Course Code	Course Name	Credits
26PH602	MAGNETISM AND SUPERCONDUCTIVITY	04

Course Objectives

- We use basic quantum mechanical models of atoms, ions, and metals to derive theoretical concepts that show why magnetism and superconductivity occur. We discuss how the key characteristics of magnetism and superconductivity are apparent in these models. We perform some hands-on demonstrations in the lectures which can be linked back to these models.

Learning Outcomes

Upon successful completion of this course it is intended that a student will be able to:

- Introduce modern quantum mechanical theories of magnetism and superconductivity.
- To show how quantum mechanics can explain the important experimental phenomena and make quantitative predictions of experimental observables.
- To introduce, where possible, topics of current research interest, such as high temperature superconductivity and advanced magnetic materials.

Unit 1 - Electrons In Bands (12 Hrs.)

Electronic band-structure. Tight binding approximation. Screening and the Mott transition.

Unit 2 – Magnetism (12 Hrs.)

Diamagnetism, paramagnetism. Hund's rules, crystal field effects. The exchange interaction. Weiss' mean field model of ferromagnetism. The Stoner band model of ferromagnetism. Antiferromagnetism. Spin waves.

Unit 3 - Superconductivity – I (12 Hrs.)

Basic features: Zero resistance, critical temperatures and fields, Type I and II behaviour. The Meissner-Ochsenfeld effect- Thermodynamics- Electrodynamics: the London theory, flux quantization, penetration depth and coherence length. The origin of the attractive interaction, electron-phonon interaction.

Unit 4 – Superconductivity –II (12 Hrs.)

Microscopic BCS theory- Cooper pairs, BCS wavefunction, variational solution, quasiparticle excitations, density of states.

Unit 5 - High Temperature Superconductors (12 Hrs.)

Electronic structure, d-wave superconducting gap, unconventional superconductors (non-phonon pairing), fluctuation effects. Single particle quasiparticle tunnelling, Josephson effect and its application in SQUIDs, and Shapiro steps.

Reference Books:

1. Solid State Physics-Gupta Kumar
2. Blundell S, Magnetism in Condensed Matter, 1st Edition, Oxford (2001)
3. Enss C and Hunklinger S, Low-Temperature Physics, 1st Edition, Springer (2005) Ashcroft N W and Mermin N D, Solid State Physics, 1st Edition, Cengage (2003)
4. Buckel W and Kleiner R, Superconductivity: Fundamentals and Applications, Taylor & Francis (1999)
5. Kittel C, Introduction to Solid State Physics, 12th Edition, Wiley (2012)
6. de Gennes P G, Superconductivity of Metals and Alloys, Taylor & Francis (1999)

Websites and eLearning Sources:

1. https://nptel.ac.in/courses/115105131
2. https://youtu.be/ots5zxbrlUk?si=pkL6h5ann9a6n1NL
3. https://youtu.be/l9sRmI1Op6A?si=xtYsLBF24JzEPbrW

COs and Bloom's Taxonomy Mapping – 26PH602		
Course Outcomes	**On successful completion of this course, students will be able to**	**BTL**
CO1	Recall and explain electronic band structure, tight binding approximation, and screening effects in solids.	K1, K2
CO2	Apply concepts of magnetism including diamagnetism, paramagnetism, exchange interaction, and ferromagnetic models.	K3
CO3	Analyze superconducting properties using London theory and electromagnetic behavior of Type I and Type II superconductors.	K4
CO4	Analyze microscopic theory of superconductivity including BCS theory, Cooper pairs, and quasiparticle excitations.	K5
CO5	Evaluate and design advanced superconducting systems including high-temperature superconductors and Josephson devices.	K6

BTL (Bloom's Taxonomy Level) - K1 – Remembering, K2 – Understanding, K3- Applying, K4 – Analyse, K5- Evaluate and K6 - Create

Relationship Matrix – 26PH602													
Course Outcomes	**Programme Outcomes (POs)**						**Programme Specific Outcomes (PSOs)**						**Mean Score of Cos**
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PSO1**	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	
CO1	3	2	1	1	1	1	3	2	1	1	1	1	1.58
CO2	3	3	2	2	1	1	2	3	2	2	2	1	2.00
CO3	3	3	3	2	1	1	2	3	3	2	2	2	2.25
CO4	3	3	3	2	2	1	2	3	3	2	2	2	2.33
CO5	3	3	3	3	2	2	3	3	3	3	2	2	2.58
												Total	2.15

Mean Score: 3- High, 2- Medium/Moderate, 1-Low