Malaviya National Institute of Technology Jaipur

Department of Physics

Course Structure and Syllabi for
B.Tech. (Minor in Physics)

Curriculum Development Workshop
March 1-2, 2024

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HOD

Proposed Course Structure of B. Tech. (Minor in Physics)

S. No.	Course Code	Title of the course	Subject Area	L-T-P	Credits
1.	24PHTXXX	Electromagnetic Theory	PC	3-0-0	3
2.	24PHTXXX	Quantum Mechanics	PC	3-0-0	3
3.	24PHTXXX	Condensed Matter Physics	PC	3-0-0	3
4.	24PHPXXX	Advanced Physics Lab	PC	0-0-6	3
5.		Program Elective I	PE	3-0-0	3
6.		Program Elective II	PE	3-0-0	3
		Total			**18**

Program Elective courses for B. Tech. (Minor in Physics)

S. No.	Course Type	Course Code	Title of the course	L-T-P	Credits
1.	PE	24PHTXXX	Surface Physics and Engineering	3-0-0	3
2.	PE	24PHTXXX	Materials Science and Engineering	3-0-0	3
3.	PE	24PHTXXX	LabVIEW for Beginners	2-0-2	3
4.	PE	24PHTXXX	Particle Detector and its Technology	3-0-0	3
5.	PE	24PHTXXX	Problem Solving in Physics with Python	2-0-2	3
6.	PE	24PHTXXX	Sensors: Materials, Fabrication & Applications	3-0-0	3
7.	PE	24PHTXXX	Introduction to Bio-inspired and bio-mimetic materials	3-0-0	3
8.	PE	24PHTXXX	Soft Materials	3-0-0	3
9.	PE	24PHTXXX	Solar Energy and Physics of solar cells	3-0-0	3
10.	PE	24PHTXXX	Nanoscience and nanofabrication	3-0-0	3
11.	PE	24PHTXXX	Magnetic Memory Devices	3-0-0	3
12.	PE	24PHTXXX	Fundamentals of Energy Materials and Devices	3-0-0	3
13.	PE	24PHTXXX	Introduction to 3D Printing Technology	3-0-0	3

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DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PC	24PHTXXX	Electromagnetic Theory	3	3	0	0	0

PREREQUISITE
None

COURSE OBJECTIVE(s)
This course aims to gain a deep understanding of the fundamental principles governing electrostatics, magnetostatics, and electrodynamics. Also, students learn how to develop problem-solving skills to analyze and solve complex problems in various practical scenarios, including applications in engineering, physics, and other fields.

COURSE OUTCOMES:

CO1	To understand the fundamental laws governing electric and magnetic fields.
CO2	Apply mathematical tools to analyze and solve electrodynamics problems.
CO3	Apply the knowledge of electrostatics, magnetostatics, and electrodynamics to real-world engineering 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

Overview of Electrostatics, Poisson and Laplace's equations, Boundary conditions and Uniqueness theorems, Electrostatic boundary value problems, Method of images, Multipole expansion, Approximate potentials at large distances, Electric field of a dipole, Polarization, field of a polarized object, Bound charges and its physical interpretation, Gauss's law in dielectrics and boundary conditions, Susceptibility, Permittivity, Applications of dielectric materials in capacitor.

(No. of lectures- 13)

Overview of Magnetostatics, Magnetization, Effect of a Magnetic Field on Atomic Orbits, Field of a Magnetized Object, Bound currents, Physical Interpretation of Bound Currents, Magnetic Field Inside Matter, Ampère's Law in Magnetized Materials, Magnetic Susceptibility and Permeability, Magnetic levitation.

(No. of lectures- 08)

Electromagnetic wave equation, Electromagnetic waves in vacuum, Energy and Momentum in Electromagnetic Waves, Electromagnetic waves in matter, Reflection and Transmission at normal and oblique incidence, Electromagnetic waves in conductors, Frequency dependence of permittivity, Wave guides, TE modes in a Rectangular Wave Guide, Optical fibers.

(No. of lectures- 08)

Scalar and vector potentials, Potential formulation of Maxwell's equations, Gauge transformations, Coulomb and Lorentz gauges, Retarded potentials, Dipole radiation, Electric dipole radiation, magnetic dipole radiation, Power radiated by a point charge, Introduction to antenna

(No. of lectures- 10)

TEXT BOOKS/ REFERENCE BOOKS: -

1. Introduction to Electrodynamics: David J. Griffiths, (Prentice Hall of India).
2. Classical Electrodynamics: J.D. Jackson, (John Wiley and Sons).
3. Elements of Electrodynamics: Matthew N. O. Sadiku (Oxford University Press)
4. Modern Electrodynamics, Andrew Zangwill (Cambridge University Press)
5. The Classical Theory of Fields: L.D. Landau, E.M. Lifshitz (Pergamon Press, Oxford).
6. Foundations of Electromagnetic Theory: J. Reitz and F.J. Milford (Addison-Wesley).
7. Electromagnetic Waves and Radiating Systems: E.C. Jordan (Prentice Hall of India).

Lecture Plan

Lecture No.	Topics to be covered
1	Overview of Electrostatics
2	Poisson and Laplace's equations
3	Boundary Conditions and Uniqueness theorems
4	Electrostatic boundary value problems
5	Method of images
6	Multipole expansion
7	Approximate potentials at large distances
8	Electric field of a dipole
9	Polarization, field of a polarized object
10	Bound charges and its physical interpretation
11	Gauss's law in dielectrics and boundary conditions
12	Susceptibility, Permittivity
13	Applications of dielectric materials in capacitor
14	Overview of Magnetostatics
15	Magnetization, Effect of a Magnetic Field on Atomic Orbits
16	Field of a Magnetized Object

17	Bound currents, Physical Interpretation of Bound Currents
18	Magnetic Field Inside Matter
19	Ampère's Law in Magnetized Materials
20	Magnetic Susceptibility and Permeability
21	Magnetic levitation
22	Electromagnetic wave equation
23	Electromagnetic waves in vacuum
24	Energy and Momentum in Electromagnetic Waves
25	Electromagnetic waves in matter
26	Reflection and Transmission at normal and oblique incidence
27	Electromagnetic waves in conductors
28	Frequency dependence of permittivity
29	Wave guides, TE modes in a Rectangular Wave Guide
30	Optical fiber
31	Scalar and vector potentials
32	Potential formulation of Maxwell's equations
33	Gauge transformations, Coulomb and Lorentz gauges
34	Retarded potentials
35	Dipole radiation, electric dipole radiation
36	Magnetic dipole radiation
37-38	Power radiated by a point charge
39	Introduction to antenna

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DEPARTMENT OF PHYSICS

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PC	24PHTXXX	Quantum Mechanics	3	3	0	0	0

PREREQUISITE COURSES
None

COURSE OBJECTIVES
Students will learn basic principles of Quantum Mechanics, and learn to study quantum mechanical systems

COURSE ASSESSMENT

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 - Inner product spaces and generalization to functions, operators, failures of classical physics, postulates of Quantum Mechanics, measurement process, uncertainty relations, Ehrenfest theorem and classical correspondence, continuity equation for probability **(No. of lectures-9)**

Simple one-dimensional quantum mechanical systems - Free particles, delta potential well, recap of particle in a box, scattering by a step barrier, harmonic oscillator using both Hermite polynomials and Dirac's method, Double well potential **(No. of lectures - 12)**

More complicated systems - Angular momentum eigenvalues and eigenstates, angular momentum in position basis, hydrogen atom, basic overview of spin and statistics potential **(No. of lectures - 11)**

Approximate methods - Variational method, time-independent non-degenerate perturbation theory potential **(No. of lectures - 7)**

TEXT / REFERENCE BOOKS

1. Principles of Quantum Mechanics (Second Edition), R. Shankar (Springer)
2. Introduction to Quantum Mechanics (Second Edition), D. J. Griffiths (Cambridge India)
3. Quantum Mechanics (Fourth Edition), Leonard Schiff (McGraw Hill Education)
4. Quantum Mechanics (Third Edition), Eugen Merzbacher (John Wiley & Sons)

Lecture Plan

Lecture No.	Topics to be covered
1	Inner product spaces and generalization to functions
2	Operators
3	Operators contd.
4	Failures of classical physics
5	Postulates of Quantum Mechanics
6	Postulates of Quantum Mechanics contd. - measurement process
7	Uncertainty relations
8	Ehrenfest theorem and classical correspondence
9	Continuity equation for probability
10	Free particles
11	Free particles contd.
12	Delta potential well
13	Delta potential well contd.
14	Recap of particle in a box
15	Scattering by an infinite step barrier
16	Scattering by an infinite step barrier contd. – interpretation of results
17	Scattering by a finite step barrier
18	Harmonic oscillator in energy basis (Dirac's method)
19	Harmonic oscillator in position basis (Hermite polynomials)
20	Harmonic oscillator – further discussion
21	Outlook
22	Angular momentum in one direction only
23	Angular momentum – general properties
24	Angular momentum – eigenstates and eigenvalues
25	Angular momentum in position basis
26	Angular momentum in position basis contd.
27	Hydrogen atom – setting up the problem
28	Hydrogen atom – energy states
29	Hydrogen atom – further discussion
30	Basic overview of spin and statistics, symmetric and anti-symmetric states
31	Energy-time uncertainty relation
32	Outlook
33	Variational Method
34	Variational Method – more examples
35	Perturbation theory (time independent, non-degenerate) – setting up
36	Perturbation theory (time independent, non-degenerate) - derivation
37	Perturbation theory (time independent, non-degenerate) - examples
38	Perturbation theory (time independent, non-degenerate) – more examples
39	Outlook

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DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PC	24PHTXX X	Condensed Matter Physics	3	3	0	0	0

PREREQUISITE – Quantum Mechanics

COURSE OBJECTIVE(s)
This course aims to equip the students with fundamental knowledge of condensed matter physics. To explain structural, electrical, and magnetic behavior of different types of condensed phases.

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

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

COURSE CONTENTS

Crystal Physics - Classification of condensed matter-crystalline and noncrystalline solids, bonding in solids - ionic, covalent and metallic solids, crystal symmetry, point groups, space groups, lattices and basis, typical crystal structures, reciprocal lattice, Brillouin zone, structure factor. Bragg's law of diffraction.

(No. of lectures- 10)

Lattice Vibrations and Thermal Properties - Monoatomic and diatomic lattices, normal modes of lattice vibration, phonons and density of states, dispersion curves, specific heat – classical, Einstein and Debye models. thermal expansion and thermal conductivity, normal and Umklapp processes.

(No. of lectures- 9)

Band theory of solids - Free electron theory of metals, density of states, origin of energy bands, Fermi energy, Bloch Theorem, Kronig-Penney Model, distinction between metals, semiconductors, and insulators, Intrinsic and extrinsic semiconductors and carrier concentration, Hall effect in metals and semiconductors. **(No. of lectures- 9)**

Magnetism - Introduction to magnetism, quantum theory of dia- and para-magnetism, magnetic ordering, Weiss molecular theory of ferromagnetism and anti-ferromagnetism. Introduction to superconductivity, Meissner Effect, concept of Cooper pairs, BCS theory, Type-I and Type-II superconductors.

(No. of lectures- 12)

TEXT/ REFERENCE BOOKS: -

1. Introduction to Solid State Physics, Kittel C, 8th Ed. (Wiley Eastern Ltd. (2004))
2. Solid State Physics, Ashcroft N M and Mermin N D, 2nd Ed. (Holt-Saunders (2004))
3. Solid State Physics, Hook J R and Hall H E (John Wiley and Sons (2001))
4. Magnetism in Condensed Matter, Blundell S (Oxford University press (2001))

Lecture Plan

Lecture No.	Topics to be covered
1	Introduction and background
2	Classification of condensed matter-crystalline and noncrystalline solids
3	Bonding in solids - Ionic, covalent and metallic solids
4	Bonding in solids - Ionic, covalent and metallic solids
5	Crystal symmetry, point groups and space groups
6	Lattices and basis
7	Typical crystal structures,
8	Introduction to reciprocal space and reciprocal lattice
9	Brillouin zone, structure factor
10	Bragg's law of diffraction
11	Monoatomic and diatomic lattices
12	Monoatomic and diatomic lattices
13	Normal modes of lattice vibration
14	Phonons, Density of states and dispersion curves
15	Specific heat – classical, Einstein and Debye models.
16	Specific heat – classical, Einstein and Debye models.
17	Thermal expansion, thermal conductivity.
18	Thermal expansion, thermal conductivity.
19	Normal and Umklapp processes
20	Free electron theory of metals
21	density of states
22	Origin of energy bands
23	Fermi energy,
24	Bloch Theorem, Kronig-Penney Model
25	distinction between metals, semiconductors, and insulators
26	Intrinsic and extrinsic semiconductors and carrier concentration
27	Hall effect in metals and semiconductors.
28	Introduction to magnetism
29	Introduction to magnetism
30	quantum theory of dia- and para-magnetism
31	quantum theory of dia- and para-magnetism
32	Weiss molecular theory of ferromagnetism and antiferromagnetism
33	Weiss molecular theory of ferromagnetism and antiferromagnetism
34	Introduction to superconductivity,
35	Meissner Effect
36	concept of Cooper pairs,
37	BCS theory
38	Type-I and Type-II superconductors.
39	Course revision

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DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PC	24PHTXX X	Advanced Physics Lab	3	0	0	6	0

COURSE OBJECTIVES

To impart knowledge of advanced experimental concepts and techniques in undergraduate Physics

COURSE CONTENTS

1. To study the temperature dependence of Hall coefficient of a given material.
2. To study the Gaussian nature of laser beams and carry out the diffraction experiments.
3. To study the speed of ultrasonic velocity in liquids and measure elasticity parameters.
4. To record a Frank Hertz curve for Mercury and measure the energy emission of free electrons in a gas filled triode.
5. To measure the magnetic susceptibility of paramagnetic solution by Quincke's method and to find the ionic molecular susceptibility and magnetic moment.
6. To determine the Curie temperature of a given solid and study the magnetic transition.
7. To study Bragg's law by microwave diffraction.
8. Low temperature electrical resistivity measurements of metals and semiconductors
9. To study the performance characteristics of an analog PID controller and measurement of Temperature using Temperature Sensors/RTD
10. To observe and measure the forces and torques acting on a magnetic dipole placed in an external magnetic field.
11. To investigate the magnetic force between two current carrying wires.
12. To measure permittivity and permeability of free space, and then calculate the speed of light.
13. Measurement of thin film thickness and optical constants using ellipsometry/quartz crystal oscillator.
14. Determination of crystallite size, and crystal structure by X-ray diffraction.
15. Determination of band gap of optical materials by UV-visible spectroscopy.
16. Measurement of pressure, strain and torque using strain gauge.
17. Measurement of speed using photoelectric transducers and compass
18. Measurement of angular displacement using Potentiometer.
19. To perform Fourier analysis of complex waves

TEXT BOOKS/ REFERENCE BOOKS: -

1. Introduction to Solid State Physics: C. Kittel, 7th Ed. (John Wiley and Sons)
2. Solid State Physics: N. Ashcroft and N.D. Mermin (Holt, Rinehart and Winston).
3. Solid State Physics: A.J. Dekker (Prentice Hall of India, New Delhi).

4. Magnetism in Condensed Matter: Stephen Blundel (Oxford Master Series in Condensed Matter Physics).
5. Purcell E., Electricity and Magnetism Berkeley Physics course, vol 2.
6. Sadiku M N O, Elements of Engineering Electromagnetics, Oxford University Press, 3rd Edition
7. Rangan C S, Sharma G R and Mani V S V, "Instrumentation Devices and Systems", 2nd Ed., Tata McGraw-Hill (2008)
8. Anand M M S, "Electronic Instruments and Instrumentation Technology", Pearson Education (2008).

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DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Surface Physics and Engineering	3	3	0	0	0

PREREQUISITE – Condensed matter physics

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. In the later sections, students would know about the different surface characterization techniques and applications of surfaces. 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.

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- Introduction to surfaces and interfaces and their importance, from solid to surface, Gibbs adsorption equation, surface tension and surface energy, morphology and structure of surfaces, reciprocal lattice of the surface, surface relaxation and reconstruction, surface defects, surface creation; surface cleaning, adsorption (physisorption & chemisorption), desorption.

(No. of lectures - 10)

Surface modifications and characterization techniques- Thermodynamics and kinetics of thin film growth, Surface Reactions: Catalysis, Crystal Growth, Chemical Reactions & Nucleation, Homogeneous nucleation kinetics, Thin Film Deposition and Surface modifications by physical vapour deposition, chemical vapour deposition, Advanced Surface Modification Practices, Auger Electron Spectroscopy, X-ray Photoelectron Spectroscopy, Secondary Ion Mass spectroscopy, Scanning Probe Microscopy: Scanning Tunnelling Microscopy, Atomic Force Microscopy, Surface structure determination by electron diffraction (LEED, RHEED).

(No. of lectures - 14)

Surfaces engineering applications- Surface coatings, Functional Coatings, Advanced Coating Practices, Applications of Nano-coatings, mechanical, physical, chemical and other properties nanostructured coatings, tribology & Its Classification, types and laws of friction, methods to control friction, Wear & Corrosion, Lubrication, Effect of Tribology on Surface of Nanomaterials, hard coatings and hardness measurements, optical applications of surfaces, Catalytic applications of surfaces, electrochemical and energy applications of nanomaterials. Semiconducting surfaces applications. Bio applications of surfaces. **(No. of lectures - 15)**

TEXT/ REFERENCE BOOKS: -

1. Surface Science- An Introduction, K Oura (Springer).
2. Surface Analysis: The Principal Techniques, John C. Vickerman, Ian S. Gilmore (Wiley).
3. Materials Degradation and its control by surface engineering, Imperial College Press, (2006)
4. Materials and Surface Engineering in Tribology, Willey (2007), London A W Batchelor et al.
5. Physics of Surfaces and Interfaces, Haralad Ibach (Springer).
6. Surface engineering in metals, CRC Press (1999) London
7. Solid Surfaces, Interfaces and Thin Films, Hans Luth (Springer).

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction to surfaces and interfaces
2.	Surfaces and Interfaces and their importance
3.	Morphology and Structure of Surfaces
4.	Basics of Scanning Tunneling Microscopy
5.	Surface relaxation
6.	Surface reconstruction
7.	Surface Defects (line and point defects)
8.	Surface Creation; Surface cleaning
9.	Physisorption & Chemisorption
10.	Desorption
11.	Significance of vacuum for surface studies
12.	Vacuum pumps and vacuum gauges
13.	Diffusion and surface-controlled growth
14.	Fundamentals of thin film growth
15.	Surface modifications by physical and chemical routes
16.	Introduction to electron spectroscopies
17.	Electron energy analysers
18.	Auger Electron Spectroscopy
19.	X-ray Photoelectron Spectroscopy
20.	X-ray Photoelectron Spectroscopy
21.	Secondary Ion Mass spectroscopy
22.	Surface structure determination by LEED and RHEED
23.	Scanning Probe Microscopy (Scanning Tunneling Microscopy)
24.	Scanning Probe Microscopy (Atomic Force Microscopy)
25.	Surface coatings

26.	Functional Coatings
27.	Advanced Coating Practices
28.	Properties nanostructured coatings
29.	Applications of Nano-coatings
30.	Optical applications of surfaces
31.	Semiconducting surfaces applications
32.	Catalytic applications of surfaces
33.	Electrochemical and energy applications of nanomaterials
34.	Bio applications of surfaces
35.	Mechanical applications of coatings (tribology & Its Classification)
36.	Hard coatings and hardness measurements techniques
37.	Wear & Corrosion, lubrication
38.	Effect of Tribology on Surface of Nanomaterials
39.	Types and laws of friction, methods to control friction

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DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Materials Science and Engineering	3	3	0	0	0

PREREQUISITE – Quantum Mechanics, Condensed Matter Physics

COURSE OBJECTIVE(s)

This course aims to provide the students an introduction to materials science and engineering, including real world applications and problems.

COURSE ASSESSMENT

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

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

COURSE CONTENTS

Classification of engineering materials, imperfections in crystals -point & linear defects, dislocations and their properties, surface imperfections, grain size determination

(No. of lectures- 06)

Diffusion in solids- Diffusion mechanisms, steady state diffusion, nonsteady state diffusion, applications based on second low of diffusion, atomic model of diffusion, factors affecting diffusion

(No. of lectures- 06)

Phase diagrams & phase transformations- solubility limit, phases & phase rule, binary isomorphous systems, interpretation of phase diagrams, binary eutectic systems, eutectoid & peritectic reactions, some typical phase diagrams, kinetics of phase transformations, nucleation & growth, applications.

(No. of lectures- 12)

Structure & properties of ceramics, crystal structures, silicates, imperfections diffusion, applications and processing of ceramics: classification of polymers, addition & condensation polymerization, degree of polymerization, thermoplastic & thermosetting polymers, defects in polymers, effect of temperature, polymer processing & recycling. **(No. of lectures- 09)**

Corrosion & degradation of materials- electrochemical properties, mechanisms of corrosion, corrosion rates, passivity, forms of corrosion, corrosion environments & corrosion preventions, oxidation, degradations in ceramics and polymers. **(No. of lectures- 06)**

TEXT/ REFERENCE BOOKS:-

1. Materials Science and Engineering, V. Raghavan, PHI
2. Materials Science and Engineering An Introduction, William D. Callister, Jr, Wiley
3. Essentials of Materials Science and Engineering, Donald R. Askeland & Pradeep P. Phule, CENGAGE Learning

Lecture Plan

Lecture No.	Topics to be covered
1.	Classification of engineering materials
2.	imperfections in crystals -point & linear defects
3.	dislocations and their properties
4.	dislocations and their properties
5.	surface imperfections
6.	grain size determination
7.	Diffusion in solids- Diffusion mechanisms,
8.	steady state diffusion
9.	nonsteady state diffusion,
10.	applications based on second low of diffusion
11.	atomic model of diffusion
12.	factors affecting diffusion
13.	Introduction, solubility limit
14.	phases & phase rule,
15.	binary isomorphous systems
16.	interpretation of phase diagrams,
17.	binary eutectic systems
18.	binary eutectic systems
19.	binary eutectic systems
20.	eutectoid & peritectic reactions
21.	some typical phase diagrams
22.	kinetics of phase transformations

23.	nucleation & growth
24.	applications
25.	Structure & properties of ceramics,
26.	crystal structures, silicates
27.	imperfections diffusion
28.	applications and processing of ceramics
29.	classification of polymers
30.	addition & condensation polymerization, degree of polymerization
31.	thermoplastic & thermosetting polymers
32.	defects in polymers, effect of temperature
33.	polymer processing & recycling
34.	electrochemical properties
35.	mechanisms of corrosion, corrosion rates
36.	passivity, forms of corrosion
37.	corrosion environments & corrosion preventions
38.	oxidation,
39.	degradations in ceramics and polymers

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DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	LabVIEW for Beginners	3	2	0	2	0

PREREQUISITE – None

COURSE OBJECTIVE(s)

After completing this course, the student should be able to write LabVIEW code to simulate or analyze their data. Students should be able to interface various instruments to acquire data. In addition, they will be able to design/write LabVIEW code to perform an experiment according to their/industry requirements. It will reduce the dependence on commercially available software because many times, these commercially available software does not provide the data acquisition options according to the requirements of the users.

COURSE ASSESSMENT

The Course Assessment (culminating in 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 of the LabVIEW, Graphical Programming Language, LabVIEW Environment, Components of Virtual Instruments, Data flow in LabView, Controls, Indicators, and Function Palettes. **(No. of lectures- 6)**

Simple Algorithm, Creating VI, Debugging the Errors, Structures and Loops, Decision-Making Algorithm, Math Script, and Sequence. **(No. of lectures- 4)**

Arrays, Clusters, Conversion of Arrays to Cluster and Matrix, Conversion of Clusters and Matrix to Arrays; String, Modular programming and sub-Vis, Charts and Graphs.

(No. of lectures- 8)

Input and Out Files handling, Simulating Signals and Analyzing the input Signals, Instrument Interfacing and Data Acquisition, Hands-on Practice: Interfacing and Data Acquisition from Various Lab Instruments. **(No. of lectures- 8)**

TEXT BOOKS / REFERENCE 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).
5. Lab View User Manual, National Instruments (NI)

Lecture Plan

Lecture No.	Topics to be covered
1	What is LabVIEW
2	LabVIEW Environment and Creating New VI
3	Components of Virtual Instruments
4	Data flow in LabView
5	Controls, Indicators
6	Function Palettes
7	Simple Algorithm, Creating VI, and Debugging the Errors
8	Structures and Loops
9	Decision-Making Algorithm
10	Math Script and Sequence
11-12	Arrays and Clusters
13	Conversion of Arrays to Cluster and matrix
14	Conversion of Clusters and Matrix to Arrays
15	String
16-17	Modular programming and sub-Vis
18	Charts and Graphs.
19	Input and Out Files handling,
20-21	Simulate Signals
22-24	Analyze the input Signals
25	Introduction to Data Acquisition
26	Interfacing Instruments

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DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Particle Detector and its Technology	3	3	0	0	0

PREREQUISITE – Particle Detector and Technology

COURSE OBJECTIVE(s)

This course aims to equip the students with fundamental knowledge of Particle Detector and Technology.

COURSE ASSESSMENT

The Course Assessment (culminating in 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

Overview of the detector technology used in particle physics experiments starting from the Rutherford scattering experiment to the present world's largest experiments at the Large Hadron Collider (LHC), basic concept of energy loss by excitation and ionization, Bethe-Bloch formula, density effects, mean energy loss as a function of velocity, fluctuations in energy loss, interaction of electrons with matter: Bremsstrahlung, interaction of photon with matter: photo-electric effect, Compton scattering, pair production. **(No. of lectures- 6)**

Fundamental physics principle of particle detectors: ionization and excitation, construction, working, and operational characteristics of particle detectors: gaseous detectors, ionization chambers, proportional counters, drift chambers, bubble chambers, semiconductor detectors: introduce silicon detectors technology, pixel and strip detectors, CCDs, electromagnetic calorimetry, hadronic calorimetry, general characteristics of particle detectors, development of a detector system concepts. **(No. of lectures- 11)**

Signal formation, electronic noise, optimization of signal-to-noise ratio, pulse processing electronics, amplification, applications: position, tracking, and energy measurements in modern particle physics experiments, radiation detection in space applications: advanced space radiation detector technology at NASA, radiation detectors for medical imaging: beam monitoring and 3D imaging, nuclear techniques for material analysis.

(No. of lectures- 9)

TEXTBOOKS/ REFERENCE BOOKS: -

1. Techniques for Nuclear and Particle Physics Experiment: W. R. Leo (Springer).
2. Radiation Detection and Measurement: Glenn F. Knoll (Wiley).
3. Particle Detectors: Claus Grupen and Boris Schwartz (Cambridge University Press).
4. Physics of Particle Detectors: Dan Green (Cambridge University Press).
5. Evaluation of Silicon sensor technology in particle physics: Frank Hartmann (Springer).
6. Semiconductor Radiation Detectors, Device Physics: Gerhard Lutz (Springer).
7. Handbook of Particle Detection and Imaging: Grupen, Claus, Buvat, Irene (Springer).

Lecture Plan

Lecture No.	Topics to be covered
1.	Overview of the detector technology used in particle physics experiments, starting from the Rutherford scattering experiment to the present world's largest experiments at the Large Hadron Collider (LHC)
2.	Basic concept of energy loss by excitation and ionization
3	Bethe-Bloch formula, density effects, mean energy loss as a function of velocity, fluctuations in energy loss
4.	interaction of electrons with matter: Bremsstrahlung
5.	interaction of photon with matter: photo-electric effect, Compton scattering
6.	pair production.
7.	Fundamental physics principle of particle detectors: ionization and excitation
8.	construction, working, and operational characteristics of particle detectors: gaseous detectors
9.	ionization chambers
10.	proportional counters
11	drift chambers
12	bubble chambers
13	semiconductor detectors: introduce silicon detector technology
14	pixel and strip detectors, CCDs
15	electromagnetic calorimetry, hadronic calorimetry
16	general characteristics of particle detectors
17	development of a detector system concept

18.	Signal formation, electronic noise
19.	optimization of signal-to-noise ratio
20.	pulse processing electronics, amplification
21.	applications: position, tracking
22.	energy measurements in modern particle physics experiments
23.	radiation detection in space applications: advanced space radiation detector technology at NASA
24.	radiation detectors for medical imaging: beam monitoring and 3D imaging
25.	radiation detectors for medical imaging: beam monitoring and 3D imaging
26.	nuclear techniques for material analysis

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Cours e Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Problem Solving in Physics with Python	3	2	0	2	0

PREREQUISITE –

COURSE OBJECTIVE(s)

This course aims to equip the students with Python Programming and how to solve Physics problems 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

Overview on the open sources for Python, for example Jupyter notebook, Google Colab etc. variables and Data Types, string: methods and manipulation, logical operators and conditional statements **(No. of lectures- 7)**

Loops: for loop, nested for loops, the While loops.
Collections: tuples, dictionaries, nested data structures , functions (default and user defined), modules in Python: math module, random module, errors. **(No. of lectures- 8)**

Introduction to Plotting (Graphs) in Python with Matplotlib, a brief Introduction to the Numpy Module: Numpy arrays and lists, representing matrices and matrix multiplication, matrices and linear systems, solving problems of physics using Python functions and modules, differential equations, Monte Carlo techniques. **(No. of lectures- 11)**

TEXT BOOKS/ REFERENCE BOOKS: -

1. Python from the Very Beginning, John Whitington, ISBN-13: 978-0-9576711-5-7 238 Pages (Second edition, May 2023).

2. Python Machine Learning - Second Edition, Sebastian Raschka , Vahid Mirjalili
3. Introduction to Machine Learning with Python, Andreas C. Müller & Sarah Guido
4. John R. Taylor. An Introduction to Error Analysis. University Science Books, 2 edition, 1997.
5. Shai Vaingast. Beginning Python Visualization: Crafting Visual Transformation Scripts. Apress, 2009.
6. Tao Pang. An Introduction to Computational Physics. Cambridge University Press, 2nd edition, 2006.

Lecture Plan

Lecture No.	Topics to be covered
1	Overview on the open sources for Python, for example Jupyter notebook, Google Colab etc
2	Variables and Data Types
3-4	Variables and Data Types
5-7	String :Methods and Manipulation Logical operators and Conditional Statements
8	Loops
9	Tuples
10	Dictionaries
11	Nested Data Structures
12	Functions
13	Math Module
14	Random Module
15	Errors
16-17	Introduction to Plotting (Graphs) in Python with Matplotlib
18-19	A brief Introduction to the Numpy Module: Numpy arrays and lists
20-22	Representing matrices and matrix multiplication, Matrices and linear systems
23-24	Solving problems of physics using Python functions and modules
25	Differential equations
26	Monte Carlo Techniques

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DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Sensors: Materials, Fabrication & Applications	3	3	0	0	0

PREREQUISITE

Basic understanding of sensors

COURSE OBJECTIVE(s)

These objectives aim to provide students with an overview of sensor fabrication and its application in various fields.

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 on assignments, quizzes, and attendance)	20%
b)	Mid-term examination	30%
c)	End Semester Examination	50%

COURSE CONTENTS

Functional elements of a measurement system and instruments, Types of measured Quantities, General concepts and terminology of Sensor systems, Transducers classification-sensors and actuators, Importance of nanoscale materials for sensing applications, Approaches used for characterizing sensors based nanomaterials, Approaches used for tailoring nanomaterials for a specific sensing application, Metallic and semiconductor nanoparticles, Optical, mechanical and chemical sensors based on nanomaterials, Hybrid nanomaterial-based sensors. **(No. of lectures: 10)**

Role of Wearables, Attributes of Wearables, The Meta Wearables – Textiles and clothing, Social Aspects: Interpretation of Aesthetics, Adoption of Innovation, On-Body Interaction; Case Study: Google Glass, health monitoring, Wearables: Challenges and Opportunities. Motivation for the development of Wearable Devices, The emergence of wearable computing and wearable electronics, Types of wearable sensors: Invasive, Non-invasive; Intelligent clothing, **(No. of lectures: 08)**

Fabrication of interdigitated (IDE) electrodes, choice of substrate, sensing film; Wearable Bioelectric impedance devices for Galvanic skin response; Basic Measurement set-up, electrodes, and instrumentation; Materials for Microfluidic Devices-Silicon, Glass, Polymer. Disposable smart lab-on-a-chip sensors **(No. of lectures: 06)**

Wearable Biochemical Sensors: Parameters of interest, System Design –Textile based, Microneedle based; Types: Noninvasive Glucose Monitoring Devices; Pulse oximeter, Portable Pulse Oximeters, wearable pulse oximeter; Wearable capnometer for monitoring of expired carbon dioxide. Wearable gas sensors: Metal Oxide (MOS) type, electrochemical type, new materials-CNTs, graphene, eolites; Detection of atmospheric pollutants. **(No. of lectures: 08)**

Wearable Blood Pressure (BP) Measurement: Cuff-based sphygmomanometer, Cuffless Blood Pressure Monitor. Study of flexible and wearable Piezoresistive sensors for cuffless blood pressure measurement. Wearable sensors for Body Temperature: Intermittent and Continuous temperature monitoring, Detection principles – thermistor, infrared radiation. Knitted Piezoresistive Fabric (KPF) sensors. Sensor Design and Packaging: Partitioning, Layout, technology constraints, scaling, compatibility study. **(No. of lectures: 07)**

TEXT/ REFERENCE BOOKS: -

1. Instrumentation, Measurement and Analysis, Nakra & Choudhury (Tata McGraw)
2. Hand Book of Modern Sensors: physics, Designs and Applications, Jacob Fraden (Springer)
3. Wearable Sensors: Fundamentals, Implementation and Applications, Sazonov and Neuman (Elsevier)
4. Wearable Electronics Sensors-For Safe and Healthy Living, S. C. Mukhopadhyay (Springer)

<u>**Lecture Plan**</u>

Lecture No.	Topics to be covered
1	Functional Elements of a Measurement System and Instruments
2	Applications and Classification of Instruments
3	Types of measured Quantities
4	General concepts and terminology of Sensor systems
5	Transducers classification-sensors and actuators,.
6	Importance of nanoscale materials for sensing applications
7	Approaches used for tailoring nanomaterials for a specific sensing application
8	Metallic and semiconductor nanoparticle
9	Optical, mechanical and chemical sensors based on nanomaterials
10	Hybrid nanomaterial-based sensors
11	Role amd Attributes of Wearables
12	The Meta Wearables – Textiles and clothing
13	Social Aspects: Interpretation of Aesthetics, Adoption of Innovation,

14	Case Study: Google Glass, health monitoring
15	Wearables: Challenges and Opportunities.
16	Motivation for the development of Wearable Devices
17	The emergence of wearable computing and wearable electronic
18	Types of wearable sensors: Invasive, Non-invasive; Intelligent clothing
19	Fabrication of interdigitated (IDE) electrodes
20	Choice of substrate, sensing film
21	Wearable Bioelectric impedance devices for Galvanic skin response
22	Basic Measurement set-up, electrodes, and instrumentation
23	Materials for Microfluidic Devices
24	Disposable smart lab-on-a-chip sensors
25	Wearable Biochemical Sensors: Parameters of interest
26	System Design –Textile based, Microneedle based
27	Noninvasive Glucose Monitoring Devices; Pulse oximeter,
28	Portable Pulse Oximeters, wearable pulse oximeter;
29	Wearable capnometer for monitoring of expired carbon dioxide.
30	Wearable gas sensors: MOS type
31	Electrochemical type
32	Detection of atmospheric pollutants.
33	Wearable Blood Pressure (BP) Measurement
34	Study of flexible and wearable Piezoresistive sensors
35	Wearable sensors for Body Temperature
36	Detection principles – thermistor, infrared radiation
37	Knitted Piezoresistive Fabric (KPF) sensors.
38	Sensor Design and Packaging (cont)
39	Sensor Design and Packaging

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DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Introduction to Bio-inspired and bio-mimetic materials	3	0	0	0	0

PREREQUISITE – Basic knowledge of biology, materials science, and engineering principles is required to comprehend the course material effectively.

COURSE OBJECTIVE(s)
This course aims to gain insight into biological and bioinspired materials, nanotechnology, and tissue engineering, with a focus on understanding design principles and applications in varios fields inspired from nature.

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 biological and bio inspired materials, biomimetic and bioinspired engineering, inspiration from nature, bio-inspired designs, biological engineering principles, basic building blocks found in biological materials, adhesive surfaces, gecko inspired adhesion, lotus surface, nature against nature: repellency against adhesion, bio-inspired nanostructures, biosensors

(No. of lectures- 12)

Introduction to nanotechnology, surface engineering, bio-inspired nanoparticles, biological membranes, polymer-reinforced and ceramic-toughened composites, lightweight biological and bioinspired materials, bio-functional interfaces, components of a bio-functional interface and fabrication, biocompatibility vs. bio-functionality, bio-inspired functional interfaces, characterization of bio-functional interfaces **(No. of lectures- 14)**

Introduction to tissue engineering, bio-inspired scaffolds for tissue engineering, self-healing and adaptive materials, bio-sensing, components of a biosensor, nature-inspired sensing, drug delivery, smart targeted drug delivery, micro and nano robots, lab-on-chip devices, examples of bio-inspired lab on chip devices, examples of organs on chips, modelling diseases on a chip

(No. of lectures- 13)

TEXT/ REFERENCE BOOKS:-

1. Bio and bioinspired nanomaterials: Daniel Ruiz-Molina, F. Novio, C. Roscini (WileyVCH).
2. Bioinspired approaches for human-centric technologies: Roberto Cingolani (Springer).
3. Biological materials science: M. A. Meyers and P-Y. Chen (Cambridge).
4. Biomimetics, biologically inspired technologies: Yoseph Bar-Cohen (Taylor and Francis).
5. Materials design inspired by nature: P. Fratzl, J. W. C. Dunlop and R. Weinkamer (RSC).
6. Nanobiotechnology: Oded Shoseyov and Ilan levy (Human Press).

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction to biological material
2.	Introduction to bio inspired material
3.	Biomimetic and bioinspired engineering
4.	Examples for inspiration from nature
5.	Bio-inspired designs,
6.	Biological engineering principles
7.	Basic building blocks found in biological materials
8.	Adhesive surfaces, gecko inspired adhesion
9.	Lotus surface properties and inspiration
10.	Nature against nature: repellency against adhesion
11.	Bio-inspired nanostructures
12.	Biosensors
13.	Introduction to nanotechnology
14.	Surface engineering
15.	Bio-inspired nanoparticles
16.	Biological membrane
17.	Synthetic membranes having similar function as biological membranes
18.	Polymer-reinforced composites
19.	Ceramic-toughened composites
20.	Lightweight biological and bioinspired materials
21.	Bio-functional interfaces
22.	Components of a bio-functional interface and fabrication
23.	Biocompatibility vs. bio-functionality
24.	Bio-inspired functional interfaces,
25.	Characterization of bio-functional interfaces (Cont)

26.	Characterization of bio-functional interfaces
27.	Introduction to tissue engineering
28.	Bio-inspired scaffolds for tissue engineering (Cont)
29.	Bio-inspired scaffolds for tissue engineering
30.	Self-healing and adaptive materials
31.	Components of a biosensor
32.	Nature-inspired sensing
33.	Drug delivery
34.	Targeted drug delivery
35.	Micro and nano robots
36.	Lab-on-chip devices
37.	Examples of bio-inspired lab on chip devices
38.	Examples of organs on chips
39.	Modelling diseases on a chip

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DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Soft Materials	3	3	0	0	0

PREREQUISITE – Basic knowledge of materials science, particularly in polymers and colloidal systems, is recommended.

COURSE OBJECTIVE(s)
This course provides an introduction to the fundamental principles, properties, and applications of soft materials including their classification and unique properties, and explore the transition from hard to soft building blocks in colloidal systems.

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)**

TEXT/ REFERENCE 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)
6. Soft materials: structure and dynamics: John R. Dutcher, A. G. Marangoni (CRC)

Lecture Plan

Lecture No.	Topics to be covered
1	Introduction to soft materials and soft matter
2	Generic aspects of soft materials
3	Classifications of soft materials
4	Introduction of Colloids
5	Introduction of polymers
6	Introduction of liquid crystals
7	Introduction of micelles and vesicles
8	Introduction of biological membranes
9	Responsive nanomaterials
10	Self-healing, Hybrid nanoparticles
11	Hard building blocks
12	Soft building blocks
13	Synthesis of hard and soft colloids
14	Hard systems
15	Softer systems
16	Dispersion forces
17	Surface and interfacial organization
18	Polymers in solution
19	Gels, emulsions and foams
20	Block copolymers,
21	Soft lithography and micro molding
22	Controlled drug delivery
23	Biomimetic engineering
24	Flexible and wearable electronics (Cont)
25	Flexible and wearable electronics
26	Organic Electronics
27	Soft robotics
28	Soft Electronics Fabrication Approaches (cont)
29	Soft Electronics Fabrication Approaches
30	General trends in soft nanomaterials research

31	Wearables: Challenges and Opportunities.
32	Motivation for the development of Wearable Devices
33	The emergence of wearable computing and wearable electronic
34	Types of wearable sensors: Invasive, Non-invasive; Intelligent clothing
35	Wearable chemiresistive Sensors
36	Wearable biochemical Sensors
37	Detection of atmospheric pollutants
38	Wearable devices for health monitoring (Cont)
39	Wearable devices for health monitoring

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DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Solar Energy and Physics of solar cells	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
d)	Internal assessment (based upon assignments, quizzes and attendance)	20%
e)	Mid-term examination	30%
f)	End Semester Examination	50%

COURSE CONTENTS

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, photo thermal conversion, types of solar energy collectors, solar fuels: electrolysis of water, photoelectrochemical splitting of water.

(No. of lectures - 10)

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 - 9)

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, PV modules, systems, and reliability, Cost, Price, Markets, & Support Mechanisms, R&D Investment & Innovation in PV.

(No. of lectures - 10)

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

Lecture Plan

Lecture No.	Topics to be covered
1	Introduction to the course syllabus
2	Solar constant, spectral distribution of solar radiation
3	Absorption of solar radiation in the atmosphere
4	Seasonal and daily variation of solar radiation
5	Measurement of solar irradiation, global and diffused radiation
6	Solar to thermal energy conversion, Solar to thermal to electrical energy conversion
7	Solar fuels: hydrogen, Hydrogen production processes
8	Hydrogen generation: Electrolysis of water, Photoelectrochemical (PEC) splitting of water
9	Fundamentals of solar cells: photo voltaic effect
10	p-n junction photodiodes, Depletion region, electron and holes transports
11	Absorption of photons

12	Surface structures for maximum light absorption
13	Thermalization losses
14	Concept of multijunction solar cells
15	Excitons and photoemission of electrons
16	Semiconductor band engineering
17	Charge carrier generation and transport
18	Charge separation
19	Recombination and other losses, and time constants
20	I-V characteristics of a diode: under dark and illumination
21	Output power, types of efficiencies
22	Fill factor and optimization for maximum power
23	Metal-semiconductor junctions
24	Operating temperature vs conversion efficiency
25	Introduction to device physics: Device structures
26	Introduction to device physics: Device construction
27	Solar cell properties and design
28	Materials for solar cells
29	Thin film materials: choices and manufacturing
30	PV efficiency: measurement and theoretical limits
31	Solar cell characterization
32	Silicon based solar cells: single crystal, polycrystalline and amorphous silicon solar cells
33	Advanced concepts in photovoltaic research: Organic solar cells, organic-inorganic hybrid solar cells
34	Advanced concepts in photovoltaic research: perovskite based solar cells
35	Nanotechnology applications and quantum dots
36	PV modules, systems, and reliability
37	Cost, Price, Markets, & Support Mechanisms
38	R&D Investment & Innovation in PV
39	Review of the classes, resolving queries, and conclusion

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DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Nanoscience and nanofabrication	3	3	0	0	0

PREREQUISITE – Quantum Mechanics, Condensed Matter Physics

COURSE OBJECTIVE(s)

This course aims to equip the students with fundamental knowledge of nanoscience and nanotechnology topics. To explain structural, electrical, and magnetic properties of different types of nanostructures. The fabrication process for nanostructures and micro-nano devices.

COURSE ASSESSMENT

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

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

COURSE CONTENTS

Physical Properties of Nanomaterials - effect of size on thermal, electrical, mechanical, optical and magnetic properties of nanoscale materials, diffusion properties, dielectric properties, Surface area to aspect ratio, quantum confinement size effects, bang gap effect at nanoscale.

(No. of lectures- 10)

Synthesis of Nanomaterials - The principles of nucleation and growth, thermodynamics, kinetics, and mechanisms of Nucleation and Growth of nanocrystals, crystallography, surfaces and Interfaces, Applications to growth from solutions, melts and vapors. **(No. of lectures- 8)**

Nano Fabrication - Introduction to micro/nano fabrication, photolithography, x-ray lithography, e-beam lithography, nanoimprint lithography, stamping techniques for micro/nano fabrication, methods and applications of lithographic techniques.

(No. of lectures- 9)

AFM based nanolithography, Dip-Pen Lithography (DPN) and nanomanipulation, self-assembly, template-based growth of nanorod arrays, 3D nanofabrication using focused ion beam (FIB), MEMS and NEMS, nano and micro-structured semiconductor materials for microelectronics.

(No. of lectures- 12)

TEXT/ REFERENCE BOOKS: -

1. The Physics and Chemistry of Nano Solids, Frank J. Owens and Charles P. Poole, Wiley-Interscience, 2008
2. Nanomaterials: An Introduction to Synthesis, Properties and Applications, Dieter Vollath, John Wiley and Sons, 2013
3. The Chemistry of Nanomaterials: Synthesis, Properties and Applications, C. N. R. Rao, Achim Mller, A. K. Cheetham, John Wiley and Sons 2007
4. Fabrication Engineering at the Micro- and Nanoscale, Stephen A. Campbell, 4th Edition. Oxford University Press 2012
5. Microchip Fabrication, P. V. Zant, McGraw-Hill Education; 5th edition 2004
6. Enabling technology for MEMS and Nanodevices, H. Baltes et al, Wiley-VCH, 2008

Lecture Plan

Lecture No.	Topics to be covered
1	Introduction and background
2	Physical Properties of Nanomaterials
3	Effect of size on thermal, electrical properties of nanoscale materials
4	Effect of size on thermal, electrical properties of nanoscale materials
5	mechanical properties of nanoscale materials
6	optical properties of nanoscale materials
7	magnetic properties of nanoscale materials
8	diffusion properties, dielectric properties
9	Surface area to aspect ratio, Quantum confinement size effects
10	bang gap effect at nanoscale
11	Synthesis of Nanomaterials overview
12	The principles of nucleation and growth
13	thermodynamics, kinetics, and mechanisms of Nucleation and Growth
14	crystallography, surfaces and Interfaces
15	crystallography, surfaces and Interfaces
16	Applications to growth from solutions, melts and vapors
17	Applications to growth from solutions, melts and vapors
18	Applications to growth from solutions, melts and vapors
19	Introduction to micro/nano fabrication
20	photolithography
21	x-ray lithography
22	e-beam lithography
23	nanoimprint lithography
24	stamping techniques for micro/nano fabrication
25	stamping techniques for micro/nano fabrication
26	methods and applications of lithographic techniques

27	methods and applications of lithographic techniques
28	AFM based nanolithography
29	Dip-Pen Lithography (DPN) and nanomanipulation
30	Dip-Pen Lithography (DPN) and nanomanipulation
31	self-assembly
32	template-based growth of nanorod arrays
33	3D nanofabrication using focused ion beam (FIB)
34	MEMS and NEMS
35	MEMS and NEMS
36	nano and micro-structured semiconductor materials for microelectronics
37	nano and micro-structured semiconductor materials for microelectronics
38	Course revision
39	Course revision

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DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Magnetic Memory Devices	3	3	0	0	0

PREREQUISITE – Condensed Matter Physics

COURSE OBJECTIVE(s)

Impart fundamentals knowledge to 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 magnetic recording, basics of magnetism, various forms of magnetic energies, hard and soft magnetic materials, magnetic anisotropies, exchange bias, spin relaxation mechanisms, concepts of spin detection and magnetic memory, magnetic domains and domain walls, single domain nano-particles. Materials for magnetic memory, thin magnetic films, particulate media, flexible media and rigid disk substrates, nanostructures for spin electronics.

(No. of lectures: 13)

Fundamental recording theory, media magnetization, erasure and overwrite, recording zone and losses, play back theory, magnetic head circuits, magnetoresistance, anisotropic magnetoresistance (AMR), giant magnetoresistance (GMR) heads, tunneling magnetoresistance (TMR) heads, field from magnetic heads, perpendicular head fields, flux linkage, and leakage.

(No. of lectures: 14)

High density data storage: MRAM, Savtchenko switching and toggle MRAM, ultra-high-density devices. Spin torque effect, current and spin transfer torque driven domain wall motion, race track memory, shift resistor, Q-bits and spin logic. **(No. of lectures: 12)**

TEXT/ REFERENCE BOOKS: -

1. Introduction to Magnetic Materials, B. D. Cullity and C. D. Grahm, Willey, 2009.
2. Magnetic Recording Technology, C.D. Mee and E.D. Daniel, McGraw-Hill Professional (1996).
3. Introduction to Spintronics, S. Bandyopadhyay, M. Cathay, CRC Press, 2008.
4. Magnetoelectronics, M. Johnson, Academic Press 2004.
5. The Physics of Ultra-high Density Magnetic Recording, Martin L. Plumer, Johannes Van Ek and D. Weller, Springer (2001).

Lecture Plan

Lecture No.	Topics to be covered
1	Introduction to the course syllabus
2	History and overview of magnetic recording
3	basics of magnetism, various forms of magnetic energies
4	hard and soft magnetic materials, magnetic anisotropies
5	exchange bias, spin relaxation mechanisms
6	concepts of spin detection and magnetic memory
7	magnetic domains and domain walls, single domain nano-particles
8	Materials for magnetic memory, thin magnetic films, particulate media
9	flexible media and rigid disk substrates, nanostructures for spin electronics
10	Fundamental recording theory
11	media magnetization, erasure and overwrite
12	recording zone and losses
13	play back theory, magnetic head circuits
14	magnetoresistance, anisotropic magnetoresistance (AMR)
15	giant magnetoresistance (GMR) heads
16	tunneling magnetoresistance (TMR) heads
17	field from magnetic heads, perpendicular head fields
18	flux linkage, and leakage
19	High density data storage: MRAM
20	Savtchenko switching and toggle MRAM
21	ultra-high density devices.
22	Spin torque effect,
23	current and spin transfer torque driven domain wall motion
24	race track memory
25	shift resistors
26	Q-bits and spin logic.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Fundamentals of 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
d)	Internal assessment (based upon assignments, quizzes and attendance)	20%
e)	Mid-term examination	30%
f)	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. electrodes and active materials, carbon and related electrodes, transparent conducting electrodes, 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 and catalyst design. basics of the photocatalytic mechanisms of water and other related systems, energy level diagram, photochemical cell designs, fabrication and performance analysis **(No. of lectures: 16)**

PV Working principle, device structure and assembly, broad classification of solar cells, important parameters in photovoltaics (describing J-V characteristics, spectral response-EQE & IQE), Shockley-Queisser limit, photon management), thin film solar cells: DSSC-oxides and dyes, pervoskites and tandem solar cells, fabrication processes, energy level diagrams, factors affecting the photovoltaic performance, exciton diffusion length, charge transport and band gap, typical characteristics and spectral response, technology limitations, comparison of the technologies.

(No. of lectures: 3)

Capacitor & supercapacitor, concept of EDLC, electrodes and electrolytes for supercapacitors, fabrication processes, 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 other batteries, battery components and design of electrodes, cell and battery fabrication, measurements- CD curves, priming & cycling, time scales, energy and power densities, charge retention, long term stability, comparison of performance, building supercap packs, voltage and current management, hybrid battery-supercap device, electric mobility.

(No. of lectures: 16)

Building block cells, battery modules and packs, voltage and current management, all solid-state batteries & new concepts in batteries beyond lithium, smart batteries; basic concepts of fuel-cells, types of fuel cells, fuels for fuel cell, catalysts, membranes fuel cell design.

(No. of lectures: 4)

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

Lecture Plan

Lecture No.	Topics to be covered
1	General introduction: Energy units, Energy requirements,
2	Natural sources, Renewable and nonrenewable sources
3	Types of energy devices-generation, storage, conversion and transport,
4	Concepts, definitions and essential performance parameters.
5	Electrodes and active materials, Carbon and related electrodes
6	Transparent conducting electrodes

7	Introduction to hydrogen as a green fuel
8	Hydrogen production technologies
9	Water splitting technologies for hydrogen and oxygen generation
10	Electrochemical water splitting; free energy adsorption, volcano plot, Basic reaction mechanism
11	Basics of the photocatalytic mechanisms of water and other related systems
12	Energy level diagram
13	Electrode design and electrode-electrolyte interface
14	Photochemical cell designs, Fabrication and performance analysis
15	Measurement modes: Cyclic voltammetry, Linear sweep voltammetry, Chronopotentiometry,
16	Impedance spectra, Tafel plot, Electrochemical cell design, Figures of merit.
17	PV Working principle, classification,
18	Shockley-Queisser limit, photon management
19	Thin Film Solar Cells
20	Typical characteristics and spectral response, Technology limitations, Comparison of the technologies
21	Capacitor & supercapacitor, Concept of EDLC
22	Pseudocapacitors
23	Electrodes and electrolytes for supercapacitors
24	Basic electrochemical concepts and definitions, Pseudo and asymmetric supercapacitors
25	Li-ion capacitors, comparison of performances and application areas
26	Fabrication processes
27	Primary and secondary batteries, Principle of operation
28	Conventional batteries, Li-ion and other batteries
29	Battery components and design of electrodes, cell and battery fabrication
30	Measurements- CD curves, priming & cycling, time scales, charge retention, coulombic efficiency, self-discharge & charge retention, long term stability
31	Ragone plot: energy and power densities, performance comparison
32	Introduction to Electrochemical Impedance Spectroscopy (EIS), Series and Parallel circuits, Nyquist plots
33	Hybrid battery-supercap device, electric mobility
34	Building block cells, battery and supercap modules and packs, Voltage and current management
35	All solid-state batteries & new concepts in Batteries beyond lithium

36	Basic concepts of fuel-cells
37	Types of fuel cells, Fuels for fuel cell
38	Catalysts, Membranes, Fuel cell design
39	Course review, resolving queries, and conclusion

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
PE	24PHTXXX	Introduction to 3D Printing Technology	3	2	0	2	0

PREREQUISITE – Engineering Drawing & Sketching

COURSE OBJECTIVE(s)

This course aims to impart students to the fundamentals of various 3D Printing Techniques for application to various industrial needs. Student will be able to convert part file into STL format and will understand the method of manufacturing of liquid based, powder based and solid based techniques.

COURSE ASSESSMENT

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

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

COURSE CONTENTS

Module I: Introduction

Introduction to Design, Prototyping fundamentals. Introduction to 3D printing, its historical development, advantages. Commonly used terms, process chain, 3D modelling, Data Conversion, and transmission, Checking and preparing, Building, Post processing, RP data formats, Classification of 3D printing process, Applications to various fields.

(no. of lectures- 10)

Module II: Liquid Based 3D Printing

Stereo lithography apparatus (SLA): Models and specifications, process, working principle, photopolymers, photo polymerization, layering technology, laser and laser scanning, applications, advantages and disadvantages, case studies. Solid ground curing (SGC): Models and specifications, process, working ,principle, applications, advantages and disadvantages, case studies.

(no. of lectures- 8)

Module III: Solid Based 3D Printing

Laminated object manufacturing (LOM): Models and specifications, Process, Working principle, Applications, Advantages and disadvantages, Case studies. Fused Deposition Modeling (FDM): Models and specifications, Process, Working principle, Applications, Advantages and disadvantages, Case studies, practical demonstration. **(no. of lectures- 8)**

Laboratory component:

Hands on exercises and fabrication of 3D objects using different types of 3D printers in the lab.

TEXT/ REFERENCE BOOKS: -

1. Chua C.K., Leong K.F. and LIM C.S Rapid prototyping: Principles an Applications, World Scientific publications, 3rd Ed., 2010
2. D.T. Pham and S.S. Dimov, Rapid Manufacturing, Springer, 2001
3. Terry Wohlers, Wholers Report 2000, Wohlers Associates, 2000
4. Paul F. Jacobs, Rapid Prototyping and Manufacturing–, ASME Press, 1996
5. Ian Gibson, Davin Rosen, Brent Stucker Additive Manufacturing Technologies, Springer, 2nd Ed, 2014

Lecture Plan

Lecture No.	Topics to be covered
1	Introduction to Design
2	Prototyping fundamentals
3	Introduction to 3D printing,
4	3D printing, its historical development, advantages
5	Commonly used terms
6	process chain, 3D modelling
7	Data Conversion, and transmission,
8	Checking and preparing, Building, Post processing RP data formats
9	Classification of 3D printing process
10	Applications to various fields.
11	Introduction to Stereo lithography apparatus (SLA)
12	Models and specifications process, working principle
13	photopolymers, photo polymerization layering technology
14	laser and laser scanning, applications
15	advantages and disadvantages, case studies
16	Solid ground curing (SGC): Models and specifications
17	working, principle, applications,
18	advantages and disadvantages, case studies.
19	Laminated object manufacturing (LOM)
20	Models and specifications, Process, Working principle
21	Models and specifications, Process, Working principle
22	Applications, Advantages and disadvantages, Case studies
23	Fused Deposition Modelling (FDM)
24	Models and specifications, Process, Working principle,
25	Applications, Advantages and disadvantages, Case studies
26	Applications, Advantages and disadvantages, Case studies