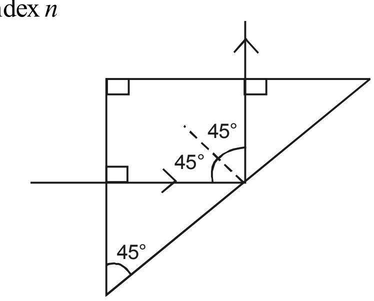
CHAPTER 23

Ray Optics and Optical Instruments

1. An astronomical telescope has a large aperture to **[2002]**
   (a) reduce spherical aberration
   (b) have high resolution
   (c) increase span of observation
   (d) have low dispersion
2. If two mirrors are kept at 60° to each other, then the number of images formed by them is **[2002]**
   (a) 5 (b) 6
   (c) 7 (d) 8
3. Which of the following is used in optical fibres? **[2002]**
   (a) total internal reflection
   (b) scattering
   (c) diffraction
   (d) refraction.
4. Consider telecommunication through optical fibres. Which of the following statements is **not** true? **[2003]**
   (a) Optical fibres can be of graded refractive index
   (b) Optical fibres are subject to electromagnetic interference from outside
   (c) Optical fibres have extremely low transmission loss
   (d) Optical fibres may have homogeneous core with a suitable cladding.
5. The image formed by an objective of a compound microscope is **[2003]**
   (a) virtual and diminished
   (b) real and diminished
   (c) real and enlarged
   (d) virtual and enlarged
6. To get three images of a single object, one should have two plane mirrors at an angle of **[2003]**
   (a) 60º (b) 90º
   (c) 120º (d) 30º
7. A light ray is incident perpendicularly to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index n **[2004]**



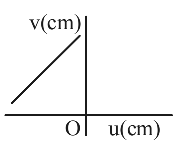
   (a) $n > \frac{1}{\sqrt{2}}$ (b) $n > \sqrt{2}$
   (c) $n < \frac{1}{\sqrt{2}}$ (d) $n < \sqrt{2}$
8. A plano convex lens of refractive index 1.5 and radius of curvature 30 cm, is silvered at the curved surface. Now this lens has been used to form the image of an object. At what distance from this lens an object be placed in order to have a real image of size of the object **[2004]**
   (a) 60 cm (b) 30 cm
   (c) 20 cm (d) 80 cm
9. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is $\frac{4}{3}$ and the fish is 12 cm below the surface, the radius of this circle in cm is **[2005]**
   (a) $\frac{36}{\sqrt{7}}$ (b) $36\sqrt{7}$
   (c) $4\sqrt{5}$ (d) $36\sqrt{5}$

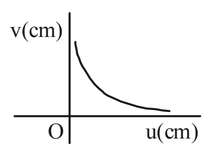
10. A thin glass (refractive index 1.5) lens has optical power of $-5\,D$ in air. Its optical power in a liquid medium with refractive index 1.6 will be **[2005]**
(a) $-1D$ (b) $1D$
(c) $-25\,D$ (d) $25\,D$

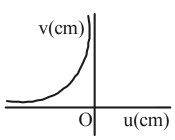
11. The refractive index of a glass is 1.520 for red light and 1.525 for blue light. Let D_1 and D_2 be angles of minimum deviation for red and blue light respectively in a prism of this glass. Then, **[2006]**
(a) $D_1 < D_2$
(b) $D_1 = D_2$
(c) D_1 can be less than or greater than D_2 depending upon the angle of prism
(d) $D_1 > D_2$

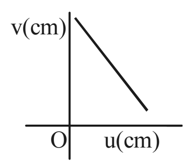
12. Two lenses of power $-15\ D$ and $+5\ D$ are in contact with each other. The focal length of the combination is **[2007]**
(a) $+10$ cm (b) -20 cm
(c) -10 cm (d) $+20$ cm

13. A student measures the focal length of a convex lens by putting an object pin at a distance 'u' from the lens and measuring the distance 'v' of the image pin. The graph between 'u' and 'v' plotted by the student should look like **[2008]**

(a) 

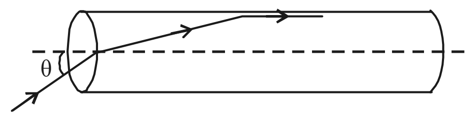
(b) 

(c) 

(d) 

14. An expermient is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are measured by **[2008]**
(a) a vernier scale provided on the microscope
(b) a standard laboratory scale
(c) a meter scale provided on the microscope
(d) a screw gauge provided on the microscope

15. A transparent solid cylindrical rod has a refractive index of $\frac{2}{\sqrt{3}}$. It is surrounded by air. A light ray is incident at the mid-point of one end of the rod as shown in the figure.



The incident angle θ for which the light ray grazes along the wall of the rod is : **[2009]**
(a) $\sin^{-1}\left(\sqrt{3}/2\right)$ (b) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$
(c) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (d) $\sin^{-1}(1/2)$

16. In an optics experiment, with the position of the object fixed, a student varies the position of a convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance u and the image distance v, from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at P. The coordinates of P will be **[2009]**
(a) $\left(\frac{f}{2},\frac{f}{2}\right)$ (b) (f, f)
(c) $(4f, 4f)$ (d) $(2f, 2f)$

17. Let the x-z plane be the boundary between two transparent media. Medium 1 in $z \ge 0$ has a refractive index of $\sqrt{2}$ and medium 2 with $z < 0$ has a refractive index of $\sqrt{3}$. A ray of light in medium 1 given by the vector $\vec{A} = 6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}$ is incident on the plane of separation. The angle of refraction in medium 2 is: **[2011]**
(a) 45° (b) 60°
(c) 75° (d) 30°

18. A car is fitted with a convex side-view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15 m/s. The speed of the image of the second car as seen in the mirror of the first one is : **[2011]**
(a) $\frac{1}{15}$ m/s (b) 10 m/s
(c) 15 m/s (d) $\frac{1}{10}$ m/s

19. A beaker contains water up to a height h_1 and kerosene of height h_2 above water so that the total height of (water + kerosene) is $(h_1 + h_2)$.

Refractive index of water is μ_1 and that of kerosene is μ_2. The apparent shift in the position of the bottom of the beaker when viewed from above is **[2011 RS]**

(a) $\left(1+\frac{1}{\mu_1}\right)h_1-\left(1+\frac{1}{\mu_2}\right)h_2$

(b) $\left(1-\frac{1}{\mu_1}\right)h_1+\left(1-\frac{1}{\mu_2}\right)h_2$

(c) $\left(1+\frac{1}{\mu_1}\right)h_2-\left(1+\frac{1}{\mu_2}\right)h_1$

(d) $\left(1-\frac{1}{\mu_1}\right)h_2+\left(1-\frac{1}{\mu_2}\right)h_1$

20. When monochromatic red light is used instead of blue light in a convex lens, its focal length will **[2011 RS]**

(a) increase
(b) decrease
(c) remain same
(d) does not depend on colour of light

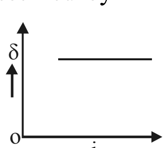
21. An object at 2.4 m in front of a lens forms a sharp image on a film 12 cm behind the lens. A glass plate 1 cm thick, of refractive index 1.50 is interposed between lens and film with its plane faces parallel to film. At what distance (from lens) should object shifted to be in sharp focus of film? **[2012]**

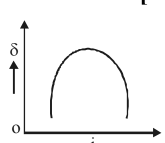
(a) 7.2 m (b) 2.4 m
(c) 3.2 m (d) 5.6 m

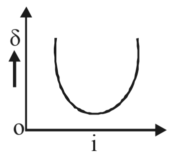
22. Diameter of a plano-convex lens is 6 cm and thickness at the centre is 3 mm. If speed of light in material of lens is 2×10^8 m/s, the focal length of the lens is **[2013]**

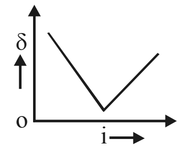
(a) 15 cm (b) 20 cm
(c) 30 cm (d) 10 cm

23. The graph between angle of deviation (δ) and angle of incidence (i) for a triangular prism is represented by **[2013]**

(a)


(b)


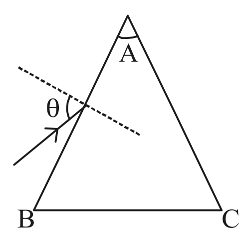
(c)


(d)


24. A thin convex lens made from crown glass $\left(\mu=\frac{3}{2}\right)$ has focal length f. When it is measured in two different liquids having refractive indices $\frac{4}{3}$ and $\frac{5}{3}$, it has the focal lengths f_1 and f_2 respectively. The correct relation between the focal lengths is: **[2014]**

(a) $f_1 = f_2 < f$
(b) $f_1 > f$ and f_2 becomes negative
(c) $f_2 > f$ and f_1 becomes negative
(d) f_1 and f_2 both become negative

25. Monochromatic light is incident on a glass prism of angle A. If the refractive index of the material of the prism is μ, a ray, incident at an angle θ, on the face AB would get transmitted through the face AC of the prism provided : **[2015]**



(a) $\theta > \cos^{-1}\left[\mu \sin\left(A+\sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(b) $\theta < \cos^{-1}\left[\mu \sin\left(A+\sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(c) $\theta > \sin^{-1}\left[\mu \sin\left(A-\sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(d) $\theta < \sin^{-1}\left[\mu \sin\left(A-\sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

26. An observer looks at a distant tree of height 10 m with a telescope of magnifying power of 20. To the observer the tree appears : **[2016]**
(a) 20 times taller (b) 20 times nearer
(c) 10 times taller (d) 10 times nearer

27. In an experiment for determination of refractive index of glass of a prism by i – δ, plot it was found thata ray incident at angle 35°, suffers a deviation of 40° and that it emerges at angle 79°. In that case which of the following is closest to the maximum possible value of the refractive index? **[2016]**
(a) 1.7 (b) 1.8
(c) 1.5 (d) 1.6

28. A diverging lens with magnitude of focal length 25 cm is placed at a distance of 15 cm from a converging lens of magnitude of focal length 20 cm. A beam of parallel light falls on the diverging lens. The final image formed is : **[2017]**
(a) real and at a distance of 40 cm from the divergent lens
(b) real and at a distance of 6 cm from the convergent lens
(c) real and at a distance of 40 cm from convergent lens
(d) virtual and at a distance of 40 cm from convergent lens.

Answer Key

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(b)	(a)	(a)	(b)	(c)	(b)	(b)	(c)	(a)	(b)	(a)	(c)	(c)	(a)	(c)
16	17	18	19	20	21	22	23	24	25	26	27	28		
(d)	(a)	(a)	(b)	(a)	(d)	(c)	(c)	(b)	(c)	(b)	(c)	(c)		

SOLUTIONS

1. (b) The resolving power of a telescope

$$R.P = \frac{D}{1.22\lambda}$$

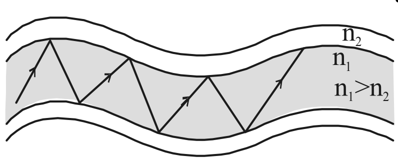
where D = diameter of the objective lens
λ = wavelength of light.
Clearly, larger the aperture, larger is the value of D, more is the resolving power or resolution.

2. (a) When two plane mirrors are inclined at each other at an angle θ then the number of the images of a point object placed between the plane mirrors is $\frac{360°}{\theta} - 1$,

if $\frac{360°}{\theta}$ is even

$\therefore$ Number of images formed $= \frac{360°}{60°} - 1 = 5$

3. (a) In an optical fibre, light is sent through the fibre without any loss by the phenomenon of total internal reflection as shown in the figure.



4. (b) Optical fibres form a dielectric wave guide and are free from electromagnetic interference or radio frequency interference.

5. (c) A real, inverted and enlarged image of the object is formed by the objective lens of a compound microscope.

6. (b) When θ = 90° then $\frac{360}{\theta} = \frac{360}{90} = 4$ is an even number. The number of images formed is given by

$$n = \frac{360}{\theta} - 1 = \frac{360}{90} - 1 = 4 - 1 = 3$$

7. (b) The incident angle is 45°.
Incident angle > critical angle, $i > i_c$

$\therefore \sin i > \sin i_c$ *or* $\sin 45 > \sin i_c$

$\sin i_c = \frac{1}{n}$

$\therefore \sin 45° > \frac{1}{n}$ *or* $\frac{1}{\sqrt{2}} > \frac{1}{n} \Rightarrow n > \sqrt{2}$

8. (c) The focal length(F) of the final mirror is

$$\frac{1}{F} = \frac{2}{f_\ell} + \frac{1}{f_m}$$

Here $\dfrac{1}{f_\ell} = (\mu - 1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

$= (1.5-1)\left[\dfrac{1}{\alpha} - \dfrac{1}{-30}\right] = \dfrac{1}{60}$

$\therefore \dfrac{1}{F} = 2 \times \dfrac{1}{60} + \dfrac{1}{30/2} = \dfrac{1}{10}$

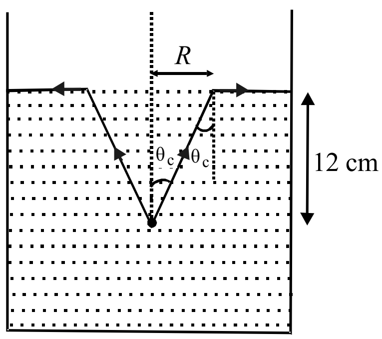
$\therefore F = 10$ cm

The combination acts as a converging mirror. For the object to be of the same size of mirror,

$u = 2F = 20$ cm

9. **(a)** $\sin\theta_c = \dfrac{1}{\mu} = \dfrac{3}{4}$

or $\tan\theta_c = \dfrac{3}{\sqrt{16-9}} = \dfrac{3}{\sqrt{7}} = \dfrac{R}{12}$



$\Rightarrow R = \dfrac{36}{\sqrt{7}}$ cm

10. **(b)** $\dfrac{1}{f_a} = \left(\dfrac{1.5}{1} - 1\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$ .... (i)

$\dfrac{1}{f_m} = \left(\dfrac{\mu_g}{\mu_m} - 1\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

$\dfrac{1}{f_m} = \left(\dfrac{1.5}{1.6} - 1\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$ .... (ii)

Dividing (i) by (ii), $\dfrac{f_m}{f_a} = \left(\dfrac{1.5-1}{\dfrac{1.5}{1.6} - 1}\right) = -8$

$P_a = -5 = \dfrac{1}{f_a} \Rightarrow f_a = -\dfrac{1}{5}$

$\Rightarrow f_m = -8 \times f_a = -8 \times -\dfrac{1}{5} = \dfrac{8}{5}$

$P_m = \dfrac{\mu}{f_m} = \dfrac{1.6}{8} \times 5 = 1\text{D}$

11. **(a)** For a thin prism, $D = (\mu - 1)A$

Since $\lambda_b < \lambda_r \Rightarrow \mu_r < \mu_b \Rightarrow D_1 < D_2$

12. **(c)** Power of combination is given by

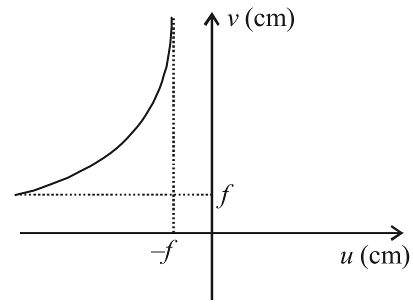
$P = P_1 + P_2 = (-15+5)D \quad = -10D.$

Now, $P = \dfrac{1}{f} \Rightarrow f = \dfrac{1}{P} = \dfrac{1}{-10}$ metre

$\therefore f = -\left(\dfrac{1}{10} \times 100\right)$ cm $= -10$ cm.

13. **(c)** This graph suggest that when

$u = -f, v = +\infty$

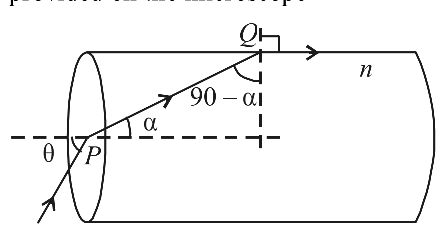


When the object is moved further away from the lens, v decreases but remains positive. When u is at $-\infty$, $v = f$.

This is how image formation takes place for different positions of the object in case of a convex lens.

14. **(a)** To find the refractive index of glass using a travelling microscope, a vernier scale is provided on the microscope

15. **(c)**



Applying Snell's law at Q

$n = \dfrac{\sin 90^\circ}{\sin(90^\circ - \alpha)} = \dfrac{1}{\cos\alpha}$

$\therefore \cos\alpha = \dfrac{1}{n}$

$\therefore \ \sin\alpha = \sqrt{1-\cos^2\alpha} = \sqrt{1-\frac{1}{n^2}} = \frac{\sqrt{n^2-1}}{n}$ ...(1)

Applying Snell's Law at P

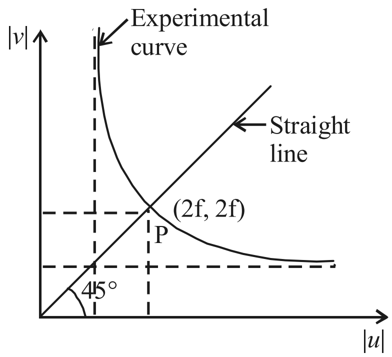
$n = \frac{\sin\theta}{\sin\alpha} \Rightarrow \ \sin\theta = n\times\sin\alpha = \sqrt{n^2-1}$;

from (1)

$\therefore \sin\theta = \sqrt{\left(\frac{2}{\sqrt{3}}\right)^2 - 1} = \sqrt{\frac{4}{3}-1} = \frac{1}{\sqrt{3}}$

or $\quad \theta = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

16. (d)



For a convex lens $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

when $u = -\alpha$, $v = +f$

when $u = -f$, $v = +\alpha$

Then $u = -2f, v = 2f$

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

As $|u|$ increases, v decreases for $|u| > f$. The graph between $|v|$ and $|u|$ is shown in the figure. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at $P(2f, 2f)$.

17. (a) Angle of incidence is given by

$\cos(\pi - i) = \frac{\left(6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}\right).\hat{k}}{20}$

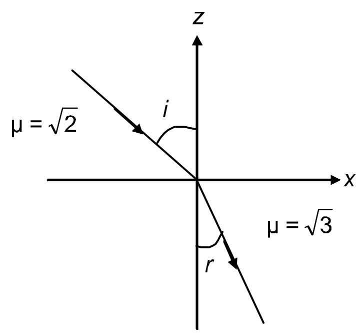
$-\cos i = -\frac{1}{2}$

$\angle i = 60°$

From Snell's law,

$\sqrt{2}\sin i = \sqrt{3}\sin r$

$\angle r = 45°$



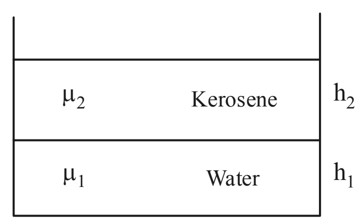
18. (a) From mirror formula

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ so, $\frac{dv}{dt} = -\frac{v^2}{u^2}\left(\frac{du}{dt}\right)$

$\Rightarrow \frac{dv}{dt} = -\left(\frac{f}{u-f}\right)^2 \frac{du}{dt}$

$\Rightarrow \frac{dv}{dt} = \frac{1}{15}$ m/s

19. (b)



Apparent shift due to water $= h_1\left[1 - \frac{1}{\mu_1}\right]$

Apparent shift due to kerosene

$= h_2\left[1 - \frac{1}{\mu_2}\right]$

Thus, total apparent shift :

$= h_1\left(1 - \frac{1}{\mu_1}\right) + h_2\left(1 - \frac{1}{\mu_2}\right)$

20. (a) We know that $\mu_R < \mu_B$

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

$\Rightarrow \ \frac{1}{f_B} > \frac{1}{f_R} \quad \Rightarrow \ f_R > f_B$.

21. (d) The focal length of the lens

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{12} + \frac{1}{240} = \frac{20+1}{240} = \frac{21}{240}$

$f = \frac{240}{21}\text{cm}$

Shift $= t\left(1 - \frac{1}{\mu}\right)$

$1\left(1 - \frac{1}{3/2}\right) = 1 \times \frac{1}{3}$

Now $v' = 12 - \frac{1}{3} = \frac{35}{3}\text{cm}$

Now the object distance u.

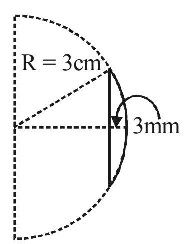
$\frac{1}{u} = \frac{3}{35} - \frac{21}{240} = \frac{1}{5}\left[\frac{3}{7} - \frac{21}{48}\right]$

$\frac{1}{u} = \frac{1}{5}\left[\frac{48-49}{7 \times 16}\right]$

$u = -7 \times 16 \times 5 = -560\text{ cm} = -5.6\text{ m}$

22. **(c)** $\therefore\ n = \frac{\text{Velocity of light in vacuum}}{\text{Velocity of light in medium}}$

$\therefore\ n = \frac{3}{2}$



$3^2 + (R - 3\text{mm})^2 = R^2$

$\Rightarrow 3^2 + R^2 - 2R(3\text{mm}) + (3\text{mm})^2 = R^2$

$\Rightarrow R \approx 15\text{ cm}$

$\frac{1}{f} = \left(\frac{3}{2} - 1\right)\left(\frac{1}{15}\right) \Rightarrow f = 30\text{ cm}$

23. **(c)** For the prism as the angle of incidence (i) increases, the angle of deviation (δ) first decreases goes to minimum value and then increases.

24. **(b)** By Lens maker's formula for convex lens

$\frac{1}{f} = \left(\frac{\mu}{\mu_L} - 1\right)\left(\frac{2}{R}\right)$

for, $\mu_{L_1} = \frac{4}{3}, f_1 = 4R$

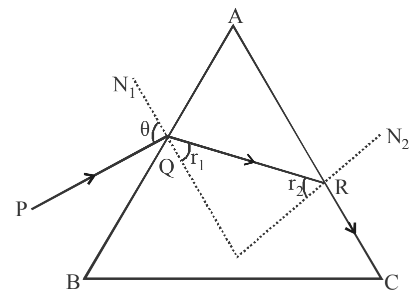
for $\mu_{L_2} = \frac{5}{3}, f_2 = -5R$

$\Rightarrow\ f_2 = (-)\text{ ve}$

25. **(c)** When $r_2 = C, \angle N_2Rc = 90°$

Where C = critical angle

As $\sin C = \frac{1}{v} = \sin r_2$



Applying snell's law at 'R'

$\mu \sin r_2 = 1 \sin 90°$ ...(i)

Applying snell's law at 'Q'

$1 \times \sin\theta = \mu \sin r_1$ ...(ii)

But $r_1 = A - r_2$

So, $\sin\theta = \mu \sin(A - r_2)$

$\sin\theta = \mu \sin A \cos r_2 - \cos A$ ...(iii)

[using (i)]

From (1)

$\cos r_2 = \sqrt{1 - \sin^2 r_2} = \sqrt{1 - \frac{1}{\mu^2}}$ ...(iv)

By eq. (iii) and (iv)

$\sin\theta = \mu \sin A\sqrt{1 - \frac{1}{\mu^2}} - \cos A$

on further solving we can show for ray not to transmitted through face AC

$\theta = \sin^{-1}\left[\mu \sin(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right]$

So, for transmission through face AC

$\theta > \sin^{-1}\left[\mu \sin(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right]$

26. **(b)** A telescope magnifies by making the object appearing closer.

27. **(c)** We know that $i + e - A = \delta$

$35° + 79° - A = 40° \quad \therefore \quad A = 74°$

$$\text{But } \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2} = \frac{\sin\left(\frac{74+\delta_m}{2}\right)}{\sin\frac{74}{2}}$$

$$= \frac{5}{3}\sin\left(37° + \frac{\delta_m}{2}\right)$$

μ_{max} can be $\frac{5}{3}$. That is μ_{max} is less than

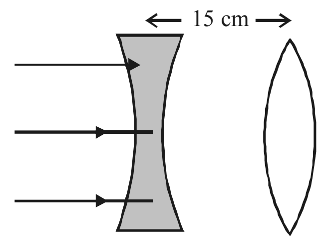
$\frac{5}{3} = 1.67$

But δ_m will be less than 40° so

$$\mu < \frac{5}{3}\sin 57° < \frac{5}{3}\sin 60° \Rightarrow \mu = 1.5$$

28. **(c)** As parallel beam incident on diverging lens will form image at focus.

$\therefore$ $v = -25\ cm$



$f = -25\ cm$ $f = 20\ cm$

The image formed by diverging lens is used as an object for converging lens,

So for converging lens $u = -25 - 15 = -40\ cm$, $f = 20\ cm$

$\therefore$ Final image formed by converging lens

$$\frac{1}{V} - \frac{1}{-40} = \frac{1}{20}$$

or, V = 40 cm from converging lens real and inverted.