applications of dielectric materials. Problems and recent developments. The complex dielectric constant, dielectric losses and relaxation time - Debye equations - theory of electronic polarisation and optical absorption. Optical Phenomena in Insulators Colour of crystals - Excitons - weakly bound and tightly bound excitons, photoconductivity. Colour centers – F-centers and other electronic centers in alkali halides. 18 hours

Unit II

Ferroelectrics: General characteristics - piezoelectric, pyroelectric and ferroelectric materials - transducer and detector applications. Classification of ferroelectrics and representative materials. Structure of KDP and explanation for its ferroelectric behaviour. Objection against dipole theory, Ionic displacement theory Barium titanate and its ferroelectric behaviour. Crystal structure and theory of spontaneous polarisation in barium titanate and related experiments. Zeroes and poles of the dielectric function – Lyddone-Sachs-Teller relation. Problems. Ferroelectric domains. Thermodynamics of ferroelectric phase transitions. Remarks on antiferroelectric materials - Materials with paired properties like ferroelectric-ferroelastic, ferroelectric-ferromagnetic and recent developments. 18 hours

Unit III

Thermal Properties of Insulators: Heat capacity - Einstein's model - quantisation of lattice vibration - continuum model - Debye's theory –phonons – problems. Vibrations of monoatomic lattice - specific heat of one-dimensional lattice of identical atoms. Vibrations of diatomic lattice - phonon spectra and phonon modes - optical properties in infra-red region and their applications. Scattering of electromagnetic waves and neutrons by phonons – phonon spectra from neutron diffraction. Thermal conductivity of insulators - lattice thermal resistivity – normal and Umklapp process – related problems. Thermal expansion: potential wells in crystal binding - anharmonic interactions and thermal expansion of insulators. 18 hours

Reference

1. Introduction to Properties of Materials – D Rosenthal and R M Asimov (East West, 1974)
2. Elements of Materials Science and Engineering – L H van Vlack (Addison Wesley, 1975)
3. Introduction to Solid State Physics – C Kittel (II & IV Ed. Wiley & sons, 1961 & 1964)
4. Solid State Physics – A J Dekker (McMillan, 1971)
5. Advances in Solid State Physics, Vol. II & V –Seitz and Turnbull (Ed) (Academic, 1957)
6. Physics of Dielectric Materials – B Tareev (MIR, 1979)
7. Crystal Structures, Vol.1-3 – W G Wyckoff (Interscience, 1963)
8. Electronic Properties of Materials – Hummel (Springer-Verlag, 1985)
9. Solid State Physics Source Book – Sybil P Parker (Ed) (McGraw Hill, 1987)
10. Principles of Solid-State Physics – Robert A Levy (Academic Press inc., 1968)
11. Elementary Solid-State Physics; Principles and Applications – Omar M A (Addison Wesley, 2001)

MSH 502 MAGNETIC MATERIALS & MAGNETIC RESONANCE (4 Credits)

Objectives:

The objectives of this course are to (i) impart an understanding of the basic phenomena in condensed matter (ii) introduce the different classes of magnetic materials, their origin, and the theories to understand their behaviour (iii) introduce the resonance concept in NMR and Mossbauer with rigorous theory (iv) enable the student to apply this theoretical foundation in spectroscopic techniques for research and other applications.

Expected course outcomes: By the end of the course, students will be able to (i) identify the basic differences and causes of various types of magnetism in materials (ii) identify the magnetic interactions with electric and magnetic fields and their applications in magnetic resonance (iii) explain the principles of resonance based spectroscopic tools in materials research (iv) acquire knowledge about the characterization techniques for magnetic materials (v) apply the knowledge in applications such as magnetic storage devices, MRI, NMR.

Unit I

Introduction to magnetic materials – magnetic susceptibility and permeability. Classification – dia- para- and ferro-magnetic materials. Amperian concepts. Langevin's theory of diamagnetism. Origin of magnetic moments. Classical and quantum theories of paramagnetism- Curie law- Effective number of Bohr magneton- Quenching of orbital magnetic moments- Experimental determination of diamagnetic and paramagnetic susceptibility- anisotropy in susceptibility. Cooling by adiabatic demagnetization. Ferromagnetism – characteristic features- hysteresis loop. Weiss concepts- Curie-Weiss law. Related problems and applications. 18 hours

Unit II

Exchange interaction and spontaneous magnetization in ferromagnetic materials - temperature dependence- Heisenberg's theory- Exchange integral. Heusler alloys. Gyromagnetic experiments- g factor. Ferromagnetic domains - origin of domains - anisotropy energy - Bloch wall - magnetostriction. Hard and soft magnetic materials – hysteresis loss – applications - Transformers, electromagnets, permanent magnets – magnetic recording - memory devices. Giant magnetoresistance, Ultrafast magnetism. Antiferromagnetism - sub lattice model - Neutron diffraction in magnetic structure analysis – Super-exchange phenomena - Ferrimagnetism and structure of ferrites and their applications. Spin waves - quantisation of spin waves - magnons. 18 hours

Unit III

Magnetic Resonance and material analysis - Nuclear Magnetic Resonance - Elements of theory –instrumentation. Population of states - rate of energy absorption – Spin-lattice and spin-spin relaxation processes-Bloch equations – Wide line NMR – Knight shift. Applications of NMR – structure of molecules, MRI. Paramagnetic resonance – principles and comparison of PMR with NMR. Electron spin resonance -– principles –comparison with NMR. Related experiment – determination of Lande splitting factor g. Areas of applications and related problems.

Mossbauer effect - elements of theory – Mossbauer spectroscopy – centre shift, chemical shift, Zeeman shift, experimental techniques and applications. Related problems. 18 hours

References

1. Modern Magnetism – L F Bates (Cambridge University Press, 1963)