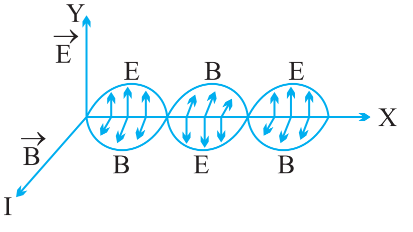
Unit V & VI
ELECTROMAGNETIC WAVES AND OPTICS

KEY POINTS

1. EM waves are produced by accelerated (only by the change in speed) charged particles.
2. $\vec{E}$ and $\vec{B}$ vectors oscillate with the frequency of oscillating charged particles.
3. Propagation of wave along *x*-direction.



4. Properties of em waves :
   (i) Transverse nature
   (ii) Can travel though vacuum.
   (iii) $\frac{E_0}{B_0} = \frac{E}{B} = \lambda v = C$ C → Speed of EM waves.
   (iv) Speed of em wave C = 3 × 10^8 m/s in vacuum and

$$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ m/sec (in vaccum)}$$

(v) In any medium $V = \frac{1}{\sqrt{\mu\varepsilon}}$

Where $\mu = \mu_r \mu_0$ $\varepsilon = \varepsilon_r \varepsilon_o$

$\sqrt{\varepsilon_r} = n$ refractive index of medium

Also $V = \frac{c}{n}$

(vi) A material medium is not required for the propagation of e.m. waves.

(vii) Wave intensity equals average of Pointing vector $I = |\vec{S}|_{av} \frac{B_0 E_0}{2\mu_0}$.

(viii) Average electric and average magnetic energy densities are equal.

$U_E = \frac{1}{2}\varepsilon_0 E^2$ and $U_B = \frac{1}{2}\frac{B^2}{\mu_0}$

(ix) The electric vecotr is responsible for optical effects due to electro magnetic wave. For this reason, electric vector is called light vector.

- In an em spectrum, diffferent waves have different frequency and wavelengths.
- Penetration power of em waves depends on frequency. Higher, the frequency larger the penetration power.
- Wavelength λ and frequency v are related with each other $\nu = \nu\lambda$. Here V is the wave velocity.
- A wave travelling along + x axis is represented by

$$E_y = E_0 \cos(\omega t - kx)$$

$$B_z = B_0 \cos(\omega t - kx)$$

$$\omega = \frac{2\pi}{T} = 2\pi v$$

$$\frac{\omega}{k} = \lambda v = V = C \text{ wave speed}$$

$$k = \frac{2\pi}{\lambda} = 2\pi\bar{v}$$

$v \rightarrow$ frequency

$\bar{v} = \frac{1}{\lambda}$ wave number.

Electromagnetic Soectrum

Name	Wavelength range	Production	Uses
Gamma Rays	$< 10^{-12}$ m	Gamma rays produced in radio active decay of nucleus	in treatment of cancer and to carry out nuclear reactions.
x-rays	10^{-9} m to 10^{-12} m	*x*-ray tubes or inner shell electrons	used as diagnostic tool in medical to find out fractures in bones. to find crack, flaws in metal part of machine
UV rays	4×10^{-7} to 10^{-9} m	by very hot bodies like sun and by UV lamps	in water purifier in detection of forged documents, in food preservation.
Visible light	7×10^{-7} m to 4×10^{-7}m	by accelerated tiny (electrons) charge particles	to see every thing around us
IR rays	10^{-3} m to 7×10^{-7} m	due to vibration of atoms	in green houses to keep plant warm to reveal secret writings on walls in photography during fog and smoke
Microwaves	10^{-1} m to 10^{-3} m	produced in klystron Valve and magnetron Valve	in RADAR in microwave ovens
Radio waves	> 0.1 m	by accelerated charged particles excited electrical circuits excited	in radio telecommunication system in radio astrology

Displacement Current—Current produced due to time varying electric field or electric flux.

$$I_D = \varepsilon_0 \frac{d\phi_e}{dt}, , \quad \phi_e \text{ is electric flux}$$

Modified Ampere's Circuital law by Maxwell

$$\oint \vec{B}.d\vec{l} = \mu_0\left(I_C + \varepsilon_0 \frac{d\phi_e}{dt}\right)$$

$$I_c \rightarrow \text{Conduction current}$$

$$I_C = I_D$$

OPTICS

RAY OPTICS

GIST

1. REFLECTION BY CONVEX AND CONCAVE MIRRORS

a. Mirror formula $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ where u is the object distance, v is the image distance and f is the focal length.

b. Magnification $m=-\frac{v}{u}=\frac{f-v}{f}=\frac{f}{f-u}$ m is $-ve$ for real images and $+ve$ for virtual images.

c. Focal length of a mirror depends up only on the curvature of the mirror $\left(f=\frac{R}{2}\right)$. It does not depend on the material of the mirror or on wave length of light.

2. REFRACTION

d. Ray of light bends when it enters from one medium to the other, having different optical densities.
When light wave travels from one medium to another, the wave length and velocity changes but frequency of light wave remains the same.

e. Sun can be seen before actual sunrise and after actual sun set due to Atmospheric refraction.

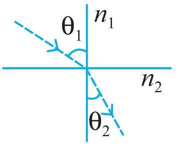
f. An object under water (any medium) appears to be raised due to refraction when observed obliquely.

$n=\frac{\text{Real depth}}{\text{apparent depth}}$ n ° refractive index

and normal 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.

g. Snell's law states that for a given colour of light, the ratio of sine of the angle of incidence to sine of angle of refraction is a constant, when light travels from one medium to another.



$n_1 \sin q_1 = n_2 \sin q_2$

h. Absolute refractive index is the ratio between the velocities of light in vacuum to velocity of light in medium. For air regractive index is 1.003 for practical uses taken to be 1

$$n = \frac{c}{v}$$

3. T.I.R.

i. When a ray of light travels from denser to rarer medium and if the angle of incidence is greater than critical angle, the ray of light is refiected back to the denser medium. This phenomenon is called total internal refiection. (T.I.R.)

$$\sin C = \frac{n_R}{n_D}$$

Essential conditions for T.I.R.

1. Light should travel from denser to rarer medium.
2. Angle of incidence must be greater than critical angle ($i > i_C$)

j. Diamond has a high refractive index, resulting with a low critical angle ($C = 24.4^0$). This promotes a multiple total internal reflection causing its brilliance and luster. Working of an optical fibre and formation of mirage are the examples of T.I.R.

4. When light falls on a convex refracting surface, the relation among, *u, v* and R is given by $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$.

5. Lens maker formula for thin lens formula is given by

$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

For Convex Lens R_1 + ve; R_2 – ve and Concave lens R_1 –ve; R_2 + ve. The way in which a lens behaves as converging or diverging depends upon the values of n_2 and n_1.

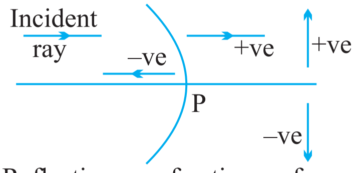
6. When two lenses are kept in contact the equivalent focal length is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$ and Power $P = P_1 + P_2$

Magnification $m = m_1 \times m_2$

7. The lens formula is given by $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Sign convention for mirrors and lenses → Distances in the direction of incident ray are taken as positive. All the mesurement is done from pole (P).



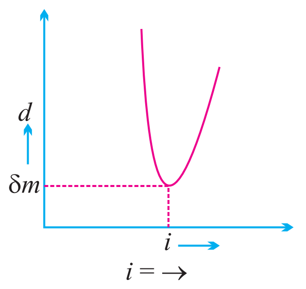
Reflecting or refracting surface

8. When ray of light passes through a glass prism it undergoes refraction, then $A + \delta = i + e$ and, the expression of refractive index of glass prism

$$n = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

As the angle of incidence increses, the angle of deviation decreases, reaches a minimum value and then increases. This minimum value of angle of deviation is called angle of minimum deviation "δ_m".

9.



Where d is minimum, $i = e$, refracted ray lies parallel to the base. For a small angled prism d min = $(n - 1)$A.

10. When white light is passed through a glass prism, it splits up into its constituent colours (Monochromatic). This phenomenon is called Dispersion.

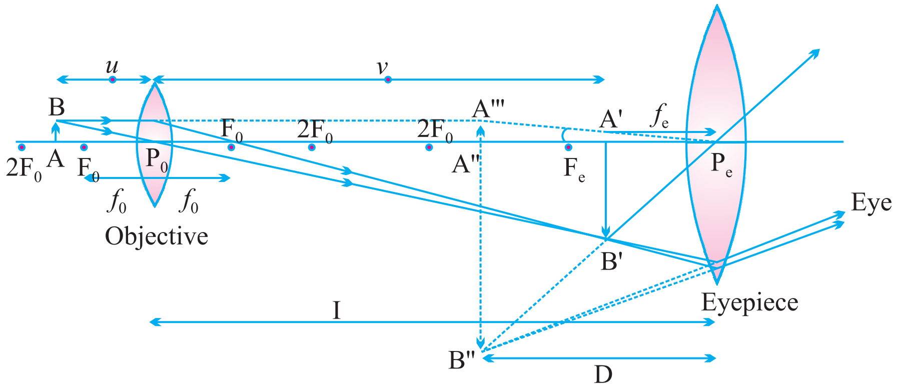
11. Scattering of light takes place when size of the particle is very small as compared to the wavelength of light.

Intensity of scattered light is $I \alpha \frac{1}{\lambda^4}$

The following properties or phenomena can be explained by scattering.

(i) Sky is blue.
(ii) Sun looks reddish at the time of sunrise and sunset.
(iii) Red light used in danger mark.
(iv) Clouds are white.

Compound Microscope :



Objective : The converging lens nearer to the object.

Eyepiece : The converging lens through which the final image is seen.

Both are of short length. Focal length of eyepiece is slightly greater than that of the objective.

4. **Angular Magnification or Magnifying Power (M) :**

$$\mathbf{M = M_e \times M_o}$$

(a) When final is formed atleast distance of distinct vision.

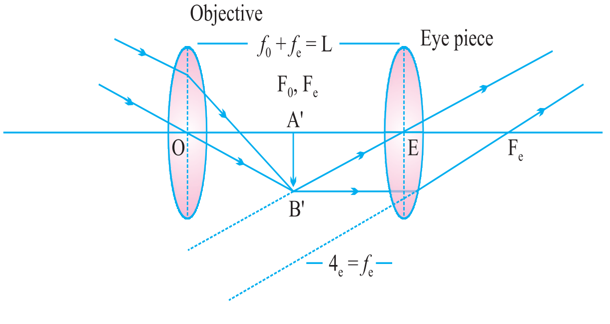
$$M = \frac{v_o}{-u_o}\left(1 + \frac{D}{f_e}\right) \qquad M = \frac{-L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

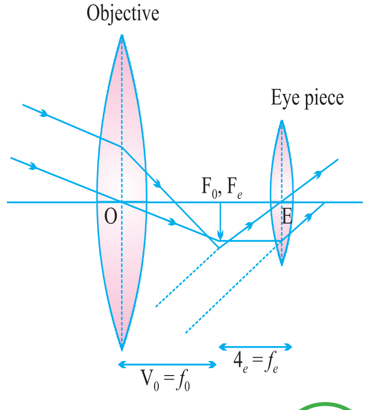
(b) When final image is formed at infinity $M = \frac{-L}{f_o}\frac{D}{f_e}$

(Normal adjustment *i.e.* image at infinity) Length of tube

$$L = |v_o| + |u_e|$$

5. **Formation of Image by Astronomical Telescope : at infinity Normal Adjustment Position)**





Focal length of the objective is much greater than that of the eyepiece. A perture of the objective is also large to allow more light to pass through it.

6. **Angular magnification or Magnifying power of a telescope.**

(a) When final image is formed at infinity (Normal adjustment)

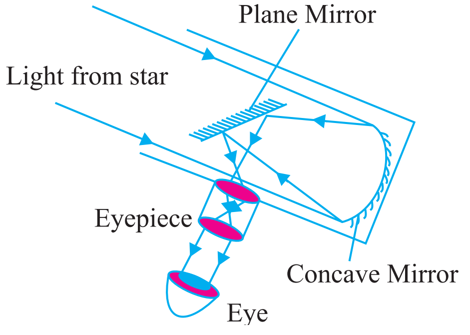
$$\boxed{M = \frac{\beta}{\alpha}} \qquad \boxed{M = \frac{-f_o}{f_e}}$$

($f_o + f_e$ = L is called the length of the telescope in normal adjustment).

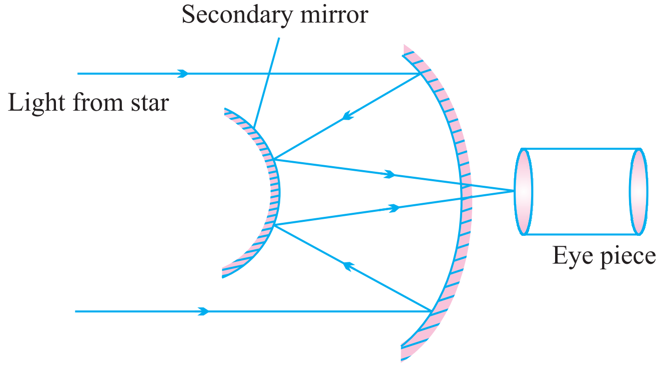
(b) When final image is formed at least distance of distinct vision.

$$m = \frac{-f_o}{f_e}\left(1 + \frac{f_o}{D}\right) \text{ and } L = f_o + |u_e|$$

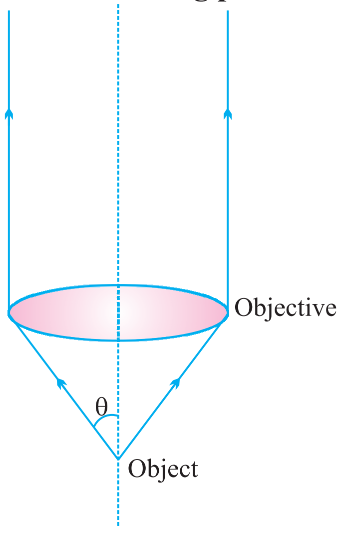
7. **Newtonian Telescope : (Reflecting Type)**



8. **Cassegrain telescope refer**



Limit of resolution and resolving power Compound Microscope



Limit of resolution $\Delta d = \dfrac{\lambda}{2\mu\sin\theta}$

Resolving Power $= \dfrac{1}{\Delta d} = \boxed{\dfrac{2\mu\sin\theta}{\lambda}}$

Resolving power depends on (i) wavelength λ, (ii) refractive Index of the medium between the object and the objective and (iii) half angle of the cone of light from one of the objects θ.

Telescope : Limit of resolution $d\theta = \dfrac{1.22\lambda}{D}$

Resolving Power $= \dfrac{1}{d\theta} = \boxed{\dfrac{D}{1.22\lambda}}$

D → diameter of objective.

Resolving power depends on (i) wavelength λ, (ii) diameter of the objective D.

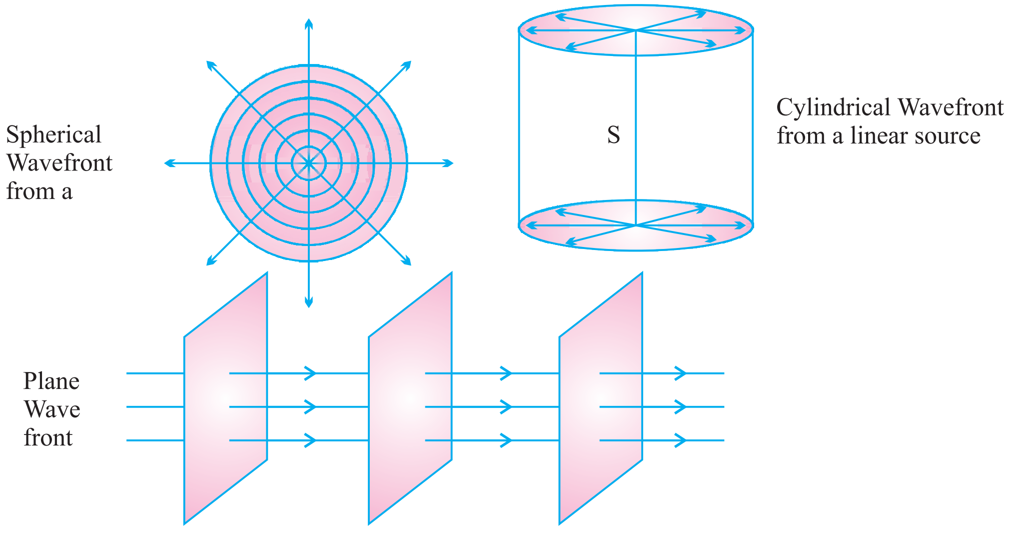
WAVE OPTICS

Wave front :

A wavelet is the point of disturbance due to propagation of light.

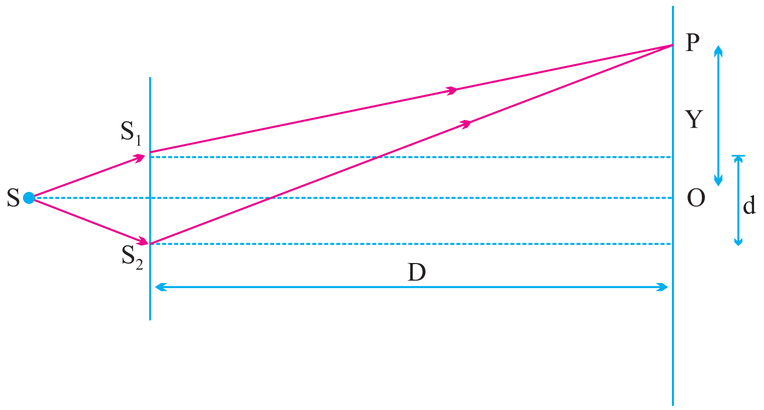
A wavefront is the locus of points (wavelets) having the same phase of oscillations.

A perpendicular to a wavefront in forward direction is called a ray.



INTERFERENCE OF WAVES

Young's Double Slit Experiment



The waves from S_1 and S_2 reach the point P with some phase difference and hence path difference

$$\Delta = S_2P - S_1P$$

$$S_2P^2 - S_1P^2 = \left[D^2 + \left\{y + \left(\frac{d}{2}\right)\right\}^2\right] - \left[D^2 + \left\{y - \left(\frac{d}{2}\right)\right\}^2\right]$$

$$(S_2P - S_1P)\,(S_2P + S_1P) = 2\,yd \qquad S_2P \approx S_1P \approx D$$

$$\Delta\,(2D) = 2\,yd$$

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

Interference phenomenon

1. Resultant intensity at a point on screen

$$I_R = R\,(a_1^2 + a_2^2 + 2a_1a_2 \cos f)$$

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi \qquad \text{Where } I_1 = ka_1^2,\; I_2 = ka_2^2$$

$$\text{If } I_1 = I_2 = I_o, \text{ then } I_R = 4I_o\cos^2\left(\frac{\phi}{2}\right)$$

2. $$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 \qquad \text{If } I_1 = I_2 = I_0,\; I_{max} = 4I_0$$

$$I_{min} = \left(\sqrt{I_1} - \sqrt{I_1}\right)^2 \qquad \text{If } I_1 = I_2 = I_0,\; I_{max} = 0$$

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

4. $$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$$

5. $$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{w_1}{w_2},$$ w_1 and w_2 are widths of two slits

6. Constructive interference

Phase difference, $\phi = 2n\pi$

Path difference, $x = n\lambda$

Destructive interference

Phase difference $\phi = (2n + 1)\pi$

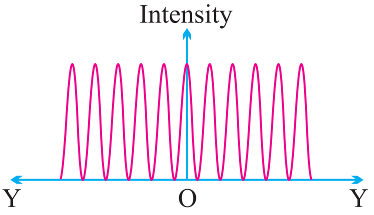
Path difference $x = (2n+1)\frac{\lambda}{2}$

Where $n = 0, 1, 2, 3, ...$

7. Fringe width (dark or bright) $\beta = \frac{\lambda D}{d}$

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

Distribution of Intensity

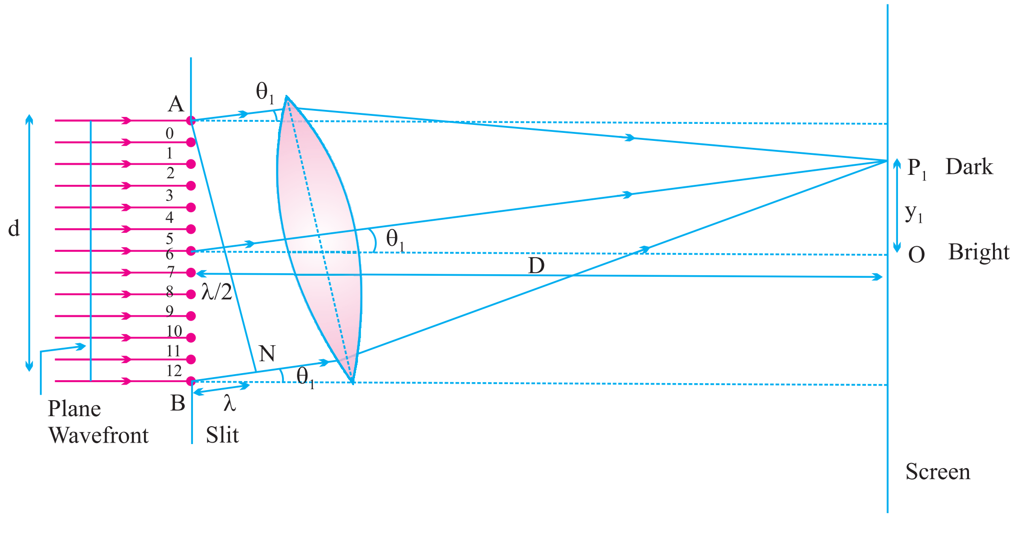


Conditions for Sustained Interference :

1. The two sources must be coherent.
2. The two interfering wave trains must have the same plane of polarisation.
3. The two sources must be very close to each other and the pattern must be observed at a large distance to have sufficient width of the fringe $b = \frac{\lambda D}{d}$ Angnlar width $a = l/d$
4. The sources must be monochromatic. Otherwise, the fringes of different colours will overlap.
5. The two waves must be having same amplitude for better contrast between bright and dark fringes.

DIFFRACTION OF LIGHT AT A SINGLE SLIT :

Width of Central Maximum :



$$y_1 = \frac{D\lambda}{d}$$

Since the Central Maximum is spread on either side of O, the width is

$$\boxed{\beta_0 = \frac{2D\lambda}{d}}$$

Fresnel's Distance :

$$y_1 = \frac{D\lambda}{d}$$

At Fresnel's distance, $y_1 = d$ and $D = D_F$

So, $$\frac{D_F \lambda}{d} = d \text{ or } D_F = \frac{d^2}{\lambda}$$

POLARISATION OF LIGHT WAVES :

Malus' Law : When a beam of plane polarised light is incident on an analyser, the intensity I of light transmitted from the analyser varies directly as the square of the cosine of the angle θ between the planes of transmission of analyser and polariser.

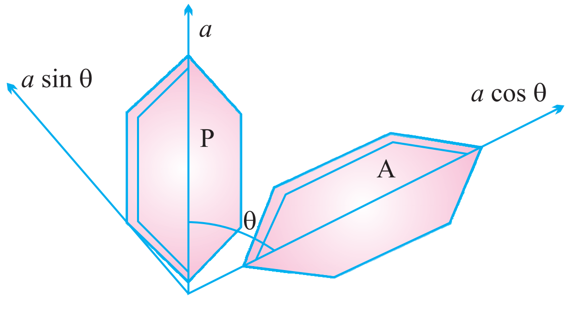
Intensity of transmitted light from the analyser is

$$\boxed{I \propto \cos^2 \theta}$$

$$I = k\,(a \cos \theta)^2$$

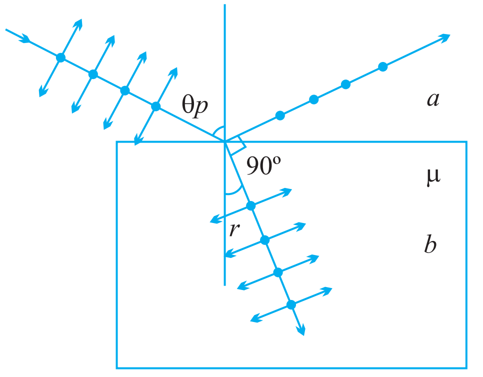
or $$I = k\,a^2 \cos^2 \theta$$

$$\boxed{I = I_0 \cos^2 \theta}$$



(where $I_0 = ka^2$ is the intensity of light transmitted from the polariser)

Polarisation by Reflection and Brewster's Law :



$$\theta_P + r = 90^\circ \text{ or } r = 90^\circ - \theta_P$$

$$_a\mu_b = \frac{\sin\theta_P}{\sin r}$$

$$_a\mu_b = \frac{\sin\theta_P}{\sin 90^\circ - \theta_P}$$

$$\boxed{_a\mu_b = \tan\theta_P}$$

QUESTIONS

VERY SHORT ANSWER QUESTIONS (I Mark)

1. Every EM wave has certain frequency. Name two parameters of an em wave that oscillate with this frequency.

Ans. Electric field vector and Magnetic field vector.

2. What is the phase difference between electric and magnetic field vectors in an em wave?

Ans. $\frac{\pi}{2}$

3. Name em radiations used for detecting fake currency notes.

Ans. U.V. Radiation.

4. Give any two uses of microwaves.

Ans. Radar, Microwave ovens

5. Name the phenomenon which justifies the transverse nature of em waves.

Ans. Polarization.

6. Arrange the following em waves in descending order of wavelengths : γ ray, microwaves UV radiations.

Ans. Microwave, U V radiation, γ-rays

7. Which component $\vec{E}$ or $\vec{B}$ of an em wave is responsible for visible effect?

Ans. $\vec{E}$

8. Write expression for speed of em waves in a medium of electrical permittivity $\in$ and magnetic permeability μ.

Ans.
$$V = \frac{1}{\sqrt{\mu \in}}$$

9. Which of the following has longest penetration power?
UV radiation, X-ray, Microwaves.

Ans. X-rays

10. Which of the following has least frequency ?
IR radiations, visible radiation, radio waves.

Ans. Radiowaves.

11. Which physical quantity is the same for microwaves of wavelength 1 mm and UV radiations of 1600 A° in vacuum?

Ans. Speed.

12. Name two physical quantities which are imparted by an em wave to a surface on which it falls.

Ans. Energy and pressure.

13. Name the physical quantity with unit same as that of

$\left| \in_0 \frac{d\phi_e}{dt} \right|$ where $\phi_e \rightarrow$ electric flux.

Ans. Current.

14. What is the source of energy associated with propagating em waves?

Ans. Oscillating/accelerated charge.

15. A plane mirror is turned through 15º. Through what angle will the reflected ray be turned ?

Ans. 30º

16. Name the device used for producing microwaves.

Ans. Klystron valve and magnetron valve

17. Relative electric permittivity of a medium is 9 and relative permeability close to unity. What is the speed of em waves in the medium.

Ans. $$V = \frac{1}{\sqrt{\mu \in}} = \frac{1}{\sqrt{(\mu_0\mu_r)(\in_0\in_r)}} = \frac{1}{\sqrt{(\mu_0\varepsilon_r)(\mu_r\varepsilon_r)}}$$

$$V = \frac{C}{\sqrt{9}} = \frac{C}{3}$$

18. Identify the part of the electromagnetic spectrum to which the following wavelengths belong :

(i) 10^{-1} m

(ii) 10^{-12} m

Ans. Microwave, γ-ray

19. Name the part of the electromagnetic spectrum of wavelength 10^{-2} m and mention its one application.

Ans. Microwave $\rightarrow$ microwave oven.

20. Which of the following act as a source of electromagnetic waves?

(i) A charge moving with a constant velocity.

(ii) A charge moving in a circular orbit with time varyinng speed.

(iii) A charge at rest.

Ans. A charge moving in a circular orbit

21. Mention the pair of space and time varying E and B fields which would generate a plane em wave travelling in Z-direction.

Ans. E_x and B_y

22. The charging current for a capacitor is 0.2A. What is the displacement current?

Ans. Remain same $I_C = I_D$

23. Give the ratio of velocities of light waves of wavelengths 4000A° and 8000A° in Vacuum.

24. Which physical quantity has the same value for waves belonging to the different parts of the electromagnetic spectrum?

Ans. Speed

25. Write the value of angle of reflection for a ray of light falling normally on a mirror.

Ans. Zero.

26. How does the dispersive power of glass prism change when it is dipped in water?

Ans. Decreases.

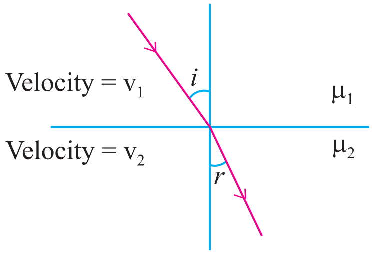
27. Light travels from glass to air. Find the angle of incidence for which the angle of refraction is 90° if refractive index of glass is $\sqrt{2}$.

Ans. 45°

28. Name the phenomenon due to which one cannot see through fog.

Ans. Scattering of light.

29. What is the ratio of sin i and sin r in terms of velocities in the given figure.

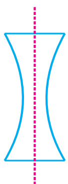


Ans. v_1/v_2

30. What is the shape of fringes in Youngs double slit experiment ?

Ans. Hyperbolic.

31. A equiconcave lens of focal length 15 cm is cut into two equal havles along dotted lines as shown in figure. What will be new focal length of each half.



Ans. 30 cm.

32. For the same angle of the incidence the angle 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?

Ans. A

33. What is the phase difference between two points on a cylindrical wave front?

Ans. Zero.

34. What is the 'power' of plane glass plate ?

Ans. Zero.

35. How does focal length of lens change when red light incident on it is replaced by violet light?

Ans. Decreases,

36. Lower half of the concave mirror is painted black. What effect will this have on the image of an object placed in front of the mirror?

Ans. The intensity of the image will be reduced (in this case half) but no change in size of the image.

37. An air bubble is formed inside water. Does it act as converging lens or a diverging lens?

Ans. Diverging lens

38. A water tank is 4 meter deep. A candle flame is kept 6 meter above the level μ for water is 4/3. Where will the image of the candle be formed?

Ans. 6 m. below the water level.

39. What is the ratio of contribution made by the electric field and magnetic field components to the intensity of an EM wave is ?

Ans. 1 : 1.

40. An EM wave of intensity 'I' falls on a surface kept in vacuum. What is the radiation pressure if wave is totally reflected?

Ans. $\frac{2I}{c}, c \rightarrow$ Speed of light

41. In a single slit diffraction pattern, how does the angular width of central maxima change when (i) slit width is decreased (ii) distance between slit & screen is increased and (iii) light of smaller visible wavelength is used ? Justify your answer.

Ans. Angular width of central maxima $\theta = \frac{\beta_0}{D} = \frac{2\lambda}{d}$

(i) If $d \rightarrow$ decreases Angular width increases.
(ii) Angular width remain same on increasing D
(iii) If λ decreases, angular width decreases.

SHORT ANSWER QUESTIONS (1 Marks)

1. It the angle between the pass axis of polorizer and analyser is 450, writhe the ratio of intensilies of orginal light an the transmitted light after passing trough anlyser [**Ans.** $\rightarrow$ 2]

2. Light of wave lenght 600nm is incident normally on a slit of with 3mm. Calculate the angular width of central maximum on a screen kept 3m away from the steb. [**Ans.** 4×10^{-4} rad]

3. If the polarising angle for air glass interface is 56.3°, lohat is the angle of refraction in glass? [**Ans.** 33.7°]

4. How does magnifying power changes with change in length of tube for a given telescope? [Ans Decreases with increase in length]

5. The magnifying power of an artronomical telescope in normal adjustment is 100 and distance between objective and eye lens in 101cm. Find the focal lenght of objective and eye piece.
[Ans *fo* = 100 cm, *fe* = 1 cm.]

SHORT ANSWER QUESTIONS (2 Marks)

1. Give one use of each of the following
(i) UV ray (ii) γ-ray.

2. Represent EM waves propagating along the x-axis in which electric and magnetic fields are along y-axis and z-axis respectively.

3. State the principles of production of EM waves. An EM wave of wavelength λ goes from vacuum to a medium of refractive index n. What will be the frequency of wave in the medium?

4. An EM wave has amplitude of electric field E_0 and amplitude of magnetic field is B_0. The electric field at some instant become $\frac{3}{4}E_0$. What will be magnetic field at this instant? (Wave is travelling in vacuum).

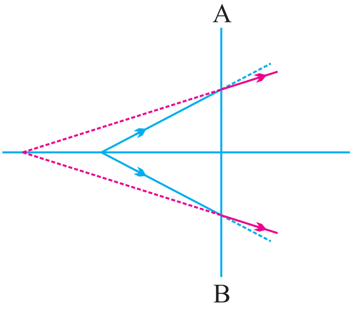
5. State two applications of infrared radiations.

6. State two applications of radio waves.

7. State two applications of x-rays.

8. Show that the average energy density of the electric field $\vec{E}$ equals the average energy density of the magnetics fields $\vec{B}$?

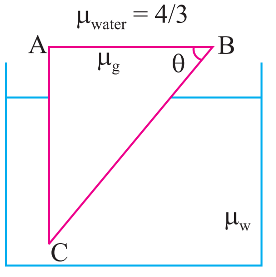
9. The line AB in the ray diagram represents a lens. State whether the lens is convex or concave.



10. Use mirror equation to deduce that an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

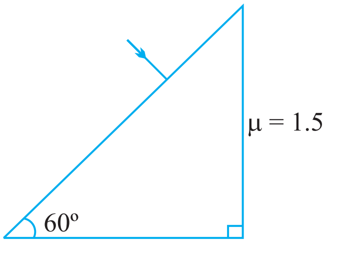
11. Calculate the value of θ, for which light incident normally on face AB grazes along the face BC.

$\mu_{glass} = 3/2$ and $\mu_{water} = 4/3$



12. Name any two characteristics of light which do not change on polarisation.

13. Complete the path of light with correct value of angle of emergence.

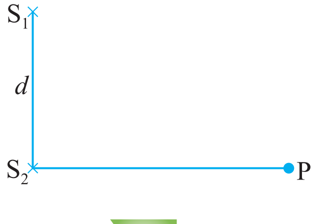


14. Define diffraction. What should be the order of the size of the aperture to observe diffraction.

15. Show that maximum intensity in interference pattern is four times the intensity due to each slit if amplitude of light emerging from slits is same.

16. Two poles-one 4 m high and the other is 4.5 m high are situated at distance 40 m and 50 m respectively from an eye. Which pole will appear taller?

17. S_1 and S_2 are two sources of light separated by a distance d. A detector can move along S_2P perpendicular to S_1S_2. What should be the minimum and maximum path difference at the detector?



18. If a jogger runs with constant speed towards a vehicle, how fast does the image of the jogger appear to move in the rear view mirror when

(i) the vehicle is stationery

(ii) the vehicle is moving with constant speed towards jogger.

Ans. The speed of the image of the jogger appears to increase substantially though jogger is moving with constant speed.

Similar phenomenon is observed when vehicle is in motion.

19. Define Brewstre's angle. Show that the Brewster's angle i_B for a given pair of media is related to critical angle i_c through the relation

$$i_c = \sin^{-1}(\cot i_B)$$

20. If angle between the pass axes of polariser & analyser is 45º. Write the ratio of the intersities of original light and transmitted light after passing through the analyser.

21. When does (i) a plane mirror and (ii) a convex mirror produce real image of objects.

Ans. Plane and convex mirror produce real image when the object is virtual that is rays convering to a point behind the mirror are reflected to a point on a screen.

22. A virtual image cannot be caught on a screen. Then how do we see it?

Ans. The image is virtual when reflected or refracted rays divergent, these are converged on to the retina by convex lens of eye, as the virtual image serves as the object.

23. Draw a diagram to show the advance sunrise and delayed sunset due to atmospheric refraction.

24. Define critical angle for total internal reflection. Obtain an expression for refractive index of the medium in terms of critical angle.

25. The image of a small bulb fixed on the wall of a room is to be obtained on the opposite wall 's' m away by means of a large convex lens. What is the maximum possible focal length of the lens required.

Ans. For fixed distance 's' between object and screen, for the lens equation to give real solution for $u = v = 2f$, 'f' should not be greater than $4f = s$.

$\therefore$ $$f = s/4$$

26. The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virtual image produced by a magnifying glass. In what sense then does magnifying glass produce angular magnification?

Ans. The absolute image size is bigger than object size, the magnifier helps in bringing the object closer to the eye and hence it has larger angular size than the same object at 25 cm, thus angular magnification is achieved.

27. Obtain relation between focal length and radius of curvature, of (i) concave mirror (ii) convex mirror using proper ray diagram.

28. Two independent light sources cannot act as coherent sources. Why?

29. How is a wave front different from a ray? Draw the geometrical shape of the wavefronts when.

(i) light diverges from a point source,

(ii) light emerges out of convex lens when a point source is placed at its focus.

30. What two main changes in diffraction pattern of single slit will you observe when the monochromatic source of light is replaced by a source of white light.

31. You are provided with four convex lenses of focal length 1cm, 3cm, 10 cm and 100 cm. Which two would you prefer for a microscope and which two for a telescope.

32. Give reasons for the following

(i) Sun looks reddish at sunset

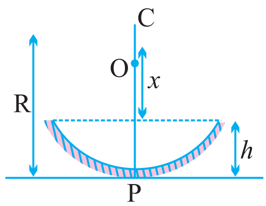
(ii) clouds are generally white

33. Using Huygens Principle draw ray diagram for the following :

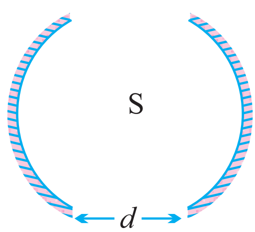
(i) Refraction of a plane wave front incident on a rarer medium

(ii) Refraction of a plane wave front incident on a denser medium.

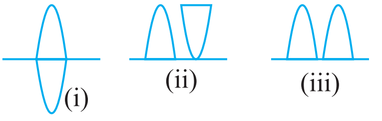
34. Water (refractive index μ) is poured into a concave mirror of radius of curvature 'R' up to a height *h* as shown in figure. What should be the value of *x* so that the image of object 'O' is formed on itself?



35. A point source S is placed midway between two concave mirrors having equal focal length *f* as shown in Figure. Find the value of *d* for which only one image is formed.

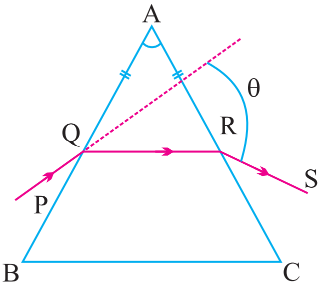


36. A thin double convex lens of focal length f is broken into two equal halves at the axis. The two halves are combined as shown in figure. What is the focal length of combination in (ii) and (iii).



37. How much water should be filled in a container 21 cm in height, so that it appears half filled when viewed from the top of the container. $({}_{a}\mu_{\omega} = 4/3.)$

38. A ray PQ incident on the refracting face BA is refracted in the prism BAC as shown in figure and emerges from the other refracting face AC as RS such that AQ = AR. If the angle, of prism A = 60° and μ of material of prism is $\sqrt{3}$ then find angle θ.



SHORT ANSWER QUESTIONS (3 Marks)

1. Name EM radiations used
- (i) in the treatment of cancer.
- (ii) For detecting flow in pipes carrying oil.
- (iii) In sterilizing surgical instruments.

2. How would you experimentally show that EM waves are transverse in nature ?

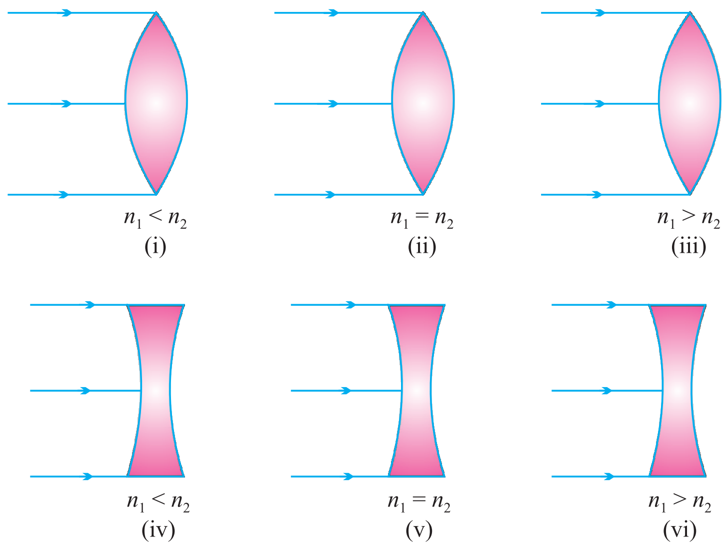
3. List any three properties of EM waves.

4. Find the wavelength of electromagnetic waves of frequency 5×10^{19} Hz in free space. Give its two applications.

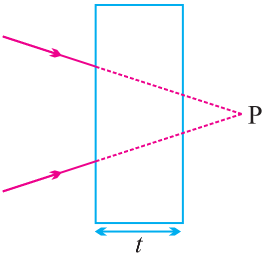
5. Using mirror formula show that virtual image produced by a convex mirror is always smaller in size and is located between the focus and the pole.

6. Obtain the formula for combined focal length of two thin lenses in contact, taking one divergent and the other convergent.

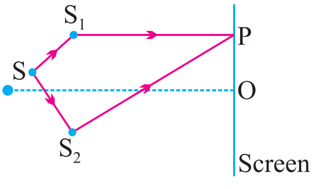
7. Derive Snell's law on the basis of Huygen's wave theory.
8. A microscope is focussed on a dot at the bottom of the beaker. Some oil is poured into the beaker to a height of '*b*' cm and it is found that microscope has to raise through vertical distance of '*a*' cm to bring the dot again into focus. Express refractive index of oil is terms of *a* and *b*.
9. Define total internal reflection. State its two conditions. With a ray diagram show how does optical fibres transmit light.
10. A plane wave front is incident on (i) a prism (ii) A convex lens (iii) a concave mirror. Draw the emergent wavefront in each case.
11. Explain with reason, how the resolving power of a compound microscope will change when (i) frequency of the incident light on the objective lens is increased, (ii) focal length of the objective lens is increased, (iii) aperture of objective lens is increased.
12. Derive Mirror formula for a concave mirror forming real Image.
13. Two narrow slits are illuminated by a single monochromatic sources.
    (a) Draw the intensity pattern and name the phenomenon
    (b) One of the slits is now completely covered. Draw the intensity pattern now obtained.
14. Explain (i) sparkling of diamond (ii) use of optical fibre in communication.
15. Using appropriate ray diagram obtain relation for refractive index of water in terms of real and apparent depth.
16. Complete the ray diagram in the following figure where, n_1 is refractive index of medium and n_2 is refractive index of material of lens.



17. A converging beam of light is intercepted by a slab of thickness t and refractive index μ, By what distance will the convergence point be shiffted? Illustrate the answer.



18. In double slit experiment SS_2 is greater than SS_1 by 0.25λ. Calculate the path difference between two interfering beam from S_1 and S_2 for minima and maxima on the point P as shown in figure.



LONG ANSWER QUESTIONS (5 MARKS)

1. With the help of ray diagram explain the phenomenon of total internal reflection. Obtain the relation between critical angle and refractive indices of two media. Draw ray diagram to show how right angled isosceles prism can be used to :
   (i) Deviate the ray through 180°.
   (ii) Deviate the ray through 90°.
   (iii) Invert the ray.
2. Draw a labelled ray diagram of a compound microscope and explain its working. Derive an expression for its magnifying power if final image is formed at leat distance of distant vision.
3. Diagrammatically show the phenomenon of refraction through a prism. Define angle of deviation in this case. Hence for a small angle of incidence derive the relation $\delta = (\mu - 1) A$.
4. Explain the following :
   (a) Sometimes distant radio stations can be heard while nearby stations are not heard.
   (b) If one of the slits in Youngs Double Slit Experiment is covered, what change would occur in the intensity of light at the centre of the screen?

5. Define diffraction. Deduce an expression for fringe width of the central maxima of the diffraction pattern, produced by single slit illuminated with monochromatic light source.
6. What is polarisation? How can we detect polarised light? State Brewster's Law and deduce the expression for polarising angle.
7. Derive lens maker formula for a thin converging lens.
8. Derive lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for

   (a) a convex lens, (b) a concave lens.
9. Describe an astronomical telescope and derive an expression for its magnifying power using a labelled ray diagram. When final image is formed at least distance of distinct vision.
10. Draw a graph to show the angle of deviation with the angle of incidence i for a monochromatic ray of light passing through a prism of refracting angle A. Deduce the relation

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

11. State the condition under which the phenomenon of diffraction of light takes place. Also draw the intensity pattern with angular position.
12. How will the interference pattern in Youngs double slit experiment change, when

    (i) distance between the slits S_1 and S_2 are reduced and

    (ii) the entire set up is immersed in water ?

    Justify your answer in each case.

Ans. Fringe width $\beta = \frac{\lambda D}{d}$

(i) If d decreases, fringe width $\beta \propto \frac{1}{d}$ increases

(ii) When apparatus is immersed in water, wavelength reduces to $\frac{\lambda}{\mu_\omega}$. Therefore, fringe width $\beta \alpha \lambda$ decreases.

NUMERICALS

1. The refractive index of medium is 1.5. A beam of light of wavelength 6000 A° enters in the medium from air. Find wavelength and frequency of light in the medium.

2. An EM wave is travelling in vacuum. Amplitude of the electric field vector is 5×10^4 V/m. Calculate amplitude of magnetic field vector.

3. Suppose the electric field amplitude of an em wave is $E_0 = 120$ NC^{-1} and that its frequency is $v = 50.0$ MHz.

(a) Determine B_0, ω, κ and λ,

(b) Find expressions for E and B.

4. A radio can tune into any station of frequency band 7.5 MHz to 10 MHz. Find the corresponding wave length range.

5. The amplitude of the magnetic field vector of an electromagnetic wave travelling in vacuum is 2.4mT. Frequency of the wave is 16 MHz. Find :

(i) Amplitude of electric field vector and

(ii) Wavelength of the wave.

6. An EM wave travelling through a medium has electric field vector. $E_y = 4 \times 10^5 \cos(3.14 \times 10^8\, t - 1.57\, x)$ N/C. Here x is in m and t in s. Then find :

(i) Wavelength,

(ii) Frequency

(iii) Direction of propagation

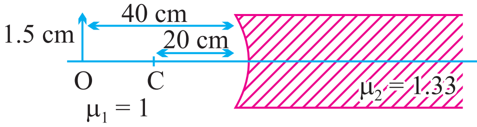
(iv) Speed of wave

(v) Refractive index of medium

(vi) Amplitude of magnetic field vector.

7. An object of length 2.5 cm is placed at a distance of 1.5 f from a concave mirror where f is the focal length of the mirror. The length of object is perpendicular to principal axis. Find the size of image. Is the image erect or inverted? [5 cm, Inverted]

8. Find the size of image formed in the situation shown in figure.



[5 cm, Inverted]

1.6 cm approx.

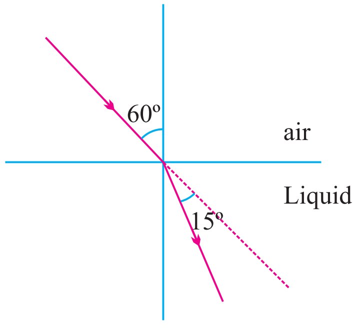
[1.2 cm, approx.]

9. A ray of light passes through an equilateral prism in such a manner that the angle of incidence is equal to angle of emergence and each of these angles is equal to 3/4 of angle of prism. Find angle of deviation.

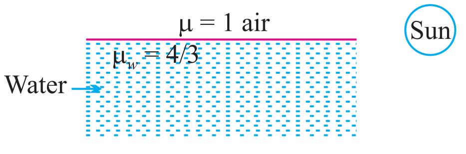
[Ans. : 30°]

10. Critical angle for a certain wavelength of light in glass is 30°. Calculate the polarising angle and the angle of refraction in glass corresponding to this. [$i_p = \tan^{-1} 2$]

11. A light ray passes from air into a liquid as shown in figure. Find refractive index of liquid. [${}^{air}\mu_{Liquid} = \sqrt{3/2}$]



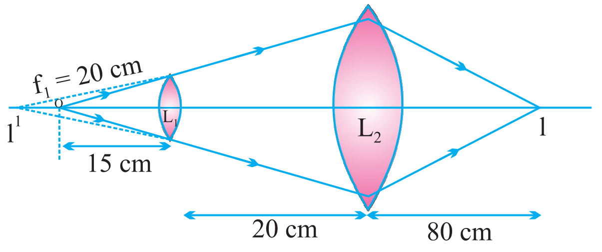
12. At what angle with the water surface does fish in figure see the setting sun ?



[C = $\sin^{-1}$ (0.7518)]

[At critical angle, fish will see the sun.]

13. In the following diagram, find the focal length of lens L_2. [40 cm]



14. Three immiscible liquids of densities $d_1 > d_2 > d_3$ and refractive indices $\mu_1 > \mu_2 > \mu_3$ are put in a beaker. The height of each liquid is $\frac{h}{3}$. A dot is made at the bottom of the beaker. For near normal vision, find the apparent depth of the dot.

Ans. (Hint : the image formed by first medium act as an object for second medium) Let the apparent depth be O_1 for the object seen from

$O_1 = \frac{\mu_2}{\mu_1} \cdot \frac{h}{3}$ image formed by medium 1, O acts as an object for medium 2. It is seen from M_3, the apparent depth is O_2.

Similarly, the image found by medium 2, O_2 act as an object for medium 3

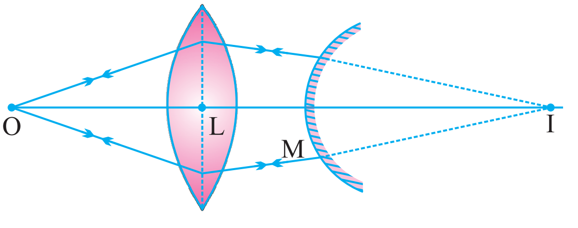
$$O_2 = \frac{\mu_3}{\mu_2}\left(\frac{h}{3} + O_1\right)$$

$$O_3 = \mu_3\left(\frac{h}{3} + O_2\right)$$ putting value of O_2 and O_1

$$O_3 = \frac{h}{3}\left(\frac{1}{\mu_1} + \frac{1}{\mu_2} + \frac{1}{\mu_3}\right)$$

15. A point object O is kept at a distance of 30 cm from a convex lens of power + 4D towards its left. It is observed that when a convex mirror is kept on right side at 50 cm from the lens, the image of object O formed by lens-mirror combination coincides with object itself. Calculate focal length of mirror.

Ans. Image formed by combination coincides with the object itself. It implies that I is the centre of curvature of convex mirror.



For lens

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

$$\frac{1}{25} = \frac{1}{v} + \frac{1}{30}$$

$$v = 150 \text{ cm}$$

$$MI = LI - LM = 150 - 50 = 100 \text{ cm}$$

$$f_m = \frac{MI}{2} = \frac{100}{2} = 50 \text{ cm}$$

16. Using the data given below, state which two of the given lenses will be preferred to construct a (i) telescope (ii) Microscope. Also indicate which is to be used as objective and as eyepiece in each case.

Lenses	Power (p)	Apetune (A)
L_1	6 D	1 cm
L_2	3 D	8 cm
L_3	10 D	1 cm

Ans. For telescope, lens L_2 is chosen as objective as it aperture is largest, L_3 is chosen as eyepiece as its focal length is smaller.

For microscope lens L_3 is chosen as objective because of its small focal length and lens L_1, serve as eye piece because its focal length is not larges.

17. Two thin converging lens of focal lengths 15 cm and 30 cm respectively are held in contact with each other. Calculate power and focal length of the combination.

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

$$= \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

$$F = 10 \text{ cm}$$

$$P = 10D$$

18. An object is placed in front of a concave mirror of focal length 20 cm. The image is formed three times the size of the object. Calculate two possible distances of the object from the mirror.

Ans. $m = \pm 3$

$$m = \frac{-v}{u} = +3 \text{ for virtual image}$$

$$v = -3u$$

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

$$\frac{1}{-34}+\frac{1}{u} = -\frac{1}{20}$$

$$u = -\frac{40}{3}\text{cm}$$

$$m = \frac{-v}{u} = -3 \text{ for real image}$$

$$v = 3u$$

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

$$\frac{1}{3u}+\frac{1}{u} = -\frac{1}{20}$$

$$u = -\frac{80}{3}\text{cm.}$$

1 MARKS QUESTIONS

1. Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.
2. How is the equation for Ampere's circuital law modified in the presence of displacement current?
3. How are electromagnetic waves produced by oscillating charges? What is the source of the energy associated with the em waves?
4. Name the radiation of the electromagnetic spectrum which is used for the following:

   (a) (i) Radar (ii) Eye surgery

   (b) To photograph internal parts of human body

   (c) For taking photographs of the sky during night and foggy conditions

   Give the frequency range in each case.
5. Two polaroids A and B are kept in crossed position. How should a third polaroid C be placed between them so that the intensity of polarised light transmitted by polaroid B reduces to $1/8^{th}$ of the intensity of unpolarised light incident on A. [Hint $I = I_0\cos^2\theta$]

Ans. 45°.

6. In young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ is "K" units. Find the intensity of light at a point where path difference is $\frac{\lambda}{3}$.

$$\text{Phase iff.} = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3} = 120°$$

and $$I = I_0 \cos^2 \frac{\phi}{2} = \frac{K}{4}$$

$$\left[\text{Hint} \quad I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi\right]$$

7. Two nicole polariods are so oriented that the maximum amount of light is transmitted. To what fraction of its maximum value is the intensity of transmitted light reduced when the analyser is rotated through (i) 30° (ii) 60°?

Ans. (i) 75% of max. intensity (ii) 25% of max. intensity

8. In young's double slit experiment, a light of wavelength 630 nm produces an interference pattern where bright fringes are separated by 8.1 mm. Another light produces the interference pattern. Where the bright fringes are separated by 72 mm. Calculate the wavelength of second light.

$$\left[\text{Hint} \quad \beta = \frac{\lambda D}{d}\right]$$

Ans. 560 nm

9. A beam of light consisting of two wavelength 800 nm and 600 nm is used to obtain the interference pattern in young's double slit experiment on a screen placed 1.4 m away. If the separation between two slits in 0.28 mm. Calculate the least distance from the central bright maximum, where the bright fringes of two wavelength coincide.

Ans. $$x = n\lambda_1 \frac{D}{d} = (n+1)\lambda_2 \frac{D}{d}$$

$\therefore$ $$n \times 800 = (n+1)\lambda_2 \frac{D}{d}$$

$\therefore \qquad n = 3$

$$\therefore \qquad x = n\lambda_1 \frac{D}{d} = 3\times 800\times \frac{10^{-9}\times 1.4}{0.28\times 10^{-3}} = 12 \text{ mm}$$

Numericals

1. The focal lengths of objective and eye peace of a microscope are 1.25 cm and 5 cm respectively find the position of the object relative to the objective in order to obtain an angular magnification of 30 in normal adjustment.

Ans. In normal adjustment

$$m_e = \frac{d}{f_e} = \frac{25}{5} = 5$$

$$m = m_0\, m_e$$

$$\therefore \qquad m_0 = \frac{m}{m_e} = \frac{30}{5} = 6$$

and $$m_0 = \frac{V_0}{u_0} = -6$$

$$\therefore \qquad V_0 = -6u_0$$

$$\therefore \qquad \frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

$$\frac{1}{-6u_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

here $\qquad f_0 = 1.25$ cm

$u_0 = -1.46$ cm

2. An small telescope has an objective lens of focal length 150 cm and an eye piece of focal length 5 cm. If his telescope is used to view a 100 m high tower 3 km away find the height of the final image when it find the height of the final image when it is formed 25 cm away from the eye pieces.

Ans. $\tan\alpha = \frac{100}{3000} = \frac{1}{30}$ radian

again $\tan\alpha = \frac{h}{f_0}$

$\therefore$ $\frac{1}{30} = \frac{h}{150}$

$h = 5$ cm

h height of image of tower

$\therefore$ $m_e = \left(1+\frac{\alpha}{f_e}\right) = \left(1+\frac{25}{5}\right) = 6$

and $m_e = \frac{h'}{h}$

$\therefore$ $h' = 5 \times 6 = 30$ cm

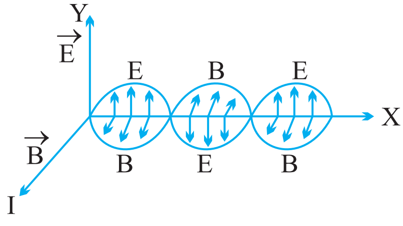
h′ height of final image.

ANSWER OF 2 MARKS QUESTIONS

1. UV ray – In water purifier.

γ ray – In treatment of cancer

2.



3. An accelerated charge produces oscillating electric field in space, which produces an oscillating magnetic field, which in turn, is a source of oscillating electric field and so on. The oscillating electric & magnetic fields produces each other & give rise to e.m. waves.

4. In vacuum $C = \frac{E_0}{B_0}$

If electric field become $\frac{3}{4}E_0$, magnetic field will be $\frac{3}{4}B_0$.

5. (i) In green houses to keep plants warm.

(ii) In reading secret writings on ancient walls.

6. (i) In radio & tele communication systems.

(ii) In radio astronomy.

7. (i) In medical to diagnose fractures in bones.

(ii) In engineering for detecting cracks, flaws & holes in metal parts of a machine.

8.
$$\mu_E = \frac{1}{2}\varepsilon_0 E^2 \quad \& \quad u_B = \frac{1}{2}\frac{B^2}{\mu_0}$$

$$\mu_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 (CB)^2 \qquad \text{As } c = \frac{E}{B}$$

$$= \frac{1}{2}\varepsilon_0 \frac{B^2}{\mu_0\varepsilon_0} \qquad c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

$$= \frac{B^2}{2\mu_0}$$

$$= \mu_B$$

10. For concave mirror

$$f < 0 \quad \text{and} \quad u < 0$$

$$f < u < 0$$

$$\frac{1}{f} > \frac{1}{u} \quad \text{or} \quad \frac{1}{f} - \frac{1}{u} > 0$$

$$\text{or} \quad \frac{1}{v} > 0$$

Virtual image is formed.

Also
$$\frac{1}{v} < \frac{1}{|u|} \quad \text{or} \quad v > |u|$$

$$m = \frac{v}{|u|} > 1$$

magnified image.

11. $\theta = \sin^{-1}(8/9)$

12. Speed and frequency

13. $\sin^{-1}(3/4)$

16. 4 m pole

17. Minimum path difference is zero (when p is at infinity).

Maximum path difference = d.

29. A wavefront is a surface obtained by joining all points vibrating in the same phase.

A ray is a line drawn perpendicular to the wavefront in the direction of propagation of light.

(i) Spherical

(ii) Plane

30. (i) In each diffraction order, the diffracted image of the slit gets dispersed into component colours of white light. As fringe width α λ, $\therefore$ red fringe with higher wavelength is wider than violet fringe with smaller wavelength.

(ii) In higher order spectra, the dispersion is more and it cause overlapping of different colours.

31. f_0 = 1 cm and f_e = 3 cm for Microscope and

f_0 = 100 cm and f_e = 1 cm for a Telescope

33. N.C.E.R.T. Fig. 10.5; Fig. 10.4.

34. Distance of object from p should be equal to radius of curvature.

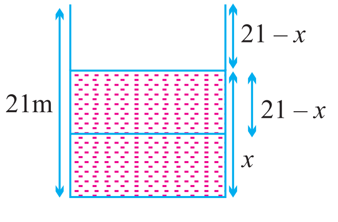
$$R = \mu x + h \Rightarrow \quad x = \frac{R - h}{\mu}$$

35. Distance between mirror will be $2f$ or $4f$.

36. (i) Focal length of combination is infinite,

(ii) $f/2$

37.



$$\frac{\text{Real depth}}{\text{Apparent depth}} = \mu$$

$$\frac{x}{21-x} = \frac{4}{3} \quad \Rightarrow \quad x = 12 \text{ cm}$$

38. This is a case of min. deviation $\theta = 60°$.

ANSWERS OF 3 MARKS QUESTIONS

11. R.P. of a compound Microscope

$$= \frac{2\mu \sin\theta}{\lambda} = 2\mu \sin\theta \frac{v}{c}$$

(i) When frequency v increases, R.P. increases

(ii) R.P. does not change with change in focal length of objective lens.

(iii) When aperture increases, θ increases

$\therefore$ R.P. increases.

17. $x = \left(1 - \frac{1}{\mu}\right)t$

18. Path difference :

$$(SS_2 + S_2P) - (SS_1 + S_1P) = (SS_2 - SS_1) + (SS_2P - S_1P)$$
$$= (0.25\lambda + S_2P - S_1P)$$

For maxima, path difference $= n\lambda$

So, $S_2P - S_1P = n\lambda - 0.25\lambda = (n - 0.25)\lambda$

For minima, path difference $= (2n+1)\frac{\lambda}{2}$

So, $S_2P - S_1P = (2n + 0.5)\ \lambda/2$.