### Exercise - 1

#### OBJECTIVE PROBLEMS (JEE MAIN)

**SECTION (A): PLANE MIRROR**

1. A point source of light is placed in front of a plane mirror.
   (A) Only the reflected rays close to the normal meet at a point when produced backward.
   (B) All the reflected rays meet at a point when produced backward.
   (C) Only the reflected rays making a small angle with the mirror, meet at a point when produced backward.
   (D) Light of different colours make different images.
   
   Sol.

2. A point object is kept in front of a plane mirror. The plane mirror is doing SHM of amplitude 2 cm. The plane mirror moves along the x-axis and x-axis is normal to the mirror. The amplitude of the mirror is such that the object is always in front of the mirror. The amplitude of SHM of the image is
   (A) zero  
   (B) 2 cm  
   (C) 4 cm  
   (D) 1 cm
   Sol.

3. A watch shows the time as 3 : 25. What will be the time that appears when seen through a plane mirror?
   (A) 8 : 35  
   (B) 9 : 35  
   (C) 7 : 35  
   (D) 8 : 25
   Sol.

4. If a ray of light is incident on a plane mirror at an angle 60° from the mirror surface, then deviation produced by mirror is:
   (A) 30°  
   (B) 60°  
   (C) 90°  
   (D) 120°
   Sol.

5. When light is reflected from a mirror a change occurs in its:
   (A) phase,  
   (B) frequency,  
   (C) wavelength,  
   (D) speed
   Sol.

6. The images of clouds and trees in water always less bright than in reality -
   (A) because water is forming the image dirty  
   (B) because there is an optical illusion due to which the image appears to be less bright  
   (C) because only a portion of the incident light is reflected and quite a large portion goes mid water  
   (D) because air above the surface of water contains a lot of moisture
   Sol.

7. A ray is incident at an angle 38° on a mirror. The angle between normal and reflected ray is
   (A) 38°  
   (B) 52°  
   (C) 90°  
   (D) 76°
   Sol.
8. Mark the correct options.
(A) If the incident rays are converging, we have a real object.
(B) If the final rays are converging, we have a real image.
(C) The image of a virtual object is called a virtual image.
(D) If the image is virtual, the corresponding object is called a virtual object.

**Sol.**

9. A point source of light is placed in front of a plane mirror.
(A) All the reflected rays meet at a point when produced backward.
(B) Only the reflected rays close to the normal meet at a point when produced backward.
(C) Only the reflected rays making a small angle with the mirror, meet at a point when produced backward.
(D) Light of different colors make different images.

**Sol.**

10. Which of the following letters do not surface lateral inversion:
(A) HGA  (B) HOX  (C) VET  (D) YUL

**Sol.**

11. An object is initially at a distance of 100 cm from a plane mirror. If the mirror approaches the object at a speed of 5 cm/s. Then after 6 s the distance between the object and its image will be:
(A) 60 cm  (B) 140 cm  
(C) 170 cm  (D) 150 cm

**Sol.**

12. Two mirrors are placed perpendicular to each other. A ray strikes the first mirror and after reflection from the first mirror it falls on the second mirror. The ray after reflection from second mirror will emerge:
(A) Perpendicular to the original ray
(B) Parallel to the original ray
(C) At 45° to the original ray
(D) At 60° to the original ray

**Sol.**

13. A person is in a room whose ceiling and two adjacent walls are mirrors. How many images are formed?
(A) 5  (B) 6  (C) 7  (D) 8

**Sol.**

14. If an object is placed unsymmetrically between two plane mirrors, inclined at the angle of 60°, then the total number of images formed is
(A) 5  (B) 4  (C) 2  (D) infinite

**Sol.**
**SECTION (B) : SPHERICAL MIRROR**

15. In image formation from spherical mirrors, only paraxial rays are considered because they:
   (A) are easy to handle geometrically  
   (B) contain most of the intensity of the incident light  
   (C) form nearly a point image of a point source  
   (D) show minimum dispersion effect.
   
   **Sol.**

16. A concave mirror of radius of curvature 20 cm forms image of the sun. The diameter of the sun subtends an angle $1^\circ$ on the earth. Then the diameter of the image is (in cm):
   (A) $2x/9$  
   (B) $x/9$  
   (C) 20  
   (D) $x/18$
   
   **Sol.**

19. An object is placed at a distance $u$ from a concave mirror and its real image is received on a screen placed at a distance of $v$ from the mirror. If $f$ is the focal length of the mirror, then the graph between $1/v$ versus $1/u$ is:

   **Sol.**

17. A convex mirror has a focal length $f$. A real object, placed at a distance $u$ in front of it from the pole, produces an image at
   (A) $2u$  
   (B) $u/2$  
   (C) $f$  
   (D) $\infty$
   
   **Sol.**

20. An infinitely long rod lies along the axis of a concave mirror of focal length $f$. The near end of the rod is at a distance $u > f$ from the mirror. Its image will have a length
   (A) $uf/(u - f)$  
   (B) $uf/(u + f)$  
   (C) $f/(u + f)$  
   (D) $uf/(u + f)$
   
   **Sol.**

18. A convex mirror has a focal length = 20 cm. A convergent beam tending to converge to a point 20 cm behind convex mirror on principal axis falls on it. The image if formed at
   (A) infinity  
   (B) 40 cm  
   (C) 20 cm  
   (D) 10 cm
### 21. A candle is kept at a distance equal to double the focal length from the pole of a convex mirror. Its magnification will be:

- (A) $-1/3$
- (B) $1/3$
- (C) $2/3$
- (D) $-2/3$

**Sol.**

### 22. A concave mirror gives an image three times as large as the object placed at a distance of 20 cm from it. For the image to be real, the focal length should be:

- (A) 10 cm
- (B) 15 cm
- (C) 20 cm
- (D) 30 cm

**Sol.**

### 23. If an object is 30 cm away from a concave mirror of focal length 15 cm, the image will be:

- (A) erect
- (B) virtual
- (C) diminished
- (D) of same size

**Sol.**

### 24. A concave mirror cannot form:

- (A) virtual image of a virtual object
- (B) virtual image of a real object
- (C) real image of a real object
- (D) real image of a virtual object

**Sol.**

### 25. The largest distance of the image of a real object from a convex mirror of focal length 20 cm can be:

- (A) 20 cm
- (B) infinite
- (C) 10 cm
- (D) depends on the position of the object

**Sol.**

### 26. A particle is moving towards a fixed spherical mirror. The image:

- (A) must move away from the mirror
- (B) must move towards the mirror
- (C) may move towards the mirror
- (D) will move towards the mirror, only if the mirror is convex

**Sol.**
27. A straight line joining the object point and image point is always perpendicular to the mirror
   (A) if mirror is plane only
   (B) if mirror is concave only
   (C) if mirror is convex only
   (D) none of these
   Sol.

28. The focal length of spherical mirror is
   (A) Maximum for red light
   (B) Maximum for blue light
   (C) Maximum for white light
   (D) Same for all lights
   Sol.

29. A virtual image, larger than the object can be produced by
   (A) convex mirror  (B) concave mirror
   (C) plane mirror   (D) concave lens
   Sol.

30. In case of concave mirror, the minimum distance between a real object and its real image is :
   (A) $f$  (B) $2f$  (C) $4f$  (D) zero
   Sol.

31. The rear-view mirror of a car is :
   (A) Plane  (B) Convex
   (C) Concave  (D) None of the above
   Sol.

32. A candle flame of 3 cm is placed at 300 cm from a wall. A concave mirror is kept at distance $x$ from the wall in such a way that image of the flame on the wall is 9 cm. Then $x$ is -
   (A) 339 cm  (B) 900 cm
   (C) 450 cm  (D) 423 cm
   Sol.

33. When a wave is refracted :
   (A) its path must change
   (B) its amplitude must change
   (C) its velocity must change
   (D) its frequency must change
   Sol.

34. A ray incident at a point at an angle of incidence of 60° enters a glass sphere of $\mu = \sqrt{3}$ and it is reflected and refracted at the farther surface of the sphere. The angle between reflected and refracted rays at this surface is
   (A) 50°  (B) 90°  (C) 60°  (D) 40°
   Sol.
35. A ray of light passes through a plane glass slab of thickness \( t \) and refractive index \( \mu = 1.5 \). The angle between incident ray and emergent ray will be

(A) \( 0^\circ \)  (B) \( 30^\circ \)  (C) \( 45^\circ \)  (D) \( 60^\circ \)

**Sol.**

38. The critical angle of light going from medium A to medium B is \( \theta \). The speed of light in medium A is \( v \). The speed of light in medium B is :

(A) \( \frac{v}{\sin \theta} \)  (B) \( v \sin \theta \)  (C) \( v \cot \theta \)  (D) \( v \tan \theta \)

**Sol.**

36. A beam of light is converging towards a point. A plane parallel plate of glass of thickness \( t \) refractive index \( \mu \) is introduced in the path of the beam. The convergent point is shifted by (assume near normal incidence) :

(A) \( \left( 1 - \frac{1}{\mu} \right) \) away  (B) \( \left( 1 + \frac{1}{\mu} \right) \) away

(C) \( \left( 1 - \frac{1}{\mu} \right) \) nearer  (D) \( \left( 1 + \frac{1}{\mu} \right) \) nearer

**Sol.**

39. A ray of light from a denser medium strike a rarer medium. The angle of reflection is \( r \) and that of refraction is \( r' \). The reflected and refracted rays make an angle of \( 90^\circ \) with each other. The critical angle will be

(A) \( \sin^{-1} (\tan r) \)  (B) \( \tan^{-1} (\sin r) \)

(C) \( \sin^{-1} (\tan r') \)  (D) \( \tan^{-1} (\sin r') \)

**Sol.**

37. A ray of light is incident on one face of a transparent slab of thickness 15 cm. The angle of incidence is \( 60^\circ \). If the lateral displacement of the ray on emerging from the parallel plane is \( 5\sqrt{3} \) cm, the refractive index of the material of the slab is

(A) 1.414  (B) 1.532  (C) 1.732  (D) none

**Sol.**

40. Two transparent media A and B are separated by a plane boundary. The speed of light in medium A is \( 2.0 \times 10^8 \) m s\(^{-1}\) and in medium B is \( 2.5 \times 10^8 \) m s\(^{-1}\). The critical angle for which a ray of light going from A to B is totally internally reflected is

(A) \( \sin^{-1} \left( \frac{1}{2} \right) \)  (B) \( \sin^{-1} \left( \frac{2}{5} \right) \)

(C) \( \sin^{-1} \left( \frac{4}{5} \right) \)  (D) \( \sin^{-1} \left( \frac{1}{3} \right) \)
41. A small source of light is 4 m below the surface of a liquid of refractive index 5/3. In order to cut off all the light coming out of liquid surface, minimum diameter of the disc placed on the surface of liquid is
(A) 3 m  (B) 4 m  (C) 6 m  (D) x

**Sol.**

42. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is 4/3 and fish is 12 cm below the surface, the radius of the circle in cm is
(A) $12 \times 3 \times \sqrt{5}$  (B) $4 \times \sqrt{5}$
(C) $12 \times 3 \times \sqrt{7}$  (D) $12 \times 3 / \sqrt{7}$

**Sol.**

43. A ray of light is incident at angle $i$ on a surface of a prism of small angle $A$ & emerges normally from the opposite surface. If the refractive index of the material of the prism is $\mu$, the angle of incidence $i$ is nearly equal to:
(A) $\frac{A}{\mu}$  (B) $\frac{A}{(2\mu)}$  (C) $\mu A$  (D) $\mu \frac{A}{2}$

**Sol.**

44. A certain prism is found to produce a minimum deviation of 38°. It produces a deviation of 44° when the angle of incidence is either 42° or 62°. What is the angle of incidence when it is undergoing minimum deviation?
(A) 45°  (B) 49°  (C) 40°  (D) 55°

**Sol.**

45. A ray incident at angle 53° on a prism emerges at an angle at 37° as shown. If the angle of incidence is made 50°, which of the following is a possible value of the angle of emergence.

(A) 35°  (B) 42°  (C) 40°  (D) 38°

**Sol.**
46. A beam of monochromatic light is incident at \( i = 50^\circ \) on one face of an equilateral prism, the angle of emergence is \( 40^\circ \), then the angle of minimum deviation is:
   (A) \( 30^\circ \)  \( (B) < 30^\circ \)  \( (C) < 30^\circ \)  \( (D) > 30^\circ \)

Sol.

47. A prism has a refractive index \( \sqrt{\frac{3}{2}} \) and refracting angle \( 90^\circ \). Find the minimum deviation produced by prism.
   (A) 40°  \( (B) 45^\circ \)  \( (C) 30^\circ \)  \( (D) 49^\circ \)

Sol.

48. A prism is made up of material of refractive index \( \sqrt{3} \). The angle of prism is \( A \). If the angle of minimum deviation is equal to the angle of the prism, then the value of \( A \) is:
   (A) 30°  \( (B) 45^\circ \)  \( (C) 60^\circ \)  \( (D) 75^\circ \)

Sol.

49. R.I. of a prism is \( \sqrt{\frac{7}{3}} \) and the angle of prism is \( 60^\circ \). The limiting angle of incidence of a ray that will be transmitted through the prism is:
   (A) 30°  \( (B) 45^\circ \)  \( (C) 15^\circ \)  \( (D) 50^\circ \)

Sol.

50. The angle of a prism is \( 60^\circ \) and the index of refraction of glass with air is 1.5. If the angle of incidence on the first face is \( I_1 \) and the angle of emergence at the second face is \( I_2 \), then the prism produces minimum deviation when
   (A) \( I_1 = 0 \)  \( (B) I_1 > I_2 \)  \( (C) I_1 < I_2 \)  \( (D) I_1 = I_2 \)

Sol.

51. In a thin prism of glass (refractive index 1.5) which of the following relations between the angle of minimum deviation \( \delta_m \) and angle of refraction \( r \) will be correct:
   (A) \( \delta_m = r \)  \( (B) \delta_m = 1.5 \times r \)  \( (C) \delta_m = 2r \)  \( (D) \delta_m = r/2 \)

Sol.
SECTION (E): REFRACTION BY SPHERICAL SURFACE

52. The image for the converging beam after refraction through the curved surface is formed at:

\[ \frac{n-1}{n+1} \]

(A) \( x = 40 \text{ cm} \)  \quad (B) \( x = \frac{40}{3} \text{ cm} \)

(C) \( x = -\frac{40}{3} \text{ cm} \)  \quad (D) \( x = \frac{180}{7} \text{ cm} \)

Sol.

SECTION (F): LENSES & MIRRORS

54. A thin lens of focal length \( f \) and its aperture diameter \( d \) forms a real image of intensity \( I \). Now the central part of the aperture up to diameter \( \frac{d}{2} \) is blocked by an opaque paper. The focal length and image intensity would change to:

\( \left( \frac{f}{2} \right) \left( \frac{1}{2} \right) \)

(A) \( f \) \( \frac{1}{2} \)

(B) \( f \) \( \frac{1}{4} \)

(C) \( \frac{3f}{4} \) \( \frac{1}{2} \)

(D) \( f \) \( \frac{3f}{4} \)

Sol.

55. A thin symmetrical double convex lens of power \( P \) is cut into three parts, as shown in the figure. Power of A is:

\( \left( \frac{P}{2} \right) \left( \frac{P}{3} \right) \left( P \right) \)

(A) \( 2P \)

(B) \( P \)

(C) \( \frac{P}{3} \)

(D) \( P \)

Sol.

56. A plano-convex lens has a curved surface of radius 100 cm. If \( \mu = 1.5 \), then the focal length of the lens is:

\( \left( \frac{50}{2} \right) \left( \frac{100}{2} \right) \left( \frac{200}{2} \right) \left( 500 \right) \)

(A) 50 cm

(B) 100 cm

(C) 200 cm

(D) 500 cm

Sol.
57. A lens of power +2.0 D is placed in contact with another lens of power -1.0 D. The combination will behave like
(A) a converging lens of focal length 100 cm
(B) a diverging lens of focal length 100 cm
(C) a converging lens of focal length 50 cm
(D) a diverging lens of focal length 50 cm.

**Sol.**

58. A biconvex lens has a focal length of 10 cm. It is cut in half and two pieces are placed as shown. The focal length of the final combination is:

(A) 10 cm (B) 20 cm (C) 40 cm (D) Not a lens

**Sol.**

59. Parallel beam of light is incident on a system of two convex lenses of focal lengths \(f_1 = 20\) cm and \(f_2 = 10\) cm. What should be the distance between the two lenses so that rays after refraction from both the lenses pass undeviated

(A) 60 cm (B) 30 cm (C) 90 cm (D) 40 cm

**Sol.**

60. A pin is placed 10 cm in front of a convex lens of focal length 20 cm and refractive index 1.5. The surface of the lens farther away from the pin is silvered and has a radius of curvature of 22 cm. How far from the lens is the final image formed?
(A) 11 cm (B) 12 cm (C) 13 cm (D) 14 cm

**Sol.**

61. When the object is at distances \(u_1\) and \(u_2\) respectively and of the same size, then focal length of the lens is:

\[
\frac{1}{f} = \frac{1}{u_1} + \frac{1}{u_2}
\]

(A) \(\frac{1}{2}\sqrt{u_1u_2}\) (B) \(\frac{1}{2}(u_1 + u_2)\)
(C) \(\sqrt{u_1u_2}\) (D) \(2(u_1 - u_2)\)

**Sol.**

62. The height of the image formed by a converging lens on a screen is 8 cm. For the same position of the object and screen again an image of size 12.5 cm is formed on the screen by shifting the lens. The height of the object

(A) 62.5/32 cm (B) 64/12.5 cm (C) 10 cm (D) none

**Sol.**
SECTION (G): DISPERSION OF LIGHT

63. The dispersion of light in a medium implies that:
(A) lights of different wavelengths travel with different speeds in the medium
(B) lights of different frequencies travel with different speeds in the medium
(C) the refractive index of medium is different for different wavelengths
(D) all of the above.
Sol.

64. Critical angle of light passing from glass to air is minimum for
(A) red   (B) green  (C) yellow  (D) violet
Sol.

65. A plane glass slab is placed over various coloured letters. The letter which appears to be raised the least is:
(A) violet  (B) yellow (C) red   (D) green
Sol.

66. A medium has $n_r = 1.56$, $n_a = 1.44$. Then its dispersive power is:
(A) $\frac{3}{50}$   (B) $\frac{6}{25}$  (C) 0.03   (D) none
Sol.

67. The refractive index of flint glass for blue line is 1.6333 and red line is 1.6161, then dispersive power of the glass is:
(A) 0.0276   (B) 0.276  (C) 2.76   (D) 0.106
Sol.

68. Indicate the correct statement in the following
(A) The dispersive power depends upon the angle of prism
(B) The angular dispersion depends upon the angle of the prism
(C) The angular dispersion does not depend upon the dispersive power
(D) The dispersive power in vacuum is one
Sol.

69. Which of the following diagrams shows correctly the dispersion of white light by a prism?

(A) \[ \text{Diagram A} \] (B) \[ \text{Diagram B} \]

(C) \[ \text{Diagram C} \] (D) \[ \text{Diagram D} \]
70. **Statement-I**: If a source of light is placed in front of rough wall its image is not seen.
   **Statement-II**: The wall does not reflect light.
   (A) Statement-1 is true, statement-2 is true; statement-2 is correct explanation for statement-1
   (B) Statement-1 is true, statement-2 is true; statement-2 is NOT correct explanation for statement-1
   (C) Statement-1 is true, Statement-2 is false.
   (D) Statement-1 is false, statement-2 is true.
   **Sol.**

71. **Statement-I**: As the distance $x$ of a parallel ray from axis increases, focal length decreases.
    **Statement-II**: As $x$ increases, the distance from pole to the point of intersection of reflected ray with principal axis decreases.
    (A) Statement-1 is true, statement-2 is true; statement-2 is correct explanation for statement-1
    (B) Statement-1 is true, statement-2 is true; statement-2 is NOT correct explanation for statement-1
    (C) Statement-1 is true, Statement-2 is false.
    (D) Statement-1 is false, statement-2 is true.
    **Sol.**

72. **Statement-I**: When an object dipped in a liquid is viewed normally, the distance between the image and the object is independent of the height of the liquid above the object.
    **Statement-II**: The normal shift is independent of the location of the slab between the object and the observer.
    (A) Statement-1 is true, statement-2 is true; statement-2 is correct explanation for statement-1
    (B) Statement-1 is true, statement-2 is true; statement-2 is NOT correct explanation for statement-1
    (C) Statement-1 is true, Statement-2 is false.
    (D) Statement-1 is false, statement-2 is true.
    **Sol.**

73. **Statement-I**: When two plane mirrors are kept perpendicular to each other as shown (O is the point object), 3 image will be formed.
    **Statement-II**: In case of multiple reflection, image of one surface can act as an object for the next surface.
    (A) Statement-1 is true, statement-2 is true; statement-2 is correct explanation for statement-1
    (B) Statement-1 is true, statement-2 is true; statement-2 is NOT correct explanation for statement-1
    (C) Statement-1 is true, Statement-2 is false.
    (D) Statement-1 is false, statement-2 is true.
    **Sol.**

74. **Statement-I**: A piece of paper placed at the position of a real image of a virtual object of intense light will burn after sufficient time.
    **Statement-II**: A virtual object is that point where the incident rays appear to converge and a real image is that point at which reflected/refracted rays actually converge.
    (A) Statement-1 is true, statement-2 is true; statement-2 is correct explanation for statement-1
    (B) Statement-1 is true, statement-2 is true; statement-2 is NOT correct explanation for statement-1
    (C) Statement-1 is true, statement-2 is false.
    (D) Statement-1 is false, statement-2 is true.
    **Sol.**
Exercise - II

JEE ADVANCED - OBJECTIVE

1. When a plane mirror AB is placed horizontally on level ground at a distance of 60 metres from the foot of a tower, the top of the tower and its image in the mirror subtends, an angle of 90° at B. The height of the tower is:

(A) 30 metre  (B) 60 metre
(C) 90 metre  (D) 120 metre.

Sol.

2. A unnumbered wall clock shows time 04 : 25 : 37, where 1st term represents hours, 2nd represents minutes & the last term represents seconds, What time will its image in a plane mirror show.

(A) 08 : 35 : 23  (B) 07 : 35 : 23
(C) 07 : 34 : 23  (D) None of these

Sol.

3. Two plane mirrors of length L are separated by distance L and a man \(M_1\) is standing at distance L from the connecting line of mirrors as shown in figure. A man \(M_2\) is walking in a straight line at distance 2L parallel to mirrors at speed \(u\), then man \(M_2\) at \(O\) will be able to see image of \(M_1\) for total time:

(A) \(\frac{4L}{u}\)  (B) \(\frac{3L}{u}\)
(C) \(\frac{6L}{u}\)  (D) \(\frac{8L}{u}\)

Sol.

4. A person is standing in a room of width 200 cm. A plane mirror of vertical length 10 cm is fixed on a wall in front of the person. The person looks into the mirror from distance 50 cm. How much width (height) of the wall behind him will he be able to see: (assume that he uses the full mirror)

(A) 30 cm  (B) 40 cm  (C) 50 cm  (D) None
5. In the diagram shown, all the velocities are given with respect to earth. What is the relative velocity of the image in mirror (1) with respect to the image in the mirror (2)? The mirror (1) forms an angle $\beta$ with the vertical.
(A) $2V \sin 2\beta$  
(B) $2V \sin \beta$  
(C) $2V / \sin 2\beta$  
(D) none

6. Two plane mirrors are inclined to each other at an angle $60^\circ$. If a ray of light incident on the first mirror is parallel to the second mirror, it is reflected from the second mirror.
(A) Perpendicular to the first mirror  
(B) Parallel to the first mirror  
(C) Parallel to the second mirror  
(D) Perpendicular to the second mirror.

7. Two mirrors are inclined at an angle $\theta$ as shown in the figure. Light ray is incident parallel to one of the mirrors. The ray will start re tracing its path after third reflection if:
(A) $\theta = 45^\circ$  
(B) $\theta = 30^\circ$  
(C) $\theta = 60^\circ$  
(D) all three

8. There are two plane mirrors with reflecting surface facing each other. Both the mirrors are moving with speed $v$ away from each other. A point object is placed between the mirrors. The velocity of the image from due to n-th reflection will be
(A) $nv$  
(B) $2nv$  
(C) $3nv$  
(D) $4nv$
9. Two plane mirrors are placed parallel to each other at a distance \(L\) apart. A point object \(O\) is placed between them, at a distance \(L/3\) from one mirror. Both mirrors form multiple images. The distance between any two images cannot be:

(A) \(3L/2\)  
(B) \(2L/3\)  
(C) \(2L\)  
(D) None  

Sol.

10. Images of an object placed between two plane mirrors whose reflecting surfaces make an angle of 90° with one another lie on:

(A) straight line  
(B) zig-zag curve  
(C) circle  
(D) ellipse  

Sol.

11. A person's eye is at a height of 1.5 m. He stands in front of a 0.3 m long plane mirror which is 0.8 m above the ground. The length of the image he sees of himself is:

(A) 1.5 m  
(B) 1.0 m  
(C) 0.8 m  
(D) 0.6 m  

Sol.

12. A man of height '\(h\)' is walking away from a street lamp with a constant speed '\(v\)'. The height of the street lamp is \(3h\). The rate at which the length of the man's shadow is increasing when he is at a distance 10 m from the base of the street lamp is:

(A) \(v/2\)  
(B) \(v/3\)  
(C) \(2v\)  
(D) \(v/6\)  

Sol.

13. A boy of height 1.5 m with his eye level at 1.4 m stands before a plane mirror of length 0.75 m fixed on the wall. The height of the lower edge of the mirror above the floor is 0.8 m. Then:

(A) the boy will see his full image  
(B) the boy cannot see his hair  
(C) the boy cannot see his feet  
(D) the boy cannot see neither his hair nor his feet  

Sol.

14. A plane mirror is moving with velocity \(4\hat{i} - 5\hat{j} + 8\hat{k}\). A point object in front of the mirror moves with a velocity \(3\hat{i} + 4\hat{j} - 5\hat{k}\). Here \(\hat{k}\) is along the normal to the plane mirror and facing towards the object. The velocity of the image is:

(A) \(-3\hat{i} - 4\hat{j} + 5\hat{k}\)  
(B) \(3\hat{i} - 4\hat{j} + 11\hat{k}\)  
(C) \(-3\hat{i} - 4\hat{j} - 11\hat{k}\)  
(D) \(7\hat{i} - 9\hat{j} + 11\hat{k}\)  

Sol.
15. A man of height 170 cm wants to see his complete image in a plane mirror (while standing). His eyes are at a height of 160 cm from the ground.
(A) Minimum length of the mirror = 80 cm
(B) Minimum length of the mirror = 85 cm
(C) Bottom of the mirror should be at a height 80 cm or less
(D) Bottom of the mirror should be at a height 85 cm

Sol.

16. A flat mirror M is arranged parallel to a wall W at a distance $l$ from it. The light produced by a point source S kept on the wall is reflected by the mirror and produces a light spot on the wall. The mirror moves with velocity $v$ towards the wall.

(A) The spot of light will move with the speed $v$ on the wall
(B) The spot of light will not move on the wall
(C) As the mirror comes closer the spot of light will become larger and shift away from the wall with speed larger than $v$
(D) The size of the light on the wall remains the same

Sol.

17. The distance of an object from the focus of a convex mirror of radius of curvature 'a' is 'b'. Then the distance of the image from the focus is:
(A) $\frac{b^2}{4a}$
(B) $\frac{a}{b^2}$
(C) $\frac{a^2}{4b}$
(D) none

Sol.

18. A boy 2 m tall stands 40 cm in front of a mirror. He sees an erect image, 1 m high. The mirror is:
(A) Concave, $f = 40$ cm
(B) Convex, $f = 40$ cm
(C) Plane
(D) Either convex or concave

Sol.

19. What is the distance of a needle from a concave mirror of focal length 10 cm for which a virtual image of twice its height is formed?
(A) 2.5 cm
(B) 5 cm
(C) 8 cm
(D) 9.1 cm

Sol.
20. A convex mirror has a focal length $f$. An object of height $h$ is placed in front of it. If an erect image of height $h/n$ is formed. The distance of the object from the mirror is:
(A) $n/f$  
(B) $1/n$  
(C) $(n+1)/f$  
(D) $(n-1)/f$
**Sol.**

21. A real inverted image in a concave mirror is represented by $(u, v, f)$ are coordinates)

(A) ![Diagram A](image)
(B) ![Diagram B](image)
(C) ![Diagram C](image)
(D) ![Diagram D](image)

**Sol.**

22. Which one of the following statements are incorrect for spherical mirrors:
(A) A concave mirror forms only virtual images for any position of real object
(B) A convex mirror forms only virtual images for any position of a real object.
(C) A convex mirror forms only a virtual diminished image of an object placed between its pole and the focus.
(D) A concave mirror forms a virtual magnified image of an object placed between its pole and the focus.

**Sol.**

23. The distance of an object from a spherical mirror is equal to focal length of the mirror. Then the image:
(A) must be at infinity  
(B) may be at infinity  
(C) may be at the focus  
(D) none

**Sol.**

24. In the figure shown, the image of a real object is formed at point I. AB is the principal axis of the mirror. The mirror must be:

(A) Convex & placed towards right of I
(B) Convex & placed towards left of I
(C) Convex and placed towards right of I
(D) Convex & placed towards left of I.

**Sol.**

25. A point object at 15 cm from a concave mirror of radius of curvature 20 cm is made to oscillate along the principal axis with amplitude 2 mm. The amplitude of its image will be
(A) 2 mm  
(B) 4 mm  
(C) 8 mm  
(D) none

**Sol.**
26. A luminous point object is moving along the principal axis of a concave mirror of focal length 12 cm towards it. When its distance from the mirror is 20 cm its velocity is 4 cm/s. The velocity of the image in cm/s at that instant is
(A) 6, towards the mirror  (B) 6, away from the mirror
(C) 9, away from the mirror  (D) 9, towards the mirror.
Sol.

27. A point object on the principal axis at a distance 15 cm in front of a concave mirror of radius of curvature 20 cm has velocity 2 mm/s perpendicular to the principal axis. The velocity of image at that instant will be:
(A) 2 mm/s  (B) 4 mm/s
(C) 8 mm/s  (D) none of these
Sol.

28. The origin of x and y coordinates is the pole of a concave mirror of focal length 20 cm. The x-axis is the optical axis with x > 0 being the real side of mirror. A point object at the point (25 cm, 1 cm) is moving with a velocity 10 cm/s in positive x-direction. The velocity of the image in cm/s is approximately
(A) -80i + 8j  (B) 160i + 8j
(C) -160i - 8j  (D) 160i - 4j
Sol.

29. The circular boundary of the concave mirror subtends a cone of half angle $\theta$ at its centre of curvature. The minimum value of $\theta$ for which ray incident on this mirror parallel to the principle axis suffers reflection more than one is

(A) 30°  (B) 45°  (C) 60°  (D) 75°
Sol.

30. An object is placed in front of a convex mirror at a distance of 50 cm. A plane mirror is introduced covering the lower half of the convex mirror. If the distance between the object and the plane mirror is 30 cm, it is found that there is no gap between the images formed by the two mirrors. The radius of the convex mirror is:
(A) 12.5 cm  (B) 25 cm  (C) 50 cm  (D) 100 cm
Sol.
31. In the figure shown find the total magnification after two successive reflections first on M₁ & then on M₂.

(A) + 1  (B) - 2  (C) + 2  (D) - 1

Sol.

32. In the figure shown if the object 'O' moves towards the plane mirror, then the image I₁ (which is formed after successive reflections from M₁ & M₂ respectively)

(A) towards right  (B) towards left  (C) with zero velocity  (D) cannot be determined

Sol.

33. A ray of light is incident on a concave mirror. It is parallel to the principal axis and its height from principal axis is equal to the focal length of the mirror. The ratio of the distance of point B to the distance of the focus from the centre of curvature is (AB is the reflected by)

(A) \( \frac{2}{\sqrt{3}} \)  (B) \( \frac{3}{2} \)  (C) \( \frac{2}{3} \)  (D) \( \frac{1}{2} \)

Sol.

34. The image (of a real object) formed by a concave mirror is twice the size of the object. The focal length of the mirror is 20 cm. The distance of the object from the mirror is (are)

(A) 10 cm  (B) 30 cm  (C) 25 cm  (D) 15 cm

Sol.
35. In the figure shown consider the first reflection at the plane mirror and second at the convex mirror. AB is object.

(A) the second image is real, inverted of 1/5th magnification
(B) the second image is virtual and erect with magnification 1/5
(C) the second image moves towards the convex mirror.
(D) the second image moves away from the convex mirror.

Sol.

37. A concave mirror cannot form
(A) virtual image of virtual object
(B) virtual image of a real object
(C) real image of a real object
(D) real image of a virtual object

Sol.

38. The x-z plane separates two media A and B with refractive indices \( \mu_A \) and \( \mu_B \), respectively. A ray of light travels from A and B. Its directions in the two media are given by the unit vectors, \( \mathbf{i}_\mathbf{a} + \mathbf{j}_\mathbf{b} \) & \( \mathbf{i}_\mathbf{a} + \mathbf{j}_\mathbf{b} \) respectively where \( \mathbf{i} \) & \( \mathbf{j} \) are unit vectors in the x and y directions. Then

(A) \( \mu_A \mathbf{a} = \mu_B \mathbf{a} \)
(B) \( \mu_A \mathbf{b} = \mu_B \mathbf{b} \)
(C) \( \mu_A \mathbf{a} = \mu_B \mathbf{a} \)
(D) \( \mu_B \mathbf{b} = \mu_B \mathbf{b} \)

Sol.

SECTION (C) : REFRACTION IN GENERAL, REFRACTION AT PLANE SURFACE AND T.I.R.

39. A ray of light moving along the unit vector \((-i-2j)\) undergoes refraction at an interface of two media, which is the x-z plane. The refractive index for \( y > 0 \) is 2 while for \( y < 0 \), it is \( \sqrt{5}/2 \). The unit vector along which the refracted ray moves is:

(A) \( \frac{-3i - 5j}{\sqrt{34}} \)
(B) \( \frac{-4i - 3j}{5} \)
(C) \( \frac{-3i - 4j}{5} \)
(D) None of these
41. A mark at the bottom of a beaker containing liquid appears to rise by 0.1 m. The depth of the liquid is 1 m. Assume the refractive index of liquid is:
(A) 1.33
(B) 3/10
(C) 10/9
(D) 1.5

42. How much water should be filled in a container of height 21 cm, so that it appears half filled (of total height of the container) when viewed from the top of the container?
(A) 18.0 cm
(B) 10.5 cm
(C) 12.0 cm
(D) 14.0 cm

43. A parallel sided block of glass of refractive index 1.5 which is 35 mm thick rests on the floor of a tank of water (refractive index = 4/3). The difference between apparent depth of floor at A & B when seen from vertically above is equal to
(A) 2 mm
(B) 3 mm
(C) 4 mm
(D) none

44. A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let O be the centre of the mirror, and C the centre of curvature. If the mirror is now filled with water, the image will be:
(A) real and located at a point between C and O
(B) real, and located at a point between C and O (virtual, and located at a point between C and O)

45. An under water swimmer is at a depth of 12 m below the surface of water. A bird is at a height of 18 m from the surface of water. The swimmer appears to be at a distance x m from the surface of water. (Refractive index of water = 4/3) The value of x is:
(A) 24 m
(B) 12 m
(C) 18 m
(D) 9 m
45. A bird is flying 3 m above the surface of water. If the bird is diving vertically down with speed = 6 m/s, his apparent velocity as seen by a stationary fish underwater is  
(A) 8 m/s  (B) 6 m/s  (C) 12 m/s  (D) 4 m/s  
Sol.

47. A light ray is incident on a transparent sphere of index $= \sqrt{2}$, at an angle of incidence = 45°. What is the deviation of a tiny fraction of the ray, which enters the sphere, undergoes two internal reflections, and then refracts out into air? 
(A) 270°  (B) 240°  (C) 120°  (D) 180°  
Sol.

48. In the figure ABC is the cross section of a right angled prism and BCDE is the cross section of a glass slab. The value of $\theta$ so that light incident normally on the face AB does not cross the face BC is (given $\sin^{-1}(3/5) = 37^\circ$)  
(A) $\theta < 37^\circ$  (B) $\theta > 37^\circ$  
(C) $\theta < 53^\circ$  (D) $\theta < 53^\circ$  
Sol.

46. Given that, velocity of light in quartz = $1.5 \times 10^4$ m/s and velocity of light in glycerine = $\frac{9}{4} \times 10^4$ m/s. Now a slab made of quartz is placed in glycerine as shown. The shift of the object produced by slab is  
(A) 6 cm  (B) $3.55$ cm  (C) 9 cm  (D) 2 cm  
Sol.

49. A cubical block of glass of refractive index $n_1$ is in contact with the surface of water of refractive index $n_w$. A beam of light is incident on vertical face of the block (see figure). After refraction, a total internal reflection at the base and refraction at the opposite vertical face, the ray emerges out at an angle $\theta$. The value of $\theta$ is given by
50. A vertical pencil of rays comes from bottom of a tank filled with a liquid. When it is accelerated with an acceleration of 7.5 m/s², the ray is seen to be totally reflected by liquid surface. What is minimum possible refractive index of liquid?
(A) slightly greater than 4/3
(B) slightly greater than 5/3
(C) slightly greater than 1.5
(D) slightly greater than 1.75
Sol.

51. A ray of light is incident normally on one face of 30° – 60° – 90° prism of refractive index 5/3 immersed in water of refractive index 4/3 as shown in figure.

(A) The exit angle θ, of the ray is sin⁻¹(5/8)
(B) The exit angle θ, of the ray is sin⁻¹(5/4√3)
(C) Total internal reflection at point P ceases if the refractive index of water is increased to 5/2√3 by dissolving some substance.
(D) Total internal reflection at point P ceases if the refractive index of water is increased to 5/6 by dissolving some substance.
Sol.

52. A ray of light in a liquid of refractive index 1.4, approaches the boundary surface between the liquid and air at an angle of incidence whose sine is 0.8. Which of the following statements is correct about the behaviour of the light?
(A) It is impossible to predict the behavior of the light ray on the basis of the information supplied
(B) The sine of the angle of refraction of the emergent ray will less than 0.8
(C) The ray will be internally reflected
(D) The sine of the angle of refraction of the emergent ray will be greater than 0.8.
Sol.
53. The figure shows ray incident at an angle $i = \pi/3$. If the plot drawn shown the variation of $|r - i|$ versus $\mu_i/\mu_2 = k$, ($r = $ angle of refraction)

(A) $\mu_1 > \mu_2 < \mu_1$  
(B) $\mu_1^2 - \mu_2^2 > \mu_1^2$  
(C) $\mu_1^2 - \mu_2^2 > \mu_1^2$  
(D) $\mu_1^2 + \mu_2^2 > \mu_1^2$

\[ \begin{align*}
\mu_i & \quad \downarrow \quad |r - i| \\
\mu_1 & \quad \downarrow \quad k
\end{align*} \]

(A) the value of $k$ is $\frac{2}{\sqrt{3}}$  
(B) the value of $\theta_1 = \pi/6$  
(C) the value of $\theta_2 = \pi/3$  
(D) the value of $k$ is 1

\[ \begin{align*}
\mu_1 & \quad \downarrow \quad |r - i| \\
\mu_1 & \quad \downarrow \quad k
\end{align*} \]

54. In the diagram shown, a ray of light is incident on the interface between 1 and 2 at angle slightly greater than critical angle. The light suffers total internal reflection at this interface. After that the light ray falls at the interface of 1 and 3, and again it suffers total internal reflection. Which of the following relations should hold true?

\[ \begin{align*}
\mu_1 & \quad \downarrow \quad |r - i| \\
\mu_1 & \quad \downarrow \quad k
\end{align*} \]

55. A ray of monochromatic light is incident on one refracting face of a prism of angle 75°. It passes through the prism and is incident on the other face at the critical angle. If the refractive index of the material of the prism is $\sqrt{2}$, the angle of incidence on the first face of the prism is

(A) $30^\circ$  
(B) $45^\circ$  
(C) $60^\circ$  
(D) $0^\circ$
56. A prism having refractive index $\sqrt{2}$ and refracting angle 30°, has one of the refracting surface polished. A beam of light incident on the other refracting surface will retrace its path if the angle of incidence is:
(A) 0° (B) 30° (C) 45° (D) 60°

58. A ray of light is incident normally on the first refracting face of the prism of refracting angle A. The ray of light comes out at grazing emergence. If one half of the prism (shaded position) is knocked off, the same ray will
(A) emerge at an angle of emergence $\sin^{-1}\left(1/2 \sec A / 2\right)$
(B) not emerge out of the prism
(C) emerge at an angle of emergence $\sin^{-1}\left(1/2 \sec A / 4\right)$
(D) None of these

57. A triangular prism of glass is shown in figure. A ray incident normally on one face is totally reflected. If $\theta$ is 45°, the index of refraction of glass is:

\[ \text{(A) Less than } \sqrt{2} \quad \text{(B) Equal to } \sqrt{2} \]
\[ \text{(C) Greater than } \sqrt{2} \quad \text{(D) None of the above.} \]

59. A ray of light is incident at an angle 60° on the face of a prism having refractive angle 30°. The ray emerging out of the prism makes an angle 30° with the incident ray. $\theta$ through which it emerges from the surface:
(A) 0° (B) 30° (C) 45° (D) 60°
60. A ray of light is incident normally on one face of an equilateral prism of refractive index 1.5. The angle of deviation is
(A) 30°   (B) 45°   (C) 60°   (D) 75°

61. Light ray is incident on a prism of angle A = 60° and refractive index \( \mu = \sqrt{2} \). The angle of incidence at which the emergent ray grazes the surface is given by
(A) \( \sin^{-1}\left(\frac{\sqrt{3} - 1}{2}\right) \)   (B) \( \sin^{-1}\left(\frac{1 - \sqrt{3}}{2}\right) \)
(C) \( \sin^{-1}\left(\frac{\sqrt{3}}{2}\right) \)   (D) \( \sin^{-1}\left(\frac{2}{\sqrt{3}}\right) \)

62. The angle of a prism is A and one of its refracting surfaces is silvered. Light rays falling at an angle of incidence 2 A on the first surface return back through the same path after suffering reflection at the second (silvered) surface. The refractive index of the material of the prism is
(A) 2 sin A   (B) 2 cos A
(C) \( \frac{1}{2} \) cos A   (C) tan A

63. A prism of refractive index \( \sqrt{2} \) has a refracting angle of 30°. One of the refracting surfaces of the prism is polished. A beam of monochromatic light will retrace its path if its angle of incidence on the refracting surface is
(A) 0°   (B) 30°   (C) 45°   (D) 60°

64. The maximum refractive index of a material of a prism of apex angle 90° for which light will be transmitted is:
(A) \( \sqrt{5} \)   (B) 1.5   (C) \( \sqrt{2} \)   (D) None
65. A prism having an apex angle of 4° and refractive index of 1.50 is located in front of a vertical plane mirror as shown. A horizontal ray of light is incident on the prism. The total angle through which the ray is deviated is

(A) 4° clockwise  (B) 178° clockwise  (C) 2° clockwise  (D) 8° clockwise

Sol.

66. A thin prism of angle 5° is placed at a distance of 10 cm from object. What is the distance of the image from object? (Given μ of prism = 1.5)
(A) x/8cm  (B) x/12 cm  (C) 5x/36 cm  (D) x/7 cm

Sol.

67. An equilateral prism deviates a ray through 40° for two angles of incidence differing by 20°. The possible angle of incidences are:
(A) 40°  (B) 50°  (C) 20°  (D) 60°

Sol.

68. A prism of refractive index 1.5 has refracting angle 60°. In order that a ray suffers minimum deviation it should be incident at an angle
(A) 45°  (B) 90°  (C) 30°  (D) none

Sol.

69. For refraction through a small angled prism, the angle of deviation:
(A) increases with the increase in R.I. of prism.
(B) will decrease with the increase in R.I. of prism.
(C) is directly proportional to the angle of prism.
(D) will be 2D for any of R.I. = 2.4 if it is D for a ray of R.I. = 1.2

Sol.
70. For the refraction of light through a prism
(A) For every angle of deviation there are two angles of incidence.
(B) The light travelling inside an equilateral prism is necessarily parallel to the base when prism is set for minimum deviation.
(C) There are two angles of incidence for maximum deviation.
(D) Angle of minimum deviation will increase if refractive index of prism is increased keeping the outside medium unchanged if $\mu_1 > \mu_2$.

Sol.

72. A concave spherical surface of radius of curvature 10 cm separates two mediums X & Y of refractive index 4/3 & 3/2 respectively. If the object is placed along principal axis in medium X then

\[ \begin{array}{c}
X \\
\end{array} \quad \begin{array}{c}
Y \\
\end{array} \]

(A) image is always real
(B) image is real if the object distance is greater than 90cm
(C) image is always virtual
(D) image is virtual if the object distance is less than 90 cm

Sol.

73. A spherical surface of radius of curvature 10 cm separates two media X and Y of refractive indices 3/2 and 4/3 respectively. Centre of the spherical surface lies in denser medium. An object is placed in medium X. For image to be real, the object distance must be

(A) greater than 90 cm   (B) less than 90 cm
(C) greater than 80 cm   (D) less than 80 cm

Sol.

SECTION (E): REFRACTION BY SPHERICAL SURFACE

71. A fish is near the centre of a spherical water filled fish bowl. A child stands in air at a distance 2 R (R is radius of curvature of the sphere) from the centre of the bowl. At what distance from the centre would the child’s nose appear to the fish situated at the centre (R.I. of water = $\frac{4}{3}$)

(A) 4R   (B) 2R   (C) 3R   (D) R

Sol.
74. A beam of diameter 'd' is incident on a glass hemisphere as shown. If the radius of curvature of the hemisphere is very large in comparison to d, then the diameter of the beam at the base of the hemisphere will be

\[ \mu = \frac{3}{2} \]

(A) 3/4 d  (B) d  (C) d/3  (D) 2/3 d

Sol.

75 A concave spherical refracting surface separates two media glass and air (\( \mu_{\text{glass}} = 1.5 \)). If the image is to be real at what minimum distance \( u \) should the object be placed in glass if \( R \) is the radius of curvature?

(A) \( u > 3R \)  (B) \( u > 2R \)  (C) \( u < 2R \)  (D) \( u < R \)

Sol.

Question No. 76 to 78 (3 questions)

The figure shows a transparent sphere of radius \( R \) and refractive index \( \mu \). An object \( O \) is placed at a distance \( x \) from the pole of the first surface so that a real image is formed at the pole of the exactly opposite surface.

76. If \( x = 2R \), then the value of \( \mu \) is

(A) 1.5  (B) 2  (C) 3  (D) none

Sol.

77. If \( x = \infty \), then the value of \( \mu \) is

(A) 1.5  (B) 2  (C) 3  (D) none

Sol.

78. If an object is placed at a distance \( R \) from the pole of the first surface, then the real image is formed at a distance \( R \) from the pole of the second surface. The refractive index \( \mu \) of the sphere is given by

(A) 1.5  (B) 2  (C) \( \sqrt{2} \)  (D) none

Sol.
79. In the figure shown a point object O is placed in air on the principal axis. The radius of curvature of the spherical is 60 cm. I, is the final image formed after all the refractions and reflections.

(A) If d, = 120 cm, then the 'I,' is formed on 'O' for any value of d,
(B) If d, = 240 cm, then the 'I,' is formed on 'O' only if d, = 360 cm.
(C) If d, = 240 cm, then the 'I,' is formed on 'O' for all value of d,
(D) If d, = 240 cm, then the 'I,' cannot be formed on 'O'.

Sol.

80. Two refracting media are separated by a spherical interface as shown in the figure. PP' is the principal axis, μ, and μ₂ are the refractive indices of medium of incidence and medium of refraction respectively. Then:

(A) if μ₁ > μ₂, then there cannot be a real image of real object.
(B) if μ₁ > μ₂, then there cannot be a real image of virtual object.
(C) if μ₁ > μ₂, then there cannot be a virtual image of virtual object.
(D) if μ₁ > μ₂, then there cannot be a real image of real object.

Sol.

Question No. 81 to 83 (3 questions)
A curved surface of radius R separates two medium of refractive indices μ₁ and μ₂ as shown in figures A and B

81. Choose the correct statement(s) related to the real image formed by the object O placed at a distance x, as shown in figure A
(A) Real image is always formed irrespective of the position of object if μ₁ > μ₂
(B) Real image is formed only when x > R
(C) Real image is formed due to the convex nature of the interface irrespective of μ₁ and μ₂
(D) None of these

Sol.
82. Choose the correct statement(s) related to the virtual image formed by object O placed at a distance x, as shown in figure A.
(A) Virtual image is formed for any position of O if \( \mu_2 < \mu_1 \)
(B) Virtual image can be formed if \( x > R \) and \( \mu_2 < \mu_1 \)
(C) Virtual image is formed if \( x < R \) and \( \mu_2 > \mu_1 \)
(D) None of these

\[ \text{Sol.} \]

83. Identify the correct statement(s) related to the formation of images of a real object O placed at x from the pole of the concave surface, as shown in figure B.
(A) If \( \mu_2 > \mu_1 \), then virtual image is formed for any value of x
(B) If \( \mu_2 > \mu_1 \), then virtual image is formed if \( x < \frac{\mu_1 R}{\mu_1 - \mu_2} \)
(C) If \( \mu_2 < \mu_1 \), then real image is formed for any value of x
(D) None of these

\[ \text{Sol.} \]

SECTION (F): LENSES/LENSES & MIRRORS.

84. Two symmetric double convex lenses A and B have same focal length, but the radii of curvature differ so that \( R_a = 0.9 \ R_b \). If \( n_2 = 1.63 \), find \( n_1 \).
(A) 1.7 \hspace{1cm} (B) 1.6 \hspace{1cm} (C) 1.5 \hspace{1cm} (D) 4/3

\[ \text{Sol.} \]

85. When a lens of power \( P \) (in air) made of material of refractive index \( \mu \) is immersed in liquid of refractive index \( \mu_2 \). Then the power of lens is:

\[ \begin{align*}
(A) \quad & \frac{\mu - 1}{\mu - \mu_2} \quad P \\
(B) \quad & \frac{\mu - \mu_2}{\mu - 1} \quad P \\
(C) \quad & \frac{\mu - \mu_2}{\mu - 1} \quad \mu_2 \\
(D) \quad & \text{none of these}
\end{align*} \]

\[ \text{Sol.} \]

86. An object is placed at 10 cm from a lens and real image is formed with magnification of 0.5. Then the lens is:
(A) concave with focal length of 10/3 cm
(B) convex with focal length of 10/3 cm
(C) concave with focal length of 10 cm
(D) convex with focal length of 10 cm

\[ \text{Sol.} \]
87. A thin linear object of size 1 mm is kept along the principal axis of a convex lens of focal length 10 cm. The object is at 15 cm from the lens. The length of the image is:
(A) 1 mm (B) 4 mm (C) 2 mm (D) 8 mm
Sol.

89. The lateral height of image
(A) increases (B) decreases
(C) remains same (D) data insufficient
Sol.

90. Suppose that the image must be formed on a card which is at a certain distance behind the lens (figure (B)), while you move the turnip away from the lens, then you should

(A) decrease the squeeze of the lens
(B) increase the squeeze of the lens
(C) keep the card and lens as it is
(D) move the card away from the lens
Sol.

88. When you squeeze the lens, the image
(A) moves towards the lens
(B) moves away from the lens
(C) shifts up
(D) remains as it is
Sol.

91. If an object is placed at A(OA > f); Where f is the focal length of the lens the image is found to be formed at B. A perpendicular is erected at O and C is chosen on it such that the angle ∠BCA is a right angle. Then the value of f will be

(A) \(\frac{AB}{OC^2}\)  (B) \(\frac{(AC)(BC)}{OC}\)
(C) \(\frac{(OC)(AB)}{AC+BC}\)  (D) \(\frac{OC}{AB}\)
92. A converging lens of focal length 20 cm and diameter 5 cm is cut along the line AB. The part of the lens shown shaded in the diagram is now used to form an image of a point P placed 30 cm away from it on the line XY. Which is perpendicular to the plane of the lens. The image of P will be formed.

(A) 0.5 cm above XY  (B) 1 cm below XY  
(C) on XY  (D) 1.5 cm below XY

Sol.

93. A point object is kept at the first focus of a convex lens. If the lens starts moving towards right with a constant velocity, the image will

(A) always move towards right  
(B) always move towards left  
(C) first move towards right & then towards left.  
(D) first move towards left & then towards right.

Solution:

94. Two plano-convex lenses each of focal length 10 cm & refractive index $\frac{3}{2}$ are placed as shown. In the space left, water (RI - $\frac{4}{3}$) is filled. The whole arrangement is in air. The optical power of the system is (in diopters):

(A) 6.67  (B) -6.67  (C) 33.3  (D) 20

Solution:
95. An object is placed at a distance of 10 cm from a co-axial combination of two lenses A and B in contact. The combination forms a real image three times the size of the object. If lens B is concave with a focal length of 30 cm, what is the nature and focal length of lens A?
(A) Convex, 12 cm  (B) Concave, 12 cm
(C) Convex, 6 cm   (D) Convex, 18 cm

Sol.

96. The curvature radii of a concavo-convex glass lens are 20 cm and 60 cm. The convex surface of the lens is silvered. With the lens horizontal, the concave surface is filled with water. The focal length of the effective mirror is (μ of glass = 1.5, μ of water = 4/3)
(A) 90/13 cm  (B) 80/13 cm
(C) 20/3 cm    (D) 45/8 cm

Sol.

97. An object is placed at a distance of 15 cm from a convex lens of focal length 10 cm. On the other side of the lens, a convex mirror is placed at its focus such that the image formed by the combination coincides with the object itself. The focal length of the convex mirror is

(A) 20 cm  (B) 10 cm  (C) 15 cm  (D) 30 cm

Sol.

98. An object is placed in front of a thin convex lens of focal length 30 cm and a plane mirror is placed 15 cm behind the lens. If the final image of the object coincides with the object, the distance of the object from the lens is
(A) 60 cm  (B) 30 cm  (C) 15 cm  (D) 25 cm

Sol.

99. Look at the ray diagram shown, what will be the focal length of the 1st and the 2nd lens, if the incident light ray passes without any deviation?

(A) –5cm and –10cm  (B) +5cm and +10cm
(C) –5cm and +5cm  (D) +5cm and +5cm
100. An object is placed in front of a symmetrical convex lens with refractive index 1.5 and radius of curvature 40 cm. The surface of the lens further away from the object is silvered. Under auto-collimation condition, the object distance is
(A) 20 cm  (B) 10 cm  (C) 40 cm  (D) 5 cm

Sol.

102. In the above question the radius of curvature of the curved surface of plano-convex lens is:

(A) $\frac{280}{9}$ cm  (B) $\frac{80}{7}$ cm
(C) $\frac{39}{3}$ cm  (D) $\frac{280}{11}$ cm

Sol.

103. A screen is placed 90 cm from an object. The image of an object on the screen is formed by a convex lens at two different locations separated by 20 cm. The focal length of the lens is
(A) 18 cm  (B) 21.4 cm  (C) 60 cm  (D) 85.6 cm

Sol.

104. In the above problem, if the size of the image formed at the positions are 6 cm and 3 cm, then the highest of the object is
(A) 4.2 cm  (B) 4.5 cm  (C) 5 cm  (D) none of these

Sol.

105. Which of the following cannot form real image of a real object?
(A) concave mirror  (B) convex mirror  (C) plane mirror  (D) diverging lens

Sol.
106. The radius of curvature of the left & right surface of the concave lens are 10 cm & 15 cm respectively. The radius of curvature of the mirror is 15 cm.

(A) equivalent focal length of the combination is -18 cm
(B) equivalent focal length of the combination is +36 cm
(C) the system behaves like a concave mirror
(D) the system behaves like a convex mirror.

Sol.

108. A convex lens forms an image of an object on screen. The height of the image is 9 cm. The lens is now displaced until an image is again obtained on the screen. The height of this image is 4 cm. The distance between the object and the screen is 90 cm.

(A) The distance between the two positions of the lens is 30 cm.
(B) The distance of the object from the lens is its first position is 36 cm.
(C) The height of the object is 6 cm.
(D) The focal length of the lens is 21.6 cm.

Sol.

109. A thin lens with focal length f to be used as a magnifying glass. Which of the following statements regarding the situations is true?

(A) A converging lens may be used, and the object be placed at a distance greater than 2f from the lens.
(B) A diverging lens may be used, and the object be placed between f and 2f from the lens.
(C) A converging lens may be used, and the object be placed at a distance less than f from the lens.
(D) A diverging lens may be used, and the object be placed at any point other than the focal point.

Sol.

110. Which of the following can form diminished, virtual and erect image of your face.

(A) Converging mirror
(B) Diverging mirror
(C) Converging lens
(D) Diverging lens

Sol.
111. Which of the following quantities related to a lens depend on the wavelength of the incident light? 
(A) Refractive index (B) Focal length 
(C) Power (D) Radii of curvature 
Sol.

112. A man wishing to get a picture of a Zebra photographed a white donkey after fitting a glass with black streaks onto the objective of his camera. 
(A) the image will look like a white donkey on the photograph. 
(B) the image will look like a Zebra on the photograph. 
(C) the image will be more intense compared to the case in which no such glass is used. 
(D) the image will be less intense compared to the case in which no such glass is used. 
Sol.

SECTION (G): DISPERSION OF LIGHT

113. A thin prism P₁ with angle 4° made of glass of refractive index 1.54 is combined with another thin prism P₂ made of glass of refractive index 1.72 to produce dispersion without deviation. The angle of the prism P₁ is: 
(A) 3° (B) 2.6° (C) 4° (D) 5.33° 
Sol.

114. Light of wavelength 4000 Å is incident at small angle on a prism of apex angle 4°. The prism has n₁ = 1.5 & n₂ = 1.48. The angle of dispersion produced by the prism in this light is: 
(A) 0.2° (B) 0.08° (C) 0.192° (D) none 
Sol.

115. Two lenses in contact made of materials with dispersive powers in the ratio 2 : 1, behaves as an achromatic lens of focal length 10 cm. The individual focal lengths of the lenses are: 
(A) 5 cm, – 10 cm (B) – 5 cm, 10 cm 
(C) 10 cm, – 20 cm (D) – 20 cm, 10 cm 
Sol.

116. A beam of light consisting of red, green and blue and is incident on a right angled prism. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. The prism will: 
(A) separate part of the red colors from the green and blue colors. 
(B) separate part of the blue colors from red and green colors. 
(C) separate all the three colors from the other two colors. 
(D) not separate even partially any colour from the other two colors. 

(A) separate part of the red colors from the green and blue colors. 
(B) separate part of the blue colors from red and green colors. 
(C) separate all the three colors from the other two colors. 
(D) not separate even partially any colour from the other two colors.
117. It is desired to make an achromatic combination of two lenses \( (L_1 \ & \ L_2) \) made of materials having dispersive powers \( \omega_1 \) and \( \omega_2 \  (\omega_2 < \omega_1) \). If the combination of lenses is converging then
(A) \( L_1 \) is converging
(B) \( L_2 \) is converging
(C) Power of \( L_1 \) is greater than the power of \( L_2 \)
(D) none of these

**Sol.**

119. By properly combining two prisms made of different materials, it is possible to
(A) have dispersion without average deviation
(B) have deviation without dispersion
(C) have both dispersion and average deviation
(D) have neither dispersion nor average deviation

**Sol.**

120. Column-I shows the optical phenomenon that can be associated with optical components given in column-I. Note that column-I may have more than one matching options in column-II.

<table>
<thead>
<tr>
<th>Column-I</th>
<th>Column-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Convex mirror</td>
<td>(A) Dispersion</td>
</tr>
<tr>
<td>(ii) Converging lens</td>
<td>(B) Deviation</td>
</tr>
<tr>
<td>(iii) Thin prism</td>
<td>(C) Real image of real object</td>
</tr>
<tr>
<td>(iv) Glass slab</td>
<td>(D) Virtual image of real object</td>
</tr>
</tbody>
</table>

**Sol.**

118. A narrow beam of white light goes through a slab having parallel faces
(A) The light never splits in different colour
(B) The emergent beam is white
(C) The light inside the slab is split into different colours
(D) The light inside the slab is white

**Sol.**
 SECTION (A): PLANE MIRROR

1. Find the angle of deviation (both clockwise and anticlockwise) suffered by a ray incident on a plane mirror, at an angle of incidence 30°.

Sol.

2. Figure shows a plane mirror onto which a light ray is incident. If the incident light ray is turned by 10° and the mirror by 20°, as shown, find the angle turned by the reflected ray.

Sol.

3. A light ray is incident on a plane mirror, which after getting reflected strikes another plane mirror, as shown in figure. The angle between the two mirrors is 60°. Find the angle 'θ' shown in figure.

Sol.

4. There are two plane mirror inclined at 40°, as shown. A ray of light is incident on mirror M₁. What should be the value of angle of incidence 'I' so that the light ray retraces its path after striking the mirror M₂.

Sol.
5. Sun rays are incident at an angle of 24° to the horizon. How can they be directed parallel to the horizon using a plane mirror?

Sol.

6. An object is placed at (0, 0) and a plane mirror is placed, inclined 30° with the x axis.

(a) Find the position of image.
(b) If the object starts moving with velocity 1 m/s and the mirror is fixed find the velocity of image.

Sol.

7. A point object is placed at (0, 0, 0) and a plane mirror is placed parallel to YZ plane at x = 2. Find the coordinate of image.

Sol.

8. A plane mirror 50 cm long, is hung parallel to a vertical wall of a room, with its lower edge 50 cm above the ground. A man stands in front of the mirror at a distance 2 m away from the mirror. If this man is at a height 1.8 m above the ground, find the length of the floor between him and the mirror, visible to him reflected from the mirror.

Sol.

9. In figure shown AB is a plane mirror of length 40 cm placed at a height 40 cm from ground. There is a light source S at a point on the ground. Find the minimum and maximum height of a man (eye height) required to see the image of the source if he is standing at a point A on ground shown in figure.

Sol.

10. A plane mirror of circular shape with radius r = 20 cm is fixed to the ceiling. A bulb is to be placed on the axis of the mirror. A circular area of radius R = 1 m on the floor is to be illuminated after reflection of light from the mirror. The height of the room is 3 m. What is maximum distance from the center of the mirror and the bulb so that the required area is illuminated?
11. A light ray I is incident on a plane mirror M. The mirror is rotated in the direction as shown in the figure by an arrow at frequency $9/\pi$ rev/sec. The light reflected the mirror is received on the wall W at a distance 10 m from the axis of rotation. When the angle of incidence becomes 37$^\circ$, find the speed of the spot (a point) on the wall.

![Diagram of light ray and mirror](image)

Sol.

14. What does point A indicate? (f is magnitude of focal length, u and v are coordinates)

![Graph with points A, B, C, D](image)

(i) Point A represents that the object is \( \begin{align*}
\text{________ (Real/Virtual)}
\text{and the image is}
\text{________ (Real/Virtual)}
\end{align*} \)

(ii) Point A represents that \( |u| \) is \( \text{________ (larger/smaller)} \) than \( |v| \) and hence image size is \( \text{________ (larger/smaller)} \) than the size of object.

15. Point B represents that the object is \( \text{________ (Real/Virtual)} \) and the image is \( \text{________ (Real/Virtual)} \).

16. Point B represents that \( |u| \) is \( \text{________ (larger/smaller)} \) than \( |v| \) and hence image size is \( \text{________ (larger/smaller)} \) than the size of object.

17. As we move from point C to D in the graph, the \( \text{________ (real/virtual)} \) object moves from \( \text{________ to ________} \) and the \( \text{________ (real/virtual)} \) image moves from \( \text{________ to ________} \). Show this movement in a diagram.

18. A point object is placed on the principal axis at 60 cm in front of a concave mirror of focal length 40 cm on the principal axis. If the object is moved with a velocity of 10 cm/s (a) along the principal axis, find the velocity of image (B) perpendicular to the principal axis, find the velocity of image at that moment.

Sol.

**SECTION (B): SPHERICAL MIRROR**

12. A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that the end farther from the pole is 20 cm away from it. Find the length of the image.

Sol.

13. A concave spherical mirror forms a threefold magnified real image of a real object. The distance from the object of the image is 2.6 m. What is the radius of curvature of the mirror?
19. A man uses a concave mirror for shaving. He keeps his face at a distance of 20 cm from the mirror and gets an image which is 1.5 times enlarged. Find the focal length of the mirror.
Sol.

20. A concave mirror of focal length 20 cm is cut into two parts from the middle and the two parts are moved perpendicularly by a distance 1 cm from the previous principal axis AB. Find the distance between the images formed by the two parts?
Sol.

21. A balloon is rising up along the axis of a concave mirror of radius of curvature 20 m. A ball is dropped from the balloon at a height 15 m from the mirror when the balloon has velocity 20 m/s. Find the speed of the image of the ball formed by concave mirror after 4 seconds? [Take: g = 10 m/s²]
Sol.

22. A thin rod of length d/3 is placed along the principal axis of a concave mirror of focal length = d such that its image, which is real elongated, just touches the rod. Find the length of the image?
Sol.

23. A point object is placed 33 cm from a convex mirror of curvature radius = 40 cm. A glass plate of thickness 6 cm and index 2.0 is placed between the object and mirror, close to the mirror. Find the distance of final image from the object?
Sol.
24. A light ray falling at an angle of 60° with the surface of a clean slab of ice of thickness 1.00 m is refracted into it at an angle of 15°. Calculate the time taken by the light rays to cross the slab. Speed of light in vacuum = 3 × 10^8 m/s.

Sol.

26. Rays incident on an interface would converge 10 cm below the interface if they continued to move in straight lines without bending. But due to refraction, the rays will bend and meet somewhere else. Find the distance of meeting point of refracted rays below the interface, assuming the rays to be making small angles with the normal to the interface.

Sol.

25. An observer in air (n = 1) sees the bottom of a beaker filled with water (n = 4/3) up to a height of 40 cm. What will be the depth felt by this observer.

Sol.

27. Find the apparent distance between the observer and the object shown in the figure and shift in the position of object.

Sol.
28. Light attempts to go from glass ($\mu = 3/2$) to air. Find the angle of incidence for which the angle of deviation is $90^\circ$.  

Solution.

29. A rectangular glass wedge is lowered into water ($\mu = 4/3$). The refractive index of glass is $\mu = 1.5$. At what angle $\alpha$ will the beam of light normally incident on AB reach AC entirely?

Solution.

30. A long solid cylindrical glass rod of refractive index 3/2 is immersed in a liquid of refractive index $3\sqrt{3} / 4$. The end of the rod are perpendicular to the central axis of the rod. A light enters one end of the rod at the central axis as shown in the figure. Find the maximum value of angle $\theta$ for which internal reflection occurs inside the rod.

Solution.

31. A slab of glass of thickness 6 cm and index 1.5 is placed somewhere in between a concave mirror and a point object, perpendicular to the mirror's optical axis. The radius of curvature of the mirror is 40 cm. If the reflected final image coincides with the object, then find the distance of the object from the mirror.

Solution.

32. A ray of light enters a diamond ($n = 2$) from air and is being internally reflected near the bottom as shown in the figure. Find maximum value of angle $\theta$ possible.

Solution.
33. A ray of light on a transparent sphere with centre at C as shown in figure. The ray emerges from the sphere parallel to line AB. Find the refractive index of the sphere.

Sol.

34. A beam of parallel rays of width b propagates in glass at an angle \( \theta \) to its plane face. The beam width after it goes over to air through this face is ________ if the refractive index of glass is \( \mu \).

Sol.

35. A cubical tank (of edge \( l \)) and position of an observer are shown in the figure. When the tank is empty, edge of the bottom surface of the tank is just visible. An insect is at the centre C of its bottom surface. To what height a transparent liquid of refractive index \( \mu = \sqrt{5}/2 \) must be poured in the tank so that the insect will become visible?

Sol.

36. Light from a luminous point on the lower face of a 2 cm thick glass slab, strikes the upper face and the totally reflected rays outline a circle of radius 3.2 cm on the lower face. What is the refractive index of the glass.

Sol.
37. A prism \((n = 2)\) of apex angle \(90^\circ\) is placed in air \((n = 1)\). What should be the angle of incidence so that light ray strikes the second surface at an angle of \(60^\circ\)?

Sol.

38. Ref. index of a prism \((A = 60^\circ)\) placed in air \((n = 1)\) is \(n = 1.5\). Light ray is incident on this prism at an angle of \(60^\circ\). Find the angle of deviation. State whether this is a minimum deviation.

Given: \(\sin^{-1} \frac{1}{\sqrt{3}} = 35^\circ\), \(\sin^{-1} 0.4 = 25^\circ\), \(\sin^{-1} 0.6 = 37^\circ\)

Sol.

40. The angle of refraction of a prism is \(60^\circ\). A light ray emerges from the prism at the same angle as it is incident on it. The refractive index of the prism is \(1.5\). Determine the angle by which the ray is deflected from its initial direction as a result of its passage through the prism.

Sol.

41. Find the angle of deviation suffered by the light ray shown in figure for following two condition The refractive index for the prism material is \(\mu = 3/2\)

\(\begin{array}{c}
\text{(i)} \text{ When the prism is placed in air } (\mu = 1) \\
\text{(ii)} \text{ When the prism is placed in water } (\mu = 4/3)
\end{array}\)

Sol.

39. The cross section of a glass prism has the form of an equilateral triangle. A ray is incident onto one of the faces perpendicular to it. Find the angle \(\beta\) between the incident ray and the ray that leaves the prism. The refractive index of glass is \(\mu = 1.5\).
42. A prism of refractive index $\sqrt{2}$ has a refracting angle of 30°. One of the refracting surface of the prism is polished. For the beam of monochromatic light to retrace its path, find the angle of incidence on the refracting surface.

45. A right angle prism (45° - 90° - 45°) of refractive index $n$ has a plate of refractive index $n_1 (n_1 < n)$ cemented to its diagonal face. The assembly is in air, a ray is incident on AB (see the figure).

(i) Calculate the angle of incidence at AB for which the ray strikes the diagonal face at the critical angle.

(ii) Assuming $n = 1.352$. Calculate the angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated.

43. An equilateral prism deviates a ray through 23° for two angles of incidence differing by 23°. Find $\mu$ of the prism?

44. A equilateral prism provides the least deflection angle 46° in air. Find the refracting index of an unknown liquid in which same prism gives least deflection angle of 30°.

46. A right angle prism (45° - 90° - 45°) of refractive index $n$ has a plate of refractive index $n_1 (n_1 < n)$ cemented to its diagonal face. The assembly is in air, a ray is incident on AB (see the figure).
46. A prism of refractive index \( n_1 \) & another prism of refractive index \( n_2 \) are stuck together without a gap as shown in the figure. The angles of the prisms are as shown \( n_1 \) & \( n_2 \) depend on \( \lambda \), the wavelength of light according to \( n_1 = 1.20 + \frac{10.8 \times 10^4}{\lambda^2} \) & \( n_2 = 1.45 + \frac{180 \times 10^4}{\lambda^2} \) where \( \lambda \) is in nm.

\[ \text{(i) Calculate the wavelength } \lambda \text{ for which rays incident at any angle on the interface BC pass through without bending at that interface.} \]
\[ \text{(ii) For light of wavelength } \lambda \text{, find the angle of incidence } i \text{ on the face AC such that the deviation produced by the combination of prisms is minimum.} \]

Sol.

48. A narrow parallel beam of light is incident paraxially on a solid transparent sphere of radius \( r \). What should be the refractive index if the beam is to be focused (a) At the surface of the sphere, (B) at the centre of the sphere.

Sol.

49. An extended object of size 2 cm is placed at a distance of 10 cm in air \( n = 1 \) from pole, on the principal axis of a spherical curved surface. The medium on the other side of refracting surface has refractive index \( n = 2 \). Find the position, nature and size of image formed after single refraction through the curved surface.

Sol.

SECTION (E): REFRACTION BY SPHERICAL SURFACE

47. A spherical surface of radius 30 cm separates two transparent media A and B with refractive indices 4/3 and 3/2 respectively. The medium A is on the convex side of the surface. Where should a point object be placed in medium A so that the paraxial rays becomes parallel after refraction at the surface?

Sol.
50. An object is placed 10 cm away from a glass piece \((n = 1.5)\) of length 20 cm bound by spherical surfaces of radii of curvature 10 cm. Find the position of final image formed after twice refractions.

![Diagram of optical system](image)

**Sol.**

51. There is a small air bubble inside a glass sphere \((\mu = 1.5)\) of radius 5 cm. The bubble is 7.5 cm below the surface of the glass. The sphere is placed inside water \((\mu = \frac{4}{3})\) such that the top surface of glass is 10 cm below the surface of water. The bubble is viewed normally from air. Find the apparent depth on the bubble.

![Diagram of bubble](image)

**Sol.**

52. A narrow parallel beam of light is incident on a transparent sphere of refractive index 'n'. If the beam finally gets focussed at a point situated at a distance \(= 2 \times \text{(radius of sphere)}\) from the centre of the sphere, then find n?

**Sol.**

53. A uniform, horizontal beam of light is incident upon a quarter cylinder of radius \(R = 5\) cm, and has a refractive index \(\frac{2}{\sqrt{3}}\). A patch on the table for a distance 'x' from the cylinder is unilluminated, find the value of 'x'?

![Diagram of light beam](image)

**Sol.**
SECTION (F): LENSES/LENS & MIRRORS.

54. A double convex lens has focal length 50 cm. The radius of curvature of one of the surfaces is double of the other. Find the radii, if the refractive index of the material of the lens is 2.

Sol.

55. Lenses are constructed by a material of refractive index 1.50. The magnitude of the radii of curvature are 20 cm and 30 cm. Find the focal lengths of the possible lenses with the above specifications.

Sol.

56. Given an optical axis MN & the positions of a real object A B and its image A' B', determine diagrammatically the position of the lens (its optical centre O) and its foci. Is it a converging or diverging lens? Is the image real or virtual?

57. A thin lens made of a material of refractive index \( \mu_i \) has a medium of refractive index \( \mu_k \) on one side and a medium of refractive index \( \mu_j \) on the other side. The lens is biconvex and the two radii of curvature have equal magnitude R. A beam of light travelling parallel to the principal axis is incident on the lens. Where will the image be formed if the beam is incident from (a) the medium \( \mu_i \) and (b) from the medium \( \mu_j \)?

Sol.

58. An object of height 6 cm is set at right angles to the optical axis of a double convex lens of optical power 5 d & 25 cm away from the lens. Determine the focal length of the lens, the position of the image, the linear magnification of the lens, and the height of the image formed by it.
59. A 5.0 diopter lens forms a virtual image which is 4 times the object placed perpendicularly on the principal axis of the lens. Find the distance of the object from the lens.
Sol.

61. A converging lens of focal length 15 cm and a converging mirror of length 10 cm are placed 50 cm apart. If a object of length 2.0 cm is placed 30 cm from the lens farther away from the mirror, where will the final image form and what will be the size of the final image?
Sol.

62. 2 identical thin converging lenses brought in contact so that their axes coincide are placed 12.5 cm from an object. What is the optical power of the system & each lens, if the real image formed by the system of lenses is four times as large as the object?
Sol.

60. A converging lens and a diverging mirror are placed at a separation of 15 cm. The focal length of the lens is 25 cm and that of the mirror is 40 cm. Where should a point source be placed between the lens and the mirror so that the light, after getting reflected by the mirror and then getting transmitted by the lens, comes out parallel to the principal axis?
Sol.

63. A point object is placed at a distance of 15 cm from a convex lens. The image is formed on the other side at a distance of 30 cm from the lens. When a concave lens is placed in contact with the convex lens, the image shifts away further by 30 cm. Calculate the focal lengths of the two lenses.
66. An object is kept at a distance of 16 cm from the thin lens and the image formed is real. If the object is kept at a distance of 6 cm from the same lens the image formed is virtual. If the size of the image formed are equal, then find the focal length of the lens.

64. A convex & a concave lens are brought in close contact along their optical axes. The focal length of the convex lens is 10 cm. When the system is placed at 40 cm from an object, a sharp image of the object is formed on a screen on the other side of the system. Determine the optical power of the concave lens if the distance r between the object & the screen is 1.6 m.

65. A point object is placed at a distance of 25 cm from a convex lens of focal length 20 cm. If a glass slab of thickness t and refractive index 1.5 is inserted between the lens and object. The image is formed at infinity. Find the thickness t.

67. A thin convex lens forms a real image of a certain object 'p' times its size. The size of real image becomes 'q' times that of object when the lens is moved nearer to the object by a distance 'a'. Find focal length of the lens.

Sol.
68. In the figure shown, the focal length of the two thin convex lenses is the same = \( f \). They are separated by a horizontal distance \( 3f \) and their optical axes are displaced by a vertical separation \( d \) (\( d \ll f \)), as shown. Taking the origin of coordinates \( O \) at the centre of the first lens, find the \( x \) and \( y \) coordinates of the point where a parallel beam of rays coming from the left finally get focused?

Sol.

69. A point source of light is kept at a distance of 15 cm from a converging lens, on its optical axis. The focal length of the lens is 10 cm and its diameter is 3 cm. A screen is placed on the other side of the lens, perpendicular to the axis of lens, at a distance 20 cm from it. Then find the area of the illuminated part of the screen?

Sol.

70. A glass hemisphere of refractive index \( 4/3 \) and of radius 4 cm is placed on a plane mirror. A point object is placed at distance \( d \) on axis of this sphere as shown. If the final image be at infinity, find the value of \( d \).

Sol.

71. A double convex lens has focal length 25.0 cm in air. The radius of one of the surfaces is double of the other. Find the radii of curvature if the refractive index of the material of the lens is 1.5.

Sol.

72. A plano convex lens \( (\mu = 1.5) \) has a maximum thickness of 1 mm. If diameter of its aperture is 4 cm. Find

(i) Radius of curvature of curved surface
(ii) Its focal length in air
73. A plano-convex lens, when silvered on the plane side, behaves like a concave mirror of focal length 30 cm. When it is silvered on the convex side, it behaves like a concave mirror of focal length 10 cm. Find the refractive index of the material of the lens.

**Sol.**

75. A flint glass prism and a crown glass prism are to be combined in such a way that the deviation of the mean ray is zero. The refractive index of flint and crown glasses for the mean ray are 1.620 and 1.518 respectively. If the refracting angle of the flint prism is 6.0°, what should be the refracting angle of crown prism?

**Sol.**

**SECTION (G): DISPERSION OF LIGHT**

74. A certain material has refractive indices 1.56, 1.60 and 1.68 for red, yellow and violet light respectively.
(a) Calculate the dispersive power.
(b) Find the angular dispersion produced by a thin prism of angle 6° made of this material.
SECTION (B): SPHERICAL MIRROR

1. An observer whose least distance of distinct vision is 'd', views his own face in a convex mirror of radius of curvature 'r'. Prove that magnification produced can not exceed \( \frac{r}{d + \sqrt{d^2 + r^2}} \).

2. A thief is running away in a car with velocity of 20 m/s. A police jeep is following him, which is sighted by thief in his rear view mirror which is a convex mirror of focal length 10 m. He observes that the image of jeep is moving towards him with a velocity of 1 cm/s. If the magnification of the mirror for the jeep at that time is 1/10. Find
   (a) actual speed of jeep
   (b) rate at which magnification is changing
   Assume that police jeep is on axis of the mirror.

3. A luminous point P is inside a circle. A ray enters from P and after two reflections by the circle, return to P. If \( \beta \) be the angle of incidence, a the distance of P from the centre of the circle and b the distance of the centre from the point where the ray in its course crosses the diameter through P, prove that
   \[ \tan \beta = \frac{a - b}{a + b}. \]

4. An object is kept on the principal axis of a convex mirror of focal length 10 cm at a distance of 10 cm from the pole. The object starts moving at a velocity 20 mm/sec towards the mirror at angle 30° with the principal axis. What will be the speed of its image and direction with the principal axis at that instant ?

5. In the figure shown L is a converging lens of focal length 10 cm and M is a concave mirror of radius of curvature 20 cm. A point object O is placed in front of the lens at a distance 15 cm. AB and CD are optical axes of the lens and mirror respectively. Find the distance of the final image formed by this system from the optical centre of the lens. The distance between CD & AB is 1 cm.

SECTION (C): REFRACTION IN GENERAL, REFRACTION AT PLANE SURFACE AND T.I.R.

6. A surveyor on one bank of canal observed the image of the 4 inch and 17 ft marks on a vertical staff, which is partially immersed in the water and held against the bank directly opposite to him, coincides. If the 17 ft mark and the surveyor's eye are both 6 ft above the water level, estimate the width of the canal, assuming that the refractive index of the water is 4/3.

7. A circular disc of diameter d lies horizontally inside a metallic hemispherical bowl radius a. The disc is just visible to an eye looking over the edge. The bowl is now filled with a liquid of refractive index \( \mu \). Now, the whole of the disc is just visible to the eye in the same position. Show that \( d = 2a \frac{(\mu^2 - 1)}{(\mu^2 + 1)}. \)

8. A ray of light travelling in air is incident at grazing angle (incidence angle = 90°) on a medium whose refractive index depends on the depth of the medium. The trajectory of the light in the medium is a parabola, \( y = 2x^2 \). Find, at a depth of 1 m in the medium.

   (i) the refractive index of the medium and
   (ii) angle of incidence \( \alpha \).

9. Two thin similar watch glass pieces are joined together, front to front, with rear portion silvered and the combination of glass pieces is placed at a distance a = 60 cm from a screen. A small object is placed normal to the optical axis of the combination such that its two times magnified image is formed on the screen. If air between the glass pieces is replaced by water (\( \mu = 4/3 \)), calculate the distance through which the object must be displaced so that a sharp image is again formed on the screen.
10. A thin plano-convex lens fits exactly into a plano concave lens with their plane surface parallel to each other as shown in the figure. The radius of curvature of the curved surface $R = 30$ cm. The lens are made of difference material having refractive index $\mu_1 = 3/2$ and $\mu_2 = 5/4$ as shown in figure.

(i) If plane surface of the plano-convex lens is silvered, then calculate the equivalent focal length of this system and also calculate the nature of this equivalent mirror.

(ii) An object having transverse length 5 cm is placed on the axis of equivalent mirror (in part 1), at a distance 15 cm from the equivalent mirror along principal axis. Find the transverse magnification produced by equivalent mirror.

11. A ray of light travelling in air is incident at grazing angle (incident angle = $90^\circ$) on a long rectangular slab of a transparent medium of thickness $t = 1.0$ cm (see figure). The point of incidence is the origin A ($O$, $O$). The medium has a variable index of refraction $n(y)$ given by: $n(y) = (ky^{1/2} + 1)^{-1}$, where $k = 1.0$ m$^{-1/2}$. The refractive index of air is 1.0.

(i) Obtain a relation between the slope of the trajectory of the ray at a point B($x$, $y$) in the medium and the incident angle at that point.

(ii) Obtain an equation for the trajectory $y(x)$ of the ray in the medium.

(iii) Determine the coordinates ($x_r$, $y_r$) of the point P, where the ray intersects the upper surface of the slab-air boundary.

(iv) Indicate the path of the ray subsequently.

12. An isosceles triangular glass prism stands with its base in water as shown. The angles that its two equal sides make with the base are $\theta$ each. An incident ray of light parallel to the water surface internally reflects at the glass-water interface and subsequently re-emerges into the air. Taking the refractive indices of glass and water to be 3/2 and 4/3 respectively, show that $\theta$ must be at least $\tan^{-1} \frac{2}{\sqrt{17}}$ or $25.9^\circ$.

13. A parallel beam of light falls normally on the first face of a prism of small angle. At the second face it is partly transmitted and partly reflected, the reflected beam striking at the first face again, and emerging from it in a direction making an angle $60^\circ$ with the reversed direction of the incident beam. The refracted beam is found to have undergone a deviation of $10^15^\prime$ from the original direction. Find the refractive index of the glass and the angle of the prism.

14. The refractive indices of the crown glass for violet and red lights are 1.51 and 1.49 respectively and those of the flint glass are 1.77 and 1.73 respectively. A prism of angle $60^\circ$ is made of crown glass. A beam of white light is incident at a small angle on this prism. The other thin flint glass prism is combined with a crown glass prism such that the net mean deviation is $1.5^\circ$ anticlockwise.

(i) Determine the angle of the flint glass prism.

(ii) A screen is placed normal to the emerging beam at a distance of 2 m from the prism combination. Find the distance between red and violet spot on the screen. Which is the topmost colour on screen.
SECTION (E): REFRACTION BY SPHERICAL SURFACE

15. A concave mirror has the form of a hemisphere with a radius of $R = 60$ cm. A thin layer of an unknown transparent liquid is poured into the mirror. The mirror-liquid system forms one real image and another real image is formed by mirror alone, with the source in a certain position. One of them coincides with the source and the other is at a distance of $f = 30$ cm from source. Find the possible value(s) of the refractive index $\mu$ of the liquid.

SECTION (F): LENSES AND COMBINATION OF LENSES/LENSES & MIRRORS

16. In the figure shown, find the relative speed of approach/separation of the two final images formed after the light rays pass through the lens, at the moment when $u = 30$ cm. The speed object = 4 cm/s. The two lens halves are placed symmetrically w.r.t. the moving object.

17. In the figure shown 'O' is point object. AB is principal axis of the converging lens of focal length F. Find the distance of the final image from the lens.

18. The rectangular box shown is the place of lens. By looking at the ray diagram, answer the following questions.
(i) If $X$ is 5 cm then what is the focal length of the lens?
(ii) If the point O is 1 cm above the axis then what is the position of the image? Consider the optical center of the lens to be the origin.

19. Two identical convex lenses $L_1$ and $L_2$ are placed at a distance of 20 cm from each other on the common principal axis. The focal length of each lens is 15 cm and the lens $L_1$ is to the right of lens $L_2$. A point object is placed at a distance of 20 cm on the left of lens $L_2$, on the common axis of two lenses. Find where a convex mirror of radius of curvature 5 cm should be placed so that the final image coincides with the object?

20. A thin plano-convex. Lens of focal length F is split into two halves, one of the halves is shifted along the optical axis. The separation between object and image planes is 1.8 m. The magnification of the image formed by one of the half lenses is 2. Find the focal length of the lens and separation between the two halves. Draw the ray diagram for image formation. [JEE 96]

21. A thin equiconvex lens of glass of refractive index $\mu = 3/2$ & of focal length 0.3 m in air is sealed into an opening at one end of a tank filled with water ($\mu = 4/3$). On the opposite side of the lens, a mirror is placed inside the tank on the tank wall perpendicular to the lens axis, as shown in figure. The separation between the lens and the mirror is 0.8 m. A small object is placed outside the tank in front of the lens at a distance of 0.9 m from the lens along its axis. Find the position (relative to the lens) of the image of the object formed by the system. [JEE 97]
1. An object 2.4 m in front of a lens forms a sharp image on a film 12 cm behind the lens. A glass plate 1 cm thick, of refractive index 1.50 is interposed between lens and film with its plane faces parallel to film. At what distance (from lens) should to be in sharp focus of film? (AIEEE 2012)
(A) 7.2 m    (B) 2.4 m    (C) 3.2 m    (D) 5.6 m
Sol.

2. A beaker contains water up to a height $h_1$ and kerosene of height $h_2$ above water so that the total height of (water + kerosene) is $(h_1 + h_2)$. Refractive index of water is $\mu_1$, and that of kerosene is $\mu_2$. The apparent shift in the position of the bottom of the beaker when viewed from above is (AIEEE 2011)

(A) $\left(1 - \frac{1}{\mu_1}\right)h_1 + \left(1 - \frac{1}{\mu_2}\right)h_2$
(B) $\left(1 + \frac{1}{\mu_1}\right)h_1 + \left(1 + \frac{1}{\mu_2}\right)h_2$
(C) $\left(1 - \frac{1}{\mu_1}\right)h_1 + \left(1 - \frac{1}{\mu_2}\right)h_2$
(D) $\left(1 + \frac{1}{\mu_1}\right)h_1 - \left(1 + \frac{1}{\mu_2}\right)h_2$
Sol.

3. When monochromatic red light is used instead of blue light in a convex lens, its focal length will
(A) does not depend on colour of light    (B) increase    (C) decrease    (D) remain same
(AIEEE 2011)
Sol.

4. Statement I : On viewing the clear blue portion of the sky through a Calcite Crystal, the intensity of transmitted light varies as the crystal is rotated.
Statement II : The light coming from the sky is polarized due to scattering of sunlight by particles in the atmosphere. The scattering is largest for blue light.
(A) Statement I is false, Statement II is true  
(B) Statement I is true, Statement II is true  
(C) Statement I is true, Statement II is true, Statement II is the correct explanation of Statement I  
(D) Statement I is true, Statement II is true; Statement II is not correct explanation of Statement I
(AIEEE 2011)
Sol.

5. Let the $x$-$z$ plane be the boundary between two transparent media. Medium 1 in $z \geq 0$ has a refractive index of $\sqrt{2}$ and medium 2 with $z < 0$ has a refractive index of $\sqrt{3}$. A ray of light in medium 1 given by the vector $\vec{A} = 6\sqrt{5} \hat{i} + 8\sqrt{5} \hat{j} - 10 \hat{k}$ is incident on the plane of separation. The angle of refraction in medium 2 is (AIEEE 2011)
(A) $45^\circ$    (B) $60^\circ$    (C) $75^\circ$    (D) $30^\circ$
6. A car is fitted with a convex side-view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15m/s. The speed of the image of the second car as seen in the mirror of the first one is (AIEE 2011)

(A) \(\frac{1}{15}\) m/s
(B) 10 m/s
(C) 15 m/s
(D) \(\frac{1}{10}\) m/s

Sol.

7. As the beam enters the medium, it will (AIEE 2010)

(A) diverge
(B) converge
(C) diverge near the axis and converge near the periphery
(D) travel as a cylindrical beam

Sol.

8. The speed of light in the medium is (AIEE 2010)

(A) minimum on the axis of the beam
(B) the same everywhere in the beam
(C) directly proportional to the intensity
(D) maximum on the axis of the beam

Sol.

9. In an optics experiments, with the position of the object fixed, a student varies the positions of a convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance \(u\) and the image distance \(v\), from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at \(P\). The coordinates of \(P\) will be (AIEE 2009)

(A) \((2f, 2f)\)
(B) \((\frac{f}{2}, \frac{f}{2})\)
(C) \((f, f)\)
(D) \((4f, 4f)\)

Sol.

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

The incident angle \(i\) for which the light ray grazes along the wall of the rod is (AIEE 2009)

(A) \(\sin^{-1}\left(\frac{1}{2}\right)\)
(B) \(\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)\)
(C) \(\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)\)
(D) \(\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)\)
11. A student measures the focal length of a convex lens by putting an object pin at a distance $u$ from the lens and measuring the distance $v$ of the image pin. The graph between $u$ and $v$ plotted by the student should look like

(A) \[\text{v (cm)}\] \[\text{u (cm)}\]
(B) \[\text{v (cm)}\] \[\text{u (cm)}\]
(C) \[\text{v (cm)}\] \[\text{u (cm)}\]
(D) \[\text{v (cm)}\] \[\text{u (cm)}\]

13. The refractive index of glass is 1.520 for red light and 1.525 for blue light. Let $D_1$ and $D_2$ be angles of minimum deviation for red and blue light respectively in a prism of this glass. Then (AIEE 2006)
(A) $D_1 < D_2$
(B) $D_1 = D_2$
(C) $D_1$ can be less than or greater than $D_2$ depending upon the angle of prism
(D) $D_1 > D_2$

Sol.

14. A fish looking up through the water sees the outside world, contained in a circular horizon. If the refractive index of water is 4/3 and the fish is 12 cm below the water surface, the radius of this circle in cm is (AIEE 2005)
(A) $36\sqrt{7}$
(B) $\frac{36}{\sqrt{7}}$
(C) $36\sqrt{5}$
(D) $4\sqrt{5}$

Sol.

15. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm. Approximately, what is the maximum distance at which these dots can be resolved by the eye? [Take wavelength of light = 500 nm] (AIEE 2005)
(A) 5 m
(B) 1 m
(C) 6 m
(D) 3 m

Sol.

16. A thin glass (refractive index 1.5) lens has optical power of -5 D in air. Its optical power in a liquid medium with refractive index 1.6 will be (AIEE 2005)
(A) 1 D
(B) -1 D
(C) 25 D
(D) -25 D
17. A light ray is incident perpendicular to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that for the refractive index \( n \) as

\[ \frac{1}{\sqrt{2}} < n < \sqrt{2} \]

18. A plano-convex lens of refractive index 1.5 and radius of curvature 30 cm is silvered at the curved surface. Now, this lens has been used to form the image of an object. At what distance from this lens, an object be placed in order to have a real image the size of the object?

\[ (A) 20 \text{ cm} \quad (B) 30 \text{ cm} \quad (C) 60 \text{ cm} \quad (D) 80 \text{ cm} \]

19. The angle of incidence at which reflected light is totally polarized for reflection from air to glass (refractive index \( n \)), is

\( (A) \sin^{-1}(n) \quad (B) \sin^{-1}(\frac{1}{n}) \quad (C) \tan^{-1}(\frac{1}{n}) \quad (D) \tan^{-1}(n) \)

20. The image formed by an objective of a compound microscope is

\( (A) \) virtual and diminished
\( (B) \) real and diminished
\( (C) \) real and enlarged
\( (D) \) virtual adn enlarged

21. The earth radiates in the infra-red region of the spectrum. The spectrum is correctly given by

\( (A) \) Rayleigh Jeans law
\( (B) \) Planck's law of radiation
\( (C) \) Stefan's law of radiation
\( (D) \) Wien's law

\( (A) 20 \text{ cm} \quad (B) 30 \text{ cm} \quad (C) 60 \text{ cm} \quad (D) 80 \text{ cm} \)

\( (A) \text{ Rayleigh Jeans law} \quad (B) \text{ Planck's law of radiation} \quad (C) \text{ Stefan's law of radiation} \quad (D) \text{ Wien's law} \)
22. To get three images of a single object, one should have two plane mirrors at an angle of \( \text{(AIEEE 2003)} \) \( 60^\circ \) \( 90^\circ \) \( 120^\circ \) \( 30^\circ \) \( \text{Sol.} \)

23. If two mirrors are kept at \( 60^\circ \) to each other, then the number of images formed by them is \( \text{(AIEEE 2002)} \) \( 5 \) \( 6 \) \( 7 \) \( 8 \) \( \text{Sol.} \)

24. Wavelength of light used in an optical instrument are \( \lambda_1 = 4000 \text{ Å} \) and \( \lambda_2 = 5000 \text{ Å} \), then ratio of their respective resolving powers (corresponding to \( \lambda_1 \) and \( \lambda_2 \)) is \( \text{(AIEEE 2002)} \) \( 16 : 25 \) \( 9 : 1 \) \( 4 : 5 \) \( 5 : 4 \) \( \text{Sol.} \)

25. An astronomical telescope has a large aperture to \( \text{(AIEEE 2002)} \) (A) reduce spherical aberration (B) have high resolution (C) increase span of observation (D) have low dispersion \( \text{Sol.} \)

26. Which of the following is used in optical fibres? \( \text{(AIEEE 2002)} \) (A) Total internal reflection (B) Scattering (C) Diffraction (D) Refraction \( \text{Sol.} \)
1. An observer can see through a pin-hole the top end of a thin rod of height $h$, placed as shown in the figure. The beaker height is $3h$ and its radius $h$. When the beaker is filled with a liquid up to a height $2h$, he can see the lower end of the rod. Then the refractive index of the liquid is $\frac{\sqrt{2}}{2}$. 

Sol. $\frac{\sqrt{2}}{2}$

(A) $\frac{\sqrt{2}}{2}$  (B) $\frac{\sqrt{2}}{2}$  (C) $\frac{\sqrt{2}}{2}$  (D) $\frac{\sqrt{2}}{2}$

2. Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surface of the lenses are as given in the diagrams.

Sol. [JEE-2002 (Scr)]

3. Two plane mirrors A and B are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle of $30^\circ$ at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is $28$.

Sol. [JEE-2002 (Scr)]

(A) 28  (B) 30  (C) 32  (D) 34

4. A convex lens of focal length 30 cm forms an image of height 2 cm for an object situated at infinity. If a concave lens of focal length 20 cm is placed coaxially at a distance of 26 cm in front of convex lens then size image would be $1.25$ cm.

Sol. [JEE 2003 (Scr)]

(A) 2.5 cm  (B) 5.0  (C) 1.25  (D) None
5. A meniscus lens is made of a material of refractive index \( \mu_1 \). Both its surfaces have radii of curvature R. It has two different media of refractive indices \( \mu_2 \) and \( \mu_3 \), respectively, on its two sides (see figure). Calculate its focal length for \( \mu_1 < \mu_2 < \mu_3 \), when light is incident on it as shown.

[**JEE 2003**]

\[
\begin{array}{c}
\mu_1 < \mu_2 < \mu_3 \\
R \\
\end{array}
\]

6. White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected then the emerging ray in air contains

[**JEE 2004 (Scr)**]

(A) yellow, orange, red  
(B) violet, indigo, blue  
(C) all colours  
(D) all colours except green

7. A ray of light is incident on an equilateral glass prism placed on a horizontal table. For minimum deviation which of the following is true?

[**JEE 2004 (Scr)**]

(A) PQ is horizontal  
(B) QR is horizontal  
(C) RS is horizontal  
(D) Either PQ or RS is horizontal.

8. A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of the sphere is

[**JEE 2004 (Scr)**]

(A) 2 cm  
(B) 4 cm  
(C) 6 cm  
(D) 12 cm
9. Figure shows an irregular block of material of refractive index \( \sqrt{2} \). A ray of light strikes the face AB as shown in the figure. After refraction it is incident on a surface CD of radius of curvature 0.4m and enters a medium of refractive index 1.514 to meet PQ at E. Find the distance OE upto two places of decimal. [JEE 2004]

![Diagram](image)

Sol.

11. The ratio of powers of a thin convex and thin concave lens is 3/2 and equivalent focal length of their combination is 30 cm. Then their focal lengths respectively are [JEE 2005 (Scr)]
(A) 75, -50
(B) 50, 75
(C) 10, -15
(D) -75, 50

Sol.

12. Figure shows object O. Final image I is formed after two refractions and one reflection is also shown in figure. Find the focal length of mirror. (in cm): [JEE' 2005(Scr)]

![Diagram](image)

(A) 10
(B) 15
(C) 20
(D) 25

Sol.

10. An object is approaching a thin convex lens of focal length 0.3 m with a speed of 0.01 m/s. Find the magnitudes of the rates of change of position and lateral magnification of image when the object is at a distance of 0.4 m from the lens. [JEE 2004]

Sol.

13. What will be the minimum angle of incidence such that the total internal reflection occurs on both the surfaces? [JEE 2005]

\[
\begin{align*}
\mu_1 &= \sqrt{2} \\
\mu_2 &= 2 \\
\mu_3 &= \sqrt{3}
\end{align*}
\]
14. Two identical prisms of refractive index $\sqrt{3}$ are kept as shown in the figure. A light ray strikes the first prism at face AB. Find, [JEE 2005]

(a) the angle of incidence, so that the emergent ray from the first prism has minimum deviation.
(b) through what angle the prism DCE should be rotated about C so that the final emergent ray also has minimum deviation.

Sol.

15. A point object is placed at a distance of 20 cm from a thin plano-convex lens of focal length 15 cm, if the plane surface is silvered. The image will form at [JEE 2006]

(A) 60 cm left of AB  (B) 30 cm left of AB
(C) 12 cm left of AB  (D) 60 cm right of AB

16. Graph of position of image vs position of point object from a convex lens is shown. Then, focal length of the lens is [JEE 2006]

(A) 0.50 \pm 0.05 cm  (B) 0.50 \pm 0.10 cm
(C) 5.00 \pm 0.05 cm  (D) 5.00 \pm 0.10 cm

Sol.

17. Parallel rays of light from Sun falls on biconvex lens of focal length $f$ and the circular image of radius $r$ is formed on the focal plane of the lens. Then which of the following statement is correct? [JEE 2006]

(A) Area of image $\propto f$ directly proportional to $f$
(B) Area of image $\propto f^2$ directly proportional to $f^2$
(C) Intensity of image increases if $f$ is increased.
(D) If lower half of the lens is covered with black paper area of image will become half.
18. A simple telescope used to view distant objects has eyepiece and objective lens of focal lengths \( f_e \) and \( f_o \), respectively. Then \[ \text{[JEE 2006]} \]

Table:
Column I
- (A) Intensity of light received by lens
- (B) Angular magnification
- (C) Length of telescope
- (D) Sharpness of image

Column 2
- (P) Radius of aperture \( R \)
- (Q) Dispersion of lens
- (R) focal length \( f_e, f_o \)
- (S) spherical aberration


19. A ray of light travelling in water is incident on its surface open to air. The angle of incidence is \( \theta \), which is less than the critical angle. Then there will be \[ \text{[JEE 2007]} \]

(A) only a reflected ray and no refracted ray
(B) only a refracted ray and no reflected ray
(C) a reflected ray and a refracted ray and the angle between them would be less than \( 180^\circ - 2\theta \)
(D) a reflected ray and a refracted ray and the angle between them would be greater than \( 180^\circ - 2\theta \)

Sol.

20. Statement - I
The formula connecting \( u, v \) and \( f \) for a spherical mirror is valid only for mirrors whose size are very small compared to their radii of curvature \[ \text{[JEE 2007]} \]

Statement - II
Laws of reflection are strictly valid for plane surfaces, but not for large spherical surfaces.

(A) Statement-I is True, Statement - II is True; Statement-II is a correct explanation for Statement-I
(B) Statement-I is True, Statement - II is True; Statement - II is NOT correct explanation for Statement-I
(C) Statement-I is True, Statement-II is False
(D) Statement-I is False, Statement-II is True

Sol.

21. Two beams of red and violet colours are made to pass separately through a prism (angle of the prism is \( 60^\circ \)). In the position of minimum deviation, the angle of refraction will be \[ \text{[JEE 2008]} \]

(A) \( 30^\circ \) for both the colours
(B) greater for the violet colour
(C) greater for the red colour
(D) equal but not \( 30^\circ \) for both the colours

Sol.

22. A light beam is travelling from Region I to Region IV (Refer Figure). The refractive index in Regions I, II, III and IV are \( n_I, n_{II}, n_{III}, n_{IV} \) and \( \frac{n_{II}}{6}, \frac{n_{III}}{6}, \frac{n_{IV}}{6} \), respectively. The angle of incidence \( \theta \) for which the beam just misses entering Region IV is Figure: \[ \text{[JEE 2008]} \]

\[
\begin{array}{c|c|c|c|c}
\text{Region I} & \text{Region II} & \text{Region III} & \text{Region IV} \\
\hline
\theta & \frac{\pi}{2} & \frac{\pi}{4} & \frac{\pi}{8} \\
\hline
\end{array}
\]

(A) \( \sin^{-1} \left( \frac{3}{4} \right) \)
(B) \( \sin^{-1} \left( \frac{1}{8} \right) \)
(C) \( \sin^{-1} \left( \frac{1}{4} \right) \)
(D) \( \sin^{-1} \left( \frac{1}{3} \right) \)
24. A ball is dropped from a height of 20 m above the surface of water in a lake. The refractive index of water is 4/3. A fish inside the lake, in the line of fall of the ball, is looking at the ball. At an instant, when the ball is 12.8 m above the water surface, the fish sees the speed of ball as \[ \text{[Take } g = 10 \text{ m/s}^2\text{]} \] [JEE 2009] (A) 9 m/s (B) 12 m/s (C) 16 m/s (D) 21.33 m/s

Sol.

25. A student performed the experiment of determination of focal length of a concave mirror by \( u-v \) method using an optical bench of length 1.5 meter. The focal length of the mirror used is 24 cm. The maximum error in the location of the image can be 0.2 cm. The 5 sets of \( (u, v) \) values recorded by the student (in cm) are (42, 56) (48, 48), (60, 40), (66, 33) and (78, 39). The data set(s) that cannot come from experiment and is (are) incorrectly recorded, is (are) [JEE 2009] (A) (42, 56) (B) (48, 48) (C) (66, 38) (D) (78, 39)

Sol.
26. A ray OP of monochromatic light is incident on the face AB of prism ABCD near vertex B at an incident angle of 60° (see figure). If the refractive index of the material of the prism is $\sqrt{3}$, which of the following is (are) correct?
(A) The ray gets totally internally reflected at face CD
(B) The ray comes out through face AD
(C) The angle between the incident ray and the emergent ray is 90°
(D) The angle between the incident ray and the emergent ray is 120°

\[ \text{JEE 2010} \]

27. The focal length of a thin biconvex lens is 20 cm. When an object is moved from a distance of 25 cm in front of it to 50 cm the magnification of its image changes from $m_{1}$ to $m_{2}$. The ratio $\frac{m_{2}}{m_{1}}$ is \[ \text{JEE 2010} \]
29. A large glass slab ($\mu = 5/3$) of thickness 8 cm is placed over a point source of light on a plane surface. It is seen that light emerges out of the top surface of the slab from a circular area of radius $R$ cm. What is the value of $R$?  
[**JEE 2010**]

**Sol.**

---------

30. Image of an object approaching a convex mirror of radius of curvature 20 m along its optical axis is observed to move from $\frac{25}{3}$ m to $\frac{50}{7}$ m in 30 seconds. What is the speed of the object in km per hours?  
[**JEE 2010**]

**Sol.**

---------

31. Two transparent media of refractive indices $\mu_1$ and $\mu_2$ have a solid lens shaped transparent material of refractive index $\mu_3$ between them as shown in figure in **Column II**. A ray traversing these media is also shown in the figure. In **Column I** different relationships between $\mu_1$, $\mu_2$, and $\mu_3$ are given. Match them to the ray diagrams shown in **Column II**  
[**JEE 2010**]

<table>
<thead>
<tr>
<th>Column I</th>
<th>Column II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) $\mu_1 &lt; \mu_2$</td>
<td>(P)</td>
</tr>
<tr>
<td>(B) $\mu_1 &gt; \mu_2$</td>
<td>(Q)</td>
</tr>
<tr>
<td>(C) $\mu_2 = \mu_3$</td>
<td>(R)</td>
</tr>
<tr>
<td>(D) $\mu_2 &gt; \mu_3$</td>
<td>(S)</td>
</tr>
<tr>
<td>(E) $\mu_3 &gt; \mu_2$</td>
<td>(T)</td>
</tr>
</tbody>
</table>

**Sol.**
32. Water (with refractive index $\frac{4}{3}$) in a tank is 18 cm deep. Oil of refractive index $\frac{7}{4}$ lies on water making a convex surface of radius of curvature $R = 6$ cm as shown. Consider oil to act as a thin lens. An object 'S' is placed 24 cm above water surface. The location of its image is at 'x' cm above the bottom of the tank, then 'x' is

[JEE 2011]

**Sol.**

Paragraph for Question Nos. 34 to 35

Most materials have the refractive index, $n > 1$. So, when a light ray from air enters a naturally occurring material, then by Snell's law, $\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1}$, it is understood that the refracted ray bends towards the normal. But it never emerges on the same side of the normal as the incident ray. According to electromagnetism, the refractive index of the medium is given by the relation, $n = \sqrt{\frac{\varepsilon \mu}{c}}$, where $c$ is the speed of electromagnetic waves in vacuum, $\varepsilon$ its speed in the medium, $\varepsilon$, and $\mu$, are the relative permittivity and permeability of the medium respectively. In normal materials, both $\varepsilon$, and $\mu$, are positive, implying positive $n$ for the medium. When both $\varepsilon$, and $\mu$, are negative, one must choose the negative root of $n$. Such negative refractive index materials can now be artificially prepared and are called meta-materials. They exhibit significantly different optical behavior, without violating any physical laws. Since $n$ is negative, it results in a change in the direction of propagation of the refracted light. However, similar to normal materials, the frequency of light remains unchanged upon refraction even in meta-materials. [JEE 2012]

34. Choose the correct statement.

(A) the speed of light in the meta-material is $v = \frac{c}{n}$

(B) The speed of light in the meta-material is $v = \frac{c}{1/n}$

(C) The speed of light in the meta-material is $v = c$.

(D) The wavelength of the light in the meta-material ($\lambda_m$) is given by $\lambda_m = \lambda_0 \frac{1}{n}$, where $\lambda_0$ is the wavelength of the light in air.

33. A bi-convex lens is formed with two thin plano-convex lenses as shown in the figure. Refractive index $n$ of the first lens is 1.5 and that of the second lens is 1.2. Both the curved surfaces are of the same radius of curvature $R = 14$ cm. For this bi-convex lens, for an object distance of 40 cm, the image distance will be

[JEE 2012]

**Sol.**

(A) 280.0 cm

(B) 40.0 cm

(C) 21.5 cm

(D) 13.3 cm
35. For light incident from air on a meta-material, the appropriate ray diagram is

(A) ![Diagram A]

(B) ![Diagram B]

(C) ![Diagram C]

(D) ![Diagram D]

36. The image of an object, formed by a plano-convex lens at a distance of 8 m, behind the lens, is real and is one-third the size of the object. The wavelength of light inside the lens is \( \frac{2}{3} \) times the wavelength in free space. The radius of the curved surface of the lens is -

(A) 1 m  (B) 2 m  (C) 3 m  (D) 6 m

37. A ray of light travelling in the direction \( \frac{1}{2} \left( \hat{i} + \sqrt{3} \hat{j} \right) \) is incident on a plane mirror. After reflection, it travels along the direction \( \frac{1}{2} \left( \hat{i} - \sqrt{3} \hat{j} \right) \). The angle of incidence is:

(A) 30°  (B) 45°  (C) 60°  (D) 75°
A right-angled prism of refractive index \( \mu_1 \) is placed in a rectangular block of refractive index \( \mu_2 \), which is surrounded by a medium of refractive index \( \mu_3 \). As shown in the figure, a ray of light 'e' enters the rectangular block at normal incidence. Depending upon the relationships between \( \mu_1, \mu_2, \text{and} \mu_3 \), it takes one of the four possible paths 'ef', 'eg', 'eh' or 'el'.

![Diagram of light path](image)

Match the paths in List I with conditions of refractive indices in List II and select the correct answer using the codes given below the lists: [JEE 2011]

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P) e → f</td>
<td>1. ( \mu_1 &gt; \sqrt{2} \mu_2 )</td>
</tr>
<tr>
<td>(Q) e → g</td>
<td>2. ( \mu_1 &gt; \mu_2 ) and ( \mu_2 &gt; \mu_3 )</td>
</tr>
<tr>
<td>(R) e → h</td>
<td>3. ( \mu_1 = \mu_2 )</td>
</tr>
<tr>
<td>(S) e → i</td>
<td>4. ( \mu_1 &lt; \mu_2 &lt; \sqrt{2} \mu_2 ) and ( \mu_2 &gt; \mu_3 )</td>
</tr>
</tbody>
</table>

**Codes:**

- P
- Q
- R
- S

**Codes:**

- (A) 2 3 1 4
- (B) 1 2 4 3
- (C) 4 1 2 3
- (D) 2 3 4 1

**Sol.**
Exercise - I

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<td>D</td>
<td>72.</td>
<td>D</td>
<td>73.</td>
<td>D</td>
<td>74.</td>
<td>A</td>
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Exercise - II

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<tr>
<td>120</td>
<td>(i) B,D;(ii)A,B,C,D;(iii) A,B,D; (iv) D</td>
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Exercise - III

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(JEE ADVANCED)

LEVEL - I

1. $120^\circ$ anticlockwise and $240^\circ$ clockwise.  
2. $30^\circ$ clockwise.  
3. $60^\circ$.  
4. $40^\circ$.  
5. Mirror should be placed on the path of the rays at an angle of $78^\circ$ or $12^\circ$ to the horizontal.
6. Position of image = \((1 \cos 60^\circ, -1 \sin 60^\circ)\), Velocity of image = \(1 \cos 60^\circ \cdot i + 1 \sin 60^\circ \cdot j \text{ m/s}\)

7. (4, 0, 0) 8. 1.23 m 9. 160 cm; 320 cm 10. 75 cm 11. 1000 m/s

12. infinitely large 13. 1.95 m 14. (i) Real object, Virtual image, (ii) smaller, larger

15. Virtual object, Real image 16. larger, smaller

17. \[ \text{Real, } 2f, \text{ infinity : real } 2f, f \]

18. (a) 40 cm/s opposite to the velocity object, (b) 20 cm/s opposite along the velocity of object.

19. 60 cm 20. 2 cm 21. 80 m/s 22. d/2 23. 42 cm 24. \(\frac{2}{3} \times 10^{-8} \text{ sec} \)

25. 30 cm 26. 25 cm 27. 35 cm, Shift() = 5 cm. 28. 45^\circ

29. \(\alpha > \sin \frac{8}{9} \) 30. \(\sin^{-1} \left( \frac{1}{\sqrt{3}} \right) \) 31. 42 cm 32. \(\sin^{-1} \left( \frac{\sqrt{3} - 1}{\sqrt{2}} \right) \) 33. \(\sqrt{3} \)

34. \(\frac{b(1 - \mu^2 \cos^2 \theta)^{1/2}}{\sin \theta} \) 35. \(h = f \) 36. \(\frac{\sqrt{41}}{4} \) 37. 90° 38. 37°, This deviation is not minimum.

39. \(\theta = 60^\circ \) 40. \(38^\circ - \delta = 2 \sin^{-1} \left( \frac{3}{4} \right) - 60^\circ \) 41. (i) 1.5°, (ii) \(\frac{3\pi}{8} \)

42. 45° 43. \(\frac{\sqrt{43}}{5} \)

44. \(\frac{8}{5\sqrt{2}} \)

45. (i) \(\sin^{-1} \left[ \frac{1}{\sqrt{2}} \left( \sqrt{n^2 - n_1^2 - n_2} \right) \right] \) (ii) \(\mu_{1} = \sin^{-1}(n \sin 45^\circ) = 72.94^\circ \)

46. (i) \(\lambda = 600 \text{ nm}, n = 1.5, (ii) l = \sin^{-1}(0.75) = 48.59^\circ \)

47. 240 cm away from the separating surface.

48. (a) 2, (b) not possible, it will focus close to the centre if the refractive index is large

49. 40 cm from pole in the medium of refractive index 1, virtual, erect and 4 cm in size.

50. 50 cm 51. 27/2 = 13.5 cm below the surface of water

52. 4/3 53. 5 cm 54. 75 cm, 150 cm 55. ± 24 cm, ± 120 cm 56. Converging

57. (a) \(\frac{\mu R}{2\mu_1 - \mu_2 - \mu_3} \) (b) \(\frac{\mu R}{2\mu_2 - \mu_1 - \mu_3} \)

58. 20 cm, 1 m, -4, 24 cm 59. 15 cm

60. 1.67 cm from the lens 61. At the object itself, of the same size

62. 10D, Optical power of each lens = 5D 63. 10 cm for convex lens and 60 cm fro concave lens.

64. \(-\frac{20}{3} \text{ D} = -6.7 \text{ D} \) 65. 15 cm 66. 11 cm 67. \(\frac{\eta p}{(\eta - p)} \)

68. (5f, 2d) 69. \((x/4) \text{ cm}^2 \) 70. 3 cm 71. 75/4 cm, 75/2 cm 72. (i) 0.2 cm, (ii) 0.4 cm

73. 1.5 74. (a) 1/5 = 0.2° (b) 0.72° 75. 7.2°

---

**LEVEL - II**

2. (a) 21 m/s, (b) \(1 \times 10^{-3} / \text{sec} \)

4. \(\tan^{-1} \frac{2}{\sqrt{3}} \) with the principal axis, \(\frac{\sqrt{3}}{4} \text{ cm/sec} \)

5. \(6\sqrt{26} \text{ cm} \) 6. 16 feet

8. \(\mu = 3, \sin^{-1}(1/3) \)

9. 15 cm towards the combination 10. +60, +4/5

11. (a) \(\tan \theta = \frac{dy}{dx} = \cot \theta \) (b) \(y = k \left( \frac{x}{4} \right)^4 \) (c) 4.0, 1 (d) It will become parallel to x-axis
13. \( \mu = \frac{13}{8}, A = 2^\circ \)  
14. (i) 2\(^\circ\), (ii) \( \frac{4\pi}{9} \) mm  
15. 1.5 or \((\sqrt{5} - 1)\)  
16. 8/5 cm/s  
17. \( f = \frac{3f - 2d}{4d - 2d^2 - f^2} \)  
18. 10 cm, 10, 2  
19. 5.9 cm, 10.9 cm  
20. \( f = 0.4 \) m, separation = 0.6 m  

Exercise - IV  
PREVIOUS YEAR QUESTIONS  
LEVEL - I  


LEVEL - II  

1. B  2. C  3. B  4. A  5. \( f = v = \frac{\mu_2 R}{\mu_3 - \mu_1} \)  
6. A  
7. B  8. C  9. \( \frac{1514 \times 0.4}{0.1} = 6.06 \) m correct upto two places of decimal.  
10. 0.09 m/s; Magnitude of the rate of change of lateral magnification is 0.3 s\(^{-1}\).  
11. C  12. C  13. 60\(^\circ\)  
14. (a) I = 60\(^\circ\), (b) 60\(^\circ\) (anticlockwise)  
18. (A) P; (B) R; (C) R; (D) P, Q, S  
23. (A) \( \rightarrow p, q, r \) & s, (B) \( \rightarrow q, \) (C) \( \rightarrow p, q, r \) & s, (D) \( \rightarrow p, q, r \) & s  
29. 6 cm  30. 3  
31. (A) \( \rightarrow P, R \); (B) \( \rightarrow Q, S, T \); (C) \( \rightarrow P, R, T \); (D) \( \rightarrow Q, S \)  
**Exercise - I**

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

   ![Diagram](image)

2. 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.

   ![Diagram](image)

   \[ II' = O'I + OO' - (OI') \]

   \[ = x + x - 2(x - 2) \]

   \[ II' = 4 \text{cm} \]

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

   ![Diagram](image)

   \[ 3 : 25 \quad \text{Object} \]

   \[ 8 : 35 \quad \text{Image} \]

4. Deviation produced by plane mirror is given by

   \[ \delta = 180 - 2i \]

   here \( i = 90 - 60 = 30^\circ \)

   \[ \delta = 180 - 60 = 120^\circ \]

5. There is a phase change of 180° in reflection.

6. 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.

   ![Diagram](image)

**Single Correct**

7. By the laws of reflection angle of incidence = angle of reflection

   \[ \theta = \theta' \]

8. 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. All the reflected rays meet at a point, when produced backwards.

10. Lateral inversion refers to inverted image of object when kept in front of mirror.

    Image of HOX appears same as HOX.

11. 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. From the following figure we can see that incident & reflected ray are parallel to one another.

   ![Diagram](image)

13. First reflection = 3

    Second reflection = 3

    Third reflection = 1

    Total = 7

14. By the formula for the number of image formed

    \[ \frac{360}{\theta} - 1 \] where \( \theta \) is angle between the mirror.

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

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

   ![Diagram](image)
16. So diameter of the image = fα
   = 10 × \left(1 \times \frac{\pi}{180}\right) = \frac{\pi}{18}

17. 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 v = \frac{f}{2}

18. Using mirror formula
   \frac{1}{v} + \frac{1}{u} = \frac{1}{f}
   Here we have a virtual object so sign of u is positive.

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

19. 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.

20. 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 \quad 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 \quad 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.

\[ \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \]

Taking \( u = -2f \) & \( f = +f \)

\[ \frac{1}{v} + \frac{1}{-2f} = \frac{1}{f} \]

\[ \frac{1}{v} = \frac{1}{f} + \frac{1}{2f} = \frac{2 + 1}{2f} \]

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

22. Magnification is \(-3\) because image is real & inverted.

\[ m = \frac{-v}{u} \]

\[-3 = \frac{-v}{u} \]

\[ v = 3u. \]

given \( u = -20 \text{ cm} \)

\[ v = -60 \text{ cm} \]

By using mirror formula

\[ \frac{1}{60} - \frac{1}{20} = \frac{1}{f} \]

\[ f = -15 \text{ cm} \]

23. Here \( u = -30 \text{ cm} \), \( f = -15 \text{ cm} \)

object is at centre of curvature

\( \Rightarrow \) image will be real and of same size.

24. By using mirror formula

\[ u = +x; f = -f \]

\[ \frac{1}{v} = \frac{1}{-f} - \frac{1}{x} \]

\[ \frac{1}{v} = \frac{1}{x} = -\frac{(x + f)}{xf} \]

so if object virtual, image always real.

25. When object is real then image move from focus to pole.

So maximum distance \( f = 20 \text{ cm} \).

26. \[ \frac{dv}{dt} = -\frac{v^2}{u^2} \frac{du}{dt} \]

\[ \Rightarrow \frac{dv}{dt} \text{ is opposite of } \frac{du}{dt} \]

So, if \( v = -\text{ve} \text{ i.e. real image then away from mirror} \)

and if \( v = +\text{ve} \text{ i.e. virtual image then toward the mirror} \).

27. Irrespective of the type of mirror.

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

29. Only concave mirror forms larger image of an object.

30. Minimum distance between object and image is zero when image coincides with the object i.e., object is placed at \( 2f \).

31. It is a convex mirror. It makes a virtual image always.

32. 

\[ \text{Magnification } = \frac{h_1}{h_2} = \frac{-v}{u} \]

\[ h_1 = \frac{-9}{3} = \frac{-v}{u} \]

\[ 3u = v \]

\[ 3(x - 300) = x \]

\[ 3x - 900 = x \]

\[ 2x = 900 \]

\[ x = 450 \text{ cm} \]

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

\[ n_2 = \frac{v_2}{v_1} \]

\[ n_1 = \frac{v_1}{v_2} \]

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

\[ \frac{\sin i}{\sin r} = \frac{H_1}{H_2} = \frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2} \]
Applying Snell's law on surface of incidence:
$$\theta = \sin^{-1} \left( \frac{\sin 60^\circ}{\sqrt{3}} \right)$$
$$\phi = 180^\circ - [60 + \theta]$$
$$\phi = 180^\circ - \left[ 60^\circ + \sin^{-1} \left( \frac{\sin 60^\circ}{\sqrt{3}} \right) \right]$$
$$= 180^\circ - [60 + 30] = 90^\circ$$

Incident angle and emergent angle will be same. ⇒ the angle between them is 0.

36. Shift by a glass slab of thickness t is given by:
$$\tan \left( \frac{1}{\mu} \right)$$
And shift is towards the path of incident light.

37. $i = 60^\circ$
Displacement $= t \sec r \sin (i - r) = 5 \sqrt{2}$
$$= 15 \sec r \left[ \frac{\sqrt{3}}{2} \cos r - \sin r \right] = 5 \sqrt{3}$$
$$\Rightarrow \frac{\sqrt{3}}{2} - \frac{\tan r}{2} = \frac{1}{\sqrt{3}}$$
$$\Rightarrow r = 30^\circ$$
Now $\mu \sin r = \sin i$
$$\mu = \frac{\sqrt{3}}{2} \times \frac{1}{2} = \sqrt{3}$$

38. If light is travelling from medium B and suffers TIR it implies $\mu_B < \mu_A$.
$$\theta_c = \sin^{-1} \left( \frac{\mu_B}{\mu_A} \right)$$
$$\theta = \sin^{-1} \left( \frac{V_A}{V_B} \right)$$
$$\Rightarrow V_B = \frac{V_A}{\sin \theta} = \frac{V}{\sin \theta}$$
40. \( \frac{\mu_A}{\mu_B} = \frac{V_A}{V_B} = \frac{2.5 \times 10^8}{2 \times 10^8} = 1.25 \)
$$\theta_c = \sin^{-1} \left( \frac{1}{1.25} \right) = \sin^{-1} \left( \frac{4}{5} \right)$$
[As \( \theta_c = \sin^{-1} \frac{\text{Rarer}}{\text{Denser}} \)]

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

42. $\tan \theta = \frac{r}{4} \Rightarrow \sin^{-1} \left( \frac{3}{5} \right) = \theta$
$$\tan^{-1} \frac{3}{4} = \theta \Rightarrow r = \frac{3}{4} \text{ m}$$
[For radius to be maximum $\theta = \theta_c \Rightarrow r = 3 \text{ m}$]
Diameter = 6 m

43. $\mu = \frac{4}{3}$
$$\tan \theta_c = \frac{R}{12} \quad \text{...... (1)}$$
A ray of light interting at 90° from rarer medium makes an angle of refraction equal to critical angle in the denser medium and critical angle is given by
$$\theta_c = \sin^{-1} \frac{3}{4}$$
$$\theta_c = \tan^{-1} \frac{3}{\sqrt{7}} \quad \text{...... (2)}$$
Equation (1) & (2)
$$\frac{3}{\sqrt{7}} = \frac{R}{12} \quad \Rightarrow \quad R = \frac{12 \times 3}{\sqrt{7}}$$
43. We know that formula for deviation
\[ \delta = i + e - A \quad \text{and} \quad r_1 + r_2 = A \]
\[ i = i \quad r_2 = 0 \quad r_1 + 0 = A \]
\[ e = 0 \quad r_1 = A \]
\[ A = A \]
\[ 1 \sin i = \mu \sin A \]
Because angles are small \[ \quad i = \mu A \]

44. For minimum deviation \( i_{\text{min}} = e \)

and \( r_1 = \frac{A}{2} = r_2 = r \)
\[ \delta = i + e - A = 2 \left( i_{\text{min}} - r \right) = 38^\circ \] \[ \ldots (1) \]
Now \[ 44^\circ = 42^\circ + 62 - 2r \Rightarrow r = 30^\circ \] \[ \ldots (2) \]
From (1) and (2)
\[ i_{\text{min}} = 49^\circ \]

45. In the graph for angle of deviation v/s angle of incidence the shift in angle of incidence on right side is more than that of left side \( \chi_s > \chi_l \).
Hence only one angle is suitable \( e = 38^\circ \).

46. From the formula
\[ \delta = i + e - A \]
\[ \delta = 50 + 40 - 60 = 30^\circ \]
\[ \delta_{\text{min}} < 30^\circ . \]

47. Using formula for relation between \( \delta_{\text{min}} \) & \( A \).
\[ \sin \left( \frac{A + \delta_{\text{min}}}{2} \right) = \frac{\mu A}{2} \]
\[ \mu = \frac{\sin \frac{A}{2}}{\sin \frac{(90 + \delta_{\text{min}})}{2}} \]
\[ \frac{\sqrt{3}}{2} = \frac{\sin \frac{90 + \delta_{\text{min}}}{2}}{\sin 45^\circ} \]
\[ \sin \left( \frac{90 + \delta_{\text{min}}}{2} \right) = \frac{\sqrt{3}}{2} \]
\[ \frac{90 + \delta_{\text{min}}}{2} = 60^\circ \Rightarrow \delta_{\text{min}} = 30^\circ \]

48. C
\[ \delta_{\text{min}} = i + e - A \]
\[ \delta_{\text{min}} = A \]
So \( 2A = 2i \)
\[ i = A \]
Now for refraction on first surface.
\[ \sin i = \mu \sin r_1 \]
\[ \sin A = \mu \sin A/2 \]
[For minimum deviation \( r_1 = r_2 = A/2 \)]
\[ 2 \cos \frac{A}{2} \sin \frac{A}{2} = \sqrt{3} \sin \frac{A}{2} \]
\[ \cos \frac{A}{2} = \frac{\sqrt{3}}{2} \]
\[ \frac{A}{2} = 30 \Rightarrow A = 60^\circ \]

49. For light to 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
\[ r_1 + r_2 = A \]
\[ (r_2)_{\text{max}} = 60^\circ - (r_1)_{\text{min}} \]
For \( r_1 \) to be minimum \( i \) should be minimum
\[ \sin (i_{\text{min}}) = \frac{\sqrt{3}}{2} \sin (r_1)_{\text{min}} \]
In limiting case \( (r_2)_{\text{max}} = \theta_c \)
\[ \theta_c = 60 - \sin^{-1} \left( \frac{\sin i_{\text{min}}}{\mu} \right) \]
\[ \left( \sin^{-1} \left( \frac{1}{\mu} \right) \right) = \left[ 60 - \sin^{-1} \left( \frac{\sin i}{\mu} \right) \right] \]
\[ \sin^{-1} \left( \frac{\sin i}{\mu} \right) = 60 - \sin^{-1} \left( \frac{3}{7} \right) \]
\[ \sin i = \frac{\sqrt{3}}{2} \cos \left( \sin^{-1} \left( \frac{3}{7} \right) \right) \quad \text{and} \quad \frac{1}{2} \frac{\sqrt{3}}{7} \]
\[ \sin i = \frac{\sqrt{3}}{3} \left[ \frac{\sqrt{3}}{2} \frac{2}{7} - \frac{\sqrt{3}}{2} \frac{\sqrt{3}}{7} \right] \]
\[ \sin i = \frac{1}{2} \quad \Rightarrow \quad i = 30^\circ \]

50. Given angle of incidence \( I_1 \)
Given angle of emergence \( I_2 \)
Condition for minimum deviation
\[ i = e \quad \Rightarrow \quad I_1 = I_2 \]

51. Using the given formula
\[ \delta = (n - 1)A \]
and \( r_1 + r_2 = A \)
and for \( r_1 + r_2 = r_2 = r = A/2 \)
Hence \( \delta_{\text{min}} = r \)

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

53. This problem can be drawn as follows

54. We know that \( P = IA \& P \times t = E \)
Hence \( IA = \frac{E}{t} \)

Initially energy/sec = \( I \times \pi \left( \frac{d}{2} \right)^2 = \frac{\pi d^2}{4} \)
Now energy/sec = \( I \left[ \pi \left( \frac{d}{2} \right)^2 - \pi \left( \frac{d}{4} \right)^2 \right] \)
\[ = \frac{\pi d^2}{16} \]

So, Now
\[ \text{Final Intensity} = \frac{I \pi d^2}{4} = \frac{3}{16} \]
Focus will not change.

55. On cutting the less parallel to its principal axis \( f \) does not change so \( P \) will not change.

56.

57. Using the formula \( P = \frac{1}{f \left( \text{in m} \right)} \)
\[ p_1 = 2D \]
\[ f_1 = \frac{100}{2} = +50 \text{ cm} \]
\[ f_2 = -10 \text{ cm} \]
\[ f'_2 = -100 \text{ cm} \]
\[ \frac{1}{f_m} = \left[ \frac{1}{f_1} - \frac{1}{f_2} \right] \]
\[ = \left[ \frac{100}{100} - \frac{10}{100} \right] = \frac{90}{100} \]
\[ f_m = 100 \text{ cm} \]
58. 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 \((P_1)_i = (P_2)_i = P/2\)
\(P_i = (P_1)_i = (P_2)_i = P\) \(\therefore P = P_i\)
No change in power hence no change in focal length.

59. 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. The focal length of mirror formed will be \(f_m = R/2\)

61. For case 1
\[ u = -u_1 \Rightarrow v = -ku_1 \Rightarrow f = -f \]
\[ \frac{1}{ku_1} + \frac{1}{u_1} = \frac{1}{f} \quad \text{...... (1)} \]
For case 2
\[ u = -u_2 \Rightarrow v = ku_2 \Rightarrow f = -f \]
\[ \frac{1}{ku_2} + \frac{1}{u_2} = \frac{1}{f} \quad \text{...... (2)} \]
On solving (1) & (2)

62. From the formula
\[ h_0 - \sqrt{h_0^2 - h_2^2} = \sqrt{8 \times 12.5 - 10} \]

63. All are true.

64. We know that \(\theta_c = \sin^{-1} \frac{1}{\mu_{\text{glass}}}\) and \(\mu_{\text{glass}}\) depends on wavelength of light
\[ \mu_{\text{glass}} = \frac{1}{\lambda} \]
When \(\lambda\) is minimum the \(\mu\) will be maximum hence \(\theta_c\) will be minimum.
\(\lambda\) is minimum for violet hence \(\theta_c\) is minimum for violet light.

65. From the formula
\[ \frac{\text{Apparent depth}}{\text{Real depth}} = \frac{n_{\text{air}}}{n_{\text{glass}}} \]
Apparent depth = Real depth \(\times\) \(\frac{n_{\text{air}}}{n_{\text{glass}}}\)
The letter which appear least raised has maximum Apparent depth and hence it has minimum \(\mu\) for glass.
\[ \mu = \frac{1}{\lambda} \]
for \(\mu\) to be minimum \(\lambda\) should be maximum which is for Red.

66. Using formula
\[ \omega = \frac{n_y - n_0}{n_y - 1} \]
\[ n_y = \frac{n_y + n_0}{2} \]
\[ \omega = \frac{1.56 - 1.44}{1.5 - 1} \]
\[ n_y = \frac{1.56 + 1.44}{2} = 1.5 \]
\[ \omega = 0.12 \]
\[ n_y = \frac{0.5}{0.24} = 0.24 \]

67. \[ 1.6333 - 1 = 1.6161 = 0.0172 \]
\[ n_y - 1 \]
\[ 1.6333 - 1.6161 = 0.276 \]

68. Disp. \((n_y - n_0)\) \(\Delta\)

69. Ray of Red light bends minimum because it has maximum \(\lambda\) & minimum \(\mu\).
Exercise - II

1. Let $A'B'$ be the image of tower $AB$. The foot of tower coincides with foot of image. Let the mirror be $CD$ then from the given condition and from $\triangle CAB$.

$$\tan 45^\circ = \frac{h}{60} \implies h = 60\text{m}$$

2. 7 : 34 : 23

The plane mirror causes latered inversion. Hence we can see that the time shown by image clock will be 7 : 34 : 23.

Hint: Make a clock on the paper & look at it from the back.

3. \(M_1\) moves on line parallel to the mirrors so to find out where \(M_1\) will be able to see image of \(M_1\), we have to find the total length where \(M_1\) is visible of \(M_1\), so rays originate from \(M_1\), & after reflection meet at \(M_1\). By using similar triangles. We find total visible length is equal to $(3L + 3L) = 6L$.

Hence time duration will be $\frac{\text{Distance}}{\text{speed}} = \frac{6L}{u}$

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4. \(\triangle DEC \sim \triangle A'B'C\)

$$\frac{250}{x} = \frac{50}{10} \implies x = 50\text{ cm}$$

5. We know that the component of velocity parallel to mirror remains same for image but for perpendicular component.

6. \(V_1 = -V_2\)

Now to find relative velocity $V_{12} = V_1 - V_2$ where $V_{12}$ is relative velocity $V_1$ is velocity of image (1) & $V_2$ is velocity of image (2).

\[V_{12} = 2 \sin \phi \text{ on performing vector subtraction.}\]
7. The ray will retrace its path if it falls normally on the mirror i.e. at third reflection angle of incidence is 0.

\[ \tan \theta + \tan \theta + 90 + \theta = 180 \]
\[ 3\theta = 90 \]
\[ \theta = 30^\circ \]

8. We know that from formula

\[ V_m = \frac{V_i - V_0}{2} \]

where

- \( V_m \) = Velocity of mirror
- \( V_i \) = Velocity of image
- \( V_0 \) = Velocity of object

We can write velocity of image for first mirror after 1st reflection

\[ V_i = 2V \]

For second reflection this velocity becomes velocity of object,

\[ V_i = 2V \]
\[ v_i = \frac{2V + V_i}{2} \]
\[ v_i = 4V \]
\[ |V_i| = 4V \]

Thus after n\textsuperscript{th} reflection

\[ V_i = 2^n V \]

9. By image formations

\[
\begin{align*}
\frac{4L}{3} & \quad \frac{2L}{3} \\
\frac{L}{3} & \quad \frac{5L}{3} \\
\frac{2L}{3} & \quad \frac{2L}{3} \\
\end{align*}
\]

10. All the images formed by two plane.

Mirror inclined to each other form images which lie on a circle.

11. Let \( AB \) be the object whose image formed by plane mirror \( CD \) is \( A'B' \). The portion visible to the object can be drawn as shown in the ray diagram and \( EF \) is the length visible to him.

To calculate \( EF : \triangle AGC \sim \triangle AA'E' \) & \( \triangle AGD \sim \triangle AA'F' \)

\[
\begin{align*}
& \text{In } \triangle AGC \& \triangle AA'E' \\
& \quad \frac{AG}{AA'} = \frac{AG}{AA'} \\
& \quad \frac{GC}{A'E'} = \frac{GC}{A'E'} \\
& \quad x = \frac{2x}{0.4} = \frac{2x}{0.7} = \frac{2x}{A'E'} = \frac{2x}{A'F'} = \frac{A'E'}{0.8} = \frac{A'F'}{1.4} \\
& \quad \text{Now } A'F' = 1.4 \cdot 0.8 = 0.6 = EF \\
& \text{In } \triangle AGD \& \triangle AA'F' \\
& \quad \frac{AG}{AA'} = \frac{AG}{AA'} \\
& \quad \frac{GD}{A'F'} = \frac{GD}{A'F'} \\
& x = \frac{2x}{0.4} = \frac{2x}{0.7} = \frac{2x}{A'F'} = \frac{A'F'}{1.4} \\
& \quad \text{Now } A'F' = 1.4 \cdot 0.8 = 0.6 = EF \\
& \text{Let } AB \text{ be the street lamp of ht } 3h \text{ and } CD \text{ be the man of height } h. \text{ From } \triangle ABE \text{ and } \triangle CDE \\
& \text{BE} = DE \\
& \frac{BE}{CD} = \frac{AB}{AB} \\
& \text{The rate at which shadow is increasing is } \frac{dy}{dt} = \frac{v}{3h} \\
& \frac{dx}{dt} = v \\
& \frac{dy}{dt} = \frac{v}{2} \\
& \text{Visible portion} \\
& \text{Let } AB \text{ be the boy with his eye level at } E \text{ and } A'B' \text{ be the image then the visible portion is } \triangle AH. \triangle EID \sim \triangle EE'H'
EI = EE'
ID = EH
Now we know that EE' = 2 EI, ID = 0.6 m
AH = A'H' = A'E' + E'H'
E'H' = 1.2 and AH = 1.2 + 0.1 = 1.3 m.
Hence boy cannot see his feet.

14. Component of velocity of object ⊥ to mirror follows the condition.
\[ V_\perp = -V_y \text{ [for z component only]} \]
\[ V_\perp = 8 - [5 - 8] \]
\[ V_\perp = 11 m/s \]
The remaining components remain same as that of the object so \[ V_\parallel = 3i + 4j + 11k \]

15. Let AB be the man with his eye level at E and A'B' be the image

Using similar \( \triangle \) EHG & \( \triangle \) EE'B'

EE' = EH
E'B' = HG
EE' = 2EH & E'B' = 160 cm
HG = 80 cm
FH = 5 cm
Hence length of mirror required is FG = 85 cm and bottom of mirror should be 80 cm or less above the ground or else feet will not be visible.

16. Field of view is same for all positions of the mirror and hence spot on wall remains unaffected.

17. Using mirror formula
\[ \frac{1}{v} = \frac{1}{f} + \frac{1}{u} \]
by solving
\[ \frac{1}{v} = \frac{4b}{(2b - a)} \Rightarrow v = \frac{a(2b - a)}{4b} \]
So \[ u = -\left( \frac{b - a}{2} \right) \]
Using mirror formula

18. Using mirror formula
\[ \frac{h}{h_0} = \frac{v}{u} \]
Given \[ \frac{h}{h_0} = \frac{1}{2} \]
hence \[ v = \frac{u}{2} \]
given \[ u = -40 \Rightarrow v = 20 \]
Using mirror formula

19. Given
\[ m = +2 = -\frac{v}{u} \]
\[ v = -2u \]
Using mirror formula
\[ -\frac{1}{u} + \frac{1}{u} = \frac{1}{10} \]
\[ \frac{1}{2u} = \frac{1}{40} \]
f = 40
Convex mirror with focal length = 40 cm

20. Given
\[ m = \frac{h}{h_0} = \frac{1}{n} = -\frac{v}{u} \]
\[ v = -\frac{u}{n} \]
Using mirror formula
\[ -\frac{1}{u} + \frac{1}{u} = \left( \frac{n-1}{u} \right) = \frac{1}{f} \]
\[ u = -f(n-1) \]
| u | = f(n - 1)
21. \[
\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{(v/f)} + \frac{1}{(u/f)} = 1
\]
\[
v f = \frac{1}{1 - \frac{u}{f}}
\]
[v and u should be of same sign]

22. Incorrect statement
A concave mirror forms only virtual image for any position of real object.

23. In convex mirror Image is not at infinity (≠)

24. Image is large and real.
Concave mirror such that object is closer than image.
Mirror should be placed towards left of I.

25. Given
\[u = -15 \text{ cm} \Rightarrow f = -10 \text{ cm} \Rightarrow v = +30 \text{ cm}
\]
(Using mirror formula)
\[
dv \over du = \frac{v^2}{u^2}
\]
\[
dv = -\left(\frac{30}{15}\right)^2 \cdot du
\]
\[
dv = -4 \times 2
\]
\[
dv = -8 \text{ mm}
\]

26. \[
\frac{4 \text{ m/s}}{20 \text{ cm}}
\]
Using mirror formula
\[
\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} + \frac{1}{-20} = \frac{1}{-12}
\]
v = -30 cm real.
\[
dv \over dt = \frac{-v^2}{u^2} \cdot v_{om}
\]

\[
(V_1 - 0) = \frac{-v^2}{u^2} (V_0 - 0)
\]
\[
V_1 = -\left(\frac{30}{20}\right)^2 \cdot u
\]
\[
V_1 = -9 \text{ cm/s towards right.}
So away from the mirror.
\]

27. Using mirror formula
\[
h_1 = \frac{-u f}{u - f}
\]
\[
h_2 = \frac{-v f}{u - f}
\]
\[
dh_1 \over dt = -f \frac{dh_2}{dt}
\]
\[
dt = u - f
\]
\[
V_1 = -20 \frac{-20}{-20/2} \times 2 = -4 \text{ mm/s}
\]

28. \[
\frac{u = -25 \text{ cm}}{f = 20 \text{ cm}}
\]
\[
f = 25 \text{ cm}
\]
\[
u = -20 \text{ cm}
\]
\[
v = -100 \text{ cm}
\]
Using mirror formula
\[
dv \over dt = \left(\frac{100}{25}\right)^2 \times 10 = -160
\]
\[
h_1 = \frac{-v f}{u - f}
\]
\[
h_0 = \frac{f}{(f - u)}
\]
\[
dh_0 \over dt = \frac{-20 \times 1}{(-20 \times 25)^2} \times 10 = 8 \text{ m/sec.}
\]

29. For II \text{nd} reflection
Minimum value of θ = 45°

30. Using mirror formula
From the data given we get
\[
v = +10, u = -50
\]
\[
\frac{1}{10} - \frac{1}{50} - \frac{1}{f} \Rightarrow f = \frac{50}{4}
\]
\[
R = \frac{50}{2} = 25 \text{ cm}
\]

31. For \(M_1, u_1 = -30 \text{ cm}, f_1 = 20 \text{ cm}\)
\[
\frac{1}{v_1} + \frac{1}{u_1} = \frac{1}{f_1} \Rightarrow \frac{1}{v_1} + \frac{1}{-30} = \frac{1}{20}
\]
\[
\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} - \frac{1}{30} = \frac{1}{20} \Rightarrow \frac{2 - 3}{60} = 0
\]

\[
v_1 = -60 \text{ cm}
\]

For \(M_2\),

\[
u_2 = +(60 - (10 + 30)) = +20 \text{ cm}
\]

\[
f_2 = +10 \text{ cm}
\]

\[
\frac{1}{v_2} + \frac{1}{20} = \frac{1}{10} \Rightarrow v_2 = +20 \text{ cm}
\]

Now for \(M_1\),

\[
m_1 = -\frac{v_1}{u_1}
\]

For \(M_2\), \(m_2 = -\frac{v_1}{u_2}\)

Total \(M = m_1 \times m_2 = \frac{v_1 \times v_2}{u_1 \times u_2}\)

\[
\begin{align*}
(-60)(+20) &= (-30)(+20) \\
M &= +2
\end{align*}
\]

32.

I₁ will behave as an object for \(M₁\). Hence

\[
\frac{dv}{dt} = -v^2 \frac{du}{dt}
\]

Image will go towards right.

33.

The ray in this case is not paraxial so ray after reflections does not pass from focus but from point \(R/2 \text{ sec from C.}\)

\[
\sin \theta = \frac{f}{CP} = \frac{1}{2}
\]

\[
\Rightarrow \theta = 30^\circ \quad [\because CP = 2f]
\]

\[
\begin{align*}
BC &= \frac{2}{f} \\
\Rightarrow \frac{L}{f} &= \sqrt{3}
\end{align*}
\]

34. Given \(-\frac{v}{u} = +2 \Rightarrow v = \pm 2\)

from \(\frac{1}{v} + \frac{1}{u} = \frac{1}{f}\)

\[
\pm \frac{1}{2u} + \frac{1}{u} = \frac{1}{f}
\]

35. After solving \(u = -30, -10 \text{ cm}\)

36. Ray becomes vertical means angle of incidence \(= 45^\circ\). \(\theta \text{ with x-axis} = 45^\circ\) Slope = \(\pm 1\)

\[
\frac{dy}{dx} = 2 \cos \frac{\pi x}{L} = \pm 1
\]

\[
\Rightarrow \cos \frac{\pi x}{L} = \pm 1 \Rightarrow \cos \frac{\pi x}{L} = \frac{1}{2}
\]

\[
\Rightarrow \frac{x}{L} = \frac{1}{2} \Rightarrow y = \frac{\sqrt{3}L}{\pi}
\]

37. \(A - \text{virtual Image of object image}\)

38. \(\mu_s \sin i = \mu_s \sin r\)

From Snell’s Law
39. \[ 2 \sin i = \frac{\sqrt{5}}{2} \sin r \]
\[ \sqrt{2} x = \frac{\sqrt{5}}{2} \sin r \]
\[ \sin r = \frac{4}{5} = 53^\circ \]
Now check options.

40. \[
\begin{array}{c}
\text{Apparent Depth} \\
\text{Real Depth} = \frac{\mu_2}{\mu_1} \\
\end{array}
\]
\[
(21/2) \cdot \frac{1}{x} = \frac{2/3}{4/3} \]
\[ x = 14 \text{ cm} \]

41. Real depth = \( d = 1 \text{ m} \)
Virtual depth = \( d' = 0.9 \text{ m} \)
\[
\frac{d}{d'} = \frac{1}{\mu} = \frac{10}{9} \]

42. \( d = \frac{3h}{4} \)
Apparent depth of \( \theta \)
\[
d_1 = n_3 \left( \frac{h}{n_1} \right) \\
= 36 \text{ mm} \]
\[
d_2 = 36 \text{ mm} / 1.5 = 4/3 \]
\[
d_2 - d_1 = \frac{36}{1.5} - \frac{36}{4/3} = 3 \text{ mm} \]

43. \[
\frac{d}{d'} = \frac{x}{3} = \mu \\
x = 18 \times \frac{4}{3} = 24 \text{ cm} \]

44. The object will now appear to be placed at \( O' \) which is a point between \( C \) & \( B \) & for mirror. So image is formed between \( C \) & \( O \).

45. \[
\begin{array}{c}
\text{y} = \frac{4}{3} \Rightarrow \frac{dy}{dt} = \frac{4}{3} \frac{dx}{dt} = 8 \text{ m/sec} \\
\end{array}
\]

46. Shift = \[
\left[ 1 - \frac{V_{\text{medium}}}{V_{\text{slab}}} \right] \cdot \frac{\mu_2}{\mu_1} = \frac{V_2}{V_1} \\
\]
So, shift = \[
\left[ 1 - \frac{V_{\text{slab}}}{V_{\text{medium}}} \right] = 18 \left[ 1 - \frac{1.5}{9/4} \right] = 6 \text{ cm} \]

47. \[ \text{Deviation} = 90^\circ \text{ clockwise or } 270^\circ \text{ anticlockwise.} \]

48. \[ 90 - \phi > \phi \Rightarrow \cos \phi > \sin \phi \]
\[ \cos \phi > \frac{6}{5} \Rightarrow \phi < 37^\circ. \]

49. \[ n_1 \sin \phi = 1 \times \sin \theta \]
\[ \Rightarrow \sin \phi = \frac{n_1}{n_i} \Rightarrow \cos \phi = \frac{\sqrt{n_1^2 - \sin^2 \theta}}{n_i} \]
For T.I.R. \( 90 - \phi > \phi \Rightarrow \cos \phi > \sin C \)
\[ \frac{\sqrt{n_1^2 - \sin^2 \theta}}{n_i} > \cos C \]
\[ \Rightarrow \sin C = \frac{n_i}{n_1} \Rightarrow \frac{n_1^2 - \sin^2 \theta}{n_i^2} > \frac{n_2^2}{n_i^2} \]
50. For TIR to take place $\theta > C$.
\[ \tan \theta = \frac{a}{g} = \frac{7.5}{10} = 0.75 \]
\[ \sin \theta > \sin C \]
\[ \frac{3}{5} > \mu \quad \Rightarrow \quad \phi > C \]

51. \[ \frac{5}{3} \sin 30^\circ = \frac{4}{3} \sin \theta_2 \]
\[ \theta_2 = \sin^{-1} \left( \frac{5}{8} \right) \]
\[ \frac{5}{3} \cdot \sin 60^\circ = \mu \sin 90^\circ \]
\[ \Rightarrow \mu = \frac{5}{2\sqrt{3}} \]

52. \[ \sin C = \frac{1}{1.4} \]
\[ C = 45.58^\circ \]
For TIR to take place $\theta > C$.

53. \[ \mu_1 = \sin r = \mu_2 \sin i \]
\[ r = \sin^{-1} \left( \frac{\mu_2 \sin i}{\mu_1} \right) \]
for zero deviation $\mu_2 = \mu_1$
I.e., $k_2 = 1$
If $\mu_2 > \mu_1$, condition for $C$.
\[ \mu_2 \cdot \sin \frac{\pi}{3} = \mu_1 \sin 90^\circ \]
\[ \Rightarrow \frac{\mu_2}{\mu_1} = \frac{\sqrt{3}}{2} = k_1 \]
If $k \to 2 \Rightarrow r \to 0$
\[ \therefore | r - i | \to \frac{\pi}{3} \]

54. For critical angle
\[ \sin C = \frac{\mu_2}{\mu_1} \]
\[ 90^\circ - C > \sin^{-1} \left( \frac{\mu_1}{\mu_2} \right) \]
\[ \cos C > \frac{\mu_1}{\mu_2} \]
\[ \sqrt{\mu_1^2 - \mu_2^2} > \mu_3 \]
\[ \mu_1^2 - \mu_2^2 > \mu_3^2 \quad \text{... (B)} \]
\[ \mu_1^2 - \mu_3^2 > \mu_2^2 \quad \text{... (C)} \]
\[ \Rightarrow \mu_1^2 + \mu_2^2 > \mu_3^2 \quad \text{... (D)} \]

55. From properties of prism $r + C = A$
\[ r = A - C = 75 - \sin^{-1} \left( \frac{1}{\sqrt{2}} \right) = 30^\circ \]
\[ 1. \sin i = \sqrt{2} \sin r \]
\[ i = \sin^{-1} \left( \sqrt{2} \times \frac{1}{2} \right) \]
\[ i = 45^\circ \]

56. Using $A = r_1 + r_2$
\[ r_1 = 30^\circ \]
\[ r_2 = 0 \]
\[ 1. \sin i = \sqrt{2} \sin 30^\circ \]
\[ i = 45^\circ \]

57. $\mu \sin \theta_c = 1$
\[ \theta_c = \sin^{-1} \left( \frac{1}{\mu} \right) \]
\[ \mu = \left( \frac{1}{\sin \theta_c} \right) \]
\[ \theta_c < \theta \]
\[ \sin \theta_c < \sin \theta \]
\[ \frac{1}{\mu} < \frac{1}{\sqrt{2}} \]
\[ \mu > \sqrt{2} \]
58. First case
\[ r_2 = 0, r_1 = A \quad \therefore \quad r_1 = 0 \]
\[ \mu \sin r_2 = 1. \sin 90^\circ \]
\[ \sin r_2 = \frac{1}{\mu} \Rightarrow \mu = \frac{1}{\sin A} \]
\[ r_2 = 0 = \frac{A}{2} \]
\[ \mu \sin r_2 = 1. \sin \text{e} \]
\[ \Rightarrow \quad \text{e} = \sin^{-1} \left( \frac{\mu \sin \frac{A}{2}}{2} \right) \]
\[ = \sin^{-1} \left( \frac{\sin \frac{A}{2}}{\sin A} \right) \]
\[ \text{e} = \sin^{-1} \left( \frac{1}{2} \sec \frac{A}{2} \right) \]

62. \[ r_2 = 0, r_1 = A \]
\[ \sin 2A = \mu \sin A \]
\[ \mu = \frac{2 \sin A \cos A}{\sin A} \]
\[ = 2 \cos A \]

63. As in previous question
\[ r_2 = 0 \text{ and } r_1 = 30^\circ \]
By using condition for prism. We have formula
\[ \sin i = \sqrt{2} \sin 30^\circ \]
\[ i = 45^\circ \]

64. \[ A < 2C \Rightarrow 90^\circ < 2C \Rightarrow 45^\circ C \]
\[ \sin 45^\circ < \sin C \]
\[ \Rightarrow \frac{1}{\sqrt{2}} < \frac{1}{n} \]
\[ n < \sqrt{2} \]

65. \[ \delta = (\mu - 1) \times 2^\circ \text{ (clockwise)} \]
\[ = (1.5 - 1) \times 2^\circ \]
\[ = 2^\circ \text{ clockwise} \]

66. \[ \delta = (1.5 - 1) \times 5^\circ = 2.5 \times \frac{\pi}{180} \]

67. \[ \delta = i + e - A \]
We know that if \( i \) and \( e \) are interchanged deviation remains same.
\[ \delta = i + (i + 20) - 60 = 40 = 2i - 40 \]
\[ i = 40^\circ (e = 60^\circ) \]
or similarly \( i = 60^\circ (e = 40^\circ) \)
68. For minimum deviation
\[ r_1 = r_2 = r \implies 2r = A \]
\[ r = \frac{A}{2} = 30^\circ \]
Now from Snell's law
\[ \sin i = \sqrt{\frac{2}{3}} \sin 30^\circ \]
\[ i = 45^\circ \]
69. \( \delta = (\mu - 1) A \implies \delta = A \& \delta = \mu - 1 \)
70. A \( \rightarrow \) for min deviation there are two angles of incidence
B \( \rightarrow \) i = e so \( r_1 = r_2 \)
C \( \rightarrow \) i = 90° or e = 90° for \( \delta_{max} \)
D \( \rightarrow \delta_{min} = (\mu - 1)A \)
71. Here \( n_2 = \frac{4}{3} \)
\[ n_1 = 1 \]
\[ u = -R \]
\[ R = +R \]
from \[ \frac{n_2 - n_1}{v} = \frac{n_2 - n_1}{u} \]
\[ \Rightarrow \frac{4}{3} + \frac{1}{3} = \frac{4(3/2 - 1)}{R} \]
\[ \Rightarrow v = -2R \]
Then the distance from the centre
\[ R + 2R = 3R \]
72. Image is always virtual because rays go from rarer to denser medium.
73. \( n_1 = 3/2 \)
\( n_2 = 4/3 \)
\[ x \quad O \quad y \quad x \]
\[ n_2 = \frac{4}{3}, \quad n_1 = \frac{3}{2} \]
\[ R = -10 \text{ cm}, \quad u = -x \]
\[ \Rightarrow \frac{4}{3v} = \frac{3}{2x} - \frac{4(3/2 - 3/2)}{2x} \]
\[ \Rightarrow \frac{1}{v} = \frac{3}{4} \left( \frac{1}{60} - \frac{3}{2x} \right) \]
for real image \( v > 0 \)
\[ \Rightarrow \frac{3}{4} \left( \frac{1}{60} - \frac{3}{2x} \right) > 0 \implies x > 90 \text{ cm} \]
74.
75. \( u = -x \)
\( n_2 = 1.5 \)
\( n_1 = 1.5 \)
\[ M = 1.5 \]
\[ M = 1 \]
\[ \Rightarrow \frac{1}{v} = \frac{3}{2x} \]
\[ \Rightarrow \frac{1}{v} > 0 \implies x > 3R \]
76. \( n_2 = \mu \)
\( n_1 = 1 \)
\( x = 2R \)
\[ V = 2R \]
\[ \Rightarrow \frac{n_2 - n_1}{v} = \frac{n_2 - n_1}{u} \]
\[ \Rightarrow \frac{\mu - 1}{2R} = \frac{\mu - 1}{R} \]
\[ \Rightarrow \mu = \frac{2R}{R} \]
\[ \Rightarrow \mu = 2 \]
77. \( n_2 = \mu \)
\( n_1 = 1 \)
\[ x = \infty \]
\[ V = 2R \]
\[ \Rightarrow \frac{\mu - 1}{R} \]
\[ \Rightarrow \mu = 2 \]
78. For first reflection
\[ u = -R, \quad v = +x \]
\[ \mu = \frac{1}{R} = \frac{\mu - 1}{R} \implies \mu = 2 \]
79. \[ u = -d, \quad R = +60, \]
\[ \mu_2 = \frac{3}{2}, \quad \mu_1 = 1 \]
\[ \Rightarrow \frac{3}{2} \cdot \frac{1}{d_1} = \frac{1.5 - 1}{60} \]
\[ \Rightarrow \frac{3}{2} \cdot \frac{1}{120} = \frac{1}{d_1} \]
If \( d_1 = 120 \Rightarrow v = \infty \)
\[ \therefore \text{Retraces path} \]
If \( d_1 = 240 \Rightarrow v = 360 = d_1 \)

80. \[
\begin{align*}
\mu_2 & \quad (\mu_1) \\
\mu_1 & \quad \mu_2 \\
p & \quad x \\
p\prime & \quad x \\
u & = -x, \quad n_2 = \mu_2, \quad n_1 = \mu_1, \quad R = -R \\
\Rightarrow \frac{\mu_2 + \mu_1}{\nu + x} = \frac{\mu_2 - \mu_1}{R} \\
\Leftrightarrow \frac{n_2 + n_1}{\nu + x} = \frac{n_2 - n_1}{R} \\
\Rightarrow \frac{n_2}{\nu} = \frac{n_1}{x} = \frac{(\mu_2 - \mu_1)}{R} \\
\text{If } \mu_2 > \mu_1 \Rightarrow v = -ve \\
\text{If } x \text{ is -ve and } \mu_2 > \mu_1 \Rightarrow v = +ve
\end{align*}
\]

81. \[
\begin{align*}
\mu_2 & \quad \mu_1 \\
\mu_1 & \quad \mu_2 \\
v & \quad x \\
R & \quad x \\
\text{For virtual image } V < 0. \\
u & = -x, \quad n_2 = \mu_2, \quad n_1 = \mu_1, \quad R = +R \\
\Rightarrow \frac{n_2 + n_1}{\nu + x} = \frac{n_2 - n_1}{R} \\
\Leftrightarrow \frac{n_2}{\nu} = \frac{n_1}{x} = \frac{(\mu_2 - \mu_1)}{R} \\
\text{If } \mu_2 < \mu_1 \Rightarrow v = -ve
\end{align*}
\]

82. \[
\begin{align*}
\mu_1 & \quad (\mu_2) \\
\mu_2 & \quad \mu_1 \\
x & \quad x \\
\text{As } f \text{ increases } h, \text{ decreases}
\end{align*}
\]

83. \[
\begin{align*}
u & = -x, \quad n_2 = \mu_2, \quad n_1 = \mu_1, \quad R = -R \\
\Rightarrow \frac{n_2 + n_1}{\nu + x} = \frac{n_2 - n_1}{R} \\
\Leftrightarrow \frac{n_2}{\nu} = \frac{n_1}{x} = \frac{(\mu_2 - \mu_1)}{R} \\
\text{As } x \text{ increases } f, \text{ decreases}
\end{align*}
\]

84. \[
\frac{1}{f_x} = \frac{1}{f_y} \quad (\mu_2 - \mu_1) \\
\frac{1}{R_a} = \frac{x_a - 1}{R_b} \\
x_a = 1.7
\]

85. \[
\frac{1}{f} = p = (\mu - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \quad ... (1)
\]
\[ \text{Now } p' = \left( \frac{\mu_0}{\mu_2} - 1 \right) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \quad ... (2) \]
\[ \frac{p'}{p} = \frac{\mu - \mu_0}{\mu_2(\mu_1 - 1)} \]

86. \[ m = -0.5 = \frac{v}{u} \]
\[ v = -\frac{u}{2} = +5cm \]
\[ \frac{1}{f} - \frac{1}{5} - \frac{1}{10} = \frac{1}{10} \]
\[ f = \frac{10}{3} \text{ cm convex lens.} \]

87. \[
\frac{dv}{du} = \frac{v^2}{u^2} \\
\frac{1}{v} = \frac{1}{10} - \frac{1}{15} \Rightarrow v = 30cm \\
\frac{dv}{du} = \left( \frac{30}{15} \right) = 2 \Rightarrow u = 15cm \\
\frac{dv}{du} = -4mm
\]

88. \[
\frac{1}{f} = (u - 1) \left( \frac{1}{R} - \frac{1}{R} \right) \\
\Rightarrow f = \frac{R}{2(u - 1)} \\
\Rightarrow f_1 \text{ and } f_2 \text{ image more towards the lens.}
\]

89. \[
\frac{h}{h_0} = \frac{v}{u} = \frac{f}{(u + f)} = \frac{1}{u + f} \\
\Rightarrow \text{As } f \text{ increases } h, \text{ decreases}
\]

90. \[
\frac{1}{v} = \frac{1}{u} - \frac{1}{f} \quad u \text{ fixed} \\
\frac{1}{v} = \frac{1}{x} \quad u = -x
\]

91. \[
OB = \gamma \text{ and } OA = x \\
y^2 + OC^2 = BC^2 \quad ... (1) \\
x^2 + OC^2 = CA^2 \quad ... (2) \\
BC^2 + CA^2 = (x + y)^2 \quad ... (3) \\
\Rightarrow xy = OC^2
\]
92.

\[ \frac{1}{v} \cdot \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{y} \cdot \frac{1}{x} = \frac{1}{f} \]

\[ f = \frac{xy}{x+y} \quad \Rightarrow \quad f = \frac{OC}{AB} \]

\[ f = 20 \text{ cm} \]

93.

\[ \frac{dv}{dt} = \frac{v^2}{u} \cdot \frac{du}{dx} \]

\[ \Rightarrow V_i = \frac{v^2}{u^2} \cdot v_p \quad \Rightarrow \quad (V_i - V_f) = \frac{v^2}{u} (v_f - v) \]

\[ \Rightarrow V_i = \frac{v^2}{u} \cdot v + v_f \]

\[ \Rightarrow V_i = V_f \left[ \frac{u^2 - v_f^2}{u^2} \right] = v \times \left[ \frac{u^2 - v_f^2}{u^2} \right] \]

upto 2f \quad u < v \quad \text{Hence} \quad v_f = -ve \]

after 2f \quad u > v \quad \text{Hence} \quad v_f = +ve

94.

There are 3 lenses touching each other and \( f_1 = f_3 = 10 \text{ cm} \). Let radius = \( R \)

then \( \frac{1}{f_1} = \frac{3}{2} - 1 \frac{1}{R} - 0 = \frac{1}{10} \)

\( R = 5 \text{ cm} \)

So, \( \frac{1}{f_2} = \frac{1}{f_1} + \frac{1}{f_3} + \frac{1}{f_4} \)

\[ \frac{1}{f_2} = \frac{2}{15} \]

\[ \frac{1}{f_3} = P_1 + P_2 + P_3 \]

So \( P_{eq} = \left( \frac{1}{f_1} + \frac{1}{f_3} + \frac{1}{f_4} \right) \times 100 \text{ (diaport)} \)

\( = \left( \frac{2}{10} - \frac{2}{15} \right) \times 100 = \frac{100}{150} \)

Power = 6.67 diaport

95.

\[ m = 3 = \frac{v}{u} \quad \Rightarrow \quad v = 3u \]

\[ u = -10 \text{ cm} \quad \Rightarrow \quad v = +30 \text{ cm} \]

\[ \frac{1}{30} + \frac{1}{10} = \frac{1}{f}\]

\[ f = \frac{30}{4} \text{ cm} \quad f_2 = -30 \]

\[ \frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{-30} + \frac{1}{30} = \frac{4}{30} \]

\( f_1 = 6 \text{ cm} \)

96.

[Diagram of convex lens showing focal length and object distance]

Ray retraces its path when it appears to come towards centre of curvature

\( R = 20 \)

\( F = 10 \text{ cm} \)

For ray to retrace its path it must fall normally on mirror.

97.

[Diagram of ray passing through convex lens]

\[ u = -x, f = 30 \text{ cm}, v = +x \]

\[ \frac{1}{u} + \frac{1}{v} = \frac{1}{f} \quad \Rightarrow \quad x = 30 \]

98.

\[ f = 30 \]

99.

1st lens \( \Rightarrow \) diverging lens (concave)

\( \Rightarrow \) focus = -5cm

2nd lens \( \Rightarrow \) converging lens (convex)

\( \Rightarrow \) focus = +5cm

100.

[Diagram of concave lens with radius of curvature]

For auto collimation the image should be formed on object so the object should be placed at centre of curvature of the equivalent mirror.
\[ \frac{1}{f_{eq}} = \frac{1}{f_1} - \frac{2}{f} \]
\[ P_m = -\frac{1}{f_m} = -\frac{1}{20} - 2(\mu - 1) \left( \frac{2}{R} \right) \Rightarrow \frac{1}{f_m} = -\frac{1}{10} \]
(Equivalent system is concave mirror with focal length 10 cm, \( R = 20 \text{ cm and hence} u = 20 \text{ cm})
\[ u = 20 \text{ cm} \]

101. \[ \frac{1}{f_1} = \frac{1}{f_m} - \frac{2}{f} \]
\[ \frac{-1}{28} = \frac{1}{\infty} - 2(\mu - 1) \left( \frac{1}{R_1} + 0 \right) \]
\[ -\frac{1}{28} = \frac{-2(\mu - 1)}{R_1} \]
\[ \frac{1}{f_2} = \frac{-2}{R_1} - 2(\mu - 1) \left( \frac{1}{R_1} + 0 \right) \]
\[ \frac{-1}{10} = \frac{-2}{R_1} - \frac{2}{R_1} (\mu - 1) \]
\[ \frac{1}{f_{eq}} = \frac{-2}{R_1} - \frac{2}{R_1} (\mu - 1) \]

Now equation (1) / equation (2)
\[ 10 = \frac{2(\mu - 1)}{2 + 2(\mu - 1)} \]
\[ 28 = \frac{1}{28} \]
\[ \frac{5}{14} = \frac{(\mu - 1)}{\mu} \Rightarrow 5\mu = 14 (\mu - 1) \]
\[ 9\mu = 14 \]

102. From the previous Question
Equation (1) - equation (2)
\[ \frac{-1}{28} + \frac{1}{10} = \frac{-2}{R_1} \]
\[ \frac{28\times 10 - 2}{28 - 10} = \frac{280}{18} = 9 \text{ cm}. \]

103. \[ f = \frac{D^2 - d^2}{4D} \]
\[ \Rightarrow f = \frac{90^2 - 20^2}{4 \times 40} \]
\[ \Rightarrow f = 21.4 \text{ cm} \]

104. \[ h_1 = \frac{\sqrt{1}, I_1}{2} \]
\[ h_2 = \frac{\sqrt{6}, I_2}{3} = 4.2 \text{ cm} \]

105. B \rightarrow convex mirror
C \rightarrow plane mirror
D \rightarrow diverging mirror

106. \[ 10 \rightarrow \]
\[ \mu = \frac{3}{2} \]
\[ 15 \rightarrow \]
\[ \mu = \frac{4}{3} \]

107. \[ \frac{1}{f_1} = \frac{3}{2} - \frac{1}{10} - \frac{1}{15} \]
\[ \Rightarrow \frac{1}{f_1} = -\frac{1}{12} \]
\[ \frac{1}{f_2} = \frac{1}{15} - \frac{1}{15} + \frac{1}{15} = \frac{2}{45} \]
\[ \frac{1}{f_3} = \frac{1}{15/2} = \frac{-2}{15} \]
\[ \frac{1}{f_{eq}} = \frac{-2}{15} - 2 \left[ \frac{1}{12} + \frac{2}{4.5} \right] = \frac{-5}{90} \]
\[ f_{eq} = -18 \text{ cm} \]

On cutting lens into two halves power of each section becomes \( P/2 \). On combining them again net power of system becomes \( P \) so focal length of two system (ii) and (iii) is same.

108. \[ 6 \text{ cm} \]
\[ x \rightarrow \]
\[ y \rightarrow \]
\[ (y - x) \rightarrow \]
\[ \text{Screen} \]

\[ D = 90 \text{ cm} \]
\[ h_1 = h_2 = \sqrt{h_1 h_2} = 6 \text{ cm} \]
\[ h_1 = \frac{v}{u} = \frac{9}{3} = 3 \]
\[ h_2 = \frac{v}{u} = \frac{6}{2} = 3 \]
\[ v : u = 3 : 2 \]
\[ uv + u = 90 \]
\[ \Rightarrow v = 54, u = 36 \Rightarrow d = 18 \]
\[ f = \frac{D^2 - d^2}{4D} \]
\[ f = \frac{90^2 - 18^2}{4 \times 90} \Rightarrow f = 21.6 \text{ cm} \]

109. C \rightarrow A converging lens may be used and the object be placed at a distance less than \( f \) from the lens.

110. B \rightarrow diverging mirror
D \rightarrow diverging lens

111. \[ \mu = a + \frac{b}{\lambda} \Rightarrow \frac{1}{f} = (m - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} \right] \]
112. A → The image will look like a white donkey on the photograph
D → The image will be less intense compared to the case in which no such glass is used.

113. \( \delta = \delta_1 - \delta_2 = 0 \)
\( (\mu_1 - 1)A_1 - (\mu_2 - 1)A_2 = 0 \)
\( (1.54 - 1)\mu - (1.72 - 1)A_2 = 0 \) \( \Rightarrow A_2 = 3^\circ \)

114. Dispersion is not possible as only one wavelength present.

\[
\begin{align*}
\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} &= 0 \\
1 &= \frac{-\omega_2}{f_1} \times \frac{1}{f_2} \left( \frac{1}{\omega_1} \right) \\
1 &= \frac{-2}{f_1} f_2 \\
&= \frac{1}{f_1} \frac{1}{f_2} \Rightarrow \frac{1}{f_1} \frac{1}{f_2} = 10 \\
&\Rightarrow \frac{f_1}{f_1} \frac{1}{f_2} = \frac{1}{10} \\
&\Rightarrow f_1 = -10 \text{cm} \Rightarrow f_2 = 5 \text{cm}
\end{align*}
\]

115. \( \frac{1}{f_1} - \frac{1}{f_2} = \frac{1}{f_1} \frac{1}{f_2} \)
\( \sin C = \frac{1}{\mu} \)
for red C > 45°

117. \( \frac{1}{f_1} = \frac{1}{f_2} = \frac{1}{f_1} \frac{1}{f_2} \) → positive
\( \frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0 \) → \( \frac{\omega_1}{f_1} = \frac{-\omega_2}{f_2} \)
\( \omega_1 < \omega_2 \) → \( f_1 < f_2 \)

118. B → The emergent beam is white.
C → The light inside the slab is split into different colours.

119. A → have dispersion without average deviation.
B → have deviation without dispersion.
C → have dispersion and average deviation.

120. Convex mirror always forms virtual image of real object.

121. Due to irregular reflection.
In this all the reflected rays doesn’t meet at one point in backward.

122. Focal length \( (f) = R - \frac{R}{2} = \frac{R}{2} \)
(for paraxial rays between pole to point of intersection distance is
\( PA = R - \frac{R}{2} \sec \theta \)
as \( \theta \) \( \frac{1}{2} \sec \theta \)
so \( PA \) decreases.

123. \( d' = n_2 \) → Apparent depth
\( d = n_1 \) → Real depth
In slab shift is independent of position of object from slab.
Shift = \( t \left( \frac{1 - \frac{1}{\mu}}{1} \right) \)

124. Real image intensity of light come the during of path.

125. In real image rays actually converge.
The ray actually converge so at the point of real image intensity of light causes the burning of paper.
1. \( \delta = 180 - 2i \) → angle of incidence
\( \delta = 180 - 2(30) \)
\( = 120^\circ \) anticlockwise
\( \delta = 180 + 2(30) \)
\( = 240^\circ \) clockwise.

2. Due to turning of incident ray by 10° reflected ray also gets turned by 10° anticlockwise. Due to turning of mirror by 20° ray gets turned by 40° (2i) clockwise.
Angle turned by reflected ray = 40 - 10
\( = 30^\circ \) clockwise

3. Deviation at A \( \delta_1 = 180 - 2i_1 \) (AC)
Deviation at B \( \delta_2 = 180 - 2i_2 \) (AC)
In \( \Delta OAB \)
\( 90 - l_1 + 90 - l_2 + 60 = 180^\circ \)
\( l_1 + l_2 = 60^\circ \)
Net deviation \( \delta = \delta_1 + \delta_2 \)
\( = 360 - 2(l_1 + l_2) \)
\( = 360 - 2 \times 60 = 240^\circ \)

From line BC
\( 180 + \theta = 240 \)
\( \theta = 60^\circ \)

4. For retracing the path the ray must be incident normally on second mirror.

5. Ray directed parallel to horizon to rotate the mirror
\( \frac{24}{2} = 12^\circ \) (Clockwise)
\( \frac{156}{2} = 78^\circ \) (anti clockwise)

6. Co-ordinate of image
\( = (1 \cos 60^\circ, -1 \sin 60^\circ) \)

Resultant velocity of 1
\( |v| = \sqrt{2 \cos^2 60^\circ + 2 \sin^2 60^\circ} \)
\( \tan \theta = \frac{1/2}{\sqrt{3}/2} = \frac{1}{\sqrt{3}} \)
\( \text{In } i, j \text{ form} \)
\( \Rightarrow v = \cos 60^\circ i + \sin 60^\circ j \text{ m/s} \)

7. Co-ordinate of image
\( = (4, 0, 0) \)

8. 180cm
9. Use similar triangles
\[ \Delta P M I \text{ and } \Delta A B I \]
\[ P M = h_{\text{max}} = 40 \]
\[ M I = 80 \]
\[ h_{\text{max}} = 160 \text{cm} \]
\[ \Delta M Q I \text{ and } A C I \]
\[ Q M = h_{\text{max}} = 80 \]
\[ M I = 80 \]
\[ h_{\text{max}} = 320 \text{cm} \]

10. \[ \Delta A B I \text{ and } \Delta O C I \]
\[ O I = A I \]
\[ O C = A B \]
\[ x = \frac{300 + x}{20} = \frac{100}{100} \]
Let \( O I = x \)
\[ 100x = 6000 + 20x \]
\[ 80x = 6000 \]
\[ x = \frac{600}{8} = 75 \text{ cm} \]
\[ 25 \times 3 \]
\[ = 75 \text{ cm} \]
\[ O S = O I = 75 \text{ cm} \]

11. \[ \omega = \frac{9}{\pi} \times 2\pi = 18 \text{ rad/s} \]

12. \[ \frac{d\theta}{dt} = 20\pi - 36 \text{ rad/s} \]
\[ \frac{dy}{dt} = 10 \sec^2 \theta \frac{d\theta}{dt} \]
\[ = 10 \times \frac{25}{9} \times 36 = 1000 \text{ m/s} \]

13. Given \[ \frac{h_o}{h_u} = -3 = \frac{-v}{u} \ldots (1) \]
\[-v + u = 2.6 \text{ m} \ldots (2) \]
from eq. \( u = -130 \text{ cm} \)
\[ v = -390 \text{ cm} \]
from \[ \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \]
we get \[ f = -97.5 \]
Radius of curvature = \( 2f = 1.95 \text{ m} \)

14. (i) Real object \( (u = -\text{ve}) \)
Virtual Image \( (v = +\text{ve}) \)
(ii) Smaller \( \left( \frac{1}{u} \right. \text{ larger so } u \text{ is smaller} \)
Larger

15. Virtual Object \( (u = +\text{ve}) \)
Real Image \( (v = -\text{ve}) \)

16. Larger
Smaller

17. Real, \( 2f \text{- infinity} \)
Real, \( 2f-f \)

18. \[ (a) V_{im} = \frac{-V' - V_{im}}{1} \]
From \( \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \), we get \( v = -120 \) cm

\[ v = -\frac{(120)^2}{60} \times 10 = -40 \text{ cm/s} \]

(b) \( \frac{dh}{dt} = -\frac{v}{u} \frac{dh}{dt} \)

\[ v = -\frac{120}{60} \times 10 \]

\[ v = -20 \text{ cm/s} \]

19. Given \( \frac{h}{h_o} = \frac{-v}{u} = 1.5 \)

\( u = -20 \) cm

\( v = 30 \) cm

from \( \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \)

\( \Rightarrow f = 60 \) cm

20. \[ \begin{array}{c}
\begin{array}{c}
\text{Given:} \\
\text{path level by the light} = \frac{t}{\cos 15^\circ} = \frac{1}{\cos 15^\circ} \cdot m \\
\text{Speed of light in ice} = \frac{3 \times 10^8}{\mu_{ic}} \\
\text{Time taken by the light to cross the slab} \end{array}
\end{array} \]

\[ T = \frac{d}{v} = \frac{1}{\cos 15^\circ} \cdot \frac{3 \times 10^8}{\mu_{ic}} \]

\[ T = \frac{2}{3} \times 10^8 \text{ sec} \]

25. \[ \frac{\text{Apparent depth}}{\text{real depth}} = \frac{1}{n_i} \]

\( h = \frac{3}{40} = 0.075 \text{ m} \)

26. \[ \frac{\text{Apparent depth}}{\text{real depth}} = \frac{n_i}{n_i} \]

\( h = 30 \text{ cm} \)

27. \[ \text{Shift} = 10 \left( 1 - \frac{1}{2} \right) \]

\( = 5 \text{ cm} \)

\( d = 10 + 10 + 15 \)

\( = 35 \text{ cm} \)

28. For \( \phi = 90^\circ \) there must be TIR

\( \phi = 180^\circ - 2l = 90^\circ \)

\( l = 45^\circ \)
29. Ray will reach to surface AC only when \( n > n_c \)
\[
\frac{4 \sin 90^\circ}{3/2} = \frac{8}{9}
\]
\[
\theta = \sin^{-1} \left( \frac{8}{9} \right)
\]

30. 
\[(90 - r) > C \Rightarrow \cos r > \sin c
\]
\[
\sin c = \frac{\sqrt{3}}{2}
\]
\[
\Rightarrow \frac{3\sqrt{3}}{4} \sin \theta = \frac{3}{2} \sin r
\]
\[
\frac{\sqrt{3}}{2} \sin \theta = \sin r
\]
\[
\sqrt{1 - \sin^2 r} = \frac{\sqrt{3}}{2} \Rightarrow \sqrt{1 - \frac{3}{4} \sin^2 \theta} > \frac{\sqrt{3}}{2}
\]
\[
\Rightarrow \theta = \sin^{-1} \frac{1}{\sqrt{3}}
\]

31. Shift = 6 \left( 1 - \frac{2}{3} \right) = 2cm
\[
u = R + 2 = 42 \text{ cm}
\]

32. \[90 + 135^\circ + 90 - r + 90 - r' = 360^\circ \]
\[
\Rightarrow r + r' = 45^\circ
\]
\[
\Rightarrow r' = \sin^{-1} (1/2) = \text{critical angle} = 30^\circ
\]

33. \[2r = 60^\circ \Rightarrow r = 30^\circ
\]
\[
\sin 60^\circ = \mu \sin 30^\circ \Rightarrow \mu = \sqrt{3}
\]

34. 
\[
\mu \sin (90 - \theta) = \sin r
\]
\[
\Rightarrow \sin r = \mu \cos \theta
\]
\[
b \csc \theta = x \sec r
\]
\[
\Rightarrow x = \frac{b}{\sin \theta \sqrt{1 - \mu^2 \cos^2 \theta}}
\]

35. 
\[
5 \left( \frac{h - 1}{2} \right) = \left( \frac{h - 1}{2} \right)^2 + h'
\]
\[
4 \left( \frac{h - 1}{2} \right)^2 = h^2
\]
\[
\Rightarrow h - \frac{1}{2} = h \Rightarrow h = 1
\]

36. 
\[
tan c = \frac{3.2/2}{2} = \frac{4}{5}
\]
\[
sinc = \frac{4}{\sqrt{41}} = \frac{1}{\mu}
\]
\[
\Rightarrow \mu = \frac{\sqrt{41}}{4}
\]
37. 
\[ n_1 = 1, \ n_2 = 2, \ A = 90^\circ, \ r_2 = 60^\circ \]
\[ r_1 = 30 \]
\[ \sin c = 2 \tan 30^\circ \]
\[ \sin i = 1 \]
\[ i = 90^\circ \]

38. 
\[ A = 60^\circ, \ n_1 = 1, \ n_2 = 1.5 = \frac{3}{2} \]
\[ i = 60^\circ \]
\[ \sin 60 = \frac{3}{2} \sin r_1 \]
\[ r_1 = \sin^{-1} \left( \frac{1}{\sqrt{3}} \right) = 35^\circ \]
\[ r_1 + r_2 = A \Rightarrow r_2 = 25 \]
\[ \frac{3}{2} \sin r_2 = 1 \sin e \]
\[ e = \sin^{-1} \left( \frac{3}{5} \right) = 37^\circ \]
\[ \delta = i + e - A \]
\[ = 60^\circ + 37 - 60 \]
\[ = 37^\circ \] (This is not minimum deviation.)
\[ \therefore \ \text{for} \ \delta_{\text{min}} \ e = i \]

39. 
\[ \theta_c = \sin^{-1} \left( \frac{1}{n} \right) = \sin^{-1} \left( \frac{2}{3} \right) \]
\[ \theta_c = 42 \]
\[ r_2 > \theta_c \quad \text{TIR takes place at AC and hence angle of deviation is} \]
\[ 180 - 2i = 60^\circ \]

40. 
\[ i = 3 \]
\[ \delta = 2i - A \]
\[ r_1 = r_2 = \frac{A}{2} - 30 \]
\[ \sin i = \frac{3}{2} \sin 30^\circ \]
\[ i = \sin^{-1} \left( \frac{3}{4} \right) \]
\[ \delta = 2 \sin^{-1} \left( \frac{3}{4} \right) - 60^\circ = 38^\circ \]

41. 
Prism angle is very small so for small angle deviation

\[ \delta = A \left( \frac{\mu_n - 1}{\mu_i} \right) \]
\[ (i) \ \delta_1 = 3 \left( \frac{3/2 - 1}{1} \right) = \frac{3}{2} \]
\[ (ii) \ \delta_2 = 3 \left( \frac{3/2 - 1}{4/3} \right) = \frac{3}{8} \]

42. 
\[ \mu = \sqrt{2} \ A = 30^\circ \]
\[ r_2 = 0 \Rightarrow r_1 = A = 30^\circ \]
\[ 1 \sin i = \sqrt{2} \sin 30^\circ \]
\[ \sin i = \frac{1}{\sqrt{2}} \]
\[ i = 45^\circ \]

43. 
\[ i - e = 23 \quad \text{\ldots(1)} \]
\[ 23 = i + e - 60^\circ \Rightarrow i + e = 83 \quad \text{\ldots(2)} \]
\[ \text{From equation (1) & (2)} \]
\[ e = 30^\circ \quad \text{&} \quad i = 53^\circ \]
\[ 1. \ \sin 53^\circ = \mu \sin r \quad \text{\ldots(3)} \]
\[ \mu \sin (60 - r) = \sin 30 \quad \text{\ldots(4)} \]
\[ \text{After solving eq (3) & (4) we get} \]
\[ \mu = \sqrt{2} \sin 30^\circ \]
\[ = 1.13 \]
\[ \mu = \frac{\sqrt{43}}{5} \]

44. 
\[ n_x = \sin \left( \frac{A - \delta_{\text{min}}}{2} \right) \]
\[ n_y = \sin A / 2 \]
\[ \sqrt{\frac{2}{\sin \left( 60 + 30 \right)}} \]
\[ \mu_x = \frac{8}{\sqrt{5}} \]

45. 
\[ (i) \]
\[ 1 \sin i = n \sin (45 - C) = \frac{n}{\sqrt{2}} \] (csc - sinc)
\[ \sin c = \frac{n}{n} \]
\[ \sin i = n \left[ \frac{\sqrt{n^2 - m^2}}{n} \right] \frac{n_i}{n} \]
\[ (ii) \ r_2 = 0^\circ \]
\[ \therefore r_1 = 45^\circ \]
\[ \Rightarrow \sin i = \frac{1.352}{1.414} \]
\[ \Rightarrow i = 72.97^\circ \]
46. (i) Not deviate if \( n_1 = n_2 \)
\[ \Rightarrow 1.20 \times 10.8 \times 10^4 \frac{9 \times 10^4}{\lambda^2} = 0.25 \]
\[ \Rightarrow \lambda_0 = 600 \text{ nm} \]
(ii) For \( \delta_m \Rightarrow r_1 = 30^\circ \)
\[ i = \sin^{-1}\left(\frac{3}{4}\right) \]

47. Let \( u = x \), \( n_2 = 3/2 \)
\[ n_1 = 4/3 \quad v = \frac{R}{u} \]
\[ \frac{n_2 - n_1}{n_1} = \frac{n_2 - n_1}{R} \]
\[ \frac{3/2}{4/3} = \frac{3/2 - 4/3}{R} \]
\[ \Rightarrow x = 240 \text{ cm away from surface} \]

48. (a)
\[ \frac{n}{2r} - \frac{1}{x} = \frac{n-1}{r} \Rightarrow n = 2 \]

(b)
\[ u = -x \quad v = +r \quad R = +r \]
\[ \frac{n}{r} = \frac{n-1}{r} \]
\[ \Rightarrow n = n-1 \text{ (only when } n > 1 \text{)} \]

49. \[ u = -10 \text{ R} = +20 \text{ cm} \]
\[ \frac{2}{v} - \frac{1}{10} = \frac{2-1}{20} \Rightarrow v = -40 \text{ cm} \]
so virtual image is formed
\[ \Rightarrow h_i = \frac{1}{2} \left(\frac{-40}{-10}\right) = 2 \]
\[ \Rightarrow h_i = 4 \text{ cm so erect, enlarged} \]

50. For 1st Refraction
\[ u_1 = -10 \text{cm} \quad R_1 = 10 \text{cm} \]
\[ n_2 = 1.5 \quad n_1 = 1 \]
\[ \frac{1.5 - 1}{v_1} = \frac{1.5 - 1}{10} \Rightarrow v_1 = -30 \text{ cm} \]
for 2nd Refraction
\[ \frac{1}{v} = \mu - \frac{1}{R_1} - \frac{1}{R_2} \]

51. \[ u_2 = -(v + 20) = -50 \text{ cm} \]
\[ R_2 = -10 \text{ cm} \]
\[ n_2 = 1.5 \quad n_1 = 1.5 \]
\[ \frac{1}{v_2} = \frac{1}{v} - \frac{1}{1.5} \]
\[ v_2 = -50 \text{ cm} \]
\[ \Rightarrow v_2 = \frac{100}{3} = -50 \text{ cm from 2nd surface} \]

52. For 1st refraction
\[ u = -x \quad R = +R \quad \mu_2 = n, \mu_1 = 1 \]
\[ \Rightarrow v = \frac{R}{n-1} \]
For 2nd refraction
\[ u = \frac{nR}{n-1} - 2R, \quad \mu_2 = 1, \mu_1 = 1 \]
\[ V = R & R = -R \]
\[ \Rightarrow n = 4/3 \]

53. \[ \sin \frac{\sqrt{3}}{2} = \frac{c}{2} \Rightarrow c = 60^\circ \]
\[ x = R \]

54. \[ \frac{1}{f} = \mu - 1 \left(\frac{1}{R_1} - \frac{1}{R_2}\right) \]
For double convex lens
\[ R_1 = R \]
\[ R_2 = -2R \]
\[ \mu = 2 \]
\[ \frac{1}{50} = \left( \frac{2 - 1}{R} \right) \left( 1 + \frac{1}{2} \right) \]
\[ \Rightarrow R = 75 \text{ cm} = R_1 \]
\[ R_2 = 150 \text{ cm} \]

55. \[ \frac{1}{f} = (1.5 - 1) \left( \frac{1}{20} - \frac{1}{30} \right) \]
\[ = \frac{0.5}{60} (\pm 2 \pm 3) \]
\[ \frac{1}{f} = \frac{0.5}{60} (3 \pm 2) \]
\[ f = \pm 120 \text{ cm} = \pm 24 \text{ cm} \]

56. \[ \frac{1}{h} = \frac{v}{u} = -v \text{e (So v and u at opposite side of lens)} \]

So lens in b/w image and object
\[ \therefore \text{object is real} \]
\[ \therefore \text{image is real} \]

It is a converging lens because it forms a real image.

57. For 1st surface \( n_2 = \mu_2 , n_1 = \mu_1 \)
\[ R_1 = +R \]
\[ u_1 = -x \]
\[ \Rightarrow \frac{v_1}{u_1} = \frac{\mu_2}{\mu_1} - \frac{\mu_2 - \mu_1}{R} \]
\[ v_1 = \frac{\mu_2 R}{\mu_2 - \mu_1} \]

for 2nd surface
\[ u_2 = v_1 \quad n_2 = \mu_3 \quad n_1 = \mu_1 \quad R = -R \]
\[ v_2 = \frac{\mu_2}{\mu_1} - \frac{\mu_2 - \mu_1}{R} \]
\[ \Rightarrow v_2 = \frac{2 \mu_2 - \mu_1 - \mu_3}{R} \]

\[ v = \frac{R \mu_3}{2 \mu_2 - \mu_1 - \mu_3} \]

(b) Replace \( \mu_1 \rightarrow \mu_3 \)
\[ \mu_3 \rightarrow \mu_1 \text{ in above formula} \]

58. \[ f = \frac{1}{P} \]
\[ 100 \text{ cm} = \frac{1}{5} \times 100 = 20 \text{ cm} \]
\[ f = -25 \text{ cm} \]
\[ \Rightarrow v = 1 \text{ m} \]
\[ m = -4 \]
\[ \Rightarrow h_1 = -4h_2 = -4 \times 6 \text{ cm} = -24 \text{ cm} \]

59. \[ P = 5D \Rightarrow f = -20 \text{ cm} \]
As it is virtual image hence v and u are of same sign
\[ v = 4u \]
\[ \Rightarrow \frac{1}{4u} = \frac{1}{-20} \]

60. \[ \Rightarrow u = -15 \text{ cm} \]

Let \( x \) be the distance of point source from mirror
\[ \text{for mirror v should be } + (25 - 15) \Rightarrow v = 10 \text{ cm} \]

So that image for mirror is made on the focus of lens so that the rays emerge parallel from lens.

so now for mirror
\[ \Rightarrow \frac{1}{10} - \frac{1}{x} = \frac{1}{40} \]
\[ \Rightarrow x = \frac{40}{3} = 13.33 \text{ from mirror} \]

61. \[ \text{The image from lens is formed at C of mirror.} \]
\[ \text{Hence the ray will retrace its path & final image is formed at object itself and of same size.} \]

62. \[ f = \frac{1}{P} \]
\[ 1 \text{ cm} = \frac{1}{5} + \frac{1}{f} = \frac{2}{f} \]
\[ f = \frac{f}{2} \]
\[ \Rightarrow m = -4 = v/u \quad (\therefore \text{Real image}) \]
\[ \Rightarrow 4u = v \]

Now \[ \frac{1}{f_{1e}} = \frac{1}{f} + \frac{1}{f_{10}} \]
\[ f_{1e} = f/2 \]
\[ \Rightarrow \text{p} = \frac{u}{f/2} = 100 \]

\[ \frac{p}{100} = \frac{5}{4 \times 12.5} \quad (\therefore \text{U} = -12.5 \text{ cm}) \]

63. For convex lens
\[ \frac{1}{f_1} = \frac{1}{15} - \frac{1}{-15} \]
\[ \Rightarrow f_1 = +20 \text{ cm} \]
When both lenses are used
\[ \frac{1}{f_1} = \frac{1}{15} - \frac{1}{10} + \frac{1}{f_2} \]
\[ \Rightarrow f_2 = -60 \text{ cm} \]

\[ f = +50 \text{ cm} \]

\[ f = +40 \text{ cm} \]

\[ f = +30 \text{ cm} \]

\[ f = +20 \text{ cm} \]
64.

\[ \frac{1}{f_1} = \frac{1}{10} \cdot \frac{1}{f_2} \]
\[ u = -40 \text{ cm}, \ v = 160 - 40 = 120 \text{ cm} \]
so \[ \frac{1}{120} - \frac{1}{-40} = \frac{1}{10} + \frac{1}{f_2} \Rightarrow f_2 = -\frac{1}{15} \]

\[ p = \frac{100}{f_2} = -\frac{20}{3} \]

65.

shift = 5 cm
\[ 5 = t \left( 1 - \frac{1}{1.5} \right) \]
\[ t = 15 \text{ cm} \]

66.

Case 1

\[ m = \frac{-h}{h_o} = -\frac{v_1}{u_1} = -16 \]
\[ h_o = -6 \text{ cm}, \ v_2 = \frac{v_2}{6} \]
\[ \frac{1}{v_1} - \frac{1}{u_1} = -\frac{1}{6}m + \frac{1}{6} = \frac{1}{f} \]
\[ \frac{1}{16m} = \frac{1}{16} - \frac{1}{f} \]
\[ 16 \left( 1 + \frac{1}{m} \right) = \frac{1}{f} \] .... (2)

From eq. (1) & (2)
\[ \Rightarrow \frac{1}{16} \left( 1 + \frac{1}{m} \right) = \frac{1}{6} \left( 1 - \frac{1}{m} \right) \]
\[ \Rightarrow m = 11 \]

From eq. (2)
\[ \frac{1}{16} \left( 1 + \frac{5}{11} \right) = \frac{1}{f} \]
\[ \Rightarrow f = 11 \text{ cm} \]

Case 2

\[ \frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f} \]
\[ m = \frac{h}{h_o} = -\frac{v_2}{u_2} \]
\[ m = -q \]
\[ v_2 = +q (x-a) \]

Case 1

\[ \frac{1}{v_1} + \frac{1}{u_1} = \frac{1}{f} \]
\[ \frac{1}{px} + \frac{1}{1} = \frac{1}{f} \]
\[ \Rightarrow \frac{1}{x} \left( 1 + \frac{1}{p} \right) = \frac{1}{(x-a)} \left( \frac{1}{q} + \frac{1}{q(p-1)} \right) \]
\[ \Rightarrow x = \frac{q(p-1)}{(q-p)} \]

From eq. (3)
\[ \frac{1}{x} \left( 1 + \frac{1}{p} \right) = \frac{1}{f} \]
\[ \Rightarrow f = \frac{apq}{(q-p)} \]

67.

68.

For second lens the image acts as object and the object for second lens is placed at 2f hence image formed is real at distance 2f on opposite side so size is same as object size = \( d \)

69.

\[ \frac{1}{v} + \frac{1}{15} = \frac{1}{10} \]
\[ v = 30 \text{ cm} \]

from similar triangle ABI and CDI
\[ \frac{3}{30} = \frac{d}{10} \Rightarrow d = 1 \text{ cm} \]

Area = \( \frac{3}{4} \text{ cm}^2 \)
70. \( \mu_2 = \frac{4}{3}; \mu_1 = 1; \)
\( R = 4 \text{ cm} \quad v = \infty \)
\( \Rightarrow u = -12 \text{ cm} \)
\( \Rightarrow v' = -12 \text{ cm} \)
\( \mu_2 = 1; \mu_1 = 4/3 \)
\( u = ? \)
\( R = -4 \text{ cm} \)
\( \Rightarrow d' = 4 \text{ cm} \)
\( n_2 = 4/3 \)
\( d = 3 \text{ cm} \)

71. \[
\frac{1}{25} = \left( \frac{\frac{3}{2} - 1}{\frac{1}{R} + \frac{1}{2R}} \right)
\]
\( 4R = 75 \)
\( R_1 = 75/4 \text{ cm} \)
\( R_2 = 75/2 \text{ cm} \)

72. \[
R = \sqrt{2^2 + (R - 0.1)^2}
\]
\( \Rightarrow R = 0.2 \text{ m} \)
\( \frac{1}{f} = \left( \frac{1}{\mu_1} - 1 \right) \left( \frac{1}{R} \right) \)
\( f = 2R_1 = 0.4 \text{ m} \)

73. \[
\frac{1}{f_e} = \frac{1}{r_e} - \frac{2}{r_i}
\]
\( \Rightarrow \frac{1}{-30} = \frac{1}{x} - \frac{2}{r_i} \quad \cdots (1) \)
\( - \frac{1}{10} = - \frac{2}{R} - \frac{2}{f} \quad \cdots (2) \)
from eq. (1) & (2)
\( R = 30; f = 60 \)
\( \Rightarrow \frac{1}{60} = (\mu - 1) \left( \frac{1}{30} \right) \)
\( \Rightarrow \mu = 1.5 \)

74. (a) \[
\alpha = \frac{1.68 - 1.56}{1.6 - 1}
\]
\( \alpha = 0.20 \)
(b) \( \theta = (1.68 - 1.56)6 \)
\( \theta = 0.72^\circ \)

75. \( \delta = \delta_1 - \delta_2 = 0 \)
\( \Rightarrow (\mu_{y_1} - 1) A_1 - (\mu_{y_2} - 1) A_2 = 0 \)
\( \Rightarrow (1.62 - 1) 6 - (1.518 - 1) A_2 = 0 \)
\( \Rightarrow A_2 = 7.2 \)
1. \[ m = \frac{d-x}{x} \]

\[ \frac{1}{d-x} \cdot \frac{1}{x} = \frac{1}{2} \Rightarrow (2x-d) \cdot r - 2(dx-x^2) \]

\[ \Rightarrow 2x^2 + 2x(r-d) - rd = 0 \]

\[ x = \frac{-2(r-d) \pm \sqrt{4(r-d)^2 + 8rd}}{2 \times 2} \]

\[ x = \frac{(d-r + \sqrt{r^2 + d^2})}{2} \]

\[ m = \frac{\frac{2d}{(d-r) - \sqrt{r^2 + d^2}}}{2} \]

\[ \left( \frac{d + r - \sqrt{r^2 + d^2}}{d - r + \sqrt{r^2 + d^2}} \right) \]

\[ \frac{(d-r)^2 - 2d \sqrt{d^2 + r^2} + d^2 + r^2}{(d-r)^2 - (r^2 + d^2)} \]

\[ \frac{2d(d- \sqrt{d^2 + r^2})}{r^2} \]

\[ \frac{2d(r + \sqrt{d^2 + r^2})}{r(d + \sqrt{d^2 + r^2})} \]

2. \[ \frac{dv}{dt} = -\frac{v^2}{u^2} \cdot \frac{du}{dt} \]

\[ V_M = -\frac{1}{u} \cdot V_m \Rightarrow V_I - V_M = -\frac{1}{100} (V_e - V_m) \]

given \( V_M = -1 \text{ cm/sec} \quad V_m = +20 \text{ m/sec} \)

\[ \Rightarrow +1 \times 10^{-2} \text{ m/sec} = -\frac{1}{100} (V_e - 20 \text{ m/sec}) \]

\[ V_e = +21 \text{ m/sec} \]

\[ m = \frac{\sqrt{1 - f}}{v} = \frac{\sqrt{1}}{v} + 1 \]

\[ \frac{dm}{dt} = \frac{-dv}{dt} \cdot f \cdot \frac{1}{v} = -1 \times 10^{-3} \text{ /sec} \]

3. \[ \cot \theta = \frac{x}{b} \quad \cot 2\theta = \frac{x}{a+b} \]

\[ \frac{\tan 2\theta}{\tan \theta} = \frac{\frac{a}{b}}{\frac{a+b}{b}} \]

\[ \Rightarrow \frac{2b}{a} = \frac{a}{b} - (a-b) \tan^2 \theta \]

\[ \Rightarrow \tan \theta = \frac{a-b}{\sqrt{a+b}} \]

4. \[ 10 \text{ mm/sec} \]

\[ 20 \text{ mm/s} \]

\[ 10 \sqrt{3} \text{ mm/sec} \]

\[ f = 10 \text{ cm} \]

\[ 10 \text{ cm} \]

\[ 20 \text{ m/sec} \]

\[ h/10 \]

\[ 1 \text{ cm/sec} \]

\[ 2.5, 3 \text{ mm/sec} \]

\[ = \frac{5}{10} \cdot 10 - 0 + 10 \]

\[ \frac{dh}{dt} = 5 \text{ mm/sec} \]

5. \[ \Rightarrow 30 \]

\[ 2 \text{ cm} \]

\[ 1 \text{ cm} \]
1st lens
\[ u = -15 \text{ cm} \quad f = 10 \text{ cm} \quad V = +30 \text{ cm} \]

2nd mirror
\[ u = -15 \text{ cm} \quad V = -30 \text{ cm} \quad f = -10 \text{ cm} \]
\[ h_v = -1 \text{ cm} \quad h_i = +2 \text{ cm} \]

3rd lens
\[ u = -15 \text{ cm} \quad V = +30 \text{ cm} \quad f = +10 \text{ cm} \]
\[ h_v = 3 \text{ cm} \quad h_i = -6 \text{ cm} \]
\[ \Rightarrow \frac{\sqrt{30^2 + (8)^2}}{6} = 6\sqrt{26} \text{ cm} \]

6. \[ \frac{6}{x} = \frac{6}{d - x} \Rightarrow x = \frac{d}{2} \]
\[ \frac{4}{3} \sin i = 1 \cdot \sin r \]
\[ \Rightarrow \frac{4}{3} \left( \frac{d^2}{4} + (10.67)^2 \right) = \frac{d^2}{4} + 6^2 \]

\[ \Rightarrow d \approx 16 \text{ feet} \]

7. \[ \sin r = \mu \cdot \sin i \]
\[ \Rightarrow \frac{1}{\sqrt{a^2 - d^2}} = \frac{1}{\sqrt{a^2 - d^2}} \]
\[ \Rightarrow \frac{a^2 - d}{a^2 - d} \]
\[ \Rightarrow 2a^2 - ad = \mu^2 (2a^2 - ad) \]
\[ \Rightarrow 2a - d = \mu^2 (2a + d) \]
\[ d = 2a \left( \frac{\mu^2 - 1}{\mu^2 + 1} \right) \]

8. \[ \frac{dy}{dx} = 4x \quad y = 2x^2 \]
\[ \tan \theta = 2\sqrt{2} \quad \Rightarrow 1 = 2x^2 \]

9. \[ u = 30 \quad f = -20 \text{ cm} \]
\[ v = 60 \]
\[ \Rightarrow \frac{1}{F_m} = \frac{1}{20} \quad \left( \frac{4}{3} - 1 \right) \left( \frac{2}{R} \right) \]
\[ \Rightarrow \frac{1}{F_m} = \frac{1}{20} \quad \left( \frac{1}{3} - 1 \right) \left( \frac{1}{12} \right) \]
\[ \Rightarrow \frac{1}{F_m} = \frac{1}{-12 \text{ cm}} \]
\[ \Rightarrow u = -15 \text{ cm} \quad v = 60 \text{ cm} \]

10. \[ \frac{1}{F_1} = \frac{5}{4} - 1 \left( \frac{1}{30} \right) \]
\[ F_1 = 120 \text{ cm} \]
\[ \frac{1}{F_2} = \frac{3}{2} - 1 \left( \frac{1}{30} \right) \]
\[ F_2 = -60 \text{ cm} \]
\[ \frac{1}{F_m} = \frac{1}{2} \left( \frac{1}{120} \right) \left( \frac{1}{60} \right) \]

11. \[ \Rightarrow \tan (90 - i) = \frac{dy}{dx} \]
\[ \Rightarrow i \sin 90^\circ = \mu(y) \sin i \]
\[ \sin i = \frac{1}{\mu(y)} \]

(i) \[ \frac{dy}{dx} = \cot i = \sqrt{\mu(y)^2 - 1} = \sqrt{k} \quad \sqrt{y^{3/4}} \]

(ii) \[ \frac{dy}{dx} = \sqrt{k} \quad y^{3/4} \quad \Rightarrow \frac{dy}{\sqrt{k} \quad y^{3/4}} = dx \]
\[ \Rightarrow \frac{4}{\sqrt{k}} \quad y^{1/4} = x \quad \Rightarrow y = k \quad \left( \frac{x}{4} \right)^4 \]

(iii) when \( y = 1 \quad \Rightarrow x = 4 \quad (4, 1) \)

(iv) \[ 1 \cdot \sin 90^\circ = 1 \sin r \quad r = 90^\circ \]
\[ \Rightarrow \text{will become parallel to x-axis} \]
12. \[ \sin(90 - \theta) = \frac{3}{2} \sin r \cos \theta = \frac{3}{2} \sin r \] 
\[ \sin r = \frac{2}{3} \cos \theta \] 
\[ 90 - x > c \] 
\[ \Rightarrow r + \theta > c \] 
\[ \Rightarrow \sin(r + \theta) > \sin c \] 
\[ \Rightarrow \sin r \cos \theta + \cos r \sin \theta > \sin c \] 
\[ \Rightarrow \frac{2}{3} \cos \theta + \sqrt{9 - 4 \cos^2 \theta} \sin \theta > \frac{8}{9} \] 
\[ \Rightarrow \sqrt{9 - 4 \cos^2 \theta} \sin \theta > \frac{8}{3} \sin \theta > 8/9 \] 
\[ \Rightarrow \frac{9 - 4 \cos^2 \theta}{\cos^2 \theta} (1 - \cos^2 \theta) > \frac{32}{3} \cos^2 \theta \] 
\[ \Rightarrow \cos^2 \theta < 17 \] 
\[ \sec^2 \theta < 21 \] 
\[ \Rightarrow \tan^2 \theta > \frac{2}{17} \] 

13. \[(\mu - 1)A = 1.25 \]
\[ \delta = (\mu - 2A) + 2A(\mu - 1) \]
\[ 180 - 2A + (\mu - 1)2A = 180 - 6.5^\circ \]

14. \[ n_y = \frac{n_y + n_F}{2} = 1.5 \text{ for crown} \]
\[ n_F = 1.75 \text{ for flint} \]
\[ S_{\text{crown}} - S_{\text{flint}} = (1.5 - 1.75) = A = 2 \]
\[ S_{\text{red}} = (1.51 - 1)6 - (1.77 - 1) \times 2 = 1.52 \text{ Anti} \] 
\[ S_{\text{violet}} = (1.49 - 1)6 - (1.73 - 1) \times 2 = 1.48 \text{ A. c} \]

15. \[ h = \frac{v}{5} \]
\[ h' = \frac{v'}{5} \]

16. \[ u = -30 \]
\[ v = -30 \]
\[ F_{\text{net}} = \frac{30}{\mu} \]
\[ \text{I}^\text{st} \text{ Case} \]
\[ u = -60 \]
\[ v = 30 \]
\[ F_{\text{net}} = \frac{30}{\mu} \]
\[ \Rightarrow \frac{1}{30} - \frac{1}{60} = \frac{-\mu}{30} \]
\[ \Rightarrow \mu = 1.5 \]
\[ \text{II}^\text{nd} \text{ Case} \]
\[ u = -60 \]
\[ v = \left(\frac{30}{\mu}\right) \]
\[ f = -30 \text{ cm} \]
\[ \Rightarrow \frac{1}{30} - \frac{1}{60} = \frac{-\mu}{30} \]
\[ \Rightarrow \mu^2 - 2\mu - 4 = 0 \]
\[ \Rightarrow \mu = 5 - 1 \]

17. \[ u = -d \]
\[ f = F \]
\[ \frac{1}{V_0} \frac{1}{d - F} = \Rightarrow \frac{V}{d - F} = \frac{dF}{d - F} \]
\[ x = d - \frac{dF}{d - F} \]

18. \[ d^2 = 2dF \frac{dF}{d - F} \]
\[ u = -(V + 2x) \]
\[ f = F \]
\[ \frac{1}{V_1} \frac{1}{V + 2x} = \frac{1}{F} \]
\[ \Rightarrow \frac{1}{V_1} = F \left( \frac{dF}{d - F} \right) \]
\[ h = \frac{v}{5} \]
\[ h' = \frac{v'}{5} \]
20. $D = 1.8 \text{ m}$
For one magnification = 2
$3x = 1.8 \text{ m} \Rightarrow x = 0.6 \text{ m}$
\[
\frac{1}{2x} \cdot \frac{1}{x} = \frac{1}{f} \Rightarrow f = \frac{2}{3} \times 0.4 \text{ m}
\]
Separation $x = 0.6 \text{ m}$

21. (i) For Lens $\Rightarrow u = 90 \text{ cm}$
\[
f = +30 \text{ cm}, \quad v = +45 \text{ cm}
\]
(2) for spherical Refraction
\[
\begin{align*}
\text{u} &= +45 \quad n_2 = 4/3 \quad n_1 = 1 \\
R &= -30 \text{ cm}
\end{align*}
\]
\[
\Rightarrow \frac{4 \times \frac{1}{3v}}{45} = \frac{4/3 - 1}{30} = -\frac{1}{90}
\]
\[
\Rightarrow \frac{4}{3v} = -\frac{1}{90} + \frac{1}{45} = \frac{1}{90} = V = 120 \text{ cm}
\]
Image through plane mirror is at Mirror 40 cm from the plane.
\[
\begin{align*}
\text{u} &= -40 \text{ cm} \quad n_2 = 1, \quad n_1 = 4/3 \\
R &= +30 \text{ cm}
\end{align*}
\]
\[
\begin{align*}
\frac{1}{v} &= \frac{4}{3 \times 40} - \frac{1}{30} - \frac{1}{90} \\
\frac{1}{v} &= \frac{-1}{90} - \frac{1}{45} - \frac{4}{90}
\end{align*}
\]
for lens
\[
\begin{align*}
\frac{1}{v} &= \frac{2}{45} - \frac{1}{30} \Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{2}{45}
\end{align*}
\]
\[
v = -90 \text{ cm}
\]
1. D
Shift in image position due to glass plate,
\[ S = \left( 1 - \frac{1}{h} \right) t = \left( 1 - \frac{1}{1.5} \right) \times 1 \text{ cm} = \frac{1}{3} \text{ cm} \]

For focal length of the lens,
\[ \frac{1}{r} - \frac{1}{v} = \frac{1}{1} - \frac{1}{12} - 240 \]
\[ \text{or } \frac{1}{r} = \frac{20 - 1}{240} \Rightarrow r = \frac{240}{21} \text{ cm.} \]
Now, to get back image on the film, lens has to form image at \( \left( 12 - \frac{1}{3} \right) \text{ cm} = \frac{35}{3} \text{ cm} \) such that the glass plate will shift the image on the film.
\[ \frac{1}{f} = \frac{1}{1} - \frac{1}{v} \quad \frac{1}{u} = \frac{1}{1} - \frac{1}{f} \quad \frac{35}{240} \]
\[ = \frac{48 \times 3 - 7 \times 21}{1680} = \frac{560}{u} \Rightarrow u = -5.6 \text{ m} \]

2. C

Apparent shift \( \Delta h = \left( 1 - \frac{1}{\mu} \right) h \)

\( \Delta h_1 = \left( 1 - \frac{1}{\mu_1} \right) h_1 \)

\( \Delta h_2 = \left( 1 - \frac{1}{\mu_2} \right) h_2 \)

\( \therefore \Delta h = \Delta h_1 + \Delta h_2 \quad \left( 1 - \frac{1}{\mu_1} \right) h_1 - \left( 1 - \frac{1}{\mu_2} \right) h_2 \)

3. B
\[ \frac{1}{r} = \left( \mu - 1 \right) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]

Also, by Cauchy's formula
\[ \mu = A + \frac{B}{\lambda_2} + \frac{B}{\lambda_3} + \ldots \]

As \( \lambda_{blue} \lt \lambda_{red} \)
\( \mu_{blue} \gt \mu_{red} \)

Hence, \( \theta_{blue} \lt \theta_{red} \)

4. C
Scattering for blue light is largest and it is polarized by scattering.
Also for polarized light
\[ I = I_0 \cos^2 \theta \]

5. A
Note: As refractive index for \( z > 0 \) and \( z \leq 0 \) is different X-Y plane should be boundary between two media. Angle of incidence

\[ \cos \theta = \frac{A_x}{\sqrt{A_x^2 + A_y^2 + A_z^2}} \]
\[ = \frac{1}{2} \]
\[ \therefore \theta = 60^\circ \]

From Snell's law
\[ \sin \theta = \frac{\sqrt{3}}{2} \]
\[ \Rightarrow \quad r = 45^\circ \]

6. A
\[ \frac{1}{u} + \frac{1}{v} = \frac{1}{f} \]
\[ \Rightarrow - \frac{1}{u} \frac{du}{dt} - \frac{1}{v} \frac{dv}{dt} = 0 \]
\[ \Rightarrow \frac{dv}{dt} = \frac{u}{v} \frac{du}{dt} \]

But \( \frac{v}{u} = \frac{1}{r} \)
\[ \Rightarrow \frac{dv}{dt} = \left( \frac{1}{f} \right) \frac{du}{dt} \]
\[ = \left( \frac{0.2}{2.8 - 0.2} \right) \times 15 = \frac{1}{15} \text{ ms}^{-1} \]

7. B
As intensity is maximum at axis,
\( \therefore \mu \) will be maximum and speed will be minimum on the axis of the beam.
\( \therefore \) beam will converge.

8. A

9. A
It is possible when object kept at centre of curvature.

\[ u = v \]
\[ u = 2f, \quad v = 2f. \]
10. D
\[ \sin C = \frac{\sqrt{3}}{2} \] ... (1)
\[ \sin r = \sin(90^\circ - C) = \cos C = \frac{1}{2} \]
\[ \sin \theta = \frac{\mu}{\sin r} \]
\[ \sin \theta = \frac{\mu}{\sqrt{3}} \]
\[ \theta = \sin^{-1} \left( \frac{1}{\sqrt{3}} \right) \]

11. C
\[ \frac{1}{V} - \frac{1}{u} = \frac{1}{f} \] is constant, so (c) is the correct graph.

12. B
Power of a lens is reciprocal of its focal length. Power of combined lens is
\[ P = P_1 + P_2 \]
\[ = -15 + \frac{5}{3} = -10 \text{ D} \]
\[ \therefore f = \frac{1}{P} = \frac{100}{-10} = -10 \text{ cm} \]

13. A
\[ D = (\mu - 1)A \]
For blue light \( \mu \) is greater than that for red light. So, \( D_b > D_r \)

14. B
The situation is shown in figure.
\[ \sin \theta_c = \frac{1}{\mu} \]
\[ \tan \theta_c = \frac{AB}{OA} \]
\[ \therefore AB = OA \tan \theta_c \]
\[ \text{or } AB = \frac{OA}{\sqrt{\mu^2 - 1}} = \frac{36}{\sqrt{4^2 - 1}} = \frac{12}{\sqrt{15}} \]

15. A
We know \( \frac{Y}{D} \geq 1.22 \frac{4}{d} \)
\[ \Rightarrow D \leq \frac{yd}{1.22} \]
\[ \Rightarrow D = \frac{10^{-3} \times 3 \times 10^{-3}}{1.22 \times 5 \times 10^{-3}} = 5 \text{ m} \]
\[ \therefore D_{\text{max}} = 5 \text{ m} \]

16. A
\[ \frac{1}{f} = (\mu - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \] ... (1)
\[ = (1.5 - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
and \[ \frac{1}{f_m} = \left( \frac{\mu - \mu_m}{\mu_m} \right) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
\[ \frac{1}{f_m} = \left( \frac{1.5 - 1}{1.6 - 1} \right) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
or \[ f_m = -8 \times f \]
\[ = -8 \times \frac{1}{5} \left( f = \frac{1}{P} = \frac{1}{5} \text{ m} \right) \]
\[ = 1.6 \text{ m} \]
\[ P_m = \mu / f_m = 1 \text{ D} \]

17. B
For total internal reflection from glass-air interface, critical angle \( \theta \) must be less than angle of incidence, i.e., \( \theta < i \)
\[ \text{or } C < 45^\circ \]
But \[ n = \frac{1}{\sin C} = C = \sin^{-1} \left( \frac{1}{n} \right) \]
\[ \text{or } \sin^{-1} \left( \frac{1}{n} \right) < 45^\circ \]
or \[ \frac{1}{n} < \sin 45^\circ \]
or \[ n > \frac{1}{\sin 45^\circ} \]
or \[ n > \frac{1}{(1/\sqrt{2})} \text{ or } n > \sqrt{2} \]

18. A
A plano-convex lens behaves as a concave mirror if its one surface (curved) is silvered. The rays refracted from plane surface are reflected from craved surface and again reflect from plane surface therefore, in this lens two refractions and one reflection occur.
Let the focal length of silvered lens is \( f \).
\[ \frac{1}{f} = \frac{1}{f} + \frac{1}{f_m} = \frac{1}{f} + \frac{1}{f_m} \]
Where, \( f \) = focal length of lens before silvering.
\[ f_m = \text{focal length of spherical mirror} \]
\[ \frac{1}{f} = \frac{2}{f} - \frac{2}{f_m} \]
\[ \text{or } \frac{1}{f} = (\mu - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \] ... (ii)
Now, \[ \frac{1}{f} = (\mu - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
here, \( R_1 = R_2 = 30 \text{ cm} \)
\[ \frac{1}{f} = (1.5 - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
19. D
The particular angle of incidence for which reflected light is totally polarized for reflection from air to glass, is called the angle of polarisation (θ) (Brewster’s law).
Accordingly, \( n = \tan \theta \)
\[ \therefore \theta = \tan^{-1}(n) \]
Where \( n \) is refractive index of glass.

20. C
Objective of compound microscope is a convex lens. Convex lens forms real and enlarged image when an object is placed between its focus and lens.

21. A

22. B
Number of images, \( n = \frac{360^3}{\theta} - 1 \)
Where \( \theta \) is angle between mirrors.
\[ \therefore 3 = \frac{360^3}{\theta} - 1 \]
or \( \theta = 90^3 \)

23. A
Number of images, \( n = \frac{360^3}{\theta} - 1 \)
Where \( \theta \) is angle between mirrors.
Thus, \( \theta = 60^3 \) (given)
So, number of images
\[ n = \frac{360^3}{\theta} - 1 = 5 \]

24. D
Resolving power of an optical instrument is inversely proportional to \( \lambda \)
\[ RP \propto \frac{1}{\lambda} \]
Resolving power at \( \lambda_1 = \frac{\lambda_2}{\lambda_1} \)
\[ \therefore \text{Resolving power at } \lambda_2 = \frac{5000}{4000} = 5 : 4 \]

25. B

26. A
Optical fibres work on the principle of total internal reflection.
1. \[ \sin 45^\circ = \mu \sin i \]
\[ \frac{1}{\sqrt{2}} = \mu \frac{h}{\sqrt{5}h} \]
\[ \mu = \frac{\sqrt{5}}{\sqrt{2}} \]

2. \[ \frac{1}{f} = \mu - 1 \left( \frac{1}{R} \right) \]
\[ \frac{1}{f} = P = 0. \]
Power = 0
so No. Dispersion.

3. \[ \tan 30^\circ = \frac{x}{0.2} \]
\[ x = \frac{0.2}{\sqrt{3}} \]
After every x distance there is a reflection so number of reflection
\[ 2\sqrt{3} \times \frac{3}{0.2} = 30 \]

4. For concave
\[ \mu = +4, \ f = -20 \text{ cm} \quad v = 5 \text{ cm} \]
\[ \frac{h}{h_0} = \frac{0.4}{5} \Rightarrow h_1 = 2.5 \text{ cm} \]

5. \[ \mu = \mu_1 = \mu_2, \quad \mu_2 - \mu_1, \quad \frac{u}{v_1} = R \]
\[ \frac{\mu_2 - \mu_1}{v_1} = R \]
\[ u = \mu_1 = \mu_2 < \mu_3 \]
\[ R = +R \]
\[ 2^\circ \mu = +\mu, \quad n_2 = \mu_3, \quad h_3 - h_2 \]
\[ \frac{h_3}{h_2} = \frac{\mu_3 - \mu_2}{\mu_2} \]

6. VIBGYOR
\[ \lambda \uparrow N \downarrow C \uparrow \]
\[ Y, O, R \]

7. In case of minimum deviation \( r = r_0 = A/2 \)
For this QR is horizontal.
\[ \frac{1}{v} + \frac{1.5}{6} = \frac{1 - 1.5}{(-6)} \]
\[ v = 6 \text{ cm} \]

9. \[ \mu_2 = 1.514, \ n_1 = \sqrt{2} \]
\[ 1 \sin 45^\circ = \sqrt{2} \sin r \]
\[ r = 30^\circ \]
\[ u = 0, \quad R = 0.4 \text{ cm} \]
\[ 1.514 = \frac{1.514 - 1.414}{v} \]
\[ \Rightarrow \frac{1}{v} = \frac{0.1}{0.4 \times 1.514} \Rightarrow v = 6.06 \text{ m} \]

10. \[ u = 40 \text{ cm} \quad f = +30 \text{ cm} \]
\[ \frac{1}{v} + \frac{1}{40} = \frac{1}{30} \Rightarrow \frac{1}{v} = -1 \]
\[ v = \frac{120}{30} \]
By lens formula
\[ \frac{dv}{dt} = \frac{v^2}{u^2} \]
\[ m = \frac{v}{u} = \frac{f}{u + f} \]
\[ \frac{dv}{dt} = \left( \frac{120}{40} \right) \times 0.01 = 0.09 \text{ m/s} \]
\[ \frac{dm}{dt} = \frac{0.01 \times 100}{40 - 30} \times 0.01 \times 100 \]
\[ = \frac{-30}{100 	imes 10^{-2}} \times 0.01 = 0.3 \text{ sec}^{-1} \]
11. \( \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{30} \) 
\( f_2 = -\infty \) 
\( f_1 = +\infty \) 
\( \frac{3}{f_1} = -\frac{3}{2} \) 

Now \( \frac{1}{f_1} \cdot \frac{2}{3f_1} = \frac{1}{30} \) 
\( \Rightarrow \frac{1}{3f_1} = -\frac{1}{10} \) 
\( \Rightarrow f_1 = 10 \text{ cm} \) 

\( f_2 = -15 \text{ cm} \)

12. 2nd Refraction \( n_2 = 1; \; n_1 = \frac{4}{3} \) 
\( d = 33.25 \) 
\( d = \frac{3}{4} \times 33.25 - 24.94 \cos x \)

15. \( \frac{1}{f_1} = \frac{1}{f_2} = \frac{2}{f} = \frac{1}{x} - \frac{2}{15} \) 
\( \Rightarrow f = 5 \text{ cm} \)

16. \( \frac{1}{10} - \left( \frac{1}{10} \right)^2 = \frac{1}{f} \) 
\( \Rightarrow f = 5 \text{ cm} \)

17. \( r = \frac{f}{x} \)

18. (A) - P; (B) - R; (C) - R; (D) - P, Q, S

19. C

20. C

21. \( r_1 = r_2 = \frac{A}{2} = 30^\circ \)

22. Just misses means we are talking about critical angle in medium 3. So angle of refraction in medium 4 is 90°.

\( \frac{n_0 \sin \theta}{\frac{n_2}{8}} = \sin 90^\circ \) 
\( \Rightarrow \theta = \sin^{-1}\left(\frac{1}{8}\right) \)

23. (A) → P, Q, R, S; (B) → Q; (C) → P, Q, R, S; (D) → P, Q, R, S

24. \( v_0 = 12m/s \)
\( \frac{4}{x} \cdot \frac{3}{3} = \frac{4}{3} \cdot \frac{dx}{dt} = \frac{4}{3} \cdot \frac{v}{3} = 12 = 16 \text{ m/s} \)

25. \( \frac{1}{v} \cdot \sin i = \frac{1}{u} \cdot \frac{1}{24} \)

(i) \( (42, 56) \Rightarrow \frac{-1}{42} \cdot \frac{1}{56} = \frac{-1}{24} \) (correctly recorded)

(ii) \( (48, 48) \Rightarrow \frac{-1}{48} \cdot \frac{1}{48} = \frac{-1}{24} \) (correctly recorded)

(iii) \( (66, 38) \Rightarrow \frac{-1}{66} \cdot \frac{1}{38} = \frac{-1}{24.1} \) 
\( = \frac{-1}{65.8} \cdot \frac{1}{37.8} = \frac{-1}{24} \) (Incorrect)

(iv) \( (78, 39) \Rightarrow \frac{-1}{78} \cdot \frac{1}{39} = \frac{-1}{26} \) (Incorrect)
26. \( \sin 60^\circ = \sqrt{3} \sin r \)

\( r = 30^\circ, \quad \alpha = 150^\circ \)

\( r + \alpha + \theta + 135^\circ = 360^\circ \Rightarrow 30 + 150 + \theta + 135 = 360^\circ \)

\( \theta = 45^\circ \)

So angle of incidence at CD is 45°

Critical Angle for the surface

\( C = \sin^{-1} \left( \frac{1}{\sqrt{3}} \right) \)

So the value of C is in between 30° & 45°

\( \delta_w = 30^\circ \) Anticlockwise + 90° clockwise + 30° clockwise

\( \delta_e = 90^\circ \) clockwise

For case (1)

\( f = 20 \text{ cm}, \ u = -25 \text{ cm} \)

\( \frac{1}{v} \ - \ \frac{1}{u} = \ \frac{1}{f} \)

\( \frac{1}{v} = \frac{1}{20} \ - \ \frac{1}{25} \Rightarrow v = 100 \)

\( M_{25} = -\frac{100}{25} = -4 \)

\( f = 20 \text{ cm} \)

\( = 25 \text{ cm} \)

Case - 2

\( u = -50 \text{ cm} \)

\( \frac{1}{v} = \frac{1}{20} \ - \ \frac{1}{50} \Rightarrow v = \frac{100}{3} \)

\( M_{50} = -\frac{100}{3 \times 50} = -\frac{2}{3} \)

\( M_{25} = -\frac{2}{3} \cdot \frac{-4}{3} = M_{25} = 6 \)

28. Object is placed at the 2f of lens. Image formed by lens

\( f = 15 \text{ cm} \)

will behave as object for plane mirror (virtual object finally)

For lens

\( u = +10 \text{ cm} \)

\( f = 15 \text{ cm} \)

\( \frac{1}{v} \ - \ \frac{1}{u} = \ \frac{1}{f} \)

\( \frac{1}{v} = \frac{1}{10} \ - \ \frac{1}{15} \Rightarrow v = 6 \text{ cm} \)

6 cm distance from lens, so from mirror its 16 cm image will be real.

29. \( \sin c = \frac{1}{53} \)

\( \tan 37^\circ = \frac{R}{8} \Rightarrow \frac{3}{4} = \frac{R}{8} \Rightarrow R = 6 \text{ cm} \)

30. For \( f = 10 \text{ m} \)

\( v = \frac{25}{3} \ - \ \frac{1}{10} \ - \ \frac{1}{f} \)

\( \frac{1}{u} = \frac{1}{10} \ - \ \frac{1}{25} \)

\( u = -50 \text{ cm} \)

For \( v = 50 \text{ cm} \)

\( \frac{1}{u_2} = \frac{1}{10} \ - \ \frac{1}{50} \Rightarrow u_2 = -25 \text{ m} \)

speed of object = \( \frac{25}{30} \times \frac{18}{5} \)

speed of object = 3 km/hr.

31. From laws of Refraction

\( n_1 \sin i = n_2 \sin r \)

Denser to Rarer → Away from normal

Rarer to Denser → Towards the normal.

32. After Critical angle all the rays are Reflected and so No transmission occurs.

33. \( \frac{1}{v} \ - \ \frac{1}{24} = \frac{1}{8} \Rightarrow \frac{1}{v} = \frac{1}{8} - \frac{1}{24} \)

\( v = 12 \text{ cm} \)

\( d = 12 \times \frac{4}{3} = 16 \)

\( \therefore d = 18 - 16 = 2 \text{ cm} \)