5) A displacement current is $\varepsilon_0 \left(\frac{d\varphi_E}{dt}\right)$ so it exists only if electric field is changing

6) C During welding, a high-intensity electric arc is generated, which emits a large amount of ultraviolet rays

7) D Frequency of an electromagnetic wave does not change when it passes from one medium to another so f=f

8) D because gamma rays has highest frequency so its energy will be the highest.

9) B The source of an electromagnetic wave is always associated with a accelerating electric charge or an oscillating charge.

10) B speed of light is c=E/B

ASSERTION AND REASON QUESTIONS

For each question, select the correct option:

(a)Both Assertion and Reason are true, and Reason is the correct explanation of Assertion.

(b)Both Assertion and Reason are true, but Reason is not the correct explanation of Assertion.

(c)Assertion is true, but Reason is false.

(d)Assertion is false, but Reason is true.

Q1.Assertion (A): Electromagnetic waves do not require a material medium for their propagation.
Reason (R): Electromagnetic waves consist of oscillating electric and magnetic fields, which are self-sustaining in vacuum.

Q2.Assertion (A): In an electromagnetic wave, the electric and magnetic fields are always perpendicular to each other.
Reason (R): The directions of electric and magnetic fields in an EM wave are independent of the direction of wave propagation.

Q3.Assertion (A): The speed of electromagnetic waves in vacuum is equal to $1/\sqrt{\mu_0\varepsilon_0}$
Reason (R): The values of μ_0 and ε_0 determine the properties of vacuum with respect to magnetic and electric fields, respectively

Q4.Assertion (A): X-rays can be used to detect fractures in bones.
Reason (R): X-rays have controlled penetrating power and are absorbed differently by different tissues.

Q5.Assertion (A): Ultraviolet rays are more energetic than infrared rays.
Reason (R): The frequency of ultraviolet rays is greater than that of infrared rays.

Q6.Assertion (A): Gamma rays have the longest wavelength in the electromagnetic spectrum.
Reason (R): Gamma rays have the lowest frequency among all EM waves.

Q7.Assertion (A): Microwaves are suitable for radar systems used in aircraft navigation.
Reason (R): Microwaves can penetrate through the ionosphere and reach long distances without significant attenuation.

Q8Assertion (A): Electromagnetic waves carry both energy and momentum.
Reason (R): The energy and momentum in EM waves are carried by the magnetic field only.

EXERCISE QUESTIONS-SOLUTIONS

1.(a) EM waves are self-propagating due to mutual induction of E and B fields and do not need a medium.

2. (c) The fields are perpendicular to each other and to the direction of wave propagation they are not independent.

3. (a) Speed of EM wave in vacuum is derived using these constants.

4. (a) Bones absorb more X-rays than soft tissue, producing contrast.

5. (a) Energy E = h; higher frequency = higher energy.

6. (d) Gamma rays have the shortest wavelength and highest frequency.

7. (a) Microwaves are used in radar as they can travel in the atmosphere and reflect from objects.

8.(c) Energy is shared by both electric and magnetic fields, not just magnetic.

9. (a) IR is emitted due to heat and used for thermal imaging.

10. (d) EM waves are transverse, not longitudinal; E field is perpendicular to propagation.

VERY SHORT ANSWER TYPE QUESTIONS (2 MARKS)

Q1 Why does microwave oven heats up a food item containing water molecules most efficiently?

SOL: Microwave ovens efficiently heat food containing water because microwaves excite the rotational motion of polar water molecules, and the resulting molecular friction generates heat. Foods with higher water content heat up faster and more uniformly.

Q2: A variable frequency a.c source is connected to a capacitor. How will the displacement current change with decrease in frequency?

SOL: Displacement current is directly proportional to frequency. As frequency decreases, the rate of change of voltage across the capacitor decreases. Therefore, the displacement current also decreases. $\varepsilon_0\left(\frac{d\varphi_E}{dt}\right) = i_d$

For current in capacitor : $I_d = C\,dV/dt$

$V = V_o \sin wt$, so $I_d \propto w$ and $w = 2\pi f$ so $I_d \propto f$

Q3 The magnetic field of a beam emerging from a filter facing a floodlight is given by $B_0 = 12 \times 10^{-8} \sin(1.20 \times 10^7 z - 3.60 \times 10^{15} t)$ T. What is the average intensity of the beam?

Sol: $I_{av} = \frac{1}{2} c \frac{B_0^2}{u_0} = \frac{1}{2} 3 \times 10^8 \times (12 \times 10^{-8})^2 / 1.26 \times 10^{-6} = 1.71\ W/m^2$

Q4 Professor C.V. Raman surprised his students by suspending freely a tiny light ball in a transparent vacuum chamber by shining a laser beam on it. Which property of EM waves was he exhibiting? Give one more example of this property.

Sol : EM waves exert radiation pressure. Tails of comets are due to solar radiation.

Q5 How are Infrared waves produced? Why are these waves referred to as heat waves? Give any two uses of infrared waves.

Sol: Infrared radiations are produced by hot bodies and vibrations of molecules. They are referred to as heat waves because they are rapidly absorbed by water molecules and increase their thermal energy and heat them.

Uses: i) dehydration of fruits ii) In green house effect iii) In remote switches

Q6 An E.M. wave, Y_1, has a wavelength of 1cm while another e.m. wave, Y_2, has a frequency of 10^{15} Hz. Name these two types of waves and write one useful application for each.

Sol: Y_1 has a wavelength of 1 cm, which lies in the microwave region. Y_2 has a frequency of 10^{15} Hz, which falls in the ultraviolet (UV) region.

Y_1:Microwave

Application: Used in microwave ovens for cooking food.

Y_2:Ultraviolet (UV)wave

Application: Used for sterilizing medical instruments.

SHORT ANSWER TYPE QUESTIONS (3 MARKS)

1. Electromagnetic waves of wavelengths γ_1, γ_2 and γ_3 are used in radar systems, in water purifiers and in remote switches of TV, respectively.
   Identify the electromagnetic waves, and Write one source of each of them.

Sol: γ_1: Microwaves, γ_2 : Ultraviolet (UV) rays , γ_3: Infrared (IR) rays .

Microwaves: Klystron or magnetron tubes (used in radar and microwave ovens) Ultraviolet rays: Mercury vapour lamps or sunlight.

Infrared rays: Heated objects or infrared LEDs (used in remote controls)

2. Identify electromagnetic waves which
   (i) Are used in radar systems. (ii) Affect a photographic plate. (iii)Are used in surgery.

Write their frequency range.

Sol: Electromagnetic waves used in radar systems is Microwaves, Frequency Range: 10^9 - 10^{11} Hz .

Electromagnetic waves that affect a photographic plate is Ultraviolet (UV) rays, Frequency Range: 10^{15} –

10^{17} Hz Infrared (IR) rays (used in thermal cauterization and healing), or sometimes X-rays in precision surgery Frequency range: $10^{12} - 4 \times 10^{14}$ Hz

3. Identify the following electromagnetic radiations as per the frequencies given below. Write one application of each. (a) 10^{20} Hz (b) 10^{9} Hz (c) 10^{11} Hz

Sol: a) Gamma Rays : Used in cancer radiotherapy to destroy malignant cells. B) Microwaves. Used in radar systems and microwave ovens for cooking. C) Used in TV remote controls and thermal imaging.

4. Identify the part of the electromagnetic spectrum which:
(a)Produces heating effect (b) Is absorbed by the ozone layer in the atmosphere,
(c) Is used for studying crystal structure

Sol: a) Infrared radiations. IR waves are absorbed by matter and increase the kinetic energy of particles, causing a heating effect. b) Ultraviolet (UV) rays . c) X rays

5. Arrange the following electromagnetic waves in the order of their increasing wavelength:
(a) γ-rays (b) Microwaves (c) X-rays (d) radio waves

How are infrared waves produced? What role does infrared radiation play in (i)maintaining the earth's warmth and (ii) physical therapy?

Sol: a) Order (increasing wavelength): γ-rays<X-rays<Microwaves<Radio waves

a) Infrared (IR) waves are produced by vibrations and rotations of atoms and molecules in a body. All objects at a temperature above absolute zero emit IR radiation due to their thermal motion.

b) Maintaining warmth of earth and Physical therapy IR radiation is used in heat lamps and therapeutic devices to relieve muscle pain, increase blood circulation, and promote healing by penetrating deep into tissues.

6. (a) Which one of the following electromagnetic radiations has least frequency:
UV radiations, X-rays, Microwaves
(b)How do you show that electromagnetic waves carry energy and momentum?
(c)How are electromagnetic waves produced by oscillating charges?
(d)State clearly how a microwave oven works to heat up a food item containing water molecules.
(e)Why are microwaves found useful for the radar systems in aircraft navigation?

Sol: a) Microwaves has least frequency and highest wavelength. Microwaves < UV < X-rays

Produced by klystrons, magnetrons, or Gunn diodes, which generate high-frequency electromagnetic oscillations.

b. EM waves consist of oscillating electric and magnetic fields that can exert force on charges, transferring energy. The energy carried is proportional to the square of the amplitude of electric and magnetic fields. The force exerted by the EM waves is given by F=p/c.

c) When charges accelerate (e.g., in an alternating current), they produce changing electric fields. A time-varying electric field creates a time-varying magnetic field, and vice versa. These changing fields propagate outward as electromagnetic waves.

7. Electromagnetic wave with wavelength
(i) λ_1 is used in satellite communication.
(ii) λ_2 is used to kill germs in water purifier.
(iii) λ_3 is used to detect leakage of oil in underground pipelines.
(iv) λ_4 is used to improve visibility in runways during fog and mist conditions.
(a)Identify and name the part of electromagnetic spectrum to which these radiations belong.
(b)Arrange these wavelengths in ascending order of their magnitude.
(c)Write one more application of each.

Sol:

λ_1	Satellite communication	Microwaves
λ_2	Kill germs in water purifier	Ultraviolet (UV) rays
λ_3	Detect leakage in underground pipelines	Infrared (IR) rays
λ_4	Improve visibility during fog/mist	Radio waves (or Near-IR)

a) ascending order of wavelength: λ_2(UV)<λ_3 (IR)< λ_1(Microwaves)< λ_4 (Radio/Near-IR)

b) Microwaves (λ_1): Used in microwave ovens for cooking food.

Ultraviolet rays (λ_2): Used in sterilizing surgical instruments.

Infrared rays (λ_3): Used in remote controls and thermal imaging.

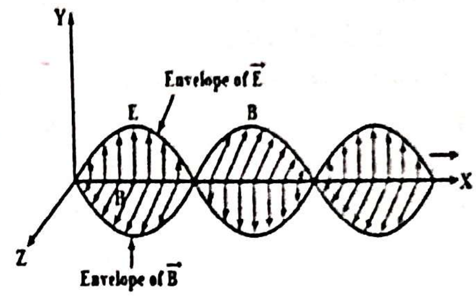
Radio waves/Near-IR (λ_4): Used in AM/FM radio broadcasting and night vision cameras.

CASE STUDY BASED QUESTIONS

Q1 Maxwell, in 1865, pointed out that when either an electric or a magnetic field is changing with time, a field of the other kind is induced in adjacent regions of space. From this Maxwell concluded that variation of electric and magnetic field vectors perpendicular to each other leads to the production of electromagnetic disturbances which show properties of waves and can travel in space even without any material medium. These waves are called electromagnetic waves.

Electromagnetic waves with macroscopic wavelengths were first produced in the laboratory in 1887 by the German physicist Heinrich Hertz. Seven years after Hertz, Jagdish Chandra Bose, working at Calcutta (now Kolkata) succeeded in producing and observing electromagnetic waves of much slower wavelength (25mm to 5mm). At around the same time, Guglielmo Marconi in Italy followed Hertz's work and succeeded in transmitting electromagnetic waves over distances of many kilometers.

Electromagnetic waves have a broad frequency range 10^3Hz to 10^{22}Hz. They can travel with speed of light(c) in vacuum. They obey the relation $c=v\lambda$, where v is frequency and λ is wavelength.



(i) Which of the following electromagnetic wave in order of increasing frequency.

(a) Microwaves<Infrared <Ultraviolet < γ-rays

(b) γ-rays < Ultraviolet < Infrared < Microwaves

(c) Ultraviolet < Infrared < Microwave < γ-rays

(d) γ-rays < Microwave < Infrared < Ultraviolet

(ii) Light wave contains

(a) Electromagnetic waves (c) Longitudinal waves

(b) Mechanical Waves (d) magnetic waves

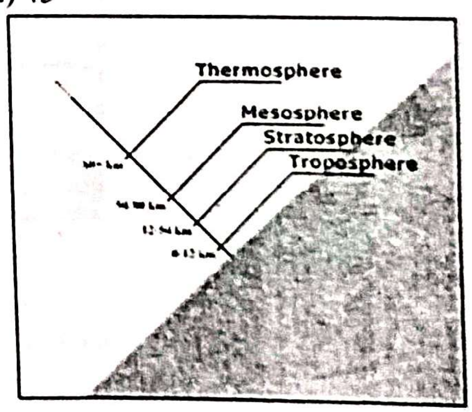
(iii) If we want to produce electromagnetic waves of wavelength 500 km by an oscillating charge the frequency must be

(a) 600 Hz (b) 500Hz (c) 167Hz (d) 15Hz

(iv) The angle between $\vec{E}$ and $\vec{B}$ in an electromagnetic wave is

(a) 180° (b) 120° (c) 90° (d) 45°

Q2 Radio waves are produced by the accelerated motion of charges in conducting wires. Microwaves are produced by special vacuum tubes. Infrared waves are produced by hot bodies and molecules also known as heat waves. UV rays are produced by special lamps and very hot bodies like Sun.



(i) Solar radiation is

(a) transverse electromagnetic wave

(b) longitudinal electromagnetic wave

(c) both longitudinal and transverse electromagnetic waves

(d) None of these

(ii) What is the cause of greenhouse effect?

(a) Infrared rays (b) Ultraviolet rays (c) X-rays (d) Radio waves

(iii) Biological importance of ozone layer is

(a) it stops ultraviolet rays (b) It layer reduces greenhouse effect

(c) it reflects radio waves (d) None of these

(iv) Earth's atmosphere is richest in
(a) ultraviolet (b) infrared (c) X-rays (d) microwaves

Q3 According to Maxwell, an accelerating charge produces electromagnetic waves. Consider a charge oscillating harmonically with time. This is an example of an accelerating charge. This charge produces an oscillating electric field in its neighborhood. This field, in turn, produces an oscillating magnetic field in its neighborhood. The process continues because the oscillating electric and magnetic fields set as sources of each other. Hence an electromagnetic wave originates from the oscillating charge. The frequency of the electromagnetic wave is equal to the frequency of oscillation of the charge. The energy carried by the wave comes from the source which makes the charge oscillating. An electric dipole is a basic source of electromagnetic waves. An LC-circuit containing inductance L and capacitance C produces electromagnetic waves of frequency, $f = \frac{1}{2\pi\sqrt{LC}}$

(i) Electromagnetic waves are produced by
(a) Accelerated charged particle (b) Charge at rest
(c) Charge in uniform motion (d) None of these.

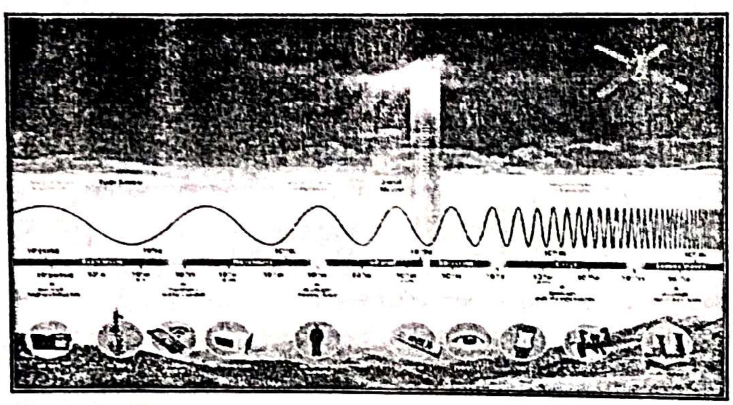
(ii) Light can travel in vacuum due to its
(a) Transverse nature (b) Electromagnetic nature
(c) Longitudinal nature (d) Both (a) and (c).

(iii) If a source is transmitting electromagnetic waves of frequency 8.2×10^6 Hz, the wavelength of electromagnetic wave transmitted from the source is
(a) 36.6 m (b) 18.8 m (c) 42.8 m (d) 58 m

(iv) (A) Wavelength of infrared radiations as compared to UV radiations is
(a) shorter (b) longer (c) no comparison (d) same

OR

(B) The quantity $1/\sqrt{\mu_0\varepsilon_0}$ represents
(a) speed of sound (b) speed of light in vacuum
(c) speed of electromagnetic wave in medium (d) inverse of speed of light in vacuum



Q4
(i). Name the type of radiation that has used in luggage security checks at airports.
(a) γ-rays (b) X-rays (c) Microwaves (d) Infrared rays

(ii). Some γ-rays emitted from a radioactive source has wavelength 1.0×10^{-12}m. The frequency of the γ-rays
(a) 3×10^{20}Hz (b) 2×10^{12} Hz (c) 2.5×10^{5} Hz (d) 3.3×10^{12} Hz

(iii). Why does a microwave oven heat up a food item containing water molecules most efficiently?
(a) Microwaves are heat waves, so always produce heating
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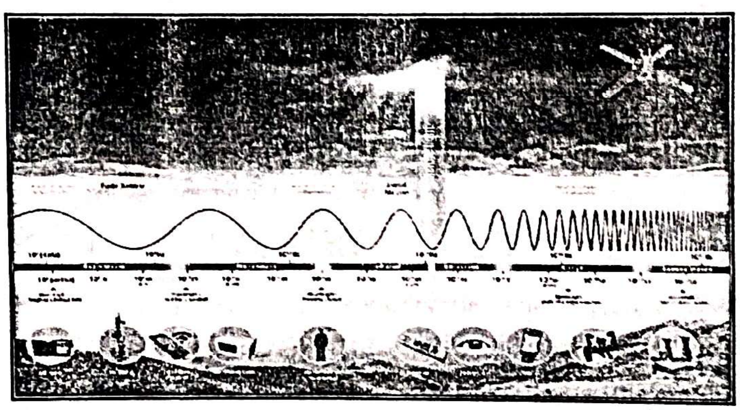

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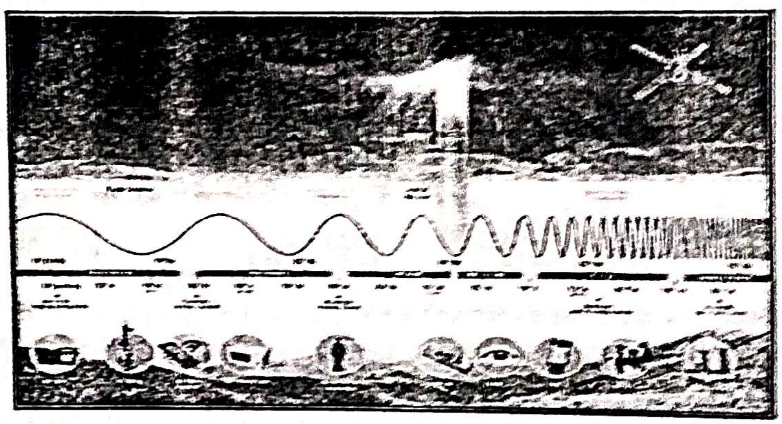

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(iii). Why does a microwave oven heat up a food item containing water molecules most efficiently?
(a) Microwaves are heat waves, so always produce heating
(b) Infrared waves produce heating in a microwave oven

(c) Energy from the microwaves is transferred efficiently to the kinetic energy of water molecules at their resonant frequency.

(d) The frequency of microwaves has no relation with natural frequency of water molecules.

(iv) (A) Which of the following electromagnetic radiations have the longest wavelength?

(a) X-rays (b) γ-rays (c) Microwaves (d) Radio waves.

OR

(B) If conducting current is 2A through a circuit the displacement current will be

(a) 1A (b) 2A (c) 3A (d) 4A

Sol:

Q1	Q2	Q3	Q4
i) A	i) a	i) a	i)d
ii) A	ii) a	ii) b	ii)a
iii)A	iii) a	iii) a	iii)c
iv)C	iv) b	iv) b or a	iv) d or b

- **Simulation for colour mixing:**

https://phet.colorado.edu/sims/html/color-vision/latest/color-vision_all.html

CHAPTER-9: RAY OPTICS

Syllabus-Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism. **Optical Instruments**: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

MIND MAP

RAY OPTICS

OPTICAL INSTRUMENTS

APPLICATIONS OF TIR

- Fiber optic communication
- Medical endoscopy
- Periscope (Using prism)
- Sparkling of diamond

TOTAL INTERNAL REFLECTION

TIR conditions

- Light must travel from denser to rarer
- Incident angle > critical angle i_c

Relation between μ and i_c: $\mu = \frac{1}{\sin i_c}$

REFRACTION OF LIGHT

Snell's law: When light travels from medium a to medium b, ${}^{a}\mu_{b} = \frac{\mu_b}{\mu_a} = \frac{\sin i}{\sin r}$

Refractive index,

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}} = \frac{c}{v}$$

Real and apparent depth

$$\mu = \frac{\text{real depth}(x)}{\text{apparent depth}(y)}$$

REFLECTION OF LIGHT

According to the laws of reflection, $\angle i = \angle r$

If a plane mirror is rotated by an angle θ, the reflected rays rotates by an angle 2θ.

SIMPLE MICROSCOPE

Magnifying power

For final image is formed at D (least distance) $M = 1 + \frac{D}{f}$

For final image formed at infinity

$$M = \frac{D}{f}$$

REFLECTING TELESCOPE

Magnifying power

$$M = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$

REFRACTION THROUGH PRISM

Relation between μ and δ_m

$$\mu = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$$

where, δ_m = angle of minimum deviation, A = angle of prism

or $\delta = (\mu - 1)A$ (Prism of small angle)

Angular dispersion

$$= \delta_V - \delta_R = (\mu_V - \mu_R)A$$

Dispersive power,

$$\omega = \frac{\delta_V - \delta_R}{\delta} = \frac{\mu_V - \mu_R}{\mu - 1}$$

Mean deviation, $\delta = \frac{\delta_V + \delta_R}{2}$

TELESCOPE

Astronomical telescope

For final image formed at D (least distance) $M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

In normal adjustment, image formed at infinity $M = f_o/f_e$

POWER OF LENSES

Power of lens: $P = \frac{1}{f\,(\text{in m})}$

Combination of lenses

Power: $P = P_1 + P_2 - dP_1P_2$

(d = small separation between the lenses)

For $d = 0$ (lenses in contact)

Power: $P = P_1 + P_2 + P_3 + \ldots$

THIN SPHERICAL LENS

Thin lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Magnification: $m = \frac{v}{u} = \frac{h_i}{h_o}$

REFRACTION BY SPHERICAL SURFACE

Relation between object distance (u), image distance (v) and refractive index (μ)

$$\frac{\mu_{2}}{v} - \frac{\mu_{1}}{u} = \frac{\mu_{2} - \mu_{1}}{R}$$

(Holds for any curved spherical surface)

Lens maker's formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

REFLECTION BY SPHERICAL MIRRORS

Mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} = \frac{2}{R}$

Magnification, $m = -\frac{v}{u} = \frac{h_i}{h_o}$

COMPOUND MICROSCOPE

Magnifying power, $M = m_o \times m_e$

For final image formed at D (least distance) $M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$

For final image formed at infinity

$$M = \frac{v_o}{u_o}\cdot\frac{D}{f_e}$$

TERRESTRIAL TELESCOPE

For normal adjustment $M = \frac{f_o}{f_e}$

Distance between objective and eyepiece $d = f_o + 4f + f_e$

GIST OF THE CHAPTER

Reflection of light: - The bouncing of light back into the same medium from a surface is called reflection of light.

Laws of reflection: - i) Angle of incidence is equal to the angle of incidence.

ii) The incidence ray, the reflected ray and normal to the surface at the point of incidence all lie in the same plane.

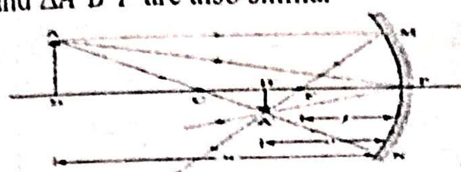
Types of spherical mirrors: Concave and Convex. The relation between object distance, image distance and the focal length of a mirror is called mirror formula. The ratio of size of image to the size of object is called the magnification produced by the mirror.

Derivation of mirror formula:

ΔABC and $\Delta A'B'C$ are similar

A'B'/AB = B'C/CB= PC-PB')/ (PB-PC) .....(1)

ΔABP and $\Delta A'B'P$ are also similar



A'B'/AB =PB'/PB .....(2)

Compare eqn (1) and (2) ...

PB'/PB = (PC-PB')/ (PB-PC)

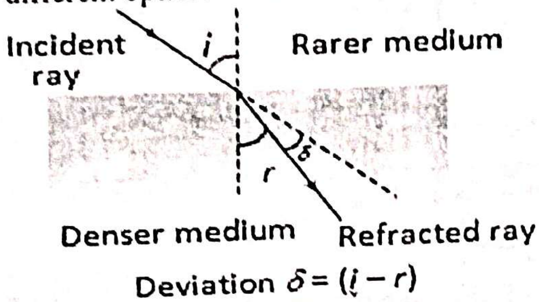
-v/-u = (2f + v)/ (-u+2f) or

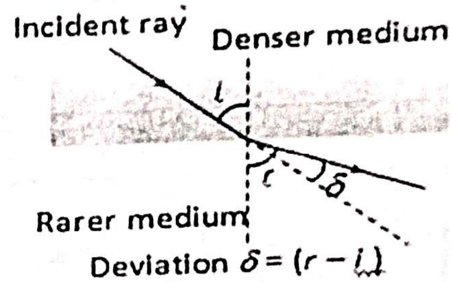
$2uv=2vf+2uf$

Dividing by $2uvf$ on both sides we get,

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Refraction of light: - Bending of light from its actual path, when it passes obliquely from one medium to another having different optical densities.





Snell's Law: -The ratio of the sine of the incident angle to the sine of the refracted angle is a constant.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = n_{21}$$

$$n_1 \sin i = n_2 \sin r$$

OR $v_2 \sin i = v_1 \sin r$

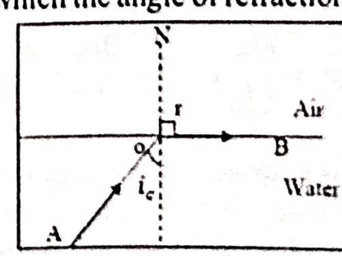
Examples :- 1.Sun can be seen before actual sunrise

2. An object under water (any medium) appears to be raised due to refraction when observed inclined n = (Real depth / Apparent depth) and Shift in the position (apparent) of object is $x = t\left(1 - \frac{1}{n}\right)$ Where t is the actual depth of the medium

Critical angle (ic): - The angle of incidence in denser medium for which the angle of refraction in rarer medium is 90° is called the critical angle.

$$\sin i_c = n_{aw} = \frac{1}{n_{wa}}$$

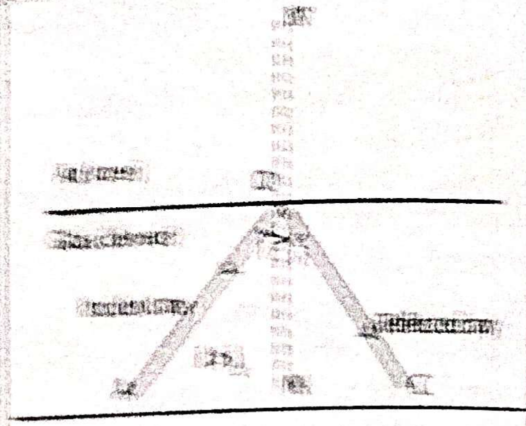
Note:- If rarer medium is not air then $\sin i_c = \frac{n_r}{n_d}$



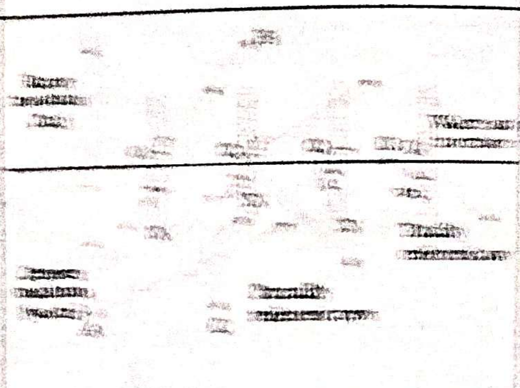
Total internal reflection: – When angle of incidence of the ray incident on rarer medium from denser medium is greater than the critical angle, the incident ray does not refract into rarer medium but is reflected back into denser medium. This phenomenon is called total internal reflection.

$$n_{21} = \frac{1}{\sin C}$$

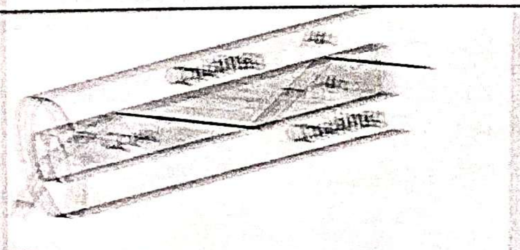
Mathematically:
Here, n_{21} is the refractive index of the denser medium 2 w.r.t. the rarer medium 1 and C is the critical angle.



Applications of Total internal reflection:
Totally reflecting prisms – Bend the light in either 90° fig (a) or 180° fig (b)



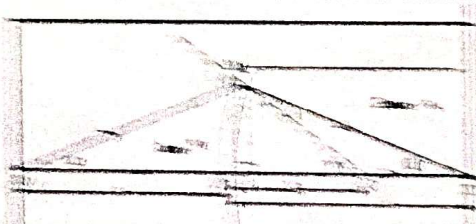
Fibre optic: – Fine fibre of glass or quartz in which light enter from one end and comes out from another end due to total internal reflection is called optical fibre.
Used in endoscopy and communication



Fibre Core → Cladding

Refraction through Spherical surface:

From fig.
in ΔMOC,
$i = \alpha + \gamma$ ——(1)
and in ΔMCI,
$\gamma = r + \beta \Rightarrow r = \gamma - \beta$ ——(2)



From laws of refraction $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ ——(3)
For small angles $\frac{i}{r} = \frac{n_2}{n_1} \Rightarrow n_1 i = n_2 r$ ——(4)
Using (1) and (2) in (4),
$n_1(\alpha + \gamma) = n_2(\gamma - \beta)$ ——(5)

$$n_1\left(\frac{ML}{PO} + \frac{ML}{PC}\right) = n_2\left(\frac{ML}{PC} - \frac{ML}{PI}\right)$$

$$\frac{n_1}{PO} + \frac{n_2}{PI} = \frac{n_2 - n_1}{PC}$$ ——(6)

Using sign convention, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

Spherical refracting surface: The portion of a refracting medium, whose curved surface forms the part of a sphere, is called spherical refracting surface.

When object is situated in the rarer medium, the relation between n_1 (refractive index of the rarer medium), n_2 (refractive index of the spherical refracting surface) and R (the radius of curvature) with the object and image distances (u and v) is given by:

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

When object is situated in the dense medium, the relation between n_1 (refractive index of the rarer medium), n_2 (refractive index of the spherical refracting surface) and R (the radius of curvature) with the object and image distances (u and v) can be obtained by interchanging n_1 and n_2. In that case, the relation becomes

$$\frac{n_1}{v}-\frac{n_2}{u}=\frac{n_1-n_2}{R}$$

Lens maker's formula. The relation connecting the focal length of the lens with the radii of curvature of its two surfaces and the refractive index of the material of the lens is called lens maker's formula. Mathematically:

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

Lens equation. The relation between the focal length, the object and image distances is called lens equation. Mathematically:

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$

Linear Magnification. The ratio of the size of the image (formed by the lens) to the size of the object is called linear magnification produced by the lens.

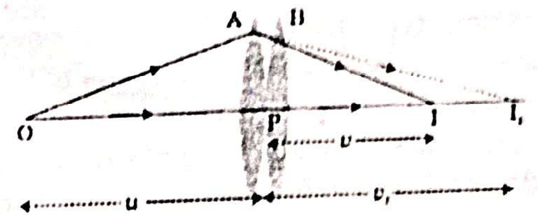
Mathematically, $$m=\frac{I}{O}=\frac{v}{u}=\frac{f}{f+u}=\frac{f-v}{f}$$

Power of a lens. It is defined as the reciprocal of the focal length of the lens in metre.

Mathematically, $$P=\frac{1}{f} \quad \text{or} \quad P=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

In the above two formulae, f, R_1 and R_2 are measured in metre.

Two thin lenses placed in contact. When two lenses of focal lengths f_1 and f_2 are placed in contact, the focal length of the combination is given by

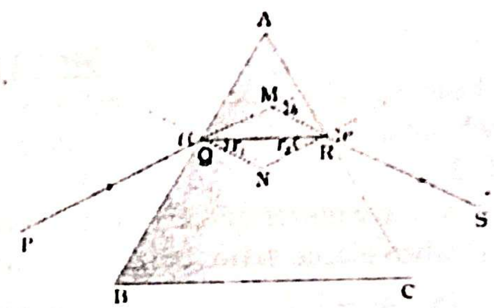


$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

Power of equivalent lens: $P = P_1 + P_2$

Magnification produced by equivalent lens: $m=m_1\times m_2$

Refraction through a prism A ray of light incident on one face of the prism suffers refraction successively at the two surfaces and then emerges out of it. Mathematically,

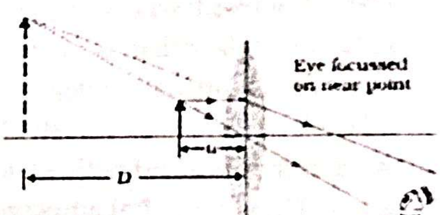


$A = r_1 + r_2$, $A + \delta = i + e$

Prism formula: $\mu=\dfrac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

Simple microscope. A convex lens of small focal length is called a simple microscope or a magnifying glass.

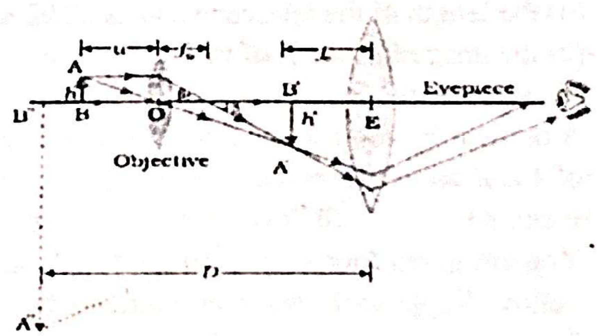
The magnifying power of a microscope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object seen directly, when both lie at the least distance of distinct vision.



Mathematically: $$M=\left(1+\frac{D}{f}\right)$$

Here, D is the least distance of distinct vision

Compound microscope. A compound microscope is a two-lens system (object lens and eye lens of focal lengths f_o and f_e). Its magnifying power is very large, as compared to the simple microscope.



Mathematically:

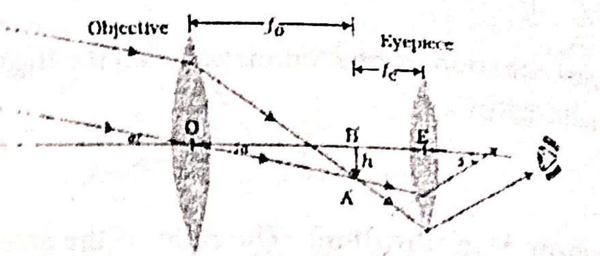
$$M=\frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)=-\frac{L}{f_o}\left(1+\frac{D}{f_e}\right)$$

Here, u_o is distance of the object from the object lens and $v_o \approx L$, (L is the length of the tube of the microscope) is the distance at which the object lens forms the image of the object.

Astronomical telescope. It is a two-lens system and is used to observe distant heavenly objects. It is called refracting type astronomical telescope.

Normal adjustment- When the final image is formed at infinity, the telescope is said to be in normal adjustment.

The magnifying power of a telescope in normal adjustment is defined as the ratio of the angle subtended by the image at the eye as seen through the telescope to the angle subtended by the object seen directly, when both the object and the image lie at infinity.



Magnifying power in normal adjustment,

$$M = -\frac{f_o}{f_e}$$

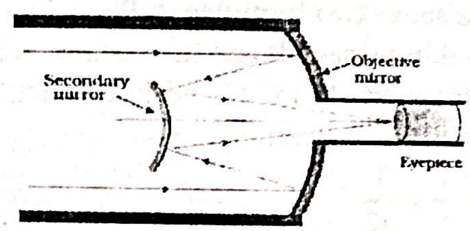
When the final image is formed at the least distance of distinct vision,

Magnifying power of the telescope,

$$M = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Reflecting type telescope. In a reflecting type telescope, the objective is a concave spherical mirror of large aperture in place of a convex lens.

The expression for magnifying power of a reflecting type telescope is same as that for refracting type astronomical telescope.



MULTIPLE CHOICE QUESTIONS

1. A beam of light is incident at 60° to a plane surface. The reflected and refracted rays are perpendicular to each other. What is the refractive index of the surface?

(a) $1\sqrt{3}$ (b) $\sqrt{3}$ (c) 1/3 (d) 3

2. A concave mirror of focal length f produces a real and virtual image of an object of magnification m (m> 1) when placed at two different positions. The distance between the positions of the object is :

(a) $(m-1)f$ (b) $(1-m)f$ (c) $\frac{2f}{m}$ (d) zero

3. The refractive index of the material of a prism is $\sqrt{2}$ and its refracting angle is 30°. One of the refracting surfaces of the prism is made a mirror. A beam of monochromatic light entering the prism from the other face retraces its path, after reflection from mirror.surface. The angle of incidence on prism is:

(a) 0° (b) 30° (c) 45° (d) 60°

4. An astronomical refractive telescope has an objective of focal length 20 m and an eyepiece of focal length 2 cm. Then in normal adjustment:

(a) the magnification is 1000

(b) the length of the telescope tube is 20.02 m

(c) the image formed is of inverted nature.

(d) all of these

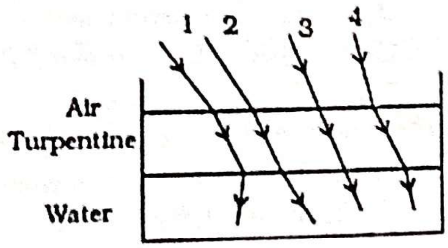
5. A particle moves towards a concave mirror of focal length 30 cm along its axis and with a constant speed of 4 cm/ sec. What is the speed of its image when the particle is at 90 cm from the mirror?

(a) 16 cm/ sec. (b) 1 cm/sec. (c) 8 cm/sec.(d) 4 cm/sec.

6. You are given four sources of light each one providing a light of a single colour – red, blue, green and yellow. Suppose the angle of refraction for a beam of yellow light corresponding to a particular angle of incidence at the interface of two media is 90°. Which of the following statements is correct if the source

of yellow light is replaced with that of other lights without changing the angle of incidence?
(a) The beam of red light would undergo total internal reflection.
(b) The beam of red light would bend towards normal while it gets refracted through the second medium.
(c) The beam of blue light would undergo total internal reflection.
(d) The beam of green light would bend away from the normal as it gets refracted through the second medium

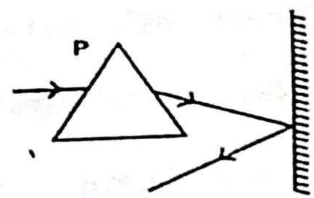
7. The optical density of turpentine is higher than that of water while its mass density is lower. Fig shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in Fig the path shown is correct?



(a) 1 (b) 2 (c) 3 (d) 4

8. If I is the image of a point object O formed by spherical mirror, then which of the following statement is incorrect:
a) If O and I are on same side of the principal axis, then they have to be on opposite sides of the mirror.
b) If O and I are on opposite sides of the principal axis, then they have to be on same side of the mirror.
c) If O and I are on opposite side of the principal axis, then they can be on opposite side of the mirror as well at same side of the mirror.
d) If O is on principal axis then I may not lie on principal axis.

9. A prism having an apex angle of 4^0 and refractive index of 1.50 is located in front of a vertical plane mirror as shown. A horizontal ray of light is incident on the prism. The total angle through which the ray is deviated is



a) 4^0 clockwise b) 178^0 clockwise
c) 2^0 clockwise d) 8^0 clockwise

10. A plano concave lens of focal length 10 cm is placed on a paper on which a coin is drawn. How far above its actual position does the coin appear to be?
a) 10 cm b) 15 cm c) 50 cm d) none of these

SOLUTIONS:

1. (b) Here $i + r = 90$, $n = \frac{\sin i}{\sin r} = \frac{\sin i}{\cos i} = \tan i = \tan 60^0 = \sqrt{3}$

2. (c) For real image, $v = -um$, $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$, $\frac{1}{-f} = \frac{1}{-um} + \frac{1}{u}$, $u = \frac{(1-m)f}{m}$

For virtual image, $v = u'm$, $\frac{1}{f} = \frac{1}{v} + \frac{1}{u'}$, $\frac{1}{-f} = \frac{1}{u'm} + \frac{1}{u'}$, $u' = \frac{-(1+m)f}{m}$

$$u - u' = \frac{2f}{m}$$

3. (c) $A = 30^\circ$, $r = 30^\circ$, $n = \frac{\sin i}{\sin r} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin 30} \Rightarrow i = 45^\circ$

4. (d) $m = \frac{f_o}{f_e} = 1000$, $L = |f_o| + |f_e| = 20.02$ m, Image is always inverted

5. (b) $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, $\frac{1}{-30} = \frac{1}{v} - \frac{1}{-90}$, $v = -45\ cm$, Now differentiate both sides of mirror formula with respect to time, we get $0 = \left(\frac{-1}{v^2}\right)\frac{dv}{dt} + \left(\frac{-1}{u^2}\right)\frac{du}{dt}$

Here, $\frac{du}{dt} = 4\ cm/s$ So, $\frac{dv}{dt} = 1\ cm/s$

6. (c) Order of wavelength: Red > yellow > green > blue

Order of refractive indices: Red < yellow < green < blue and $i_c \propto \frac{1}{refractive\ index}$

7. (b) 2
8. (c)
9. $\delta = (\mu - 1)A$, $\delta = 2^\circ$, Total deviation $= 180^\circ - 2^\circ = 178^\circ$
10. Use lens makers formula and get position at 10 cm above its actual position

ASSERTION-REASON TYPE QUESTIONS

For these Questions two statements are given one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below

A. If both Assertion and Reason are true and Reason is correct explanation of Assertion.

B. If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

C. If Assertion is true but Reason is false.

D. If both Assertion and Reason are false.

1. **Assertion:** A real image of a very intense virtual light source can burn a paper.
   Reason: A virtual image is one when light rays seem to be meeting at a point after reflection/refraction and for real image they actually meet.
2. **Assertion:** In passing through a lens or prism, the phase difference between two waves does not change.
   Reason: The optical path lengths of all rays are same when medium is same.
3. **Assertion:** A convex lens may be diverging.
   Reason: The nature of a lens depends upon the refractive indices of the material of lens and surrounding medium besides its geometry.
4. **Assertion:** When a glass prism is immersed in water, the deviation caused by prism decreases.
   Reason: Refractive index of glass prism relative to water is less than relative to air.
5. **Assertion:** Hollow prism forms no spectra as a solid equilateral prism of glass.
   Reason: Neglecting the thickness of hollow glass surface. The media is same. So, dispersion is not to take place.
6. **Assertion:** The images formed by total internal reflections are much brighter than those formed by mirrors or lenses.
   Reason: There is no loss of intensity in total internal reflection.
7. **Assertion:** When light enters inside perfectly spherical water droplet it should not show total internal reflection inside the water droplet.
   Reason: When light enters non perpendicular to spherical water droplet it is internally reflected.
8. **Assertion:** Law of reflection is applicable for all type of mirrors.
   Reason: Rays which are parallel to principal axis are known as paraxial rays

SOLUTIONS/HINTS

1.B A real image, being formed by actual convergence of light rays, reason does not explain *why* a real image can burn paper.

2. A When a lens or prism forms an image without aberration, the optical path length for all rays from a point on the object to the corresponding point on the image is the same. This implies no change in phase difference.

3. A A convex lens can act as a diverging lens if the refractive index of the surrounding medium is greater than that of the lens material. This is precisely explained by the reason.

4. A. The deviation produced by a prism depends on the relative refractive index. When immersed in water, the relative refractive index of glass with respect to water is less than that with respect to air, leading to a decrease in deviation

5.A The hollow prism acts as if light is passing through a uniform medium, thus no dispersion occurs. Dispersion requires a change in refractive index with wavelength, which happens when light passes from one medium to another with different properties.

6.A Images formed by total internal reflection are indeed brighter because there is ideally no loss of light intensity during total internal reflection, unlike reflection from mirrors or refraction through lenses where some light is absorbed or transmitted.

7.C Total internal reflection does not take place in perfect spherical drop.Internal reflection occurs when light travels from a denser to a rarer medium and the angle of incidence exceeds the critical angle, not simply when it enters non-perpendicularly.

8.C The law of reflection holds true for all types of mirrors. Paraxial rays are rays close to and making small angles with the principal axis, not just parallel rays

SHORT ANSWER TYPE QUESTIONS

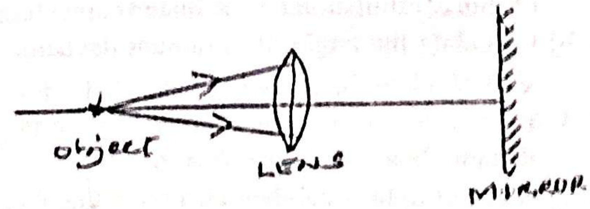
1. The refractive index of diamond is much greater than that of ordinary glass. Is this fact of some use to a diamond cutter?
2. Does the apparent depth of a tank of water change if viewed obliquely at different angles? If so, does the apparent depth increase or decrease?
3. For a glass prism ($\mu = \sqrt{3}$) the angle of minimum deviation is equal to the angle of the prism. Find the angle of the prism.
4. Justify using a diagram "To form an image using a lens all types of rays cannot be used."
5. When the object is at distances u_1 & u_2 the images formed by the same lens are real and virtual respectively and of the same size. Calculate focal length of the lens?
6. Will the focal length of a lens for red light be more, same or less than that for blue light? Justify?
7. The focal length of an equiconvex lens is equal to the radius of curvature of either face. What is the value of refractive index of the material of the lens?
8. Write advantages of reflecting type telescope over refracting type telescope.
9. Show that for a material with refractive index $\mu \geq \sqrt{2}$, light incident at any angle shall be guided along a length perpendicular to the incident face.
10. A ray of light is incident on a parallel slab of thickness t and refractive index n. If the angle of incidence θ is small, Express the displacement in the incident and emergent ray?

SOLUTIONS/HINTS

1. No , there is no relationship , it is due to its hardness.
2. Decreases as light ray traveling from denser to rarer medium (bending of light away from normal)
3. Use prism formula. $A = 60^0$
4. Paraxial rays and marginal rays shall not be included because they do not meet at one point i.e, focus.
5. $|m_1| = |m_2|$, use lens formula for real and virtual image formations, $f = \frac{u_1+u_2}{2}$
6. $refractive\ index \propto \frac{1}{wavelength}$, Use lens maker's formula [$f_{red} > f_{blue}$]
7. Use lens maker's formula. $n = 1.5$
8. No chromatic aberration, easy to provide mechanical support, can easily minimize spherical aberration
9. Use Snell's law and condition of total internal reflection
10. Use Snell's formula and approximation for small angle. Lateral displacement $= t\theta \frac{n-1}{n}$

SHORT ANSWER TYPE

1. A convex lens of focal length f is placed x metre apart from a plane mirror. As shown in figure an object is placed at x distance from the lens away from the mirror get a relation between x and f for following conditions



   a) if final image is formed at x. (at the position of object itself)
   b) if no images formed.
   c) if virtual images are formed.

2. A convex lens and a concave lens have power in ratio 3:2 when placed in contact effective focal length of combination is found 30 cm. We get real image of an object which is placed at 15 cm in front of convex

lens. This image is shifted by 20 cm when same concave lens is introduced between convex lens and image. Calculate the position of the lens introduced. Hence draw necessary ray diagram.

3.You have a concave mirror placed horizontally on a Floor. An all pin when placed at D_1 meter above it, its real image coincide with itself. This mirror is filled with a liquid of refractive index n_1 new image is found at D_2 if this liquid is replaced by another liquid of refractive index n_2 new image is found at D_3 If $n_1 > n_2$ give a relation between D_2 and D_3 with proper justification using a diagram.

4.A prism with angles 30°,90°,60° is placed with smallest face vertical. When a laser torch is aimed horizontally at its vertical face, angle of deviation is found 30°. Using a diagram explain how this angle of deviation would be changed If the torch is rotated a) slightly clockwise, b) slightly anti clockwise.

5.A curved mirror forms five times magnified virtual image of an object if distance between object and images is 25 cm identify its nature and calculate its focal length.

6.In case of a concave mirror magnification is found to be - 0.5 for a certain position of object, when object is displaced by 5 cm from its position, magnification becomes 0.25.What will be the focal length of the mirror? Draw ray diagram to support your answer.

7.You have two mirrors one is concave other is convex focal of each mirror is 30 cm are placed D m apart such that their principal axis are common to each other. An object is placed between them at a point P which is 45 cm from concave mirror. It is found that final images formed on object itself Draw probable ray diagram and calculate value of D?

SOLUTIONS/HINTS

1.a) $x = 2f$ *and* f, b) not possible c) $u > f \Rightarrow x > 2f$

2. $f_1 : f_2 = 2:3$, using formula $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{30} \Rightarrow f_1 = 10\ cm$ *and* $f_2 = -15\ cm$

use lens formula to calculate the position of image formed by convex lens v = +30 cm

On introduction of concave lens, image will be shifted by 20 cm towards right. From lens formula position of concave can be calculated. Answer- 10 cm(approx..) from first image

3.Based on the experiment "to find refractive index of the liquid using concave mirror".

4. Using the concept of total internal reflection find critical angle (60^0).

a) for clockwise, $i > i_c$ (TIR takes place) b) for anticlockwise, $i < i_c$ (Refraction takes place)

5. Solution/Hint: Concave mirror, m= 5 and use mirror formula to find object and image distance $u = \frac{25}{4} cm$, $v = \frac{125}{4} cm$, $f = \frac{-125}{24} cm$

6. $v_1 = 0.5u_1, v_2 = 2f = u_1 - 30$, using mirror formula $f = 30\ cm$

7. Use Snell's law, $n = \frac{\sin i}{\sin r} = \frac{D/2H}{x/H} = \frac{D}{2x} \Rightarrow x = \frac{D}{2n}$, Now x xan be these can be $\frac{D}{2}, D, D + \frac{D}{2}$, and many more.

LONG ANSWER TYPE QUESTIONS

1. a)Draw a labeled ray diagram of a simple microscope in normal adjustment.

b) A thin pencil of length (f/4) is placed coinciding with the principal axis of a mirror of focal length f. The image of the pencil is real and enlarged, just touches the pencil. Calculate the magnification produced by the mirror.

2. a)A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?

b) Calculate the angle of minimum deviation of an equilateral prism. The refractive index of the prism is $\sqrt{3}$.Calculate the angle of incidence for this case of minimum deviation also.

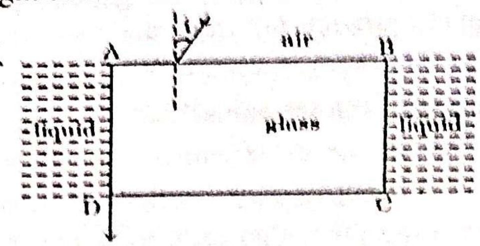
3. a) Draw a schematic arrangement of a reflecting telescope (Cassegrain) showing how rays coming from a distant object are received at the eyepiece.

b) A ray of light is incident on a refracting face AB of a prism ABC at an angle of 45^0.The ray emerges from face AC and the angle of deviation is 15^0.The angle of prism is 30^0.Show that the emergent ray is normal to the face AC from which it emerges out. Find the refractive index of the material of the prism.

4. a) For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25°

and 35° respectively. In which medium would the velocity of light be minimum?

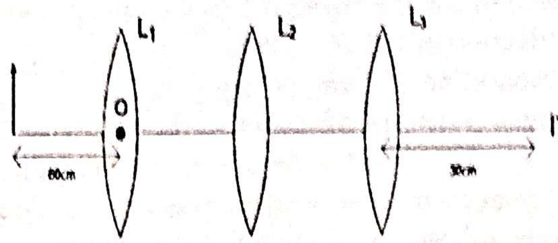
b) A rectangular glass slab ABCD ($n_1 = 1.5$) is surrounded by a transparent liquid ($n_2 = 1.25$)as shown in the figure. A ray of light is incident on face AB at an angle i such that it is refracted out grazing the face AD. Find the value of angle i.



5. a)An optical instrument uses eye-lens of power 20 D and the objective lens of power 50 D. Name the optical instrument and calculate its magnifying power if it forms the final image at infinity.

b)Three lenses L_1 L_2, L_3 each of focal length 30 cm are placed co-axially as shown in the figure. An object is held at 60 cm from the optic centre of Lens L_1. The final real image is formed at the focus of L_3. Calculate the separation between

(i) (L_1 and L_3) and (ii) (L_2 and L_3).



SOLUTION/HINTS

1. a) refer to the gist b) position of the other end $u = \frac{-7f}{4}$, $m = \frac{f}{f-u} = -4/3$

2. a) light rays from the object must fall on plane mirror normally. For this $f = u = 20\ cm$

 b) use prism formula to find $\delta = 60^0$ *and then* $i + e = A + \delta\ (i = 60^\circ)$

3. a) refer to the gist b)$i + e = A + \delta$ =>$e = 0^0$=>$r_2 = 0^0$

4.a)Use snell's law and the relation, $n = \frac{\text{speed of light in vacuum}}{\text{speed of light in th medium}}$ (Ans: Medium A)

 b) Use the relation $\sin i_c = \frac{1}{n_{12}} = \frac{5}{6}$, $\sin r = \frac{\sqrt{11}}{6}$ Use Snell's law to find $i = \sin^{-1}\frac{\sqrt{11}}{4}$

5. a) Compound microscope, *calculate* f_0.For image is at infinity, $m = \frac{D}{f_0}$

 b) Use lens law to find the image distance at first place, $v_1 = 60\ cm$, then the light rays must be parallel between L_2 *and* L_3.Use this concept to find the answer. (i) > 90 cm (ii) any value

CASE STUDY/PASSAGE-BASED QUESTIONS

1. A prism is a portion of a transparent medium bounded by two plane faces inclined to each other at a suitable angle. A ray of light suffers two refractions on passing through a prism and hence deviates through a certain angle from its original path. The angle of deviation of a prism is, $\delta = (\mu - 1)A$,
Through which a ray deviates on passing through a thin prism of small refracting angle A. If μ is refractive index of the material of the prism, then prism formula is,$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

(i) For which color, angle of deviation is maximum?

a) Red b) Yellow c)Violet d)Blue

(ii) When white light moves in gravity free region

a) all colors have same speed b) different colors have different speeds
c) violet has more speed than red d) red has more speed than violet.

(iii) The deviation through a prism is maximum when angle of incidence is

a) 45^0 b)70^0 c)90^0 d)60^0

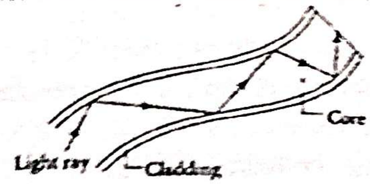
(iv) What is the deviation produced by a prism of angle 6°? (Refractive index of the material of the prism is 1.644).

a) 3.864° b)4.595° c)7.259° d)1.252°

(v) A ray of light falling at an angle of 50° is refracted through a prism and suffers minimum deviation. If the angle of prism is 60°, then the angle of minimum deviation is

a) 45° b)75° c)50° d)40°

2. An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It make use of total internal reflection. These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length.



(i) Which of the following is based on the phenomenon of total internal reflection of light?

a)Sparkling of diamond b) Optical fibre communication
c)instrument used by doctors for endoscopy d)All of these

(ii) A ray of light will undergo total internal reflection inside the optical fibre, if it

a) goes from rarer medium to denser medium
b) is incident at an angle less than the critical angle
c) strikes the interface normally
d) is incident at an angle greater than the critical angle

(iii) If in core, angle of incidence is equal to critical angle, then angle of refraction will be

a) 0° b)45° c)90° d)180°

(iv) In an optical fibre correct relation for refractive indices of core (n_1) and cladding (n_2) is

a) $n_1 = n_2$ b)$n_1 > n_2$ c)$n_1 < n_2$ d)$n_2 = 2$

(v) If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre is

a) 10^8 m s^{-1} b)1.5×10^8 m s^{-1} c)6×10^8 m s^{-1} d) 4.5×10^8 m s^{-1}

SOLUTIONS /HINTS:

1. i. c)$Deviation \propto \frac{1}{wavelength}$ ii. a)a gravity-free region is essentially a vacuum for the purpose of light propagation

iii. c)The deviation is maximum when the ray either just enters the prism (grazing incidence) or just exits the prism (grazing emergence).iv.a) use formula $\delta = (\mu - 1) A$

v) d) use formula $i + e = \delta + A$

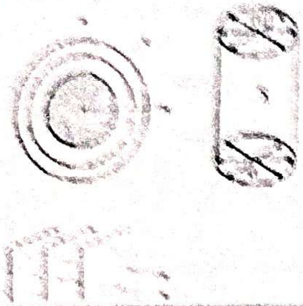
2. i. d) ii. d) iii. c) iv. c) For TIR, light must travel from a denser medium to a rarer medium v. b) Using formula $\sin i_c = \frac{1}{n_{21}}$ $and\ then\ use\ Snell's formula$

CHAPTER-10 : WAVE OPTICS

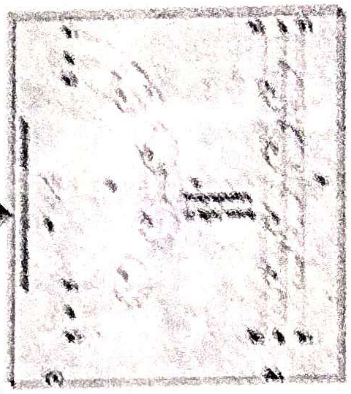
Chapter-10: Wave optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width (No derivation final expression only), coherent sources and sustained interference of light, diffraction due to a single slit, width of central maxima (qualitative treatment only).

A wavefront is a surface of constant phase

Shape of Wave front



Huygen's principle of the secondary wavelets-Each point on the wavefront is the source of a secondary wavelets.



WAVE OPTICS

Young's Double-Slit Experiment (YDSE)

$\Delta = \frac{yd}{D}$

d is distance between slits S_1 and S_2

D is distance between slit and screen

y	0	$\frac{\lambda D}{2d}$	$\frac{\lambda D}{d}$	$\frac{3\lambda D}{2d}$	$\frac{2\lambda D}{d}$
Max /Min	central Maxima	1st Minima	1st Maxima	2nd Minima	2nd Maxima

Path difference $\Delta = \frac{yd}{D}$

Position of n^{th} bright fringe $x_n = \frac{n\lambda D}{d}$ (where n=0,1,2,3...)

Position of n^{th} dark fringe
$x_n = \frac{(2n-1)\lambda D}{2d}$ (where n=1,2,3...

Fringe width $\beta = x_n - x_{n-1} = \beta_{bright} = \beta_{dark} = \frac{\lambda D}{d}$

Fringe width in medium $\beta_{med} = \frac{\beta_{air}}{\mu}$

Angular width of fringe $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

Interference of light

- Phase difference does not change with time – coherent sources
- $A^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$
- $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

YDSE

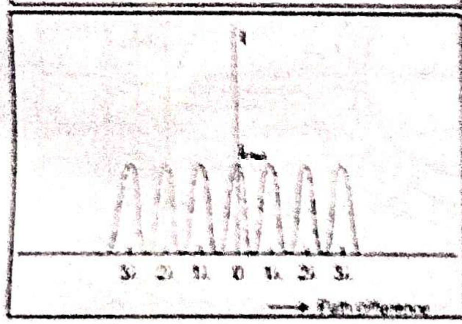
- Fringe width, $\beta = \frac{\lambda D}{d}$
- Position of n_{th} bright fringe,

$y_{bright} = \frac{n\lambda D}{d}$

- Position of n_{th} dark fringe,

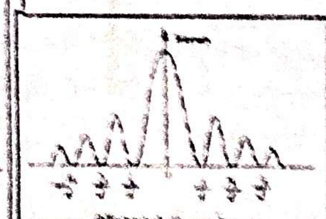
$y_{bright} = \frac{(2n-1)\lambda D}{2d}$

- For bright fringe, $\Delta x = n\lambda$
- For dark fringe, $\Delta x = \left(n + \frac{1}{2}\right)\lambda$



Diffraction

1.Path difference Δ= BP-AP = BE =a sin θ2. Position of minima- Position of n^{th} dark fringe a sin θ_n = nλ (where n =1,2,3...)
3.Position of secondary maxima- a sin θ_n' = (2n+1) λ/2 where n =1,2,3...4.angular width of central maxima = 2θ =2λ/a5. Linear width of central maxima= 2x or D(2θ) = 2λD/a

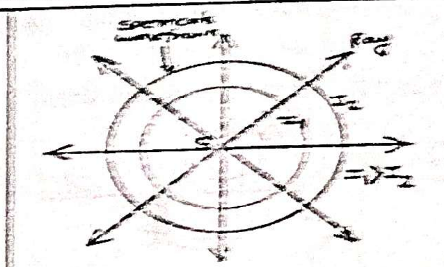
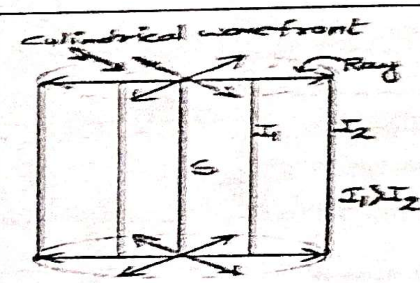
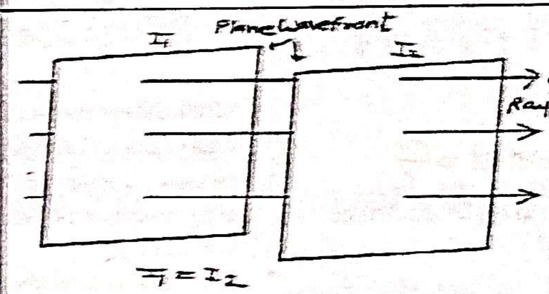


WAVE OPTICS: CONCEPT OF WAVEFRONT.

1.Nature of light-The phenomena like interference, diffraction and polarization establish the wave nature of light. Whereas the phenomena like photo electric effect, Raman effect, Compton effect establish the particle nature of light.

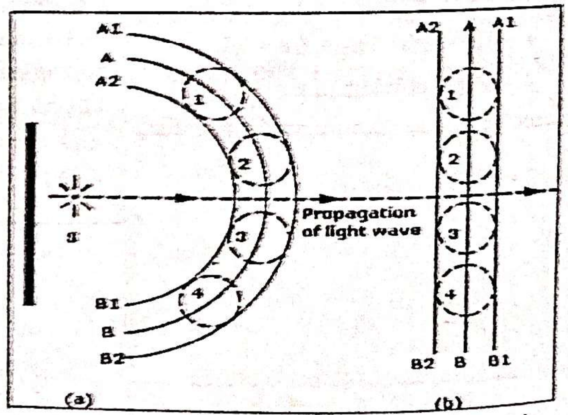
2.Wavefront-It is defined as the continuous locus of all the particles of the medium vibrating in the same phase at any instant. A wavefront is a surface of constant phase. The speed with which the wavefront moves outwards from the source is called the phase speed (wave speed).Note-1. Rays are perpendicular to wavefronts. 2. No backward wavefront is possible.

3.Types of wavefront-It is depends on the source of disturbance.

Spherical wavefront	Wavefront formed by the point source	
Cylindrical wavefront	Wavefront formed by linear or cylindrical shape source	
Plane wavefront	As a spherical or cylindrical wavefront advances, its curvature decreases, so small portion of such a wavefront at a large distance from the source will be a plane wavefront	

4. Huygen's principle of the secondary Wavelets-It is the basis of wave theory of light. It tells how a wavefront propagates through a medium. It is based on the following assumptions

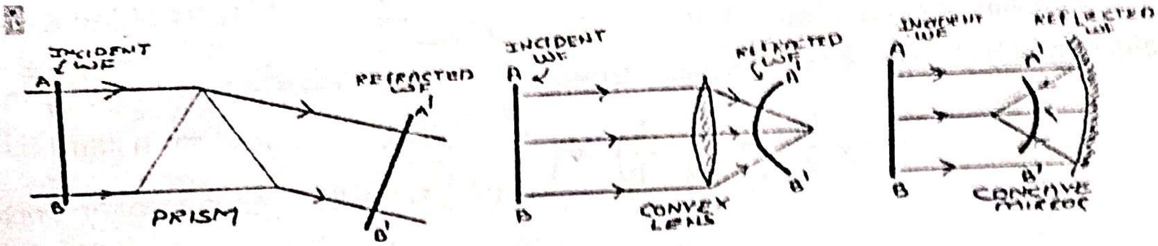
i)Each point on a wavefront acts as a source of new disturbance called secondary wavelets. These secondary wavelets spread out in all directions with the speed of light in the given medium ii)The wavefront at any later time is given by the forward envelope of the secondary wavelets at that time.

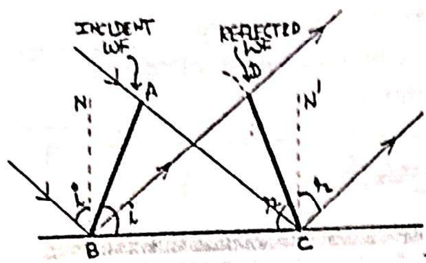
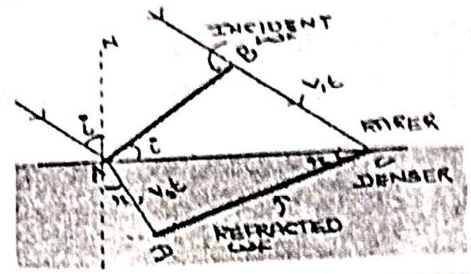
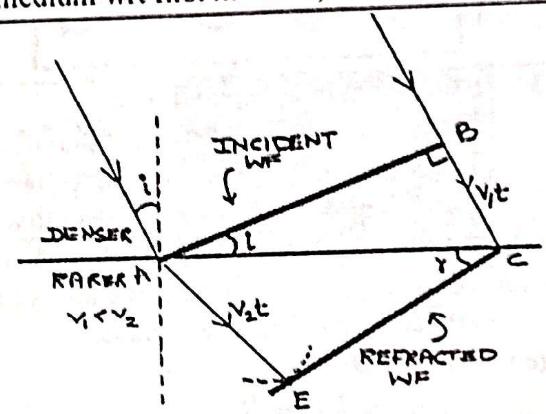


5.During refraction- Frequency of light remains constant, wavelength and speed of light get changed depending on the refractive index. ($\lambda' = \lambda/\mu$ and $v' = v/\mu$) (here μ is the refractive index)

6.Behaviour of a prism, lens and mirror-

7.



	Reflection on the basis of wave theory	Refraction on the basis of wave theory
i)		
ii)	In triangle ΔABC and ΔDCB $\angle BAC = \angle CDB$ (Each 90°) BC=BC AC=BD (each equal to ct) $\therefore \Delta ABC \cong \Delta DCB$ Hence $\angle i = \angle r$	From ΔABC, sin i =BC/AC From ΔADC, sin r = AD/AC $\therefore \frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t}$ Or $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \mu_{21}$(refractive index of second medium wrt first medium)
	Note-for denser to rarer medium	

8.Coherent and Incoherent Sources-Two sources are coherent if they have the same frequency and with a constant phase difference. They are incoherent if phase difference is not constant.

9.Interference of light-When two light waves of the same frequency and having constant phase difference(coherent), travelling in the same direction superpose each other, the intensity gets redistributed, becoming maximum at some points and minimum at others, this phenomenon is called interference of light.

Let two waves from two coherent source of light be $y_1 = a \sin \omega t$ and $y_2 = b \sin(\omega t + \emptyset)$

Where a and b are amplitudes and Ø is the phase difference

So $y = y_1 + y_2$ after solving we get $\mathbf{y = A\sin(\omega t + 0)}$

- Where A is the resultant amplitude so $\mathbf{A_{net} = \sqrt{(a^2 + b^2 + 2ab\cos\emptyset}}$
- And Resultant intensity is $\mathbf{I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\emptyset}$

- Resultant amplitude when a = b $\qquad A_{net} = 2a\cos\frac{\phi}{2}$
- Resultant intensity when $I_1 = I_2 = I$ $\qquad I_{net} = 4I\cos^2\frac{\phi}{2}$

NOTE- Ratio of maximum intensity to minimum intensity

$$\frac{I_{max}}{I_{min}} = \left(\frac{a+b}{a-b}\right)^2 = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}+\sqrt{I_2}}\right)^2$$

10.Types of Interference-

S.no	Constructive interference	Destrulcive Interference
1	Point where resultant intensity is max	Point where resultant intensity is minimum
2	• For $I_{max} \rightarrow \cos\phi = +1$ • Phase difference $\phi = 0, 2\pi, 4\pi, \ldots, 2n\pi$ where $n = 0, 1, 2, \ldots$ • Path difference $\Delta = 0, \lambda, 2\lambda, \ldots, n\lambda$ • $A_{max} = a + b$ • $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$	• For $I_{min} \rightarrow \cos\phi = -1$ • Phase difference $\phi = \pi, 3\pi, 5\pi, \ldots, (n-1)\pi$ where $n = 1, 2, 3, \ldots$ • Path difference $\Delta = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots, \frac{(2n-1)\lambda}{2}$ • $A_{min} = a - b$ • $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$
3	Resultant intensity at a point is maximum when the phase difference is even multiple of π or path difference is an integral multiple of wavelength λ	Resultant intensity at a point is minimum when the phase difference is odd multiple of π or path difference is an odd multiple of wavelength $\lambda/2$

11.Young's Double Slit Experiment-It is the practical verification of interference. In this we get two coherent source by dividing wavefront. We always get bright fringe at the center of the screen and both side alternately bright and dark fringes are made.

a) Fringe width in YDSE-

In $\Delta S_1S_2L \qquad \sin\theta = \frac{S_2L}{S_1S_2} = \frac{\Delta}{d}$

Now in $\Delta DOP \quad \tan\theta = \frac{x}{D}$

If θ is small $\sin\theta \approx \tan\theta \approx \theta$

So $\frac{\Delta}{d} = \frac{x}{D}$

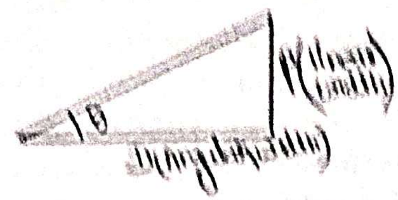
b)Path difference $\qquad \Delta = \frac{xd}{D}$

c)Position of n[th] bright fringe $\qquad x_n = \frac{n D\lambda}{d}$ where $n = 0, 1, 2, 3\ldots$

d)Position of n[th] dark fringe $\qquad x_n = \frac{(2n-1)D\lambda}{2d}$ where $n = 1, 2, 3\ldots$

e) Fringe width –Separation between position two consecutive maxima or minima. Width of bright and dark fringe will be same.

$$\beta = x_n - x_{n-1} = \beta_{bright} = \beta_{dark} = \frac{\lambda D}{d}$$



f)Fringe width in medium $\beta_{med} = \frac{\beta_{air}}{\mu}$

g)Angular width of fringe $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

h) overlapping of fringes

if n_1^{th} bright fringe overlapped on n_2^{th} bright fringe then $n_1\lambda_1 = n_2\lambda_2$

if bright overlapped dark $n_1\lambda_1 = (2n_2 - 1)\lambda_2/2$

i)Dependence of fringe width $\beta = \frac{\lambda D}{d}$ ($\beta \propto \lambda$, $\beta \propto D$, $\beta \propto 1/d$)

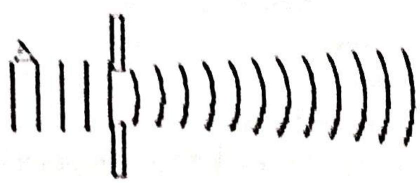
j) Intensity distribution curve-

k) Condition for sustained interference-

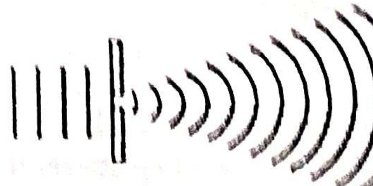
i)Two source of light must be coherent(ii) Having same frequency (iii)source should be monochromatic (iv)wave must travel in same direction(v) for a better contrast amplitude of waves should be approximately equal

12.Diffraction

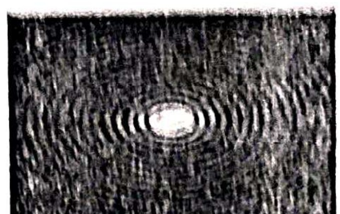
It is the phenomena of bending of light around corners of an obstacle or aperture in the path of light. Due to this bending, light goes into the geometrical shadow region of the obstacle or aperture.This bending becomes more when the dimensions of the aperture or the obstacle are comparable of the wavelength of light.



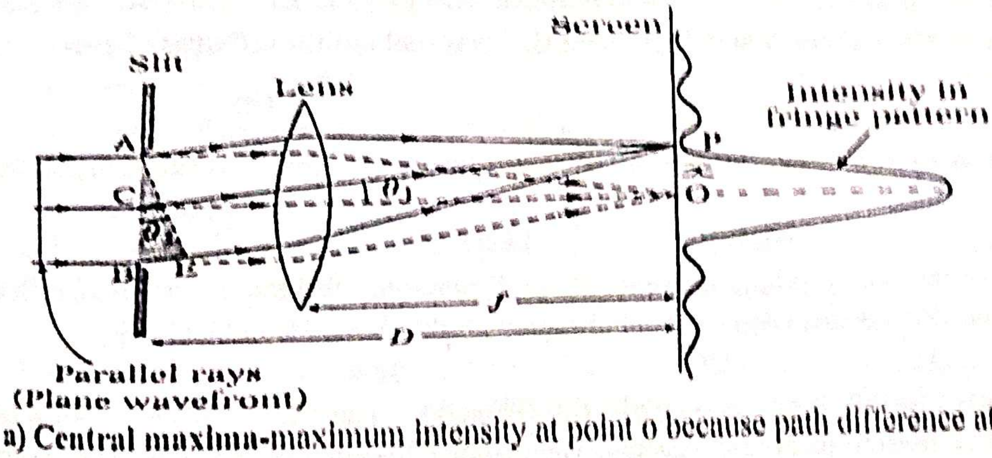
Large Aperture - Low Levels of Diffraction



Small Aperture - High Levels of Diffraction



13.Diffraction of light from a single slit-



a) Central maxima-maximum intensity at point o because path difference at o is zero.

b) Path difference $\Delta = BP - AP = BE = a \sin\theta$

c) Position of minima: Position of n^{th} dark fringe

$a \sin\theta_n = n\lambda$ where $n = 1, 2, 3, \ldots$

d) Position of secondary maxima:

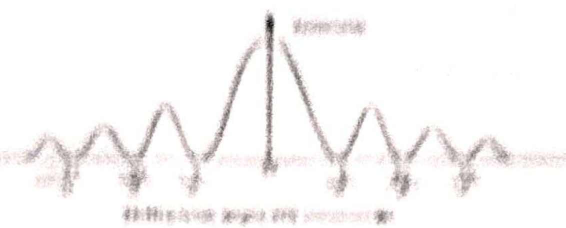
$a \sin\theta_n' = (2n+1)\lambda/2$ where $n = 1, 2, 3, \ldots$

e) width of central maxima: the direction of first minima $\theta = \lambda/a$, this angle is called half angular width of central maxima angular width of central maxima $= 2\theta = 2\lambda/a$

f) Linear width of central maxima $= 2x$ or $D(2\theta) = 2\lambda D/a$

g) Graph

Note: width of secondary maxima $\alpha \frac{1}{\text{slit width}}$



MULTIPLE CHOICE QUESTIONS

1. The resultant amplitude of a vibrating particle by the superposition of the two waves $y_1 = a \sin(\omega t + \pi/3)$ and $y_2 = a \sin \omega t$ is :-
   a) a b) $\sqrt{2}$ a c) 2a d) $\sqrt{3}$ a
2. A double slit experiment is performed with light of wavelength 500 nm. A thin film of thickness 2μm and refractive index 1.5 is introduced in the path of the upper beam. The location of the central maximum will
   a) Remain unshifted b) Shift downward by nearly two fringes
   c) Shift upward by nearly two fringe d) Shift downward by 10 fringes
3. Which of following is a true statement, if in Young's experiment, separation between the slits is gradually increased :
   a) fringe width increases and fringes disappear
   b) fringe width decreases and fringes disappear
   c) fringes become blurred
   d) fringe width remains constant and fringes are more bright
4. In an interference of yellow light derived from two slit apertures, if at some point on the screen, yellow light has a path difference of $3\lambda/2$, then the fringe at that point will be :
   a) yellow in colour b) white in colour c) dark d) bright
5. Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beam is $\pi/2$ at point A and 2π at point B. Then find out the difference between the resultant intensities at A and B.
   a) 2I b) 5I c) I d) 4I
6. In an interference pattern of two waves fringe width is β . If the frequency of source is doubled then fringe width will become :
   a) (1/2) β b) β c) 2β d) (3/2) β
7. Find the half angular width of the central bright maximum in the Fraunhofer diffraction pattern of a slit of width 12×10^{-5} cm when the slit is illuminated by monochromatic light of wavelength 6000 Å.
   a) 40° b) 45° c) 30° d) 60°
8. A light source of 5000Å wave length produces a single slit diffraction. The first minima in diffraction pattern is seen, at a distance of 5mm from central maxima. The distance between screen and slit is 2metre. The width of slit in mm will be :
   a) 0.1 b) 0.4 c) 0.2 d) 2

SOLUTIONS/HINTS

1.d use the formula $A^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$

2.b The optical path difference introduced by the film is (n−1)t, where n is the refractive index and t is the thickness. The central maximum (where the path difference is zero) will shift to a point where the path difference due to the film is compensated by the path difference due to the geometrical shift

Optical path difference introduced by the film $=(1.5-1)\times2\times10^{-6}$ m$=0.5\times2\times10^{-6}$ m$=1\times10^{-6}$ m.

Wavelength $\lambda=500$ nm$=500\times10^{-9}$ m$=0.5\times10^{-6}$ m.

Number of fringes shifted, N=λ Optical path difference$=0.5\times10^{-6}$ m1×10^{-6} m=2.

3.b Use formula, $\beta=\lambda D/d$ If the separation between the slits (d) is gradually increased, then the fringe width (β) will decrease. As the fringes become narrower, they become harder to distinguish, and eventually, they will disappear

4.c path difference, $3\lambda/2$ as $(1+\frac{1}{2})\lambda$-condition for dark fringe

5.d Use the formula $I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\phi$

6.a) use the formula $\beta = \frac{\lambda D}{d} = \frac{cD}{vd}$

7.c condition for the first minimum is $a\sin\theta = \lambda$

8.c use the formula $y = \frac{\lambda D}{a}$

ASSERTION-REASON QUESTION

For these Questions two statements are given one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below

A. If both Assertion and Reason are true and Reason is correct explanation of Assertion.
B. If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
C. If Assertion is true but Reason is false.
D. If both Assertion and Reason are false.

1. **Assertion:** In YDSE if a monochromatic source of light is placed in front of one slit we do not get any interference pattern.
   Reason: in YDSE source shall be placed at equal distance from two slits.
2. **Assertion:** Two equal wavelengths meet at point when coming from opposite direction may give brightest spot at the point of meeting.
   Reason: Two waves moving in opposite directions meet in opposite phase.
3. **Assertion:** The two slits in YDSE are illuminated by two different sodium lamps emitting light of same wavelength. No interference pattern will be observed.
   Reason: Two independent light sources (except LASER) cannot be coherent.
4. **Assertion:** In calculating the disturbance produced by a pair of superimposed incoherent wave trains, you can add their intensities.
   Reason: $I = I_1 + I_2 + 2(I_1I_2)^{1/2}\cos\Theta$. The average value of $\cos\Theta = 0$, for incoherent waves.
5. **Assertion:** Thin films such as soap bubble or thin layer of oil spread on water show beautiful colors when illuminated by white light.
   Reason: It is due to interference of Sun's light reflected from upper and lower surfaces of the film.
6. **Assertion:** In YDSE central fringe may not be a bright fringe.
   Reason: If path difference at central fringe is zero then it will be a bright fringe.
7. **Assertion:** Fringe width in single slit experiment depends upon refractive index of the medium.
   Reason: Refractive index changes optical path of ray of light forming fringe pattern also changes.
8. **Assertion:** In YDSE a monochromatic source of light is placed symmetrically in front of two slits placed in vertical line at small separation. If lower half of the setup is filled with water no pattern is obtained at the screen.
   Reason: Due to water wavelength of light changes hence no pattern is seen.

ANSWERS

1. D, both are wrong, General concept
2. C, Direction of motion do not have definite relation with phase difference
3. D, both are wrong, only coherent sources can produce interference
4. A, can be calculated, Correct explanation
5. A, both are correct, General concept, Correct explanation
6. A, both are correct, General concept, Correct explanation
7. A, $\beta \propto \lambda$ & λ depends on μ, Correct explanation
8. D, both are wrong, no interference but another pattern will be seen

VERY SHORT ANSWER TYPE

1. Three wavelength λ_1, λ_2 & λ_3 are used in YDSE experiment respectively. If N_1, N_2 & N_3 are number of fringes obtained at the screen respectively. If $N_1 - N_2 = 2N_3$ and $3N_3 - N_1 = 2N_2$. Arrange λ_1, λ_2 & λ_3 in ascending order.
2. If a monochromatic source of light is placed symmetrically near two slits of slightly unequal width. Explain pattern of fringes obtained at the screen? How would it be changed if monochromatic source of light is placed asymmetrically?
3. When white light is used in YDSE we say Central band is white surrounded by colored bands with inner edge as red and outer edge violet. justify it, as well as explain pattern of width of fringes obtained.
4. In a single-slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band. What happen if it is made extremely narrow
5. Answer the following questions: (i) In what way is diffraction from each slit related to the interference pattern in a double slit experiment? (ii) When a tiny circular obstacle is placed in the path of light from a distance source, a bright spot is seen at the center of the shadow of the obstacle. Explain, why.
6. (a) The ratio of the widths of two slits in Young's double slit experiment is 4: 1. Evaluate the ratio of intensities at maxima and minima in the interference pattern.
   (b) Does the appearance of bright and dark fringes in the interference pattern violate, in any way, conservation of energy?
7. Two plane monochromatic waves propagating in the same direction with amplitudes A and 2A and differing in phase by $\pi/3$ superimpose. Calculate the amplitude of resulting wave.
8. Two spectral lines of sodium D_1 and D_2 have wavelengths approximately 5890Åand 5896Å. A sodium lamp sends incident plane wave on to a slit of width 2 micrometer. A screen is located 2m from the slit. Find the spacing between the first maxima of two sodium lines as measured on the screen.

SOLUTIONS/HINTS

1. For same distance, $N_1\lambda_1 = N_2\lambda_2 = N_3\lambda_3$, by solving we get $N_2 = 5N_3$ and $N_1 = 7N_3$
   $\Rightarrow N_1 > N_2 > N_3 \Rightarrow \lambda_3 > \lambda_2 > \lambda_1$
2. If width is unequal $I_1 \neq I_2$ – Bright and dark fringe (bands) have less contrast
   Central band may not be bright
3. Since white light is a combination of all visible colors, the superposition of all colors at the central maximum results in a bright white band. Also the position of bright fringe is directly proportional to the wavelength of light. Thus, the first order bright fringe will be a spectrum with violet light at the inner edge and red light at the outer edge.
4. For small angles, $\theta \approx \frac{\lambda}{a}$ So, the angular width $\propto \frac{1}{a}$. If the slit width 'a' is doubled, the angular width of the central maximum will be halved. The linear width of the central maximum= $\frac{2\lambda D}{a}$. So, the central band becomes narrower. $I \propto A^2 \propto a^2$ central band becomes four times more intense. If the slit is made extremely narrow (i.e., $a \approx \lambda$ or $a < \lambda$), the condition for the first minimum ($a \sin\theta = \lambda$) implies that $\sin\theta$ becomes large, The intensity of the diffracted light will be very low because the amount of light passing through an

extremely narrow slit is very small or no diffraction takes place if become less than wavelength of light.

5.(i) The observed double-slit interference pattern is actually the interference pattern modulated by the single-slit diffraction pattern.

(ii) Due to the symmetry of the circular obstacle, the diffracted wavelets from all points along the circumference of the obstacle's edge travel the same optical path length to the exact center of the shadow. Because they travel the same path length, they arrive in phase at the center of the shadow. This in-phase superposition leads to constructive interference at the exact center of the shadow, resulting in a bright spot.

6. Intensity ∝ *width of slit* and use the formula $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$ Ans. 9:1

7. Use the formula $A^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$ Ans $A\sqrt{3}$

8. Position of first maximum for $D_1, \lambda_1 = \frac{3\lambda D}{2d} = 0.8835$ mm

Position of first maximum for $D_2, \lambda_2 = \frac{3\lambda D}{2d} = 0.8844$ mm Ans. 0.0009

SHORT ANSWER TYPE

1. What is the effect on the interference fringes if the monochromatic source is replaced by a source of polychromatic light. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1.0 m away from the slits. (a) Find the distance of the second (i) bright fringe, (ii) dark fringe from the central Maximum.
   (b) How will the fringe pattern change if the screen is moved away from the slits?
2. In a modified set-up of Young's double slit experiment, it is given that $SS_2 - SS_1 = \lambda/4$, i.e. the source 'S' is not equidistant from the slits S_1 and S_2.
   (a) Obtain the conditions for constructive and destructive interference at any point P on the screen in terms of the path difference $\delta = S_2P - S_1P$.
   (b) Does the observed central bright fringe lie above or below 'O'? Give reason to support your answer P_3.
3. A parallel beam of monochromatic light falls normally on a narrow slit of width 'a' to produce a diffraction pattern on the screen placed parallel to the plane of the slit. Use Huygens' principle to explain that
   (i) the central bright maxima is twice as wide as the other maxima.
   (ii) the intensity falls as we move to successive maxima away from the centre on either side.
4. (a) Why are coherent sources necessary to produce a sustained interference pattern?
   (b) In Young's double slit experiment using mono-chromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is 2λ.
5. Define the term wave front. State Huygen's principle.
   Consider a plane wave front incident on a thin convex lens. Draw a proper diagram to show how the incident wave front traverses through the lens and after refraction focuses on the focal point of the lens, giving the shape of the emergent wave front.
6. A coloured alternate bands of diffraction pattern appears on a screen due to a specific wavelength λ passing through a single slit of width 1.5 mm. If this wavelength is replaced with another wavelength 2.5λ and whole apparatus is immersed in a liquid of refractive index 1.2 to what width should you change the slit in order to get the original pattern back? (Ignore effect on focal length of the lens due to change in wavelength or medium)
7. Which of the following statements DOES NOT correctly comply with Huygens' Principle of constructing a secondary wavefront from a primary wavefront? Justify each case?
   a) After some time interval, the new position of the wave front is the surface tangent to the secondary wavelets.
   b) Secondary wavelets propagate outward through a medium with speeds characteristic of waves in that medium.
   c) A secondary wavefront is always a plane wavefront irrespective of whether the primary wavefront is

planar or spherical.

8. (a) In a Young's double slit experiment, the two slits are illuminated by two different lamps having same wavelength of light. Explain with reason, whether interference pattern will be observed on the screen or not.

(b) Light waves of intensities I_0 each from two coherent sources arrive at two points on a screen with path differences of $5\lambda/2$ and 5λ. Find the intensities at the points.

SOLUTIONS/HINTS

1. fringes will become coloured near to edge of central band lower wavelength will be seen.

i) Distance of second bright fringe is $= \frac{2\lambda D}{d}$ = 6mm

ii) Distance of second dark from central maxima , $= \frac{\lambda D}{2d}$ = 1.5mm

iii) Increase since $\beta = \frac{\lambda D}{d}$

2. a) $(SS_2 - SS_1) = \Delta = xd/D$, net path difference $= \lambda/4 + xd/D$

For constructive interference $\lambda/4 + xd/D = n\lambda$, $(4n-1)\lambda D/4d = (x_n)bright$

for destructive interference , $\lambda/4 + xd/D = (2n-1)\lambda D/4d$

$(x_n)dark = (4n-3)\lambda D/4d$

b)For central bright fringe n=0 and hence $(x_0)bright = -\lambda D/4d$. Thus, the observed central bright fringe shifts towards the line of slit S_2 because the optical path of light coming from S_1 will increase.

3. i) Describe single slit exp using wave theory ii) This is because the waves diffracting from different parts of the slit interfere with each other, and the interference pattern creates both bright and dark fringes (minima). The central bright fringe is the brightest and widest, and the intensity of the secondary maxima (bright fringes) decreases as you move further away from the center.

4. a) If sources are not coherent then phase difference will be time varying.

b) phase difference $= \phi = 2\pi/\lambda \times 2\lambda = 4\pi$ intensity $I = I_0 \cos^2(\frac{\phi}{2})$, $I_0 = I_0$, so $I = I_0$

5. general concepts and definitions, refer gist of the chapter.

6. on immersing the apparatus , wavelength decreases by μ so $\lambda' = \lambda/\mu$,

The angular position of the minima is given by $a\sin\theta = n\lambda$

Since we want the same pattern, the angular positions of the minima must be the same in both wavelength and refractive index. So $a_1\lambda_1 = a_2\lambda'$ so $a_1 = a_2(2.5/1.2)$, new slit width is 0.72mm.

7. a) It is always perpendicular and not tangential

b) Speed depends on refractive index of the medium.

c) Secondary and primary wavefront are of the same nature always

8. a) no interference pattern will be observed as the sources are two independent sources.

b) use direct formula and values will be 0 and $4I_0$ respectively.

THREE MARKS QUESTIONS

1. State the essential condition for diffraction of light to take place. Use Huygen's principle to explain diffraction of light due to a narrow single slit and the formation of a pattern of fringes obtained on the screen. Sketch the pattern of fringes formed due to diffraction at a single slit showing variation of intensity with angle θ.

2. Red colour of light of wavelength λ is passed from two narrow slits which are distance d apart and interference pattern is obtained on the screen distance D apart from the plane of two slits. Then find the answer to following parts assuming that slit widths are equal to produce intensity I_0 from each slit.

a. Intensity at a point on the screen, situated at a distance 1/4 th of fringeseparation from centre.

b. Intensity in the screen, if the sources become incoherent by using twodifferent lamps behind lamps S1 and S2.

c. Angular position of 10th maxima, and the angular width of that fringe.

d. Find the distance between 5th maxima and 3rd minima, at same side ofcentral maxima.

3. (a) In a diffraction experiment, the slit is illuminated by light of wavelength 600 nm. The first minimum of the pattern falls at $\theta = 30^\circ$ .Calculate the width of the slit.

(b) Show that the angular width of the first diffraction fringe is half of that of the central fringe.

(c) If a monochromatic source of light is replaced by white light, what change would you observe in the diffraction pattern?

4. (a) In Young's double slit experiment, derive the condition for (i) constructive interference and (ii) destructive interference at a point on the screen.

(b) A beam of light consisting of two wavelengths, 800 nm and 600 nm is used to obtain the interference fringes in a Young's double slit experiment on a screen placed 1.4 m away. If the two slits are separated by 0.28 mm, calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

5. Explain Huygen's principle. Name the types of wavefronts that corresponds to a beam of light

(a) coming from a convex lens when point source placed at focus.

(b) coming from very far off source.

(c) coming from a convex lens $\mu = 1.1$ when point source placed at its focus inside water $\mu = 1.33$.

(d) wave front from a distant source fall perpendicular to an equilateral hollow prism placed in side water.

SOLUTIONS/HINTS

1. Essential condition for diffraction: the size of the obstacle or aperture (slit) must be comparable to the wavelength of the light being used. For another part of the question refer the gist of the chapter

2. a) $\Delta x = \frac{yd}{D} = \frac{\lambda}{4}$; $\Phi = \frac{\pi}{2}$; $I = 4I_0 \cos^2\frac{\Phi}{2} = 2I_0$

b) No interference pattern observed, $I_{total} = 2I_0$

c) $d\sin\theta = 10\lambda$, find θ using this formula ; Angular width, $\Delta\theta = \frac{\lambda}{d}$

d) distance $= |y_5 - y_5|$ Ans - $5\lambda D/2d$

3. a) Condition for minima; $a\sin\theta = n\lambda$ use this formula to find a = 1.2 nm

b) Condition for first minimum, $a\sin\theta = \lambda$; $\theta_1 = \frac{\lambda}{a}$ $\theta_2 = -\frac{\lambda}{a}$

Angular width $= 2\theta_1 = 2\lambda/a$

c) The central maximum will remain white, secondary maxima will become colored fringes and the overlapping of different colored secondary maxima will increase.

4. a) Refer to the gist of this chapter

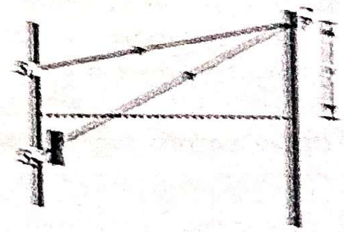
b) Here $y_1 = y_2$ to find the order of the bright fringes. Then calculate the position of this coinciding fringe using both pair of values. Ans: 12 mm

5. Refer to the gist of this chapter for Huygen's principle

a) plane wavefronts b) plane wavefronts c) Using lens maker's formula, we will find that lens will behave diverging. So we get diverging wavefront d) Plane wavefront

CASE STUDY/PASSAGE-BASED QUESTIONS

1. Interference of light:- If double slit apparatus is immersed in a liquid of refractive index μ, the wavelength of light reduces to λ/μ and fringe width also reduces to $\beta' = \beta/\mu$. The given figure shows a double-slit experiment in which coherent monochromatic light of wavelength λ from a distant source is incident upon the two slits, each of width w (w >> λ) and the interference pattern is viewed on a distant screen. A thin piece of glass of thickness t and refractive index n is placed between one of the slit and the screen, perpendicular to the light path.



(i) In Young's double slit interference pattern, the angular fringe width

(a) can be changed only by changing the wavelength of incident light