# K.K. UNIVERSITY

**NALANDA, BIHAR - 803115**

# School of Applied Sciences

## Master of Physics (M.Sc.)

(Two Years Full Programme)

**2024-2025**

## SCHEME OF EXAMINATION

## &

## DETAILED SYLLABUS



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KK University
Berauti, Nepura, Bihar Sharif
Nalanda - 803115 (Bihar)

# M.Sc. PHYSICS

## Programme/Course Structure

## (For total credits: 80)

| Year | Semester | Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|---|---|
| 1 | 1 | MSPH 1101 | Mathematical Methods in Physics | 4 | 1 | 0 | 5 |
| | | MSPH 1102 | Quantum Mechanics-I | 4 | 1 | 0 | 5 |
| | | MSPH 1103 | Spectroscopy | 4 | 1 | 0 | 5 |
| | | MSPH 1104-P | Practical-I | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |
| | 2 | MSPH 1201 | Solid State Physics and General Electronics | 4 | 1 | 0 | 5 |
| | | MSPH 1202 | Quantum Mechanics -II | 4 | 1 | 0 | 5 |
| | | MSPH 1203 | Nuclear Physics – I | 4 | 1 | 0 | 5 |
| | | MSPH 1204-P | Practical-II | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |
| 2 | 3 | MSPH 2101 | Numerical Methods and Simulation | 4 | 1 | 0 | 5 |
| | | MSPH 2102 | Statistical Physics | 4 | 1 | 0 | 5 |
| | | MSPH 2103 | Nuclear Physics –II | 4 | 1 | 0 | 5 |
| | | MSPH 2104-P | Practical-III | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |
| | 4 | MSPH 2201 | Nanophysics and Nano-materials – I | 4 | 1 | 0 | 5 |
| | | MSPH 2202 | Condensed Matter Physics | 4 | 1 | 0 | 5 |
| | | MSPH 2203 | Nanophysics and Nano-materials – II | 4 | 1 | 0 | 5 |
| | | MSPH 2204-P | Project and Dissertation | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |

**Total Credits: 80 (Four Semesters)**

L = 48; T = 12; P = 20

L = Lecture; T = Theory; P = Practical/Project

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# SEMESTER – I

| Year | Semester | Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|---|---|
| **1** | **1** | MSPH 1101 | Mathematical Methods in Physics | 4 | 1 | 0 | 5 |
| | | MSPH 1102 | Quantum Mechanics-I | 4 | 1 | 0 | 5 |
| | | MSPH 1103 | Spectroscopy | 4 | 1 | 0 | 5 |
| | | MSPH 1104-P | Practical-I | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |

## Mathematical Methods in Physics

## Course Code: MSPH - 1101

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify scientific phenomena and problems.
4. Participate in experiments and independent lifelong learning projects useful for everyday life and societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. Understand the use of mathematical methods and techniques in physics.
2. Evaluate the role of tensor, matrix operator, functions, electrodynamics, and data processing in physics.
3. Identify and analyze the mathematical requirements to solve real problems and group operations.

### Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | LECTURE HOURS | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Matrices and Tensors:**<br><br>Introduction of matrices through rotation of co-ordinate systems, Orthogonal, Hermitian, Unitary, Null and Unit matrices, Singular and Non-singular matrices, Inverse of a matrix, Trace of a matrix, Eigenvalues and Eigenvectors, Diagonalization. The tensorial character of physical entities, Covariant, Contravariant, and Mixed tensors, Contraction, Quotient rule, Differentiation, Kronecker tensor, Pseudotensor, Symmetric and Anti-symmetric tensors. | **15** | **1-3** |
| **Unit II** | **Green's Functions:**<br><br>Introduction Construction of the Green's function for 1d, 2d, and 3d problems. Solution of some standard problems using Green's function technique. | **15** | **4-6** |
| **Unit III** | **Group Theory:**<br><br>Definition and examples of physically important finite groups, Basic symmetry operations and their matrix representations, Multiplication table, Cyclic groups and subgroups, and Classes. Reducible and Irreducible representation, Schur's lemma, Orthogonality theorem, Character of a representation, Construction character tables. | **15** | **7-9** |
| **Unit IV** | **Electrodynamics and Relativity:**<br><br>Lorentz transformation as orthogonal transformation in 4-dimensions, 4 vectors and light cone, energy-momentum 4-vectors, Relativistic force equation, Covariance of Maxwell's equation, Transformation of electromagnetic fields, Solution of the wave equation in covariant form, Field due to a charge | **15** | **10-12** |

| | | | |
|---|---|---|---|
| | moving with constant velocity, Radiation from oscillating dipole, Total power radiated from an accelerated charge, Larmor formula, Principle of equivalence, Principle of covariance, Covariant differentiation, Curvature tensor, field equation, Reduction to Newton's laws of gravitation. | | |
| **Unit V** | **Signal Processing and Data Analysis:**<br><br>Fast transforms, Random noise and signal, White and colored noise, Power spectrum, Convolution, Auto-correlation and cross-correlation, Matched filtering techniques, and Maximum entropy method. | **15** | **13-15** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLqGm0yRYwThklRVGuMC01Gl7m1YSv_qn&si=QOGB1zFeZ8kQvEAu

## Books Recommended:

- Mathematical Methods for Physics; Arfken G. and Weber H.J.
- Mathematical Physics; Rajput B.S.
- Mathematical Methods in the Physical Sciences; Boas M.L. John Wiley & Sons, NewYork.
- Mathematical Physics; H.K. Das.

# Quantum Mechanics – I

## Course Code: MSPH - 1102

## Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

## Course Outcomes:

1. Understand the role of quantum mechanics in the evolution of microscopic physical systems.
2. Apply quantum mechanics to calculate physically observable quantities with the help of Schrodinge's wave functions and operators.
3. Interpreted the key concepts and principles of quantum physics to solve the energy eigenstates for atoms and molecules.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Mathematical Foundation of Quantum Mechanics:**<br><br>Vectors and Linear vector space, Closure property, Linear independence of vectors, Bases and dimensions. Some examples of linear vector spaces, Dirac's notations, Bra and Ket vectors, Combining bras with kets, Inner product, and inner product space, Orthonormality of vectors, Gram Schmidt orthogonalization of vectors in a linear vector | **18** | **1-3** |



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| | | | |
|---|---|---|---|
| | space, Schwartz inequality, Arbitrary Vectors in an orthonormal basis, Completeness condition, Outer product, Hilbert spaces, Operator on a linear vector space, Algebra of linear operators, Hermitian operators and their properties, Unitary, Projection, Commuting operators and related theorems, Complete set of commuting operators, Eigenvalues and eigenfunctions (continuous and bounded operators), Co-ordinate and momentum representation, Time differentiation of operators. | | |
| **Unit II** | **Hilbert Space Formalism of Quantum Mechanics:**<br><br>Postulates, Expectation values and probabilities, Explicit representation of operators, The general uncertainty relationship, and The minimum uncertainty product. | **18** | **4-6** |
| **Unit III** | **Quantum Dynamics:**<br><br>The equation of motion- The Schrodinger; the Heisenberg and the Interaction pictures; Applications to the linear harmonic oscillator and the hydrogen atom. Linear harmonic oscillator using Creation and annihilation operator. | **18** | **7-9** |
| **Unit IV** | **Angular Momentum:**<br><br>Commutation relations for angular momentum operators, Eigenvalues and eigenvectors, Pauli spin matrices and spin eigenvectors, Addition theorem, Clebsch- Gordon co-efficient, Angular momentum and rotation, Motion in a centrally symmetric field. | **18** | **10-12** |
| **Unit V** | **Invariance Principle and Conservation Laws:**<br><br>Space-time symmetries and conservation Laws for linear momentum, Angular momentum, Energy, and Parity. | **18** | **13-15** |

**Useful links:**



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https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PL74Pz7AXMAnOrUGJ5MqTOUoa1gczsxI91&si=dZ7u3KVK5mFVyOLd

https://youtube.com/playlist?list=PLbGHLEQLE2Y6pOMVq2lx3VEVs3Az9puoZ&si=idghQmVuKlZ6OmeM

## Books Recommended:

- Quantum Mechanics; Schiff L.I.; McGraw-Hill (2008).
- Quantum Mechanics; Ghatak & Loknathan MacMillan India Ltd (2004).
- Quantum Mechanics; Satya Prakash.
- Quantum Mechanics; Sakurai J.J. Addison Wesley (1967).
- Quantum Mechanics: Concepts and Applications; Nouredine Zettili, Wiley.

## Spectroscopy

## Course Code: MSPH - 1103

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. Understand the basic principle of various types of spectroscopy.
2. Interpretate data from UV-Vis, IR, NMR, Raman, elemental analysis, fluorescence, and atomic absorption spectroscopy.
3. Demonstrate and develop practical and technical skills to explain the data obtained from various characterization techniques based on light energy.

### Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

### Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Atomic Spectra:**<br><br>Space quantization, Relation between angular momentum and magnetic moment, Bohr magnetron. Fine structure of spectral lines, Term symbols of alkali and alkaline earth atoms. LS and JJ coupling. Quantum theory of Zeeman effect (normal and | **15** | **1-3** |

| | | | |
|---|---|---|---|
| | anomalous), Paschen-Back effect, Stark effect (linear and non-linear). Hyperfine structure of spectral lines, X-ray spectra characteristics, and absorption. | | |
| **Unit II** | **The Rotation of the Molecule:**<br><br>Rotational Spectra-Rigid diatomic molecule, The intensities of spectral lines, Effect of isotopic substitution, the non-rigid rotator, Simple harmonic oscillator, The an- harmonic oscillator, Diatomic vibrating rotator, Born Oppenheimer approximation, Techniques and instrumentation applications. | **15** | **4-6** |
| **Unit III** | **Molecular Spectra:**<br><br>Infrared and Raman spectra of diatomic molecules using an-harmonic oscillator, non-rigid rotator, and vibrating rotator as models. Electronic states and electronic transitions in diatomic molecules, Frank Condon principle. | **15** | **7-9** |
| **Unit IV** | **Resonance Spectroscopy:**<br><br>Nature of spinning particles, Interaction between spin and a magnetic field, Larmor Precession, Theory of NMR, Chemical shift-relaxation Mechanism, experimental study of NMR, Theory and experimental study of NQR, Theory of ESR, Hyperfine structure and fine structure of ESR, Experimental studies and applications, Mossbauer spectroscopy, Principle-Isomer shift, Quadrupole effect, effect of magnetic field, Instrumentation applications. | **12** | **10-12** |
| **Unit V** | **Laser Holography:**<br><br>Spontaneous and stimulated emission, Einstein A and B coefficients, Basic Principles of Laser, Population Inversion Two level and Three level Laser system, optical pumping- 3+ rate equation, modes of resonator and coherence length, The Nd, YAG laser, The Neodymium Glass laser, The $CO_2$ Laser, Organic Dye lasers, Semi-conductor Laser, Liquid Laser. Principle of Holography, Theory-practical applications including data storage. | **12** | **13-15** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLHs0Ha1N2sgdhps7XcrvC6Ecay4BcvA2B&si=gWhrI1Z21S9P_iwu

https://youtube.com/playlist?list=PLLf6O8XdGj03ktP4MHmIV87pHZHBEUF6f&si=Y08dpwCjOa5Bn3WI

## Books Recommended:

- Introduction to Atomic Spectra; White H.E.
- Fundamentals of Molecular Spectroscopy; Banwell C.N. and McCash E.M.
- Atomic and Molecular Physics; Rajkumar.
- Solid State Spectroscopy; H. Kuzmany, Springer.
- Spectroscopy; H. Kaur, Pragati Publications.

# Practical-I

## Course Code: MSPH 1104 - P

## Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

## Course Outcomes:

1. **Hands-on Experience:**
   Give students real-world experience in a variety of physics topics to help them retain the theoretical information they learned in class.
2. **Skill Development:**
   Gain and improve the practical knowledge and abilities needed to carry out research on physical science and experiments, including lab procedures.
3. **Experimental Design and Execution:**
   Enable students to design and execute the project/working model including planning, execution, data collection, and interpretation.
4. **Laboratory Techniques:**
   Introduce students to a variety of physics-related laboratory procedures, including magnetic field measurement, light absorption and emission, light scattering, etc.
5. **Identify Research Gap:**
   Enable students to formulate pertinent questions to be addressed in their project work via article review, data simulation and analysis.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| S. No. | Objective/Aim |
|---|---|
| **1.** | To study the Michelson's Interferometer. |
| **2.** | To study the Fabre-Perot Etalon. |
| **3.** | To study the Edser-Butler Plate. |
| **4.** | To study the phenomena with polarized light. |
| **5.** | Verification of Rayleigh's criterion for the limit of resolution of spectral lines using (a) Prism spectrum and (b) grating spectrum. |
| **6.** | To study the Edser-Butler Plate. |
| **7.** | To determine the optical constants of metal in thin film form. |
| **8.** | To study the Zeeman effect. |

## Useful links:

https://youtu.be/yQsEw7EdNVk?si=4sltW7owFXQ5Im2u

https://youtu.be/CwOhiRiZ4xs?si=_MB453e47SCF_0jc

https://youtu.be/6ZFmWHnNQrs?si=qCAE4EXGV2awa0yq

## SEMESTER – II

| Year | Semester | Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|---|---|
| **1** | **2** | MSPH 1201 | Solid State Physics and General Electronics | 4 | 1 | 0 | 5 |
| | | MSPH 1202 | Quantum Mechanics -II | 4 | 1 | 0 | 5 |
| | | MSPH 1203 | Nuclear Physics – I | 4 | 1 | 0 | 5 |
| | | MSPH 1204-P | Practical-II | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |

## Solid State Physics and General Electronics

## Course Code: MSPH - 1201

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify scientific phenomena and problems.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. Understand the scientific and broader community value of solid-state physics.
2. Analyze the theoretical strategies for answering crystallographic and material science-related problems.
3. Expand the basic knowledge and properties of solid-state physics to scientific areas like phonons dispersion, superconductors, dielectric, crystalline structures, solid-state devices, etc.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Crystal Physics**<br><br>Laue theory of X-ray diffraction, Geometrical structure factor, and intensity of diffraction maxima. Calculation of structure factor for bcc, fcc, and diamond structure, Intensity of diffraction maxima, Extinction due to Lattice cantering. | **15** | **1-3** |
| **Unit II** | **Electronic Properties:**<br><br>Electron in a Periodic lattice, Block Theorem, Band Theory, Tight Binding, Cellular and Pseudo potential method, Fermi surface, de Haas van Alphen Effect, Cyclotron resonance, Magneto resistance, Quantum Hall Effect. | **15** | **4-6** |
| **Unit III** | **Magnetism:**<br><br>Exchange interaction, Heisenberg model and molecular field theory, spin waves and magnons, | **15** | **7-9** |

| | | | |
|---|---|---|---|
| | Ferri and Anti-ferromagnetic order, Domains, and Bloch Wall energy.<br>**Superconductivity:**<br><br>Basic properties of superconductors, Josephson Effect, BCS theory, High-temperature superconductivity. | | |
| **Unit IV** | **Microwave Components/Devices:**<br><br>Attenuators, phase shifters, directional couplers, T junction, Magic Tee, Standing wave detectors, and cavity resonators (circular). Reflex klystron, TWT, Velocity modulation, Magnetron, Cavity Magnetron, Principle of operation of magnetrons in pi-mode and anode strapping. | **15** | **10-12** |
| **Unit V** | **Photonic Devices:**<br><br>Radiative and non-radiative transitions, optical absorption, bulk and thin film photoconductive devices (LDR), diode photodetectors, solar cells (open circuit voltage and short circuit current, fill factor), LED (high-frequency limit, effect of surface and indirect recombination current, operation of LED), Blue LED, LEDs as commercial sources of lighting, diode lasers conditions for population inversion in active region, optical gain and threshold current for lasing. | **15** | **13-15** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PL0vbmKf7BZLPYukj_HEwJZmCxEPPPBOod&si=5ghvA2Rgr1uPI4NY

**PDF solutions:** Solid State Physics and General Electroni

## Books Recommended:

- Introduction to Solid-State Physics; Kittel C. John Willey (2004).
- Introduction to Solid-State Physics; Mayers H.P. Taylor & Francis (1997).
- Elements of Solid-State Physics; Srivastava J.P. Prentice-Hall of India Pvt. Ltd.
- Solid State Physics; Ashcroft N.W. and Mermin.
- Solid State Physics; S.O. Pillai.
- Principle of Electronics; V.K. Mehta, S. Chand..
- Principle of Electronics Devices and Circuits (Analog and Digital); B.L. Theraja and Dr. R.S. Sedha, S. Chand.
- Microwave Devices and Circuits; Samuel Y. Liao, Pearson.

## Quantum Mechanics – II

## Course Code: MSPH - 1202

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. Understand the use of advanced quantum mechanics and quantum field theories.
2. Explore common approximation techniques to model physical systems such as harmonic oscillators and bound state systems.
3. Analyze and discuss the failure and difficulties with the theory of quantum measurements and local realism.
4. Critically analyze the quantum problems involving Heisenberg, Dirac notation, Lagrangian, Hermitian, Schrodinger, scattering, and interaction pictures.

### Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Approximation Method**<br><br>The WKB approximation and its application to one-dimensional bound systems and barrier penetration problems, the vibrational method (Ritz method) and its application to linear harmonic oscillator and helium atom, Stationary perturbation theory, non-degenerate and degenerate cases and applications to an-harmonic oscillator; linear Stark effect; Zeeman effect and spin-orbit coupling in the hydrogen atom. Time-dependent perturbation theory, constant perturbation, and Fermi Golden rule, harmonic perturbation (Einstein's A and B coefficient). | **18** | **1-3** |
| **Unit II** | **Theory of Scattering:**<br><br>Scattering amplitude and cross-section, Partial wave analysis, Born approximation and its validity with application to Rutherford's alpha-particle scattering. | **18** | **4-6** |
| **Unit III** | **Identical Particles:**<br><br>Many particles Schrodinger equation, The indistinguishability principle, Symmetric and anti-symmetric wave functions. Pauli exclusion principle, Importance of symmetry character of the wave function in the dynamics of the bound system (helium atom), Hydrogen molecule (Heitler-London theory). | **18** | **7-9** |

| | | | |
|---|---|---|---|
| | | | |
| **Unit IV** | **Relativistic Quantum Mechanics:**<br><br>The Klein-Gordon equation for a free particle, Dirac equation, Properties of Dirac matrices, Probability and current densities, Covariance of Dirac equation, Free particle solution and negative energy states, magnetic moment and spin of an electron, Dirac equation for the central field, Energy states of the hydrogen atom. | **18** | **10-12** |
| **Unit V** | **Second Quantization:**<br><br>Number representation of fermions and bosons, Creation and annihilation operator, Electromagnetic field in vacuum. | **18** | **13-15** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PL74Pz7AXMAnOrUGJ5MqTOUoa1gczsxI91&si=dZ7u3KVK5mFVyOLd

https://youtube.com/playlist?list=PLbGHLEQLE2Y6pOMVq2lx3VEVs3Az9puoZ&si=idghQmVuKlZ6OmeM

**PDF Solutions:** Quantum Mechanics -II.pdf

## Books Recommended:

- Quantum Mechanics; Leonard I. Schiff, McGraw-Hill (2008)..
- Quantum Mechanics; Ghatak & Loknathan MacMillan India Ltd (2004).
- Advance Quantum Mechanics; Satya Prakash.
- Quantum Mechanics; J.J. Sakurai,



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Addison Wesley (1967).

- Introduction to Quantum Mechanics; David J. Griffiths and Darrel F. Schroeter, Cambridge University Press.

## Nuclear Physics - I

## Course Code: MSPH - 1203

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. Understand the basic properties of nuclear physics such as interactions, structures, forces, and reactions.
2. Evaluate the role of tensor, matrix operator, functions, electrodynamics, and data processing in physics.
3. Identify and analyze the mathematical requirements to solve real problems and group operations.

### Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Nuclear Size and Shape:**<br><br>Scattering and electromagnetic methods for determining the nuclear radius, Wave mechanical properties of the nucleus and statistics, Electric and magnetic moments, and nuclear properties in detail. | **15** | **1-3** |
| **Unit II** | **Nuclear Force:**<br><br>Types of nuclear potentials, Exchange forces and mass formula, Properties of nuclear forces. Yukawa exchange interaction. n-p scattering at low energies, scattering length, Spin dependence of n-p scattering, effective range theory in n-p scattering, p-p scattering at low energy, Phenomenological two nucleon potential. | **15** | **4-6** |
| **Unit III** | **Nuclear Shell Model:**<br><br>Liquid drop model, extreme single particle model, and analysis of its predictions, Spin-orbit coupling, Single particle model, Magnetic moment, Electric quadrupole moment. | **15** | **7-9** |
| **Unit IV** | **Collective Model of Nucleus:**<br>Collective motion, parametrization of nuclear surface Rotation of deformed nuclei, Collective model Hamiltonian, the nuclear wave function for even-even nuclei and odd-A nuclei, Rotation-vibrational coupling, Nilsson model, Cranking shell model.<br>**Nucleus Reactions:** | **15** | **10-12** |

| | | | |
|---|---|---|---|
| | Type of reactions, reaction cross section, conservation laws, Q-values and their significance, Coulomb excitation, Breit-Wigner formula, compound nucleus, energy of excitation, Direct reactions. Mechanism of Nuclear Fusion and Fission, Nuclear Reactors. | | |
| **Unit V** | **Energy Loss of Charge Particles and Gamma Rays:**<br><br>Mechanism, Ionization formula, stopping power and range, radiation detectors – multi-wire proportional counter, scintillation counter, and Cerenkov detector. Discriminator, different distributions law with associated statistics. | **15** | **13-15** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLRN3HroZGu2n_j3Snd_fSYNLvCkao8HIx&si=1_T_IsHP17kcyWgr

**PDF solutions:** Nuclear Physics – I.pdf

## Books Recommended:

- Nuclear Physics; S.N. Ghoshal, S. Chand.
- Nuclear Physics: An Introduction; S.B. Patel, New Age International Publisher.
- Introductory Nuclear Physics; Samuel S.M. Wong, Wiley-VCH.
- Structure of Nucleus; M.A. Preston and R.K. Bhaduri.
- Theory of Nuclear Structure; M.K. Pal.
- Nuclear Physics; D.C. Tayal.
- Introductory Nuclear Physics; Kenneth S. Krane, Wiley.
- Nuclear Physics; Roy R.R. & Nigam B.P.



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## Practical-II

## Course Code: MSPH 1204 - P

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. **Hands-on Experience:**

   Give students real-world experience in a variety of physics topics to help them retain the theoretical information they learned in class.

2. **Skill Development:**

   Gain and improve the practical knowledge and abilities needed to carry out research on physical science and experiments, including lab procedures.

3. **Experimental Design and Execution:**

   Enable students to design and execute the project/working model including planning, execution, data collection, and interpretation.

4. **Laboratory Techniques:**

   Introduce students to a variety of physics-related laboratory procedures, including magnetic field measurement, light absorption, and emission, light scattering, etc.

5. **Identify Research Gap:**

   Enable students to formulate pertinent questions to be addressed in their project work via article review, data simulation and analysis.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| S. No. | Objective/Aim |
|---|---|
| **1.** | e/m' measurement by Braun's tube and by the Magnetron valve method. |
| **2.** | 'e' measurement by Millikan oil drop apparatus. |
| **3.** | Design and characteristics of passive attenuators (T- and $\pi$-types). |
| **4.** | BJT-based voltage amplifier: design and performance study with and without negative feedback. |
| **5.** | JFET based voltage amplifier: design and performance study. |
| **6.** | Half- and Full-wave rectifiers with and without filters. |

## Useful links:

https://youtu.be/rntSh_CbDdg?si=nJoUyXzVWaVBs2v3

https://youtu.be/cpXndKi2Wyo?si=AD31N0P_n4tPamsP

https://youtu.be/Td- TGwNE9AY?si=nJXjMe9yhJrmS-rk

## SEMESTER – III

| Year | Semester | Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|---|---|
| 2 | 3 | MSPH 2101 | Numerical Methods and Simulation | 4 | 1 | 0 | 5 |
| | | MSPH 2102 | Statistical Physics | 4 | 1 | 0 | 5 |
| | | MSPH 2103 | Nuclear Physics –II | 4 | 1 | 0 | 5 |
| | | MSPH 2104-P | Practical-III | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |

## Numerical Methods and Simulations

## Course Code: MSPH - 2101

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites

and root causes to address actual problems.

3. Apply the principles to simplify scientific phenomena and problems.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

## Course Outcomes:

1. Understand common numerical methods and how to use them to approximate solutions to mathematical problems.
2. Identify, analyze, and interpret the mathematical requirements to solve numerical problems.
3. Apply numerical methods to solve mathematical problems.
4. Understanding the simulation and modeling techniques including MATLAB/SIMULINK.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Numerical Methods and Simulation:**<br><br>Numerical solution of algebraic equations, Iteration, Newton Raphson method, Solution of Linear system, Direct method, Gauss, Gauss-Jordon elimination method, Matrix inversion and LU decomposition, Eigen values and Eigen vectors, Applications.<br>Interpolation, Lograngе approximation, Newton and Chebyshev Polynomials, least square fitting, Application in some physical problems | **15** | **1-3** |

| | | | |
|---|---|---|---|
| **Unit II** | **Numerical Differentiation and Integration:**<br><br>Numerical solution of the ordinary differential equation, Iteration method, Picard's method, Euler's method, and improved Euiler's method. Introduction to quadrature, trapezoidal and Simpson'srule Applications. | **15** | **4-6** |
| **Unit III** | **Numerical Solutions of Partial Differential Equations:**<br><br>First and second order, Linear and non-linear differential equations, Solution by method of iteration, Euler and Runge Kutta methods. Finite difference method, Relaxation, Fourier and cyclic reduction and the Rayleigh-Ritz method, Application to diffusion of dopant in a semiconductor, Wave equation in a coaxial cable, Vibrating strings and membranes, Poison equation, Schrodinger equations. | **15** | **7-9** |
| **Unit IV** | **Monte Carlo Technique:**<br><br>Evaluation of single and multi-dimensional integrals, Optimization problems, Applications to statistical mechanics, Metropolis algorithm.<br><br>**Simulation/Modelling:**<br><br>Concept of modeling, Introduction to techniques of modeling, State variable model of the system, Model parameters and simulation using SCILAB/MATLAB/SIMULINK, Time domain and frequency domain analysis of systems using SCILAB/MATLAB, Spice modeling of semiconductor devices (PN diode and BJT) and programming methodology, Circuit simulation using PSpice/LabView/ORCAD. | **15** | **10-12** |



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## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLwdnzlV3ogoUY43XoMwVVCWDSImC9mVQB&si=NIOjMNAlPbS72T6o

## Books Recommended:

- Introduction to Numerical Analysis; S.S. Sastry, PHI Learning Pvt. Ltd.
- Schaum's Outline of Programming with C++; J. Hubbard, McGraw-Hill Pub..
- A First Course in Numerical Methods; U.M. Ascher & C. Greif, PHI Learning.
- Numerical Methods for Scientists & Engineers; R.W. Hamming, Courier Dover Pub.

# Statistical Physics

## Course Code: MSPH - 2102

## Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

## Course Outcomes:

1. Understand statistical physics and thermodynamics as the logical consequences of the postulates of statistical mechanics.

2. Apply the concepts and laws of statistical physics to solve problems like gases, partition functions, microstates, macrostates, phase space, and phase diagrams.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Quantum Ensemble Theory:**<br><br>Micro-canonical Canonical and Grand Canonical ensembles, Phase space, Distribution functions, Partition function and relationship to thermodynamic quantities, Fluctuations in energy, particle density, Pressure and volume, Equivalence of ensembles. | **15** | **1-3** |
| **Unit II** | **Quantum Statistics:**<br><br>Equation of state of ideal Fermi and Bose gases, Degenerate electron gas, and specific heat, Degenerate Bose gas, Bose-Einstein condensation, Evaluation of constant $\alpha$ and $\beta$ and its thermodynamics interpretation, Thermal properties of Bose-Einstein and liquid He4, the Lambda transition, two-fluid model, Black body distribution law. Density matrix and classical limit for N- particle partition function.<br>**Imperfect Gases:**<br><br>Classical and Quantum cluster expansion, Virial equation of state, Virial coefficients in the classical limit, Second Virial coefficients for hard-sphere and square-well potentials. | **15** | **4-6** |
| **Unit III** | **Phase Transitions:**<br>Ising model, Bragg-Williums Approximation, Mean field | **15** | **7-9** |

| | | | |
|---|---|---|---|
| | theories of the Ising model In three, two, and one dimension, Exact solutions in one dimension, Landau theory of phase transition, Critical indices, Scale transformation, and dimensional analysis. | | |
| **Unit IV** | **High-Density Gases:**<br><br>Thermo-ionic and photoelectric emission, Spin Para-magnetism, Landau Diamagnetism, Equation of state at very high density, Equilibrium of bodies of large mass, Chandrasekhar mass limit, White dwarf and neutron stars. | **15** | **10-12** |
| **Unit V** | **Non-Equilibrium Statistical Mechanics:**<br><br>Boltzmann Transport equation, Boltzmann H-theorem, Equations of motion in classical mechanics, Time correlation function, Linear response theory, Electrical conduction, Langevin's equation and Brownian motion, Debye theory of dielectric relaxation. Motion due to fluctuating force. The Fokker-Planck Equation, Solution on Fokker-Planck Equation. | **15** | **13-15** |

## Use links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLbkGrqpCOeWdoFHdvQ0L1yOZaGARzkBz7&si=dJeJVW1mVNhHk0lO

## Books Recommended:

- Statistical Mechanics; Pathria R.K.
- Fundamental of Statistical and Thermal Physics; Reif F.
- Statistical Mechanics; Gambhir and Lokanathan.
- Statistical Mechanics; Kerson Huang.

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## Nuclear Physics – II

## Course Code: MSPH - 2103

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. Understand the properties of advanced nuclear physics, high-energy particle physics, and astrophysics.

2. Explore the radioactive, alpha, beta, and gamma decay including the selection and transition rules.
3. Apply the quark model/theory to solve high-energy particle physics problems.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Alpha, Beta, and Gamma Decay:**<br><br>Gamow's Theory of alpha decays. Fermi theory of beta-decay, Kurie plots, Comparative half-life, Allowed and forbidden transitions, Detection, and properties of the neutrino, selection rules, non-conservation of parity in beta decay, gamma–decay, and selection rules. Internal Conversion and Mossbauer Effect. | **15** | **1-3** |
| **Unit II** | **Two Body Problem:**<br><br>Deuteron problem, Tensor force, S and D states, Neutron-Proton and proton-proton scattering, Effective range theory, Spin-dependence of nuclear forces, Charge independence and charge symmetry of nuclear forces, Isospin formalism. | **15** | **4-6** |
| **Unit III** | **Particle Physics/High Energy Physics:**<br><br>Types of interaction in typical strengths, range and time scales, classification of elementary particles, quark hypothesis, gluons, quark-confinement, and asymptotic freedom.<br>Conservation laws and Symmetry, charge- | **15** | **7-9** |

| | | | |
|---|---|---|---|
| | conjugation, Parity and Time reversal, Strangeness, Hypercharge, CPT theorem, SU (2) and SU (3) symmetries and their applications. Gell-Mann-Nishijima formula, intrinsic parity of pions, resonances. | | |
| **Unit IV** | **Nuclear Astrophysics:**<br><br>Thermonuclear reactions in stars, pp chains and CNO cycle, Solar Neutrino problem, subsequent thermonuclear reactions, Helium burning And onwards, nucleosynthesis beyond iron, r- and s- processes. | **15** | **10-12** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLbMVogVj5nJRvq-w3zway7k3GzmUDte3a&si=qLwA_ImiMHRVpPpZ

## Books Recommended:

- Introduction to high energy physics (Cambridge University Press); Donald Hill Perkins.
- Introductory Nuclear Physics; Samuel S.M. Wong.
- Nuclear and Particle Physics (Prentice Hall); W.E. Burcham, M. Jobes.
- Nuclear Physics; Roy R.R. & Nigam B.P.
- Structure of Nucleas; Preston M.A. and Bhaduri R.K.
- Theory of Nuclear Structure; Pal M.K.
- Nuclear Physics; Tayal D.C.

## Practical-III

## Course Code: MSPH 2104 - P

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. **Hands-on Experience:**

Give students real-world experience in a variety of physics topics to help them retain the theoretical information they learned in class.

2. **Skill Development:**

   Gain and improve the practical knowledge and abilities needed to carry out research on physical science and experiments, including lab procedures.

3. **Experimental Design and Execution:**

   Enable students to design and execute the project/working model including planning, execution, data collection, and interpretation.

4. **Laboratory Techniques:**

   Introduce students to a variety of physics-related laboratory procedures, including magnetic field measurement, light absorption and emission, light scattering, etc.

5. **Identify Research Gap:**

   Enable students to formulate pertinent questions to be addressed in their project work via article review, data simulation and analysis.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| S. No. | Objective/Aim |
|---|---|
| **1.** | Frank Hertz Experiment. |
| **2.** | Experiment with Hall apparatus. |
| **3.** | Four-Probe set up for mapping the resistivity of a large sample. |
| **4.** | Measurement of magnetoresistance of a semiconductor sample. |
| **5.** | Measurement of Susceptibility of paramagnetic solution by Quinke's tube method. |
| **6.** | Study of the energy band gap and diffusion potential of p-n junction. |

## Useful links:

https://youtu.be/4fLbARE1cBo?si=Bb_9_8nh5TbnfYRJ

https://youtu.be/ATFs4MGrIrU?si=TXoTFYshdUbN9A5S

https://youtu.be/KU3c5WaEwkI?si=opLvPzYkgE2sVqWn

## SEMESTER – IV

| Year | Semester | Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|---|---|
| 2 | 4 | MSPH 2201 | Nanophysics and Nano-materials – I | 4 | 1 | 0 | 5 |
| | | MSPH 2202 | Condensed Matter Physics | 4 | 1 | 0 | 5 |
| | | MSPH 2203 | Nanophysics and Nano-materials – II | 4 | 1 | 0 | 5 |
| | | MSPH 2204-P | Project and Dissertation | 0 | 0 | 5 | 5 |
| | | | **Total** | **12** | **3** | **5** | **20** |

## Nanophysics and Nanomaterials – I

## Course Code: MSPH - 3201

## Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify scientific phenomena and problems.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

## Course Outcomes:

1. Understand the effect of quantum confinement properties of nanomaterials and nanophysics.
2. Analyze the various synthesis methods and characterization techniques of nanomaterials for nano-application-based studies.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **Nanophysics:**<br><br>Introduction to nanophysics and quantum size effect, Dimensionalities and density of states, Optical and transport properties of two-dimensional electron gas formed at heterostructures and within novel graphene monolayers with internal folds, Quantum Hall effects, Physics of one- one-dimensional electron systems including carbon nanotubes and | **15** | **1-3** |

| | | | |
|---|---|---|---|
| | semiconductor nanowires, Fundamental Physics of zero-dimensional electron system, Single electron effects, Quantum dots and nanocrystals, Fundamental principles and applications of scanning tunneling microscopy in the study of nanophysics. | | |
| **Unit II** | **Synthesis of Nanomaterials:**<br><br>Top-down and Bottom-up approach, Synthetic procedures and their significance, Types of nanomaterials synthesis processes, ROHS and WEEE guideness, Physics method, Photolithography, Advanced Ceramics (Solid State reaction method), Ball milling method, Chemical method, Co-precipitation technique, So-gel method, Soft chemical technique (citrate tartrate, etc.), Hydrothermal method, Bio-chemical method, Thin film technology, Thermal Evaporation method, Sputtering (RF and DC), Spray pyrolysis method, Spin coating method, Pulsed laser deposition method, Vacuum arc discharge, Chemical vapor deposition method (CVD), MOCVD, MBE, Ion beam deposition, Electron-beam lithography. MBE growth of quantum dots. | **15** | **4-6** |
| **Unit III** | **Magnetism:**<br><br>Introductory remarks, Structural, X-ray and neutron diffraction, XPS, Electron beam techniques, Scanning Electron Microscope, Transmission Electron Microscope, Scanning Tunnelling Microscope, Atomic Force Microscope, Photoluminescence Cathode-luminescence, Electro-luminescence, UV-visible and Fourier transformed infrared spectrophotometry, Thermal analysis, Thermogravimetry analysis, Differential Scanning Calorimeter, Dielectric and Impedance analysis, Magnetic measurements. | **15** | **7-9** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLO1URmIbkyNuT_PY3KPEXeCyZ_pgeKJAT&si=bEmsEKC0Im7TA2Bo

**PDF Solutions:** Nanophysics and Nanomaterials - I Solu

## Books Recommended:

- Introduction to Nanotechnology (Wiley); Charles P. Poole and Frank J. Owens
- Nanotechnology: The Science of Small (Wiley); M.A. Shah, K.A. Shah
- An Introduction to Nanoscience and Nanotechnology (Wiley); Alain Nouailhat
- Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience (Wiley); Edward L. Wolf
- Nanotechnology-Molecularly Designed Materials; Chow G-M & Gonsalves K.E.
- Physics of Semiconductor Nanostructures; Jain K.P.
- Nanostructures & Nanomaterials: Synthesis, Properties & Application; Cao G.

# Condensed Matter Physics

# Course Code: MSPH - 2202

## Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent

lifelong learning projects for societal benefits.

5. Expand the basic knowledge to the broader interdisciplinary area of physics.

## Course Outcomes:

1. Understand the basic requirement of condensed matter physics i.e. density functional theory.
2. Evaluate the role of bonding, interaction, and transport phenomena between atoms and molecules.
3. Analyze the crystal diffraction pattern in terms of phonons.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| **Unit I** | **X-ray Diffraction Theory:**<br><br>Coherent and incoherent scattering, Derivation of Laue equations and expression for structure factor, Data reduction.<br>**Crystal Structure Determination**<br><br>The phase problem in crystallography, Electron density as Fourier transform of structure factor and vice versa, Techniques to solve the phase problem – Fourier and Patterson methods, Heavy atom technique, Single Isomorphous Replacement (SIR) and Multiple Isomorphous Replacement (MIR) techniques, Anomalous scattering technique, and Direct methods. | **18** | **1-3** |
| **Unit II** | **Experimental Techniques:** | **18** | **4-6** |

| | | | |
|---|---|---|---|
| | The Weissenberg and Precession methods, The Diffractometer, Area Detector and Image Plate.<br>**Fermi Surface:**<br><br>Construction of Fermi surface, Zone schemes, Electron, hole and open orbits, Cyclotron resonance. *Determination of Fermi surface* – Quantization of orbits in the magnetic field; de-Hass – van-Alfen effect; External orbits; Outline of other methods. | | |
| **Unit III** | **Phonons:**<br><br>*Harmonic crystals*, Crystal potential; Harmonic and adiabatic approximations; Normal modes and phonons; Phonon spectrum by neutron scattering; Crystal momentum. *Anharmonic crystals*, Anharmonicity, Lattice thermal conductivity, Umklapp process; Second sound. | **15** | **7-9** |
| **Unit IV** | **Magnetism:**<br><br>Interaction of solids with magnetic fields, Magnetization density and susceptibility, Calculation of atomic susceptibility, Susceptibility of insulators (Larmor diamagnetism), Ground state of ions with partially filled shells (Hund's rule), van Vleckpara magnetism, Curie laws for free ions and solids, Pauli paramagnetism, Conduction electron diamagnetism, Exchange interaction, Ferromagnetic domains, Anisotropy energy, Thickness and energy of Bloch walls, Ising model, Bragg-Williams approximation, Solution of Ising problem for a linear chain. | **15** | **10-12** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLO1URmIbkyNuT_PY3KPEXeCyZ_pgeKJAT&si=bEmsEKC0Im7TA2Bo

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**PDF Solutions:** Condensed Matter Physics solution.pdf

## Books Recommended:

- Digital Systems-Principles and Applications; Tocci R.J.
- Microprocessor Architecture, Programming & Applications; Gaonkar R.S.
- Digital Computer Electronics; Malvino A.P.
- Introduction to Microprocessors; Mathur A.P.

## Nanophysics and Nanomaterials-II

## Course Code: MSPH - 2203

## Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the

scientific phenomena and problems of Physical Science.

4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

## Course Outcomes:

1. Understand the optical, morphological/structural, electronic, and spintronic properties of nanomaterials.
2. Explore the various types of nanomaterials that are desirable for optoelectronic devices.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| UNITS | CONTENTS | Lecture Hours | WEEK ALLOTMENT |
|---|---|---|---|
| Unit I | **Optical Properties:**<br><br>Coulomb interaction in nanostructures, Concept of dielectric constant for nanostructures and charging of nanostructure, Quasi-particles, and excitons, Excitons in direct and indirect band gap semiconductor Nano-crystals, Quantitative treatment of quasi-particles and excitons, charging effects, Radiative processes, General formalization, absorption, emission and luminescence, Optical properties of hetero-structure and nanostructures. | 15 | 1-3 |
| Unit II | **Electron Transport:**<br><br>Electrical properties of Polymers, Ceramics, Dielectrics, and Amorphous Materials, Electrical conduction in Metals, Alloys and Semiconductors, Band structure, Carrier transport in nanostructures, Coulomb blockade | 15 | 4-6 |

| | | | |
|---|---|---|---|
| | effect, thermionic emission, tunneling and hoping conductivity, Defects and impurities, Deep level and surface defects. | | |
| **Unit III** | **Magnetic Properties of Materials:**<br><br>Classification of magnetic materials, Magnetic materials of technical importance, Magnetization processes, Superparamagnetic, Magnetic domain structure, Superconductivity, Phenomenology of superconductivity. | **15** | **7-9** |
| **Unit IV** | **Applications:**<br><br>Applications of nanoparticles, quantum dots, nano-wires, and thin films for photonic devices (LED, Solar Cells). Single electron devices (no derivation). CNT-based transistors.<br>Nano-material Devices, Quantum dots hetero-structure lasers, optical switching, and optical data storage. Magnetic quantum well, magnetic dots – magnetic data storage, Micro Electromechanical systems (NEMS), Nano, Electromechanical Systems (NEMS). Integrated optical devices, SQUIDS, Spintronic devices, Ferroelectric, Pyro-electric, Piezoelectric and electro-optic devices. | **15** | **10-12** |

## Useful links:

https://www.csirnetphysics.in/?m=

https://play.google.com/store/apps/details?id=csirnet.physics

https://youtube.com/playlist?list=PLO1URmIbkyNuT_PY3KPEXeCyZ_pgeKJAT&si=bEmsEKC0Im7TA2Bo

**PDF solutions:** Nanophysics and Nanomaterials - II.pdf

## Books Recommended:



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- Introduction to Nanotechnology (Wiley); Charles P. Poole and Frank J. Owens
- Nanotechnology: The Science of Small (Wiley); M.A. Shah, K.A. Shah
- An Introduction to Nanoscience and Nanotechnology (Wiley); Alain Nouailhat
- Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience (Wiley); Edward L. Wolf
- Nanotechnology-Molecularly Designed Materials; Chow G-M & Gonsalves K.E.
- Physics of Semiconductor Nanostructures; Jain K.P.
- Nanostructures & Nanomaterials: Synthesis, Properties & Application; Cao G.


## Project and Dissertation

## Course Code: MSPH 2204 - P

### Program Outcomes:

1. Explore and comprehend the basic principles and fundamental concepts of Physical Science.
2. Evaluate the essential prerequisites and root causes to address actual problems.
3. Apply the principles to simplify the scientific phenomena and problems of Physical Science.
4. Participate in experiments and independent lifelong learning projects for societal benefits.
5. Expand the basic knowledge to the broader interdisciplinary area of physics.

### Course Outcomes:

1. **Hands-on Experience:**
   Give students real-world experience in a variety of physics topics to help them retain the theoretical information they learned in class.
2. **Skill Development:**
   Gain and improve the practical knowledge and abilities needed to carry out research on physical science and experiments, including lab procedures.
3. **Experimental Design and Execution:**
   Enable students to design and execute the project/working model including planning, execution, data collection, and interpretation.
4. **Laboratory Techniques:**
   Introduce students to a variety of physics-related laboratory procedures, including magnetic field measurement, light absorption,

and emission, light scattering, etc.

5. **Identify Research Gap:**
   Enable students to formulate pertinent questions to be addressed in their project work via article review, data simulation and analysis.

## Objective of the Program:

The primary objective of this program is to impart quality education both in theoretical as well as experimental physics through well-designed courses of fundamental interest such as Nanoscience, High energy physics, Photonics, Condensed matter physics, and Nuclear physics.

## Syllabus details:

| S. No. | Objective/Aim |
|---|---|
| **1.** | To study the Michelson's Interferometer. |
| **2.** | To study the Fabre-Perot Etalon. |
| **3.** | To study the Edser-Butler Plate. |
| **4.** | To study the phenomena with polarized light. |
| **5.** | Verification of Rayleigh's criterion for the limit of resolution of spectral lines using (a) Prism spectrum and (b) grating spectrum. |
| **6.** | To study the Edser-Butler Plate. |
| **7.** | To determine the optical constants of metal in thin film form. |
| **8.** | To study the Zeeman effect. |



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