WAVE OPTICS

① A screen is seperated from a double-slit source by 1.2 m, The distance between the two slits is 0.03 mm. The second order bright fringe ($n = 2$) is measured to be 4.5 cm from the centre line.

(a) Determine the wave length of light used,

(b) Calculate the distance between adjacent bright fringes [Ans. (a) 5625 A° (b) 2.25 cm]

② A light source emits lights of two wavelengths in the visible region, given by $\lambda = 430$ nm and $\lambda' = 510$ nm. The source is used in a double-slit interference experiment in which $D = 1.5$ m and $d = 0.025$ mm. Find the seperation between the third order bright fringes corresponding to these wave lengths. [Ans. 1.44 cm]

③ A double slit arrangement produces interference fringes for sodium light ($\lambda = 589$ nm) that are 0.0035 rad apart. For what wavelength would the angular separation be 10 % greater? [Ans 647.9 nm]

④ The yellow component of light from a helium discharge tube ($\lambda = 587.5$ nm) is allowed to fall on a plane containing parallel slits that are 0.2 mm apart.

A screen is located so that the second bright band in in the interference pattern is at a distance equal to 90 slit spacings from the central maximum. what is the distance between the source plane and the screen?

Ans. 0.340 m

(5) Two sources of intensities I and 4 I are used in an interference experiment. Obtain intensities at points where the waves from two sources superimpose with a phase difference of : (a) 0 (b) π/2 (c) π.

Ans (a) 9I (b) 5I (c) I

(6) A Young's double-slit experiment produces interference fringers for sodium light ($\lambda = 5890 Å$) that are $0.20°$ apart. what is the angular fringe separation if the entire arrangement is immersed in water? μ for water is 4/3. Ans. 0.15°

(7) A double slit experiment is performed with sodium light of wavelength 589.3 nm and the interference pattern is observed on a screen 100 cm away. The tenth bright fringe has its centre at a distance of 12 mm from the central maximum, Find the seperation between the slits. Ans. 0.49 mm

(8) The intensity of light coming from one of the slits in a Young's double-slit experiment is double the intensity from the other. Find the ratio of the maximum intensity to the minimum intensity in the interference fringe pattern observed. [Ans. 34]

(9) The width of one of the two slits in a Young's double-slit experiment is double the other. Assuming that the amplitude of light coming from a slit is proportional to the slit width, find the ratio of the maximum to the minimum intensity in the interference pattern [Ans. 9]

(10) A parallel beam of monochromatic light of wavelength 450 nm passes through a long slit of width 0.2 mm. Find the angular divergence in which most of the light is diffracted. [Ans. 4.5×10^{-3} rad]

(11) In a Young's double-slit experiment, the separation between the slits is 2×10^{-3} m whereas the distance of the screen from the slits is 2.5 m. A light of wavelengths in the range of 2000 - 8000 Å is allowed to fall on the slits. Find the wavelengths in the visible region that will be present on the

maximum in the interference pattern obtained on the Screen. If the Wavelength of the incident light were changed to 480 nm, find the shift in the position of the third bright fringe from the Central maximum.

[Ans 1.26 mm, 0.25 mm]

(12) A two slits Young's interference experiment is done with monochromatic light of wavelength 6000Å. The slits are 2mm apart and fringes are observed on a Screen 10 cm away from the slits and it is found that the interference pattern shifts by 5 mm when a transport plate of thickness 0.5 mm is introduced in the path of the one of the slits. what is the refractive index of the transparent plate? [Ans. 1.2]

(13) A linear aperture whose width is 0.002 cm is placed immediately in front of a lens of focal length 60 cm. The aperture is illuminated by a beam of parallel rays whose angle of incidence is Zero and whose wavelength is 5000 Å. what will be the distance between the centre of the first dark band of the diffraction Pattern on a Screen placed 60 cm from the lens?

[Ans 1.5 cm]

(14) Determine the angular separation between central maximum and first order maximum of the diffraction pattern due to a single slit of width 0.25 mm when light of wavelength 5890 Å is incident on it normally.

[Ans. 3.5×10^{-4} rad]

(15) Light of wavelength 5×10^{-7} m is diffracted by an aperture of width 2×10^{-3} m. For what distance travelled by the diffracted beam does the spreading due to diffraction become greater than the width of aperture?

[Ans. 8m]

(16) A double-slit of separation 1.5 mm is illuminated by white light (between 4000 - 8000 Å) on a screen 120 cm away, coloured interference pattern is formed. If a pinhole is made on this screen at a distance 3.0 mm from the central white fringe, what wavelengths will be absent in the transmitted light?

[Ans. 6800 Å, 5800 Å, 5000 Å, 4400 Å, 4000 Å]

(17) In young's double-slit experiment, monochromatic light of wavelength 600 nm illuminates the pair of slits and produces an interference pattern in which two consecutive bright fringes are separated by 10 mm. Another source of monochromatic light produces the

interference pattern in which the two Consecutive bright fringes are Separated by 8 nm. Find the wavelength of light of the second source. What is the effect on the interference fringes if the monochromatic source is replaced by a source of white light?

[Ans. 480 nm; central fringe is completely white, all other fringes are coloured, where β_{red} is maximum and β_{blue} is the least]

(18). On introducing a thin sheet of mica (thickness = 8×10^{-5} cm) in the path of one of the interfering beams in Young's double slit experiment, the central fringe is shifted through a distance equal to the spacing between successive bright fringes. Calculate the refractive index of mica.

[Ans. 1.75]

(19) In a double-slit experiment, fringes are produced using light of wavelength 4800Å. One slit is covered by a thin plate of glass ($\mu = 1.4$) and the other slit by another plate of glass of same thickness (but $\mu = 1.7$). On doing so, the central fringe shifts to the position originally occupied by the fifth bright fringe from the centre. Find the thickness of the plate. [Ans. 8×10^{-4} cm]

(20) (a) In a single-slit diffraction experiment, a slit of width 'd' is illuminated by red light of wavelength 650 nm. For what value of 'd' will?

(i) the first minimum fall at an angle of diffraction of $30°$ and

(ii) the first maximum fall at an angle of $30°$?

(b) Why does the intensity of the secondary maxima become less as compared to that of the central maximum?

Ans (a) (i) 1.3×10^{-6} m (ii) 1.95×10^{-6} m

(b) Central maximum is due to the whole wavefront; Secondary maxima are due to $1/3, 1/5, 1/7 \ldots$ of the whole wavefront]

(21) 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 out the intensity of light at a point where the path difference is $\lambda/3$. [Ans k/4]

screen 10^{-3} m from the central maximum. Also find the wavelength that will be present at that point of screen in the infrared as well as the ultraviolet region

[Ans. 4000 A°, 8000 A°; 2667 A°, 2000 A°]

(12) In Young's double-slit experiment, red light of wavelength 6000 A° is used and the nth bright fringe is obtained at a point P on the screen. keeping the same setting, the source is replaced by green light of 5000 A° and now (n+1) th fringe is obtained at the point P. Calculate the value of n. [Ans. 5]

(13) In a Young's interference experimental arrangement, the yellow light is composed of two wavelengths 5890 A° and 5895 A°. The distance between the two slits is 10^{-3} m and screen is placed 1 m away. Upto what order can fringes be seen on the screen and how far from the centre of the screen does this occur?

[Ans. 589, 0.347 m]

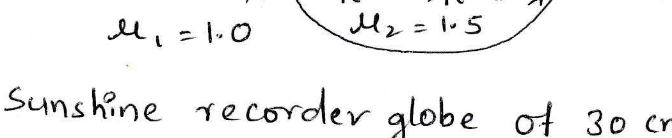
(14) In young's double-slit experiment, the two slits are 2 mm apart and the screen is positioned 140 cm away from the plane of the slits. The slits are illuminated with light of wavelength 600 nm. Find the distance of the third fringe from the central

REFRACTION AT SPHERICAL SURFACES AND LENSES

(1) A small air bubble is entrapped in a sphere with diameter 6 cm and refractive index 1.5. When looked along the diameter, the bubble appears to be 1 cm inside the sphere. Find the true location of the bubble
[Ans 1.3 cm from the refracting surface]

(2) Calculate the focal length of a lens in the form of a sphere of glass of radius 5 cm ($\mu = 1.5$). [Ans. 7.5 cm]

(3) A spherical surface of radius of curvature R separates air ($\mu = 1.0$) from glass ($\mu = 1.5$). The centre of curvature is in the glass. A point object P placed in air is found to have real image Q in the glass. The line PQ cuts the surface at a point O and PO = OQ. Find the distance of object from the spherical surface. [Ans. 5R]



(4) A Sunshine recorder globe of 30 cm diameter is made of glass of refractive index $\mu = 1.5$. A ray enters the globe parallel to the axis. Find the position from

the centre of the sphere where the ray crosses the axis.

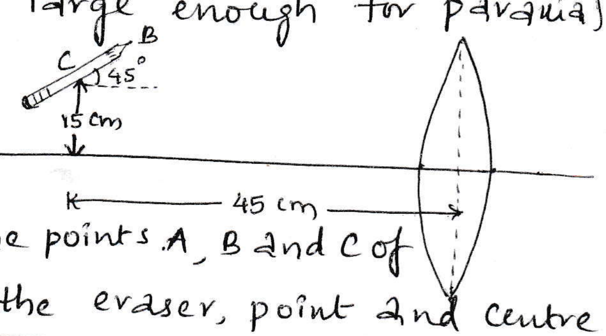
[Ans . 22.5 cm]

5) An empty spherical flask of diameter 15 cm is placed in water of refractive index 4/3. A parallel beam of light strikes the flask. Where will it get focused when observed from within the flask? [Ans. 22.5 cm]

6) The distance between an object and screen is D. A convex lens of focal length f is placed between them. If m be the magnification of the image, then show that

$$f = \frac{mD}{(m+1)^2}$$

7) A 16 cm long pencil is placed at a 45° angle, with its centre 15 cm above the optic axis and 45 cm from a lens with a 20 cm focal length as shown in fig (Note that the figure is not drawn to scale). Assume that the diameter of the lens is large enough for paraxial approximation to be valid.



a) Where is the image of the pencil? (Give locations of the images of the points A, B and C of the object, which are located at the eraser, point and centre of the pencil, respectively.) [Ans. (a) 33 cm, 40.7 cm, 36 cm (b) 17.1 cm]

b) What is the length of the image (that is, the distance between the images of points A and B)?

c) Show the orientation of the image in a sketch.

(8) A telescope objective is made by Cementing two lenses, the cemented surfaces having the same radius of Curvature. The Combination is plano - convex and has Power equal to 1 dioptre. Calculate the radii of curvatu -res of the component lenses. Given that refractive index of crown glass is 1.50 and that of flint glass is 1.60 The dispersive powers of crown and flint glasses are 0.02 and 0.03 respectively. The plano - Concave lens is of flint glass. [Ans. 30 cm for plano - Concave lens and +30 cm and -37.5 cm for the convex lens].

(9) If the local lengths of a convex lens are 25 cm and 24 cm for red and violet rays respectively, calculate the chromatic oberration and the dispersive power of the material of the lens [Ans. 1 cm, 0.0408]

(10) A double convex lens made of crown glass has radii of curvatures 10 cm and 20 cm respectively. Calculate the chromatic aberration. Given that $\mu_v = 1.524$ and $\mu_r = 1.516$. [Ans. 0197 cm]

(11) A beam of white light is incident on a thin biconvex lens in a direction parallel to its axis. If the refractive indices of the lens are 1.514 and 1.524 for red and violet lights respectively and if the radii of curvatures of its faces are 30 cm and 20 cm, calculate

the separation of the foci for red and violet lights.

[Ans. 0.4454 cm]

(12) A compound achromatic lens of focal length 40 cm is to be made from two different glasses. Find the focal lengths of the component lenses if the dispersive power of crown glass is 0.21 and that of flint glass is 0.46.

[Ans. +21.74 cm, −47.62 cm]

(13) An achromatic converging combination of focal length 50 cm is formed with a convex lens of crown glass and a concave lens ~~with~~ of flint glass placed in contact with each other. If dispersive power of crown glass is 0.03 and that of flint glass is 0.05, calculate their focal lengths. [Ans 20 cm, −33.3 cm]

(14) How will you correct the chromatic aberration of a plano-convex crown glass lens of 30 cm mean focal length, the following data being given. Refractive indices for red and blue light respectively are 1.52 and 1.54 for crown glass and 1.63 and 1.66 for flint glass? Various lenses of these materials are given with any desired focal length and radii of curvatures [Ans. A concave lens of flint glass of focal length 37 cm and radii of curvatures 15.9 cm and 47.7 cm]

(15) The dispersive powers of crown and flint glasses are 0.015 and 0.030 respectively. Calculate the focal lengths of lenses (made of crown and flint glasses) which form an achromatic doublet of focal length 80 cm, when placed in contact. [Ans. Crown glasses lens :- 40 cm ; flint glass lens :- 80 cm]

(16) Two lenses, one of flint glass and the other of crown glass, are combined to make an achromatic diverging lens of focal length 200 cm. If the ratio of dispersive powers of flint and crown glasses be 3/2, calculate the focal lengths of both the lenses and indicate which of them is converging. [Ans. Crown glass lens :- 66.66 cm ; flint glass lens : 100 cm]

(17) An achromatic combination of a convex lens of crown glass and a concave lens of flint glass is formed. If its power is +5 diopters, calculate the focal lengths of the two lenses. Dispersive power of crown glass is 0.015 and that of flint glass is 0.030.

[Ans + 10 cm ; - 20 cm]

(18) Given the dispersive powers of crown glass and flint glass 0.03 and 0.04 respectively. Find the focal length of the components of an achromatic lens. The combination is of focal length 60 cm. [Ans 15 cm ; -20 cm]

(19) A telescope objective is made by cementing two lenses so as to make an achromatic combination. The cemented surfaces have the same radii of curvatures. The combination is plano-convex lens of focal length 60 cm. Calculate the radii of curvatures of component lenses. Given that mean refractive indices of crown and flint glasses are 1.5 and 1.6 respectively and their dispersive powers are 0.02 and 0.04 respectively. Plano-concave lens is made of flint glass and convex lens of crown glass. [Ans. 25.71 cm; 36 cm]

OPTICAL INSTRUMENTS

(1) The desired overall magnification of a compound microscope is 140 x. The objective alone produces a lateral magnification of 12 x. Determine the required focal length of the eyepiece. (Assume that the final image will be 25 cm from the eye) [Ans. 2.34 cm]

(2) A compound microscope is used to enlarge an object kept at a distance of 0.03 m from its objective which consists of several convex lenses and has focal length 0.02 m. If a lens of focal length 0.1 m is removed from the objective, find out the distance by which the eyepiece of the microscope must be moved to refocus the image. [Ans 9 cm].

(3) A model of a compound microscope is made up of two converging lenses of 3 cm and 9 cm focal lengths at a fixed seperation of 24 cm. Where must the object be placed so that the final image may be at infinity? What will be the magnifying power if the microscope thus arranged is used by a person whose nearest distance of distinct vision is 25 cm? State what is the best position for the observer's eye and explain why. [Ans 3.75 cm, 11.1, eye-ring]

(4) An astronomical telescope has two lenses of powers 10D and 1D. (a) State the reason, which lens is preferred as objective and eyepiece. (b) Calculate the magnifying power of the telescope if the final image is formed at near point. (c) How do the light gathering power and resolving power of a telescope change if the aperture of the objective lens is doubled?

[Ans. (a) objective: 1D eyepiece: 10D (b) 14 (c) light gathering power increases 4 times and resolving power is doubled]

(5) A telescope has an objective of focal length 50 cm & an eyepiece of focal length 5 cm. The least distance of distinct vision is 25 cm. The telescope is focussed for

distinct vision on a scale 200 cm away from the object.

Calculate : (a) Seperation between the objective and eyepiece and (b) the magnification produced [Ans (a) 70.8 cm (b) -2]

(6) A telescope has an objective of focal length 30 cm and an eyepiece of focal length 3.0 cm. It is focussed on a scale distant 2.0 m. for seeing with relaxed eye, Calculate the separation between the objective and the eyepiece. [Ans 38.3 cm]

(7) A telescope has a focal length of 100 cm. when the final image is formed at the least distance of distinct vision, the distance between the lenses is 105 cm. Calculate the focal length of the eyepiece and the magnifying power of the telescope. [Ans. 6.25 cm, 20]

(8) A refracting telescope has an objective of focal length 1 m and an eyepiece of focal length 20 cm. The final image of the sun is 10 m in diameter and is formed at a distance of 24 cm from the eyepiece. what angle does the sun subtend at the objective?

[Ans. (1/22) rad]

REFRACTION At Plane Surfaces

① A beam of light of wavelength 550 nm is incident on a slab of transparent material. The incident beam makes an angle of 40° with the normal, and the refracted beam makes an angle of 26° with the normal.

(a) Find the index of refraction of the material.

(b) What is the wavelength of light in the material?

[Ans. (a) 1.46, (b) 377 cm]

② A ray of light falls on a transport glass plate of refractive index 1.62 (w.r.t. air). If the reflected and refracted rays are mutually perpendicular, what is the angle of incidence? [Ans. 58.3°]

③ A fish rising vertically at the rate of 3 m/s observes a kingfisher above the water, diving vertically towards is at the rate of 9 m/s. The refractive index of water is 4/3. Calculate the actual velocity of the kingfisher. [Ans. 4.5 m/s]

④ Calculate the critical angle for fused quartz for which the index of refractive is 1.458 at a wavelength of 580 nm. [Ans. 43.3°]

(5) A light ray initially in water enters a transport substance at an angle of incidence of 37° and the transmitted ray is refracted at an angle of 25°. Calculate the speed of light in the transparent material. [Ans. 1.58×10^8 m/s]

(6) An object is placed 21 cm is front of a concave mirror of radius of curvature 40 cm. A glass slab of thickness 3 cm and refractive index 1.5 is then placed close to the mirror in the space between the object and the mirror. Find the position of the final image formed. [Ans. 4.93 cm]

(7) Light of wavelength λ_0 in vaccum has a wavelength of 438 nm in water and a wavelength of 390 nm in benzene what is the index of refraction of water relative to benzene at the wavelength λ_0? [Ans. 0.890]

(8) A ray of light is incident at an angle of 60° on one face of a 30° prism. The emergent ray makes an angle of 30° with the incident ray. show that the emergent ray is normal to the surface from which it emerges. Calculate the refractive index of the material of the prism. [Ans. $\sqrt{3}$]

(9) One face of a rectangular glass slab of thickness 6 cm is silvered. An object held 8 cm in front of its front face forms an image 10 cm behind the silvered face. Find the refractive index of glass? [Ans. 1.5]

(10) A direct vision prism spectroscope is made of two prisms, one of flint glass and other of crown glass. The flint glass prism has an angle of 10°, and the mean refractive index of 1.650. What must be the angle of crown glass prism if its mean refractive index is 1.5237? Given that dispersive power of flint and crown glasses are 0.0296 and 0.0175 respectively. Find the angular separation of red and blue light on emergence. [Ans. 12.4°, 0.0786°]

(11) A ray of light passes through an equilateral glass prism such that the angle of incidence is equal to the angle of emergence. If the angle of emergence is (3/4) times the angle of prism, calculate the refractive index of the glass prism.

[Ans. $\sqrt{2}$]

(12) Show that the angle of minimum deviation produced by a thin prism is reduced to one-fourth with respect to air when it is immersed in water. Given ${}^{a}\mu_{g} = \frac{3}{2}$ and ${}^{a}\mu_{w} = \frac{4}{3}$.

(13) A ray of light passes through an equilateral prism ($\mu = 1.5$) such that the angle of incidence is equal to the angle of emergence and the latter is equal to $(3/4)$th of angle of prism. Calculate the angle of deviation [Ans. 30°]

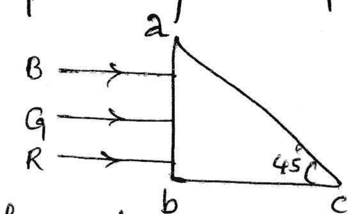
(14) Calculate the limiting angle of a glass prism of refractive index 1.5 for no emergent ray when it is immersed in water (${}^{a}\mu_{w} = 4/3$). [Ans. $2\sin^{-1}(8/9)$]

(15) A glass prism of refracting angle 60° and refractive index 1.5 is completely immersed in water of refractive index 1.33. Calculate the angle of minimum deviation of the prism in this situation. ($\sin^{-1} 0.56 = 34.3^\circ$) [Ans 8.6°]

(16) (a) Find the lateral displacement of a light ray incident at an angle of 45° on a glass slab ($\mu = 1.5$) of 2.0 cm thickness.

(b) If $\mu = 1.6$, would lateral displacement be the same, larger, (or) smaller? Explain your answer conceptually and the calculate the actual value to verify your reasoning. [Ans. (a) 0.66 cm (b) 0.72 cm]

(17) Three light rays: red (R), green (G) and blue (B) are incident on a right angled prism 'abc' at the face 'ab', as shown in fig. 13.45. The refractive indices of the material of the prism for red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. Out of the three, which colour ray will emerge out of the face 'ac'? Justify the answer. Trace the paths of these rays after they pass through the face 'ab'. [Ans. Red colour ray]



(18) One face of a prism of refractive index 1.5 and angle 75° is covered with a liquid of refractive index $(3\sqrt{2})/4$. What should be the angle of incidence of light on the clear face of the prism for which light is just totally reflected at the liquid covered face? [Ans. $\sin^{-1}(3/4)$]

(19) A ray of light, incident on an equilateral glass prism ($\mu_g = \sqrt{3}$) moves parallel to the base of the prism inside it. Find the angle of incidence for this ray [Ans. 60°]

REFLECTION AT PLANE AND SPHERICAL SURFACES

① A Convex mirror produces a magnification of 1/2 when an object is placed at a distance of 60 cm from it. Where should the object be placed so that the size of the image becomes 1/3 of the object?
[Ans. 120 cm]

② An object is placed in front of a Concave mirror of focal length 20 cm. The image formed is three times the size of the object. Calculate two possible distances of the object from the mirror. [Ans. − 80/3 cm, −40/3 cm]

③ An object is placed at 40 cm from a Concave mirror of focal length 15 cm. If the object is displaced 20 cm towards the mirror, what would be the displacement of the image? [Ans. 36 cm away from mirror]

④ An object is placed at a distance of 36 cm from a Convex mirror. A plane mirror is placed in between so that the two virtual images coincide. If the plane mirror is at a distance of 24 cm from the object, find the radius of Curvature of Convex mirror.
[Ans. 36 cm].

(5) Find the number of images that will be formed of an object placed between two mirrors inclined at an angle of 45°. [Ans. 7].

(6) Find the angular deviation of a light ray incident at an angle 30° (with the normal) to a plane mirror.
[Ans. 120°]

(7) A 12 m tall tree is to be photographed with a pin-hole camera. It is situated 15 m away from the pin-hole. How far should the screen be placed from the pin-hole to obtain a 12 cm tall image of the three?
[Ans. 15 cm]

(8) Size of an object P is four times that of Q. It is required that the sizes of the images of P and Q, placed one after the other from a concave mirror of radius of curvature 20 cm, should be equal. To achieve this, if the distance of P from the mirror is 50 cm, what must be the distance of Q? [Ans. −20 cm]