Indian Institute of Information Technology, Allahabad

Department of Applied Sciences

Minor: Frontiers in Physics

1. Light Matter Interaction
2. Physics of Space and Time
3. Quantum Materials & Devices
4. Green Energy Physics

Light Matter Interaction

COURSE OBJECTIVE: The course focuses on the applications of Maxwell's equation and optical phenomena. The course is designed to let the students handle the optical instruments and expose them to advanced theoretical and experimental techniques of optics.

Course content

Maxwell's equations and propagation of light, Fourier analysis, Lorentz model of optical response, optical response of various natural and artificial materials, plasmonics.

Metamaterials, photonic crystals, polarization of light, scattering phenomena.

Lasers, nonlinear light-matter interaction, ultrafast phenomena, strong light matter interaction.

Applications of light-matter interactions like photovoltaics and optical switching.

Textbooks and references:

1. Eugene Hecht, *Optics*, Pearson (23 February 2017), Fifth Edition.
2. Robert Boyd, *Introduction to Nonlinear Optics*, Academic Press (13 May 2008), Third Edition.
3. Claude Rulliè, *Femtosecond Laser Pulses: Principles and Experiments*, Springer; 2nd ed. 2005.
4. Introduction to Electrodynamics by D. J. Griffiths;

Physics of Space and Time

Course Outcome:

Students will be able to

1. understand modern concepts of space and time.
2. study the fundamental concepts of special and general relativity and their applications.
3. use mathematical techniques like tensor algebra and tensor calculus to apply in physics and engineering problems.
4. develop knowledge and skills to study celestial objects.

Course Content

Galilean concept of space and time, Michelson-Morley experiment and constancy of the speed of light, postulates of special relativity, Lorentz transformations, Time dilation, Length

contraction, Twin paradox; Relativistic mechanics, Mass energy equivalence, Bridging Electricity & Magnetism

Elementary introduction of Manifolds; Tangent and Cotangent spaces, Vectors and Tensors; Christoffel symbol; Geodesic deviation and Curvature.

Limitations in Newton's approach to gravitation, Equivalence Principle, Gravity as spacetime curvature; General Relativity (GR), and Einstein's Equation; Applications of GR in GPS etc. Black holes as an outcome of GR, Gravitational waves.

Textbooks and references:

1. Concepts of Modern Physics by A. Beiser; Mcgraw-Hill (2003)
2. Introduction to Special Relativity by R. Resnick; Wiley India Pvt. Limited (2007)
3. General Relativity: An Introduction for Physicists by M. P . HOBSON, G . P . EFSTATHIOU and A . N . LASENBY; Cambridge University Press (2006)
4. Gravity by J. B. Hartle, Pearson Education (2003)

Quantum Materials & Devices

COURSE OBJECTIVE :

This course aims to introduce the fundamentals of quantum materials and a broad survey of their applications in devices. The experimental techniques for engineering solid-state quantum phenomena will also be covered. The topics covered in this course have a wide range of applications including industry.

Course Content:

Review of Quantum Mechanics; Dirac's Bra-Ket notation, Angular momentum and Spin; Topological invariant and Berry phase in solids, Symmetries and SSH-model, Introduction to superconductivity, Kitaev model.

Introduction to classical and quantum hall effect, Landau Levels, Properties of Landau levels, Edge modes of Landau levels, Kubo formula, Hall quantization and topological invariants.

Topological insulators and their device applications, Dirac, Weyl semimetals and their device applications, On-demand topological band engineering.

Low-dimensional quantum materials: Quantum confinement, Van der Waals materials and their optoelectronic properties, Color centers in solids, Quantum dots and single-photon sources.

Textbooks and references:

1. Introduction to Quantum Mechanics by D. J. Griffiths, Pearson Education (2008)
2. Solid State Physics: An introduction, by Hofmann [online @ UW library]
3. Electronic Properties of Materials, by Rolf Hummel [online @ UW library]
4. Semiconductor Photonics of Nanomaterials and Quantum Structures, by Arash Rahimi-Iman [online @ UW library]

Green Energy Physics

COURSE OBJECTIVE :

For a country like India, renewable energy will play an important role in ensuring energy safety, security and sustainability. With the fast growing demand in off-grid applications in areas extending from villages to hills, newer technologies will have to be MADE IN INDIA. We will start with the basics of energy sources ranging from thermal, mechanical, and photovoltaic sources. The lectures will cover the topics on electricity generation using solar cells, use of solar heaters, solar based mobile chargers and the use of solar cookers in India. Subsequently, we will shift our attention to wind, water, tidal and geothermal power. At the end, the need for efficient energy storage technologies will be discussed. These include Li batteries and supercapacitors. This is a research labs-based course. This would be relevant for industries also.

L-T-P structure: 3-0-0

Course Content

Basics of semiconductor, nanomaterials and nanotechnology, Renewable energy sources and classifications, Solar Power .

Wind Power, Hydro, Tidal and Geothermal Systems, Energy storage Technology: Classification and principle.

Fuel cells: Principles, Classifications and Operations, Supercapacitors and Battery, Energy storage mechanism.

Effect of double layer in energy storage: Chemical approach, Characterization techniques: I, Characterization techniques II

Text Books and references:

1. Physics of Energy Sources, G. C. King
2. Physics and Technology of Sustainable Energy; E L Wolf
3. Advanced renewable Energy Systems, S C Bhatia
4. Renewable Energy: Power for a Sustainable Future, Godfrey Boyle
5. Electrochemical Supercapacitors, B. E. Conway
6. Renewable Energy Resources, John Twidell and Tony Weir
7. Sustainable Energy – without the hot air, David J. C. MacKay
8. Solar Photovoltaics: Fundamentals, Technologies and Applications, Chetan Singh Solanki
9. Handbook of Materials Characterization, Surender Kumar Sharma