# मोहनलाल सुखाड़िया विश्वविद्यालय, उदयपुर

# MOHANLAL SUKHADIA UNIVERSITY, UDAIPUR

## Curriculum Framework, General Rules and Syllabus of Physics

for

Two -Year Postgraduate (M.Sc.) Program in Physics

**(Program Code: PG410XX)**

As per the Choice Based Credit System (CBCS)

Designed in accordance with Learning Outcomes-Based Curriculum Framework (LOCF) of National Education Policy (NEP-2020)

The DCC and DSE/GEC courses of M.Sc. Physics of III Semester for Academic Year 2023-2025

(Effective from Academic Year 2024-25)

# General Provisions and Rules

1. **Duration of the Course**
The M.Sc. Physics program will be of four semesters duration under Choice based Credit system as per New Education Policy-2020, which will be conducted in two years.

2. **Eligibility**:
Candidates seeking admission to the first semester of M.Sc. (CBCS) Physics must have a B.Sc. degree with Physics as one of the optional subjects or as an honor's subject (Level 5.5 or equivalent) with minimum 48% marks from a UGC recognized University.

3. **Admissions**:
Admissions to the first semester of M.Sc. (Physics) will be made as per admission rules for M.Sc. (CBCS) as prescribed in information bulletin.

4. **Medium of Instruction**
The medium of instruction and examination shall be English.

5. **No. of Seats**
Total number of seats: As per information bulletin

6. **Curriculum and Syllabi**
M.Sc. (Physics) program is of two years (four semesters) as prescribed in course structure and framework approved by the academic council held on June 26, 2023. Course structure is prescribed in Table-I and syllabi are given in Table-II. The program will be governed by the Common Rules and Regulations of Master's degree program under CBCS following NEP-2020 approved by the Academic Council of the University.

7. **Examinations of Practical Papers**
End of semester (EoS) practical examination will be conducted by a board of examiners (one internal and one external). Internal examination (three hours test) will be conducted at the departmental level.

8. **Internal Examinations of Theory Papers**
**I**nternal examination (one hour test) of theory papers will be conducted at the departmental level.

9. **Exit and Lateral Entry Policy**
Exit and Lateral Entry Policy shall be as prescribed in course structure and framework approved by the academic council held on June 26, 2023.

10. **Choice of the DSE Courses**
The DSE courses listed in the program shall be offered depending upon the resources available in the department. A minimum ten students should opt for such a DSE paper.

# Table-I: Course structure

| Level | Sem | Course Type | Course Code | Course Title | Delivery Type | | | Total Hours | Credit | Internal Assessment | EoS Exam | M.M. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | L | T | P | | | | | | |
| 8 | I | DCC | PHY8000T | Mathematical Methods in Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY8001T | Classical Mechanics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY8002T | Quantum Mechanics-I | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY8003T | Electronics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY8004P | General Physics Lab | - | - | P | 120 | 4 | 20 | 80 | 100 | |
| | | | PHY8005P | Electronics Lab | - | - | P | 120 | 4 | 20 | 80 | 100 | |
| | II | DCC | PHY8006T | Computational Methods in Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY8007T | Electrodynamics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY8008T | Quantum Mechanics-II | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY8009P | Electronics Project and Microprocessor Lab | - | - | P | 120 | 4 | 20 | 80 | 100 | |
| | | | PHY8010P | Computational Physics Lab | - | - | P | 120 | 4 | 20 | 80 | 100 | |
| | | DSE | PHY8100T<br>PHY8101T<br>PHY8102T<br>PHY8103T<br>PHY8104T | Statistical Physics<br>Ionospheric Physics<br>Astronomy and Astrophysics<br>Atmospheric Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| 9 | III | DCC | PHY9011T | Atomic and Molecular Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY9012T | Solid State Physics | L | T | | 60 | 4 | 20 | 80 | 100 | |
| | | DSE | PHY9105T<br>PHY9106T<br>PHY9107T<br>PHY9108T<br>PHY9109T | Semiconductor Physics and Devices<br>Fundamentals of Nanoscience<br>Industrial Electronics<br>Condensed Matter Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | | PHY9110P<br>PHY9111P<br>PHY9112P<br>PHY9113P<br>PHY9114P | Semiconductor Physics Lab<br>Nanoscience Lab<br>Advanced Electronics Lab<br>Data Analysis Techniques in Experimental Physics | - | - | P | 120 | 4 | 20 | 80 | 100 | |
| | | GEC | PHY9115T | Radiation Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PHY9116T<br>PHY9117T<br>PHY9118T<br>PHY9119T | Fundamental Quantum Chemistry<br>General Theory of Relativity<br>Biophysics<br>Elements of Quantum Computing | | | | | | | | | |
| | | | PHY9120P<br>PHY9121P<br>PHY9122P<br>PHY9123P<br>PHY9124P | Radiation Physics Lab<br>Materials Characterization Lab | - | - | P | 120 | 4 | 20 | 80 | 100 | |
| | IV | DCC | PHY9013T | Nuclear and Particle Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | DSE | PHY9125T<br>PHY9126T<br>PHY9127T<br>PHY9128T<br>PHY9129T | Experimental Techniques in Physics<br>Plasma Physics<br>High Energy Physics<br>Solar Physics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | DSE | PHY9130T<br>PHY9131T<br>PHY9132T<br>PHY9133T<br>PHY9134T | Materials Science<br>Quantum Theory of Solids<br>Quantum Field Theory<br>Laser and Spectroscopy | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | DSE | PHY9135T<br>PHY9136T<br>PHY9137T<br>PHY9138T<br>PHY9139T | Microwave Electronics<br>Fiber Optics and Communication<br>Non-Linear Physics<br>Nanoelectronics | L | T | - | 60 | 4 | 20 | 80 | 100 | |
| | | DSE | PHY9140P<br>PHY9141P<br>PHY9142P<br>PHY9143P<br>PHY9144P | Modern Physics Lab<br>Materials Synthesis Lab | - | - | P | 120 | 4 | 20 | 80 | 100 | |
| | | DSE | PHY9145P<br>PHY9146P<br>PHY9147P<br>PHY9148P<br>PHY9149P | Microwave Electronics Lab<br>Simulations Lab | - | - | P | 120 | 4 | 20 | 80 | 100 | |

## Table-II: Course Contents

# M.Sc. III Sem. (Physics)

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9011T |
| **Title of the Course** | Atomic and Molecular Physics |
| **Qualification Level of the Course** | *NHEQF Level 6.5* |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Centric Compulsory (DCC) Course in Physics |
| **Delivery type of the Course** | Lecture and tutorial, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | B.Sc. or advanced level courses of Physics or Mathematics |
| **Co-requisites** | None |
| **Objectives of the course** | *The main objective is to teach the students the basics of atomic and molecular physics with quantum mechanical approach leading to their fundamental spectroscopies. This course will give description of origin of atomic spectra of one and two valence electron atoms and response to the applied electric and magnetic fields. Moreover, basic theories of the rotational, vibrational and electronic spectra of polyatomic molecules, instrumentation, principles and details of the molecular spectroscopic methods are elucidated in length.* |
| **Learning outcomes** | Students will be able to understand:<br>• Spectrum of Hydrogen atom, Spectra of alkali atoms, Spin orbit interaction, Fine structure in alkali Spectra, Equivalent and non-equivalent electrons.<br>• Normal and anomalous Zeeman Effect, Paschen back effect, Stark Effect, Two electron systems, LS and JJ coupling.<br>• Rotation spectra of molecules, Diatomic vibrating rotator,<br>• The interaction of rotation and vibration, Vibration of polyatomic molecules, Techniques and instrumentation of Microwave and IR Spectroscopies.<br>• Pure rotational Raman Spectra, Vibrational Raman Spectra, Polarization of light and Raman Effect.<br>• Structure determination from Raman, IR and microwave spectroscopies.<br>• Electronic spectra of diatomic and polyatomic molecules.<br>• Molecular Photoelectron Spectroscopy, NMR Spectroscopy, ESR spectroscopy. |

| Syllabus | |
|---|---|
| **UNIT-I** | Atomic orbital, Electromagnetic spectrum, Hydrogen atom spectrum, Fine structure of hydrogenic atoms, The Lamb shift and its determination, Hyperfine structure and isotopic shifts, Pauli's Principle, Equivalent and nonequivalent electrons, Spectra of alkali atoms, Alkali spectra and elementary ideas of quantum defects, Rydberg and Exotic atoms, Spin orbit interaction, Fine structure in alkali Spectra **(8+4=12 )** |
| **UNIT -II** | Normal Zeeman Effect, Anomalous Zeeman Effect, Paschen back effect, Stark Effect, Two electron systems, LS and JJ coupling, Interpretation of hyperfine structure: nuclear spin and nuclear 'g' factor, transition probabilities and line width, Doppler broadening, natural broadening, External effects: collision, asymmetry and stark broadening **(8+4=12 )** |
| **UNIT-III** | Rotational spectra of diatomic molecule: rigid rotator and non-rigid rotator, Rotation spectra of Polyatomic molecules, Techniques and instrumentation, Chemical analysis by Microwave spectroscopy, Diatomic vibrating rotator, The interaction of rotation and vibration, Vibration of polyatomic Molecules, I-R- Spectrometer **(8+4=12)** |
| **UNIT-IV** | Quantum theory of Raman Effect, Pure rotational Raman Spectra – linear molecules, symmetric and spherical top molecules, Vibrational Raman Spectra, Rotational fine structure, Polarization of light and Raman Effect, Structure determination from Raman and infra-red IR spectroscopy, Raman Spectrometer, Near IR Raman Spectroscopy, FT Raman Spectroscopy **(8+4=12)** |
| **UNIT-V** | Electronic Spectra of Diatomic molecules, The Born Oppenheimer Approximation, Rotational structure of electronic bands (Fine structure)-P, Q, R branches, Fortrat diagram, Franck -Condon principle, Electronic Spectra of poly atomic molecules, Molecular Photoelectron Spectroscopy, General Introduction – Resonance Spectroscopy, NMR Spectroscopy, Chemical shifts, ESR Spectroscopy **(8+4=12)** |
| Tutorials | Examples and problems from Text books will be listed in the Lecture schedule as Tutorials and assignments |
| **Text Books** | 1. Elementray Atomic Structure by G.K. Woodgate, Second Edition, Clarendon Press, Oxford (1980).<br>2. Fundamentals of Molecular Spectroscopy by Colin N. Banwell and Elaine M McCash, Third Edition, McGraw-Hill (1983),<br>3. Atomic Spectra and Atomic Structure by G. Herzberg, Dover Publications (2003)<br>4. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by R. M. Eisberg and R. Resnick, Wiley (1985).<br>5. Quantum Mechanics: A Modem Approach by Ashok Das and A.C. Melissinos, Gordon and Breach Science Publishers (1986).<br>6. Atomic Spectra by H. E. White, McGraw-Hill (1934).<br>7. Molecular Spectra and Molecular Structure by G. Herzberg, Van Nostrand (1950) |
| **Reference Books** | 1. Physics of Atoms and Molecules by B. H. Bransden and C. J. Jochain , 2nd Ed., Pearson Education (2003)<br>2. Basic atomic & Molecular Spectroscopy by J. M. Hollas, Royal Society of Chemistry (2002)<br>3. Atoms, Molecules and Photons by W. Demtroder, Springer (2006) |
| **Suggested E-resources** | 1. MIT open Course ware, Introduction to atomic physics, https://ocw.mit.edu/courses/8-422-atomic-and-optical-physics-ii-spring-2013/resources/lecture-1-introduction-to-atomic-physics/<br>2. MIT open Course ware, Small molecule spectroscopy and dynamics, https://ocw.mit.edu/courses/5-80-small-molecule-spectroscopy-and-dynamics-fall-2008/<br>3. MIT open Course ware, Atomic and Optical Physics I, https://ocw.mit.edu/courses/8-421-atomic-and-optical-physics-i-spring-2014/ |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9012T |
| **Title of the Course** | Solid State Physics |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Centric Compulsory (DCC) Course in Physics |
| **Delivery type of the Course** | Lecture and tutorial, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Mathematics |
| **Co-requisites** | None |
| **Objectives of the course** | • *To strengthen the concepts of Solid State Physics which are basic building block of the research associated to the modern cutting edge technology.*<br>• *To establish synergy between the undergraduate curriculum and thrust research areas catering present need of the society.*<br>• *To cover curriculum aspects to all the competitive examinations associated to civil services and research institutions entrance.*<br>• *To frame the curriculum in equivalence with the top academic institutions across the globe.*<br>• *To ensure contribution of the deliverables in main stream of development of the society, nation and world.* |
| **Learning outcomes** | • The target students stuff would be trained for curriculum associated to the Solid State Physics.<br>• Synergy would be established between the bridging curricula covered by the associated students stuff.<br>• The associated student stuff would compete in all the examinations associated to civil services and research institutions entrance.<br>• The student stuff would cover curriculum in equivalence with all the top institutions across the globe.<br>• The associated student stuff would contribute in main stream of development of the society, nation and world. |
| **Syllabus** | |

| | |
|---|---|
| **UNIT-I** | **Crystallinity and Forms of Solid**<br>Crystal classes and systems, periodic array of atoms, fundamental types of lattices, 2d and 3d lattices, index system for crystal planes, simple crystal structures, nonideal crystal structures. Elementary ideas of point defects, line defects, planar faults, surface and volume defects, lattice vacancies, interstitials, colour centers, F-centers.<br>Reciprocal lattice, diffraction of waves by crystals, scattered wave amplitude, structure factor, Brillouin zones. **(8+4=12)** |
| **UNIT -II** | **Lattice Dynamics**<br>Lattice vibrations, phonons, vibrations of crystals with monoatomic basis, two atoms per primitive basis, quantization of elastic waves, phonon momentum, inelastic scattering by phonons. Specific heat of solids, phonon heat capacity, anharmonic crystal interactions, thermal conductivity. **(8+4=12)** |
| **UNIT-III** | **Electrons in Solids**<br>Free electron theory- Fermi statistics, effect of temperature on the Fermi- Dirac distribution function, free electron gas in three dimensions, heat capacity of electron gas, electron motion in magnetic fields and Hall effect.<br>Number of orbitals in a band, energy bands in metals, insulators and semiconductors, tight binding approximations. **(8+4=12)** |
| **UNIT-IV** | Idea of reduced and periodic zones, construction of Fermi surfaces, electron orbits, hole orbits, open orbits, de Haas van Alfen effect for Fermi surface (no derivation). **(4+2=6)**<br>**Superconductivity:** Superconductivity, Meissner effect, type-I and type-II superconductors, BCS theory of superconductors, Josephson junctions. **(4+2=6)** |
| **UNIT-V** | **Magnetic Phenomena in Solids**<br>Langevin diamagnetism equation, quantum theory of diamagnetism of mononuclear systems, paramagnetism, quantum theory of paramagnetism, Hund's rules. Ferromagnetic order, magnons, neutron magnetic scattering, ferromagnetic order, Antiferromagnetic order, Ferromagnetic domains, single domain particle. **(8+4=12)** |
| Tutorials | Examples and problems from Text books will be listed in the Lecture schedule as Tutorials and assignments |
| **Text Books** | 1. Introduction to Solid State Physics, 7th Edition, C, Kittel, Wiley, 1996<br>2. Introduction to Solid State Physics, 8th Edition, C, Kittel, Wiley, 2005<br>3. Solid State Physics, C. M. Kachhava, Tata McGraw-Hill, 1990<br>4. Solid State Physics, A.J. Dekker, Prentice-Hall, 1957 |
| **Reference Books** | 1. Solid State Physics, An Introduction to Theory, J.S. Gaslin, Elsevier, 2019.<br>2. Solid State Physics, 3rd Edition, V.K. Jain, Springer, 2022<br>3. Solid-State Physics, Introduction to the Theory, 3rd Edition, J.D. Patterson and B.C. Bailey, Springer, 2018\<br>4. Solid State Physics, N.W. Ashcroft and N. David Mermin Cengage learning , New Delhi, 1976 |
| **Suggested E-resources** | 1. https://teachmint.storage.googleapis.com/public/748762270/StudyMaterial/c031dee9-7360-43e8-94ef-f26ca036ed0f.pdf<br>2. https://www.sciencedirect.com/book/9780128171035/solid-state-physics<br>3. https://link.springer.com/book/10.1007/978-3-319-75322-5 |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| Third Semester | |
| Subject-Physics | |
| **Code of the Course** | PHY9105T |
| **Title of the Course** | Semiconductor Physics and Devices |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DCC) Course in Physics |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Electronics. |
| **Co-requisites** | None |
| **Objectives of the course** | *The course focuses on physics of semiconductors and various types of devices based on diverse types of semiconductors with emphasis on the Physics behind the working of such devices.* |
| **Learning outcomes** | The students would be able to understand the properties of semiconductors along with their devices:<br>• Charge carriers in semiconductors, dopant and energy levels, extrinsic semiconductors, charge neutrality and position of Fermi levels, carrier drift and diffusion<br>• Characteristics of excess carriers, Ambipolar transport and quasi-Fermi energy levels, Excess carrier lifetime.<br>• Surface effects, basics of p-n junction, built-in potential barrier, electric field and space charge width, junction capacitance.<br>• Metal-semiconductor junction, semiconductor-semiconductor junction,<br>• The Physics of BJT and the FET, Photo-detectors, Light emitting diodes (LEDs), Laser diodes.<br>• Photovoltaic cells, and its characteristics, detailed balance, photo-current, device current, limiting efficiency, effect of band gap and spectrum on efficiency, depletion approximation and calculation of carrier and carrier densities, general solution for J (V),<br>• The p-n junction in dark and under illumination, effects of parasitic resistance, irradiation, temperature on p-n junction characteristics. |
| **Syllabus** | |

| | |
|---|---|
| **UNIT -I** | Semiconductor Concepts and Energy Bands; energy band diagram, semiconductor statistics, extrinsic semiconductors, compensation doping and degenerate and non-degenerate semiconductors, Direct and indirect band gap semiconductors **(6+3=9)**<br>Carrier Transport Phenomena: Carrier drift and diffusion. Graded impurity distribution **(2+1=3)** |
| **UNIT-II** | Non-equilibrium excess carriers in semiconductors: Carrier generation and recombination, Characteristics of excess carriers, Ambipolar transport, Quasi-Fermi energy levels, Excess carrier lifetime; Shockley-Read-Hall theory of recombination,<br>pn Junction Principles; open circuit, forward and reversed bias, Depletion layer capacitances Recombination lifetime<br>Metal-semiconductor junctions; Ohmic and non-Ohmic contacts **(8+4=12)** |
| **UNIT-III** | Bipolar Transistors: Bipolar transistor action and minority carrier distribution **(3+1=4)**<br>Field Effect Transistors: JFET; concept and characterization, MOSFET; two terminal MOS structure, energy band diagrams, depletion layer thickness and work function differences **(3+2=5)**<br>Light-Emitting Diodes: Principles and device structure, Homojunction and Heterostructure LEDs, LED characteristics **(2+1=3)** |
| **UNIT-IV** | Principle of the Laser diode, Heterostructure laser diodes, Elementary laser diode characteristics, Steady state semiconductor rate equations, Quantum well devices **(4+2=6)**<br>Photodetectors: Principle of the pn Junction Photodiode, Quantum efficiency and responsivity, pin Photodiode, Avalanche photodiode, Phototransistors, Photoconductive detectors and Photoconductive gain **(4+2=6)** |
| **UNIT-V** | Photovoltaic Devices: Solar energy spectrum, Photovoltaic device principle, Photovoltaic I-V characteristics; photocurrent and quantum efficiency, dark current, open circuit voltage, short circuit current, Fill factor and efficiency, Effect on p-n junction characteristics; irradiation, temperature, band gap and parasitic resistance, Depletion approximation, Calculation of carrier and carrier densities, General solution for J (V), p-n junction in dark and under illumination (8+4=12) |
| **Tutorials** | Examples and problems from Text books will be listed in the Lecture schedule as Tutorials and assignments |
| **Text Books** | 1. S. O. Kasap; Optoelectronics and Photonics: Principles and Practices, Pearson 2009<br>2. Donald A. Neamen and Dhrubes Biswas; Semiconductor Physics and Devices, 4th edition, McGraw Hill, 2003.<br>3. Jenny Nelson; The Physics of Solar Cells, 1st edition, Imperial College press, 2003. |
| **Reference books** | 1. S.M. Sze; Semiconductor Device Physics and Technology, John Wiley and Sons, 2002.<br>2. Ben. G. Streetman and Sanjay K. Banerjee, Solid Sate Electronics Devices, 7th edition, PHI, 2014.<br>3. T. Markvart and L. Castaner; Solar Cells: Materials, Manufacture and Operations, Elsevier, 2005. |
| **Suggested E-resources** | 1. *https://archive.nptel.ac.in/courses/108/108/108108122/*<br>2. *https://onlinecourses.nptel.ac.in/noc21_ee80/preview*<br>3. *https://ocw.mit.edu/courses/6-772-compound-semiconductor-devices-spring-2003/pages/lecture-notes/* |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9106T |
| **Title of the Course** | Fundamentals of Nanoscience |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DCC) Course in Physics |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics and Chemistry. |
| **Co-requisites** | None |
| **Objectives of the course** | *This course gives an overview of a currently important field in Physics including basic theories/devices and characterization techniques.* |
| **Learning outcomes** | The students would be able to understand Nanoscience, synthesis of nanomaterials and their characterization:<br>• Classifications of nanostructured materials, effect size on properties.<br>• Bottom-up synthesis and top-down approach for synthesis of nanomaterials.<br>• Introduction to Lithography systems and processes.<br>• Clean rooms: specifications and design, services and facilities required, sample cleaning, chemical purification, chemical and biological contamination, safety issues, flammable and toxic hazards, biohazards.<br>• X-ray diffraction technique, scanning electron microscopy, transmission electron microscopy, surface analysis techniques |
| **Syllabus** | |
| **UNIT-I** | Introduction: Nanoscale Science and Technology - Implications for Physics, Chemistry, Biology and Engineering - Classifications of nanostructured materials - nano particles - quantum dots, Nanowires – ultra – thinfilms - multilayered materials. Length Scales involved and effect on properties: Mechanical, Electronic, Optical, Magnetic and Thermal properties. Introduction to properties and motivation for study (qualitative only). **(8+4=12)** |

| | |
|---|---|
| **UNIT -II** | Preparation Methods :Bottom-up Synthesis -Top-down Approach: Precipitation, Mechanical Milling, Colloidal routes, Self-assembly, Vapour phase deposition, MOCVD, Sputtering, Evaporation, Molecular Beam Epitaxy, Atomic Layer Epitaxy, MOMBE. **(8+4=12)** |
| **UNIT-III** | Patterning and Lithography for Nanoscale Devices: Introduction to optical/UV electron beam and X-ray Lithography systems and processes, Wet etching, dry (Plasma /reactive ion) etching, Etch resists-dip pen lithography **(8+4=12)** |
| **UNIT-IV** | Preparation Environments: Clean rooms: specifications and design, air and water purity, requirements for particular processes, Vibration free environments: Services and facilities required. Working practices, sample cleaning, Chemical purification, chemical and biological contamination, Safety issues, flammable and toxic hazards, biohazards. **(8+4=12)** |
| **UNIT-V** | Characterization Techniques: X-ray diffraction technique, Scanning Electron Microscopy - environmental techniques, Transmission Electron Microscopy including high-resolution imaging, Surface Analysis techniques - AFM, SPM, STM, SNOM, ESCA, SIMS - Nanoindentation. **(8+4=12)** |
| **.Tutorials** | Examples and problems from Text books will be listed in the Lecture schedule as Tutorials and assignments |
| **Text Books** | 1. A.S. Edelstein and R.C. Cammearata, eds., Nanomaterials: Synthesis, Properties and Applications, (Institute of Physics Publishing, Bristol and Philadelphia, 1996)<br>2. N John Dinardo, Nanoscale charecterisation of surfaces & Interfaces, Second edition, Weinheim Cambridge, Wiley-VCH, 2000<br>3. Sulabha K. Kulkarni, Nanotechnology: Principles and Practices, 3$^{rd}$ edition, Springer<br>4. Charles P. Poole Jr. and Frank J. Owens, Introduction to Nanotechnology, John Wiley &. Sons<br>5. Guozhong Cao. Nanostructures And Nanomaterials: Synthesis, Properties And Applications, Imperial College Press |
| **Reference Books** | 1. G Timp (Editor), Nanotechnology, AIP press/Springer, 1999<br>2. Akhlesh Lakhtakia (Editor) The Hand Book of Nano Technology, "Nanometer Structure", Theory, Modeling and Simulations. Prentice-Hall of India (P) Ltd, New Delhi, 2007. |
| **Suggested E-resources** | 1. https://web.pdx.edu/~pmoeck/phy381/intro-nanotech.pdf<br>2. https://onlinecourses.swayam2.ac.in/cec24_cy03/preview<br>3. https://ocw.mit.edu/courses/2-57-nano-to-macro-transport-processes-spring-2012/resources/lecture-1-intro-to-nanotechnology-nanoscale-transport-phenomena/<br>4. https://serc.carleton.edu/msu_nanotech/nano_intro.html |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9107T |
| **Title of the Course** | Industrial Electronics |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DSE) Course in Physics |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Electronics |
| **Co-requisites** | None |
| **Objectives of the course** | *This course is designed to understand the importance of power electronics and operation of power devices.* |
| **Learning outcomes** | The students would be able to understand and elaborate the functioning of industrial devices such as:<br>• Power diodes, Power transistors, electronic timers, counters, voltage regulators, UPS etc. |
| **Syllabus** | |
| **UNIT-I** | **Power Devices**: Power diodes, Power transistors, Power MOSFETs, SCR, TRIAC, GTO, IGBT, MCT, Protection of power devices. **(8+4=12)** |
| **UNIT -II** | **Converters**: Introduction to half wave, full wave and bridge rectifiers – Single phase and three phase, Half controlled and fully controlled converters, Dual converters, Introduction to cyclo-converters and ac-controllers. **(8+4=12)** |
| **UNIT-III** | **Inverter and Chopper**: Voltage, current and load commutation, Voltage Source Inverter (VSI), Series and Parallel inverter, Bridge inverters – Single and three phase, Voltage control using PWM, Current Source Inverter (CSI), Choppers: Step-up and step-down choppers, Chopper classification: Class A, B, C, D, E and AC choppers. **(8+4=12)** |

| | |
|---|---|
| **UNIT-IV** | **DC and AC Drives**: Steady state characteristic of dc motors, Control of DC motor using converters and choppers, Regenerative and dynamic braking, Closed loop control scheme, Speed-torque characteristic of induction motor, Static stator voltage control, V/f control, Static rotor resistance control, Slip power recovery scheme, self-control of synchronous motor. **(8+4=12)** |
| **UNIT-V** | **Applications**: Electronic timers, Digital counters, Voltage regulators, Online and offline UPS, Switched mode power supply, Principle and application of induction and dielectric heating. **(8+4=12)** |
| **Tutorials** | Examples and problems from standard books will be listed in the Lecture schedule as Tutorials and assignments. |
| **Text Books** | 1. G. K. Mithal, "Industrial Electronics", Khanna Publishers, Delhi, 2000.<br>2. Paul B. Zbar, "Industrial Electronics", Tata McGraw Hill, New Delhi, 1994. |
| **Reference Books** | 1. M. H. Rashid, "Power Electronics Circuits, Devices and Application", PHI, 3rd edition, 2004.<br>2. G. M. Chute and R. D. Chute, "Electronics in Industry", McGraw Hill Ltd, Tokyo, 1995.<br>3. F. D. Petruzulla, "Industrial Electronics", McGraw Hill, Singapore, 1996. |
| **Suggested E-resources** | 1. Freely available Lecture Notes by the Eminent Teachers and Instrument Manuals available on www.google.com |

| M.Sc. (Two Year Degree Program) | |
| --- | --- |
| Third Semester | |
| Subject-Physics | |
| **Code of the Course** | PHY9108T |
| **Title of the Course** | Condensed Matter Physics |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DCC) Course in Physics |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Electronics. |
| **Co-requisites** | None |
| **Objectives of the course** | *This course deals with a few properties of the condensed matter, it covers, the elastic, dielectric and magnetic properties of solids in particular. Theoretical foundation of the collective states and quasiparticles is also laid down. The defects, imperfections and dislocations in crystals are also illustrated.* |
| **Learning outcomes** | The students would be able to understand :<br>• Binding in crystals and theory of Elastic properties.<br>• Types, properties and theory to deal with Defects, dislocations and imperfections in crystals<br>• Basic theory of dielectric properties and optical response of solids and get exposure to experimental techniques to measure optical properties.<br>• Theory and properties of Ferro and antiferromagnetic materials.<br>• Theory of quasiparticles to explain optical and magnetic properties. |
| **Syllabus** | |
| **UNIT-I** | **Crystal Binding and Elastic Constants:**<br>Crystals of inert gases, Ionic and Covalent crystals, Analysis of Elastic strains, Elastics and stiffness constants of cubic crystals, Elastic energy density, Elastic waves in cubic crystals, Van der Waal interaction **(6+3=9)** |

| | |
|---|---|
| **UNIT -II** | **Point Defects and Dislocations :**<br>Imperfections- Types and classifications, Point Defects- Lattice vacancies and diffusion, Color centres-F centres, other centres in Alkali Halides, Schottky defects, Frenkel defects, Disordered crystals, Line defects-Dislocation types and theory **(4+2=6)**<br>Dislocations- Shear strength of single crystals, Slip, Burger vectors, Stress field dislocations, Grain boundaries, dislocation densities, Strength of alloys, Dislocation and crystal growth, Whiskers, Hardness **(4+2=6)**<br>Hume-Rothery rules, Order-disorder transition,, Kondo effect. **(2+1=3)** |
| **UNIT-III** | **Dielectric Properties of Solids:**<br>Macroscopic electric field, Local field at an atom, Dielectric constant and polarizability, Clausius-Mossotti relation, Structural phase transitions, Ferroelectric crystals and classifications, Displacive transitions **(5+3=8)**<br>Landau theory of phase transition, Antiferroelectricity and Ferroelectric domains, Piezoelectricity **(3+1=4).** |
| **UNIT-IV** | **Dielectric Properties of Electron Gas & Optical Processes:**<br>Dielectric function of electron gas, Plasmons, Polaritons, Electron-electron interaction, Electron-phonon interaction. **(3+1=4)**<br>Optical reflectance-KK Relations, interband transitions; Excitons-Frenkel, Mott-Wannier and condensation in Electron-Hole drops, Raman effect in crystals, Energy loss of Fast electrons in solids **(3+2=5)**<br>Optical processes: Absorption process, Photoconductivity, Luminescence. **(2+1=3)** |
| **UNIT-V** | **Ferro and Anti-ferromagnetism:**<br>Ferromagnets-Curie point and exchange Integral, Curie-Weiss law, Temperature dependence of saturation magnetization **(3+1=4)**<br>Magnons- Magnon dispersion in Ferro and antiferromagnets, Neel Temperature Ferrimagnetic order and susceptibility, Domains-Anisotropy energy, Bloch Wall, and origin of domains, Hysteresis, Geomagnetism and biomagnetism, Nuclear magnetic resonance **(5+3=8)** |
| **.Tutorials** | Some of the problems in the text and reference books. |
| **Text Books** | 1. Introduction to Solid State Physics, 8$^{th}$ Edn., C. Kittel, Wiley India Ltd (2004).<br>2. Solid State Physics, A.J. Dekker, MaccMillan Press Ltd, Prentice-Hall Edition, London (1981).<br>3. Introduction to Solids, Leonid V. Azaroff, Tata McGraw Hill (2004). |
| **Reference Books** | 1. Elementary Solid State Physics, 1/e M. Ali Omar, Pearson India (1999).<br>2. Solid-state Physics-An Introduction to Principles of Materials Science, H. Ibach and H Luth, Springer (2009).<br>3. Solid State Physics, Rita John, Tata McGraw Hill (2014).<br>4. Solid State Physics by M A Wahab, Narosa Publishing House, New Delhi (2016). |
| **Suggested E-resources** | 1. https://youtu.be/_Ckh-60B6LY?si=0LfmGLjOI2H_JfUW nptel hrd series of lectures<br>2. https://youtube.com/playlist?list=PLd9hKAUC3AZuo7is-aN45pmfDwJHOqKAj&si=jluGphD8mQhWW0-pQ series of lectures by Omar |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Second Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9110P |
| **Title of the Course** | Semiconductor Physics Lab |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DSE) Course in Physics |
| **Delivery type of the Course** | Practicum 80+40=120. The 80 hrs for the hands on experiments, observations and record of the data, 20 hours for the experiment, instruments demonstration, lab practices and 20 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Electronics |
| **Co-requisites** | None |
| **Objectives of the course** | *Objectives are to enable the students to understand the characterization of various semiconducting devices. Students are exposed to the laboratory practices and practicals to measure electrical properties of semiconducting devices* |
| **Learning outcomes** | The students would be able to study the:<br>• Characteristics of photo-diode, photo transistor, solar cell, LDR, LED and Laser diode.<br>• Bending loss in multimode fibers<br>• Beam profile of laser diode and LED |
| **Syllabus** | |
| | **The student has to perform a number of experiments from the following list.**<br>1. To study the characteristics of photo transistor<br>2. To study the characteristics of photo diode<br>3. To study the characteristics of light dependent resistor (LDR)<br>4. To study the characteristics of solar cell<br>5. To study the characteristics of light emitting diode (LED) |

| | |
|---|---|
| | 6. To study the characteristics of opto–coupler<br>7. Numerical aperture measurement semiconductor laser diode<br>8. Determination of bending loss in multi-mode fibers<br>9. Polarization of light and verification of Malus law<br>10. Determination of refractive index of transparent material by finding Brewster's angle<br>11. To study the laser beam profile of laser diode<br><br>**Any other relevant experiment set by the faculty may also be included.** |
| **Text Book** | 1. Kate Timberlake, Optoelectronics: A Practical Approach, Murphy & Moore<br>2. James M. Fiore, Semiconductor Devices: Theory and Application, Laboratory Manual Laboratory,<br>3. Lab manuals |
| **Reference book** | 1. S. O. Kasap; Optoelectronics and Photonics: Principles and Practices, Pearson 2009<br>2. Donald A. Neamen and Dhrubes Biswas; Semiconductor Physics and Devices, 4th edition, McGraw Hill, 2003.<br>3. Jenny Nelson; The Physics of Solar Cells, 1st edition, Imperial College press, 2003 |
| **E-resources/Virtual Labs** | |
| **EoSE** | The duration of the examination shall be Five hours wherein the student has to perform allotted experiment.<br>The distribution of marks is as follows:<br>1 Experimental work: 50<br>(Circuit diagram- 10, Formula(e)-5, Observations-20, Calculations-5, Result(s)-5, Precautions-5).<br>2. Viva Voce : 20<br>3. Evaluation of the record book of experiments performed in the semester: 10 |

| Third Semester | |
|---|---|
| **Subject-Physics** | |
| **Code of the Course** | PHY9111P |
| **Title of the Course** | Nanoscience Lab |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DSE) Course in Physics |
| **Delivery type of the Course** | Practicum 80+40=120. The 80 hrs for the hands on experiments, observations and record of the data, 20 hours for the experiment, instruments demonstration, lab practices and 20 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Chemistry |
| **Co-requisites** | None |
| **Objectives of the course** | *Objectives are to enable the students to understand about types of nanomaterials, their synthesis methods and experimental techniques used for characterization. Students can grasp the sense underlying chemical and physical routes and see the effect on the synthesized nanomaterials.* |
| **Learning outcomes** | The students would be able to:<br>• Synthesize nanoparticles using several methods<br>• Characterize nanomaterials using various experimental tools.<br>• Understand the concept underlying top-bottom and bottom-up approaches<br>• Understand and compare various characterization techniques.<br>• Understand the errors involved in synthesis and characterization of nanomaterials. |
| **Syllabus** | |

| | |
|---|---|
| | **The student has to perform a number of experiments from the following list.**<br>1. Synthesis of nanomaterial sample using Sol-gel technique.<br>2. Synthesis of polycrystalline sample using solid state reaction technique<br>3. Synthesis of nanomaterials using microwave technique.<br>4. Synthesis of nanomaterial using hydrothermal method<br>5. Synthesis of nanomaterial using Co-precipitation method<br>6. Preparation of nanoparticles by using Ball milling<br>7. Synthesis of nanomaterial using Sono-chemical route<br>8. Preparation of silver nanoparticles and its PL measurement<br>9. Synthesis of Gold Nanoparticles by chemical and biogenic methods and characterization<br>10. Synthesis Zinc selenide quantum dot and its band gap determination.<br>11. Synthesis of Iron Oxide Nanoparticle and its<br>12. Synthesis of Nickel metal nanoparticle by urea decomposition method<br>13. Synthesis of Zinc Oxide nanoparticle and its PL measurement<br>14. Synthesis of CdS nanomaterial using chemical method and its band gap determination.<br>15. Synthesis of ZnS nanomaterial using chemical method and its PL measurement<br>16. Synthesis of PbS nanomaterial using chemical method and its band gap determination<br><br>**Any other relevant experiment set by the faculty may also be included.** |
| **Text Book** | 1. Sulabha K. Kulkarni, Nanotechnology: Principles and Practices, 3rd edition, Springer<br>2. Guozhong Cao. Nanostructures And Nanomaterials: Synthesis, Properties And Applications, Imperial College Press<br>3. Atul Thakur, Preeti Thakur, S.M. Paul Khurana, Synthesis and Applications of Nanoparticles,Springer |
| **Reference book** | 1. A.S. Edelstein and R.C. Cammearata, eds., Nanomaterials: Synthesis, Properties and Applications, (Institute of Physics Publishing, Bristol and Philadelphia, 1996)<br>2. N John Dinardo, Nanoscale charecterisation of surfaces & Interfaces, Second edition, Weinheim Cambridge, Wiley-VCH, 2000 |
| **E-resources/Virtual Labs** | |
| **EoSE** | The duration of the examination shall be Five hours wherein the student has to perform allotted experiment.<br>The distribution of marks is as follows:<br>1 Experimental work: 50<br>(Block diagram for preparation - 10, Formula(e)-5, Observations-20, Calculations-5, Result(s)-5, Precautions-5).<br>2. Viva Voce : 20<br>3. Evaluation of the record book of experiments performed in the semester: 10 |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9112P |
| **Title of the Course** | Advance Electronics Lab |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DSE) Course in Physics |
| **Delivery type of the Course** | Practicum 80+40=120. The 80 hrs for the hands on experiments, observations and record of the data, 20 hours for the experiment, instruments demonstration, lab practices and 20 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Electronics |
| **Co-requisites** | None |
| **Objectives of the course** | *Objectives are to enable the students to understand the operation of advanced electronic devices. Proper conduction and execution of experiments; troubleshoot experiments; appropriately recording of data and their analysis; understand what constitutes "reasonable" data; estimate the error bounds on their measurements. The deduction and presentation of experimental results using graphs and tables.* |
| **Learning outcomes** | The students would be able to:<br>• Hand on experience on the design and fabrication of electronic circuits for the lab experiments and their testing for smooth operation.<br>• Collect data and update the experimental process iteratively and reflectively<br>• Assess the procedure and outcomes of an experiment quantitatively and qualitatively<br>• Extend the scope of an experiment if or not results are as per expectation<br>• Communicate the process and outcomes of an experiment<br>• Perform an experiment collaboratively and ethically<br>• Understand the meaning of a good or rich data, precision and accuracy.<br>• Get an idea of the magnitude of the measured property and compare that with other similar objects and its relation to the applied/pure science. |
| **Syllabus** | |

| | |
|---|---|
| | **List of experiments**<br>1. To simulate the acceleration condition of a falling body by using analogue computation circuits and measure the velocity as well as displacement at a particular time says t seconds from its initial fall.<br>2. To solve the given equations by designing necessary analogue circuits.<br>3. To identify different section of a microwave set up given to you and feed microwave signal using Klystron/gun diode as source and draw the modulation output waveform also measure radiated signal from a horn antenna and find out the radiation lobe.<br>4. To establish the digital link optical fiber as transmission medium and set up the above circuit for TDM mode of operation also examine the operation of Time Division Multiplexing and De-Multiplexing through generation of frame clock, slot clock and bit clock. To draw the frame and Slot timing diagrams. To study the role of Marker in Time Division Multiplexing.<br>5. To establish voice communication link taking optical fiber as transmission medium and draw the output wave-form of the modulating signal also draw the circuit lay out for establish this link. To measure the loss of a signal at different bands of the optical fiber.<br>6. To identify the different sections of a TV receiver. To draw in details (component wise) the horizontal and vertical synchronizing sections of the receiver and measure the output and draw the wave-forms from these two sections and also video output from IF amplifier sections.<br>7. To use DSP technique for controlling system hardware functions. Write software necessary for this purpose.<br>8. To get familiarization with different system parts of Robotics such as (i) AD/DA converter unit (ii) amplifier units (iii) servo system (iv) software and measure the A/D and D/A outputs for given signals also find out the quantization error. To design a Robotic arm and implement necessary hardware and software for controlling its movement.<br>9. To use embedded board and control of servo & microcontroller/ microprocessor<br><br>Note: Minimum number of experiments to be performed is 6 |
| **Text Book** | 1. Paul B. Zbar, "Industrial Electronics", Tata McGraw Hill, New Delhi, 1994. |
| **Reference book** | 1. M. H. Rashid, "Power Electronics Circuits, Devices and Application", PHI, 3rd edition, 2004.<br>2. G. M. Chute and R. D. Chute, "Electronics in Industry", McGraw Hill Ltd, Tokyo, 1995.<br>3. F. D. Petruzulla, "Industrial Electronics", McGraw Hill, Singapore, 1996. |
| **E-resources/Virtual Labs** | 1. Freely available Lecture Notes by the Eminent Teachers and Instrument Manuals available on www.google.<br>2. https://www.electronics-notes.com/articles/basic_concepts<br>3. https://www.javatpoint.com/digital-electronics<br>4. https://www.electronics-tutorials.ws |
| **EoSE** | The duration of the examination shall be Five hours wherein the student has to perform allotted experiment.<br>The distribution of marks is as follows:<br>1 Experimental work: 50<br>(Circuit diagram- 10, Formula(e)-5, Observations-20, Calculations-5, Result(s)-5, Precautions-5).<br>2. Viva Voce : 20<br>3. Evaluation of the record book of experiments performed in the semester: 10 |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9113P |
| **Title of the Course** | Data Analysis Techniques in Experimental Physics |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DSE) Course in Physics |
| **Delivery type of the Course** | Practicum 80+40=120. The 80 hrs for the hands on experiments, observations and record of the data, 20 hours for the experiment, instruments demonstration, lab practices and 20 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Mathematics |
| **Co-requisites** | None |
| **Objectives of the course** | *Objective of this practical based course is to introduce the student to analyse the given experimental data making use of several different types of software with due consideration of the limitations of the same. Since the data used is actual research level experimental data, the student is also exposed to methods of extraction of information/analysis. The course enables the students to assess quality and richness of data* |
| **Learning outcomes** | The students would be able:<br>• To analyse given data by the Gaussian fit and perform pulse height analysis.<br>• To perform linear fit of given data set for calibration and find error on interchanging axes (say I versus B in Hall measurement set up or Deflection angle versus Temperature in Driven oscillator set up) .<br>• To determine size of nanoparticles characterised by TEM, SEM and X-ray diffraction.<br>• To analyse VSM spectrum of a sample and to find the magnetic moment.<br>• To index peaks of XRD pattern of samples with different crystal structures.<br>• To find lattice constant and the density of a crystalline material using XRD pattern.<br>• The role of convolution and deconvolution in spectroscopic methods |
| **Syllabus** | |

| | |
|---|---|
| | Students are required to complete at least eight experiments. Students are expected to carry out the data analysis after understanding theoretical principle behind each experiment. The results of the experiments carried out by the students will be reported to the teacher in regular manner in a specified format written in the Practical records book.<br><br>1. To calculate the average particle size of the given sample from the given TEM micrograph by generating a histogram and fitting with a Gaussian<br>2. To determine(a)average size by the Scherrer method (b) average size and strain using the Williamson-Hall method of the given nanosample<br>3. To index the XRD spectrum, calculate the lattice parameter ($a_0$) by fitting all peaks with a Gaussian/Lorentzian and hence calculate the crystallographic density of the given nano sized sample<br>4. To determine the saturation magnetization of the given ferromagnetic sample through extrapolation and determine other magnetic parameters (coercivity, retentivity and susceptibility).<br>5. To determine the magnetic parameters (saturation magnetization, coercivity, retentivity) of the given ferromagnetic sample by fitting the given curve<br>6. To generate the intensity spectrum of Si XRD spectrum and compare with experimental data<br>7. To generate the intensity spectrum of NaCl XRD spectrum and compare with experimental data<br>8. To generate the intensity spectrum of KCl XRD spectrum and compare with experimental data<br>9. To generate the intensity spectrum of Al XRD spectrum and compare with experimental data<br>10. To fit a straight line to a given set of data and to fit the same data by interchanging the axis.<br>11. To determine energy band gap of a given semiconductor sample using method of absorption.<br>12. To determine energy band gap of a given semiconductor sample using method of reflection.<br><br>Any other experiment can be designed based on the sample data of experimental techniques used in physics. |
| **Text Book** | X-ray Diffraction: A Practical Approach, C. Suryanarayana and M. Grant Norton, Springer (2013). |
| **Reference book** | Data analysis techniques for physical scientists, Claude A. Pruneau, Cambridge University Press (2017). |
| **E-resources/Virtual Labs** | 1. MIT x Online, Computational Data Science in Physics I, https://mitxonline.mit.edu/courses/course-v1:MITxT+8.S50.1x/ |
| **EoSE** | The duration of the examination shall be five hours wherein the student has to perform any one experiment. The marks distribution shall be the following:<br>1. One experiment: 50<br>2. Viva Voce : 20<br>3. Evaluation of the record book of experiments performed in the semester: 10 |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9115T |
| **Title of the Course** | Radiation Physics |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course (GEC)** | Discipline Specific Elective (DSE) Course in Physics (GEC) |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Mathematics or Chemistry or Environmental Science or Life Sciences. |
| **Co-requisites** | None |
| **Objectives of the course** | *This course aims to aware the students about different types of nuclear radiations and their interaction with matter, to learn various techniques for detection of radiations and to study the biological effects of radiation. It also includes solving problems related to safety aspects of nuclear radiation and protection.* |
| **Learning outcomes** | Students will be able to understand<br>• Sources of radiation such as reactors and accelerators and interaction of radiation with matter and its measurement.<br>• Biological effects of radiation.<br>• The nuclear radiation and its detection procedure.<br>• The methods to calculate the radiation exposure, and various units of Dosimetry.<br>• How to solve problems related to safety aspect of nuclear radiation.<br>• The basics of nuclear medicine and radiotherapy. |
| **Syllabus** | |
| **UNIT-I** | **Sources of Radiation:**<br>Environmental and artificial radioactive sources-Cosmic rays, radioactive sources, Accelerators: Cockroft Walton generator, Van de Graff accelerator, linear accelerators (LINACS), cyclotron, electron synchrotron, Neutron Sources: Reactors, Neutrons from reactors, charged particle and photon induced reactions. **(4+2=6)**<br>**Biological Effects of Radiation:**<br>Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, deterministic and stochastic (probabilistic) effects, radiation carcinogesis, partial body and whole body exposures. **(4+2=6)** |

| | |
|---|---|
| **UNIT-II** | **Interaction of Charged Particles with Matter:**<br>Definition of range, Continuous slowing down approximation (CSDA) - straight ahead approximation, transmission and depth dependence methods for determination of particle penetration, types of charged particle interaction, Passage of heavy charged particles through matter: Energy loss by collision, Range-energy relationship, Bragg curve, Specific ionization, mean excitation energies, Bethe-Bloch formula for stopping power, Electron absorption process – Scattering, Excitation and Ionization - Radiative collision –Bremsstrahlung, Cerenkov radiation. **(6+3=9)**<br>**Interaction of Neutrons with Matter:**<br>Classification of neutron interaction, neutron induced nuclear reactions. **(2+1=3)** |
| **UNIT-III** | **Interaction of gamma rays with matter:**<br>Attenuation coefficients, Coherent and incoherent scattering, Photoelectric absorption, Characteristic X-rays, Auger electrons, Pair production. **(4+2=6)**<br>**Radiation Quantities and Units:**<br>Particle flux and fluence, energy flux and fluence, cross section, linear energy transfer (LET), linear and mass attenuation coefficients, mass stopping power, W-value, Activity, Kerma, Exposure, absorbed dose, radiation weighting factors, tissue weighting factors, equivalent dose, effective dose**. (2+1=3)**<br>**Dosimetry:**<br>Primary radiation effects, Charged particle equilibrium (CPE) – Relationship between kerma, absorbed dose and exposure under CPE, measurement of exposure, ionization chamber dosimetry. **(2+1=3)** |
| **UNIT-IV** | **Radiation Detection and Measurement:**<br>Basic principles of radiation detection, modes of detector operation, Pulse height spectra, Counting curves and plateaus, Energy resolution, Detector efficiency, dead time and recovery time, detector window Gas Filled detectors: Various regions of operation of gas filled detectors, Ionization chambers-Theory and design; Gas multiplication, Proportional and GM Counters, Characteristics of organic and inorganic scintillation detectors, Semiconductor detectors, Thermoluminescent dosimeter (TLD), Neutron detectors, Direct reading devices, Calorimetry, Chemical dosimeters, Solid state and film dosimeters, Radiation survey meter for area monitoring. **(8+4=12)** |
| **UNIT-V** | **Radiation Hazard Evaluation and Control:**<br>Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, Internal hazard evaluation and control, Individual and workplace monitoring, Annual limit of intake (ALI) **(4+2=6)**<br>**Radiation Protection standards:**<br>Principles of radiation protection, Maximum permissible levels for radiation workers and general public, ALARA principle, Principles of Time, Distance, Shielding. Half Value Thickness (HVT) & Tenth Value Thickness (TVT) and its relevance in shielding calculations. **(2+2=4)**<br>Brief introduction to radiotherapy and radiation imaging techniques. **(2)** |
| **Tutorials** | Problems based on the text and reference books will be discussed. |
| **Text Books** | 1. A Primer in Applied Radiation Physics by F.A. Smith (World Scientific).<br>2. Nuclear Radiation Physics by R.E. Lapp and H.L. Andrews (Prentice-Hall, New Jersey, 1972).<br>3. F.H. Attix: Introduction to Radiological Physics and Radiation Dosimetry-Wiley-VCH, 1986.<br>4. G.F. Knoll, Radiation detection and measurement, John Wiley & sons, New York, (2000)<br>5. K. Thayalan, Basic radiological physics, Jaypee brothers medical Publishers, New Delhi, (2003) |
| **Reference Books** | 1. A. Edward Profio: Radiation Biology-Radiation Bio/Prentice Hall, 1968<br>2. W.J. Meredith and J.B. Masse, Fundamental Physics of radiology, Varghese publishing house , Bombay (1992)<br>3. M.A.S. Sherer, P.J. Visconti, E.R Ritenour, Radiation Protection in medical radiography, Mosbey Elsevier,(2006) |
| **Suggested E-Resources** | 1. https://www.fisica.net/nuclear/a_primer_in_applied_radiation_physics.pdf<br>2. https://sci-hub.se/https://doi.org/10.1007/978-3-319-53181-6<br>3. https://indico-tdli.sjtu.edu.cn/event/171/contributions/2123/attachments/982/1592/Knoll4thEdition.pdf<br>4. https://phyusdb.wordpress.com/wp-content/uploads/2013/03/radiation_biophysics__second_edition.pdf |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9116T |
| **Title of the Course** | Fundamental Quantum Chemistry |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course (GEC)** | Discipline Specific Elective (DSE) Course in Physics and GEC |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or mathematics or Chemistry |
| **Co-requisites** | None |
| **Objectives of the course** | *Applications of quantum chemistry calculations are manifold. The organic chemistry students can calculate the lowest energy of possible structures. The physical chemistry students can compute the potential energy surface of the reaction coordinate in simple reactions. Biochemistry students take advantage of calculations to elucidate the pathways to creation of designer drugs. This hands-on approach to quantum chemistry calculations is not unique to a discipline. This course introduces the methods of HF, DF and a few allied theories to understand properties of atoms, molecules and solids. The rudiments and formalism of these theories are given and computational aspects are briefed.* |
| **Learning outcomes** | The students of Physics, Chemistry major, materials science, biochemistry would be able to understand:<br>• Basic quantum mechanical machinery to apply to study atoms, simple systems, molecules.<br>• Basic formulation of HF theory, LCAO method, Huckel theory for atoms and molecules.<br>• To exploit symmetry properties to unravel electronic spectra, dissociation energy, reactivity, chemical bonds and their characteristics. |
| **Syllabus** | |
| **UNIT-I** | **Molecular symmetry**: Symmetry operations and elements- Rotations around axes, Reflections through, symmetry planes, Inversion through a center of symmetry, Improper rotations around improper axes; Classification of molecular symmetry; Implications of symmetry **(4+2=6)**<br>**Basic quantum mechanics:** Wave functions specify a system's state; Operators and observables-Operators, Quantum chemical operators; Schrödinger's equation; Measured and average values **(4+2=6)** |

| | |
|---|---|
| | |
| **UNIT-II** | **A particle on a wire**- Solving the Schrödinger equation, The energies are quantized, Understanding and using the wave functions; A harmonic oscillator-Molecular vibrations **(3+2=5)**<br>**Symmetry and degeneracy-** A particle in a rectangular plate, Symmetry and degeneracy, Probabilities in degenerate states, Symmetry of wave functions **(2+1=3)**<br>**Rotational motion-** A particle on a ring, A particle on a sphere, Rotational wave functions, The rigid rotor model **(3+1=4)** |
| **UNIT-III** | **A one-electron molecule $H_2^+$:** The LCAO method, LCAO potential energy curves, The variation method, Beyond the LCAO method, Force constant and dissociation energy, Excited states **(4+2=6)**<br>**Many-electron systems:** The helium atom- Spin and the Pauli postulate, Electron densities, The Hartree–Fock method, Matrix formulation; Atoms; Diatomic molecules; The Kohn–Sham theory **(4+2=6)** |
| **UNIT-IV** | **Qualitative MO theory:** The Huckel model; Cumulenes ; Annulenes ; Other planar conjugated hydrocarbons; Charges, bond orders, and reactivity; The Huckel model and its quantitative limitation **(4+2=6)**<br>**Computational chemistry:** Computations are now routine, Choice of the method, Selection of a basis set, Selecting a functional; Heavy atoms and relativistic effects ;Accounting for a solvent; Practical calculations **(4+2=6)** |
| **UNIT-V** | **The Chemical Bond in Diatomic Molecules:** Generating Molecular Orbitals from Atomic Orbitals; The Simplest One-Electron Molecule $H_2^+$; The Energy Corresponding to the $\mathbf{H_2}^+$Molecular Wave Functions $\psi_g$ and $\psi_u$ ; A Closer Look at the Molecular Wave Functions $\psi_g$ and $\psi_u$ **(4+2=6)**<br>Homonuclear Diatomic Molecules; The Electronic Structure of Many-Electron Molecules-Bond Order; Bond Energy & Bond Length; Heteronuclear Diatomic Molecules; The Molecular Electrostatic Potential **(4+2=6)** |
| **Tutorials** | Particle in a box, Operators, Commutation relations, Simple problems on Variational method. |
| **Text Books** | 1. Quantum Chemistry, A.J. Thakkar, Morgan & Claypool Publishers, San Rafael, CA, USA (2014).<br>2. Quantum chemistry and spectroscopy, Thomas Engel and Warren Hehre, Pearson Publications, Delhi (2013). |
| **Reference Books** | 1. Fundamentals of Quantum Chemistry-Molecular Spectroscopy and Modern Electronic Structure Computations, Michael Mueller, Kluwer Academic Publishers, New York (2002).<br>2. Introductory Quantum Chemistry, A.K. Chandra, IV Edn., McGraw Hill Education India, Bengaluru (2019).<br>3. Quantum Chemistry, I. N. Levine, V Edn.; Prentice-Hall of India, New Delhi (2000). |
| **Suggested E-Resources** | 1. Lectures on Quantum Chemistry visit nptel on http://nptel.iitm.ac.in<br>2. Series of lectures on https://youtube.com/playlist?list=PLyqSpQzTE6M-XY8cj7UNm7JHhSrenw1rV&si=Z3ds2weVp7fxk0dc |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9117T |
| **Title of the Course** | General Theory of Relativity |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course (GEC)** | Discipline Specific Elective (DSE) Course in Physics (GEC) |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or mathematics or Computer science |
| **Co-requisites** | None |
| **Objectives of the course** | *This course introduces principles of general relativity. It also provides the mathematical structure and geometrical aspects of the general relativity. It lays foundation of the advance courses in the area of astronomy, cosmology and gravity.* |
| **Learning outcomes** | The students will be able to understand:<br>• The basic idea of general relativity and its difference with special theory of relativity<br>• Concepts, need and usage of Tensors as mathematic instrument in theory of relativity<br>• Connection between geodesic, curvature, relativity and gravity<br>• Idea, importance and consequences of Einstein equation<br>• Experiments performed to test GTR<br>• Primer of the Black holes-theory, concepts and allied mathematical equations<br>• Various cosmological models and the Big bang theory<br>• The limitations of GTR and need of quantum gravity |
| **Syllabus** | |
| **UNIT-I** | **Basics of geometry and relativity:** Two dimensional geometry, Inertial and gravitational masses, Relativity-Special relativity, Lorentz transformation **(3+2=5)** |

| | |
|---|---|
| | **Relativistic dynamics**: Relativistic point particle, Current and charge densities, Maxwell's equations in the presence of sources, Motion of a charged particle in EM field, Energy-momentum tensor, Angular momentum **(5+2=7)** |
| **UNIT-II** | **Principle of general covariance:** Principle of equivalence, Principle of general covariance, Tensor densities **(1+1=2)** **Usage of Tensor, affine connection and covariant derivative:** Parallel transport of a vector, Christoffel symbol, Covariant derivative of contravariant tensors, Metric compatibility, Covariant derivative of covariant and mixed tensors, Electromagnetic analogy , Gradient, divergence and curl **(7+3=10)** |
| **UNIT-III** | **Geodesic equation** : Covariant differentiation along a curve, Curvature from derivatives, Parallel transport along a closed curve, Geodesic equation , Derivation of geodesic equation from a Lagrangian **(2+1=3)** **Applications of the geodesic equation:** Geodesic as representing gravitational effect, Rotating coordinate system and the Coriolis force, Gravitational red shift, Twin paradox and general covariance, Other equations in the presence of gravitation **(6+3=9)** |
| **UNIT-IV** | **Curvature tensor and Einstein's equation**: Curvilinear coordinates versus gravitational field, Definition of an inertial coordinate frame, Geodesic deviation, Properties of the curvature tensor, Einstein's equation, Cosmological constant, Initial value problem, Einstein's equation from an action **(6+2=8)** **Schwarzschild solution:** Line element, Connection, Solution of the Einstein equation, Properties of the Schwarzschild solution, Isotropic coordinates **(2+2=4)** |
| **UNIT-V** | **Tests of general relativity** : Radar echo experiment, Motion of a particle and light rays in a Schwarzschild background, Vertical free fall, Circular orbit, Perihelion advance of Mercury **(1+1=2)** **Black holes:** Singularities of the metric, Singularities of the Schwarzschild metric, Black holes **(2+1=3)** **Cosmological models and the big bang theory:** Homogeneity and isotropy; Different models of the universe- Close universe, Flat universe, Open universe; Hubble's law; Evolution equation- $k = 1$, $k = 0$, $k = -1$; Big bang theory and blackbody radiation **(5+2=7)** |
| **Tutorials** | 1. The intermediate steps in the derivations 2. The experimental evidences in support of GTR 3. Simple solved and unsolved problems in the textbook 3. Simple exercises of Tensor analysis |
| **Text Books** | 1. Lectures on Relativity, Ashok Das, World Scientific Publishing, Chennai (2011). |
| **Reference Books** | 1. A First Course on General Relativity, B. Schutz, 2nd Edn., Cambridge University Press (2009). 2. Relativity-The special and General Theory, A. Einstein, Translated by R. W. Lawson, Henry Holt & Company, New York (1920). 3. Spacetime and Geometry-An Introduction to General Relativity, Sean Carroll, Addison Wesley Pearson Education New York (2004). 4. Introduction to General Relativity, Gerard 't Hooft, Monogram of Institute for Theoretical Physics, Utrecht University and Spinoza Institute, Utrecht, Netherlands (2010). 5. Theory of Relativity, Roy and Bali, JPH, Jaipur (2020) |
| **Suggested E-Resources** | 1. Introduction to General Relativity and Cosmology, Dirk Putzfeld, Living Script 405/505, Iowa State University, USA (2004). 2. www.thp.uni-koeln.de/~dp 3. http://www.phys.uu.nl/~thooft/ |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| Third Semester | |
| Subject-Physics | |
| **Code of the Course** | PHY9118T |
| **Title of the Course** | Biophysics |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course (GEC)** | Discipline Specific Elective (DSE) Course in Physics (GEC) |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or mathematics or Biotech or Botany or Zoology |
| **Co-requisites** | None |
| **Objectives of the course** | *This course will introduce students to selected biological phenomena from the point of view of physics. It will enable students from non-biology backgrounds to gain an overview of living systems, and those from biology backgrounds to perform mathematical modelling of certain biological processes.* |
| **Learning outcomes** | The students will be able to:<br>• Gain knowledge of structures and processes in living systems at multiple length and time scales, including at the level of molecules, cells, multi-cellular organisms and ecosystems.<br>• Learn certain mathematical methods of dynamical systems, probability and information theory and will be able to apply these methods to model certain biological phenomena.<br>• Learn essential physical principles, concepts and theories related to the structural and dynamical aspects of biomolecules and cells.<br>• Understand Amino acids-the building blocks of the proteins, bonding and the resultant different types of structures, crystallization techniques for the proteins.<br>• Learn experimental separation and spectroscopic techniques necessary for study of biomolecules and cells. |
| **Syllabus** | |

| | |
|---|---|
| **UNIT-I** | **Molecular forces in biological structure:** Dispersion forces, Hydrophobic forces, Hydration forces, Hydrogen bonds, Steric repulsions, Bond flexing and harmonic potentials. **(4+2=6)**<br><br>Structural and dynamical aspects of Biomacromolecules: Flexibility of macromolecules, Elasticity, Dynamics of polymer chains, Topology of polymer chains– Super Coiling **(4+2=6)** |
| **UNIT-II** | **Biophysical phenomena:** Aggregating self-assembly, Surfactants, Viruses, Self-Assembly of proteins **(2+1=3)**<br>Biological membranes physics: Lipid bilayers and membrane proteins, Undulations, Bending resistance, Elasticity, Intermembrane Forces **(4+2=6)**<br>**Cellular dynamics:** Dynamical systems, Coupled ordinary differential equations, Experiments on cellular physiology, Phenomena and models of intracellular chemical dynamics, metabolism and gene regulation, cell growth and division. **(2+1=3)** |
| **UNIT-III** | **Proteins & Nucleic acids**: Protein – Amino acids and the primary structure and secondary structure of proteins, tertiary structure, quaternary structure. Organization of nucleic acid - Primary, secondary, tertiary structure of DNA, Structure of RNA, Sequencing of nucleic acids, antigens and antibodies. Crystallization of protein – few general methods of crystallization – vapor diffusion and micro techniques. Biological applications of delocalization in molecules, radiation damage in biological molecules, ESR studies of Myoglobin and haemoglobin molecules, electronic properties of proteins, enzyme studies, carcinogenic activity, NMR applications: biochemistry, biophysics and in medicine. **(8+4=12)** |
| **UNIT-IV** | **Ecosystems:** Growth of a bacterial colony, Ecological interactions, Lotka-Volterra and other ecological dynamics, models of ecosystems. **(4+2=6)**<br>**The brain:** Dynamics of a single neuron, Neural networks, Learning, Memories as attractors of neural network dynamics. **(2+1=3)**<br>Information in living systems: Probability, entropy and information, Applications of information theory in genetics, neuroscience, and ecology. **(2+1=3)** |
| **UNIT-V** | **Spectroscopic techniques used for studying biological molecules:** Light scattering, small angle X-ray scattering, Mass Spectrometry: MALDI- TOF, Ultraviolet/visible spectroscopy, circular dichroism(CD) and optical rotatory dispersion(ORD), fluorescence spectroscopy, Infrared spectroscopy, Raman spectroscopy. **(4+2=6)**<br>Experimental techniques for separation and study of biomolecules and cells: Chromatography, Electrophoresis, Optical tweezers, Patch- clamping. **(4+2=6)** |
| **Tutorials** | Tutorials based on the mathematical modeling of the relevant biological systems. |
| **Text Books** | 1. Biophysics, V. Pattabhi and N. Gautham, Kluwer Academic Publishers (2002)<br>2. Bio-Physics, Principles and techniques: M. A Subramanian, MJP Publishers (2005)<br>3. Molecular and Cellular Biophysics, Meyer B. Jackson, Cambridge University Press (2006)<br>4. Biophysics - An Introduction, Rodney M. J. Cotterill, John Wiley & Sons, Ltd (2002)<br>5. Physics in Molecular Biology, Kim Sneppen and Giovanni Zocchi, CUP (2005)<br>6. Physical Biology of the Cell (2nd Edition), Rob Phillips et al, Garland Science, Taylor & Francis Group (2013) |
| **Reference Books** | 1. Elementary Solid State Physics: Principles and Applications M. A. Omar, Addison-Wesley Publishing Co. (1975)<br>2. Applied Biophysics: A Molecular Approach for Physical Scientists. Tom A. Waigh, John Wiley & Sons, Ltd (2007)<br>3. Biological Physics: Energy, Information, Life, Philip Nelson, W. H. Freeman &Co, NY (2004)<br>4. Biophysics: Searching for Principles, William Bialek (Princeton University Press (2012)<br>5. Mathematical Biology: I. An Introduction, J. D. Murray, 3rd Ed., Springer (2004) |
| **Suggested E-Resources** | 1. A course on introduction to Biophysics https://canvas.ucsc.edu/courses/1077, https://canvas.ucsc.edu/courses/1077/pages/useful-links<br>2. MIT OpenCourseWare, Topics in Biophysics and Physical Biology, https://ocw.mit.edu/courses/20-416j-topics-in-biophysics-and-physical-biology-fall-2014/pages/syllabus/<br>3. MIT OpenCourseWare, https://ocw.mit.edu/courses/20-416j-topics-in-biophysics-and-physical-biology-fall-2014/ |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9119T |
| **Title of the Course** | Elements of Quantum Computing |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course (GEC)** | Discipline Specific Elective (DSE) Course in Physics (GEC) |
| **Delivery type of the Course** | Lectures and tutorials, 40+20=60. The 40 lectures for content delivery, 10 hours for the tutorial, and 10 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving etc. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or mathematics or Computer science |
| **Co-requisites** | None |
| **Objectives of the course** | *Quantum Computation and information has emerged as an interdisciplinary field at the intersection of theoretical and experimental quantum physics, computer science, mathematics and quantum engineering. This course is aimed to describe basic elements of quantum computing, fast quantum algorithms and quantum error-correction. Quantum mechanics and computer science are introduced, before moving on to describe what a quantum computer is, how it can be used to solve problems faster than "classical" computers, and its real-world implementation. It concludes with rudimentary treatment of quantum information.* |
| **Learning outcomes** | The students would be able to learn:<br>• Basic elements of quantum computing-qubits, quantum gates, quantum circuits and their relation with the fundaments elements of quantum mechanics.<br>• Some rudiments of quantum physics with specific reference to the quantum computation.<br>• Qubit operations, quantum gates and quantum circuit models of computation<br>• QFT and its applications, Model Quantum search algorithms<br>• Guiding principles of Quantum computers and error corrections in quantum coding. |
| **Syllabus** | |
| **UNIT-I** | **Introduction and overview:** Global perspectives-History of quantum computation and quantum information, Future directions; Quantum bits-Multiple qubits; Quantum computation-Single qubit gates, Multiple qubit gates, Measurements in bases other than the computational basis, Quantum circuits, Qubit copying circuit, Example: Bell states, Example: quantum teleportation; Quantum algorithms-Classical computations on a quantum computer, Quantum |

| | |
|---|---|
| | parallelism, Deutsch's algorithm, The Deutsch–Jozsa algorithm, Quantum algorithms summarized; Experimental quantum information processing-The Stern–Gerlach experiment, Prospects for practical quantum information processing **(8+4=12)** |
| **UNIT-II** | **Introduction to quantum mechanics:** Linear algebra- Bases and linear independence, Linear operators and matrices, The Pauli matrices, Inner products, Eigenvectors and eigenvalues, Adjoints and Hermitian operators, Tensor products, Operator functions,<br>The commutator and anti-commutator; The postulates of quantum mechanics-State space, Evolution, Quantum measurement, Distinguishing quantum states, Projective measurements, POVM measurements, Phase, Composite systems; Application: superdense coding; The density operator- Ensembles of quantum states, General properties of the density operator, The reduced density operator; The Schmidt decomposition and purifications; EPR and the Bell inequality **(8+4=12)** |
| **UNIT-III** | **Quantum circuits:** Quantum algorithms; Single qubit operations; Controlled operations; Measurement; Universal quantum gates-<br>Two-level unitary gates are universal, Single qubit and CNOT gates are universal, A discrete set of universal operations, Approximating arbitrary unitary gates is generically hard, Quantum computational complexity; Summary of the quantum circuit model of computation; Simulation of quantum systems-Simulation in action, The quantum simulation algorithm, An illustrative example, Perspectives on quantum simulation **(8+4=12)** |
| **UNIT-IV** | **The quantum Fourier transform and its applications:** The quantum Fourier transform; Phase estimation- Performance and requirements; Applications: order-finding and factoring; General applications of the quantum Fourier transform- Period-finding, Discrete logarithms, The hidden subgroup problem, Other quantum algorithms **(4+2=6)**<br>**Quantum search algorithms:** The quantum search algorithm- Oracle, The procedure, Geometric visualization, Performance; Quantum search as a quantum simulation; Quantum counting ; Speeding up the solution of **NP**-complete problems; Quantum search of an unstructured database; Optimality of the search algorithm Black box algorithm limits **(4+2=6)** |
| **UNIT-V** | **Quantum computers: Physical realization:** Guiding principles; Conditions for quantum computation-Representation of quantum information, Performance of unitary transformations, Preparation of fiducial initial states, Measurement of output result; Harmonic oscillator quantum computer- Physical apparatus,The Hamiltonian, Quantum computation, Drawbacks; Optical photon quantum computer-Physical apparatus, Quantum computation, Drawbacks, Optical cavity quantum electrodynamics-Physical apparatus, The Hamiltonian, Single-photon single-atom absorption and refraction, Quantum computation; Other implementation schemes **(5+2=7)**<br>**Quantum error-correction:** Introduction; The Shor code; Theory of quantum error-correction; Constructing quantum codes; Stabilizer codes; Fault-tolerant quantum computation **(3+2=5)** |
| **Tutorials** | Tutorials on intermediate steps and some examples of the textbook |
| **Text Books** | 1. Quantum Computation and Quantum Information, Michael A. Nielsen & Isaac L. Chuang, CUP, New Delhi (2010). |
| **Reference Books** | 1. Problems and Solutions in Quantum Computing and Quantum Information, W.-H Steeb & Y. Hardy, World Scientific Publications, Singapore (2004).<br>2. Quantum Computing For Computer Scientists, N. S. Yanofsky & M. A. Mannucci, CUP, New Delhi (2008).<br>3. Quantum Computing Explained, D. McMohan, Wiley Interscience, John Wiley & Sons, Singapore (2008).<br>4. Explorations in Quantum Computing, C.P.Williams, Springer, New York (2018).<br>5. Quantum Computing in Practice with Qiskit and IBM Quantum Experience, Packt Publishing, Birmingham (2020). |
| **Suggested E-Resources** | 1. Lecture Notes on quantum Information-http://www.theory.caltech.edu/preskill/ph229#lecture<br>2. Swayam portal<br>3. Quantum Computing Labs (qiskit.org or https://qiskit.org/) |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9120P |
| **Title of the Course** | Radiation Physics Lab |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DSE) Course in Physics |
| **Delivery type of the Course** | Practicum 80+40=120. The 80 hrs for the hands on experiments, observations and record of the data, 20 hours for the experiment, instruments demonstration, lab practices and 20 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or Mathematics or Chemistry or Environmental Science, or Life |
| **Co-requisites** | None |
| **Objectives of the course** | *This course aims to familiarize the students with the experimental aspects of some concepts introduced in Radiation Physics paper and familiarize with the effect of radiation on materials.* |
| **Learning outcomes** | The students will acquire an experience of analyzing multiple scattering of photons in in-vivo tissues and compute photons cross-section and attenuation coefficients and will understand some of the results that they learn in theory. |
| **Syllabus** | |
| | Experiments based on Monte Carlo Simulations for multiple scattering of photons in in-vivo tissues, skeleton bones, water, etc., computation of photon cross-sections and mass attenuation coefficients of various biological tissues and tissue-equivalent materials using XCOM program of J.H. Hubbel, Use of HPGe detector in analysis of γ-ray spectra.<br>Another relevant experiment desired by the faculty may also be introduced. |
| **Text Books** | 1. Nuclear Physics Experiments-Jagdish Varma, New Age International Limited, Publishers.<br>2. J. Felsteiner et al. Philos. Mag. 30, 537 (1974).<br>3. XCOM code by J. H. Hubbel, university of California, USA. |

| | |
|---|---|
| **Reference Books** | 1. G. F. Knoll, Radiation detection and measurement, John Wiley & sons, New York, (2000). |
| **Suggested E-Resources/Virtual Labs** | 1. https://phyusdb.wordpress.com/wp-content/uploads/2013/03/radiationdetectionandmeasurementbyknoll.pdf<br>2. https://inis.iaea.org/collection/NCLCollectionStore/_Public/19/009/19009871.pdf<br>3. https://sci-hub.se/10.1080/14786439808206579 |
| **EoSE** | The duration of the examination shall be six hours wherein the student has to perform any one experiment. The marks distribution shall be the following:<br>1. One experiment: 50<br>2. Viva Voce : 20<br>3. Evaluation of the record book of experiments performed in the semester: 10 |

| M.Sc. (Two Year Degree Program) | |
|---|---|
| **Third Semester** | |
| **Subject-Physics** | |
| **Code of the Course** | PHY9121P |
| **Title of the Course** | Materials Characterization Lab |
| **Qualification Level of the Course** | NHEQF Level 6.5 |
| **Credit of the course** | 4 |
| **Type of the course** | Discipline Specific Elective (DSE) Course in Physics |
| **Delivery type of the Course** | Practicum 80+40=120. The 80 hrs for the hands on experiments, observations and record of the data, 20 hours for the experiment, instruments demonstration, lab practices and 20 hours on diagnostic assessment, formative assessment, subject/class activity, problem solving. |
| **Prerequisites** | Intermediate or advanced level courses of Physics or mathematics |
| **Co-requisites** | *None* |
| **Objectives of the course** | *To strengthen knowledge and working on basic research characterization tools which play principal role in present thrust research domains associated to the societal need including the renewable energy, climate change, food security, information security, public health etc.*<br>*To ensure contribution of the deliverables in main stream of development of the society, nation and world.* |
| **Learning outcomes** | The target student stuff would be trained on basic research characterization tools to ensure contribution in research catering present societal needs.<br>The deliverables/ trained student stuff would contribute in main stream of development of the society, nation and world by undertaking research on thrust domains comprising of renewable energy, climate change, food security, information security, public health etc. |
| **Syllabus** | |
| | **The student has to perform a number of experiments from the following list.**<br><br>1. To find out optical energy band gap of a given thin film sample using UV Vis. Spectrophotometer.<br>2. To undertake refractive index v/s. wavelength behavior of a given thin film using UV Vis. Spectrophotometer.<br>3. To explore optical conductivity of a given thin film sample using UV Vis. Spectrophotometer. |

| | |
|---|---|
| | 4. To undertake surface roughness of a given thin film sample by using atomic force microscopy.<br>5. To explore electrical resistivity of a given thin film sample using source meter.<br>6. To find out thickness of a given thin film sample using UV Vis. Spectrophotometer<br>7. To find out optical energy band gap of a given thin film sample using photoluminescence spectroscopy.<br>8. To find out crystallite size of a given thin film/ powder sample using X-ray diffraction equipment.<br>9. To find out micro strain of a given thin film/ powder sample using X-ray diffraction equipment.<br>10. To undertake dislocation density of a given thin film/ powder sample using X-ray diffraction equipment.<br>11. To explore number of crystallites in unit area of a given thin film/ powder sample using XRD equipment.<br>12. To explore glass transition temperature of a given sample using TGA equipment.<br>13. To explore admittance parameters of a given thin film sample using LCR Meter.<br>14. To undertake performance parameters of a given solar cell device using solar simulator.<br>15. To undertake Compton profile of a given powder samples using Cs source based Compton spectrometer.<br><br>**Any other relevant experiment set by the faculty may also be included.** |
| **Text Books** | |
| **Reference Books** | 1. X-ray Diffraction, A Practical Approach, C. Suryanarayana and M.G. Norton, Plenum Press, New Yark, 1998.<br>2. UV-VIS Spectroscopy and Its Applications, Heinz-Helmut Perkampus, Springer, 1992.<br>3. Photoluminescence, T.S. Teets, American Chemical Society, 2021.<br>4. Atomic Force Microscopy, B.Voigtländer, Springer, 2019.<br>5. Thermogravimetric Analysis (TGA), J.D. Menczel, R.B. Prime, Wiley, 2008. |
| **Suggested E-Resources/Virtual Labs** | 1. https://www.academia.edu/35663767/XRD_Textbook_Suryanarayana_pdf<br>2. https://pubs.acs.org/doi/book/10.1021/acsinfocus.7e5014<br>3. https://link.springer.com/book/10.1007/978-3-642-77477-5<br>4. https://link.springer.com/book/10.1007/978-3-030-13654-3<br>5. https://onlinelibrary.wiley.com/doi/10.1002/9780470423837.ch3<br>6. https://www.tek.com/en/products/keithley/source-measure-units/2400-standard-series-sourcemeter |
| **EoSE** | The duration of the examination shall be five hours wherein the student has to perform any one experiment. The marks distribution shall be the following:<br>1. One experiment: 50<br>2. Viva Voce : 20<br>3. Evaluation of the record book of experiments performed in the semester: 10 |