Central University of South Bihar

Integrated Bachelor's - Master's Degree Programme (Physics)

Multiple Entry and Exit

Syllabus

(Effective from Academic Session 2024-2025)

Department of Physics

School of Physical and Chemical Sciences

Central University of South Bihar, Gaya-824236

Course Title: Mechanics & General Properties of Matter

Course Code	PHY51MJ00104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	1	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The aims of this course is to provide a thorough understanding and comprehensive knowledge of fundamentals of dynamics, gravitation force, surface tension, viscosity, elasticity and its applications.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Describe the surface tension and its basic properties.
2. Explain the viscosity and Poiseuille's method.
3. Students wisll learn different kind of elastic modulus.

Course Contents:

Unit-1

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum.

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.

(25 % Weightage)

Unit-2

Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field: Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications.

(25 % Weightage)

Unit-3

Surface Tension: Molecular forces, Surface tension and its explanation, pressure difference across a curved surface, expression for excess pressure inside a spherical drop and spherical soap bubble surface tension by Jaeger's method, surface tension by Ferguson method. Viscosity: Introduction, Coefficient of viscosity, streamline flow, critical velocity, Reynolds number and its significance, Bernoulli's theorem, Poiseuille's equation for the flow of liquid through a tube.

(25 % Weightage)

Unit-4

Elasticity: Elasticity, Stress, Strain, Hook's law, behaviour of wire under increasing load, Young modulus, Bulk Modulus, Isothermal and adiabatic elasticities of a gas, Modules of rigidity or shear modulus, Poissons Radio, Relations connecting various elastic constants,work done per unit volume in deforming a body, twisting couple on a cylindrical rod or wire, bending beas, bending moment, cantilever, determination of elastic constants by searles method.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum.
8-15	Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.
16-20	Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere.
21-25	Motion of a particle under a central force field: Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications.
26-35	Surface Tension: Molecular forces, Surface tension and its explanation, pressure difference across a curved surface, expression for excess pressure inside a spherical drop and spherical soap bubble surface tension by Jaeger's method, surface tension by Ferguson method.
36-40	Viscosity: Introduction, Coefficient of viscosity, streamline flow, critical velocity, Reynolds number and its significance, Bernoulli's theorem, Poiseuille's equation for the flow of liquid through a tube.
41-50	Elasticity: Elasticity, Stress, Strain, Hook's law, behaviour of wire under increasing load, Young modulus, Bulk Modulus, Isothermal and adiabatic elasticities of a gas.
51-60	Modules of rigidity or shear modulus, Poissons Radio, Relations connecting various elastic constants,work done per unit volume in deforming a body, twisting couple on a cylindrical rod or wire, bending beas, bending moment, cantilever, determination of elastic constants by searles method.

Essential Readings:

1. *Elements of properties of Matter* , D. S. Mathur, S. Chand & Company Limited, 2000
2. *General properties of Matter*, J C Upadhayay, Himalaya Publishing House

Additional/Advance/Further Readings:

1. *Concepts of Modern Physics*, Arthur Beiser, McGraw-Hill
2. *Concepts of Modern Physics*, Paul G. Hewitt, Pearson

Note: Latest edition of text books may be used

Course Title: Basic Physics Laboratory - I

Course Code	PHY51SE00203	Credits	3
L+T+P	0+0+3	Course Duration	One Semester
Semester	1	Contact Hours	90(P) Hours

Course Type	Discipline Based Core (Skill Enhancement)
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to:

1. Enhance the understanding of the students of procedural knowledge of Mechanics physics.
2. Enhance the ability of the students to explain the processes and applications related to mechanics physics.
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the students towards experiment reserach.
5. Dnhance the scientific understanding of radiation safety.
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Handle the sophisticated instruments.
2. Express the basic concepts of mechanics in more general language.
3. Demonstrate experimental skills.
4. Demonstrate appropriate data analysis skills.

Course Contents:

1. Range and least count of Instruments, measurements using various instruments and error analysis (vernier callipers, screw gauge, traveling microscope, spectrometer etc.) Determination of Spring constant of a spring by (a) static method, and (b) dynamic method.
2. Study of the dependence of the normal mode frequencies on the strength of the coupling in coupled oscillator
3. Determination of Moment of Inertia of Fly wheel.
4. Determination of Acceleration due to gravity by compound pendulum.
5. Determination of acceleration due to gravity using compound pendulum or Bar pendulum
6. Determination of modulus of Rigidity and moment of inertial of a body using Torsional pendulum.
7. Determination of Surface tension by capillary ascent, variation with concentration of salt.
8. To study variation of magnetic field along the axis of Helmholtz coil and to determine reduction factor.
9. Determination of Coefficient of viscosity by Stokes method.
10. Verification of parallel and perpendicular axis theorem.
11. Surface tension of a liquid by Quincke's method.
12. Determination of Young's modulus by bending of beam

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiments__.

Course Title: The Science of Mindfulness: A path to Well-being

Course Code	PHY51VA00302	Credits	2
L+T+P	2+0+0	Course Duration	One Semester
Semester	1	Contact Hours	30(L) Hours

Course Type	Value Added Course (VACC)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Value Addition, Concept Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

Objectives of the Valued-Added Course The Science of Mindfulness: A Path to Well-being are :

1. Introduce students to the science and principles of mindfulness as a holistic approach to well-being.
2. Explore the theoretical foundations and empirical evidence supporting the efficacy of mindfulness practices.
3. Provide practical tools and techniques for cultivating mindfulness, stress reduction, and emotional regulation.
4. Foster an understanding of the physiological and psychological benefits associated with consistent mindfulness practice.
5. Encourage self-reflection and personal growth through mindfulness-based exercises and meditation.
6. Cultivate a supportive and interactive learning environment to enhance participants' engagement and understanding of mindfulness principles.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Demonstrate knowledge of the theoretical foundations and historical background of mindfulness.
2. Apply mindfulness principles to enhance self-awareness and cultivate a present-moment focus.
3. Implement various mindfulness techniques and practices for stress reduction and emotional regulation.
4. Evaluate scientific evidence supporting the physiological and psychological benefits of mindfulness.
5. Explore ways to apply mindfulness principles in professional settings for increased effectiveness and resilience.

Course Contents:

Unit-1

Mindfulness: definition and why it Matters, Our Troublesome Brains, Informal, Formal, and Intensive Practices, Who Am I? The Perils of Self, Mindfulness or Psychotherapy?

(25 % Weightage)

Unit-2

Attention and Empathy in Relationships, The Science of Compassion and Self-Compassion, Tailoring Practices to Fit Changing Needs, Modifying Our Brain Function and Structure, Solitude—An Antidote to Loneliness

(25 % Weightage)

Unit-3

Connecting with Children and Adolescents, Seeing Sadness and Depression in a New Light, Befriending Fear, Worry, and Anxiety, Illness, and the Power of Belief, Interrupting Addiction and Troublesome Habits

(25 % Weightage)

Unit-4

The Neurobiology of Self-Preoccupation, Toward a Science of Wisdom, The Promise of Enlightenment, The New Science of Happiness

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Mindfulness: definition and why it Matters, Our Troublesome Brains, Informal,
10-8	Formal, and Intensive Practices, Who Am I? The Perils of Self, Mindfulness or Psychotherapy?
9-12	Attention and Empathy in Relationships, The Science of Compassion and Self-Compassion, Tailoring Practices to Fit Changing Needs,
13-15	Modifying Our Brain Function and Structure, Solitude—An Antidote to Loneliness Unit 3
16-18	Connecting with Children and Adolescents, Seeing Sadness and Depression in a New Light, Befriending Fear,
19-23	Worry, and Anxiety, Illness, and the Power of Belief, Interrupting Addiction and Troublesome Habits
23-27	The Neurobiology of Self-Preoccupation, Toward a Science of Wisdom,
28-30	The Promise of Enlightenment, The New Science of Happiness

Essential Readings:

1. *The Science of Mindfulness: A Research-Based Path to Well-Being*, Ronald D. Siegel, The Teaching Company, 2014

Additional/Advance/Further Readings:

1. *The Wisdom of Wallace D. Wattles*, Wallace Delois Wattles, EN Publishing, 2008

2. *The Science of Stress Management: A Guide to Best Practices for Better Well-Being*, Amitava Dasgupta, Rowman & Littlefield Publishers, 2018

Note: Latest edition of text books may be used

Course Title: Mechanics & General Properties of Matter (Minor)

Course Code	PHY51MN00404	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	1	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The aims of this course is to provide a thorough understanding and comprehensive knowledge of fundamentals of dynamics, gravitation force, surface tension, viscosity, elasticity and its applications.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Describe the surface tension and its basic properties.
2. Explain the viscosity and Poiseuille's method.
3. Students wisll learn different kind of elastic modulus.

Course Contents:

Unit-1

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum.

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.

(25 % Weightage)

Unit-2

Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field: Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications.

(25 % Weightage)

Unit-3

Surface Tension: Molecular forces, Surface tension and its explanation, pressure difference across a curved surface, expression for excess pressure inside a spherical drop and spherical soap bubble surface tension by Jaeger's method, surface tension by Ferguson method. Viscosity: Introduction, Coefficient of viscosity, streamline flow, critical velocity, Reynolds number and its significance, Bernoulli's theorem, Poiseuille's equation for the flow of liquid through a tube.

(25 % Weightage)

Unit-4

Elasticity: Elasticity, Stress, Strain, Hook's law, behaviour of wire under increasing load, Young modulus, Bulk Modulus, Isothermal and adiabatic elasticities of a gas, Modules of rigidity or shear modulus, Poissons Radio, Relations connecting various elastic constants, work done per unit volume in deforming a body, twisting couple on a cylindrical rod or wire, bending beas, bending moment, cantilever, determination of elastic constants by searles method.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum.
8-15	Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.
16-20	Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere.
21-25	Motion of a particle under a central force field: Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications.
26-35	Surface Tension: Molecular forces, Surface tension and its explanation, pressure difference across a curved surface, expression for excess pressure inside a spherical drop and spherical soap bubble surface tension by Jaeger's method, surface tension by Ferguson method.
36-40	Viscosity: Introduction, Coefficient of viscosity, streamline flow, critical velocity, Reynolds number and its significance, Bernoulli's theorem, Poiseuille's equation for the flow of liquid through a tube.
41-50	Elasticity: Elasticity, Stress, Strain, Hook's law, behaviour of wire under increasing load, Young modulus, Bulk Modulus, Isothermal and adiabatic elasticities of a gas.
51-60	Modules of rigidity or shear modulus, Poissons Radio, Relations connecting various elastic constants, work done per unit volume in deforming a body, twisting couple on a cylindrical rod or wire, bending beas, bending moment, cantilever, determination of elastic constants by searles method.

Essential Readings:

1. *Elements of properties of Matter* , D. S. Mathur, S. Chand & Company Limited, 2000
2. *General properties of Matter*, J C Upadhayay, Himalaya Publishing House

Additional/Advance/Further Readings:

1. *Concepts of Modern Physics*, Arthur Beiser, McGraw-Hill
2. *Concepts of Modern Physics*, Paul G. Hewitt, Pearson

Note: Latest edition of text books may be used

Course Title: Mechanics & General Properties of Matter (Minor)

Course Code	PHY51MN00503	Credits	3
L+T+P	3+0+0	Course Duration	One Semester
Semester	1	Contact Hours	45(L) Hours

Course Type	Generic Elective (Interdisciplinary)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

Course Objectives:

The aims of this course is to provide a thorough understanding and comprehensive knowledge of fundamentals of dynamics, gravitation force, surface tension, viscosity, elasticity and its applications.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Describe the surface tension and its basic properties.
2. Explain the viscosity and Poiseuille's method.
3. Students wisll learn different kind of elastic modulus.

Course Contents:

Unit-1

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum.

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.

(30 % Weightage)

Unit-2

Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field: Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications.

(35 % Weightage)

Unit-3

Surface Tension: Molecular forces, Surface tension and its explanation, pressure difference across a curved surface, expression for excess pressure inside a spherical drop and spherical soap bubble surface tension by Jaeger's method, surface tension by Ferguson method. Viscosity: Introduction, Coefficient of viscosity, streamline flow, critical velocity, Reynolds number and its significance, Bernoulli's theorem, Poiseuille's equation for the flow of liquid through a tube. (35 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-15	Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum.
16-25	Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.
25-30	Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere.
31-35	Motion of a particle under a central force field: Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications.
36-40	Surface Tension: Molecular forces, Surface tension and its explanation, pressure difference across a curved surface, expression for excess pressure inside a spherical drop and spherical soap bubble surface tension by Jaeger's method, surface tension by Ferguson method.
40-45	Viscosity: Introduction, Coefficient of viscosity, streamline flow, critical velocity, Reynolds number and its significance, Bernoulli's theorem, Poiseuille's equation for the flow of liquid through a tube.

Essential Readings:

1. *Elements of properties of Matter* , D. S. Mathur, S. Chand & Company Limited, 2000
2. *General properties of Matter*, J C Upadhayay, Himalaya Publishing House

Additional/Advance/Further Readings:

1. *Concepts of Modern Physics*, Arthur Beiser McGraw-Hill
2. *Concepts of Modern Physics*, Paul G. Hewitt, Pearson

Note: Latest edition of text books may be used

Course Title: Electronics

Course Code	PHY52MJ00604	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	2	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of the course are as follows:

1. Introduce students to the basic concepts of p-n junctions and their applications in electronic devices.
2. Familiarize students with the basic principles of rectifiers and their role in converting alternating current (AC) to direct current (DC).
3. Provide students with an understanding of bipolar junction transistors (BJTs) and their applications in electronic circuits.
4. Orient students with the functions and operation of Cathode-Ray Oscilloscopes (CROs) in electronic measurements and analysis.
5. Introduce students to Light Emitting Diodes (LEDs) and their applications in various electronic devices.
6. Familiarize students with the basic concepts of data processing circuits, including amplifiers, filters, and signal processing techniques.
7. Provide an introduction to the fundamental concepts of flip-flops, registers, and counters used in digital electronics for memory and counting applications.

Course Learning Outcomes:

After completion of the course, students will be able to:

1. Describe the basic concepts of p-n junctions and rectifiers, including their principles of operation and applications in electronic circuits.
2. Explain the fundamental principles of bipolar junction transistors (BJTs), including their structure, modes of operation, and applications in amplification and switching circuits.
3. Describe the basic concepts of Cathode-Ray Oscilloscopes (CROs), including their functionality and use in electronic measurements and analysis.
4. Explain the working principles of Light Emitting Diodes (LEDs) and their applications in various electronic devices.

5. Describe the basic concepts of data processing circuits, including amplifiers, filters, and signal processing techniques used in electronic systems.
6. Explain the basic concepts of flip-flops, registers, and counters used in digital electronics for memory storage and counting operations.

Course Contents:

Unit-1

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, (2) Zener Diode and Voltage Regulation. Principle, structure and characteristics of Zener Diode, LED, Photodiode and Solar Cell, Qualitative idea of Schottky diode and Tunnel diode.

(25% Weightage)

Unit-2

n-p-n and p-n-p Transistors. I-V characteristics of CB and CE Configurations. Active, Cutoff and Saturation Regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Transistor Biasing, Amplifier: RC-coupled amplifier Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

(25% Weightage)

Unit-3

Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. Digital Circuits: Difference between Analog and Digital Circuits. Examples of linear and digital ICs, Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra.

(25% Weightage)

Unit-4

Multiplexers, De-multiplexers, Decoders, Encoders. Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor, Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop. Applications of flip-flops

(25% Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. A

6-10	Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, (2) Zener Diode and Voltage Regulation.
11-15	Principle, structure and characteristics of Zener Diode, LED, Photodiode and Solar Cell, Qualitative idea of Schottky diode and Tunnel diode.
16-20	n-p-n and p-n-p Transistors. I-V characteristics of CB and CE Configurations. Active, Cutoff and Saturation Regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors.
21-30	DC Load line and Q-point. Transistor Biasing, Amplifier: RC-coupled amplifier Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.
31-35	Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.
36-40	Digital Circuits: Difference between Analog and Digital Circuits. Examples of linear and digital ICs, Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers.
41-45	Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra.
46-50	Multiplexers, De-multiplexers, Decoders, Encoders. Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor,
51-55	Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop.
56-60	Applications of flip-flops as counters & Shift registers

Essential Readings:

1. *Integrated Electronics*, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2. *Electronics: Fundamentals and Applications*, J.D. Ryder, 2004, Prentice Hall.

Additional/Advance/Further Readings:

1. *Solid State Electronic Devices*, B.G. Streetman & S.K. Banerjee, 6th Edn.,2009, PHI Learning
2. *Digital Principles and Applications*, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw
3. *Digital fundamentals*, Thomas L. Floyd, Pearson

Note: Latest edition of text books may be used

Course Title: Basic Physics Laboratory - 2

Course Code	PHY52SE00703	Credits	3
L+T+P	0+0+3	Course Duration	One Semester
Semester	2	Contact Hours	90(P) Hours

Course Type	Discipline Based Core (Skill Enhancement)
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to :

1. Enhance the understanding of the students of procedural knowledge of basic electronics.
2. Enhance the ability of the students to explain the processes and applications related to basic electronic
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the students towards experiment reserach.
5. Enhance the scientific understanding of electronics.
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to :

1. Handle the sophisticated electronics components.
2. Express the basic concepts of electronics in more general language.
3. Demonstrate experimental skills.
4. Demonstrate appropriate data analysis skills.

Course Contents:

1. To familiarize with basic electronic components (R, C, L, diodes, transistors), digital Multimeter, Function Generator and Oscilloscope. (b) Measurement of Amplitude, Frequency & Phase difference using Oscilloscope.
2. Verification of Network Theorems: (i) Superposition, (ii) Thevenin, (iii) Norton, (iv) Maximum Power transfer.
3. Measurement of resistance by Wheatstone bridge
4. Study of the I-V Characteristics of p-n junction Diode.
5. To study the I-V characteristics of zener diode.
6. To draw the input and output characteristics of a p-n-p transistor.
7. Study of characteristics of field effect transistor.
8. Study of Fixed Bias and Voltage divider bias configuration for CE transistor.
9. To study series and parallel resonant L. C. R. circuit and determination of quality factor.
10. To study phase relation between L and C, L and R, L and C and LCR Circuits.
11. Study of (a) Half wave rectifier and (b) Full wave rectifier (FWR).
12. Construction of three-input 'OR' 'AND' 'NOT' and 'NOR, NAND' gates using diode logic and to verify their truth tables.

***Any experiment can be added / deleted at any time during the course in / from the list of the experiments.**

Course Title: Biography of Indian Scientists

Course Code	PHY52VA00803	Credits	2
L+T+P	2+0+0	Course Duration	One Semester
Semester	2	Contact Hours	30(L) Hours

Course Type	Value Added Course (VACC)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Value Addition, Indian Knowledge Systems
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term Examination

Course Objectives:

The main objective of this course is to introduce the students with the indian contribution to the world in the field of science and encourage them to get inspiration from the life of different indian scientists.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Develop a global understanding of science in general.
2. Keep himself/herself motivated for whole life.
3. Develop an idea of societal upliftment through science.

Course Contents:

Unit-1

Historical Accounts of Ancient Indian Scientists: Baudhaayana, Aaryabhata, Brahmagupta, Bhaaskaraachaarya, Mahaaviiraachaarya, Kanaad, Varaahamihira, Naagaarjuna, Sushruta, Charak, Vaagbhatta, Patanjali, PaNini, Chaanakya, Pingala, Lagaadha, Bharata Muni, Maadhava, Dhanvantari, Kapila Muni, Bhaaradwaj Muni.

(50 % Weightage)

Unit-2

Biographical Sketch of Modern Indian Scientists: Sir J C Bose, Prafulla Chandra Roy, Srinivas Ramanujan, Sir C Venkata Raman, Meghnad Saha, S N Bose, Shanti Swarup Bhatnagar, Homi Jehangir Bhabha, S Chandrashekhar, Vikram Sarabhai, C R Rao, K V Chandrashekhar, Har Govind Khurana, G N Ramachandran, Harish Chandra, M K Vainu Bappu, M Visvesvaraya, Subhash Mukhopadhyay, Raja Ramanna, A P J Abdul Kalam, Vashishtha Narayan Singh

(50 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-5	Baudhaayana, Aaryabhata, Brahmagupta, Bhaaskaraachaarya, Mahaaviiraachaarya, Kanaad, Varaahamihira
6-10	Naagaarjuna, Sushruta, Charak, Vaagbhatta, Patanjali, PaNini, Chaanakya
11-15	Pingala, Lagaadha, Bharata Muni, Maadhava, Dhanvantari, Kapila Muni, Bhaaradwaj Muni
16-20	Sir J C Bose, Prafulla Chandra Roy, Srinivas Ramanujan, Sir C Venkata Raman, Meghnad Saha, S N Bose, Shanti Swarup Bhatnagar
21-25	Homi Jehangir Bhabha, S Chandrashekhar, Vikram Sarabhai, C R Rao, K V Chandrashekhar, Har Govind Khurana, G N Ramachandran
25-30	Harish Chandra, M K Vainu Bappu, M Visvesvaraya, Subhash Mukhopadhyay, Raja Ramanna, A P J Abdul Kalam, Vashishtha Narayan Singh

Essential Readings:

1. Biography of Indian Scientist - A Chattopadhyay
2. Bharat Ke Mahan Vaigyanik Famous Indian Scientists And Their Biographies - Arvind Gupta

Additional/Advance/Further Readings:

1. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala
2. The history of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited
3. Some Eminent Indian Scientists, Jagjit Singh, Publications Division Ministry of Information & Broadcasting
4. आचार्य जगदीश चन्द्र बसु : १५०वीं जयन्ती पर श्रद्धाञ्जलि – निताई चन्द्र मण्डल (अनुवादक – डॉ. वीरेन्द्र कुमार सिंह)
5. Wings of Fire: An Autobiography - A P J Abdul Kalam with Arun Tiwari; University Press (अग्नि की उड़ान : आत्मकथा – डॉ. ए. पी. जे. अब्दुल कलाम व अरुण तिवारी ; प्रभात प्रकाशन)
6. महान खगोलविद् – गणितज्ञ आर्यभट – दीनानाथ साहनी ; प्रभात पेपरबैक्स (प्रभात प्रकाशन)
7. कौटिल्य अर्थशास्त्र ; न्यू साधना पॉकेटबुक्स

Course Title: Electronics (Minor)

Course Code	PHY52MN00904	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	2	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of the course are as follows:

1. Introduce students to the basic concepts of p-n junctions and their applications in electronic devices.
2. Familiarize students with the basic principles of rectifiers and their role in converting alternating current (AC) to direct current (DC).
3. Provide students with an understanding of bipolar junction transistors (BJTs) and their applications in electronic circuits.
4. Orient students with the functions and operation of Cathode-Ray Oscilloscopes (CROs) in electronic measurements and analysis.
5. Introduce students to Light Emitting Diodes (LEDs) and their applications in various electronic devices.
6. Familiarize students with the basic concepts of data processing circuits, including amplifiers, filters, and signal processing techniques.
7. Provide an introduction to the fundamental concepts of flip-flops, registers, and counters used in digital electronics for memory and counting applications.

Course Learning Outcomes:

After completion of the course, students will be able to:

1. Describe the basic concepts of p-n junctions and rectifiers, including their principles of operation and applications in electronic circuits.
2. Explain the fundamental principles of bipolar junction transistors (BJTs), including their structure, modes of operation, and applications in amplification and switching circuits.
3. Describe the basic concepts of Cathode-Ray Oscilloscopes (CROs), including their functionality and use in electronic measurements and analysis.

4. Explain the working principles of Light Emitting Diodes (LEDs) and their applications in various electronic devices.
5. Describe the basic concepts of data processing circuits, including amplifiers, filters, and signal processing techniques used in electronic systems.
6. Explain the basic concepts of flip-flops, registers, and counters used in digital electronics for memory storage and counting operations.

Course Contents:

Unit-1

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, (2) Zener Diode and Voltage Regulation. Principle, structure and characteristics of Zener Diode, LED, Photodiode and Solar Cell, Qualitative idea of Schottky diode and Tunnel diode.

(25% Weightage)

Unit-2

n-p-n and p-n-p Transistors. I-V characteristics of CB and CE Configurations. Active, Cutoff and Saturation Regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Transistor Biasing, Amplifier: RC-coupled amplifier Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

(25% Weightage)

Unit-3

Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. Digital Circuits: Difference between Analog and Digital Circuits. Examples of linear and digital ICs, Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra.

(25% Weightage)

Unit-4

Multiplexers, De-multiplexers, Decoders, Encoders. Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor, Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop. Applications of flip-flops

(25% Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**

1-5	P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. A
6-10	Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, (2) Zener Diode and Voltage Regulation.
11-15	Principle, structure and characteristics of Zener Diode, LED, Photodiode and Solar Cell, Qualitative idea of Schottky diode and Tunnel diode.
16-20	n-p-n and p-n-p Transistors. I-V characteristics of CB and CE Configurations. Active, Cutoff and Saturation Regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors.
21-30	DC Load line and Q-point. Transistor Biasing, Amplifier: RC-coupled amplifier Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.
31-35	Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.
36-40	Digital Circuits: Difference between Analog and Digital Circuits. Examples of linear and digital ICs, Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers.
41-45	Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra.
46-50	Multiplexers, De-multiplexers, Decoders, Encoders. Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor,
51-55	Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop.
56-60	Applications of flip-flops as counters & Shift registers

Essential Readings:

1. *Integrated Electronics*, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2. *Electronics: Fundamentals and Applications*, J.D. Ryder, 2004, Prentice Hall.

Additional/Advance/Further Readings:

1. *Solid State Electronic Devices*, B.G. Streetman & S.K. Banerjee, 6th Edn.,2009, PHI Learning
2. *Digital Principles and Applications*, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw
3. *Digital fundamentals*, Thomas L. Floyd, Pearson

Note: Latest edition of text books may be used

Course Title: Electronics (Minor)

Course Code	PHY52MN01003	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	2	**Contact Hours**	45(L) Hours

Course Type	Generic Elective (Interdisciplinary)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of the course are as follows:

1. Introduce students to the basic concepts of p-n junctions and their applications in electronic devices.
2. Familiarize students with the basic principles of rectifiers and their role in converting alternating current (AC) to direct current (DC).
3. Provide students with an understanding of bipolar junction transistors (BJTs) and their applications in electronic circuits.
4. Orient students with the functions and operation of Cathode-Ray Oscilloscopes (CROs) in electronic measurements and analysis.
5. Introduce students to Light Emitting Diodes (LEDs) and their applications in various electronic devices.
6. Familiarize students with the basic concepts of data processing circuits, including amplifiers, filters, and signal processing techniques.
7. Provide an introduction to the fundamental concepts of flip-flops, registers, and counters used in digital electronics for memory and counting applications.

Course Learning Outcomes:

After completion of the course, students will be able to:

1. Describe the basic concepts of p-n junctions and rectifiers, including their principles of operation and applications in electronic circuits.
2. Explain the fundamental principles of bipolar junction transistors (BJTs), including their structure, modes of operation, and applications in amplification and switching circuits.
3. Describe the basic concepts of Cathode-Ray Oscilloscopes (CROs), including their functionality and use in electronic measurements and analysis.

4. Explain the working principles of Light Emitting Diodes (LEDs) and their applications in various electronic devices.
5. Describe the basic concepts of data processing circuits, including amplifiers, filters, and signal processing techniques used in electronic systems.
6. Explain the basic concepts of flip-flops, registers, and counters used in digital electronics for memory storage and counting operations.

Course Contents:

Unit-1

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, (2) Zener Diode and Voltage Regulation. Principle, structure and characteristics of Zener Diode, LED, Photodiode and Solar Cell, Qualitative idea of Schottky diode and Tunnel diode.

(30% Weightage)

Unit-2

n-p-n and p-n-p Transistors. I-V characteristics of CB and CE Configurations. Active, Cutoff and Saturation Regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Transistor Biasing, Amplifier: RC-coupled amplifier Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

(35% Weightage)

Unit-3

Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. Digital Circuits: Difference between Analog and Digital Circuits. Examples of linear and digital ICs, Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra.

(35% Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. A
6-10	Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, (2) Zener Diode and Voltage Regulation.
11-15	Principle, structure and characteristics of Zener Diode, LED, Photodiode and Solar Cell, Qualitative idea of Schottky diode and Tunnel diode.

16-20	n-p-n and p-n-p Transistors. I-V characteristics of CB and CE Configurations. Active, Cutoff and Saturation Regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors.
21-30	DC Load line and Q-point. Transistor Biasing, Amplifier: RC-coupled amplifier Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.
31-35	Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.
36-40	Digital Circuits: Difference between Analog and Digital Circuits. Examples of linear and digital ICs, Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers.
41-45	Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra.

Essential Readings:

1. *Integrated Electronics*, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2. *Electronics: Fundamentals and Applications*, J.D. Ryder, 2004, Prentice Hall.

Additional/Advance/Further Readings:

1. *Solid State Electronic Devices*, B.G. Streetman & S.K. Banerjee, 6th Edn.,2009, PHI Learning
2. *Digital Principles and Applications*, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw
3. *Digital fundamentals*, Thomas L. Floyd, Pearson

Note: Latest edition of text books may be used

Course Title: Mathematical Physics - I

Course Code	PHY61MJ01104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	3	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The main objective of this course is to provide the basic mathematical skills used in physics.

Course Learning Outcomes:

After completion of the course the learners will be able to :

1. Understand the basic concepts of Calculus.
2. Understand the basic concepts of Vector Calculus.
3. Understand the basic concepts of Curvilinear coordinates.
4. Understand the basic concepts of Dirac delta function.

Course Contents:

Unit-1

Calculus: Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). First Order Differential Equations and Integrating Factor. Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.

(25 % Weightage)

Unit-2

Vector Calculus: Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields. Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Gradient, divergence, curl and Laplacian in spherical and cylindrical coordinates. Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line,

surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).

(25 % Weightage)

Unit-3

Complex Analysis: Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals.

(25 % Weightage)

Unit-4

Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. Dirac Delta function and its properties: Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). First Order Differential Equations and Integrating Factor.
6-18	Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral.
19-24	Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.
25-29	Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.
30-39	Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Gradient, divergence, curl and Laplacian in spherical and cylindrical coordinates.
40-53	Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).
54-58	Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

59-60	Dirac Delta function and its properties: Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

Essential Readings:

1. *Vector Analysis*, Murray R Spiegel , Schaum's Outline Series
2. *Mathematical Methods for Physicists* G.B. Arfken, H.J. Weber, F.E. Harris, Elsevier.

Additional/Advance/Further Readings:

1. *An introduction to ordinary differential equations*, E.A. Coddington, 2009, PHI learning Differential Equations, George F. Simmons, 2007, McGraw Hill.
2. *Mathematical Tools for Physics*, James Nearing, 2010, Dover Publications.
3. *Mathematical methods for Scientists and Engineers*, D.A. McQuarrie, 2003, Viva Book
4. *Advanced Engineering Mathematics*, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
5. *Advanced Engineering Mathematics*, Erwin Kreyszig, 2008, Wiley India.
6. *Essential Mathematical Methods*, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press

Note: Latest edition of text books may be used

Course Title: Waves and Optics

Course Code	PHY61MJ01204	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	3	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory and Practical
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar, Practical
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course reviews the concepts of waves and optics learnt at school from a more advanced perspective and goes on to build new concepts. It begins with explaining ideas of superposition of harmonic oscillations leading to physics of travelling and standing waves. The course also provides an in depth understanding of wave phenomena of light, namely, interference and diffraction with emphasis on practical applications of the same.

Course Learning Outcomes:

Upon completion of this course, the student should able to:

1. Recognize and use a mathematical oscillator equation and wave equation, and derive these equations for certain systems.
2. Apply basic knowledge of principles and theories about the behavior of light and the physical environment to conduct experiments.
3. Understand the principle of superposition of waves and formation of standing waves.
4. Explain several phenomena we can observe in everyday life that can be explained as wave phenomena.
5. Use the principles of wave motion and superposition to explain the Physics of polarisation, interference and diffraction.
6. Understand the working of selected optical instruments like biprism, interferometer, diffraction grating,
7. In the laboratory course, student will gain hands-on experience of using various optical instruments and making finer measurements of wavelength of light using Newton Rings experiment, Fresnel Biprism etc. Resolving power of optical equipment can be learnt firsthand. The motion of coupled oscillators, study of Lissajous figures and behaviour of transverse, longitudinal waves can be learnt in this laboratory course.

Course Contents:

Unit-1

Superposition of Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies

(Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies and their uses. Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Waves. Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.

(35 % Weightage)

Unit-2

Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Interference: Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index. Interferometer: Michelson Interferometer, Fabry-Perot interferometer.

(35 % Weightage)

Unit-3

Fraunhofer diffraction: Single slit. Circular aperture, Double slit. Multiple slits. Diffraction grating. Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Straight edge, a slit and a wire.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-10	Superposition of Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies and their uses.
11-18	Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Waves.
18-30	Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.
31-21	Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle.
22-30	Interference: Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment.

31-40	Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index. Interferometer: Michelson Interferometer, Fabry-Perot interferometer
41-45	Fraunhofer diffraction: Single slit. Circular aperture, Double slit. Multiple slits. Diffraction grating.
46-52	Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light.
52-60	Theory of a Zone Plate: Multiple Foci of a Zone Plate. Straight edge, a slit and a wire.

Essential Readings:

1. *Vibrations and Waves*, A.P. French, 1stEdn., 2003, CRC press.
2. *Fundamentals of Optics*, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
3. *The Physics of Vibrations and Waves*, H. J. Pain, 2013, John Wiley and Sons.
4. *The Physics of Waves and Oscillations*, N.K. Bajaj, 1998, Tata McGraw Hill.
5. *Waves: Berkeley Physics Course, vol. 3*, Francis Crawford, 2007, Tata McGraw-Hill.

Additional/Advance/Further Readings:

1. *Principles of Optics*, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
2. *Optics*, (2017), Ajoy Ghatak, McGraw-Hill Education, New Delhi
3. *Fundamental of Optics*, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications
4. *Optics* , Eugene Hecht, 4thEdn., 2014, Pearson Education

Note: Latest edition of text books may be used

Course Title: Physics Laboratory - I

Course Code	PHY61SE01303	**Credits**	3
L+T+P	0+0+3	**Course Duration**	One Semester
Semester	3	**Contact Hours**	90(P) Hours

Course Type	Discipline Based Core (Skill Enhancement)
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

This course reviews the concepts of waves and optics learnt at school from a more advanced perspective and goes on to build new concepts. It begins with explaining ideas of superposition of harmonic oscillations leading to physics of travelling and standing waves. The course also provides an in depth understanding of wave phenomena of light, namely, interference and diffraction with emphasis on practical applications of the same. The main objectives of this course are to :

1. Enhance the understanding of the students of procedural knowledge optical instruments .
2. Enhance the ability of the students to explain the processes and applications related to wave and optics
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the students towards experiment reserach.
5. Enhance the scientific understanding of electrical instruments .
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to :

1. Handle the sophisticated electrical instruments components.
2. Express the basic concepts of electrical instruments in more general language.
3. Demonstrate experimental skills.
4. Demonstrate appropriate data analysis skills.

Course Contents:

1. To determine the wavelength and speed of sound using resonance tube.
2. To study the relation between frequency and length of a given wire under constant tension using sonometer.
3. Determination of focal length of combination of lenses.
4. Determination of dispersive power of material of a prism.
5. Determination of wavelength of sodium yellow line by Newton's rings.
6. Determination of wavelength of mercury lines by diffraction grating.
7. Determination of specific rotation of cane sugar by polarimeter.
8. Determination of wavelength of sodium yellow line by Fresnal's Biprism.
9. To determine diameter/thickness of a thin wire by diffraction method.
10. Verification of Malu's Law
11. To determine the resolving power of a grating.
12. Polarization of light using Quarter-Wave Plate

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiment.__

Course Title: Mathematical Physics - I (Minor)

Course Code	PHY61MN01404	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	3	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The main objective of this course is to provide the basic mathematical skills used in physics.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Understand the basic concepts of Calculus.
2. Understand the basic concepts of Vector Calculus.
3. Understand the basic concepts of Curvilinear coordinates.
4. Understand the basic concepts of Dirac delta function.

Course Contents:

Unit-1

Calculus: Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). First Order Differential Equations and Integrating Factor. Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.

(25 % Weightage)

Unit-2

Vector Calculus: Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields. Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Gradient, divergence, curl and Laplacian in spherical and cylindrical coordinates. Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line,

surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).

(25 % Weightage)

Unit-3

Complex Analysis: Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals.

(25 % Weightage)

Unit-4

Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

Dirac Delta function and its properties: Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). First Order Differential Equations and Integrating Factor.
6-18	Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral.
19-24	Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.
25-29	Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.
30-39	Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Gradient, divergence, curl and Laplacian in spherical and cylindrical coordinates.
40-53	Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).
54-58	Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

59-60	Dirac Delta function and its properties: Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

Essential Readings:

1. *Vector Analysis*, Murray R Spiegel, Schaum's Outline Series
2. *Mathematical Methods for Physicists*, G.B. Arfken, H.J. Weber, F.E. Harris; Elsevier.

Additional/Advance/Further Readings:

1. *An introduction to ordinary differential equations*, E.A. Coddington, 2009, PHI learning Differential Equations, George F. Simmons, 2007, McGraw Hill.
2. *Mathematical Tools for Physics*, James Nearing, 2010, Dover Publications.
3. *Mathematical methods for Scientists and Engineers*, D.A. McQuarrie, 2003, Viva Book
4. *Advanced Engineering Mathematics*, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
5. *Advanced Engineering Mathematics*, Erwin Kreyszig, 2008, Wiley India.
6. *Essential Mathematical Methods*, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press

Note: Latest edition of text books may be used

Course Title: Waves and Optics (Minor)

Course Code	PHY61MN01504	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	3	Contact Hours	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory and Practical
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar, Practical
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course reviews the concepts of waves and optics learnt at school from a more advanced perspective and goes on to build new concepts. It begins with explaining ideas of superposition of harmonic oscillations leading to physics of travelling and standing waves. The course also provides an in depth understanding of wave phenomena of light, namely, interference and diffraction with emphasis on practical applications of the same.

Course Learning Outcomes:

Upon completion of this course, the student should able to:

1. Recognize and use a mathematical oscillator equation and wave equation, and derive these equations for certain systems.
2. Apply basic knowledge of principles and theories about the behavior of light and the physical environment to conduct experiments.
3. Understand the principle of superposition of waves and formation of standing waves.
4. Explain several phenomena we can observe in everyday life that can be explained as wave phenomena.
5. Use the principles of wave motion and superposition to explain the Physics of polarisation, interference and diffraction.
6. Understand the working of selected optical instruments like biprism, interferometer, diffraction grating,
7. In the laboratory course, student will gain hands-on experience of using various optical instruments and making finer measurements of wavelength of light using Newton Rings experiment, Fresnel Biprism etc. Resolving power of optical equipment can be learnt firsthand. The motion of coupled oscillators, study of Lissajous figures and behaviour of transverse, longitudinal waves can be learnt in this laboratory course.

Course Contents:

Unit-1

Superposition of Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies

(Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies and their uses. Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Waves. Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.

(35 % Weightage)

Unit-2

Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Interference: Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index. Interferometer: Michelson Interferometer, Fabry-Perot interferometer.

(35 % Weightage)

Unit-3

Fraunhofer diffraction: Single slit. Circular aperture, Double slit. Multiple slits. Diffraction grating. Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Straight edge, a slit and a wire.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-10	Superposition of Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies and their uses.
11-18	Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Waves.
18-30	Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.
31-21	Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle.
22-30	Interference: Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment.

31-40	Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index. Interferometer: Michelson Interferometer, Fabry-Perot interferometer
41-45	Fraunhofer diffraction: Single slit. Circular aperture, Double slit. Multiple slits. Diffraction grating.
46-52	Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light.
52-60	Theory of a Zone Plate: Multiple Foci of a Zone Plate. Straight edge, a slit and a wire.

Essential Readings:

1. *Vibrations and Waves*, A.P. French, 1stEdn., 2003, CRC press.
2. *Fundamentals of Optics*, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
3. *The Physics of Vibrations and Waves*, H. J. Pain, 2013, John Wiley and Sons.
4. *The Physics of Waves and Oscillations*, N.K. Bajaj, 1998, Tata McGraw Hill.
5. *Waves: Berkeley Physics Course, vol. 3*, Francis Crawford, 2007, Tata McGraw-Hill.

Additional/Advance/Further Readings:

1. *Principles of Optics*, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
2. *Optics*, (2017), Ajoy Ghatak, McGraw-Hill Education, New Delhi
3. *Fundamental of Optics*, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications
4. *Optics* , Eugene Hecht, 4thEdn., 2014, Pearson Education

Note: Latest edition of text books may be used

Course Title: Mathematical Physics - I (Minor)

Course Code	PHY61MN01603	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	3	**Contact Hours**	45(L) Hours

Course Type	Generic Elective(Interdisciplinary)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The main objective of this course is to provide the basic mathematical skills used in physics.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Understand the basic concepts of Calculus.
2. Understand the basic concepts of Vector Calculus.
3. Understand the basic concepts of Curvilinear coordinates.
4. Understand the basic concepts of Dirac delta function.

Course Contents:

Unit-1

Calculus: Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). First Order Differential Equations and Integrating Factor. Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.

(30 % Weightage)

Unit-2

Vector Calculus: Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields. Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Gradient, divergence, curl and Laplacian in spherical and cylindrical coordinates. Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line,

surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).

(35 % Weightage)

Unit-3

Complex Analysis: Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals.

(35 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). First Order Differential Equations and Integrating Factor.
6-10	Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral.
11-15	Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.
16-20	Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.
21-30	Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Gradient, divergence, curl and Laplacian in spherical and cylindrical coordinates.
31-35	Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).
36-40	Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts.
41-45	Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals.

Essential Readings:

1. *Vector Analysis*, Murray R Spiegel, Schaum's Outline Series
2. *Mathematical Methods for Physicists* G.B. Arfken, H.J. Weber, F.E. Harris, Elsevier.

Additional/Advance/Further Readings:

1. *An introduction to ordinary differential equations*, E.A. Coddington, 2009, PHI learning Differential Equations, George F. Simmons, 2007, McGraw Hill.
2. *Mathematical Tools for Physics*, James Nearing, 2010, Dover Publications.
3. *Mathematical methods for Scientists and Engineers*, D.A. McQuarrie, 2003, Viva Book
4. *Advanced Engineering Mathematics*, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
5. *Advanced Engineering Mathematics*, Erwin Kreyszig, 2008, Wiley India.
6. *Essential Mathematical Methods*, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press

Note: Latest edition of text books may be used

Course Title: Waves and Optics (Minor)

Course Code	PHY61MN01704	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	3	**Contact Hours**	60(L) Hours

Course Type	Generic Elective (Interdisciplinary)
Nature of the Course	Theory and Practical
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar, Practical
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course reviews the concepts of waves and optics learnt at school from a more advanced perspective and goes on to build new concepts. It begins with explaining ideas of superposition of harmonic oscillations leading to physics of travelling and standing waves. The course also provides an in depth understanding of wave phenomena of light, namely, interference and diffraction with emphasis on practical applications of the same.

Course Learning Outcomes:

Upon completion of this course, the student should able to:

1. Recognize and use a mathematical oscillator equation and wave equation, and derive these equations for certain systems.
2. Apply basic knowledge of principles and theories about the behavior of light and the physical environment to conduct experiments.
3. Understand the principle of superposition of waves and formation of standing waves.
4. Explain several phenomena we can observe in everyday life that can be explained as wave phenomena.
5. Use the principles of wave motion and superposition to explain the Physics of polarisation, interference and diffraction.
6. Understand the working of selected optical instruments like biprism, interferometer, diffraction grating,
7. In the laboratory course, student will gain hands-on experience of using various optical instruments and making finer measurements of wavelength of light using Newton Rings experiment, Fresnel Biprism etc. Resolving power of optical equipment can be learnt firsthand. The motion of coupled oscillators, study of Lissajous figures and behaviour of transverse, longitudinal waves can be learnt in this laboratory course.

Course Contents:

Unit-1

Superposition of Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies

(Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies and their uses. Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Waves. Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.

(50 % Weightage)

Unit-2

Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Interference: Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index. Interferometer: Michelson Interferometer, Fabry-Perot interferometer.

(50 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-10	Superposition of Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies and their uses.
11-15	Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Waves.
16-25	Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.
26- 30	Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle.
31-38	Interference: Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment.
39-45	Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index. Interferometer: Michelson Interferometer, Fabry-Perot interferometer

Essential Readings:

1. *Vibrations and Waves*, A.P. French, 1stEdn., 2003, CRC press.
2. *Fundamentals of Optics*, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
3. *The Physics of Vibrations and Waves*, H. J. Pain, 2013, John Wiley and Sons.
4. *The Physics of Waves and Oscillations*, N.K. Bajaj, 1998, Tata McGraw Hill.
5. *Waves: Berkeley Physics Course, vol. 3*, Francis Crawford, 2007, Tata McGraw-Hill.

Additional/Advance/Further Readings:

1. *Principles of Optics, Max Born and Emil Wolf*, 7th Edn., 1999, Pergamon Press.
2. *Optics*, Ajoy Ghatak, McGraw-Hill Education, New Delhi
3. *Fundamental of Optics*, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications
4. *Optics* , Eugene Hecht, 4th Edn., 2014, Pearson Education

Note: Latest edition of text books may be used

Course Title: Mathematical Physics - II

Course Code	PHY62MJ01804	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	4	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The main objective of this course is to provide the basic mathematical skills used in physics.

Course Learning Outcomes:

After completion of the course the learners will be able to understand the basic concepts of Fourier Series, Frobenius Method, Special Functions, Some Special Integrals, theory of errors and learn techniques to solve certain Partial Differential Equations.

Course Contents:

Unit-1

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

(25 % Weightage)

Unit-2

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions and Orthogonality.

(25 % Weightage)

Unit-3

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral). Theory of Errors: Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error.

(25 % Weightage)

Unit-4

Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-14	Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.
15-38	Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions and Orthogonality.
39-42	Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).
43-46	Theory of Errors: Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error.
47-60	Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

Essential Readings:

1. *Mathematical Methods for Physicists*: Arfken, Weber, 2005, Harris, Elsevier.
2. *Fourier Analysis* by M.R. Spiegel, 2004, Tata McGraw-Hill.

Additional/Advance/Further Readings:

1. *Mathematics for Physicists*, Susan M. Lea, 2004, Thomson Brooks/Cole.
2. *Differential Equations*, George F. Simmons, 2006, Tata McGraw-Hill.
3. *Partial Differential Equations for Scientists & Engineers*, S.J. Farlow, 1993, Dover Pub.
4. *Mathematical methods for Scientists & Engineers*, D.A. McQuarrie, 2003, Viva Books.

Course Title: Electricity and Magnetism

Course Code	PHY62MJ01904	Credits	4
L+T+P	3+1+0	Course Duration	One Semester
Semester	4	Contact Hours	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. Acquaint the students with basic knowledge of electricity and Magnetism.
2. Introduction about polar and cylinderical coordinate system
3. Familiarize the student Ampere law, Gauss law and Maxwell Equation.
4. Acquaint the students with the theory of Magnetism.
5. Concept of different electrical circuit and Laws.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Understand the fundamentals of Electricity.
2. Understand the fundamentals of Different circuits LC, LCR, and LR.
3. Understand resonance phenomenon.
4. Understand the basic concepts of Resonance Phenomenon.
5. Describe the Maxwell Equations.
6. Different types of theorem for circuits.

Course Contents:

Unit-1

Scalar and Vector Field, Gradient, Curl, Divergence, (Spherical and Cylindrical Coordinate system), and their Physical Significance, Line surface and Volume Integral. Electrostatics: Electric field: Electric field lines. Continuous charge distribution, Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry, Divergence and curl of Electric Field and their Physical Signifiance. Conservative nature of Electrostatic Field Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness

Theorem. Potential and Electric Field of a dipole. Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors Parallel-plate capacitor. Capacitance of an isolated conductor, cylindrical and Spherical capacitor, Dielectric Properties of Matter: Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss'Law in dielectrics.

(35 % Weightage)

Unit-2

Magneto statics :Magnetic force between current elements and definition of Magnetic Field B. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability. Relation between B, H, M. Ferromagnetism. B-H curve and hysteresis. Electromagnetic Induction Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field.

(35 % Weightage)

Unit-3

Electrical Circuits: AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and(3) Quality Factor, and (4) Band Width. ParallelLCR-Circuit. Network theorems: Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-10	Scalar and Vector Field, Gradient, Curl, Divergence, (Spherical and Cylindrical Coordinate system), and their Physical Significance, Line surface and Volume Integral.
11-20	Electric field: Electric field lines. Continuous charge distribution, Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry, Divergence and curl of Electric Field and their Physical Signifiance. Conservative nature of Electrostatic Field Electrostatic Potential. Laplace's and Poisson equations.
11-14	The Uniqueness Theorem. Potential and Electric Field of a dipole. Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor.
21-34	Parallel-plate capacitor. Capacitance of an isolated conductor, cylindrical and Spherical capacitor, Dielectric Properties of Matter: Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss'Law in dielectrics.
35-42	Magnetic force between current elements and definition of Magnetic Field B. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment

42-46	Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field
47-50	Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability. Relation between B, H, M. Ferromagnetism. B-H curve and hysteresis. Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field.
50-54	AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and(3) Quality Factor, and (4) Band Width. ParallelLCRCircuit.
54-57	Network theorems: Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem,
57-60	Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping.CDR.

Essential Readings:

1. *Electricity, Magnetism & Electromagnetic Theory*, S. Mahajan and Choudhury, 2012, Tata McGraw
2. *Electricity and Magnetism*, Edward M. Purcell, 1986 McGraw-Hill Education
3. *Electricity & Magnetism*, D.L. Sehgal, K.L. Chopra, and N. K. Sehgal, Publisher, Sultan Chand & Sons.
4. *Introduction to Electrodynamics*, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
5. *Elements of Electromagnetics*, M.N.O. Sadiku, 2010, Oxford University Press.
6. *Electricity and Magnetism*, J.H.vFewkes & J. Yarwood. Vol. I, 1991, Oxford Univ. Press.

Additional/Advance/Further Readings:

1. *Concept of Physics-II* by H.C. Verma
2. *Advanced Practical Physics for students*, B.L. Flint and H.T. Worsnop, 1971, Asia PublishingHouse
3. *A Text Book of Practical Physics*, I. Prakash & Ramakrishna, 11th Ed., 2011
4. *The Feynman Lectures on Physics*, Vol. II, By Richard P. Feynman, Robert B. Leighton, Matthew Sands, 2011, Basic Books.

Note: Latest edition of text books may be used

Course Title: Physics Laboratory - II

Course Code	PHY62MJ02004	Credits	3
L+T+P	0+0+3	Course Duration	One Semester
Semester	4	Contact Hours	90(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to :

1. Enhance the understanding of the students of procedural knowledge of basic electrical instruments .
2. Enhance the ability of the students to explain the processes and applications related to basic electronic
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the students towards experiment reserach.
5. Enhance the scientific understanding of electrical instruments .
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to :

1. Handle the sophisticated electrical instruments components.
2. Express the basic concepts of electrical instruments in more general language.
3. Demonstrate experimental skills.
4. Demonstrate appropriate data analysis skills.

Course Contents:

1. To study charging and discharging of a condenser through a resistor R.
2. To find low resistance by Carey Fosters bridge.
3. To study growth/decay of current in LR circuit.
4. Verification of Kirchhoff's laws, using electrical network.
5. Determination of dielectric constant of a solid.
6. Determination of internal resistance of micro ammeter and conversion of micro-ammeter into voltmeter, milli-ammeter.
7. Determination of Stefan's constant.
8. Thermal conductivity of a bad conductor by Lee's disc method.
9. To determine specific heat of a given liquid by method of cooling.
10. Study of heating efficiency of electrical kettle with varying voltages.
11. Determination of mutual inductance of a pair of coils.
12. To study the Characteristics of LDR and Photodiode with (i) Variable Illumination intensity, and (ii) Linear Displacement of source.

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiment.__

Course Title: Heat and Thermodynamics

Course Code	PHY62MJ02102	**Credits**	2
L+T+P	2+0+0	**Course Duration**	One Semester
Semester	4	**Contact Hours**	30(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives

The objectives of this course are:

1. To familiarize students with the foundational principles of the kinetic theory of gases.
2. To develop an understanding of the characteristics and behavior of ideal gases.
3. To explore Van der Waals' equation and its limitations in describing real gas behavior.
4. To comprehend the fundamental laws of thermodynamics and their applications in understanding the behavior of gases and other systems.

Course Learning Outcomes

After the completion of this course, the student should be able to:

1. Demonstrate understanding of the concept of degree of freedom in thermodynamics.
2. Understand the Zeroth law of thermodynamics and its implications in defining temperature and thermal equilibrium.
3. Grasp the basic principles of the first law of thermodynamics, including concepts of energy conservation, heat transfer, and work done in thermodynamic processes.
4. Understand the concept of entropy and its role in quantifying the disorder or randomness of a system, as well as its relationship to the second law of thermodynamics.
5. Explain the principles of the Carnot ideal heat engine, including its theoretical efficiency and the limitations imposed by the laws of thermodynamics.

Course Contents:

Unit-1

Laws of thermodynamics: Thermo dynamical system, Zeroth law of thermodynamics, concept of heat, thermodynamical equilibrium, work, internal energy, first law of thermodynamics, internal energy as a state function, specific heats of a gas, Application of first law of thermodynamics, work done during isothermal and adiabatic process, slopes of adiabatic and isothermal, reversible and irreversible process, heat engines, definition of efficiency, Carnot ideal heat engine, Carnot's cycle, Second law of thermodynamics, Carnot's theorem.

(50 % Weightage)

Unit-2

Concept of entropy, change in entropy, T-S diagram, change in entropy in adiabatic process,, change of entropy in reversible and irreversible cycle, principle of increase of entropy, Physical significance of entropy, entropy of a perfect gas, third law of thermodynamics, thermodynamical variables, extensive and intensive variables, Maxwell's thermodynamical relations, Application of Maxwell's thermodynamical relations: eg. Specific heat equation, Joule-Thomson cooling, Joule-Thomson coefficient, Clausis-Clapeyron's equation.Thermodynamic potentials, Relation of thermodynamical potentials with their variables, relations between C_p, C_v and μ, The T-dS equations,Entropy and second law of thermodynamics,

(50 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Laws of thermodynamics: Thermo dynamical system, Zeroth law of thermodynamics, concept of heat, thermodynamical equilibrium,
6-10	work, internal energy, first law of thermodynamics, internal energy as a state function, specific heats of a gas, Application of first law of thermodynamics, work done during isothermal and adiabatic process.
11-15	slopes of adiabatic and isothermal, reversible and irreversible process, heat engines, definition of efficiency, Carnot ideal heat engine, Carnot's cycle, Second law of thermodynamics, Carnot's theorem.
16-18	Concept of entropy, change in entropy, T-S diagram, change in entropy in adiabatic process, change of entropy in reversible and irreversible cycle.
19-21	principle of increase of entropy, Physical significance of entropy, entropy of a perfect gas, third law of thermodynamics, thermodynamical variables, extensive and intensive variables.
22-24	Maxwell's thermodynamical relations, Application of Maxwell's thermodynamical relations: eg. Specific heat equation, Joule-Thomson cooling, Joule-Thomson coefficient.
25-27	Clausis-Clapeyron's equation.Thermodynamic potentials, Relation of thermodynamical potentials with their variables.
28-30	relations between C_p, C_v and μ, The T-dS equations,Entropy and second law of thermodynamics.

Essential Readings:

1. *Heat and Thermodynamics*, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
2. *Heat, Thermodynamics and Statistical Physics*, Brij Lal, Revised Edition, S. Chand.
3. *Statistical Mechanics*, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
4. *Statistical and Thermal Physics*, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall.

Additional/Advance/Further Readings:

1. *Thermodynamics, Kinetic Theory and Statistical Thermodynamics*, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.

2. *Modern Thermodynamics with Statistical Mechanics*, Carl S. Helrich, 2009, Springer.

3. *Concepts in Thermal Physics* by Stephen J. Blundell, Katherine M. Blundell, 2010, OUP Oxford

Course Title: Mathematical Physics - II (Minor)

Course Code	PHY62MN02204	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	4	Contact Hours	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The main objective of this course is to provide the basic mathematical skills used in physics.

Course Learning Outcomes:

After completion of the course the learners will be able to understand the basic concepts of Fourier Series, Frobenius Method, Special Functions, Some Special Integrals, theory of errors and learn techniques to solve certain Partial Differential Equations.

Course Contents:

Unit-1

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

(25 % Weightage)

Unit-2

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions and Orthogonality.

(25 % Weightage)

Unit-3

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral). Theory of Errors: Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error.

(25 % Weightage)

Unit-4

Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-14	Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.
15-38	Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions and Orthogonality.
39-42	Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).
43-46	Theory of Errors: Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error.
47-60	Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

Essential Readings:

1. *Mathematical Methods for Physicists*: Arfken, Weber, 2005, Harris, Elsevier.
2. *Fourier Analysis* by M.R. Spiegel, 2004, Tata McGraw-Hill.

Additional/Advance/Further Readings:

1. *Mathematics for Physicists*, Susan M. Lea, 2004, Thomson Brooks/Cole.
2. *Differential Equations*, George F. Simmons, 2006, Tata McGraw-Hill.
3. *Partial Differential Equations for Scientists & Engineers*, S.J. Farlow, 1993, Dover Pub.
4. *Mathematical methods for Scientists & Engineers*, D.A. McQuarrie, 2003, Viva Books.

Course Title: Electricity and Magnetism (Minor)

Course Code	PHY62MN02304	**Credits**	4
L+T+P	3+1+0	**Course Duration**	One Semester
Semester	6	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Tutorial, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to :

1. Acquaint the students with basic knowledge of electricity and Magnetism.
2. Introduction about polar and cylinderical coordinate system
3. Familiarize the student Ampere law, Gauss law and Maxwell Equation.
4. Acquaint the students with the theory of Magnetism.
5. Concept of different electrical circuit and Laws.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Understand the fundamentals of Electricity.
2. Understand the fundamentals of Different circuits LC, LCR, and LR.
3. Understand resonance phenomenon.
4. Understand the basic concepts of Resonance Phenomenon.
5. Describe the Maxwell Equations.
6. Different types of theorem for circuits.

Course Contents:

Unit-1

Scalar and Vector Field, Gradient, Curl, Divergence, (Spherical and Cylindrical Coordinate system), and their Physical Significance, Line surface and Volume Integral. Electrostatics: Electric field: Electric field lines. Continuous charge distribution, Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry, Divergence and curl of Electric Field and their Physical Signifiance. Conservative nature of Electrostatic Field Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors Parallel-plate capacitor. Capacitance of an isolated conductor, cylindrical and Spherical capacitor, Dielectric Properties of Matter: Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss'Law in dielectrics.

(35 % Weightage)

Unit-2

Magneto statics :Magnetic force between current elements and definition of Magnetic Field B. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability. Relation between B, H, M. Ferromagnetism. B-H curve and hysteresis. Electromagnetic Induction Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field.

(35 % Weightage)

Unit-3

Electrical Circuits: AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and(3) Quality Factor, and (4) Band Width. ParallelLCR-Circuit. Network theorems: Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-10	Scalar and Vector Field, Gradient, Curl, Divergence, (Spherical and Cylindrical Coordinate system), and their Physical Significance, Line surface and Volume Integral.
11-20	Electric field: Electric field lines. Continuous charge distribution, Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry, Divergence and curl of Electric Field and their Physical Signifiance. Conservative nature of Electrostatic Field Electrostatic Potential. Laplace's and Poisson equations.
11-14	The Uniqueness Theorem. Potential and Electric Field of a dipole. Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor.
21-34	Parallel-plate capacitor. Capacitance of an isolated conductor, cylindrical and Spherical capacitor, Dielectric Properties of Matter: Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss'Law in dielectrics.

35-42	Magnetic force between current elements and definition of Magnetic Field B. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment
42-46	Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field
47-50	Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability. Relation between B, H, M. Ferromagnetism. B-H curve and hysteresis. Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field.
50-54	AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and(3) Quality Factor, and (4) Band Width. ParallelLCRCircuit.
54-57	Network theorems: Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem,
57-60	Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping.CDR.

Essential Readings:

1. *Electricity, Magnetism & Electromagnetic Theory*, S. Mahajan and Choudhury, 2012, Tata McGraw
2. *Electricity and Magnetism*, Edward M. Purcell, 1986 McGraw-Hill Education
3. *Electricity & Magnetism*, D.L. Sehgal, K.L. Chopra, and N. K. Sehgal, Publisher, Sultan Chand & Sons.
4. *Introduction to Electrodynamics*, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
5. *Elements of Electromagnetics*, M.N.O. Sadiku, 2010, Oxford University Press.
6. *Electricity and Magnetism*, J.H.vFewkes & J. Yarwood. Vol. I, 1991, Oxford Univ. Press.

Additional/Advance/Further Readings:

1. *Concept of Physics-II* by H.C. Verma
2. *Advanced Practical Physics for students*, B.L. Flint and H.T. Worsnop, 1971, Asia PublishingHouse
3. *A Text Book of Practical Physics*, I. Prakash & Ramakrishna, 11th Ed., 2011
4. *The Feynman Lectures on Physics*, Vol. II, By Richard P. Feynman, Robert B. Leighton, Matthew Sands, 2011, Basic Books.

Note: Latest edition of text books may be used

Course Title: Quantum Mechanics

Course Code	PHY71MJ02404	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	5	Contact Hours	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course will teach you the basic principles of Quantum Mechanics. Students will learn theoretical principles and problem solving skills applied to the quantum world of atoms, molecules and photons. The knowledge obtained in this class will serve as a foundation for further advanced classes such as Advanced Quantum Mechanics, Statistical Mechanics, and various electives.

Course Learning Outcomes:

Upon completion of this course, the student should:

1. Master the central aspects of basic quantum mechanics, including understanding the fundamental postulates and central theorems, eigenfunctions and eigenvalues, expansions utilizing eigenfunctions, and concepts related to stationary and nonstationary states. They should be proficient in applying these concepts to various scenarios such as the square-well potential, harmonic oscillator, and the hydrogen atom.
2. Have acquired proficiency in utilizing the Dirac formalism and applying operator algebra to quantize angular momentum and the harmonic oscillator, thus enabling them to solve more complex quantum mechanical problems.
3. Be familiar with the spin formalism and adept at handling the addition of angular momenta, which is crucial for understanding quantum systems with spin degrees of freedom.
4. Comprehend the theory and implications of identical particles, particularly ideal Fermi and Bose gases, including their statistical properties and behavior in quantum systems.
5. Understand the main concepts of perturbation theory, which is a powerful tool used to analyze and solve problems in quantum mechanics involving small deviations from known solutions.

Course Contents:

Unit-1

Introductory concepts of Quantum Mechanics: Wave-particle duality, electron diffraction, Wave packets, Gaussian wave packet, Spreading of Gaussian wave packet, Heisenberg uncertainty principle for position and momentum, Schrodinger equation, conservation of probability, probability interpretation of wave function, expectation values, Ehrenfest theorem, measurement in quantum theory, time independent Schrodinger equation, stationary states, momentum space representation.

(20 % Weightage)

Unit-2

One Dimensional and Three Dimensional Problems: One Dimensional: Particle in a box – simple harmonic oscillator - Square well potential – Barrier penetration – Three Dimensional: Orbital angular momentum and spherical harmonics - Central forces and reduction of two body problem - Particle in a Spherical well - Hydrogen atom.

(20 % Weightage)

Unit-3

General formalism of quantum theory: operator methods: Hilbert space and observables, linear operators and observables, Dirac notation, degeneracy and simultaneous observables, generalized uncertainty principle for two non-commuting observables, Unitary dynamics, projection operators and measurements, time-dependence of observables: Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method.

(20 % Weightage)

Unit-4

UNIT-IV: Approximation methods: Time-independent perturbation theory for non- degenerate and degenerate levels - Application to ground state of an harmonic oscillator and Stark effect in Hydrogen - Variation method - Application to ground state of Helium atom - WKB approximation - WKB quantization rule - Application to simple Harmonic Oscillator.

(20 % Weightage)

Unit-5

Angular momentum : Orbital angular momentum commutation relations, Eigen values and eigen functions, Central potential, separation of variables in the Schrodinger equation, the radial equation. The Hydrogen atom. General operator algebra of angular momentum operators J_x, J_y, J_z . Ladder operators, Eigen values and eigenkets of J^2 and J_z, Matrix representations of angular momentum operators, Pauli matrices, Addition of angular momentum, Clebsch-Gordan coefficients, computation of Clebsch- Gordan coefficients in simple cases ($j_1 = j_2 = 1/2$).

(20 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Wave-particle duality, electron diffraction, Wave packets, Gaussian wave packet, Spreading of Gaussian wave packet,
5-8	Heisenberg uncertainty principle for position and momentum, Schrodinger equation, conservation of probability, probability interpretation of wave function, expectation values,
9-12	Ehrenfest theorem, measurement in quantum theory, time independent Schrodinger equation, stationary states, momentum space representation.
13-17	One Dimensional problems: Particle in a box – simple harmonic oscillator - Square well potential – Barrier penetration
18-24	Three Dimensional problems: Orbital angular momentum and spherical harmonics - Central forces and reduction of two body problem - Particle in a Spherical well - Hydrogen atom.

25-26	Hilbert space and observables, linear operators and observables, Dirac notation,
27-28	degeneracy and simultaneous observables, generalized uncertainty principle for two non-commuting observables,
29-32	Unitary dynamics, projection operators and measurements,
33-36	time-dependence of observables: Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method.
37-41	Time-independent perturbation theory for non- degenerate and degenerate levels - Application to ground state of an harmonic oscillator and Stark effect in Hydrogen
42-44	Variation method -Application to ground state of Helium atom
45-48	WKB approximation - WKB quantization rule - Application to simple Harmonic Oscillator.
49-50	Orbital angular momentum commutation relations, Eigen values and eigen functions,
51-52	Central potential, separation of variables in the Schrodinger equation, the radial equation. The Hydrogen atom.
53-55	General operator algebra of angular momentum operators J_x, J_y, J_z . Ladder operators, Eigen values and eigenkets of J^2 and J_z,
56-58	Matrix representations of angular momentum operators, Pauli matrices
59-60	Addition of angular momentum, Clebsch-Gordan coefficients, computation of Clebsch-Gordan coefficients in simple cases ($j_1 = j_2 = 1/2$).

Essential Readings:

1. *Introduction to Quantum Mechanics* – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.

2. *Quantum Mechanics Vol I & II* - C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Interscience Publication, 1977.

Additional/Advance/Further Readings:

1. *Quantum Mechanics - L.I. Schiff, Third Edition*, Mc Graw Hill Book Company, 1955.

2. *Quantum Mechanics* - B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.

3. *Modern Quantum Mechanics* - J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.

4. *Principles of Quantum Mechanics* - R. Shankar, Second Edition, Springer, 1994.

5. *Quantum Mechanics* - E. Merzbacher, John Wiley and Sons, 1998.

6. *Quantum Physics* - S. Gasiorowicz, John Wiley and Sons.

Course Title: Solid State Physics

Course Code	PHY71MJ02504	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	5	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce the concept of crystallography, structural aspects of materials, different properties of solids and their structure property correlation, and develop the framework and analytical skills necessary to understand these phenomena in nature. This course aims are

1. Students will be able to learn basics of solid state Physics.
2. Students will be able to correlate its applications in the area of advanced condensed matter physics.
3. Students will develop an ability to understand and assimilate higher level topics by themselves.
4. The student will learn the basics understanding of structure and different phenomenon of sold state physics.
5. This course should give the student confidence to undertake higher level education or job assignments in various institutes in India or in abroad.

Course Learning Outcomes:

After completion of the course learners will be able to:

1. Understand the fundamentals of atomic arrangements in solids.
2. Realize basic symmetry elements and how these symmetry operations are important in solid sate physics.
3. Understand basic concept crystallography .
4. Understand the arrangements of solid and visualize different important structures of solids.
5. Understand the basics of diffraction phenomenon lattice planes and information contained in the X-Ray diffraction data.
6. Understand basics phenomenon and their theory of solids
7. Understand Electrical, dielectric , magnetic, superconducting properties and their theory.
8. Understand structure property correlation.

Course Contents:

Unit-1

Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis– Central and Non-Central Elements. Symmetry Elements Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Laue Condition, Atomic and Geometrical Factor. Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T3 law.

(35 % Weightage)

Unit-2

Electrons in metals- Drude Model, Density of states (1-D,2-D,3-D), Elementary band theory: Kronig Penny model. Band Gap., Effective mass, mobility, Hall Effect (Metal and Semiconductor).

(20 % Weightage)

Unit-3

Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia- and Paramagnetic Domains. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains, B-H Curve. Hysteresis, soft and hard material and Energy Loss. Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Ferroelectric Properties of Materials: Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

(35 % Weightage)

Unit-4

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation)

(10 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis– Central and Non-Central Elements. Symmetry Elements Unit Cell. Miller Indices.
5-8	Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Laue Condition, Atomic and Geometrical Factor.
9-12	Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons.
13-16	Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T3 law.
17-20	Electrons in Solids: Electrons in metals- Drude Model, Density of states (1-D,2-D,3-D),
21-24	Elementary band theory: Kronig Penny model. Band Gap., Effective mass, mobility, Hall Effect (Metal and Semiconductor).

25-28	Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia- and Paramagnetic Domains.
28-32	Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains, B-H Curve. Hysteresis, soft and hard material and Energy Loss.
32-36	Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation.
36-40	Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant.
41-44	Ferroelectric Properties of Materials: Classification of crystals, Piezoelectric effect, Pyroelectric effect,
45-48	Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.
49-52	Superconductivity: Experimental Results. Critical Temperature.
53-56	Critical magnetic field. Meissner effect. Type I and type II Superconductors,
57-60	London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation)

Essential Readings:

1. *Introduction to Solid State Physics*, Charles Kittel, 8th Edn., 2004, Wiley India Pvt. Ltd.
2. *Crystallography Applied to Solid State Physics* By A. R. Verma, O. N. Srivastava, 1991, Wiley Eastern Limited

Additional/Advance/Further Readings:

1. *Elements of Solid State Physics*, J.P. Srivastava, 2nd Edn., 2006, Prentice-Hall of India.
2. *Introduction to Solids*, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill.
3. *Solid State Physics*, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning.
4. *Solid-state Physics*, H.Ibach and H. Luth, 2009, Springer.
5. *Solid State Physics*, Rita John, 2014, McGraw Hill
6. *Solid State Physics*, M.A. Wahab, 2011, Narosa Publications.

Course Title: Physics Laboratory - III

Course Code	PHY71MJ02604	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	5	**Contact Hours**	90(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to :

1. Enhance the understanding of the students of procedural knowledge of basic modern instruments .
2. Enhance the ability of the students to explain the processes and applications related to modern physics
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the students towards experiment reserach.
5. Enhance the scientific understanding of modern instruments .
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Handle the sophisticated instruments.
2. Express the basic concepts of modern physics in more general language.
3. Demonstrate experimental skills.
4. Demonstrate appropriate data analysis skills.

Course Contents:

1. To verify the laws of probability distribution throwing one coin, two coins and ten coins.
2. To construct SC, BCC, FCC and to find packing fraction, coordination number.
3. To determine lattice parameter ‘a’ of a unit cell of a cubic crystal using X-ray diffraction pattern.
4. To determine the energy gap of a semiconductor using four probe method.
5. To determine energy gap of a semiconductor using PN junction diode in reverse bias mode.
6. To determine the value of e/m of an electron by Thomson method.
7. To determine the plank’s constant ‘h’ by photovacuum tube.
8. To determine Planck’s constant by solar cell.
9. To determine Planck’s constant by LED.
10. To determine the first ionization potential of Argon atom by Frank-Hertz apparatus.
11. To determine Hall coefficient and mobility of charge carriers in a semiconductor.
12. To determine charge on electron by Millikan’s oil drop method
13. To draw the Hysteresis loop of the given specimen and to determine the Energy loss per unit volume per cycle of magnetization with Universal B-H curve Tracer.
14. To determine the transmission coefficient of a transmitting plate using photometer.
15. To determine wavelength of sodium light using Michelson’s Interferometer.
16. Study of Lissajous’s figure

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiments.__

Course Title: Theory of Relativity

Course Code	PHY71MJ02702	**Credits**	2
L+T+P	2+0+0	**Course Duration**	One Semester
Semester	5	**Contact Hours**	30(L) Hours

Course Type	Discipline Based Core (Vocational)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The course objectives for the Theory of Relativity typically include:

1. Develop a comprehensive understanding of the principles and concepts underlying the Theory of Relativity.
2. Derive and comprehend the Lorentz transformation, a key mathematical framework in the theory, and its implications for spacetime transformations.
3. Apply relativistic kinematics to understand the behavior of particles moving at speeds comparable to the speed of light.

Course Learning Outcomes:

After successfully completing the course, students will have developed a subject-specific understanding that enables them to explain in detail:

1. The role and function of special relativity.
2. Inertial frames, including their existence, definition, and utilization.
3. The Lorentz transformation, and its derivation.
4. Space-time and related concepts.
5. General tensors and vectors, encompassing their definition and special cases of particular importance.
6. Relativistic collision problems.

Course Contents:

Unit-1

Difficuties of Pre-relativity Phsyics, Galilean relativity, Review of Newtonian mechanics - Inertial frames, Absolute Time, Absoulte Space, Wave Equation under Galilean Transformation, Seacrh for a Universal Frame of Reference: Michelson–Morley Experiment, Modern version of MM experiment, Kennedy–Thorndyke Experiment, Modern re-enactments of the Kennedy–Thorndyke experiment, Trouton and Noble Experiment, Experiment with Ammonia Masers

(40 % Weightage)

Unit-2

Einstein's Postulates of Special Theory of Relativity Relativistic kinematics - Composition of parallel velocities, Length contraction, Time dilation, Transformation equations for components of velocity and acceleration of a particle and Lorentz contraction factor, Geometrical representation of space-time-Four dimensional Minkowskian space-time of special relativity, Time-like, Lightlike, space-like intervals, Null Cone, Proper Time, World Line of a Particle, Four Vectors, Tensors in Minkowskian space-time, Relativistic Mechanics of a Particle, Collisions and Conservation Laws, Basic Introudction of General Theory of Relativity.

(60 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Difficuties of Pre-relativity Phsyics, Galilean relativity, Review of Newtonian mechanics - Inertial frames. Absolute time and absoulte space, Wave Equation under Galilean Transformation,
6-10	Seacrh for a Universal Frame of reference: Michelson–Morley Experiment, Modern version of MM experiment, Kennedy–Thorndyke Experiment, Modern re-enactments of the Kennedy–Thorndyke experiment, Trouton and Noble Experiment, Experiment with Ammonia Masers
11-15	Einstein's Postulates postulate of special relativity Relativistic kinematics - Composition of parallel velocities. Length contraction. Time dilation.
16-24	Length contraction. Time dilation. Transformation equations for components of velocity and acceleration of a particle and Lorentz contraction factor. Geometrical representation of space-time - Four dimensional Minkowskian space-time of special relativity. Time-like, lightlike and space-like intervals.
25-30	Null cone, Proper time. World line of a particle. Four vectors and tensors in Minkowskian space-time. Relativistic Mechanics of a Particle. Collisions and Conservation Laws, basic introudction of general theory of relativit

Essential Readings:

1. *Special Theory of Relativity*, S. P. Puri, Pearson Education in South Asia, 2013
2. *The Theory of Relativity*, C. Moller, Oxford Clarendon Press, 1952.
3. *Introduction to the Theory of Relativity*,P.G. Bergman, Prentice Hall of India, Pvt.Ltd., 1969.

Additional/Advance/Further Readings:

1. *Principles of Relativity Physics*, J.L. Anderson, Academic Press, 1967.
2. *Essential Relativity*, W.Rindler, Van Nostrand Reinhold Company, 1969.
3. *Special Theory of Relativity*, V.A. Ugarov, Mir Publishers, 1979.
4. *Introduction to Special Relativity*, R. Resnick, Wiley Eastern Pvt.Ltd., 1972.
5. *Relativity; The Special Theory*, J.L. Synge, North-Holland Publishing Company, 1956.
6. *Special Relativity : The Foundation of Microscopic Physics*, W.G. Dixon Cambridge University Press, 1982.
7. *Lectures on Special Relativity*, T.M. Karade, K.S. Adhau & Maya S.Bendre, Sonu-Nilu Publication, Nagpur

Note: Latest edition of text books may be used

Course Title: Quantum Mechanics (Minor)

Course Code	PHY71MN02904	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	4	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course will teach you the basic principles of Quantum Mechanics. Students will learn theoretical principles and problem solving skills applied to the quantum world of atoms, molecules and photons. The knowledge obtained in this class will serve as a foundation for further advanced classes such as Advanced Quantum Mechanics, Statistical Mechanics, and various electives.

Course Learning Outcomes:

Upon completion of this course, the student should:

1. Master the central aspects of basic quantum mechanics, including understanding the fundamental postulates and central theorems, eigenfunctions and eigenvalues, expansions utilizing eigenfunctions, and concepts related to stationary and nonstationary states. They should be proficient in applying these concepts to various scenarios such as the square-well potential, harmonic oscillator, and the hydrogen atom.
2. Have acquired proficiency in utilizing the Dirac formalism and applying operator algebra to quantize angular momentum and the harmonic oscillator, thus enabling them to solve more complex quantum mechanical problems.
3. Be familiar with the spin formalism and adept at handling the addition of angular momenta, which is crucial for understanding quantum systems with spin degrees of freedom.
4. Comprehend the theory and implications of identical particles, particularly ideal Fermi and Bose gases, including their statistical properties and behavior in quantum systems.
5. Understand the main concepts of perturbation theory, which is a powerful tool used to analyze and solve problems in quantum mechanics involving small deviations from known solutions.

Course Contents:

Unit-1

Introductory concepts of Quantum Mechanics: Wave-particle duality, electron diffraction, Wave packets, Gaussian wave packet, Spreading of Gaussian wave packet, Heisenberg uncertainty principle for position and momentum, Schrodinger equation, conservation of probability, probability interpretation of wave function, expectation values, Ehrenfest theorem, measurement in quantum theory, time independent Schrodinger equation, stationary states, momentum space representation.

(20 % Weightage)

Unit-2

One Dimensional and Three Dimensional Problems: One Dimensional: Particle in a box – simple harmonic oscillator - Square well potential – Barrier penetration – Three Dimensional: Orbital angular momentum and spherical harmonics - Central forces and reduction of two body problem - Particle in a Spherical well - Hydrogen atom.

(20 % Weightage)

Unit-3

General formalism of quantum theory: operator methods: Hilbert space and observables, linear operators and observables, Dirac notation, degeneracy and simultaneous observables, generalized uncertainty principle for two non-commuting observables, Unitary dynamics, projection operators and measurements, time-dependence of observables: Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method.

(20 % Weightage)

Unit-4

UNIT-IV: Approximation methods: Time-independent perturbation theory for non- degenerate and degenerate levels - Application to ground state of an harmonic oscillator and Stark effect in Hydrogen - Variation method - Application to ground state of Helium atom - WKB approximation - WKB quantization rule - Application to simple Harmonic Oscillator.

(20 % Weightage)

Unit-5

Angular momentum : Orbital angular momentum commutation relations, Eigen values and eigen functions, Central potential, separation of variables in the Schrodinger equation, the radial equation. The Hydrogen atom. General operator algebra of angular momentum operators J_x, J_y, J_z . Ladder operators, Eigen values and eigenkets of J^2 and J_z, Matrix representations of angular momentum operators, Pauli matrices, Addition of angular momentum, Clebsch-Gordan coefficients, computation of Clebsch- Gordan coefficients in simple cases ($j_1 = j_2 = 1/2$).

(20 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Wave-particle duality, electron diffraction, Wave packets, Gaussian wave packet, Spreading of Gaussian wave packet,
5-8	Heisenberg uncertainty principle for position and momentum, Schrodinger equation, conservation of probability, probability interpretation of wave function, expectation values,
9-12	Ehrenfest theorem, measurement in quantum theory, time independent Schrodinger equation, stationary states, momentum space representation.
13-17	One Dimensional problems: Particle in a box – simple harmonic oscillator - Square well potential – Barrier penetration
18-24	Three Dimensional problems: Orbital angular momentum and spherical harmonics - Central forces and reduction of two body problem - Particle in a Spherical well - Hydrogen atom.

25-26	Hilbert space and observables, linear operators and observables, Dirac notation,
27-28	degeneracy and simultaneous observables, generalized uncertainty principle for two non-commuting observables,
29-32	Unitary dynamics, projection operators and measurements,
33-36	time-dependence of observables: Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method.
37-41	Time-independent perturbation theory for non- degenerate and degenerate levels - Application to ground state of an harmonic oscillator and Stark effect in Hydrogen
42-44	Variation method -Application to ground state of Helium atom
45-48	WKB approximation - WKB quantization rule - Application to simple Harmonic Oscillator.
49-50	Orbital angular momentum commutation relations, Eigen values and eigen functions,
51-52	Central potential, separation of variables in the Schrodinger equation, the radial equation. The Hydrogen atom.
53-55	General operator algebra of angular momentum operators J_x, J_y, J_z . Ladder operators, Eigen values and eigenkets of J^2 and J_z,
56-58	Matrix representations of angular momentum operators, Pauli matrices
59-60	Addition of angular momentum, Clebsch-Gordan coefficients, computation of Clebsch-Gordan coefficients in simple cases ($j_1 = j_2 = 1/2$).

Essential Readings:

1. *Introduction to Quantum Mechanics* – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. *Quantum Mechanics Vol I & II* - C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Interscience Publication, 1977.

Additional/Advance/Further Readings:

1. *Quantum Mechanics* - L.I. Schiff, Third Edition, Mc Graw Hill Book Company, 1955.
2. *Quantum Mechanics* - B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
3. *Modern Quantum Mechanics* - J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
4. *Principles of Quantum Mechanics* - R. Shankar, Second Edition, Springer, 1994.
5. *Quantum Mechanics* - E. Merzbacher, John Wiley and Sons, 1998.
6. *Quantum Physics* - S. Gasiorowicz, John Wiley and Sons.

Course Title: Solid State Physics (Minor)

Course Code	PHY71MN03004	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	5	Contact Hours	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Conceptual and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce the concept of crystallography, structural aspects of materials, different properties of solids and their structure property correlation, and develop the framework and analytical skills necessary to understand these phenomena in nature. This course aims are

1. Students will be able to learn basics of solid state Physics.
2. Students will be able to correlate its applications in the area of advanced condensed matter physics.
3. Students will develop an ability to understand and assimilate higher level topics by themselves.
4. The student will learn the basics understanding of structure and different phenomenon of sold state physics.
5. This course should give the student confidence to undertake higher level education or job assignments in various institutes in India or in abroad.

Course Learning Outcomes:

After completion of the course learners will be able to:

1. Understand the fundamentals of atomic arrangements in solids.
2. Realize basic symmetry elements and how these symmetry operations are important in solid sate physics.
3. Understand basic concept crystallography .
4. Understand the arrangements of solid and visualize different important structures of solids.
5. Understand the basics of diffraction phenomenon lattice planes and information contained in the X-Ray diffraction data.
6. Understand basics phenomenon and their theory of solids
7. Understand Electrical, dielectric , magnetic, superconducting properties and their theory.
8. Understand structure property correlation.

Course Contents:

Unit-1

Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis– Central and Non-Central Elements. Symmetry Elements Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Laue Condition, Atomic and Geometrical Factor. Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T3 law.

(35 % Weightage)

Unit-2

Electrons in metals- Drude Model, Density of states (1-D,2-D,3-D), Elementary band theory: Kronig Penny model. Band Gap., Effective mass, mobility, Hall Effect (Metal and Semiconductor).

(20 % Weightage)

Unit-3

Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia- and Paramagnetic Domains. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains, B-H Curve. Hysteresis, soft and hard material and Energy Loss. Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Ferroelectric Properties of Materials: Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

(35 % Weightage)

Unit-4

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation)

(10 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis– Central and Non-Central Elements. Symmetry Elements Unit Cell. Miller Indices.
5-8	Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Laue Condition, Atomic and Geometrical Factor.
9-12	Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons.
13-16	Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T3 law.
17-20	Electrons in Solids: Electrons in metals- Drude Model, Density of states (1-D,2-D,3-D),
21-24	Elementary band theory: Kronig Penny model. Band Gap., Effective mass, mobility, Hall Effect (Metal and Semiconductor).

25-28	Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia- and Paramagnetic Domains.
28-32	Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains, B-H Curve. Hysteresis, soft and hard material and Energy Loss.
32-36	Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation.
36-40	Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant.
41-44	Ferroelectric Properties of Materials: Classification of crystals, Piezoelectric effect, Pyroelectric effect,
45-48	Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.
49-52	Superconductivity: Experimental Results. Critical Temperature.
53-56	Critical magnetic field. Meissner effect. Type I and type II Superconductors,
57-60	London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation)

Essential Readings:

1. *Introduction to Solid State Physics*, Charles Kittel, 8th Edn., 2004, Wiley India Pvt. Ltd.
2. *Crystallography Applied to Solid State Physics* By A. R. Verma, O. N. Srivastava, 1991, Wiley Eastern Limited

Additional/Advance/Further Readings:

1. *Elements of Solid State Physics*, J.P. Srivastava, 2nd Edn., 2006, Prentice-Hall of India.
2. *Introduction to Solids*, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill.
3. *Solid State Physics*, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning.
4. *Solid-state Physics*, H.Ibach and H. Luth, 2009, Springer.
5. *Solid State Physics*, Rita John, 2014, McGraw Hill
6. *Solid State Physics*, M.A. Wahab, 2011, Narosa Publications.

Course Title: Nuclear and Particle Physics

Course Code	PHY72MJ03104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	6	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce students with a diverse range of phenomena within the field of nuclear and particle physics. It aims to cultivate the foundational framework and analytical skills essential for understand these phenomena in nature. The course serves as an introduction to modern nuclear and particle physics, including various decay modes of the nucleus, nuclear reactions, particle detection methods, fundamental constituents of matter, their classifications, symmetry laws, and the fundamental interactions between particles. Through this course, students will gain insight into the intricate dynamics and principles governing the behavior of particles at the nuclear and subatomic levels.

Course Learning Outcomes:

On completion successful students will be able to demonstrate knowledge and understanding of:

1. The atomic nucleus and its general properties, including its composition, structure, and behavior within the atom.
2. Various decay processes of nuclei and the kinematics involved in radioactive decay phenomena.
3. Basic aspects of nuclear structure and the fundamentals of radioactivity, including the mechanisms and implications of radioactive decay.
4. Different types of nuclear reactions and their applications in various fields such as energy production, medicine, and research.
5. Radiation interaction with matter and the basic principles underlying the operation of particle detectors used to detect and measure radiation.
6. The principle and working of particle accelerators, including the mechanisms by which particles are accelerated and their applications in fundamental research.
7. The fundamental constituents of matter, including elementary particles and their properties, and the conservation laws governing particle interactions, such as conservation of energy, momentum, and charge.

Course Contents:

Unit-1

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

(20 % Weightage)

Unit-2

Radioactivity decay:(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion. Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering). Nuclear Astrophysics: Early universe, primordial nucleosynthesis (particle nuclear interactions), stellar nucleosynthesis, concept of gamow window, heavy element production: r- and s-process path.

(35 % Weightage)

Unit-3

Interaction of Nuclear Radiation with matter: Energy loss due to ionization (BetheBlock formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.

Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.

(35 % Weightage)

Unit-4

Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons. (10 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number
5-8	main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states.

9-12	Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, evidence for nuclear shell structure
13-16	nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.
17-20	Radioactivity decay:(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay,
21-24	positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion.
25-28	Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section,
28-32	Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).
32-36	Nuclear Astrophysics: Early universe, primordial nucleosynthesis (particle nuclear interactions), stellar nucleosynthesis, concept of gamow window, heavy element production: r- and s-process path.
36-40	Interaction of Nuclear Radiation with matter: Energy loss due to ionization (BetheBlock formula), energy loss of electrons,
41-44	Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.
45-48	Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT)
49-52	Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.
53-56	Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number,
57-60	Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons.

Essential Readings:

1. *Introduction to Nuclear Physics*, Kenneth Krane, Wiley India Pvt. Ltd.
2. *Introduction to Nuclear Physics*, H. A. Enge, Eddison Wesley
3. *Experimental and Theoretical Nuclear Physics*, H. S. Hans, New Age International
4. *Nuclear Physics*, S. N. Ghoshal, Publisher S. Chand.
5. *Nuclear Physics*, D. C. Tayal, Himalaya Publishing House Pvt. Ltd.

Additional/Advance/Further Readings:

1. *Nuclei and Particle*, E. Segre, W. A Benjamin,
2. *Concepts of Nuclear Physics*, B. L. Cohen
3. *Introduction to Nuclear and Particle Physics*, A. Das & T. Ferbel, World Scientific
4. *Nuclear and Particle Physics*, W. E. Burcham and M. Jobes, Addison Wesley

5. *Nuclear Physics-An Introduction*, S. B. Patel, New Age International

Note: Latest edition of text books may be used

Course Title: Atomic and Molecular Physics

Course Code	PHY72MJ03204	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	6	Contact Hours	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The course objectives of Atomic and Molecular Physics typically include:

1. Introduce students to the fundamental principles and concepts of atomic and molecular physics.
2. Provide a deep understanding of quantum mechanics as it applies to atomic and molecular systems.
3. Explore the structure of atoms, including electron configurations, energy levels, and spectroscopic properties.
4. Examine the structure of molecules, bonding theories, and molecular spectroscopy.
5. Familiarize students with experimental techniques and methods used in the spectroscopy of atoms and molecules.
6. Study the quantum states of atoms and molecules, as well as transitions between these states.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. describe the atomic spectra of one and two valance electron atoms.
2. explain the change in behavior of atoms in external applied electric and magnetic field.
3. explain rotational, vibrational, electronic and Raman spectra of molecules.
4. describe electron spin and nuclear magnetic resonance spectroscopy and their applications.

Course Contents:

Unit-1

Absorption and emission of radiation: Interaction of radiation with matter: Einstein's coefficients, Beer's law for attenuation and amplification of light. The width and shape of spectral lines: natural broadening, Doppler broadening-estimation of half width, General treatment of other broadening mechanisms-collision and power broadening.

(25% Weightage)

Unit-2

Atomic Physics: Brief review of early atomic models. Hydrogenic atoms: Energy levels and selection rules, Relativistic corrections and fine structure, hyperfine structure, Lamb shift and isotope shift. Interaction with external fields: Zeeman effect, Paschen-Back effect, Stark effect. Two electron atom: Ortho and para states and role of Pauli's exclusion principle, level schemes of two electron atoms. Many electron atoms: LS and JJ coupling schemes, Lande interval rule.

(25% Weightage)

Unit-3

Molecular Physics-A: Born-Oppenheimer approximation, Rotational spectroscopy: Classification of rotors. Diatomic molecule as a rigid rotator, Centrifugal distortion and non − rigid rotator, energy levels and spectra, Intensity of rotational lines, experimental techniques. Raman scattering, Polarizability, Rotational Raman spectroscopy (diatomics). Experimental technique.

(25% Weightage)

Unit-4

Molecular Physics-B: Diatomic molecule as a simple harmonic oscillator, anharmonicity, effect of anharmonicity on vibrational terms, energy levels and selection rules. Vibrating rotator-energy levels and rovibrionic spectra, Experimental technique and IR spectrometry. Applications of IR spectroscopy. Mutual exclusion principle. Electronic spectra of diatomic molecules: vibrational coarse structure and rotational fine structure in electronic spectra, intensity of vibrational bands in electronic spectra – Frank- Condon principle. Dissociation and predissociation.

(25% Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Interaction of radiation with matter: Einstein's coefficients, Beer's law for attenuation and amplification of light.
7-13	The width and shape of spectral lines: natural broadening, Doppler broadening-estimation of half width, General treatment of other broadening mechanisms-collision and power broadening.
14-19	Brief review of early atomic models. Hydrogenic atoms: Energy levels and selection rules, Relativistic corrections and fine structure, hyperfine structure, Lamb shift and isotope shift.
20-23	Interaction with external fields: Zeeman effect, Paschen-Back effect, Stark effect.
24-27	Two electron atom: Ortho and para states and role of Pauli's exclusion principle, level schemes of two electron atoms.
28-30	Many electron atoms: LS and JJ coupling schemes, Lande interval rule.
31-34	Born-Oppenheimer approximation, Rotational spectroscopy: Classification of rotors.
35-39	Diatomic molecule as a rigid rotator, Centrifugal distortion and non − rigid rotator, energy levels and spectra, Intensity of rotational lines, experimental techniques.
40-45	Raman scattering, Polarizability, Rotational Raman spectroscopy (diatomics). Experimental technique.
46-49	Diatomic molecule as a simple harmonic oscillator, anharmonicity, effect of anharmonicity on vibrational terms, energy levels and selection rules.
50-52	Vibrating rotator-energy levels and rovibrionic spectra, Experimental technique and IR spectrometry.

53-55	Applications of IR spectroscopy.
56-57	Mutual exclusion principle.
58-59	Electronic spectra of diatomic molecules: vibrational coarse structure and rotational fine structure in electronic spectra, intensity of vibrational bands in electronic spectra – Frank- Condon principle.
60	Dissociation and pre-dissociation.

Essential Readings:

1. *Atomic and molecular physics*, Raj Kumar, 2009, Campus Books.
2. *Physics of atoms and molecules*, Bransden and Joachain, (2nd Edition) Pearson Education, 2004
3. *Introduction to Atomic Spectra*, H.E. white, McGraw Hill

Additional/Advance/Further Readings:

1. *Fundamentals of Molecular Spectroscopy*, Banwell and McCash, Tata McGraw Hill,1998.
2. *Modern Spectroscopy*, J.M. Hollas, John Wiley, 1998.
3. *Molecular Spectroscopy*, Jeanne L. McHale, Pearson Education, 2008
4. *Molecular Quantum Mechanics*, P.W. Atkins and R.S. Friedman, 3rd Edition, Oxford Press (Indian Edition), 2004.
5. *Molecular Structure and Spectroscopy*, G. Aruldhas, Prentice Hall of India, New Delhi, 2001

Note: Latest edition of text books may be used

Course Title: Statistical Mechanics

Course Code	PHY72MJ03304	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	6	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. Acquaint the students with basic knowledge of the kinetic theory of gases.
2. Familiarize the student with macrostate & microstate.
3. Acquaint the students with elementary idea of the concept of ensemble.
4. Orient the student with the theory of radiation.
5. Familiarize the student with Bose-Einstein and Fermi-Dirac Statistics.
6. Familiarize the student with Bose Einstein condensations.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. describe the surface tension and its basic properties.
2. Understand the mean free path and collision probability.
3. Understand the basic idea of partition function.
4. Understand the theory of radiation: blackbody radiation, Kirchhoff's law, Stefan-Boltzmann law and radiation pressure.
5. Demonstrate understanding of the Bose-Einstein and Fermi-Dirac Statistics.
6. Demonstrate the ability to justify and explain their thinking and approach towards application of statistical mechanics.
7. Investigate the real world problems with acquire the knowledge from this course.

Course Contents:

Unit-1

Kinetic Theory of Gases Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.

(25 % Weightage)

Unit-2

Classical Statistics: Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy – Applications to Specific Heat and its Limitations. Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature.

(25 % Weightage)

Unit-3

Theory of Radiation: Properties of Thermal Radiation. Blackbody Radiation. Kirchhoff's law. Stefan-Boltzmann law. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law. Ultraviolet Catastrophe. Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.

(25 % Weightage)

Unit-4

Bose-Einstein and Fermi-Dirac Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law. Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Kinetic Theory of Gases Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment.
8-15	Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. Mean Free Path. Collision Probability.
16-20	Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.
21-25	Classical Statistics: Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law.

26-35	Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation.
36-40	Law of Equipartition of Energy – Applications to Specific Heat and its Limitations. Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature.
41-44	Theory of Radiation: Properties of Thermal Radiation. Blackbody Radiation. Kirchhoff's law. Stefan-Boltzmann law. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law.
45-47	Ultraviolet Catastrophe. Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification.
48-51	Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.
52-55	Bose-Einstein and Fermi-Dirac Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description).
56-58	Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law. Fermi-Dirac Distribution Law
59-60	Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

Essential Readings:

1. *Heat and Thermodynamics*, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill
2. *Concepts of Modern Physics*, Arthur beiser, Sixth Edition, McGraw-Hill.
3. *Statistical Mechanics*, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
4. *Statistical Physics*, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill.
5. *Statistical and Thermal Physics*, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall.

Additional/Advance/Further Readings:

1. *Thermodynamics, Kinetic Theory and Statistical Thermodynamics*, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
2. *Modern Thermodynamics with Statistical Mechanics*, Carl S. Helrich, 2009, Springer.
3. *An Introduction to Statistical Mechanics & Thermodynamics*, R.H. Swendsen, 2012, Oxford Univ. Press.
4. *Statistical Physics Volume 5*, L D Landau, E.M. Lifshitz, 2013, Elsevier Science

Note: Latest edition of text books may be used

Course Title: Physics Laboratory - IV

Course Code	PHY72MJ03404	**Credits**	3
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	6	**Contact Hours**	90(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to

1. Enhance the understanding of the students of procedural knowledge of basic modern instruments .
2. Enhance the ability of the students to explain the processes and applications related to modern physics
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the students towards experiment reserach.
5. Enhance the scientific understanding of modern instruments .
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Handle the sophisticated instruments.
2. Express the basic concepts of modern physics in more general language.
3. Demonstrate experimental skills.
4. Demonstrate appropriate data analysis skills.

Course Contents:

1. Characteristics of GM counter.
2. Resolving-Time Corrections for the Geiger Counter
3. Linear and Mass Absorption Coefficient of Al using GM counter.
4. Verification of Inverse square law using GM counter.
5. Study of nuclear counting statistics
6. Characteristics of NaI(Tl) Scintillator.
7. Study of Cs-137 spectrum and calculation of FWHM & resolution for a given scintillation detector using SCA.
8. Study of Co-60 spectrum and calculation of resolution of detector for a given scintillation detector using SCA.
9. Verification of Beer-Lambert Law.
10. Determination of value of Bohr Magneton using Zeeman effect.
11. Study of statistical distribution from the given data and to find most probable, average value and RMS value.
12. To determine the Rydberg constant for Hydrogen.
13. Determination of ionization potential of Mercury
14. To study the photoelectric effect: variation of photocurrent versus intensity and wavelength of light.
15. To show the tunneling effect in tunnel diode using I-V characterisation.
16. To study the PE hysteresis of ferroelctric crystal.

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiments.__

Course Title: Nuclear and Particle Physics (Minor)

Course Code	PHY72MN03504	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	6	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce students with a diverse range of phenomena within the field of nuclear and particle physics. It aims to cultivate the foundational framework and analytical skills essential for understand these phenomena in nature. The course serves as an introduction to modern nuclear and particle physics, including various decay modes of the nucleus, nuclear reactions, particle detection methods, fundamental constituents of matter, their classifications, symmetry laws, and the fundamental interactions between particles. Through this course, students will gain insight into the intricate dynamics and principles governing the behavior of particles at the nuclear and subatomic levels.

Course Learning Outcomes:

On completion successful students will be able to demonstrate knowledge and understanding of:

1. The atomic nucleus and its general properties, including its composition, structure, and behavior within the atom.
2. Various decay processes of nuclei and the kinematics involved in radioactive decay phenomena.
3. Basic aspects of nuclear structure and the fundamentals of radioactivity, including the mechanisms and implications of radioactive decay.
4. Different types of nuclear reactions and their applications in various fields such as energy production, medicine, and research.
5. Radiation interaction with matter and the basic principles underlying the operation of particle detectors used to detect and measure radiation.
6. The principle and working of particle accelerators, including the mechanisms by which particles are accelerated and their applications in fundamental research.
7. The fundamental constituents of matter, including elementary particles and their properties, and the conservation laws governing particle interactions, such as conservation of energy, momentum, and charge.

Course Contents:

Unit-1

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

(20 % Weightage)

Unit-2

Radioactivity decay:(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion. Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering). Nuclear Astrophysics: Early universe, primordial nucleosynthesis (particle nuclear interactions), stellar nucleosynthesis, concept of gamow window, heavy element production: r- and s-process path.

(35 % Weightage)

Unit-3

Interaction of Nuclear Radiation with matter: Energy loss due to ionization (BetheBlock formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter. Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.

(35 % Weightage)

Unit-4

Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons. (10 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number
5-8	main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states.
9-12	Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, evidence for nuclear shell structure

13-16	nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.
17-20	Radioactivity decay:(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay,
21-24	positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion.
25-28	Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section,
28-32	Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).
32-36	Nuclear Astrophysics: Early universe, primordial nucleosynthesis (particle nuclear interactions), stellar nucleosynthesis, concept of gamow window, heavy element production: r- and s-process path.
36-40	Interaction of Nuclear Radiation with matter: Energy loss due to ionization (BetheBlock formula), energy loss of electrons,
41-44	Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.
45-48	Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT)
49-52	Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.
53-56	Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number,
57-60	Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons.

Essential Readings:

1. *Introduction to Nuclear Physics*, Kenneth Krane, Wiley India Pvt. Ltd.
2. *Introduction to Nuclear Physics*, H. A. Enge, Eddison Wesley
3. *Experimental and Theoretical Nuclear Physics*, H. S. Hans, New Age International
4. *Nuclear Physics*, S. N. Ghoshal, Publisher S. Chand.
5. *Nuclear Physics*, D. C. Tayal, Himalaya Publishing House Pvt. Ltd.

Additional/Advance/Further Readings:

1. *Nuclei and Particle*, E. Segre, W. A Benjamin,
2. *Concepts of Nuclear Physics*, B. L. Cohen
3. *Introduction to Nuclear and Particle Physics*, A. Das & T. Ferbel, World Scientific
4. *Nuclear and Particle Physics*, W. E. Burcham and M. Jobes, Addison Wesley
5. *Nuclear Physics-An Introduction*, S. B. Patel, New Age International

Note: Latest edition of text books may be used

Course Title: Atomic and Molecular Physics (Minor)

Course Code	PHY72MN03604	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	6	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The course objectives of Atomic and Molecular Physics typically include:

1. Introduce students to the fundamental principles and concepts of atomic and molecular physics.
2. Provide a deep understanding of quantum mechanics as it applies to atomic and molecular systems.
3. Explore the structure of atoms, including electron configurations, energy levels, and spectroscopic properties.
4. Examine the structure of molecules, bonding theories, and molecular spectroscopy.
5. Familiarize students with experimental techniques and methods used in the spectroscopy of atoms and molecules.
6. Study the quantum states of atoms and molecules, as well as transitions between these states.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Describe the atomic spectra of one and two valance electron atoms.
2. Explain the change in behavior of atoms in external applied electric and magnetic field.
3. Explain rotational, vibrational, electronic and Raman spectra of molecules.
4. Describe electron spin and nuclear magnetic resonance spectroscopy and their applications.

Course Contents:

Unit-1

Absorption and emission of radiation: Interaction of radiation with matter: Einstein's coefficients, Beer's law for attenuation and amplification of light. The width and shape of spectral lines: natural broadening, Doppler broadening-estimation of half width, General treatment of other broadening mechanisms-collision and power broadening.

(25% Weightage)

Unit-2

Atomic Physics: Brief review of early atomic models. Hydrogenic atoms: Energy levels and selection rules, Relativistic corrections and fine structure, hyperfine structure, Lamb shift and isotope shift. Interaction with external fields: Zeeman effect, Paschen-Back effect, Stark effect. Two electron atom: Ortho and para states and role of Pauli's exclusion principle, level schemes of two electron atoms. Many electron atoms: LS and JJ coupling schemes, Lande interval rule.

(25% Weightage)

Unit-3

Molecular Physics-A: Born-Oppenheimer approximation, Rotational spectroscopy: Classification of rotors. Diatomic molecule as a rigid rotator, Centrifugal distortion and non – rigid rotator, energy levels and spectra, Intensity of rotational lines, experimental techniques. Raman scattering, Polarizability, Rotational Raman spectroscopy (diatomics). Experimental technique.

(25% Weightage)

Unit-4

Molecular Physics-B: Diatomic molecule as a simple harmonic oscillator, anharmonicity, effect of anharmonicity on vibrational terms, energy levels and selection rules. Vibrating rotator-energy levels and rovibrionic spectra, Experimental technique and IR spectrometry. Applications of IR spectroscopy. Mutual exclusion principle. Electronic spectra of diatomic molecules: vibrational coarse structure and rotational fine structure in electronic spectra, intensity of vibrational bands in electronic spectra – Frank- Condon principle. Dissociation and predissociation.

(25% Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Interaction of radiation with matter: Einstein's coefficients, Beer's law for attenuation and amplification of light.
7-13	The width and shape of spectral lines: natural broadening, Doppler broadening-estimation of half width, General treatment of other broadening mechanisms-collision and power broadening.
14-19	Brief review of early atomic models. Hydrogenic atoms: Energy levels and selection rules, Relativistic corrections and fine structure, hyperfine structure, Lamb shift and isotope shift.
20-23	Interaction with external fields: Zeeman effect, Paschen-Back effect, Stark effect.
24-27	Two electron atom: Ortho and para states and role of Pauli's exclusion principle, level schemes of two electron atoms.
28-30	Many electron atoms: LS and JJ coupling schemes, Lande interval rule.
31-34	Born-Oppenheimer approximation, Rotational spectroscopy: Classification of rotors.
35-39	Diatomic molecule as a rigid rotator, Centrifugal distortion and non – rigid rotator, energy levels and spectra, Intensity of rotational lines, experimental techniques.
40-45	Raman scattering, Polarizability, Rotational Raman spectroscopy (diatomics). Experimental technique.
46-49	Diatomic molecule as a simple harmonic oscillator, anharmonicity, effect of anharmonicity on vibrational terms, energy levels and selection rules.
50-52	Vibrating rotator-energy levels and rovibrionic spectra, Experimental technique and IR spectrometry.

53-55	Applications of IR spectroscopy.
56-57	Mutual exclusion principle.
58-59	Electronic spectra of diatomic molecules: vibrational coarse structure and rotational fine structure in electronic spectra, intensity of vibrational bands in electronic spectra – Frank- Condon principle.
60	Dissociation and pre-dissociation.

Essential Readings:

1. *Atomic and molecular physics*, Raj Kumar, 2009, Campus Books.
2. *Physics of atoms and molecules*, Bransden and Joachain, (2nd Edition) Pearson Education, 2004
3. *Introduction to Atomic Spectra*, H.E. White, McGraw Hill

Additional/Advance/Further Readings:

1. *Fundamentals of Molecular Spectroscopy*, Banwell and McCash, Tata McGraw Hill, 1998.
2. *Modern Spectroscopy*, J.M. Hollas, John Wiley, 1998.
3. *Molecular Spectroscopy*, Jeanne L. McHale, Pearson Education, 2008
4. *Molecular Quantum Mechanics*, P.W. Atkins and R.S. Friedman, 3rd Edition, Oxford Press (Indian Edition), 2004.
5. *Molecular Structure and Spectroscopy*, G. Aruldhas, Prentice Hall of India, New Delhi, 2001

Note: Latest edition of text books may be used

Course Title: Statistical Mechanics

Course Code	PHY72MN03704	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	6	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. Acquaint the students with basic knowledge of the kinetic theory of gases.
2. Familiarize the student with macrostate & microstate.
3. Acquaint the students with elementary idea of the concept of ensemble.
4. Orient the student with the theory of radiation.
5. Familiarize the student with Bose-Einstein and Fermi-Dirac Statistics.
6. Familiarize the student with Bose Einstein condensations.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Describe the surface tension and its basic properties.
2. Understand the mean free path and collision probability.
3. Understand the basic idea of partition function.
4. Understand the theory of radiation: blackbody radiation, Kirchhoff's law, Stefan-Boltzmann law and radiation pressure.
5. Demonstrate understanding of the Bose-Einstein and Fermi-Dirac Statistics.
6. Demonstrate the ability to justify and explain their thinking and approach towards application of statistical mechanics.
7. Investigate the real world problems with acquire the knowledge from this course.

Course Contents:

Unit-1

Kinetic Theory of Gases Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.

(25 % Weightage)

Unit-2

Classical Statistics: Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy – Applications to Specific Heat and its Limitations. Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature.

(25 % Weightage)

Unit-3

Theory of Radiation: Properties of Thermal Radiation. Blackbody Radiation. Kirchhoff's law. Stefan-Boltzmann law. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law. Ultraviolet Catastrophe. Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.

(25 % Weightage)

Unit-4

Bose-Einstein and Fermi-Dirac Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law. Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Kinetic Theory of Gases Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment.
8-15	Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. Mean Free Path. Collision Probability.
16-20	Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.
21-25	Classical Statistics: Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law.

26-35	Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation.
36-40	Law of Equipartition of Energy – Applications to Specific Heat and its Limitations. Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature.
41-44	Theory of Radiation: Properties of Thermal Radiation. Blackbody Radiation. Kirchhoff's law. Stefan-Boltzmann law. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law.
45-47	Ultraviolet Catastrophe. Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification.
48-51	Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.
52-55	Bose-Einstein and Fermi-Dirac Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description).
56-58	Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law. Fermi-Dirac Distribution Law
59-60	Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

Essential Readings:

1. *Heat and Thermodynamics*, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill
2. *Concepts of Modern Physics*, Arthur beiser, Sixth Edition, McGraw-Hill.
3. *Statistical Mechanics*, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
4. *Statistical Physics*, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill.
5. *Statistical and Thermal Physics*, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall.

Additional/Advance/Further Readings:

1. *Thermodynamics, Kinetic Theory and Statistical Thermodynamics*, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
2. *Modern Thermodynamics with Statistical Mechanics*, Carl S. Helrich, 2009, Springer.
3. *An Introduction to Statistical Mechanics & Thermodynamics*, R.H. Swendsen, 2012, Oxford Univ. Press.
4. *Statistical Physics Volume 5*, L D Landau, E.M. Lifshitz, 2013, Elsevier Science

Note: Latest edition of text books may be used

Course Title: Advance Mathematical Physics

Course Code	PHY81MJ03804	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	7	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The main objective of this course is to provide some advanced mathematical skills used in physics.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Understand the basic concepts of linear algebra.
2. Understand the basic concepts of linear transformations.
3. Understand the basic concepts of calculus of variations.
4. Understand the basic concepts of Legendre transformation.
5. Understand the basic concepts of tensors.

Course Contents:

Unit-1

Linear Algebra: Vector Spaces over Fields of Real and Complex numbers, Linear independence of vectors. Basis and dimension of a vector space, Change of basis, Inner product and Norm, Inner product of functions, Triangle and Cauchy Schwartz Inequalities. Linear Transformations: Introduction, Identity and inverse, Singular and non-singular transformations, Representation of linear transformations by matrices, Similarity transformation, Linear operators, Differential operators as linear operators on vector space of functions, Commutator of operators, Orthogonal and unitary operators and their matrix representations, Adjoint of a linear operator, Hermitian operators and their matrix representation, Hermitian differential operators and boundary conditions, Eigenvalues and eigenvectors of linear operators, Properties of eigenvalues and eigenvectors of Hermitian and unitary operators.
(25 % Weightage)

Unit-2

Calculus of Variations: Variational Principle, Euler's Equation, Application to Simple Problems, Several Dependent Variables and Euler's Equations, Hamilton's Principle and the Euler-Lagrange equations of motion, geodesic equation as a set of Euler's equations. Constrained Variations: Variations with constraints, Applications: motion of a simple pendulum, particle constrained to move on a hoop. Legendre Transformation: Legendre Transformation and its application in Thermodynamics and Classical Mechanics

(25 % Weightage)

Unit-3

Fourier Transforms: Fourier Integral theorem, Fourier Transform, Fourier transform of trigonometric, Gaussian, finite wave train & other functions, Representation of Dirac delta function as a Fourier Integral, Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms, Three dimensional Fourier transforms with examples, Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations. Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions, Convolution Theorem, Inverse LT. Application of Laplace Transforms.

(25 % Weightage)

Unit-4

Tensors: Index notation, dummy and floating indices, Kronecker delta and Levi-Civita Symbols, Summation Convention, Matrices in index notation, Multidimentional Spaces, Coordinate Transformation, Contravariant and Covariant Vectors, Contravariant, Covariant and Mixed Tensors, Tensors of rank greater than two, Fundamental Operations with Tensors, Components of a tensor in basis, Change of basis, Symmetric and Anti-Symmetric Tensors, Line element and metric tensor, Associated tensors, Concept of length and angle, Tensor Fields, Derivative of a tensor, Christoffel's symbols, Covariant Differentiation.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-12	Linear Algebra: Vector Spaces: Vector Spaces over Fields of Real and Complex numbers. Examples. Vector space of functions. Linear independence of vectors. Basis and dimension of a vector space. Change of basis. Subspace. Isomorphisms. Inner product and Norm. Inner product of functions: the weight function. Triangle and Cauchy Schwartz Inequalities. Orthonormal bases. Sine and cosine functions in a Fourier series as an orthonormal basis. Gram Schmidt orthogonalisation.
13-30	Linear Transformations: Introduction. Identity and inverse. Singular and non-singular transformations. Representation of linear transformations by matrices. Similarity transformation. Linear operators. Differential operators as linear operators on vector space of functions. Commutator of operators. Orthogonal and unitary operators and their matrix representations. Adjoint of a linear operator. Hermitian operators and their matrix representation. Hermitian differential operators and boundary conditions. Examples. Eigenvalues and eigenvectors of linear operators. Properties of eigenvalues and eigenvectors of Hermitian and unitary operators. Functions of Hermitian operators/ matrices.
31-42	Calculus of Variations: Variational Principle: Euler's Equation. Application to Simple Problems (shape of a soap film, Fermat's Principle, etc.). Several Dependent Variables and Euler's Equations. Example: Hamilton's Principle and the Euler-Lagrange equations of motion. Geodesics: geodesic equation as a set of Euler's equations. Constrained Variations: Variations with constraints. Applications: motion of a simple pendulum, particle constrained to move on a hoop.

43-44	Legendre Transformation: Legendre Transformation and its application in Thermodynamics and Classical Mechanics.
45-60	Tensors: Index notation, dummy and floating indices, Kronecker delta and Levi-Civita Symbols, Summation Convention, Matrices in index notation, Multidimentional Spaces, Coordinate Transformation, Contravariant and Covariant Vectors, Contravariant, Covariant and Mixed Tensors, Tensors of rank greater than two, Fundamental Operations with Tensors, Components of a tensor in basis, Change of basis, Symmetric and Anti-Symmetric Tensors, Line element and metric tensor, Associated tensors, Concept of length and angle, Tensor Fields, Derivative of a tensor, Christoffel's symbols, Covariant Differentiation, Tensors in Euclidean Geometry, Tensors in Classical Mechanics, Tensors in Special Relativity.

Essential Readings:

1. *Mathematical Methods for Physicists*, G.B. Arfken, H.J. Weber, and F.E. Harris, 1970, Elsevier.
2. *Vector Analysis*; Murray R Spiegel; Schaum's Outline Series.
3. *Tensor Calculus*; David C Kay; Schaum's Outline Series.

Additional/Advance/Further Readings:

1. *Mathematical Tools for Physics*, James Nearing, 2010, Dover Publications.
2. *Introduction to Matrices and Linear Transformations*, D.T. Finkbeiner, 1978, Dover Pub.
3. *Linear Algebra*, W. Cheney, E.W.Cheney & D.R.Kincaid, 2012, Jones & Bartlett Learning.
4. *Mathematics for Physicists*, Susan M. Lea, 2004, Thomson Brooks/Cole.
5. *Mathematical Methods for Physicis & Engineers*, K.F.Riley, M.P.Hobson, S.J.Bence, 3rd Ed., 2006, Cambridge University Press.

Note: Latest edition of text books may be used

Course Title: Classical Mechanics

Course Code	PHY81MJ03904	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	7	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The objectives of the course in Classical Mechanics are:

1. Develop a deep understanding of the foundational principles and laws governing classical mechanics.
2. Explore Lagrangian and Hamiltonian mechanics to describe and analyze complex dynamical systems.
3. Analyze physical systems in the contexts rigid bodies, and systems with constraints.
4. Develop problem-solving skills by engaging with real-world applications in classical mechanics.

Course Learning Outcomes:

Upon completion of the course, learners will be able to:

1. Grasp the fundamental principles of Lagrangian formulation in classical mechanics.
2. Demonstrate knowledge of Hamiltonian formulation and its significance in describing dynamical systems.
3. Apply symmetries in physics to analyze and understand physical phenomena.
4. Understand the principles governing motion under a central force field.
5. Demonstrate knowledge of rotating frames and their implications in classical mechanics.
6. Analyze and interpret the dynamics of rigid bodies within the framework of classical mechanics.
7. Understand the principles underlying small oscillations and their behavior in mechanical systems.
8. Apply problem-solving techniques to address challenges in classical mechanics effectively.

Course Contents:

Unit-1

System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum. Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the first kind, Lagrange's equations of motion of the second kind, Non-uniqueness of the Lagrangian, Simple applications of the Lagrangian formulation

(25 % Weightage)

Unit-2

Symmetries of space time: Cyclic coordinates and Conservation theorems, Conservation of linear momentum, angular momentum and energy. Variational Principle and its application, Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Application of Hamiltonian formulation to different problems, derivation of Hamilton's equations from variational principle. Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force). Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory co-ordinate systems, transformations of the scattering angle and cross- sections between them.

(25 % Weightage)

Unit-3

Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum. Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia, classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.

(25 % Weightage)

Unit-4

Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula. Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-3	System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum.
4-8	Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the first kind, Lagrange's equations of motion of the second kind, Non-uniqueness of the Lagrangian
9-15	Simple applications of the Lagrangian formulation
16-17	Symmetries of space time: Cyclic coordinate, Conservation of linear momentum, angular momentum and energy.
18-20	Variational Principle and its application
21-25	Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Application of Hamiltonian formulation to different problems, derivation of Hamilton's equations from variational principle.

26-28	Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force).
29-30	Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory coordinate systems, transformations of the scattering angle and cross-sections between them.
31-34	Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum.
35-40	Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia
41-45	Classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.
46-50	Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula.
51-60	Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method

Essential Readings:

1. *Classical mechanics*, H. Goldstein, C. Poole, J. Saflco, Pearson Education Inc.
2. *Classical mechanics*; L. D. Landau and E. M. Lifshitz; Pergamon press.

Additional/Advance/Further Readings:

1. *Classical Mechanics: A Course of Lectures*; A K Raychoudhuri; Oxford University Press.
2. *Classical Mechanics*; J C Upadhyay; Himalaya Publishing House.
3. *Classical mechanics*; N. C. Rana and P. S. Joag, Tata McGraw-Hill.
4. *Introduction to classical mechanics*; Takwale and Puranik;Tata McGraw-Hill.

Note: Latest edition of text books may be used

Course Title: Electronics Lab

Course Code	PHY81MJ04004	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	7	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to :

1. Enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. Enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the master students towards experiment research.
5. Enhance the scientific understanding of advanced instruments which will help them for research.
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. Express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.
5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. Study of basic OPAMP configurations (IC741) and simple mathematical operations
2. Study OPAMP as comparator and Schmitt Trigger
3. Differentiator, Integrator and active filter circuits using OPAMP (IC741)
4. Phase shift oscillator using OPAMP (IC741)
5. Study of Boolean logic operations using ICs
6. Design and study of various flip flops circuits (RS, D, JK, T)
7. Design and study of various counter circuits (up, down, ring, mod-n)
8. Design and study of multivibrator circuits using IC555
9. Study of the output and transfer I-V characteristics of common source JFET.
10. Study the Colpitt's oscillator.
11. To design a Wien bridge oscillator for given frequency using an op-amp.
12. Design and study of Half Adder and Full Adder, Half Subtractor and Full Subtractor.
13. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND
14. To design an inverting amplifier of given gain using Op-amp 741 and study its frequency response.
15. To design a non-inverting amplifier of given gain using Op-amp 741 and study its Frequency Response.
16. To design a Wien Bridge Oscillator using an op-amp.

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiments.__

Course Title: Electronics and Experimental Methods

Course Code	PHY81MJ04104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	7	**Contact Hours**	60 (L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group Discussions , Self-Study , Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of this course, aimed at introducing students to the fundamentals of electronic devices, are as follows:

1. Familiarize students with the basic concepts of operational amplifiers. item Introduce students to the fundamental principles of inverting and non-inverting configurations of operational amplifiers.
2. Provide students with an understanding of the basic applications of operational amplifiers.
3. Orient students with digital techniques used in electronic devices.
4. Introduce students to Digital-to-Analog converters and their functionality.
5. Explain the basic concepts of transducers and particle detectors to students.
6. Familiarize students with data interpretation and analysis techniques relevant to electronic devices and their applications.

Course Learning Outcomes:

After completion of the course the students will be able to:

1. Describe the basic concepts of operational amplifiers.
2. Explain the fundamentals of digital techniques.
3. Discuss the operation of Digital-to-Analog converters.
4. Identify the difference between inverting and non-inverting configurations of operational amplifiers.
5. Describe the functionality of Digital-to-Analog converters.
6. Describe the operation of Analog-to-Digital converters.
7. Explain the basic concepts of Read-Only Memory (ROM) and Random Access Memory (RAM).
8. Understand the basic principles of transducers and particle detectors.
9. Interpret and analyze data effectively.

Course Contents:

Unit-1

Block diagram of an operational amplifier - Characteristics of an ideal operational amplifier - comparison with 741 - Operational amplifier as an open loop amplifier - Limitations of open loop configuration - Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain.

(7 % Weightage)

Unit-2

Linear applications - Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier-inverting and non-inverting configurations, subtractor, difference amplifier, ideal and practical Differentiator, Integrator. Nonlinear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers. basic comparator, zero-crossing detector, Schmitt trigger, Oscillators

(28 % Weightage)

Unit-3

Boolean laws and theorems, simplification using Karnaugh Map technique (4 variables) - conversion of binary to Grey code. Flip flops using NAND and NOR gates, Shift Registers basics - Counters: Ripple counters truth table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counter. Visual displays: Single-element displays, seven-segment displays, decoder logic. Digital to Analog converters: ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter. Specifications and application of DAC and ADC. Microprocessors and Microcontroller Basics.

(35 % Weightage)

Unit-4

Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Particle detectors (GM-Counter, Proportional counter, Scintillation counter, Semiconductor detector) Characteristics of measurement systems. Modulation techniques (ASK, FSK, PSK). Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Linear and nonlinear curve fitting, chi-square test.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Block diagram of an operational amplifier - Characteristics of an ideal operational amplifier – comparison with 741 - Operational amplifier as an open loop amplifier - Limitations of open loop configuration
5-8	Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain.
9-12	Linear applications – Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier–inverting and non-inverting configurations,
13-16	subtractor, difference amplifier, ideal and practical Differentiator, Integrator.
17-20	Nonlinear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers.

21-24	basic comparator, zero-crossing detector, Schmitt trigger, Oscillators
25-28	Boolean laws and theorems, simplification using Karnaugh Map technique (4 variables)- conversion of binary to Grey code.
28-32	Flip flops using NAND and NOR gates, Shift Registers basics - Counters: Ripple counters truth table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counter.
32-36	Visual displays: Single-element displays, seven-segment displays, decoder logic.
36-40	Digital to Analog converters: ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter.
41-45	Specifications and application of DAC and ADC. Microprocessors and Microcontroller Basics.
46-50	Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors).
51-55	Particle detectors (GM-Counter, Proportional counter, Scintillation counter, Semiconductor detector) Characteristics of measurement systems. Modulation techniques (ASK, FSK, PSK).
56-60	Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Linear and nonlinear curve fitting, chi-square test.

Essential Readings:

1. *Op-Amps and Linear Integrated Circuits*, Ramakant A Gayakwad, (Third Edition, 2004), Eastern Economy Edition.
2. *Operational Amplifiers with Linear Integrated Circuits*, William Stanley, (1988), CBS Publishers and Distributors.

Additional/Advanced/Further Readings:

1. *Linear Integrated Circuits*, D Roy Choudhury and Shail Jain, (1991), New Age International (P) Limited.
2. *Digital principles and applications*, Donald P Leach and Albert Paul Malvino, (Fifth Edition, 2002), Tata McGraw Hill.
3. *Digital systems, Principles and applications*, Ronald J Tocci and Neal S Widmer, (Eighth Edition, 2001), Pearson Education. Physics of Semiconductor Devices, Shur, PHI P
4. *Microprocessor Architecture Programming & Applications* – R.S. Gaonkar.
5. *Microprocessor 8085: Architecture, Programming*, & Interfacing – A. Wadhwa

Note: Latest edition of text books may be used

Course Title: Classical Mechanics (Minor)

Course Code	PHY81MN04204	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	7	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term External Examination

Course Objectives:

The objectives of the course in Classical Mechanics are:

1. Develop a deep understanding of the foundational principles and laws governing classical mechanics.
2. Explore Lagrangian and Hamiltonian mechanics to describe and analyze complex dynamical systems.
3. Analyze physical systems in the contexts rigid bodies, and systems with constraints.
4. Develop problem-solving skills by engaging with real-world applications in classical mechanics.

Course Learning Outcomes:

Upon completion of the course, learners will be able to:

1. Grasp the fundamental principles of Lagrangian formulation in classical mechanics.
2. Demonstrate knowledge of Hamiltonian formulation and its significance in describing dynamical systems.
3. Apply symmetries in physics to analyze and understand physical phenomena.
4. Understand the principles governing motion under a central force field.
5. Demonstrate knowledge of rotating frames and their implications in classical mechanics.
6. Analyze and interpret the dynamics of rigid bodies within the framework of classical mechanics.
7. Understand the principles underlying small oscillations and their behavior in mechanical systems.
8. Apply problem-solving techniques to address challenges in classical mechanics effectively.

Course Contents:

Unit-1

System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum. Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the first kind, Lagrange's equations of motion of the second kind, Non-uniqueness of the Lagrangian, Simple applications of the Lagrangian formulation

(25 % Weightage)

Unit-2

Symmetries of space time: Cyclic coordinates and Conservation theorems, Conservation of linear momentum, angular momentum and energy. Variational Principle and its application, Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Application of Hamiltonian formulation to different problems, derivation of Hamilton's equations from variational principle. Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force). Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory co-ordinate systems, transformations of the scattering angle and cross- sections between them.

(25 % Weightage)

Unit-3

Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum. Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia, classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.

(25 % Weightage)

Unit-4

Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula. Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-3	System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum.
4-8	Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the first kind, Lagrange's equations of motion of the second kind, Non-uniqueness of the Lagrangian
9-15	Simple applications of the Lagrangian formulation
16-17	Symmetries of space time: Cyclic coordinate, Conservation of linear momentum, angular momentum and energy.
18-20	Variational Principle and its application
21-25	Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Application of Hamiltonian formulation to different problems, derivation of Hamilton's equations from variational principle.

26-28	Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force).
29-30	Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory coordinate systems, transformations of the scattering angle and cross-sections between them.
31-34	Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum.
35-40	Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia
41-45	Classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.
46-50	Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula.
51-60	Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method

Essential Readings:

1. *Classical mechanics*, H. Goldstein, C. Poole, J. Saflco, Pearson Education Inc.
2. *Classical mechanics*; L. D. Landau and E. M. Lifshitz; Pergamon press.

Additional/Advance/Further Readings:

1. *Classical Mechanics: A Course of Lecture*s; A K Raychoudhuri; Oxford University Press.
2. *Classical Mechanics*; J C Upadhyay; Himalaya Publishing House.
3. *Classical mechanic*s; N. C. Rana and P. S. Joag, Tata McGraw-Hill.
4. *Introduction to classical mechanics*; Takwale and Puranik;Tata McGraw-Hill.

Note: Latest edition of text books may be used

Course Title: Electronics and Experimental Methods (Minor)

Course Code	PHY81MN04304	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	7	Contact Hours	60 (L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture,Group Discussuions, Self-Study,Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of this course, aimed at introducing students to the fundamentals of electronic devices, are as follows:

1. Familiarize students with the basic concepts of operational amplifiers. item Introduce students to the fundamental principles of inverting and non-inverting configurations of operational amplifiers.
2. Provide students with an understanding of the basic applications of operational amplifiers.
3. Orient students with digital techniques used in electronic devices.
4. Introduce students to Digital-to-Analog converters and their functionality.
5. Explain the basic concepts of transducers and particle detectors to students.
6. Familiarize students with data interpretation and analysis techniques relevant to electronic devices and their applications.

Course Learning Outcomes:

After completion of the course the students will be able to:

1. Describe the basic concepts of operational amplifiers.
2. Explain the fundamentals of digital techniques.
3. Discuss the operation of Digital-to-Analog converters.
4. Identify the difference between inverting and non-inverting configurations of operational amplifiers.
5. Describe the functionality of Digital-to-Analog converters.
6. Describe the operation of Analog-to-Digital converters.
7. Explain the basic concepts of Read-Only Memory (ROM) and Random Access Memory (RAM).
8. Understand the basic principles of transducers and particle detectors.
9. Interpret and analyze data effectively.

Course Contents:

Unit-1

Block diagram of an operational amplifier - Characteristics of an ideal operational amplifier - comparison with 741 - Operational amplifier as an open loop amplifier - Limitations of open loop configuration - Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain.

(7 % Weightage)

Unit-2

Linear applications - Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier-inverting and non-inverting configurations, subtractor, difference amplifier, ideal and practical Differentiator, Integrator. Nonlinear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers. basic comparator, zero-crossing detector, Schmitt trigger, Oscillators

(28 % Weightage)

Unit-3

Boolean laws and theorems, simplification using Karnaugh Map technique (4 variables) - conversion of binary to Grey code. Flip flops using NAND and NOR gates, Shift Registers basics - Counters: Ripple counters truth table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counter. Visual displays: Single-element displays, seven-segment displays, decoder logic. Digital to Analog converters: ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter. Specifications and application of DAC and ADC. Microprocessors and Microcontroller Basics.

(35 % Weightage)

Unit-4

Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Particle detectors (GM-Counter, Proportional counter, Scintillation counter, Semiconductor detector) Characteristics of measurement systems. Modulation techniques (ASK, FSK, PSK). Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Linear and nonlinear curve fitting, chi-square test.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Block diagram of an operational amplifier - Characteristics of an ideal operational amplifier – comparison with 741 - Operational amplifier as an open loop amplifier - Limitations of open loop configuration
5-8	Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain.
9-12	Linear applications – Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier–inverting and non-inverting configurations,
13-16	subtractor, difference amplifier, ideal and practical Differentiator, Integrator.
17-20	Nonlinear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers.

21-24	basic comparator, zero-crossing detector, Schmitt trigger, Oscillators
25-28	Boolean laws and theorems, simplification using Karnaugh Map technique (4 variables)- conversion of binary to Grey code.
28-32	Flip flops using NAND and NOR gates, Shift Registers basics - Counters: Ripple counters truth table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counter.
32-36	Visual displays: Single-element displays, seven-segment displays, decoder logic.
36-40	Digital to Analog converters: ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter.
41-45	Specifications and application of DAC and ADC. Microprocessors and Microcontroller Basics.
46-50	Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors).
51-55	Particle detectors (GM-Counter, Proportional counter, Scintillation counter, Semiconductor detector) Characteristics of measurement systems. Modulation techniques (ASK, FSK, PSK).
56-60	Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Linear and nonlinear curve fitting, chi-square test.

Essential Readings:

1. *Op-Amps and Linear Integrated Circuits*, Ramakant A Gayakwad, (Third Edition, 2004), Eastern Economy Edition.

2. *Operational Amplifiers with Linear Integrated Circuits*, William Stanley, (1988), CBS Publishers and Distributors.

Additional/Advanced/Further Readings:

1. *Linear Integrated Circuits*, D Roy Choudhury and Shail Jain, (1991), New Age International (P) Limited.

2. *Digital principles and applications*, Donald P Leach and Albert Paul Malvino, (Fifth Edition, 2002), Tata McGraw Hill.

3. *Digital systems, Principles and applications*, Ronald J Tocci and Neal S Widmer, (Eighth Edition, 2001), Pearson Education. Physics of Semiconductor Devices, Shur, PHI P

4. *Microprocessor Architecture Programming & Applications* – R.S. Gaonkar.

5. *Microprocessor 8085: Architecture, Programming, & Interfacing* – A. Wadhwa

Note: Latest edition of text books may be used

Course Title: Advanced Quantum Mechanics

Course Code	PHY82MJ04404	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	8	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are as follows:

1. Enhance understanding of Quantum Mechanics by delving into advanced concepts and principles.
2. Develop proficiency in applying the acquired knowledge and techniques to solve complex problems in Quantum Mechanics.
3. Equip students with the necessary foundational knowledge and skills to excel in subsequent courses, particularly in Quantum Field Theory and Gauge Theory.

Course Learning Outcomes:

On completion successful students will be able to:

1. Apply time-dependent perturbation theory to variety of problems.
2. Derive a mathematical description of quantum motion in electromagnetic fields.
3. Demonstrate an understanding of the founding principles of relativistic quantum mechanics;
4. Demonstrate a working knowledge of Dirac gamma matrices and their role in the Lorentz transformations of Dirac Spinors;
5. Use projection operators to filter spin and positive/negative energy solutions;
6. Demonstrate an understanding of the modern field-theoretic description of negative energy states.

Course Contents:

Unit-1

Scattering Theory: Kinematics of Scattering Process: differential and total cross-section -Asymptotic from of scattering wave function. Scattering amplitude by Green's method. Born approximation method and screened potential and square well potential as examples - Partial wave analysis and phase shift-Optical Theorem- Relationship between phase shift and Potential. Scattering by Hard sphere.

(25 % Weightage)

Unit-2

Time Dependent Perturbation Theory: Time dependent perturbation theory - Constant and harmonic perturbations - Transition probabilities - Fermi's-Golden rule - Selection rules for dipole radiation - Adiabatic approximation - Sudden approximation - The density matrix - spin density matrix and magnetic resonance - Semi classical treatment of an atom with electromagnetic radiation.

(25 % Weightage)

Unit-3

Many Electron Atom and Molecules: Thomas-Fermi atom – Self consistent method. Hartee - Fock method. Constants of motion in central field approximation-Corrections to the central field approximation. Born-Oppenheimer method-Molecular orbital theory. Valance bond theory. H_2^+ ion- Hydrogen molecule.

(25 % Weightage)

Unit-4

Relativistic Quantum Mechanic: Klein-Gordon Equation, Plane wave solution and Equation of continuity, Probability density-Dirac Equation, alpha, beta- matrices, Plane wave solution, significance of negative energy states. Spin of Dirac particle Relativistic particle in central potential –Total Angular Moment, Particle in a magnetic field - Spin Magnetic moment, properties of gamma matrices- Dirac's equation in covariant form.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Kinematics of Scattering Process: differential and total cross-section - Asymptotic from of scattering wave function.
5-7	Scattering amplitude by Green's method.
6-8	Born approximation method and screened potential and square well potential as examples
9-12	Partial wave analysis and phase shift-Optical Theorem- Relationship between phase shift and Potential. Scattering by Hard sphere.
13-20	Time dependent perturbation theory - Constant and harmonic perturbations - Transition probabilities - Fermi's-Golden rule - Selection rules for dipole radiation
21-30	Adiabatic approximation - Sudden approximation - The density matrix - spin density matrix and magnetic resonance - Semi classical treatment of an atom with electromagnetic radiation.
31-36	Thomas -Fermi atom – Self consistent method.
37-38	Hartee – Fock method
39-40	Constants of motion in central field approximation-Corrections to the central field approximation.
41-43	Born-Oppenheimer method-Molecular orbital theory.
44-46	Valance bond theory. H2+ ion- Hydrogen molecule
47-50	Klein –Gordon Equation, Plane wave solution and Equation of continuity, Probability density.
51-55	Dirac Equation, alpha, beta- matrices, Plane wave solution, significance of negative energy states.
56-60	Spin of Dirac particle Relativistic particle in central potential –Total Angular Moment, Particle in a magnetic field – Spin Magnetic moment, properties of gamma matrices- Dirac's equation in covariant form.

Essential Readings:

1. *Introduction to Quantum Mechanics*, David J. Griffiths Third Edition, Pearson Prentice Hall.
2. *Quantum Mechanics Concepts and Applications*, Nouredine Zettili Second Edition (Indian Adaptation), Wiley
3. *Relativistic Quantum Mechanics*, J.D. Bjorken ,S.D. Drell 1st Edition, McGraw-Hill Book Company.

Additional/Advance/Further Readings:

1. *Quantum Mechanics*, B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
2. *A First Book on Quantum Field Theory*, Amitabha Lahiri and P.B. Pal.
3. *Modern Quantum Mechanics*, J.J. Sakurai.
4. *Principles of Quantum Mechanic*, R. Shankar.

Note: Latest edition of text books may be used

Course Title: Classical Electrodynamics

Course Code	PHY82MJ04504	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	8	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to :

1. To understand how materials are affected by electric and magnetic fields.
2. To understand the relation between the fields under time varying situations and also the Maxwell equations.
3. To understand principles of propagation of uniform plane waves.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Recall the concepts of electrostatics for different charge distribution systems.
2. Comprehend the basics of magnetostatics and their applications to understand the concepts of magnetism in magnetic materials.
3. Demonstrate the knowledge of electricity and magnetism to derive Maxwell's equations and be able to apply them to real electromagnetic systems.
4. Derive the electromagnetic wave equations from Maxwell's equations and calculate the energy carried by electromagnetic waves.
5. Analyze the propagation of electromagnetic waves and the phenomena of reflection, refraction, transmission of these waves in different mediums.
6. Realise the concepts of waveguides/transmission lines and modes of electromagnetic waves.
7. Develop understanding of dynamics of charges in electromagnetic fields and generation of electromagnetic radiations from moving charge systems such as dipole.

Course Contents:

Unit-1

Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems, theMethod of Images, Separation of Variables and Multipole Expansion. Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces.

(25 % Weightage)

Unit-2

Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials, gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.

(25 % Weightage)

Unit-3

Electromagnetic waves in non-conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces. Fresnel's laws, interference, coherence transmission line and wave guides; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion: Dispersion in non-conductors, free electrons in conductors and plasmas. Guided waves.

(25 % Weightage)

Unit-4

Retarded potentials, Electric dipole radiation, magnetic dipole radiation. Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, Power radiated by a point charge.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems, the Method of Images, Separation of Variables and Multipole Expansion.
8-15	Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces.,
16-25	Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials.
26-35	Gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.
36-45	Electromagnetic waves in non-conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reection and transmission at interfaces.
46-50	Fresnel's laws, interference, coherence transmission line and wave guides; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion.

51-55	Dispersion in non-conductors, free electrons in conductors and plasmas. Guided waves.
56-60	Retarded potentials, Electric dipole radiation, magnetic dipole radiation, Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion. Power radiated by a point charge.

Essential Readings:

1. *Introduction to Electrodynamics*, D. J. Griffith, 4th edition, Addison-Wesley Professional, Boston, 2012.
2. *Foundations of Electromagnetic Theory*, J.R. Reitz., F.J. Milford and R. W. Christy, 2010, 4th edition, Pearson.

Additional/Advance/Further Readings:

1. *Classical Electrodynamics*, J.D. Jackson, 3rd edition, Wiley-India, Delhi, 2011.
2. *Classical Electrodynamics*, W. Greiner, 3rd edition, Springer, New York, 2010.

Note: Latest edition of text books may be used

Course Title: Computational Physics Lab

Course Code	PHY82MJ04604	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	8	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to

1. Enhancing students' proficiency in utilizing computational tools and software relevant to the field of study.
2. Fostering the ability to apply computational methods to solve real-world problems and challenges.
3. Developing a solid understanding of algorithms and their applications through practical implementation.
4. Building and refining programming skills in languages relevant to the course, fostering competence in coding.
5. Encouraging a mindset of continuous learning and adaptation to new computational tools and technologies within the field.

Course Learning Outcomes:

The course learning outcomes for a computational laboratory may include:

1. Demonstrate proficiency in using relevant computational software tools essential to the field.
2. Apply computational methods to effectively solve problems within the scope of the course.
3. Understand and implement algorithms to address specific computational challenges.
4. Develop and exhibit competence in coding using programming languages pertinent to the course.
5. Acquire skills in data analysis, interpretation, and visualization through computational techniques.
6. Apply computational methods to simulate and model systems, demonstrating a practical understanding of theoretical concepts.
7. Apply critical thinking skills to assess and adapt computational solutions based on changing requirements or new information.

Course Contents:

1. Data handling: find standard deviation, mean, variance, moments etc. of at least 25 entries.
2. Choose a set of 10 values and find the least squared fitted curve.
3. To find the roots of quadratic equations.
4. Perform numerical integration on 1-D function using Simpson rules.
5. Perform numerical integration on 1-D function using Trapezoid rule.
6. To generate random numbers between (i) 1 and 0, (ii) 1 and 100.
7. To find the value of π using Monte Carlo simulation.
8. Write a program for finding the inverse of a 3 x 3 matrix using Gauss / Gauss-Jordan method.
9. To find the solution of differential equation using Runge-Kutta method.
10. To find the solution of differential equation using Euler's method.
11. To find the value of y for given value of x using Newton's interpolation method.
12. Plotting Spherical harmonics and understanding their relation to atomic orbitals.
13. Plotting the radial probability distribution function of atomic orbitals.
14. Computing the band structure of the Krong-Penney model
15. Solve the simple harmonic oscillator problem with /without damping and visualize the phase-space diagram.

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiments.__

Course Title: Introduction of Research Methodology

Course Code	PHY82MJ04704	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	8	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are to :

1. Develop the understand of ethical considerations and guidelines in research.
2. identifying research problems, employing research methods, and effectively interpreting results.
3. Developing the necessary skills to communicate research findings with academic integrity, ensuring adherence to ethical standards and practices.
4. Developing effective communication skills for presenting research findings.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Understand the various steps of the scientific method along with the meaning of and need for research
2. Identify a research problem and formulate the objectives efficiently
3. Analyse and evaluate reliability of academic sources and carry out a survey of literature
4. Apply statistical analysis methods and techniques to data and interpret the results.
5. Design effective structures for communication of research results in different forms
6. Evaluate any academic source for plagiarism

Course Contents:

Unit-1

Research Methodology: An Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India. Defining the Research Problem: What is a Research Problem?, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem. (30 % Weightage)

Unit-2

Statistical analysis: Error analysis and propagation, types of data. Representation of data: tabular and diagrammatic methods, inference from data: averages and higher moments. Scatter plots: Correlation tests, Conditional probability, Bayes theorem, Probability distributions, likelihood estimation, Model fitting on data (regression), types of errors, hypothesis testing and confidence limits.

(35 % Weightage)

Unit-3

Communicating research and academic integrity:Structure and components of a written report, types of reports: thesis versus research paper, basic language/grammar rules for effective writing, making effective tables and graphs, bibliography and citation styles, Oral communication: seminars, posters, interacting with other researchers at conferences, Plagiarism: meaning, why and how to avoid it, self-plagiarism, Intellectual Property, Rights, copyrights and patents, Introduction to tools: LaTeX, natbib, Zotero, Turnitin

(35 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Research Methodology: An Introduction, Meaning of Research, Objectives of Research, Motivation in Research,
5-15	Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method,
16-20	Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India.
21-24	Defining the Research Problem: What is a Research Problem?, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem.
25-28	Statistical analysis: Error analysis and propagation, types of data. Representation of data: tabular and diagrammatic methods,
28-32	inference from data: averages and higher moments. Scatter plots: Correlation tests, Conditional probability,
32-36	Bayes theorem, Probability distributions, likelihood estimation, Model fitting on data (regression),
36-40	types of errors, hypothesis testing and confidence limits.
41-44	Communicating research and academic integrity:Structure and components of a written report, types of reports: thesis versus research paper,
45-48	basic language/grammar rules for effective writing, making effective tables and graphs,
49-52	bibliography and citation styles, Oral communication: seminars, posters, interacting with other researchers at conferences,
53-56	Plagiarism: meaning, why and how to avoid it, self-plagiarism, Intellectual Property, Rights, copyrights and patents,
57-60	Introduction to tools: LaTeX, natbib, Zotero, Turnitin

Essential Readings:

1. *Research methodology techniques and methods* by C L Kothari, New age International publishers
2. *Research Methodology: A step-by-step guide for beginners, 3rd Edition*, Ranjit Kumar, SAGE Publications

3. *A Manual for Writers of Research Papers, Theses, and Dissertations, 8th Edition*, Kate Turabian, The University of Chicago Press

4. *The Craft of Research, 4th Edition*, Wayne Booth, Gregory Colomb, Joseph Williams, Joseph Bizup, William Fitzgerald, The University of Chicago Press

5. *Scientific Inference: Learning from Data*, Simon Vaughan, Cambridge University Press

6. *Data Reduction and Error Analysis for Physical Sciences*, P. R. Bevington and D. K. Robinson, McGraw Hill

Additional/Advance/Further Readings:

1. *Basic statistics*, B. L. Agrawal, New Delhi, New Age publishers.

2. *A Research Methods*, Ahuja Ram(2006) Jaipur, Rawat Publication.

3. *Numerical Methods*, E. Balagurusamy, Tata Mc. Graw Hill.

4. *Numerical methods problems and solutions*, M. K. Jain and Iyengar, New Age International Ltd.

5. *Elements of Probability and Principles of Statistics*, A. C .Rosander (1965) Calcutta, East West Press.

6. *Numerical Mathematical Analysis*, J. B. Scarborough (1971) New Delhi: Oxford & IBH Pub. Co.

Note: Latest edition of text books may be used

Course Title: Classical Electrodynamics (Minor)

Course Code	PHY82MN04804	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	8	**Contact Hours**	60(L) Hours

Course Type	Discipline Specific Elective (Minor)
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to :

1. To understand how materials are affected by electric and magnetic fields.
2. To understand the relation between the fields under time varying situations and also the Maxwell equations.
3. To understand principles of propagation of uniform plane waves.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Recall the concepts of electrostatics for different charge distribution systems.
2. Comprehend the basics of magnetostatics and their applications to understand the concepts of magnetism in magnetic materials.
3. Demonstrate the knowledge of electricity and magnetism to derive Maxwell's equations and be able to apply them to real electromagnetic systems.
4. Derive the electromagnetic wave equations from Maxwell's equations and calculate the energy carried by electromagnetic waves.
5. Analyze the propagation of electromagnetic waves and the phenomena of reflection, refraction, transmission of these waves in different mediums.
6. Realise the concepts of waveguides/transmission lines and modes of electromagnetic waves.
7. Develop understanding of dynamics of charges in electromagnetic fields and generation of electromagnetic radiations from moving charge systems such as dipole.

Course Contents:

Unit-1

Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems, theMethod of Images, Separation of Variables and Multipole Expansion. Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces.

(25 % Weightage)

Unit-2

Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials, gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.

(25 % Weightage)

Unit-3

Electromagnetic waves in non-conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces. Fresnel's laws, interference, coherence transmission line and wave guides; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion: Dispersion in non-conductors, free electrons in conductors and plasmas. Guided waves.

(25 % Weightage)

Unit-4

Retarded potentials, Electric dipole radiation, magnetic dipole radiation. Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, Power radiated by a point charge.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems, the Method of Images, Separation of Variables and Multipole Expansion.
8-15	Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces.,
16-25	Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials.
26-35	Gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.
36-45	Electromagnetic waves in non-conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reection and transmission at interfaces.
46-50	Fresnel's laws, interference, coherence transmission line and wave guides; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion.

51-55	Dispersion in non-conductors, free electrons in conductors and plasmas. Guided waves.
56-60	Retarded potentials, Electric dipole radiation, magnetic dipole radiation, Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion. Power radiated by a point charge.

Essential Readings:

1. *Introduction to Electrodynamics*, D. J. Griffith, 4th edition, Addison-Wesley Professional, Boston,2012.
2. *Foundations of Electromagnetic Theory*, J.R. Reitz., F.J. Milford and R. W. Christy, 2010, 4th edition, Pearson.

Additional/Advance/Further Readings:

1. *Classical Electrodynamics*, J.D. Jackson, 3rd edition, Wiley-India, Delhi, 2011.
2. *Classical Electrodynamics*, W. Greiner, 3rd edition, Springer, New York, 2010.

Note: Latest edition of text books may be used

Course Title: Advanced Physics Lab

Course Code	PHY82MJ05004	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	8	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to :

1. Enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. Enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the master students towards experiment research.
5. Enhance the scientific understanding of advanced instruments which will help them for research.
6. Eevelop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.
5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. Study of basic OPAMP configurations (IC741) and simple mathematical operations
2. Study the OPAMP as comparator and Schmitt Trigger
3. Differentiator, Integrator and active filter circuits using OPAMP (IC741)
4. Phase shift oscillator using OPAMP (IC741)
5. Study of Boolean logic operations using ICs
6. Design and study of various flip flops circuits (RS, D, JK, T)
7. Design and study of various counter circuits (up, down, ring, mod-n)
8. Design and study of multivibrator circuits using IC555
9. Study of the output and transfer I-V characteristics of common source JFET.
10. Perform numerical integration on 1-D function using Simpson rules.
11. Perform numerical integration on 1-D function using Trapezoid rule.
12. To generate random numbers between (i) 1 and 0, (ii) 1 and 100.
13. To find the value of π using Monte Carlo simulation.
14. To find the solution of differential equation using Runge-Kutta method.
15. Plotting Spherical harmonics and understanding their relation to atomic orbitals.
16. Plotting the radial probability distribution function of atomic orbitals.
17. Computing the band structure of the Krong-Penney model

*__Any experiment can be added / deleted at any time during the course in / from the list of the experiment.__

Course Title: Condensed Matter Physics

Course Code	PHY92MJ05104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	9	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to :

1. The course is to give a broad phenomenological overview and background to cutting-edge topics of modern condensed matter physics.
2. Students will learn the advanced topics in solid state theory to apply in materials science research.
3. The goal is to address many-body effects in solid state systems.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Understand the electronic states govern the material properties microscopically.
2. Learn the free-electron metallic states as the simplest itinerant electron system.
3. Comprehend the electron states of solid crystals become Bloch states.
4. Apply many-body effects among electrons reduce the Coulomb-repulsion energy.
5. Understand the basics of first-principles electron theory to describe electronic states non-empirically.
6. Demonstrate the above mentioned ideas from industrial perspective.

Course Contents:

Unit-1

Boltzmann transport equation, resistivity of metals and semiconductors, Fermi surfaces – determination, Landau levels, de Hass van Alphen effect, Quantum Hall effect- Integral quantum Hall effect and. Magnetoresistance.
(25 % Weightage)

Unit-2

Dielectrics and ferroelectrics, macroscopic electric field, local field at an atom, dielectric constant and polarizability, ferroelectricity, antiferroelectricity, piezoelectric crystals, ferroelasticity, electrostriction.

(25 % Weightage)

Unit-3

Optical constants and their physical significance, Reflectivity in metals, plasmonic properties of metals, determination of band gap in semiconductors: direct and indirect band gap, defect mediated optical transitions, excitons, photoluminescence, Electroluminesence.

(25 % Weightage)

Unit-4

Types of magnetic materials, Quantum theory of paramagnetism, Hund's rule, Ferromagnetism, antiferromagnetism: molecular field, Curie temperature. Domain theory, Magnetic Anisotropy, Magnetic interactions, Heitler-London method, exchange and superexchange, magnetic moments and crystal-field effects, spin-wave excitations and thermodynamics, antiferromagnetism, Magnetostriction.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-8	Boltzmann transport equation, resistivity of metals and semiconductors.
9-11	Fermi surfaces – determination, Landau levels.
12-15	de Hass van Alphen effect, Quantum Hall effect- Integral quantum Hall effect.
16-19	Magnetoresistance and Dielectrics and ferroelectrics
20-24	macroscopic electric field, local field at an atom, dielectric constant and polarizability.
25-27	ferroelectricity, antiferroelectricity
28-30	piezoelectric crystals, ferroelasticity, electrostriction.
31-33	Optical constants and their physical significance
34-37	Reflectivity in metals, plasmonic properties of metals
38-42	determination of band gap in semiconductors: direct and indirect band gap,
43-46	defect mediated optical transitions, excitons, photoluminescence
47-50	Electroluminesence, Types of magnetic materials, Quantum theory of paramagnetism,
51-54	Hund's rule, Ferromagnetism, antiferromagnetism: molecular field,
55-57	Curie temperature. Domain theory, Magnetic Anisotropy, Magnetic interactions, Heitler-London method, exchange and superexchange, magnetic moments
58-60	crystal-field effects, spin-wave excitations and thermodynamics, antiferromagnetism, Magnetostriction.

Essential Readings:

1. *Introduction to Solid State Theory*, Otfried Madelung, Springer (2008).
2. *Solid State Physics*, Giuseppe Grosso and Giuseppe Pastori Parravicini, Elsevier (2012).

3. *Quantum Theory of Solids*, Charles Kittel, Wiley (1987).

4. *Solid State Theory*, Walter A. Harrison, Dover Publications (2012).

Additional/Advance/Further Readings:

1. *Advanced Solid State Theory*, Thomas Pruschke, Morgan and Claypool (2014).

2. *Advanced Solid State Physics*, Philip Phillips, Cambridge University Press (2012).

3. *Solid State Physics: Introduction to the Theory*, James Patterson and Bernard Bailey, Springer (2010).

4. *Many-Body Quantum Theory in Condensed Matter*, Henrik Bruus and Karsten Flensberg, Oxford University Press (2005),

Note: Latest edition of text books may be used

Course Title: Condensed Matter Physics Lab-1

Course Code	PHY92MJ05204	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	9	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to :

1. Enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. Enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the master students towards experiment research.
5. Enhance the scientific understanding of advanced instruments which will help them for research.
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. Express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.
5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. To study the relationship between temperature of given samples (1&2) and its time of cooling by plotting a cooling curve and identify the samples.
2. To study Hall Effect in semiconductor and determine Hall coefficient (Rh) & charge career density.
3. To evaluate modest nano-particles concentrations in the fluid for significant enhancement of its property.
4. Study of phase transition and to detect/assess weak and strong molecular interactions in nano-fluids.
5. To determine the Stefan's constant by using an incandescent lamp and Photovoltaic cell.
6. To demonstrate Hysteresis curve of hard magnet.
7. To determine Dielectric constant of specimen at high frequency by Lecher wires.
8. To study the dispersion relation for mono-atomic lattice and determine the cut of frequency.
9. To determine heat capacity of solids
10. Measurement of Planck's constant using LED.
11. Measurement of Planck's constant using photo voltaic cell
12. Phase problem and determination of crystal structures.
13. Indexing of X-Ray powder diffraction patterns.
14. Atomic scattering factor and structure factor determination.
15. Experimental determination of space group and inversion symmetry.
16. Refinement procedures

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Physics of Materials

Course Code	PHY92MJ05304	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	9	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This main objective of this course to provide the deep understanding of materials science, how the properties of material associated to crystal structure. create understanding the composites, polymers and mechanical behavior of these materials in details. Describe and discuss novel technological important materials. This course aims to :

1. To provide broad knowledge of the material properties, their utilization, and development of these properties to meet the requirements set by different applications.
2. To acquaint students about the development, properties and behaviour of metallic, ceramic, and polymeric materials under various conditions and in different applications.
3. To facilitate the understanding of manufacturing technologies and how they are used to affect properties and structure
4. Familiarize the student with new technological important materials and their properties.
5. This course should give the student confidence to undertake higher level education or job assignments in various institutes in India or in abroad.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Describe different materials at the structural level.
2. Explain mechanical and thermal properties of materials based on the inner structure.
3. Understand basic structure-property relationships.
4. Mathematically model for diffusion processes, creep, and corrosion behavior of materials
5. Understanding how to utilize material properties in practice, apply knowledge in materials selection

Course Contents:

Unit-1

Introduction to material science and engineering, Classification of Materials, Atomic structures, atomic bonding in solids, crystal structures, crystallographic points, directions and planes, crystalline and nano-crystalline materials, Defects, Dislocations & Imperfections in solids, grain size determination. Diffusion mechanism, Fick's Law.

(30 % Weightage)

Unit-2

Mechanical Property of Metals, Concept of Stress and Strain, Elastics and plastics behaviour of materials, deformation and strengthening mechanisms, Concept of phase diagram, Gibbs Phase Rule.

(20 % Weightage)

Unit-3

Ceramic structures, Processing of ceramics and applications, Introduction to polymer science, classification of polymers, synthesis and processing of polymers and its applications, classification, processing and properties of composites, corrosion and degradation of materials.

(30 % Weightage)

Unit-4

Electrical, Magnetic, Thermal and Optical property of materials and applications

(20 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Introduction to material science and engineering, Classification of Materials,
6-10	Atomic structures, atomic bonding in solids, crystal structures,
11-15	crystallographic points, directions and planes, crystalline and nano-crystalline materials,
16-20	defects, Dislocations & Imperfections in solids, grain size determination. Diffusion mechanism, Fick's Law.
21-25	Mechanical Property of Metals, Concept of Stress and Strain,
26-30	Elastics and plastics behaviour of materials, deformation and strengthening mechanisms,
31-35	Concept of phase diagram, Gibbs Phase Rule.
36-40	Ceramic structures, Processing of ceramics and applications, Introduction to polymer science,
41-45	classification of polymers, synthesis and processing of polymers and its applications, classification,
46-50	processing and properties of composites, corrosion and degradation of materials.
51-60	Electrical, Magnetic, Thermal and Optical property of materials and applications

Essential Readings:

1. *Materials Science and Engineering: An Introduction*, 10 edition, William D. Callister, David G. Rethwisch, Wiley
2. *Materials Science and Engineering*, V. Ragharan, Prentice Hall

Additional/Advance/Further Readings:

1. *Elements of Materials Science and Engineering*: Lowrence H. Van Vlack, Addison Wesley,
2. *Polymer Science, V. R Gowariker, N.V. Vishwanathan, JoydevShreedhar*, Wiley
3. *Foundations of Materials Science and Engineering*-William F. Smith, McGraw Hills International Edition
4. *Introduction to Ceramics*: W D Kingery, H K Bower and VR'uhlman, John Wiley
5. *Structure and Properties of materials*-vol I-IV Rose, Shepard and Wul
6. *Text of Polymer Science*, Fred. W.Billmeyer, John Wiley and Sons, Inc.

Note: Latest edition of text books may be used

Course Title: Experimental Techniques

Course Code	PHY92MJ05404	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	9	Contact Hours	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The course objectives are outlined to achieve a foundational understanding of modern experimental techniques in solid-state, nuclear, and particle physics. The key objectives include:

1. Attain a basic understanding of the principles underlying modern experimental techniques in the fields of solid-state, nuclear, and particle physics.
2. Explore the concepts and functionalities of various instruments used in experimental studies within these physics domains.
3. Develop proficiency in characterization techniques essential for in-depth analysis and investigation in solid-state, nuclear, and particle physics.
4. Equip students with the necessary skills to conduct advanced research studies by building upon the foundational knowledge gained in the course.
5. Bridge theoretical concepts with practical applications, allowing students to implement experimental techniques in real-world scenarios.
6. Develop critical thinking skills to assess and adapt experimental techniques based on specific research objectives and challenges.

Course Learning Outcomes:

After the successful completion of the course, students will be equipped with the following skills and capabilities:

1. Demonstrate a comprehensive understanding of modern experimental techniques in solid-state, nuclear, and particle physics.
2. Exhibit proficiency in operating and understanding various instruments used in experimental studies within the specified physics domains.
3. Apply advanced characterization techniques to analyze materials and particles, enhancing their ability to contribute to research studies.
4. Demonstrate hands-on proficiency in handling and operating instruments relevant to the experimental studies covered in the course.

Course Contents:

Unit-1

Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar,viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion). Diffraction Techniques: Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction. Microscopic Techniques: Optical Microscopy; Scanning Electron Microscopy;Scanning Tunneling Microscopy; Atomic Force Microscopy; Transmission Electron Microscopy.

(25 % Weightage)

Unit-2

Spectroscopic Techniques: Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR,Raman and surface enhanced Raman Spectroscopy. X-ray Fluorescence; Rutherford back scattering; UV VIS NIR spectrophotometer, Ellipsometry; Differential scanning calorimeter; Differential Thermal Analyzer

(25 % Weightage)

Unit-3

Gas Filled Ionization Detectors : Production of Electron-Ion Pairs , Diffusion and Drift of Charges in Gases, Regions of Operation of Gas Filled Detectors, Detector Efficiency. Liquid Filled Detectors : Properties of Liquids, Liquid Ionization Chamber, Liquid Proportional Counters, Commonly Used Liquid Detection Media, Sources of Error in Liquid Filled Ionizing Detectors, Cherenkov Detectors, Bubble Chamber, Liquid Scintillator Detectors.

Solid State Detectors : Materials Suitable for Radiation Detection, pn-Junction, Modes of Operation of a pn-Diode, Specific Semiconductor Detectors, Radiation Damage in Semiconductors, High Pure Germanium Detectors and differnet configuration, Thermoluminescent Detectors. Scintillation Detectors: Scintillation Mechanism and Scintillator Properties, Organic Scintillators, Inorganic Scintillators Transfer of Scintillation Photons, Photodetectors, PhotodiodeDetectors, Avalanche Photodiode Detectors (APD), Silicon Photomultipliers (SiPMs)

(35 % Weightage)

Unit-4

Signal Processing: Preamplification, Signal Transport, Pulse Shaping, Filtering, Amplification, Discrimination, Analog to Digital Conversion, A/D-Conversion Related Parameters, A/D Conversion Methods, Digital Signal Processing, SCA, MCA, Electronics Noise.

(15 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar,viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion).
8-15	Diffraction Techniques: Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction. Microscopic Techniques: Optical Microscopy; Scanning Electron Microscopy;Scanning Tunneling Microscopy; Atomic Force Microscopy; Transmission Electron Microscopy.
16-20	Spectroscopic Techniques: Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR,Raman and surface enhanced Raman Spectroscopy.

21-25	X-ray Fluorescence; Rutherford back scattering; UV VIS NIR spectrophotometer, Ellipsometry; Differential scanning calorimeter; Differential Thermal Analyzer
26-30	Gas Filled Ionization Detectors : Production of Electron-Ion Pairs , Diffusion and Drift of Charges in Gases, Regions of Operation of Gas Filled Detectors, Detector Efficiency.
31-35	Liquid Filled Detectors : Properties of Liquids, Liquid Ionization Chamber, Liquid Proportional Counters, Commonly Used Liquid Detection Media, Sources of Error in Liquid Filled Ionizing Detectors, Cherenkov Detectors, Bubble Chamber, Liquid Scintillator Detectors.
36-45	Solid State Detectors : Materials Suitable for Radiation Detection, pn-Junction, Modes of Operation of a pn-Diode, Specific Semiconductor Detectors, Radiation Damage in Semiconductors, High Pure Germanium Detectors and differnet configuration, Thermoluminescent Detectors.
46- 50	Scintillation Detectors: Scintillation Mechanism and Scintillator Properties, Organic Scintillators, Inorganic Scintillators Transfer of Scintillation Photons, Photodetectors, PhotodiodeDetectors, Avalanche Photodiode Detectors (APD)
51-60	Signal Processing: Preamplification, Signal Transport, Pulse Shaping, Filtering, Amplification, A/D-Conversion Related Parameters, A/D Conversion Methods, Digital Signal Processing, Electronics Noise.

Essential Readings:

1. *Physics and Engineering of Radiation Detection*, Syed Naeem Ahmed, Academic Press, Elsevier, 2007.
2. *Radiation detection and measurement*, Glenn F. Knoll (Wiley), 2010.
3. *Techniques in Nuclear and particle Experiments*, W.R. Leo (Springer), 1994
4. *Measurement, Instrumentation and Experiment Design in Physics and Engineering*, Sayer Michael and Mansingh Abhai, PHI (2000).
5. *Nanotechnology-Molecularly Designed Materials*, G.M. Chow and K.E. Gonsalves (American Chemical Society), 1996

Additional/Advance/Further Readings:

1. *Nanotechnology-Molecularly Designed Materials*, G.M. Chow and K.E. Gonsalves (American Chemical Society), 1996.
2. *Nanoparticles and Nanostructured Films–Preparation*, characterization and Application : J.H. Fendler (Wiley), 1998
3. *Crystallography Applied to Solid State Physics*, A.R. Verma and O.N. Srivastava.

Note: Latest edition of text books may be used

Course Title: Advanced Condensed Matter Physics

Course Code	PHY92MJ05504	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to:

1. The course is to give a broad phenomenological overview and background to cutting-edge topics of modern condensed matter physics.
2. Students will learn the advanced topics in solid state theory to apply in materials science research.
3. The goal is to address many-body effects in solid state systems.
4. To know the basic science of magnetism and visualize the applications.
5. To understand the theory of magnetization dynamics and the necessity magnetic anisotropy.

Course Learning Outcomes:

Upon completion of this course, the student should able to:

1. Understand the electronic states govern the material properties microscopically.
2. Learn the free-electron metallic states as the simplest itinerant electron system.
3. Comprehend the electron states of solid crystals become Bloch states.
4. Apply many-body effects among electrons reduce the Coulomb-repulsion energy.
5. Understand the basics of first-principles electron theory to describe electronic states non-empirically.
6. Demonstrate the above mentioned ideas from industrial perspective.
7. Explain the fundamentals of magnetism by molecular field theory and band theory.
8. Apply solid state physics to appreciate domain wall mechanism.
9. Analyze the magnetization dynamics through various characterization techniques.
10. Interpret the physical origin of magnetic anisotropy and its effects.
11. Evaluate the magnetostriction for various single and polycrystalline materials.
12. Recall the mechanism of Magnetocalorics and Magnetoelectronics.

Course Contents:

Unit-1

Diamagnetism, Paramagnetism of atoms with permanent magnetic moment, Pauli paramagnetism of conduction electrons, magnetic exchange interaction, Heisenberg model for ferro and antiferromagnetic insulators, magnons in ferro and antiferro-magnets, magnon contribution to specific heat, Stoner theory of ferro-magnetism of itinerant electrons (brief), second quantization (brief), local moment formation in metals, brief discussion of Kondo effect and Heavy fermion systems.

(40 % Weightage)

Unit-2

Phenomenological theories of superconductivity, Meissner effect, thermodynamics of superconductors, London's phenomenological theory, flux quantization, Copper instability, BCS theory of superconductivity, Coulomb pseudo-potential, strong coupling effects, Josephson effects, High temperature superconductors – applications, Ginzburg- Landau theory.

(20 % Weightage)

Unit-3

Integral and fractional quantum Hall effect: electron in a strong magnetic field, Landau levels and their degeneracy, simple explanation of IQHE; Metal-Insulator transitions: Mott- Hubbard and impurity induced; Landau theory of Fermi liquid, Mott variable range hopping, Bose- Einstein condensation. Introduction of cryogenic systems.

(40 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Diamagnetism, Paramagnetism of atoms with permanent magnetic moment
5-8	Pauli paramagnetism of conduction electrons, magnetic exchange interaction,
9-15	Heisenberg model for ferro and antiferromagnetic insulators, magnons in ferro and antiferro-magnets, magnon contribution to specific heat,
16-20	Stoner theory of ferro-magnetism of itinerant electrons (brief), second quantization (brief), local moment formation in metals, brief discussion of Kondo effect and Heavy fermion systems.
21-24	Phenomenological theories of superconductivity, Meissner effect, thermodynamics of superconductors, London's phenomenological theory, flux quantization, Copper instability,
25-28	BCS theory of superconductivity, Coulomb pseudo-potential, strong coupling effects, Josephson effects,
28-32	High temperature superconductors – applications, Ginzburg- Landau theory.
32-36	Integral and fractional quantum Hall effect: electron in a strong magnetic field, Landau levels and their degeneracy,
36-44	simple explanation of IQHE; Metal-Insulator transitions: Mott- Hubbard and impurity induced; Landau theory of Fermi liquid,
45-50	Mott variable range hopping, Bose- Einstein condensation.
51-60	Introduction of cryogenic systems

Essential Readings:

1. *Introduction to Solid State Theory*, Otfried Madelung, Springer (2008).
2. *Solid State Physics*, Giuseppe Grosso and Giuseppe Pastori Parravicini, Elsevier (2012).
3. *Quantum Theory of Solids*, Charles Kittel, Wiley (1987).
4. *Solid State Theory*, Walter A. Harrison, Dover Publications (2012).
5. *Introduction to magnetism and magnetic materials*, Jiles David,3rd edition, 2015, London: Chapman & Hall.
6. *Handbook of Magnetic Materials*, K.H.J.Buschow, 1 edition, 2014, North Holland Publisher.

Additional/Advance/Further Readings:

1. *Advanced Solid State Theory*, Thomas Pruschke, Morgan and Claypool (2014).
2. *Advanced Solid State Physics*, Philip Phillips, Cambridge University Press (2012).
3. *Solid State Physics: Introduction to the Theory*, James Patterson and Bernard Bailey, Springer (2010).
4. *Many-Body Quantum Theory in Condensed Matter*, Henrik Bruus and Karsten Flensberg, Oxford University Press (2005).
5. *Allan H Morrish, The Physical Principle of Magnetism*, 2001, willey- IEEE press.
6. *Magnetism is Solids, D.H.Martin,* 1967, The MIT press Ltd

Note: Latest edition of text books may be used

Course Title: Condensed Matter Physics Lab-II

Course Code	PHY92MJ05604	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to:

1. Enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. Enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the master students towards experiment research.
5. Enhance the scientific understanding of advanced instruments which will help them for research.
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. Express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.
5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. To study characteristics of a solar cell.
2. To measure the charge Q on a plate capacitor as a function of the applied voltage E.
3. To determine the capacitance C as a function of areas A of plates.
4. To determine the capacitance C with different dielectrics between the plates.
5. To determine the capacitance C as a function of the distances d between the plates.
6. To determine resistivity of a given semiconductor by Four probe.
7. To determine the Band gap in a semiconductor using a junction diode.
8. To study Hall effect in semiconductor and determine Hall coefficient (Rh), mobility, Hall angle tan (θ) & conductivity.
9. Crystallographic measurements using XRD.
10. DTA/TGA and DSC
11. IV characteristics using keithley instruments

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Solid State Devices

Course Code	PHY92MJ05704	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60(L)Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to familiarize students with the fundamentals of semiconductors and their practical applications in electronic devices. The specific objectives of the course are outlined below:

1. To acquaint students with the basic theories of solid-state structure, providing them with a foundational understanding of the arrangement and properties of solid materials at the atomic level.
2. To teach students how to apply the free electron theory to solid materials, enabling them to describe and analyze the electronic behavior of semiconductors and other solid-state materials.
3. To help students understand the origin of energy bands in solid-state materials and how these bands influence electronic behavior, providing insight into the electrical properties of semiconductors and their role in device operation.
4. To instruct students in the application of different models of solid-state physics to describe the properties of solids and electronic devices, allowing them to analyze and predict the behavior of semiconductor devices using theoretical frameworks and mathematical models.

Course Learning Outcomes:

Upon successful completion of the course, students will be able to demonstrate:

1. A comprehensive understanding of the elastic properties of solids and the phenomenon of lattice vibrations, providing insight into the mechanical behavior of materials at the atomic level.
2. A thorough understanding of the properties of metals based on the principles of the free and nearly-free electron gas models, enabling the analysis of electrical conductivity and thermal properties in metallic systems.
3. Proficiency in demonstrating a clear understanding of density functional theory (DFT) and its foundational components, allowing them to comprehend the theoretical framework used to describe electronic structure and properties in condensed matter systems.
4. A deep understanding of the electrical, magnetic, and superconducting properties of condensed matter, including their underlying principles and the mechanisms governing their behavior, facilitating analysis and interpretation of material properties in various contexts.

Course Contents:

Unit-1

Classification of Semiconductors; Crystal structure with examples of Si, Ge & GaAs semiconductors; Energy band structure of Si, Ge & GaAs; Extrinsic and compensated Semiconductors; Temperature dependence of Fermi-energy and carrier concentration. Drift, diffusion and injection of carriers; Carrier generation and recombination processes- Direct recombination, Indirect recombination, Surface recombination, Auger recombination; Continuity Equation, Haynes Shockley experiment, Hall effect; Four probe resistivity measurement; Carrier life time measurement. Semiconductor Crystals growth techniques.

(35 % Weightage)

Unit-2

Fabrication of p-n junction by diffusion and ion-implantation; Abrupt and linearly graded junctions; Transition and Diffusion capacitance, Special Diodes and their characteristics (Zener, Backward, Varactor, step recovery, point contact Schottky, Tunnel, IMPATT, PIN, LASER diodes)

(35 % Weightage)

Unit-3

Schottky barrier - Energy band relation, Capacitance- voltage (C-V) characteristics, Current-voltage (I-V) characteristics; Ohmic contacts. Bipolar Junction Transistor (BJT): Static Characteristics; Frequency Response and Switching.

(15 % Weightage)

Unit-4

Junction Field Effect Transistor (JFET) - Construction, Characteristic parameters, Transfer Characteristics, applications; Introduction to ideal MOS device; MOSFET fundamentals, Measurement of mobility, channel conductance, Metal-semiconductor field effect transistor, (MESFET)- Device structure, Principles of operation, Current voltage (I-V) characteristics.

(15 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Classification of Semiconductors; Crystal structure with examples of Si, Ge & GaAs semiconductors;
5-8	Energy band structure of Si, Ge & GaAs; Extrinsic and compensated Semiconductors;
9-12	Temperature dependence of Fermi-energy and carrier concentration. Drift, diffusion and injection of carriers;
13-16	Carrier generation and recombination processes- Direct recombination, Indirect recombination, Surface recombination,
17-20	Auger recombination; Continuity Equation, Haynes Shockley experiment, Hall effect; Four probe resistivity measurement;
21-24	Carrier life time measurement. Semiconductor Crystals growth techniques.
25-28	Fabrication of p-n junction by diffusion and ion-implantation;
28-32	Abrupt and linearly graded junctions; Transition and Diffusion capacitance,
32-36	Special Diodes and their characteristics (Zener, Backward, Varactor, step recovery, point contact Schottky, Tunnel, IMPATT, PIN, LASER diodes)

36-40	Schottky barrier - Energy band relation, Capacitance- voltage (C-V) characteristics, Current-voltage (I-V) characteristics; Ohmic contacts.
41-44	Bipolar Junction Transistor (BJT): Static Characteristics; Frequency Response and Switching.
45-48	Junction Field Effect Transistor (JFET) - Construction, Characteristic parameters, Transfer Characteristics, applications;
49-52	Introduction to ideal MOS device; MOSFET fundamentals, Measurement of mobility, channel conductance etc.
53-56	from Ids vs Vds and Ids vs Vg characteristics; Metal-semiconductor field effect transistor,
57-60	(MESFET)- Device structure, Principles of operation, Current voltage (I-V) characteristics,

Essential Readings:

1. *Semiconductor Devices: Physics and Technology*, S.M. Sze, 2nd edition, John Wiley, New York, 2002.
2. *Solid State Electronic Devices*, B.G. Streetman and S. Benerjee 5th edition, Prentice Hall of India, NJ, 2000.
3. *Semiconductor Measurements and Instrumentation*, W.R. Runyan McGraw Hill, Tokyo, 1975.

Additional/Advance/Further Readings:

1. *Semiconductors and Electronic devices*, Adir Bar-Lev, 2nd edition, Prentice Hall, 1984.
2. *Semiconductor Physics and Devices: Basic Principles*, Donald A. Neamen, 3rd edition, Tata McGraw-Hill, New Delhi, 2002.
3. *Physics of Semiconductor Devices*, M. Shur, Prentice Hall of India, New Delhi, 1995.
4. *Integrated Electronics* by Jacob Millman, Christos Halkias, Tata McGraw-Hill Education Private Limited, 2009

Course Title: Advance Nuclear Physics

Course Code	PHY91MJ05904	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	9	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This main objective of this course to provide the deep understanding of nuclear phenomena. Starting with an overview of the development of nuclear and particle physics, the course builds on previous learning in quantum mechanics and electromagnetism to develop student's understanding of the properties of the nucleus. This course aims to:

1. Impart knowledge of nuclear models and all types of radioactivity.
2. Intoduce with nuclear two-body problem.
3. Acquaint the students with a understanding of the role of nuclear physics in the astrophysics modeling
4. Familiarize the student with the experimental set-ups and current nuclear physics research

Course Learning Outcomes:

Upon successful completion of the course, learners will be equipped with the following skills and capabilities:

1. Describe nuclear forces and nuclear properties.
2. Explain the behavior of the deuteron at ground and excited states.
3. Understand various nuclear models including the Fermi gas model, Liquid drop model, Shell Model, Single particle shell model, Magic numbers, and Collective nuclear model.
4. Provide theoretical descriptions of radioactive decays such as α-particle emission, beta decays, gamma decay, and internal conversion.
5. Apply various aspects of nuclear reactions in the context of compound nuclear dynamics.
6. Describe nuclear reactions and their properties.
7. Engage in elementary problem-solving in nuclear physics, and relate theoretical predictions to measurement results.
8. Describe various nuclear processes in Astrophysics.

Course Contents:

Unit-1

Nuclear Two-Body Problem : Binding Energy of Deuteron, Ground State of Deuteron, Excited States of Deuteron, Root Mean Square Radius, Inclusion of Hard Core Potential in the Square Well, Magnetic Dipole Moment of Deuteron, Tensor Force, Quadrupole Moment, Nucleon-Nucleon Interaction: Two Nucleon Scattering, n-p Scattering, Partial Wave Analysis, Phase-Shift, Scattering Length, p-p Scattering (Qualitative Discussion)

(25 % Weightage)

Unit-2

Liquid Drop Model: Semi-Empirical Mass Formula, Nuclear Instability Against Alpha Decay, β Emission, Neutron Decay, Fission and Fusion, Defects of Liquid Drop Model, Criticism of Liquid Drop Model. Fermi Gas Model: Fermi Energy, Asymmetric Term in the Mass Formula, Odd-Even Term in the Mass Formula, Threshold for Particle Production in Complex Nuclei, Application to Neutron Stars, Energy Levels of Individual Nucleons, Shell Model: Magic Numbers, LS Coupling, Predictions of the Shell Model, Magnetic Moments, Schmidt Lines, Parity of Nuclei, Nuclear Isomerism , Criticism of the Shell Model. Collective Model or Unified Model : Rotational States, Vibrational States, Electric Quadrupole Moments, General Theory of Deformed Nuclei, Rotational Model Vibrational Model, Collective Oscillations, Giant Resonances, Nilsson Model,

(25 % Weightage)

Unit-3

Nuclear Reactions: Types of Reactions, Energy and Mass Balance, Conservation Laws for Nuclear Reactions, Cross-Sections, Exoergic and Endoergic Reactions, Behaviour of Cross-Sections near Threshold, Inverse Reaction, Qualitative Features of Nuclear Reactions, Reaction Mechanisms Nuclear Reactions via Compound Nucleus Formation Partial Wave Analysis of Nuclear Reactions, Slow Neutron Resonances and the Breit-Wigner Theory, Optical Model, Direct Reactions, Inelastic Scattering, Charge-Exchange Reactions, Nucleon Transfer Reactions, Break-up Reactions, Knock-out Reactions, Heavy-Ion Reactions, Characteristics of Heavy Ion Reactions, Types of Interactions, Distant Collisions, Deep Inelastic Collisions, Quark-Gluon Plasma.

(25 % Weightage)

Unit-4

Nuclear Astrophysics: Brief Overview of Stellar Evolution, Big-bang nucleosynthesis, Stellar nucleosynthesis, Rate for Nonresonant Reaction, Conversion of Proton into Helium, Solar Neutrino Problem, Reactor Neutrino Anomaly, Helium Burning and Beyond, Supernova and Synthesis of Heavy Nuclei.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-4	Binding Energy of Deuteron, Ground and Excited States of Deuteron State, Root Mean Square Radius
5-8	Inclusion of Hard Core Potential in the Square Well, Magnetic Dipole Moment of Deuteron, Tensor Force, Quadrupole Moment,
9-12	Nucleon-Nucleon Interaction
13-16	Liquid Drop Model, Fermi Gas Model
17-20	Shell Model, Collective Model
21-24	General Theory of Deformed Nuclei, Giant Resonances, Nilsson Model
25-28	Types of Reactions, Energy and Mass Balance, Conservation Laws for Nuclear Reactions

28-32	Cross-Sections, Exoergic and Endoergic Reactions, Behaviour of Cross-Sections near Threshold, Inverse Reaction, Qualitative Features of Nuclear Reactions
32-36	Reaction Mechanisms, Partial Wave Analysis of Nuclear Reactions, Slow Neutron Resonances and the Breit-Wigner Theory, Optical Model, Direct Reactions, Inelastic Scattering,
36-40	Charge-Exchange Reactions, Nucleon Transfer Reactions, Break-upReactions, Knock-out Reactions, Heavy-Ion Reactions,
41-44	Characteristics of Heavy Ion Reactions, Types of Interactions, Distant Collisions, Deep Inelastic Collisions, Quark-Gluon Plasma
45-48	Brief Overview of Stellar Evolution, Big-bang nucleosynthesis
49-52	Stellar nucleosynthesis, Rate for Nonresonant Reaction, Conversion of Proton into Helium
53-56	Solar Neutrino Problem, Helium Burning and Beyond
57-60	Supernova and Synthesis of Heavy Nuclei.

Essential Readings:

1. *Nuclear Physics*, Anwar Kamal, Springer Berlin, Heidelberg
2. *Introductory Nuclear Physics*, Samuel S.M. Wong, Second Edition, Wiley-VCH Verlag GmbH & Co. KaGaA
3. *Introduction to Nuclear Physics*, Kenneth Krane, Wiley India Pvt. Ltd.
4. *Introduction to Nuclear and Particle Physics*, A. Das & T. Ferbel, World Scientific
5. *Concepts of Nuclear Physics*, B. L. Cohen, Tata McGraw-Hill.
6. *Nuclear physics in a nutshell*, Carlos A Bertulani, Princeton University Press, 2007.

Additional/Advance/Further Readings:

1. *Nuclear Physics:Principles and Applications* John Lilley, Wiley 2013 ·
2. *Nuclei and Particle*, E. Segre, Publisher: W. A Benjamin
3. *Nuclear Physics, Experimental and Theoritical*, H. S. Hans, New Age International
4. *Nuclear and Particle Physics*, W. E. Burcham & M. Jobes, Addison Wesley.
5. *Nuclear Physics-An Introduction*, S. B. Patel, New Age International

Note: Latest edition of text books may be used

Course Title: Nuclear and Particle Physics Lab. – I

Course Code	PHY91MJ06004	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	9	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. The main objectives of this course are to:

1. Enhance the understanding of the students of procedural knowledge of nuclear physics.
2. Enhance the ability of the students to explain the processes and applications related to nuclear and particle physics.
3. Develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. Develop interest and motivate the master students towards experiment reserach.
5. Enhance the scientific understanding of radiation safety.
6. Develop ability to work together.
7. Develop an ability to express themselves coherently and logically.
8. Develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Handle the sophisticated detectors.
2. Express the basic concepts of nuclear physics in more general language.
3. Express the radioactive decays.
4. Express the types of gamma decay.
5. List the types of beta decays and can express reaction equations and related Q values and enegy of beta particles.
6. Demonstrate knowledge of personal radiation safety
7. Demonstrate appropriate data analysis skills.

Course Contents:

1. Study of the Characteristics of a G. M. Counters – characteristics, dead-time and counting statistics
2. Verification of Inverse square Law for Gamma-rays.
3. Esitmation of efficiency of the G.M. detector for Gamma and Beta source.
4. To Study Beta particle range and maximum energy.
5. Study of energy resolution characteristics of a scintillation spectrometer as a function of applied high voltage and to determine the best operating voltage.
6. Study of Cs-137 spectrum and calculation of FWHM & resolution for a given scintillation detector.
7. NaI(Tl) – Calibration and characteristic study, resolution and determination of gamma ray energy
8. Study of Co-60 spectrum and calculation of resolution of detector in term of energy.
9. Identification of unknown gamma ray source using known gamma emitter sources with the help of NaI(Tl) detector.
10. Setup the coincidence circuit in the a cosmic muon test bench and measure the cosmic ray muon flux in side and outdie the building.
11. Angular correlation ratio using NaI(Tl) detector.
12. Design the simple geometry of give detector setup and visualize in Geant4.
13. Absorption of γ-rays - Determination of the Half-value Thickness of Absorber Materials (Pb, Al, Fe)

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Introduction of Astroparticle Physics

Course Code	PHY91MJ06104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	9	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce students to various phenomena in the field of Astroparticle Physics and to develop the framework and analytical skills necessary to understand these phenomena in nature. This course aims to:

1. Familiarize students with basic knowledge of the Universe outside the Solar System.
2. Introduce the concept of nucleosynthesis in stars.
3. Familiarize students with the Hertzsprung–Russell Diagram.
4. Introduce the theory of the birth of cosmic rays.
5. Orient students with the current status of high-energy neutrino and gamma-ray astronomy.

Course Learning Outcomes:

After the successful completion of the course, students will be equipped with the following knowledge and skills:

1. Demonstrate a solid understanding of the fundamental concepts and theories within the field of astroparticle physics.
2. Recognize the interdisciplinary nature of astroparticle physics, integrating principles from astrophysics, particle physics, and cosmology.
3. Describe Hertzsprung–Russell Diagram.
4. Demonstrate the basic concepts of helioseismology and solar neutrino experiments.
5. Describe the Ultra High Energy Cosmic Ray (UHECR) interactions on the microwave background.
6. Comprehend the GZK cutoff, current status of the field.
7. Understand the interactions of particles in cosmic rays and the implications for understanding the universe's fundamental processes.
8. Be well-prepared to pursue advanced studies or research in astroparticle physics or related fields.

Course Contents:

Unit-1

Basic Equations of Stellar Structure: Hydrostatic Equilibrium in Stars, Virial Theorem, Energy Transport inside Stars, Convection inside stars; Constructing Stellar Models, Stellar Observational Data, Main Sequence, Red Giantsm, White Dwarfs, Eddington Luminosity Limit, Hertzsprung–Russell Diagram.

(25 % Weightage)

Unit-2

Nucleosynthesis: The possibility of nuclear reactions in stars, Calculation of nuclear reaction rates, Important nuclear reactions in stellar interiors, Stellar Models and Experimental Confirmation: Helioseismology, Solar neutrino experiments; Stellar evolution, Evolution in binary systems, Mass Loss from Stars, Stellar winds, Degeneracy Pressure of a Fermi gas, Structure of White Dwarfs, Chandrasekhar Mass Limit, Supernovae, The neutron drip and neutron stars, Pulsars.

(25 % Weightage)

Unit-3

The Birth of Cosmic Ray: Stellar evolution, the *pp* chain, Solar Neutrinos, Supernova Explosions, Supernova Neutrinos, Supernova Remnants, Acceleration of cosmic Rays: Stochastic Acceleration of Charged Particles, Fermi Mechanism, Acceleration with Energy Loss, Energy Spectra, Interstellar Matter and Magnetic Field, Diffuse Galactic Gamma Rays, Comsic Rays in Atomsphere, Cosmic Rays in Underground

(25 % Weightage)

Unit-4

Cosmic Microwave Background, Ultra High Energy Cosmic Ray interactions, Propagation of UHE protons and nuclei, Possible Astrophysical Sources of UHECR, GZK Cutoff, Current Status of the Field, High Energy Neutrino and Gamma-Ray Astronomy (review), Grapes Experiment (otty)

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Basic equations of stellar structure Hydrostatic equilibrium in stars, Virial theorem for stars, Energy transport inside stars, Convection inside star,
5-8	Constructing stellar models, Stellar observational data and HR diagrams, Main sequence, red giants and white dwarfs, Eddington luminosity limit
9-12	Nucleosynthesis: The possibility of nuclear reactions in stars, Calculation of nuclear reaction rates, Important nuclear reactions in stellar interiors,
13-16	Stellar models and experimental confirmation: Helioseismology, Solar neutrino experiments,
17-20	Stellar evolution, Evolution in binary systems,
21-24	Mass loss from stars, Stellar winds, Degeneracy pressure of a Fermi gas, Structure of white dwarfs,
25-28	Chandrasekhar mass limit, Supernovae, The neutron drip and neutron stars, Pulsars
28-32	The Birth of Cosmic Ray: Stellar evolution, the *pp* chain, Solar neutrinos, Supernova explosions, Supernova neutrinos, Supernova remnants,
32-36	Acceleration of cosmic rays: Stochastic acceleration of charged particles, Fermi mechanism, acceleration with energy loss, energy spectra, Interstellar matter and magnetic field,

36-40	Diffuse galactic gamma rays, Comsic rays in atomsphere, Cosmic rays underground
41-44	Ultra High Energy Cosmic Ray (UHECR) : Cosmic microwave background,
45-48	UHECR interactions on the microwave background,
49-52	Propagation of UHE protons and nuclei,
53-56	Possible astrophysical sources of UHECR, GZK cutoff, current status of the field,
57-60	High energy neutrino and gamma-ray astronomy (review), Grapes Experiment (otty)

Essential Readings:

1. *Astrophysics for Physicists*, Arnab Rai Choudhuri, Cambridge University Press.
2. *High Energy Cosmic Rays* , Todorstanev, Springer
3. *Cosmic Rays and Particle Physics*, By Thomas K. Gaisser, Cambridge University Press.
4. *An Introduction to the Theory of Stellar Structure and Evolution*, Dina Prialnik, Latest Edition, Cambridge University Press

Additional/Advance/Further Readings:

1. *High Energy Radiation from Black Holes: Gamma Rays, Cosmic Rays, and Neutrinos*, By Charles D. Dermer, Charles Dermer, GovindMenon, Princeton University Press.
2. *Ultra-high Energy Particle Astrophysics*, By Shigeru Yoshida, Nova Science Publishers, Inc. New York.
3. *High Energy Astrophysics*, Malcolm Longair, vols 1-2, Latest Edition, Cambridge University Press.
4. *An Introduction to Modern Astrophysics*, B.W. Carroll & DA Ostlie, Latest Edition, Addison-Wesley

Note: Latest edition of text books may be used

Course Title: Nuclear Reactor Physics

Course Code	PHY91MJ06204	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	9	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
1 **Methods of Content Interaction**	Lecture, Group discussion, Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are to:

1. Understand the fundamental principles and concepts underlying the operation of nuclear reactor cores.
2. Familiarize students with different types of nuclear reactors, including pressurized water reactors (PWR), boiling water reactors (BWR), and other advanced reactor designs.
3. Develop a deep understanding of neutronic aspects, including neutron production, moderation, and absorption within the reactor core.
4. Learn about the physics and dynamics of nuclear fission chain reactions, including the role of control rods and feedback mechanisms.
5. Explore heat generation mechanisms in the reactor core and the transfer of heat to the coolant for electricity generation.
6. Understand various coolant systems used in nuclear reactor cores, such as water, gas, or liquid metal cooling.
7. Examine the design, fabrication, and characteristics of fuel elements used in nuclear reactors, including fuel enrichment considerations.
8. Gain knowledge about control systems and safety mechanisms designed to manage reactor power levels and respond to abnormal conditions.
9. Learn about emergency response procedures and protocols in the event of abnormal situations or accidents involving nuclear reactor cores.
10. Explore the environmental impact of nuclear reactor operations and the importance of sustainable practices.

Course Learning Outcomes:

After the successful completion of the Introduction to Nuclear Reactor course, students will gain the following knowledge and skills:

1. Develop a solid understanding of the basic principles governing nuclear reactors, including the physics of nuclear fission and chain reactions.

2. Familiarize themselves with various types of nuclear reactors, their designs, and operational characteristics, including pressurized water reactors (PWR), boiling water reactors (BWR), and advanced reactor concepts.
3. Gain knowledge about the essential components of a nuclear reactor, such as fuel assemblies, control rods, coolant systems, and reactor pressure vessels.
4. Understand the kinetics of neutron behavior within a reactor, including neutron production, moderation, absorption, and the factors influencing reactor criticality.
5. Comprehend the principles of heat generation through fission reactions and the transfer of heat to produce electricity using various cooling systems.
6. Understand ethical considerations related to nuclear reactor operation, emphasizing safety, transparency, and responsible conduct.

Course Contents:

Unit-1

Types of Nuclear Reactors: 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, 11, 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,

(25 % Weightage)

Unit-2

Nuclear Fuels: 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

(25 % Weightage)

Unit-3

Neutrino Diffusion and Moderation : Neutron Flux, Fick's Law, Equation of Continuity, Diffusion Equation. Neutron-Nuclear Reactions: Neutron-Induced Nuclear Fission, Stable Nuclides, Binding Energy, Threshold External Energy for Fission, Neutron-Induced Fission, Neutron Fission Cross Sections, Products of the Fission Reaction, Energy Release,

(25 % Weightage)

Unit-4

Radiation shielding : Gamma-Ray Shielding, Infinite Planar and Disc Sources, Line Source, Internal Sources, Multilayered Shields, NuclearReactorShielding, Removal Cross-Sections, Reactor Shield Design: Removal-Attenuation Calculatons, Removal-Diffusion Method, Exact Methods, Coolant Activation, Ducts in Shields.

Reactor Licensing, Safety and environment: Governmental Authority and Responsibility, Reactor Licensing, Principles of Nuclear Power Plant Safety, Dispersion of Effluents from Nuclear Facilities, Radiation Doses from Nuclear Plants, Reactor Siting, Reactor Accidents, Accident Risk Analysis, Environmental Radiation Doses.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Introduction:- Types of Nuclear Energy, Neutron Classification and Neutron Sources.
5-8	Interactions of Neutrons with Matter. Definition of Neutron Flux and Fluence, Neutron Cross Section, Reactor Flux Spectrum
9-12	Types of Reactors
13-16	Reactor Core Materials:- Structural/Fuel Cladding Materials, Moderators and Reflectors Control Mat erials, Coolants
17-20	Reactor start Up and Shutdown Principle, Nuclear Reactors in India
21-24	Introduction to Uranium, Plutonium and Thorium Fuels Shielding Materials
25-28	Crystal Structure and Physical Properties, Extraction, Alloying, Fabrication and Radiation effect
28-32	Ceramic Fuels:- Ceramic Uranium Fuels, Uranium Dioxide (Urania), Uranium Carbide, Uranium Nitride
32-36	Plutonium-Bearing Ceramic Fuels, Thorium-Bearing Ceramic Fuels
36-40	Neutrino Diffusion and Moderation : Neutron Flux, Fick's Law, Equation of Continuity, Diffusion Equation Binding Energy
41-44	Neutron-Nuclear Reactions: Neutron-Induced Nuclear Fission, Stable Nuclides, Binding Energy
45-48	Neutron-Induced Fission, Neutron Fission Cross Sections, Products of the Fission Reaction, Energy Release
49-52	Radiation shielding
53-56	Reactor Shield Design
57-60	Reactor Licensing, Safety and environment

Essential Readings:

1. *An Introduction to Nuclear Materials - Fundamentals and Applications*, K. Linga Murty and Jndraj it Charit (Wiley-VCH Verlag, Gennany).

2. *Introduction to Nuclear Reactor Theory*, John.R Lamarsh, Third Edition, Prentice Hall Upper Saddle River, New Jersey.

3. *Reactor Physics*, Paul .F. Zweifel, McGraw Hill Book Company (1973) India.

4. *Introduction to Nuclear Engineering*, Richard Stepheson, McGraw Hill Book Company (1974) New York.

5. *Physics of Nuclear Reactors*, Suresh Gard, Feroz Ahmed and L. S Kothari, Tata McGraw Hill Pub. Co. Ltd, London.

6. *Nuclear reactor theory*, Samuel Glasstone and Edmund ,

Additional/Advance/Further Readings:

1. *Material development for India's nuclear power programme*, A K Suri (BARC, Mumbai) Sadhana, Vol. 38, Part5, October 2013, pp. 859-895.

2. *Nuclear Fuels and development of nuclear fuel elements*, C V Sundaram and S L Mannan, (IGCAR Kalpakkam) , Sadhana Vol.l4, Part I, June 1989, pp 21-57.

Note: Latest edition of text books may be used

Course Title: Experimental Techniques

Course Code	PHY92MJ05404	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	9	Contact Hours	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The course objectives are outlined to achieve a foundational understanding of modern experimental techniques in solid-state, nuclear, and particle physics. The key objectives include:

1. Attain a basic understanding of the principles underlying modern experimental techniques in the fields of solid-state, nuclear, and particle physics.
2. Explore the concepts and functionalities of various instruments used in experimental studies within these physics domains.
3. Develop proficiency in characterization techniques essential for in-depth analysis and investigation in solid-state, nuclear, and particle physics.
4. Equip students with the necessary skills to conduct advanced research studies by building upon the foundational knowledge gained in the course.
5. Bridge theoretical concepts with practical applications, allowing students to implement experimental techniques in real-world scenarios.
6. Develop critical thinking skills to assess and adapt experimental techniques based on specific research objectives and challenges.

Course Learning Outcomes:

After the successful completion of the course, students will be equipped with the following skills and capabilities:

1. Demonstrate a comprehensive understanding of modern experimental techniques in solid-state, nuclear, and particle physics.
2. Exhibit proficiency in operating and understanding various instruments used in experimental studies within the specified physics domains.
3. Apply advanced characterization techniques to analyze materials and particles, enhancing their ability to contribute to research studies.
4. Demonstrate hands-on proficiency in handling and operating instruments relevant to the experimental studies covered in the course.

Course Contents:

Unit-1

Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar,viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion). Diffraction Techniques: Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction. Microscopic Techniques: Optical Microscopy; Scanning Electron Microscopy;Scanning Tunneling Microscopy; Atomic Force Microscopy; Transmission Electron Microscopy.

(25 % Weightage)

Unit-2

Spectroscopic Techniques: Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR,Raman and surface enhanced Raman Spectroscopy. X-ray Fluorescence; Rutherford back scattering; UV VIS NIR spectrophotometer, Ellipsometry; Differential scanning calorimeter; Differential Thermal Analyzer

(25 % Weightage)

Unit-3

Gas Filled Ionization Detectors : Production of Electron-Ion Pairs , Diffusion and Drift of Charges in Gases, Regions of Operation of Gas Filled Detectors, Detector Efficiency. Liquid Filled Detectors : Properties of Liquids, Liquid Ionization Chamber, Liquid Proportional Counters, Commonly Used Liquid Detection Media, Sources of Error in Liquid Filled Ionizing Detectors, Cherenkov Detectors, Bubble Chamber, Liquid Scintillator Detectors.

Solid State Detectors : Materials Suitable for Radiation Detection, pn-Junction, Modes of Operation of a pn-Diode, Specific Semiconductor Detectors, Radiation Damage in Semiconductors, High Pure Germanium Detectors and differnet configuration, Thermoluminescent Detectors. Scintillation Detectors: Scintillation Mechanism and Scintillator Properties, Organic Scintillators, Inorganic Scintillators Transfer of Scintillation Photons, Photodetectors, PhotodiodeDetectors, Avalanche Photodiode Detectors (APD), Silicon Photomultipliers (SiPMs)

(35 % Weightage)

Unit-4

Signal Processing: Preamplification, Signal Transport, Pulse Shaping, Filtering, Amplification, Discrimination, Analog to Digital Conversion, A/D-Conversion Related Parameters, A/D Conversion Methods, Digital Signal Processing, SCA, MCA, Electronics Noise.

(15 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar,viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion).
8-15	Diffraction Techniques: Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction. Microscopic Techniques: Optical Microscopy; Scanning Electron Microscopy;Scanning Tunneling Microscopy; Atomic Force Microscopy; Transmission Electron Microscopy.
16-20	Spectroscopic Techniques: Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR,Raman and surface enhanced Raman Spectroscopy.

21-25	X-ray Fluorescence; Rutherford back scattering; UV VIS NIR spectrophotometer, Ellipsometry; Differential scanning calorimeter; Differential Thermal Analyzer
26-30	Gas Filled Ionization Detectors : Production of Electron-Ion Pairs , Diffusion and Drift of Charges in Gases, Regions of Operation of Gas Filled Detectors, Detector Efficiency.
31-35	Liquid Filled Detectors : Properties of Liquids, Liquid Ionization Chamber, Liquid Proportional Counters, Commonly Used Liquid Detection Media, Sources of Error in Liquid Filled Ionizing Detectors, Cherenkov Detectors, Bubble Chamber, Liquid Scintillator Detectors.
36-45	Solid State Detectors : Materials Suitable for Radiation Detection, pn-Junction, Modes of Operation of a pn-Diode, Specific Semiconductor Detectors, Radiation Damage in Semiconductors, High Pure Germanium Detectors and differnet configuration, Thermoluminescent Detectors.
46- 50	Scintillation Detectors: Scintillation Mechanism and Scintillator Properties, Organic Scintillators, Inorganic Scintillators Transfer of Scintillation Photons, Photodetectors, PhotodiodeDetectors, Avalanche Photodiode Detectors (APD)
51-60	Signal Processing: Preamplification, Signal Transport, Pulse Shaping, Filtering, Amplification, A/D-Conversion Related Parameters, A/D Conversion Methods, Digital Signal Processing, Electronics Noise.

Essential Readings:

1. *Physics and Engineering of Radiation Detection*, Syed Naeem Ahmed, Academic Press, Elsevier, 2007.
2. *Radiation detection and measurement*, Glenn F. Knoll (Wiley), 2010.
3. *Techniques in Nuclear and particle Experiments*, W.R. Leo (Springer), 1994
4. *Measurement, Instrumentation and Experiment Design in Physics and Engineering*, Sayer Michael and Mansingh Abhai, PHI (2000).
5. *Nanotechnology-Molecularly Designed Materials*, G.M. Chow and K.E. Gonsalves (American Chemical Society), 1996

Additional/Advance/Further Readings:

1. *Nanotechnology-Molecularly Designed Materials*, G.M. Chow and K.E. Gonsalves (American Chemical Society), 1996.
2. *Nanoparticles and Nanostructured Films–Preparation*, characterization and Application : J.H. Fendler (Wiley), 1998
3. *Crystallography Applied to Solid State Physics*, A.R. Verma and O.N. Srivastava.

Note: Latest edition of text books may be used

Course Title: Advance Particle Physics

Course Code	PHY92MJ06304	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60 (L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The course objectives for Advanced Particle Physics typically include:

1. Introduce the role of symmetries and conservation laws in particle physics, emphasizing their significance in understanding fundamental forces and particle interactions.
2. Develop an in-depth understanding of quantum field theory, focusing on its advanced applications in the context of particle physics.
3. Prepare students for research work in nuclear and particle physics.
4. Provide an overview of basic relativistic quantum mechanics and quantum electrodynamics relevant to particle physics.
5. Prepare students for courses in quantum field theory and gauge theory.
6. Familiarize students with Feynman rules for quantum electrodynamics.
7. Introduce students to scattering amplitudes and decay width calculations.
8. Orient students with the principles of quantum chromodynamics.

Course Learning Outcomes:

Upon completion of this course, the student should be able to:

1. Understand symmetries and groups in the context of particle physics.
2. Be familiar with the principles of quantum electrodynamics.
3. Grasp the rules governing scattering amplitudes in particle interactions.
4. Comprehend the concepts of the parton model and Bjorken scaling.
5. Understand the basic principles of quantum chromodynamics.
6. Read, understand, and explain scholarly journal articles in the fields of nuclear and particle physics.

Course Contents:

Unit-1

Symmetries and Quarks : Symmetries in Physics, Symmetries and Groups (Brief Introduction), Group SU(2), Combining Representations, Finite Symmetry Groups: P and C, SU(2) of Isospin, Isospin for Antiparticles, Group SU(3), Example of an SU(3) Group: Isospin and Strangeness, Quark-Antiquark States : Mesons, Three-Quark States: Baryons, Magnetic Moments, Heavy Quarks: Charm and Beyond, Hadron Masses, Color Factors.

(25 % Weightage)

Unit-2

Quantum Electrodynamics (QED) : Nonrelativistic Quantum Mechanics, Lorentz Covariance and Four-Vector Notation, The Klein-Gordon Equation, The Feynman-Stiickelberg Interpretation, Nonrelativistic Perturbation Theory, Rules for Scattering Amplitudes, Feynman-Stiickelberg Approach, Electron (Spinless) in an Electromagnetic Field, Electron-Muon Scattering (Spinless), The Cross Section in Terms of the Invariant Amplitude, The Decay Rate Electron-Electron Scattering (Spinless), Electron-Positron Scattering: An Application of Crossing, Invariant Variables, The Origin of the Propagator.

(25 % Weightage)

Unit-3

Electrodynamics of Spin-half Particles: An Electron Interacting with an Electromagnetic Field, Mo11er Scattering, Electron-Muon Scattering (spin), Trace Theorems and Properties of γ-Matrices, Helicity Conservation at High Energies, Photons Polarization Vectors, Electron Propagator, Photon Propagator, Massive Vector Particles, Real and Virtual Photons, Compton Scattering, Pair Annihilation, Feynman Rules for QED,

(25 % Weightage)

Unit-4

Electrodynamics of Quarks and Hadrons: Electron-Quark Interactions, Hadron Production in e^+e^- Scattering, Elastic Electron-Proton Scattering, Inelastic Electron-Proton Scattering, The Parton Model and Bjorken Scaling, Quark Distribution Functions. Feynman Rules for Chromodynamics, The Quark-Quark Interaction, Pair Annihilation in QCD, Asymptotic Freedom. g-2 anomaly.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Symmetries in Physics, Symmetries and Groups
5-8	Group SU(2), Combining Representations, Finite Symmetry Groups: P and C, SU(2) of Isospin, Isospin for Antiparticles
9-12	Group SU(3), Example of an SU(3) Group: Isospin and Strangeness, Quark-Antiquark States : Mesons, Three-Quark States: Baryons, Magnetic Moments
13-16	Heavy Quarks: Charm and Beyond, Hadron Masses, Color Factors.
17-20	Nonrelativistic Quantum Mechanics, Lorentz Covariance and Four-Vector Notation, The Klein-Gordon Equation, The Feynman-Stiickelberg Interpretation
21-24	Nonrelativistic Perturbation Theory, Rules for Scattering Amplitudes, Feynman-Stiickelberg Approach, Electron (Spinless) in an Electromagnetic Field , Electron-Muon Scattering (Spinless), The Cross Section in Terms of the Invariant

25-28	Electron-Muon Scattering (Spinless), The Cross Section in Terms of the Invariant Amplitude, The Decay Rate Electron-Electron Scattering (Spinless)
28-32	Electron-Positron Scattering: An Application of Crossing, Invariant Variables, The Origin of the Propagator
32-36	Electrodynamics of Spin-half Particles: An Electron Interacting with an Electromagnetic Field, Mo11er Scattering, Electron-Muon Scattering (spin)
36-40	Trace Theorems and Properties of γ-Matrices, Helicity Conservation at High Energies
41-44	Photons Polarization Vectors, Electron Propagator, Photon Propagator, Massive Vector Particles, Real and Virtual Photons
45-48	Electrodynamics of Quarks and Hadrons: Electron-Quark Interactions, Hadron Production in e^+e^- Scattering, Compton Scattering, Pair Annihilation,
49-52	Feynman Rules for QED, Elastic Electron-Proton Scattering
53-56	Inelastic Electron-Proton Scattering, The Parton Model and Bjorken Scaling, Quark Distribution Functions
57-60	Feynman Rules for Chromodynamics, The Quark-Quark Interaction , Pair Annihilation in QCD, Asymptotic Freedom, g-2 anomaly

Essential Readings:

1. *Introduction to Elementary Particles* by D. Griffiths (2nd Ed., Wiley-VCH, 2008).
2. *Quarks and Leptons*, by F. Halzen and A.D. Martin (Wiley 1984).
3. *Particle Physics*, by B.R. Martin and G. Shaw (Wiley 2008).
4. *Particle and Astroparticle Physics*, by Utpal Sarkar, Taylor & Francis Group, LLC

Additional/Advance/Further Readings:

1. *Elementary Particles and the Laws of Physics* by R. P. Feynman and S. Weinberg (Cambridge University Press, 1999)
2. *Introduction to Elementary Particle Physics* by A. Bettini (Cambridge University Press, 2008)
3. *Elementary Particle Physics* by S. Gasiorowicz (John Wiley, 1966)

Course Title: Nuclear and Particle Physics Lab. – II

Course Code	PHY92MJ06404	Credits	4
L+T+P	0+0+4	Course Duration	One Semester
Semester	10	Contact Hours	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. The course objectives for Nuclear and Particle Physics Lab – II typically include:

1. Familiarize students with advanced experimental techniques used in nuclear and particle physics research.
2. Provide hands-on experience with various detector systems used in experimental setups, such as scintillation detectors, semiconductor detectors, and Cherenkov detectors.
3. Develop proficiency in data acquisition systems, including the operation of electronics and computer-based systems for collecting experimental data.
4. Understand and perform calibration procedures for experimental equipment to ensure accurate and precise measurements.
5. Gain skills in advanced data analysis techniques, including statistical methods, error analysis, and modeling, to extract meaningful information from experimental data.
6. Emphasize and adhere to strict safety protocols and procedures when working with radioactive materials and experimental setups.
7. Enhance communication skills through the preparation of detailed and comprehensive experimental reports, documenting procedures, results, and conclusions.

Course Learning Outcomes:

After the successful completion of the Nuclear and Particle Physics Lab – II, students will have achieved the following outcomes:

1. Acquire hands-on proficiency in advanced experimental techniques used in nuclear and particle physics research, including the operation of various detector systems.
2. Develop advanced skills in data acquisition systems, electronics, and computer-based tools for collecting and analyzing experimental data.

3. Conduct experiments related to radioactive decay, including measurements of half-life, decay constants, and the properties of decay products.
4. Foster teamwork and collaboration by engaging in group-based experiments.
5. List the types of beta decays and can express reaction equations and related Q values and enegy of beta particles.
6. Demonstrate knowledge of personal radiation safety
7. Demonstrate appropriate data analysis skills.

Course Contents:

1. Geiger Counter Experiment: Capturing and Dectecting Radon in the Environment
2. Backscattering of Beta particles
3. Measurement of short half-life
4. Linear Absorption Coefficient
5. Energy calibration of Gamma Ray Spectrometer (Study of linearity)
6. Energy Analysis of an Unknown Gamma Source
7. Study the activity of a given Gamma Source using relative method and absolute Method.
8. Study the mass absorption coefficient for 662 keV gamma rays in lead
9. To study the absorption of gamma-radiation by different media like Lead, Aluminium, and Plastic.
10. Stuy the photoelectric absorption of photons and verify the strong dependence of this process on the atomic number of the absorbing material.
11. LabView: reading and writing to text files.
12. LabView: Design a coincidence trigger using FPGA.
13. Comapre the energy resoltion of NaI and HPGe Detectors.
14. Bubble chamber photographs tracks

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Computational and Simulation

Course Code	PHY92MJ06504	**Credits**	4
L+T+P	3+1+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorial, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to introduce students to fundamental computational methods and techniques used in nuclear and high energy physics. The specific objectives of the course are as follows:

1. Familiarize students with fundamental computational methods and techniques commonly employed in scientific and engineering fields.
2. Equip students with programming skills necessary for implementing numerical algorithms and conducting simulations.
3. Introduce simulation techniques and tools relevant for modeling nuclear and particle physics phenomena.
4. Enhance students' problem-solving capabilities by employing computational and simulation approaches.
5. Provide an understanding of numerical analysis principles and their applications in solving mathematical and scientific problems.
6. Enable students to utilize computational tools to analyze complex systems, make predictions, and interpret results effectively.

Overall, this course aims to empower students with the knowledge and skills required to apply computational methods in various scientific and engineering contexts, particularly focusing on nuclear and particle physics simulations and analyses.

Course Learning Outcomes:

After completion of the course, students should be able to:

1. Apply fundamental computational techniques to solve mathematical and scientific problems.
2. Demonstrate proficiency in programming languages commonly used in computational applications.
3. Implement numerical algorithms to solve mathematical problems and simulate dynamic processes
4. Apply simulation techniques to solve physics particle physics.
5. Utilize computational tools and software effectively to conduct simulations and analyze data with precision.

Course Contents:

Unit-1

Differentiation: Numerical methods, forward difference and central difference methods, Lagrange's interpolation method. Integration: Newton-cotes expression for integral, trapezoidal rule, Simpsons's rule, Gauss quadrature method. Solution of differential equations: Taylor series method, Euler method, Runge Kutta method, predictor-corrector method. Roots of equations: Polynomial equations, graphical methods, bisectional method, Newton-Raphson method, false position method.

(25 % Weightage)

Unit-2

Solution of simultaneous equations: Elimination method for solving simultaneous linear equations, Gauss elimination method, pivotal condensation method, Gaussseidal iteration method, Gauss Jordan method, matrix inversion method. Eigen values and Eigen vectors of matrix: Determinant of a matrix, characteristic equation of a matrix, eigen values and eigen vectors of a matrix, power method.

(25 % Weightage)

Unit-3

Introduction to Programming: Overview of programming languages, Importance and applications of C/C++, Basics of programming logic and syntax, Introduction to C Programming: Characteristics and features of C, Data Types and Variables, Operators and Expressions, Control Flow Statements, Looping constructs, Functions and Scope, Scope rules and storage classes, Arrays and Strings, Pointers and Dynamic Memory Allocation, Structures and Unions, File Input/Output, Introduction to C++, Differences between C and C++, Object-Oriented Programming Concepts: Classes and objects, Encapsulation, inheritance, and polymorphism, Constructors and destructors, Function overloading and operator overloading, Advanced C++ Features:, Templates and generic programming, Exception handling, Standard Template Library (STL), Introduction to C++11/14/17.

(25 % Weightage)

Unit-4

Software for Data Analysis : Standard Analysis Packages, Cern Root, Basic idea of ROOT: Histogram, Graph, fitting to Pseudo Data, Math Libraries in ROOT, Linear Algebra in ROOT, Trees: Data Handling, Organization, Storage, Data Analysis Capabilities. GEANT4 Simualtion : Geant4 Scope of Application, Overview of Geant4 Functionality including tracking, geometry, physics models and hits. Examples: nuclear physics and medical physics.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Differentiation: Numerical methods, forward difference and central difference methods, Lagrange's interpolation method.
5-8	Integration: Newton – cotes expression for integral, trapezoidal rule, Simpsons's rule, Gauss quadrature method.
9-12	Solution of differential equations: Taylor series method, Euler method, Runge Kutta method, predictor-corrector method.
13-16	Roots of equations: Polynomial equations, graphical methods, bisectional method, Newton-Raphson method, false position method.
17-20	Solution of simultaneous equations: Elimination method for solving simultaneous linear equations, Gauss elimination method, pivotal condensation method,

21-24	Gaussseidal iteration method, Gauss Jordan method, matrix inversion method. Eigen values and Eigen vectors of matrix: Determinant of a matrix,
25-28	characteristic equation of a matrix, eigen values and eigen vectors of a matrix, power method.
28-31	Introduction to Programming: Overview of programming languages, Importance and applications of C/C++, Basics of programming logic and syntax,
31-36	Introduction to C Programming: Characteristics and features of C, Data Types and Variables, Operators and Expressions, Control Flow Statements, Looping constructs, Functions and Scope, Scope rules and storage classes, Arrays and Strings, Pointers and Dynamic Memory Allocation, Structures and Unions, File Input/Output,
36-44	Introduction to C++, Differences between C and C++, Object-Oriented Programming Concepts: Classes and objects, Encapsulation, inheritance, and polymorphism, Constructors and destructors, Function overloading and operator overloading, Advanced C++ Features:, Templates and generic programming, Exception handling, Standard Template Library (STL), Introduction to C++11/14/17.
45-52	Software for Data Analysis : Standard Analysis Packages, Cern Root, Basic idea of ROOT: Histogram, Graph, fitting to Pseudo Data, A Little C++, Math Libraries in ROOT, Linear Algebra in ROOT Trees:Data Handling, Organization, Storage, Data Analysis Capabilities.
53-60	GEANT4 Simualtion : Geant4 Scope of Application, Overview of Geant4 Functionality including tracking, geometry, physics models and hits. Examples: nuclear physics and medical physics.

Essential Readings:

1. *"Computational Physics"*, Rubin H Landau & Manuel Jose Paez Mejia, Wiley & Sons
2. *"Computer Applications in Physics"*, Suresh Chandra, Narosa Publishing House, New Delhi
3. *System Simulation with Digital Computer*, Narsingh Deo, PHI Learning

Additional/Advance/Further Readings:

1. *M Hijroth Jensen, Department of Physics*, University of Oslo, 2003 (Available in the Web)
2. *Programming in ANSI C*, E.Balgurusamy: Tata McGraw Hill
3. *Computer Oriented Numerical Methods*, VRajaraman, 3rd Ed. (Prentice-Hall, New Delhi, 1993).
4. *https://root.cern.ch/guides/users − guide*
5. *https://geant4.web.cern.ch/support/userdocumentation*

Course Title: Particle Accelerator Physics

Course Code	PHY92MJ06604	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	10	Contact Hours	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Concept and Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course is to introduce students to the physics and technology of charged particle accelerators. The objectives of the course are as follows:

1. To provide an overview of various types of accelerators and the principles governing particle transport.
2. To impart a fundamental understanding of accelerator physics, including the essential components and structures involved.
3. To familiarize students with the technological aspects of accelerators and beam instrumentation.
4. To introduce the theory of synchrotron radiation and its relevance in accelerator physics.
5. To acquaint students with the principles of linear beam optics, including beam focusing and manipulation.
6. To introduce the concepts of injection and extraction processes in particle accelerators.
7. To familiarize students with beam monitoring techniques and the key parameters used for monitoring beam characteristics.

Overall, this course aims to provide students with a comprehensive foundation in accelerator physics and technology, enabling them to understand the operation and design principles of charged particle accelerators.

Course Learning Outcomes:

Upon completion of the course, students will be able to:

1. Understand the fundamental operations of accelerators and identify their key components.
2. Describe various types of accelerators, including linear accelerators, cyclotrons, microtrons, betatrons, and synchrotrons.
3. Comprehend the basic principles and definitions of beam dynamics.
4. Understand the fundamental aspects of linear beam optics.
5. Describe the essential components of storage rings used in accelerators.

6. Grasp the basic concepts of injection and extraction processes in accelerators.
7. Understand the methodology for diagnosing beam characteristics.
8. Describe the RF systems used for particle acceleration in accelerators.
9. Explain the damping of synchrotron oscillations and its significance in accelerator physics

Course Contents:

Unit-1

Particle Accelerators: A Brief History, Introduction to accelerators : Direct-voltage accelerator, Cockroft-Walton Cascade generator, Marx generator, Van de Graaff accelerator, Linear accelerator, Cyclotron, Microton, Betatron, Synchrotron. Particle Production by colliding Beams.

(25 % Weightage)

Unit-2

Synchrotron Radiation: Radiation from relativistics particles, Angular distribution of synchrotron radiation, Time dependence and frequency spectrum of the radiation Storage rings for synchrotron radiation. Linear Beam optics: Charged particle motion in a magnetic field, Equation of motion in a co-moving coordinate system, Beam streeing magnets, Particle trajectories and transfer matrices, Beta function and betatron oscillation, Phase space ellipse and Liouville's Theorem.

(25 % Weightage)

Unit-3

Injection and Extraction: The process of inhection and extraction, Partilce Sourcces, Injection of high proton beams, Injection into an electron storge ring, Kicker and septum magnets, RF systems for particle accerleration: Waveguide and their properties, Resonant cavites, Accelerating structures for linacs, Klystrons as power generators for accelerators, Phase focusinhg and synchrotron frequency, Region of phase stability, RF-cavity accelerator.

(25 % Weightage)

Unit-4

Radiative effects: Damping of Synchrotron oscillations, Damping of betatron oscillations, Robinson theorem, beam emittance, Luminosity: Beam current restriction due to the space charge effect, Min-Beta principle, Stochastic cooling. Diagnostics : Fluorescent screen, Faraday Cup, Wall current monitor, current transformer, Derternmination of the beam lifetime in a storage ring, Measurement of the momentum and energy of a particle beam, Measurement of the optical parameter of the beam.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Introduction to accelerators: Direct-voltage accelerator, Cockroft-Walton Cascade generator, Marx generator,
5-8	Van de Graaff accelerator, Linear accelerator, Cyclotron
9-12	Microton, Betatron, Synchrotron. Particle Production by colliding Beams
13-16	Synchrotron Radiation: Radiation from relativistics particles, Angular distribution of synchrotron radiation
17-20	Time dependence and frequency spectrum of the radiation Storage rings for synchrotron radiation.

21-24	Linear Beam optics: Charged particle motion in a magnetic field, Equation of motion in a co-moving
25-28	coordinate system, Beam streeing magnets, Particle trajectories and transfer matrices,
28-32	Beta function and betatron oscillation, Phase space ellipse and Liouville's Theorem
32-36	Injection and Extraction: The process of inhection and extraction, Partilce Sourcces, Injection of high proton beams
36-40	Injection into an electron storge ring, Kicker and septum magnets
41-44	RF systems for particle accerleration: Waveguide and their properties, Resonant cavites, Accelerating structures for linacs
45-48	Klystrons as power generators for accelerators, Phase focusinhg and synchrotron frequency, Region of phase stability
49-52	Radiative effects: Damping of Synchrotron oscillations, Damping of betatron oscillations, Robinson theorem, beam emittance
53-56	Luminosity: Beam current restriction due to the space charge effect, Min-Beta principle
57-60	Diagnostics

Essential Readings:

1. *The Physics of Particle Accelerators*, Klaus Wille, European Scientfic Institute.
2. *Particle Accelerator Physics, Vol I and II*, H. Wiedmann, (Springer Verlag), 1998.
3. *Particle Accelerators*, M.S. Livingston and J.P. Blewel, (McGraw-Hill Book Press), 1962.
4. *An Introduction to the Physics of High Energy Accelerators*, D. A. Edwards and M. J. Syphers , WILEY-VCH Verlag GmbH & Co. KGaA

Additional/Advance/Further Readings:

1. *Nuclear Spectroscopy and Reactions Part-A*, Ed. J. Cerny, (Academic Press), 1974.
2. *Theory of Resonance Linear Accelerators*, I.M. Kapchenkey, (Harwood Academic Publishers).
3. *A Brief History and Review of Accelerators*, P.J. Bryant CERN, Geneva, Switzerland

Course Title: Physics of Magnetism and Spintronics

Course Code	PHY91DC06704	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	9	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to:

1. To know the basic science of magnetism and visualize the applications.
2. To understand the theory of magnetization dynamics and the necessity magnetic anisotropy.
3. To know MCE at the first order & second order phase transitions for refrigeration applications.
4. To know Physics of different kind of thin films/coating.

Course Learning Outcomes:

Upon completion of this course, the student should able to:

1. Explain the fundamentals of magnetism by molecular field theory and band theory.
2. Apply solid state physics to appreciate domain wall mechanism.
3. Analyze the magnetization dynamics through various characterization techniques.
4. Interpret the physical origin of magnetic anisotropy and its effects.
5. Evaluate the magnetostriction for various single and polycrystalline materials.
6. Recall the mechanism of Magnetocalorics and Magnetoelectronics.
7. Having a clear understanding of the subject related concepts and of contemporary issues.
8. Having critical thinking and innovative skills.

Course Contents:

Unit-1

Magnetism in metals: Free electron model, Pauli paramagnetic, Spontaneously spin-split bands, Landau levels, Landau diamagnetism, Magnetism of the electron gas, Excitations in the electron gas, Spin density waves, Kondo effect. Magnetic anisotropy: Shape anisotropy, Magneto-crystalline anisotropy and its origin, Induced anisotropy Competing interactions and low dimensionality: Magnetic frustration, Spin glasses, Superparamagnetic, One and two-dimensional magnets.

(25 % Weightage)

Unit-2

Introduction- overview of development of Spintronics and its future scope, Magnetic multilayers, Magnetic Anisotropy of thin films, Interlayer Exchange Coupling and Exchange Bias, Spin dependent transport - Anisotropic magnetoresistance, Giant Magneto Resistance (GMR) effect - Phenomenological theory, Microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-flip scattering Spin tunneling, Tunnel Magnetoresistance (TMR), Effects of Fermi surface, Effect of interfacial states, diffusive tunneling, Spin flip tunneling, Bias voltage dependence of TMR, Magnetic tunnel Junctions (MTJ), Tunnel Junctions with Half Metals.

(25 % Weightage)

Unit-3

Introduction to thin films, Technology as a drive and vice versa, Basics of vacuum science and technology, Vacuum pumps and gauges. Physical vapor deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys, Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity.

(25 % Weightage)

Unit-4

Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGAs and GSMBE), Role of Kinetics of Adsorption and Desorption, Surface reconstruction, In-situ film characterization of MBE films by LEED and RHEED, & RHEED Oscillations, Pulsed Laser deposition (PLD process steps, congruent evaporation, advantages and disadvantages of PLD). CVD advantages, CVD Reaction types, Thermodynamics of CVD, Gas Transport, Viscous flow, Close-Spaced Vapor Transport (CSVT), Convection, Film Growth Kinetics, Axial and radial film thickness uniformity, Classification of CVD systems, APCVD, LPCVD & MOCVD and Examples of CVD growth.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Free electron model, Pauli paramagnetic, Spontaneously spin-split bands
5-8	Landau levels, Landau diamagnetism, Magnetism of the electron gas, Excitations in the electron gas. ,
9-12	Spin density waves, Kondo effect. Magnetic anisotropy: Shape anisotropy, Magneto-crystalline anisotropy and its origin.
13-16	Induced anisotropy Competing interactions and low dimensionality: Magnetic frustration, Spin glasses, Superparamagnetic, One and twodimensional magnets.
17-20	Introduction- overview of development of Spintronics and its future scope, Magnetic multilayers, Magnetic Anisotropy of thin films

21-24	Interlayer Exchange Coupling and Exchange Bias, Spin dependent transport - Anisotropic magneto-resistance, Giant Magneto Resistance (GMR) effect - Phenomenological theory.
25-28	Microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-flip scattering Spin tunneling, Tunnel Magnetoresistance (TMR), Effects of Fermi surface, Effect of interfacial states, diffusive tunnelling.
28-32	Spin flip tunneling, Bias voltage dependence of TMR, Magnetic tunnel Junctions (MTJ), Tunnel Junctions with Half Metal
33-36	Introduction to thin films, Technology as a drive and vice versa, Basics of vacuum science and technology, Vacuum pumps and gauges.
37-40	Physical vapor deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys.
41-44	Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity
45-48	Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGAs and GSMBE), Role of Kinetics of Adsorption and Desorption
49-52	Surface reconstruction, In-situ film characterization of MBE films by LEED and RHEED, & RHEED Oscillations, Pulsed Laser deposition (PLD process steps, congruent evaporation,
53-56	Advantages and disadvantages of PLD). CVD advantages, CVD Reaction types, Thermodynamics of CVD, Gas Transport, Viscous flow, Close-Spaced Vapor Transport (CSVT), Convection,
57-60	Film Growth Kinetics, Axial and radial film thickness uniformity, Classification of CVD systems, APCVD, LPCVD & MOCVD and Examples of CVD growth.

Essential Readings:

1. *Magnetism in Condensed Matter*, 1st edition, Oxford University Press, 2001-S. Blundell.
2. *Modern Magnetic Materials*, John Wiley & Sons, Inc., 2000-R. C. O' Handley.
3. *Nanomagnetism and Spintronics*, 1st edition, Elsevier, 2009-3. T. Shinjo (Ed.).
4. *Handbook of Spin Transport and Magnetism*, CRC Press, 2012-4. E. Y. Tsymbal and I Zutic.

Additional/Advance/Further Readings:

1. *Materials Science of Thin Films Deposition and Structure-Milton Ohring.*
2. *Thin Film Solar Cells*-Chopra and Da.

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Course Title: Fundamentals of Scanning Probe Microscopy

Course Code	PHY91DC06804	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	9	**Contact Hours**	60(L) Hours

Course Type	Discipline Based core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

Following are the main objectives of this course:

1. to present a unified discussion of the fundamentals of atomic force microscopy and scanning tunneling microscopy
2. To acquaint the students with the instrumental aspects and basics like the tip-sample interaction, contact mechanics etc.
3. To introduce several specialized techniques based on atomic force microscopy and scanning tunneling microscopy

Course Learning Outcomes:

Upon completion of this course, the student should:

1. understand the basic aspects of tip-surface interactions in contact and non-contact regime.
2. be able to describe the basic components necessary to build a basic AFM instrument and carry out contact mode imaging.
3. understand the interactions of an oscillating probe with the surface as in dynamic AFM.
4. comprehend the methodology of using dynamic AFM for measuring electric and magnetic forces on the surface and in liquid medium.
5. understand the basic concepts of quantum tunneling and its application in imaging and manipulation at the surface with atomic resolution.

Course Contents:

Unit-1: Tip-Surface Interaction

Non-contact regime Intra-molecular Interactions, Electric Dipoles, Inter-molecular interactions: Physical models, ion-dipoles, Keesom forces, Dispersion Force, Contact regime Hamaker theory, surface energies, Dejaugin approximation, contact mechanics, Hertz model, JKR model, DMT model

(20 % Weightage)

Unit-2: Atomic Force Microscope (AFM)

AFM components, AFM calibration, Contact Mode Scans Force Spectroscopy Cantilever mechanics, Approach-retract curves, Processing Force curves, Modulus and adhesion Maps, Lateral Force Microscopy Conducting Atomic Force Microscopy, Nano-indentation

(20 % Weightage)

Unit-3: Dynamic AFM methods

Point Mass Model of Dynamic AFM, frequency response, conservative and dissipative interaction forces, interacting with the surface Analytical theory of Dynamic AFM : Excited probe interacting with sample (linear theory), Amplitude and Frequency modulation AFM, Non-linear/dissipative interactions, Attractive and Repulsive Regimes and Phase Contrast Modualtion AFM, Reconstructing Surface Forces: Relationship between Frequency shift and Potential Energy, reconstruction of interaction force from frequency shift in FM-AFM, Experimental details of FM-AFM measurements

(20 % Weightage)

Unit-4: Dynamic AFM for Electrostatics/Magnetic/Biology

Measuring Electrostatic Forces, Measuring Magnetic Forces, Dynamic AFM in Liquids Specialized dynamic-AFM based techniques for physical property measurements: Piezo-response force microscopy, Scanning non-linear dielectric microscopy, Magnetic exchange force microscopy

(20 % Weightage)

Unit-5: Scanning Tunneling Microscopy

Quantum tunneling, WKB approximation for field emission, STM instruments and its components, Scanning tunneling spectroscopy, Inelastic electron tunneling spectroscopy, Atomic/molecular manipulations, spin-polarized STM, radio-frequency STM

(20 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Tip-sample interactions in non-contact regime
7-12	Tip-sample interactions in contact regime
13-16	AFM components, AFM calibration, Contact Mode Scans
17-20	Force Spectroscopy, Cantilever mechanics, Approach-retract curves, Processing Force curves, Modulus and adhesion Maps, Lateral Force Microscopy
21-24	Conducting atomic force microscopy, Nano-indentation
25-28	Point Mass Model of Dynamic AFM, frequency response, conservative and dissipative interaction forces, interacting with the surface
29-32	Analytical theory of Dynamic AFM : Excited probe interacting with sample (linear theory), Amplitude and Frequency modulation AFM, Non-linear/dissipative interactions, Attractive and Repulsive Regimes and Phase Contrast Modualtion AFM
33-36	Relationship between Frequency shift and Potential Energy, reconstruction of interaction force from frequency shift in FM-AFM, Experimental details of FM-AFM measurements
37-38	Measuring Electrostatic Forces
39-40	Measuring Magnetic Forces
41-42	Dynamic AFM in Liquids

43-48	Special AFM techniques: Piezo response force microscopy (PFM), Scanning non-linear dielectric microscopy (SNDM), Magnetic exchange force microscopy
49-60	Scanning Tunneling Microscoopy, STM instruments and its components, Scanning tunneling spectroscopy, Inelastic electron tunneling spectroscopy, Atomic/molecular manipulations, spin-polarized STM, radio-frequency STM

Essential Readings:

1. *Scanning Probe Microscopy and Spectroscopy: Methods and Applications*, R. Wiesendanger Cambridge University Press, 1994.

2. *Intermolecular and Surface Forces*, J.N.Israelachvili, Third Edition, Elsevier

Additional/Advance/Further Readings:

1. *Fundamentals of Scanning Probe Microscopy*, V. L. Mironov, The Russian Academy of Sciences, Institute for Physics of Microstructures, 2004

2. *Scanning Probe Microscopy: Electrical and Electromechanical Phenomena at the Nanoscale*, Sergei V. Kalinin, Alex Gruverman, Springer-Verlag New York, 2007.

3. *Springer Handbook of Nanotechnology*, Ed. Bharat Bhushan, Springer-Verlag Berlin Heidelberg, 2010

Note: Latest edition of text books may be used

Course Title: Nanoscience and Nanotechnology

Course Code	PHY92DC06904	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Group discussion, Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are

1. To provide broad knowledge of Nanostructures.
2. To acquaint students about the important Carbon based Nanostructures and Their Applications
3. To acquaint students about the important nanoparticles different nanostructures and their applications
4. To facilitate the understanding of synthesis of Carbon based Nanostructures.
5. To generate the skill for synthesis of nanoparticles.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. have knowledge about the basic concept of nanomaterterials
2. impart the importance of overall design of carbon based nanomaterials.
3. understand advanced nanostructres
4. attain sound knowledge on microstructures, properties, and applications of different nanostructures.
5. design different carbon based nanostructures.
6. develop new materials and which can be useful in new technologies.

Course Contents:

Unit-1

Introduction to nanomaterials Size Dependent properties. Bulk to Nano Transitions. Method of Synthesis: Thermal and ultrasound decomposition methods. Reduction methods.Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nano-particles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapour deposition. Molecular beamepitaxy. Thermal spraying. Electro and electroless deposition. Brief description of OD,1D,2D nanomaterials e.g. Quantum wells, wires and dots. Size and dimensionality effects.Excitons.Single electron tunneling. Applications in infrared detectors and quantum dot lasers. Magnetic properties of nanocrystalline materials. Nanostructured ferroelectric materials and their properties.

(35 % Weightage)

Unit-2

Carbon Nanostructures: Nature of Carbon Clusters, Discovery of ^{60}C, Structure of C60 and its Crystal, Superconductivity in ^{60}C, Carbon Nanotubes: Synthesis, Structure, Electrical and Mechanical Properties. Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes. Inorganic nanotubes and nanorods, nanoporous materials.

(35 % Weightage)

Unit-3

Optical properties: Optical properties and radiative processes: General formulation absorption, emission and luminescence; Optical properties of heterostructures and nanostructures. Carrier transport in nanostructures: Coulomb blockade effect, scattering and tunneling of 1D particle; applications of tunneling, single electron transistors. Defects and impurities: Deep level and surface defects.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Introduction to nanomaterials Size Dependent properties. Bulk to Nano Transitions.
6-15	Method of Synthesis: Thermal and ultrasound decomposition methods. Reduction methods. Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nanoparticles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapour deposition. Molecular beamepitaxy. Thermal spraying. Electro and electroless deposition.
15-35	Brief description of OD,1D,2D nanomaterials e.g. Quantum wells, wires and dots. Size and dimensionality effects. Excitons. Single electrontunneling. Applications in infrared detectors and quantum dot lasers. Magnetic properties of nanocrystalline materials. Nanostructured ferroelectric materials and their properties.
36-45	Carbon Nanostructures: Nature of Carbon Clusters, Discovery of ^{60}C, Structure of ^{60}C and its Crystal, Superconductivity in ^{60}C, Carbon Nanotubes Synthesis, Structure, Electrical and Mechanical, Properties; Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes, Properties;
45-50	Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes,Inorganic nanotubes and nanorods, nanoporous materials.:
50-54	Optical properties and radiative processes: General formulation absorption, emission and luminescence; Optical properties of heterostructures and nanostructures.
55-60	Carrier transport in nanostructures: Coulomb blockade effect, scattering and tunneling of 1D particle; applications of tunneling, single electron transistors. Defects and impurities: Deep level and surface defects.

Essential Readings:

1. *Introduction to Nanotechnology* Poole and Owners
2. *Nano Essentials* T. Pradeep
3. *Handbook of Nanostructured Materials and Nanotechnology* Nalva
4. *Nano Technology/ Principles and Practices* S.K. Kulkarni

Additional/Advance/Further Readings:

1. *Quantum Dots* Jacak, Hawrylak and Wojs
2. *Carbon Nanotubes* Silvana Fiorito
3. *Nanotechlongy* Richard Booker and Earl Boysen

Note: Latest edition of text books may be used

Course Title: Renewable Energy: Solar and Hydrogen

Course Code	PHY92DC07004	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are:

1. Understand the various forms of conventional energy resources.
2. Learn the present energy scenario and the need for energy conservation
3. Explain the concept of various forms of renewable energy
4. Outline division aspects and utilization of renewable energy sources for both domestics and industrial application.
5. Analyze the environmental aspects of renewable energy resources.

Course Learning Outcomes:

Upon completion of this course, the student should able to:

1. Describe the environmental aspects of non-conventional energy resources.
2. Know the need of renewable energy resources, historical and latest developments. Describe the use of solar energy.
3. Understand the concept of Hydrogen energy and economy.
4. Acquire the knowledge of fuel cells, wave power, tidal power and geothermal principles and applications.

Course Contents:

Unit-1

Solar Energy: Fundamental and Material Aspects: Fundamentals of photovoltaic Energy Conversion Physics and Material Properties, Basic to Photovoltaic Energy Conversion: Optical properties of Solids. Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.

(25 % Weightage)

Unit-2

Solar Energy: Different Types of Solar Cells: Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current, Brief description of single crystal silicon and organic and Polymer Solar Cells, Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor, Principles of Photoelectrochemical Solar Cells.

(25 % Weightage)

Unit-3

Hydrogen Energy: Fundamentals, Production and Storage: Relevance in relation to depletion of fossil fuels and environmental considerations. Solar Hydrogen through Photoelectrolysis, Physics of material characteristics for production of Solar Hydrogen. Brief discussion of various storage processes, special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials. New Storage Modes.

(25 % Weightage)

Unit-4

Hydrogen Energy: Safety and Utilization: Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular transport, Hydrogen for Electricity Generation, Fuel Cells, Various type of Fuel Cells, Applications of Fuel Cell, Elementary concepts of other Hydrogen- Based devices such as Hydride Batteries.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Fundamentals of photovoltaic Energy Conversion Physics and Material Properties,
6-10	Basic to Photovoltaic Energy Conversion: Optical properties of Solids
11-15	Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.
16-20	Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current,
20-22	Description of single crystal silicon and organic and Polymer Solar Cells,
23-26	Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor,
27-30	Principles of Photoelectrochemical Solar Cells.
31-35	Relevance in relation to depletion of fossil fuels and environmental considerations. Solar Hydrogen through Photoelectrolysis,
36-40	Physics of material characteristics for production of Solar Hydrogen. Brief discussion of various storage processes,
41-45	special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials. New Storage Modes.
46-50	Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular transport, Hydrogen for Electricity Generation, Fuel Cells,
50-55	Various type of Fuel Cells, Applications of Fuel Cell,
56-60	Elementary concepts of other Hydrogen- Based devices such as Hybrid Batteries.

Essential Readings:

1. *Solar Cell Devices-Physics* :Fonash
2. *Fundamentals of Solar Cells Photovoltaic Solar Energy* :Fahrenbruch& Bube
3. *Phoptoelectrochemical Solar Cells*: Chandra
4. *Hydrogen as an Energy Carrier Technologies Systems Economy* : Winter & Nitch (Eds.)

Additional/Advance/Further Readings:

1. *Hydrogen as a Future Engery Carrier* : Andreas Zuttel, Andreas Borgschulte and Louis Schlapbach
2. *Hydrogen Storage Technologies Mehmet Sankir*, Nurdan Demirci Sankir John Wiley and Sons

Note: Latest edition of text books may be used

Course Title: Nanoelectronics

Course Code	PHY92DC07104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

Following are the main objectives of this course:

1. To acquaint the students about the miniaturization driven progress in electronics
2. To acquaint the students with the failure of classical models to describe behavior of devices at nanometer length scale.
3. To introduce a theory of current, voltage, and resistance from atoms up.
4. To familiarize the student with the electronic properties of molecules, carbon nanotubes, crystals.
5. To acquaint the students with the theory of energy band formation and the origin of metals, insulators, and semiconductors.
6. To acquaint the students with a theory of electron conduction beginning with ballistic transport and concluding with a derivation of Ohm's law.
7. To acquaint the students about how to go from ballistic to bulk MOSFET devices.
8. To orient the student with the basics of nano-fabrication techniques.

Course Learning Outcomes:

Upon completion of this course, the student should:

1. To describe the Moore's law
2. To describe the impact of nanotechnology
3. To describe the experimental observables in a mesoscopic system.
4. To describe the basics properties of new types of molecular materials used in devices.
5. To calculate the density of states of model 0D, 1D, 2D and 3D materials.
6. To describe the basic concepts of HOMO and LUMO
7. To calculate the conductance in a two terminal quantum device.
8. To calculate the conductance in ballistic FETs.
9. To describe the basic nanofabrication techniques.

Course Contents:

Unit-1

Introduction to Nanoelectronics, Device scaling, Moore's law, limitations, role of quantum mechanics, Nanostructures: Impact, technology and physical consideration; Mesoscopic observables: Ballistic transport, phase interference, universal conductance fluctuations, weak localization; Carrier heating. Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers (Polyacetylene, P3HT, PEDOT:PSS etc.).

(25 % Weightage)

Unit-2

Preliminaries : Basic Quantum mechanics and Fermi statistics, Metals, Insulators and Semiconductor, Density of states (DOS) in 0D, 1 D, 2D and 3D, DOS in disordered materials, Physics of organic semiconductors: concept of HOMO and LUMO, band gap.

(25 % Weightage)

Unit-3

Two terminal quantum dot and quantum wire devices: Equilibrium in two terminal devices, Current flow in the presence of a bias, numerical technique for self-consistent estimation of V-I , Current flow, quantum of conductance, Landauer theory; Field Effect Transistors (FETs): Ballistic quantum wire FETs, conventional MOSFETs, CMOS, short channel and narrow width, hot electron effect, punch-through and thin gate oxide breakdown, OFET; Spintronics: Spin, propagation, detection, spinFETs. (25 % Weightage)

Unit-4

Nano-fabrication techniques: Top-down and bottom-up strategies, advantages/disadvantages/ limitations, e-beam lithography, Focussed Ion beam milling, self-organized structures, laser nanopatterning, nano-imprint, electrochemical synthesis, Fabrication of organic electronic devices (OEDs) etc.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Introduction to Nanoelectronics, Device scaling, Moore's law, limitations, role of quantum mechanics
5-6	Nanostructures: Impact, technology and physical consideration;
7-13	Mesoscopic observables: Ballistic transport, phase interference, universal conductance fluctuations, weak localization; Carrier heating.
14-15	Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers (Polyacetylene, P3HT, PEDOT:PSS etc.)
16-19	Preliminaries : Basic Quantum mechanics and Fermi statistics, Metals, Insulators and Semiconductor
20-26	Density of states (DOS) in 0D, 1 D, 2D and 3D, DOS in disordered materials
27-30	Physics of organic semiconductors: concept of HOMO and LUMO, band gap
31-35	Two terminal quantum dot and quantum wire devices: Equilibrium in two terminal devices, Current flow in the presence of a bias, numerical technique for self-consistent estimation of V-I
36-38	Current flow, quantum of conductance, Landauer theory;
39-43	Field Effect Transistors (FETs): Ballistic quantum wire FETs, conventional MOSFETs, CMOS, short channel and narrow width, hot electron effect, punch-through and thin gate oxide breakdown, OFET;

44-45	Spintronics: Spin, propagation, detection, spinFETs.
46-49	Nano-fabrication techniques: Top-down and bottom-up strategies, advantages/disadvantages/ limitations
50-60	e-beam lithography, Focussed ion beam milling, laser nanopattering, nano-imprint, electrochemical synthesis, self-organized nanostructures.

Essential Readings:

1. *Quantum Transport: Atom to Transistor; First Edition*, S. Datta, Cambridge University Press (2005).
2. *Molecular Quantum Mechanics*, P.W. Atkins, R.S. Friedman, Oxford University Press, 3rd edition (1997).
3. *Nanoscale Transistors; Physics, Modeling, and Simulation, First Edition*, M. Lundstrom and J. Guo, Springer (2006).
4. *Nanofabrication: Techniques and Principles*, M. Stepanova and S. Dew, Springer-Verlag (2012).

Additional/Advance/Further Readings:

1. *Introduction to Nanoelectronics*, M. Baldo (Lecture Notes; May 2011 MIT)
2. *Electronic Transport in Mesocopic Systems*, S. Datta, Cambridge University Press (1995).
3. *Transport in Nanostructures*, David Ferry, Cambridge University Press (1995)

Course Title: Low Temperature Physics

Course Code	PHY92DC07204	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	10	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

1. To understand that physical phenomena are often studied at low temperature, particularly within condensed matter physics.
2. To understand properties of superfluid helium and Bose-Einstein condensates, i.e. of macroscopic quantum fluids.
3. To gain knowledge of different cooling methods, thermal properties of materials, thermometry, etc.
4. The course is suitable for those that want to do research in Physics.

Course Learning Outcomes:

Upon completion of this course, the student should able to:

1. Describe the phase diagrams for both helium-3 and helium-4.
2. Describe how Bose-Einstein condensation comes about.
3. Describe superfluid phenomena such as, rollin film, the fountain effect and second sound.
4. Describe different cooling methods which are used both above and below 1 Kelvin.
5. Explain physical properties of different materials at low temperature.

Course Contents:

Unit-1

Production of Low Temperature: Introduction - Joule Thomson effect - Regenerative cooling - Vacuum pumps - liquefaction of air - Hydrogen - Helium - Maintenance of low temperature - production of temperature below 1 K - Adiabatic demagnetization - Evaporative cooling of He-3 - Dilution refrigeration - Laser cooling - Nuclear demagnetization.

(20 % Weightage)

Unit-2

Measurement of Low Temperatures : The gas thermometer and it corrections - Secondary thermometers - resistance thermometers, thermocouples - vapour pressure thermometers - magnetic thermometers. (20 % Weightage)

Unit-3

Cryogenic Liquids and Solids: Liquid Nitrogen - Liquid oxygen - Liquid hydrogen - Liquid He-4 and He-3, Solid He - 4 and He-3 - Lamda point - Superfluidity - Density - Compressibility factor - viscosity and thermal properties - Velocity of sound in liquid helium.

(20 % Weightage)

Unit-4

Electrical and Magnetic Properties: Experimental Observations - Theories of sommerfield and block - Superconductivity - magnetic properties of superconductors - Thermal properties of superconductors - penetration depth and high frequency resistance - Ferromagnetism - Diamagnetism - paramagnetism - Paramagnetic saturation.

(20 % Weightage)

Unit-5

Specific Heats, Spectroscopic, and Hyperfine Properties: Specific heats - Rotational specific heat of Hydrogen - Einstein's and Debye's theories Schottky effect - Anomalies in specific heats at low temperature - Infrared - visible spectra - Zeeman spectra at low temperature - Dielectric constant and its measurement - Magnetic susceptibility - NMR and electron paramagnetic resonance at low temperature - Nuclear magnetic properties - Mossbauer effect and other hyperfine properties at low temperature, bolometer.

(20 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Introduction - Joule Thomson effect - Regenerative cooling - Vacuum pumps - liquefaction of air- Hydrogen - Helium
7-12	Maintenance of low temperature -production of temperature below 1 K -Adiabatic demagnetization - Evaporative cooling of He-3 - Dilution refrigeration- Laser cooling- Nuclear demagnetization
13-18	The gas thermometer and it corrections - Secondary thermometers
19-24	resistance thermometers, thermocouples- vapour pressure thermometers- magnetic thermometers
25-30	Liquid Nitrogen - Liquid oxygen - Liquid hydrogen - Liquid He -4 and He -3 - Solid He– 4 and He -3 - Lamda point
31-36	Superfluidity - Density - Compressibility factor - viscosity and thermal properties - Velocity of sound in liquid helium
37-40	Experimental observations - Theories of sommerfield and block
41-44	Superconductivity - magnetic properties of superconductors - Thermal properties of superconductors - penetration depth and high frequency resistance
45-48	Ferromagnetism - Diamagnetism - paramagnetism – Paramagnetic saturation
49-52	Specific heats - Rotational specific heat of Hydrogen - Einstein's and Debye's theories Schottky effect - Anomalies in specific heats at low temperature - Infrared- visible spectra -

53-56	Zeeman spectra at low temperature - Dielectric constant and its measurement – Magnetic susceptibility - NMR and electron paramagnetic resonance at low temperature
57-60	Nuclear magnetic properties - Mossbauer effect and other hyperfine properties at low temperature

Essential Readings:

1. *Progress in Low Temperature Physics*, Cornelis Jacobus Gorter, D. F. Brewer, Elsevier Ltd, 2011.
2. *Low Temperature Physics*, Christian E. and Siegfried H,Springer, 2005.

Additional/Advance/Further Readings:

1. *Experimental Techniques for Low-Temperature Measurements*, Jack Ekin, OUP Oxford, 2006.
2. *Superconductivity*, Charles P. Poole Jr., Horacio A. Farach, Richard J. Creswick and RuslanProzorov Elsevier Ltd, 2007.
3. *Properties of Liquid and Solid Helium*, John Wilks, Oxford University Press, 1967.
4. *Low Temperature Physics*, Jackson L.C., Methuen and Company,1962.
5. *High Pressure and Low Temperature Physics*, Ching Wu Chu and J.Woollam, Plenum Press, 1978.

Note: Latest edition of text books may be used