission microscopy, scanning force microscopy.

IV Quantum Dots : Electron confinement in infinitely deep square well, confinement in one and two-dimensional wells, idea of quantum well structure, Examples of quantum dots, spectroscopy of quantum dots.

V Other Nanomaterials : Properties and applications of carbon nanotubes and nanofibres, Nanosized metal particles, Nanostructured polymers, Nanostructured films and Nano structured semiconductors.

TUTORIALS : Relevant problems pertaining to the topics covered in the course.

Books

1. Nanotechnology - Molecularly Designed Materials : G.M. Chow & K.E. Gonsalves (American Chemical Society), 1996.
2. Nanotechnology Molecular Speculations on Global Abundance : B.C. Crandall (MIT Press), 1996.
3. Quantum Dot Heterostructures: D. Bimerg, M. Grundmann and N.N. Ledentsov (Wiley), 1998.
4. Nanoparticles and Nanostructured Films–Preparation, Characterization and Application : J.H. Fendler (Wiley), 1998.
5. Nanofabrication and Bio-system: H.C. Hoch, H.G. Craighead and L. Jelinski (Cambridge Univ. Press), 1996.
6. Physics of Semiconductor Nanostructures: K.P. Jain (Narosa), 1997.
7. Physics of Low-Dimension Semiconductors: J.H. Davies (Cambridge Univ. Press) 1998.

8. Advances in Solid State Physics (Vo.41) : B. Kramer (Ed.) (Springer), 2001.

PHY- MDS12 SCIENCE OF RENEWABLE ENERGY SOURCES

Max. Marks: 20+80 = 100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Introduction : Production and reserves of energy sources in the world and in India, need for alternatives, renewable energy sources.

II Solar Energy : Thermal applications, solar radiation outside the earth's atmosphere and at the earth's surface, fundamentals of photovoltaic energy conversion. Direct and indirect transition semi-conductors, interrelationship between absorption coefficients and band gap recombination of carriers.

Types of solar cells, p-n junction solar cell, Transport equation, current density, open circuit voltage and short circuit current, description and principle of working of single crystal, polycrystalline and amorphous silicon solar cells, conversion efficiency. Elementary ideas of Tandem solar cells, solid-liquid junction solar cells and semiconductor-electrolyte junction solar cells. Principles of photoelectrochemical solar cells. Applications.

III Hydrogen Energy : Environmental considerations, solar hydrogen through photo electrolysis and photocatalytic process, physics of material characteristics for production of solar hydrogen. Storage processes, solid state hydrogen storage materials, structural and electronic properties of storage materials, new storage modes, safety factors, use of hydrogen as fuel; use in vehicles and electric generation, fuel cells, hydride batteries.

IV Other sources : Nature of wind, classification and descriptions of wind machines, power coefficient, energy in the wind, wave energy, ocean thermal energy conversion (OTEC), system designs for OTEC.

TUTORIALS : Relevant problems on the topics covered in the course.

Books:

1. Solar Energy : S.P. Sukhatme (Tata McGraw-Hill, New Delhi), 2008.
2. Solar Cell Devices : Fonash (Academic Press, New York), 2010.
3. Fundamentals of Solar Cells, Photovoltaic Solar Energy : Fahrenbruch and Bube (Springer, Berlin), 1983.
4. Photoelectrochemical Solar Cells : Chandra (New Age, New Delhi).

PHY-MDS13 ADVANCED STATISTICAL MECHANICS (Special paper)

Max. Marks: 20+80=100

Note:

(i) The pattern of the question papers for the mid-term and end-semester examinations are given in the beginning of the syllabus.

(ii) The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

I Interacting Systems : Deviation of a real gas, Cluster expansion for a classical gas, Virial expansion of equation of state, Evaluation of virial coefficients, General remarks on cluster expansion; quantum mechanical ensemble theory, the density matrix, density matrix for a linear harmonic oscillator; cluster expansion for a quantum mechanical system. Bose condensation.

II Phase Transitions and Critical Phenomena : Phase transitions – General remarks on the problems of condensation, Dynamical model for phase transition—Ising and Heisenberg models, the lattice gas and binary alloy, Ising model in the Zeroth approximation, Matrix method for onedimensional Ising model. The critical indices, Law of Corresponding States,
thermodynamic inequalities, Landau's phenomenological theory; Scaling hypothesis.

III Brownian Motion : Spatial correlation in a fluid, Einstein-Smoluchowski theory, Langevin theory, The Fokker-Planck equation.

IV The Time Correlation Function Formalism : Concept of time correlation function, derivation of basic formulas of linear response theory, Time-Correlation function expressions for thermal transport coefficients and their applications. The Wiener - Khintchine theorem, the fluctuation dissipation theorem. The Onsagar relations.

TUTORIALS : Relevant problems given at the end of each chapter in books 1 and 2.

Books:

1. Statistical Mechanics : R.K. Pathria (Butterworth-Heinemann, Oxford), 3rd ed, 2011.
2. Statistical Mechanics : D.A. Mc Quarrie (Harper and Row), 2000.
3. Introduction to Modem Statistical Mechanics : D. Chandler (Oxford Univ. Press), 1987.
4. Statistical Mechanics : K. Huang (Wiley Eastern, Delhi), 1987.
5. Statistical Mechanics and Properties of Matter : ESR Gopal (Macmillan India, Delhi), 1988.

B. One of the following will be offered in each of semester IV. Allottment will be on merit of results of Semesters I and II: (teaching 9hrs)

15. PHY-MDS14 Physics Laboratory-IV
16. PHY-MDS15 (i) Project work (Nuclear Physics) Experimental
17. PHY-MDS15 (ii) Project work (Particle Physics) Experimental
18. PHY-MDS15 (iii) Project work (Condensed Matter Physics) Experimental
19. PHY-MDS15 (iv) Project work (Atomic and Molecular Physics) Experimental
20. PHY-MDS15 (iv) Project work Electronics) Experimental
21. PHY-MDS15 (v) Project work (Nuclear Physics) Theory
22. PHY-MDS15 (vi) Project work (Particle Physics) Theory
23. PHY-MDS15 (vii) Project work (Condensed Matter Physics) Theory
24. PHY-MDS15 (viii) Project work (Atomic and Molecular Physics) Theory
25. PHY-MDS15 (ix) Project work (Astrophysics) Theory
26. PHY-MDS15 (x) Project work (Non-linear Physics) Theory

PHY-MDS14 Physics Laboratory IV

Max. Marks: 20+80=100

Note:

(i) Students are expected to perform at least 10 experiments in each semester. The experiments performed in first semester cannot be repeated in second Semester.

(ii) Each student will complete a project work and give seminar on one of the topics on Advances in Electronics during first year. Project work will consist of understanding, handling and repair of Audio-Video and communication Electronics Equipment.

(iii) The evaluation procedure for the Practical examination is given in the beginning of the syllabus.

List of Experiments :

1. To determine the g-factor of free electron using ESR.
2. To measure dielectric constant of barium titanate as function of temperature and frequency and hence study its phase transition.
3. To study thermo luminescence of F-centres in alkali halide crystals.
4. To study Raman scattering in CCl_4 .
5. To study Zeeman effect by using Na lamp.
6. Determination of velocity of light using modulated Laser method
7. Hands on experience on X-ray diffractometer for studying (i) Crytal structure (ii) Phase identification and (iii) size of nanoparticles.
8. Experiments with microwave (Gunn diode): Young's double slit experiment, Michelson interferometer, Febry-Perot interferometer, Brewester angle, Bragg's law, refractive index of a prism.
9. To measure (i) dielectric constant of solid/liquid; (ii) Q of a cavity. Use of Klystron-based microwave generator.
10. To plot polar pattern and gain characteristics of Pyramidal horn antenna and parabolic dish for microwaves.
11. Scanning tunneling microscope – hardware and software familiarization, Atomic lattice image of graphite, Study of thin film and nanogrid .
12. Energy calibration of a gamma-ray spectrometer and determination of the energy resolution by using multi-channel analyzer.
13. To study time resolution of a gamma-gamma ray coincidence set-up.
14. To study anisotropy of gamma-ray cascade emission in ^{60}Ni (^{60}Co source) using a coincidence set-up.
15. Time calibration and determination of the time resolution of a coincidence set-up using a multi- channel analyzer.
16. To study calibration of a beta-ray spectrometer.
17. To study scattering of gamma rays from different elements.
18. To determine range of Alpha-particles in air at different pressure and energy loss in thin foils.
19. To determine strength of alpha particles using SSNTD.
20. To measure p(of a particle using emulsion track.
21. To study p-p interaction and find the cross-section of a reaction using a bubble chamber.
22. To study n-p interaction and find the cross-section using a bubble chamber.

23. To study k-d interaction and find its multiplicity and moments using a bubble chamber.
24. To study a ((event using emulsion track.
25. To design (i) Low pass filter (ii) High pass filter (iii) All-pass filter (iv) Band pass filter (v) Band-reject filter using 741 OPAMP.
26. To study of Switched-mode power supply.
27. To study Phase Locked Loop (PLL) – (i) adjust the free running frequency (ii) determination of lock range and capture range (iii) determine the dc output from Frequency modulated wave.
28. Frequency modulation using Varactor and Reactance modulator and Frequency demodulation using Quadrature detector and Phased Locked Loop detector.
29. Computer controlled experiments and measurements (Phoenix kit and Python language) – Digital and analog measurements based experiments.
30. Control of devices and data logger using parallel port of PC – programming using Turbo C.
31. Programming of parallel port of PC using C-language and control of devices connected.
32. Microprocessor kit: (a) hardware familiarization
    (b) programming for (i) addition and subtraction of numbers using direct and indirect addressing modes (ii) Handling of 16 bit numbers (iii) use of CALL and RETURN instructions and block data handling.
33. (a) Selection of port for I & O and generation of different waveforms (b) control of stepper motor.
34. Microcontroller kit: hardware familiarization of (Controller and universal programmer and programming for four digit seven segment multiplexed up-conter upto 9999.
35. (a) EEPROM based 8 to 3 encoder using microcontroller (b) interfacing with ADC (temperature sensor) and DAC (variable voltage source).

Project Work : Develop a new experiment or perform open-ended thorough investigations using the available set-up. Weightage of the project work equal to few experiments to be decided by the teachers.

PHY-MDS15 PROJECT WORK

Max. Marks: 20+80=100

The aim of project work in M.Sc.(H.S.) 4th semesters is to expose some of the students (20) to preliminaries and methodology of research and as such it may consist of review of some research papers, development of a laboratory experiment, fabrication of a device, working out some problem, participation in some ongoing research activity, analysis of data, etc. Project work can be in Experimental Physics or Theoretical Physics in the thrust as well as non-thrust research areas of the department.
A student opting for this course will be attached to one teacher of the department before the end of the 3rd semester. A report of about 30 pages about the work done in the project (typed on both the sides of the paper and properly bound) will be submitted by a date to be announced by the PGAPMEC. Assessment of the work done under the project will be carried out by a committee on the basis of effort put in the execution of the project, interest shown in learning the methodology, report prepared, grasp of the problem assigned and viva-voce/seminar, etc as per guidelines prepared by the PGAPMEC.

This load (equivalent to 2 hours per week) will be counted towards the normal teaching load of the teacher.

PHY-MDS15 Quantum Computations

Max. Marks: 20+80=100

Review of Mathematical Physics

1. Number systems: Decimal and binary numbers
2. Basic linear algebra: vector space, superposition, linear dependence, basis states, tensor sum, inner products, tensor products
3. Operator algebra: Basic operators, brackets and algebra, functions, identities, eigenvalue equations, representations
4. Basic group theory and algebra: SL (2, C), SO(n), SU(n), Lie algebra, permutation group
5. Fourier transforms: Discrete and fast Fourier transforms

Review of Quantum mechanics

1. Dirac bra-ket notation: State and operator representation, base kets and matrix representation
2. Superposition principle: superposition of states
3. Measurement collapse of wave-function
4. Unitary operations: Hermiticity, Pauli operators, infinitesimal operators
5. Stern-Gerlach experiment: collapse of states, weight redistribution
6. Density matrix and pure vs mixed ensembles: Properties of density matrix

Classical Computation

7. How many digits?
8. Logic gates: AND, OR, N OT, NOR, XOR, NAND, FAN
9. Classical circuits: flip-flop, half and full adders, counters
10. Encoders and decoders:

Quantum Computation

11. Quantum bits: Multiple qubits
12. Physics of a single qubit: Mathematical and geometrical representation.
13. Hadamard and other quantum gates.
14. EPR paradox
15. Quantum entanglement
16. Bell's Inequalities
17. Experimental test of Bell's inequalities: Aspect experiment.
18. Quantum circuits: Single qubit operations, universal quantum gates, measurement.
19. Quantum algorithms: DJ Algorithm, Grover's algorithm and Shor's algorithm.
20. Quantum noise and quantum operations: Environment and quantum operations. Examples of quantum noise and quantum operations.

Physical Implementation of Quantum Computers

21. Divincenzo’s criteria for constructing quantum computers.
22. Superconducting qubits: Qubits and gates of superconducting quantum systems
23. NMR quantum computing: Basic unit of information and gates.
24. Quantum optics: Photons as qubits, optical elements used as gates.
25. Ion traps: Qubits and basic gate implementation in an ion trap.

Reference:

1. George B. Arfken and Hans J. Weber, Mathematical Methods for Physicists
2. J. J. Sakurai: Modern Quantum Mechanics,
3. DJ Griffiths, Introduction to Quantum Mechanics
4. Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information
5. Dancing with QUBITS: Robert S. Sutor

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