

# **Blow-up Syllabus**

**Course Code and Title**

**1BPHEE102/202 Physics of Electrical and Electronic Materials (EEE)**

### Dielectric and Magnetic Materials:

#### Dielectrics :

Introduction, Electrical Polarization Mechanisms, Internal fields in solids (qualitative), Clausius-Mossotti relation (Derivation) and its implications, Properties and Frequency dependence of Dielectric constant, Dielectric loss, Solid, Liquid and Gaseous dielectrics. Application of dielectrics in Capacitors, Transformers (Oils), SF<sub>6</sub> in High Voltage application, Numerical Problems.

#### Magnetic material :

Classification of magnetic materials, Weiss Molecular field theory of ferromagnetism(Qualitative), Importance of Curie Temperature, Ferromagnetic Hysteresis and Explanation using Domain theory, Energy loss, Hard and soft ferromagnetic materials and Applications, Transformer Cores, Armature, Inductors and chokes, Permanent Magnets, Numerical Problems

# Module - 1 Blow-up

Subtopics	Topics to be covered	Duration
Introduction, Electrical Polarization Mechanisms, Internal fields in solids (qualitative),	Fundamental definitions of dielectrics such as dielectric constant, electric polarization, Polarization vector, electric displacement vector and electric susceptibility. Internal Fields: Definition, Explanation, and Mention of expression for one dimensional array of dipoles and explaining all notations used, Extension to three dimension and expression for Lorentz Field.	1½ Hour
Clausius-Mossotti relation (Derivation) and its implications, Properties and Frequency dependence of Dielectric constant	Clausius-Mossotti relation(Derivation) and its implications and limitations, Variation of dielectric constant as a function of frequency and complex dielectric constant	1 Hour
Dielectric loss, Solid, Liquid and Gaseous dielectrics. Application of dielectrics in Capacitors, Transformers (Oils), SF6 in High Voltage application,	Dielectric loss, Solid, Liquid and Gaseous dielectrics, Mention and Applications of Solid dielectric in capacitors, Ceramic, Glass, Mica and Polymer, Application of Liquid Dielectrics, Oils in Transformers, Mineral oils and Synthetic oils, use of gas dielectric Sulphur Hexafluoride SF <sub>6</sub> in high voltage applications.	1 Hour
Numerical Problems	Numerical Problems on Clausius-Mossotti Relation, Polarization $P = \epsilon(\epsilon_r - 1) E$	½ Hour
Classification of magnetic materials, Weiss molecular field theory of ferromagnetism, importance of Curie temperature.	Classification – Diamagnetic, Paramagnetic, Ferromagnetic, Antiferromagnetic and Ferrimagnetic. Weiss molecular field theory of ferromagnetism Qualitative-Curie-Weiss Law(Mention), importance of Curie temperature.	1½Hour
Ferromagnetic Hysteresis and Explanation using Domain theory, Energy loss, Hard and soft ferromagnetic materials	Ferromagnetic Hysteresis and Explanation using Domain Theory (Explanation for Domain wall movements), Hard and Soft Ferromagnetic materials: Properties and Applications.	1 Hour
and Applications, Transformer Cores, Armature, Inductors and chokes, Permanent Magnets, Numerical Problems	Distinguishing Hard and Soft based on properties and hysteresis, Explanation for applications of magnetic materials in Transformer cores, Armatures, Inductors and Chokes, Permanent Magnets and mentioning type hard or soft.	1 Hour
Numerical problems	Numerical problems on Curie-Weiss Law $\chi = C/(T-T_c)$	½ Hour

### Thermoelectric materials and devices: Dielectric and Magnetic Materials:

Thermo emf and thermo current, Seebeck effect, Peltier effect, Seebeck and Peltier coefficients, figure of merit (Mention Expression), laws of thermoelectricity. Expression for thermo emf in terms of  $T_1$  and  $T_2$ , Thermo couples, Thermopile, Construction and Working of Thermoelectric generators (TEG) and Thermoelectric coolers (TEC), Low, mid and high temperature thermoelectric materials, Applications: Exhaust of Automobiles, Refrigerator, Space Program (Radioisotope Thermoelectric Generator), Numerical Problems.

## Module - 2 Blow-up

Subtopics	Topics to be covered	Duration
Thermo emf and thermo current, Seeback effect, Peltier effect,	Introduction and definition of thermo emf and current, Qualitative explanation of both the effects along with relevant diagrams.	1 Hour
Seeback and Peltier coefficients, Figure of merits	Mention Neutral temperature, thermo electric power, Seeback and Peltier coefficients, Figure of merit along with equations	1 Hour
Laws of thermoelectricity	Statement and brief explanation of Law of homogeneous circuit, law of intermediate metals and law of intermediate thermo couple	½ Hour
Expression for thermo-emf in terms of $T_1$ and $T_2$ ,	To derive the equation Using thermodynamics and Peltier effect	1 Hour
Thermocouple and Thermopile	Construction and working, Mention of Advantages and disadvantages	1 Hour
Thermoelectric generators (TEG), Thermoelectric coolers (TEC)	Construction and working of both and mention of applications.	1 Hour
Thermoelectric materials	Low, medium and high temperature TE materials with examples	½ Hour
Applications	Applications: Exhaust of Automobiles, Refrigerator, Space Program (RTG)	1 Hour
Numerical Problems	Numerical Problems on Thermo emf, Figure of Merit.	1 Hour

### **Electrical Properties of Metals and Semiconductors:**

Failures of classical free electron theory, Mechanisms of electron scattering in solids, Matheissen's rule, Assumptions of Quantum Free Electron Theory, Density of States, Fermi Dirac statistics, Fermi Energy, Variation of Fermi Factor With Temperature and Energy, Expression for carrier concentration, Derivation of electron concentration in an intrinsic semiconductor, Expression for electron and hole concentration in extrinsic semiconductor, Fermi level for intrinsic(with derivation) and extrinsic semiconductor (no derivation), Hall effect, Numerical Problems. Numerical Problems.

**Number of Hours - 8**

# Module - 3 Blow-up

Subtopics	Topics to be covered	Duration
Failures of classical free electron theory, Mechanisms of electron scattering in solids,	Introduction, Classical Free electron theory of metals, expression for electrical conductivity(Self Learning and flipped Class content). Mobility Failures of Classical free electron theory of metals, Mechanisms of electro scattering in solids	1 Hour
Matheissen's rule, Assumptions of Quantum Free Electron Theory, Density of States,	Mathiessen's Rule, Assumptions of Quantum free electron theory of metals, Density of States: Explanation, Mention of expression mention of expression, Graphical representation of Density of states with Energy.	1 Hour
Fermi Dirac statistics, Fermi Energy, Variation of Fermi Factor With Temperature and Energy,	Fermi Dirac Statistics, Fermi Energy, Fermi Factor, Variation of Fermi factor with temperature and energy,	1 Hour
Expression for carrier concentration,	$N(E) dE = g(E) dE \cdot f(E)$ , Graphical Representation, Derivation of Expression for carrier concentration.	1 Hour
Derivation of electron concentration in an intrinsic semiconductor, Expression for electron and hole concentration in extrinsic semiconductor,	Derivation of expression for electron concentration in an intrinsic semiconductor, Expression for electron and hole concentration in extrinsic semiconductor,	1 Hour
Fermi level for intrinsic(with derivation) and extrinsic semiconductor (no derivation),	Fermilevel for Intrinsic Semiconductor (Derivation) and Explanation in extrinsic semiconductor (No derivation)	1 Hour
Hall effect	Principle, Explanation with diagram, Hall Voltage and Hall Coefficient, Derivation of Expressions, Explanation for the identification for the type of charge carriers.	1 Hour
Numerical Problems.	Numerical Problems on Carrier concentration in conductors, Hall Voltage and Constant.	1 Hour

### Superconductivity :

Zero resistance state, Persistent current, Meissner effect, Critical temperature, Critical current (Silsbee Effect) – Derivation for a cylindrical wire using ampere's law, Critical field, Formation of Cooper pairs - Mediation of phonons, Two-fluid model, BCS Theory - Phase coherent state, Limitations of BCS theory, Type-I and Type-II superconductors, High  $T_c$  superconductors, Formation of Vortices, Explanation for upper critical field, Josephson junction, Flux quantization, DC Squid, Superconducting Magnet, MAGLEV, Numerical Problems.

**Number of Hours - 8**

## Module - 4 Blow-up

Subtopics	Topics to be covered	Duration
Zero resistance state, Persistent current, Meissner effect, Meissner effect, Critical temperature,	Zero resistance state, Persistent current, Meissner effect, Meissner effect(Negative Magnetic Moment, Perfect Diamagnetism, Critical temperature,	1 Hour
Critical current (Silsbee Effect) – Derivation for a cylindrical wire using ampere’s law	Critical current (Silsbee Effect) –Derivation for a cylindrical wire using ampere’s law(Derivation of expression for Critical Current).	1 Hour
Critical field, Formation of Cooper pairs - Mediation of phonons, Two-fluid model, BCS Theory - Phase coherent state,	Critical field, Variation of critical field with temperature below critical temperature. Formation of Cooper pairs - Mediation of phonons, Two-fluid model, BCS Theory - Phase coherent state,	1 ½ Hour
Limitations of BCS theory, Type-I and Type-II superconductors,	Limitations of BCS theory, Type-I and Type-II superconductors : Explanation with Graphs and mention of material examples	1 Hour
Formation of Vortices, Explanation for upper critical field, Josephson Junction	Formation of Vortices, Explanation for upper critical field, Josephson junction : Construction, Explanation for cooper pair tunneling	1 Hour
Flux quantization,DC Squid, Superconducting Magenet, MAGLEV	Flux quantization,, DC Squid : Construction, Explanation and application, Superconducting Magnet: Construction, Explanation, Application, MAGLEV – Principle, Generation of Magnetic Levitation, Working	1 ½ Hour
Numerical Problems.	Numerical Problems on Critical Current and Critical Field and Critical Temperature	1 Hour

### Electrical Engineering Materials :

Rare earth materials, Role in energy systems, Electrical & Magnetic phase diagram, Examples & high magnetic field applications, Ceramics: Types, Materials, Applications, Electrostriction, Strain proportional to square of the electric field, Comparison with piezoelectric effect, Materials, Applications, Electrorheological (ER) materials, Principle, Viscosity changes under applied electric field, ER Fluids, Applications, Magnetorheological (MR) materials, Principle, Magnetic field-induced change in viscosity, MR Fluids, Applications

**Number of Hours - 8**

# Module - 5 Blow-up

Subtopics	Topics to be covered	Duration
Rare earth materials, Role in energy systems, Electrical & Magnetic phase diagram, Examples & high magnetic field applications,	Role of materials in energy systems and devices, Electrical and Magnetic Phase diagram of Rare Earth Materials: Heavy Lanthanides (Gadolinium (Gd) and Terbium (Tb)) Applications: NdFeB and SmCo for high magnetic field applications in transformers, MRI.	1 ½ Hour
Ceramics: Types, Materials, Applications,	Electrical Ceramics, Types: Ferroelectric, Piezoelectric, Magnetic ceramics, Materials: BaTiO <sub>3</sub> , Al <sub>2</sub> O <sub>3</sub> , SiC, ZnO, Applications: Capacitors, surge protectors,	1 Hour
Electrostriction, Strain proportional to square of the electric field, Comparison with piezoelectric effect, Materials, Applications,	Electrostrictive Materials, Electrostriction: Strain proportional to the square of electric field, Comparison with piezoelectric effect, Materials: PMN (Lead Magnesium Niobate), PLZT, Applications: High-precision actuators, adaptive lenses Magnetostrictive Materials, Magnetostriction: Dimensional change under magnetic field, Materials: Terfenol-D, Galfenol, Nickel Applications: Sonar,	1 ½ Hour
Electrorheological (ER) materials, Principle, Viscosity changes under applied electric field, ER Fluids, Applications,.	Electrorheological (ER) Materials, Principle: Viscosity changes under applied electric field, ER fluids: Suspensions of polarizable particles in insulating oil, Applications: ER clutches, valves,	1 ½ Hour
Magnetorheological (MR) materials, Principle, Magnetic field-induced change in viscosity, MR Fluids, Applications	Magnetorheological (MR) Materials, Principle: Magnetic field-induced change in viscosity, MR fluids: Suspensions with magnetic particles (e.g., carbonyl iron), Applications: robotic actuators	1 ½ Hour
Numerical Problems	Electrostrictive Strain ( $S = ME^2$ ), Electrical Energy Density ( $u_e = \frac{1}{2} \epsilon_0 E^2$ for vacuum or $u_e = \frac{1}{2} \epsilon E^2$ in a material,), Magnetostriction strain [saturation magnetostriction coefficient, $\lambda = \Delta L/L$ ]	1 Hour