SHORT QUESTIONS AND ANSWERS

(A) (B)

Complete Video Lecture

Q No.10.1: What do you understand by linear magnification and angular magnification? Explain how a convex lens is used as a magnifier? (RWP-2021) (MU-2021) (GUJ-2019) (LHR-2018)

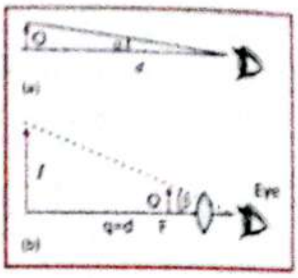
Linear magnification

The ratio of the size of the image to the size of the object is called linear magnification.

$$M = \frac{\text{size of image}}{\text{size of object}} = \frac{I}{O} \quad ; \quad M = \frac{\text{Distance of image from lens}}{\text{Distance of object from lens}} = \frac{q}{p}$$

Angular magnification

The ratio of the angle subtended by the image as seen through the optical device to that angle subtended by the object on unaided eye.



$$\text{angular magnification} = \frac{\beta}{\alpha} \qquad \text{Angular magnification} = \frac{\theta}{\theta_o}$$

Convex Lens as Magnifier

When an object is brought within the focal length of the convex lens i.e. between the lens and its focus, an erect virtual and magnified image is formed on the same side of object.

Q No.10.2: Explain the difference between angular magnification and resolving power of an optical instrument. What limits do the magnification of an optical instrument have? (BWP-2021) (SHW-2021) (LHR-2019) (SGD-2018) (RWP-2017) (SGD-2017) (DGK-2016)

Angular magnification

Resolving power the ability to reveal minor details of the object under examination.

$$\alpha_{min} = 1.22\frac{\lambda}{D}$$

Angular magnification alone has no use until details of the object can be seen distinctly. It is also limited due to defects in lens.

Q No.10.3: Why would it be advantageous to use blue light with a compound microscope? (FSB-2021) (GUJ-2021) (GUJ 2021) (FSB-2019) (BWP-2019) (DGK-2019) (SHW-2019) (MUL-2019) (RWP-2019) (FSB-2018) (LHR-2018) (RWP-2018) (SHW-2018) (FSB-2017) (DGK-2017) (GUJ-2017) (BWP-2016) (LHR-2016) (RWP-2016)

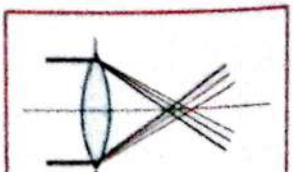
The resolving power

$$R = \frac{1}{\alpha_{min}} = \frac{D}{1.22\lambda}$$

A wider objective and use of blue light (short wavelength) produce less diffraction and allow more detail to be viewed.

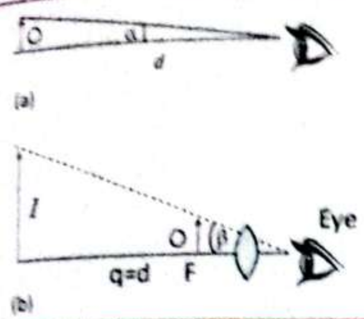
Q No.10.4: One can buy a cheap microscope for use by the children. The images seen in such a microscope have coloured edges. Why is this so? (MUL-2019) (LHR-2018) (RWP-2017) (FSB-2016) (SGD-2016)

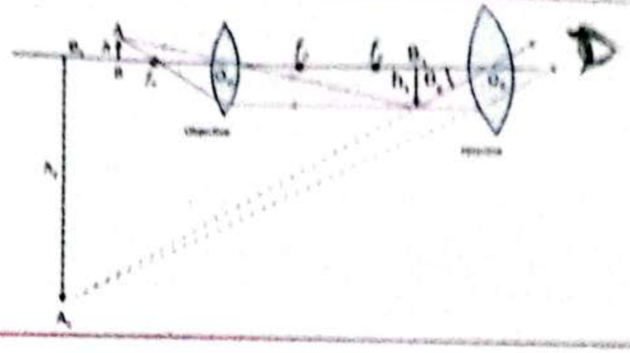
The images in microscope have colored edges because of defects in lenses called chromatic aberration. In such problem/defect a lens cannot bring all rays of white light to a single point . So image is not sharp and has colored edges.



Chromatic aberration

Q No.10.5: Describe with the help of diagrams, how (a) a single biconvex lens can be used as a magnifying glass, (b) biconvex lenses can be arranged to form a microscope. (General)





Q No.10.6: If a person was looking through a telescope at the full moon, how would the appearance of the moon be changed by covering half of the objective lens. (FSB-2021) (DGK-2021) (LHR-2021) (BWP-2019) (DGK-2019) (DGK-2018) (BWP-2017) (LHR-2017)

A full image can be observed but the brightness will be reduced.

For higher magnification the focal length of the objective should be large. When distant stars and planets are viewed through the telescope, it is desired to get maximum available light. That is why the aperture of objective is made large. If the objective is covered or size is reduced, the light will get reduced and so as the brightness.

Q No.10.7: A magnifying glass gives a five times enlarged image at a distance of 25 cm from the lens. Find, by ray diagram, the focal length of the lens. (LHR-2019) (FED-2018)

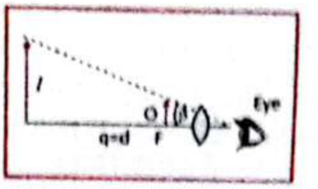
Solution $M = 5$

$d = q = 25$ cm

$M = 1 + \frac{d}{f}$

$f = \frac{d}{M-1}$

$= \frac{25}{5-1} = 6.25$ cm



Q No.10.8: Identify the correct answer.

The resolving power of a compound microscope depends on;

a. Length of the microscope.
b. The diameter of the objective lens.
c. The diameter of the eyepiece.
d. The position of an observer's eye with regard to the eye lens.

Reason As $R = \frac{D}{1.22\lambda}$ where D is diameter of lens which defines the focal length of lens.

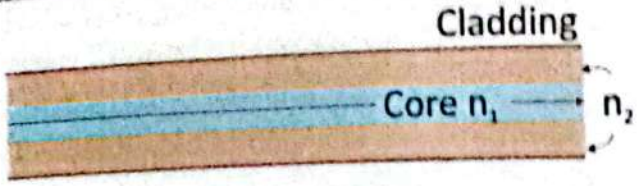
The resolving power of an astronomical telescope depends on:

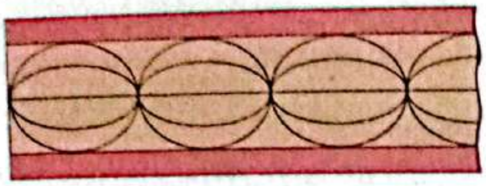
a. The focal length of the objective lens.
b. The least distance of distinct vision of the observer.
c. The focal length of the eye lens.
d. The diameter of the objective lens.

Reason As $R = \frac{D}{1.22\lambda}$ where D is aperture of lens which defines the focal length of lens.

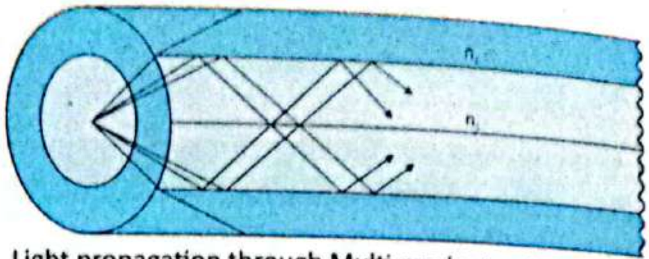
Q No.10.9: Draw sketches showing the different light paths through a single-mode and a multi mode fibre. Why is the single-mode fibre preferred in telecommunications?

Single mode step index fibre is preferably used in telecommunication system because its core is very thin and strong monochromatic light (LASER) is used in it. It has less dispersion effect and carries 14 TV channels and 14000 phone cells.





Light propagation through multi-mode graded-index fibre



Light propagation through Multi-mode step-index fibre.

Q No.10.10: How is the light signal transmitted through the optical fibre?

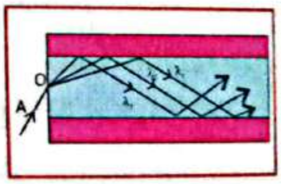
A signal is transmitted through optical fibre by fulfilling the following precedes

(i) Total internal reflection

(ii) Continuous reflection

Q No.10.10: How is the power lost in optical fibre through dispersion? Explain. (LHR-2019) (FED-2018) (SGD-2018) (GUJ-2018) (SGD-2017) (FSB-2016) (DGK-2016)

When a light signal is transmitted through optical fibre, the power loss is due to dispersion.



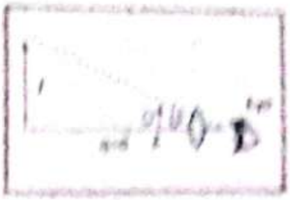
- When a white light is used as input signal its constituent wavelengths reflect according to their respective angles so different wavelengths take different time to reach final position and a weak and distorted output is shown.

Remedies

To reduce the dispersion

- A strong monochromatic source of light is recommended instead of white light.
- By using graded index fibre.

Q No.10.1: A converging lens of focal length 5.0 cm is used as a magnifying glass. If the near point of the observer is 25 cm and the lens is held close to the eye, calculate (i) the distance of the object from the lens (ii) the angular magnification. What is the angular magnification when the final image is formed at infinity?



Give

Focal length of lens = f = 5 cm = 5×10^{-2} m

Near point = d = q = 25 cm = 25×10^{-2} m

To Find

(i) Distance of object = p = ?

(ii) Magnification = M = ?

(iii) Angular magnification = M_i = ?

When q = ∞

Solution

(i)
$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$
$$\frac{1}{f} = \frac{1}{p} - \frac{1}{q}$$
$$\frac{1}{p} = \frac{1}{f} + \frac{1}{q}$$
$$= \frac{1}{5 \times 10^{-2}} + \frac{1}{25 \times 10^{-2}}$$
$$\frac{1}{p} = \frac{6}{25}$$
$$p = \frac{25}{6} = 4.2 \text{ cm}$$

(ii) Angular magnification $= 1 + \frac{d}{f}$
$$= 1 + \frac{25}{5} = 6$$

Result $\boxed{M = 6}$

(iii) When object is formed at infinity
$$M = \frac{d}{f} = \frac{25}{5} = 5$$

Result $\boxed{M = 5}$

Q No.10.2: A telescope objective has focal length 96 cm and diameter 12 cm. Calculate the focal length and minimum diameter of a simple eye piece lens for use with the telescope, if the linear magnification required is 24 times and all the light transmitted by the objective from a distant point on the telescope axis is to fall on the eye piece.

Give

Focal length of objective = f_o = 96 cm

Diameter of objective = d_o = 12 cm

Linear Magnification M = 24

To Find

Focal length of eyepiece = f_e = ?

Diameter of eyepiece = d_e = ?

Solution

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

$$f_e = \frac{f_o}{M} = \frac{96}{24}$$

$$f_e = 4\text{ cm}$$

As $$\frac{d_o}{d_e} = \frac{f_o}{f_e}$$

$$d_e = d_o \times \frac{f_e}{f_o}$$

$$d_e = 12 \times \frac{4}{96}$$

Result $\boxed{d_e = 0.5\text{ cm}}$

Q No.10.3: A telescope is made of an objective of focal length 20 cm and an eye piece of 5.0 cm, both convex lenses. Find the angular magnification. (MUL-2021) (SHW-2019) (RWP-2019) (FED-2018)

Data

Focal length of objective = f_o = 20 cm = 0.2 m

Focal length of eye piece = f_e = 5.0 cm = 0.5 m

To Find

Magnification = M = ?

Solution

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

$$M = \frac{0.2}{0.5}$$

Result $\boxed{M = 4}$

Q No.10.4: A simple astronomical telescope in normal adjustment has an objective of focal length 100 cm and an eye piece of focal length 5.0 cm. (i) Where is the final image formed? (ii) Calculate the angular magnification. (FSB-2021)

Give

Focal length of objective = f_o = 100 cm = 1 m

Focal length eyepiece = f_e = 5.0 cm = 0.05 m

To Find

(i) Distance of final image = q_e = ?

(ii) Angular magnification = M = ?

Solution

(i) $$\frac{1}{f_e} = \frac{1}{p_e} + \frac{1}{q_e} \qquad \because p_e = f_e$$

$$\frac{1}{q_e} = \frac{1}{f} - \frac{1}{p_e}$$

$$\frac{1}{q_e} = \frac{1}{0.05} - \frac{1}{0.05} = 0$$

$$q_e = \frac{1}{0} = \infty$$

(ii) $$M = \frac{f_o}{f_e} = \frac{1}{0.05}$$

Result $\boxed{M = 20}$

Q No.10.5: A point object is placed on the axis at 3.6 cm from a thin convex lens of focal length 3.0 cm. A second thin convex lens of focal length 16.0 cm is placed coaxial with the first and 26.0 cm from it on the side away from the object. Find the position of the final image produced by the two lenses.

Given

Distance of object = P_1 = 3.6 cm = 0.036 m
Focal length of first lens = f_1 = 3.0 cm = 0.03 m
Focal length of second lens = f_2 = 16.0 cm = 0.16 m
Distance from second lens = L = 26 cm = 0.26 m

To Find

Distance of final image = q_2 = ?

Solution

$$\frac{1}{f_1}=\frac{1}{P_1}+\frac{1}{q_1}$$

$$\frac{1}{q_1}=\frac{1}{f_1}-\frac{1}{P_1}$$

$$=\frac{1}{0.03}-\frac{1}{0.036}$$

$$\frac{1}{q_1}=\frac{1}{0.18}$$

$$q_1 = 0.18\text{ m} = 18\text{cm}$$

$$\frac{1}{f_2}=\frac{1}{P_2}+\frac{1}{q_2}$$

$$\frac{1}{q_2}=\frac{1}{f_2}-\frac{1}{P_2}$$

$$L = q_1 + P_2$$

$$P_2 = 26 - 18 = 8\text{ cm}$$

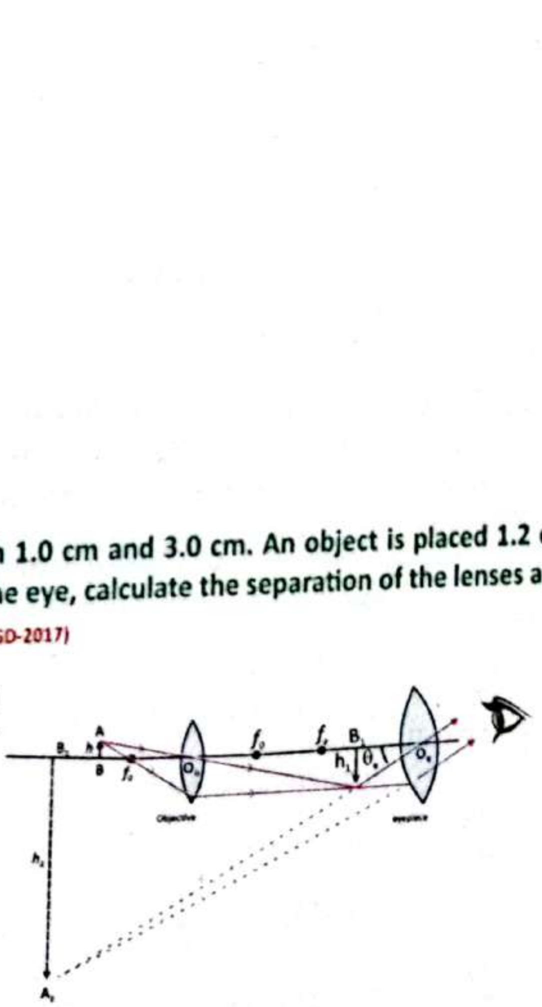
$$\frac{1}{q_2}=\frac{1}{16}-\frac{1}{8}$$

Result $\boxed{q_2 = -16\text{ cm}}$

Q No.10.6: A compound microscope has lenses of focal length 1.0 cm and 3.0 cm. An object is placed 1.2 cm from the object lens. If a virtual image is formed, 25 cm from the eye, calculate the separation of the lenses and the magnification of the instrument. (RWP-2021) (BWP-2019) (LHR-2017) (SGD-2017)

Given

Focal length of objective = f_o = 1.0 cm = 0.01 m
Distance of object p_o = 1.2 cm = 0.012 m
Focal length of eyepiece = f_e = 3.0 cm = 0.03 m
Least distance d = q_e = 25 cm = 0.25 m



To Find

(i) Separation between lens = L = ?
(ii) Magnification = M = ?

Solution

(i)
$$\frac{1}{f_o}=\frac{1}{p_o}+\frac{1}{q_o}$$

$$\frac{1}{q_o}=\frac{1}{f_o}-\frac{1}{p_o}$$

$$=\frac{1}{1}-\frac{1}{1.2}$$

$$\frac{1}{q_o}=\frac{1}{6}$$

Result $\boxed{q_o = 6\text{ cm}}$

For eye Piece

$$\frac{1}{f_e}=\frac{1}{p_e}+\frac{1}{q_e}$$

$$\frac{1}{f_e}=\frac{1}{p_e}-\frac{1}{q_e}$$

$$\frac{1}{p_e}=\frac{1}{f_e}+\frac{1}{q_e}$$

$$=\frac{1}{3}+\frac{1}{25}$$

$$\frac{1}{p_o}=\frac{28}{75}$$

As

$$L = q_o + p_e = 6 + 2.7 = 8.7\text{ cm}$$

(ii)

$$M=\frac{q_o}{p_o}(1+\frac{d}{f_o})$$

$$=\frac{6}{1.2}(1+\frac{25}{3}) = 46.65$$

Result $\boxed{M = 47}$

Q No.10.7: Sodium light of wavelength 589 nm is used to view an object under a microscope. If the aperture of the objective is 0.90 cm, (i) find the limiting angle of resolution (ii) using visible light of any wavelength, what is the maximum limit of resolution for this microscope?

Given

Wavelength of sodium light = λ = 589 nm = 589×10^{-9} m
Aperture of objective = D = 0.90cm = 0.90×10^{-2} m

To Find

(i) Limiting angle of resolution = α_{min} = ?
(ii) Maximum limit of resolution = α =?

Solution

(i) For minimum limit

$$\alpha_{min}=1.22\frac{\lambda}{D}$$

$$=1.22\times\frac{589\times10^{-9}}{0.9\times10^{-2}}$$

$$\alpha_{min}=8\times10^{-5}\text{ rad}$$

(ii) For maximum limit

$$\alpha_{min}=1.22\frac{\lambda}{D}$$

$$= 1.22 \times \frac{(400 \times 10^{-9})}{0.9 \times 10^{-2}}$$

Result $\boxed{\alpha_{min} = 5.42 \times 10^{-5}\,\text{rad}}$

Q No.10.8: An astronomical telescope having magnifying power of 5 consists of two thin lenses 24 cm apart. Find the focal lengths of the lenses. (RWP-2021) (DGK-2021) (MUL-2021) (SGD-2021) (GUJ-2021) (FSB-2019) (BWP-2019) (GUJ-2019) (SHW-2018) (FSB-2017) (LHR-2017) (SGD-2017) (FSB-2016) (DGK-2016)

Given

Magnification power of telescope = M = 5

At normal adjustment = L = 24 cm = 0.24 m

To Find

(i) Focal length of objective = f_o = ?

(ii) Focal length of eyepiece = f_e = ?

Solution

(i) Length of telescope = $L = f_o + f_e$

$$24 = f_o + f_e$$

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

$$5 = \frac{f_o}{f_e}$$

$$f_o = 5f_e$$

Substitute back

$$24 = 5f_e + f_e$$

$$6f_e = 24$$

$$f_e = 4\text{ cm}$$

(ii) $f_o = 5f_e$

$$= 5 \times 4$$

Result $\boxed{f_o = 24\text{ cm}}$

Q No.10.9: A glass light pipe in air will totally internally reflect a light ray if its angle of incidence is at least 39°. What is the minimum angle for total internal reflection if pipe is in water? (Refractive Index of water = 1.33) (LHR-2019) (MUL-2019) (LHR-2018) (DGK-217) (RWP-2017) (BWP-2016) (RWP-2016)

Given

Angle of incidence = $\theta_1 = 39°$

Refractive index of water = $n_2 = 1.33$

To Find

Minimum angle = θ_c = ?

Solution

For glass air boundary

$$n_1\sin\theta_1 = n_2\sin\theta_2 \qquad \because \left\{\begin{array}{l} n_1 = \text{refractive index of glass} \\ n_2 = \text{refractive index of air} \end{array}\right\}$$

$$n_1 = \frac{n_2 \sin 90°}{\sin\theta_c} = 1.59$$

For glass water boundary

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\sin\theta_c = \frac{1.33}{1.59}\ (1)$$

Result $\boxed{\theta_c = \sin^{-1}\left(\frac{1.33}{1.59}\right) = 57°}$

Q No.10.10: The refractive index of the core and cladding of an optical fibre are 1.6 and 1.4 respectively. Calculate (i) the critical angle for the interface (ii) the maximum angle of incidence in the air of a ray which enters the fibre and is incident at the critical angle on the interface. (SGD-2018)

Given Refractive index of core = $n_1 = 1.66$

Refractive index of cladding = $n_2 = 1.4$

To Find $\theta_c = ?$

$\theta_1 = ?$

Solution

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad \because \left\{ \begin{array}{l} n_1 = \text{refractive index of core} \\ n_2 = \text{refractive index of cladding} \end{array} \right\}$

$\sin\theta_c = \dfrac{1.4}{1.6}$ $\quad$ when $\theta_1 = \theta_c$ then $\theta_2 = 90^\circ$

$\theta_c = 61^\circ$

$\theta_2 = 90^\circ - 61^\circ = 29^\circ$

$n_1 \sin\theta_1 = n'_2 \sin\theta'_2$ $\quad \because \left\{ \begin{array}{l} n_1 = \text{refractive index of air} \\ n_2 = \text{refractive index of core} \end{array} \right\}$

Result $\boxed{\theta_1 = \dfrac{1.6}{1} \sin 29^\circ = 51^\circ}$