Bio-inspired and Bio-mimetic Materials

Semester: VII/VIII | **Code: PHT 411**
Subject: Bio-inspired and bio-mimetic materials | **Credits: L-T-P: 2-1-0**
Total Theory Periods: 27 | **Total Tutorial Periods: 12**

Marks: Mid-Term: 30, End-Term: 50, and Internal assessment: 20

Module 1 [Lectures: 09, Tutorials: 04]
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

Module 2 [Lectures: 09, Tutorials: 04]
Introduction to nanotechnology, surface engineering, bio-inspired nanoparticles, 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

Module 3 [Lectures: 09, Tutorials: 04]
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

Text books:

1. Bio and bioinspired nanomaterials: Daniel Ruiz-Molina, F. Novio, C. Roscini (Wiley-VCH).
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).

Introduction to Biophysics

Semester: VII/VIII **Code: PHT 731**
Subject: Introduction to Biophysics **Credits: L-T-P: 2-1-0**
Total Theory Periods: 27 **Total Tutorial Periods: 12**

Marks: Mid-Term: 30, End-Term: 50, and Internal assessment: 20

Module 1 [Lectures: 09, Tutorials: 04]
Life and energy, forces and energies at nanometer scales, intermolecular interactions and electrostatic screening, chemical bonding and stability of molecules, entropy, energy and electrostatics, laws of thermodynamics, brownian motion, metabolism in animals and photosynthesis in plants, chemical composition of living systems, structure and physical properties DNA & RNA, cell membrane, protein, stability of proteins, motions within proteins, how enzymes work

Module 2 [Lectures: 09, Tutorials: 04]
Nucleic acid and genetic information, deciphering the genetic code, how structure stores information, replication process, from DNA to RNA to protein, mechanics and circuits in the cell, the cell as a basic unit of life's organization, the cell interior, brownian motion and viscosity and their influence on particle motion in the cell, basic structure of mitochondria and the generation of ATP, energy and information flow in the cell

Module 3 [Lectures: 09, Tutorials: 04]
The role of the cytoskeleton in cell motion, the role of motors within the cell, muscle, random walks, sense of a remarkable array of biophysical processes, from the diffusion of molecules to the swimming strategies of bacteria, life at low Reynolds number, the neuron, the role of channels and pumps, the biophysics of the synapse, two cases: muscle and retina

Text books:

1. Biophysics: Rodney M.J (Wiley).
2. The rainbow and the worm: Mae-Wan Ho (World Scientific).
3. Newton rules biology: C.J. Pennycuick (Oxford).
4. How life learned to live: Helmut Tributsch (Cambridge).
5. Essentials of biophysics: P Narayanan (New Age International).
6. An introduction to biophysics: M.R. Rajeswari (Rastogi Publications)

Introduction to Elementary Particle Physics

Semester: VII/VIII **Code: PHT414**
Subject: Introduction to Elementary Particle Physics **Credits: L-T-P: 2-1-0**
Total Theory Periods: 26 **Tutorial Periods: 13**
Marks: 30 in Mid-Term, 50 in End-Term and 20 in internal assessment

Module 1 [Lectures: 9, Tutorial: 5]

History of particle physics, particle zoo, an introduction to the Standard model and its components, antiparticles, symmetries and conservation laws and their significance in particle physics, hadron-hadron interactions, relativistic kinematics, Feynman calculus, quark model including spectroscopy.

Module 2 [Lectures: 9, Tutorial: 6]

Quantum Chromo Dynamics (QCD), electromagnetic interactions - form factors, parton model and deep inelastic scattering - structure functions, weak interactions including beta decay, Cabbibo-Kobayashi-Maskawa mixing, unified electroweak interaction, W, Z, Higgs boson, gauge principle, Higgs mechanism.

Module 3 [Lectures: 8, Tutorial: 2]

Beyond the Standard model: the unification of strong and electroweak interaction, neutrino oscillations, supersymmetry, experimental techniques for particle acceleration and particle detection, prospects for discoveries of new phenomena, e.g. in the LHC-experiments at CERN and B-factory at KEK, Japan, international linear collider.

Text Books:

1. Introduction to the Elementary Particle Physics: David Griffith (Wiley).
2. Introduction to High Energy Physics by Donald H. Perkins (Cambridge University Press).
3. Quark and Leptons: An Introductory Course in Modern Particle Physics: Francis Halzen, Alan D. Martin (John Wiley and Sons).
4. Introduction to Elementary Particle Physics: Alessandro Bettini (Cambridge University Press).
5. The Higgs Hunter's Guide: John F. Gunion, Howard H. Haber, Gordon Kane and Sally Dwason (Westview Press).
6. Techniques for Nuclear and Particle Physics Experiment: W. R. Leo (Springer).
7. Radiation Detection and Measurement: Glenn F. Knoll (Wiley).

Introduction to Theory of Relativity and Cosmology

Semester: VII/VIII | **Code: PHT 415**
Subject: Introduction to theory of relativity and cosmology | **Credits: L-T-P: 2-1-0**
Total Theory Periods: 28 | **Total Tutorial Periods: 12**
Marks: 30 in Mid-Term, 50 in End-Term and 20 in internal assessment

Module 1 [Lectures: 07, Tutorials: 3]

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, consequences of Lorentz transformations.

Module 2 [Lectures: 06, Tutorials: 3]

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.

Module 3 [Lectures: 06, Tutorials: 3]

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

Module 4 [Lectures: 07, Tutorials: 3]

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.

Text 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
7. General relativity: R.M.Wald

Reference Books:

1. Cosmology: S.Weinberg (Oxford).
2. Introducing Einstein's Relativity : Ray D'Inverno

Magnetic Memory Devices

Semester: VII/VIII **Code: PHT418**
Subject: Magnetic Memory Devices **Credits: L-T-P: 2-1-0**
Total Theory Periods: 26 **Total Tutorial Periods: 13**

Marks: Mid-Term: 30, End-Term: 50, and Internal assessment: 20

Module 1 [Lectures: 9, Tutorials: 4]
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.

Module 2 [Lectures: 9, Tutorials: 5]
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.

Module 3 [Lectures: 8, Tutorials: 4]
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.

Text 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.

Reference Books:

1. Magnetoelectronics, M. Johnson, Academic Press 2004.
2. The Physics of Ultra-high Density Magnetic Recording, Martin L. Plumer, Johannes Van Ek and D. Weller, Springer (2001).

Physics of Nanomaterials

Semester: Odd/Even **Code: PHT 419**
Subject: Physics of Nanomaterials **Credits: L-T-P: 2-1-0**
Total Theory Periods: 26 **Total Tutorial Periods: 13**

Marks: Mid-Term: 30, End-Term: 50, and Internal assessment: 20

Module 1 [Lectures: 5, Tutorials: 3]

Basics of nanomaterials:

Introduction to nanomaterials, fundamental concepts and properties of nanomaterials, classification of nanomaterials, quantum confinement, quantum wells, quantum wires, quantum dots, density of states, effect of reduction of dimensions and size dependent properties of nanomaterials.

Module 2 [Lectures: 9, Tutorials: 4]

Synthesis of Nanomaterials: Synthesis of nanomaterials using top-down & bottom-up approaches, thin film deposition methods, RF sputtering, e-beam evaporation, pulsed laser deposition, lithography, sol-gel, chemical vapor deposition, Ball milling, Modification of nanomaterials.

Module 3 [Lectures: 8, Tutorials: 4]

Characterization of Nanomaterials: Characterization of nanomaterials using atomic force microscopy, X-ray diffraction, scanning electron microscopy, transmission electron microscopy, Dynamic light scattering, and Raman spectroscopy.

Module 4 [Lectures: 4, Tutorials: 2]

Application of Nanomaterials: Applications of nanomaterials in energy, electronics and medicine. Future challenges and limitations of Nanoscience and Nanotechnology.

TEXT BOOKS:

1. Nanostructures and Nanomaterials Synthesis, Properties and Applications: G. Cao (Imperial College Press-2006).
2. Introduction to Nanotechnology: Charles P. Poole Jr. and Frank J. Owens (Wiley Publications- 2003).
3. Introduction to Nanoscience and Nanotechnology, K K Chattopadhyay & A N Banerjee (PHI, EEE, October 2012)

4. Concepts of Modern Physics by Arthur Beiser, McGraw-Hill

REFERENCE BOOKS:

1. Nanomaterials: Synthesis, Properties and Applications, A. S. (Alan S.) Edelstein, R. C. (Robert C.) Cammarata, Taylor & Francis Group.
2. Nanomaterials: Research Towards Applications, Hideo Hosono, Yoshinao Mishima, Hideo Takezoe, Kenneth J.D. MacKenzie, Elsevier (2006)
3. Swift Heavy Ions for Materials Engineering and Nanostructuring (D K Avasthi and G K Mehta) (Dordrecht: Springer Netherlands)
4. Thin Film Phenomena by K L Chopra, McGraw Hill
5. Nano: The Essentials, T. Pradeep (McGraw Hill Education; 2017).

Physics of Particle Detectors and Technology

Semester: VII/VIII **Code: PHT420**
Subject: Physics **Credits: L-T-P: 2-1-0**
Total Theory Periods: 26 **Tutorial Periods: 13**
Marks: 30 in Mid-Term, 50 in End-Term and 20 in internal assessment

Module 1 [Lectures: 9, Tutorial: 5]

Overview on the detector technology used in the particle physics experiments starting from Rutherford scattering experiment to the present world's largest experiments at 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.

Module 2 [Lectures: 9, Tutorial: 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 concept.

Module 3 [Lectures: 8, Tutorial: 2]

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.

Text 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 Shwartz (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).

Solar Energy and Physics of Photovoltaics

Semester: VII/VIII | **Code: PHT421**
Subject: Solar Energy and Physics of Photovoltaics | **Credits: L-T-P: 2-1-0**
Total Theory Periods: 26 | **Total Tutorial Periods: 13**

Marks: Mid-Term: 30, End-Term: 50, and Internal assessment: 20

Module 1 [Lectures: 6, Tutorials: 4]
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, concentrating/non-concentrating solar collectors, collector efficiency and its dependence on various parameters, solar fuels: electrolysis of water, photoelectrochemical splitting of water.

Module 2 [Lectures: 8, Tutorials: 3]
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,

Module 3 [Lectures: 6, Tutorials: 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.

Module 4 [Lectures: 6, Tutorials: 3]
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.

Text books:

1. Nelson, J. *The Physics of Solar Cells*. Imperial College Press, 2003. ISBN: 9781860943409.
2. 2. *Solar Engineering of Thermal Process*: Duffie and Beckman, John Wiley, 2013. ISBN: 9780470873663
3. S*olar 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.

Reference Books:

1. Wenham, S., M. Green, et al., eds. *Applied Photovoltaics*. 2nd Ed. Routledge, 2006. ISBN: 9781844074013.
2. Luque, A., and S. Hegedus, eds. *Handbook of Photovoltaic Science and Engineering*. John Wiley & Sons, Ltd, 2003. ISBN: 9780471491965
3. *Semiconductor Devices, Physics, and Technology*, Second Edition, S. M., Sze, New York, NY: Wiley.
4. Green, M. *Silicon Solar Cells: Advanced Principles and Practice*. Centre Photovoltaic Devices & Systems, 1995. ISBN: 9780733409943
5. Aberle, A. *Crystalline Silicon Solar Cells: Advanced Surface Passivation and Analysis*. University of New South Wales, 1999. ISBN: 9780733406454.
6. Green, M. A. *Solar Cells: Operating Principles, Technology, and System Applications*. Prentice Hall, 1981. ISBN: 9780138222703.

Review Articles:

Kazmerski, L. "*Solar Photovoltaics R&D at the Tipping Point: A 2005 Technology Overview*." Journal of Electron Spectroscopy and Related Phenomena 150, no. 2-3 (2006): 105–35.

Organic Electronics Material & Devices

Semester: VII/VIII **Code: PHT 422**
Subject: Organic Electronics Material and Devices **Credits: L-T-P: 2-1-0**
Total Theory Periods: 26, Tutorials: 13
Marks: 30 in Mid-Terms, 50 in End-Term (20 Marks to internal assessment)

Module 1 [Lectures: 6, Tutorials: 5]
Fundamental physics and electronic properties: Introduction; Schrodinger equation; Particle in a Box; Fundamentals of Semiconductors: semiconductors and their uses; Junctions: Ohmic and Schottky Junction; Introduction to I/V curve; General Devices: Diode, PV, Transistor, Sensor.

Module 2 [Lectures: 5, Tutorials: 0]
Introduction of Conducting Polymers; Synthesis and types of conducting polymer; General synthesis methods for each type; Processing and Fabrication: Spin coating, Evaporation, Sputtering, Electrospinning, Drop casting, Templating.

Module 3 [Lectures: 7, Tutorials: 4]
Charge Transport: Generation of the charged species, Conduction of the charges, Collection of charges at the electrode; Organic Devices: Conduction in Organic devices, Conduction at the junction and electrode, Space charge limited current, Specific Organic devices: Transistors, OPV, OLED and Sensors.

Module 4 [Lectures: 8, Tutorials: 4]
Organic Light Emitting Devices: How Do We Perceive Color, Basic OLED Properties and Performance;
Organic LEDs: Electrical Current in Organic Thin Films; Display Driving Schemes; Different types of Organic LEDs: Conventional (OLED), Transparent (TOLED), Inverted (OILED), Metal-Free (MF-TOLED), Flexible (FOLED), Stacked (SOLED), Organic LED Displays; Device Characterizations and Stability: Quantum efficiency, Impedance Spectroscopy, Degradation issues; Modern devices: Flexible Glass material, Advance 2D and 3D materials

Text Books:

1. Organic Field Effect Transistors - Theory, Fabrication and Characterization, I. Kysmissis, Springer (2009)
2. Physics of Organic Semiconductors, Wiley-VCH, edited by W. Brütting (2005)
3. Organic Electronics, Materials, Processing, Devices and Applications, d. by F. So, CRC Press (2010)

Reference Books:

1. Zhenan Bao and Jason Locklin, Organic Field-Effect Transistors (Optical Science and Engineering), CRC Press, 2007
2. Ioannis Kymissis, Organic Field-Effect Transistors: Theory, Fabrication and Characterization (Integrated Circuits and Systems), Springer, 2009
3. Qiquan Qiao (Editor), Organic Solar Cells: Materials, Devices, Interfaces, and Modeling (Devices, Circuits, and Systems), CRC Press, 2015
4. Christoph Brabec, Ullrich Scherf, Vladimir Dyakonov (Editors), Organic Photovoltaics: Materials, Device Physics, and Manufacturing Technologies, Wiley-VCH, 2014
5. Frederik C. Krebs, Stability and Degradation of Organic and Polymer Solar Cells, Wiley, 2012
6. Hagen Klauk (Editor), Organic Electronics: Materials, Manufacturing, and Applications, Wiley-VCH, 2006; Organic Electronics II: More Materials and Applications, Wiley-VCH, 2012
7. Franky So (Editor), Organic Electronics: Materials, Processing, Devices and Applications, CRC Press, 2009
8. Mario Pagliaro, Flexible Solar Cells, Wiley-VCH, 2008