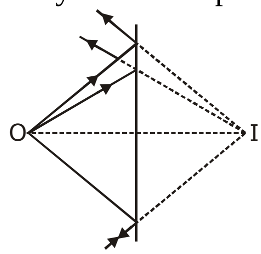
JEE Main Exercise

1. (b)
All the reflected rays meet at a point, when produced backwards.



2. (c)
Perpendicular distance between object & mirror is equal to perpendicular distance between image & mirror.
Fig.1 shows original condition when object distance is x & mirror is at mean and fig.2 shows final condition then mirror perform SHM of amplitude 2 cm.

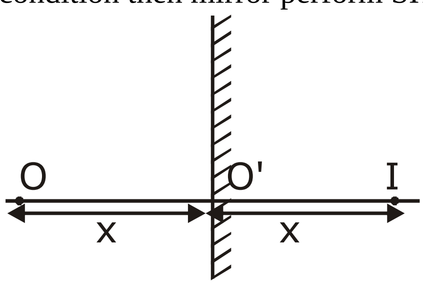


Fig. 1

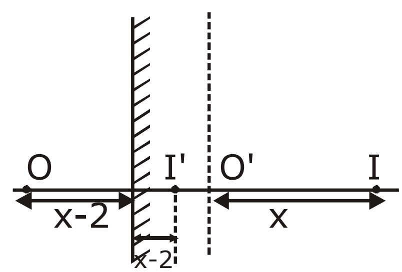
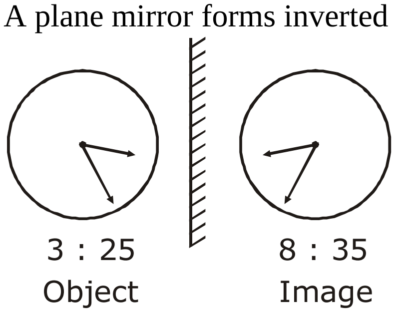


Fig. 2

II′ = O′I + OO′ – (OI′)
= x + x – 2 (x – 2)
II′ = 4 cm

3. (a)
A plane mirror forms inverted image of object line perpendicular to it.



4. (d)
Deviation produced by plane mirror is given by
$\delta = 180 - 2i$
here i = 90 – 60 = 30º
δ = 180 – 60 = 120º

5. (a)
There is a phase change of 180^o in reflection.

6. (c)
Only a portion of incident light is reflected by mirror and rest is transmitted in mid water. So intensity of reflected light is less than intensity of incident light & hence image formed is less bright.

7. (a)
By the laws of reflection angle of incidence = angle of reflection
$\angle i = \angle r$

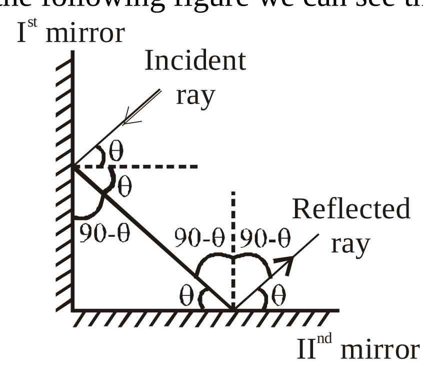
8. (b)
An image is called a real image if the rays after reflection or refraction actually meet hence converging rays from real image.
When rays actually meet real image is formed

9. (a)
All the reflected rays meet at a point, when produced backwards.

10. (b)
Lateral inversion refers to inverted image of object when kept in front of mirror.
Image of HOX appears same as HOX.

11. (b)
Perpendicular distance between object & mirror is equal to perpendicular distance between image & mirror.
Initially the separation between object and image is 200 cm. After 6s the mirror has moved 30 cm towards the object. Hence object-mirror separation is 70 cm. So object image separation is 140 cm.

12. (b)
From the following figure we can see that incident & reflected ray are parallel to one another.



13. (c)
First reflection = 3
Second reflection = 3
Third reflection = 1
Total = 7

14. (a)

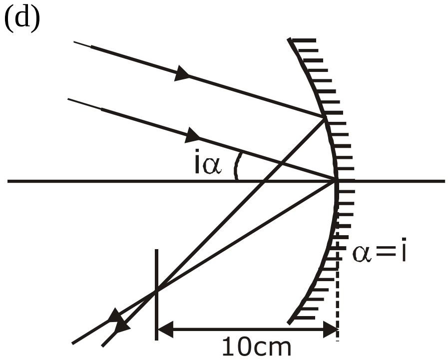
By the formula for the number of image formed $\frac{360}{\theta}-1$ where θ is angle between the mirror.

No. of images = $\frac{360}{\theta}-1=5$

15. (c)

Paraxial rays are considered because they form nearly a point image of a point source.

16. (d)



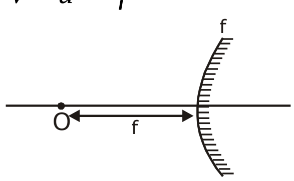
So diameter of the image = $f\alpha$

$=10\times\left(1\times\frac{\pi}{180}\right)=\frac{\pi}{18}$

17. (b)

Using mirror formula

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



Here $u=-f$, $f=+f$

$\frac{1}{v}+\frac{1}{(-f)}=\frac{1}{f}$

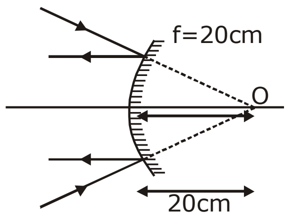
$\Rightarrow\quad v=\frac{f}{2}$

18. (a)

Using mirror formula

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

Here we have a virtual object so sign of u is positive.



Here $f = +20$

$u = 20$

$$\frac{1}{v} + \frac{1}{20} = \frac{1}{20} \Rightarrow \frac{1}{v} = 0$$

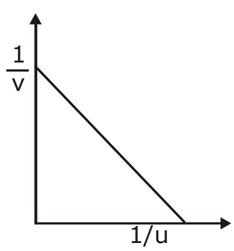
$v = \infty$

19. (b)

Using mirror formula

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

The equation is in the form of $y = mx + c$. On comparing we see that taking $\frac{1}{v}$ on y-axis and $\frac{1}{u}$ on x-axis than m (slope) is –1 and $\frac{1}{f}$ is intercept on y-axis.



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

20. (a)

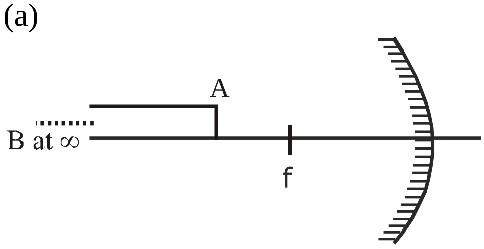


Figure shows a rod of infinite length with point A at distance u and B at infinity.

By using mirror formula we find the image of point A & B.

Point A

$u = -u \qquad f = -f$

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

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

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

Point B

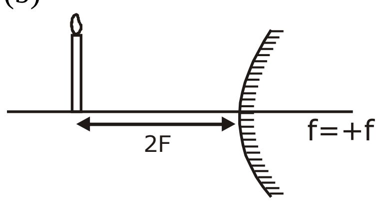
$u=-\infty \qquad f=-f$

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

$v=-f$.

Distance $=\frac{uf}{u-f}-f=\frac{f^2}{u-f}$

21. (b)



Taking $u=-2f$ & $f=+f$

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

$$\frac{1}{v}+\frac{1}{-2f}=\frac{1}{f}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{f}+\frac{1}{2f}=\frac{2+1}{2f}$$

$$m=-\frac{v}{u}=\frac{-2f/3}{-2f}=\frac{1}{3}$$

22. (b)

Magnification is –3 because image is real & inverted.

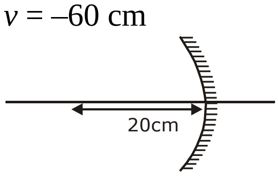
$$m=\frac{-v}{u}$$

$$-3=\frac{-v}{u}$$

$v=3u$.

given $u=-20$ cm

$v=-60$ cm



By using mirror formula

$$\frac{1}{60}-\frac{1}{20}=\frac{1}{f}$$

$f=-15\,\text{cm}$

23. (d)
Here $u = -30$ cm, $f = -15$ cm
Object is at centre of curvature
$\Rightarrow$ image will be real and of same size.

24. (a)
By using mirror formula
$u = +x$; $f = -f$
$$\frac{1}{v} = \frac{1}{-f} - \frac{1}{x}$$
$$\frac{1}{v} = \frac{1}{v} = \frac{-(x+f)}{xf} = -\text{ve (always)}$$
So if object virtual, image always real.

25. (a)
When object is real then image move from focus to pole.
So maximum distance $f = 20$ cm.

26. (c)
$$\frac{dv}{dt} = \frac{-v^2}{u^2}\frac{du}{dt}$$
$\Rightarrow \frac{dv}{dt}$ is opposite of $\frac{du}{dt}$
So, if $v = -$ve i.e. real image then away from mirror and if $v = +$ve i.e. virtual image then toward the mirror.

27. (d)
Irrespective of the type of mirror.

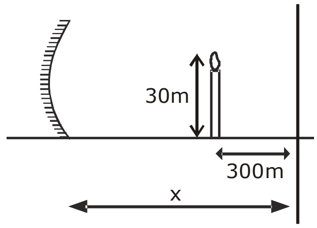
28. (d)
Focal length of the mirror is $R/2$ which depends on the sphere from which the mirror is cut out.

29. (b)
Only concave mirror forms larger image of an object.

30. (d)
Minimum distance between object and image is zero when image concides with the object i.e., object is placed at $2F$.

31. (b)
It is a convex mirror. It makes a virtual image always.

32. (c)



Magnification $= \frac{h_i}{h_0} = \frac{-v}{u}$

$\frac{h_i}{h_0} = \frac{-9}{3} = \frac{-v}{u}$

$3u = v$

$3(x - 300) = x$

$3x - 900 = x$

$2x = 900$

$x = 450$ cm.

33. (c)

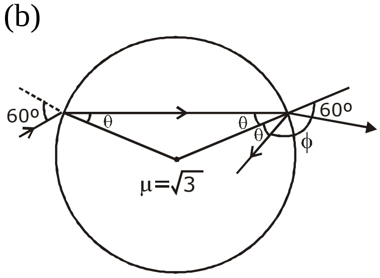
Velocity of light varies with medium. The relation between velocity & refractive index is given as

$\frac{n_2}{n_1} = \frac{v_2}{v_1}$

Where n is refractive index & v velocity of light in medium.

$\frac{\sin i}{\sin r} = \frac{H_2}{H_1} = \frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2}$

34. (b)



Applying Snell's law on surface of incidence

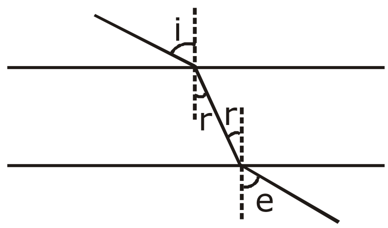
$\theta = \sin^{-1}\left(\frac{\sin 60}{\sqrt{3}}\right)$

$\phi = 180 - [60 + \theta]$

$\phi = 180 - \left[60^\circ + \sin^{-1}\left(\frac{\sin 60^\circ}{\sqrt{3}}\right)\right]$

$= 180^\circ - [60 + 30] = 90^\circ$

35. (a)



Incident angle and emergent angle will be same.
$\Rightarrow$ the angle between them is 0.

36. (a)

Shift by a glass slab of thickness t is given by $t\left(1-\frac{1}{\mu}\right)$

And shift is towards the path of incident light.

37. (c)
$i = 60°$
Displacement $= t\sec r\sin(i-r) = 5\sqrt{2}$

$= 15\sec r\left[\frac{\sqrt{3}}{2}\cos r - \frac{\sin r}{2}\right] = 5\sqrt{3}$

$\Rightarrow \frac{\sqrt{3}}{2} - \frac{\tan r}{2} = \frac{1}{\sqrt{3}}$

$\Rightarrow r = 30°$

Now, $\mu\sin r = \sin i$

$\mu = \frac{\sqrt{3}}{2}\times\frac{1}{2} = \sqrt{3}$

38. (a)
If light is travelling from medium B and suffers TIR it implies $\mu_B < \mu_A$.

$\theta_C = \sin^{-1}\left(\frac{\mu_B}{\mu_A}\right)$

$\theta = \sin^{-1}\left(\frac{V_A}{V_B}\right)$ $\left[\text{As } \frac{\mu_2}{\mu_1} = \frac{V_1}{V_2}\right]$

$\Rightarrow V_B = \frac{V_A}{\sin\theta} = \frac{V}{\sin\theta}$

39. (a)

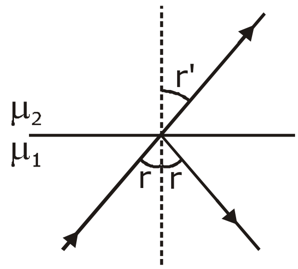
$r + r' = 90° \Rightarrow r' = (90 - r)$

$\mu_1 \sin r = \mu_2 \cos r$

$\tan r = \frac{\mu_2}{\mu_1}$

Critical angle $= \sin^{-1}\frac{\mu_2}{\mu_1}$

$= \sin^{-1}(\tan r)$



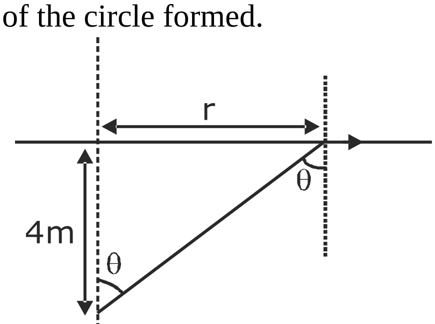
40. (c)

$\frac{\mu_A}{\mu_B} = \frac{V_B}{V_A} = \frac{2.5\times10^8}{2\times10^8} = 1.25$

$\theta_C = \sin^{-1}\left(\frac{1}{1.25}\right) = \sin^{-1}\left(\frac{4}{5}\right)$ [As $\theta_C = \sin^{-1}\frac{\mu_{\text{rarer}}}{\mu_{\text{denser}}}$]

41. (c)

In order to find the minimum diameter to block all the light we need to find the maximum radius of the circle formed.



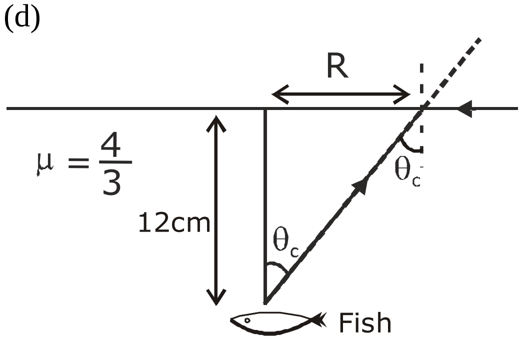
$\tan\theta = \frac{r}{4}$ $\Rightarrow$ $\sin^{-1}\frac{3}{5} = \theta$

$\tan^{-1}\frac{3}{4} = \theta$ $\Rightarrow$ $\frac{r}{4} = \frac{3}{4}$

[For radius to be maximum $\theta = \theta_C$] $\Rightarrow r = 3\,\text{m}$

Diameter = 6 m

42. (d)



$\tan\theta_C = \frac{R}{12}$ .....(1)

A ray of light interring at 90º from rarer medium makes an angle of refraction equal to critical angle in the denser medium and critical angle is given by

$$\theta_C = \sin^{-1}\frac{3}{4}$$

$$\theta_C = \tan^{-1}\frac{3}{\sqrt{7}} \qquad .....(2)$$

Equation (1) & (2)

$$\frac{3}{\sqrt{7}} = \frac{R}{12} \qquad \Rightarrow \qquad R = \frac{12\times 3}{\sqrt{7}}$$

43. (c)

We know that formula for deviation

$$\delta = i + e - A \quad \& \quad r_1 + r_2 = A$$

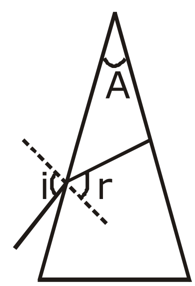
$$i = i \quad r_0 = 0 \quad r_1 + r_2 = A$$

$$e = 0 \quad r_1 = A$$

$$A = A$$

$$1\sin i = \mu \sin A$$

Because angles are small $i = \mu A$



44. (b)

For minimum deviation $i_{\min} = e$ and $r_1 = \frac{A}{2} = r_2 = r$

$$\delta = i + e - A = (i_{\min} - r) = 38° \qquad ...(1)$$

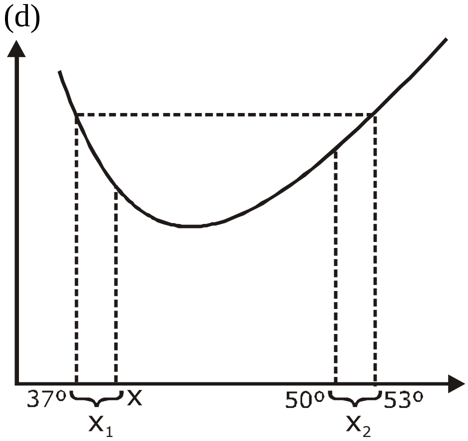
Now,

$$44° = 42° + 62 - 2r \quad \Rightarrow \quad r = 38° \qquad ...(2)$$

From (1) and (2)

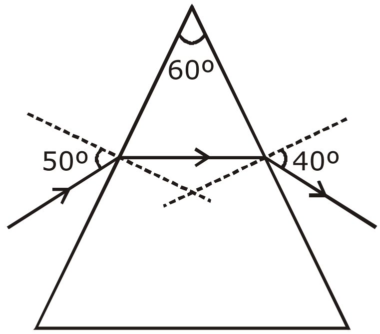
$$i_{\min} = 90°$$

45. (d)



In the graph for angle of deiration v/s angle of incidence the shift in angle of incidence on right side is more than that of left side $x_2 > x_1$. Hence only one angle is suitable e = 38º.

46. (b)

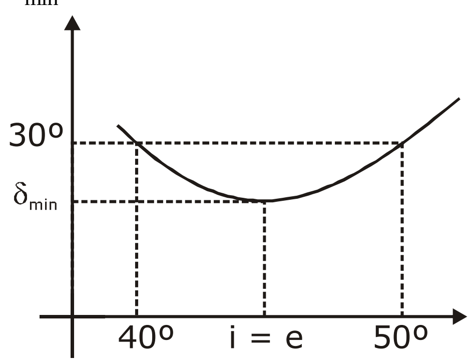


From the formula

$\delta = i + e - A$

$\delta = 50 + 40 - 60 = 30°$

$\delta_{min} < 30°$.



47. (c)

Using formula for relation between δ_{min} & A.

$$\mu = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\frac{A}{2}}$$

$$\sqrt{\frac{3}{2}} = \frac{\sin\left(\frac{90+\delta_{min}}{2}\right)}{\sin 45°}$$

$$\sin\left(\frac{90+\delta_{min}}{2}\right) = \frac{\sqrt{3}}{2}$$

$$\frac{90+\delta_{min}}{2} = 60° \quad \Rightarrow \quad \delta_{min} = 30°$$

48. (c)

$\delta_{min} = i + e - A$

$\delta_{min} = A$

So, $2A = 2i$

$i = A$

Now for refraction on first surface.

$\sin i = \mu \sin r_1$

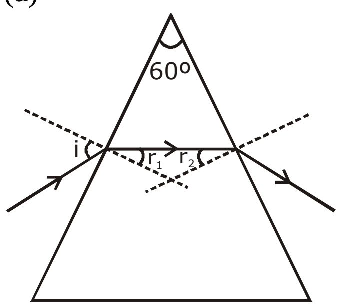
$\sin A = \frac{\mu \sin A}{2}$ [For minimum deviation $r_1 = r_2 = \frac{A}{2}$]

$2\cos\frac{A}{2}\sin\frac{A}{2} = \sqrt{3}\sin\frac{A}{2}$

$\cos\frac{A}{2} = \frac{\sqrt{3}}{2}$

$\frac{A}{2} = 30 \quad \Rightarrow \quad A = 60°$

49. (a)



For light be transmitted the ray should not suffer TIR at second refraction.
Hence $r_2 < \theta_C$.

If maximum value of r_2 is less than C then the ray will be always transmitted

$r_1 + r_2 = A$

$(r_2)_{max} = 60° - (r_1)_{min}$

For r_1 to be minimum i should be minimum

$\sin(i_{min}) = \sqrt{\frac{7}{3}}\sin(r_1)_{min}$

In limiting case $(r_2)_{max} = \theta_C$

$\theta_C = 60 - \sin^{-1}\left(\frac{\sin i_{min}}{\mu}\right)$

$\left(\sin^{-1}\left(\frac{1}{\mu}\right)\right) = \left[60 - \sin^{-1}\left(\frac{\sin i_{min}}{\mu}\right)\right]$

$\sin^{-1}\left(\frac{\sin i}{\mu}\right) = 60 - \sin^{-1}\sqrt{\frac{3}{7}}$

$\frac{\sin i}{\mu} = \frac{\sqrt{3}}{2}\cos\left(\sin^{-1}\sqrt{\frac{3}{7}}\right) - \frac{1}{2}\sqrt{\frac{3}{7}}$

$\sin i = \sqrt{\frac{7}{3}}\left[\frac{\sqrt{3}}{2}\times\frac{2}{\sqrt{7}} - \frac{\sqrt{3}}{2\sqrt{7}}\right]$

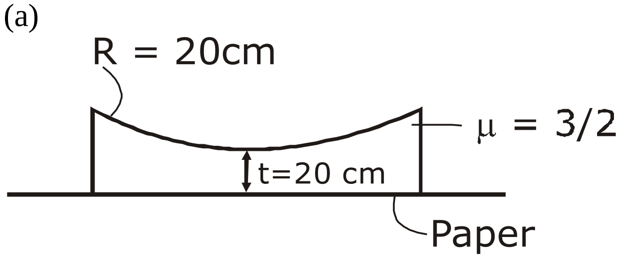
$\sin i = \left[1 - \frac{1}{2}\right] \quad \Rightarrow \quad i = 30°$

50. (d)
Given angle of incidence I_1
Given angle of emergence I_2
Condition for minimum devidation
$i = e \Rightarrow \therefore\ I_1 = I_2$

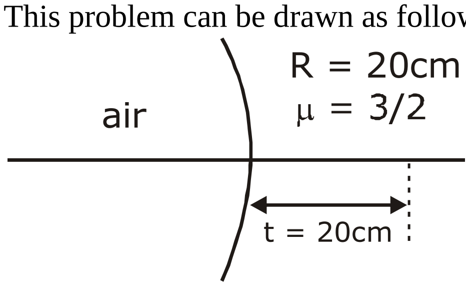
51. (a)
Using the given formula
$\delta = (n-1)A$ and $r_1 + r_2 = A$ and δ_{min} $r_1 = r_2 = r = \frac{A}{2}$
Hence, $\delta_{min} = r$.

52. (a)
Using the formula for refraction at spherical surface
$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$
$n_1 = \frac{3}{2}$
Here $n_1 = 1$
$u =$ 30 cm
$R = +20\,\text{cm}$
$\frac{1}{v} - \frac{3}{2\times 30} = \frac{1-3/2}{20}$
$v = +40\,\text{cm}$

53. (a)



This problem can be drawn as follows



$u = -20$ cm $\qquad$ $R = +20$ cm
$n_1 = \frac{3}{2}$ $\qquad$ $n_2 = 1$
From $\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$

$$= \frac{1}{v} + \frac{3}{2\times 20} = \frac{1-3/2}{20}$$
$$v = -10\text{ cm}$$

54. (d)
We know that $P = IA$ & $P \times t = E$

Hence $IA = \frac{E}{t}$

Initially energy/sec $= I \times \pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2 I}{4}$

Now energy/sec $= \left[\pi\left(\frac{d}{2}\right)^2 - \pi\left(\frac{d}{4}\right)^2\right]$

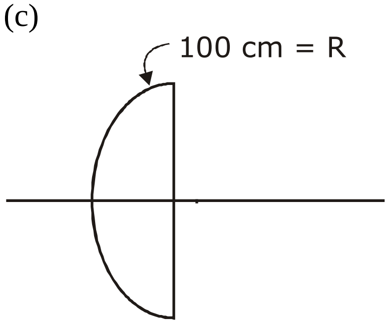
$= I\pi d^2\left[\frac{3}{16}\right]$

So, Now $\frac{\text{Final Intensity}}{\text{Initial Intensity}} = \frac{I\pi d^2\, 3/16}{I\pi d^2/4} = \frac{3}{4}$

Focus will not change.

55. (d)
On cutting the less parallel to its principal axis
f does not changes
So P will not change.

56. (c)



$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$
$$= \frac{1}{2}\left[\frac{1}{100} - \frac{1}{\infty}\right] = \frac{1}{200}$$
$$f = 200\text{ cm}$$

57. (a)

Using the formula $P = \frac{1}{f\,(\text{in m})}$

$p_1 = 2D$

$f_1 = \frac{100}{2} = +50\,\text{cm}$

$f_2 = -10$

$f_2 = -100\ \text{cm}$

$\frac{1}{f_{eq}} = \left[\frac{1}{f_1} - \frac{1}{f_2}\right]$

$= \left[\frac{1}{50} - \frac{1}{100}\right] = \left[\frac{2-1}{100}\right] = \frac{1}{100}$

$f_{eq} = 100\ \text{cm}$

58. (a)

We know that on cutting the lens into two parts perpendicular to its principal axis power of the two parts will be $P/2$ each. Let initial power of lens be P.

Then $(P_1)_f = (P_2)_f = \frac{P}{2}$

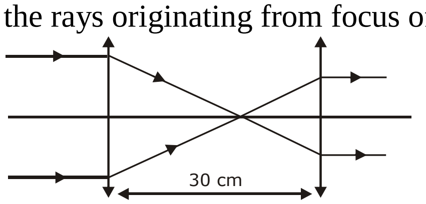
$P_f = (P_1)_f = (P_2)_f = P$

$\therefore \ P_i = P_f$

No change in power hence no change in focal length.

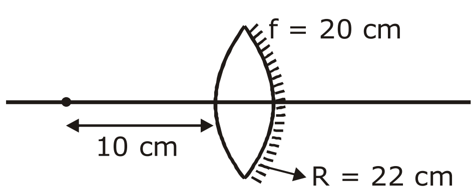
59. (b)

The rays coming from infinity parallel to principal axis and paraxial meet on focus after refraction and the rays originating from focus of the lens originate parallel to principal axis after refraction.



60. (b)

The focal length of mirror formed will be $f_m = \frac{R}{2}$



$f_m = -11\,\text{cm}$ [–ve sign as concave mirror is formed]

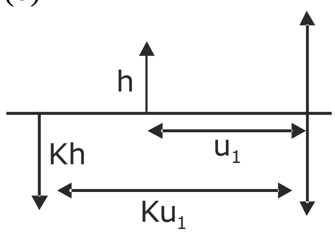
$f_\ell = 20\ \text{cm}$

$\frac{1}{f_{eq}} = \frac{1}{f_m} - 2\left[\frac{1}{f_\ell}\right]$

$= \frac{-1}{11} - \frac{-2}{20} = \frac{-10-11}{110}$

$f_{eq} = \frac{-110}{21}$

61. (b)



For case 1

$u = -u_1 \Rightarrow v = -ku_1 \Rightarrow f = -f$

$\frac{1}{ku_1} + \frac{1}{u_1} = \frac{1}{f}$ ...(1)

For case 2

$u = -u_2 \Rightarrow v = ku_2 \Rightarrow f = -f$

$-\frac{1}{ku_2} + \frac{1}{u_2} = \frac{1}{f}$ ...(2)

On solving (1) & (2)

$f = \frac{1}{2}(u_1 + u_2)$

62. (c)

From the formula

$h_0 = \sqrt{h_1 \times h_2} = \sqrt{8 \times 12.5} = 10\,\text{cm}$

63. (d)

All are true.

64. (d)

We know that $\theta_C = \sin^{-1}\frac{1}{\mu_{\text{glass}}}$ and μ_{glass} depends on wavelength of light $\mu_{\text{glass}} \propto \frac{1}{\lambda}$

When λ is minimum the m will be maximum & hence θ_C will be minimum.

λ is minimum for voilet hence θ_C is minimum for voilet light.

65. (c)

From the formula

$\frac{\text{Appartent depth}}{\text{Real depth}} = \frac{n_{air}}{n_{glass}}$

Apparent depth = Real depth $\times \frac{n_{air}}{n_{glass}}$

The letter which appear least raised has
maximum Apparent depth and hence it has minimum μ for glass.

$\mu \propto \frac{1}{\lambda}$

for μ to be minimum λ should be maximum which is for Red.

66. (b)

Using formula

$\omega = \frac{n_v - n_R}{n_y - 1}$ $\qquad$ $n_y = \frac{n_v + n_R}{2}$

$\omega = \frac{1.56 - 1.44}{1.5 - 1}$ $\qquad$ $n_y = \frac{1.56 + 1.44}{2} = 1.5$

$\omega = \frac{0.12}{0.5} = 0.24$

67. (a)

1.6333 – 1 = 1.6161 = 0.0172

$n_y - 1$

$\frac{1.6333 - 1.6161}{1.6247 - 1} = 0.276$

68. (b)

Disp. $(n_v - n_R)\, A$

69. (b)

Ray of Red light bends minimum because it has maximum λ & minimum μ.

70. (a)

71. (c)

72. (d)

73. (c)

74. (a)

75. (c)

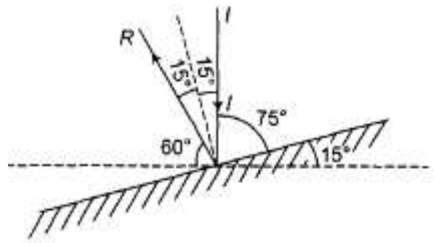
76. (b)

77. (a)

78. (a)

79. Image distance from plane mirror = object distance. Lateral magnifications = 1

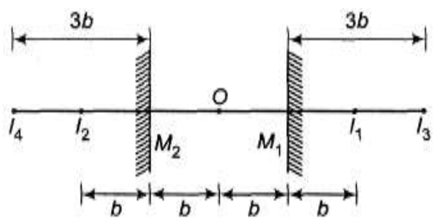
80.



I → Incident ray
R → Reflected ray
Angle of incidence = 15°
Angle between reflected ray and horizontal = 60°

81. Image from one mirror will behave like object for other mirror.

82.



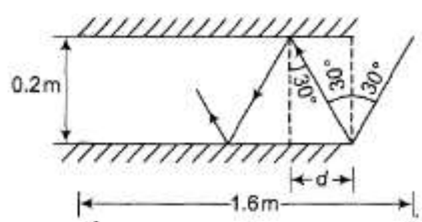
$OI_1 = OI_2 = 2b$

I_3 is the image of I_2 from mirror M_1 similarly I_4 is the image of I_1 from mirror M_2.

$OI_3 = OI_4 = 4b$

83. See point number - 3 of important points in reflection from plane mirror.

84.

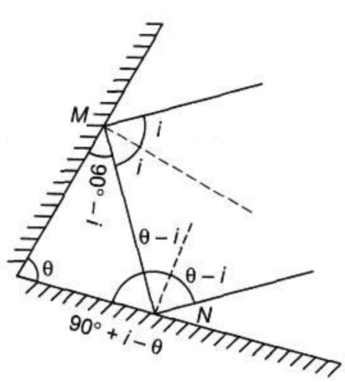


$\frac{d}{0.2} = \tan 30° = \frac{1}{\sqrt{3}} \quad \therefore \quad d = \frac{0.2}{\sqrt{3}}$

$N = \frac{1.6}{d} = 8\sqrt{3} = 13.85$

Therefore, actual number of reflections required are 14.

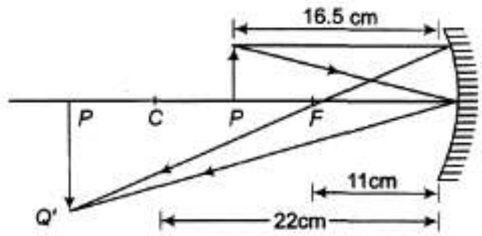
85.



$\delta_{total} = \delta_M + \delta_N$

$= (180- 2i) +[180 - 2 (\theta - 0]=360 - 2\theta$

86. **(a)**



(b) Apply, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ and

$m=-\frac{v}{u}$

87. $f = \frac{R}{2} = -18$ cm

Let u = -x cm

Then $v = -\frac{x}{9}$ cm for real image of $\frac{1}{9}$th size.

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

we have, $\frac{1}{(-x/9)}+\frac{1}{(-x)}=\frac{1}{-18}$

Solving we get, x = 180 cm

88. Image is inverted. So, it should be real and v should be negative.

u = – 30 cm

Then, v = – 15 cm as magnification is half.

Now, applying the equations

$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}=\frac{1}{-15}+\frac{1}{-30}$

f = – 10 cm

89. (a) $f = \frac{R}{2} = -12$ cm

Let u = (- x) cm

Then, v = (+ 3x) cm as image is virtual and three times magnified.

Using the equation

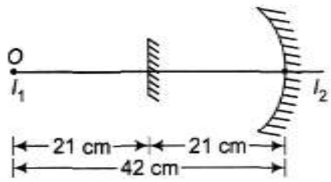
$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

we have, $\frac{1}{3x}+\frac{1}{-x}=\frac{1}{-12}$ *

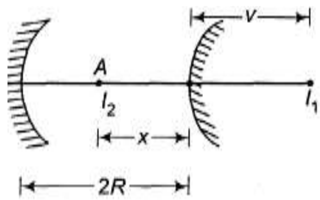
x = 8 cm

Similarly, other parts can be solved in the similar manner. For real image v should be negative and $|v| = m\,|u|$

90. O is placed at centre of curvature of concave mirror (= 42 cm). Therefore, image from this mirror I_1 will coincide with object O.



Now plane mirror will make its image I_2 at the same distance from itself.

91. 

For convex mirror.

$$\frac{1}{v}+\frac{1}{-x}=\frac{1}{+R/2}$$

∴ $$\frac{1}{v}=\frac{2}{R}+\frac{1}{x}$$

or $$v=\frac{Rx}{R+2x}$$

Now applying mirror formula for concave mirror we have

$$\frac{1}{-(2R-x)}+\frac{1}{-(2R+v)}=\frac{1}{-R/2}$$

Solving this equation, we can find value of x.

92. Actual distance from one side = μ - times = 6 × 1.5 = 9 cm
From other side = 4 × 1.5 = 6 cm
∴ Total thickness = (9 + 6) cm = 15 cm

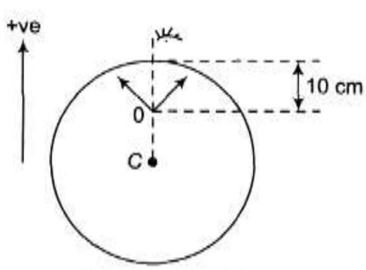
93. $_1\mu_2 \times {_2\mu_3} \times {_3\mu_1} = 1$

∴ $\frac{4}{3}\times\frac{3}{2}=\frac{1}{_3\mu_1}={_1\mu_3}$ or ${_1\mu_3}=2$

94. $\mu=\frac{c}{v}=\frac{c}{f\lambda}$

$=\frac{3\times10^8}{6\times10^{14}\times300\times10^{-9}}$

= 1.67

95. 

Using, $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$ we get,

$$\frac{1}{v}-\frac{1.5}{-10}=\frac{1-1.5}{-15}$$

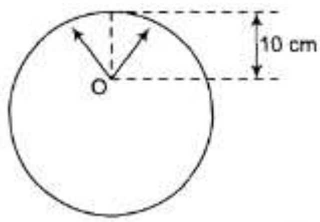
Solving we get v = - 8.57 cm

96. 

(a) Using, $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ we get,

$$\frac{1.5}{v} - \frac{1.0}{-20} = \frac{1.5 - 1.0}{+6}$$

Solving we get v = + 45 cm Similarly other parts can be solved.

97. 

Using $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ we get

$$\frac{1}{v} - \frac{4/3}{-10} = \frac{1 - 4/3}{-15}$$

Solving we get v = -9.0 cm

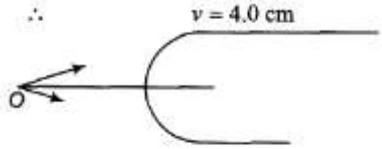
98. 

Using the equation,

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$ we get,

$$\frac{1.44}{v} - \frac{1.0}{\infty} = \frac{1.44 - 1.0}{+1.25}$$

$\therefore$ $v = 4.0$ cm

99. 

Using $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

we get, $\frac{1.635}{v} - \frac{1.0}{-9.0} = \frac{1.635 - 1.0}{+2.5}$

v = + 1.4 cm

Now, $m = \left(\frac{\mu_1}{\mu_2}\right)\left(\frac{v}{u}\right)$

$= \left(\frac{1.0}{1.635}\right)\left(\frac{1.14}{9.0}\right)$

= - 0.0777

100. $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\therefore \frac{1}{-20} - \frac{1}{-60} = (1.65 - 1)\left(\frac{1}{-R} - \frac{1}{+R}\right)$

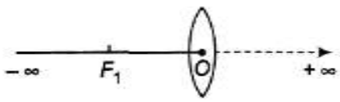
Solving we get, R = 39 cm

101. $\frac{1}{-50} - \frac{1}{u} = \frac{1}{+30}$

Solving we get u = - 18.75 cm

$m = \frac{v}{u} = \frac{(-50)}{(-18.75)} = 2.67$

I = m(O) = 2.67 × 2 = 5.33cm

102. 

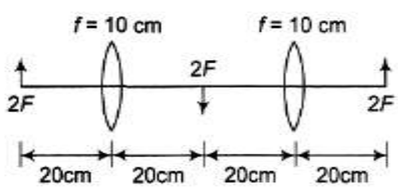
When object is moved from O to F_1 its virtual, erect and magnified image should vary from O to -∞.

103. (a) $\frac{1}{f} = \left(\frac{1.3}{1.8} - 1\right)\left(\frac{1}{-20} - \frac{1}{+20}\right)$

f = +36cm

(b) Between O and F_1 image is virtual. Hence for real image.

| μ | < f or 36 cm

104. 

105. It is just like a concave mirror

|f| = 0.2m |R|=0.4m Focal length of this equivalent mirror is

$\frac{1}{F} = \frac{2(\mu_2/\mu_1)}{R_2} - \frac{2(\mu_2/\mu_1 - 1)}{R_1}$ (extra points)

$= \frac{2(4/3)}{-0.4} - \frac{2(4/3-1)}{+0.4}$

or F= — 0.12 m or -12 cm

106. | R | = 0.5 m (from first case)

In the shown figure, object appears at distance

d = u_e(0.2) + 0.2

Now, for image to further coincide with the object,

d = |R| Solving we get, μ_e = 1.5

107. $O = \sqrt{I_1 I_2}$ (Displacement method)

$= \sqrt{6 \times \frac{2}{3}}$

= 2 cm

108. Virtual, magnified and erect image is formed by convex lens.

Let u = -x

Then v =-3x

Now, $\frac{1}{-3x}-\frac{1}{-x}=\frac{1}{+12}$

x = 8 cm

Distance between object and image = 3x - x = 2x = 16 cm

109. Diminished erect image is formed by concave lens.

Let u = - x then $v=-\frac{x}{2}$

Now, |u| - |v| = 20 cm $\frac{x}{2}$ =20 cm

or x = 40 cm

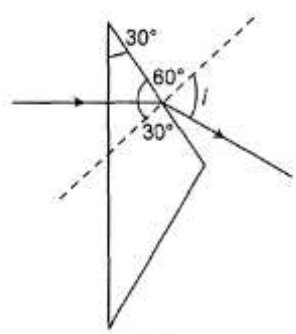
u = -40cm and v = -20cm

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

or f = -40cm

110. If object is placed at focus of lens (= 10 cm), rays become parallel and fall normal on plane mirror. So, rays retrace their path.

111.



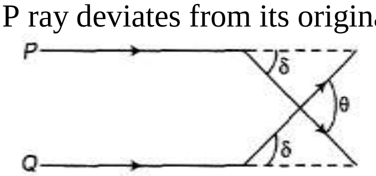
$\mu=\frac{\sin i}{\sin 30°}$

$\Rightarrow$ sin i = μ sin 30°

$= (1.6)\left(\frac{1}{2}\right) = 0.8$

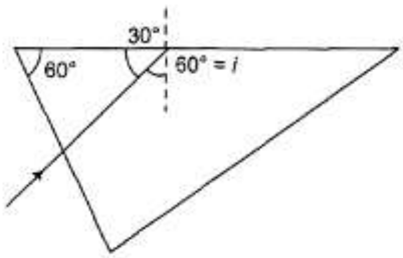
$\Rightarrow$ i = 53°

P ray deviates from its original path by an angle, δ = i - 30° = 23°



∴ Angle between two rays, θ = 2δ

= 46°

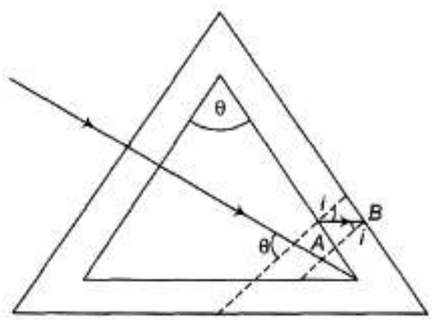
112. 

Critical angle = i = 60° = θ_c

$$\sin\theta_c = \frac{\mu_R}{\mu_D}$$

or $$\sin 60^\circ = \frac{\mu}{\sqrt{3}}$$

Solving we get, μ = 1.5

113. 

$i = \theta_c$

∴ $$\sin i = \sin\theta_c = \frac{1}{\mu_g} = \frac{2}{3}$$

Applying Snell's law at point A, We have

$$\mu_w \sin\theta = \mu_g \sin i$$

∴ $$\frac{4}{3}\sin\theta = \frac{3}{2}\times\frac{2}{3}$$

∴ $$\sin\theta = \frac{3}{4}$$

114. Deviation by prism,

$\delta = (\mu - 1)A$

$= (1.5 - 1)(4^\circ)$

$= 2^\circ$

Without prism ray of light is falling normal on the mirror.

So, they retrace their path. Prism has rotated it by 2°, so we should also rotate the mirror by 2° for again falling normally on it.

115. $$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin(A/2)}, \delta_m = 30^\circ$$

116. $i_1 = 0^\circ \Rightarrow \quad r_1 = 0^\circ$

or $r_2 = A$

Now $r_2 = \theta_c = A$

∴ $\sin A = \sin\theta_c = \frac{1}{\mu} = \frac{2}{3}$

or $A = \sin^{-1}\left(\frac{2}{3}\right)$

117. $\delta = i_1 + i_2 - A$

$30° = 60° + i_2 - 30°$ $i_2 = 0$ or $r_2 = 0$.

$\Rightarrow$ $r_1 = A = 30°$

Now, $\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin 60°}{\sin 30°} = \sqrt{3}$

118. $\sqrt{2} = \frac{\sin i_1}{\sin (i_1/2)} = \frac{2\sin(i_1/2)\cos(i_1/2)}{\sin (i_1/2)}$

Solving this we get $i_1 = 90°$ and $r_1 = \frac{i_1}{2} = 45^o$

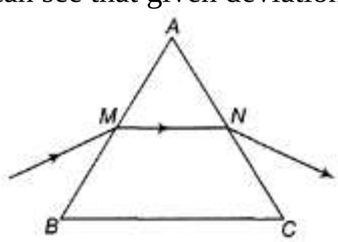
At minimum deviation,

$r_2 = r_1 - 45^o$

$A = r_1 + r_2 = 90°$

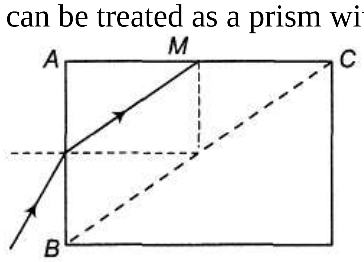
119. From $\mu = \sin\left(\frac{A+\delta_m}{2}\right) / \sin(A/2)$

We can see that given deviation is the minimum deviation.



At minimum deviation, MN is paralled to BC is $\angle B = \angle C$.

120. ABC can be treated as a prism with angle of prism A = 90°. Condition of no emergence is



$A \geq 2\theta_c$ or $\sin\theta_c \leq \sin\left(\frac{A}{2}\right)$

or $\frac{1}{\mu} \leq \sin 45°$ or $\frac{1}{\mu} \leq \frac{1}{\sqrt{2}}$

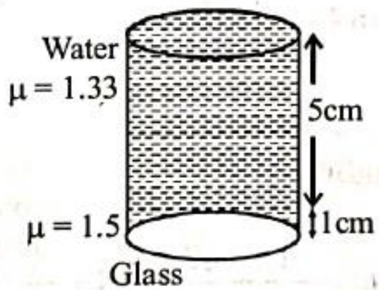
∴ $\mu \geq \sqrt{2}$

PYQ : JEE Main

MCQs with One Correct Answer

1. (c)

(c) Real depth = 5 cm + 1cm = 6 cm



Apparent depth $= \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} = \frac{5}{1.33} + \frac{1}{1.5}$

$\simeq 3.8 + 0.7 \simeq 4.5$ cm

$\therefore$ Shift = 6 cm – 4.5 cm $\cong$ 1.5 cm

So most appropriate option will be (c).

2. (b)

(b) Velocity of light in medium

$$V_{med} = \frac{3\,\text{cm}}{0.2\,\text{ns}} = \frac{3 \times 10^{-2}\,\text{m}}{0.2 \times 10^{-9}\,\text{s}} = 1.5 \times 10^{8}\,\text{m/s}$$

Refractive index of the medium

$$\mu = \frac{V_{air}}{V_{med}} = \frac{3 \times 10^{8}}{1.5 \times 10^{8}\,\text{m/s}} = 2$$

As $\mu = \frac{1}{\sin C}$ $\therefore$ $\sin C = \frac{1}{\mu} = \frac{1}{2} = 30°$

Condition of TIR is angle of incidence i must be greater than critical angle. Hence ray will suffer TIR in case of (B) $(i = 40° > 30°)$ only.

3. (c)

(c) One side of mirror is opaque and another side is reflecting this is not in case of lens hence, it is easier to provide mechanical support to large size mirrors than large size lenses. Reflecting telescopes are based on the same principle except that the formation of images takes place by reflection instead of refraction.

4. (d)

(d) If side of object square = ℓ
and side of image square = ℓ'

From question, $\dfrac{\ell'^2}{\ell^2} = 9$

or $\dfrac{\ell'}{\ell} = 3$

i.e., magnification m = 3
u = – 40 cm
v = 3 × 40 = 120 cm
f = ?

From formula, $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f} \Rightarrow \dfrac{1}{120} - \dfrac{1}{-40} = \dfrac{1}{f}$

or, $\dfrac{1}{f} = \dfrac{1}{120} + \dfrac{1}{40} = \dfrac{1+3}{120}$ $\therefore$ f = 30 cm

5. (c)

(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.

6. (d)

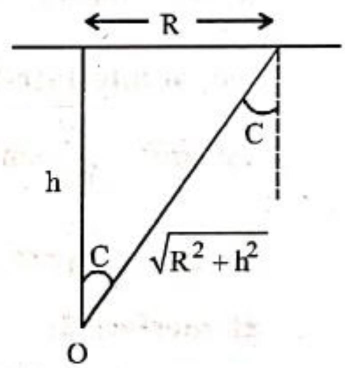
(d) Given, Focal length of objective, $f_0 = 30$ cm
focal length of eye lens, $f_e = 3.0$ cm
Magnifying power, M = ?
Magnifying power of the Galilean telescope,

$$M_D = \frac{f_0}{f_e}\left(1 - \frac{f_e}{D}\right) = \frac{30}{3}\left(1 - \frac{3}{25}\right) \quad [\because D = 25 \text{ cm}]$$

$$= 10 \times \frac{22}{25} = 8.8 \text{ cm}$$

7. (d)

(d) $\sin C = \frac{1}{\mu} = \frac{R}{\sqrt{R^2+h^2}} = \frac{3}{4}$



$\Rightarrow \quad 16\,R^2 = 9\,R^2 + 9\,h^2$

$\Rightarrow 7R^2 = 9\,h^2$

$\Rightarrow \quad R = \frac{3}{\sqrt{7}} h = \frac{3}{\sqrt{7}} \times 15\,\text{cm}$

8. (d)

(d) Ist position:

$u = -x, v = +y$

$m_1 = \frac{v}{u} = \frac{+y}{-x}$

IInd position:

$u = -y, v = +x$

$m_2 = \frac{v}{u} = \frac{+x}{-y}$

Here, $\frac{m_1}{m_2} = \frac{3}{2} \Rightarrow \frac{y}{x} = \sqrt{\frac{3}{2}}$ ...(i)

Also, $y - x = 10$ ...(ii)

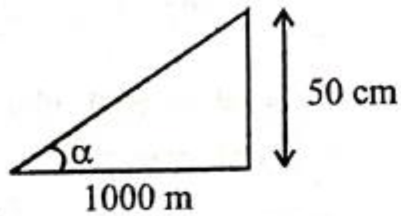
solving (i) & (ii), we get

$y = 44.5$ cm and $x = 54.5$ cm

So, $d = x + y = 99$ cm

9. (c)

(c) $M.P = \frac{f_0}{f_e} = \frac{150}{5} = 30$



$\tan\alpha = \frac{50}{1000} = \frac{1}{20}$

According to the question,
angle formed by the image of the tower is θ. We can write

$\tan\beta = \tan\theta$ ...(i)

$\tan\beta = (M.P)\tan\alpha$ [∵ α and β are small]

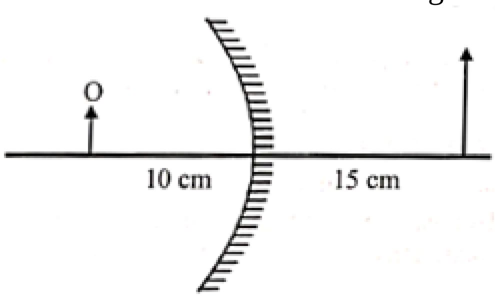
$= 30\times\frac{1}{20} = \frac{3}{2} = 1.5$

from (i), $\tan\theta = 1.5$

$\theta = \tan^{-1}(1.5) = 56.31°$

10. (c)

Convex mirror is used as a shaving mirror.



From question : $v = 15\,\text{cm}, u = -10\,\text{cm}$

Radius of curvature, $R = 2f = ?$

Using mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$\frac{1}{15} + \frac{1}{(-10)} = \frac{1}{f} \Rightarrow f = -30\,\text{cm}$

Therefore radius of curvature, $R = 2f = -60\,\text{cm}$

11. (d)

(d) $P=\frac{1}{f}$

$|P| = P_1 + P_2 = \frac{1}{f}+\frac{1}{f}=\frac{2}{f}$

As there is reflection happening, the power will have negative sign so

$$P=-\frac{2}{f}\Rightarrow f_{eff}=-\frac{f}{2}$$

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

$$\frac{1}{\frac{-a}{3}}+\frac{1}{-a}=\frac{1}{\frac{-f}{2}}\Rightarrow\frac{-3}{a}+\frac{-1}{a}=\frac{-2}{f}\Rightarrow a=2f$$

12. (c)

(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°

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

13. (b)

(b) $M=\frac{\theta_2}{\theta_0},\ 20=\frac{h/d_i}{h/d_0}\Rightarrow 20=\frac{d_0}{d_i}\Rightarrow d_i=\frac{d_0}{20}$

14. (b)

(b) Given, radius of hemispherical glass R = 10 cm

$\therefore$ Focal length $f = \frac{10}{2} = -5$ cm

$u = (10 - 6) = -4$ cm.

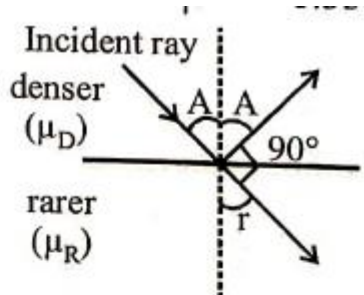
By using mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} + \frac{1}{-4} = \frac{1}{-5} \Rightarrow v = 20 \text{ cm.}$$

Apparent height, $h_a = h_r . \frac{\mu_r}{\mu_i} = 30 \times \frac{1}{1.5} = 20$ cm below flat surface.

15. (d)

(d)



From Snell's law, $\frac{\mu_R}{\mu_D} = \frac{\sin i}{\sin r}$ ..... (i)

If $\angle i = A$ and $\angle r = (90° - A)$

We also know that, $\sin\theta_C = \frac{\mu_R}{\mu_D}$

From equation (i), $\sin\theta_C = \frac{\sin A}{\sin(90° - A)}$

$\Rightarrow \sin\theta_C = \frac{\sin A}{\cos A}$

$\Rightarrow \sin\theta_C = \tan A \Rightarrow A = \tan^{-1}(\sin\theta_C)$

16. (a)

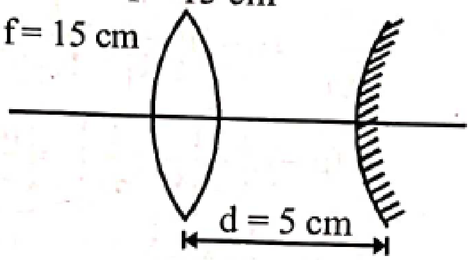
(a) Given, focal length of lens (f) = 15 cm
object is placed at a distance (u) = – 20 cm
By lens formula,

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, u = – 20 cm, f = 15 cm

$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{15} - \frac{1}{20}$

$\Rightarrow \frac{1}{v} = \frac{4-3}{60}$

v = 60 cm

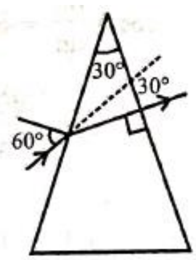


for mirror, u = 55 cm
for the mirror to form image at 'O'

$u = R = 2f \Rightarrow f = \frac{R}{2} = 27.5\text{cm}$

17. (c)

(c) Angle of prism, A = 30°, i = 60°,
angle of deviation, δ = 30°
Using formula, δ = i + e – A
$\Rightarrow e = \delta + A - i$
$= 30° + 30° - 60° = 0°$
∴ Emergent ray will be perpendicular to the face
So it will make angle 90° with the face through which it emerges.



18. (a)

(a) For minimum spherical aberration separation,
$d = f_1 - f_2 = 2$ cm
Resultant focal length = F = 10 cm

Using $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$ and solving, we get f_1, f_2 as 18 cm and 20 cm respectively.

19. (c)

4. **(c)** For minimum deviation:

$$r_1 = r_2 = \frac{A}{2} = 30^o$$

by Snell's law $\mu_1 \sin i = \mu_2 \sin r$

$$1 \times \sin i = \sqrt{3} \times \frac{1}{2} = \frac{\sqrt{3}}{2} \Rightarrow i = 60$$

20. (c)

$$5 = -\frac{v}{u} \Rightarrow v = -5u$$

Using $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{-5u} + \frac{1}{u} = \frac{1}{0.4}$

$\therefore \; u = 0.32\text{ m}$

21. (c)

(c) If v is the distance of image formed by mirror, then

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} + \frac{1}{-5} = \frac{1}{-20} \quad \therefore \; v = \frac{20}{3}\text{cm}$$

Distance of this image from water surface

$$= \frac{20}{3} + 5 = \frac{35}{3}\text{cm}$$

Using, $\frac{RD}{AD} = \mu$

$$\therefore \; AD = d = \frac{RD}{\mu} = \frac{(35/3)}{1.33} = 8.8\text{ cm}$$

22. (d)

(d) From the equation of line

$m = k_1 v + k_2 \quad (\because y = mx + c)$

$$\Rightarrow \frac{v}{u} = k_1 v + k_2 \quad \left(\because m = \frac{v}{u}\right)$$

$$\Rightarrow \frac{1}{u} = k_1 + \frac{k_2}{v} \quad \text{(Dividing both sides by v)}$$

$$\Rightarrow \frac{k_2}{v} = \frac{1}{u} - k_1 \Rightarrow \frac{k_2}{v} - \frac{1}{u} = -k_1$$

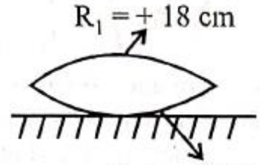
Comparing with lens formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$, we get

$$k_1=\frac{1}{-f}\Rightarrow f=-\frac{1}{k_1}=-\frac{1}{\text{slope of m - v graph}}$$

$$\therefore f=\frac{-1}{\text{slope of } m-v \text{ graph}}=-\frac{b}{c}$$

23. (a)

(a) $\frac{1}{f_{lens}}=(\mu_\ell-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

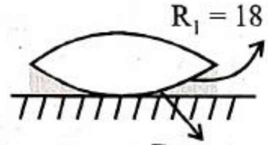


$=(1.5-1)\left(\frac{1}{-18}-\frac{1}{-18}\right)=\frac{1}{18}$

$\therefore f_{lens}=18$ cm

For liquid in between lens

$\frac{1}{f_{liq}}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$



$=(\mu-1)\left(\frac{1}{-18}-\frac{1}{\infty}\right)=\left(\frac{\mu-1}{-18}\right)$

$\therefore \frac{1}{f}=\frac{1}{f_{liq}}+\frac{1}{f_{lens}}$

$\Rightarrow \frac{1}{27\text{cm}}=\frac{1}{18\text{cm}}-\frac{(\mu-1)}{18\text{cm}} \quad \Rightarrow \mu=\frac{4}{3}$

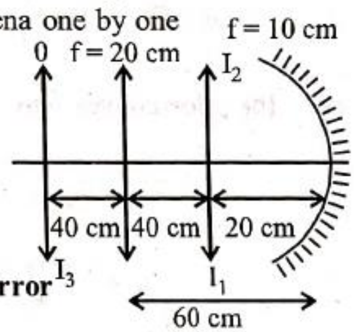
24. (b)

(b) We will have 3 phenomena one by one

(i) Refraction from lens.

(ii) Reflection from mirror

(iii) Refraction from lens



Ist refraction from lens

$u=-40, f=+20\text{cm}$

$\Rightarrow V=+40$ cm (I_1), $m_1=-1$

Reflection from concave mirror

$u=-20\text{cm}, f=-10\text{cm}$

$\Rightarrow V=-20$ cm (I_2) and $m_2=-1$

2nd refraction from lens

$u=-40\text{cm}, f=+20\text{cm}$

$\Rightarrow V=40$ cm (I_3) and $m_3=-1$

So, $M_{net}=-1\times-1\times-1=-1$

$\therefore$ Final image is formed at distance 40 cm from the convergent lens and is of same side as the object

25. (d)

(d) By lens formula

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}-\frac{1}{(-20)}=\frac{10}{3}$$

$$\frac{1}{v}=\frac{10}{3}-\frac{1}{20}\Rightarrow\frac{1}{v}=\frac{197}{60}\Rightarrow v=\frac{60}{197}$$

Magnification of lens (m) is given by

$$m=\left(\frac{v}{u}\right)=\frac{\left(\frac{60}{197}\right)}{20}$$

velocity of image wrt. to lens is given by

$v_{I/L}=m^2v_{O/L}$

direction of velocity of image is same as that of object

$v_{O/L}=5$ m/s

$$v_{I/L}=\left(\frac{60\times1}{197\times20}\right)^2(5)=1.16\times10^{-3}\text{ m/s towards the lens}$$

26. (d)

(d) For telescope

Tube length (L) $=f_o+f_e=60$

and magnification $(m)=\frac{f_o}{f_e}=5\Rightarrow f_0=5f_e$

$\therefore\quad f_o=50$ cm and $f_e=10$ cm

Hence focal length of eye-piece, $f_e=10$ cm

27. (a)

(a) According question, $M=375$

$L=150$ mm, $f_0=5$ mm and $f_e=?$

Using, magnification, $M=\frac{L}{f_0}\left(1+\frac{D}{f_e}\right)$

$$\Rightarrow375=\frac{150}{5}\left(1+\frac{250}{f_e}\right)\quad(\because D=25\text{ cm}=250\text{ mm})$$

$$\Rightarrow12.5=1+\frac{250}{f_e}\Rightarrow f_e=\frac{250}{11.5}=21.7\approx22\,mm$$

28. (b)

(b) As, $n=\sqrt{\mu_r\varepsilon_r}=\sqrt{\frac{4}{3}\times 3}=2$

And, $\sin\theta_c=\frac{1}{n}=\frac{1}{2}$ $\therefore$ Critical angle, $\theta_c=30°$

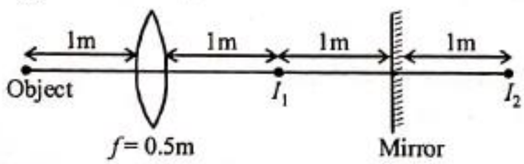
29. (a)

(a) Focal length of the convex lens, $f=0.5$ m

Object is at $2f$ so, image (I_1) will also be at $2f$.

Image of I_1 i.e., I_2 will be 1 m behind mirror.

Now I_2 will be object for lens.



$\therefore u=(-1)+(-1)+(-1)=-3$ m

Using lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\Rightarrow \frac{1}{v}=\frac{1}{f}+\frac{1}{u}=\frac{1}{+0.5}+\frac{1}{-3}$ or $v=\frac{3}{5}=0.6$ m

Hence, distance of image from mirror

$=2+0.6=2.6$ m and real.

30. (50)

(50) Given : Length of compound microscope, $L=10$ cm

Focal length of objective $f_0=1$ cm and of eye-piece, $f_e=5$ cm

$u_0=f_e=5$ cm

Final image formed at infinity (∞), $v_e=\infty$

$v_0=10-5=5$

Using lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\frac{1}{v_0}-\frac{1}{u_0}=\frac{1}{f_0}\Rightarrow\frac{1}{5}-\frac{1}{u_0}=\frac{1}{1}\Rightarrow u_0=-\frac{5}{4}$ cm

$\Rightarrow\frac{5}{4}=\frac{N}{40}\Rightarrow N=\frac{200}{4}=50$ cm.

31. (a)

(a) According to prism formula,

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

Here, δ_m = angle of minimum deviation

A = angle of prism

We have given, $\delta_m = A$

$$\therefore \quad \mu = \frac{\sin A}{\sin A/2} \Rightarrow \mu = 2\cos\frac{A}{2} \Rightarrow A = 2\cos^{-1}\left(\frac{\mu}{2}\right)$$

32. (d)

Mirror will be convex mirror

$V_i = -m^2 v_0$

V_i is velocity of image w.r.t. mirror

V_0 is velocity of object w.r.t. mirror

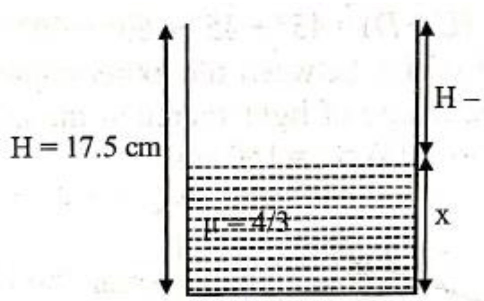
$V_0 = 40$ m/s

Magnification $m = \frac{f}{f-u} = \frac{10}{10+190} = \frac{1}{20}$

$v_i = -\frac{1}{20^2} \times 40 = -0.1$ m/s

33. (a)

(a)



For an observer outside the water, height of water

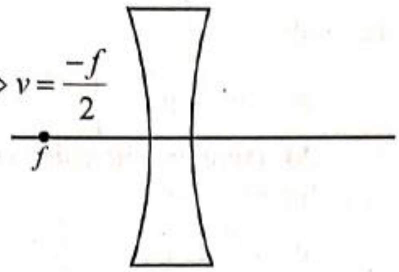
$$= \frac{x}{\mu_w} = \frac{x}{(4/3)} = \frac{3x}{4}$$

Now, $\frac{3x}{4} = \frac{17.5}{2} \Rightarrow x = \frac{35}{3} = 11.7$ cm

34. (c)

(c) $u=-f$

Using lens formula



$$\frac{1}{v}-\frac{1}{u}=\frac{1}{-f}\Rightarrow\frac{1}{v}=-\frac{2}{f}\Rightarrow v=\frac{-f}{2}$$

$$m=\frac{v}{u}=\frac{1}{2}$$

Distance $=\dfrac{f}{2}$

35. (b)

(b) Focal length of plano-convex lens

$$\frac{1}{f_1}=(\mu_1-1)\left(\frac{1}{R}\right) \qquad [\because R_1=\infty \text{ and } R_2=-R]$$

Focal length of plano-concave lens

$$\frac{1}{f_2}=(\mu_2-1)\left(\frac{-1}{R}\right) \qquad [\because R_1=-R \text{ and } R_2=\infty]$$

Focal length of combination

$$\frac{1}{f_{eq}}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{(\mu_1-1)-(\mu_2-1)}{R}$$

$$\Rightarrow\frac{1}{f_{eq}}=\frac{(\mu_1-\mu_2)}{R}\Rightarrow\frac{R}{f_{eq}}=(\mu_1-\mu_2)$$

36. (d)

(d) In given case, medium 1 has refractive index 1.25 and medium 2 has refractive index 1.4.

From the refraction formula

$$\frac{n_2}{v}-\frac{n_1}{u}=\frac{n_2-n_1}{R}\Rightarrow\frac{1.4}{v}-\frac{1.25}{-40}=\frac{1.4-1.25}{(-25)}$$

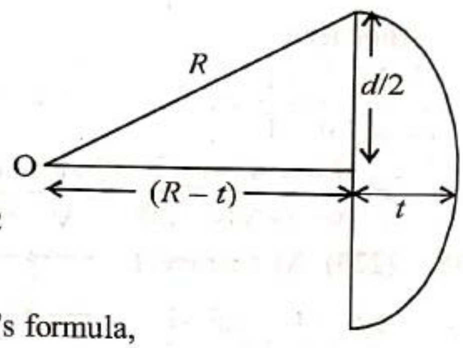
$$\Rightarrow\frac{1.4}{v}=\frac{-0.15}{25}\frac{-1.25}{40}\Rightarrow v=-37.58\text{cm}$$

37. (d)

(d) From figure,

$t = 0.3$ cm

$\frac{d}{2} = 3$ cm



So, $R^2 = (R - 0.3)^2 + 3^2$

$\Rightarrow \quad R = 15$ cm

Now from Lens maker's formula,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_{flat}} - \frac{1}{R_2}\right)$$

$$\Rightarrow \quad \frac{1}{f} = (\mu - 1) \times \frac{1}{R} \qquad [\because R_{flat} = \infty \text{ and } R_2 = -R]$$

$$\Rightarrow \quad \frac{1}{f} = \frac{(1.5 - 1)}{15} \Rightarrow f = 30 \text{ cm}$$

38. (c)

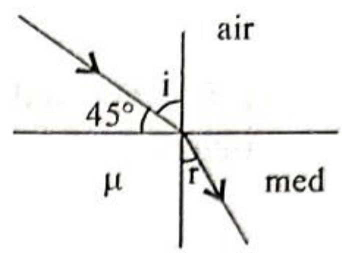
(c) $i = 45°, D = 15°$

$D = i - r$

$15° = 45° - r \Rightarrow r = 30°$

$n_1 \sin 1 = n_2 \sin r$ (from snells's law)

$1 \sin 45° = \mu \sin 30°$



39. (a)

(a) $n_d \sin i_c = n_r \sin 90°$ ($\because$ From Snell's law)

$$\sin i_c = \frac{n_r}{n_d} = \frac{v_d}{v_r} \qquad \left(\therefore v = \frac{c}{n}\right)$$

$$\sin i_c = \frac{1.5 \times 10^8}{2 \times 10^8} = \frac{1.5}{2}$$

$$\sin i_c = \frac{3}{4}$$

$$\tan i_c = \frac{3}{\sqrt{4^2 - 3^2}} \Rightarrow \frac{3}{\sqrt{7}}$$

The critical angle between them, $i_c = \tan^{-1}\left(\frac{3}{\sqrt{7}}\right)$

40. (a)

(a) $t_2 - t_1 = 5 \times 10^{-10}$

$$\Rightarrow \frac{d}{v_B} - \frac{d}{v_A} = 5\times10^{-10} \Rightarrow \frac{d\mu_B}{C} - \frac{d\mu_A}{C} = 5\times10^{-10}$$

$$\Rightarrow d\left(\frac{\mu_B}{C} - \frac{\mu_A}{C}\right) = 5\times10^{-10}$$

$$\Rightarrow d\left(\frac{2\mu_A}{C} - \frac{\mu_A}{C}\right) = 5\times10^{-10}$$

$$\Rightarrow d = \frac{5\times10^{-10}}{\frac{\mu_A}{C}} = 5\times10^{-10} V_A m$$

41. (d)

(d) We know that critical angle is given by

$$\sin C = \frac{\mu_r}{\mu_d} \text{ and } \mu \propto \frac{1}{V} \Rightarrow \frac{\mu_r}{\mu_d} = \frac{v_d}{v_r} = \frac{1.5\times10^{10}}{2\times10^{10}} = \frac{3}{4}$$

So, $\sin C = \frac{3}{4} \Rightarrow C = \sin^{-1}\left(\frac{3}{4}\right)$

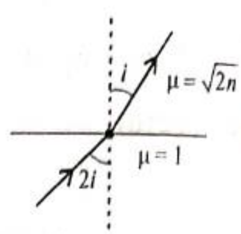
Therefore, for TIR

$$\theta > C \Rightarrow \theta > \sin^{-1}\left(\frac{3}{4}\right)$$

42. (d)

(d) Let $2i$ be angle of incidence

By Snell's law



$$\Rightarrow 1 \sin 2i = \sqrt{2n} \sin i$$

$$\Rightarrow 2 \sin i \cos i = \sqrt{2n} \sin i$$

$$\Rightarrow \cos i = \sqrt{\frac{n}{2}} \Rightarrow i = \cos^{-1}\left(\sqrt{\frac{n}{2}}\right)$$

$$\Rightarrow 2i = 2\cos^{-1}\left(\sqrt{\frac{n}{2}}\right)$$

43. (c)

(c) On going from rare to denser, frequency remain unchanged, whereas speed and wavelength decreases because $V \propto \frac{1}{\mu}$ and $\lambda \propto \frac{1}{\mu}$.

44. (d)

(d) $P = \frac{1}{f} = (\mu_1 - \mu_2)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

(μ_1 is refractive index of lens and μ_2 is of surrounding medium)

$\Rightarrow 1.25 = (1.5 - \mu_2)\left(\frac{1}{0.2} + \frac{1}{0.4}\right)$

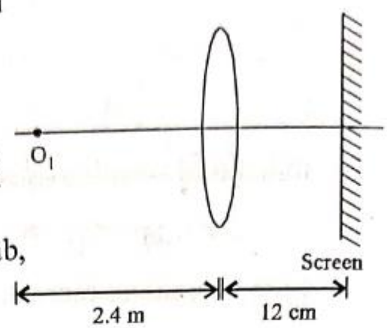
$\Rightarrow \frac{1.25 \times 0.08}{0.6} = (1.5 - \mu_2) \Rightarrow \mu_2 = \frac{4}{3}$

45. (b)

(b) Applying lens formula

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

$\frac{1}{0.12} + \frac{1}{2.4} = \frac{1}{r} \Rightarrow \frac{1}{f} = \frac{210}{24}$



Upon putting the glass slab, shift of image is

$\Delta x = t\left(1 - \frac{1}{\mu}\right) = \frac{1}{3}\text{cm}$

Now $v = 12 - \frac{1}{3} = \frac{25}{3}$ cm

Again apply lens formula

$\frac{1}{0.12} + \frac{1}{u} = \frac{1}{f} = \frac{210}{24} \Rightarrow \frac{1}{u} = \frac{210}{24} - \frac{1}{0.12}$

Solving we get u = –5.6 m

Thus shfit of object is 5.6 – 2.4 = 3.2 m

46. (a)

(a) In primary rainbow red is at top and violoet is at bottom becuase violet colour has smallest wavelength and it suffer maximum refraction.

47. (a)

(a) We known that

$$\mu = \frac{\frac{\sin(A+\delta m)}{2}}{\sin\left(\frac{A}{2}\right)} \Rightarrow \cot\frac{A}{2} = \frac{\sin\left(\frac{A+\delta m}{1}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\Rightarrow \cos\left(\frac{A}{2}\right) = \sin\left(\frac{A+\delta m}{2}\right)$$

$$\Rightarrow \sin\left(\frac{\pi}{2}-\frac{A}{2}\right) = \sin\left(\frac{A}{2}+\frac{\delta m}{2}\right)$$

$$\Rightarrow \frac{\pi}{2}-\frac{A}{2} = \frac{A}{2}+\frac{\delta m}{2} \Rightarrow \frac{\pi}{2}-A = \frac{\delta m}{2}$$

$$\therefore\ \delta m = \pi - 2A$$

Numerical Value Answer

48. (1)

Distance of object, $u = -30$ cm

Distance of image, $v = 10$ cm

Magnification, $m = \frac{-v}{u} = \frac{(-10)}{-30} = \frac{1}{3}$

Speed of image $= m^2 \times$ speed of object $= \frac{1}{9} \times 9 = 1\ \text{cm s}^{-1}$

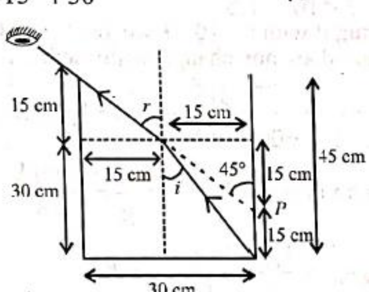
49. (158)

(158) From figure, $\sin i = \frac{15}{\sqrt{15^2+30^2}}$

$\sin r = \frac{15}{15} = 1 \Rightarrow r = 45°$

From Snell's law, $\mu \times \sin i = 1 \times \sin r$

$$\Rightarrow \mu \times \frac{15}{\sqrt{15^2+30^2}} = 1 \times \sin 45° = \frac{1}{\sqrt{2}}$$

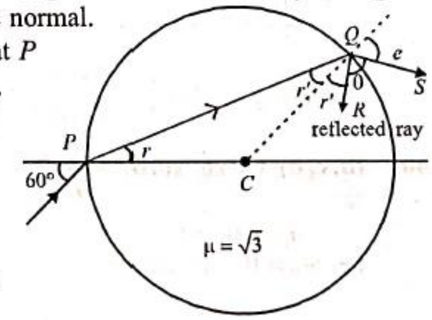


$$\therefore \mu = \frac{\frac{1}{\sqrt{2}}}{\frac{15}{\sqrt{1125}}} = 158 \times 10^{-2} = \frac{N}{100}$$

Hence, value of $N \simeq 158$.

50. (90)

(90.00) In the figure, QR is the reflected ray and QS is refracted ray. CQ is normal.



Apply Snell's law at P

$$1\sin 60° = \sqrt{3}\sin r$$

$$\Rightarrow \sin r = \frac{1}{2}$$

$$\Rightarrow r = 30°$$

From geometry,

$CP = CQ =$ radius

$$\therefore r' = 30°$$

Again apply snell's law at Q,

$$\sqrt{3}\sin r' = 1\sin e \Rightarrow \frac{\sqrt{3}}{2} = \sin e \Rightarrow e = 60°$$

From geometry

$r' + \theta + e = 180°$ (As angles lies on a straight line)

$$\Rightarrow 30° + \theta + 60° = 180° \Rightarrow \theta = 90°.$$

51. (476.19)

- **(476.19)** Given,

Distance between an object and screen, $D = 100$ cm

Distance between the two position of lens, $d = 40$ cm

Focal length of lens,

$$f = \frac{D^2 - d^2}{4D} = \frac{100^2 - 40^2}{4(100)} = \frac{(100+40)(100-40)}{4(100)} = 21 \text{ cm}$$

Power, $P = \frac{1}{f} = \frac{100}{21} = \frac{N}{100}$

$$\therefore N = 476.19.$$

52. (60)

(60) Given : $\mu = 1.5$; $R_{curved} = 30$ cm

Using, Lens-maker formula

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

For plano-convex lens

$R_1 \to \infty$ then $R_2 = -R$

$$\therefore f = \frac{R}{\mu - 1} = \frac{30}{1.5 - 1} = 60 \text{ cm}$$

53. (50)

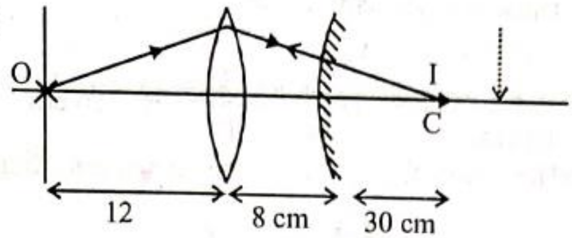


Image will coincide with object, if light fall perpendicularly to mirror. Which is possible if light converge at C of mirror. In the absence of mirror, light will be converging at centre of curvature. Distance = 12 + 8 + 30 = 50 cm

54. (15)

(15) $m = \frac{f}{f+u}$

As, $m_1 = -m_2$

$$\frac{f}{f-10} = \frac{-f}{f-20} \Rightarrow f = 15 \text{ cm}$$

55. (60)

(60) Given $i = 2r_1 = A$

And at minimum deviation $r_1 = r_2 = \frac{A}{2}$

From Snell's law,

$\mu_1 \sin i = \mu_2 \sin r_1$

$\therefore 1.\sin i = \sqrt{3} \sin r_1$

$$\Rightarrow 1 \sin A = \sqrt{3} \sin\frac{A}{2} \Rightarrow 2\sin\frac{A}{2}\cos\frac{A}{2} = \sqrt{3}\sin\frac{A}{2}$$

$$\Rightarrow \cos\frac{A}{2} = \frac{\sqrt{3}}{2} \Rightarrow \frac{A}{2} = 30° \text{ or, } A = 60°$$

Hence angle of prism = 60°

56. (12)

(12) Using $\delta = \delta_1\left(1 - \frac{\omega_1}{\omega_2}\right)$

$$2 = \delta_1\left(1 - \frac{.02}{.03}\right) \Rightarrow \delta_1\left(\frac{1}{3}\right) \Rightarrow \delta_1 = 6$$

Also, $\delta_1 = A(\mu_1 - 1) = A(1.5 - 1) \Rightarrow A = 12°$

57. (25)

(25) In case of simple microscope,

Magnification, $m = 1 + \frac{D}{f_0}$ or, $6 = 1 + \frac{D}{f_0}$

$\Rightarrow \quad 5 = \frac{25}{f_0} \quad \therefore f_0 = 5\text{cm}$

As total magnification double using an eyepiece along with the given lens i.e, case of compound microscope,

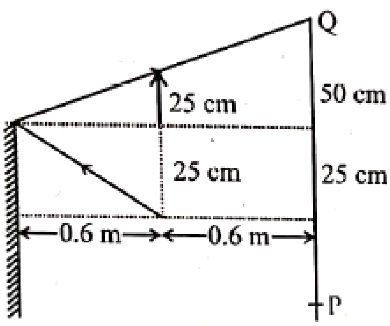
Magnification, $m = \frac{\ell . D}{f_0 . f_e}$

or, $12 = \frac{60 \times 25}{5 . f_e} \qquad \therefore f_e = 25\text{cm}$

58. (150)

The distance between the extreme points where man can see the image of light source in the mirror,

$PQ = 2 \times (50 + 25)\text{cm} = 150 \text{ cm}$



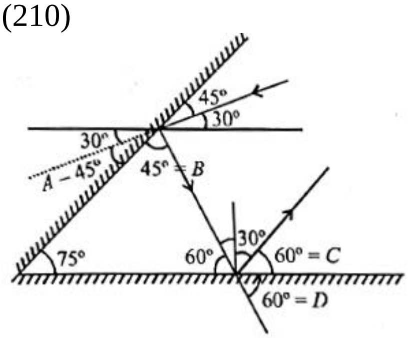
59. (400)

After 10 sec.

$u = -80 \text{ cm}, \; f = -100 \text{ cm}$

By mirror formula $\Rightarrow \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow v = 400 \text{ cm}$

60. (210)

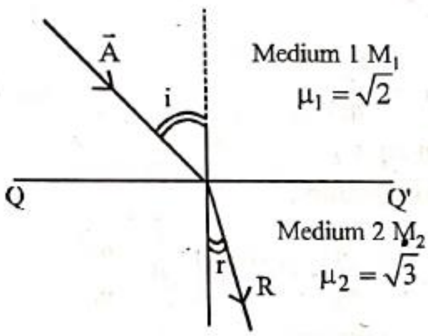


We have, $\delta = \delta_1 + \delta_2$

$= (A + B^\circ) + (C + D) = 45^\circ + 45^\circ + 60^\circ = 210^\circ$

61. (15)

(15) $\vec{A} = 4\sqrt{3}\hat{i} - 3\sqrt{3}\hat{j} - 5\hat{k}$



As incident vector A makes i angle with normal z-axis and refracted vector R makes r angle with normal z-axis with help of direction cosine

$$i = \cos^{-1}\left(\frac{A_z}{A}\right) = \cos^{-1}\left(\frac{5}{\sqrt{(4\sqrt{3})^2 + (3\sqrt{3})^2 + 5^2}}\right)$$

$$\cos^{-1}\left(\frac{5}{10}\right) \Rightarrow i = 60^\circ$$

By Snell's law, we have

$\sqrt{2}\sin 60^\circ = \sqrt{3} \times \sin r \;\Rightarrow\; r = 45^\circ$

Difference between i and $r = 60^\circ - 45^\circ = 15^\circ$

62. (27)

(27) Using Snell's law at face AC

$\mu \sin 60^\circ = n \times \sin 90^\circ$

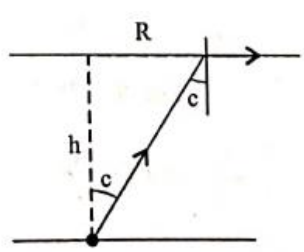
$1.5 \sin 60^\circ = n \times \sin 90^\circ$

$$1.5 \times \frac{\sqrt{3}}{2} = n = \frac{\sqrt{x}}{4} \Rightarrow 3\sqrt{3} = \sqrt{x} \Rightarrow x = 27$$

63. (9)

(9) We have, $\sin c = \frac{1}{\mu} = \frac{3}{4}$

So, $\tan c = \frac{3}{\sqrt{7}}$



Also, $\tan c = \frac{R}{h} \Rightarrow \frac{3}{\sqrt{7}} = \frac{R}{\sqrt{7}} \Rightarrow R = 3m$

So, area of illumination = $\pi \times 3^2 = 9\pi m^2$

64. (12)

(12) The formula of lateral shift in glass slab is given by

$$l = t\sin i\left[1 - \frac{\cos i}{\sqrt{\mu^2 - \sin^2 i}}\right] \Rightarrow 4\sqrt{3} = t\sin 60^\circ\left[1 - \frac{\cos 60^\circ}{\sqrt{3 - \frac{3}{4}}}\right]$$

$$\Rightarrow 4\sqrt{3} = t \times \frac{\sqrt{3}}{2}\left[1 - \frac{\frac{1}{2}}{\frac{3}{2}}\right] \Rightarrow 4\sqrt{3} = \frac{\sqrt{3}t}{2} \times \frac{2}{3}$$

$\Rightarrow t = 12$ cm

65. (15)

(15) By Newton's formula

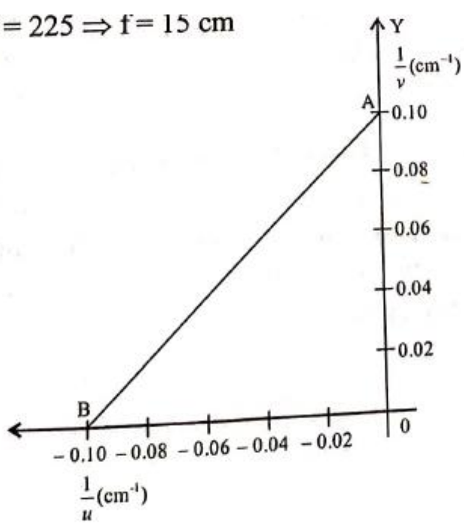
$vu = f^2$

$\Rightarrow f^2 = 225 \Rightarrow f = 15$ cm

66. (10)

$\Rightarrow f^2 = 225 \Rightarrow f = 15$ cm

(10)



For point B, $\frac{1}{u} = -0.10\ \text{cm}^{-1}$, $\frac{1}{v} = 0$

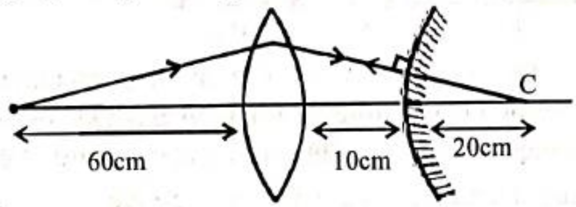
$\therefore$ Thus, u = –10 cm, v = ∞

i.e, f = 10 cm

$$\Rightarrow \frac{1}{10\text{ cm}} = (1.5 - 1)\left(\frac{2}{R}\right) = \frac{1}{R} \Rightarrow R = 10\text{ cm}$$

67. (10)

(10) The given figure shows the schematic diagram



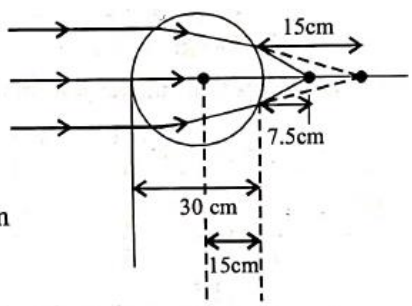
For lens

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

$$\Rightarrow \frac{1}{v}-\frac{1}{(-60)}=\frac{1}{20} \Rightarrow \frac{1}{v}+\frac{1}{60}=\frac{1}{20} \Rightarrow v = 30 \text{ cm}$$

68. (225)

(225) At surface 1



$$\frac{1.5}{v_1}-\frac{1}{\infty}=\frac{1.5-1}{15}$$

$$\frac{1.5}{v_1}=\frac{1}{30} \Rightarrow v = 45 \text{ cm}$$

For surface 2

$$\frac{1}{v}-\frac{1.5}{15}=\frac{1-1.5}{-15} \Rightarrow \frac{1}{v}-\frac{1}{10}=\frac{1}{30}$$

$$\frac{1}{v}=\frac{1}{30}+\frac{1}{10}=\frac{1+3}{30}$$

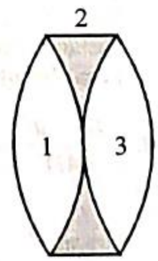
$\therefore\ v=\frac{30}{4} \Rightarrow v = 7.5$ cm. So required distance $= (15+7.5)$cm

$= 22.5$ cm $= 225$ mm.

69. (10)

(10) By lens maker formula,

$$\frac{1}{f}=({}^{g}\mu_a-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$



For Lens 1:

$$\frac{1}{f_1}=(1.5-1)\left(\frac{1}{R}-\frac{1}{-R}\right)$$

$$\Rightarrow\frac{1}{f_1}=0.5\times\frac{2}{R}$$

$$\Rightarrow f_1=R\Rightarrow R=15\text{ cm}$$

For Lens 2:

$$\frac{1}{f_2}=(1.25-1)\left(\frac{1}{-R}-\frac{1}{+R}\right)$$

$$=-0.25\times\frac{2}{R}=-\frac{0.5}{R}=\frac{-1}{2R}$$

$$\therefore f_2=-2R$$

For Lens 3:

Similarly like lens 1, $f_3=R$

So, $\frac{1}{f_{net}}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}=\frac{1}{R}+\frac{1}{-2R}+\frac{1}{R}$

$$=\frac{3}{2R}=\frac{2}{2\times15}=\frac{1}{10}\qquad\therefore\ f_{net}=10\text{ cm}$$

70. (4)

(4) Deviation produced by glass prism for yellow light

$=A(\mu_y-1)$

$$\delta=A(\mu_y-1)-A'(\mu_y'-1)\quad(\because\ A_1=6°,A_2=5°)$$

$$=6(1.5-1)-5(1.55-1)=\frac{1}{4}$$

71. (45)

(45) Refractive index

$$\mu=\frac{\sin\left(\frac{A+\delta\sin}{2}\right)}{\sin\left(\frac{A}{2}\right)}\Rightarrow\sqrt{2}=\sin\frac{\left(\frac{60+\delta_{min}}{2}\right)}{\sin 30°}$$

$$\Rightarrow\frac{1}{2}=\sin\left(\frac{60+\delta_{min}}{2}\right)\Rightarrow 45°=\frac{60+\delta_{min}}{2}$$

$\Rightarrow\delta_{min}=30°$

$\delta=i+e-A$

Here, $e=i$

So, $\delta_{min}=2e-A\Rightarrow 2e=\delta_{min}+A$

$$e=\frac{\delta_{min}+A}{2}=\frac{30°+60°}{2}=45°$$

PYQ : JEE Advanced

Only One Option Correct

1. (D)

Apply snell's law

2. (C)

3. (B)

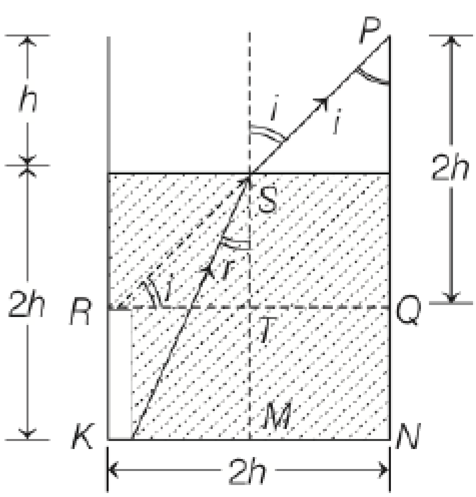
B

$$PQ = QR = 2h \Rightarrow \angle i = 45Υ$$

$\therefore$ $$ST = RT = h = KM = MN$$

So, $$KS = \sqrt{h^2 + (2h)^2} = h\sqrt{5}$$

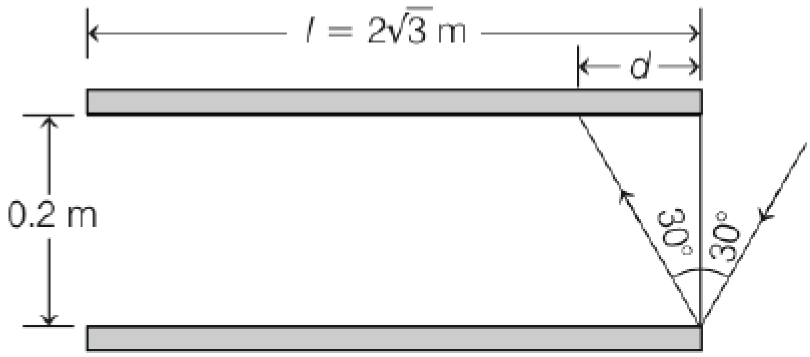
$\therefore$ $$\sin r = \frac{h}{h\sqrt{5}} = \frac{1}{\sqrt{5}}$$



$\therefore$ $$\propto = \frac{\sin i}{\sin r} = \frac{\sin 45Υ}{1/\sqrt{5}} = \sqrt{\frac{5}{2}}$$

4. (B)

$$d = 0.2 \tan 30Υ = \frac{0.2}{\sqrt{3}}$$



$$\frac{l}{d} = \frac{2\sqrt{3}}{0.2/\sqrt{3}} = 30$$

Therefore, maximum number of reflections are 30.

5. (B)

Image formed by convex lens at I_1 will act as a virtual object for concave lens. For concave lens

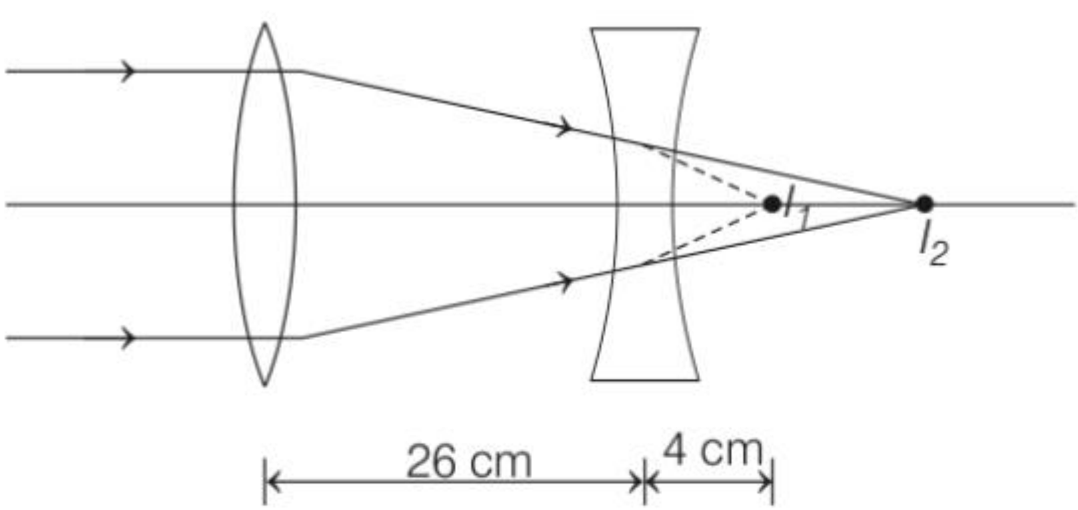
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

or $$\frac{1}{v} - \frac{1}{4} = \frac{1}{-20}$$

or $$v = 5 \text{ cm}$$

Magnification for concave lens

$$m = \frac{v}{u} = \frac{5}{4} = 1.25$$



As size of the image at I_1 is 2 cm. Therefore, size of image at I_2 will be $2 \times 1.25 = 2.5$ cm.

6. (B)

7. (C)

8. (A)

9. (C)
None of the option given by JEE are correct.
The correct Answer is 18.3 cm
Distance of object from mirror

$$= 15 + \frac{33.25}{1.33} = 40 \text{ cm}$$

Distance of image from mirror $= 15 + \frac{25}{1.33}$

$$= 33.8 \text{ cm}$$

For the mirror, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\therefore \quad \frac{1}{-33.8} + \frac{1}{-40} = \frac{1}{f}$$

$$\therefore \quad f = -18.3 \text{ cm}$$

$\therefore$ Most suitable answer is (c).

10. (C)

Refraction from lens : $\frac{1}{v_1} - \frac{1}{-20} = \frac{1}{15}$

$\therefore \quad v = 60\,\text{cm} \qquad \xrightarrow{\hspace{1cm}}$ + ve direction

i.e. first image is formed at 60 cm to the right of lens system.

Reflection from mirror

After reflection from the mirror, the second image will be formed at a distance of 60 cm to the left of lens system.

Refraction from lens

$$\frac{1}{v_3} - \frac{1}{60} = \frac{1}{15} \qquad \longleftarrow + \text{ve direction}$$

or $\qquad v_3 = 12$ cm

Therefore, the final image is formed at 12 cm to the left of the lens system.

11. (B)

12. (C)

From the lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \text{we have,}$$

$$\frac{1}{f} = \frac{1}{10} - \frac{1}{-10}$$

or $\quad f = +5$

Further, $\quad \Delta u = 0.1$

and $\quad \Delta v = 0.1 \quad$ (from the graph)

Now, differentiating the lens formula, we have

$$\frac{\Delta f}{f^2} = \frac{\Delta v}{v^2} + \frac{\Delta u}{u^2}$$

or $$\Delta f = \left(\frac{\Delta v}{v^2} + \frac{\Delta u}{u^2}\right) f^2$$

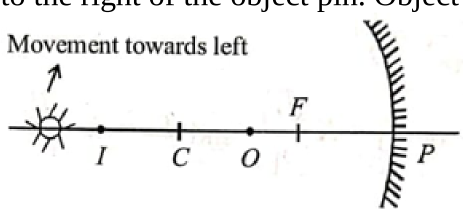
Substituting the values, we have

$$\Delta f = \left(\frac{0.1}{10^2} + \frac{0.1}{10^2}\right)(5)^2 = 0.05$$

$\therefore \quad f \pm \Delta f = 5 \pm 0.05$

13. (B)

As shown in the figure, when the object (O) is placed between F and C, the image (I) is formed beyond C. It is in this condition that when the student shifts his eyes towards left, the image appears to the right of the object pin. Object O lies between focus (f) and centre of curvature ($2f$) $f < x < 2f$.



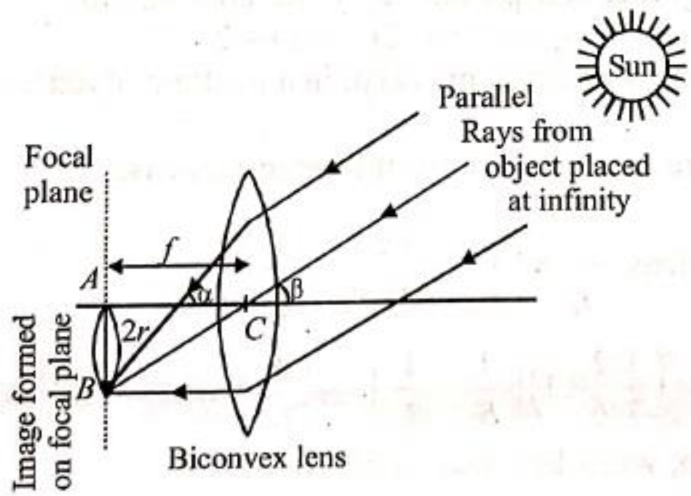
14. (B)

(b) From the figure in ΔABC, $\tan\beta = \frac{AB}{AC}$

$\Rightarrow AB = AC \tan\beta$

$\Rightarrow 2r = f\tan\beta \;\therefore\; r = \frac{f}{2}\tan\beta$

$\therefore$ Area of image formed by sun $= \pi r^2 = \pi \frac{\tan^2\beta}{2} f^2 \propto f^2$

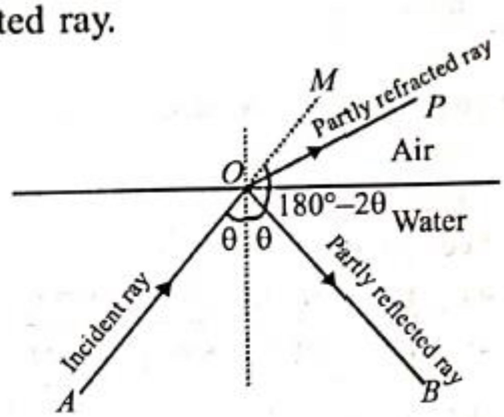


15. (C)

The formula connecting u, v and f for a spherical mirror $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ is valid only for mirrors of small apertures where size of aperture is very small as compared to the radius of curvature of the mirror. Laws of reflection are valid for plane as well as large spherical surfaces. The laws of reflection are valid when ever the light is reflected.

16. (C)

(c) The incident ray is partly reflected and partly refracted. $\angle MOB = 180° - 2\theta > \angle POB$ the angle between refracted and reflected ray.



17. (A)

At minimum deviation ($\delta = \delta_m$):

$$r_1 = r_2 = \frac{A}{2} = \frac{60\Upsilon}{2} = 30\Upsilon \quad \text{(For both colours)}$$

18. (C)

(c) Ball falling P to Q

Applying $v^2 - u^2 = 2gh$

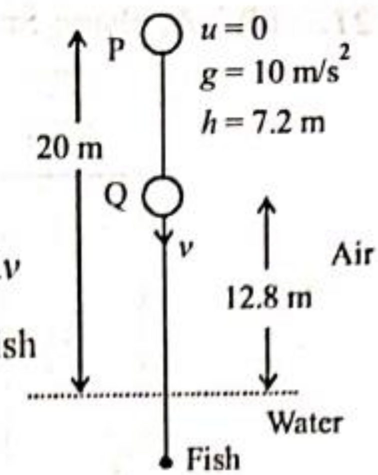
$v^2 - 02 = 2 \times 10 \times 7.2$

$\Rightarrow v = 12$ m/s

as $x' = \mu x \Rightarrow \frac{dx'}{dt} = \frac{\mu dx}{dt} \Rightarrow v' = \mu v$

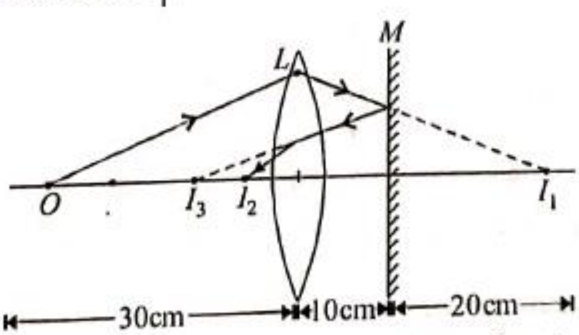
Velocity of ball as perceived by fish

$$v' = {}_{w}\mu \times v = \frac{4}{3} \times 12 = 16 \text{ m/s}$$



19. (B)

(b) Focal length of the biconvex lens L is 15 cm. A small object is placed at a distance of 30 cm from the lens i.e. at a distance of 2f. Therefore the image should form at 30 cm from the lens at I_1.



The image I_1 acts as a virtual object for the mirror. The mirror forms an image I_2 at a distance of 20 cm in front of it.

The image I_2 acts as an object for the lens.

Here, $u = +10$ cm, $f = +15$cm

20. (C)

After critical angle reflection will be 100% and transmission is 0%. Options (b) and (c) satisfy this condition. But option (c) is the correct option. Because in option (b) transmission is given 100% at $\theta = 0$Ÿ, which is not true.

21. (B)

(b) The focal length (f_1) of the plano-convex lens with $n = 1.5$ using lens-maker formula

$$\frac{1}{f_1} = (n_1 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] = (1.5-1)\left[\frac{1}{14} - \frac{1}{\infty}\right] = \frac{1}{28}$$

The focal length (f_2) of the plano-convex lens with $n = 1.2$

$$\frac{1}{f_2} = (n_2 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] = (1.2-1)\left[\frac{1}{\infty} - \frac{1}{-14}\right] = \frac{1}{70}$$

Focal length F of the combination

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{20}$$

Now, applying lens formula for the combination of lens

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{F} \Rightarrow \frac{1}{V} - \frac{1}{-40} = \frac{1}{20} \qquad [\text{Given } \mu = 40 \text{ cm}]$$

$\therefore \quad V = 40$ cm

22. (C)

(c) Here $\mu = \frac{\lambda_{air}}{\lambda_{medium}} = \frac{1}{\frac{2}{3}} = \frac{3}{2} = 1.5$

Also $m = \frac{v}{u} = -\frac{1}{3}$ ($\because v = 8m$)

$\therefore u = -24$ cm.

For a plano-convex lens

$$\frac{1}{f} = \frac{(\mu - 1)}{R} = \frac{1}{v} - \frac{1}{u} \text{ or } \frac{1.5-1}{R} = \frac{1}{8} - \left(\frac{1}{-24}\right) = \frac{1}{8} + \frac{1}{24} = \frac{1}{6}$$

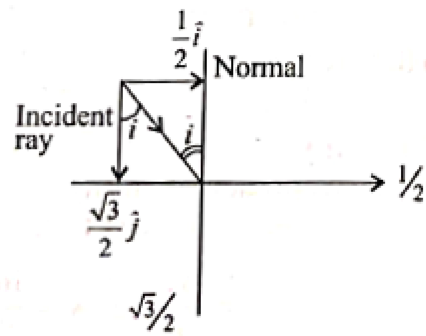
$\therefore R = 3$m

23. (A)

From figure, tan

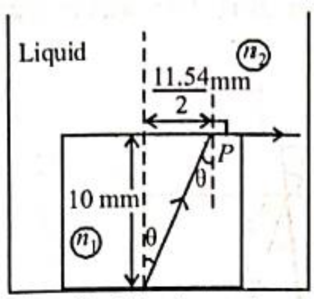
$i = \frac{1/2}{\sqrt{3}/2} = \frac{1}{\sqrt{3}}$

$\therefore\ i = 30^\circ$ (Angle of incidence)



24. (C)

(c)



Applying Snell's law at point P

$n_1 \sin\theta = n_2 \sin 90^\circ$

$\sin\theta = \frac{11.54/2}{\sqrt{10^2 + (11.54/2)^2}}$ and n_2 = refractive index of liquid

$\therefore\quad n_2 = 2.72 \times \frac{11.54/2}{\sqrt{(10)^2 + \left(\frac{11.54}{2}\right)^2}}$ $\therefore\ n_2 = 1.36$

25. (B)

(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, $\mu_2 = 1 \Rightarrow f = R$

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

for $\mu_{L_2} = \frac{5}{3}, f_2 = -5R \Rightarrow f_2 = (-)$ ve

26. (C)

(c) When $r_2 = C, \angle N_2RC = 90°$
Where C = critical angle

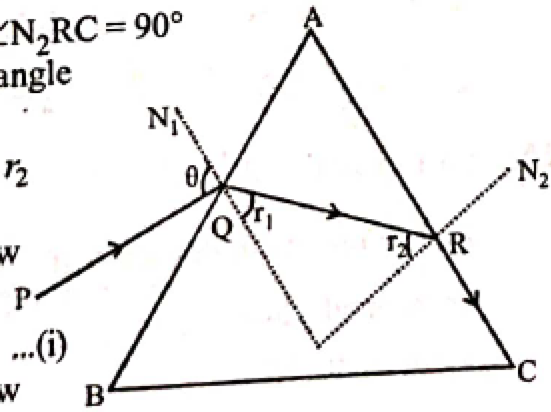
As $\sin C = \frac{1}{\mu} = \sin r_2$

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 (i)

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

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

27. (D)

(d) Numerical aperture, $NA = \frac{1}{n_s}\sqrt{n_1^2 - n_2^2}$

Here, $NA_2 < NA_1 \Rightarrow i_{m_2} < i_{m_1}$

$\therefore$ Numerical aperture, of combined structure is equal to the smaller value of the two numerical apertures.

28. (B)

$R = 10\,\text{cm}$

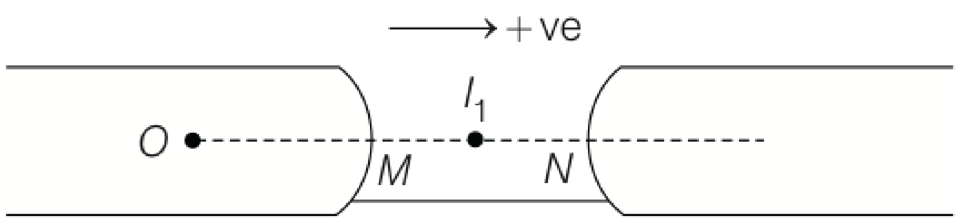
Applying $\frac{\propto_2}{v} - \frac{\propto_1}{u} = \frac{\propto_2 - \propto_1}{R}$ two times

$$\frac{1}{v} - \frac{1.5}{-50} = \frac{1-1.5}{-10}$$

$$\frac{1}{v} + \frac{1.5}{50} = \frac{0.5}{10}$$

$$\frac{1}{v} = \frac{0.5}{10} - \frac{1.5}{50} = \frac{2.5-1.5}{50} \Rightarrow v = 50$$

$$MN = d,\ MI_1 = 50\,\text{cm},$$
$$NI_1 = (d-50)\,\text{cm}$$



Again, $\frac{1.5}{\infty} - \frac{1}{-(d-50)} = \frac{1.5-1}{10}$

$$\frac{1}{d-50} = \frac{1}{20}$$

$$d = 70$$

29. (A)

(a) Applying Snell's law at A

$1 \times \sin 45° = \sqrt{2} \times \sin r_1 \quad \therefore r_1 = 30°$

$\sin C = \frac{1}{n} = \frac{1}{\sqrt{2}}$

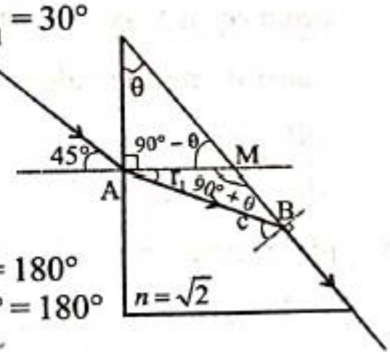
$\therefore \quad C = 45°$

In ΔAMB,

$90° + \theta + r_1 + (90° - C) = 180°$

$\Rightarrow \quad 90° + \theta + 30° + 90° - 45° = 180°$

$\therefore \quad \theta = 15°$

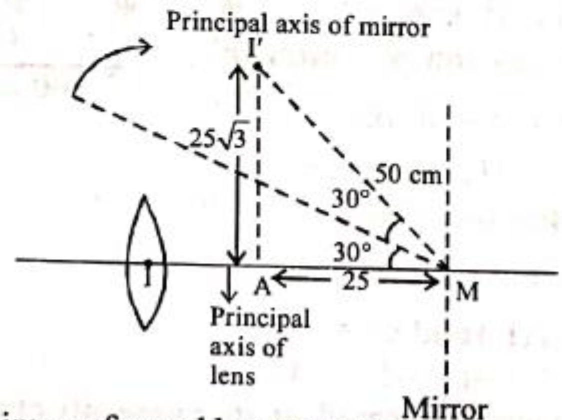


30. (C)

(c) *For convex lens* $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\Rightarrow \quad \frac{1}{v}-\frac{1}{-50}=\frac{1}{30}$ $\qquad (\because v=-50\text{ cm}, f=30\text{ cm})$

$\therefore \quad v=75\text{ cm}$



The image formed by convex lens acts as an object for mirror.

For minor $\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \;\therefore\; \frac{1}{v}+\frac{1}{25}=\frac{1}{50} \;\therefore\; v=-50\text{ cm}$

The image I would have formed as shown had the mirror been straight. But here the mirror is tilted by 30°. Therefore the image will be tilted by 60° and will be formed at A.

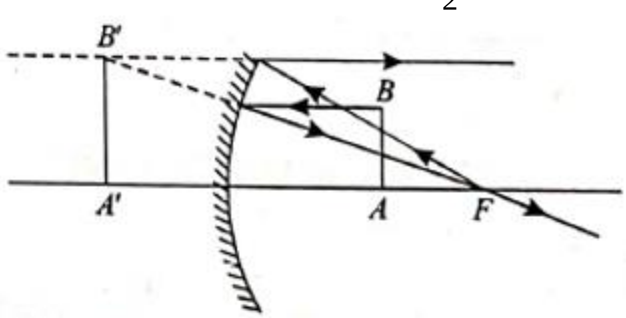
Here MA = 50 cos 60° = 25 cm (x-coordinate of the image)

and I'A = 50 sin 60° = $25\sqrt{3}$ cm (y-coordinate of the image)

Hence, coordinate of the point at which image is formed $(25, 25\sqrt{3})$.

31. (D)

Distance of point A from the mirror is $\frac{f}{2}$.



From mirror formula,

$$\frac{1}{v}+\frac{1}{f/2}=\frac{1}{-f} \Rightarrow \frac{1}{v}=\frac{2}{f}-\frac{1}{f}=\frac{1}{f} \qquad \therefore v=f$$

Image $A'B'$ of line AB should be I principle axis. Image of F will be formed at infinity.
Also light ray from infinity or towards infinity seems parallel to the principle axis of the mirror.

32. (B)

(b) From lens maker's formula, focal length of convex lens (f_1)

$$\frac{1}{f_1}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]=(1.5-1)\left[\frac{1}{20}-\left(\frac{1}{-20}\right)\right]\frac{1}{f_1}=\frac{1}{20}$$

$\therefore\ f_1=+20$ cm

Similarly, focal length of concave lens (f_2)

$$\frac{1}{f_2}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\Rightarrow \frac{1}{f_2}=(1.5-1)\left[-\frac{1}{20}-\frac{1}{20}\right]=\frac{1}{-20}$$

$\therefore\ f_2=-20$ cm

Now for lens L_1

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

$$\Rightarrow \frac{1}{v}=\frac{1}{20}+\frac{1}{-10} \quad \therefore \quad v=-20\text{ cm}$$

$$\therefore \text{ Magnification } M_1=\frac{v}{u}=\frac{-20}{-10}=2$$

Again for Lens L_2

$$u=-20-10=-30\text{ cm},\ f_2=-20\text{ cm}$$

$$\frac{1}{v}=\frac{1}{f}+\frac{1}{u}=\frac{1}{-20}+\frac{1}{-30} \Rightarrow \frac{1}{v}=\frac{-5}{60} \quad \therefore \quad v=-12$$
cm

So, magnification,

$$m_2=\frac{v}{u}=\frac{-12}{-30}=\frac{2}{5}$$

$\therefore$ Net magnification,

$$m=m_1m_2=2\times\frac{2}{5}=\frac{4}{5}=0.8$$

One or More than One Option Correct

1. (C, D)

Given $f = -24\,\text{cm}$

Applying mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

u-v values of options (a) and (b) match with mirror formula.
Where option (c) and (d) do not match with mirror formula.
For (66, 33)

$$\Rightarrow \quad \frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-24}+\frac{1}{66}=\frac{-66+24}{24\times 66}=\frac{-42}{24\times 66}$$

$$\Rightarrow \quad v=-\frac{24\times 66}{42}=-37.7$$

But the value of v = 33. The absolute error is 37.7 – 33 = 4.7 cm which is greater then 0.2 cm. Therefore a wrong reading. For (78, 39) when u = 78 then

$$\frac{1}{v}+\frac{1}{-78}=\frac{1}{-24} \Rightarrow v=-34.67$$

The absolute error is 39 – 34.67 = 4.33 which is greater than 00.2 cm.

2. (AC)

$$\frac{1}{f_{\text{film}}}=(n_1-1)\left(\frac{1}{R}-\frac{1}{R}\right) \Rightarrow f_{\text{film}}=\infty \qquad \text{(infinite)}$$

$\therefore$ There is no effect of presence of film.

From Air to Glass

Using the equation $\quad \frac{n_2}{v}-\frac{1}{u}=\frac{n_2-1}{R}$

$$\frac{1.5}{v}-\frac{1}{\infty}=\frac{1.5-1}{R} \Rightarrow v=3R$$

$$\therefore \qquad f_1=3R$$

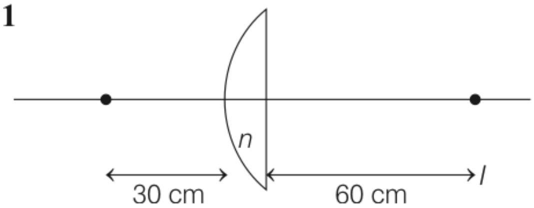
From Glass to Air Again using the same equation

$$\frac{1}{v}-\frac{n_2}{u}=\frac{1-n_2}{-R} \Rightarrow \frac{1}{v}-\frac{1.5}{\infty}=\frac{1-1.5}{-R} \Rightarrow v=2R$$

$$\therefore \qquad f_2=2R$$

3. (AD)

Case 1



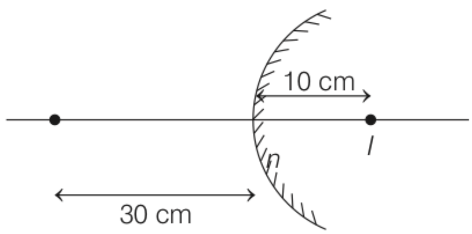
Using lens formula,

$$\frac{1}{60}+\frac{1}{30}=\frac{1}{f_1} \Rightarrow \frac{1}{f_1}=\frac{1}{60}+\frac{2}{60}$$

$$\Rightarrow \qquad f_1 = 20\,\text{cm}$$

Further, $\frac{1}{f_1}=(n-1)\left(\frac{1}{R}-\frac{1}{\infty}\right) \Rightarrow f_1=\frac{R}{n-1}=+20\,\text{cm}$

Case 2



Using mirror formula

$$\frac{1}{10}-\frac{1}{30}=\frac{1}{f_2}$$

$$\frac{3}{30}-\frac{1}{30}=\frac{1}{f_2}=\frac{2}{30}$$

$$f_2=15=\frac{R}{2} \Rightarrow R=30$$

$$R = 30\,\text{cm}$$

$$\frac{R}{n-1}+20\,\text{cm}=\frac{30}{n-1}$$

$$\Rightarrow \qquad = 2n-2=3 \Rightarrow f_1=+20\,\text{cm}$$

Refractive index of lens is 2.5.

Radius of curvature of convex surface is 30 cm.

Faint image is erect and virtual focal length of lens is 20 cm.

4. (a, c, d)

(a, c, d) From Snell's law, $n_1 \sin\theta_i = n_2 \sin\theta_f$ [$\because$ 1 and 2 interfaces are parallel]
l depends on the refractive index of transparent slab $n(z)$ but not on n_2. But θ_f depends, on n_2.
Because lateral displacement (l) is possible due μ of slab and angle of incidence θ_i.

5. (ACD)

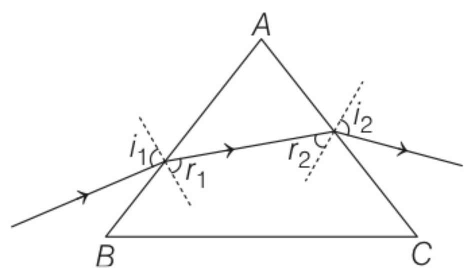
The minimum deviation produced by a prism

$$\delta_m = 2i - A = A$$

$\therefore \quad i_1 = i_2 = A$ and

$$r_1 = r_2 = A/2$$

$\therefore \quad r_1 = i_1/2$



Now, using Snell's law

$$\sin A = \propto \sin A/2$$

$\Rightarrow \quad \propto = 2\cos(A/2)$

For this prism when the emergent ray at the second surface is tangential to the surface

$$i_2 = \pi/2 \Rightarrow r_2 = \theta_c \Rightarrow r_1 = A - \theta_c$$

so, $\sin i_1 = \propto \sin(A - \theta_c)$

so, $$i_1 = \sin^{-1}\left[\sin A\sqrt{4\cos^2\frac{A}{2} - 1} - \cos A\right]$$

For minimum deviation through isosceles prism, the ray inside the prism is parallel to the base of the prism if $\angle B = \angle C$.

But it is not necessarily parallel to the base if,

$$\angle A = \angle B \text{ or } \angle A = \angle C$$

6. (BCD)

When $n_1 = n_2 = n$

$$\frac{1}{f} = (n-1)\left(\frac{2}{R}\right) \qquad \text{...(i)}$$

When, $n_1 = n$ and $n_2 = n + \Delta n$

$$\frac{1}{f+\Delta f}=(n-1)\left(\frac{1}{R}\right)+(n+\Delta n-1)\left(\frac{1}{R}\right) \quad ...(ii)$$

So from equation (i) and (ii)

$$\frac{1}{f}-\frac{1}{f+\Delta f}=-(\Delta n)\left(\frac{1}{R}\right)$$

$$\Rightarrow \frac{\Delta f}{f^2}=-(\Delta n)\left(\frac{1}{R}\right)$$

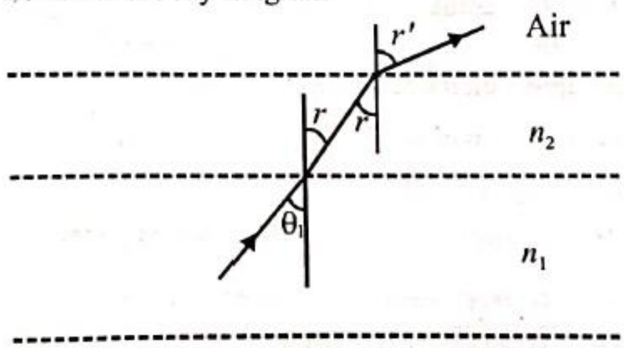
So, $\frac{\Delta f}{f}=-\frac{\Delta n}{2(n-1)}\approx\frac{\Delta n}{2n}$

7. (B, C, D)

(b, c, d) Given, $\sin\theta_1 > \frac{1}{n_1}$

$n_1 \sin\theta_1 > 1$

Let draw the ray diagram



So, by Snell's law,

$n_1 \sin\theta_1 = n_2 \sin r = 1 \times \sin r'$

$\Rightarrow \sin r' = n_1 \sin\theta_1$

As $n_1 \sin\theta_1 > 1 \Rightarrow \sin r' > 1$, which is impossible.

Therefore, r' does not exist i.e., light will never enter the air.

So, light will always reflected back into medium 1 whatever is the value of n_1 and n_2. So option (b), (c), (d) is correct.

8. (BC)

B, C

Diagram at minimum deviation for $n_1 = n_2 = n$

$n = 1.5$

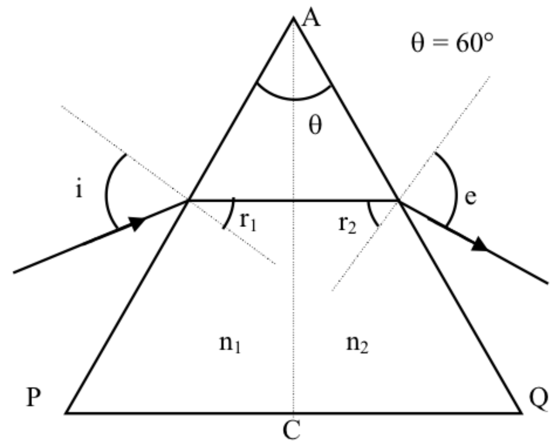
$r_1 = r_2 = \theta/2 = 30°$

for face AQ

$n\sin r_2 = \sin e$

$1.5 \sin 30° = \frac{3}{2} \times \frac{1}{2} = \sin e$

$\sin e = \frac{3}{4}, \qquad \cos e = \frac{\sqrt{7}}{4}$



When n_2 is given small variation there will be no change in path of light ray inside prism. As deviation on face AC is zero.

So, $r_2 = 30°$

Now for face AQ

$n_2 \sin 30° = \sin e$

for small change in n_2 change in e is given by

$dn_2 \sin 30° = \cos e\, de$

or $dn_2 = \Delta n \quad de = \Delta e$

$\Delta n \sin 30° = \cos e\, \Delta e$

$\Delta n \frac{1}{2} = \frac{\sqrt{7}}{4} \Delta e$

$\Delta n = \frac{\sqrt{7}}{2} \Delta e \qquad \ldots(i)\ \Delta n > \Delta e$

$\Delta n \propto \Delta e$

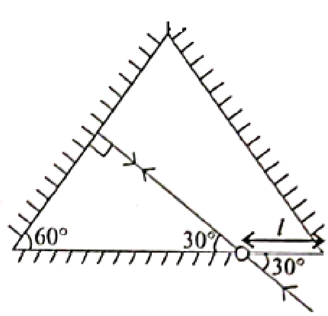
Hence, option (B) is correct.

$$\Delta e = \frac{2.8 \times 10^{-3} \times 2}{\sqrt{7}}$$

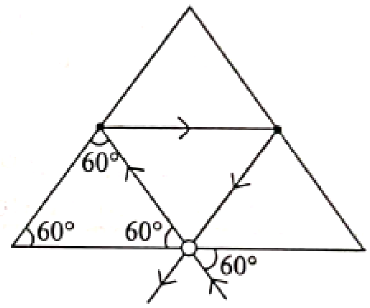
Hence, option (C) is correct.

9. (A, B)

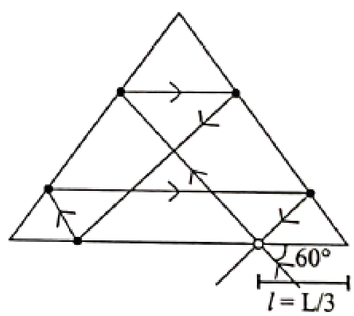
As we can see, for $\theta = 30°$ the way ray will incident normally and hence will retrace its path $\Rightarrow$ (a) is correct.



For $\theta = 60°, \ell = \frac{L}{2}$. Then, we get ray diagram sown below. Clearly ray of light comes after tow reflections $\Rightarrow$ (b) is correct.



If $\theta = 60°$ and $\ell = \frac{L}{3}$, then we get ray diagram as shown below



Clearly, after 5 reflections, ray comes out. So (c) and (d) are incorrect.

<u>**Comprehensions Type Questions**</u>

Comprehension - 1

1. (C)

2 Since value of n in meta-material is negative. (C)

$\therefore \quad v = \frac{c}{|n|}$

2. (B)

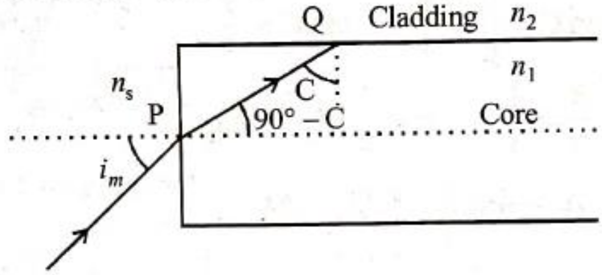
1 According to the paragraph, refracted ray in meta-material should be on same side of normal. (B)

Comprehension - 2

3. (A, C)

(a, c) Using Snell's law at P; $n_s \sin i_m = n_1 \sin(90° - C)$ ...(i)

n_s = Refractive index of surrounding



Also $\sin C = \dfrac{n_2}{n_1}$ $\quad\therefore\quad$ $\cos C = \sqrt{1 - \left(\dfrac{n_2}{n_1}\right)^2}$

Now from eq. (i)

Numerical aperture,

$$NA = \sin i_m = \frac{n_1}{n_s}\cos C = \frac{n_1}{n_s}\sqrt{1 - \frac{n_2^2}{n_1^2}}$$

$$\therefore \quad NA = \frac{\sqrt{n_1^2 - n_2^2}}{n_s}$$

For S_1 (in air)

$$NA = \sqrt{\frac{45}{16} - \frac{9}{4}} = \frac{3}{4}$$

For S_1 (in water)

$$NA = \frac{3}{4}\sqrt{\frac{45}{16} - \frac{9}{4}} = \frac{9}{16}$$

For s_1 $\left(\text{in } n_s = \dfrac{6}{\sqrt{15}}\right)$

$$NA = \frac{\sqrt{15}}{6}\sqrt{\frac{45}{16} - \frac{9}{4}} = \frac{3\sqrt{15}}{24} = \frac{3}{4}\,\frac{\sqrt{15}}{5}$$

For S_2 (in water)

$$NA = \frac{3}{4}\sqrt{\frac{64}{25} - \frac{49}{25}}$$

For S_2 (in air)

$$NA = \sqrt{\frac{64}{25} - \frac{49}{25}} = \frac{\sqrt{15}}{5}$$

For S_2 (in $n_s = \dfrac{4}{\sqrt{15}}$)

$$NA = \frac{\sqrt{15}}{4}\sqrt{\frac{64}{25} - \frac{49}{25}} = \frac{3}{4}$$

For S_2 $\left(\text{in } n_s = \dfrac{16}{3\sqrt{15}}\right)$

$$NA = \frac{3\sqrt{15}}{16}\sqrt{\frac{64}{25} - \frac{49}{25}} = \frac{9}{16}$$

4. (D)

Numerical aperture, $NA = \frac{1}{n_s}\sqrt{n_1^2 - n_2^2}$

Here, $NA_2 < NA_1 \Rightarrow i_{m_2} < i_{m_1}$

$\therefore$ Numerical aperture, of combined structure is equal to the smaller value of the two numerical aperture.

Matrix Match Type

1. (D)

2. (B)

3. (A)

(a) (i) $u_1 = -20$ cm
$f_1 = +10$ cm

$$\frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u} \Rightarrow v = \frac{uf}{u+f}$$

So, $v_1 = \frac{-20 \times 10}{-20+10} = 20\text{cm}$

Now, $u_2 = +15$ cm, $f_2 = +15$ cm

So, $v_2 = \frac{15 \times 15}{15+15} = 7.5\text{cm}$ (from lens 2). So (I) $\rightarrow$ (P)

(ii) $u_1 = -20$ cm
$f_1 = +10\text{cm}$

So, $v_1 = \frac{-20 \times 10}{-20+10} = 20\text{cm}$

Now, $u_2 = +15$ cm, $f_2 = -10$ cm

$$\text{So, } v_2 = \frac{15 \times -10}{15-10} = -30\text{cm. So (II)} \rightarrow \text{(R)}$$

(iii) Preceeding as above

$u_2 = +15$ cm, $f_2 = -20$ cm

$$\text{So, } v_2 = \frac{15 \times -20}{15-20} = 60 \text{ cm. So (III)} \rightarrow \text{(Q)}$$

(iv) $u_1 = -20$ cm, $f_1 = -20$ cm

$$v_1 = \frac{-20 \times -20}{-20-20} = -10\text{cm}$$

So, $u_2 = -15$ cm and $f_2 = +10$ cm

$$\text{Then, } v_2 = \frac{-15 \times 10}{-15+10} = 30\text{cm . So (IV)} \rightarrow \text{(T)}$$

Numerical Value Answer

1. (6)

(6) When $u = -25$ cm

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{-25} = \frac{1}{100} \Rightarrow v = 100 \text{ cm}$$

$$m_{25} = \frac{-v}{u} = \frac{-100}{-25} = 4$$

When $u = -50$ cm

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{-50} = \frac{3}{100} \Rightarrow v = \frac{100}{3} \text{ cm}$$

$$m_{50} = \frac{-v}{u} = \frac{-1000}{3} \times \frac{-1}{50} = \frac{2}{3}$$

$$\text{So, } \frac{m_{25}}{m_{50}} = \frac{4}{2/3} = 6$$

2. (3)

Using mirror formula for first position

$u_1 = ?, v_1 = \frac{25}{3}\text{cm}, \ f = +10 \text{ cm}\left(=\frac{R}{2}\right)$

$\frac{1}{v_1}+\frac{1}{u_1}=\frac{1}{f}, \ \frac{3}{25}+\frac{1}{u_1}=\frac{1}{10} \quad \therefore \ u_1 = -50 \text{ m}$

Using mirror formula for the second position

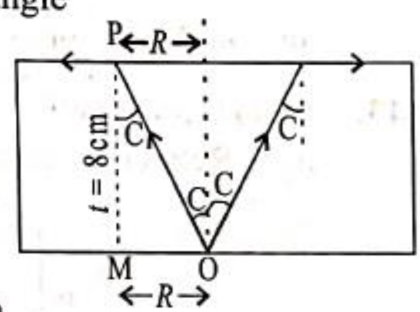
$u_2 = ?, \ v = \frac{50}{7}$ and $f = 10\text{cm}$

$\frac{1}{v_2}+\frac{1}{u_2}=\frac{1}{f} \Rightarrow \frac{7}{50}+\frac{1}{u_2}=\frac{1}{10} \Rightarrow \frac{1}{u_2}=\frac{1}{10}-\frac{7}{50}$

3. (6)

(6) In the figure, C = critical angle

In ΔPOM, $\tan C = \frac{\text{OM}}{\text{PM}} = \frac{R}{8}$



$\because \quad \sin C = \frac{1}{\mu} = \frac{3}{5} \quad \therefore \ \tan C = \frac{3}{4}$

$\therefore \quad \frac{R}{8} = \frac{3}{4} \quad \therefore \ R = \frac{3}{4} \times 8 = 6\,\text{cm}$

4. (2)

$1.0 = m \times 0.1 \quad \therefore \ m = 8$

(2) For the convex spherical refracting surface i.e., air-oil interface. Since oil is acting as thin lens we will ignore its dimension

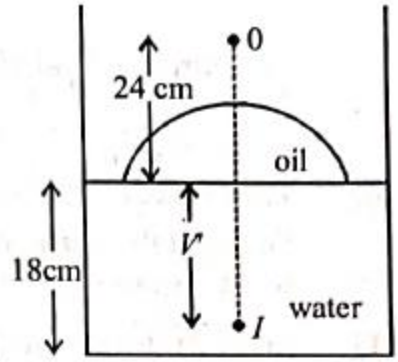
$u = -24 \text{ cm}, v = ?, \mu_1 = 1, \mu_2 = \frac{7}{4}$ and $R = 6$ cm

$$\frac{-\mu_1}{u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R}$$

$$\therefore \quad \frac{-1}{(-24)}+\frac{7/4}{v}=\frac{\frac{7}{4}-1}{6}$$

$\therefore \quad v=21$ cm

This image will act as object for the water-oil interface



$u=21$ cm, $v=v'$, $\mu_1=\frac{7}{4}$, $\mu_2=\frac{4}{3}$ and $R=\infty$

$$\frac{\frac{-7}{4}}{+21}+\frac{\frac{4}{3}}{V'}=0$$

$\therefore \quad V'=16$ cm.

Therefore the distance of the image from the bottom of the tank $=18-16=2$ cm.

(6) In the figure C = critical angle

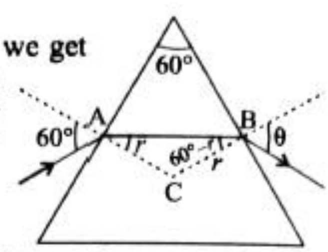
5. 2

(2) Applying Snell's law at A

$\sin 60° = n \sin r$ ...(i)

Differentiating w.r.t 'n' we get

$$0=\sin r+n\cos r\times\frac{dr}{dn} \quad \text{...(ii)}$$



Again, applying Snell's law at B

$\sin\theta = n\sin(60°-r)$ ...(iii)

Differentiating w.r.t 'n' we get

$$\cos\theta\frac{d\theta}{dn}=\sin(60°-r)+n\cos(60°-r)\left[-\frac{dr}{dn}\right]$$

$$\therefore \quad \cos\theta\frac{d\theta}{dn}=\sin(60°-r)-n\cos(60°-r)\left[-\frac{\tan r}{n}\right]$$

[from (ii)]

$$\therefore \quad \frac{d\theta}{dn} = \frac{1}{\cos\theta}[\sin(60^\circ - r) + \cos(60^\circ - r)\tan r] \quad ...(iv)$$

From eq. (i), for $n = \sqrt{3}$ we get $r = 30^\circ$

From eq (iii), for $n = \sqrt{3}$, $r = 30^\circ$ we get $\theta = 60^\circ$

Substituting the values of r and θ in eq (iv) we get

$$\frac{d\theta}{dn} = \frac{1}{\cos 60^\circ}[\sin 30^\circ + \cos 30^\circ \tan 30^\circ] = 2\left(\frac{1}{2} + \frac{1}{2}\right) = 2$$

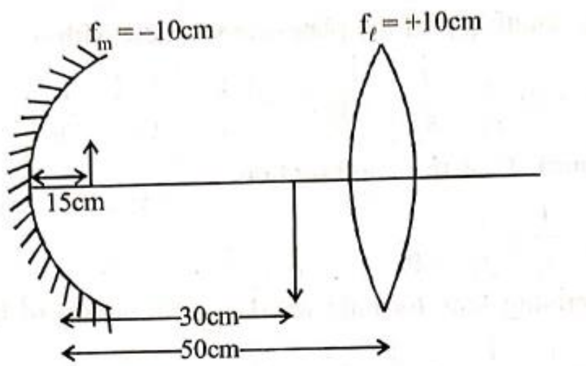
6. (7)

(7) Applying mirror formula

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \text{or} \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-10} + \frac{1}{15}$$

$$\therefore \quad \frac{1}{v} = \frac{-15+10}{150} = \frac{-5}{150} = \frac{-1}{30} \quad \therefore v = -30\text{cm}$$

And magnification, $m_1 = -\frac{v}{u} = -\frac{-30}{-15} = -2$



Now for refraction from lens, $u = -(50 - 30) = -20$ cm

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} \Rightarrow \frac{1}{v} - \frac{1}{-20} = \frac{1}{10}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20} \quad \therefore \; v = 20 \text{ cm}$$

Magnification, $m_2 = \dfrac{v}{u} = \dfrac{20}{-20} = -1$

Magnification produced by the combination,

$M_1 = m_1 \times m_2 = (-2) \times (-1) = 2$

Again, when system is kept in a medium of refractive index 7/6.

There is no change for mirror in this case,

For lens, $\dfrac{1}{f_l'} = \left(\dfrac{\mu_l}{\mu_s} - 1\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

$$\frac{1}{f_l'} = \left(\frac{3/2}{7/6} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow \frac{1}{f_l'} = \frac{2}{7}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Also, when lens was in air

$$\frac{1}{f_l} = (1.5 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{10} \quad \therefore \; \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{5}$$

Using this result in eqn. (i), we get

$$\frac{1}{f_l'} = \frac{2}{7} \times \frac{1}{5} \quad \therefore \; f_l' = \frac{35}{2} \text{ cm}$$

Again using lens formula, $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f_l'}$

$$\frac{1}{v} - \frac{1}{-20} = \frac{2}{35} \Rightarrow \frac{1}{v} = \frac{2}{35} - \frac{1}{20} = \frac{1}{140} \quad \therefore \; v = 140 \text{ cm}$$

Magnification, $m_2' = \dfrac{v}{u} = \dfrac{140}{-20} = -7$

Magnification produced by the combination,

$M_2 = m_1 \times m_2' = (-2) \times (-7) = 14$

$$\therefore \quad \left|\frac{M_2}{M_1}\right| = \frac{14}{2} = 7$$

7. (8)

(8) Here, $n \sin\theta = (n - m\Delta n) \sin 90°$

$\Rightarrow$ $n \times \sin 30° = [n - m \times 0.1] \sin 90°$

$\therefore$ $1.6 \times \sin 30° = 1.6 - m \times 0.1 \quad \therefore \quad m = 8$

(2) For the

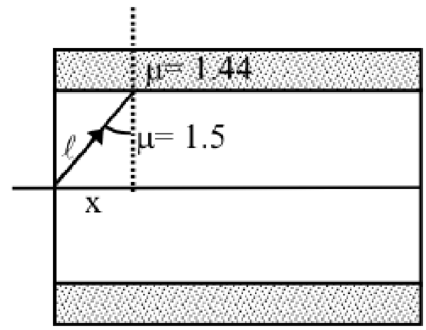
8. (50)

50.00

$1.5 \sin\theta_C = 1.44 \sin 90°$

$\sin\theta_C = \frac{24}{25}$

$\ell = \frac{x}{\sin\theta_C} = \frac{25}{4} x$



total length for light to travel

$\ell' = \frac{25}{4} \times 9.6 = 10\text{m}$

$\therefore \text{time} = \frac{\ell'}{c/1.5} = 5 \times 10^{-8}\text{s} \Rightarrow 50 \times 10^{-9}\text{s}$

t = 50.00

9. (150)

1.50

When angle of incidence on first face of the prism is 60° the angle of incidence on the other surface of the prism will be slightly greater than critical angle.

For refraction at first surface of the prism

$\sin 60° = \sqrt{3} \sin r_1$

$\Rightarrow r_1 = 30°$

For second surface $r_2 = 75° - 30° = 45°$

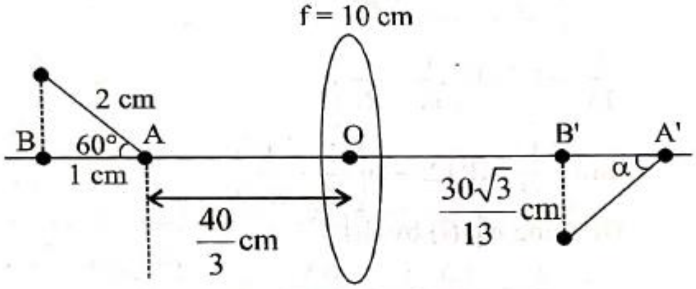
Since $r_2 \approx \theta_C$

$\Rightarrow \sin 45° = \frac{n}{\sqrt{3}}$

$\Rightarrow n^2 = 1.50$

10. (6)

(6)



By lens formula, $\frac{1}{v}=\frac{1}{f}+\frac{1}{u} \Rightarrow v=\frac{uf}{f+u}$

So, $OA' = \frac{-\frac{40}{3}\times 10}{-\frac{40}{3}+10} = 40$ cm

and, $OB' = \frac{-\frac{43}{3}\times 10}{-\frac{43}{3}+10} = \frac{430}{13}$ cm

So, $A'B' = OA' - OB' = 40 - \frac{430}{13} = \frac{90}{13}$ cm

Therefore, $\tan\alpha = \frac{\frac{30\sqrt{3}}{13}}{\frac{90}{13}} = \frac{1}{\sqrt{3}} \Rightarrow \alpha = 30° = \frac{\pi}{6}$

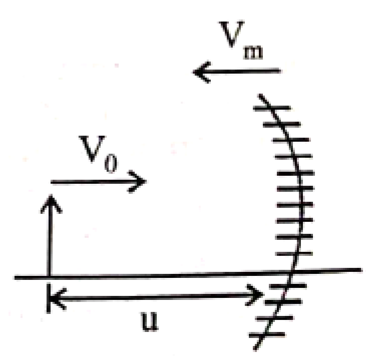
So, n = 6

11. (3)

We have, $u = -30$ cm, $f = -10$ cm

$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-10}-\frac{1}{-30}=\frac{1}{30}-\frac{1}{10}=\frac{1-3}{30}=\frac{-1}{15}$

So, $v = -15$ cm



As, $\vec{V}_{I,M} = -\left(\frac{v}{u}\right)^2 \vec{V}_{O,M}$

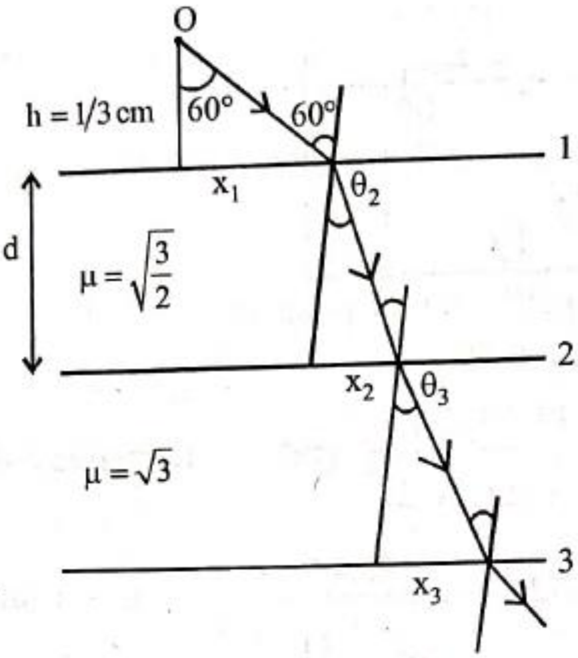
$\Rightarrow \vec{V}_I - \vec{V}_M = -\left(\frac{v}{u}\right)^2 \left(\vec{V}_0 - \vec{V}_m\right)$

$\Rightarrow 0 - \vec{V}_m = -\frac{1}{4}\left(-15\hat{i} - \vec{V}_m\right)$

$\Rightarrow -\vec{V}_m = -\frac{15}{4}\hat{i} + \frac{1}{4}\vec{V}_m \Rightarrow -\frac{5}{4}\vec{V}_m = -\frac{15}{4}\hat{i} \Rightarrow \vec{V}_m = 3\hat{i}$

12. (4)

(4)



$$x_1 = \frac{1}{3} \times \tan 60° = \frac{1}{\sqrt{3}} \text{cm}$$

and, **at interface-1**

$$1 \sin 60° = \sqrt{\frac{3}{2}} \sin \theta_2 \Rightarrow \theta_2 = 45°$$

$$\text{So, } x_2 = d \tan 45° = \frac{\sqrt{3}-1}{2}$$

at interface 2:

Again, $\sqrt{\frac{3}{2}}\sin 45^\circ = \sqrt{3}\sin\theta_3$

$\Rightarrow \quad \theta_3 = 30^\circ$

So, $x_3 = d\tan 30^\circ = \frac{\sqrt{3}-1}{2\sqrt{3}}$

So, $x_1 + x_2 + x_3 = \frac{1}{\sqrt{3}} + \frac{\sqrt{3}-1}{2}\left(1+\frac{1}{\sqrt{3}}\right)$

$= \frac{1}{\sqrt{3}} + \frac{(\sqrt{3}-1)(\sqrt{3}+1)}{2\sqrt{3}} = \frac{1}{\sqrt{3}} + \frac{1}{\sqrt{3}} = \frac{2}{\sqrt{3}}\text{cm}$

So 1 unit shift light ray by $\frac{2}{\sqrt{3}}$, therefore to shift light ray by $\ell = \frac{8}{\sqrt{3}}$, no. of units needed, $n = \frac{\frac{8}{\sqrt{3}}}{\frac{2}{\sqrt{3}}} = 4$

(8) Here $n \sin\theta = (n$ ...

Subjective

1. $\sqrt{3}$

2.

3. 4/3

4. 15 cm, –3/2

5. $4^\circ, -0.04^\circ$

6. 1.6

7. $\frac{\mu_3 R}{\mu_2 - \mu_1}$

8. 6.06 m

9. 0.09 m/s, 0.3 /s

10. 60°

11. 60^o, 60^o

Ex-1.

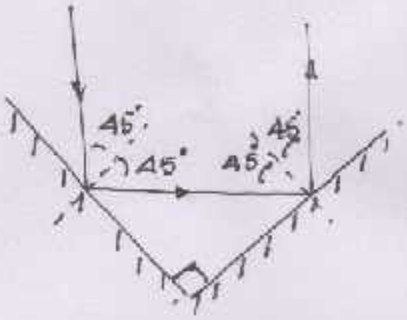
1. (D)

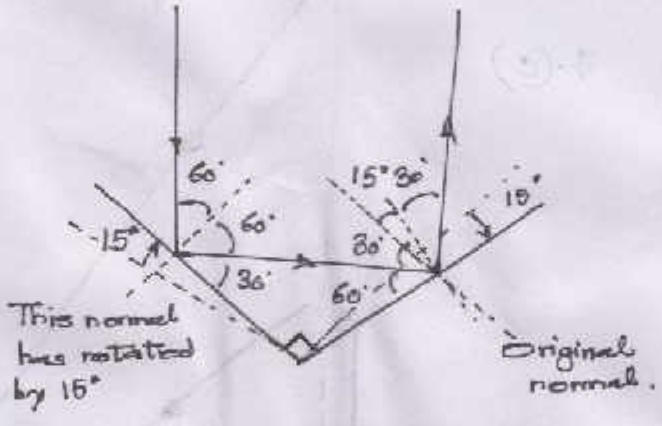
$v_{OM} = v_O - v_M = u - v$

$v_{IM} = -v_{OM} = -(u-v)$

$v_{OI} = v_{OM} - v_{IM} = 2(u-v)$

2. (D)

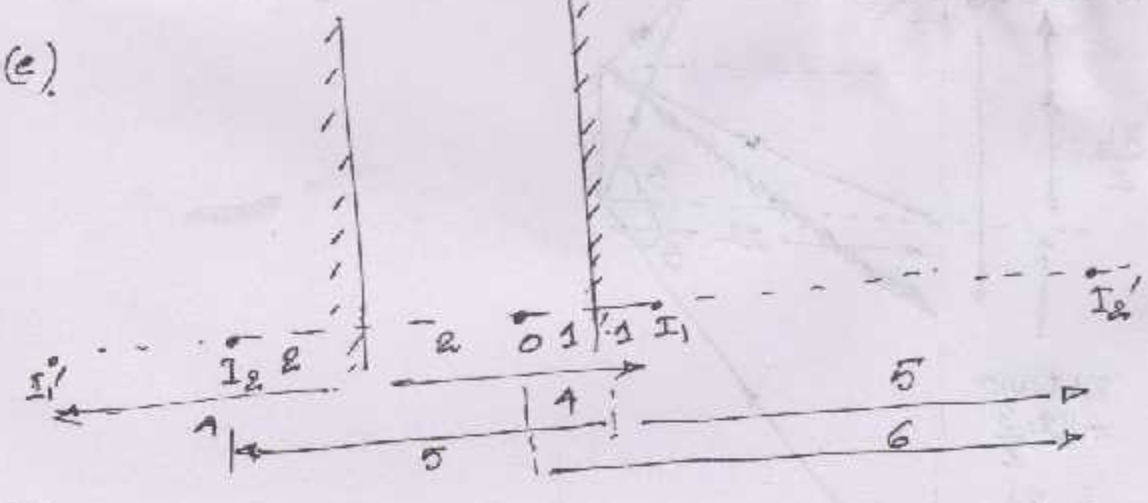




The emergent ray still makes 45° with the original normal.

∴ It is still parallel to the incident beam.

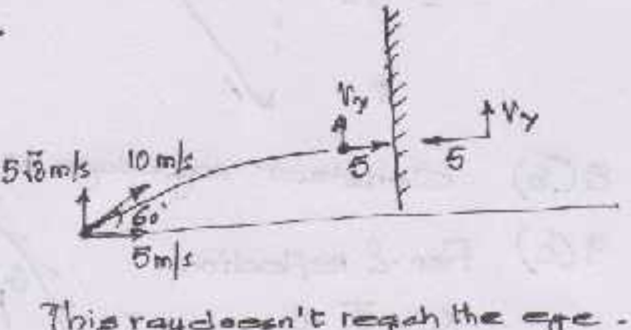
3. (e)



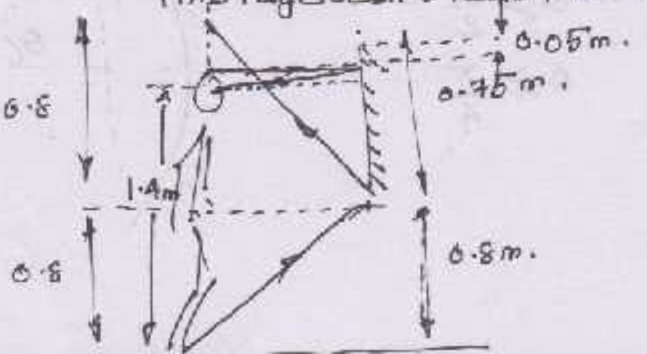
4. (A)

v_y isn't imp. in rel. vel. as it cancels out.

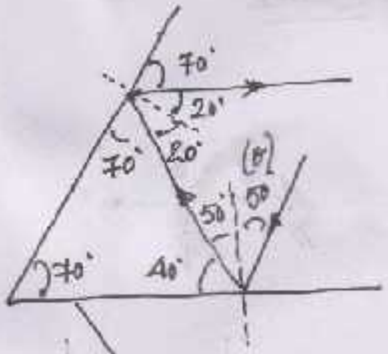
$v_r = 5 - (-5) = 10\,m/s$.



5. (C)

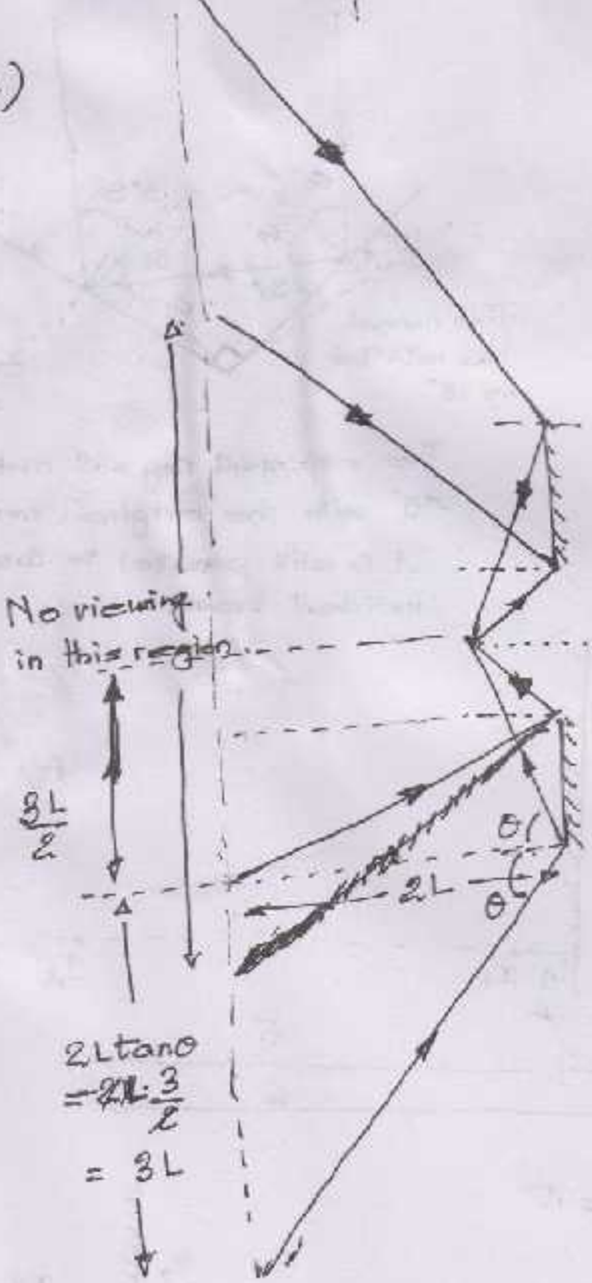


6(A)



Start from the reflected ray.

7.(c)



Time taken

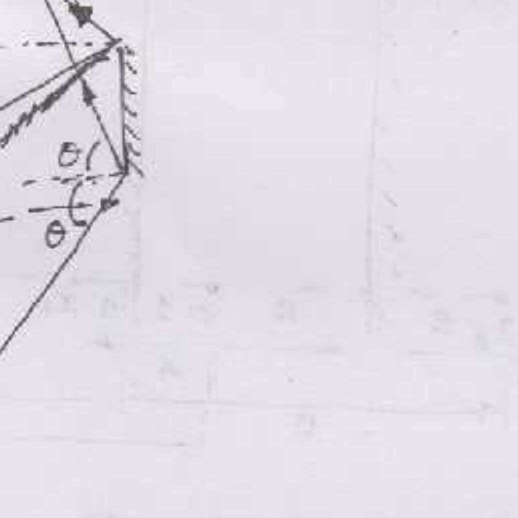
$= \frac{9L - 3L}{u} = \frac{6L}{u}$.

8(b) Construct ray diagrams.

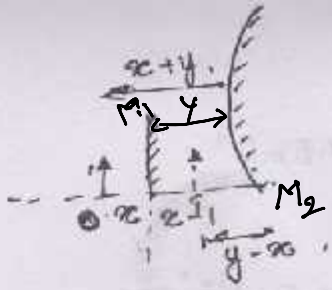
9(c) For 2 reflections

$\theta \geq \frac{\pi}{2} - \theta$

$\theta \geq \frac{\pi}{4}$.



10. (A)



For the mirror.

$$\frac{-1}{f} = \frac{1}{-(y-x)} + \frac{1}{-(x+y)}$$

$$f = \frac{x^2 - y^2}{2y}$$

11. (A) Discussed in theory.

12. (C) Apply mirror formula or Newton's formula $x_1 x_2 = f^2$, $b x_2 = \frac{a^2}{4} \Rightarrow x_2 = \frac{a^2}{4b}$.

13. (B) Lesser rays for the image
Intensity decreases.

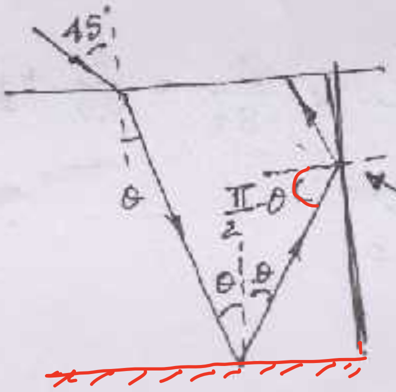
14. (C) $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \dot{v} = -\frac{v^2}{u^2}\dot{u} \Rightarrow v_{IM} = -m^2 v_{OM} = -\frac{9}{4} \times 4 = -9\text{cm/s}$.

$$\left[m = \frac{f}{f-u} = -\frac{3}{2} \right]$$

15. ~~(A)~~ D For plane mirrors, $v_{IM} = -v_{OM}$
" curved ", $v_{IM} = -m^2 v_{OM}$

16. (B) $\sqrt{3}\sin 30^\circ = 1 \cdot \sin \theta$

17. (C)



$$\frac{\sin 45^\circ}{\sin\theta} = \frac{2}{1} \Rightarrow \sin\theta = \frac{1}{2\sqrt{2}}$$

$\Rightarrow \cos\theta = \sqrt{7}/2\sqrt{2}$

Also, $\sin i_c$ $= \sin^{-1}\frac{1}{2} = 30^\circ$

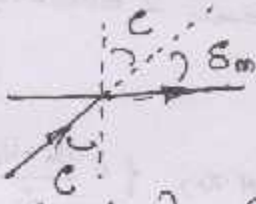
$\cos\theta > \sin i_c$

$\Rightarrow \frac{\pi}{2} - \theta > i_c$

$\Rightarrow$ TIR occurs here

$\therefore$ Deviation $- 180^\circ$

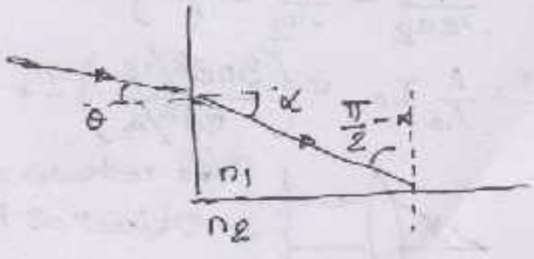
18. (D)



$\delta_{max} = \frac{\pi}{2} - C$

19. (A) $t\left(1 - \frac{1}{3/2}\right) = 2$

20. (A) $\frac{\sin\theta}{\sin\alpha} = n_1$



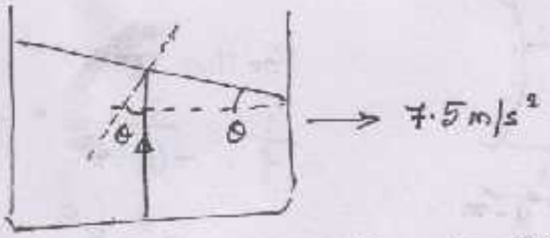
For TIR,

$\frac{\pi}{2} - \alpha > i_c$

$\Rightarrow \cos\alpha > \sin i_c$

$\Rightarrow \sqrt{1 - \frac{\sin^2\theta}{n_1^2}} > \frac{n_2}{n_1}$

21. (B)



$\tan\theta = \frac{a}{g} = \frac{7.5}{10} = \frac{3}{4} \Rightarrow \theta = 37^\circ$

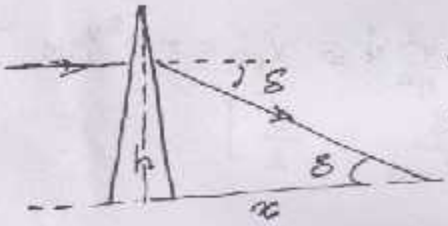
For TIR at water surface,

$\theta > i_c$

$\Rightarrow \sin\theta > \sin i_c$

$\Rightarrow \frac{3}{5} > \frac{1}{\mu}$.

22. (C)



$\delta = (\mu - 1)A$

$\tan\delta = \frac{h}{x}$

As δ is small, $\tan\delta \approx \delta$

$x = \frac{h}{\delta} \Rightarrow x = \frac{h}{(\mu-1)A}$.

23. (C) $\frac{3}{2v} - \frac{4}{3u} = \frac{3/2 - 4/3}{-10} \Rightarrow \frac{3}{2v} = \frac{4}{3u} - \frac{1}{60}$

$\because u < 0 \Rightarrow v < 0$

24. (D) $\frac{4}{3v} - \frac{3}{2u} = \frac{4/3 - 3/2}{-10} \Rightarrow \frac{4}{3v} = \frac{3}{2u} + \frac{1}{60}$

For real image, $v > 0$

$\Rightarrow \frac{3}{2u} + \frac{1}{60} > 0$

$\Rightarrow u > -90$

$\Rightarrow |u| < 90$.

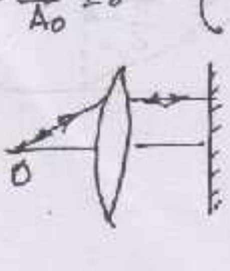
25. (B) In one case the image is real & other virtual.

$v_1 = xu_1$ & $v_2 = -xu_2$

$\left.\begin{array}{l} \frac{1}{xu_1} - \frac{1}{-u_1} = \frac{1}{f} \\ \frac{1}{-xu_2} - \frac{1}{-u_2} = \frac{1}{f} \end{array}\right\}$ Eliminating x, $f = \frac{u_1 + u_2}{2}$

26. (D) $I = \frac{A}{A_0} I_0 = \left(\frac{3\pi d^2/16}{\pi d^2/4}\right) I_0 = \frac{3}{4} I_0$

27. (B)



Rays retrace path ⇒ Normal incidence on mirror ⇒ Ray ∥ P.A after refraction ⇒ Object at F

28. (D) Entire image formed, brightness halved.

29. (A) $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v^2} dv + \frac{1}{u^2} du = \frac{1}{f^2} df$

$f = \frac{R}{2(\mu - 1)}$. If squeezed, $R\downarrow \Rightarrow f\downarrow \Rightarrow df$ -ve

But $du = 0 \Rightarrow dv$ -ve $\Rightarrow$ Moves towards lens.

30. (B) $h_i = \frac{v}{u} h_0$

$v\downarrow \Rightarrow h_i \downarrow$

31. (B) For $dv = 0$, $\frac{1}{u^2} du = \frac{1}{f^2} df$

du -ve

$\Rightarrow$ df -ve

$\Rightarrow f\downarrow \Rightarrow R\downarrow$

$\Rightarrow$ squeeze.

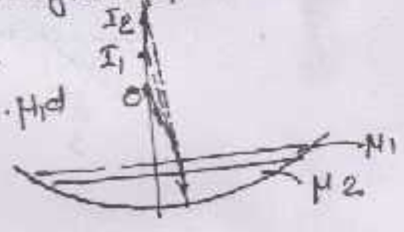
32. (C) Apply snell's Law with small angle approximation.

33. (D) Neglect thickness of layer

$AO = d$, $AI_1 = \mu d$, $AI_2 = \frac{\mu_2}{\mu_1} \cdot \mu_1 d$

$= \mu_2 d$

$= R$



34. (A) $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$.

35. (C)

36. (C)

37. (B) $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

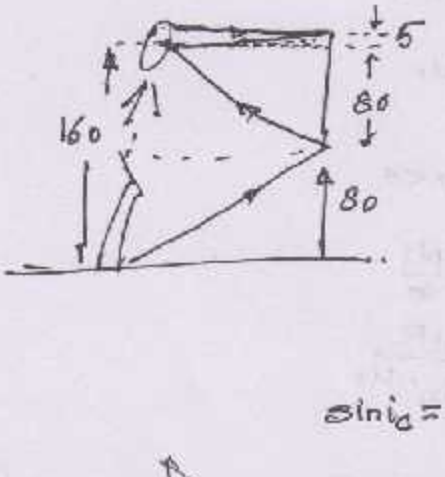
$\frac{1}{v} + \frac{1}{10} = \frac{1}{30}$

$v = -15$ cm

38. A.

Ex-II.

1. A, B
2. B
3. B, C



4. A, C, D
5. C, D
6. C, D.
7. A, C

$\sin i_c = \frac{4/3}{5/3} = 4/5 \Rightarrow \sin i_c = \frac{4}{5}$

$\sin 60° = \frac{\sqrt{3}}{2} > \frac{4}{5} \Rightarrow 60° > i_c$

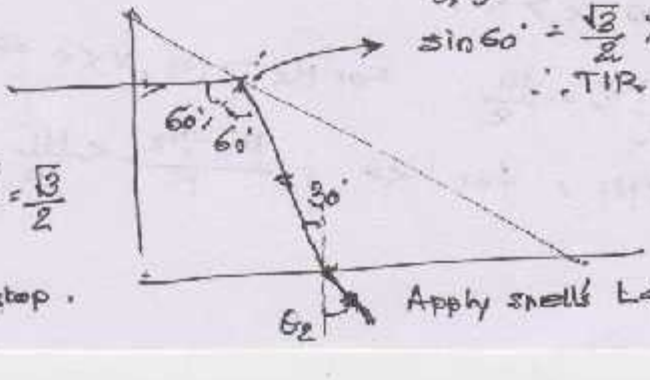
$\therefore$ TIR occurs here.

If $\mu_\omega = \frac{5}{2\sqrt{3}}$

$\sin i_c = \frac{5/2\sqrt{3}}{5/3} = \frac{\sqrt{3}}{2}$

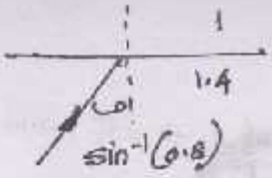
$i_c = 60°$

TIR will stop.



Apply snell's Law.

8. (c)



$\sin i_c = \frac{1}{1.4} = \frac{5}{7}$

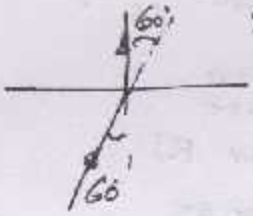
$0.8 > 5/7$

∴ TIR.

9. B, C, D At k_2 $\delta = 0$, $\mu_1 = \mu_2 \Rightarrow k_2 = 1$.

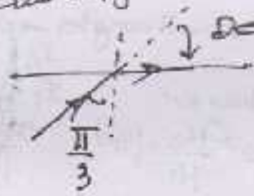
θ_2 - Max deviation For $\mu_1 > \mu_2$,

Ray bends towards normal.



$\delta_{max} = 60° = \theta_2$

θ_1 corresponds to critical angle



10. (A)

11. A, D.

12. (D) $\frac{\mu_2}{v} - \frac{\mu_1}{-x} = \frac{\mu_2 - \mu_1}{R} \Rightarrow \frac{\mu_2}{v} = \frac{\mu_1}{-x} + \frac{\mu_2-\mu_1}{R}$.

If $\mu_2 > \mu_1$, then even v can be $-ve$.

For $v > 0$ $\frac{\mu_2-\mu_1}{R} > \frac{\mu_1}{x} \Rightarrow x > \frac{\mu_1 R}{\mu_2 - \mu_1}$ provided $\mu_2 > \mu_1$.

Real image depends on x, R, μ_1, μ_2, not on R only.

13. A, B $\frac{\mu_2}{v} = \frac{\mu_2-\mu_1}{R} - \frac{\mu_1}{x} < 0$

if $\mu_2 < \mu_1$

$v < 0$.

If $\mu_2 < \mu_1$, for $v < 0$

$-\frac{(\mu_2-\mu_1)}{R} < \frac{\mu_1}{x}$

$x > -\frac{\mu_1 R}{\mu_2 - \mu_1}$

$\Rightarrow x > R$.

14. A, B $\frac{\mu_2}{v} = \frac{\mu_1-\mu_2}{R} - \frac{\mu_1}{x}$ For $\mu_2 > \mu_1$, $v < 0 \Rightarrow$ (A)

For $\mu_2 < \mu_1$, for $v < 0$, $\frac{\mu_1 - \mu_2}{R} < \frac{\mu_1}{x}$.

15. B, C, D. Apply displacement method.

16. (A, B, C, D)

17. (A, C, D)

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

then apply lens formula and mirror formula.

18. (C, D)

$$\mu = \frac{1}{\sin\theta_c} = \frac{1}{\sin 45^\circ} = \frac{1}{1/\sqrt{2}} = \sqrt{2} = 1.41$$

possible values are 1.5 & 1.6.

Ex - III .

1(C)

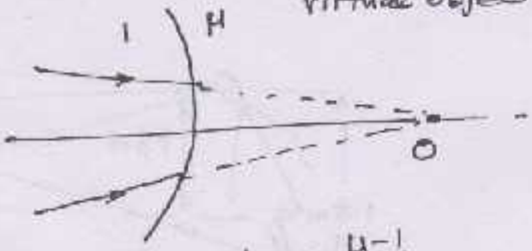
Real object.

$$\frac{\mu}{v} = -\frac{1}{x} - \frac{\mu-1}{R}$$

$\Rightarrow v < 0 \;\; \forall x$

$\Rightarrow$ virtual image

virtual object.



$$\frac{\mu}{v} = \frac{1}{x} - \frac{\mu-1}{-R}$$

v isn't −ve for all x.

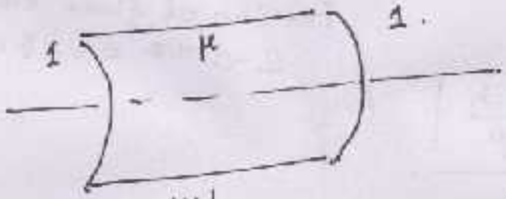
2.(D)

$$\frac{\mu}{v_1} - \frac{1}{-x} = \frac{\mu-1}{-R}$$

$$\frac{1}{v} - \frac{\mu}{v_1'} = \frac{1-\mu}{R}$$

$$\mu\left[\frac{1}{v_1} + \frac{1}{v_1'}\right] + \frac{1}{x} - \frac{1}{v} = -\frac{2(\mu-1)}{R}$$

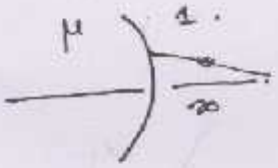
v depends on v_1, v_1'



$v_1 \neq v_1'$

As thickness is unspecified.

3.(A)



$$\frac{\mu}{v} - \frac{1}{-x} = \frac{\mu-1}{-R}$$

$$\frac{\mu}{v} = -\frac{1}{x} - \frac{\mu-1}{R}$$

$v < 0 \;\; \forall x$

$\Rightarrow$ Real image.

4(A) All dimensions of disc are ⊥r to the P.A

$\Rightarrow$ " " " " equally magnified.

∴ Image − circular disc.

5(B) At t = 1 , r = 0.6

$$m = \frac{f}{f-u} = \frac{-10}{-10+15} = -2$$

Radius of image = 2r = 1.2 cm.

Area " " $= \pi(.12)^2 = 1.44\pi \text{ cm}^2$ $\pi(1.2)^2$

6.(A) $\frac{dR}{dt} = \frac{d}{dt}(2r) = 0.2 \text{ cm/se}$

7. A → p, r As μ↑, f↓ ∴ object dist. > focal length

$\Rightarrow$ Final image − Real & small in size in comparision to image before change.

B → q, r As R is doubled, f↓ ∴ obj. dist. < focal length.

$\Rightarrow$ Final imge − virtual.

∴ Final image becomes smaller as compared to image before change.

C → q, r Slab introduction shifts the effective object for lens rightward.

Final image − virtual

Final image size ↓

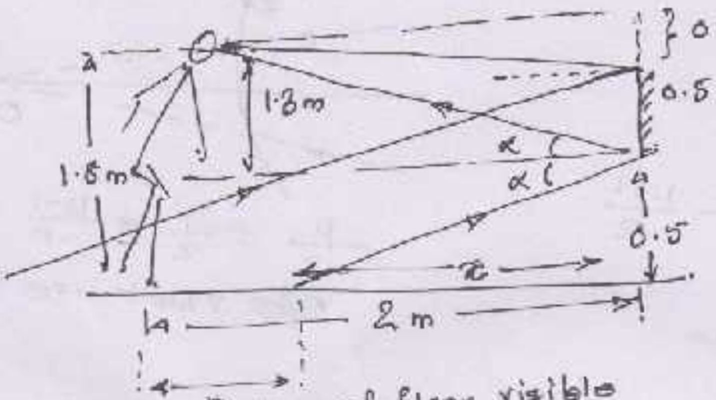
D → q, r Object is at C $\Rightarrow$ Final image virtual

" " " size ↓ before change.

8. A − S, B − P, S, C − R, T, D − Q, R

Ex-IV

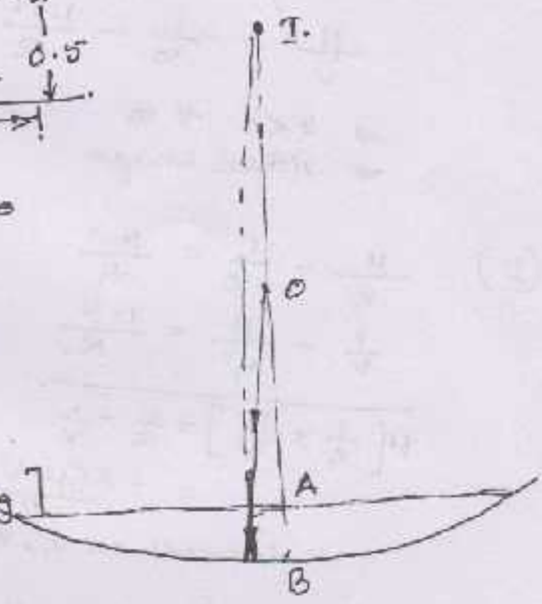
1. **1.23 m**



$$\frac{1.3}{2} = \frac{0.5}{x}$$
$$\Rightarrow x = 0.77\text{m} = 77\text{cm}.$$

Portion of floor visible
$2 - 0.77 = 1.23$ m

2. $\boxed{\frac{R-h}{\mu}}$.



$AO = x$
$AI = \mu x$
$BI = \mu x + h = R$ [For retracing]
$x = \frac{R-h}{\mu}$

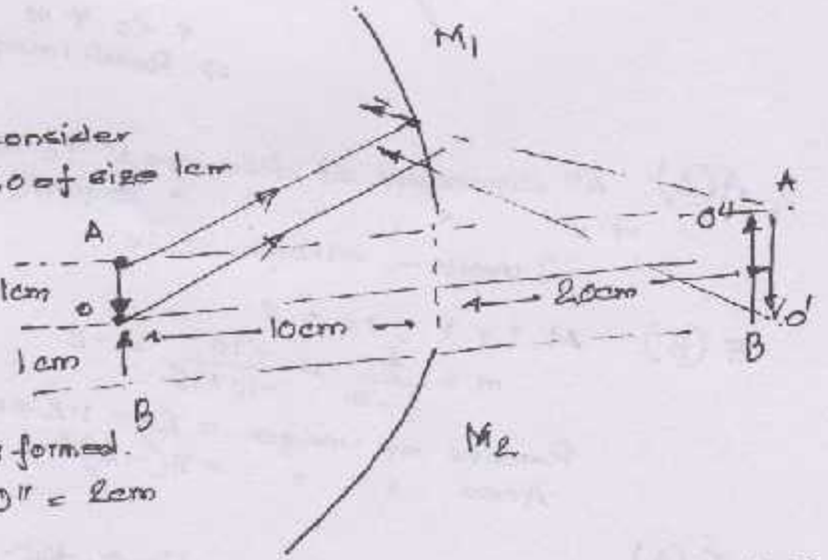
3. **2cm**

For upper half mirror, consider an extended object AO of size 1cm

$$\frac{1}{v} + \frac{1}{-10} = \frac{1}{-20}$$
$$\Rightarrow v = 20\text{cm}$$

$$\frac{h_i}{-1} = -\frac{20}{-10} \Rightarrow h_i = -2\text{cm}$$

Similarly for M_2, BO″ is formed.
Dist. bet. images, O′O″ = 2cm

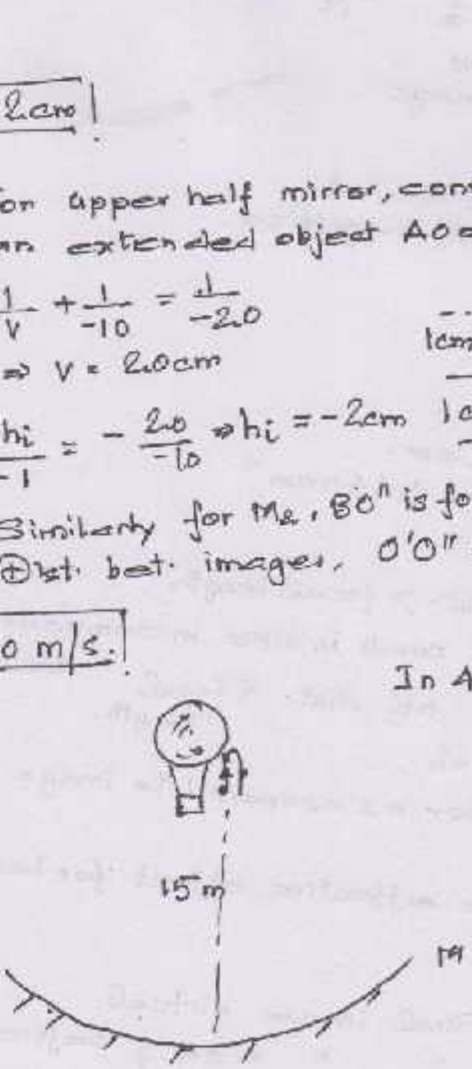


4. **80 m/s.**

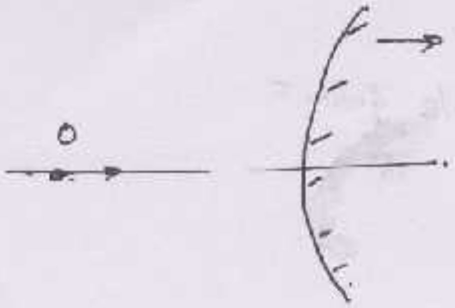
In A_2, the ball reaches the same ht. of 15 m

$$v_{IM} = -m^2 v_{OM} = -(-2)^2(-20) = 80\text{m/s}$$

$$m = \frac{f}{f-u} = \frac{-10}{-10-(-15)} = -2.$$



5. $v_M = 20\,m/s$ (th = it)



$V_{OI} = 1\,m/s \qquad m = 1/10$

$V_{OI} = V_{OM} - V_{IM} = V_{OM} + m^2 V_{OM}$

$V_{OI} = (1+m^2)\, V_{OM}$

$\therefore\ V_{OM} = \frac{100}{101}\ m/s$

$V_O = V_{OM} + V_M = \frac{2120}{101} \simeq \boxed{21\,m/s}$

$m = \frac{f}{f-u} \Rightarrow \frac{1}{10} = \frac{10}{10-u} \rightarrow u = -90$

$v = -mu = -\frac{1}{10}(-90) = 9\,m$

$m = -\frac{v}{u}$

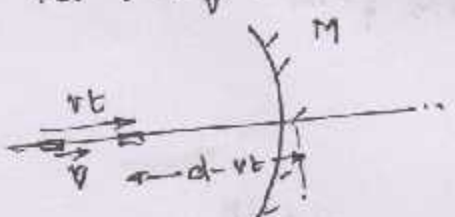
$\Rightarrow \frac{dm}{dt} = \frac{1}{u^2}\left[v \cdot v_{OM} - u\, v_{IM} \right]$

$V_{IM} = -m^2 V_{OM} = -\frac{1}{100} \times 1 = \frac{-1}{100}\,m/s$

$= \frac{1}{8100}\left[9 \times 1 - (-90)\left(-\frac{1}{100}\right) \right]$

$$\boxed{\frac{dm}{dt} = 10^{-3}\,/s}$$

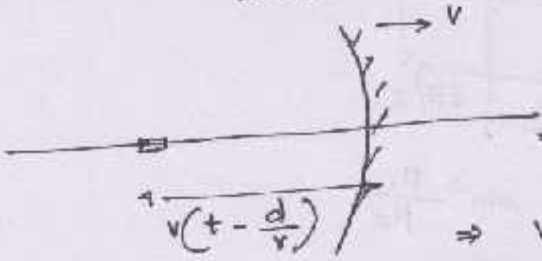
6. For $t < \frac{d}{v}$, M is stationary



$V_{IM} = -m^2 V_{OM} = -\frac{f^2}{(f-u)^2} v = -\frac{R^2/4\ v}{\left[-R/2 - [-(d-vt)]\right]^2}$

$$\boxed{V_{IE} = V_{IM} = \frac{-R^2 v}{\left[2(d-vt) - R\right]^2}}$$

For $t > \frac{d}{v}$, M moves with speed v & block is at rest.



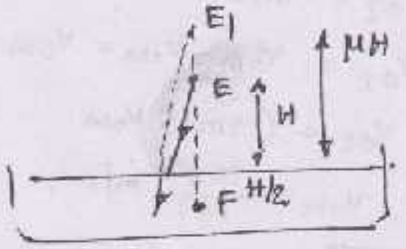
$V_{IM} = -m^2 V_{OM}$

$\Rightarrow V_{IE} = V_{ME} - \left(\frac{f}{f-u}\right)^2 (V_{OE} - V_{ME})$

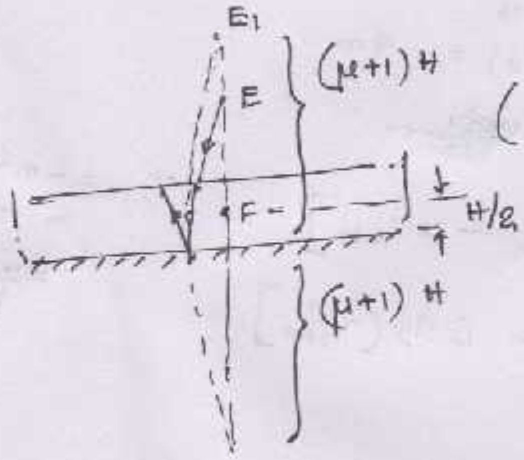
$\Rightarrow V_{IE} = v - \left[\frac{-R/2}{-R/2 - (-(vt-d))}\right]^2 (0 - v)$

$$\boxed{V_{IE} = v\left[1 - \frac{R^2}{[2(vt-d) - R]^2}\right]}$$

7 (a)



$\mu H + H/2$ from F



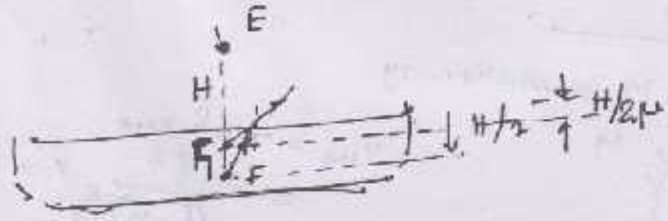
$(\mu+1)H + H/2$

$\left(\mu + \frac{3}{2}\right) H$ below F.

$H + \frac{H}{2\mu}$ from E

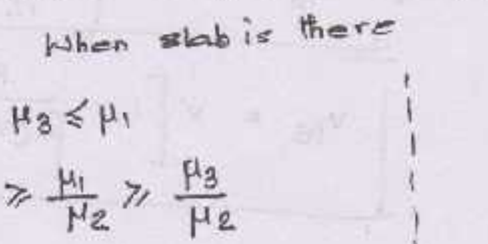
$H\left(1 + \frac{1}{2\mu}\right)$

(b)



$H + \frac{3H}{2\mu}$

$= H\left(1 + \frac{3}{2\mu}\right)$



8. Case I : No slab $\theta \geq i_c = \sin^{-1}\frac{\mu_1}{\mu_2}$

Case II : When slab is there

$\mu_3 \leq \mu_1$

$\sin\theta \geq \frac{\mu_1}{\mu_2} \geq \frac{\mu_3}{\mu_2}$

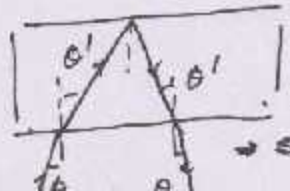
⇒ TIR

⇒ Ray back to med. II

$\mu_3 > \mu_1$

$\sin\theta \geq \frac{\mu_1}{\mu_2} < \frac{\mu_3}{\mu_2}$

∴ Ray enters med III

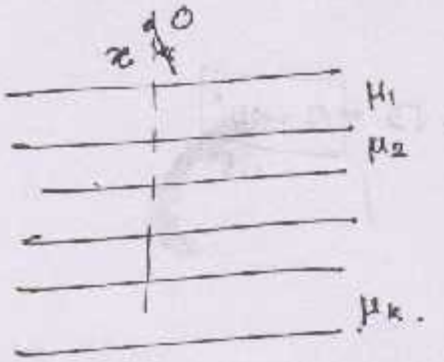


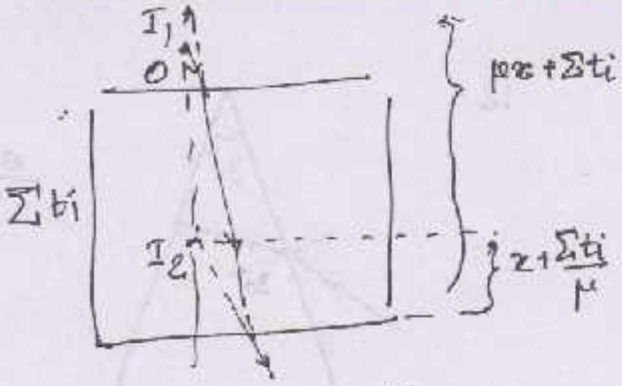
$\frac{\sin\theta}{\sin\theta'} = \frac{\mu_3}{\mu_2}$

$\Rightarrow \sin\theta' = \frac{\mu_2}{\mu_3}\sin\theta \geq \frac{\mu_2}{\mu_3}\cdot\frac{\mu_1}{\mu_2}$

$\Rightarrow \sin\theta' \geq \frac{\mu_1}{\mu_3}$ ⇒ TIR occurs again

9.



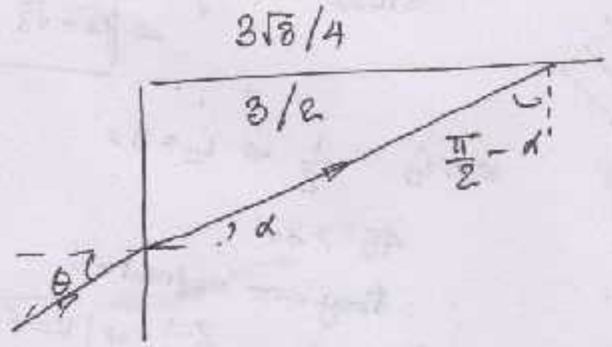


$$\frac{1}{\mu_k}\left[\frac{\mu_k}{\mu_{k-1}}\left[\cdots \frac{\mu_3}{\mu_2}\left(\frac{\mu_2}{\mu_1}(\mu_1 x + t_1) + t_2\right) + \cdots\right] + t_k\right] = x + \frac{\Sigma t_i}{\mu}.$$

$$\Rightarrow \quad x + \sum \frac{t_i}{\mu_i} = x + \frac{\Sigma t_i}{\mu}.$$

$$\Rightarrow \boxed{\mu = \frac{\Sigma t_i}{\Sigma t_i/\mu_i}}$$

10.



$$\sin i_c = \frac{3\sqrt{3}/4}{3/2}$$

$$\Rightarrow i_c = 60^\circ$$

For TIR,

$$\frac{\pi}{2} - \alpha \geq i_c$$

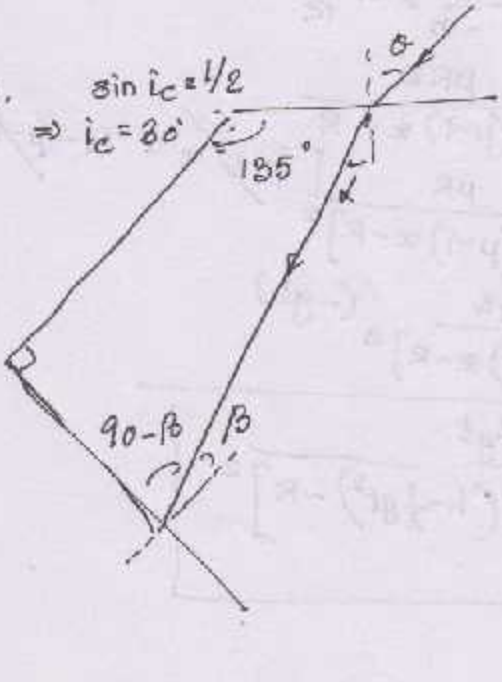
$$\sin\alpha \leq \frac{1}{2}$$

$$\Rightarrow \frac{\sqrt{3}}{2}\sin\theta \leq \frac{1}{2} \qquad \left[\frac{\sin\theta}{\sin\alpha} = \frac{3/2}{3\sqrt{3}/4}\right]$$

$$\Rightarrow \boxed{\theta \leq \sin^{-1}\frac{1}{\sqrt{3}}}.$$

11. $\sin i_c = 1/2$

$\Rightarrow i_c = 30^\circ$



$$90 - \alpha + 90 - \beta + 135^\circ + 90^\circ = 360^\circ$$

$$\Rightarrow \alpha + \beta = 45^\circ.$$

For TIR, $\beta \geq i_c$

$$\Rightarrow 45 - \alpha \geq 30^\circ$$

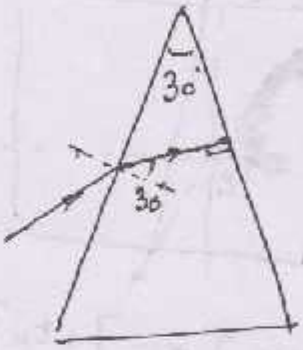
$$\Rightarrow \alpha \leq 15^\circ$$

$$\sin\alpha \leq \frac{\sqrt{3}-1}{2\sqrt{2}} \qquad \left[\frac{\sin\theta}{\sin\alpha} = \frac{2}{1}\right]$$

$$\frac{\sin\theta}{2} \leq \frac{\sqrt{3}-1}{2\sqrt{2}}$$

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

12.

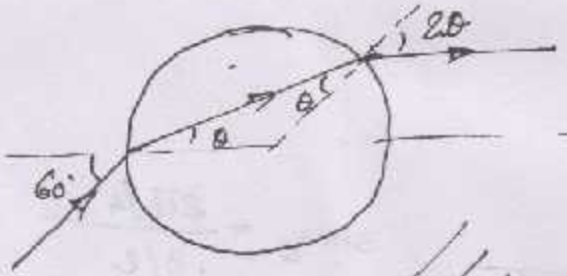


$$\frac{\sin\theta}{1/2} = \sqrt{2} \Rightarrow \boxed{\theta = 45^\circ}$$

13. $$\mu = \frac{\sin\left(\frac{A + \delta_{min}}{2}\right)}{\sin\left(\frac{A}{2}\right)} \leq \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin(A/2)} = \frac{\sin 45^\circ}{\sin 30^\circ} = \sqrt{2}.$$

$$\therefore \boxed{\mu \leq \sqrt{2}}$$

14.



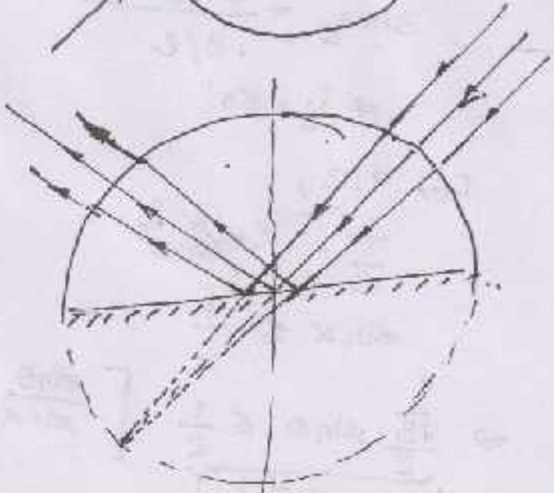
$$\left.\begin{aligned} \frac{\sqrt{3}/2}{\sin\theta} &= \mu \\ \frac{\sin\theta}{\sin 2\theta} &= \frac{1}{\mu} \end{aligned}\right\} \Rightarrow \sin 2\theta = \sqrt{3}/2$$

$$2\theta = 60^\circ$$

$$\boxed{\theta = 30^\circ}$$

$$\Rightarrow \boxed{\mu = \sqrt{3}.}$$

15.



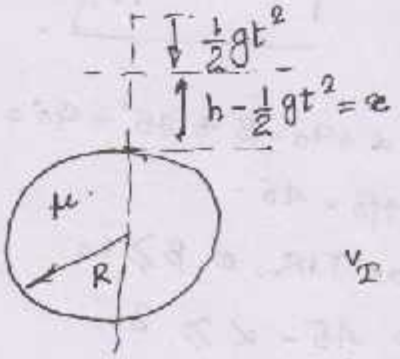
$$\sin i_c = \frac{1}{2} \Rightarrow i_c = 30^\circ$$

$$45^\circ > 30^\circ$$

$\therefore$ They are refracted.

$$\frac{2}{v} - \frac{1}{-\infty} = \frac{2-1}{3} \Rightarrow \boxed{v = 6.}$$

16.



$$\frac{\mu}{v} - \frac{1}{-x} = \frac{\mu - 1}{R}$$

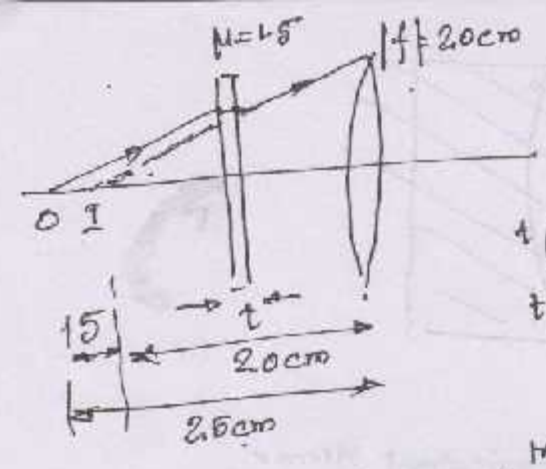
$$v = \frac{\mu R x}{(\mu-1)x - R}$$

$$v_I = \dot{v} = \frac{\mu R}{[(\mu-1)x - R]^2}\left[(\mu-1)x - R - (\mu-1)x\right]\dot{x}$$

$$v_I = -\frac{\mu R^2}{[(\mu-1)x - R]^2}(-gt)$$

$$\boxed{v_I = \frac{\mu R^2 g t}{\left[(\mu-1)\left(h - \frac{1}{2}gt^2\right) - R\right]^2}}$$

17.

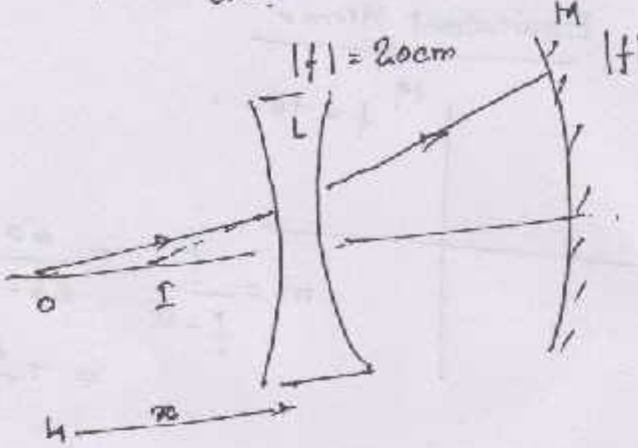


The image by slab must be at the focus of the lens.

$t\left(1-\frac{1}{\mu}\right) = 5$

$t\left(1-\frac{1}{3/2}\right) = 5 \Rightarrow \boxed{t = 15cm}$

18.



For L,

$\frac{1}{v} - \frac{1}{-x} = \frac{1}{-20}$

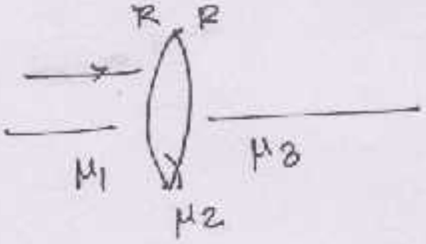
$\Rightarrow v = -\frac{20x}{20+x}$

Must be virtual. & must be at C of M.

$\frac{20x}{x+20} + 5 = 20$

$\Rightarrow \boxed{x = 60\ cm}$

19. (a)

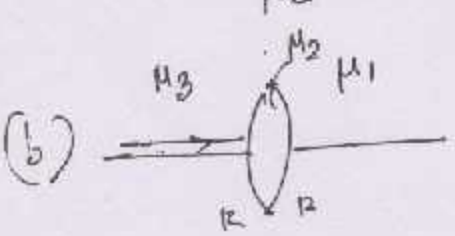


$\frac{\mu_2}{v_1} - \frac{\mu_1}{-\infty} = \frac{\mu_2 - \mu_1}{R}$

$\frac{\mu_3}{v} - \frac{\mu_2}{v_1} = \frac{\mu_3 - \mu_2}{-R}.$

$v = \frac{\mu_3 R}{2\mu_2 - \mu_1 - \mu_3}$

(b)

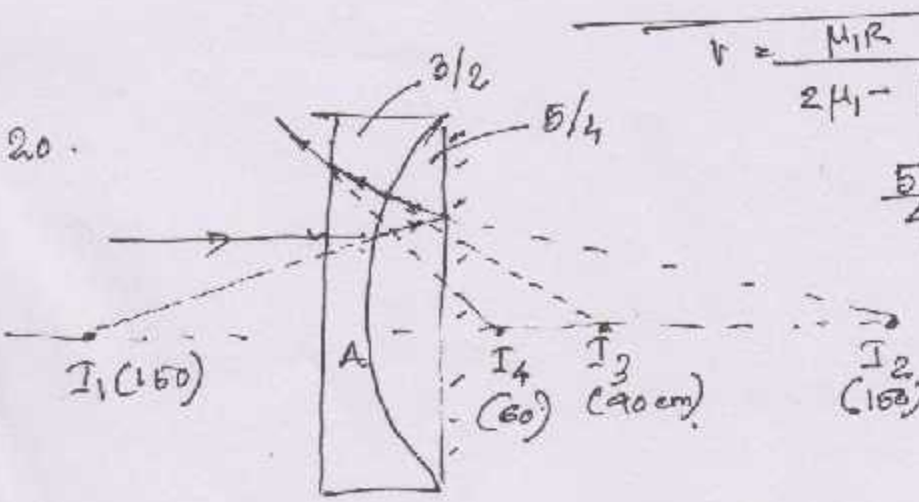


$\frac{\mu_2}{v_1} - \frac{\mu_3}{-\infty} = \frac{\mu_2 - \mu_3}{R}$

$\frac{\mu_1}{v} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{-R}.$

$v = \frac{\mu_1 R}{2\mu_1 - \mu_1 - \mu_3}.$

20.



$\frac{5}{4v_1} - \frac{1}{-\infty} = \frac{5/4 - 3/2}{30}$

$\Rightarrow v_1 = -150$

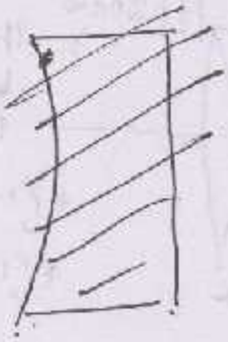
$\frac{3}{2v_3} - \frac{5}{4(-150)} = \frac{3/2 - 5/4}{-30}$

$\Rightarrow v_3 = -90cm$

$AI_3 = 90cm \Rightarrow AI_4 = \frac{90}{3/2}$

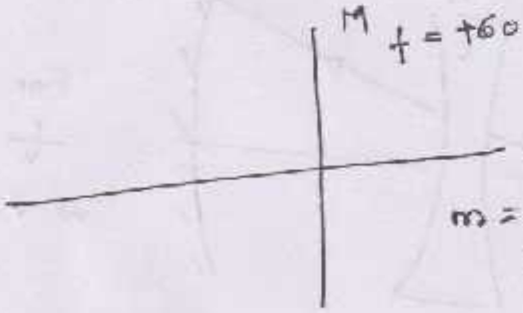
$= 60cm.$

(b)



(b)

Equivalent Mirror



$$m = \frac{f}{f-u} = \frac{60}{60-(-15)} = +\frac{4}{5}.$$