<table>
<tr><td colspan="2" align="center">UNIVERSITY OF MADRAS<br>DEPARTMENT OF NUCLEAR PHYSICS</td></tr>
<tr><td>Programme:</td><td>M.Sc., Physics</td></tr>
<tr><td>Programme Code:</td><td>PHYB</td></tr>
<tr><td>Duration:</td><td>2 years</td></tr>
<tr><td>Programme Outcomes:</td><td>1. To impart quality education in physical sciences helpful for societal improvement<br>2. To acquire a comprehensive understanding of advanced principles and concepts in Physics.<br>3. To include recent developments in the advanced level of Theoretical and Experimental Physics<br>4. To enhance the syllabus qualitatively for teaching, research, consultancy and industry<br>5. To build the students with sound analytical and experimental capabilities<br>6. To visualize and create solutions for multidisciplinary tasks<br>7. To transform the lives and society through efficient learning<br>8. To provide opportunity for higher learning and job<br>9. To experience a conducive and vibrant academic environment to improve confidence among students<br>10. To demonstrate a standard ethical conduct and professional behavior with interpersonal and communication skills</td></tr>
<tr><td>Programme Specific Outcomes:</td><td>1. Students will be analytically and experimentally equipped<br>2. They will be able to apply the knowledge of principles and concepts of Physics to build models and to solve practical problems.<br>3. Students will develop confidence at the advanced level of Physical sciences leading them to compete at the national and international levels<br>4. They will have the capability to emerge as globally competitive academicians/ researchers/ consultants in the diverse areas of physics<br>5. They will recognize the need to update and develop themselves for a successful career in academic, research, job and interdisciplinary tasks.</td></tr>
</table>

**List of Courses:**

| Semester | Course Code | Title of the Course | Core / Elective / Soft Skill | Credits |
|---|---|---|---|---|
| I | PHY C101 | Mathematical Physics | Core | 4 |
| | PHY C102 | Electronic Devices and Circuits | Core | 4 |
| | PHY C103 | Classical Mechanics | Core | 4 |
| | PHY C104 | Practical I – General Physics | Core | 4 |
| | PHY E101 | Laser, Nonlinear Optics & Integrated Optics | Elective | 3 |
| | PHY E102 | Nuclear Detectors and Techniques | Elective | 3 |
| | PHY E103 | Electronic Communications | Elective | 3 |
| | UOM S001 | Error Analysis for Physical Sciences | Soft Skill | 2 |
| II | PHY C105 | Molecular Physics and Spectroscopy | Core | 4 |
| | PHY C106 | Quantum Mechanics – I | Core | 4 |
| | PHY C107 | Electromagnetic Theory | Core | 4 |
| | PHY C108 | Practical II – Nuclear Physics & Optical Physics | Core | 4 |
| | PHY E104 | Radiological Safety Aspects | Elective | 3 |
| | PHY E105 | Nuclear Materials | Elective | 3 |
| | UOMS002 | Scientific Writing and Enhancing Professional Research Skills | Soft Skill | 2 |
| | UOM I001 | Internship | | 2 |
| III | PHY C109 | Quantum Mechanics II | Core | 4 |
| | PHY C110 | Statistical Physics | Core | 4 |
| | PHY C111 | Nuclear Physics & Elementary Particle Physics | Core | 4 |
| | PHY C112 | Condensed Matter Physics | Core | 4 |
| | PHY E106 | Physics of Thin Films and Device Fabrication | Elective | 3 |
| | PHY E107 | Introduction to Spintronics | Elective | 3 |
| | PHY E108 | Materials Characterisation | Elective | 3 |
| | UOMS003 | Soft Skill – online/other Dept. | Soft Skill | 2 |
| IV | PHY C113 | Materials Physics | Core | 4 |
| | PHY C114 | Computational Techniques & Programming | Core | 4 |
| | PHY C115 | Project & Viva–Voce | Core | 4 |
| | PHY E109 | Reactor Physics | Elective | 3 |
| | PHY E110 | Physics of Nano Materials and Structures | Elective | 3 |
| | UOMS004 | Soft Skill - online/other Dept. | Soft Skill | 2 |

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|---|---|---|
| **Subject Code** | **PHY C101** | **Core** |
| **Title of the Course:** | **MATHEMATICAL PHYSICS** | |
| **Credits:** | 4 | |
| **Pre-requisites, if any:** | Basic knowledge in vectors, scalars, differentiation and integration | |
| **Course Objectives** | 1. Introduces students to use Mathematical methods which they apply to solve problems in Physics<br>2. Provide students with basic skills necessary for the application of Vectors, Matrices, Tensors, and Differential equations as quantities in Physics.<br>3. Apply the basic elements of complex mathematical analysis, including the integral theorems, obtain the residues of a complex function and to use the residue theorem to evaluate definite integrals<br>4. Demonstrate the applications of special functions in physics<br>5. Expand a function in terms of a Fourier series, with knowledge of the conditions for the validity of the series expansion. | |
| **Course Outcomes** | **Description** | **Knowledge Level** |
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | **Recall** the concept of Vector Algebra and its application in physics. **Understand** in detail different concepts and identities in vector algebra. **Modeling** Gauss divergence, Stokes and Green's theorem. **Interpret** Gauss divergence theorem to derive important laws of Physics such as Gauss law in electrostatics. | **K1**<br>**K2**<br>**K3**<br>**K5** |
| **CO2** | **Recall** the definition and algebraic operations of matrices, **Explain** Hermitian, anti-Hermitian matrices**,** eigenvalues and eigenvectors, **Apply** it for physics problems such as moment of inertia and normal modes of oscillation, **Distinguish** Hermitian, anti-Hermitian matrices | **K1**<br>**K2**<br>**K3**<br>**K4** |
| **CO3** | **Recal**l complex numbers and their properties. **Extend** the idea to complex variables and **outline** the concepts of analyticity, poles and residues. **Identify** analytic functions and Harmonic functions. **Develop** Cauchy-Riemann equations, Cauchy's integral formula and Cauchy's integral theorem for analytic | **K1**<br>**K2**<br>**K3**<br>**K5**<br>**K6** |

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| | functions. **Compare and contrast** Taylors and Laurent's series for simply and multi-connected regions and apply the same. **Evaluation** of definite integrals of trigonometric functions round the Unit circle. | |
| **CO4** | **What** the special functions, such as the Legendre and Laguerre functions and their differential equations. **Develop** the polynomial of Legendre and Laguerre functions and **estimate** the values of polynomials. **Discuss** their properties such as orthogonality | **K1**<br>**K2**<br>**K3**<br>**K4** |
| **CO5** | **What** are periodic functions and explain the Fourier analysis of periodic functions with Dirichlet conditions - **Application** of Fourier series to generate square, triangular and saw tooth wave. Fourier and Laplace transform –Properties- Fourier sine and cosine transform **-Interpretation** of Fourier Transform-Heat transfer equations-**Problems**. Application of Laplace transforms to **solve** differential equations with constant coefficients-Problems | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| | **Units** | |
| I | **Vector Analysis:** Scalars and Vectors - Elementary Vector algebra (Revision) ; Scalar / Vector Fields - Vector Differentiation and Del operator - Laplacian Operator and applications in 3D space - Laplacian in special coordinate systems ; Vector integration - Gauss, Green's and Stokes' theorems.<br>Contravariant and covariant vectors - tensors of rank 2 - basic tensor operations. | |
| II | **Matrices:** Basic algebraic operations for matrices (Revision); Power, Transpose, Symmetry and Inverse of matrix - linear equations ; Complex conjugate and Hermitian/anti-Hermitian matrix - Orthogonal, Unitary matrices and transformations ; Eigenvalues and eigenvectors : determination, eigenvalues of Hermitian and of commuting matrices - Cayley-Hamilton theorem ; Physical applications: examples for Moment of Inertia and Normal modes. | |
| III | **Complex variables:** Complex numbers and their representations ; Differential calculus of complex functions: analytic functions - Cauchy-Riemann conditions ; Elementary functions: exponential, trigonometric, hyperbolic ; Integral calculus of complex variables: Cauchy's integral theorem and formulas ; Series representations of analytic (functions: Ratio and Convergence Tests - Taylor series of elementary functions - singularity - Laurent series ; Integration by residues and Residue theorem - examples of evaluation of real definite integrals | |

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| IV | **Special functions:** Equations, (Rodrigues') formulas, recurrence relations and generating functions for Legendre, Hermite, Laguerre polynomials - Othogonality of these polynomials - Associated Laguerre polynomials - Bessel functions of second kind, recurrence formulas and generating functions -Orthogonality - Bessel integral - Spherical Bessel functions - Applications of special functions in physics |
| V | **Analysis of Periodic Functions:** Periodic functions - Fourier series representation – convergence - Dirichlet conditions- Parseval's identity - Integration and differentiation of Fourier series–Examples of vibrating string, RLC circuit - Fourier integrals and transforms - Examples of wave packet, heat conduction, delta function - convolution theorem ; Laplace transform concept and transforms for elementary functions - shifting theorem - transform of periodic (function – transforms of derivatives and integrals). |
| **Reading List (Print and Online)** | 1. Contemporary Topics in Mathematical Physics, Vincent Bouchard, University of Alberta http://www.birs.ca/events/2017/2-day-workshops/17w2694/videos/watch/201710281436-Bouchard.html<br>2. Mathematical Methods In Physics –I, Prof. Samudra Roy, IIT Kharagpur https://nptel.ac.in/courses/115/105/115105097/<br>3. Selected topics in mathematical Physics, Prof. Hari Shankar Mahato, IIT Kharagpur (NPTEL) https://nptel.ac.in/courses/111/105/111105122/<br>4. Selected topics in mathematical Physics, Prof. V. Balakrishnan, IIT Madras (NPTEL) https://nptel.ac.in/courses/115/106/115106086/<br>5. Selected topics in Mathematical Physics, coordinated-IIT Kharagpur (NPTEL) https://nptel.ac.in/courses/115/105/115105097/ |

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| **Recommended Texts** | 1. Erwin Kreyszig, Advanced Engineering Mathematics, 9' Edition, John Wiley & Sons,Inc. (2006).<br>2. M. Boas, Mathematical Methods in Physical Sciences, 3rd Edition, Wiley International Edition (2005).<br>3. G. Arflcen and H.J. Weber, Mathematical Methods for Physicists, Academic Press, 6$^{th}$ Edition, Indian Edition (2005).<br>4. L.A. Pipes and L.R. Harwell, Applied Mathematics for Engineers and Physicists, McGraw-Hill (1995).<br>5. Murray R Spiegel and Seymour Lipschutz, Schaum's Outline of Vector Analysis, 2$^{nd}$ Edition, McGraw-Hill (1964).<br>6. Jr. Frank Ayres, Schaum's Outline of Theory and Problems of Matrices, McGraw-Hill (1974).<br>7. B.D. Gupta, Mathematical Physics, 4th Edition, Vikas Pub., Noida (2015).<br>8. H.K. Dass and Rama Verma, Mathematical Physics, S. Chand, New Delhi (2008). |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | L | M | M | L | L | S | S | L |
| **CO 2** | S | M | - | M | L | M | M | S | S | L |
| **CO 3** | S | S | - | M | M | L | - | M | - | L |
| **CO 4** | S | S | S | M | M | M | - | M | - | - |
| **CO 5** | S | S | - | M | M | L | - | M | - | - |

**S-Strong M-Medium L-Low**

<table>
<tr><td>Subject Code</td><td>PHY C102</td><td>Core</td></tr>
<tr><td>Title of the Course:</td><td colspan="2">ELECTRONIC DEVICES AND CIRCUITS</td></tr>
<tr><td>Credits:</td><td colspan="2">4</td></tr>
<tr><td>Pre-requisites, if any:</td><td colspan="2">UG level Physics</td></tr>
<tr><td>Course Objectives</td><td colspan="2">1. To understand the fundamental knowledge on the physics of semiconductor devices and fabricating methodologies<br>2. To revise and employ the various transport phenomena like drift, diffusion, tunnelling and impact ionization for determining the device characteristics<br>3. To compare and interpret the basic transport phenomenon in microwave device technology<br>4. To employ the understanding of a basic differential amplifier along with the mathematical treatment for designing circuits of practical applications<br>5. To analyse OP AMP circuits like Amplifiers, Oscillators and filters and recognize their application in instrument design.</td></tr>
<tr><td>Course Outcome</td><td>Description</td><td>Knowledge Level</td></tr>
<tr><td colspan="3">On the successful completion of the course, student will be able to:</td></tr>
<tr><td>CO1</td><td>Will explain the theory of Semiconductor-Semiconductor, Metal-Semiconductor, Metal-Insulator-Semiconductor junctions that provide a strong basis for the critical analysis and design of electronic devices.</td><td>K1<br>K2<br>K4<br>K5</td></tr>
<tr><td>CO2</td><td>Will understand energy band, carrier distribution, and transport properties that can be employed in determining the device characteristics.</td><td>K1<br>K2<br>K4<br>K5</td></tr>
</table>

| | | |
|---|---|---|
| **CO3** | Will **conceive** the theories on novel microwave devices | **K1**<br>**K2**<br>**K6** |
| **CO4** | Will **interpret** the OP AMP principles and theory to **analyze** and design circuits for instruments. | **K1**<br>**K2**<br>**K3** |
| **CO5** | Will **critically assess** nuclear spectrometry with confidence and meet the challenge in teaching, research and industry<br><br>Will **employ** the concepts for further learning/ update/ research | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| | **Units** | |
| **I** | **Physics of Semiconductor Devices**<br><br>**A.** p-n Junction Diode: Basic Device Technology – Depletion region and depletion capacitance – Current Voltage characteristics – Junction Breakdown – Transient behaviour and Noise – Tunnel diode – p-i-n diode – Varactor diode. **B.** Metal Semiconductor Contacts: Energy band relation – Schottky effect –Current transport Processes – Device structure – Ohmic contact **C.** MIS diode and Charge Coupled Device. | |
| **II** | **Transistors & Thyristors**<br><br>Bipolar transistors – JFET: Pinch-off voltage – Volt-Ampere characteristics – MOSFET: Low frequency and high frequency amplifiers including design aspects – FET as VVR – MESFET – SCR and TRIAC - characteristics – Triggering and turn off methods – Applications – UJT: Basic theory of operation – characteristics – Relaxation oscillator including design aspects – UJT-Thyristor trigger circuits. | |
| **III** | **Negative Conductance Microwave Devices**<br><br>**A.** Transit Time Devices: IMPATT diode – QWITT diode – TRAPATT diode – BARITT diode **B.** Gunn effect and related devices: The transferred electron mechanism – Formation and drift of space charge, domains – Modes of operation in resonant circuit – Fabrication and applications. | |
| **IV** | **OP AMP – Linear and Non linear circuits**<br><br>Differential amplifier – Transfer characteristics – Voltage amplifier – Current amplifier – Voltage follower– Frequency response of OP AMP. Non-linear applications: Log and antilog amplifiers – Half-wave | |

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| | and Full- wave rectifiers – Curve shapers – Clippers – Zero crossing detector – Voltage comparator. |
| **V** | **OP AMP – Applications**<br><br>Sample and hold circuit – Schmidt trigger – Peak detector – Active filters – Low-pass, high-pass, bandpass, notch, band - Reject and state – variable biquad filters – Oscillators: Wien bridge, phase-shift, relaxation, triangle, square wave oscillators – Phase Locked Loop Amplifier. |
| **Reading List (Print and Online)** | 1. S. M. Sze, Physics of Semiconductor Devices, Wiley Eastern Ltd., 1981.<br>2. Millman, Halkias and Satyabrata Jit, Electronic Devices and Circuits, Tata McGraw-Hill, 2007.<br>3. B. G. Streetman, Solid State Electronic Devices, 4th Edn., Prentice-Hall of India,1995.<br>4. Millman and Halkias, Integrated Electronics, Tata McGraw-Hill, 1993.<br>5. R. A. Gayakwad**,** OP AMPS and Linear Integrated Circuits, 3rd Edn., Prentice-Hall of India, 1995. |
| **Recommended Texts** | 1. Joseph Lindmeyer and Charles Y. Wrigley, Fundamentals of Semiconductor Devices, D. Van Nostrand Company, INC, 1965.<br>2. M. Shur, Physics of Semiconductor Devices, Prentice-hall of India, 1995.<br>3. Robert L. Boylestad and Lois Nashelsky, Electronic Devices and Circuit Theory, Pearson Education, Inc., 2002.<br>4. S. Y. Liao, Microwave Devices and Circuits, Prentice-Hall of India, 3rd Edn.<br>5. R. J. Irvine, Operational Amplifier: Characteristics and Applications, Prentice-Hall Inc., 2nd Edn., 1987. |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CO 1 | M | S | S | M | S | M | L | S | M | L |
| CO 2 | S | S | S | S | S | M | M | S | S | M |
| CO 3 | M | L | M | S | S | L | L | M | S | M |
| CO 4 | M | M | L | S | S | L | M | M | L | M |
| CO 5 | S | S | M | M | S | S | L | S | M | S |

**S-Strong M-Medium L-Low**

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|---|---|---|
| **Subject Code** | **PHY C103** | **Core** |
| **Title of the course** | **Classical Mechanics** | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Basic knowledge in Newtonian Mechanics and mathematics knowledge in vector calculus and tensors. | |

**Course Objectives:**

1. To show how Newtonian mechanics is not sufficient to understand the physics concepts.
2. To develop the analytical skill of solving mechanics problem through Lagrangian and Hamiltonian formulations.
3. To learn the basic foundations such as scattering, rigid body dynamics, small oscillations and canonical transformation and To appreciate how these concepts form a basic tool to do any other disciplines of physics.
4. To equip students in solving physics problems in order to develop both theoretical and experimental rigor in research.
5. To emphasize the transition from classical to quantum mechanics

**Course Outcomes:**

**On the successful completion of the course, student will be able to:**

| | | |
|---|---|---|
| **CO1** | **Emphasize** the limitations of Newtonian programme. **Familiarize** the importance of degrees of freedom and constraints. **Formulate** analytical way of solving mechanics problems through Lagrangian and Hamiltonian dynamics. **Setup** Lagrangian and Hamiltonian of few physical systems. **Demonstrate** the importance of gauge invariance and symmetrical properties of Lagrangian. **Emphasize** the significance of formulating Hamiltonians. **Introduce** the concept of phase space and **solve** equation of motions through Hamilton's equations | **K1 K2 K3 K4 K5 K6** |
| **CO2** | **Introduce** the concepts of central force problem, scattering and reduced mass and the laboratory frame of reference. **Develop** the theory of small oscillations. **Familiarize** eigenvalue problems in mechanical systems. **Demonstrate the** finding s of normal modes of two-coupled oscillators. **Appreciate** how theory of small oscillation is central in spectroscopy and dispersion relation in condensed matter physics. | **K1 K2 K3 K4 K5** |
| **CO3** | **Introduce** rigid body dynamics to students with an aim to solve equation of motion of few rigid body systems. **Identify** moment of inertial tensor of a few rigid body systems. **Demonstrate** transformation from body-set of axes to space-set of axes. **Reveal** how gyroscope works. | **K1 K2 K3 K4 K5** |
| **CO4** | **Develop** and **understand** the basics such as canonical transformation (CT), generating function, Poisson Brackets. **Solve** many problems in CT, phase-space, and passion brackets | **K1 K2 K3 K4 K5** |
| **CO5** | **Introduce the** nuances of special theory and general theory of relativity. | **K1** |

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| | Demonstrate relativity based tensor analysis . | **K2**<br>**K3**<br>**K4**<br>**K5** |
| **Units** | | |
| **I** | **Lagrangian and Hamiltonian Formulation:** Limitations of Newton's method, Constraints and their classifications, Degrees of freedom, D'Alembert's principle, Lagrange's equation of motion for conservative and nonconservative systems, Generalized potential, energy and momenta, Gauge invariance and symmetry properties. Hamilton's Principle, Hamilton's equations and Examples for Hamiltonian dynamics. | |
| **II** | **Classical Mechanics Applications:** Two body central force problem, Kepler's problem, scattering by central potential, two-particle scattering, cross section in laboratory system. Small oscillations, transformation to normal coordinates and frequencies of normal modes. | |
| **III** | **Rigid Body Dynamics:** Angular momentum and Kinetic Energy, Moment of Inertia tensor, Euler angles, Euler's equation of motion, torque-free motion, symmetrical top. | |
| **IV** | **Canonical Transformation:** Principle of least action, Possion brackets, Canonical transformations and their generators, simple examples, Hamilton Jacobi theory, Action angle variables, application to harmonic oscillator problem. | |
| **V** | **Relativity**: Lorentz transformations, relativistic mechanics, relativistic Lagrangian and Hamiltonian for a particle, Space-time and energy-momentum four vectors, centre of mass systems for two relativistic particles | |
| **Reading List (Print and Online)** | 1. Classical Mechanics-Theoretical Minimum, Leonard Susskind and George Hrabovsky, Penguin Books (2013) –**Intended for preliminary reading**<br>2. Keith R. Symon- Mechanics<br>3. Kibble and Berkshire-Classical Mechanics<br>4. Landau and Lifshitz; Course on theoretical physics, Volume-1: Mechanics.<br>5. Science in History by J. D. Bernal | |
| **Text Book(s)** | | |
| 1. Classical Mechanics, H. Goldstein et al., III Ed., Eighteenth impression 2017, Pearson.<br>2. Classical Mechanics, N C Rana and P S Joag, McGraw Hill, 2015, New Delhi.<br>3. Classical Mechanics, J. C. Upadhyaya, Himalaya Publishing Home, Ed. II, 2005. (**For Problem Solving**)<br>**4.** R. Resnick, Introduction to special theory of relativity. | | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | M | S | S | M | L | L | S | M |
| **CO 2** | S | S | M | S | S | M | L | L | S | M |
| **CO 3** | M | S | M | S | S | M | L | M | S | M |
| **CO 4** | S | S | S | S | S | M | L | M | S | M |
| **CO 5** | M | S | S | S | S | S | L | M | S | M |

**S-Strong M-Medium L-Low**

| Subject Code | PHY C104 | Core |
|---|---|---|
| **Title of the Course:** | **Practical I - General Physics** | |
| **Credits:** | **4** | |
| **Pre-requisites, if any:** | UG level physics | |
| **Course Objectives** | **1.** To provide practical hands on experience with OP-AMP, UJT, MOSFET and SCR characterisation<br>**2.** Provide a comprehensive understanding on electronic devices such as OPAMP, FET and 555 Timer<br>**3.** Introduce the basic concepts in Modern Optics, LASER, Fiber Optics and chracterisation of Magnetic and Dielectric materials<br>4. Learn experimental physics in correspondence with the theory<br>5. Inculcate skill component in practical Physics | |
| **Course Outcome** | **Description** | **Knowledge Level** |
| | | |
| **CO1** | Will demonstrate skills and competencies to conduct scientific experiments | **K1**<br>**K2**<br>**K4**<br>**K5** |
| **CO2** | Will demonstrate group coordination | **K4**<br>**K5** |
| **CO3** | Critically assess and plan execution of experiments, analysis and interpretation of experimental data. | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| **CO4** | Apply principles and concepts of Physics to practical problems | **K1**<br>**K2**<br>**K4**<br>**K5** |
| **CO5** | Develop written and oral skills<br>Demonstrate ability to plan, undertake, and report an experimental outcome | **K3**<br>**K4**<br>**K5** |

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| **Unit** | |
| (Analog Electronics, Optics, Laser, Condensed Matter Physics)<br>Any **FIFTEEN** experiments only | |
| **1** | Generation of simple waveforms using an Operational Amplifier. |
| **2** | Analog computation and solution of simultaneous equations using an Op-Amp circuit. |
| **3** | Construction and assessment of Regulated Power Supplies |
| **4** | Characteristics of a Silicon Controlled Rectifier (SCR) and Firing Angle Control. |
| **5** | Characteristics and applications of a Triac. |
| **6** | Characteristics of a Unijunction Transistor (UJT) and UJT as a relaxation oscillator. |
| **7** | Triggering of SCR by UJT relaxation oscillator. |
| **8** | Construction of a stable and monostable multivibrators using IC NE-555. |
| **9** | Characteristics of a Metal-Oxide Semiconductor Field-Effect Transistor (MOSFET) and construction of a common-source amplifier. |
| **10** | Construction and frequency measurement of series-fed and shunt-fed Hartley oscillators. |
| **11** | Construction and frequency determination of a crystal oscillator. |
| **12** | Construction and analysis of a differential amplifier. |
| **13** | Construction and assessment of class B push-pull complementary-pair audio amplifiers. |
| **14** | Construction of a phase-locked loop circuit |
| **15** | Monochromatic and white interference fringes using a Michelson Interferometer. |

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| **16** | Interference fringes using a Lummer-Gherke plate. |
| **17** | Use of Fabry-Perot etalon to excite interference fringes. |
| **18** | Analysis of Edser-Butler fringes. |
| **19** | Analysis of a solar spectrum. |
| **20** | Laser – Determination of wavelength, Thickness of a Thin Wire/Slit width, Particle size. |
| **21** | Fiber Optics – Determination of Numerical Aperture, Estimation of Loss, Audio transmission. |
| **22** | Determination of Cell Parameters from powder XRD pattern |
| **23** | Electrical Resistivity Measurement by four probe method and Band Gap Determination. |
| **24** | Study of the B-H curve of a Ferro Magnetic material. |
| **25** | Determination of Curie temperature of a Ferro Electric material |
| **26** | Photoconductivity |
| **Reading List (Print and Online)** | 1. Paul B. Zbar, Basic Electronics - A Text-lab Manual III Edition Tata McGraw-HillPublishing Co. Ltd., New Delhi,1979.<br>2. Lab Manuals, Department of Nuclear Physics, University of Madras<br>3. T.G. Ramesh and R. Srinivasan, Manual on Material Preparation and Measurement of Properties, Indian Academy of Sciences, Bangalore, 2014<br>4. Rajendar Singh, Introduction to Basic Manufacturing Processes and Workshop Technology, New Age International, 2010. |
| **Recommended Texts** | 1. Colin Cooke, An introduction to Experimental Physics, UCL Press, 1996.<br>2. K. And Johnson, Vivian A. (Editors) Lark-Horovitz - Methods of Experimental Physics Solid State Physics (Volume 6_Part B) Academic Press Inc, 1964.<br>3. Videos and tutorials from standard websites. |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | S | L | L | M | L | L |
| **CO 2** | S | S | S | S | S | - | - | L | - | L |
| **CO 3** | S | S | S | M | S | L | M | S | L | L |
| **CO 4** | S | S | S | M | S | - | - | M | L | - |
| **CO 5** | S | S | S | S | S | M | L | S | - | - |

**S-Strong M-Medium L-Low**

| Subject Code | PHY E101 | | Elective |
|---|---|---|---|
| **Title of the Course:** | **LASER, NONLINEAR OPTICS AND INTEGRATED OPTICS** | | |
| **Credits:** | 3 | | |
| **Pre-requisites, if any:** | Interest to study basic optics and photonics, and problem solving ability. | | |
| **Course Objectives** | 1. Understand the principle, theory and working of various lasers.<br>2. Understand the principle, theory and applications of nonlinear optics.<br>3. Understand materials processing and medical applications of lasers.<br>4. Develop skills to deliver seminar on laser physics.<br>5. Create problem solving ability.<br>6. Carryout research in photonics & optoelectronics. | | |
| **Course Outcomes** | **Description** | | **Knowledge Level** |
| **On the successful completion of the course, student will be able to:** | | | |
| **CO1** | To explain the principles and properties of lasers, about pumping and energy levels of various types of lasers. | | **K1**<br>**K2** |
| **CO2** | To describe the theory of Gaussian beam optics, optical gain, threshold condition, Q-switching and mode-locking of lasers | | **K1**<br>**K2**<br>**K3** |
| **CO3** | To generalize the principle, working and fabrication of semiconductor lasers (homojunction and heterojunction lasers, VCSEL, Fibre Bragg Grating and Distributed Feedback laser). | | **K1**<br>**K2**<br>**K3**<br>**K5** |
| **CO4** | To conceptualize the basics of nonlinear optics and integrated optics. | | **K1**<br>**K2**<br>**K4** |

| | | |
|---|---|---|
| **CO5** | To employ knowledge on laser applications for materials processing, optical communications, biophotonics, biosensing and medicine.<br>To create problem solving skills in the laser topics. | **K1**<br>**K2**<br>**K4**<br>**K5** |
| | **Units** | |
| I | **Fundamentals of Lasers:**<br><br>Basic Properties of lasers, Stimulated Emission, Population Inversion, Einstein Coefficient, Gain Coefficient, Threshold Condition, Q-switching, mode locking – simple problems. | |
| II | **Solid state and Gas Lasers:**<br><br>Solid state and gas lasers: Ruby laser, Nd:YAG laser, He-Ne laser, Ar-ion laser, and CO2 laser – Working Principle – simple problems. | |
| III | **Semiconductor Lasers:**<br><br>Basic semiconductor theory, semiconductor laser principle, VCSEL, distributed-feedback (DFB) laser, distributed Bragg reflection (DBR) laser, high power diode lasers, Quantum dot lasers, diode end-pumped lasers. | |
| IV | **Nonlinear Optics and Integrated Optics:**<br><br>Basic Nonlinear Optics, Classical Theory, Second Harmonic Generation (SHG), Birefringence, Phase matching, Pockels effect, Kerr effect, Nonlinear optical crystals, Solitons; Basics Integrated Optics, Waveguide fabrication,Waveguide loss Measurement by End-fire coupling and Prism Coupling. | |
| V | **Laser Applications:**<br><br>Laser applications in materials processing, optical communication, holography, biophotonics, bio-sensing and medicine. | |

| | |
|---|---|
| **Reading List (Print and Online)** | This advanced elective course requires text books based study and as well include research papers and reviews from scientific journals.<br>1. Laser Fundamentals: William T. Silfvast (Cambridge Univ. Press).<br>2. Lasers: Theory and Applications. Thyagarajan and A.K. Ghatak, (Springer Publications)<br>3. D.C. O'Shea, W.R. Callen & W.T. Rhodes. Introduction to Lasers and their Applications (Addison-Wesley).<br>4. Semiconductor Optoelectronic Devices: Pallab Bhattacharya<br>5. Integrated optics - Theory & Technology: R.G.Hunsperger,<br>6. Laser Material Processing: W.M.Steen, (Springer Verlag).<br>7. Biophotonics Concepts to Applications: Keiser, Gerd, (Springer)<br>**WebResources**<br>https://ocw.mit.edu/ (MIT OPEN COURSEWARE)<br>https://www.tos.rwth-aachen.de/go/id/gush/lidx/1 (GERMANY) |
| **Recommended Texts** | 1. Photonics and Lasers: An Introduction, Richard S. Quimby (John Wiley & Sons, Inc).<br>2. Lasers and Nonlinear Optics: B.B. Laud, (New Age International).<br>3. Fundamentals of Photonics- Saleh and Teich ( Wiley India)<br>4. Solid-State Laser Engineering, W.Koechner, (Springer)<br>5. Optoelectronics & Photonics: Principles & Practices, S.O. Kasap, (Pearson)<br>6. Optical Fiber Communications Principles and Practice, John M.Senior (Prentice Hall)<br>Introduction to Biophotonics. Paras N. Prasad. (Wiley) |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | S | S | L | S | S | S |
| **CO 2** | S | S | S | M | M | S | M | M | S | S |
| **CO 3** | S | S | S | M | S | M | L | S | M | S |
| **CO 4** | S | S | S | M | S | M | M | S | S | S |
| **CO 5** | S | S | S | M | L | M | L | S | S | S |

**S-Strong M-Medium L-Low**

| Subject Code | PHY E102 | Elective |
|---|---|---|
| **Title of the Course:** | **Nuclear Detectors and Techniques** | |
| **Credits:** | **2-1-0-3** | |
| **Pre-requisites, if any:** | UG level Physics | |
| **Course Objectives** | 1. To impart knowledge on the various types of radiation, their sources, and the mechanisms by which radiation interacts with matter<br>2. To recognise the concepts, such as electron-ion pair generation, recombination, drift and diffusion of charges, avalanche creation, and breakdown with necessary mathematics.<br>3. To understand the theories, methodologies, and technologies that are fundamental for the conceptual basis of radiation devices.<br>4. To introduce the working principles of different types of radiation detectors.<br>5. To gain knowledge on the aspects of design, development, and effective use of the detection devices. | |
| **Course Outcome** | **Description** | **Knowledge Level** |
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | Will **understand** the different types of interaction of nuclear radiation with matter | **K1<br>K2<br>K4<br>K5** |
| **CO2** | Will **realise** rapid advancements in theory and **applications** of radiation interactions and their measurements. | **K1<br>K2<br>K3** |
| **CO3** | Will **analyze** the basic principle, design and the use of gas-filled detectors | **K1<br>K2<br>K4<br>K5** |

| | | |
|---|---|---|
| **CO4** | Will **compare** and **contrast** the advantage of semiconductor detectors and how it overcomes the gas ionization chambers in modern technology. | **K1**<br>**K2**<br>**K4**<br>**K5** |
| **CO5** | Will **recognize** the employability of different electronic circuits in detectors, as signal processing is the heart of today's electronic radiation detectors<br><br>Will **apply** the knowledge for further study, research and application. | **K3**<br>**K4**<br>**K5**<br>**K6** |
| | **Units** | |
| **I** | **INTERACTION OF NUCLEAR RADIATION WITH MATTER**<br><br>Interaction of charged particles and Radiation with matter - Photon interactions with matter – Mechanism of charge production in detector media. | |
| **II** | **GAS FILLED IONIZATION DETECTORS**<br><br>Features governing behavior of Gas Ionization Detectors - Ionization Chambers - Proportional Counters - Geiger Muller Counters. | |
| **III** | **SEMICONDUCOR DETECTORS**<br><br>Interaction of Radiation with Silicon and Germanium - Semiconductor Properties - Physics of Semiconductor Detectors - lon-Implanted Detectors -<br>Position Sensitive Detectors - Anger camera - High purity germanium detectors - X-ray and gamma ray semiconductor detector spectrometers - Semiconductor detector applications - Particle Identification - X-ray spectroscopy - Compound semiconductor detectors – CdTe detectors - Hgl2 detectors. | |
| **IV** | **SCINTILLATION DETECTORS**<br><br>Scintillation mechanism and classification of materials - Mechanism of scintillation in Inorganic and Organic scintillators - Noble Gas scintillators - Factors affecting the performance of scintillation detectors - Detection efficiency of scintillation detectors - Photomultiplier tubes, channel electron multipliers and microchannel plates - Gamma ray spectrometry with NaI(Ti) detectors and BF3 counters. | |

| | |
|---|---|
| **V** | **NUCLEAR ELECTRONIC INSTRUMENT**<br><br>Detector bias supply - Delay Amplifiers Pre-Amplifiers -Linear Amplifier Fast/Slow coincidence circuit - Universal coincidence Circuit -<br>Delay generators - Pulse generators - Pulse amplifier -Pulse height, shapes and rise time for different detectors – Pulse shape discrimination - Pulse height analysis - Pulse height resolution and time resolution - Constant fraction discriminators - Time to amplitude converters – Fine gain and Offset control amplifiers -Single channel analyser - Multichannel devices for pulse height analysis - Nuclear ADC's - Counters and Timers – Contamination, Environmental and Area Monitors - Count rate meter. |
| **Reading List (Print and Online)** | 5. W. J. Price, Nuclear Radiation Detectors, McGraw-Hill, 1964.<br>6. G. F. Knoll, Radiation Detection and Measurement, Third Edition-Wiley (2000)<br>7. S. S. Kapoor and V. S. Ramamurthy - Nuclear Radiation Detectors, Wiley Eastern Limited, 1986.<br>8. Nicholson - Nuclear Electronics, 1974.<br>9. Dearnaley and D. C. Northrop, Semiconductor Counters for Nuclear Radiation, 1964.<br>10. Syed Naeem Ahmed, Physics and Engineering of Radiation Detection, Academic Press, 2007. |
| **Recommended Texts** | 1. J. M. Taylor, Semiconductors particle detectors, Butterworth, 1963.<br>2. B. Rossi and H. H. Staub, Ionization chambers and counters, 1949.<br>3. J. B. Birks, Scintillation counters, 1953.<br>4. A. K. Shell, Nuclear Instruments and their uses, John Wiley, 1960.<br>5. EPJ Nuclear Sci. Technol.Volume 3, 2017, Nuclear instrumentation and measurement: a review based on the ANIMMA conferences (Journal) |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CO 1 | M | - | M | - | S | - | L | L | M | M |
| CO 2 | S | M | M | L | L | S | S | L | S | L |
| CO 3 | M | M | S | S | S | M | M | S | S | M |
| CO 4 | S | S | M | M | S | S | L | L | M | M |
| CO 5 | S | M | M | S | M | L | L | M | M | S |

**S-Strong M-Medium L-Low**

| Subject Code | PHY E103 | Elective |
|---|---|---|
| Title of the course | **Electronic Communications** | |
| Credits | 03 | |
| Pre-requisites, if any: | Elementary level Electronics or Physics. | |

**Course Objectives:**

1. Fundamentals of transmission, Wave dynamics.
2. Introduction to Wave guides, TE, TM , TEM waves, Challenges in propagation & Attenuation, Effect of Antennas.
3. Working principle of Resonators, Microwave devices, Diodes & device measurement techniques.
4. Basics of Satellite communications, Working of Transponders & devices, Uses Uplinks & digital carrier transmission.
1. Introduction to Mobile communication, Cellular network protocols, architecture, design. Optimization of cellular networks, Interfaces, Brief analysis of types of cellular networks, ad-hoc configurations.

**Course Outcomes:**

**On the successful completion of the course, student will be able to:**

| | | |
|---|---|---|
| **CO1** | Understand the working of transmission networks. | K3. |
| **CO2** | Evaluate network devices & their working protocols. | K2, K3. |
| **CO3** | Identify & Understand Microwave devices & analyse their measurement data. | K3 |
| **CO4** | Advanced knowledge of satellite communication technology. | K4 |
| **CO5** | Advanced understanding of Modern Mobile devices & working design. | K4 |

**Units**

| | |
|---|---|
| **I** | **Propagation of waves and Transmission lines:** Fundamentals of electromagnetic waves - Power density – Electric field strength – Ground waves – Sky waves – Radio horizon – Ionospheric layers – Skip wave – Space waves - Fundamentals of transmission lines – Characteristics of impedance losses in transmission line – standing waves – Reactance properties of transmission lines |

| | |
|---|---|
| | – Smith chart . |
| II | **Wave Guides, Antennas and Resonators :**Wave Guides -Attenuation in parallel plane guides – Attenuation for TE waves, TM waves and TEM waves – Rectangular and Circular wave guides- Field configurations for dominant TM and TE modes - Wave guide couplings matching and attenuation – Cavity resonator.<br>Basic considerations of antennas - Wire radiators in space - antenna parameters – Effect of ground on antennas – Different types of antennas – Impedance matching to antenna – Directional high frequency antennas - Microwave antennas - Wideband, Special purpose antennas - Antenna arrays. |
| III | **Microwave Devices :**Cavity resonators, Multicavity and Reflex klystrons - Cavity magnetron - Traveling wave tube - Circulators, Magic TEE and Hybrid rings – Microwave diodes and Field-effect transistors: Parametric amplifiers, Tunnel diodes, Gunn diodes, PIN diodes and Schlocky diodes.<br>Measurements of Impedance, frequency, Power, VSWR, Q factor, dielectric constants and S-parameter. |
| IV | **Satellite Communications** Introduction – Kepler's Laws – Geostationary orbit – Power systems – Attitude Control – Satellite Station keeping – Antenna Look Angles – Limits of visibility – Frequency plans and polarization – Transponders – Uplink power budget calculations – Down link power budget calculations – Overall link budget – Digital carrier Transmission – Multiple-access Methods. |
| V | **Mobile communication**: Evolution of Mobile communication - Multiplexing - Modulation - Spread spectrum & hopping - fading and Doppler spread - Cellular systems - Medium access control - Principles of SDMA, FDMA, TDMA & CDMA and their comparison - GSM - Radio interface - Localization and calling - Handover - Security & Authentication - GPRS - Protocol architecture - UMTS & IMT-2000 - Mobile IP - IP packet delivery - Optimization - Dynamic host configuration Protocol - Mobile ad-hoc networks. |
| **Text Book(s)** | |

1. G. Kennedy, **Electronic Communication Systems,** *3rd Ed., McGraw Hill.*
2. Louis E. Frenzel, 2008, **Principles of Electronic Communication systems**, *3rd Ed., Tata-McGraw-Hill, New Delhi.*
3. E. C. Jordan and K. G. Balmain, 1995, **Electromagnetic Waves & Radiating Systems,** *2nd Ed., Prentice-Hall of India, New Delhi.*
4. John D Kraus, **Antennas**, *McGraw Hill, 2002.*
5. Jochen H. Schiller, **Mobile Communication,** *Pearson Education, 2004.*

**Reference Books**

1. David K Cheng, **Field and wave electromagnetic**, *Addision Wesley*, New Delhi, 1999.
2. E.C. Jordan and G.K. Balman, **Electromagnetic waves and Radiating Systems**, *Printice Hall*, 1995.
3. Taub and Shilling, **Communication systems**, *McGraw Hill*
4. K.C. Gupta, **Microwaves**, *Wiley Eastern* Ltd., 1995.
5. John D Ryder, **Networks lines and Fields,** *Printice Hall of India, 2000.*
6. A. Amsaveni, **Antennas and Wave Propagation**, *Anuradha Publications, 2006.*

**MAPPING – Course Outcome (CO) with Program Outcome (PO)**

| CO/PSO | PO 1 | PO | PO | PO | PO | PO | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | S | L | L | S | S | L |
| **CO 2** | S | S | S | S | M | S | M | S | S | S |
| **CO3** | S | S | S | S | S | M | L | S | S | M |
| **CO 4** | S | S | S | S | S | S | M | S | S | M |
| **CO 5** | S | S | S | S | S | S | S | S | S | S |

**S-Strong M-Medium L-Low**

<table>
<tr><td>Subject Code</td><td>UOM S001</td><td colspan="2">Soft Skill</td></tr>
<tr><td>Title of the course</td><td colspan="3">Error Analysis for Physical Sciences</td></tr>
<tr><td>Credits</td><td colspan="3">02</td></tr>
<tr><td>Pre-requisites, if any:</td><td colspan="3">None</td></tr>
<tr><td colspan="4">Course Objectives:</td></tr>
<tr><td colspan="4">1. To gain fundamental practice in analyzing errors involved in physical measurements.<br>2. To understand the various error measurement techniques and statistical distributions in experiments including nuclear physics, optical physics and condensed matter physics<br>3. To equip students to report their research outcomes with standard error analysis.<br>4. To emphasize equipment care and safety during practical courses.</td></tr>
<tr><td colspan="4">Course Outcomes:</td></tr>
<tr><td colspan="4">On the successful completion of the course, student will be able to:</td></tr>
<tr><td>CO1</td><td colspan="2">Familiarize the safety handling of various instruments. Demonstrate safety protocols to students. Emphasize the importance of significant figures. Learn and estimate error calculation in various experiments</td><td>K1<br>K2<br>K3<br>K4<br>K5<br>K6</td></tr>
<tr><td>CO2</td><td colspan="2">Introduce various statistical distributions and histrogram. Evaluate standard deviation in physical measurements.</td><td>K1<br>K2<br>K3<br>K4<br>K5</td></tr>
<tr><td>CO3</td><td colspan="2">Know about various fitting techniques. Practice the linear and non-linear fitting wizard with origin and matlab. Emphasize the importance of least square fitting.</td><td>K1<br>K2<br>K3<br>K4<br>K5</td></tr>
<tr><td colspan="4" align="center">Units</td></tr>
</table>

| | |
|---|---|
| **I** | **Instrument handling and Error analysis:** Errors as uncertainties-Importance of knowing the uncertainties-Estimating uncertainties-How to report and use uncertainties-Significant figures-Comparison of measured and accepted values-Propagation of uncertainties-Sums and differences; products and quotients-Examples-General formula for error propagation. |
| **II** | **Statistical analysis of random uncertainties:** Random and systematic errors, Mean and standard deviation, Standard deviation of the mean, Examples-Systematic errors -Normal Distribution-Histogram-Acceptability of a measured answer |
| **III** | **Data Analysis and fitting techniques:** Rejection of data-Weighted-average-The problem of combining separate measurements-Least square fitting-Covariance and correlation-Binomial distribution and its application-Poisson distribution and its application, chi-square fitting. |
| **Reading List (Print and Online)** | 1. John R. Taylor, An introduction to error analysis: The study of uncertainties in physical measurements, Ed-II, University science books (California), 1997. |
| **Text Book(s)** | |
| 1. G. L. Squires, Practical Physics, Ed-4, Cambridge University Press, 2001. | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | M | S | S | S | S | L | L | S | M | S |
| **CO 2** | M | S | S | S | M | L | M | S | M | S |
| **CO 3** | M | S | S | S | S | L | L | S | M | S |

**S-Strong M-Medium L-Low**

| Subject Code | PHY C105 | Core |
|---|---|---|
| Title of the Course: | MOLECULAR PHYSICS AND SPECTROSCOPY | |
| Credits: | 4 | |
| Pre-requisites, if any: | Physics, Chemistry and Materials Science Students. | |
| Course Objectives | 1. Understand the basic theories of atomic and molecular spectroscopy.<br>2. Understand the principle of various spin resonance spectroscopy.<br>3. Understand the basic theories of fluorescence spectroscopy, laser spectroscopy and Raman Spectroscopy.<br>4. Understand the basic instrumentation of various spectrometers.<br>5. Develop problem solving skills in spectroscopy.<br>6. Provide interest to pursue research in optical spectroscopy. | |
| **Course Outcome** | **Description** | **Knowledge Level** |
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | The course describes the theory of Atomic spectra and Molecular Spectroscopy of molecules and Spin Resonance Spectroscopy (NMR, ESR, NQR and Mossbauer spectroscopy). It explains the theory of hyperfine splitting of spectra based on the electron-electron and electron-nuclear charge distribution interaction. | **K1**<br>**K2**<br>**K3**<br>**K5** |
| **CO2** | The course explains the fundamental concepts of light-matter interaction related to atomic and molecular spectroscopy. Also explains fluorescence spectroscopy, laser spectroscopy, upconversion spectroscopy and Raman spectroscopy. | **K1**<br>**K2**<br>**K3**<br>**K5** |
| **CO3** | Course explain the instrumentation of UV-VIS-NIR spectrometer, steady state spectrofluorometer, Time Correlated Single Photon Counting system for Time-resolved fluorescence spectrometers, and these techniques will be useful for project research activities. | **K1**<br>**K2**<br>**K3** |

| | | |
|---|---|---|
| **CO4** | The course also outline about nanophosphor materials for luminescence applications | **K1**<br>**K2**<br>**K4** |
| **CO5** | students can use this knowledge for their research projects and as well as to higher research studies. | **K1**<br>**K2**<br>**K5**<br>**K6** |
| | **Units** | |
| I | **Atomic Spectra:** Hydrogen Atomic Orbitals Depend upon Three Quantum Numbers ; Spectroscopic terms; Fine and hyperfine structure of atoms, Selection rules, Lande g factor, L S and j j coupling schemes - examples, derivation of interaction energy; Normal and anomalous Zeeman effects; Paschen–Back effect in one electron system, Hund's rule; Lande interval rule; Hyperfine structure and width of spectral lines (qualitative ideas)<br><br>**Electronic Spectroscopy of molecules:** Electronic spectra of diatomic molecules, Progressions and sequences, Intensity of spectral lines, Franck – Condon principle, Dissociation energy. | |
| II | **Spin Resonance Spectroscopy**<br><br>**Nuclear Magnetic Resonance (NMR) Spectroscopy;** Basic Principles: Resonance Condition, Larmor precession; Spin-Lattice and Spin-Spin Relaxation Mechanisms; Chemical Shift, Coupling Constant; Experimental - Continuous Wave and FT NMR Spectrometer, Free Induction Decay; NMR Applications, Magic Angle Spinning; NMR - Simple Problems. | |
| III | **Electron Spin Resonance (ESR) Spectroscopy:** Basic Principles; ESR Instrumentation Details, Typical ESR Spectrum; Hyperfine Interactions; Prediction of Expected Number ESR Transitions, Crystal Field Effect - Kramers and John Teller principles Applications; ESR - Simple Problems.<br><br>**Nuclear quadrupole resonance (NQR) spectroscopy:** Fundamentals - Quadrupole nucleus, Quadrupole Moment, Electric Field Gradient; Quadrupole Coupling Energy Derivation; NQR Transition Frequencies for Symmetric and Asymmetric cases; Applications of NQR; NQR - Simple Problems. | |

| | |
|---|---|
| IV | **Mossbauer Spectroscopy:** Basics - Recoilless emission, Resonance Fluorescence, and Zero phonon emission, Mossbauer Isotopes (57Co and 119Sn Isotopes); Experimental Details, Doppler Velocity Shift; Hyperfine Interaction Details; Applications to Magnetism and Biology; Simple Problems. |
| V | **Laser Spectroscopy:**<br><br>Fundamentals of Laser; Laser sources in spectroscopy - Nd: YAG Laser, Argon-ion Laser, Diode Pumped Solid State Laser, Tunable Ti-Sapphire Laser; Q-switching and the generation of nanosecond pulses, Mode locking and the generation of picosecond and femtosecond pulses.<br><br>**Nonlinear Optics:** Non-linear crystal and frequency-mixing processes, Optical parametric oscillation spectroscopy, Upconversion spectroscopy, Raman Spectroscopy: Classical and Quantum Theory of Raman Effect; Raman Spectrometer Instrumentation and Applications.<br><br>**Spectrometer Instrumentation and Application:** UV-VIS-NIR spectrometer and its applications; Luminescence spectroscopy, Principle and applications, Jablonski diagram, Luminescent Nanophosphors; steady state spectrofluorometer; Fluorescence lifetime measurements, Time Correlated Single Photon Counting system for Time-resolved fluorescence spectrometers |
| **Reading List (Print and Online)** | 1. Introduction of Atomic Spectra, H.E. White, McGraw Hill<br>2. Spectroscopy (Vol. 2 & 3), B.P. Straughan & S. Walker, Science paperbacks 1976<br>3. Raman Spectroscopy, D.A. Long, McGraw Hill, 1977<br>4. Introduction to Molecular Spectroscopy, G.M. Barrow, McGraw Hill<br>5. Molecular Spectra and Molecular Structure Vol 2&3. G. Herzberg, Van Nostrand, London.<br>6. Elements of Spectroscopy, Gupta, Kumar & Sharma, Pragathi Prakshan.<br>7. Luminescent Materials and Applications, Adrian Kitai (Wiley) |

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|---|---|
| **Recommended Texts** | 1. Fundamentals of Molecular Spectroscopy, C.N.Banwell, (Tata McGraw Hill, Delhi)<br>2. Molecular Spectroscopy, (2017) Jeanne L. McHale (CRC Press)<br>3. Modern Spectroscopy (2004) J. Michael Hollas (Wiley)<br>4. Molecular Structure And Spectroscopy, Aruldhas,( Prentice Hall India Learning Private Limited)<br>5. Atomic & Molecular Spectra: Laser, Rajkumar, KNRN Publications, Delhi<br>6. Physical Chemistry, Atkins, Julio de Paula, James Keeler (2019) (Oxford University Press;)<br>7. Laser fundamentals: (1998) W. T. Silfvast (Cambridge University press,)<br>8. Lasers and Nonlinear Optics: B.B. Laud, (New Age International Ltd, Delhi).<br>9. Laser Chemistry: Spectroscopy, Dynamics and Applications, (2007) Helmut H. Telle, Angel González Ureña, Robert J. Donovan (Wiley)<br>10. Laser Spectroscopy: Basic Concepts and Instrumentation Demtroder Wolfgang, Springer Berlin Heidelberg.<br>11. Principles of Fluorescence Spectroscopy, (2006) Lakowicz, Joseph R. (Springer , US)<br>12. Instrumental methods of analysis, 7th edition, (2004) Willard, H H; Merritt, Jr, L L; Dean, J A; Settle, Jr, F A; (CBS Publishers & Distributors)<br>13. Principles of Instrumental Analysis, 6th Edition (2006) , by Douglas A. Skoog, F. James Holler , Stanley R. Crouch (Cengage Learning Publication) |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | S | S | S | S | S | S |
| **CO 2** | S | S | S | S | M | S | M | M | S | S |
| **CO 3** | S | S | S | S | M | S | M | S | M | S |
| **CO 4** | S | S | S | M | M | S | M | S | S | S |
| **CO 5** | S | S | S | S | M | S | S | S | S | S |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C106** | **Core** |
| **Title of the course** | Quantum Mechanics I | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | UG Level Physics | |
| **Course Objectives** | 1. Apply principles of quantum mechanics to calculate observables on known wave functions<br>2. To understand time-dependent and time-independent Schrödinger equation for simple potentials<br>3. Apply simple harmonic oscillator to solve simple problems<br>4. To interpret matrix formulation of quantum mechanics<br>5. To differentiate Schrödinger, Heisenberg and Interaction pictures | |
| **Course Outcome** | **Description** | **Knowledge Level** |
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | To Develop knowledge and understanding of the concept that quantum states in a vector space | **K1**<br>**K2** |
| **CO2** | To Solve quantum mechanics problems | **K4** |
| **CO3** | To Understand the approximate methods for solving time-dependent and time-independent problems | **K2**<br>**K4** |
| **CO4** | To gain the knowledge about fundamental quantum mechanical processes in nature | **K2**<br>**K3**<br>**K6** |
| **CO5** | To understand the various interaction pictures | **K1**<br>**K2** |
| **Units** | | |
| **I** | Schrodinger equation-Max Born's interpretation of wave function-Normalisation-scattering states and bound states-admissibility conditions for a quantum mechanical wave function-Equation of continuity and conservation of probability-Time independent Schrodinger equation-stationary eigenstates- | |

| | |
|---|---|
| | particle in a box-square well potential-Rectangular potential Barrier –tunnelling |
| **II** | Linear vector space-scalar product-Hilbert space-Linear operator-adjoint of an operator-self adjoint operator-eigenvalues and eigenfunctions-complete set-Dirac delta function-Postulates of quantum mechanics-commutation relations-compatible observables-Uncertainty relation-constants of motion-Ehrenfest theorem |
| **III** | Simple harmonic oscillator-Momentum eigenfunction-Box normalisation and delta function normalisation of momentum eigenfunction-Orbital angular momentum-Central potential-Radial probability-Boundary conditions for radial wave functions-Spherically symmetric square well-Hydrogen atom |
| **IV** | Dirac's bra ket vectors-abstract state vectors abstract operators-Hilbert space-Projection operator and Identity operator-Matrix Representation-Co ordinate and momentum representation-Harmonic oscillator using ladder operator method |
| **V** | Symmetries and Unitary transformations-Time evolution operator -Schrödinger, Heisenberg and Interaction pictures- Density matrix-Pure and mixed states-Identical particles and principles of indistinguishability-Symmetrisation Postulate-Pauli's exclusion principle |
| **Reading List (Print and Online)** | 1. P. M. Mathews and K. Venkatesan: A text book of Quantum Mechanics<br>2. L.I. Schiff: Quantum Mechanics (third edition)<br>3. Merzbacher: Quantum Mechanics (third edition)<br>4. Nouredine Zettili: Quantum Mechanics Concepts and Applications |
| **Text Book(s)** | |
| 1. J. L. Powell and B. Crasemann : Quantum Mechanics<br>2. Y. R. Waghmare: Fundamentals of Quantum Mechanics<br>3. W. Greiner : Quantum Mechanics. | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | M | S | M | L | L | M | M | S | M | M |
| **CO 2** | M | S | M | L | L | L | L | M | M | L |
| **CO 3** | M | S | S | M | L | M | M | S | M | M |
| **CO 4** | M | S | M | L | L | L | L | L | L | L |
| **CO 5** | M | M | M | M | L | L | L | L | L | L |

**S-Strong M-Medium L-Low**

<table>
<tr><td>Subject Code</td><td>PHY C107</td><td colspan="2">Core</td></tr>
<tr><td>Title of the course</td><td colspan="3">Electromagnetic Theory</td></tr>
<tr><td>Credits</td><td colspan="3">4</td></tr>
<tr><td>Pre-requisites, if any:</td><td colspan="3">Basic knowledge in Newton equation of motion, Simple harmonic motion</td></tr>
<tr><td colspan="4">Course Objectives:</td></tr>
<tr><td colspan="4">1. Understand the basic ideas of electrostatics and electrostatics in material media<br>2. Facilitates the understanding of the basic concepts on magnetostatics, vector potential and its applications.<br>3. Provides the students with an overview of electrodynamics including gauge transformation, energy conservation law in electrodynamics<br>4. Gives a view of the propagation of electromagnetic waves in different media.<br>5. Provides sufficient fundamental and theoretical knowledge on general and special theory of relativity, and transformation equations, relativistic dynamics.</td></tr>
<tr><td colspan="4">Course Outcomes:</td></tr>
<tr><td colspan="4">On the successful completion of the course, student will be able to:</td></tr>
<tr><td>Course Outcome</td><td colspan="2">Description</td><td>Knowledge Level</td></tr>
<tr><td>CO1</td><td colspan="2">Recall Gauss' Law, compare Poisson and Laplace equation, solve Laplace's equation for rectangular box, analyze multipole expansion of the potential due to a charge distribution, interpretation of boundary conditions.</td><td>K1<br>K2<br>K3<br>K4<br>K5</td></tr>
<tr><td>CO2</td><td colspan="2">What is magnetic vector potential, apply it for the determination of magnetic field of a localized current distribution, explain magnetic induction and magnetic field in macroscopic media analyze magnetic field of a uniformly magnetized sphere.</td><td>K1<br>K2<br>K3<br>K4<br>K5</td></tr>
<tr><td>CO3</td><td colspan="2">Recall Faraday's law of Induction, interpret Maxwell's displacement current, outline Vector and Scalar potentials, importance of Maxwell's correction to Ampere's law, analyze Lorentz force in terms of potentials.</td><td>K1<br>K2<br>K3<br>K4</td></tr>
</table>

| | | |
|---|---|---|
| **CO4** | **Explain** the propagation of electromagnetic waves in matter, **apply** for the Propagation of em wave in linear media, **analyze** reflection and transmission at normal and oblique incidence, **interpret** retarded potential. | **K2**<br>**K3**<br>**K4**<br>**K5** |
| **CO5** | **Explain** the oscillation of electric dipole, **recall** special theory of relativity, **apply** tensors in electrodynamics, **interpret** Lorentz covariance | **K1**<br>**K2**<br>**K3** |

| **Units** | |
|---|---|
| **I** | **Electrostatics:** Gauss' Law, Poisson and Laplace equation, Green's theorem, Green's functions, potential with Dirichlet and Neumann boundary conditions, solution of Laplace's equation in a rectangular box, solution by separation in spherical polar coordination's. Multipole expansion of the potential due to a charge distribution. Electrostatics in material media: electric displacement vector, boundary conditions, dielectric sphere in a uniform filed, molecular polarisbility and electrical susceptibility, Electrostatic energy in dielectric media. |
| **II** | **Magnetostatics:** Magnetic vector potential and magnetic field, of a localised current distribution, magnetic moment, force and torque on a current distribution in an external magnetic field, magnetostatic energy, magnetic induction and magnetic field in macroscopic media, boundary conditions, uniformly magnetised sphere. |
| **III** | **Electrodynamics:** Faraday's laws of induction, Maxwell's displacement current, Maxwell's equations. Poynting's theorem, vector and scalar potentials, gauge invariance, Coulomb and Lorentz gauges, Lorentz force, equation of continuity. |
| **IV** | **Electromagnetic Waves**: Plane electromagnetic waves: propagation in a nonconducting medium, reflection and refraction at a plane interface between dielectrics, polarisation by reflection and total internal reflection, waves in a conducting media, Propagation of e.m waves in rectangular wave guides. |
| **V** | **Radiation and Special Theory of Relativity**: Radiation from an oscillating electric dipole, multipole radiation. Tensors and Lorentz covariance of Electrodynamics. |

| | |
|---|---|
| **Reading List (Print and Online)** | 1. Electromagnetic waves, Relativity and Electrodynamics, Prof. Amol Dighe, IIT Bombay https://nptel.ac.in/courses/115/101/115101004/<br>2. Maxwell's equations and electromagnetic waves, Prof. Partha Roy Choudhuri, IIT Kharagpur https://nptel.ac.in/courses/115/105/115105104/<br>3. Electromagnetic theory, Dr. K. Pradeep Kumar ,IIT Kanpur https://nptel.ac.in/courses/108/104/108104087/<br>4. Introduction to Electromagnetic Theory, Prof. Manoj K Harbola, IIT Kanpur https://nptel.ac.in/courses/115/104/115104088/<br>5. Electromagnetic Theory, Prof. D.K. Ghosh, IIT Bombay https://nptel.ac.in/courses/115/101/115101005/ |

**Text Book(s)**

1. D.J.Griffiths, Introduction to Electrodynamics,3rd Edition, Prentice – Hall of India, New Delhi, (2002)
2. J.D.Jackson, Classical Electrodynamics, Wiley Easter Ltd, New Delhi, (1975)

3.Walter Greiner, Classical Electrodynamics, Springer, (1996)

4. P. Lorrain and D. Corson, Electromagnetic Fields and Waves. CBS Publishers and Distributors (1986).

5.Edward. M. Purcell, Electricity and Magnetism, McGraw-Hill (1985).

4.E.C. Jordan and K.G. Balmain, Electromagnetic Waves and Radiating Systems, PHI, New Delhi, (2015)

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | L | - | L | M | L | L | M | L | L |
| **CO 2** | S | L | - | - | L | - | - | L | - | L |
| **CO 3** | S | L | L | - | M | L | M | S | L | L |
| **CO 4** | S | L | - | M | L | - | - | M | L | - |
| **CO 5** | M | S | - | - | L | M | L | S | - | - |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C108** | Core |
| **Title of the course** | **General Practical –II**<br>**(Part A: Nuclear Physics)** | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Elementary Nuclear Physics. | |
| **Course Objectives:** | | |

1. Fundamental understanding of radiation attenuation and Gamma Ray spectrometer.
2. Understand Working principle behind Counters, practical usage of Greiger Muller Counter.
3. Handling Nuclear measurement equipment such as Dosimeters & spectrometers with working knowledge.
4. Practical analysis of radiation sources, Identification of types of radiation sources through Instrumentation.
5. To equip & effectively encourage the students to take up careers at Nuclear physics and radiation research establishments.

*Note: At the end of the course students will be able to set and perform the experiment, collect the data, properly document the procedures, analyze the data, identify the errors, interpret the results and correlate it with relevant applications in Nuclear physics.*

**Course Outcomes:**

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | To provide the experimental, technical and analytical skills on Gamma ray spectroscopy, Beta spectroscopy. | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| **CO2** | To provide in-depth knowledge on Nuclear spectroscopy techniques, detectors & their working principles, working of radiation counters. | **K1**<br>**K2**<br>**K5** |
| **CO3** | To enable the students for developing practical skills on handling Nuclear spectroscopy instrumentation. | **K1**<br>**K2**<br>**K3** |

| | | |
|---|---|---|
| | | **K4**<br>**K5** |
| **CO4** | To develop skills for accurate measurement of data, analysis and interpretation of results and report writing with dedication sincerity. | **K1**<br>**K2**<br>**K4**<br>**K5** |
| **CO5** | To develop research skills by doing experiments related to identifying types of radiation sources, radiation levels and optimization of sources. | **K2**<br>**K4**<br>**K5** |
| **Units** | | |
| 1 | **Gamma Ray Spectrometer : Characteristics**<br>To determine the best operating voltage of the gamma ray spectrometer & resolutions. | |
| 2 | **Calibration of Gamma Ray Spectrometer**<br>Energy calibration of the gamma ray spectrometer for different gamma source and to find the energy of the unknown gamma source | |
| 3 | **Geiger-Muller counter Characteristics**<br>To find the best operating voltage and to find the dead time, resolving time of the GM counter. | |
| 3 | **Energy calibration & Resolution of detector using MCA**<br>To determine the best operating voltage & resolution of the of Multi Chanel Analyser (MCA). To compare energy and intrinsic peak efficiency of the radioactive source. | |
| 4 | **Mass Attenuation coefficient of different materials using Gamma spectrometer**<br>To determine mass attenuation coefficient of different shielding materials using Gamma ray spectrometer. | |
| 5 | **Determination of strength of Source using Gamma Ray spectrometer.**<br>To determine strength of monochromatic source using gamma ray spectrometer. | |
| 6 | **Determination of Half-Value thickness and Full Value thickness using Dosimeter**<br>To determine half-value thickness and tenth value thickness of the given absorbers. | |
| 7 | **Determination of back scattering & absorption factor Gamma & Beta rays Using GM Counter**<br>To calculate backscattering factor & absorption of various shielding materials for gamma and beta ray sources using GM counter. | |

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| 8 | **Feather's Analysis using Geiger Muller counter**<br>To determine range of beta rays of unknown energy using known energy by Feather's analysis. |
| 9 | **Determination of strength of Source & energy of Gamma sources using MCA**<br>To determine energy and strength of unknown gamma source using MCA |
| 10 | **Determination of Half-Value thickness & Full Value thickness using GM counter**<br>To determine half-value thickness and tenth value thickness of the given absorbers. |
| 11 | **Fermi-Kurie plot using Gamma Ray spectrometer.**<br>To determine end point energy of beta rays emitted by the source using FK plot. |
| **Reading List (Print and Online)** | The practical course requires various book materials, articles and e-links.<br><br>Practical Gamma-Ray Spectrometry, 2nd Edition, Gordon R. Gilmore.<br>http://experimentationlab.berkeley.edu/sites/default/files/writeups/GMAf<br>Knoll, G, Radiation Detection and Measurement, Chapters 2 and 10. |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | S | M | L | M | L | L |
| **CO 2** | M | M | S | S | S | M | L | L | S | S |
| **CO 3** | S | S | S | M | S | L | M | S | S | L |
| **CO 4** | S | M | M | M | S | S | L | M | L | S |
| **CO 5** | S | S | S | S | S | M | S | S | S | S |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C108** | Core |
| **Title of the course** | **General Practical –II<br>(Part B: Optics & Spectroscopy, Materials Analysis)** | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Basic knowledge on optics, lasers and spectroscopy | |

**Course Objectives:**

1. Students will understand the fundamental concepts about Gaussian beam characteristics of LASER, optics and spectroscopy.

2. Student will understand the concept of optical absorption and emission by working with research based spectrometer instruments.

3. Working with nanomaterials and handling of spectrometer equipments will help students for their future research carrier.

4. Student will understand the principle of Silicon solar cells, measurement of I-Characteristics and device parameters;

5. To encourage students for higher research career.

Note: At the end of the course students will be able to set and perform the experiment, collect the data, properly document the procedures, analyze the data, identify the errors, interpret the results and correlate it with relevant applications in physics.

**Course Outcomes:**

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | To provide the experimental, technical and analytical skills on laser, optics and spectroscopy based physics experiments. | **K1<br>K2<br>K3<br>K4<br>K5** |

| | | |
|---|---|---|
| **CO2** | To provide in-depth knowledge on laser, optics and spectroscopy experiments based on the concepts of diffraction, interference, polarization and absorption and emission of light. | **K1**<br>**K2**<br>**K5** |
| **CO3** | To enable the students for developing practical skills on the optical alignment and electrical circuitry of simple experiments. | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| **CO4** | To develop skills for accurate measurement of data, analysis and interpretation of results and report writing with dedication sincerity. | **K1**<br>**K2**<br>**K4**<br>**K5** |
| **CO5** | To develop research skills by doing experiments with nanomaterials, UV-VIS spectrometer and Spectrofluorometer and solar cell. | **K2**<br>**K4**<br>**K5** |
| | **Units** | |
| **1** | **Laser beam parameters**<br>**Determination of laser beam spot size, divergence, $M^2$ parameter.**<br>To understand the concept of Gaussian Beam Optics<br>To study the near field pattern and far field pattern of a laser beam<br>To study the Knife Edge Method of determining Laser Beam Diameter | |
| **2** | **Polarization of light and Malus' Law**<br>**Study of Polarization of light and verification of Malus's law**<br>To understand the concepts of optical polarization.<br>To study the optical polarization effect on intensity variation of light.<br>https://www.scielo.br/j/rbef/a/ddC3XKMkGPmPLQSNSz6pfkQ/?lang=en | |
| **3** | **Fabry-Perot interferometer**<br>**Study of Fabry-Perot interferometer by multiple beam interference**<br>To understand the principle of light waves.<br>To study the theory of interference of light by FP Etalon.<br>To determine the thickness, resolution and Fineness of Etalon.<br>To determine the wavelength separation of the Sodium lines.<br>To study applications of FP Etalon in Zeeman Effect and Astrophysics. | |

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| **4** | **Farady effect and optical rotation**<br><br>**Determination of Verdet constant by Faraday Effect optical rotation**<br><br>To study the interaction of light with matter in magnetic field.<br>To study the effect of optical rotation of materials under magnetic field. |
| **5** | **Planck's constant**<br><br>**Determination of Planck's constant and work function of metals using photoelectric effect**<br>To study the principle of photoelectric electric effect and determine Planck's constant by measuring stopping potential at different frequencies of light and determine the work function of Cesium metal. |
| **6** | **Bromine/Iodine Absorption Spectra**<br><br>**Determination of spectroscopic parameters of Bromine molecule by using a simple prism spectrometer, Grating and Bromine Cell**<br><br>To understand the vibrational spectroscopy of diatomic molecule.<br>To understand anharmonic oscillator, Frank Condon Principle and Birge - Sponer Plot<br><br>To determine the fundamental frequency, Zero point energy, dissociation energy, anharmonicity constant and force constant of diatomic molecule by using a grating spectrometer and bromine vapor. |
| **7** | **Metal Arc Emission Spectra**<br><br>**Study of emission spectra of metals using constant deviation spectrometer and determination of wavelengths of spectral lines of metal arc using Hartmann formula.**<br><br>To record the spectral lines of metal arc in a photographic film/digital image using constant deviation spectrometer and estimation of the unknown wavelength of the corresponding spectral lines.<br><br>To determine the wavelength of unknown spectral lines by Hartmanns formula and by forming the Deslanders Table. |

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| **8** | **UV-visible spectrophotometer**<br><br>Determination of energy band gap of silver and gold nanocolloids and $TiO_2$ nanoparticle from absorption spectrum using UV-VIS spectrometer<br><br>To study the optical absorption and verification of Beer-Lambert's Law<br>To find the optical absorption wavelength of nanomaterials.<br>To find out the unknown concentration of the sample. |
| **9** | **UV-visible spectrophotometer**<br><br>To study the photocatalytic degradation behavior of nanomaterials<br>To understand the physics and chemistry of photocatalytic reactions<br><br>To explore the influence of UV irradiation intensity on the photocatalytic degradation of methylene blue dye molecule by using the wideband semiconductor $TiO_2$ and ZnO Nanoparticles. |
| **10** | **Solar Cell Characteristics**<br>**To study the principle and working of solar cells and determination of the power conversion efficiency from device parameters.**<br><br>To study the I-V characteristics of Si solar cell and measure the device parameters such as open circuit voltage, short circuit current and fill factor for estimating the efficiency by using Keithley PicoAmmeter.<br><br>To study the (I-V) characteristics of a solar photovoltaic (PV) module in the laboratory by using high power LED array or 100 W bulb as light source, Voltmeter, Ammeter, Variable Resister and Pyrometer, and to determine the operating conditions such as Open circuit voltage, Short circuit current, Maximum power point and to determine the Fill Factor and Efficiency of a Solar PV module. |
| **11** | **Research spectral data analysis: Photoluminescence**<br><br>To analyze the Photoluminescence spectrum of nano phosphors.<br><br>Hands on training will be provided by utilizing facilities available at the University central instrumental laboratory facility. |
| **12** | **Research spectral data analysis: Raman Spectra**<br><br>To analyze the Raman Spectrum of Carbon allotropes and chemical functionalized nanomaterial samples of biological interest.<br><br>Hands on training will be provided by utilizing facilities available at the University central instrumental laboratory facility. |

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| **13** | **Research spectral data analysis: FTIR**<br><br>To analyze FTIR spectrum of nanomaterial samples prepared at heat treat treatment conditions and functionalized with chemical molecules.<br><br>To identify the chemical functional groups and interpret it for optical applications. |
| **14** | **Hall Effect:**<br>**Determination of hall voltage, hall coefficient, hall angle and charge carrier concentration of the given semiconductor.**<br><br>To study the principle of semiconductor and hall effect of materials<br><br>To study the effect of applied magnetics and electric field direction on the charge carrier drift, mobility, and hall coefficient of p-type or n-type semiconductors. |
| **Reading List (Print and Online)** | The practical course requires various book materials, articles and e-links.<br>**Laser and optics**<br>A multimedia interactive guide: http://www.laboratoryoptics.com/About.html<br>Laboratory Optics: A practical guide to working in an optics lab,<br>by Peter T. Beyersdor<br>Laboratory Manual for Physics of Lasers and Modern Optics,<br>Stephen Ducharme, DigitalCommons@University of Nebraska - Lincoln.<br>Optics Experiments and Demonstrations for Student Laboratories,<br>Stephen G Lipson, IOP Publishing Ltd 2020, Online ISBN: 978-0-7503-2300-0<br>Experimental optics: a manual for the laboratory,<br>by G. F. C. Searle, Cambridge University Press, reissue edition.<br>Low-cost nonlinear optics experiment for undergraduate instructional laboratory and lecture demonstration, Rozane de F. Turchiello, et al.,)<br>American Journal of Physics 85, 522 (2017); https://doi.org/10.1119/1.4984808<br>Understanding the concept of resolving power in the Fabry–Perot interferometer using a digital simulation, I Juvells , A Carnicer, J Ferre-Borrull,E Mart´ın-Badosa and M Montes-Usategui, Eur. J. Phys. 27 (2006) 1111–1119, DOI:10.1088/0143-0807/27/5/010<br>Malus Law<br>https://www.scielo.br/j/rbef/a/ddC3XKMkGPmPLQSNSz6pfkQ/?lang=en<br>UV VIS and Spectrofluorometer, FTIR, RAMAN<br>Instrumental Analysis Manual.pdf - La Salle University |

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|---|---|
| | A Laboratory Course in Nanoscience and Nanotechnology<br>By Gerrard Eddy Jai Poinern<br>Published March 31, 2021 by CRC Press; ISBN 9780367783679<br>Spectrochemical Analysis: Ingle and Crouch,. PrenticeHall.<br>Spectrochemical Analysis by Atomic Absorption and Emission, 2nd Edition<br>Lajunen and Peramaki, ISBN: 9780854046249,0854046240, RSC publ.<br><br>FTIR<br>Introduction to Experimental Infrared Spectroscopy: Fundamentals and Practical Methods<br>Mitsuo Tasumi (Editor) ISBN: 978-0-470-66567-1 November 2014 (Wiley)<br>Practical Undergraduate Instrumental Analysis Laboratory Experiments<br>by N.H. Chen (Author) ISBN-13: 978-0615742526<br>Solar Cell<br>Sukhatne S. P. Solar Energy Conversion, Tata McGraw-Hill Education, 1996,<br>Iodine Spectra<br>Absorption spectra of Iodine vapor – an experiment. S.George and N.Krishnamurthy, Am.J.Physics, Vol.57, No.9, Sept 1989,<br>https://www.tau.ac.il/~phchlab/exp-laser-fluorescence-procedure.html<br>**PHYWE Systeme GmbH, Germany (Scientific Instrument Makers)**<br>https://www.phywe.com/physics/light-and-optics/<br>**LEYBOLD Germany (Scientific Instrument Makers)**<br>https://www.leybold-shop.com<br>Solar Cell:<br>https://www.pveducation.org/pvcdrom/solar-cell-operation/open-circuit-voltage<br>**Simulation of optical experiments and Python programming**<br>https://opticspy.github.io/lightpipes/index.html |
| **Text Book(s)** | |
| Practical Physics, G. L. Squires (Cambridge University Press)<br>A Course of Experiments with He-Ne Laser, R. S. Sirohi, (New Age International)<br>Fundamentals of Optics, Francis Jenkins and Harvey Elliott White, McGraw Hill Education<br>Basics of INTERFEROMETRY, Second Edition, P. HARIHARAN (University of Sydney, Australia) Elsevier Academic Press | |

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| Photonics and Lasers: An Introduction, Richard S. Quimby, (Wiley publication)<br>A Practical Guide to Handling Laser Diode Beams,<br>Haiyin Sun, Springer, (DOIhttps://doi.org/10.1007/978-94-017-9783-2) |


**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | S | L | L | M | L | L |
| **CO 2** | S | S | S | S | S | - | - | L | - | L |
| **CO 3** | S | S | S | M | S | L | M | S | L | L |
| **CO 4** | S | S | S | M | S | - | - | M | L | - |
| **CO 5** | S | S | S | S | S | M | L | S | - | - |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY E104** | Elective |
| **Title of the course** | Radiological Safety Aspects | |
| **Credits** | 3 | |
| **Pre-requisites, if any:** | Elementary level Physics. | |

**Course Objectives:**

1. Introduce Radioactivity and Elementary processes involved in Ionizing Radiation.
2. To understand the working principle behind detectors and dosimeters, their limits and capabilities.
3. Analyse & effectively calculate parameters for radiation dosage, exposure units, Optimized levels & Shielding.
4. To know the role of Radiological Safety Officers & emergency procedures on spillage control and Radioactive waste disposal methods & techniques.
5. To analyze and work on Laboratory design for radiation experiments and methods for safe transportation of radioactive materials.

**Course Outcomes:**

| **Couse Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | Gain understanding of types of Ionizing radiation, calculate the properties of Ionizing radiation & their behaviour through matter. | **K2** |
| **CO2** | Analyze various types of detectors and their effective detection range. | **K3** |
| **CO3** | Calculate dose levels, exposure levels of radiation, thickness of shielding materials, optimization of protection guards | **K4**<br>**K5** |
| **CO4** | Role of Radiological Safety Officers, emergency procedures & control of radioactivity and radioactive waste disposal methods & techniques | **K4** |
| **CO5** | Develop Laboratories, design principles and planning of radioactive transportation | **K6** |

**Units**

| | |
|---|---|
| **I** | **RADIATION PHYSICS:** Introduction to Radioactivity – Radioactive disintegration – Properties of nuclear radiation – Decay & half-life – type of decay - Interaction of Ionizing radiation with Matter – interaction of charge particles – Electromagnetic interactions – Photoelectric absorption – Compton scattering - Attenuation of Gamma radiation in matter – Biological effects: Radiation damage - Molecular level & Cellular level – Deterministic effects – Stochastic effects. moment- Quadrupole moment –S and D state admixtures - Effective range theory. |
| **II** | RADIATION DETECTION : Detectors & Monitoring Instruments: Gas Filled Detectors: GM counter & Proportional Counter - Scintillation Detectors – Semiconductor Detectors - Radiation survey meters – Beta & Gamma detection - Neutron detector - Thermo-Luminescent dosimeters. |
| **III** | PRINCIPLES OF RADIOLOGICAL PRODTECTION, HAZARDS EVALUATION & CONTROL: Radiation Quantities and Units - Dose, equivalent dose and effective dose – ALI & DAC Radiological protection – Optimization of protection – Dose limits for radiation workers – internal exposure, Occupational exposure and members of public - Occupational exposure levels - Radiation hazards evaluation - Specific Gamma constant - Principles to control external hazards - Radiation shield – half-value thickness – Tenth value thickness. |
| **IV** | RADIOACTIVE DECAYS: Alpha decay - Beta decay – Energy release in beta decay –Fermi theory of beta decay – Shape of the beta spectrum – decay rate Fermi-Curie plot – Fermi & G.T Selection rules - Comparatives half - lives and forbidden decays-Gama decay - Multipole radiation – Angular momentum and parity selection rules – Internal conversion – Nuclear isomerism. |
| **V** | PLANNING OF ISOTOPE LABORATORIES & TRANSPORT OF ISOTOPES: Calcification of radioisotopes – Types of radioisotope laboratories – Design of radioisotope lab. - Specifications & requirements - types of operations – Transport of radioisotopes – Condition for transport – selection of package & design requirements – types of package - safety aspects of transport. |

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|---|---|
| **Reading List (Print and Online)** | 1. 1.Glenn F. Knoll 'Radiation Detection and Measurement', John wiley& sons Inc.<br>2. 2.Training course material on 'Safety Aspects in Ionizing Radiation' by Indian Association for Radiation Protection.<br>3. http://www.fisicanucleare.it/documents/wong_chap_3.pdf<br>4. http://www.umich.edu/~ners311/CourseLibrary/bookchapter17.pdf<br>5. https://ocw.mit.edu/courses/nuclear-engineering/22-02-introduction-to-applied-nuclear-physics-spring-2012/lecture-notes/MIT22_02S12_lec_ch7.pdf<br>6. http://web.mst.edu/~sparlin/Phys107/Lecture/chap11.pdf<br>7. https://swayam.gov.in/nd1_noc20_ph19/preview |
| **Text Book(s)** | |
| 1. Govinda Rajan, Advanced Medical Radiation Dosimetry, Prentice hall of India Pvt.Ltd., New Delhi, 1992.<br>2. AERB Radiation Production Rules 2004 Reading MA. 1975.<br>3. K. Muraleedhara varier, 'Nuclear radiation detection, measurements and analysis'-Narosa.<br>4. S. S. Kapoor and V.S. Ramamurthy- 'Nuclear Radiation Detectors', Wiley | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | S | L | L | S | S | L |
| **CO 2** | S | S | S | S | M | S | M | S | S | S |
| **CO 3** | S | S | S | S | S | M | S | S | S | M |
| **CO 4** | S | S | S | S | S | S | M | S | S | M |
| **CO 5** | S | S | S | S | S | S | S | S | S | S |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY E105** | **Elective** |
| **Title of the course** | NUCLEAR MATERIALS | |
| **Credits** | 3 | |
| **Pre-requisites, if any:** | Basic knowledge on Nuclear Physics and Materials Science | |

**Course Objectives:**

1. Understand the basic and theory of nuclear Reactors.
2. Describe the nuclear fuel processing and waste disposal techniques.
3. Understand the radiation induced damage mechanism and properties
4. Acquire knowledge on the basics of nuclear metallurgy
5. Create ability for solving numerical problems.

**Course Outcomes:**

| **Couse Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | To explain the types of nuclear reactors, nuclear fuel processing, and nuclear waste disposal. To make them to develop problem solving ability in the topics of nuclear reactor physics. | **K1**<br>**K2** |
| **CO2** | To provide knowledge about various type alloy structures used in nuclear reactors, iron carbon alloy phase diagram, high strength alloys used in nuclear reactors and microstructural transformation. | **K2**<br>**K3** |
| **CO3** | To describe nuclear radiation induced degradation mechanisms such as swelling, creep, phase transformations, embrittlement and segregation to materials in the reactor environment. | **K2** |
| **CO4** | To discuss about the nuclear disasters and its societal implications. | **K2**<br>**K3**<br>**K4** |
| **CO5** | To impart knowledge on the peaceful application of nuclear energy. | **K5** |

| Units | |
|---|---|
| **I** | **Types of Nuclear Reactors**<br><br>Introduction: Types of Nuclear Energy, Neutron Classification and Neutron Sources, Interactions of Neutrons with Matter, Definition of Neutron Flux and Fluence, Neutron Cross Section, Reactor Flux Spectrum, Types of Reactors:- Simple Reactor Design and Operation, Generation-I, II, III, IV Reactors, Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANDU Reactor, RMBK Reactor, Fast Breeder Test Reactor, Fusion Reactor, Reactor Core Materials:- Structural/Fuel Cladding Materials, Moderators and Reflectors Control Materials, Coolants, Shielding Materials, Reactor start Up and Shutdown Principles, Nuclear Reactors in India. |
| **II** | **Nuclear Fuels**<br><br>Introduction to Uranium, Plutonium and Thorium Fuels:- Crystal Structure and Physical Properties, Extraction, Alloying, Fabrication and Radiation effects, Ceramic Fuels:- Ceramic Uranium Fuels, Uranium Dioxide (Urania), Uranium Carbide, Uranium Nitride, Plutonium-Bearing Ceramic Fuels, Thorium-Bearing Ceramic Fuels |
| **III** | **Structural Materials in Nuclear Reactors:**<br><br>Fundamentals of iron carbon alloys and phase diagram, time temperature transformation diagram and heat treatments, special steels and their properties for nuclear reactor components, Pressure vessel steels, Nickel-base alloys, stellites and hard facing materials |
| **IV** | **Radiation Damage:**<br><br>Physics of Radiation Damage in Metals and Effects of Radiation on Core Internal Materials:- Microstructural Changes: Cluster Formation, Extended Defects, Nucleation and Growth of Dislocation Loops, Void/Bubble Formation and Consequent Effects, Radiation-Induced Segregation, Radiation-Induced Precipitation or Dissolution, Mechanical Properties: Radiation Hardening, Saturation Radiation Hardening, Radiation Anneal Hardening, Radiation Embrittlement, Irradiation Creep, Radiation Effect on Fatigue Properties. |
| **V** | **Mechanical Properties:**<br><br>Mechanical Properties:- Tensile Properties and Stress–Strain Curves, Ductile–Brittle Transition Behavior, Fracture Toughness, Creep and Fatigue:- Properties |

| | |
|---|---|
| | and Mechanisms, Creep Constitutive Equation, Stress and Creep Rupture, Fatigue Properties, Fatigue Curve, Creep–Fatigue Interaction, Factors Affecting Fatigue Life, Protection Methods against Fatigue, Hardness:- Principle, type of hardness testing and applications, Corrosion:- Basics and High temperature corrosion |
| **Reading List (Print and Online)** | 1. 1.Glenn F. Knoll 'Radiation Detection and Measurement', John wiley& sons Inc.<br>2. Training course material on 'Safety Aspects in Ionizing Radiation' by Indian Association for Radiation Protection.<br>3. http://www.fisicanucleare.it/documents/wong_chap_3.pdf<br>4. http://www.umich.edu/~ners311/CourseLibrary/bookchapter17.pdf<br>5. https://ocw.mit.edu/courses/nuclear-engineering/22-02-introduction-to-applied-nuclear-physics-spring-2012/lecture-notes/MIT22_02S12_lec_ch7.pdf<br>6. http://web.mst.edu/~sparlin/Phys107/Lecture/chap11.pdf<br>7. https://swayam.gov.in/nd1_noc20_ph19/preview |
| **Text Book(s)** | |

1. Nuclear Materials Science (2nd Ed.), Karl Whittle, Published in 2020, IOP Publishing Ltd 2020

2. Nuclear Materials, Pavel V. Tsvetkov, Published in 2021, IntechOpen Limited (Open access DOI: 10.5772/intechopen.83315)

3. Physics and Technology of Nuclear Materials, IOAN URSU, Published in 1985, Elsevier Ltd.

**Web Resources:**

1. **MIT OPENCOURSEWARE**

Michael Short. 22.14 Materials in Nuclear Engineering. Spring 2015. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu. License: Creative Commons BY-NC-SA.

2. **Regional Center for Nuclear Education & Training, USA**
   http://gonuke.org
3. **International Atomic Energy Agency**

https://www.iaea.org/topics/nuclear-science

4. **U.S. Nuclear Regulatory Commission**
   https://www.nrc.gov/

**Reference Journals for current trends about Nuclear Materials**

1. Nuclear Materials and Energy (Open access, Free download)
2. https://www.journals.elsevier.com/nuclear-materials-and-energy

**Text Books**


1. An Introduction to Nuclear Materials - Fundamentals and Applications, K. Linga Murty and Indrajit Charit (Wiley-VCH Verlag, Germany).

2. Introduction to Nuclear Engineering, John R. Lamarsh and Anthony J. Baratta, (Prentice Hall New Jersey, USA).


**Research Articles:**


3. C V Sundaram and S L Mannan, (IGCAR Kalpakkam) Nuclear Fuels and development of nuclear fuel elements, Sadhana Vol.14, Part 1, June 1989, pp 21-57.

4. A K Suri (BARC, Mumbai) Material development for India’s nuclear power programme, Sadhana, Vol. 38, Part 5, October 2013, pp. 859–895.

5. Allen, Todd, Jeremy Busby, et al. **"Materials Challenges for Nuclear Systems."** Materials Today 13, no. 12 (2010): 14–23.

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | S | M | M | L | M | S | S |
| **CO 2** | S | S | S | M | M | M | L | M | S | S |
| **CO 3** | S | S | S | M | S | M | L | M | M | S |
| **CO 4** | S | S | S | M | S | M | M | S | S | S |
| **CO 5** | S | S | S | M | S | M | S | M | S | S |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | UOM S002 | Soft Skill |
| **Title of the course** | Scientific Writing and Enhancing Professional Research Skills | |
| **Credits** | 02 | |
| **Pre-requisites, if any:** | The course is designed to cover the basic skill set such as the introduction of scientific writing, use of latex and latex beamer for typesetting research paper and thesis, plotting high quality illustration using Origin and MATLAB and improving the habit of reading scientific magazines to update state-of-art knowledge in physical sciences. | |

**Course Objectives:**

1. To study the general guidelines, outline preparation, words and grammar usages in different sections like Introduction, Methods, Results and Discussion for writing the scientific paper.
2. To learn the type setting Latex software for describing their original results in the form of scientific paper or dissertation/thesis.
3. To learn the basic features of scientific plotting using Origin and MATLAB software.
4. To develop the skill on creating a single or multi plots for reporting the results in both experimental or theoretical on physical science projects.
5. To learn the reading skills on scientific magazine to inculcate the scientific outlook on different fields including physics today, physics.org, resonance, Electromagnetism, Dielectrics, Electrochemistry, optics and photonics news, etc.
6. To encourage the graduate students to write the articles or reports with an adequate scientific information for encouraging the reader's interest.

**Course Outcomes:**

**On the successful completion of the course, student will be able to:**

| | | |
|---|---|---|
| **CO1** | The students will be able to describe their original research results in the form of Scientific paper, thesis/dissertation, magazines, etc. | **K1 K3** |
| **CO2** | Students will be able to develop the ability to plan, undertake, and describing their original result including the planning and execution of experiments, the analysis and interpretation of experimental results. | **K2 K5** |
| **CO3** | The graduate students will be able to apply the practical knowledge for developing the scientific report, magazines or thesis/dissertation | **K3 K6** |
| **CO4** | The students will be able to draw a scientific plot using Origin and MATLAB software for the scientific paper. | **K1 K2** |

| | | |
|---|---|---|
| **CO5** | The graduate students will be able to develop the written as well as reading skills for scientific magazines. Developing the ability to write a Review on Scientific outlook for the recent trends in Physical Science. | **K1**<br>**K2** |
| **Units** | | |
| **I** | ***Scientific writing***<br>Introduction-General guidelines-rules for scientific writing-Use of outline to prepare a paper-Word usage in scientific writing-Grammar-Writing the introduction, result and discussions-Examples of good scientific writing-Citing references. | |
| **II** | ***Type-setting thesis using latex***<br>Knowing the importance of typesetting documents in latex-Learning the basics of latex including style files, notations, templates, compiling and pdf production. | |
| **III** | ***Plotting Skills using Origin and MATLAB***<br>Basic features of scientific plotting using Origin and MATLAB. | |
| **IV** | ***Nurturing reading skills of scientific magazines***<br>Reading latest theoretical and experimental results in physics through summary and review articles in physics today, physics.org, resonance, optics and photonics news. Encouraging students to write scientific articles for common man. | |
| **Reading List (Print and Online)** | 2. M. E. Tischler, Scientific writing booklet, University of Arizona<br>3. Andre Heck, Learning Latex by doing, 2002.<br>4. N. Majumdar and S. Banerjee, MATLAB graphics and data visualization cookbook,2012. | |
| **Text Book(s)** | | |

2. M. E. Tischler, Scientific writing booklet, University of Arizona
3. Andre Heck, Learning Latex by doing, 2002.
4. N. Majumdar and S. Banerjee, MATLAB graphics and data visualization cookbook,2012.


**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | S | - | - | M | - | S | - |
| **CO 2** | M | S | - | M | - | M | - |
| **CO 3** | S | - | S | - | M | - | - |
| **CO 4** | M | - | S | M | L | - | - |
| **CO 5** | S | M | S | L | - | - | - |

**S-Strong    M-Medium    L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C109** | Core |
| **Title of the course** | Quantum Mechanics II | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | UG Level Physics / Quantum Mechanics-I | |
| **Course Objectives:** | | |
| 1. To explain the angular momentum concept in quantum mechanics and the superposition theorem, the concept of the commuting operators and the Dirac bra-ket notation.<br>2. To compute wavefunctions and energy eigenvalues via degenerate and non-degenerate perturbation theory, both time-dependent and time-independent.<br>3. To obtain the perturbative expansion and use the perturbative solution for some physical problems.<br>4. To compute the quantum mechanics scattering cross section for particles scattering on potentials/other particles in a variety of situations, including low energy, high energy and for identical particles<br>5. To investigate the addition of angular momenta and calculates the Clebsh-Gordon coefficients. | | |
| **Course Outcomes:** | | |
| **Outcomes** | **Description** | **Knowledge Level** |
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | To Develop knowledge and understanding of the concept for commuting operators and the Dirac bra-ket notation | **K2**<br>**K3** |
| **CO2** | To Solve energy eigenvalues via degenerate and non-degenerate perturbation theory | **K2**<br>**K5** |
| **CO3** | To learn the perturbative expansion and use of perturbative solution for some physical problems | **K3**<br>**K6** |
| **CO4** | To Understand the scattering cross section for particles having low and high energy | **K1**<br>**K2** |

| | | |
|---|---|---|
| **CO5** | To gain the knowledge To investigate the addition of angular momenta and calculates the Clebsh-Gordon coefficients | **K1**<br>**K2** |
| | **Units** | |
| **I** | Angular momentum algebra-Eigen values of $J^2$ and $J_z$ -Spin angular momentum-Pauli's matrices-Addition of angular moments-Coupled and uncoupled representations-Clebsh Gordon coefficients | |
| **II** | Time independent perturbation theory-Degenerate and non degenerate perturbation theory-Stark effect-Atoms in a magnetic field-Paschen Back effect-Normal and anomalous Zeeman effect-Variational method-Helium atom-Hydrogen molecule | |
| **III** | Time dependent perturbation theory-Fermi's Golden rule-Harmonic Perturbation theory-Semi classical theory of Electromagnetic radiation-Einstein's coefficients | |
| **IV** | Scattering Theory-scattering cross section-scattering amplitude-Partial wave analysis-Low energy scattering -Scattering by square well potential-Scattering length-resonant scattering-Ramsauer Townsend effect-Breit Wigner formula-Born approximation-Rutherford scattering-validity of Born approximation. | |
| **V** | Relativistic wave equation-Klien Gordon equation-Equation of continuity-Shortcomings of Klien Gordon equation-Dirac equation-Equation of continuity –Free particle solution-Dirac's interpretation of negative energy states-Spin angular momentum from Dirac's equation-Magnetic moment of an electron due to spin | |
| **Reading List (Print and Online)** | 1. P. M. Mathews and K. Venkatesan: A text book of Quantum Mechanics<br>2. L.I. Schiff: Quantum Mechanics (third edition)<br>3. P. A. M. Dirac: The principles of Quantum Mechanics<br>4. Nouredine Zettili: Quantum Mechanics Concepts and Applications | |
| **Text Book(s)** | | |
| 6. J. L. Powell and B. Crasemann : Quantum Mechanics<br>7. Y. R. Waghmare : Fundamentals of QuantumMechanics<br>8. W. Greiner : Quantum Mechanics<br>9. L. D. Landau and E. M. Lifschitz: Quantum Mechanics | | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | M | M | M | M | L | M | L | M | M | M |
| **CO 2** | M | S | M | M | L | M | L | M | L | L |
| **CO 3** | S | S | S | M | M | M | L | L | L | L |
| **CO 4** | M | M | M | S | M | S | M | S | M | M |
| **CO 5** | M | M | M | M | L | L | L | M | L | L |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C110** | Core |
| **Title of the course** | **Statistical Physics** | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Basic knowledge in Newton equation of motion, Simple harmonic motion | |
| **Course Objectives:** | | |
| 1. facilitates the students understanding the generalized coordinates, construction and applications of Lagrange's equation of motion<br>2. helps students to extend their fundamental understanding canonical transformation, Hamilton- Jacobi method and its application, normal modes and normal coordinates<br>3. gives knowledge of thermodynamic potentials, phase rule, phase transitions<br>4. helps the student describe the concepts in the postulates of statistical mechanics and provide statistical interpretation of thermodynamics, microcanonical, canonical and grand canonical ensembles, mixing of entropies.<br>5. Provides knowledge of MB, BE and FD statistics and their applications in condensed matter physics. | | |
| **Course Outcomes:** | | |

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | **Recall** first, second, and zeroth law of thermodynamics, **explain** thermodynamic potentials, **develop** Maxwell's thermodynamic relations and first and second Tds equations, **apply** and estimate reversible isothermal and adiabatic change of pressure, **Classify** the phase transition and demonstrate with examples, deduct Clausius – Clayperon equation | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5**<br>**K6** |
| **CO2** | **What** are the postulates of classical statistical mechanics, **understand** the concept of Phase space, micro and macro states, **state** and prove Liouville's theorem, **compare** the different types of ensembles, **utilize** them to arrive thermo dynamical functions of perfect gas, **apply** partition function and c**orrelate** entropy of an ideal gas, **explain** entropy and Gibb's paradox, **understand** the postulates of quantum statistical mechanics, **explain** Ising model and **analyse** the result. | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |

| | | |
|---|---|---|
| **CO3** | **Define** Bose-Einstein statistics, **Outline** B-E distribution law**,** **Develop** the equation of state of Bose and Einstein gas, **determine** the lattice heat capacity & heat capacity, **analyze** Bose-Einstein condensation and Landau's theory of liquid helium. | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| **CO4** | **Define** Femi-Dirac statistics, **Outline** F-E distribution law**,** **Develop** the equation of state of Fermi gas, **determine** the heat capacity of free electron and paramagnetic susceptibility, **explain** thermionic emission | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| **CO5** | **Recall** n-type and p-type semiconductors, **compare** non-degenerate and degenerate semiconductors, **make use of** F-D statistics obtain carrier concentration and band gap, **analyze and interpret** the random walk and Brownian motion. | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| **Units** | | |
| **I** | **Thermodynamics:** Laws of thermodynamics- Thermodynamic potentials – Euler equation – Maxwell's relations and applications – Chemical Potential- Gibbs phase rule – phase equilibrium - Ehrenfest's classification- Clausius – Clayperon equation – law of mass action – first order phase transition in single component systems – Second order phase transition. | |
| **II** | **Basic Principles of Statistical Mechanics:** Postulates of classical statistical mechanics- Liouville's theorem- microcanonical, canonical and grand canonical ensembles- partition function, entropy of an ideal gas- Gibbs paradox- Density operator- postulates of quantum statistical mechanics- Langevin theory of paramagnetism- one-dimensional Ising chain. | |
| **III** | **Ideal Bose and Fermi Gas:** Bose-Einstein distribution, Equation of state of a Bose gas, Bose-Einstein condensation, Landau's theory of liquid He II, Einstein and Debye theories of lattice heat capacity. | |
| **IV** | **Ideal Fermi Gas:** Fermi-Dirac distribution, Equation of state of a Fermi gas, free electron gas in metals, heat capacity, paramagnetic susceptibility, thermionic emission. | |
| **V** | **Semiconductor Statistics and Fluctuations**: Non-degenerate semiconductors, Degenerate semiconductors, Random walk, Brownian motion. | |

| Reading List (Print and Online) | 1. Thermodynamics: Classical to statistical, Prof. Sandip Paul, IIT Guwahati https://nptel.ac.in/courses/104/103/104103112/<br>2. Basic Statistical Mechanics, Prof. Biman Bagchi, IIT Bombay https://nptel.ac.in/courses/104/101/104101125/<br><br>3. Chemical Principles II(Basic thermodynamics : Classical and Statistical Approaches), Prof. Arnab Mukherjee, IISER Pune https://nptel.ac.in/courses/104/106/104106107/<br>4. Statistical Mechanics, Prof. Dipanjan Chakraborty, IISER Mohali https://nptel.ac.in/courses/115/106/115106126/<br>5. Introduction To Statistical Mechanics, Prof.Girish S. Setlur, IIT Guwahati https://nptel.ac.in/courses/115/103/115103113/ |
|---|---|

**Text Book(s)**

1. Mark W. Zemansky, Richard H. Dittman, Heat and Thermodynamics-An Intermediate Textbook, 7th edition, McGraw-HILL Companies, Inc. (1997)
2. K. Huang , Statistical Mechanics, 2nd Edition, John Wiley & Sons (1987)
3. B. K. Agarwal and M. Eisner, Statistical Mechanics, Second Edition, New age international. Publishers, New Dehli (1998)
4. F. Reif, Statistical and Thermal Physics, Fifth Edition, McGraw Hill (2010).
5. W. Greiner, L. Neise and H. Stoecker, Thermodynamics and statistical Mechanics, Springer (1995).

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | M | L | - | L | L | - | L | L | L |
| **CO 2** | S | M | L | L | L | L | - | - | - | - |
| **CO 3** | S | M | M | L | L | M | L | L | - | L |
| **CO 4** | S | - | M | - | L | - | - | - | L | - |
| **CO 5** | M | S | - | L | - | - | - | L | - | - |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C111** | Core |
| **Title of the course** | NUCLEAR PHYSICS AND ELEMENTARY PARTICLE PHYSICS | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Elementary quantum mechanics, Angular momentum concepts | |

**Course Objectives:**

2. To understand the nature of nuclear forces and their interactions, that describes the fundamental physics from Quantum Mechanical viewpoint.
3. To understand nuclear structure from various Models, developed specifically for each unique nuclei characteristics.
4. To Identify, analyze, and critically assess nuclear reactions and their complexities with direct correspondence to reactions in the nuclear reactors.
5. To understand nuclear decays with domain specific in-depth calculations selection rules & infer the experimental observations.
6. To compare, classify & understand the zoo of Elementary particles present in the nature, and study the internal symmetries of their nature.

**Course Outcomes:**

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | Describe the basic nuclear properties, like size, moments, forces, and to analyze the nature of interactions of nuclei. | **K3**<br>**K4** |
| **CO2** | Predictions of nuclear models to describe the properties and account for the fission process, shell structure, collective behaviour. | **K3**<br>**K4**<br>**K5** |
| **CO3** | Describe the different types of nuclear reactions and predictions of cross sections. | **K4**<br>**K5** |
| **CO4** | Identify different decay types (α, β, γ) and assess the parameters, selection rules to explain the stability of the nuclei. | **K4** |
| **CO5** | Study, Classify elementary particles, associated symmetries, conservations, their behaviour, physical structure and model. | **K2**<br>**K3**<br>**K4** |

| Units | |
|---|---|
| **I** | **NUCLEAR FORCES**: Nucleon – Nucleon-nucleon interaction –Exchange forces and tensor forces – Meson theory of nuclear forces- Nucleon-nucleon scattering singlet and triplet parameters – charge independence-Spin dependence – Nucleon-Nucleon scattering: Cross-section, Differential Cross-section, Scattering Cross-sections Isospin – Ground state of deuteron-magnetic moment-Quadrupole moment –S and D state admixtures - Effective range theory. |
| **II** | **NUCLEAR MODELS**: Binding energy & mass defect - Weizacker's formula - mass parabola - Liquid drop model - Bohr-Wheller theory of fission- Activation energy for fission- Shell model- Spin –Orbit coupling-Spins of nuclei- Magnetic moments – Schmidt lines- Electric quadrupole moments - Collective model of Bohr and Motteision: Nuclear vibration – Nuclear rotation –Nelson model. |
| **III** | **NUCLEAR REACTIONS**: Nuclear reaction - Q-equations – Cross section - Direct Nuclear Reactions: Knock out reaction, Pick-up reaction, Stripping reaction - Compound nucleus reactions – Partial wave analysis of Nuclear reaction cross-section - Resonance Scattering and Reaction cross-section (Breit-Wigner dispersion formula) – - Scattering matrix - Reciprocity theorem – Breit - Wigner one level formula – Resonance scattering – Absorption cross section at high energy. |
| **IV** | **RADIOACTIVE DECAYS**: Alpha decay - Beta decay – Energy release in beta decay –Fermi theory of beta decay – Shape of the beta spectrum – decay rate Fermi-Curie plot – Fermi & G.T Selection rules - Comparatives half - lives and forbidden decays- Gama decay - Multipole radiation – Angular momentum and parity selection rules – Internal conversion – Nuclear isomerism. |
| **V** | **ELEMENTRY PARTICLE PHYSICS**: Types of interaction between elementary particles –Hadrons and leptons –Symmetry and conservation laws-CPT theorem –classification of hadrons – Quark model - Isospin multiples - SU(2)- SU(3) multiplets- Gell-Mann -Okubo mass formula for octet and decuplet hadrons – Phenomenology of weak interaction hadrons and leptons - Universal Fermi interaction – Elementary concepts of weak interactions. |
| **Text Book(s)** | |

1. B. B. Cohen, “Concepts of Nuclear Physics”, TMGH, Bombay, 1971.
2. K. Krane, ”Introductory Nuclear Physics”, Wiley, New York, 1987.
3. V. Devanathan, “Nuclear Physics” Narosa Publishing house
4. D. Griffiths, “Introduction to Elementary Particles”, 2nd Ed., Wily-Vch, 2008

**Reference Books**

1. R. D. Evans, “Atomic Nucleus”, Mcgraw-Hill NY.1955.
2. J. M. Blatt and V. F. Weisskopf, “Theoretical Nuclear Physics”. Berlin 1979.
3. H. Enge, “ Introduction to Nuclear Physics Addision-Wesley”. Reading MA. 1975.
4. R. R. Roy and B. P. Nigam, “Nuclear Physics”, Wiley Eastern, Madras1993.
5. D.C. Tayal ‘Nuclear Physics’
6. A. Bohr and B. R. Mottelson, “Nuclear Structure” Vol. I (1969) and Vol.II(1975), Benjamin Reading .

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | **M** | **S** | **S** | **S** | **S** | **M** | **L** | **S** | **S** | **L** |
| **CO 2** | **S** | **S** | **S** | **S** | **S** | **M** | **S** | **S** | **S** | **M** |
| **CO 3** | **S** | **S** | **S** | **S** | **S** | **M** | **M** | **M** | **S** | **L** |
| **CO 4** | **S** | **S** | **S** | **S** | **S** | **M** | **M** | **S** | **M** | **L** |
| **CO 5** | **S** | **S** | **S** | **S** | **S** | **M** | **S** | **S** | **S** | **L** |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C112** | **Core** |
| **Title of the course** | **Condensed Matter Physics** | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Physics, Materials Science | |

**Course Objectives:**

1. To introduce condensed matter physics subjects on crystal physics, phonon physics, free electron theory, band theory of solids, semiconductor physics, magnetism and superconductivity.

2. To provide in-depth knowledge about crystal structures, packing fraction, X-ray diffraction and associated numerical problems.

3. To explain the theory of lattice vibrations, phonon momentum, heat capacity, Debye and Einstein model, Umklapp process.

4. To describe free electron theory on metals, Fermi surfaces, band energy semiconductors, effective mass, band theory of solids

5. To explain different types of polarizations, dielectric constant, relaxation time, dielectric loss and theory of various concepts of magnetism.

6. To describe the Meissner’s effect, London theory, properties of superconductor, flux quantization, BCS theory, high Tc superconductors.

7. To provide a focused learning on various concepts of condensed matter physics to equip students for higher research in interdisciplinary field connecting physics, chemistry, materials science and engineering.

8. To create numerical problem solving skills in solid state physics.

**Course Outcomes:**

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |

| | | |
|---|---|---|
| **CO1** | Understand the fundamentals of Crystal structure of materials, theory and experiment of X-ray diffraction and problem solving | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| **CO2** | Explain the theory of lattice vibrations, phonon momentum, heat capacity, Debye and Einstein model, Umklapp process. | **K1**<br>**K2**<br>**K4**<br>**K5** |
| **CO3** | Understand the free electron theory of metals, Drude theory, Fermi-Dirac statistics, and theory of electrical and thermal conductivity | **K1**<br>**K2**<br>**K4**<br>**K5** |
| **CO4** | Explain the band theory of Solids, Bloch theorem, Kronig Penny model, effective mass of an electron and holes, Fermi surface | **K1**<br>**K2** |
| **CO5** | Learn the principle and theory of magnetism and superconductivity.<br>Solve numerical problems in condensed matter physics. | **K1**<br>**K2**<br>**K4**<br>**K5** |

| **Units** | |
|---|---|
| **I** | **Crystals and Reciprocal lattice**<br>Structure of solids, Bravais lattices, unit Cell, Wigner-Seitz cell, index system for crystal planes, Miller indices, directions and position orientation of planes in crystal, crystal structures with examples, packing fractions, point group and space group, concept of reciprocal lattice, concept of Brillouin zones, diffraction of X-rays in periodic structures, Laue condition, Bragg's law, atomic scattering factor, structure factor, electron density equation, intensity of scattered X-ray, Friedel's law, anomalous scattering, Ewald's sphere construction, powder X-ray diffraction analysis of materials - application examples |
| **II** | **Phonon Physics**<br>Elastic Vibrations of one dimensional mono atomic lattice – vibrations of one dimensional diatomic lattice – phonons momentum of phonons – phonon heat capacity and density of states – Debye and Einstein model of density of states – Anharmonic crystal interaction – thermal expansion – thermal conductivity – Umklapp process. |
| **III** | **Free Electron Theory**<br>Drude theory, free electron gas in one dimensional box, free electron in three |

| | |
|---|---|
| | dimensional gas, Density of states, FD statics ( no derivation), application of k-space and free electron gas, electronic specific heat, electrical and thermal conductivity, Wiedeman Franz law, failure of free electron theory ( Hall effect) |
| **IV** | **Band theory**<br>Band theory, origin of energy gaps, Bloch theorem, Kronig Penny model, Wave equations in potential, solution for wave equation near zone boundary, velocity and effective mass of an electron, effective mass concept (holes) and its properties, nearly free electron model, tight binding app, Fermi surface, construction of Fermi surface for simple metals. |
| **V** | **Magnetism and Superconductivity**<br>Magnetism: Magnetic susceptibility, Langevin equation, Quantum theory of Paramagnetism and Diamagnetism, Hund's rule for rare earth ions, Crystal field splitting, Pauli spin magnetism, ferromagnetism and antiferromagnetism interactions, interaction, order of magnetism in FM and AFM, Bloch wall<br>Superconductivity: Experimental survey, Meissner effect, Physical properties (entropy, specific heat, isotope effect), London equation, BCS theory, Josephson's effect and quantum interference, application of superconductors, High Tc Superconductors: An overview. |
| **Reading List (Print and Online)** | This study material includes text books and journal research papers.<br><br>1. Condensed Matter in a Nutshell, Gerald D. Mahan, Princeton University Press.<br><br>2. Principles of Condensed Matter Physics, P. M. Chaikin, T. C. Lubensky, Cambridge University Press.<br><br>3. Solid State Physics, Grosso and Parravicini, Academic Press.<br><br>4. Introductory Solid State Physics, H.P. Myers, Taylor and Francis.<br><br>5. Solid State Physics (Introduction to the theory), James Patterson, Bernald Bailey.<br><br>6. Theoretical Solid State Physics, Vol. 1: Perfect Lattices in Equilibrium, William Jones, Norman H. March, (Dover Books on Physics)<br><br>7. Theoretical Solid State Physics, Vol. 2: Non-Equilibrium and Disorder, William Jones, Norman H. March, (Dover Books)<br>Crystallography<br>https://www.xtal.iqfr.csic.es/Cristalografia/index-en.html |

| | |
|---|---|
| | Oxford University (podcasts) Solid state physics video lectures<br>https://podcasts.ox.ac.uk/series/oxford-solid-state-basics |
| **Text Book(s)** | |

1. Introduction to Solid state physics, C. Kittel, John – Wiley
2. Solid State Physics, Neil W. Ashcroft, N.David Mermin, Cengage Learning.
3. Solid State Physics, A.J. Dekker, Macmillan India Ltd.
4. Solid State Physics, S.O.Pillai, New Age International Pvt. Ltd.
5. Solid state Physics, R.L.Singhal and P.A. Alvi, KNRN Publications
6. Solid State Physics: Structure and Properties of Materials, A.M. Wahab, Narosa publishing.
7. Elements of X-Ray Diffraction, B.D. Cullity, S.R. Stock , Pearson
8. Structure Determination by X-Ray Crystallography, Ladd and Palmer
9. X-ray structure determination: A Practical Guide (2nd Ed.) by George H. Stout and Lyle H Jensen, Wiley-Interscience.
10. Introduction to Magnetic Materials, B.D. Cullity and C.D. Graham, 2nd Edn, Wiley publications.
11. Essentials of Materials Science and Engineering, Donald R. Askeland, Pradeep P. Fulay, (Cengage Learning)
12. Materials Science and Engineering, William. D. Callister, Wiley.

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CO 1 | S | S | S | S | S | S | S | S | S | S |
| CO 2 | S | S | S | S | M | S | M | S | M | M |
| CO 3 | S | S | S | M | M | M | M | S | M | M |
| CO 4 | S | S | S | M | M | S | M | S | S | S |
| CO 5 | S | S | S | S | S | S | S | S | S | S |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY E106** | **Elective** |
| **Title of the course** | **Physics of Thin Films and Device Fabrication** | |
| **Credits** | 3 | |
| **Pre-requisites, if any:** | Interest to study basic optics and photonics. Problem solving ability. | |

**Course Objectives:**

1. To explain the nucleation and growth theory of thin film.
2. To discuss about vacuum systems used in thin film technology.
3. To provide knowledge on PVD and CVD thin film deposition.
4. To describe principle of various thin film characterization methods.
5. To understand optoelectronic and photonic thin film applications

**Course Outcomes:**

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | Understand thin film deposition and device fabrication techniques. | **K1<br>K2<br>K6** |
| **CO2** | Acquire knowledge about thin film applications on optoelectronics | **K1<br>K2<br>K3<br>K4<br>K5** |
| **CO3** | Understand the basics of thin film characterization techniques. | **K1<br>K2<br>K3** |
| **CO4** | Develop problem solving skills. | **K1<br>K2<br>K3** |
| **CO5** | Conceive and gain interest to pursue research in thin film science. | **K1<br>K2<br>K3** |

| | | |
|---|---|---|
| | | **K4**<br>**K6** |
| | **Units** | |
| **I** | **Fundamentals of Thin film deposition**<br><br>Introduction to Science and Technology of Thin Films, Nucleation and Growth, Adsorption, Surface diffusion, models for 3D and 2D nucleation, coalescence and depletion, grain structure and microstructure and its dependence on deposition parameters, | |
| **II** | **Thin film deposition techniques**<br><br>Sol gel, Spray Pyrolysis, Thermal evaporation, electron beam evaporation, Sputtering techniques, Pulsed Laser Deposition), Molecular Beam epitaxial technique, CVD techniques (CVD, Laser CVD and ALD) | |
| **III** | **Thin film device fabrication**<br><br>Substrate selection and preparation, Patterning (lithography), Material removal (wet and dry etching: plasma etching mechanisms; etch rate and selectivity, orientation dependent etching), Doping (diffusion, ion implantation), .Oxidation, Metallization and interconnects, Process Integration with examples (Si and III-V solar cell). | |
| **IV** | **Thin film Applications**<br><br>Thin film applications: Electronic Devices (PN junction devices, CMOS, Solar Cell), Optoelectronic (Optical coating, Waveguide), Sensors, Surface Engineering (Nanostructured Superhard Coatings), | |
| **V** | **Thin film Characterization Techniques**<br><br>Thickness measurement (Stylus profilometry, laser elipsometer, optical profilometer), Structural (GXRD), Micro/Nanostructure (FESEM, HRTEM, AFM), Optical (Refractive Index, Spectroscopic), Electrical (Four Probe Resistive Measurement), Depth Profile Analysis (Secondary Ion Mass Spectroscopy, EPMA) | |
| **Reading List (Print and Online)** | This study material includes text books and journal research papers.<br><br>1. Thin Film Growth: Physics, Materials Science and Applications by Zexian Cao (Woodhead Publishing).<br>2. Thin Film Device Applications by Kasturi Lal Chopra and Inderjeet Kaur, Plenum Press, NewYork, 1983 | |

| | |
|---|---|
| | 3. Thin Film Solar Cells: Fabrication, Characterization and Applications, Jef Poortmans (Ed.), Vladimir Arkhipov, Wiley 2006<br>4. Nanostructured Thin Films and Coatings: Functional Properties by Sam Zhang, CRC Press, 2010<br>5. Handbook of Thin Film Technology, Meisel and Glang, Academic Press 1970.<br><br>**Web resources**<br><br>1. http://www.uccs.edu/~tchriste/courses/PHYS549/549Info.html#Books<br>2. http://www.ocw.titech.ac.jp/index.php?lang=EN<br>3. http://www.nptel.ac.in/syllabus/syllabus.php?subjectId=115102019<br><br>**Research Journals on Thin Film Science**<br><br>https://www.journals.elsevier.com/thin-solid-films<br><br>https://avs.scitation.org/ (Journals on Vacuum technique) |
| **Text Book(s)** | |
| 1. Materials Science of and Thin Films, Milton Ohring, Academic Press<br>2. Thin Film Deposition: Principles and Practice, Donald L. Smith, McGraw Hill 1995.<br>3. Thin Film Phenomena, K. L. Chopra, McGraw Hill 1969.<br>4. Semiconductor Materials for Solar Photovoltaic Cells, M Parans Paranthaman and Winnie (Springer Series in Materials Science) | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CO 1 | S | S | S | S | M | S | S | S | S | S |
| CO 2 | S | S | S | M | M | S | S | S | S | S |
| CO 3 | S | S | S | M | M | M | M | S | S | S |
| CO 4 | S | S | S | M | M | M | M | S | S | S |
| CO 5 | S | S | S | M | M | M | M | S | S | S |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY E107** | Elective |
| **Title of the course** | Introduction to Spintronics | |
| **Credits** | 3 | |
| **Pre-requisites, if any:** | UG Level Physics | |

**Course Objectives:**

1. To learn the fundamental concepts on spin electronics, classes of magnetic materials, magnetic anisotropy, magnetic domain and magnetic hysteresis.
2. To understand the anisotropic magnetoresistance effect and its application to magnetic sensor and giant magnetoresistance effect
3. To understand various spin-dependent transport phenomena in tunneling magnetoresistance and spin Hall effect
4. To understand the device structure, operating principle, and materials of magnetoresistive memory (MRAM) and spin-torque transfer phenomenon as a new data writing mechanism of MRAM
5. To investigate the device structures and materials of semiconductor in spintronics and their application in biology

**Course Outcomes:**

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | To develop knowledge and understand the fundamentals of magnetism | **K2**<br>**K3** |
| **CO2** | To learn about spin torque transfer: Current-induced domain switching and current-induced domain wall motion | **K1**<br>**K2** |
| **CO3** | To understand about spin-based transport in the device | **K3**<br>**K5** |
| **CO4** | To understand the spin injection, spin accumulation, and spin current, spin hall effect and silicon based spin electronic devices. | **K2**<br>**K3** |
| **CO5** | To gain the knowledge about the various type of spintronics- | **K2** |

| | | |
|---|---|---|
| | based devices | **K6** |
| **Units** | | |
| **I** | Definition and Units - Experimental Methods - Diamagnetism and Paramagnetism–Antiferromagnetism–Ferrimagnetisms– Ferromagnetism - Magnetization and the magnetic moment - Magnetic hysteresis loop - magnetic ordering and the Curie temperature - Different types of magnetic anisotropy - Magnetostriction and the effect of stress - Nano-magnetic materials thermal stability - Size effect of fine particles and thin films - Domains and Domains walls - soft Magnetic and Hard Magnetic Materials. | |
| **II** | Giant magnetoresistance effect - semiclassical theory of CIP giant magnetoresistance - current perpendicular to plane giant magnetoresistance - basic properties of spin valves - magnetic properties exchange anisotropy - interlayer coupling - CIP transport properties - spin valves optimization - improved spin-valve design (dual spin valves, spin filter spin valves) - spin valves in magnetoresistive read heads. | |
| **III** | Spin-filter effect - Ferromagnetic-Ferromagnetic tunneling - bias voltage dependence - exchange biasing of tunnel junctions - temperature effect - temperature stability and annealing effect - Half-metallic ferromagnets, observation of resonant effects in MTJs - Tunneling role of the interface. | |
| **IV** | History of MRAM - pseudo-spin valve MRAM - Magnetic tunnel junction MRAM - MRAM developments - extending density/reducing write currents - spin momentum switch - new spintronics effects - potential MRAM enhancements. | |
| **V** | MTJ – MRAM, basic cell operation - MTJ material for MRAM - magnetic switching - high speed switching behavior - single MTJ/single transistor (ITIMTJ) MRAM cell - 1MB MRAM circuit - **Magnetoelectronics application**: spin injected FET - spin injected semiconductor - spin diodes - spin bipolar transistor. **Magnetoresistive DNA Chips**: Magnetoresistive biochips - sensor characteristics - MR biochips prototype fabrication - Biological applications - Surface functionalization - DNA- cDNA hybridization detection | |
| **Reading List (Print and Online)** | 1 Introduction to Magnetism and Magnetic Materials, 2$^{nd}$ edition, David Jiles, Chapman & Hall/CRC<br>2 Modern Magnetic Materials: Principles and Applications, Robert C. O’Handley, John Wiley & sons. Inc<br>3 Nanomagnetism and spintronics, Edited by Teruya shinjo, 2009, Elsevier | |

| | |
|---|---|
| | 4 Magnetoelectronics, Edited by Mark Johnson, Elsevier Academic Press, 2004<br>5 Introduction to spintronics, Supriyo Bandyopadhyay and Marc Cahay, Taylor & Francis, CRC press.<br>6 Spin Electronics, David D. Awschalom, Kluwer Academic Publisher |
| **Text Book(s)** | |
| 1 Thin film Magnetoresistive Sensors, S. Tumanski, IOP publishing<br>2 Spin dependent Transport in Magnetic Nanostructures, Sadamichi Maekawa and Teruya shinjo, Taylor & Francis<br>3 Spintronic Materials and Technology, Y B Xu and S. M. Thompson, Taylor & Francis | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | **S** | **M** | **M** | **M** | **M** | **S** | **S** | **M** | **M** | **M** |
| **CO 2** | **S** | **M** | **M** | **M** | **M** | **M** | **M** | **M** | **L** | **L** |
| **CO 3** | **S** | **S** | **S** | **M** | **L** | **M** | **L** | **M** | **L** | **L** |
| **CO 4** | **S** | **S** | **M** | **M** | **L** | **L** | **M** | **M** | **L** | **L** |
| **CO 5** | **S** | **M** | **L** | **M** | **M** | **M** | **M** | **S** | **M** | **L** |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY E108** | Elective |
| **Title of the course** | **MATERIALS CHARACTERIZATION** | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Materials Science | |

**Course Objectives:**

1. To introduce Electron Microscopy, uses, working principle, Instrumentation and its uses. To help students critically chose the type of spectroscopy for the Research & Industrial requirement.
2. Describe and analyze Transmission Electron Microscopy & its advantages.
3. Evaluate, conceptualize the Microscopy technique and the Instrumentation of TEM.
4. To introduce, demonstrate and analyze photoelectron spectroscopy and their applications in Materials Characterization.
5. Develop skills to interpret spectral analysis and correlate data for applications.

**Course Outcomes:**

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | Calculate analysis of the Material using TEM, SAED and analyze the microscopic structure to infer the Physical & Chemical properties. | **K3**<br>**K4** |
| **CO2** | Study pattern formations and analyze sample properties for scientific & Industrial application | **K3**<br>**K4** |
| **CO3** | Debug Instrumentation errors and critically analyze the sample property | **K5** |
| **CO4** | Set up experimental parameters, Instrumentation parameters & debugging errors. | **K4**<br>**K5** |
| **CO5** | Calculate spectral analysis, improving analytical correlations on data to get desired outcome. | **K5** |

**Units**

| | |
|---|---|
| **I** | ELECTRON MICROSCOPY *Introduction:* Interaction of electrons with matter – Why electron scattering? – scattering– characteristics of electron scattering – the interaction cross section – the mean free path – the differential cross section – other factors affecting scattering – Fraunhofer and Fresnel diffraction – diffraction of light from slits – coherent interference. |
| **II** | TRANSMISSION ELECTRON MICROSCOPY - Sample preparation. *TEM:* Diffraction from small volumes - diffraction from wedge shaped specimens, diffraction from planar defects, diffraction from particles, Diffraction from dislocations–<br><br>*SAED images:* ring pattern from polycrystalline materials, ring patterns from amorphous materials. |
| **III** | **TEM INSTRUMENTATION:** Electron sources: electron guns - thermionic guns, field emission guns thermionic emission, field emission – characteristics of the electron beam: brightness, temporal coherency and energy spread, spatial coherency and source size, stability–gun characteristics: beam current, convergence angle, calculating the beam - SEM &TEM |
| **IV** | PHOTOELECTRON SPECTROSCOPY *Introduction:* Spectroscopic notation, X-ray notation – Atomic model and electron configuration- principle of XPS – principle of AES - charge compensation in XPS. *Instrumentation:* Electron sources: thermionic emitter, lanthanum hexaborate emitter, cold field emitter, hot field emitter – analyzers: cylindrical mirror analyzers - hemispherical sector analyser – detectors: channel electron multipliers, channel plates. |
| **V** | PES SPECTRAL ANALYSIS*:* Unwanted features in electron spectra, data acquisition – chemical state information – shake-up satellites – multiplet splitting – factors affecting the quantification of XPS spectrum - AES analytical techniques. |
| **Reading List (Print and Online)** | 1. https://nptel.ac.in/courses/113/106/113106034/<br>2. https://nanohub.org/resources/27532<br>3. https://freevideolectures.com/course/5303/fundamentals-xray-diffraction-transmission-electron-microscopy/ |
| **Text Book(s)** | |

| |
|---|
| 1. J. F. Watts, An introduction to surface analysis by Electron Spectroscopy, Oxford University press, Oxford, 1990.<br>2. John F. Watts, John Wolstenholme, An Introduction to Surface Analysis by XPS and AES. John Wiley & Sons Ltd, 2003.<br>3. T.A. Carlson, Photoelectron and Auger Spectroscopy , Plenum press, 1975. |
| **Reference Books** |
| 1. D. B. Williams and C. B. Carter, Transmission Electron microscopy basics, Springer, 1996.<br>2. Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2ndEdn. Wiley VCH, Germany<br>3. Sam Zhang, Lin Li and Ashok Kumar, Materials Characterization Techniques, CRC Press |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | M | S | S | S | S | M | L | S | S | L |
| **CO 2** | S | S | S | M | S | M | S | S | M | M |
| **CO 3** | S | S | S | S | S | M | M | M | S | L |
| **CO 4** | S | S | S | M | S | M | S | S | M | M |
| **CO 5** | S | S | S | S | S | M | S | S | S | M |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY C113** | Core |
| **Title of the course** | **Materials Physics** | |
| **Credits** | 4 | |
| **Pre-requisites, if any:** | Applicable to Physics, Chemistry and Materials Science Students | |

| |
|---|
| **Course Objectives:** |
| 1. Understand Fick's laws, solutions, applications, Kirkendall effect.<br>2. Explain phase diagrams, TTT diagram, microstructural changes.<br>3. Acquire knowledge on solid solution and imperfections of materials.<br>4. Understand the heat treatment of alloys and mechanical properties.<br>5. Create the numerical problem solving skill in materials science. |
| **Course Outcomes:** |

| **Course Outcome** | **Description** | **Knowledge Level** |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |
| **CO1** | To impart in-depth knowledge about the atomic diffusion, solid solution, defects and imperfections of materials by considering alloys and semiconductors as examples | **K2**<br>**K3** |
| **CO2** | To explain the phase diagrams of iron-carbon alloy, binary alloys and ceramics and lever-rule for binary alloy composition | **K2**<br>**K5** |
| **CO3** | To understand about TTT diagrams, heat treatments, phase transformation, microstructure and mechanical properties of alloys. | **K3**<br>**K6** |
| **CO4** | To give an overview about band gap engineering of semiconductors and Perovskite, by which students can transfer the knowledge to pursue research in optoelectronics and photovoltaics | **K1**<br>**K2** |
| **CO5** | To enable students for problem solving skills in diffusion theory, phase diagrams, solid solution and heat treatments. To enable the students for pursuing research in materials science and engineering, and condensed mater physics. | **K1**<br>**K2**<br>**K3** |
| | **Units** | |

| | |
|---|---|
| **I** | **Imperfection & Diffusion in solids**<br><br>Point defects – Dislocations – bulk & volume defects - Solid state diffusion - Diffusion mechanisms, Self-diffusion, Impurity diffusion coefficient, Fick's second law - Experimental determination of diffusion coefficient, Various methods, Random walk diffusion and correlated and uncorrelated motions, Diffusion in a simple cubic structure, Diffusion under external field, Nernst, Einstein relation, Correlation factor 'f', Kirkendall shift - Ionic conductivity, Ionic conductivity of alkali halides, Mechanisms, intrinsic region, Extrinsic regions, Activation energy, Theory of ionic conductivity. |
| **II** | **Phase diagram**<br><br>Solubility limit, phases, micro structures, phase equilibria; Equilibrium phase diagrams: Binary Isomorphous systems, interpretation of phase diagrams, development of microstructures in isomorphous alloys, mechanical properties of Isomorphous alloys; Eutectic, Pertitectic, Eutectoid and Peritectoid systems – Gibbs phase rule. |
| **III** | **Solid Solution**<br><br>Types of solid solution, solid solution factors governing substitutional solubility, Hume-Rothery rules, intermediate phases, solid solution alloys, Vegards law, Lever rule, mechanical mixtures, Iron-Carbon equilibrium diagram, Aluminum alloys, Copper alloys – Effect of alloying elements; Experimental determination of equilibrium diagram. |
| **IV** | **Phase transformations**<br><br>The kinetics of phase transformation - Kinetics of solid state reaction - Multiphase transformation - Microstructural and property changes in iron carbon alloys - Isothermal transformation diagrams - Continues cooling transformation diagram-mechanical behavior of iron carbon alloy - Tempered martensite - review of phase transformation for iron carbon alloy. |
| **V** | **Heat Treatments**<br><br>Cold working and hot working: Recovery, Recrystallisation and grain growth. T-T-T diagrams and C-C-T diagrams, Heat-treatment processes: Annealing, quenching and tempering, baths used in heat treatment; hardenability: Jominy's end quench test, martempering and austempering, case hardening: induction, flame, laser, carburising, cyaniding, nitriding, carbo nitriding. |

<table>
<tr><td>Reading List (Print and Online)</td><td>This study material includes text books and journal research papers.<br>To know the recent trends in band gap engineering of semiconductors, pervoskites and nanoscale materials, students should refer Review Articles and journal articles.<br><br>1. Materials Science and Engineering, V. Raghavan, Prentice Hall of India Pvt. Ltd. New Delhi<br><br>2. An Introduction to Metallurgy, By Sir Alan Cottrell, Springer.<br><br>3. Materials science for Engineers, 5th Ed. J. C. Anderson, K.D. Leaver, P. Leevers and R.D. Rawlings, Ed. Nelson Thornes Ltd.<br><br>4. Metallurgy & Heat Treatment - The Pocket Book by Atif A. Odeh<br><br>5. Heat Treatment Of Steels by S K Mandal, McGraw Hill<br><br>6. The Theory Of Laser Materials Processing by DOWDEN J (Springer Series In Materials Science Vol 119)<br><br>7. Solid State Physics, A J Dekker, Macmillan India Ltd.<br><br>8. Introductory solid state physics, H.P. Myers, 2nd edition, Taylor and Francis Ltd.<br><br>9. Solid State Physics (Introduction to the theory), James Patterson, Bernald Bailey,<br><br>Web references<br>1. University of Cambridge: (DoITPoMS)<br>Dissemination of IT for the Promotion of Materials Science<br>https://www.doitpoms.ac.uk/tplib/dislocations/index.php<br><br>2. (Universität Kiel, Germany) Heroes of dislocation science<br>https://www.tf.uni-kiel.de/matwis/amat/iss/index.html<br><br>3. 2021 Copyright Materials Science & Engineering Student<br>https://msestudent.com/<br>https://msestudent.com/the-hume-rothery-rules-for-solid-solution/</td></tr>
<tr><td colspan="2">Text Book(s)</td></tr>
<tr><td colspan="2">1. Essentials of Materials Science and Engineering, Donald R. Askeland, Pradeep P. Fulay, (Cengage Learning)<br><br>2. Materials Science and Engineering, William. D. Callister, John - Wiley Delhi</td></tr>
</table>

3. Introduction to Solid state physics, C. Kittel, John - Wiley

4. Solid State Physics : Structure and Properties of Materials, A.M. Wahab, Narosa publishing.

5. Introduction to Physical Metallurgy by Sidney H Avner, McGraw-Hill, Publishing.

6. A Text-book of Material Science and Metallurgy, O.P.Khanna,

7. Laser Material Processing, Authors: Steen, William; and Mazumder, Jyotirmoy (Springer)

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CO 1 | S | S | S | S | S | S | S | S | S | S |
| CO 2 | S | S | S | S | S | S | M | M | M | M |
| CO 3 | S | S | S | M | S | M | M | M | M | M |
| CO 4 | S | S | S | M | S | S | L | M | S | S |
| CO 5 | S | S | S | S | S | S | S | S | S | S |

**S-Strong M-Medium L-Low**

| Subject Code | PHY C114 | Core |
|---|---|---|
| Title of the course | COMPUTATIONAL TECHNIQUES & PROGRAMMING IN C++ | |
| Credits | 4 | |
| Pre-requisites, if any: | | |

**Course Objectives:**

1. Determine the solutions of various $n^{th}$-order polynomial functions by Bi-section and Newton Rapson methods.
2. Solve linear and non-linear equation through Gauss Elimination and Matrix inversion methods.
3. Determine the Eigen value and Eigen Vector of Matrices by power and Jacobi methods.
4. Evaluate cubic polynomial interpolation function using Newton forward and Backward.
5. Solving the Numerical differentiation Trapezoidal and Simpson $3^{rd}$ rules.
6. Estimate the error with various errors parameters.
7. Solving Numerical integration by Euler and Runge-Kutta methods.
8. Fundamental on Arithmetic, logarithmic operations of programming writing using C languages.
9. Methods of declaring integer, sting and float array variables using iterative programs.
10. Input and file output statements with a syntax in C programming.
11. Solving the first order differential equation using C program.
12. Learning Matlab operations with suitable functions and solving the differential, integral equations using Matlab functions.

**Course Outcomes:**

| Course Outcome | Description | Knowledge Level |
|---|---|---|
| **On the successful completion of the course, student will be able to:** | | |

| | | |
|---|---|---|
| **CO1** | Solving linear, interpolation and curve fitting equations by Bi-section, Newton Rapson, Gauss, Matix inversion, Newton's forward, backward interpolation formulas. | **K3**<br>**K4** |
| **CO2** | Solution of Numerical differentiation and integrations by various methods. | **K3**<br>**K5** |
| **CO3** | Fundamental of computer architecture operations. Exercising Arithmetic, logical operations with C & C++ languages. | **K4** |
| **CO4** | Methods of declaring integer, sting and float array variables using iterative programs. Input and output statements with a syntax in C programming.<br>Solving the first order differential equation using C program. | **K4** |
| **CO5** | Learning Matlab operations with suitable functions and solving the differential, integral equations using Matlab functions. | **K5**<br>**K3** |
| **Units** | | |
| **I** | Solutions of equations, linear system, interpolation and curve fitting. Determination of zero's polynomials- root of non-linear algebraic equations and transcendental equations- Bisection and Newton Rapson methods-Convergence of solutions. Solutions of simultaneous linear equations- Gaussian eliminations – Matrix inversion – Eigen values, Eigen vector of matrices – Power and Jacobi's methods. Interpolations with equally spaced and unevenly spaced points (Newton forward and backward interpolations, Lagrange interpolations) – Curve fitting – Polynomial least squares fitting- Cubic spinel fitting. | |
| **II** | Differentiation, integration and solutions: Numerical differentiation – Numerical integration – Trapezoidal rule – Simpson rule – Error estimates – Gauss Legendre, Gauss Laguere, Gauss-Hermite and Gauss-Chebyshev quadrates – Numerical solution of ordinary differential equations – Euler and Runge Kutta methods | |
| **III** | C/C++ programming concepts overview – Fundamental of computer architecture and operation – Programming in C and C++ languages – Data types int, char, float etc. – C expressions arithmetic operations, relation and logic operations – Concept of variables, statement and functional calls – Assignment statements, extension of assignment to the operations – primitive input output and print functions – conditional execution using if, else. Switch and break statements – Concepts of loops, for while and do-while – Array and pointers – one/two dimensional arrays – Matrix computations – Sub programming, functions – stings – structure and unions – Defining C structures, passing structures as arguments – File I/O – simple programs | |

| | |
|---|---|
| **IV** | Computational techniques in MATLAB/Scilab – Introduction, basic usage, variables, scripts, operations – Functions, flow control, Line Plots, m-files, graphics, Image surface plots, Yectorization – Solving equations and curve fitting, linear algebra, Polynomial, optimization, differentiations, Integration, Differential equations – Advanced methods, File I/O visualization |
| **V** | Programming: Zero of the Legendre polynomials, Laguerre, Hermite, Chebyshev polynomials, Lagrange interpolations, Newton forward interpolations, Newton backward interpolations, Curve fitting, least square fitting with algorithm, Numerical integration by trapezoidal rule, Numerical integration by Simpson rule, Numerical solutions of ordinary first – order differential equations by the Euler method. Numerical solution of ordinary first order differential equations by the Runge-Kutta method. |
| **Reading List (Print and Online)** | 1. www.nr.com/oldverswitcher.html - Online books<br>2. www.mathworks.in, www.scilab.org |

**Reference Books**


1. S.S. Shastry, "Numerical Methods " Prentice Hall Inc., India, 1998.
2. Stanton, Ralph G, "Numerical methods for Engineering" Englewood Cliffs, N.J. Prentice Hall Inc, 1961.
3. V. Rajaraman., Computer oriented Numerical methods, 3rd Edition, (Prentice Hall New Delhi, 1993).
4. M.K. Jain, S.R. Iyengar and R.K. Jain, Numerical methods for scientific and engineering.
5. Computation, 3rd Edition (New age international, New Delhi 1995).
6. F. Scheid, Numerical analysis 2nd Edition (Schaum's Series McGraw – Hill, NY 1998).
7. W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery, Numerical Recipes in FORTRAN, rd Edition (Cambridge University Press, 1992); First Indian Edition (Foundation books New Delhi, 1993).
8. W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery, Numerical Recipes in C, rd Edition (Cambridge University Press, 1992); First Indian Edition (Foundation books New Delhi, 1993).

9. Grewal B.S., “Numerical methods“ Khanna Pub., New Delhi 1998.
10. Kernighan, B. Wand, D.M. Ritchie., “The C Programming Language “, Prentice Hall of India, 1998.
11. Byron, S. Gotifreid, “Programming with C“ Tata McGraw Hill, 2nd Edition 1998.
12. E. Balaguruswamy, Object Oriented Programming with C++, Tata McGraw Hill, Publishing company Ltd., 1995.
13. Bjarne Stroustrup, The C++ programming language, Addison Wesley.
14. H.M. Deitel, and P.J. Deitel, C++ how to program, Prentice Hall

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | M | S | S | S | S | S | S | M | S | S |
| **CO 2** | S | S | M | S | S | S | M | M | M | M |
| **CO 3** | S | M | S | L | M | M | S | S | M | M |
| **CO 4** | S | S | S | M | M | M | S | S | S | S |
| **CO 5** | M | S | S | S | S | S | M | M | S | S |

**S-Strong M-Medium L-Low**

| | | |
|---|---|---|
| **Subject Code** | **PHY E109** | Elective |
| **Title of the course** | **REACTOR PHYSICS** | |
| **Credits** | 03 | |
| **Pre-requisites, if any:** | Advanced level Physics | |

**Course Objectives:**

1. Advanced level introduction to Nuclear Energy fundamentals, Fission processes & Nuclear reactions.
2. Intermediate level Nuclear fission principles, Reactor types, Neutron diffusion processes.
3. Detailed analysis of reactor processes, Techniques Maintaining fission ratio etc.
4. Calculation of reactivity rates useful to control fission processes for practical purposes, Finding optimised reaction rate processes.
5. Introduction to Reactor controls & Safety measure protocols, Analysis of control rod usage.

**Course Outcomes:**

**On the successful completion of the course, student will be able to:**

| | | |
|---|---|---|
| **CO1** | Understand Fundamental Nuclear fission processes & Working | K3 |
| **CO2** | Able to handle Nuclear reactor Instrumentations & Knowledge of processes involved. | K3, K4 |
| **CO3** | Advanced working knowledge of Nuclear reactors & protocols | K4 |
| **CO4** | Analysis of Fission parameters useful for production level. | K3, K4 |
| **CO5** | Able to do Basic analysis of safety measures in Nuclear environment. | K4 |

**Units**

| | |
|---|---|
| **I** | **Nuclear energy** Nuclear mass - Binding energy-Radioactivity - Nuclear reactions - Nuclear fission - Mechanism of fission – Fuels - Products of fission - Energy release from fission - Reactor power - Fuel burn up – Consumption. |

| | |
|---|---|
| **II** | **Neutron diffusion** Multiplication factor **- n**eutron balance and conditions for criticality - Conversion and breeding – Classification of reactors. Diffusion of neutrons**:** Flux and current density - Equation of continuity - Fick's law - Diffusion equation - Boundary conditions and solutions - Diffusion length - Reciprocity theorem |
| **III** | **Neutron moderation** Energy loss in elastic collision - moderation of neutrons in Hydrogen - lethargy - Space dependent slowing down - Fermi's age theory - Moderation with absorption. Fermi theory of Bare thermal reactor **:** Criticality of an infinite reactor - One region finite thermal reactor - Critical equation - Optimum reactor shape. |
| **IV** | **Reactor kinetics** Infinite reactor with and without delayed neutrons - Stable period - Prompt jump - Prompt criticality - Negative reactivity - Changes in reactivity - Temperature coefficient - Burn up and conversion |
| **V** | **Control and shielding** Reactor control: Road worth - One control rod - modified one group, two group theory - ring of rods. Radiation shielding: Reactor safeguards - Reactor properties over life - core life estimation. |

**Text Book(s)**


1. John.R Lamarsh, Introduction to Nuclear Reactor TheoryAddison Wesley Publishing Company 2nd printing (1992)
2. Paul .F. Zweifel, Reactor Physics, Mc Graw Hill Book Company (1973) India.


**Reference Books**


1. Richard Stepheson ,Introduction to nuclear Engineering ,Mc Graw Hill Book Company (1974) New York.
2. Suresh Gard, Feroz Ahmed and L.S Kothari ,Physics of Nuclear Reactors , Tata McGraw
3. Hill Pub.Co.Ltd, London.
4. Samuel Glasstone and Edmund , Nuclear reactor theory*Hill*, 1998.

**MAPPING – Course Outcome (CO) with Program Outcome (PO)**

| CO/PSO | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | S | S | M | S | L | L | S | S | S |
| **CO 2** | S | S | M | S | M | S | M | S | L | S |
| **CO3** | S | S | S | S | S | M | L | S | S | M |
| **CO 4** | S | M | S | M | S | S | M | L | S | S |
| **CO 5** | S | S | S | S | S | M | S | S | S | S |

**S-Strong M-Medium L-Low**

| Subject Code | **PHY E110** | Elective |
|---|---|---|
| **Title of the course** | Physics of Nanomaterials and Structures | |
| **Credits** | 3 | |
| **Pre-requisites, if any:** | Condensed Matter Physics and Quantum Physics | |

**Course Objectives:**

1. To understand the basic principles of thermodynamics and obtain considerable knowledge about electron density
2. To explain and summarise the measuring techniques in nanoscale regime, like MRI and Raman spectroscopy
3. To explain and understand the film fabrication techniques
4. Contrast the role of quantum dots and nanolayers on comparing with bulk material
5. Differentiate and understand the role of nano-scale in magnetism and evaluate its use.

**Course Outcomes:**

**On the successful completion of the course, student will be able to:**

| | | |
|---|---|---|
| **CO1** | Explain the role of electron and also list down the various laws of thermodynamics | **K1 K2** |
| **CO2** | Explain the underlying principles and working of nanoscale measuring techniques | **K2** |
| **CO3** | Enumerate the role of heterostructure thin films in recent technology | **K1** |
| **CO4** | Compare the role of nanoscale and Q-DOT in recent advancements | **K4 K5** |
| **CO5** | Evaluate the role of magnetism in nanoscale regime and compare with bulk compounds | **K4 K5** |

**Units**

| | |
|---|---|
| **I** | **Introduction to Physical Principles:** Thermal Properties of Nanostructures - Violation of the Second Law of Thermodynamics for Small Systems and Short Timescales – Surface Energy - Thermal Conductance - Melting of Nanoparticles - Lattice Parameter - Phase Transitions - Electronic Properties - Electron States in Dependence of Size and Dimensionality – The Electron Density of States D(E) - Luttinger Liquid Behavior of Electrons in 1D Metals – Superconductivity. |
| **II** | **Nanoscale Measuring Techniques:** Displacement Sensing - Mass Sensing – Sensing of Weak Magnetic Fields at the Nanoscale - Nuclear Magnetic Resonance Imaging (MRI) at the Nanoscale - Probing Superconductivity at the Nanoscale by Scanning Tunneling Microscopy (STM) - Raman Spectroscopy on the Nanometric Scale - "Nanosized Voltmeter" for Mapping of Electric Fields in Cells. |
| **III** | **Nanostructures & Techniques:** RF and DC sputtering **-** Layered Oxide Heterostructures by Molecular – Beam Epitaxy (MBE) - Atomic Layer Deposition (ALD) - Shape Control of Nanoparticles - Nanostructures with Complex Shapes - Nanostructures by Ball Milling or Strong – Plastic Deformation. |
| **IV** | **Quantum Dots and Nanolayers:** Semiconductor Quantum Dots - Double Quantum Dots for Operating Single-Electron Spins as Qubits for Quantum Computing - Quantum Dot Data Storage Devices -Nanowires and Metamaterials - Metallic Nanowires - Negative-Index Materials (Metamaterials) with Nanostructures - Semiconductor Nanowires - Molecular Nanowires - Conduction Through Individual Rows of Atoms and Single-Atom Contacts - Nanolayers and Multilayers - 2D Quantum Wells - 2D Quantum Wells in High Magnetic Fields – CNT's and applications. |
| **V** | **Nanomagnetism:** Giant Magnetoresistance (GMR) and Spintronics - Giant Magnetoresistance (GMR) and Tunneling Magnetoresistance (TMR) - Spintronics in Semiconductors – Spin Hall Effect - Self-Assembly. |
| **Reading List (Print and Online)** | 1. Hans-Eckhardt Schaefer, Nanoscience: The Science of the Small in Physics,Engineering, Chemistry, Biology and Medicine, Springer, 2010.<br>2. C. P. Poole, Jr. and F. J. Owens, Introduction to Nanotechnology, Wiley India, 2006<br>3. V.V. Mittin, V. A. Kochelap, M. A. Stroscio, Quantum Heterostructures: Microelectronics and optoelectronics, Cambridge University Press, 1999 |

| | |
|---|---|
| | B. G. Streetman and S. Banerjee, Solid State Electronic Devices, Prentice Hall of India, 2001 |
| **Text Book(s)** | |
| 1. Mark S. Lundstrom, Jing Guo, Nanoscale Transistors: Device Physics, Modeling and Simulation, Springer, 2006<br>2. M.Pustilnik,L.I.Glazman,D.H.Cobden,L.P.Kouwenhoven(auth.),Prof.Rolf Haug, Prof. Herbert Schoeller eds., Interacting Electrons in Nanostructures, Springer, 2001. | |

**Mapping with Programme Outcomes:**

**Map course outcomes for each course with programme outcomes (PO) in the 3-point scale of Strong, Medium and Low**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | S | M | S | L | S | M | M | S | S | L |
| **CO 2** | M | L | S | M | M | M | M | L | S | S |
| **CO 3** | M | M | L | M | S | M | L | L | M | L |
| **CO 4** | M | L | S | S | M | L | L | M | S | L |
| **CO 5** | S | M | L | S | M | L | S | S | M | S |

**S-Strong M-Medium L-Low**

**Method of Evaluation (Theory)**

| Sessional I | Sessional II | End Semester Examination | Total | Grade |
|---|---|---|---|---|
| 20 | 20 | 60 | 100 | |

**Methods of assessment (Theory)**

| Description | Knowledge Level |
|---|---|
| Sessional Test I: 20%<br>(Multiple Choice Questions, Definitions, Descriptive Essay, Problem Solving questions, Assignment, Seminar, Presentation, Oral Exam) | **K1**<br>**K2**<br>**K3**<br>**K4**<br>**K5** |
| Sessional Test II : 20%<br>(MCQ, Descriptive, Problems, Assignment, Seminar, Presentation) | **K1**<br>**K2**<br>**K4**<br>**K6** |
| End Semester Examination : 60%<br>(Objective, Descriptive, Problems) | **K1**<br>**K2**<br>**K4** |

**Recall (K1) -** Simple definitions, MCQ, Recall steps, Concept definitions

**Understand/ Comprehend (K2) -** MCQ, True/False, Short essays, Concept explanations, Short summary or overview

**Application (K3) -** Suggest idea/concept with examples, Suggest formulae, Solve problems, Observe, Explain

**Analyse (K4) -** Problem-solving questions, Finish a procedure in many steps, Differentiate between various ideas, Map knowledge

**Evaluate (K5) -** Longer essay/ Evaluation essay, Critique or justify with pros and cons

**Create (K6) -** Check knowledge in specific or offbeat situations, Discussion, Debating or Presentations

**Method of Evaluation (Practical)**

| Sessional I | Sessional II | End Semester Examination | Total | Grade |
|---|---|---|---|---|
| 20 | 20 | 60 | 100 | |

**Methods of assessment (Practical)**

| Description | Knowledge Level |
|---|---|
| Sessional Test I: 20%<br>(Practical Test-1, Record, Viva voce, Theory of Practical - Seminar) | **K3**<br>**K4**<br>**K6** |
| Sessional Test II : 20%<br>(Practical Test-1, Record, Viva voce, Theory of Practical - Seminar) | **K3**<br>**K4**<br>**K6** |
| End Semester Examination : 60%<br>(Practical Test 3, Record Note, Viva voce, Theory of Practical, Seminar) | **K3**<br>**K4**<br>**K6** |

**Recall (K1) -** Simple definitions, MCQ, Recall steps, Concept definitions

**Understand/ Comprehend (K2) -** MCQ, True/False, Short essays, Concept explanations, Short summary or overview

**Application (K3) -** Suggest idea/concept with examples, Suggest formulae, Solve problems, Observe, Explain

**Analyse (K4) -** Problem-solving questions, Finish a procedure in many steps, Differentiate between various ideas, Map knowledge

**Evaluate (K5) -** Longer essay/ Evaluation essay, Critique or justify with pros and cons

**Create (K6) -** Check knowledge in specific or offbeat situations, Discussion, Debating or Presentations