B.Sc. III SEMESTER PHYSICS

ELECTROMAGNETIC THEORY AND MODERN OPTICS

Electrostatics : Electrostatics is the study of stationary electric charges at rest. An electroscope is used to detect the presence of a charge on a body. Electrostatics is the study of the accumulation of charge on the surface of objects as a result of contact with other surfaces.

Electric Charge: It is the property associated with the matter because of which it produces and experiences electrical and magnetic effects. There are two kinds of charges: Positive charge (+) and Negative charge (-).

Properties of Electric Charges:

Charge could also be a scalar quantity: Charges can be added or subtracted algebraically.

- **Charges are transferable:** If a charged body is put in tune with the uncharged body, the uncharged body becomes charged because of the transfer of electrons.
- **Charge is typically associated with mass:** Charge cannot exist without mass, though mass can exist without charges.
- **Charge can produce electric and magnetic fields:** If a charge is at rest or unaccelerated, it produces an electric field in the space around it.
- **Charges reside to stay on the surface of the conductor:** Charges reside on the outer surface of a conductor because like charges repel each other.
- **Quantization of charge:** The Quanta of charge on a body is getting to be an integral multiple of electrons i.e. $Q = \pm$ ve with $n = 0, 1, 2\ldots$

Coulomb's Law of Electrostatics: Coulomb's law of Electrostatics could also be a quantitative statement about the force between two point charges. It is given by $F = k\, q_1\, q_2/ r^2$ Where k = proportionality constant.

Electric Field: The electric field is the space around an electric charge in which its influence can be felt. It is denoted by 'E' .The magnitude of the electric field is simply defined as the force per charge on the test charge

Electric Dipole: A pair of equal and opposite charges, +q and -q, is separated by a very small distance from an electric dipole.Dipole Moment = either one of charges × distance between the +ive and -ive charge. Magnitude of dipole moment is $|\vec{p}|=q\times 2a$.

Electric Flux: Assume a plane surface of area ΔS in a uniform electric field E in space. Electric flux of the electric field through the chosen surface is then, $\Delta\varphi = E\Delta S\cos\theta$

Energy Density of Electric Field : To find the energy density U_E stored between the plates of a charged parallel-plate capacitor, we have to divide the potential energy {U} by the volume Ad of space between the plates and for a parallel-plate capacitor, We have $E=\sigma/\epsilon 0$ & $C=\epsilon 0A/d$

Magnetostatics: Magnetostatics deals with stationary electric currents, as opposed to electrostatics, which deals with static electric charges. According to him, when charges are in motion they are surrounded by a magnetic field. Therefore a current-carrying conductor is always surrounded by a magnetic field.

Magnetic Fields: A magnetic field is defined as the region around a magnet where the influence of the magnet is felt. This field is simply a representation of imaginary lines surrounding the magnet, also known as magnetic lines of force or magnetic flux lines. It is given by $B=\mu_0 I / 2\pi r$

Magnetic Field Intensity: It is defined as the ratio of the magnetic field in free space to the permeability of the free space. It is measured in amperes per metre and is expressed as the vector H.

Magnetic Flux: Magnetic flux is a measurement of the total magnetic field that flows through a specific area. The SI unit of magnetic flux is Weber (Wb). Magnetic flux formula is: $\phi B = B \cdot A = BA\cos\Theta$

Ampere's Law : The law explains the relationship between the magnetic field and the current field that produces it. The law is named after its discoverer Andre Marie Ampere, a French scientist. Integral form is $\oint B.dl = \mu 0\ I$ and Differential form $B = 0J$

Applications of Ampere's law: 1. Calculate the magnetic field within the conductor. **2.** Determine magnetic induction by a long wire using Ampere's Law. **3.** Calculate the magnetic field produced by a long current-carrying conducting cylinder.

Electromagnetic Induction: The induction of an electromotive force by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field is called Electromagnetic Induction**.** This law of electromagnetic induction was found by Michael Faraday**.**

Faraday's law of Electromagnetic Induction:

First law: Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is a closed circuit than the induced current flows through it.

Second law: The magnitude of the induced EMF is equal to the rate of change of flux linkages.

Lenz's law : Lenz law of electromagnetic induction states that, when an emf induces according to Faraday's law, the polarity (direction) of that induced emf is such that it opposes the cause of its production. According to Lenz's law: $\mathbf{E = -N\ (d\Phi/\ dt)}$ **(volts)**

Ballistic Galvanometer: The ballistic galvanometer is a galvanometer that is used to measure small-duration electric charge. It can be a moving coil or a moving magnet. It is given by $q = K\theta$

Advantages of Ballistic Galvanometer: 1. The measurement is accurate and precise. 2. The torque to weight ratio is high in a ballistic galvanometer. This avoids errors.

Disadvantages of Ballistic Galvanometer: 1. It generates mistakes due to the ageing of components such as springs, permanent magnets and so on. 2. Because it operates on the permanent magnet moving coil principle, it can only be used for DC measurements.

Applications of Ballistic Galvanometer: 1. It is used in laser displays and laser engraving. 2. It is used to detect the presence of current in the loop in the Wheatstone bridge. 3. It can measure current by connecting a low resistance in parallel to it.

Electromagnetic Waves: Electromagnetic waves are coupled time-varying electric and magnetic field that propagate in space. The broad spectrum of electromagnetic waves stretches from gamma radiation to radio waves. **Properties of Electromagnetic Waves** : 1. The electric and magnetic fields in an electromagnetic wave are perpendicular to each other and to the direction of propagation. 2. Electromagnetic waves carry energy and momentum like other waves**.**

Energy density stored in the Electric and Magnetic Field: The properties of electromagnetic waves are that they transport energy from one point to another and this energy density of a wave (U) is the amount of energy radiated per unit volume. The total stored energy can be given as $U = (UE+UB) = \epsilon o E^2$

Group Velocity: The Group Velocity of a Wave is defined as the Velocity at which an entire envelope of Waves moves through a medium. The group velocity of the wave can be expressed mathematically as $V_g = d\omega / dk$.

Phase velocity: The phase velocity of the wave is actually the velocity of its phase, which propagates along with the wave. Phase velocity is defined as the rate of propagation of phase of waves through the space. Phase velocity of wave can be calculated using the expression, $V_p = \lambda / T$ here, λ = wavelength and T =Time period.

Diffraction: Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening.It can occur only when the wavelength of light is comparable to the size of the obstacle or the width of the slit. Diffraction are of two types.

Single Slit Diffraction of Light: When the monochromatic light ray falls on a single slit then it gets diffracted from the slit and forms a bright and dark band on the screen. This phenomenon is known as Single Slit Diffraction. he bright pattern is also called maxima and the dark band is called minima. At maxima, the intensity is maximum and at minima, the intensity of light is minimum. The width of the maxima is given by: $a\sin\theta = n\lambda$.

Diffraction Grating: A diffraction grating is an extremely useful device, and one of it consists of a large number of narrow slits side by side.The formula for the diffraction grating is given $d\sin\theta = m\lambda m = 0, \pm1, \pm2, \ldots$

Rayleigh Scattering: The scattering of light by particles in a medium, without a change in wavelength, is called Rayleigh scattering. Rayleigh scattering can be considered to be elastic scattering since the photon energies of the scattered photons are not changed.

Resolving Power: The capacity of an optical instrument to show separate images of very closely placed two objects is called resolving power. .

Resolving the Power of a Telescope: The reciprocal of the smallest angle subtended at the objective lens of a telescope by two-point objects which can be just distinguished as separate is called the resolving power of a telescope.The resolving power of a telescope is given by: $\theta R = \sin^{-1}(1.22\lambda / d) \approx 1.22 \times \lambda / d$

Transverse waves are waves, in which the movement of the particles in the wave is perpendicular to the direction of motion of the wave.**Example:** ripples in water when you throw a stone.

Longitudinal waves are formed when the particles of the medium travel in the direction of motion of the waves.**Example:** the motion of sound waves through the air.

Polarization of Light: When we restrict vibration to an electrical vector in an unpolarized light we get plane polarized light. In this the direction of vibration of electric vector and direction of light propagation are perpendicular to each other as shown below.

Unpolarized Light: When light wave propagates it consists of vibration of electric field in all possible direction, which are perpendicular to its direction of propagation and such light waves are said to be unpolarized light.

Types of Polarization: There are three main types of polarization namely, linear polarization, circular polarization, and elliptical polarization.

1. Linear polarization is when the oscillation of a wave is constrained to a single plane. This is the plane of polarization. **2. Circular polarization** is when two linear components of a wave oscillate perpendicular to each other such that their amplitudes are equal. **3. Elliptical polarization** is the same as circular polarization except that the amplitudes and phase differences are not the same.

Terminology of Polarization:

- **Plane of vibration**: The plane in which vibration of electric field vectors are restricted are termed as plane of vibration.
- **Plane of polarization**: The plane which is perpendicular to the plane of vibration i.e., the plane in which there is no vibration of electric field vectors are known as planes of polarization.
- **Polarizers**: The device which is used to polarize an unpolarized light are known as polarizers and some of its examples are Nichol prism, Tourmaline crystal, etc.
- **Analyzer**: The device which is used to determine the plane of polarization is termed as analyzer.
- **Polaroids**: It is a large sheet made up of microscopic diachronic crystals which can produce a beam of polarized light.

Applications of Polarization: 1. Polarization is used in sunglasses to reduce the glare. 2. Polaroid filters are used in plastic industries for performing stress analysis tests. 3. Three-dimensional movies are produced and shown with the help of polarization..

Brewster's Law (Polarization by Reflection): Brewster's law states that the tangent polarized angle is equal to the refractive index of the refracting medium at which partial reflection of light took place.Now according to Brewster's law angle of polarization is given as $\tan_\theta = \mu_2 / \mu 1 = n$

Laser: LASER is an abbreviation of Light Amplification by Stimulated Emission of Radiation. Lasers are light beams so powerful that they can travel miles into the sky, and they can also cut through the surfaces of metals.

List of Laser Types: Lasers are classified into 6 types based on the types of medium used in them, and they are: Solid-state lasers, Gas lasers, Liquid lasers, Semiconductor lasers, Chemical lasers, Metal-vapor lasers

Solid-State Lasers: The solid-state laser is a type of laser where the medium used is solid. The solid material used in these lasers is either glass or crystalline materials.

Application of Solid-State Laser: 1. They find application in the military and are used in the target destination system. 2. The drilling of holes in the metals becomes easy with these lasers.

Advantages of Solid-State Lasers: There is very less or zero chance of material in active medium going waste. The efficiency of these lasers is high.

Disadvantages of Solid-State Lasers: The divergence of this laser is not constant and varies between 1 mill radian to 20 mill radians. The output of solid-state lasers is not high.

Gas Lasers: Gas lasers have an active medium made up of one or more gases or vapors. These lasers are classified as: Ion gas lasers that are Argon laser, Atomic gas lasers which is He-Ne laser and Molecular gas lasers which is CO_2 laser

Liquid Lasers: Liquid lasers are also known as dye lasers.This is a type of laser in which liquids are used as an active medium.The active material used in the liquid laser is known as a dye and the commonly used dyes are sodium fluorescent, rhodamine B and rhodamine 6G.

Application of Liquid Laser: These lasers are commonly used for medical purposes as a research tool.

Advantages of Liquid Lasers: 1. The efficiency is greater by 25%. **2.** The wavelengths that are produced can be of varied ranges. **3.** The diameter of the beam is less.

Disadvantages of Liquid Lasers: 1. It is difficult to determine which element is responsible for lasers. **2.** These lasers are expensive.

Semiconductor Lasers: The semiconductor laser is a type of laser that is small in appearance and size. The operation of this laser is similar to LED but the characteristics of the output beam are of laser light.

Application of Semiconductor Lasers: 1. This laser is a transmitter of digital data naturally as the laser can be pulsed at different rates and pulse widths. 2. These lasers find applications in optic cable communication.

Advantages of Semiconductor Lasers: 1. They find many applications due to their small size and appearance. **2.** These lasers are economical.

Disadvantages of Semiconductor Lasers: 1. The working of this laser type is dependent on the temperature **2.** The divergence of the beam is more than 125 to 400 mill radians which is greater than other laser types.