MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF PHYSICS

Syllabus of Open Electives for UG students

Sr. No.	Name of the Course	Credits
1.	Applied Quantum Mechanics for Engineers	3 (3 0 0)
2.	Introduction to Theory of Relativity and Cosmology	3 (2 1 0)
3.	Sensors: Materials, Fabrication & Applications	3 (2 1 0)
4.	Advanced Energy Materials and Systems	3 (3 0 0)
5.	Solar Energy and Photovoltaics	3 (3 0 0)

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
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DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
OE	26PHTXXX	Applied Quantum Mechanics for Engineers	3	3	0	0	0

PREREQUISITE – Engineering Mathematics, Basic concept of Quantum Mechanics

COURSE OBJECTIVE(s)
Introduce undergraduate engineering students to the principles of quantum mechanics with emphasis on applications. Provide conceptual clarity with manageable mathematical depth. Develop ability to apply quantum concepts to semiconductor devices, nanotechnology, and modern engineering 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
Fundamentals of Quantum Mechanics: Historical background, wave-particle duality, uncertainty principle, postulates of quantum mechanics, operators and eigenvalues, Dirac notation, Schrödinger equation basics, particle in a box, tunneling phenomena, harmonic oscillator (concepts only), hydrogen atom overview. **(No. of lectures: 12)**

Band Theory and Quantum Models in Materials: Introduction to band theory of solids, effective mass approximation, Kronig–Penney model, semiconductors, superconductors, nanostructures overview, quantum wells, wires, dots, density of states in low dimensions, optical transitions, and case studies in materials. **(No. of lectures: 15)**

Quantum Devices and Applications: Tunneling diodes, MOSFET quantum effects, quantum Hall effect (introductory), superconducting devices, Josephson junctions (conceptual), spintronics overview, quantum sensors, photonics, nanogenerators, introduction to qubits, superposition and entanglement, quantum gates and circuits, and basic algorithms with engineering applications. **(No. of lectures: 12)**

TEXT/ REFERENCE BOOKS: -

1. Principles of Quantum Mechanics – R. Shankar
2. Quantum Mechanics for Scientists and Engineers – D.A.B. Miller
3. Introduction to Quantum Mechanics – D.J. Griffiths
4. Quantum Transport: Atom to Transistor – S. Datta
5. Applied Quantum Mechanics – A.F.J. Levi

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DETAILS OF THE COURSE

Course Type	Course Title	Credits	Lecture	Tutorial	Practical	Studio
26PHTXXX	Introduction to Theory of Relativity and Cosmology	3	2	1	0	0

PREREQUISITE: None

COURSE OBJECTIVE(s)

Objective of the course title "Introduction to theory of relativity and cosmology" is to introduce the concept of relativity and early universe cosmology to various branches of Engineering students. This subject will be very much fascinating and Interesting to the students as they will learn the mysteries of the early universe. They will also learn the concept of relativity both in special and as well as general case.

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

Galilean transformations, principle of relativity, transformation of force from one inertial system to another, covariance of the physical laws, principle of relativity and speed of light, Michelson-Morley experiment, ether hypothesis, postulates of special theory of relativity, Lorentz transformations, Inverse Lorentz transformations, Length contraction, Time dilatation and Relativistic addition of velocities.

(No. of lectures- 7)

Module 2

Relativistic energy: mass-energy relation, examples of mass-energy conversion, relation between momentum and energy, transformation of momentum and energy, particles with zero rest mass, force in relativistic mechanics. **(No. of lectures- 6)**

Module 3

Four-vector formalism, introduction to tensor analysis, Euclidean and non-Euclidean geometry, basic idea of general theory of relativity, principle of equivalence, geodesics, space-time curvature.

(No. of lectures- 6)

Module 4

Composition of the universe, the expanding universe, mapping the universe. Cosmological principle, homogeneous, isotropic space times, cosmological red-shift, FRW models, matter, radiation and vacuum evolution of the flat FRW Models, the big-bang and age and size of the universe.

(No. of lectures- 7)

TEXT BOOKS/ REFERENCE BOOKS: -

1. Theory of relativity: P.G.Bergman (Dover)
2. Gravitation and Cosmology: principals and application of general theory of relativity S.Weinberg (John Wiley and Sons)
3. Gravity: An introduction to Einstein's general relativity J. B. Hartle (Pearson Education)
4. Introduction to Cosmology:J.V.Narlikar (Cambridge University Press)
5. Introduction to Relativity: J.V.Narlikar (Cambridge University Press)
6.Cosmology and particle astrophysics: A Goobar (Springer)
7.General relativity: R.M.Wald (The University of Chicago Press)
8.Cosmology: S.Weinberg (Oxford University Press)
9.Introducing Einstein's Relativity: Ray D'Inverno (Oxford University Press)
10.Principles of Physical Cosmology by P.J.E. Peebles (Princeton University Press)

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR
DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
OE	Sensors: Materials, Fabrication & Applications	3	2	1	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

Unit:1 Scope and Introduction of Wearable Devices
General concepts and terminology of Sensor systems, Transducers classification-sensors and actuators. 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- 9)**

Unit:2 Wearable Biochemical and Gas Sensors
Wearable Biochemical Sensors: Parameters of interest, System Design –Textile based, Microneedle based; Types: Non-invasive 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, Zeolites; Detection of atmospheric pollutants. **(No. of lectures- 8)**

Unit:3 Wearable Devices for Healthcare
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. Conductive textile electrodes, Knitted Piezoresistive Fabric (KPF) sensors. **(No. of lectures- 9)**

TEXT/ REFERENCE BOOKS: -

1. Jacob Fraden, “Hand Book of Modern Sensors: physics, Designs and Applications”, 3rd ed., Springer, 2010.
2. Edward Sazonov, Michael R Neuman, “Wearable Sensors: Fundamentals, Implementation and Applications” Elsevier, 2014.
3. Subhas C. Mukhopadhyay, “Wearable Electronics Sensors-For Safe and Healthy Living”, Springer International Publishing, 2015.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
OE	26PHTxxx	Advanced Energy Materials and Systems	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: 06)**

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.
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.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF PHYSICS

DETAILS OF THE COURSE

Course Type	Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
OE	26PHTxxx	Solar Energy and Photovoltaics	3	3	0	0	0

PREREQUISITE – Basic concepts of Solid-State Physics and 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

Module 1

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)**

Module 2

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)**

Module 3

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)**

Module 4

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.
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.