PHY-931 Magnetism & Applications

Credit Hours: 3-0
Prerequisite: None

Objectives and Goals: Magnetism and applications is an introductory course to the students intending to do specialization in magnetism, nanoscience, and nanotechnology. The course shall cover one of the fundamental concepts in Physics i.e., Magnetism. The course shall also prepare students for the state-of-the-art technologies based on magnetism *viz.* Spintronics.

Core Contents: Magnetism, Diamagnetism, Paramagnetism, Ferromagnetism, Antiferromagnetism, Anisotropy, Spin Orbit coupling, Magnetoresistance, Spintronics devices

Detailed Course Contents: The course include brief history of magnetism, magnetic hysteresis, anisotropy, magnetic dipole moment, Susceptibility and permeability, Orbital and spin moments, Spin moment, Spin–orbit coupling, Angular momentum, Orbital Diamagnetism, Curie-law and Magnetic Susceptibility, Paramagnetism, Brillouin Theory, Langevin Theory, Ferromagnetism and Exchange Interaction, Mean Field Theory, Antiferromagnetism, Ferrimagnetism, Spin Waves, Shape Anisotropy, Magnetocrystalline Anisotropy, Induced Anisotropy, Multiferroics, Rare-earth metals and inter-metallics compounds, Spin-polarized Currents, Spin Polarization, Spin Injection and Spin Accumulation, Spin Currents, Materials for Spin Electronics, The Quantum of Conductance, Potential Profile, Coulomb Blockade, Spin-orbit Coupling, Spin Hamiltonian, Spin Density/Current, Spin Voltage, Spin Transistor, Magnetoresistances, Magnetic semiconductors and insulators, and Fabrication of Spintronics Devices.

Course Outcomes: The students shall be able to understand:

- The concept of origin of magnetism.
- Various kinds of magnetic phenomenon such as paramagnetism, diamagnetism in materials.
- The origin of magnetic ordering including ferromagnetic and antiferromagnetic ordering and its consequences.
- The magnetic domains and related effects.
- The concept of spin and the devices based upon spin-motion.
- Ferromagnetic ordering and its applications.

Textbook: Nicola A. Spaldin, Hisao Nakanishi, Magnetic Materials Fundamentals and Applications, 2nd ed. Cambridge University Press 2011. (referred as NS)

Reference Book: J. M. D. Coey, Magnetism and Magnetic Materials, Cambridge University Press 2009. (referred as JC)

Weekly Breakdown		
Week	***Section***	***Topics***
1	NS 1.1-1.2, 2.1-2.6	Introduction, Magnetic poles, Ampere's law, Magnetic moment and circulating current, Magnetization, Susceptibility, Permeability, Hysteresis loop, Coercivity
2	NS 3.1-3.5	Solutions of Schrodinger wave equation, Normal Zeeman effect, Spin, Pauli exclusion principle and many electrons system, Spin Orbit coupling and Anomalous Zeeman Effect
3	NS 4.1-4.5, 5.1	Diamagnetism, Diamagnetic susceptibility, Superconductivity, Meissner effect, Langevin theory of Paramagnetism
4	NS 5.2-5.6	Curie-Weiss law, Quenching of orbital angular momentum, Pauli Paramagnetism, Paramagnetic Oxygen
5	NS 6.1-6.3 + JC 5.1-5.2	Molecular Weiss Theory, Spontaneous Magnetization, Curie Temperature, Temperature dependence of magnetization, Exchange Interaction
6	NS 7.1-7.4	Ferromagnetic domains, magnetic energies, Domain wall, Magnetization and Hysteresis
7	NS 8.1-8.2	Neutron diffraction, Weiss theory of antiferromagnetism, Neel temperature, Susceptibility above and below Neel temperature
8	NS 5.4-5.5	Ferrimagnetism, Weiss theory of ferrimagnetism, Cubic and Hexagonal Ferrites
9	NS 11.1 – 11.3	Anisotropy, Magnetocrystalline Anisotropy, Shape Anisotropy, Induced Magnetic Anisotropy
10	JC 14.1 – 14.2	Spin-polarized Currents, Spin Polarization, Spin Injection and Spin Accumulation, Spin Currents, Materials for Spin Electronics
11	Handout	Spin-orbit Coupling, Spin Hamiltonian, Spin Density/Current, Spin Voltage, Spin Transistor
12	Handout	An Atomistic View of Electrical Resistance, Energy Level Diagram, What Makes Electrons Flow? The Quantum of Conductance, Potential Profile, Coulomb Blockade, Towards Ohm's Law
13	NS 13.1-13.3	Magnetoresistance in metals and ferromagnetic materials, Anisotropic magnetoresistance, Giant Magnetoresistance, Colossal Magnetoresistance, Super exchange and double exchange
14	NS 17.1, 17.2, 17.4, 17.5	Magnetic semiconductors and insulators, Exchange interactions in magnetic semiconductors and insulators, Bimetallic and Oxide-based diluted magnetic semiconductors, Ferromagnetic insulators
15	NS 18 + Handouts	Multiferroics