Wave Optics

① Interference:-

when two (or more light waves are super imposed in the medium then a/c to super position principle, the resultant displacement at any point is equal to the algebraic sum of the displacements of the individual waves.
The resultant displacement of the resultant wave is given by $y = y_1 + y_2$.
The variation in the resultant displacement influences amplitude variation, which causes intensity variation.
This modification in the distribution of intensity in the region of super position is known as " Interference ".

② Constructive Interference:-

The resultant amplitude is equal to the sum of the amplitudes of the two light waves is called constructive interference. $y = y_1 + y_2$

③ Distructive Interference:-

The resultant amplitude is equal to the difference of the amplitudes of the two light waves is called distructive interference. $y = y_1 - y_2$.

④ Coherence:-

If the two light waves are said to be coherent they have same frequency and wavelength. The process of maintaining constant phase relation is known as coherence.

⑤ Temparal Coherence:-

It is possible to predict the phase relation at a point on the wave w.r.to another point on the same wave. It is known as temparal coherence.

⑥ Spatial Coherence:-

It is possible to predict the phase relation b/w at a point on the wave w.r.to another point on the another wave. It is known as spatial coherence.

⑦ Newton's Rings:-

When a plano convex lens with its convex surface is placed on a plane glass plate an air film of increasing thickness is formed b/w them.
The thickness of the air film at the point of contact is '0'. If monochromatic light is falls normally and the film is viewed in the reflected light alternat dark and bright rings concentric around the point of contact b/w the lens and the glass plate. These circles are discovered by Newton and are called as "Newton's Rings".

⑧ Applications of Interference:-

(i) Interference is used in signal processing.
(ii) It is also used in image processing.
(iii). Interference phenomenon is used in both wave and light simplifications.
(iv) It is used to determine the elastic constants of materials.
(v). It is used to know the refractive index of the liquid.

⑨ Diffraction:-

When the light falls on the obstacle whose size is comparable with the wavelengths of the light, then the light bends around the obstacle and enters in the geometrical shadow. The bending of light is called diffraction.

(10) Fresnel Diffraction:-

In this diffraction the source and the screen are seperated at finite distance. To study this diffraction lenses are not used. The incident wave front either sphericle or cylindrical.

(11) Fraunhofer Diffraction:-

In this diffraction the source and the screen are seperated at infinite distance. To study this diffraction lenses are used. The incident wave front must be plane.

(12) Polarisation:-

The phenomenon of restricting the vibration of light in a particular direction $\perp$ to the direction of the wave motion is called as polarisation.

(13) Polarisation by Reflection:-

The production of polarised light by the method of reflection from the reflecting surface is called polarisation by reflection..

(14) Polarisation by refraction (Malus law):-

The phenomenon of production of polarised light by the method of refraction is known as polarisation by ~~reflect~~ refraction. (or Malus law.

(15) Polarisation by Double Refraction:-

The phenomenon of splitting of light into two refracted ray namely ordinary and extraordinary ray on passing through a double refracting crystal is known as double refraction.

(16) Quater Wave plate (or $\frac{\lambda}{4}$ plate):-

A double refracting crystal plate having a thickness to produce a path difference of $\frac{\lambda}{4}$ (or) a phase difference of $\frac{\pi}{2}$ between O-ray and E-ray is called as "Quater Wave plate". (or) $\lambda/4$ plate.

(17) Half Wave Plate (or $\frac{\lambda}{2}$ plate):-

A double refracting crystal plate having a thickness to produce a path difference of $\frac{\lambda}{2}$ (or) a phase difference of π between O-ray and E-ray is called as "Half Wave plate" (or) $\lambda/2$ plate

(18) Conditions for interference and sustained interference

(i) The two light waves should be coherent.

(ii). The two sources must be emit continuously. They have same frequency and wavelength.

(iii) The seperation b/w the two sources should be small.

(iv) The distance b/w the sources and the screen should be large.

(v) To view interference pattern the background should be dark.

(vi) The amplitudes of the light waves should be equal (or) nearly equal.

(vii) The sources should be narrow.

(viii) The sources should be monochromatic.

(19) Polarised Light:-

The resultant light wave in which the vibrations are confined in a particular direction of propagation of light wave, such light waves are called polarised light.

(20) Plane of Vibration:-

The plane containing the direction of vibration and the direction of propagation of light is called plane of vibration.

(21) Plane of polarisation:-

The plane passing through the direction of propagation and containing no vibration is called plane of polarisation.

(22) Brewster's law:-

Brewsters law states that when an unpolarised light is incident at polarising angle 'i_p' on an interface seperating air from a medium of refractive index 'μ' then the reflected light is fully polarised.

i.e, $\mu = \tan i_p$.

(23) Malus Law:-

Malus law states that when a beam of completely plane polarised light incident on the plane of analyser, the intensity of the transmitted light directly proportional to the square of the cosine angle b/w plane of polariser and plane of analyser.

$I \propto \cos^2\theta$

$I = I_0 \cos^2\theta \quad \downarrow \quad I_0 = K\epsilon_0^2$

(24) Nicol's Prism:-

It is an optical device made from a calcite crystal for producing and analysing plane polarised light.
It works on the principle of double refraction.
It eliminates O-ray by TIR and E-ray becomes plane polarised emerges through it.

(25) Uses of Quater wave plate & Half wave plate :-

(i) It is used for producing circularly and eleptically polarised light.

(ii) In addition with Nicol prism, It is used for analyzing all kind of polarised light.

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(1) Laser & characteristics of laser :-

A laser is a device that generates light by a process called stimulated emission.

LASER – Light Amplification by Stimulated Emission of Radiation

The characteristics of laser are

(i) High directionality (iii) High monochromatic

(ii) High intensity (iv) High Coherence

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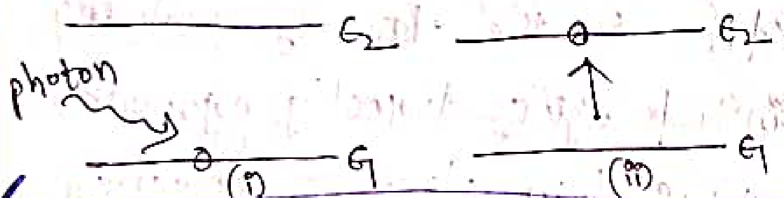
(2) Stimulated Absorption :-

It is the process of excitation atom from ground state to excited state by absorbing incident photon. is called stimulated Absorption



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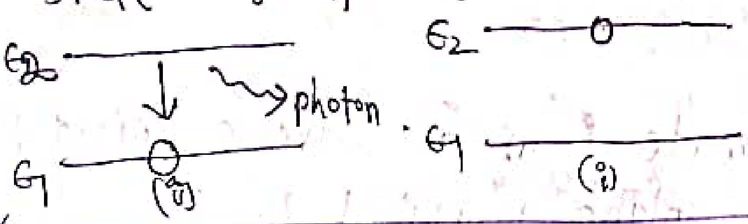
(3) Spontaneous Emission :-

It is the process of de-excitation of atom into ground state from the excited state by emitting a photon. is called spontaneous emission.



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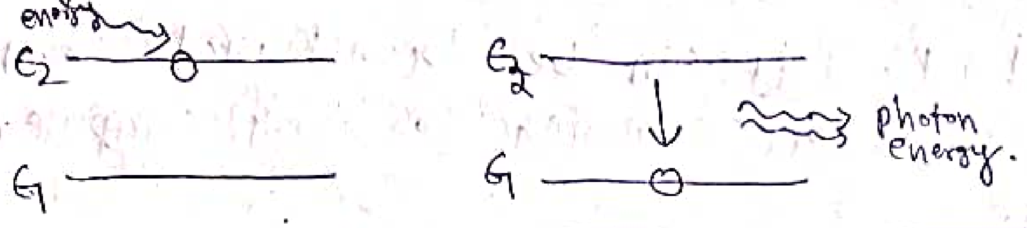
(4) Stimulated Emission :-

It is the process of de-excitation of atom into ground from the excited state by interacting with an additional photon within its lifetime by emitting a additional photon. is called stimulated emission.



⑤ Population Inversion:-

The stage of making population of higher energy level is greater than the population of lower energy level is called population inversion. $N_2 > N_1$ & $E_2 > E_1$

⑥ Pumping & Pumping Mechanisms:-

The process of achieving population inversion is called pumping.

The pumping mechanisms are

(i) Optical pumping
(ii) Electrical discharge pumping
(iii) chemical Pumping.
(iv) Injection current Pumping.

⑦ Types of lasers:-

On the basis of active medium used in the lasers, they are classified into several types

(i) Solid lasers ex:- Ruby laser, Nd:YAG laser
(ii) Liquid lasers ex:- $SeOCl_2$, Europium Chelate laser.
(iii) Gas Lasers ex:- CO_2, He-Ne laser, Ar-Ion laser
(iv) Semi Conductor lasers ex:- InP, GaAs
(v) Chemical Lasers ex:- HF, DF

⑧ Applications of lasers in Communication:-

(i) In case of optical communication, semiconductor lasers are used. They have high band width (10^{14} Hz).
(ii) More channels can be sent simultaneously.
(iii) Signal can not be trapped. Due to high band width more data can be sent.

⑨ Applications of lasers in Computers:-

(i) In LAN, data can be transferred from memory storage of one computer to other computer using laser.
(ii) Lasers are used in CD-ROMs during recording and reading the data.

⑩ Applications of lasers in Chemistry:-

(i) Lasers are used ~~to~~ in molecular structure identification.
(ii). Lasers are used to accelarate some chemical reactions.
(iii) New chemical compounds can be created by breaking bond b/w atoms (or) molecules.

⑪ Applications of lasers in photography:-

(i) Lasers are used in the construction of holograms.
(ii) Lasers are used to get 3D lens photography.

⑫ Applications of Lasers in Industry:-

(i) Lasers are used to blast holes in diamonds and hard steel.
(ii) To drill holes in ceramics.
(iii) To cut glass and quartz.
(iv) To weld (or) melt any material, high power lasers are used.
(v) To cut teeth in saws and test the quality of fabric.

⑬ Applications of Lasers in Medicine:-

(i) Lasers are used for cataract removal.
(ii) Used for eye lens curvature corrections.
(iii) Used in bloodless surgery.

(iv) Used in cancer diagnosis and therapy.
(v) Used in destroying kidney stones and gallstones.
(vi) Used in endoscopy to scan the inner parts of the body.
(vii) Used in elimination of moles, plastic surgery and treatement of mouth diseases.

⑭ Applications of lasers in military:-

(i) Used as a war weapon.
(ii) High energy lasers are used to destroy the enemy aircrafts and missiles.
(iii) Used in detection and ranging like RADAR.

⑮ Applications of lasers in Scientific fields:-

(i) Lasers are used for isotope propagation.
(ii) Used in air pollution, to estimate the size of the dust particles.
(iii) To produce certain chemical reactions.
(iv) Used in Raman spectroscopy, to identify the structure of the molecule.
(v) Lasers are used to create plasma.

⑯ Optical Fibre, Principle:-

Optical fibre is a thin transparent guiding medium, which guides the information carrying light waves. It is works on the principle of TIR.

⑰ Total Internal Reflection:-

When the light ray travels from denser medium to rarer medium the refracted ray bends away from the normal. When the angle of incidence is greater than the critical angle the refracted ray again reflects in to the same medium. this phenomenon is called TIR

(18) Critical Angle:-

When the angle of incidence increased the angle of reflection also increases and for a particular angle of incidence ($i = \theta_c$) the refracted ray travels along the interface of two mediums. This angle of incidence is known as critical angle. (θ_c).

(19) Parts of the Optical Fibre:-

It consists mainly 6 parts

(i) Core (ii) Cladding (iii) Si Coating

(iv) Buffer Jacket (v) strength Member (vi) Outer Jacket.

(20) Acceptance Angle (θ_a):-

It is defined as the maximum angle of incidence at the interface of air and core mediums for which the light ray enters into the core medium and travels along the interface of core and cladding.

(21) Acceptance Cone:-

A cone obtained by rotating a ray at the end face of an optical fibre, around the fibre axis with acceptance angle is known as acceptance cone.

(22) Numerical Aperture (NA):-

The light gathering capacity of an optical fibre is directly proportional to the acceptance angle.

NA = sin (acceptance angle).

(23) Attenuation:-

The ratio of optical o/p power to the optical i/p power, from a fibre of length 'L'.

units:- dB/km.

(14) **Components of Fibre Optic Communication system:-**

It consist 3 important components. these are

(i) Optical Transmitter

(ii) Fibre Repeater

(iii) Optical Receiver

(15) **Applications of Optical Fibres in Medicine:-**

(i) Used in endoscopy, to view the internal parts of the disease affected body.

(ii) Used in photodynamic therapy for cancer.

(iii) Used in treatment of lung disorders, treatement of bleeding ulcers.

(iv) Used in investigation of heart, respiratory system.

(16) **Applications of Optical Fibres in Communication:-**

(i) Used in optical communication system.

(ii) Nearly, 10000 information carry signals can be transmitted simultaneously through it.

(iii) Due to higher band width optical fibres carries more information.

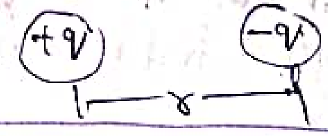
(iv) During war time they are used for secret communication.

(v) Used for guiding weapons and submarine communication systems.

(1) **Electric dipole:-**

The arrangement of equal and opposite charges seperated by a distance is called electric dipole (or) Dipole.

When the dielectric material is placed in an electric field, dipoles are created. This phenomenon is called polarization.



② Dipole Moment:-

Electric dipole moment is the product of magnitude of charge and distance between the two charges.

$$\mu = qr.$$

③ Dielectric Constant (or) Relative Permitivity:-

The ration b/w the permitivity of the material to the permitivity of the free space.

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}.$$

④ Electric Field Intensity (E):-

Electric field intensity at any point in the electric field is defined as the force experienced by a unit +ve charge placed at that point.

$$E = \frac{F}{q} \quad \downarrow F = Eq.$$

⑤ Dielectric Polarization (P):-

The induced dipole moment per unit volume of the dielectric medium placed in the external field is called dielectric polarization.

$$P = \frac{\mu}{V} = \frac{q'}{A}.$$

⑥ Electric Displacement (D):-

It is the product of permitivity of the medium and the resultant electric field intensity.

i.e, $D = \varepsilon E. = \frac{q}{A}.$

⑦ Polarisability (α):-

The dipole moment is directly proportional to the electric field intensity. i.e, $\mu = \alpha E.$

⑧ Electric Susceptibility (χ_e):-

The electric polarization is directly proportional to the electric field intensity.

i.e., $P \propto E$ $P = \varepsilon_0 \chi_e E$.

$$\chi_e = \frac{P}{\varepsilon_0 E}.$$

⑨ Relation b/w 'D', 'E' and 'P':-

The relation is given by

$$D = \varepsilon_0 E + P.$$

where, D = Electric displacement.
E = Electric field intensity.
P = Dielectric Polarization.

⑩ Relation b/w χ_e and ε_r:-

The relation is given by

$$\varepsilon_r = 1 + \chi_e.$$

where, ε_r = Relative permitivity (or) Dielectric Constant.
χ_e = Electric Susceptibility.

⑪ Internal Field (or) Local Field (or) Lorentz Field:-

The electric field experienced by a dipole inside the dielectric medium is called internal field (or) Local field (or) Lorentz field.

⑫ Clausius Mossotti Equation:-

It is the relation b/w the dielectric constant and the polarisability is known as clausius mossotti equation.

$$\frac{N\alpha}{3\varepsilon_0} = \frac{\varepsilon_r - 1}{\varepsilon_r + 2}$$

(13) Electronic Polarisation :-

When ~~the~~ an electric field is applied to the atom, the e^- in the atom are displaced relative to the nucleus and produce dipole moment. Polarisation arises due to the displacement of electrons relative to the nucleus within the same atom is called electronic polarisation.

(14) Ionic Polarisation :-

When an electric field is applied +ve and -ve ions displace in opposite directions causing a change in length of ionic bond, which causes to dipole moment. Polarisation arises due to relative desplacements of ions is called ionic polarisation.

(15) Orientation (or) Dipolar Polarisation :-

When an electric field is applied, dipole moment is induced in polar molecules. This polarisation is known as dipolar (or) orientation polarisation.

(16) Magnetisation :-

It is defined as the process of converting non-magnetic material into magnetic material.

(17) Magnetic Field :-

The space around the magnet where its magnetic influence is experienced is called magnetic field.

(18) Magnetic dipole moment (Mm) :-

The arrangement of two equal and opposite charges seperated by a distance is called magnetic dipole. Magnetic dipole moment is defined as the product of length of the magnet (2l) and its pole strength (m).

$$\mu_m = 2l \cdot m.$$

(1) Magnetic Intensity (or) Magnetic Field strength (H):-

Magnetic field intensity at any point in the magnetic field is defined as the magnetising force experienced by a unit north pole placed at that point.

(20) Magnetic Induction (or) Magnetic Flux density:-

The total number of magnetic lines of force passing through the unit cross sectional area is called magnetic flux density.

$$B = \frac{\phi}{A}.$$

(21) Intensity of Magnetisation (I):-

The induced magnetic moment per unit volume of the substance, when it is placed in the magnetic field is called intensity of magnetisation.

$$I = M = \frac{m}{A} = \frac{\mu_m}{V}$$

(or)

The induced pole strength per unit area of the substance, when it is placed in the magnetic field

(22) Magnetic Permeability (μ):-

It is the ratio of magnetic induction to the magnetic field strength.

(or)

The magnetic induction is directly proportional to the magnetic field strength.

$$B \propto H \Rightarrow B = \mu H \Rightarrow \mu = \frac{B}{H}.$$

(23) ## Relative Permeability (μ_r):-

It is the ratio of permeability of the medium to the permeability of the free space is called as relative permeability. $\mu_r = \frac{\mu}{\mu_0}$.

(24) ## Magnetic Susceptibility (χ):-

The intensity of magnetisation (I) is directly proportional to the magnetic ~~induction~~ intensity (H).

$$M \propto H \quad (\text{or}) \quad I \propto H$$

H = Magnetic field strength

$$I = \chi H$$

$$\chi = \frac{I}{H} = \frac{M}{H}.$$

It is the ratio of intensity of magnetisation to the magnetic field intensity.

(25) ## Relation between B, H and M:-

The relation is given by

$$B = \mu_0 (H + M).$$

where, B = Magnetic flux density

H = Magnetic field strength

I (or) M = Intensity of Magnetisation.

μ_0 = Permeability of free space $= 4\pi \times 10^{-7}$ H/m.

(26) ## Relation b/w μ_r and χ:-

The relation is given by,

$$\mu_r = 1 + \chi$$

where χ = Magnetic susceptibility,

μ_r = Relative Permeability.

(27) Bohr-Magneton :-

$\mu_B = \frac{eh}{4\pi m}$ is called Bohr-Magneton (or) Origin of magnetic moment. The value of the μ_B is 9.27×10^{-24} Amp-m^2.
It is the fundamental unit of atomic magnetic moment.

(28) Hysteresis Curve (or) B-H Curve :-

Hysteresis means lagging.
It shows the lagging of magnetic flux density behind the magnetic field strength.
, The plot of B and H gives the Hysteresis Curve (or) B-H Curve

(29) Soft Magnetic Materials :-

The ferro magnetic materials which can be easily magnetized and de-magnetized are known as "soft magnetic materials".
ex: Iron-Si alloy, Ni-~~Fe~~ alloy, ~~Iron~~-Co alloy.

(30) Hard Magnetic Materials :-

The ferro magnetic materials which are hard to magnetize and de-magnetize is known as "Hard magnetic materials".
ex: Carbon steels, Cr-steels, Alnico etc...

(1) Semi Conductor :-

A substance which has resistivity in b/w conductors and insulators is known as semi conductor.
Semi conductors are two types
(i) Intrinsic semi conductors
(ii) Extrinsic semi conductors.

② Intrinsic Semi Conductors :-

Pure semi conductors are called intrinsic semi conductors
ex :- Pure Ge, Pure Si

③ Fermi Level :-

It indicates that the probability of occupation of electrons in the energy levels VB and the CB.

④ Extrinsic Semi Conductors :-

Impure semi conductors are called extrinsic semi conductors

(or)

Adding impurities to the ~~extr~~ intrinsic semiconductor is known as extrinsic semi conductors.

Extrinsic SC are two types

(i) n-type SC (ii) p-type SC.

⑤ n-type SC :-

The adding of pentavalent impurities to the intrinsic SC ~~are~~ is known as n-type SC.

Examples of pentavalent impurities are P, As, Sb, Bi

⑥ P-type SC :-

Adding of trivalent impurities to the intrinsic SC is known as p-type SC.

Examples of trivalent impurities are B, Al, Ga, In.

⑦ Drift :-

Under the influence of an electric field the charge carriers are forced to move in a particular direction. This phenomenon is known as drift.

⑧ Diffusion :-

Due to non-uniform carrier concentration the charge carriers moves from a region of higher concentration to a region of lower concentration. This phenomenon is known as diffusion.

⑨ Einstein Relation:-

The relation b/w mobility (μ) and the diffusion coefficient (D) of the charge carriers in a SC is known as Einstein relation.

$$\frac{D_n}{D_p} = \frac{\mu_n}{\mu_p}.$$

⑩ Hall Effect:-

If a SC ~~is placed~~ carrying current is placed in a magnetic field with the direction of the field ⊥ to the direction of current then a potential difference is developed across the SC in a direction ⊥ to both current and magnetic field. This phenomenon is called "Hall Effect".

⑪ Hall Potential:-

The Hall potential gives an electric field called "Hall field".

$$V_H = \frac{IB}{\rho e t}$$

⑫ Hall Coefficient (R_H):-

It is defined as the Hall field per unit current density and per unit magnetic induction.

$$R_H = \frac{E_H}{J \cdot B} = \frac{1}{\rho e}$$

⑬ Applications of Hall Effect:-

(i) To determine the nature of the SC. (whether P-type or n-type)

(ii). To determine the concentration of the charge carriers.

(iii). To determine the mobility of holes & electrons.

(iv) Strong magnetic field can be measured by Hall Effect.

(14) Super Conductor:-

The electrical resistivity of many metals and alloys drops suddenly to zero, when the materials are colled to a sufficient low temparature called critical (or) Transition temparature. This phenomenon is known as super conductivity.

(15) Critical (or) Transition Temparature:-

The temparature at which the normal conductor losses its resistivity and becomes a super conductor is known as critical | transition temparature.

(16) Critical Magnetic Field (H_c):-

The minimum magnetic field is required to destroy the super conducting state is called the critical magnetic field (H_c).

$$H_c = H_0\left[1-\left(\frac{T}{T_c}\right)^2\right]$$

(17) Important Factors to define a super conducting state:-

(i) Critical Temparature (T_c)

(ii) Critical Magnetic Field (H_c)

(iii) Critical current (I_c)

(18) Meissner Effect:-

When a weak magnetic field is applied to a super conducting material at a temparature of below the transition temparature (T_c), the magnetic flux lines are expelled. The material acts as an ideal diamagnet. This effect is called Meissner Effect.

(19) **Types of Super Conductor:-**

In the presence of critical magnetic field, a super conductor converts into a normal conductor. Based on the conversion process, super conductors are two types.

(i) Type-I super conductor

(ii) Type-II super conductor.

(20) **Josephson Effect:-**

The insulator which forms the junctions b/w the super conductor is known as Josephson junction and this effect is called Josephson effect.

(21) **DC-Josephson effect:-**

Without any applied voltage, a small direct super current (dc) will flows across the junction due to the tunneling of cooper pairs. This effect is known as DC-Josephson effect.

(22) **AC-Josephson Effect:-**

When a potential (V_0) is applied across the junction then the cooper pairs start oscillating through the insulating layer. As a result an alternating super curren (ac) will flows through the junction. This effect is known as AC-Josephson effect.

(23) **Applications of Super Conductors:-**

(i) Super conducting generators are smaller in size. with less weight, consume very low energy.

(ii) Super conducting wires are ~~smaller~~ used as electric cables, the transmission losses are minimized.

(iii) Super conductors are used for winding of transformer, the power losses will be very small.

(iv) Super conducting materials are used for producing high magnetic fields.

(v) When the magnetic field is greater than the critical field, the super conductor changes in to normal conductor.

(vi) The C-V characteristics of Josephson effect is used for memory elements in computers.