भारतीय प्रौद्योगिकी संस्थान पटना
INDIAN INSTITUTE OF TECHNOLOGY PATNA
Department of Physics
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List of Elective Courses for B.Tech. (EP):

S.No.	Course Number	Course Credit (L-T-P-C)	Course Title
1.	EP418	3-0-0-6	Micro-and Nano-scale Photonic Devices: Fabrication, Theory, and Their Applications
2.	EP420	3-0-0-6	Advanced Techniques in Theoretical Condensed Matter Physics
3.	EP422	3-0-0-6	Modern microscopy techniques
4.	EP426	3-0-0-6	Physics of nanomaterials
5.	EP428	3-0-0-6	Transport properties of the Materials
6.	EP436	3-0-0-3	Ultrafast Spectroscopy
7.	EP442	3-0-0-6	Nanoelectronics
8.	EP444	3-0-0-6	Quantum Materials

The above-mentioned elective courses are for **B.Tech. (Engineering Physics) 2021 batch students.**

Course Number	EP418
Course Credit (L-T-P-C)	3-0-0-6
Course Title	Micro-and Nano-scale Photonic Devices: Fabrication, Theory, and Their Applications
Learning Mode	Lectures
Learning Objectives	The main objective is to learn the fabrication, theory, and applications of several micro-and nano-scale photonic devices
Course Description	This course allows engineering students to learn several advanced micro-and nano-scale photonic devices, essential to pursue research and scientific jobs in advanced photonics-based engineering applications.
Course Outline	Review of Maxwell's equations, Electromagnetic radiations and evanescent wave, Quantum mechanics wrt to band theory of solids, Wave particle duality, Linear Optical properties and non-linear effects, Introduction, theory, fabrication, and applications of Photonic microresonators, Micro and Nanoscale waveguides, Photonic crystal fibers, Propagating and localized Surface plasmon polariton (SPP) and manipulation of resonance conditions for photonic devices development, Quantum confinement, Quantum dots based photonic devices, Fabrication and Modal analysis of Nanofiber, Nanofibers based photonic devices and its usage in quantum optics, carbon nanotube, and monolayer graphene-based photonic devices, Latest in photonics devices.
Learning Outcome	The students will be fully aware of the theory, fabrication, and applications of advanced micro-and nano-scale photonic devices.
Assessment Method	Assignments, Quizzes, Mid-semester and End-semester examination
Suggested Readings:	Fundamental of Photonics by Saleh and Teich
Textbooks:	[1]. J. Heebner, R. Grover, and T. A. Ibrahim, Photonic microresonators, Springer Sciences, 2010. [2]. K. Busch, S. Lölkes, R. B. Wehrspohn, and H. Föll, Photonic crystals, Wiley-VCH, 2004. [3]. J. W. M. Chon, K. Iniewski, Nanoplasmonics, CRC press, 2014 [4]. K. Y. Kim, Advances in optical and photonic devices, InTech, 2010. [5]. L. Tong, M. Sumetsky, Subwavelength and nanometer diameter optical fiber, Zhejiang University Press, 2010. [6]. Constantin Simovski, Sergei Tretyakov, An introduction to metamaterials and Nanophotonics, Cambridge University Press, 2020 [7]. Arthur McGurn, Nanophotonics, Springer International Publishing, 2019

Course Number	EP420
Course Credit	3-0-0-6
Course Title	Advanced Techniques in Theoretical Condensed Matter Physics
Learning Mode	Lectures and Tutorials
Learning Objectives	The objective of the course is to introduce Advanced Techniques in Theoretical Condensed Matter Physics and its applications
Course Description	Equips the students with advanced techniques in Theoretical Condensed Matter Physics and allows them to apply these techniques in both research and industrial scenarios
Course Outline	Unit 1: Broken symmetry state, Order-disorder transition, Ginzburg-Landau theory, mean-field approach, examples from ordinary solids, magnetism and superconductivity, flux quantization and vortices Unit 2: Second quantization and second quantized Hamiltonians, Introduction to topological aspects, Berry phase and Aharonov-Bohm effect, Kane-Mele model and Topological Insulators, Integer quantum Hall effect Unit 3: Basic models for strong correlation effects: Anderson impurity model, Hubbard and t-J models, connection with experiments
Learning Outcome	Students will study the advanced techniques in Theoretical Condensed Matter Physics and learn to apply these techniques in both research and industrial scenarios
Assessment Method	Assignments, Quizzes, Mid-semester examinations and End-semester examinations
Prerequisites	Courses in Quantum Mechanics, Statistical Physics, and Solid State Physics
Suggested Readings:	**Textbooks:** 1. Steven M. Girvin and Kun Yang, Modern Condensed Matter Physics, Cambridge University Press, USA (2019). 2. P. M. Chaikin and T. C. Lubensky, Principles of Condensed Matter Physics, Cambridge University Press, USA (2012). **References:** 1. P. W. Anderson, Basic Notions of Condensed Matter Physics, Benjamin/Cummings Publication Co. USA (1994). 2. Philip L. Taylor and Ole Heinonen, *A Quantum Approach to Condensed Matter Physics*, Cambridge University Press, USA (2002).

Course Number	EP422
Course Credit (L-T-P-C)	3-0-0-6
Course Title	Modern microscopy techniques
Learning Mode	Lectures
Learning Objectives	The objective of the course is to introduce the student to electron microscopy and its utilization in modern technology, as well as Atomic Force Microscopy (AFM) and Scanning Tunneling Microscopy (STM). The students will learn about the electron-matter interaction, and the working principle of electron microscopes. The principle of electron optics and its use will be learned by the students. The opportunity in the electron microscopy area will be known to the student. Also a modern microscope without any electromagnetic radiation will be understood by the student.
Course Description	The course discusses different kinds of electron microscopy and electron spectroscopy. Analysis of TEM and SEM image, electron diffraction pattern, X-ray spectra analysis, and their applications in industry will be covered in this course. Also, the course will introduce the student on AFM and STM i.e. Scanning Probe Microscopy (SPM)
Course Content	**Unit 1:** Introduction to Microscopy, Limitations of the Human Eye, Optics, The X-ray Microscope, Electron Microscope, Low-Energy and Photoelectron Microscopes, Atom-Probe Microscopy. **Unit 2:** Electron Sources, safety and precautions, Electron optics, electromagnetic lenses, Comparison of Magnetic and Electrostatic Lenses, Aberration Correctors and Monochromators, Electron and matter interaction, Scattering and diffraction, reciprocal space, Bloch waves, Diffraction from crystal, diffraction from small volume, elastic and inelastic scattering, absorption, dispersion, polarization, reflection, Imaging with Electrons, radiation damage, electron tomography, electron holography. **unit 3:** Transmission Electron Microscopy: Instrument, holders, lenses, cameras, apertures and resolution, imaging, amplitude contrast, phase contrast, bending effect, planer defects, bright field imaging, dark field imaging, high-resolution imaging, Scanning transmission electron microscopy, image simulation, and image analysis, Spectroscopy, X-ray spectroscopy, qualitative and quantitative X-ray analysis, electron energy loss spectroscopy and images, fine structure, diffraction pattern, indexing diffraction pattern, specimen (hard, soft, powder, and biological) preparation, Industrial applications. **Unit 4:** Scanning Electron Microscopy: Instrument, holders, lenses, apertures, resolution, Electron detectors, Back scattered electron, Secondary electron, Auger electron, imaging, Auger electron spectroscopy. Augur electron microscopy, image simulation, and image analysis, Spectroscopy, X-ray spectroscopy, qualitative and quantitative X-ray analysis, EBSD, diffraction pattern and analysis, specimen preparation, Industrial applications. **Unit 5:** Atomic Force Microscopy: Working principle, Detector arrangement in the AFM, Constant Current and Constant Height mode, Magnetic Force Microscopy, Electric Force Microscopy. Scanning Tunneling Microscopy: Working principle, Low Current STM. **Please include SPM (as it is mentioned earlier and below)**
Learning Outcome	The student will introduce himself/herself to electron microscopy and SPM. The industrial applications of electron microscopy and SPM will be known. There are lots of opportunities in electron microscopy and SPM as these are modern techniques, and it has lots of industrial applications. Hence, the students can take jobs in the electron microscopy industries and SPM, or they can become entrepreneurs for supporting the electron microscopy industries and SPM.

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<tr><td>Assessment Method</td><td>Assignments, mini projects, Quizzes, Mid-semester examinations, and End-semester examinations.</td></tr>
<tr><td>Suggested Readings:</td><td>Textbooks:
1. Physical Principles of Electron Microscopy, Ray F. Egerton, springer, 2005, New York
2. Scanning Electron Microscopy, Ludwig Reimer, springer, 1998, New York,
3. Transmission Electron Microscopy, David B. Williams, C. Barry Carter, springer, 2009.
4. Scanning Probe Microscopy: Atomic Force Microscopy and Scanning Tunneling Microscopy, Bert Voigtländer, Springer, 2015.
5. Springer Handbook of Microscopy, Peter W Hawkes, John C.H. Spence, Springer Cham, 2019.

References:
1. Electron Microscopy: Principles and Fundamentals, S. Amelinckx (Editor), Dirk van Dyck (Editor), J. van Landuyt (Editor), Gustaaf van Tendeloo (Editor), Wiley, 2007.
2. Electron microscopy Methods and Protocols, John Kuo, Springer, 2014.
3. The principles and Practice of Electron Microscopy, Ian M. Watt, Cambridge University Press, 1997.</td></tr>
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Course Number	EP426
Course Credit (L-T-P-C)	3-0-0-6
Course Title	Physics of nanomaterials
Learning Mode	Lectures
Learning Objectives	The objective of the course is to introduce the student to the fundamentals and physics of Nanomaterials. Mostly students will learn the physics to explain the phenomena observed for nanomaterials. .
Course Description	The course discusses the theories to explain the properties of nanomaterials. The student will learn about the applications of quantum mechanics, Quantum confinement, and the significance of surface-to-volume ratio in nanomaterials. Also applications of nanomaterials will be learned by the students.
Course Content	Unit 1: Introduction, Structure, Length scales, Excitons, Quantum mechanics review, Various 1D potentials, Mathcad solutions, Particle in an infinite circle, Particle in a sphere. Unit 2: Confinement, Nondegenerate perturbation theory, Density of states: 3D, 2D, 1D, 0D, CB and VB states, 3D Fermi level, 2D and 1D density of CB and VB states, Vertical transitions, joint density of states, Einstein A and B coefficients, More density of states, Even more density of states, Joint density of states Unit 3: Absorption, Interband transitions, Emission, Properties of nanoscales: Mechanical properties, Magnetic properties and Electrical properties, Unit 4: Tunneling, The WKB approximation, Synthesis, Applications: Nanowire sensor, Quantum dot/dye photobleaching, Quantum dot/dye absorption/emission spectra, Density of states for lasing, Solar spectrum and QD absorption/emission spectra, Quantum dot LED schematic, Orthodox model of single electron tunneling, Coulomb Staircase. Single-nanoparticle devices;
Learning Outcome	The student will introduce himself/herself to the nanomaterials. They will understand the details of the physics of nanomaterials. The industrial applications of nanomaterials will be learned.
Assessment Method	Assignments, mini projects, Quizzes, Mid-semester examinations, and End-semester examinations.
Suggested Readings:	Textbooks: 1. Introduction to Nanotechnology; Charles P. Poole, Jr. and Frank J. Owens, Wiley – Interscience, 2003. 2. Introductory Nanoscience: Physical and Chemical Concept, Masaru Kuno, Garland Science, 2011. Reference Books: 1. Introduction to Nanoscience; Gabor L. Hornyak, Joydeep Dutta, Harry F. Tibbals, A. K. Rao, CRC Press, Taylor and Francis Group, 2008. 2. Nanomaterials, Nanotechnologies, and Design: An Introduction for Engineers and Architect, M. F. Ashby, Paulo J. Ferreira, D. L. Schodek, Elsevier, 2009. 3. Introduction to Nanoscience and Nanotechnology, Chris Binns, Wiley, 2022.

Course Number	EP428
Course Credit	3-0-0-6
Course Title	Transport properties of the Materials
Learning Mode	Lectures
Learning Objectives	The student will understand the electron transport in solids. Thermoelectric power and magnetotransport properties.
Course Description	The course covers various transport phenomena in the solid. The techniques to measure the transport phenomena is covered in the course. The course also introduces the quantum transport phenomena.
Course Outline	Unit 1: Introduction: The Boltzmann Equation, Electrical Conductivity, Electrical Conductivity of Metals, Electrical Conductivity of Semiconductors, Ellipsoidal Carrier Pockets, electrons and Holes in Intrinsic Semiconductors, Donor and Acceptor Doping of Semiconductors, Characterization of Semiconductor, Metal and Insulator Unit 2: Thermal Transport: Thermal Conductivity, General Considerations, Thermal Conductivity for Metals, Thermal Conductivity for Semiconductors, Thermal Conductivity for Insulators, Thermoelectric Phenomena, Thermopower for Semiconductors, Effect of Thermoelectricity on the Thermal Conductivity, Thermoelectric Measurements, Seebeck Effect (Thermopower), Peltier Effect, Thomson Effect, The Kelvin Relations, Figure of Merit Unit 3: Electron, Electron and Phonon Scattering, Ionized Impurity Scattering, Other Scattering Mechanisms, Screening Effects in Semiconductors, Electron Scattering in Metals, Electron-Phonon Scattering, Other Scattering Mechanisms in Metals, Phonon Scattering, Phonon-phonon scattering, Phonon-Boundary Scattering, Defect-Phonon Scattering, Electron-Phonon Scattering, Temperature Dependence of the Electrical and Thermal Conductivity. Unit 4: Magneto-transport Phenomena, Magneto-transport in the classical regime ($\omega_c\tau<1$), Classical Magneto-transport Equations, Magnetoresistance, The Hall Effect, Derivation of the Magneto-transport Equations from the Boltzmann Equation, Two Carrier Model Dynamics of Electrons in a Magnetic Field. Unit 5: Two-Dimensional Electron Gas, Quantum Wells & Semiconductor, Super-lattices, Two-Dimensional Electronic Systems, MOSFETS, Quantum Wells and Superlattices, Bound States, Tunneling Kronig–Penney Model, 1-D Rectangular Well Resonant, Tunneling in Quantum Wells. Unit 6: Transport in Low Dimensional Systems, Observation of Quantum Effects in Reduced Dimensions, Density of States in Low Dimensional Systems, Quantum Dot, One Dimensional Transport and Quantization of the Ballistic Conductance, Ballistic Transport in 1D Electron Waveguides, Single Electron Charging Devices.
Learning Outcome	Student will learn about transport phenomena in solids. The semiconductor devices will be understood.
Assessment Method	Quiz/project, Mid-semester examinations, End-semester examinations
Suggested Readings:	
Textbooks:	1. Ziman, Principles of the Theory of Solids, Cambridge Univ. Press, 1972. 2. Ashcroft and Mermin, Solid State Physics, Holt, Rinehart and Winston, 1976. 3. Smith, Janak and Adler, Electronic Conduction in Solids, McGraw-Hill, 1967.
References:	1. Reif, Fundamentals of Statistical and Thermal Physics, McGraw-Hill, 1965,

	2. Wolfe, Holonyak and Stillman, Physical Properties of Semiconductors, Prentice Hall, 3. Hang, Theoretical Solid State Physics, Volume 2, Pergamon 1972 4. Pippard, Magnetoresistance in Metals, Cambridge University Press, 1989 5. Kittel, Introduction to Solid State Physics, 7th Ed., Wiley, 1996 6. B.G. Streetman, Solid State Electronic Devices, Series in Solid State Physical Electronics, Prentice-Hall (1980). 7. S.T. Picraux, Physics Today, November (1984)

Course Number	EP436
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Ultrafast Spectroscopy
Learning Mode	Lectures
Learning Objectives	Students will learn about ultrafast spectroscopy and its applications
Course Description	Students will be equipped with ultrafast lasers, their pulsing methods with linear and non-linear spectroscopic methods. Their usages in applications to research in imaging, nanoscopy and excitonic dynamics
Course Content	Ultrafast optics: Generation, propagation, and applications of ultrashort pulses (nano-, pico-, femto-, attosecond pulses); Time Resolution, Nonlinearities, Fourier Transform, Uncertainty Principle, wavelength, repetition rate. Linear and nonlinear pulse shaping processes: second order, third order, higher-order non-linear phenomenon, Dispersion in ultrafast optics, Q-switching, Active and passive mode-locking. Ultrafast spectroscopy: Pump-probe techniques, Time-resolved fluorescence, Up-conversion, Higher harmonic generation. Applications of ultrafast spectroscopy: Super-resolution imaging, Exciton dynamics in chemistry, material science, and semiconductor nanocrystals. Ultrafast transient absorption.
Learning Outcome	The students will know about various applications, generation etc about ultrafast spectroscopy
Assessment Method	Assignments, Quizzes, Presentation, Mid-semester examination and End-semester examination

Course Number	EP442
Course Credit(L-T-P-W-C)	3-0-0-6
Course Title	Nanoelectronics
Learning Mode	Lectures
Learning Objectives	The objective of the course is to introduce concept of nanomaterials and its applications in nanoelectronics
Course Description	Students will learn basic concepts of nanoelectronics, nanodevices, molecular electronics, and spintronics. The role of quantum mechanics behind nanoelectronics will be explored to explain many exotic phenomena on the nanoscale. This course will describe the principle and the operation of nanoelectronics and spintronics devices.
Course Content	Unit 1: Moore's law, limitations, role of quantum mechanics; Unit 2: Nanostructures: Impact, technology, and physical consideration; Ballistic transport, phase interference, universal conductance fluctuations, and weak localization; Unit 3: Carrier heating; Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers; Fermi statistics, Metals, Insulators and Semiconductor, Density of states (DOS) in 3D-0D; Physics of organic semiconductors: the concept of HOMO and LUMO, and band gap. Unit 4: Two terminal quantum dot and quantum wire devices: Equilibrium in two-terminal devices; I-V Characteristics; quantum of conductance, Landauer theory; SET as a FET: Ballistic quantum wire FETs, conventional MOSFETs, CMOS
Learning Outcome	Students will learn about nanomaterials and its applications
Assessment Method	Assignments, Quizzes, Seminars, Mid-semester examinations, End-semester examinations
Prerequisites	Courses in Quantum Mechanics and Electronics
Suggested Readings:	
Textbooks:	1. Nanoelectronics: Physics, Technology and Applications Rutu Parekh, 2023 2. Nanoelectronics Fundamentals: Materials, Devices and Systems Hassan Raza, 2019 3. M. Baldo, Introduction to Nanoelectronics, Lecture Notes MIT, 2011. 4. S. Datta, Electronic Transport in Mesoscopic Systems; Cambridge University Press, 1995. 5. Fundamentals of nanoelectronics, George W. Hansen, Pearson Education, 2009. 6. **Nanoelectronics. Physics, technology and applications, IOP, 2023**
References:	7. J. Knoch, Nanoelectronics: Device Physics, Fabrication, Simulation, De Gruyter, 2020. 8. S. Datta, Quantum Transport: Atom to Transistor; Cambridge University Press, 2005. 9. M. Lundstrom and J. Guo, Nanoscale Transistors; Physics, Modeling, and Simulation, Springer, 2006. 10. P.W. Atkins and R.S. Friedman, Molecular Quantum Mechanics; Oxford University Press, 3rd Edition, 1997. 11. David Ferry, Transport in Nanostructures Cambridge Univ. Press, 1995.

Course Number	EP444
Course Credit	3-0-0-6
Course Title	Quantum Materials
Learning Mode	Lectures
Learning Objectives	The student will understand the applications of quantum mechanics. Quantum materials are the heart of the modern technology. Hence, it is necessary for everybody to understand the quantum material.
Course Description	The course covers various quantum mechanical phenomena occurring in condensed matter systems and the ways to tune and control them, for designing various quantum-controlled operations to develop relevant devices and technologies.
Course Outline	Unit 1: Theories of electronic structure: Fermi Liquid Theory, Model Hamiltonian, Density Functional Theory. Unit 2: Quantum ordering: Superconductivity; Quantum Criticality; Magnetism; Spin Ice and magnetic monopoles; Topological materials; Weyl Semimetal; Majorana Fermions; Skyrmions; Quantum hall effect; Dirac Materials and Van der Waals magnet; Moiré lattice and Twistronics; Metamaterials and photonic crystals. Unit 3: Application: Qubits; quantum simulation; quantum technology (quantum communications, quantum sensing and metrology, and quantum computing) Unit 4: Experimental Probes: Large-scale facilities (ex: Neutron, muon, and Angle-resolved photoemission spectroscopy, synchrotron beamlines); Local probes for the quantum phenomenon
Learning Outcome	Students will learn about modern gadgets and the importance of quantum materials.
Assessment Method	Quiz/project, Mid-semester examination, End-semester examination
Suggested Readings:	
Textbooks:	1. J Annett, Superconductivity, Superfluids and Condensates, Oxford Univ. Press, 2004 2. Quantum Magnetism, edited by Ulrich Schollwöck, Johannes Richter, Damian J. J. Farnell, Raymod F. Bishop, Springer, 2008 3. Topological Insulators, Shun-Qing Shen, Springer, 2013
References:	4. A. Damascelli, Z. Hussain and Z.X. Shen, Rev. Mod. Phys. 75, 473, 2003. 5. A.J. Schofield, Contemp. Phys. 40, 95, 1999, 6. D. Shoenberg, *Magnetic Oscillations in Metals*, Cambridge Univ. Press, 1984 7. C. Bergemann, A. P. Mackenzie, S. R. Julian, D. Forsythe, and E. Ohmichi, Adv. Phys. 52, 639, 2003. 8. H. Ibach and H. Luth, *Solid-state Physics: An Introduction to Principles of Materials Science*, Springer-Verlag, 2003 9. N.W. Ashcroft and N.D. Mermin, *Solid State Physics*, Saunders College Publs,, 1976 10. Quantum Information, Stephen Barnett, Oxford Univ. Press, 2009 11. Quantum Hybrid Electronics and Materials edited by Yoshiro Hirayama, Kazuhiko Hirakawa, Hiroshi Yamaguchi, Springer, 2022 12. Principles of Neutron Scattering from Condensed Matter, Andrew T. Boothroyd, , Oxford Univ. Press, 2020 13. Muon Spin Rotation, Relaxation, and Resonance: Applications to Condensed Matter, Alain Yaouanc, Pierre Dalmas de Réotier, Oxford Univ. Press, 2010

	14. An Introduction to Synchrotron Radiation: Techniques and Applications, 2nd Edition, Philip Willmott, Wiley,2019.