Program Elective Courses for M.Sc. Physics

5. Program Elective Courses

S. No.	Course code	Course Title	Course Coordinator
1.	21PHT801	Advanced Quantum Mechanics	Dr. K Venkataratnam Kamma
2.	21PHT802	Advanced Techniques for Materials Characterization	Dr. Manoj Kumar
3.	24PHT807	Basic LabVIEW Programming	Dr. Anirban Dutta
4.	24PHT803	Basics of Astronomy & Astrophysics	Dr. Subhayan Mandal
5.	21PHT809	Introduction To Quantum Field Theory	Dr. Anees Ahmed
6.	24PHT805	Machine Learning in Physics	Dr. Kavita Lalwani
7.	24PHT808	Membrane Technology for Energy Applications	Dr. Kamakshi Pandey
8.	26PHTXXX	Monte Carlo Simulations using Geant4	Dr. Kavita Lalwani
9.	21PHT812	Nanostructured Materials and Applications	Dr. Srinivasa Rao Nelamarri
10.	21PHT814	Numerical Methods and Computer Programming	Dr. Rahul Singhal
11.	21PHT817	Semiconductor Physics and Devices	Prof. Kanupriya Sachdev
12.	24PHT806	Soft Materials	Dr. Kamlendra Awasthi
13.	21PHT819	Solar Energy and Applications	Dr. Debasish Sarkar
14.	21PHT821	Surface Physics	Dr. Rajnish Dhiman
15.	24PHT802	Energy Materials and Devices	Dr. Debasish Sarkar
16.	21PHT806	General Theory of Relativity	Dr. Akhilesh Nautiyal
17.	21PHT716	Materials Science and Engineering	Dr. Rahul Singhal
18.	21PHT813	Nanotechnology for Energy Applications	Dr. Kamlendra Awasthi
19.	21PHT816	Plasma Physics	Dr. Subhayan Mandal
20.	26PHTXXX	Quantum Computing using Quantum Physics	Dr. Kavita Lalwani
21.	26PHTXXX	Quantum Materials and Applications	Dr. Manoj Kumar
22.	24PHT801	Spintronics for Quantum Technology	Dr. Manoj Kumar
23.	26PHTXXX	Statistical Data Analysis in Physics	Dr. Kavita Lalwani
24.	26PHTXXX	Electrochemical Energy Storage	Dr. Rajnish Dhiman
25.	26PHPXXX	Applied Physics Lab	Dr. Manoj Kumar

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DEPARTMENT OF PHYSICS

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DETAILS OF THE COURSE

Course code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT801	Advanced Quantum Mechanics	3	3	0	0	0

PREREQUISITE: None

COURSE OBJECTIVE(s)
This is an advanced level course in Quantum mechanics which objects to teach about various approximation methods in physics to calculate the approximate values of energy for various systems. Students will be able to learn the methods to find transition probability for absorption and emission. The objective is to give them ideas about laboratory and center of mass frame and study the scattering phenomena in both these frames. This course will let students appreciate the beauty of quantum mechanics in the form of the Born approximation and its validity. Students will be able to study the wave functions of system of identical particles.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Time dependent perturbation theory, first order perturbative expression for the transition amplitude and probability, harmonic perturbations, transition probability under constant perturbation, Fermi's golden rule.

(No. of lectures: 06)

Interaction of radiation with matter, spontaneous emission, absorption, induced emission, dipole transitions, selection rules, identical particles, Pauli exclusion principle.

(No. of lectures: 10)

Non-relativistic scattering, solution of scattering problem by the method of Green's function, Born approximation and its validity for scattering problems, partial wave analysis, optical theorem.

(No. of lectures: 10)

Introduction to relativistic wave equations, Klein-Gordon equation, plane wave solution of Klein-Gordon equation, Dirac equation for a free particle, Dirac matrices, Dirac spinors, covariant form of Dirac equation, plane wave solutions of Dirac equation: energy spectrum, negative energy states, spin of the Dirac particle, Dirac, Weyl and Majorana equation.

(No. of lectures: 13)

TEXT BOOKS/ REFERENCE BOOKS: -

1. L. I. Schiff, Quantum Mechanics, 3rd edition, (McGraw Hill Book Co., New York 1968).
2. E. Merzbacher, Quantum Mechanics, 3rd edition, (John Wiley & Sons, Inc1997)
3. Quantum Mechanics, Nouredine Zettili, Wiley
4. A. Ghatak & S. Lokanathan, Quantum Mechanics: Theory and Applications, 5^{th} Edition, (Macmillan India, 2004)
5. Quantum Mechanics A Modern Approach: A. Das and A. C. Milissiones (CRC Press).
6. Quantum Mechanics: E. Merzbacher (Wiley).
7. Advanced Quantum Mechanics: J.J. Sakurai (Addison Wesley Publishing Co.)
8. Principles of Quantum Mechanics: R. Shankar.
9. Introduction to Quantum Mechanics: David J. Griffiths (Pearson Education).
10. Quantum Mechanics by Mathews and Venkatesan (McGraw Hill)

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT802	Advanced Techniques for Materials Characterization	3	3	0	0	0

PREREQUISITE - None

COURSE OBJECTIVE(s)
Impart fundamentals knowledge to masters' students in the field of Materials characterization using different techniques. Describe (phenomenologically) the principal phenomena behind different characterization techniques. Developing capability to use fundamental knowledge in application, and to solve problems independently based on these concepts.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Introduction to surfaces, interfaces and bulk of solid materials, classification, distinction and overview of surface and bulk characterization techniques. Techniques for atomic structure and surface morphology determination: working principle and data analysis for X-ray Diffraction (XRD), high-resolution transmission electron microscopy (HRTEM), low energy electron diffraction and microscope (LEED and LEEM), scanning tunneling microscopy (STM) and atomic force microscopy (AFM).

(No. of lectures: 16)

Techniques for compositional analysis: working principle and data analysis for the techniques- electron probe micro analysis (EPMA) and energy dispersive analysis (EDAX), X-ray fluorescence (XRF) and X-ray photoelectron spectroscopy (XPS).

(No. of lectures: 10)

Thermal analysis and other techniques: working principle and data analysis for the techniques-differential scanning calorimetry (DSC), differential thermal analysis (DTA) and thermo-gravimetric analysis (TGA).

(No. of lectures: 07)

Mini Project: Processing and analysis of selected characterization techniques data using Softwares.

(No. of lectures: 06)

Recommended Readings

Text books –

1. Surface Analysis Methods in Materials Science: D. J. O. Conner (Springer Verlag).
2. Surface and Interfaces of Solids: H. Lueth (Springer).
3. Advanced Techniques for Materials Characterization: A. K. Tyagi, M. Roy, S. K. Kulshrestha, S. Banerjee (Materials Science Foundations-Trans Tech Publications).

Reference books –

1. Vacuum Science and Technology: V. V. Rao, T. B. Ghosh, K. L. Chopra (Allied Publishers).
2. Instrumental Methods of Chemical Analyses: G.W. Ewing (McGraw Hill).
3. Characterization of Solid Surface: P.F. Kane (Plenum).

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
24PHT807	Basic LabVIEW Programming	3	3	0	0	0

COURSE OUTCOME (s)

After completing this course, students should be able to write LabVIEW code to simulate or analyse their own data. Students should be able to interface with various lab instruments to acquire data. In addition, they will be able to design/write LabVIEW code to experiment according to their requirements. It will definitely reduce dependence on commercially available software, because these software products often do not provide data acquisition options that meet researchers' requirements.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Module 1

Basic of programming language, Programming in LabVIEW Environment, Front Panel and Block Diagram, Types of Data in LabView, Controls, Indicators and Function Palettes, Wiring and Debugging the Problems to run a Programme.

(No. of lectures: 13)

Module 2
Algorithm, Structures and Loop: For Loop, While Loop, Timed Structures, Case Structures, Event Structures, Math Script and Sequence.

(No. of lectures: 07)

Module 3
Arrays: Introduction and Elements, Creating Arrays and Programming using Arrays; Clusters, Conversion of Arrays to Cluster and matrix, Conversion of Clusters and Matrix to Arrays; Strings: Properties and Creation of Strings; LabVIEW programming using Charts and Graphs. Example of inbuild Programmes.

(No. of lectures: 12)

Module 4
Simulate Signals and Analyse the input Signals, File Handling using LabVIEW Environment, Connecting Instrument with LabVIEW and Data Acquisition, Hands-on Practice: Interfacing and Data Acquisition from Various Lab Instruments

(No. of lectures: 07)

TEXT BOOKS :

1. Virtual instrumentation using LabVIEW: Sanjay Gupta, Joseph John (Tata McGraw-Hill)
2. LabVIEW for Everyone: Graphical Programming Made Easy and Fun: Jeffrey Travis, Jim Kring (Prentice Hall).
3. LabVIEW based Advanced Instrumentation Systems: LabVIEW based Advanced Instrumentation Systems: S. Sumathi and P. Surekha (Springer).
4. Analog Electronics with LabVIEW: Kenneth L. Ashley (Prentice Hall).

REFERENCE BOOKS:

1. LabVIEW User Manual, National Instruments (NI)

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DETAILS OF THE COURSE

Course code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
24PHT803	**Basics of Astronomy & Astrophysics**	**3**	**3**	**0**	**0**	**0**

PREREQUISITES: Thermodynamics, Classical Mechanics & Quantum Mechanics.

COURSE OBJECTIVES:

1. To impart fundamentals and application based knowledge education to Masters' students of Physics, primarily in areas: Astronomy & Astrophysics.
2. To enable students to solve problems independently based on these concepts.
3. To equip students with the basics of the field so that they may pursue it as a career.
4. To have periodic evaluation of students through class work sessionals / mid-term and end term examinations.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Astronomy - Coordinate Systems for Celestial Objects & Their Interrelations, Cardinal Points In The Sky, Time Measurements in Astronomy, Proper & Peculiar Motion of Stars, Astronomical Observations and Instruments, Parallaxes, Photometry, Magnitude System, Distance Modulus, Color Indices;

(No. of lectures: 13)

Astrophysics-I - Stellar spectra and Structure, Ionization Equation & Elemental Abundances, H-R Diagram, Stellar Evolution, Nucleosynthesis and Formation of Elements, Variable stars, Compact stars, Star clusters and Binary stars;

(No. of lectures: 13)

Astrophysics-II - Galaxies & their Evolution and Origin, Milky Way & Spiral arm, Hubble Classification of Galaxies: elliptical, spiral & irregular, Galaxy Distance & Cosmic Ladder, Active Galaxies and Quasars, Starburst galaxies, Dark matter: Galaxy mass , Galaxy Clusters & Superclusters.

(No. of lectures: 13)

TEXT BOOKS/ REFERENCE BOOKS: -

1. An Introduction to Modern Astrophysics: by B. W. Carrol & D. A. Ostlie (Addison Wesley)
2. Textbook of Astronomy & Astrophysics with Elements of Cosmology: V. B. Bhatia (Narosa)
3. An introduction to astronomy & cosmology: by Ian Morrisson (John Wiley)
4. An Introduction to Astrophysics, B. Basu, T. Chattopadhyay, S.N. Biswas

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DETAILS OF THE COURSE

Course code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT809	Introduction to Quantum Field Theory	3	2	1	0	0

PREREQUISITE COURSES
Advanced Quantum Mechanics

COURSE OBJECTIVES

Students will learn the development of Quantum Field Theory from first principles. They will also learn to develop theories of practical importance, as well as understand the underlying framework that leads to the modern understanding of microscopic matter and forces.

COURSE ASSESSMENT

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Introduction: Basics of Special Relativity, Lorentz and Poincare group, problems with old relativistic quantum theory

(No. of Lectures: 3)

Free spinless particles: classical theory of scalar fields, Klein-Gordon equation, Noether's Theorem, canonical quantisation of Klein-Gordon theory, propagators and Green's functions, complex scalar theory and anti-particles, discrete symmetries

(No. of Lectures: 9)

Interacting spinless particles: Interacting scalar fields, path integrals, cross sections and S-matrix, LSZ reduction formula, perturbation theory and Feynman diagrams, Wilson's approach to renormalization

(No. of Lectures: 9)

Particles with spin: relativistic origins of spin and Dirac algebra, Dirac fields, problem with standard commutation relations and fermions, brief introduction to Quantum Electrodynamics

(No. of Lectures: 5)

TEXT BOOKS

1. An Introduction To Quantum Field Theory, Michael E. Peskin & Daniel V. Schroeder (CRC Press)
2. Quantum Field Theory, Mark Srednicki (Cambridge University Press)

REFERENCE BOOKS & NOTES

1. The Quantum Theory of Fields: Steven Weinberg (Cambridge University Press)
2. David Tong's lecture notes on QFT
3. Quantum Field Theory In A Nutshell, A. Zee (Princeton University Press)
4. Classical Theory of Gauge Fields, Valerie Rubakov (Princeton University press)

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
24PHT805	**Machine Learning in Physics**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE – None

COURSE OBJECTIVE(s)

This course aims to provide students with programming knowledge from basics of Python to the advanced level of Machine Learning using Python.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Machine learning software packages (open sources, e.g., python) and their installation, Basics of Python, Supervised and Unsupervised learning.

(No. of lectures: 3)

Regression, Classification, Principal component analysis, Singular value decomposition, Support vector machines, Clustering, K-Nearest Neighbors, Decision trees, Neural Networks, Deep Learning.

(No. of lectures: 16)

Applications of machine learning in physics research, Preparation of mini projects in the interdisciplinary field of physics such as Statistical Physics, Electromagnetism, Nuclear Physics, Device Physics etc.

(No. of lectures: 7)

Recommended Readings

TEXTBOOKS/ REFERENCE BOOKS: -

1. Introduction to Machine Learning, 3rd ed., E. Alpaydin, MIT Press (2014)
2. Introduction to Machine Learning with Python, Andreas C. Müller & Sarah Guido
3. Python Machine Learning - Second Edition, Sebastian Raschka , Vahid Mirjalili
4. Data Analysis Software, ROOT User Guide: https://root.cern.ch/
5. Statistics: R J Barlow (John Wiley and Sons)
6. A Practical Guide to Data Analysis for Physical Science Students –L. Lyons (Cambridge University Press)
7. Data analysis techniques for HEP, Fruhwirth et al (Cambridge University Press)
8. The Elements of Statistical Learning, 2nd ed., T. Hastie, R. Tibshirani, & J. Friedman, Springer (2016)
9. Handbook of Radiotherapy Physics, Theory and Practice: P Mayles, A Nahum, J.C Rosenwald (Taylor & Francis)
10. Hands-On Machine Learning: Concepts, Tools, and Techniques to Build Intelligent Systems 2nd Edition, Aurélien Géron

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
24PHT808	**Membrane Technology for Energy Applications**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: BSc Physics or equivalent, with basic knowledge of thermodynamics, solid-state/materials science.

COURSE OBJECTIVE(s): These objectives are designed to provide a basic understanding of the fundamental concepts and operational principles of Membrane Technology for Energy Applications.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Fundamentals and Membrane Materials: Types and uses of membranes; Isotropic Membranes, Anisotropic membranes, Ceramic, Metallic, and Liquid Membranes; Zeolite, Carbon, and Glass Membranes; Porous Membranes, Dense Membranes, Mixed-Matrix Membranes, Hollow-Fiber Membranes, Ion-exchange Membranes, Recent development in membranes; Solution-diffusion model, Pore-flow membranes.

(9-Lectures)

Membrane Modules and Configurations: Types and uses of modules: Plate and frame module, Spiral wound module, Tubular module, Capillary module, Comparison of module configurations.
(5-Lectures)

Transport Phenomena and Pressure-Driven Processes: Concentration polarization in liquid separation processes, Gel layer model, Osmotic pressure model, Boundary layer resistance model, Concentration polarization in gas separation processes, Membrane fouling and fouling control; Reverse Osmosis, Ultrafiltration and Microfiltration and their applications; Dialysis and Electrodialysis and their applications.

(9-Lectures)

Advanced Separation Processes and Fabrication: Membrane reactors and membrane bioreactors; Prevaporation and its applications; Gas separation; Membrane Contactors; Introduction of synthetic membrane, Preparation of synthetic membranes, Phase inversion membranes, Preparation technique for composite membranes.

(8-Lectures)

Energy Applications and Characterization: Fuel cell, Batteries, Hydrogen production, Membranes for coal and gas power plants; Membrane Characterization Techniques: Characterization of porous membranes, Characterization of ionic membranes, Characterization of non-porous membranes.

(8-Lectures)

TEXT BOOK:

1. Baker, R. W. (2012), Membrane Technology and Applications, 3rd Ed., Wiley.

REFERENCE BOOKS: -

1. Mulder, M. (1996), Basic Principles of Membrane Technology, Kluwer Academic.
2. W. S. W. Ho and K. K. Sirkar (1992), Membrane Handbook, Chapman & Hall, NY.
3. Li, N. N., Fane, A. G., Ho, W. S. W., and Matsuura (2008), Advanced Membrane Technology, Wiley.
4. M. Cheryan (1998), Ultrafiltration and Microfiltration Handbook, CRC Press.

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
26PHTXXX	Monte Carlo Simulations using Geant4	3	3	0	0	0

PREREQUISITE – None

COURSE OBJECTIVE(s)

- To understand the fundamental principles of Monte Carlo methods, random processes, and particle interactions with matter used in radiation transport and detector simulations.
- To develop knowledge of the Geant4 simulation toolkit, including detector geometry construction, physics processes, particle generation, tracking, and event simulation.
- To acquire practical skills in designing detector systems, performing Monte Carlo simulations, and analyzing simulation data using ROOT for applications in high-energy physics, medical physics, space science, and solid-state physics.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Fundamentals of Monte Carlo Methods

Fundamentals of Monte Carlo approach to simulate the particle interactions with detector materials, random number generation, landau distribution of energy deposited, convolution with Poisson distribution, advantages of Monte Carlo method, basic Geant4 concepts, important features of Geant4.

(No. of lectures: 10)

Class Structure of Monte Carlo Simulation (Geant4)
User classes: mandatory classes and action classes, detector construction, physics processes: electromagnetic, hadronic and decays, generation of primary particles through gun, action classes:run, event and tracking of particles in the experiment, Geant4 examples: basic, extended and advanced examples, design of simple geometry e.g. calorimeter to the real life experiment e.g. hadron therapy. **(No. of lectures: 13)**

Designing the Detector Geometry in Geant4
How to design the experiment, compile and run in geant4 simulation environment, analysis of simulated data from Geant4 using ROOT software: 1D, 2D and 3D histogram plotting, curve fitting, storing data in Tree and Ntuples, applications: computed tomography, 3D image reconstruction in medical physics, design optimization of any complex detector geometry in high energy physics experiments, radiation effects analysis in space science, application in solid state physics. **(No. of lectures: 16)**

Text books

1. Techniques for Nuclear and Particle Physics Experiment: W. R. Leo (Springer).
2. Radiation Detection and Measurement: Glenn F. Knoll (Wiley).
3. Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications: I. Kawrakow, in A. Kling et al (edts.) (Springer).

Reference Books:

4. Statistics: R J Barlow (John Wiley and Sons)
5. A Practical Guide to Data Analysis for Physical Science Students –L. Lyons (Cambridge University Press)
6. Data analysis techniques for HEP, Fruhwirth et al (Cambridge University Press)
7. Handbook of Radiotherapy Physics, Theory and Practice: P Mayles, A Nahum, J.C Rosenwald (Taylor & Francis).

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DETAILS OF THE COURSE

Course code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT812	Nanostructured Materials and Applications	3	3	0	0	0

PREREQUISITE
None

COURSE OBJECTIVE(s)
This course gives an overview of nanomaterials. After successful completion of this course, the student should be able to understand the fundamentals, synthesis, characterization, and applications of nanostructured materials. Students would learn the size-dependent properties of nanomaterials and characterization techniques such as XRD, AFM, SEM, TEM, etc. Students will be able to analyze and interpret data obtained from various characterization techniques and understand the future challenges of nanomaterials.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade) will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Basics of nanoscience & nanotechnology- Overview of nanostructures, top-down and bottom-up approaches, size-dependent properties of nanomaterials, zero, one and two-dimensional nanostructures, density of states, physics of 2D materials, growth mechanism of nanoparticles, superlattice structures, structural, optical, electrical, dielectric, and chemical properties of nanomaterials.

(No. of lectures- 12)

Synthesis and Characterization of Nanomaterials- Synthesis of nanostructured materials using various methods: RF/DC sputtering, Electron beam evaporation, Pulsed Laser Deposition, Ball milling, lithography, CVD, Sol-gel, spin coating. Tailoring of nanomaterials' properties, Modification of nanomaterials using ion implantation and high energy ion irradiation, analysis of nanostructured materials using XRD, STM, AFM, Raman, Dynamic light scattering, Photoluminescence, SEM, and TEM.

(No. of lectures- 20)

Applications of Nanomaterials - Applications of nanotechnology in energy, space, medicine, agriculture, and electronics. Environmental, health, and safety issues, Limitations, challenges, and future aspects of nanotechnology.

(No. of lectures- 7)

TEXT BOOKS:

1. Introduction to Nanotechnology: Charles P. Poole, Jr. and Frank J. Owens (Wiley).
2. Introduction to Nanoscience and Nanotechnology, K K Chattopadhyay & A N Banerjee (PHI, EEE, October 2012)

REFERENCE BOOKS:

1. Nanostructures and Nanomaterials Synthesis, Properties and Applications: G. Cao (Imperial College Press-2006).
2. Nanotechnology: Basic Science & Emerging Technology: M. Wilson, K. Kannangara, G. Smith, M. Simmons and B. Raguse (Overseas Press-2005).
3. Nanotechnology: Principles and Practices, Sulabha K. Kulkarni (Springer)

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT814	**Numerical Methods and computer programming**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE – basic knowledge about computer programming

COURSE OBJECTIVE(s)

To develop the mathematical skills of the students in the areas of numerical methods. To apply computer programming to solve numerical methods and to find the solution of algebraic equations using different methods under different conditions, and numerical solution of system of algebraic equations

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Basics of MATLAB programming, Array operations in MATLAB, Loops and execution control, working with files: Scripts and Functions, Plotting and program output

(No. of lectures: 10)

Linear Equations: Linear algebra in MATLAB, Gauss Elimination. LU decomposition and partial pivoting, Iterative methods: Gauss Siedel, Special Matrices: Tri-diagonal matrix algorithm Nonlinear Equations: Nonlinear equations in single variable, Fixed-point iteration in single variable, Newton-Raphson in single variable, MATLAB function solve in single and multiple variables, Newton-Raphson in multiple variables

(No. of lectures: 09)

UNIT 3: Numerical Differentiation and Integration: Numerical Differentiation in single variable, Numerical differentiation: Higher derivatives, Differentiation in multiple variables Newton-Cotes integration formulae, multi-step application of Trapezoidal rule, MATLAB functions for integration

(No. of lectures: 10)

UNIT 4: Ordinary Differential Equations (ODE) Introduction to ODEs; Implicit and explicit Euler's methods, Second Order Runge-Kutta Methods, MATLAB ode45 algorithm in single variable, Higher order Runge-Kutta methods, Error analysis of Runge-Kutta method, Practical example for ODE. Solving particle in 1 D box using programming and similar problems, monte carlo simulation, projectile motion, random walk problem, Rutherford scattering

(No. of lectures: 10)

Text /Reference Books:

1. Computer Oriented Numerical Methods: V. Rajaraman (Prentice Hall of India).
2. Numerical Analysis: M. K. Jain.
3. Introduction Methods of Numerical Analysis: C.S. Sastry (PHI).
4. Numerical Analysis: E. Krishnamurthy.
5. Monte Carlo Simulation: Binder and Herman.
6. An Introduction to Computation Physics: T. Tang (Cambridge Univ. Press 1997).
7. Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers by Rudra Pratap (Oxford University Press)

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT817	**Semiconductor Physics and Devices**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE – None

COURSE OBJECTIVE(s)
This course aims to equip the students with fundamental knowledge of semiconductor physics and explain the working and design of p-n junctions and semiconductor devices viz. BJTs and FETs. Preliminary knowledge of IC fabrication is also given.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Bipolar junction transistors, transistor as an amplifier and switch, junction field effect transistors, MOS capacitor, MOSFET devices, metal-semiconductors FET, hetero junctions- quantum wells,
(No. of lectures: 15)

Photonic devices-, Current and voltage in an illuminated junction solar cells, photo detectors, LEDs, semiconductor lasers, Hetero junction laser; techniques to measure properties of semiconductors- Resistivity measurement of a semiconductor, four probe method, Correction factors, arbitrary samples, Van der pauw technique, hall effect, spreading resistance for diffusion measurements

(No. of lectures: 14)

An overview of IC fabrication technology- Introduction, epitaxial growth, diffusion, oxidation, wafer doping and etching, photolithographic processing, ion implantation, clean room design, Wafer packaging

(No. of lectures: 10)

Recommended Readings

Text books-

1. Solid State Electronic Devices: B. G. Streetman and Banerjee (Prentice Hall of India)
2. Physics of Semiconductor Devices: S.M. Sze (John Wiley and Sons)

Reference books-

1. Principles of Electronic Materials: S.O. Kasap (McGraw Hill)
2. Principles of Semiconductor Devices: Sima Dimitrijev (Oxford University Press)
3. Physics of Semiconductor Devices: M. Schur (Prentice Hall of India)
4. Electrical Characterization of Semiconductor Materials and Devices, (Chapter 20) Springer Handbook of Electronic and Photonic Materials, ISBN 978-0-387- 26059-4, Springer-Verlag US
5. Semiconductor Physics and Devices: D A Neamen TMH III ed.

Online/E- resources

Nptel Video - Electronic Materials, Devices & Fabrication, IIT Madras, Mod 1, Lec 20-31

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
24PHT806	Soft Materials	3	3	0	0	0

PREREQUISITE – Understanding of basic material science

COURSE OBJECTIVE(s)

This course is an introduction to soft materials. Soft matter (or soft condensed matter) is a multidisciplinary field: as such, this class includes chemistry, physics, thermodynamics, and materials science content. Applications of the above in life and in research. The goal is to enjoy the science behind these "everyday" applications of soft materials.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Introduction to soft materials and soft matter, generic aspects of soft materials, classification in terms of their thermal, mechanical and often unusual physical properties. examples of soft systems: polymers, foams, granular media, colloids, liquid crystals, micelles, vesicles and biological membranes, Responsive nanomaterials, Self-healing, Hybrid nanoparticles

(No. of lectures: 10)

From hard to soft building blocks, synthesis of hard and soft colloids, hard systems, softer systems and their characterization, dispersion forces, polymers in solution, gels, emulsions and foams, Block copolymers, Soft lithography and micro molding

(No. of lectures: 11)

Controlled drug delivery, Biomimetic engineering, Flexible electronics, Wearable electronic, Organic Electronics, Soft robotics, Soft Electronics Fabrication Approaches, General trends in soft nanomaterials research

(No. of lectures: 09)

Wearable and flexible gas sensors, Types of wearable sensors: Invasive, Non-invasive; Intelligent clothing, Wearable chemiresistive and biochemical Sensors, Detection of atmospheric pollutants, Wearable devices for health monitoring

(No. of lectures: 09)

Recommended Readings Text books

1. Fundamentals of soft matter science: Linda S. Hirst (CRC).
2. Introduction to soft matter: Ian W. Hamle (Wiley).
3. Polymer surfaces and interfaces: M Stamm (Springer).
4. Soft condensed matter: R.A.L. Jones (Oxford)
5. Wearable Sensors: Fundamentals, Implementation and Applications (Elsevier)

Reference books:

1. Soft materials: structure and dynamics: John R. Dutcher, A. G. Marangoni (CRC)

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT819	Solar Energy and Applications	3	3	0	0	0

PREREQUISITE – Solid State Physics, Materials Science

COURSE OBJECTIVE(s)

This course aims to equip the students with fundamental knowledge of solar energy resource, solar energy conversion techniques, basics of semiconductor junction, design and operation of solar cells, performance testing and analyses.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Renewable and non-renewable energy resources, solar energy: origin, solar constant, spectral distribution of solar radiation, absorption of solar radiation in the atmosphere, global and diffused radiation, seasonal and daily variation of solar radiation, measurement of solar radiation, solar to thermal conversion, types of solar energy collectors, concentrating/non-concentrating solar collectors, collector efficiency and its dependence on various parameters, solar fuels: electrolysis of water, photoelectrochemical splitting of water.

(No. of lectures: 12)

Fundamentals of solar cells: photo voltaic effect, p-n junction photodiodes, depletion region, electron and holes transports, absorption of photons, excitons and photoemission of electrons, band engineering, charge carrier generation, charge separation, recombination and other losses

(No. of lectures: 10)

I-V characteristics, output power, efficiency, fill factor and optimization for maximum power, metal-semiconductor heterojunctions, surface structures for maximum light absorption, operating temperature vs conversion efficiency.

(No. of lectures: 10)

Device physics, device structures, device construction, solar cell properties and design, materials for solar cells, silicon based solar cells: single crystal, polycrystalline and amorphous silicon solar cells, organic solar cells, organic-inorganic hybrid solar cells, advanced concepts in photovoltaic research, nanotechnology applications, plasmonic based solar cells.

(No. of lectures: 7)

TEXT/ REFERENCE BOOKS: -

1. Nelson, J. The Physics of Solar Cells. Imperial College Press, 2003. ISBN: 9781860943409.
2. Solar Engineering of Thermal Process: Duffie and Beckman, John Wiley, 2013. ISBN: 9780470873663
3. Solar Energy: S. P. Sukhatme, Tata McGraw Hill, 1996. ISBN: 1259081966, 9781259081965.

REFERENCE BOOKS: -

1. Principles of Solar Engineering, D. Yogi Goswami, Taylor and Francis, 2015. ISBN: 9781138569478.
2. Wenham, S., M. Green, et al., eds. Applied Photovoltaics. 2nd Ed. Routledge, 2006. ISBN: 9781844074013.
3. Green, M. A. Solar Cells: Operating Principles, Technology, and System Applications. Prentice Hall, 1981. ISBN: 9780138222703.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT821	**Surface Physics**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE - None

COURSE OBJECTIVE(s)

The aim of this course is to give a comprehensive introduction of solid surfaces and interfaces and physics and chemistry on an atomic length scale. After successfully completing this course student should be able to understand the fundamental importance of surfaces, and how their structures and properties differ from that of bulk materials. They should be able to understand the results of surface science techniques such as XPS, AES, RBS, STM etc.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Physics of Surfaces

Physics of Surfaces: What is a surface? Surfaces and Interfaces and their importance, Surface Thermodynamics, From Solid to Surface, Morphology and Structure of Surfaces, Interfaces and Thin films, Surface geometry: truncated bulk, relaxation, reconstruction, defects and super-structures, Surface Defects, Surface Creation; Surface cleaning

(No. of lectures: 14)

Adsorption, Desorption, Chemical Reactions & Nucleation: Chemisorption, Physisorption, Adsorption, Desorption, Mechanisms of Adsorption/Diffusion/Desorption, Thermodynamics and kinetics of thin film growth, Surface Reactions: Catalysis, Crystal Growth, Chemical Reactions & Nucleation, Homogeneous and Heterogeneous nucleation kinetics, Thin Film Deposition techniques

(No. of lectures: 9)

Vacuum Technology for Applied Surface Science: Ultra High Vacuum (UHV), Basic Principles of UHV, Why UHV is required? How to attain UHV ?, UHV Setups, Vacuum Pumps, Vacuum Gauges, Surfaces in UHV, Sample preparation in UHV, Vacuum Gauges

(No. of lectures: 5)

Surfaces characterization Techniques: Auger Electron Spectroscopy (AES): Principle, Instrumentation, Chemical Analysis, X-ray Photoelectron Spectroscopy (XPS): Basics of XPS, Instrumentation, Vacuum Systems, X-ray Sources, Analyzer, Chemical Analysis, Depth Profiling, Secondary Ion Mass spectroscopy (basics, instrumentation, depth profiling, Surface structure determination by electron diffraction: LEED, RHEED, Scanning Tunneling Microscopy

(No. of lectures: 11)

Recommended Readings

Text books –

1. Surface Science- An Introduction, K Oura (Springer).
2. Physics at Surfaces, Andrew Zangwill (Cambridge University Press).
3. Surface Analysis: The Principal Techniques, John C. Vickerman, Ian S. Gilmore (Wiley).
4. Solid Surfaces, Interfaces and Thin Films, Hans Luth (Springer).

Reference books –

1. Lecture Notes on Surface Science, Philip Hofmann.
2. Physics of Surfaces and Interfaces, Haralad Ibach (Springer).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
24PHT802	**Energy Materials and Devices**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE – None

COURSE OBJECTIVE(s)

This course aims to equip the students with fundamental knowledge of renewable energy resource, energy conversion techniques, hydrogen energy, energy storage devices, batteries, fuel-cells, working principle and device structure.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Energy units, Energy requirements, Natural sources, Renewable and nonrenewable sources, Types of energy devices-generation, storage, conversion and transport, Concepts, definitions and essential performance parameters. Introduction to hydrogen as a green fuel, Water splitting technologies for hydrogen and oxygen generation, Electrochemical water splitting; free energy adsorption, volcano plot, Basic reaction mechanism, Energy level diagram, Photochemical cell designs, fabrication and performance analysis

(No. of lectures: 10)

Introduction to solar energy and solar resource, optical absorption and losses, charge generation, charge separation, charge collection, 1-D device model, Important parameters in photovoltaics (Describing J-V characteristics, Spectral response-EQE & IQE), Shockley-Queisser limit, photon management), single and multi-junction tandem solar cells, Energy level diagrams

(No. of lectures: 6)

Capacitor & supercapacitor, Concept of EDLC, Basic electrochemical concepts and definitions, Pseudo and asymmetric supercapacitors, Microsupercapacitors, Li-ion capacitors, comparison of performances and application areas, Primary and secondary batteries, Principle of operation, Conventional batteries, Li-ion and beyond Li-ion other batteries, Battery components and design of electrodes, cell and battery fabrication, Measurements- CD curves, priming & cycling, time scales, charge retention, coulombic efficiency, self-discharge & charge retention, long term stability

(No. of lectures: 14)

Hybrid battery-supercap devices, electric mobility, Building block cells, battery/supercap modules and packs, voltage and current management, all solid-state batteries & new concepts in Batteries beyond lithium, smart photorechargeable batteries; basic concepts of fuel-cells, Types of fuel cells, fuels for fuel cell, catalysts, membranes fuel cell design.

(No. of lectures: 09)

TEXT/ REFERENCE BOOKS: -

1. Energy Materials: Fundamentals to Applications, Sanjay J. Dhoble, N. Thejo Kalyani, B. Vengadaesvaran, Abdul Kariem Arof, Elsevier, 2021, ISBN: 0128237112, 9780128237113.
2. Introduction to Materials for Advanced Energy Systems, Colin Tong, Springer Cham, 2019, ISBN: 978-3-319-98001-0.

REFERENCE BOOKS: -

1. Green, M. A. Solar Cells: Operating Principles, Technology, and System Applications. Prentice Hall, 1981. ISBN: 9780138222703.
2. Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications, B. E. Conway, 1999, ISBN: 978-0-306-45736-4
3. Fuel Cells and Hydrogen: From Fundamentals to Applied Research, Viktor Hacker, Shigenori Mitsushima, 2018, ISBN: 9780128114599.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT806	General Theory of Relativity	3	3	0	0	0

PREREQUISITE - None

COURSE OBJECTIVE(s)
This course aims to introduce the basic concepts and formalism of general theory of relativity. The course will also cover basic cosmology, and generation and detection of gravitational waves.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Why general relativity, Review of special theory of relativity: Inertial observers, Minkowski metric, spacetime diagrams, light cone, invariant hyperbolae, Lorentz transformations, vectors and vector spaces, Four-vector formulation of special relativity, Tensors and tensor manipulation, Energy and momentum in special relativity and energy-momentum tensor for perfect fluid.

(No. of lectures: 10)

Riemannian geometry: manifolds, curve on a manifold, functions on manifolds, vectors and vector fields on manifolds, tensors on manifolds, metric tensor and tensor densities, tensor calculus, Christoffel symbols and covariant derivative, parallel transport and geodesics, Riemann curvature tensor, general properties of Riemann tensor, Ricci tensor and scalar, Weyl tensor. Geodesic deviation

(No. of lectures: 12)

Equivalence principle, principle of general covariance, Physics in curved spacetime, Conservation of energy-momentum tensor in curved spacetime. geodesics as trajectories under the influence of gravitational field, Weak field limit of geodesic equation, Einstein's field equation.

(No. of lectures: 5)

Schwarzchild solutions of Einstein's field equation, construction of metric and its symmetries, motion of a particle in Schwarzchild metric, experimental tests of general relativity, precession of the perihelion, bending of light, gravitational redshift, singularities, horizons, black holes. FRW metric, Friedmann equation, Radiation and matter dominated universe, Cosmological Constant, Inflation and CMBR

(No. of lectures: 7)

Gravitation radiation: Weak field approximation, Gauge transformations, Degrees of freedom, Plane gravitational waves solutions, Generation of gravitational waves, quadrupole radiation, Energy loss due to gravitational waves, Detection of gravitational waves.

(No. of lectures: 5)

Recommended Readings

Text books –

1. A First Course in General Relativity: Bernard Schutz (Cambridge University Press).
2. Spacetime and Geometry: An Introduction to General Relativity, Sean M. Carroll (Pearson Indian Education)
3. Gravity: An introduction to Einstein's General Relativity; J. B. Hartle (Pearson India Education)
4. Introducing Einstein's Relativity: Ray D'Inverno (Oxford University Press).

Reference Books-

1. General Relativity: R. M. Wald (University of Chicago Press).
2. Gravitation and Cosmology: S. Weinberg (Wiley India PVT. LTD).
3. Classical Theory of Fields: L. D. Landau and E. M. Lifshitz (CBSPD).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT716	Materials Science and Engineering	3	3	0	0	0

PREREQUISITE – basic knowledge about solid state physics

COURSE OBJECTIVE(s)

To describe the fundamental knowledge about the materials science and engineering, the structure and related properties of individual materials, classified as metals, ceramics or polymers by free hand sketching and by calculation of specific physical and chemical properties

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Defects-types of defects, motion and properties of dislocation, diffusion in solids, Fick's laws of diffusion, solutions to Fick's second law, applications of Fick's law, atomic theory of diffusion, mechanism of diffusion, basics of microscopy, SEM and TEM, deep level transient spectroscopy (DLTS)

(No. of lectures: 9)

Phase transformations in solids- solid solutions, phase rule, binary phase diagrams, binary isomorphous systems, binary eutectic systems, types of transformations, homogeneous and heterogeneous transformation, thermodynamics of transformation, nucleation and growth kinetics, overall kinetics, recovery, recrystallization and grain growth.

(No. of Lectures: 15)

Properties of materials- mechanical properties of materials-elastic and plastic deformation, hardness, dislocations and strengthening mechanisms, failure-fatigue and creep, corrosion and degradation of materials- corrosion rates, forms of corrosion

(No. of Lectures: 15)

Text Books:

1. Materials Science and Engineering, An Introduction by W.D.Callister, Wiley Publications.
2. Materials Science and Engineering by V.Raghvan, PHI
3. Solid State Phase Transformations by V.Raghvan, PHI
4. Essential Materials- Science and Engineering by Askeland and Phule, CENGAGE Learning
5. Basics of Materials Science and Engineering by W F Smith, Mc Graw Hill

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT813	**Nanotechnology for Energy Applications**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE – Fundamentals of nanomaterial

COURSE OBJECTIVE(s)

This course focuses on the careful selection of nanomaterials for applications in energy harvesting and storage. It explores the challenges associated with enhancing the performance of devices and techniques related to energy harvesting and storage. Throughout the course, various energy harvesting and storage methods will be discussed, along with an examination of the critical parameters involved in the selection of nanomaterials for these applications.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Energy challenge in the 21st century, Introduction of nanotechnology, Synthesis and characterization methods of nanomaterials, Energy storage and energy harvesting technologies, Criteria for choosing the nanomaterials for energy harvesting and storage applications, Application of nanotechnologies in the energy value chain

(No. of lectures: 10)

Renewable and non-renewable energy sources, Development and implementation of renewable energy technologies, Examples of nanotechnology energy production and energy storage, Nanotechnology for Solar Energy Collection and Conversion, Nanotechnology for water technologies, Nanotechnology for water treatment and desalination

(No. of lectures: 10)

Nanomaterials used for hydrogen energy generation, Methods to produce hydrogen energy, Hydrogen production from fossil fuels and biomass, Role of nanotechnology for hydrogen energy generation, Fuel cells, Proton exchange membrane (PEM) cell, Membrane and its type, Membrane fabrication and its engineering, Methods for separation of hydrogen, Membranes for gas separation.

(No. of lectures: 10)

Energy storage, Nanomaterials used for energy storage, Key challenges for energy storage, Solution of key challenges, Type of energy storages, Nanomaterials for Solid State Hydrogen Storage, Hydrogen Detection Technologies for Hydrogen Safety

(No. of lectures: 09)

Recommended Readings Text books

1. Nanotechnology for the energy challenge, Javier Garcia-Martinez (WILEY- VCH)
2. Renewable energy resources: John Twidell, Anthony D. Weir (Taylor and Francis).
3. Hydrogen fuel: production, transport and storage, Gupta (CRC Press)
4. Nanomaterials for sustainable energy, Quan Li (Springer)

Reference books:

1. Energy efficiency and renewable energy through nanotechnology: Ling Zang (Springer).
2. Materials in energy conversion, harvesting and storage,Kathy Lu (Wiley)
3. Energy storage systems and components, Alfred Rufer (CRC Press)
4. Handbook of Hydrogen energy, S.A. Sherif (CRC Press)

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
21PHT816	Plasma Physics	3	3	0	0	0

PREREQUISITE – Classical Mechanics, Electrodynamics

COURSE OBJECTIVE(s)

After successfully completing this course student should be able to understand plasma as a fourth state of matter. They shall learn the appropriate techniques to deal with with tenuous / dense plasma regimes. They will learn about the waves & instabilities grown in plasma. Basic applications of plasma in the fields of space propulsion / nuclear fusion shall also be learned.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
1.	Internal assessment (based upon assignments, quizzes and attendance)	20%
2.	Mid-term examination	30%
3.	End Semester Examination	50%

COURSE CONTENTS

Basic properties, occurrence of plasma, criteria for plasma behavior, plasma oscillations, quasineutrality, Debye shielding, plasma parameters

(No. of lectures: 8)

Charged particle motion and drifts, guiding center motion of charged particles, motion in uniform electric and magnetic fields, motion in non-uniform magnetic field, principle of magnetic mirror, loss cone, motion in non-uniform electric field for small Larmor radius, time varying electric field, time varying magnetic field, adiabatic invariance of magnetic moment

(No. of lectures: 14)

Brief discussion of methods of plasma production, DC discharge, RF discharge, Photoionization, plasma diagnostics, Langmuir probe.

(No. of lectures: 5)

Plasma as fluids, equation of motion, convective derivative, Waves in plasma, Electrostatic waves Instabilities, two stream instability. Collision and diffusion parameters, Fick's Law. Fusion energy, Lawson criterion, Controlled fusion schemes (Tokamak, ITER). Principle of MHD power

(No. of lectures: 12)

TEXT/ REFERENCE BOOKS:-

1. Introduction to Plasma Physics and Controlled Fusion: Francis F. Chen (Springer).
2. Principles of Plasma Physics for Engineers and Scientists: Umran Inan and Marek Golkowski (CambridgeUniversity Press).
3. Fundamentals of Plasma Physics: Paul M. Bellan (Cambridge University Press)).
4. Introduction to plasma Physics: R. J. Goldston & P. H.Rutherford (IoP Publication).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
26PHTXXX	**Quantum Computing using Quantum Physics**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE – Quantum Mechanics Course

COURSE OBJECTIVE(s)

- To understand the fundamental principles of quantum mechanics relevant to computation, such as qubits, superposition, entanglement, and measurement.
- To develop a strong mathematical foundation required for quantum computing, including vector spaces, linear algebra, and Hilbert space formalism.
- To introduce quantum operators, gates, and circuit models used in quantum information processing.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Module I: Introduction to Quantum Mechanics
Introduction to Quantum Physics: Classical vs. Quantum physics, Key concepts: wave-particle duality, uncertainty principle, Historical context and early developments (Planck, Einstein,

Schrödinger). Quantum States and Wave Functions:Superposition principle, Probability amplitudes and Born's rule, The role of measurement in quantum mechanics.

(No. of lectures: 9)

Module II: Mathematical formalism

Basics of Quantum Mathematics: Vector spaces, inner products, and Hilbert spaces Operators, eigenvalues, and eigenvectors; Quantum States as Vectors: Bra-ket notation and wavefunctions, State vectors and density matrices.

(No. of lectures: 9)

Module III: Quantum Computing Foundations, Algorithms & Applications

Introduction to Quantum Computing: Classical bits vs. quantum bits (qubits), Qubit states: and superposition, Quantum gates: Pauli gates, Hadamard gate, Phase gates, and Controlled gates and circuits, Entangled quantum states and their significance. Overview on the open sources to implement the quantum gates and circuits, basics, and the physical interpretation of quantum algorithms: Simon's problem, Grover's quantum search algorithm, Shor algorithm, Deutsch-Jozsa Algorithm.

Applications: New materials discoveries, Advanced complex simulations for drug discovery, Quantum sensors for Space & Earth observation, Weather forecasting.

(No. of lectures: 21)

Text books

1. Nielsen, M. A., & Chuang, I. L. (2010). Quantum computation and quantum information (10th anniversary ed.). Cambridge University Press.
2. Hidary, J. D. (2019). Quantum computing: An applied approach. Springer Nature Switzerland AG.
3. Griffiths, D. J., & Schroeter, D. F. (2018). Introduction to quantum mechanics (3rd ed.). Cambridge University Press.
4. Zettili, N. (2009). Quantum mechanics: Concepts and applications (2nd ed.). John Wiley & Sons.

Reference Books

5. Javadi-Abhari, A., Treinish, M., Krsulich, K., Wood, C. J., Lishman, J., Gacon, J., Martiel, S., Nation, P., Bishop, L. S., Cross, A. W., Johnson, B. R., & Gambetta, J. M. (2024). Quantum computing with Qiskit. arXiv:2405.08810. https://doi.org/10.48550/arXiv.2405.08810
6. IBM Quantum. (2024). IBM Quantum documentation. IBM Corporation. https://docs.quantum.ibm.com
7. Bernhardt, C. (2019). Quantum computing for everyone. The MIT Press.

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DEPARTMENT OF PHYSICS

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DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
26PHTXXX	Quantum Materials and Applications	3	3	0	0	0

PREREQUISITE – Solid State Physics and Quantum Mechanics courses

COURSE OBJECTIVE(s)
To impart fundamentals understanding of electronic, superconducting, magnetic, and topological quantum phases. Students will explore specialized material synthesis techniques and gain foundational insights into real-world applications of quantum materials across quantum technologies.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Basics of band theory and band structures, operating principles of electronic and quantum optical semiconductor devices. Coherent states and magnetic phenomena, microscopic and phenomenological foundations of superconductivity (BCS and Ginzburg-Landau theories), the AC/DC Josephson effects, a survey of superconducting devices. Electronic and optical properties of single/few-layer graphene and Transition Metal Dichalcogenides (TMDCs). Magnetic measurements, the Hall effect, magnetoresistance, and the Faraday and Kerr magneto-optical effects.

(No. of lectures: 10)

Fundamentals of topology in condensed matter, geometric phases highlighted by the Berry Phase, and the Aharonov-Bohm effect. Topological phases of matter, topological insulators and edge states. Survey of material growth, processing, and crystal fabrication techniques: Molecular Beam Epitaxy (MBE), Chemical Vapor Deposition (CVD), Metal-Organic Vapor Phase Epitaxy (MOVPE), Pulsed Laser Deposition (PLD), and generalized bulk crystal growth methods.

(No. of lectures: 15)

Introduction to quantum sensing architectures using atomic state-based sensing and solid-state spin systems, Nitrogen-Vacancy (NV) centers in diamond for precision magnetometry and gravimetry. Quantum materials in quantum communication infrastructure, materials engineered for single-photon emitters, detectors, and quantum memories. Material applications in quantum computing hardware, surveying topological quantum computing platforms, and quantum-material-based memristors for neuromorphic computing.

(No. of lectures: 14)

Recommended Readings

Text books –

1. Marder, M. P. Condensed Matter Physics, 2nd Edition, John Wiley and Sons (2010).
2. Nielsen, M. A., & Chuang, I. L. Quantum Computation and Quantum Information, Cambridge University Press (2010).

Reference books –

1. Bernevig, B. A., & Hughes, T. L. Topological Insulators and Topological Superconductors, Princeton University Press (2013).
2. Kittel, C. Introduction to Solid State Physics, Wiley India Edition (2019)
3. Tinkham, M. Introduction to Superconductivity, 2^{nd} Edition, McGraw-Hill (Medtech reprint).
4. Relevant modules from online platforms

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
24PHT801	**Spintronics for Quantum Technology**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE – Solid State Physics

COURSE OBJECTIVE(s)
Impart fundamentals knowledge to masters' students in the field of Spintronics and spin-based devices. Describe (phenomenologically) the principal phenomena behind spin-based electronics. Developing capability to use fundamental knowledge in application, and to solve problems independently based on these concepts.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

History and overview of spin electronics, classes of magnetic materials, quantum mechanics of spin, spin-orbit interaction, exchange bias, spin relaxation mechanisms, pure spin and charge currents.

(No. of lectures: 10)

Spin-Hall effect and inverse spin-Hall effect, spin Seebeck effect, magneto caloric effect, the spin galvanic effect, basic electron transport, spin-dependent electron transport, spin-dependent tunneling, the basic theory of Andreev reflection, ferromagnet/ superconductor/ ferromagnet double junctions. Semiclassical transport models, spin injection, spin accumulation, spin current.

(No. of lectures: 10)

Spin-transfer torque and its magnetic dynamics, current-driven switching of magnetization and domain wall motion, domain wall scattering and current-induced switching in ferromagnetic wires. basics of spin valve and magnetic tunnel junctions, tunnel magneto resistance, quantum mechanical model of coherent tunnelling and giant TMR, read heads, MRAMS, spin transistors, spintronic biosensors.

(No. of lectures: 12)

History of quantum computation and quantum information, quantum bits and quantum circuits, quantum computation and quantum measurements, nanostructures for quantum electronics, Spin-based qubits: principle and working.

(No. of lectures: 7)

Recommended Readings

Text books –

1. Introduction to Spintronics, S. Bandyopadhyay, M. Cathay, CRC Press, 2008.
2. Magnetoelectronics, M. Johnson, Academic Press 2004.
3. Concepts in Spin Electronics, S. Maekawa, Oxford University Press, 2006.
4. Quantum Computation and Quantum Information, Michael A. Nielsen, and Isaac L. Chuang, Cambridge University Press, 2010
5.Introduction to Quantum Information Science, Vlatko Vedral, Oxford University Press, 2006.

Reference books –

1. Spintronic materials and technology, Y.B. Xu and S. M. Thompson, Taylor & Francis, 2006.
2. Magnetic Recording Technology, C.D. Mee and E.D. Daniel, McGraw-Hill Professional (1996).
3. Semiconductor Spintronics and Quantum Computation, D. D. Awschalom, D. Loss, N. Samarth, Springer Berlin Heidelberg (2010)

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
26PHTXXX	**Statistical Data Analysis in Physics**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE – None

COURSE OBJECTIVE(s)

To train students in statistical methods for data analysis using python programming and build strong mathematical foundations and physics understanding of experimental data from physics analysis.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Module I: Fundamentals of Statistics and Python for Physics

Introduction to Python (Jupyter Notebook, NumPy, Pandas, Matplotlib), types of data in physics experiments, descriptive statistics, mean, median, mode, variance, standard deviation, probability basics, random variables, normal distribution, error representation, Plotting scientific data.

(No. of lectures: 12)

Module II: Experimental Data Analysis and Uncertainty Estimation

Measurement errors and uncertainties, propagation of errors, confidence intervals, weighted mean, histogram analysis, curve fitting using least squares method, linear regression, chi-square test, Monte Carlo simulation basics, data handling from Physics experiments.

(No. of lectures: 15)

Module III: Advanced Statistical Methods for Physics Applications

Hypothesis testing, p-value and significance, correlation and covariance, Poisson statistics, counting experiments, signal vs background analysis, maximum likelihood estimation, time series data analysis, Case studies: nuclear physics, solid state physics, astronomy, Space Physics and particle physics datasets.

(No. of lectures: 12)

Books and References

Text Books

1. The Elements of Statistical Learning, 2nd ed., T. Hastie, R. Tibshirani, & J. Friedman, Springer (2016)
2. Python Machine Learning - Second Edition, Sebastian Raschka, Vahid Mirjalili
3. Statistics, R J Barlow (John Wiley and Sons)

References

4. A Practical Guide to Data Analysis for Physical Science Students, L. Lyons (Cambridge University Press)
5. Data analysis techniques for HEP, Fruhwirth et al (Cambridge University Press)
6. Introduction to Machine Learning, 3rd ed., E. Alpaydin, MIT Press (2014)

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Programme: M.Sc. Physics

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
26PHTXXX	Electrochemical Energy Storage	3	3	0	0	0

PREREQUISITE – Basic understanding of Physics, Chemistry and Mathematics

COURSE OBJECTIVE(s)

This course provides a fundamental understanding of electrochemical principles governing energy storage systems, including thermodynamics, kinetics, and transport processes. It covers batteries, capacitive systems, and emerging beyond-lithium technologies, enabling students to analyze performance, mechanisms, and limitations of electrochemical storage devices.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Module 1: Thermodynamics and Interface Fundamentals
Redox reactions, Gibbs free energy, and cell potential; Nernst equation, reversibility, and OCV; thermodynamic efficiency in electrochemical cells; structure of the electrode–electrolyte interface and double layer models.

(No. of lectures: 6)

Module 2: Kinetics and Transport Phenomena
Charge transfer kinetics, overpotential, and polarization; Butler–Volmer equation, Tafel behavior, and exchange current density; reaction mechanisms and mass transport (diffusion, migration, convection); Fick's laws, concentration polarization, and limiting current.

(No. of lectures: 7)

Module 3: Battery Principles and Intercalation

Battery working principles and performance metrics (capacity, density, efficiency); lead-acid and NiMH systems; Lithium-ion chemistry, intercalation mechanisms, and electrode reactions; voltage profiles and structural evolution of materials.

(No. of lectures: 7)

Module 4: Capacitive and Hybrid Storage

Physics of EDLCs and interfacial charge storage; pseudocapacitance in oxides and conductive polymers; advanced electrodes (graphene, CNTs, MXenes); design of asymmetric and hybrid devices; power–energy trade-offs via Ragone plots.

(No. of lectures: 7)

Module 5: Next-Generation Systems

Sodium-ion and Potassium-ion principles; Redox Flow Batteries (RFB) for stationary use; Metal–air chemistry (Zn–air and Li–air); Solid-state ionics in ceramic/polymer electrolytes; multivalent systems (Mg and Zn-ion).

(No. of lectures: 6)

Module 6: Degradation, Diagnostics, and Management

Failure modes: SEI formation, dendrite growth, and structural decay; thermal safety and runaway; Electrochemical Impedance Spectroscopy (EIS) and equivalent circuit modeling; BMS fundamentals and lifetime analysis.

(No. of lectures: 6)

TEXT/ REFERENCE BOOKS: -

1. Engineering Energy Storage, Lamb, J. J. and Burheim, O. S. 2024 (2^{nd} ed).
2. Renewable Energy - Volume 4: Energy Storage Systems - Mechanical, Hydro, and Thermal, Olabi, A. G. (Ed.). 2025 (1^{nd} ed).
3. Energy Storage and Conversion Materials: Properties, Methods, and Applications, Tran, N. T. T., Jan, J. S., Hsu, W. D., Lin, M. F., and Huang, J. L. 2023 (1^{nd} ed).
4. Materials for Sustainable Energy: A Collection of Peer-Reviewed Research and Review Articles, Dusastre, V. 2011 (1^{nd} ed).
5. Electrolytes for Energy Storage Applications: Fundamentals and Advances, Guduru, R. K. et al. 2025 (1st ed).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

Program: M.Sc. (Physics)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
26PHPXXX	Applied Physics Lab	3	0	0	6	0

PREREQUISITE – A foundational understanding of statistical principles, and familiarity with computer programming is desired**.**

COURSE OBJECTIVE(s)
The course aims to equip PG and Ph.D. students with hands-on skills in data automation, material characterization, and system design, bridging the gap between theoretical physics and industrial R&D requirements.

COURSE ASSESSMENT
The Course Assessment (culminating to the final grade), will be made up of the following three components;

S. No.	Component	Weightage
a)	Internal assessment (based upon assignments, quizzes and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Note: The student will be required to perform any Eight selected experiments

1. Interfacing an Arduino or DAQ card with a sensor (e.g., PT100 or Thermistor) to log real-time temperature data.
2. To measure and analyse the Hall coefficient, carrier concentration, and mobility of a semiconductor sample with temperature.
3. To measure Numerical Aperture (NA), attenuation, and bending losses in multi-mode fibers.
4. To use Python (OpenCV) or ImageJ to analyze SEM/Optical micrographs for grain size distribution and porosity.
5. To deposit a thin metal film (via thermal evaporation/sputtering) and measure its sheet resistance and band gap using the Four-Probe Method.

6. To measure the absorbance spectrum of a sample and utilize a Tauc Plot to determine the optical bandgap.

7. To analyse provided XRD patterns to determine crystal structure and calculate crystallite size using the Scherrer Equation.

8. To capture an analog noisy signal from a physical system (like a vibrating beam) and identify dominant frequencies using FFT algorithms in MATLAB or Python.

9. To implement a Proportional-Integral-Derivative (PID) controller to maintain a constant temperature in a small oven.

10. (Mini-Project) Use open-source DFT software (like Quantum Espresso) to simulate the band structure of a simple material like Graphene or Silicon.

11. To measure the critical temperature of a High-T_c Superconductor (like YBCO) using the Four-Point Probe Method in a liquid nitrogen environment. Additionally, demonstrate the Meissner Effect (magnetic levitation) and calculate magnetic susceptibility.

12. (Mini-Project) Design and execute a Bell State (entanglement) circuit on a real quantum processor via the IBM Quantum Learning cloud platform.

13. To implement the Metropolis-Hastings Algorithm to simulate a 2D Ferromagnetic Ising Model.

14. To solve the time-independent Schrödinger Equation for non-trivial potentials (e.g., Anharmonic Oscillator or Double Well) using numerical eigenvalue solvers in Python.

15. To perform Galvanostatic Charge-Discharge (GCD) cycles on a commercial coin cell or a fabricated half-cell.

16. To use a potentiostat to perform CV on a supercapacitor (carbon-based or pseudocapacitive).

17. To setup and operate a Proton Exchange Membrane (PEM) fuel cell using hydrogen and oxygen/air.

18. To set up an alkaline or PEM electrolyzer and its electrochemical performance evaluation.

19. To use a three-electrode electrochemical cell to study the corrosion rate of different current collectors (e.g., Aluminum, Copper, or Coated Stainless Steel) in a simulated battery electrolyte.

20. (Mini-Project) Photolithography and Micro-patterning for Nanocircuitry using a cleanroom environment or a tabletop setup.

21. To optimize 3D printing infill geometry and mechanical strength.

Recommended Softwares:

Programming: Python (NumPy, SciPy, Matplotlib), Hardware Interfacing: LabVIEW / Arduino IDE, Data Analysis: OriginPro / ImageJ / MATLAB, Simulation: COMSOL Multiphysics / Lumerical (Optional), Qiskit