Oscillation and waves – Optics

1991 A/L - 5 (b)

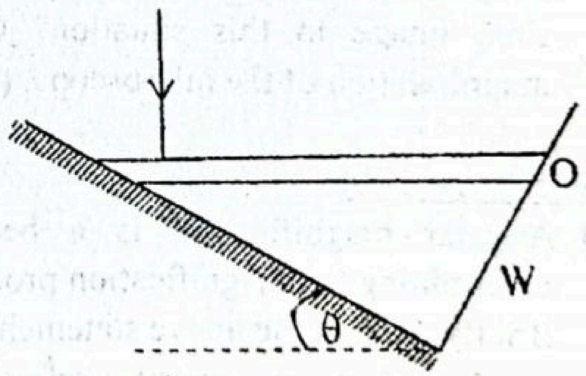
1) A compound microscope in normal adjustment is used to view a point object situated off the axis. Draw the paths of two light rays from the object to the eye through the microscope. Define the magnifying power of a microscope and explain why a compound microscope is usually employed rather than a single lens, when a large magnifying power is required.

The desired overall magnifying power of a compound microscope is 140. The objective itself has a magnifying power of 12. Find the required focal length of the eye piece assuming that the final image will be formed 25 cm from the eye. Derive any formula you may use.

In a certain experiment it is necessary to place a cross-wire in the compound microscope. Show on a diagram where this would be located. Assume that the final image is formed at infinity in this case.

1993 A/L - 5 (a)

2) State the conditions necessary for total internal reflection of light to occur. Describe a method of determining the refractive index of the material of a glass prism using the critical angle method with pins.

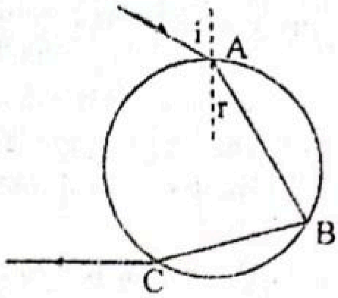


A layer of clear oil (O) is contained over some water (W) in a wide rectangular dish tilted at an angle θ. The bottom of this dish is silvered like a plane mirror a ray of monochromatic light is incident on the surface of oil normal to it. If the refractive indices of water and oil are $^4/_3$ and $^7/_5$ respectively determine the maximum value of θ for which light after traveling through the liquids emerges from the oil-air interface.

1994 A/L - 5

3) a) Why does the refractive index vary from medium to medium?

As shown in the figure a monochromatic ray of light in air is incident on the surface of a spherical water drop at A, with an angle of incidence i. The ray is refracted into the water with a refractive angle r. Reaching the opposite side of the drop at B, the ray is partly reflected back and emerges into air at C.



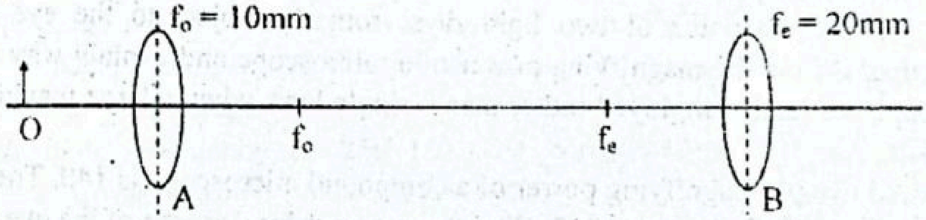
i) What is the value of the angle of emergence?

ii) Derive an expression for the total deviation of the ray in terms of i and r

iii) If I = 30^0 , and the ray is fully deviated by an angle of 156^0 calculate the refractive index of water for the given colour.

iv) Can the ray suffer total internal reflection at the opposite side for some values of i? Justify your answer.

(b) The diagram shows two converging lenses arranged as a compound microscope



The focal length of the objective lens, A is 10 mm and that of the eye piece lens, B is 20 mm, If the final image of an object placed at O, 12 mm from the objective lens is formed at infinity, trace the paths of two rays coming from the head of the object through the microscope to the eye. Calculate the angular magnification (magnifying power) of the microscope

The separation of the lenses is changed keeping the object distance fixed until the angular magnification of the microscope attains its maximum value. What is the position of the final image in this situation? Calculate the new lens separation and the angular magnification of the microscope. (The least distance of distinct vision is 25 cm)

1995 A/L – 5 (b)

4) Angular magnification is a better measure compared to linear magnification in determining the magnification produced by an optical instrument.

Briefly explain the above statement.

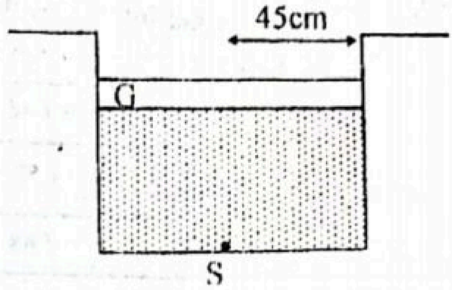
i) A student constructed a refracting telescope using a cardboard tube and two convex lenses of focal length 100 cm and 20 cm. He observed the image of a distant building with the telescope in normal adjustment. Calculate the magnifying power of the telescope. Derive any formula that you may use.

ii) Later he has converted the instrument into a terrestrial telescope in normal adjustment by placing another convex lens of focal length 8 cm between the objective and eye piece while keeping the distance between the objective and the eye piece as short as possible.

a) Why is it convenient to use the arrangement mentioned in (ii) over the one given in (i) to view the distant building?

1996 A/L - 5

5) (a) Figure shows a vertical cross section of a shallow circular pond covered with a thick glass plate (G) of thickness 4 cm and refractive index 3/2. The pond contains water upto the lower surface of the glass plate, and a point source of light S is placed at the bottom of the pond as shown. Depth of water in the pond is 30 cm and the refractive index of water is 4/3.



i) A person when looking at the pond from above sees a circular patch of light. Explain briefly how a circular patch of light is formed.

ii) Using only the standard laws of refraction and geometry calculate the radius of the circular light patch seen on the glass plate.

iii) What will happen to the diameter of the circular patch of light when another layer of water is placed on the glass plate? Briefly explain your answer.

iv) If the radius of the pond is 45 cm calculate the minimum thickness of a water layer needed in (iii) to make sure that the light patch covers its entire top surface.

(b) Write down the main advantage of viewing an object with both eyes.

A certain far sighted person cannot see objects closer than 275 cm from his eyes clearly.

(i) What type of spectacle lens will bring objects situated at 25 cm from his eyes into focus? Find the focal length of these lenses.

(ii) If the distance between the eye lens and the retina is 2.5 cm what is the focal length of the eye lens when viewing the object mentioned in (i) with the spectacles on.

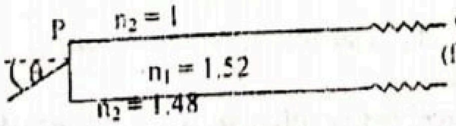
(iii) Later, the person decides to remove his eye lenses and replace them with artificial lenses. For proper vision of distant objects what should be the focal length of the implanted artificial lenses?

(iv) Does he have to wear spectacles for normal reading even after the above mentioned implantation? Explain your answer.

(v) If the answer is 'yes' to part (iv) above, what type of spectacle lens does he have to wear, for a reading distance of 30 cm? find the focal length of these lenses.

1997 A/L -3

6) State the necessary conditions that has to be satisfied in order for a ray of light to undergo total internal reflection.



(figure (1))

i) A ray of monochromatic light traveling in air enters a long solid cylindrical fibre made of plastic material of refractive index n_1 = 1.52 as shown in the figure (1). Calculate the critical angle for plastic – air interface. Hence show that the ray undergoes total internal reflection at the surface PQ for any angle of incidence θ for a ray which would undergo total internal reflection at the interface PQ.

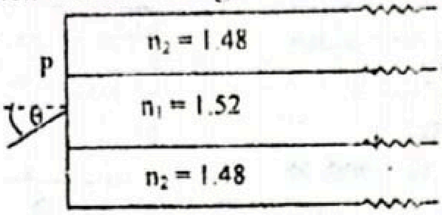


figure (2)

ii) Now the above fiber is completely surrounded with a different plastic material of refractive index $n_2 = 1.48$, as shown is figure (2). Determine the maximum value of angle θ for a ray which would undergo total internal reflection at the interface PQ

iii) Show that a ray incident with $\theta = 80^0$ will not emerge into the air.

2000 A/L -2

07) The near point of a far-sighted person is at 100 cm and that for a normal person is at 25cm

i) Sketch two separate ray diagrams. one for the defective eye, and other for a normal eye to illustrate where the image of an object which is at a distance of 25 cm. is focused by the eye lenses.

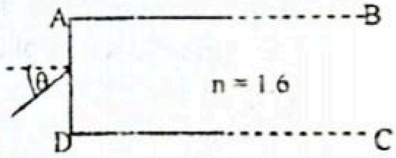
ii) What is the focal length and the type of the lens of the eye glass that the person should wear in order to correct his near point to 25cm? State clearly the sign convention you used.

iii) Considering that the lens of the eye glass and the eye lens are in contact, calculate the focal length of the eye lens when an object at a distance of 25 cm is focused. The distance to the retina from the eye lens is 2.5 cm.

iv) When an object at infinity is focused on the retina by the eye without the eye glass. What is the power of the eye lens?

2002 A/L -2

08) A monochromatic ray of light is falling with an angle of incidence θ on long glass block ABCD of refractive index n = 1.6 placed in air as shown in the figure. Consider only the rays falling on the surface AB after the refraction at the surface AD in answering following questions. (Disregard θ = 0 situation)



i) Find the critical angle for the glass.

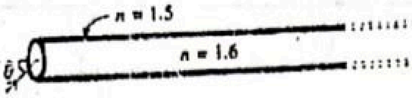
ii) Show that the ray must undergo total internal reflection at the surface AB for all possible values of θ.

iii) When θ = 30° calculate the angle of refraction at the surface AD, and the angle of incidence at the surface AB.

iv) If the space above the surface AB is filled with a transparent material of refractive index 1.7, then draw the ray diagram after calculating the relevant angles for θ = 30°.

v) (a) If the space above the surface AB is filled with a transparent material of refractive index 1.5, find the maximum value of angle θ (i.e. θ_m), that the ray could undergo total internal reflection at AB. What happens if θ is greater than θ_m?

(b)



An optical fiber is made as shown in the figure. A monochromatic ray of light enters the fiber from air at an angle θ which is slightly less than θ_m. Draw the path of the ray in the fiber.

2003 A/L -2

9) The angular magnification (m) of a telescope is given by $m = \frac{\alpha'}{\alpha}$. Identify α' and α.

With a suitable diagram / diagrams, show that a higher angular magnification will produce a larger image on the eye.
An astronomical telescope is made with an objective of focal length 100 cm and air eyepiece of focal length 5cm.

i) Draw a ray diagram for the telescope when it is in normal adjustment. Clearly label the objective and the eyepiece.
ii) Use the ray diagram drawn in (i) to calculate the angular magnification of the telescope
iii) The telescope is used to observe the moon. Its eyepiece was adjusted to form the final image at the near point of the eye. The moon subtends an angle 0.25^0 at the unaided eye. You can assume that the near point of the eye is at a distance of 25 cm and the distance between the eye and the eyepiece is negligible. (You may use $1° = 0.018$ radians)
iv) The objective of the telescope in the above adjustment has to be moved by 10 cm in order to focus an object at a closer distance. Find the distance to the object from the objective of the telescope.

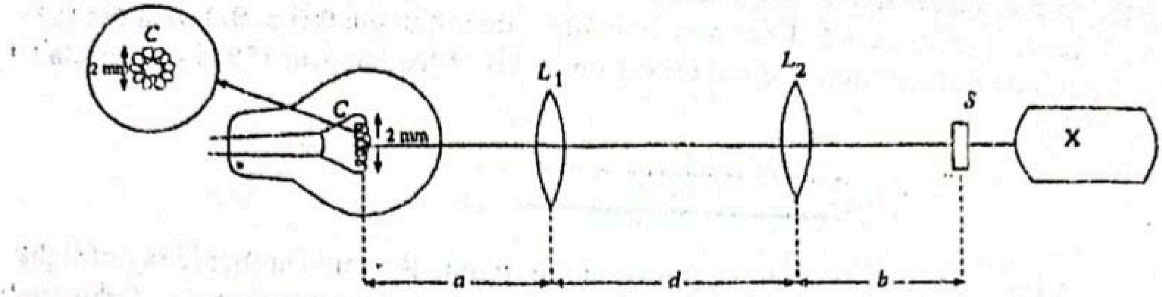
2005 A/L - 2

10) i) Drawing the usual ray diagram, show that the angular magnification M of a compound microscope is given by,

$$M = \frac{l}{f_0}\frac{25}{f_E}$$

When the microscope is adjusted to form the final image ad infinity. Here f_0 is the focal length of the objection, f_E is the focal length of the eyepiece and l is the distance between the focal points of the objective and the eyepiece lying between the two lenses. Here all distances are in cm.

ii) When a microscope is used, care should be taken to illuminate the specimen to achieve better viewing. The following figure shows an arrangement consisting of a lens combination and a lamp, used to illuminate the specimen S. The microscope is indicated by X.



Each lens has focal length of 20 mm and diameter of 20 mm. The filament C has an effective diameter of 2 mm. The distance a and d are adjusted so that the image of the filament formed by L_1 is positioned on L_2 and fills all of L_2.

a) In this situation
   i) What linear magnification does L_1 produce?
   ii) What are the value of a and d?

b) For better viewing, the specimen S should be placed at the point where the image of L_1 is formed by L_2. In this situation
   i) What is the value of b?
   ii) What is the illuminated area of the specimen?

2007 A/L -2

11) Figure (a) shows a cross sectional of a human eye. Although it is normally considered that the eye lens is responsible for the formation of the image on the retina, actually it is the combination of the cornea and the eye lens that forms the image. The cornea can be considered as a convex lens with a fixed focal length while the focal length of the eye lens can be adjusted through muscle movements.

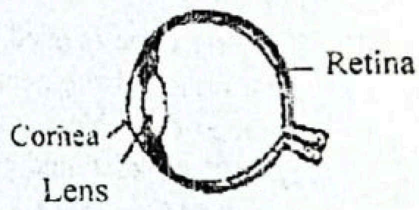


Figure (a)

i) Assume that the cornea and the eye lens can be considered as a composite lens consisting of two thin lenses in contact. The distance from the composite lens to the retina is 2 cm.
   (a) Calculate the power in dioptres, of the composite lens when it is adjusted for (1) far point (infinity) (2) near pint (25 cm). (Take the power of a convex lens as positive.)
   (b) Is the image on the retina real or virtual, and erect or inverted?
   (c) If the power of the cornea is 40 dioptres, calculate the power of the eye lens for the two cases mentioned in part (a) above.

ii) Consider two tiny dots, with a small separation d, on a paper placed at the near point of the eye as shown in figure (b).
   (a) Obtain an expression for the distance s between the two images formed by the two dots on the retina in terms of d.

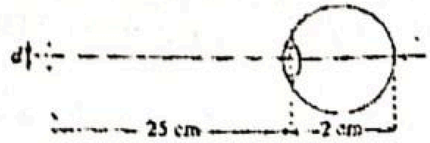


Figure (b)

(b) Letters and images printed by some computer printers consist of many closely spaced tiny dots which are not visible to normal eye.

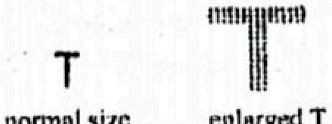


Figure (c)

For example, the enlarged letter T in figure (c), formed by many dots, appears without dots when viewed at normal size. For this to happen, the separation of the images of the retina formed by any two adjacent dots must be less than a certain value s_{max}.

If the value for s_{max} is 8 μn, show that a dots separation of 0.08 mm (300 dots per inch) is sufficient, for a letter to be seen without dots.

(c) If it is necessary to see the dots contained in a letter printed with 0.08 mm dots separation with a magnifying glass, what is the maximum focal length of the magnifying glass that should be used?

<u>2009 A/L - 2</u>

12) Figure (1) shows a monochromatic ray of light entering a spherical raindrop at A and emerging from C after a single reflection at P.

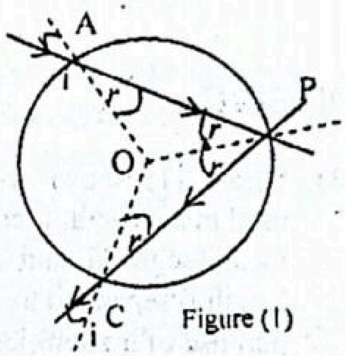


Figure (1)

a) If the refractive index of water is $\frac{4}{3}$, calculate the critical angle for water air interface ($\sin 48.6° = 0.750$).

b) Giving reasons, show that the ray of light can never be totally internally reflected from the opposite surface of the raindrop for any angle of incidence i.

c) i) Write down an expression for the angle of deviation of the ray due to the refraction at A in terms of i and r.

ii) Write down an expression for the angle of deviation of the ray AP due to the reflection at P in terms of r.

iii) Write down and expression for the angle of deviation of the ray PC due to the refraction at C in terms of i and r.

iv) Hence, write down an expression for the total angle of deviation (D) of the emergent ray relative to the incident ray in terms of i and r.

A rainbow can be seen due to the emergence of incident sunlight from refracts at A. it separates into its colours. Figure (2) shows such a refracted red colour ray(R)and blue colour ray (B).

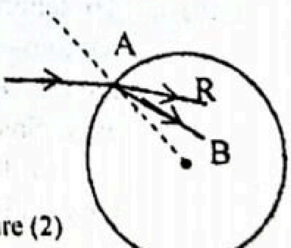


Figure (2)

d) Copy the figure (2) onto your answer sheet and complete the subsequent paths of the red and blue rays.

e) The expression obtained in (c) (iv) above shows that D varies i. It has been found that when $i = 52°$. the blue rays emerge from the raindrop with the angle of minimum deviation.

i) Determine the corresponding angle of minimum deviation D_{min} for blue rays. ($\sin 52° = 0.788$, $\sin 36.25° = 0.591$, Take the refractive index of water for blue colour also to be $\frac{4}{3}$)

ii) Assuming $i = 52°$ in your ray diagram drawn in (*d*) above mark D_{min}.

The light of any colour that emerges from the rain drop with the angle of minimum diviation corresponding to that colour is especially bright as rays bunch up at that angle. There bright colour bands which are deviated with minimum angles of deviation enter the eyes of an observer on the ground, and thereby a rainbow is seen.

iii) Determine the angle made by the blue colour of the rainbow with the horizontal relative to the observer on the ground.

iv) Which colour forms the outer edge of the rainbow?

2011 A/L -2

13) Figure (1) shows a zoom lens arrangement used in a camera. It consists of a convex lens of focal length f_1 and a concave lens of focal length f_2 separated by a variable distance d. The purpose of a zoom lens is to vary the effective focal length of the lens combination significantly with a small variation of d thereby providing variable magnification of the object.

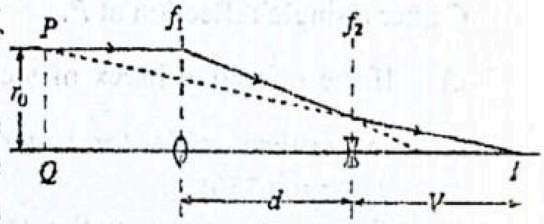


Figure 1

(a) What is the inequality that should be satisfied by d and f_1 in order to form a real image at I ?

(b) The lens combination forms an image I at a distance V to the right of the concave lens. Derive an expression for V in terms of f_1 , f_2 and d.

(c) i) To determine the effective focal length of the combination, consider a parallel ray incident on the convex lens at a distance r_0 from the principal axis. Show that the distance r from the optical axis to this ray at the point it enters the concave lens is given

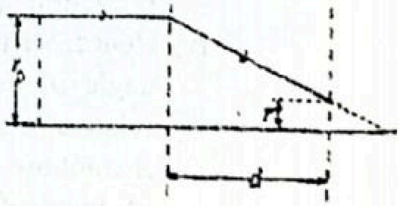


Figure 2

by, $r = \frac{r_0(f_1 - d)}{f_1}$. Use the geometry of the diagram in figure (2) to obtain your expression.

ii) If the ray shown in figure (1) that emerges from the concave lens and reaches the final image I is extended backward to the left of the concave lens, it will eventually meet the incident ray at point P. The distance from the final image I to the point Q is the effective focal length f of the lens combination.

Show that this focal length is given by $f = \frac{f_1 f_2}{f_2 - f_1 + d}$

(Hint : Use the results obtained in (b), (c) (i) above, and geometry to obtain your expression)

iii) If f_1 = 12.0cm, f_2 = 18.0cm and the separation d, is adjustable between 0 and 4.0 cm., find the minimum and maximum focal l3engths of the combination.

iv) Do your result justify the purpose of the zoom lens ? Give reasons for you answer.

2013 A/L - 6

14) In modern world optical fibres are used in numerous fields such as telecommunication and medicine. Figure (1) shows a cross-section of an optical fibre known as the core is made of a transparent material of refractive index 1.50 and the outer layer of the fibre known as the cladding is made of another transparent material of refractive index 1.44.

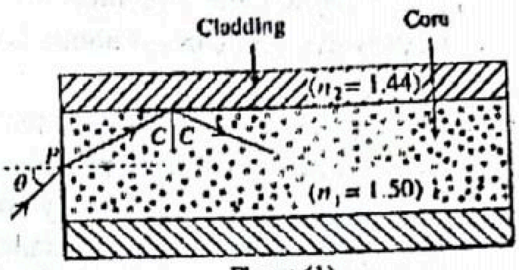


Figure (1)

a) As shown in figure (1) a monochromatic ray of light travelling in air and entering one end of the fibre with an angle of incidence θ is refracted into the core. Then the ray is incident on the core – cladding interface at an angle corresponding to the critical angle C of that interface. [sin 16° = 0.28; sin 25° = 0.42; sin 74° = 0.96] .

i) Calculate the value of C.

ii) Hence calculate the value of θ

iii) Find the range of values θ must have for the ray to be totally internally reflected from the core – cladding interface and transmit along the fibre.

iv) Write down an important advantage of using such fibres in telecommunication.

v) Draw the paths of emergent rays from the other end of the fibre for (1) odd number of reflections and (2) even number of reflections.

vi) Copy the figure (1) onto your answer sheet with the existing incident ray and show the complete path of a ray incident at P and subsequently falls at the core – cladding interface but does not undergo total internal reflection.

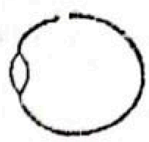
b) Two short red and blue light pulses are sent into one end a straight optical fibre of 3 km length simultaneously and perpendicular to it. Calculate the time interval between the red and blue light pulses when emerging at the other end. The speed of light in air is 3.00×10^8 ms^{-1} and the refractive indices for blue and red light are 1.53 and 1.48 respectively.

c) i) To transmit light signals more efficiently some optical fibres are made so as to decrease its refractive index gradually and continuously from the middle (axis) of the fibre to the outer surface of the fibre. This type of optical fibre is called a 'graded –index' fibre. Draw the path of a monochromatic light ray transmitting along such a fibre in a span of two total internal reflections.

ii) If the incident ray consists of blue and red colours instead of being monochromatic, will they travel along the same path inside the fibre? Explain your answer with a help of a diagram.

2016 A/L - 6

15) The effective focal length of the cornea and the eye - lens can be considered as the focal length of an eye. The muscles controlling the curvature of the lens permit the eye to focus on the retina light from objects at different distances from the eye. The figure shows a simplified diagram of the eye with en eye - lens of effective focal length. When the eye muscles are relaxed the focal length of a healthy eye of a child is about 2.5 cm. The near point of his eye is at a distance of 25 m.



(Copy the diagram given in the figure and use it when drawing ray diagrams.)

a) Draw a ray diagram for the situation where light from a far away object is focused onto the retina of the eye of the child with healthy eye when his eye muscles are relaxed. What is the distance between the eye - lens and the retina?

b) Draw a ray diagram for a situation where a point source of light is placed at the near point, is clearly seen by the child with healthy eye. Calculate the focal length of the eye at this instant:.

c) Another child has the focal length equal to that of the healthy child when the eye muscles are relaxed and also has the focal length calculated for the situation in (*b*). However, the position of his retina is located 0.2 cm behind the position of the retina of the healthy child

i) Using the image produced by a point source of light as mentioned in (*b*) above, indicate his near point and far point by drawing two separate ray diagrams. Calculate the distances from the eye - lens to the near point and to the far point of this child.

ii) Sketch a ray diagram illustrating as to how the required correction can be done using a suitable lens. Calculate the focal length of the corrective lens needed.

d) When a person becomes older the ability to change the focal length of eyes gets weaker and the distance to the near point of the eye increases. If the child mentioned in part (*c*) above would face such a situation. What is the type of additional corrective lens that the child should wear (convergent / divergent)? Give easons for you answer.

2017 A/L - 6

16) a) i) A thin convex lens of focal length *f* is used as a simple microscope. Draw a ray diagram for a situation when a distinct image is seen using the simple microscope by a person having the least distance distinct vision *D*. Clearly mark the positions of the eye, *f* and *D*.

ii) Derive an expression for the linear magnification of a simple microscope in terms of *f* and D.

iii) A thin convex lens of focal length 10 *cm* is used by the person mentioned in (*i*) above as a simple microscope to read very small letters. To see the clear image of a letter, what would be the distance from the lens to the letter. Calculate the linear magnification of the simple microscope. Take the value of *D* as 25 *cm*.

iv) A historical document placed in a museum is framed using a transparent glass plate of 2 *cm* thickness to protect it. Assume that the inner surface of the glass plate touches the document. Take the refractive index of glass as 1.6. Find the distance to the apparent position of the document from the front surface of the glass plate.

v) Consider that the same person mentioned in part (*i*) is reading the document using the simple microscope mentioned in part (*iii*).

1) What is the distance from the lens, to the image of the document produced by the lens when the letters are clearly seen by the person?

2) What is the distance to the document from the lens when the letters in the document are clearly seen?

b) i) Draw a **complete** ray diagram indicating all relevant lengths for an astronomical telescope in normal adjustment labeling the objective and the eyepiece clearly. Take f_0 and f_e as the focal lengths of the objective and the eyepiece respectively.

ii) Derive an expression for the angular magnification of the telescope when it is in normal adjustment using the ray diagram drawn in part (*b*) (*i*).

iii) An astronomical telescope is made using two thin convex lenses of focal lengths 100 *cm* and 10 *cm*. Calculate the angular magnification of the telescope in normal adjustment.

iv) What is the practical advantage of using a convex lens with large aperture area as the objective of an astronomical telescope? Explain your answer.