29 Ray Optics and Optical Instruments

BRIEF REVIEW

Reflection Rebounding of light from a polished surface is called reflection.

Laws of reflection

(*a*) $i = r$

(*b*) Incident ray, normal and reflected ray are coplanar. If mirror rotates by θ, reflected ray moves by 2θ.

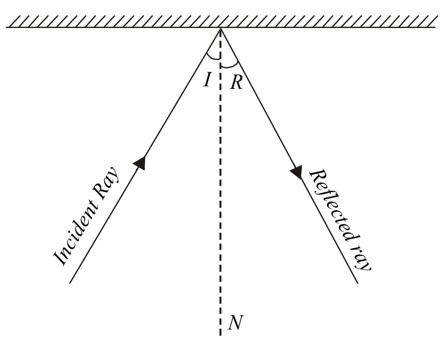


Fig. 29.1 Reflection from a polished surface

Diffusion Reflection from a rough surface like a wall is called diffusion. A parallel beam will not emerge out parallel because it meets different angles at the reflecting surface, (see Fig. 29.2)

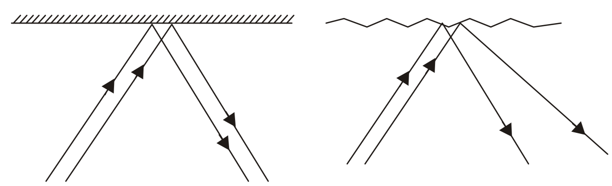
Characteristics of image formed with a plane mirror

(a) Erect (b) Virtual

(c) Size of image = Size of object

(d) Image distance = Object distance (measured from mirror).

(e) Lateral inversion (left appears right and right appears left).



(a) Reflection (b) Diffusion

Fig. 29.2 Illustration of diffusion.

Number of Images If two mirrors are inclined at an angle θ the number of images formed for an object placed in front of them is given by

(a) number of images $n = \frac{360}{\theta}$ if $\frac{360}{\theta}$ is odd and object does not lie on angle bisector or is placed symmetrically.

$n = \frac{360}{\theta} - 1$ if $\frac{360}{\theta}$ is odd and object is placed on angle bisector.

(b) Number of images $n = \frac{360}{\theta} - 1$ if $\frac{360}{\theta}$ is even (object placed non-symmetric).

$n = \frac{360}{\theta}$ if $\frac{360}{\theta}$ is even (object placed symmetrically).

If two mirrors are parallel ($\theta = 0$) $n = \infty$.

A, H, I, M, O, ... U, V, X, Y etc. 11 letters show lateral symmetry.

If mirror is thick, second image (formed due to first reflection from polished surface) is the brightest.

When a ray is reflected from a plane mirror, angle of deviation $\delta = \pi - 2\theta$ as shown in Fig. 29.3.

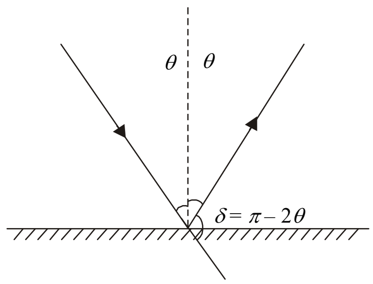


Fig. 29.3 **Finding angle of deviation**

Minimum height of a mirror so that a person can see his full image in the mirror is half the height of the mirror when standing at a distance = half the height away from the mirror.

Spherical mirrors are of two types: convex and concave as shown in Fig. 29.4.

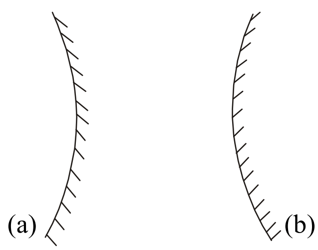


Fig. 29.4 **(a) Concave and (b) Convex mirror**

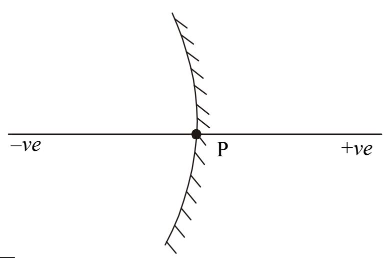


Fig. 29.5 **Illustration of sign convention**

Sign convention Consider pole P as origin. All distances to its left are negative and all distances to its right are positive.

Mirror formulae $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ and $f = \frac{R}{2}$ where

v = image distance from pole to mirror

u = object distance from pole to mirror

f = focal length

R = radius of curvature.

Table No. 29.1

Real Image		Virtual Image
1.	Rays actually converge to form image.	Rays appear to diverge from image
2.	Image can be obtained on screen.	Image cannot be taken on screen.
3.	Image is inverted	Image is erect.
4.	Magnification is negative.	Magnification is positive

Magnification M_{lat} (lateral) or linear magnification

$$M_{lat} = \frac{I}{o} = \frac{-v}{u} = \frac{v-f}{f} = \frac{f}{u-f}$$ See Fig. 29.6 (a)

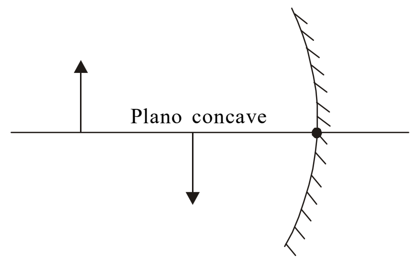


Fig. 29.6 (a) **Lateral magnification**

Magnification (axial) $M_{axial} = \frac{-v^2}{u^2}$ (used for small objects only). See Fig. 29.6 (b)

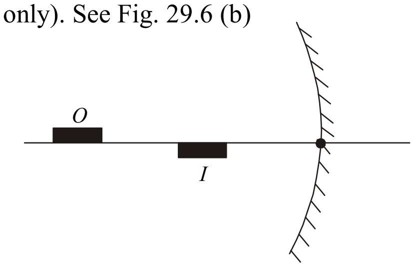


Fig. 29.6 (b) **Axial magnification**

Lens The part of an isotropic transparent medium bounded by at least one curved surface. Lenses are of two types. (a) convex (b) concave

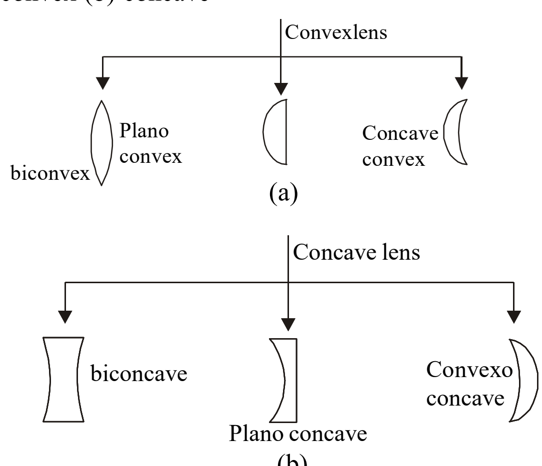


Fig. 29.7

Image formation information for convex lens and concave mirrors

Table. 29.2

Position of object	Position of image and its nature
At ∞	At focus (real, inverted, diminished).
Away from $2f$	Between f and $2f$ (real, inverted and diminished).
At $2f$	At $2f$ (real, inverted and equal in size)
Between f and $2f$	Away from $2f$, (real, inverted and magnified).
At f	At ∞ (real, inverted and magnified)
Between pole and f	Behind the mirror (virtual, erect and magnified)
	In front of lens, i.e., on the same side of object.

Remember spherical mirrors have one principal focus while lenses have two principal focus one on each side as shown in Fig. 29.8.

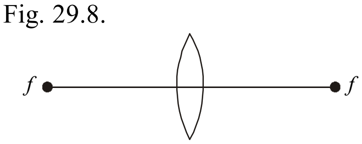


Fig. 29.8 Illustration of principal foci in a lens.

Lens formulae for thin lenses

$$\frac{1}{f} = (\mu_2 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \text{ (lens maker's formula) when}$$

surrounding medium is air or vacuum.

$$\frac{1}{f} = \left(\frac{\mu_2}{\mu_m} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \text{ if surrounding medium has}$$

refractive index μ_m.

Lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ (in air or vacuum)

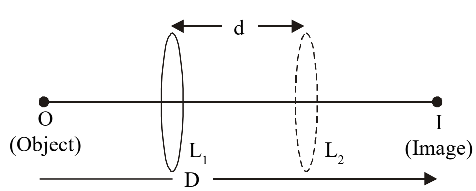


Fig. 29.9 Displacement method to find focal length of a convex lens.

Displacement method If object and image (or screen) are fixed at a distance D (> $4f$) [Fig. 29.9]. Lens is set at L_1 to form a magnified sharp image at I_0. Then lens is displaced by d again to form a sharp image at I (diminished), Then $f = \frac{D^2 - d^2}{4d}$ and O = $\sqrt{I_1 I_2}$ where I_1 and I_2 are sizes of image in magnified and diminished position of lens L_1 and L_2 respectively O is size of object.

Lateral magnification

$$M_{\text{lateral}} = \frac{v}{u} = \frac{I}{O} \text{ for a convex lens.}$$

$$M_{\text{lateral}} = \frac{-v}{u} = \frac{I}{O} \text{ for a concave lens.}$$

$$M_{\text{lateral}} = \frac{f}{u+f} = \frac{f-v}{f}$$

Axial magnification

$$M_{\text{axial}} = \frac{-v^2}{u^2} \text{ (for small objects)}$$

If object and image are formed in different media then use

$$\frac{\mu_3}{f} = \frac{\mu_2 - \mu_1}{R_1} - \frac{\mu_2 - \mu_3}{R_2} \text{ to find focal length}$$

$$\frac{\mu_3}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} - \frac{\mu_2 - \mu_3}{R_2} \text{ to find } v \text{ or } u$$

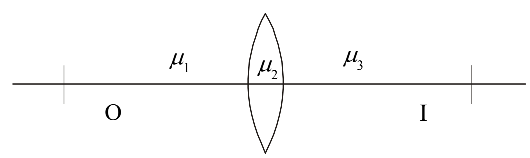


Fig. 29.10 Image formation when lens lies in two different media

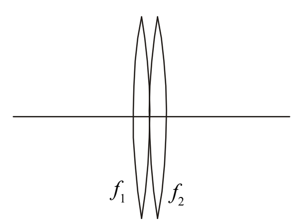


Fig. 29.11 Combination of two thin lenses

If two thin lenses are in contact as shown in Fig. 29.11 then $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

Newtons formula $x_1 x_2 = f_2$ [Fig. 29.12]

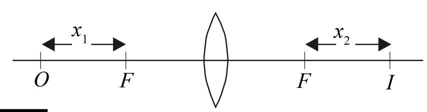


Fig. 29.12 Focal length using Newton's formula

If focal length on two sides is not equal then $f_1 f_2 = x_1 x_2$ (in case O and I are in different mediums)

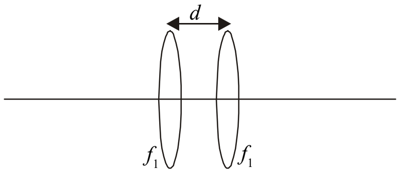


Fig. 29.13 **Combination of lenses when at a distance *d* apart.**

If two lenses are distance d apart as shown in Fig. 29.13

then their combined focal length $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

Focal length of a thick lens of thickness *t*

$$\frac{1}{f} = (\mu_2 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2} - \frac{t(\mu_2 - 1)}{\mu_2 R_1 R_2}\right]$$

Cardinal points There are three sets of cardinal points.

(a) set of focal points

(b) principal points $x_1 x_2 = f_2$ (if lens is in air)

(c) nodal points.

Flare spots If strong light is used, more than one refraction occurs in a lens and hence more than one image is formed called flare spots. For nth flare spot

$$\frac{1}{f_n} = \frac{(n+1)\mu - 1}{f(\mu - 1)}$$

Power of the lens $P = \frac{1}{f(m)} = \frac{100}{f(cm)}$ The unit is dioptre (D).

Defects in lenses

(a) **Spherical aberration** (or monochromatic aberration): occurs as paraxial and marginal rays fail to meet at a point as illustrated in Fig. 29.14. Spherical aberration can be removed using optical stops or aplanatic lens. Astigmatism is cured by cylindrical lens.

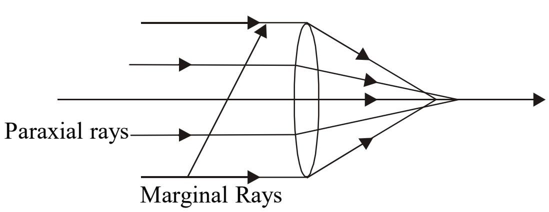


Fig. 29.14 **Spherical aberration illustration**

(b) **Chromatic aberration:** A white object when seen through a lens appears coloured. Such a defect is called chromatic aberration. Its removal is called achromatism. For achromatic aberration, a combination of a convex and a concave lens is needed such that $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$ where ω_1 and ω_2 are dispersive powers of two lenses of focal length f_1 and f_2 respectively. Their combined focal length is

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$. See Fig. 29.15 (a).

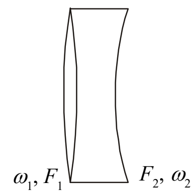


Fig. 29.15 (a) **Achromat combination**

Achromatic aberration can also be removed using two lenses of same kind separated by a small distance if

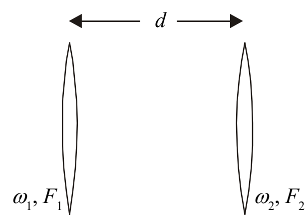


Fig. 29.15 (b) **Achromatism using two convex lens**

$$d = \frac{\omega_1 f_2 + \omega_2 f_1}{\omega_1 + \omega_2}$$ as illustrated in Fig. 29.15 (b).

Note: If $\omega_1 = \omega_2$ then $d = \frac{f_1 + f_2}{2}$.

If $d = f_1 - f_2$, spherical aberration is also removed.

Thus if $f_1 = 3f_2$ and $d = 2f_2$ then both the defects can be removed simultaneously. This approach is employed in Huygen's eye piece.

***Refraction** When **an oblique ray** of light enters from one medium to another (**optically different** or **dispersive medium**) then it changes its path. Such a phenomenon is called refraction. (See Fig. 29.16).

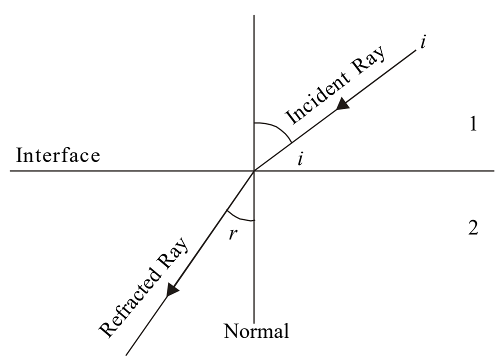


Fig. 29.16 **Refraction in a dispersive medium**

Note: *Most of the authors do not write the exact definition of refraction. This is correct definition. Words in bold, when added, make the definition correct.*

Note: It does not mean that if the ray is incident normal, it is not refracted.

Laws of refraction There are two laws of refraction.

(a) ${}^1\mu_2$ or $\mu = \dfrac{\sin i}{\sin r}$

(b) Incident ray, normal and refracted rays are coplanar.

$$\mu = \frac{\sin i}{\sin r} = \frac{c}{v} \text{ or } \frac{v_1}{v_2} = \frac{1}{\sin C}$$ where C is critical angle.

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$ (Apply this formula when incidence is normal)

$$\mu = \frac{\lambda_1}{\lambda_2} = \tan\theta_P$$ where θ_P is polarising angle and is equal to angle of incidence if angle between reflected and refracted rays is 90°.

$$\mu = \frac{\sin\frac{A+D_m}{2}}{\sin\frac{A}{2}}$$ in a prism. $\delta = (\mu - 1)\,\alpha$ where α is angle of prism and δ is angle of minimum deviation in a prism of small angle α (angle of prism).

$$\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}$$ is called Cauchy's principle.

$${}^1\mu_2 = \frac{1}{{}^2\mu_1} \text{ (principle of reciprocity)} \quad {}^1\mu_3 = {}^1\mu_2 \times {}^2\mu_3$$

Fermat's principle When a ray of light passes from one point to another by any number of reflections or refractions, the path taken by the light is the one for which corresponding time taken is the least (or has shortest optical path).

Optical path length is μl if l is the distance travelled in a medium of refractive index μ.

Refraction through a curved surface

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$ (See Fig. 29.17)

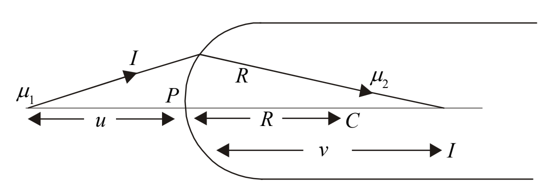


Fig. 29.17 Refraction through a curved surface

Note: that $\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} = \dfrac{\mu_2 - \mu_1}{R}$ can be applied for all curved surfaces with appropriate sign convention and remembering that μ_1 is the refractive index of the medium in which object lies.

Dispersion Splitting of a complex light into its constituent colours is called dispersion. For example, white light splits into seven colours when passed through a prism.

In a prism $i + e = A + D$ (See Fig. 29.18)

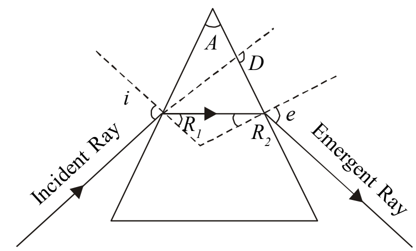


Fig. 29.18 Refraction through a prism

Fig. 29.19 shows graph between angle of deviation D and angle of incidence i. D_m is angle of minimum deviation.

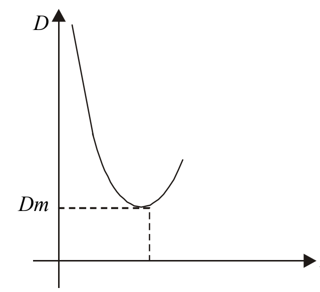


Fig. 29.19

At minimum deviation $i = e$ and $r_1 = r_2$. The ray through the prism is parallel to the base of the prism.

Under minimum deviation condition $\mu = \dfrac{\sin\frac{A+D_m}{2}}{\sin\frac{A}{2}}$

Dispersive power $\omega = \dfrac{\delta_v - \delta_r}{\delta} = \dfrac{\mu_v - \mu_r}{\mu - 1}$

where δ_v and δ_r are minimum deviations for violet and red colours, δ is mean deviation (for yellow colour). μ_v and μ_r are the refractive index for voilet and red colours and μ is the refractive index for yellow or mean colour.

Note: Use $\delta = \dfrac{\delta_v + \delta_r}{2}$ if δ is not given. Similarly use

$$\mu = \frac{\mu_v + \mu_r}{2} \text{ if } \mu \text{ is not given.}$$

$$\omega\delta = \delta_v - \delta_r \text{ is called angular dispersion.}$$

Rainbow Two types of rainbows are known: primary rainbow and secondary rainbow.

1. **Primary Rainbow** is formed when one total internal reflection (TIR) and two refractions occur from the suspended raindrops as illustrated in Fig. 29.20 (a). Voilet colour on inner edge and red colour on outer edge are seen, as shown in Fig. 29.20 (c). Angles subtended with the direction of sun are 42° (red) and 40° (violet) above the horizon.

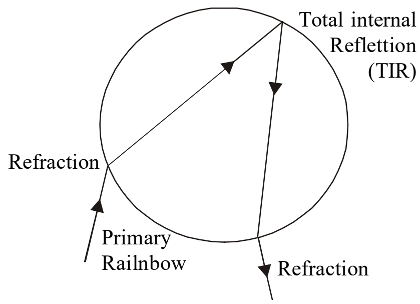


Fig. 29.20 (a) **Primary rainbow formation**

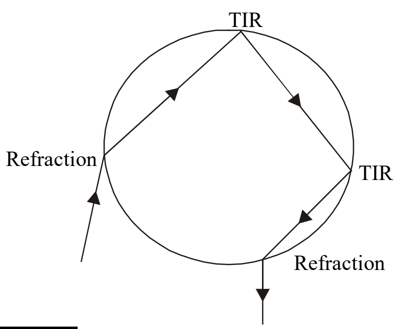


Fig. 29.20 (b) **Secondary rainbow formation**

2. **Secondary Rainbow** is formed due to two TIRs and two refractions from the raindrops suspended in air as shown in Fig. 29.20 (b). Inner edge has red colour and outer edge voilet, i.e., there is colour reversal from primary rainbow. It occurs due to an additional reflection which causes 180° phase shift. Angles are 51° for red and 54° for voilet.

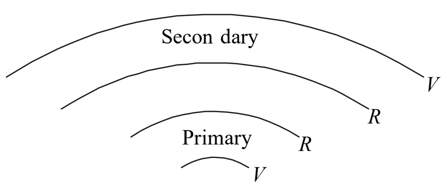


Fig. 29.20 (c) **Rainbow**

Deviation without dispersion See Fig. 29.21 (a)

Condition $\left(\delta_{v_1} - \delta_{r_1}\right) = \left(\delta_{v_2} - \delta_{r_2}\right)$

or $\left(\mu_{v_1} - \mu_{r_1}\right)\ \alpha_1 = \left(\mu_{v_2} - \mu_{r_2}\right)\ \alpha_2$

or $\delta_1 \omega_1 = \omega_2 \delta_2$

Dispersion without deviation See Fig. 29.21 (b). The mean colour should be parallel to incident ray.

$(\mu_1 - 1)\ \alpha_1 = (\mu_2 - 1)\ \alpha_2$

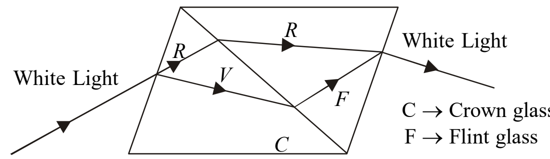


Fig. 29.21 (a) **Deviation without dispersion**

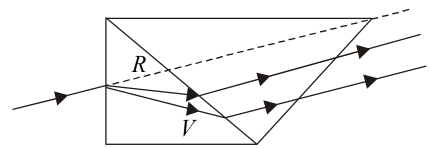


Fig. 29.21 (b) **Dispersion without deviation**

The prisms which produce dispersion without deviation are called direct vision prism and are employed in direct vision spectroscope. If more than two prisms are used the resolving power of the spectroscope is increased.

Defects in human eye

1. Myopia or shortsightedness
2. Hypermetropia or longsightedness
3. Presbyopia
4. Astigmatism
5. Colour blindness

1. **Myopic** eye is treated by concave lens. (Image is formed in front of the retina).
2. **Hypermetropic** eye is treated by convex lens. (Image is formed beyond the retina).
3. **Presbyopia:** Eye with this defect can neither see near objects nor far objects clearly. It is treated by bifocal lens (upper half concave and lower half convex).
4. **Astigmatism** is treated by specially prepared cylindrical lens.
5. **Colour blindness** Eye cannot differentiate between colours. Remedy is not available.

An alternative approach for correcting many defects of vision is to reshape the cornea. It is done using a procedure called **Laser assisted in situ Keratomileusis** or LASIK. An incision is made into the cornea and a flap of outer corneal tissue is folded back. A pulsed uv laser with a beam only 50 μm wide (< $\frac{1}{200}$th width of the hair) is then used to vaporise away microscopic area underlying the tissue. The flap is then folded back to the position where it conforms to the new shape carved by the laser.

Visual acuity or Resolving power of eye is $\frac{1}{60°}$ or 1 min.

Near point is 15 cm and least distance of distinct vision (normal near point) = 25 cm.

Eye pieces or occular Commonly used eyepieces are Huygen's and Ramsden. In Huygen eyepiece both the defects, spherical aberration and chromatic aberration, are removed

If $f_1 = 3f_2$ and $d = 2f_2$ then $d = \frac{f_1 + f_2}{2}$ removes chromatic aberration and $d = f_1 - f_2$ removes spherical aberration. The drawback in Huygen's eyepiece is that crosswire cannot be fitted. Therefore it can be used for qualitative work. Wherever quantitative (measurements) work is involved Ramsden's eyepiece is used. Ramsden eyepiece comprises of two lenses of equal focal length. $d = \frac{2}{3}f$. It is achromated for two selected colours. Spherical aberration is not removed completely. But crosswires can be connected.

Simple microscope or magnifier

Magnification $M = \left(1 + \frac{D}{f}\right)$.

Compound microscope

Magnification $M = \frac{v_o}{u_o}\left(1 + \frac{D}{f}\right) \approx \frac{L}{f_o} \cdot \frac{D}{f_e}$ for normal adjustment where L is length of the microscope tube.

$$M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) \text{ for least distance vision.}$$

Length of microscope tube or separation between two lenses $L = v_o + u_e$

Resolving power of microscope R.P. $= \frac{\mu \sin\theta}{0.61\lambda}$ for self luminous points.

$$\text{R.P.} = \frac{2\mu \sin\theta}{\lambda} \text{ for non luminous points.}$$

Note: Resolving power can be increased if we immerse the objective in an oil and use uv light.

However, resolving power of electron microscope is maximum. Magnification is as high as 80,000. Limit of resolution $= \frac{1}{R.P.}$

Telescope (Astronomical) is of three types:

(a) Reflecting (b) Refracting

(c) Radio telescope.

Reflecting type is made with concave mirror. Focal length of concave mirror > 1 m (objective).

In refracting type telescope, objective has large focal length and large aperture $f \geq 1$ m, aperture ≥ 2 inch.

Magnification (Normal setting) $M_N = \frac{f_o}{f_e}$

and $L = f_o + f_e$.

Least distance of distinct vision setting

$$M_{LD} = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

and $L = f_o + u_e$

Resolving power of telescope R P $= \frac{a}{1.22\lambda}$ where a is aperture.

Terrestrial Telescope

Magnification (Normal setting) $M_N = \frac{f_o}{f_e}$ and

$L = f_o + 4f_{er} + f_e$ where f_{er} is focal length of erecting lens.

Least distance setting $M_{LD} = \frac{-f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

and $L = f_o + 4\,f_{er} + u_e$.

Rayleigh's scattering $\propto \frac{1}{\lambda^4}$. That is why sky appears blue. Rising and setting sun appear red and danger signals are red in colour.

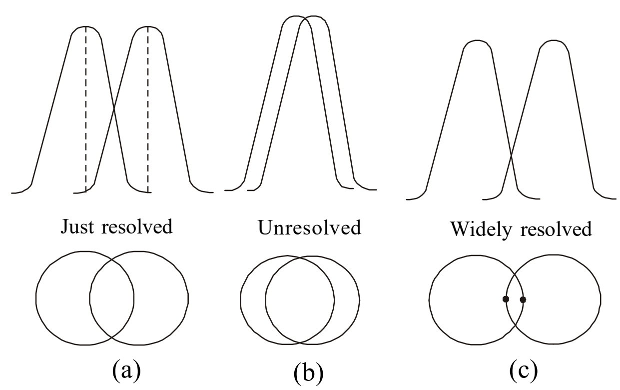


Fig. 29.22

Rayleigh's criterion for just resolution Two light sources close together are said to be just resolved if minima of one falls on the maxima of other as shown in Fig. 29.22(a).

SHORTCUTS AND POINTS TO NOTE

1. If two mirrors are inclined at an angle $\theta (0 \leq \theta \leq 90°)$ the number of images formed for an object placed in front of them is $\frac{360}{\theta}$ if $\frac{360}{\theta}$ is odd and number of

images formed = $\frac{360}{\theta} - 1$ if $\frac{360}{\theta}$ is even.

Number of images formed are even only if the object lies on angle bisector.

2. Use geometry to solve problems in optics. It is very helpful.
3. Second image is the brightest in a thick plane mirror.
4. Even virtual images can be photographed.
5. In spherical mirrors $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ and $f = \frac{R}{2}$. Lateral magnification $M = \frac{-v}{u}$.
6. If a lens of focal length f (in air) and refractive index μ_L is immersed in a liquid of refractive index μ_m then new focal length f_{new} is given by

$$\frac{f_{new}}{f} = \frac{(\mu_L - 1)}{\left(\frac{\mu_L}{\mu_m} - 1\right)}$$

If $\mu_L = 1.5$ and $\mu_m = \frac{4}{3}$ (water) then $f_{new} = 4f$

If one side of the lens is in air and the other side in water as illustrated in Fig. 29.23 and $\mu_L = 1.5$,

$\mu_m = \frac{4}{3}$ then $f_{new} = 2f$

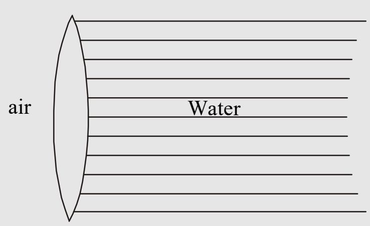


Fig. 29.23

7. If $\mu_L = 1.5$ and lens is equiconvex then $f = R$ and for a plano convex lens $f = 2R$
8. If a lens of refractive index μ_1 is immersed in a medium of refractive index μ_2 then if $\mu_1 > \mu_2$ lens behaves normal, i.e., a convex lens behaves as a convex lens and a concave lens behaves as a concave lens.

If $\mu_1 = \mu_2$ the system acts as a slab i.e. rays pass undeviated. It ceases to act as a lens.

If $\mu_1 < \mu_2$ lens behaves opposite, i.e., a convex lens behaves as a diverging lens and a concave lens acts as a converging lens.

9. In a system of three medias as shown in Fig. 29.24 focal length is determined using

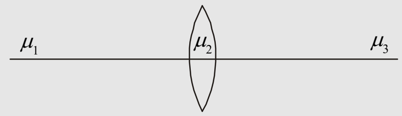


Fig. 29.24

$$\frac{\mu_3}{f} = \frac{\mu_2 - \mu_1}{R_1} - \frac{\mu_2 - \mu_3}{R_2}$$

To find v, apply $\frac{\mu_3}{v} - \frac{\mu_1}{u} = \frac{\mu_3 - \mu_1}{R_1} - \frac{\mu_2 - \mu_1}{R_2}$

10. If two thin lenses are joined then $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ (Fig. 29.25 (a)

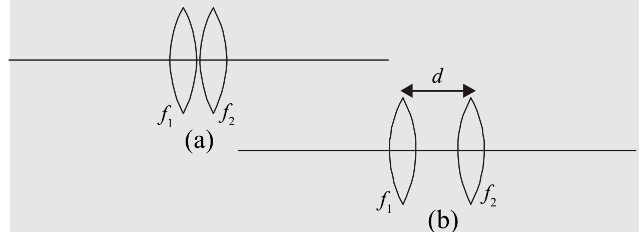


Fig. 29.25

If there is a separation d between the lenses,

then $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

Note: $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$ can be used to find focal length of the combination. It cannot help to find v (image distance). While finding v, apply two lens theory, i.e. image formed by 1st acts as an object for the second.

11. In displacement method $f = \frac{D^2 - d^2}{4D}$. Note that D ≥ $4f$ and size of object $O = \sqrt{I_1 I_2}$
12. Power of the lens $P = \frac{1}{f(m)} = \frac{100}{f(\text{cm})}$ Unit is Diopter. If lenses are in contact, power is added i.e. $P_{net} = P_1 + P_2 + ...$
13. If the lens is silvered from one side use power to find new focal length.

Fig. 29.26

$P = 2P_L + P_M$ or

$$\frac{1}{f_{new}} = \frac{2}{f} + \frac{2}{R} = \frac{2}{f} + \frac{1}{f(\mu-1)}$$ or

$f_{new} = \dfrac{f(\mu-1)}{2\mu-1}$ for the case shown in Fig. 29.26, i.e., for equiconvex lens silvered on one side.

Note: If $\mu = 1.5$, then $f_{new} = f/4$.

14. Due to refraction the sun appears to rise a little earlier and appears to set a little later (about 3 minutes difference).

15. If the angle of prism is small, use $\delta = (\mu - 1)a$;

otherwise use $\mu = \dfrac{\sin\left(\frac{A+D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$. Constant deviation prisms are used in special type of spectrometers.

16. While finding position of spot when two or more medias are placed,

shift $\Delta y = \left(t_1 - \dfrac{t_1}{\mu_1}\right) + \left(t_2 - \dfrac{t_2}{\mu_2}\right)$ as shown in Fig. 29.27.

Fig. 29.27

17. Lateral shift in slab as shown in Fig. 29.28

$$y = \frac{t\sin(i-r)}{\cos r}$$

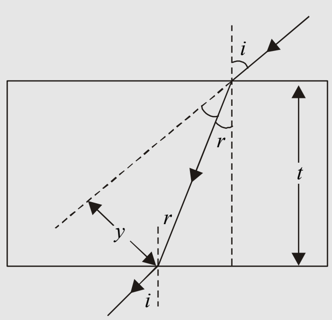


Fig. 29.28

18. A body disappears if its refractive index is equal to the reflective index of surrounding medium.

19. During refraction wavelength varies but frequency remains unchanged.

20. If a lens is partly covered, intensity or brightness of the image will decrease.

21. If a lens is cut horizontally, its focal length remains unchanged but if cut vertically focal length will change. For example, if an equiconvex lens is cut vertically then focal length of each planoconvex lens is $2f$. See Fig. 29.29.

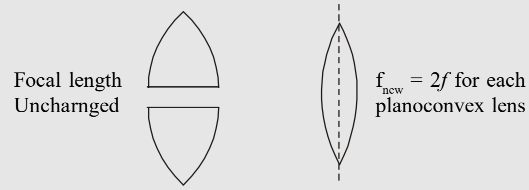


Fig. 29.29

22. If t is thickness and α is absorption coefficient then for incident light of intensity I_0, the emergent light intensity

$$I = I_0 e^{-\alpha t}$$

23. Apply $\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} = \dfrac{\mu_2 - \mu_1}{R}$ to find v and to find magnification in spherical surfaces shown in Fig. 29.30 use the formula

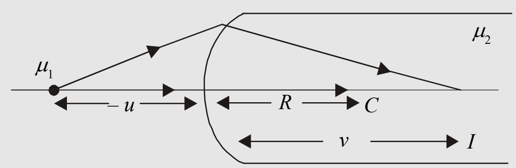


Fig. 29.30

$$M_{lateral} = \frac{\mu_1 v}{\mu_2 u}\ ;\ M_{axial} = \frac{\mu_1 v_1^2}{\mu_2 u^2}$$

Note: If the image is formed at the object side then image is virtual. If the image is formed on the other side then image is real.

24. Primary colours are Red, Blue and Green. Complementary colours of primary colours are Cyan for Red; brown/orange for blue and purple or magenta for green.

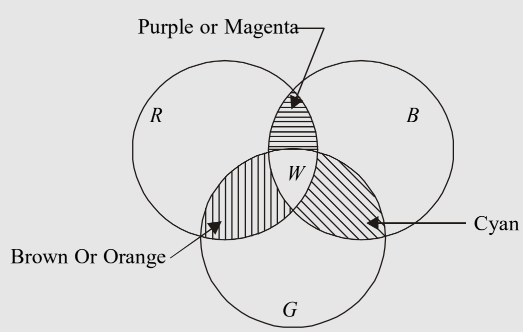


Fig. 29.31

25. The minimum distance between object and screen $= 4f$ to form a real image in case of a lens.

26. For deviation without dispersion

$$\delta_{v_1} - \delta_{r_1} = \delta_{v_2} - \delta_{r_2}$$

or $\left(\mu_{v_1} - \mu_{r_1}\right) \alpha_1 = \left(\mu_{v_2} - \mu_{r_2}\right) \alpha_2$

27. To achieve dispersion without deviation $\delta_1 = \delta_2$

or $(\mu_1 - 1)\,\alpha_1 = (\mu_2 - 1)\,\alpha_2$

28. There are two types of defects in lens: spherical aberration and chromatic aberration. Spherical aberration is removed if $d = f_1 - f_2$

To achieve achromatism $\dfrac{\omega_1}{f_1} + \dfrac{\omega_2}{f_2} = 0$

if combination of a convex and a concave lens is used.

If two lenses of different material are kept d distance apart then to achieve achromatism $d = \dfrac{\omega_1 f_1 + \omega_2 f_2}{\omega_1 + \omega_2}$

$d = \dfrac{f_1 + f_2}{2}$ if lenses are made of same material.

29. f number in camera is given by

$$f \text{ number} = \frac{\text{Focal length}}{\text{Aperture diameter}} = \frac{f}{D}.$$

If one f number is known, the next number is obtained by multiplying by $\dfrac{1}{\sqrt{2}}$ i.e. $\dfrac{f}{2}, \dfrac{f}{2.8}, \dfrac{f}{4}, \dfrac{f}{5.6}, \dfrac{f}{8}, \dfrac{f}{11}, \dfrac{f}{16}$.

Thus if $\dfrac{f}{4}$ requires $\dfrac{1}{500}\,s$, then $\dfrac{f}{5.6}$ requires $\dfrac{1}{250}\,s$ and $\dfrac{f}{8}$ requires $\dfrac{1}{125}\,s$ for the same kind of exposure.

30. Zoom lens is based on $\dfrac{1}{f} = \dfrac{1}{f_1} + \dfrac{1}{f_2} - \dfrac{d}{f_1 f_2}$ such that f can be varied 0 to ∞ by changing d.

31. In a pinhole camera $\dfrac{I}{O} = \dfrac{l_2}{l_1}$ (See Fig. 29.32)

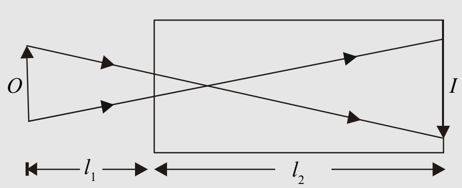


Fig. 29.32 **Pinhole Camera**

CAUTION

1. Considering that real image cannot be formed with a plane mirror.

⇒ If the incident light beam is convergent, real image can be formed.

2. Considering that during refraction, ray must bend.

⇒ Rays incident normal do not bend and still refraction occurs. We apply $\mu = \dfrac{\text{Real depth}}{\text{Apparent depth}}$ in such cases.

3. Not differentiating between linear (lateral) and axial magnifications.

⇒ Lateral magnification is $M_{\text{lat}} = \dfrac{v}{u}$ and axial magnification for small objects is $\dfrac{-v^2}{u^2}$.

4. Considering that frequency varies during refraction.

⇒ Frequency does not vary during refraction. All other characteristics of wave like wavelength, velocity and amplitude vary.

5. Considering refraction is 100% or could be 100%.

⇒ Refraction can never be 100%. A fraction of light is always reflected from the interface of two media.

6. Considering that focal length found using $\dfrac{1}{f} = \dfrac{1}{f_1} + \dfrac{1}{f_2} - \dfrac{d}{f_1 f_2}$ can be used to determine v also.

⇒ Individual lens analysis be employed to find v or u. Its use is limited to finding the focal length of the combination only.

7. Considering refraction through a slab can produce deviation.

⇒ Only lateral shift can be produced. The lateral shift is

$y = \dfrac{t\sin(i - r)}{\cos r}$. The lateral shift can be helpful in making images sharp without disturbing object lens or screen. The change in distance in such cases is equal to $\Delta l = \left(t - \dfrac{t}{\mu}\right)$.

8. Not being sure if colour is determined by wavelength or frequency.

⇒ Colour is determined by wavelength.

9. Assuming that achromat is made using two lenses, one convex and one concave, made of two different materials.

⇒ Two similar lenses (both convex) and made of same material (having equal dispersive power) can be used to achieve achromatism if $d = \frac{f_1 + f_2}{2}$.

If $d = f_1 - f_2$, then spherical aberration is also removed.

10. Considering that refractive index does not depend upon colour or wavelength.

⇒ Refractive index varies with colour or wavelength according to Cauchy's formula

$$\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}$$

11. Considering optical path length always greater than real path length.

⇒ Optical path length = μx. If $\mu > 1$, optical path length > real path length (say x). If $\mu = 1$, optical path length = x and if $\mu < 1$ optical path length < x.

12. Considering magnifying/resolving power of a microscope as fixed.

⇒ If we immerse the microscope lens/slide in an oil of refractive index μ, resolving power will increase. If uv light is selected, it will further increase.

13. Taking power $P = \frac{1}{f}$ and f in cm.

⇒ use $P = \frac{100}{f}$ if f is in cm.

14. Not knowing when the ray retraces its path.

⇒ The ray retraces its path only when it is incident normal on a reflecting surface.

15. Considering that in a camera, if f number increases exposure time decreases.

⇒ If f number increases exposure time increases, for example, if $\frac{f}{2}$ has exposure time $\frac{1}{1000}$ s, then $\frac{f}{2.8}$ has exposure time $\frac{1}{500}$ s and $\frac{f}{4}$ has exposure time $\frac{1}{250}$ s and so on.

SOLVED PROBLEMS

1. A light beam travels at a speed 1.94×10^8 ms^{-1} in quartz. The wavelength found in quartz is 355 nm. What would be the wavelength in air?

(a) 179 nm (b) 549 nm
(c) 355 nm (d) 707 nm

Solution (b) $\mu = \frac{c}{v} = \frac{\lambda}{\lambda'}$ or $\frac{3\times10^8}{1.94\times10^8} = \frac{\lambda}{355}$

or $\lambda = \frac{1065}{1.94} = 594$ nm.

2. In 11.5ns light travels 2.5 m in plastic find its refractive index.

(a) 1.38 (b) 1.48
(c) 1.18 (d) 1.58

Solution (a) $\mu = \frac{c}{v} = \frac{3\times10^8}{\frac{2.5}{11.5\times10^{-9}}} = \frac{3\times11.5\times10^{-1}}{2.5}$

$= 1.38$

3. Two mirrors are inclined at an angle θ. For an object placed in front of them, 11 images are noticed. Find the angle between the mirrors.

(a) 30° (b) 32.8°
(c) 16.4° (d) 15°

Solution (a) No. of images = $11 = \frac{360}{\theta} - 1 \Rightarrow \theta = 30°$

4. A ray deviates at 90° after suffering reflection from a mirror. The angle of incidence is

(a) 90° (b) 30°
(c) 60° (d) 45° (e) none of these

Solution (d) $2\theta = 180 - \delta$ or $2\theta = 180 - 90 \Rightarrow \theta = 45°$

5. To what depth can a vessel be filled with water so that it appears half filled?

(a) $\frac{3}{4}h$ (b) $\frac{2}{3}h$
(c) $\frac{5}{7}h$ (d) $\frac{3}{5}h$

Solution (b) App. depth = $\frac{\text{Real depth}}{\mu}$

∴ Real depth = $\frac{4}{3}\left(\frac{h}{2}\right) = \frac{2}{3}h$

6. A room is 3m high and 5m long. A man is standing in front of one of the walls 1m from the wall. A mirror is to be installed on the wall. Find the height (minimum) of the mirror so that complete image of the wall behind him is seen.

(a) 1.5 m (b) 1 m

(c) 2 m (d) 0.5 m

Solution (d) $\Delta\, ABM$ and $\Delta\, KLM$ are similar

$$\therefore \quad \frac{KL}{AB} = \frac{KM}{MB} \Rightarrow \text{KL} = \frac{3\times 1}{6} = \frac{1}{2}\text{ m}$$

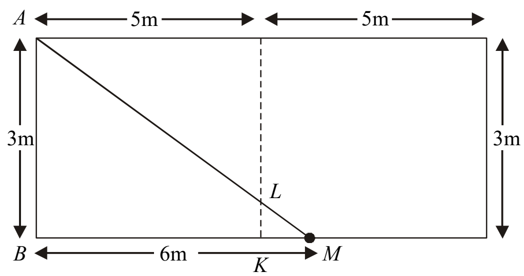


Fig. 29.33

7. A beam is incident parallel on the prism shown in Fig. 29.34 (a). Find the angle between emerging rays. $\mu_{\text{prism}} = 1.66$.

(a) 180° (b) 120°

(c) 135° (d) 40°

Solution (d) $\sin C = \dfrac{1}{1.66}$ or $C = 37°$

$\therefore$ ray is referacted out

$\sin r = \sin 25\ (1.66)$

$= 0.4226\ (1.66) = .706$

$\therefore$ $r = 45°$

$\theta = 360 - 230 - 90 = 40°$

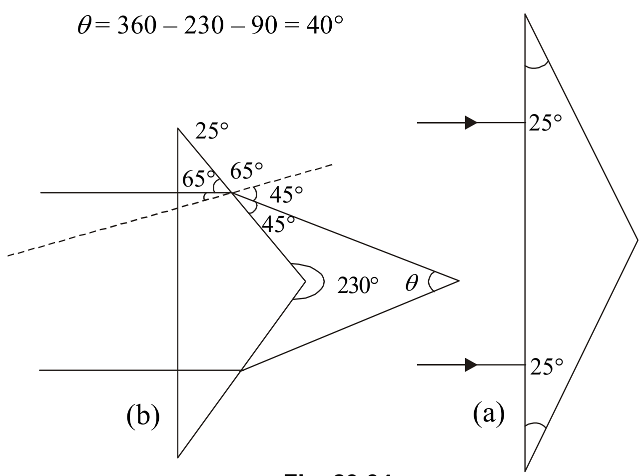


Fig. 29.34

8. A white light is incident at 20° on a material of silicate flint glass slab as shown. $\mu_{\text{voilet}} = 1.66$ and $\mu_{\text{r}} = 1.6$. For what value of d will the separation be 1mm in red and voilet rays.

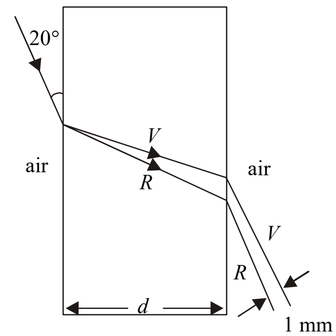


Fig. 29.35

(a) $\dfrac{5}{3}$ cm (b) $\dfrac{10}{3}$ cm

(c) 5 cm (d) $\dfrac{20}{3}$ cm

Solution (b) $\sin r_1 = \dfrac{\sin 70}{1.66} = \dfrac{.9397}{1.66}$ or $r_1 = 34°\ 30'$

$$\sin r_2 = \frac{\sin 70}{1.6} = \frac{.9397}{1.6} \text{ or } r_2 = 36°$$

$$\text{Using} \quad y = \frac{t\sin(i-r)}{\cos r}$$

$$y_1 - y_2 = d\left[\frac{\sin(i-r_1)}{\cos r_1} - \frac{\sin(i-r_2)}{\cos r_2}\right]$$

$$0.1 = d\left[\frac{\sin 35°30'}{\cos 34°30'} - \frac{\sin 34°}{\cos 36°}\right]$$

$$\text{or} \quad 0.1 = d\left[\frac{0.5807}{0.8241} - \frac{0.5592}{0.8090}\right] = d\,[0.71 - 0.68]$$

$$\text{or} \quad d = \frac{0.1}{0.03} = \frac{10}{3}\text{ cm}$$

9. A glass whose one end is hemispherical of radius 2 cm ($\mu_{\text{red}} = 1.52$) is kept in water ($\mu = 1.33$). The object is kept 8 cm in front of convex surface. Find the magnification.

(a) 2.33 (b) 1.33

(c) 2.66 (d) 1.76

Solution (a) $\dfrac{1.52}{v} - \dfrac{1.33}{-8} = \dfrac{1.52 - 1.33}{2}$

or $v = -21.3$ cm;

$$M = -\frac{1.33(-21.3)}{1.52(8)} = 2.33$$

10. Refractive index of water in the situation shown in Fig. 29.36 is μ. Find the distance seen by the fish F of human eye E.

(a) $H + \frac{H}{2\mu}$ (b) $\frac{3H}{2\mu}$

(c) $\frac{H}{2} + H\mu$ (d) $\frac{3\mu H}{2}$

Solution (c) $\frac{H}{2} + \frac{H}{{}^{w}\mu_a} = \frac{H}{2} + \frac{H}{\frac{1}{\mu}}$

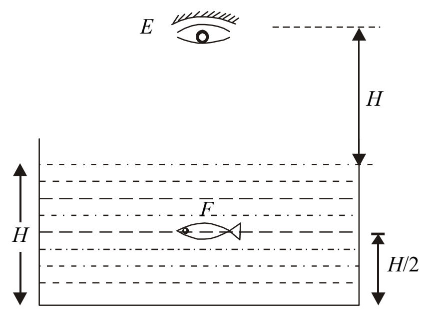


Fig. 29.36

11. In the previous question what is the distance of fish F seen by human eye E?

(a) $H + \frac{H}{2\mu}$ (b) $\frac{H}{\mu} + \frac{H}{2}$

(c) $\frac{3H}{2\mu}$ (d) None of these

Solution (a) $H + \frac{H/2}{{}^{a}\mu_w} = H + \frac{H}{2\mu}$

12. A point object O is placed midway between the concave mirrors, distance d apart. What is the value of d for which object and images coincide? Each mirror has focal length F.

(a) F, 2 F (b) 2 F, 3 F

(c) F, 4 F (d) 2 F, 4 F

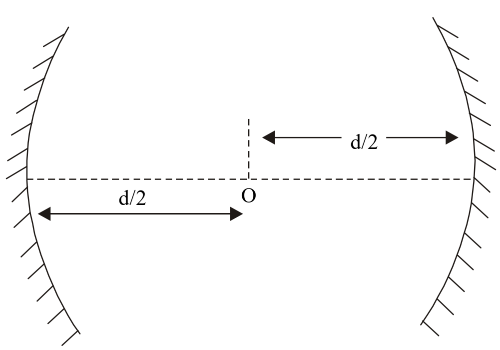


Fig. 29.37

Solution (d) When $\frac{d}{2} = F$, the rays from one mirror after reflection will reach parallel to the other mirror. Second mirror will refocus them at O. When object is at $2F$, image is formed at $2F$.

13. A cylindrical vessel of diameter 12 cm has 800 π cm^3 water. A cylindrical glass piece of diameter 8 cm and height 8 cm is placed in it as shown in Fig. 29.38. What is the position of image of bottom of the vessel seen through paraxial rays passing through the glass cylinder?

(a) 6.2 cm above the bottom

(b) 7.1 cm above the bottom

(c) 6.6 cm above the bottom

(d) none of these

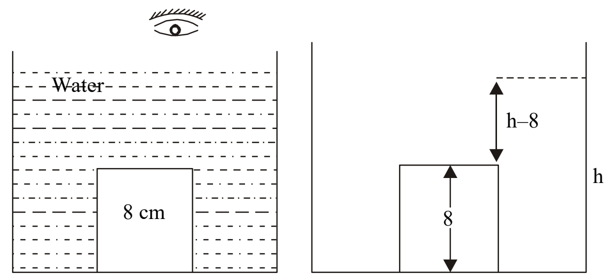


Fig. 29.38

Solution (b) $\pi\, 6^2\, h = 800\, \pi + \pi\, 4^2\, (8)$ or $h = \frac{928}{36}$

$= 25.8$ cm

$$\Delta y = \left(17.8 - \frac{17.8}{4/3}\right) + \left(8 - \frac{8}{1.5}\right)$$

$= 4.45 + 2.67 = 7.1$ cm above the bottom.

14. Find angle of minimum deviation of an equilateral prism ($\mu = 1.732$). Also find angle of incidence for this deviation.

(a) 60°, 75° (b) 60°, 55°

(c) 60°, 50° (d) 60°, 60°

Solution (d) $\mu = \dfrac{\sin \frac{A + D_m}{2}}{\sin \frac{A}{2}}$

or $\sqrt{3} \times \frac{1}{2} = \sin \frac{A + D_m}{2} \Rightarrow D_m = 60°.$

Using $2i = A + D_m$, we get $i = 60°$.

15. An equiconvex lens is made from $\mu = 1.5$ and $r = 20$ cm. It is 5 cm thick in the middle. Find the position of image far away from the lens.

(a) 10 cm (b) 9.2 cm

(c) 8.72 cm (d) 9.48 cm (e) 9.68 cm

Solution (b) Image is formed at focus.

$$\frac{1}{f} = (\mu - 1)\left[\frac{2}{R} + \frac{(\mu-1)t}{\mu R^2}\right]$$

$$= \frac{1}{2}\left[\frac{2}{10} + \frac{2.5}{150}\right] = \frac{13}{120}$$

or $$f = \frac{120}{13} = 9.2$$

16. A slide projector is to project a (35 mm × 23 mm) slide on a 2m × 2m screen. Find the focal length of the lens used if screen is 10 m away from the lens.

(a) 15.1 cm (b) 17.2 cm

(c) 16.1 cm (d) 18.2 cm

Solution (b) $M = \frac{200}{3.5} = \frac{10}{u}$ or $u = \frac{7}{40}$ m; using

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f},$$ i.e.,

$$\frac{1}{f} = \frac{1}{10} + \frac{40}{7} \text{ or } f = 17.2 \text{ cm}$$

17. A paper weight is hemispherical with radius 3 cm. It is kept on a printed page, the printed letter will appear at a height _____ cm from the centre of the hemisphere when viewed vertically.

(a) 0 (b) 1 cm

(c) 2 cm (d) 1.21 cm

Solution (a) $\frac{1.5}{v} - \frac{1}{-3} = \frac{1.5-1}{-3}$ $v = -3$ cm.

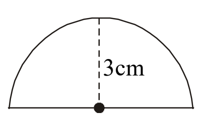


Fig. 29.39

18. A 1m long rod is half dipped in a swimming pool. The sunlight is incident at 45° on the rod. Find the length of the shadow on the bed of swimming pool.

(a) 73 cm (b) 78.25 cm

(c) 74.17 cm (d) 81.5 cm

Solution (d) Length of shadow = x + 0.5 m

$$x = 0.5 \tan r$$

$$\sin r = .707 \times \frac{3}{4} \text{ or}$$

$$r = 32° \, 12'$$

Thus $$l = 50 (\tan 32° \, 12') + 50 \text{ cm}$$

$$= 50 (.6297) + 50 = 81.5 \text{cm}$$

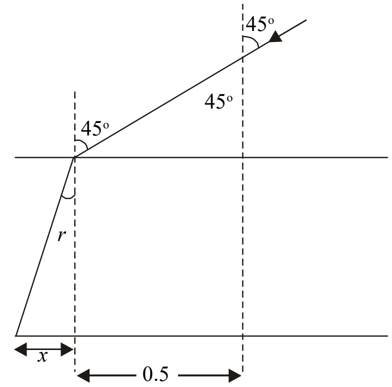


Fig. 29.40

19. A diverging lens of f = 20 cm and a converging mirror f = 10 cm are placed 5 cm apart coaxially. Where shall an object be placed so that object and its real image coincide?

(a) 60 cm away from lens (b) 15 cm away from lens

(c) 20 cm away from lens (d) 45 cm away from lens

Solution (a) If the rays are to retrace the path, light ray must fall normal on the mirror. Hence I' should be 20 cm from mirror and 15 cm from lens.

$$\frac{1}{-15} - \frac{1}{x} = \frac{1}{-20}$$

or $$\frac{1}{x} = \frac{1}{-15} + \frac{1}{20} = \frac{1}{-60}$$

x = – 60 cm i.e. 60 cm away from lens.

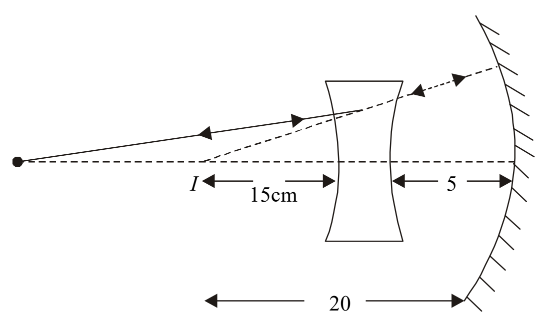


Fig. 29.41

20. A fish looking up through the water sees outside world contained in a circular horizon. The refractive index of water is $\frac{4}{3}$ and the fish is 12 cm below the surface. The radius of this circle in cm is

[AIEEE 2005]

(a) $36\sqrt{7}$ (b) $\frac{36}{\sqrt{7}}$

(c) $36\sqrt{5}$ (d) $4\sqrt{5}$

Solution (b) $\sin C = \frac{3}{4}$ and $\tan C = \frac{3}{\sqrt{7}} = \frac{r}{12}$

or $r = \frac{36}{\sqrt{7}}$ cm.

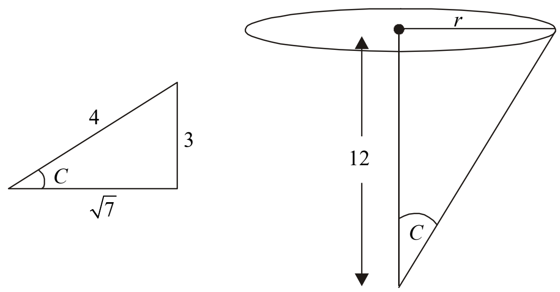


Fig. 29.42

21. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil of diameter 3 mm. Approximately what is the maximum distance upto which these dots can be resolved by the eye.

[AIEEE 2005]

(a) 5 m (b) 6 m

(c) 1 m (d) 4 m

Solution (a) $\frac{1.22\lambda}{3mm} = \frac{1mm}{d}$

or $d = \frac{3\times10^{-6}}{1.22\times5\times10^{-7}} = 5$ m

22. A thin glass (μ = 1.5) lens has power $-5D$ in air. Its power in a medium of refractive index 1.6 will be

(a) $\frac{5}{8}D$ (b) $\frac{25}{8}D$

(c) $-\frac{5}{8}D$ (d) $-\frac{25}{8}D$

Solution (a) $f_m = \frac{(\mu_L - 1)}{\left(\frac{\mu_L}{\mu_m} - 1\right)} f_a = \frac{\frac{1}{2}\times(-20)}{\frac{\frac{3}{2}}{1.6} - 1}$

$$= \frac{\frac{1}{2}\times20\times3.2}{.2} = 160 \text{ cm}$$

$$P = \frac{100}{160} = \frac{5}{8}$$

23. The angular resolution of a telescope of 10 cm diameter at a wavelength of 5000 A° is of the order of

[CBSE 2005]

(a) 10^6 rad (b) 10^{-2} rad

(c) 10^{-4} rad (d) 10^{-6} rad

Solution (d) $\frac{\lambda}{d} = \frac{5\times10^{-7}}{10^{-1}} = 10^{-6}$

24. A tank of height 33.25 cm is completely filled with liquid (μ = 1.33). An object is placed at the bottom of the tank on the axis of concave mirror as shown in Fig. 29.43. Image of the object is formed at 25 cm below the surface of the liquid. Focal length of the mirror is

[IIT 2005]

(a) 10 cm (b) 15 cm
(c) 20 cm (d) 25 cm

Solution (c) Apparent depth $= \frac{33.25}{1.33} = 25$ cm

when object is at $2f$ image is formed at $2f$.

$\therefore$ $2f = 15 + 25 = 40$ cm and $f = 20$ cm

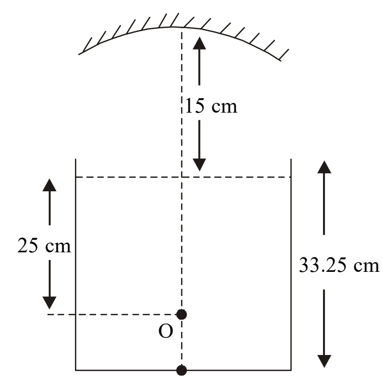


Fig. 29.43

25. A telescope has an objective lens of focal length 200 cm and an eyepiece with focal length 2 cm. It is used to see a 50 m tall building at a distance of 2 km. What is the height of the image of the building formed by the objective lens ?

[AIIMS 2005]

(a) 5 cm (b) 10 cm
(c) 1 cm (d) 2 cm

Solution (a) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

or $\frac{1}{v} = \frac{1}{200} - \frac{1}{2000\times100}$

or $v = 200$ cm.

Using $\frac{v}{u} = \frac{I}{O}$

$$I = \frac{2}{2000} \times 50 = \frac{1}{20} \text{ m or 5 cm.}$$

26. *A*. Resolving power of a telescope is more if the diameter of the objective lens is more.

R. Objective lens of large diameter collects more light.

[AIIMS 2005]

(a) both *A* and *R* are correct and *R* is correct explanation of *A*

(b) *A* and *R* both are correct but *R* is not correct explanation of *A*

(c) *A* is true but *R* is false

(d) both *A* and *R* are false

Solution (b) $RP = \frac{D}{1.22\lambda}$ $\therefore$ *A* is correct. Though *R* is correct but for larger resolution objects making small angle be distinguished or very close objects should be distinguished.

27. Focal number of the lens of a camera is $5f$ and that of another is $2.5f$. The time of exposure for the second is......... if that for the first is $\frac{1}{200}s$

$\left(\text{Given } f = \frac{\text{focal length}}{\text{aperature}}\right)$

(a) $\frac{1}{200}$ s (b) $\frac{1}{800}$ s

(c) $\frac{1}{3200}$ s (d) $\frac{1}{6400}$ s

[BHU 2005]

Solution (b) f number decreases by 2 $\therefore$ time of exposure should decrease by (2^2).

$$\therefore \quad t_{new} = \frac{1}{4} \times \frac{1}{200} = \frac{1}{800} \text{ s.}$$

28. A convex lens of focal length 80 cm and a concave lens of focal length 50 cm are combined together. What will be their resultant power?

[BHU 2005]

(a) 0.65 D (b) –0.65 D

(c) 0.75 D (d) –0.75 D

Solution (d) $P_1 = 1.25\ D$ and $P_2 = -2\ D$

$P_{net} = P_1 + P_2 = -0.75\ D$

29. A plane slab is kept over various colour letters. The letter which appears least raised is

[BHU 2005]

(a) Red (b) Green

(c) Voilet (d) Blue

Solution (a) $\mu = A + \frac{B}{\lambda^2}$

$\therefore \mu$ is minimum for Red and App. depth $= \frac{\text{Real depth}}{\mu}$

30. A convex lens forms the full image of the object on a screen. If half of the lens is covered with an opaque object then

[BHU 2005]

(a) the image disappears

(b) half the image is seen

(c) full image of same intensity is seen

(d) full image of decreased intensity is seen.

Solution (d)

31. Time taken by light to pass through 4 mm thick glass slab of refractive index 1.5 will be

(a) 8×10^{-11} s (b) 2×10^{-11} s

(c) 8×10^{-8} s (d) 2×10^{-8} s

[BHU 2005]

Solution (b) $t = \frac{4 \times 10^{-3} \times 1.5}{3 \times 10^8} = 2 \times 10^{-11}$ s

32. A lens acts as a converging lens in air and diverging lens in water. The refractive index of the lens is

[BHU 2005]

(a) = 1 (b) < 1.33

(c) > 1.33 (d) < 1

Solution (b)

33. A light passing through air has wavelength 6000 A°. Wavelength when same ray passes through a glass slab of refractive index 1.5 is

[BHU 2005]

(a) 4000 A° (b) 2000°

(c) 8000 A° (d) 1200 A°

Solution (a) $\lambda' = \frac{\lambda}{\mu} = \frac{6000}{1.5} = 4000$ A°

34. Which of the following is a wrong statement?

[CET Karnataka 2005]

(a) $D = \frac{1}{f}$ where f is focal length and D is optical power of lens.

(b) Power is in diopter when f is in meters.

(c) Power is in diopter and does not depend upon the system of unit used to measure f.

(d) D is positive for convergent lens and D is negative for divergent lens.

Solution (c)

$$\because \quad P = \frac{1}{f(m)} = \frac{100}{f(cm)}$$

[CET Karnataka 2005]

35. Identify the wrong description of the given figures.

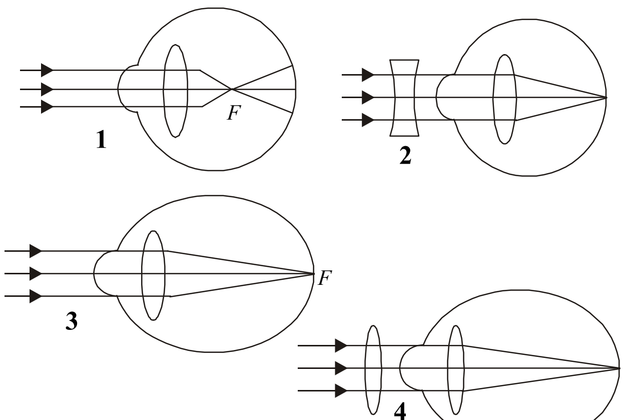


Fig. 29.44

(a) 1 represents far sightedness

(b) 2 is correction for short sightedness

(c) 3 represents far sightedness

(d) 4 represents correction for far sightedness

Solution (a)

36. Which mirror be used to obtain a parallel beam of light from a small lamp?

(a) plane mirror (b) convex mirror

(c) concave mirror (d) any of the above

[CET Karnataka, 2005]

Solution (c)

37. As shown in Fig. 29.45 $AB = AC$. Find the minimum value of refractive index μ for the given material.

(a) $\sqrt{2}$ (b) $\sqrt{3}$

(c) 1.5 (d) 1.6

Solution (a)

$$\mu = \frac{1}{\sin c} = \frac{1}{\sin 45} = \sqrt{2}$$

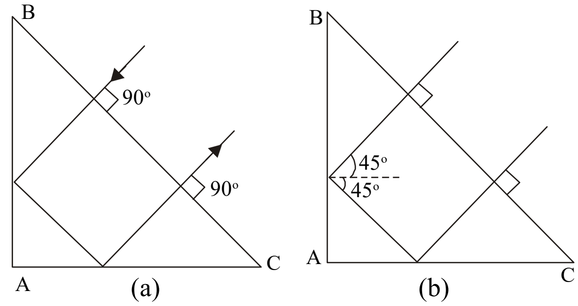


Fig. 29.45

38. The eyepiece of a refracting telescope has $f = 9$ cm. In the normal setting, separation between objective and eyepiece is 1.8 m. Find the magnification.

(a) 20 (b) 19

(c) 18 (d) 21

Solution (b) $f_0 = 1.8 - 0.09 = 1.71$ m

$$M = \frac{f_0}{f_e} = \frac{171}{9} = 19$$

39. The focal length of an $\frac{f}{4}$ camera lens is 300 mm. What is the aperture diameter of the lens?

(a) 75 mm (b) 650 mm

(c) 800 mm (d) 1200 mm

Solution (a) aperture $= \frac{300}{4} = 75$ mm

40. An object is placed at 15 cm in front of a convex lens of focal length 10 cm. Where shall we place a convex mirror of focal length 13 cm so that real image and object coincide?

(a) 6 cm from lens (b) 3 cm from lens

(c) 4 cm from lens (d) 2 cm from lens.

Solution (c) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$; $\frac{1}{v} = \frac{1}{10} - \frac{1}{15}$

or $v = 30$ cm. In order the ray to retrace the path, the ray must be incident normal on the mirror. Hence distance of mirror from I′ should be equal to $R = 2f = 26$ cm or 4 cm from lens.

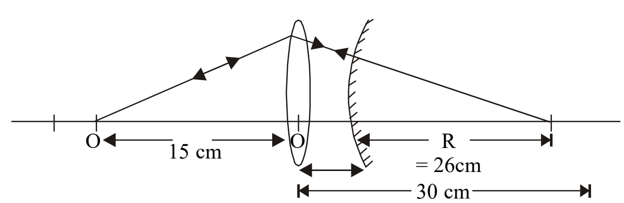


Fig. 29.46

41. In Fig. 29.47 a parallel beam emerges parallel. The relation between μ, μ_1 and μ_2 is

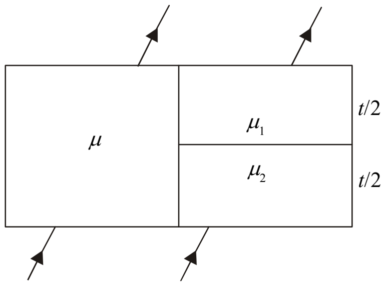


Fig. 29.47

(a) $\mu = \mu_1 + \mu_2$ (b) $\frac{1}{\mu} = \frac{1}{\mu_1} + \frac{1}{\mu_2}$

(c) $\mu = \frac{\mu_1 + \mu_2}{2}$ (d) $\frac{2}{\mu} = \frac{1}{\mu_1} + \frac{1}{\mu_2}$

Solution (d)

$$\frac{t}{\mu} = \frac{t/2}{\mu_1} + \frac{t/2}{\mu_2} \text{ or } \frac{2}{\mu} = \frac{1}{\mu_1} + \frac{1}{\mu_2}$$

TYPICAL PROBLEMS

42. A 16 cm long pencil is placed as shown in Fig. 29.48. The central point C is 45 cm away from a 20 cm focal length lens and 15 cm above the optic axis. Find the co-ordinates of image of points A, B and C and length of image.

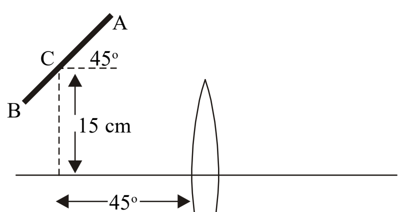


Fig. 29.48

Solution **For point C** $\frac{1}{v} - \frac{1}{-45} = \frac{1}{20}$ or $v = 36$ cm

Using $M = \frac{I}{O} = \frac{v}{u}$ $y'_C = \frac{-36}{45} \times 15 = -12$. Thus co-ordinates of C' are (36, –12)

For point B $u = 45 + 8 \cos 45 = 45 + 5.656$

$$\frac{1}{v} = \frac{1}{20} - \frac{1}{50.66}$$

or $$v = \frac{50.66 \times 20}{30.66} = 33 \text{ cm},$$

$$y'_B = \frac{-33}{50.66} \times (15 - 4\sqrt{2}).$$

Thus co-ordinates of B' are (33, –6.1)

For point A $u = 45 - 4\sqrt{2} = 39.34$ cm

$$\frac{1}{v} = \frac{1}{20} - \frac{1}{39.34}$$

or $$v = \frac{39.34 \times 20}{19.34} = 40.70 \text{ cm},$$

$$y'_A = \frac{-40.7}{39.34}\ (15 + 4\sqrt{2}) = 21.4 \text{ cm}$$

Thus coordinates of A' are (40.7, –21.4)

Length of Image $A'B' = \sqrt{(40.7 - 33)^2 + (21.4 - 6.1)^2}$

$$= \sqrt{7.7^2 + 15.3^2} = 17.1 \text{ cm}$$

43. A lady cannot see objects closer than 40 cm from the left eye and closer than 100 cm from the right eye. On a mountaineering trip, she is lost from her team. She tries to make an astronomical telescope from her reading glass. (a) Which glass should be used as the eyepiece? (b) What is the magnification of relaxed eye?

Solution (a) Right eye glass be used as eyepiece.

$$\frac{1}{f_{\text{Left}}} = \frac{1}{25} - \frac{1}{40} = \frac{1.5}{100} \text{ or}$$

$$f_{\text{Left}} = \frac{100}{1.5} \text{ cm}$$

$$\frac{1}{f_{\text{Right}}} = \frac{1}{25} - \frac{1}{100} = \frac{3}{100} \text{ or}$$

$f_{\text{Right}} = \frac{100}{3}$ cm. In telescope eyepiece of shorter focal length is used.

(b) $M = \frac{f_o}{f_e} = 2$

44. Converging rays are incident on a sphere of radius 10 cm ($\mu = 1.4$). In the absence of sphere the rays would have converged to 40 cm. Find the position of image.

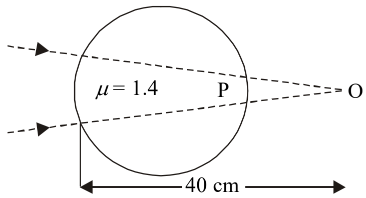


Fig. 29.49

Solution $\frac{1.4}{v} - \frac{1}{40} = \frac{1.4-1}{10}$ or $v = 21.58$ cm

Since the rays cross the sphere they will be refracted again.

$$\frac{1}{v} - \frac{1.4}{1.58} = \frac{1-1.4}{-10}$$

or $\frac{1}{v} = \frac{1.4}{1.58} + \frac{.4}{10}$ or

$$= \frac{15.8}{14+0.632} = 1.08 \text{ cm, i.e., } \mathbf{1.08\ cm\ from\ P}$$

45. A professor reads a greeting card on his 50th birthday with + 2.5 D glasses keeping the card 25 cm away. 10 years later he reads the greeting card with same glass keeping the card 50 cm away. What power glasses should he wear now?

(a) 2D (b) 0.5 D

(c) 2.25 D (d) 4.5 D

Solution (d) $\frac{1}{f'} = \frac{1}{25} - \frac{1}{50} = \frac{1}{50}$ or

$$P = 2\,\text{D}$$

$$P_{\text{net}} = 2.5 + 2 = 4.5\,\text{D}$$

46. A simple microscope is rated 5 × for a normal relaxed eye. What will be its magnifying power for a farsighed man whose near point is 40 cm ?

(a) 5 × (b) 3 ×

(c) 8 × (d) 13 ×

Solution (c) For a relaxed eye $M = \frac{D}{f}$ $\therefore f = 5$ cm

In case II $M = \frac{40}{5} = 8$

47. A particle is moving at a constant speed v from a large distance towards a concave mirror of radius R along the principal axis. Find the speed of the image as a function of the distance x of the particle from the mirror.

Solution Let y represent the image distance and x the object distance from the mirror. Then

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

or $\frac{1}{y} = \frac{-2}{R} + \frac{1}{x} = \frac{-2x+R}{Rx}$

or $y = \frac{Rx}{R-2x}$ .... (1)

Differentiating equation. (1)

$$\frac{dy}{dt} = \frac{R\frac{dx}{dt}}{(R-2x)} + \frac{2Rx\frac{dx}{dt}}{(2-2x)^2}$$

or $\frac{dy}{dt} = \frac{\left[R(R-2x)+2Rx\right]\frac{dx}{dt}}{(R-2x)^2} = \frac{R^2 v}{(R-2x)^2}$

48. When an equiconvex lens ($\mu_{\text{lens}} = 1.5$) is placed over a plane mirror as shown, then object needle and its image coincide at 15 cm. When a liquid of refractive index μ is filled in the gap between mirror and lens, the object needle and its image coincide at 40 cm. Find the ref. index μ of the liquid.

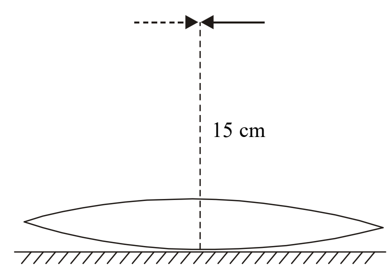


Fig. 29.50

(a) $\frac{8}{5}$ (b) $\frac{5}{8}$

(c) $\frac{13}{8}$ (d) $\frac{5}{13}$

(e) $\frac{13}{5}$

Solution (c) From case (i) we get $f_{\text{lens}} = 15$ cm

since $\mu_{\text{lens}} = 1.5$ $\therefore$ $f_{\text{lens}} = R_{\text{lens}} = 15$ cm

In case (ii) focal length of the combination = 40 cm [combination of lens + combination of (planoconcave) liquid lens].

$$\frac{1}{40} = \frac{1}{15} + \frac{1}{f_{\text{liquid lens}}}$$

or $\frac{1}{f_{\text{liq. lens}}} = -\frac{1}{15} + \frac{1}{40}$

$$f_{\text{liq. lens}} = -24 \text{ cm}$$

$$\frac{1}{f_{\text{liq. lens}}} = (\mu - 1)\left[\frac{1}{R} - \frac{1}{\infty}\right] \text{ or } \frac{1}{-24}$$

$$= (\mu - 1)\left[\frac{1}{-15}\right] \text{ or}$$

$$\mu = \frac{13}{8}$$

49. A particle executes SHM of amplitude 1 cm along principal axis of a convex lens of focal length 12 cm. The mean position of oscillation is at 20 cm from the lens. Find the amplitude of oscillation of the image of the particle.

(a) 2 cm (b) 2.6 cm

(c) 1 cm (d) 2.3 cm

Solution (d) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{v_1} = \frac{1}{12} - \frac{1}{21} = \frac{9}{21 \times 12}$$

or $v_1 = 28$ cm

$$\frac{1}{v_2} = \frac{1}{12} - \frac{1}{19} = \frac{7}{19 \times 12}$$

or $v_2 = \frac{19 \times 12}{7} = \frac{228}{7} = 32.6$ cm

$$\Delta x = 32.6 - 28 = 4.6 \text{ cm amplitude} = \frac{\Delta x}{2}$$

$$= 2.3 \text{ cm}$$

50. Object and screen are fixed 90 cm apart. The lens is displaced. Two sharp images are obtained when lens is at L_1 and L_2 respectively such that $I_1 = 4I_2$. Find the focal length of the lens.

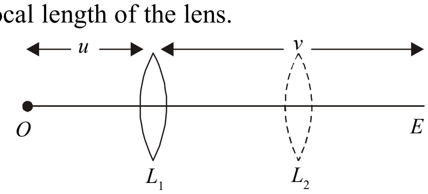


Fig. 29.51

(a) 18 cm (b) 15 cm

(c) 16 cm (d) 20 cm

Solution (d) $O = \sqrt{I_1 I_2} = 2\, I_2 = \frac{I_1}{2}$

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

$$v = 2u$$

$$v + u = 90 \text{ cm}$$

$$3u = 90 \text{ cm or } u = 30 \text{ cm}$$

$$\frac{1}{f} + \frac{1}{v} + \frac{1}{u} = \frac{1}{60} + \frac{1}{30} = \frac{3}{60}$$

or $f = 20$ cm

51. You are looking at the rim from the vertical side to see the opposite edge at the bottom of a 16 cm high and 8 cm diameter vessel. A friend fills it with a liquid of refractive index μ so that a coin placed at the centre becomes visible. What is the value of μ?

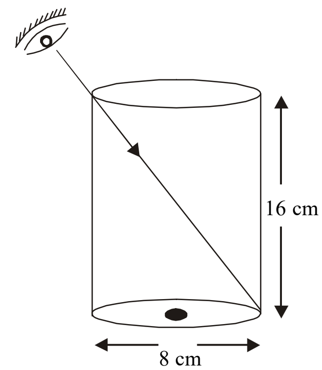


Fig. 29.52

(a) 1.34 (b) 1.6

(c) 1.73 (d) 1.84

Solution (d) $\tan i = \frac{1}{2}$ $\mu = \frac{\sin i}{\sin r} = \frac{1/\sqrt{5}}{1/\sqrt{17}}$

$$= \sqrt{\frac{17}{5}} = \sqrt{3.4} = 1.84$$

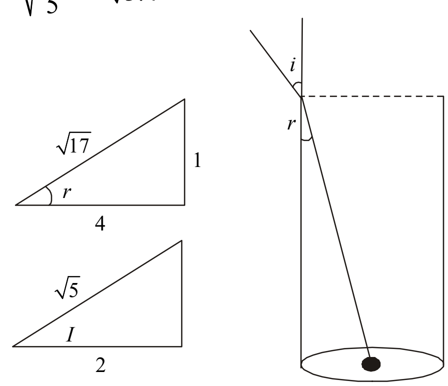


Fig. 29.53

52. A gun of mass M fires a bullet of mass m with a horizontal speed v. The gun is fitted with a concave mirror of focal length f facing towards the receding bullet. Find the speed of separation of the bullet and image just after the gun is fired.

Solution $m\nu = -M\nu'$ or $\nu' = \dfrac{-m\nu}{\mathrm{M}}$

$$\frac{dx}{dt} = \nu_{\text{bullet}} - \nu_{\text{gun}} = \left(1+\frac{m}{M}\right)\nu$$

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

or $$\frac{1}{y}-\frac{1}{x}=\frac{1}{-f}$$

or $$y = \frac{-xf}{f-x}$$

or $$\frac{dy}{dt} = \left[\frac{-f}{f-x}+\frac{fx}{(f-x)^2}\right] = \frac{dx}{dt}\left[\frac{-f^2}{(f-x)^2}\right]$$

Velocity of separation $\dfrac{dy}{dt}-\dfrac{dx}{dt} = \dfrac{dx}{dt}\left[\dfrac{-f^2}{(f-x)^2}-1\right]$

$$= \frac{dx}{dt}\left[\frac{-2f^2+2fx-x^2}{(f-x)^2}\right]$$

$$\underset{x\to 0}{Lt}\left|\frac{dy}{dt}-\frac{dx}{dt}\right| = \frac{2dx}{dt} = 2\left(1+\frac{m}{M}\right)\nu$$

53. At what angle should a ray of light be incident on the face of a prism of refracting angle 60° so that it just suffers total internal reflection at the other face. The refractive index of the prism is 1.524.

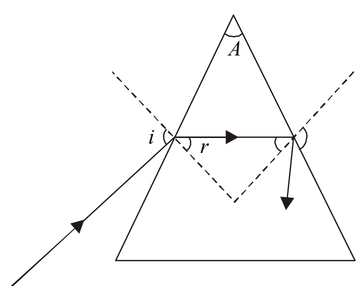


Fig. 29.54

(a) 30° (b) 40°
(c) 50° (d) 60°
(e) none of these

Solution (a) $\sin c = \dfrac{1}{\mu} = \dfrac{1}{1.524} = 0.65$ or $c = 40°30'$

$$r = 19°\,30' = [180° - 120° - 40°\,30']$$

$$\mu = \frac{\sin i}{\sin r} \text{ or } \sin i = 1.524 \sin 19°\,30'$$

$$= 1.524\,(.33\,40) = 0.5$$

or $i = 30°$

54. A crown glass prism of refracting angle 6° is to be used for deviation without dispersion with a flint glass of angle of prism α. Given: for crown glass $\mu_r = 1.513$ and $\mu_v = 1.523$, for flint glass $\mu_r = 1.645$ and $\mu_v = 1.665$. Find α.

(a) 3° (b) 4°
(c) 4.5° (d) 5°
(e) 6°

Solution (a) $\left(\mu_{v_1}-\mu_{r_1}\right)\alpha_1 = \left(\mu_{v_2}-\mu_{r_2}\right)\alpha_2$

or $$\alpha_2 = \frac{(1.523-1.513)}{(1.665-1.645)}\,6° = 3°.$$

55. Find the angle of incidence for which angle of deviation from a liquid drop is minimum in a primary rainbow.

(a) 30° (b) 40°
(c) 50° (d) 60°

Solution (d) $\sin i = \mu \sin r$ .... (1)

differentiating eq. (1) $\cos i\; di = \mu \cos r\; dr$

or $$\frac{dr}{di} = \frac{\cos i}{\mu\cos r} = \frac{1}{2}$$

or $2\cos i = \mu \cos r$

or $4\cos^2 i = \mu^2\cos^2 r = \mu^2(1-\sin^2 r)$

or $4\cos^2 i = \mu^2\left(1-\dfrac{\sin^2 i}{\mu^2}\right) = \mu^2 - (1-\cos^2 i)$

or $3\cos^2 i = \mu^2 - 1$

or $$\cos i = \sqrt{\frac{\mu^2-1}{3}} = \sqrt{\frac{\left(\frac{4}{3}\right)^2-1}{3}} = \sqrt{\frac{7}{27}}$$

or $\cos i = \sqrt{.26} = .5$

or $i \approx 60°$

PASSAGE 1

Read the following passage and answer the questions given at the end.

Since the objective lens merely forms an enlarged real image that is viewed by the eyepiece, the overall angular magnification M of the compound microscope is the product of the lateral magnification m_1 of the objective and the angular magnification M_2 of the eyepiece. The former is given by

$$m_1 = \frac{S_1'}{S_1}$$

where S_1 and S_1' are the object and image distances for the objective lens. Ordinarily the object is very close to the focus, resulting in an image whose distance from the objective is much larger than the focal length f_1. Thus S_1 is approximately equal to f_1 and $m_1 = -\dfrac{S_1'}{f_1}$, approximately. The angular magnification of the eyepiece from $M = \dfrac{u'}{u}$ $= \dfrac{y/f}{y/25} = \dfrac{25}{f}$ (f in centimeters) is $M_2 = 25$ cm/f_2, where f_2 is the focal length of the eyepiece, considered as a simple lens. Hence the overall magnification M of the compound microscope is, apart from a negative sign, which is customarily ignored,

$$M = m_1 M_2 = \frac{(25\text{cm})S_1'}{f}$$

1. What is the resolving power of the instrument whose magnifying power is given in the passage?

(a) $\dfrac{\mu \sin\theta}{.61\lambda}$ (b) $\dfrac{\mu \sin\theta}{1.22\lambda}$

(c) $\dfrac{\mu \sin\theta}{\lambda}$ (d) $\dfrac{\sin\theta}{1.22\lambda}$

2. How can resolving power of the instrument be increased?

(a) use UV light (b) immerse in oil

(c) use IR light (d) use one more lens.

3. The magnifying power given in the paragraph is approximate. What is maximum magnification?

(a) $\dfrac{V_0}{u_0}\left(1+\dfrac{D}{f_e}\right)$ (b) $\dfrac{V_0}{u_0}\left(1-\dfrac{D}{f_e}\right)$

(c) $\dfrac{V_0}{u_0}\left(1+\dfrac{f_e}{D}\right)$ (d) $\dfrac{V_0}{u_0}\left(1-\dfrac{f_e}{D}\right)$

Solution **1.** (a)

Solution **2.** (a, b)

Solution **3.** (a)

PASSAGE 2

Read the following passage and answer the questions given at the end.

If a beam of light enters one end of a transparent rod as in Fig. 29.55 the light is totally reflected internally and is "trapped" within the rod even if it is curved, provided the curvature is not too great. The rod is sometimes referred to as a light pipe. A bundle of fine fibers will behave in the same way and has the advatage of being flexible. The study of the properties of such a bundle is an active field of research known as fiber optics.

A bundle may consist of thousands of individual fibers, each of the order of 0.002 to 0.01 mm in diameter. If the fibers can be assembled in the bundle so that the relative positions of the ends are the same at both ends, the bundle can transmit an image as shown in Fig. 29.55 (b). Bundles several km in length have been made. Devices using fiber optics are finding a wide range of applications in medical science.The interior of lungs and other passages in the human body can be viewed by insertion of a fiber bundle that can be enclosed in a hypodermic needle for the study of tissues and blood vessels far beneath the skin. Despite the enormus technical difficulties of manufacturing fiber-optic components, such systems promise to become an extremely important class of optical systems.

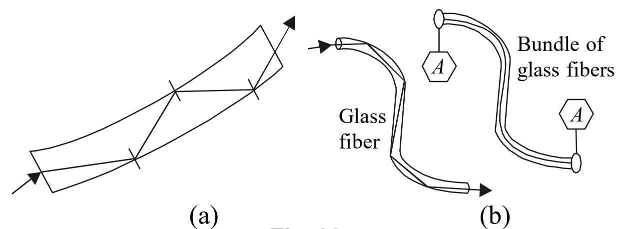


Fig. 29.55

1. What are the losses in fiber optic?

(a) Brillouin zone and Raman scattering

(b) polarisation (c) Evanscent field

(d) diffraction

2. What is the maximum range upto which fiber optic can be used without repeater in communication systems?

(a) 4 km (b) 10 km

(c) 100 km (d) 500 km

3. Differential refractive index is used in core to minimise loss due to

(a) Evanscent field (b) diffraction

(c) polarisation (d) interference

4. If parabolic profile is used for refractive index in the core, what is the name given to such core?

(a) single mode core

(b) multi mode core

(c) differential mode core

(d) curvilinear differential core

Solution **1.** (a), (b), (c), (d)

Solution **2.** (c) with optical amplifiers upto 500 km.

Solution **3.** (b)

Solution **4.** (d)

PASSAGE 3

Read the following passage and answer the questions given at the end.

Several common defects of vision result from an incorrect relation between the parts of the optical system of the eye. A normal eye forms an image on the retina of an object at infinity when the eye is relaxed as in Fig. 29.54 (a). In the myopic (nearsighted) eye, the eye ball is too long from front to back in comparison with the radius of curvature of the cornea, and rays from an object at infinity are focused in front of the retina. The most disant object for which an image can be formed on the retina is then nearer than infinity. In the hyperopic (farsighted) eye, the eye ball is too short and the image of an infinitely distant object would be formed behind the retina. By accommodation, these parallel rays may be made to converge on the retina, but evidently, if the range of accomodation is normal, the near point will be more distant than that of a normal eye. The myopic eye produces too much convergence in a parallel bundle of rays for an image to be formed on the retina; the hyperopic eye, not enough convergence.

Astigmatism refers to a defect in which the surface of the cornea is not spherical, but is more sharply curved in one plane than another. (It should not be confused with the lens aberration of the same name, which applies to the behavior, after passing through a lens having spherical surfaces, of rays making a large angle with the axis) Astigmatism makes it impossible, for example, to focus clearly on the horizontal and vertical bars of a window at the same time.

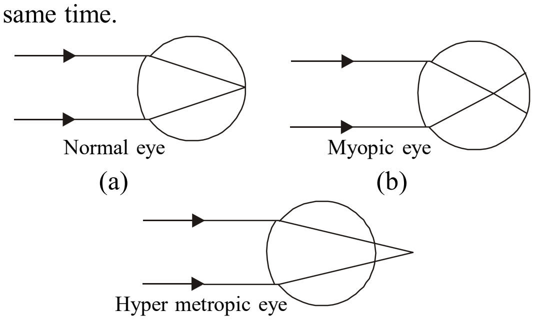


Fig. 29.56

1. Which type of defect cannot be corrected?

   (a) astigmatism (b) night blindness
   (c) cataract (d) colourblindness

2. Using LASIK we can treat

   (a) astigmatism (b) hypermetropia
   (c) myopia (d) colour blindness

Solution **1.** (b), (d)

Solution **2.** (a), (b), (c)

PASSAGE 4

Read the following passage and answer the questions given at the end.

After a long day of driving you take a late night swim in a swimming pool in your hotel. When you go to your room you find that you have lost the key of your room in the pool. You borrow a powerful flash light from the hotel manager and work around the pool, shining the light into it. The light shines on the key which is lying at surface and is directed at the bottom of the pool when the flash light is held 1.2 m above the surface a horizontal distance of 1.5 m from the edge. Water is 4m deep.

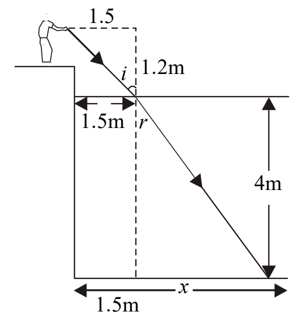


Fig. 29.57

1. How far is the key from the edge of the pool?

   (a) 4 m (b) 4.16 m
   (c) 4.86 m (d) 4.36 m

2. Where does the key appear?

   (a) < 4.36 m (b) = 4.36 m
   (c) > 4.36 m (d) none of these

3. A person in the position of key looks to the person holding flashlight. He appears to be at a distance

   (a) less than usual (b) greater than actual
   (c) equal to the actual (d) none

Solution **1.** (d) $\tan i = \frac{1.5}{1.2} = \frac{5}{4}$

$$\sin i = \frac{5}{\sqrt{41}}$$

$$\sin r = \frac{5}{\sqrt{41} \times \frac{4}{3}} = \frac{15}{4\sqrt{41}}$$

$$\tan r = \frac{x}{4} = \frac{15}{\sqrt{431}} \Rightarrow x = 2.86\,m$$

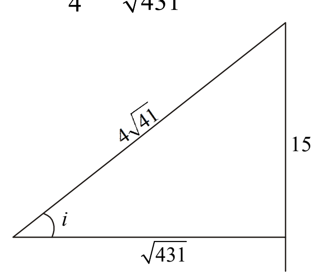


Fig. 29.58

$$x = 1.5 + 2.86 = 4.36\,m$$

Solution **2.** (a)

Solution **3.** (b) When ray passes from a denser to rarer medium, the distance appears to increase.

QUESTIONS FOR PRACTICE

1. A stationary swimmer S, inside a liquid of refractive index μ_1, is at a distance d from a fixed point P inside the liquid. A rectangular block of width t and refractive index μ_2 ($\mu_2 < \mu_1$) is now placed between S and P. S will observe P to be at a distance

(a) $d - t\left(\frac{\mu_1}{\mu_2} - 1\right)$ (b) $d - t\left(1 - \frac{\mu_2}{\mu_1}\right)$

(c) $d + t\left(1 - \frac{\mu_2}{\mu_1}\right)$ (d) $d + t\left(\frac{\mu_2}{\mu_1} - 1\right)$

2.

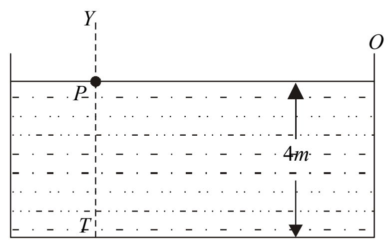
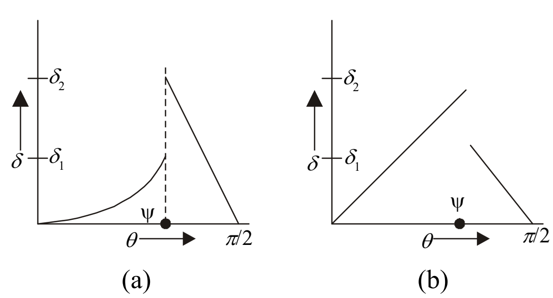


Fig. 29.59

T is a point at the bottom of a tank filled with water, as shown. The refractive index of water is $\frac{4}{3}$. YPT is the vertical line through T. To an observer at the position O, T will appear to be

(a) to the left of YT
(b) somewhere on YT
(c) at a depth 3 m below T
(d) at a depth < 3 m below T

3. A ray of light travels from a medium of refractive index μ to air. Its angle of incidence in the medium is θ, measured from the normal to the boundary, and its angle of deviation is δ. δ is plotted against θ. Which of the following best represents the resulting curve?



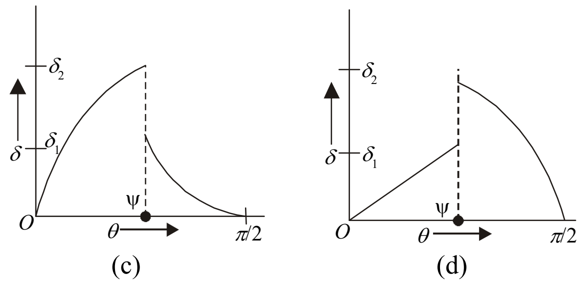


Fig. 29.60

4. A thin, symmetric double-convex lens of power P is cut into three parts A, B and C as shown. The power of

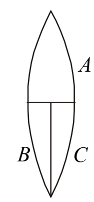


Fig. 29.61

(a) A is P (b) A is $2P$

(c) B is $\frac{P}{2}$ (d) B is $\frac{P}{4}$

5.

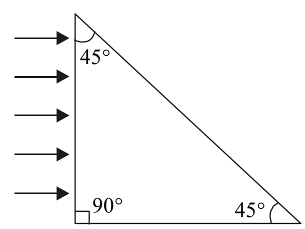


Fig. 29.62

A beam of light, consisting of red, green and blue colours, is incident on a right-angled prism, as shown. The refractive indices 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 colour from the green and blue colours
(b) separate part of the blue colour from the red and green colours
(c) separate all the three colours from one another
(d) not separate even partially any colour from the other two colours

6. A watch glass has uniform thickness, and the average radius of curvature of its two surfaces is much larger than its thickness. It is placed in the path of a beam of parallel light. The beam will

(a) converge slightly
(b) diverge slightly
(c) be completely unaffected
(d) converge or diverge slightly depending on whether the beam is incident from the concave or the convex side

7. A ray of light enters a medium of refractive index μ from air. Its angle of incidence is θ(normal to boundary) and angle of deviation is

(a) $\psi = \sin^{-1}\left(\frac{1}{\mu}\right)$ (b) $\psi = \frac{\pi}{2} - \sin^{-1}\left(\frac{1}{\mu}\right)$

(c) $\frac{\delta_2}{\delta_1} = \mu$ (d) $\frac{\delta_2}{\delta_1} = 2$

8. A thin concavo-convex lens has two surfaces of radii of curvature R and $2R$. The material of the lens has a refractive index μ. When kept in air, the focal length of the lens

(a) will depend on the direction from which light is incident on it
(b) will be the same, irrespective of the direction from which light is incident on it
(c) will be equal to $\frac{R}{\mu - 1}$
(d) will be equal to $\frac{2R}{\mu - 1}$

9. A ray of light travelling in a transparent medium falls on a surface separating the medium from air, at an angle of 45°. The ray undergoes total internal reflection. If n is the refractive index of the medium with respect to air, select the possible values of n from the following.

(a) 1.3 (b) 1.4
(c) 1.5 (d) 1.6

10. A solid, transparent sphere has a small, opaque dot at its centre. When observed from outside, the apparent position of the dot will be

(a) closer to the eye than its actual position
(b) farther away from the eye than its actual position
(c) the same as its actual position
(d) independent of the refractive index of the sphere

11. If a glass prism is dipped in water, its dispersive power

(a) increases (b) decreases
(c) does not change
(d) may increase or decrease depending on whether the angle of the prism is less than or greater than 60°.

12. 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.

13. A prism can produce a minimum deviation δ in a light beam. If three such prisms are combined, the minimum deviation that can be produced in this beam is

(a) 0 (b) δ
(c) 2δ (d) 3δ.

14. The focal length of a converging lens are f_v and f_r for violet and red light respectively.

(a) $f_v > f_r$ (b) $f_v = f_r$ (c) $f_v < f_r$
(d) Any of the three is possible depending on the value of the average refractive index μ.

15. In producing a pure spectrum, the incident light is passed through a narrow slit placed in the focal plane of an achromatic lens because a narrow slit

(a) produces less diffraction
(b) increases intensity
(c) allows only one colour at a time
(d) allows a more parallel beam when it passes through the lens.

16. Which of the following quantities increase when wavelength is increased? Consider only the magnitudes.

(a) The power of a converging lens.
(b) The focal length of a converging lens.
(c) The power of a diverging lens.
(d) The focal length of a diverging lens.

17. A narrow beam of white light goes through a slab having parallel faces.

(a) The light never splits in different colours.
(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.

18. Consider the following two statements:

(A) Line spectra contain information about atoms.
(B) Band spectra contain information about molecules.

(a) Both A and B are wrong
(b) A is correct but B is wrong
(c) B is correct but A is wrong
(d) Both A and B are correct.

19. Which of the following quantities related to a lens depend on the wavelength or wavelengths of the incident light?

(a) Power. (b) Focal length.

(c) Chromatic aberration. (d) Radii of curvature.

20. If the light moving in a straight line bends by a small but fixed angle, it may be a case of

(a) reflection (b) refraction

(c) diffraction (d) dispersion.

21. Consider three converging lenses L_1, L_2 and L_3 having identical geometrical construction. The index of refraction of L_1 and L_2 are μ_1 and μ_2 respectively. The upper half of the lens L_3 has a refractive index μ_1 and the lower half has μ_2 (Fig. 29.63). A point object O is imaged at O_1 by the lens L_1 and at O_2 by the lens L_2 placed in same position. If L_3 is placed at the same place,

(a) there will be an image at O_1

(b) there will be an image at O_2

(c) the only image will form somewhere between O_1 and O_2

(d) the only image will form away from O_2.

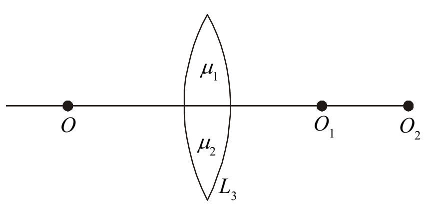


Fig. 29.63

22. Choose 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.

23. A convex lens forms a real image of a point object placed on its principal axis. If the upper half of the lens is painted black,

(a) the image will be shifted downward

(b) the image will be shifted upward

(c) the image will not be shifted

(d) the intensity of the image will decrease

24. A screen is placed a distance 40 cm away from an illuminated object. A converging lens is placed between the source and the screen and it is attempted to form the image of the source on the screen. If no position could be found, the focal length of the lens

(a) must be less than 10 cm

(b) must be greater than 20 cm

(c) must not be greater than 20 cm

(d) must not be less than 10 cm

25. The image of an extended object, placed perpendicular to the principal axis of a mirror, will be erect if

(a) the object and the image are both real

(b) the object and the image are both virtual

(c) the object is real but the image is virtual

(d) the object is virtual but the image is real

26. Which of the following (referred to a spherical mirror) do (does) not depend on whether the rays are paraxial or not?

(a) Pole (b) Focus

(c) Radius of curvature (d) Principal axis

27. If a convergent beam of light passes through a diverging lens, the result

(a) may be a convergent beam

(b) may be a divergent beam

(c) may be a parallel beam

(d) must be a parallel beam

28. A concave mirror is placed on a horizontal table with its axis directed vertically upwards. Let O be the pole of the mirror and C be its centre of curvature. A point object is placed at C, whose real image is also formed at C. If the mirror is now filled with water, the image will be

(a) real, and will remain at C

(b) real, and will be located above C

(c) virtual, and will be located below O

(d) real, and will be located between C and O

29. Which of the following form virtual and erect images for all positions of the object?

(a) Convex lens (b) Concave lens

(c) Convex mirror (d) Concave mirror

30. A diverging lens of focal length f_1 is placed in front of and coaxially with a concave mirror of focal length f_2. Their separation is d. A parallel beam of light incident on the lens returns as a parallel beam from the arrangement.

(a) The beam diameters of the incident and reflected beams must be the same.

(b) $d = 2|f_2| - |f_1|$

(c) $d = |f_2| - |f_1|$

(d) If the entire arrangement is immersed in water, the conditions will remain unaltered.

31. Two thin lenses, when in contact, produce a combined power + 10 dioptres. When they are 0.25 m apart, the power reduces to + 6 dioptres. The powers of the lenses in dioptres, are

(a) 1 and 9 (b) 2 and 8
(c) 4 and 6 (d) 5 each

32.

Fig. 29.64

Two points P and Q lie on either side of an axis XY as shown. It is desired to produce an image of P at Q using a spherical mirror, with XY as the optic axis. The mirror must be

(a) converging (b) diverging
(c) positioned to the left of P
(d) positioned to the right of Q

33. A converging lens of focal length f_1 is placed in front of and coaxially with a convex mirror of focal length f_2. Their separation is d. A parallel beam of light incident on the lens returns as a parallel beam from the arrangement.

(a) The beam diameters of the incident and reflected beams must be the same.
(b) $d = f_1 - 2\,|f_2|$
(c) $d = f_1 - |f_2|$
(d) If the entire arrangement is immersed in water, the conditions will remain unaltered.

34. An object and a screen are fixed at a distance d apart. When a lens of focal length f is moved between the object and the screen, sharp images of the object are formed on the screen for two positions of the lens. The magnifications produced at these two positions are M_1 and M_2.

(a) $d > 2f$ (b) $d > 4f$
(c) $M_1M_2 = 1$ (d) $|M_1| - |M_2| = 1$

35. If a converging beam of light is incident on a concave mirror, the reflected light

(a) may form a real image
(b) must form a real image
(c) may be a parallel beam
(d) may form a virtual image

36. The size of an object as perceived by an eye depends primarily on

(a) actual size of the object
(b) distance of the object from the eye
(c) aperture of the pupil
(d) size of the image formed on the retina

37. When we see an object, the image formed on the retina is

(a) real (b) virtual
(c) erect (d) inverted

38. A normal eye is not able to see objects closer than 25 cm because

(a) the focal length of the eye is 25 cm
(b) the distance of the retina from the eye-lens is 25 cm
(c) the eye is not able to decrease the distance between the eye-lens and the retina beyond a limit
(d) the eye is not able to decrease the focal length beyond a limit

39. An object is placed at a distance u from a simple microscope of focal length f. The angular magnification obtained depends

(a) on f but not on u (b) on u but not on f
(c) on f as well as u (d) neither on f nor on u.

40. The focal length of a normal eye-lens is about

(a) 1 mm (b) 2 cm
(c) 25 cm (d) 1 m.

41. The muscles of a normal eye are least strained when the eye is focused on an object

(a) far away from the eye
(b) very close to the eye
(c) at about 25 cm from the eye
(d) at about 1 m from the eye.

42. A person A can clearly see objects between 25 cm and 200 cm. Which of the following may represent the range of clear vision for a person B having muscles stronger than A, but all other parameters of eye identical to that of A?

(a) 25 cm to 200 cm (b) 18 cm to 200 cm
(c) 25 cm to 300 cm (d) 18 cm to 300 cm.

43. In which of the following is the final image erect?

(a) Simple microscope.
(b) Compound microscope.
(c) Astronomical telescope.
(d) Galilean telescope.

44. A man is looking at a small object placed at his near point. Without altering the position of his eye or the object, he puts a simple microscope of magnifying power 5 X before his eyes. The angular magnification achieved is

(a) 5 (b) 2.5

(c) 1 (d) 0.2

45. The focal length of the objective of a compound microscope is f_0 and its distance from the eyepiece is L. The object is placed at a distance u from the objective. For proper working of the instrument,

(a) $L < u$ (b) $L > u$

(c) $f_0 < L < 2f_0$ (d) $L > 2f_0$.

46. When objects at different distances are seen by the eye, which of the following remain constant?

(a) The focal length of the eye-lens.

(b) The object-distance from the eye-lens.

(c) The radii of curvature of the eye-lens.

(d) The image-distance from the eye_lens.

47. The maximum focal length of the eye-lens of a person is greater than its distance from the retina. The eye is

(a) always strained in looking at an object

(b) strained for objects at large distances only

(c) strained for objects at short distances only

(d) unstrained for all distances

48. To increase the angular magnification of a simple microscope, one should increase

(a) the focal length of the lens

(b) the power of the lens

(c) the aperture of the lens

(d) the object size

49. A thin biconvex lens of focal length f is used to form a circular image of the sun on a screen placed in its focal plane. The radius of the image formed on the screen is r. Then

(a) $\pi r^2 \propto f$ (b) $\pi r^2 \propto f^2$

(c) If the focal length of the lens is doubled keeping its aperture constant, the brightness of the image will increase

(d) If half of the lens is covered the area of image will become $\frac{\pi r^2}{2}$

[IIT 2006]

50.

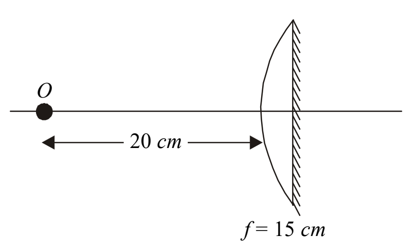


Fig. 29.63

An object is placed 20 cm in front of a plano convex lens of focal length 15 cm. The plane surface of the lnes is silvered. The image will be formed at a distance

[IIT 2006]

(a) 60 cm to the left of the lens

(b) 60 cm to the right of the lens

(c) 12 cm to the left of the lens

(d) 12 cm to the right of the lens.

51. The distance of the eye-lens from the retina is x. For a normal eye, the maximum focal length of the eye-lens

(a) $= x$ (b) $< x$

(c) $> x$ (d) $= 2x$.

52. A single converging lens is used as a simple microscope. In the position of maximum magnification,

(a) the object is placed at the focus of the lens

(b) the object is placed between the lens and its focus

(c) the image is formed at infinty

(d) the object and the image subtend the same angle at the eye

53. A point object P moves towards a convex mirror with a constant speed v, along its optic axis. The speed of the image

(a) is always $< v$

(b) may be $>$, $=$ or $< v$ depending on the position of P

(c) increases as P comes closer to the mirror

(d) decreases as P comes closer to the mirror

54. An astronomical telescope and a Galilean telescope use identical objective lenses. They have the same magnification, when both are in normal adjustment. The eyepiece of the astronomical telescope has a focal length f.

(a) The tube lengths of the two telescopes differ by f.

(b) The tube lengths of the two telescopes differ by $2f$.

(c) The Galilean telescope has shorter tube length.

(d) The Galilean telescope has longer tube length.

55. A ray of white light passes through a rectangular glass slab, entering and emerging at parallel faces. The angle of incidence, measured from the normal to the glass surface, is large.

(a) White light will emerge from the slab.

(b) The light emerging from the slab will have a number of parallel, coloured rays.

(c) The emergent rays will not form a spectrum on a screen.

(d) Colours will be seen if the emergent rays enter the eye directly.

56. A battery-operated torch is adjusted to send an almost parallel beam of light. It produces an illuminance of 40 lux when the light falls on a wall 2 m away. The illuminance produced when it falls on a wall 4 m away is close to

(a) 40 lux (b) 20 lux
(c) 10 lux (d) 5 lux

57. Light from a point source falls on a screen. If the separation between the source and the screen is increased by 1%, the illuminance will decrease (nearly) by

(a) 0.5% (b) 1%
(c) 2% (d) 4%

58. The brightness producing capacity of a source

(a) does not depend on its power
(b) does not depend on the wavelength emitted
(c) depends on its power
(d) depends on the wavelength emitted.

59. Figure (29.65) shows a glowing mercury tube. The intensities at point A, B and C are related as

(a) $B > C > A$ (b) $A > C > B$
(c) $B = C > A$ (d) $B = C < A$.

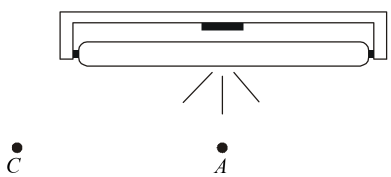


Fig. 29.65

60. The one parameter that determines the brightness of a light source sensed by an eye is

(a) energy of light entering the eye per second
(b) wavelength of the light
(c) total radiant flux entering the eye
(d) total luminous flux entering the eye

61. The intensity produced by a long cylindrical light source at a small distance r from the source is proportional to

(a) $\frac{1}{r^2}$ (b) $\frac{1}{r^3}$
(c) $\frac{1}{r}$ (d) none of these.

62. A room is illuminated by an extended source. The illuminance at a particular portion of a wall can be increased by

(a) moving the source (b) rotating the source
(c) bringing some mirrors in proper positions
(d) changing the colour of the source.

63. A point source of light moves in a straight line parallel to a plane table. Consider a small portion of the table directly below the line of movement of the source. The illuminance at this portion varies with its distance r from the source as

(a) $I \propto \frac{1}{r}$ (b) $I \propto \frac{1}{r^2}$
(c) $I \propto \frac{1}{r^3}$ (d) $I \propto \frac{1}{r^4}$

64. An electric bulb is hanging over a table at a height of 1 m above it. The illuminance on the table directly below the bulb is 40 lux. the illuminance at a point on the table 1 m away from the first point will be about

(a) 10 lux (b) 14 lux
(c) 20 lux (d) 28 lux

65. A photographic plate is placed directly in front of a small diffused source in the shape of a circular disc. It takes 12 s to get a good exposure. If the source is rotated by 60° about one of its diameters, the time needed to get the same exposure will be

(a) 6 s (b) 12 s
(c) 24 s (d) 48 s.

66. Choose the correct options.

(a) The luminous efficiency of a monochromatic source is always greater than that of a white light source of same power.
(b) The luminous efficiency of a monochromatic source of wavelength 555 nm is always greater than that of a white light source of same power.
(c) The illuminating power of a monochromatic source is always greater than that of a white light source of same power.

67. A photographic plate placed at a distance of 5 cm from a weak point source is exposed for 3 s. If the plate is kept at a distance of 10 cm from the source, the time needed for the same exposure is

(a) 3 s (b) 12 s
(c) 24 s (d) 48 s.

68. Choose the correct options.

(a) Luminous flux and radiant flux have same dimensions.
(b) Luminous flux and luminous intensity have same dimensions.
(c) Radiant flux and power have same dimensions.
(d) Relative luminosity is a dimensionless quantity.

69. Three light sources A, B and C emit equal amount of radiant energy per unit time. The wavelengths emitted by the three sources are 450 nm, 555 nm and 700 nm respectively. The brightness sensed by an eye for the sources are X_A, X_B and X_C respectively. Then,

(a) $X_A > X_B, X_C > X_B$ (b) $X_A > X_B, X_B > X_C$
(c) $X_B > X_A, X_B > X_C$ (d) $X_B > X_A, X_C > X_B$

70. As the wavelength is increased from violet to red, the luminosity
(a) continuously increases
(b) continuously decreases
(c) increases, then decreases
(d) decreases, then increases.

71. The danger signals are made red because
(a) people may get frightened
(b) our eyes are most sensitive to red colour
(c) the red colour is scattered maximum
(d) the red colour is scattered minimum

72. The refracting angle of the prism is 4.5° and its refractive index is 1.52. The angle of minimum deviation will be
(a) 2° (b) 2.3°
(c) 4.5° (d) 1.5°

73. The angle of the prism for which there is no emergent ray will be, if its critical angle is i_c
(a) greater than i_c (b) less than i_c
(c) 2 i_c (d) greater than 2 i_c

74. A ray of light is incident on a glass slab of refractive index 1.52. If the reflected and refracted rays of light are mutually perpendicular to each other then the angle of incidence will be
(a) 90° (b) 60°
(c) 56°40' (d) 19°58'

75. A fish looks outside water. It is situated at a depth of 12 cm below water surface. If the refractive index of water is 4/3 then the radius of the circle through which it can see will be
(a) $12 \times \frac{3}{\sqrt{7}}$ cm (b) 12×3 cm
(c) $12 \times 3\sqrt{5}$ cm (d) $12 \times \frac{\sqrt{5}}{3}$

76. The cause of mirage in desert areas is
(a) the refractive index of atmosphere decreases with height
(b) the refractive index of atmosphere increases with height
(c) the refractive index of atmosphere does not change with height
(d) scattering

77. A glass plate inside a colourless liquid becomes invisible because
(a) the densities of both are same
(b) the refractive indices of both are same
(c) the colours of both are same
(d) liquid wets glass surface

78. An equilateral prism is lying on the prism table of a spectrometer in minimum deviation position. If the angle of incidence is 60° then the angle of deviation will be.
(a) 90° (b) 60°
(c) 45° (d) 30°

79. When a ray of light enters from one medium to another its velocity in second medium becomes double. The maximum value of angle of incidence so that total internal reflection may not take place will be
(a) 60° (b) 180°
(c) 90° (d) 30°

80. A beam of light is incident at point 1 on a screen. A plane glass plate of thickness t and refractive index n is placed in the path of light. The displacement of point will be
(a) $t\left(1-\frac{1}{n}\right)$ *nearer* (b) $t\left(1+\frac{1}{n}\right)$ *nearer*
(c) $t\left(1-\frac{1}{n}\right)$ *farther* (d) $t\left(1+\frac{1}{n}\right)$ *farther*

81. The relation between energy E and momentum p of a photon is
(a) $E = pc$ (b) $E = \frac{p}{c}$
(c) $p = Ec$ (d) $E = \frac{p^2}{c}$

82. The effective mass of photon of wavelength 40 Å will be
(a) 55.2×10^{-35} Kg (b) 55.2×10^{-33} gm
(c) 55.2×10^{-17} Kg (d) 55.2×10^{-38} Kg

83. The momentum of photon of frequency 10^{14} Hz will be
(a) 2.2×10^{-26} Kg/m/sec (b) 2.21×10^{-28} Kg/m/sec
(c) 10^{-28} Kg/m/sec (d) 0.21×10^{-2} Kg/m/sec

84. A ray of light takes 10^{-19} second to cross a glass slab of refractive index 1.5. The thickness of the slab will be

(a) 10 cm (b) 20 cm
(c) 30 cm (d) 40 cm

85. If the frequencies of an ultrasonic wave and an electromagnetic wave are same, then
(a) their wavelengths will be same
(b) wavelength of electromagnetic wave will be less than that of ultrasonic wave
(c) wavelength of electromagnetic wave will be more than that of ultrasonic wave
(d) the wavelengths of both will be nearly equal

86. The Poynting vector for an electromagnetic wave is
(a) $\vec{S} = \vec{E} \times \vec{H}$ (b) $\vec{S} = \vec{E} \times \vec{B}$
(c) $\vec{S} = \left(\vec{E} \times \vec{H}\right)/2$ (d) $\vec{S} = \left(\vec{E} \times \vec{B}\right)/2$

87. The total energy density for an electromagnetic wave in vacuum is
(a) $e_0 \dfrac{E^2}{3}$ (b) $e_0 E^2$
(c) $\dfrac{\varepsilon_0 E^2}{2}$ (d) $\dfrac{E^2}{\varepsilon_0}$

88. If radiations are incident obliquely on a perfectly reflecting surface then the pressure exerted by radiation on the surface will be
(a) $\dfrac{2}{3}\, e_0 E^2$ (b) $\dfrac{1}{3}\, e_0 E^2$
(c) $e_0 E^2$ (d) $\dfrac{\varepsilon_0 E^2}{4}$

89. Out of the following, whose velocity is equal to that of light?
(a) of *b*-rays (b) of sound waves
(c) of ultrasonic waves (d) of thermal waves

90. The correct formula for intensity of electromagnetic wave is
(a) $I = \langle P \rangle$ (b) $I = c \langle u \rangle$
(c) $I = \dfrac{\varepsilon_0 E^2}{2}$ (d) $I = \dfrac{\varepsilon_0 E^2}{4}$

91. The hours in a clock are marked by points. When it is put in front of a mirror and seen in the mirror, then time noted is 8.20 The correct time is
(a) 4 : 40 (b) 8 : 20
(c) 2 : 40 (d) 3 : 40

92. The correct curve between the energy of photon (E) and its wavelength (l) is

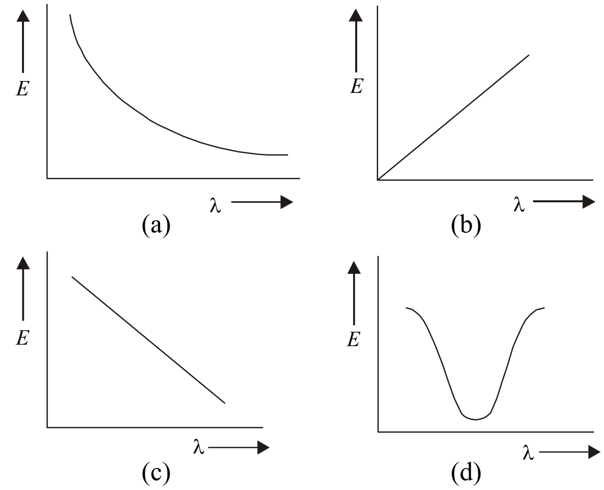


Fig. 29.66

93. All particles of a wave front vibrate
(a) in same phase (b) in opposite phase
(c) up and down (d) left and right

94. The unit of Poynting vector is
(a) Watt (b) Joule
(c) $\dfrac{\text{Watt}}{\text{m}^2}$ (d) $\dfrac{\text{Joule}}{\text{m}^2}$

95. For the propagation of electromagnetic waves
(a) Medium is required (b) no medium is required
(c) E and B are in mutually opposite phase
(d) E and B do not contriute

96. When a ray of light enters from air into water then its wavelength
(a) decreases (b) increases
(c) remains unchanged (d) becomes infinity

97. The value of $\dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$
(a) 3×10^6 m/s (b) 3×10^8 m/s
(c) 3×10^4 m/s (d) 332 m/s

98. The radius of a wavefront as the waves propagate
(a) decreases (b) increases
(c) becomes zero
(d) sometimes decreases and sometimes increases.

99. The ratio of E to B in electromagnetic waves is equal to
(a) c (b) $\dfrac{1}{c}$
(c) $4c$ (d) $\dfrac{1}{Z}$

100. The transverse nature of light waves is verified by
(a) reflection of light (b) polarisation of light
(c) refraction of light (d) interference of light

101. The velocity of light in a piece of matter is v. The thickness of the piece is t and its refractive index is μ. The distance travelled by light in air in time t/v is

(a) μt (b) μt^2

(c) μt^3 (d) μt^4

102. The spin of photon is

(a) $\hbar$ (b) $\frac{\hbar}{2}$

(c) $\frac{\hbar}{3}$ (d) none

103. The cause of shining in diamond is

(a) scattering of light

(b) refraction of light

(c) total internal reflection of light

(d) dispersion of light.

104. An optical fibre (m = 1.72) has coating of glass (m = 1.5). The critical angle for total internal reflection is

(a) $\sin^{-1}\left(\frac{75}{86}\right)$ (b) $\sin^{-1}\left(\frac{86}{75}\right)$

(c) $\sin^{-1}(0.8)$ (d) $\sin^{-1}(0.82)$.

105. Which of the following colours is scattered minimum?

(a) violet (b) blue

(c) red (d) yellow

106. The image in Fig shown Ts formed at

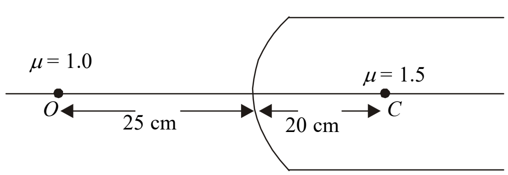


Fig. 29.67

(a) + 100 cm (b) – 100 cm

(c) + 80 cm (d) – 80 cm.

107. In the absence of atmosphere, the sky appears

(a) coloured (b) blue

(c) indigo (d) black

108. For total internal reflection the ray of light enters

(a) from rarer to denser medium

(b) from denser to rarer medium

(c) medium of same refractive index

(d) medium with same coefficient of reflection

109. The speeds of light in two media I and II are 2.2×10 m/s and 2.4×10^8 m/s respectively. The critical angle for light refracting from I to II medium will be

(a) $\sin -\frac{112}{11}$ (b) $\sin -\frac{111}{12}$

(c) $\sin -\frac{121}{24}$ (d) $\sin -\frac{124}{21}$

110. If $n_{ag} = 3/2$ and $n_{aw} = 4/3$, then the refractive index of glass with respect to water will be

(a) $\frac{9}{8}$ (b) $\frac{8}{9}$

(c) 4 (d) $\frac{1}{4}$

111. If the refractive index of water is 4/3 and that of glass is 5/3, then the critical angle of light entering from glass into water will be

(a) $\sin -\frac{14}{5}$ (b) $\sin -\frac{15}{4}$

(c) $\sin -\frac{11}{2}$ (d) $\sin -\frac{12}{1}$

112. A ray of light is incident on an equilateral prism in such a way that the angle of incidence is equal to the angle of emergence and each is equal to 3/4 of the prism angle. The angle of deviation for the ray of light is

(a) 45° (b) 30°

(c) 39° (d) 20°

113. An equilateral prism has μ = 1.732. The angle of incidence for minimum deviation is

(a) 60° (b) 30°

(c) 45° (d) none of these

114. A biconvex lens has focal length of 25 cm. The radius of curvature of one the surfaces is double of the other. Find the radii. Given μ_{lens} = 1.5

(a) 37.5 cm, 75 cm (b) 18.75 cm, 37.5 cm

(c) 7.5 cm, 15 cm (d) 15 cm, 30 cm

115. The sun appears elliptical before sun set because of

(a) refraction (b) reflection

(c) scattering

(d) sun contracts itself at that time.

116. Sunlight can undergo internal reflection if it enters from

(a) glass to air (b) air to glass

(c) air to water (d) water to glass.

117. The ratio of refractive indices of red and blue light in air will be

(a) $n_{12} < 1$ (b) $n_{12} > 1$

(c) $n_{12} = 1$ (d) $n_{12} = 8$

118. The refractive index of diamond is 2. The velocity of light (in cm/sec) in diamond will be

(a) 1.5×10^{10} (b) 2×10^{13}
(c) 6×10^{10} (d) 3×10^{10}

119. When a ray of light is made incident upon an isosceles right angle prism, then the following event takes place:
(a) reflection (b) total internal reflection
(c) refraction (d) dispersion

120. You have to design a compound microscope with objective lens of focal length 1 cm. The object should be placed at _____ distance from the lens.
(a) 8 mm (b) 11 mm
(c) 22 mm (d) 2 cm.

121. A 5 D lens forms an image four times the size of an object. The objects distance is
(a) 15 cm (b) 16 cm
(c) 18 cm (d) 12.5 cm.

122. A pencil dipped partially into water appears bent because of
(a) reflection at water surface
(b) diffraction at water surface
(c) refraction at water surface
(d) water is flowing

123. A particle is moving with a speed v along the principal axis towards a concave mirror of radius of curvature R. The speed of the image as observed is
(a) $\frac{R^2 v}{(2x-R)^2}$ (b) $\frac{R^2 v}{(x-R)^2}$
(c) $\frac{2R^2 v}{(2x-R)^2}$ (d) $\frac{R^2 v}{2(x-R)^2}$

124. The correct curve between refractive index n and wavelength A will be

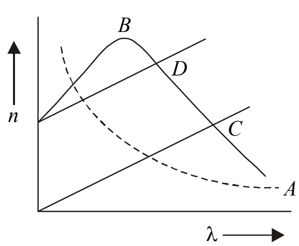


Fig. 29.68

(a) A (b) D
(c) B (d) C

125. A red flower when viewed through blue light appears
(a) red (b) blue
(c) black (d) violet

126. The frequency and wavelength of light in a material are 4×10^{14} Hz and 5×10^{-7} meter. The refractive index of material is
(a) 1.33 (b) 1.5
(c) 1 (d) 0.77

127. Electromagnetic flux of 1380 watt/m^2 is obtained on earth from the sun. The total power incident on 25 m × 50 m surface will be
(a) 1.725×10^6 watt (b) 3.45×10^6 watt
(c) 6.9×10^6 watt (d) 1.38×10^7 watt

128. An astronomical telescope with magnification 50 is to be designed in normal adjustment. Length of the tube is 102 cm. The powers of objective and eyepiece are repectively
(a) 2 D, 50 D (b) 1.5 D, 20 D
(c) 1 D, 40 D (d) 1 D, 50 D

129. The maximum value of E in an electromagnetic wave propagating in X-direction is 1000 Newton/Coulomb which is in Z direction. The value of magnetic field at that point will be (in Wb/m^2)
(a) 7.5×10^{-6} in X-direction
(b) 3.33×10^{-6} in Y-direction
(c) 6×10^{-7} in Z-direction
(d) 10^{-5} in any other direction.

130. The maximum electric field at a distance of 11.2 m from a point source is 1.96 v/m. The maximum magnetic field will be (in nanotesla)
(a) 6.53 (b) 9.87
(c) 2.38 (d) 7.99

131. In Q. 130 the output power of the source will be
(a) 80.4 watt (b) 804 watt
(c) 0.804watt (d) 8.04 watt

132. The lens in the Fig. 29.69 is equiconvex ($\mu = 1.5$). The radius of curvature of the lens is

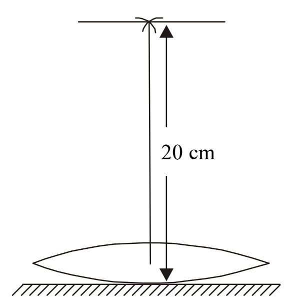


Fig. 29.69

(a) 15 cm (b) 20 cm
(c) 40 cm (d) none

133. Assume you are sitting in sun for 2.5 hours. The area of your body exposed normally to sun rays is 1.3 m^2. The intensity of sun rays is 1.1 kilowatt/m^2. If your body completely absorbs the sun rays then the momentum transferred to your body will be (in Kg-m/s)

(a) 0.043 (b) 0.037

(c) 0.61 (d) – 0.91

134. The value of electric field in an electromagnetic wave originating from a point source of light at a distance of 10 meter is $E = 500$ volt/m. The electric field at a distance of 5 meter will be

(a) 1000 Volt/meter (b) 200 Volt/meter

(c) 50 Volt/meter (d) 25 Volt/meter

135. If the relative permeability of a medium is μr and its dielectric constant is er then the velocity of light in that medium will be

(a) $\frac{1}{\sqrt{\mu_r \varepsilon_r}}$ (b) $\frac{1}{\sqrt{\mu_r \varepsilon_r}}$

(c) $\sqrt{\mu_r \varepsilon_r / \mu_{\varepsilon_0}}$ (d) $\sqrt{\mu_0 \varepsilon_0 / \mu_r \varepsilon_r}$

136. The correct statement from the following is:

(a) Light exhibits particle nature in propagation and wave nature in mutual interaction with matter.

(b) Light exhibits both wave nature and particle nature in mutual interaction with matter.

(c) Light exhibits both wave and particle nature in propagation.

(d) Light exhibits wave nature in propagation and panicle nature in mutual interaction with matter.

137. A sphere ($\mu = 1.5$) has a small bubble 6 cm from the centre. Radius of the sphere is 10 cm. When seen normally from shorter side the bubble appears

(a) 3 cm below the surface

(b) 3 cm above the surface

(c) 7 cm inside the surface

(d) 4.6 cm below the surface

138. A magnifying glass has $f = 12$ cm. Where shall an object be placed to produce maximum angular magnification? Least distance of clear vision = 25 cm.

(a) 7.1 cm (b) 6.8 cm

(c) 8.4 cm (d) 8.1 cm

139. A plane mirror and a concave mirror are 50 cm apart. An object is 30 cm from a concave mirror such that image of the two coincide. The focal length concave mirror is

(a) 21 cm (b) 18 cm

(c) 15 cm (d) none of these

140. Photon is a

(a) Fermion (b) Boson

(c) Nucleon (d) Baryon

141. The chromatic aberration in Huygen's eyepiece is corrected using $f_1 = 3 f_2$ and separation between the lenses is

(a) f_2 (b) $\frac{3}{2} f_2$

(c) $1.2 f_2$ (d) $2 f_2$

142. The correct statement out of the following is:

(a) The nature of elecrtromagnetic radiations in travelling from one place of another is wave nature.

(b) The nature of electromagnetic radiations in mutual interaction with matter is photon.

(c) The main cause of microwaves being unfit for vision is the particle nature of electromagnetic waves.

(d) All of above.

143. The correct statement out of the following is:

(a) The wave theory and quantum theory both are valid for the whole electromagnetic spectrum.

(b) Wave theory is valid for long wavelength region and quantum theory is valid for short wavelength region.

(c) Wave theory is valid for short wavelength region whereas the quantum theory is valid for long wavelength region.

(d) Wave theory and quantum theory both are valid for short wavelength region.

144. If the velocity of light in glass is 2×10^8 m/s then its velocity in water will be, if $n_g = 1.5$ and $n_w = 4/3$,

(a) 3×10^8 m/s (b) 2.66×10^8 m/s

(c) 1.5×10^5 m/s (d) 2.25×10^8 m/s

145. If the velocity of light in water is 2.25×10^8 m/s then its velocity in carbondisulphide will be (n for carbon-disulphide = 1.63)

(a) 1.84×10^8 m/s (b) 2.25×10^8 m/s

(c) 2×10^8 m/s (d) 3×10^8 m/s

146. The refractive index of glass is 1.5 and velocity of light in vacuum is 3×10 m/s. Time taken by light in traveling 500 m in glass will be

(a) 1 μs (b) 1.5 μs

(c) 4.5 μs (d) 2.5 μs

147. A point object O is placed midway between the two converging mirrors of focal length f each. Find d so that object and image coincide

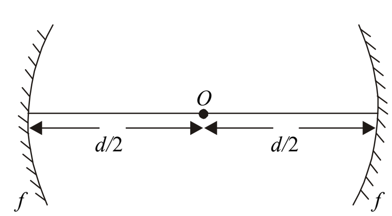


Fig. 29.70

(a) $2f, 4f$ (b) $2f, 3f$

(c) $4f$ (d) $2f, f$

148. A light wave of frequency 5×10 Hz passes through a medium of refractive index 2.4. Its wavelength in the medium will be

(a) 1×10^{-7} m (b) 4×10^{-7} m

(c) 3.3×10^{-7} m (d) 2.5×10^{-7} m

149. The effective mass of photon in microwave region, visible region and x-ray region is in the following order:

(a) microwave > x-ray > visible

(b) x-ray > microwave > visible

(c) microwave > visible > x-ray

(d) x-ray > visible > microwave

150. A converging lens of focal length 30 cm and a diverging lens of focal length 20 cm are kept 15 cm apart with their principal axes coinciding. Where shall an object be placed to form an image at infinity.

(a) 60 cm from converging lens

(b) 60 cm from diverging lens

(c) 210 cm from diverging lens

(d) 210 cm from converging lens

PASSAGE 1

Read the following passage and answer the questions given at the end.

A ray of light travelling with a speed c leaves point 1 shown in Fig. 29.71 and is reflected to point 2. The ray strikes the reflecting surface at a distance x from point 1. According to Fermat's principle of least time, among all possible paths between two points, the one actually taken by a ray of light is that for which the time taken is the least (In fact there are some cases in which the time taken by a ray is maximum rather than a minimum).

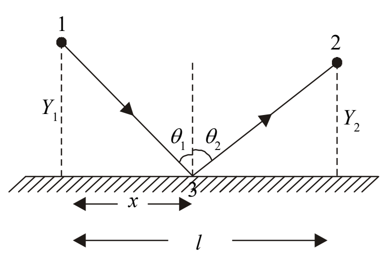


Fig. 29.71

1. Find the time for the ray to reach from point 1 to point 2.

(a) $\dfrac{\sqrt{Y_1^2+x^2}+\sqrt{(l-x)^2+Y_2^2}}{c}$ (b) $\dfrac{l}{c}$

(c) $x = l - x$ (d) $Y_1 = Y_2$

2. Under what condition is time taken least?

(a) $\theta_1 = \theta_2$ (b) $\theta_1 = 90 - \theta_2$

(c) $\theta_2 = 90 - \theta$ (d) none of these

3. List a condition when time taken is maximum rather than minimum.

(a) When ray passes from rarer to denser medium

(b) When ray is dispersed by prism

(c) When ray passes from denser to rarer medium

(d) None

Solution **1.** (a)

$$t = \frac{13+23}{c} = \frac{\sqrt{Y_1^2+x^2}+\sqrt{(l-x)^2+Y_2^2}}{c}$$

Solution **2.** (a)

$$\frac{dt}{dx} = \frac{1}{c}\,(Y_1^2+x^2)^{-1/2}(2x) + [(l-x)^2+Y_2]^{-1/2}(-2)(l-x) = 0$$

$$2x\,[(l-x)^2+Y_2^2]^{1/2} - (Y_1^2+x^2)^{+1/2}(-2l+2x) = 0$$

$$\frac{\left[(l-x)^2+Y_2^2\right]^{1/2}}{(l-x)} = \frac{\left(Y_1^2+x^2\right)^{1/2}}{x}$$

cosec $(90-\theta_1)$ = cosec $(90-\theta_2)$ $\theta_1 = \theta_2$

Solution **3.** (c)

PASSAGE 2

Read the following passage and answer the questions given at the end.

A lens obeys Snell's law that light rays bend at each surface by an amount determined by index of refraction of the lens and index of the medium in which the lens is located.

$\dfrac{1}{f} = (n-1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$ assumes that the lens is surrounnded by air. Consider instead a thin lens immersed in a liquid of rafractive index n_{liq}.

Fig. 29.72

1. Find the focal length f' in liquid in terms of f.

(a) $f' = \left[\dfrac{n_{liq}(n-1)}{n-n_{liq}}\right] f$ (b) $f' = \dfrac{n_{liq}}{n-n_{liq}} f$

(c) $f' = \dfrac{(n_{liq}-1)}{n-n_{liq}} f$ (d) $f' = \left(\dfrac{n-1}{n_{liq}-n}\right) f$

2. If the lens is thick what will be its focal length in air?

(a) $\dfrac{1}{f} = (n-1)\left[\dfrac{1}{R_1} - \dfrac{1}{R_2} + \dfrac{t(n-1)}{nR_1R_2}\right]$

(b) $\dfrac{1}{f} = (n-1)\left[\dfrac{1}{R_1} - \dfrac{1}{R_2} - \dfrac{t(n-1)}{nR_1R_2}\right]$

(c) $\dfrac{1}{f} = (\text{n}-1)\left[\dfrac{1}{R_1} - \dfrac{1}{R_2} + \dfrac{t(n+1)}{nR_1R_2}\right]$

(d) none of these

3. If the lens is silvered at one side what will be the new focal length?

Fig. 29.73

(a) $f' = \dfrac{f}{2}$ (b) $f' = \dfrac{f(n)}{4}$

(c) $f' = \dfrac{f(n-1)}{2n-1}$ (d) $f' = \dfrac{f(n+1)}{(2n-1)}$

Solution **1.** (a) $\dfrac{1}{f} = (n-1)\left[\dfrac{1}{R_1} - \dfrac{1}{R_2}\right]$ ....(1)

$$\frac{1}{f'} = \left(\frac{n}{n_{liq}} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad ....(2)$$

dividing (1) by (2)

$$f' = \frac{f(n-1)}{\left(\dfrac{n}{n_{liq}} - 1\right)} = \frac{fn_{liq}(n-1)}{(n-n_{liq})}$$

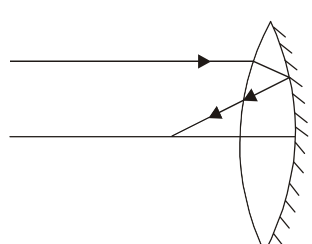


Fig. 29.74

Solution **2.** (a)

Solution **3.** (c) $P = 2P_L + P_M$

$$\frac{1}{f} = \frac{2}{f_L} + \frac{1}{f_m} = \frac{2}{f_L} + \frac{2}{R} \quad ....(1)$$

$$\frac{1}{f_L} = (n-1)\frac{2}{R}$$

or $$\frac{2}{R} = \frac{1}{f_L(n-1)} \quad ....(2)$$

From (1) and (2)

$$f' = \frac{f(n-1)}{2n-1}$$

PASSAGE 3

Read the following passage and answer the questions given at the end.

Fig. 29.75 shows a simple version of zoom lens. The converging lens has focal length f_1 and diverging lens has focal length $f_2 = |f_2|$. The two lenses are separated by a variable distance d that is always less than f_1. Also, the magnitude of the focal length of the diverging lens satisfies the inequality $|f_2| > f_1 - d_0$. To find the focal length of the combination lens consider a bundle of parallel rays of radius r_0 entering the converging lens.

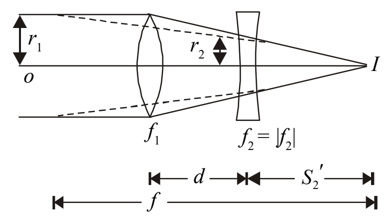


Fig. 29.75

1. Find the radius of the ray bundle r_2 at the entrance of diverging lens.

(a) $r_2 = \dfrac{r_1 f_1}{f_1 + d}$ (b) $r_2 = \dfrac{r_1(f_1 - d)}{f_1}$

(c) $r_2 = \dfrac{r_1 d}{f_1}$ (d) $r_2 = \dfrac{r_1 d}{f_1 + d}$

2. Find the position of the final image I'.

(a) $\dfrac{|f_2| f_1}{f_1 + |f_2| - d}$ (b) $\dfrac{|f_2|(f_1 - d)}{f_1 + |f_2| - d}$

(c) $\dfrac{|f_2|(f_1 - d)}{f_1 - |f_2| + d}$ (d) $\dfrac{|f_2|(f_1 - d)}{|f_2| - f_1 + d}$

3. Find the effective focal length. (If they rays meeting at I are extended backward they would meet the original bundle of rays at $0'$. $0'$ I is effective focal length.

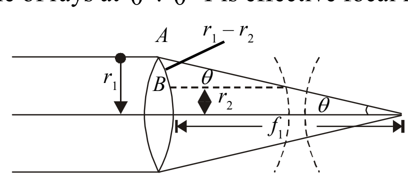


Fig. 29.76

(a) $f = \dfrac{f_1 |f_2|}{(|f_2| - f_1 + d)}$ (b) $\dfrac{f_1 |f_2|}{(|f_2| + f_1 - d)} = f$

(c) $f = \dfrac{f_1 |f_2|}{|f_2| + f_1 + d}$ (d) $\dfrac{f_1 |f_2|}{f_1 + d - |f_2|}$

Solution **1.** (b) $\dfrac{r_1}{f_1} = \dfrac{r_1 - r_2}{d} = \tan\theta$

$$\frac{r_2}{d} = \frac{r_1(f_1 - d)}{f_1 d}$$

or $$r_2 = \frac{r_1(f_1 - d)}{f_1}$$

Solution **2.** (d) $\dfrac{1}{V_1} - \dfrac{1}{u_1} = \dfrac{1}{f_1}$

or $$\frac{1}{V_1} = \frac{1}{f_1} \because u_1 = \infty$$

$$\frac{1}{V_2} = \frac{1}{-|f_2|} + \frac{1}{u_2}$$

$$\frac{1}{V_2} = \frac{1}{-|f_2|} + \frac{1}{(f_1 - d)}$$

or $$V_2 = \frac{|f_2|(f_1 - d)}{|f_2| - (f_1 - d)}$$

$$= \frac{|f_2|(f_1 - d)}{(|f_2| - f_1 + d)}$$

Solution **3.** (a) $\dfrac{1}{f} = \dfrac{1}{f_1} + \dfrac{1}{|f_2|} - \dfrac{d}{-f_1|f_2|}$

or $$\frac{1}{f} = \frac{1}{f_1} - \frac{1}{f_2} + \frac{d}{f_1|f_2|}$$

or $$f = \frac{|f_2| f_1}{[|f_2| - f_1 + d]}$$

PASSAGE 4

Read the following passage and answer the questions given at the end.

The eye forms a real and inverted image of an object on the retina. If the eye lens is defective, the image of objects may be formed in front of or behind the retina. Persons in whom the image is formed in front of the retina are not able to see distant objects clearly while if the image is formed behind the retina the person is not able to see near objects clearly. The latter kind of people are said to be longsighted.

1. Persons suffering from myopia cannot see the _ _ _ clearly.

(a) distant objects (b) near objects
(c) spherical objects (d) neither near nor distant

Solution (a)

2. The hyperopic eye can be corrected using _ _ _ lens.

(a) concave (b) convex
(c) plano convex (d) plano concave

Solution (b)

3 Hypermetropia is

(a) samething as shortsightedness
(b) samething as longsightedness
(c) same as cataract
(d) another name of night blindness

Solution (b)

Answers to Questions for Practice

1.	(d)	**2.**	(a,d)	**3.**	(a)	**4.**	(a,c)	**5.**	(a)	**6.**	(b)	**7.**	(a,d)
8.	(b,d)	**9.**	(c,d)	**10.**	(c,d)	**11.**	(b)	**12.**	(a,b,c)	**13.**	(b)	**14.**	(c)
15.	(d)	**16.**	(b,d)	**17.**	(b,c)	**18.**	(d)	**19.**	(a,b,c)	**20.**	(a,b)	**21.**	(a,b)
22.	(b)	**23.**	(c,d)	**24.**	(b)	**25.**	(c,d)	**26.**	(a,c,d)	**27.**	(a,b,c)	**28.**	(d)
29.	(b,c)	**30.**	(a,b)	**31.**	(b)	**32.**	(a,c)	**33.**	(a,b)	**34.**	(b,c)	**35.**	(a,c,d)
36.	(d)	**37.**	(a,d)	**38.**	(d)	**39.**	(c)	**40.**	(b)	**41.**	(a)	**42.**	(b)
43.	(a,d)	**44.**	(c)	**45.**	(b,d)	**46.**	(d)	**47.**	(a)	**48.**	(b)	**49.**	(b)
50.	(c)	**51.**	(a)	**52.**	(b,d)	**53.**	(a)	**54.**	(b,c)	**55.**	(a,b,c)	**56.**	(a)
57.	(c)	**58.**	(c,d)	**59.**	(d)	**60.**	(d)	**61.**	(c)	**62.**	(a,b,c,d)	**63.**	(c)
64.	(b)	**65.**	(c)	**66.**	(b,c)	**67.**	(b)	**68.**	(b,c,d)	**69.**	(c)	**70.**	(c)
71.	(d)	**72.**	(b)	**73.**	(d)	**74.**	(c)	**75.**	(a)	**76.**	(b)	**77.**	(b)
78.	(b)	**79.**	(d)	**80.**	(a)	**81.**	(a)	**82.**	(a)	**83.**	(b)	**84.**	(b)
85.	(c)	**86.**	(a)	**87.**	(b)	**88.**	(a)	**89.**	(d)	**90.**	(b)	**91.**	(a)
92.	(a)	**93.**	(a)	**94.**	(c)	**95.**	(b)	**96.**	(a)	**97.**	(b)	**98.**	(b)
99.	(a)	**100.**	(b)	**101.**	(a)	**102.**	(a)	**103.**	(c)	**104.**	(a)	**105.**	(c)
106.	(b)	**107.**	(d)	**108.**	(b)	**109.**	(b)	**110.**	(a)	**111.**	(a)	**112.**	(b)
113.	(a)	**114.**	(b)	**115.**	(a)	**116.**	(a)	**117.**	(a)	**118.**	(a)	**119.**	(b)
120.	(b)	**121.**	(a)	**122.**	(c)	**123.**	(a)	**124.**	(a)	**125.**	(b)	**126.**	(b)
127.	(a)	**128.**	(a)	**129.**	(b)	**130.**	(a)	**131.**	(c)	**132.**	(b)	**133.**	(a)
134.	(a)	**135.**	(b)	**136.**	(d)	**137.**	(a)	**138.**	(d)	**139.**	(a)	**140.**	(b)
141.	(d)	**142.**	(d)	**143.**	(b)	**144.**	(d)	**145.**	(a)	**146.**	(d)	**147.**	(a)
148.	(d)	**149.**	(d)	**150.**	(b,d)								

EXPLANATION

1. (d) $t' = t\left(1-\frac{1}{\pi}\right) = t\left[1-\frac{\mu_1}{\mu_2}\right] < 0.$

Apparent distance from S to $P = d - t' = d + t\left(\frac{\mu_1}{\mu_2}-1\right)$.

2. (b, d)

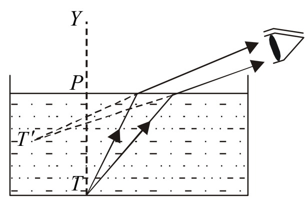


Fig. 29.77

The image of T is formed at T'. The position of T' will change with the angle of viewing.

3. (a) For $\theta < c$, $\delta = \phi - \theta$ with $\frac{\sin\phi}{\sin\theta} = \mu$ or $\phi = \sin^{-1}$ $(\mu \sin \theta)$.

$\therefore \quad \delta = \sin^{-1}(\mu\sin\theta) - \theta$

This is a nonlinear relation. The maximum value of δ is

$\delta_1 = \frac{\pi}{2} - c$ for $\theta = c$ and $\phi = \frac{\pi}{2}$.

For $\theta > c$, $\delta = \pi - 2\theta$.

δ decreases linearly with θ.

$\delta_{max} = \pi - 2c = \delta_2 = 2\delta_1$.

5. (a) The angle of incidence of all the rays is 45° at the hypotenuse. For a critical angle of 45°, the refractive index must be

$(\sin 45°)^{-1} = \sqrt{2} = 1.414$.

For red light, $\mu = 1.39 < 1.414$. Hence, its critical angle is > 45°. Therefore, red light will pass through the surface into air.

For green and blue lights, $\mu > 1.414$. Hence, their critical angles are < 45°. They will be reflected internally and emerge from the surface at the bottom.

6. (b)

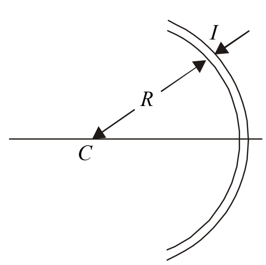


Fig. 29.78

As the watch glass is of uniform thickness, the two curved surfaces must have a common centre of curvature (C). Let R be the radius of curvature of the inner surface, t = thickness of the watch glass. Let light parallel to the optic axis be incident from the left. For refraction at the first surface, let image be formed at a distance x.

$$\frac{\mu}{x} - \frac{1}{\infty} = \frac{\mu-1}{-R}$$

or $\quad \frac{\mu}{x} = -\frac{\mu-1}{R}$, where μ = refractive index of glass.

For refraction at the second surface,

$$\frac{1}{v} - \frac{\mu}{x} = \frac{1-\mu}{-(R+t)}$$

or $\quad \frac{1}{v} = (\mu - 1)\left(\frac{1}{R+t}\frac{1}{R}\right) = \frac{1}{f} > 0.$

$\therefore \quad f < 0$ (diverging).

9. (c, d) See the first part of Q. No. 5.

10. (c, d) $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2-\mu_1}{r}$.

Here, $\mu_1 = \mu$ = refractive index of glass, $\mu_2 = 1$ $u = -R$ = radius of sphere, $r = -R$.

$$\frac{1}{v} - \frac{\mu}{-R} = \frac{1-\mu}{-R}$$

or $\quad \frac{1}{v} = \frac{1}{-R}$ or $v = -R$.

30. (a, b)

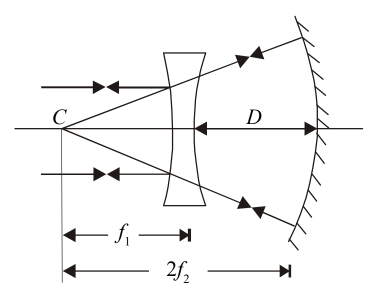


Fig. 29.79

31. (d) Let the two lenses have focal lengths f_1 and f_2, in metres.

In contact, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ = power = 10

or $\quad \frac{f_1+f_2}{f_1f_2} = 10$

For a separation of $d = 0.25$ m,

$$\frac{1}{F'} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} = 6$$

or $\quad 10 - \dfrac{d}{f_1 f_2} = 6$

or $\quad f_1 f_2 = \dfrac{1}{16}$

In (1), $f_1 + f_2 = 10 f_1 f_2 = \dfrac{10}{16} = \dfrac{5}{8}$ or $f_2 = \dfrac{5}{8} - f_1$.

In (2), $f_1\left(\dfrac{5}{8} - f_1\right) = \dfrac{1}{16}$ or $f_1(10 - 16f_1) = 1$.

or $\quad 16 f_1^2 - 10 f_1 + 1 = 0$

or $\quad f_1 = \dfrac{1}{2}$ or $\dfrac{1}{8}$.

33. (a, b)

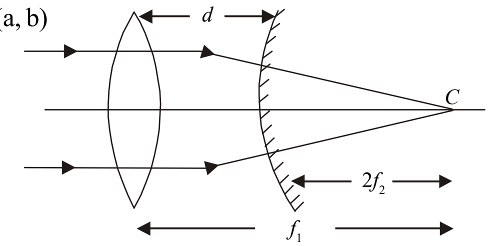


Fig. 29.80

53. (a) As the object moves from infinity to the pole of the mirror, the virtual image moves from its focus to the pole.

54. (b, c) In normal adjustment, tube length of an astronomical telescope is $(f_0 + f_e)$ and that of a Galilean telescope is $(f_0 + f_e)$, where f_0 and f_e are the focal lengths of the objective and the eyepiece respectively.

Here, $f_e = f$.

Magnification $= \dfrac{f_0}{f_e}$ for both telescopes.