CHAPTER

5

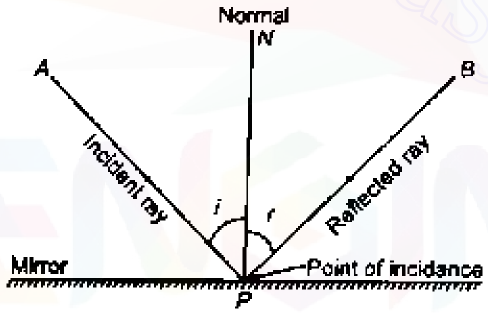
Light

Light

Light is a form of energy which enables us to view distinct objects.

Reflection of Light

When light falls on a surface, a part of it is thrown back in a definite direction. This process is known as reflection of light.



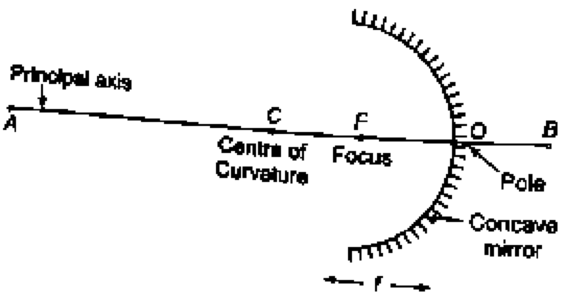
Laws of Reflection

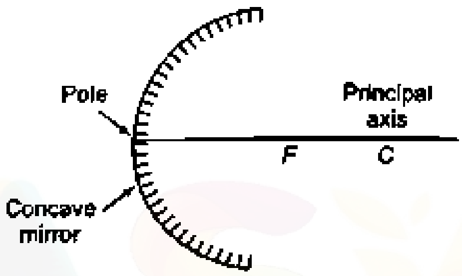
- The angle of reflection ($\angle r$) is always equal to the angle of incidence ($\angle i$) i.e. $\angle i = \angle r$.
- The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

Spherical Mirrors

Spherical mirrors can be regarded as a part of a hollow reflecting spheres of glass. *These are of two types*

(a) Concave mirror (b) Convex mirror





Real and Virtual Images

Real Image

- Real images can be formed on a screen.
- Real image is formed by the actual intersection of reflected (or refracted) light rays.
- The image formed on a cinema screen is a real image.
- A concave mirror forms real image when an object is placed beyond its focus.

Virtual Image

- Virtual images cannot be formed on the screen.
- Virtual image is formed by the apparent intersection of reflected (or refracted) light rays.
- The image of our face when we look into a plane mirror is a virtual image. A concave mirror forms a virtual image when an object is placed between focus and pole of the mirror.

Image Formation by Concave Mirror

S.N.	Position of object	Position of image	Size of image	Nature of image
(1)	At infinity	At F	Highly diminished	Real and inverted
(2)	Between infinity and C	Between F and C	Diminished	-do-
(3)	At C	At C	Same size	-do-
(4)	Between F and C	Between infinity and C	Enlarged	-do-
(5)	At F	At infinity	Highly enlarged	-do-
(6)	Between F and P	Behind the pole	Enlarged	Virtual and erect

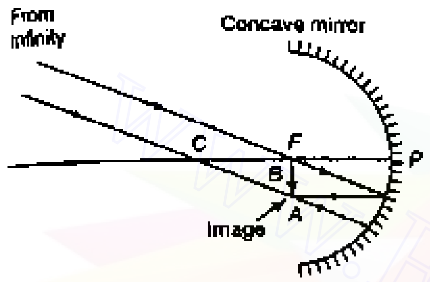
Image Formation by Convex Mirror

Position of object	Position of image	Size of image	Nature of image
At infinity	At F	Highly diminished	Erect and virtual
Between infinity and pole	Between F and P	Diminished in size	Erect and virtual

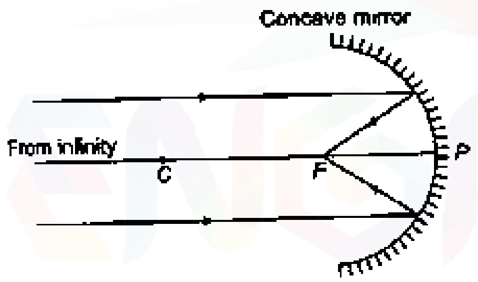
Image formed by a convex mirror is always virtual, erect and diminished.

The following are the positions and nature of the images formed in a concave mirror for different positions of the object.

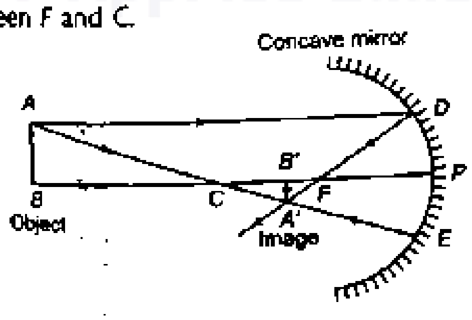
(i) **When the object is at infinity** Image is formed at F.



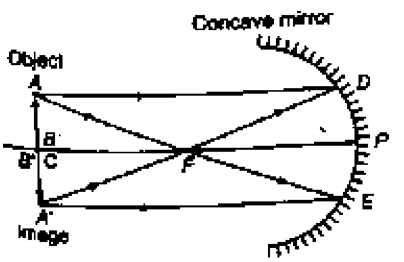
(ii) **When the rays are parallel to the principal axis** The image is formed at F.



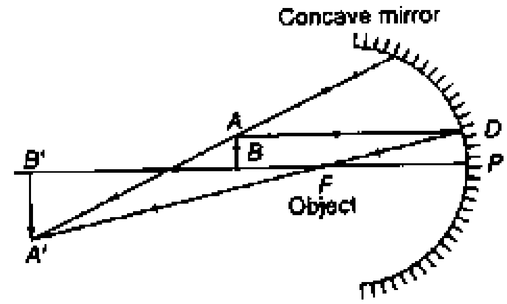
(iii) **When the object is between infinity and C** The image formed is real, inverted and smaller in size and is formed between F and C.



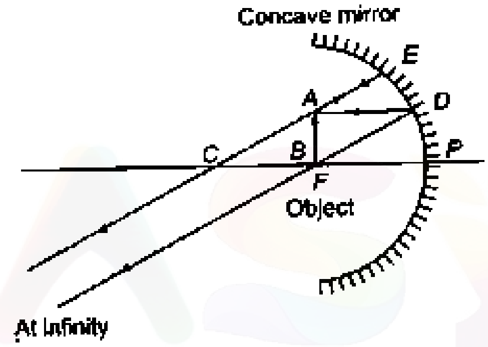
(iv) **When the object is at C** The image formed is inverted, real, equal in size and is formed at C itself.



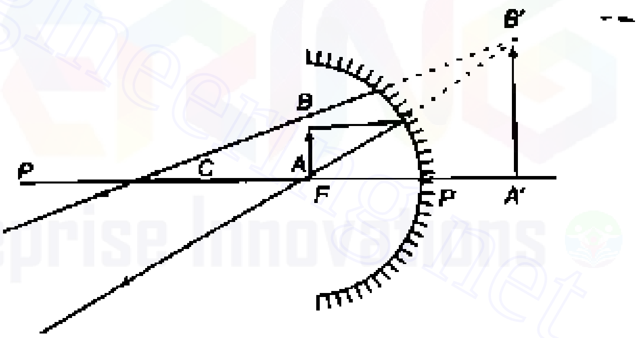
(v) **When the object is between F and C** The image is formed beyond C and is inverted, real and larger than the object.



(vi) **When the object is at focus** The image is formed at infinity. The image is real, inverted and infinitely large in size.



- **When the object is between F and P** The images formed behind the pole. The image is virtual, erect and large.



Uses of Spherical Mirrors

Concave Mirrors

- These are used as reflectors in automobiles (car, buses etc.), head light, search light, hand torches and table lamps.
- These are used as shaving mirrors.
- These are used by doctors for focussing intense light to examine inside of eye, ears etc.

Convex Mirrors

- These are used as rear-view mirrors in automobiles as they give large view of the traffic.
- These are used wherever we want to see erect images.

Mirror Formula

- If v is the image distance, u is the object distance and f is the focal length of a mirror, then $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}=\frac{2}{R}$
- The linear magnification (m) produced by a mirror is equal to the ratio of the image distance to the object distance with negative sign $m=-\frac{v}{u}=\frac{f}{f-u}=\frac{f-v}{f}$

Refraction of Light

- When a ray of light passes from one medium to other, it bends from its path. This phenomenon of bending of light is called as refraction of light
- When light passes from rarer medium to a denser medium, it bends towards the normal at the point of incidence.
- When light passes from a denser medium to a rarer medium, it bends away from the normal.
- When a ray of light enters from one medium to other medium its frequency and phase do not change but wavelength and velocity change.

Laws of Refraction

- The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane.
- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a given medium

$$\frac{\sin i}{\sin r}=\mu \qquad \text{\{Snell's law\}}$$

where, μ is refractive index of the second medium with respect to first.

$$\because \quad \mu=\frac{\mu_2}{\mu_1}=\frac{c/v_2}{c/v_1}$$

$$\therefore \quad \mu=\frac{v_1}{v_2} \text{ or, } \mu_2=\frac{v_1}{v_2}$$

v_1 is speed of light in first medium and
v_2 is speed of light in second medium.

Some Illustration of Refraction

- Twinking of stars.
- Oval shake of sun in the morning and evening.
- Bending of a linear object when it is partially dipped in a liquid inclined to the surface of the liquid.
- A fish is a pond when viewed from air appears to be at a smaller depth them actual depth.
- A coin at the base of a vessel filled with water appears raised.

Total Internal Reflection

In case of propagation of light from denser to rarer medium through a plane boundary. **Critical angle** is the angle of incidence for which angle of refraction is 90°.

- If light is propagating from denser medium towards the rarer medium and angle of incidence is more than critical angle, then the light incident on the boundary is reflected back in the denser medium, obeying the law of reflection. This phenomenon is called total internal reflection.

Condition of Total Internal Reflection

(a) Light must be propagating from denser to rarer medium.
(b) Angle of incidence, must exceeds the critical angle.

Sparkling of diamond mirage and looming, shinning of air dubble in water and optical fibre are examples of total internal reflection.

Spherical Lenses

A lens is a piece of transparent glass bounded by two spherical surfaces.

There are two types of lenses

(a) Convex lens (converging lens) and
(b) Concave lens (diverging lens)

Image Formation by a Convex Lens

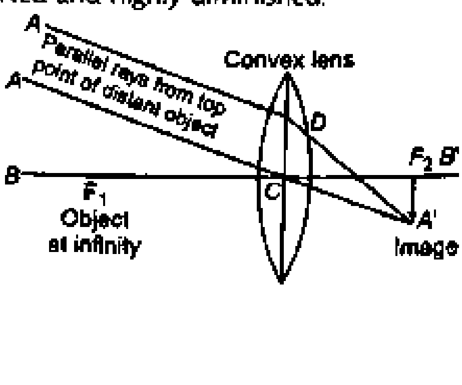
S.No.	Position of object	Position of image	Size of image	Nature of image
(1)	At infinity	At F_2	Highly diminished	Real and inverted
(2)	Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	-do-
(3)	At $2F_1$	At $2F_2$	Same size	-do-
(4)	Between $2F_1$ and F_1	Beyond $2F_2$	Enlarged	-do-
(5)	At F_1	At infinity	Highly enlarged	-do-
(6)	Between F_1 and lens	Behind the object, on the same side of the object	Enlarged	Virtual and erect

Image Formation by a Concave Lens

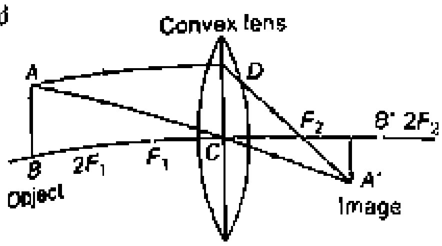
S.No.	Position of object	Postion of image	Size of image	Nature of image
(1)	At infinity	At F_2	Diminished	Erect and virtual
(2)	Between infinity and lens	Between F_2 and lens	Diminished	Erect and virtual

Image Formation by a Convex Lens

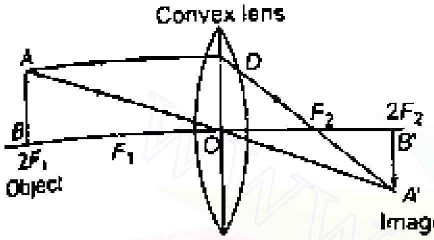
- **Object at infinity** The image formed is at second focus, real, inverted and highly diminished.



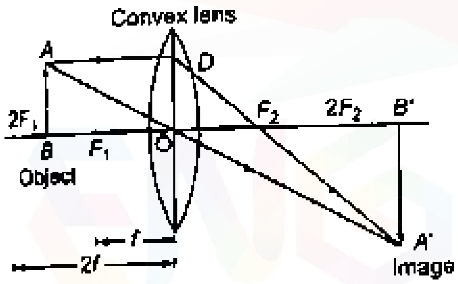
- **Object beyond $2F_1$** The image formed is between F_2 and $2F_2$ on the right side of the lens, real, inverted and diminished.



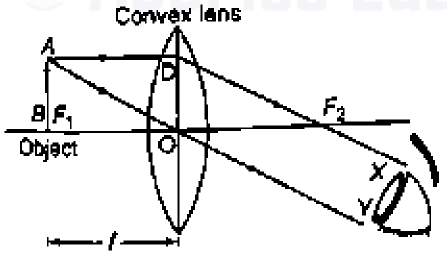
- **Object at $2F_1$** The image formed is at $2F_2$, real, inverted and of same size as that of the object.



- **Object between F_1 and $2F_1$** The image formed is beyond $2F_2$, real, inverted and magnified.



- **Object at F_1** The image formed is real, inverted, highly enlarged and at infinity.



- **Object between F_1 and O** The image formed is behind the object, virtual, erect and enlarged.

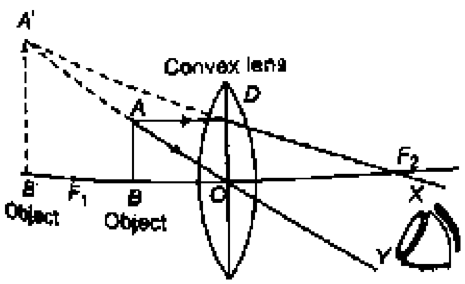
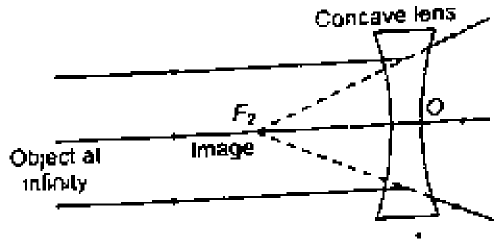
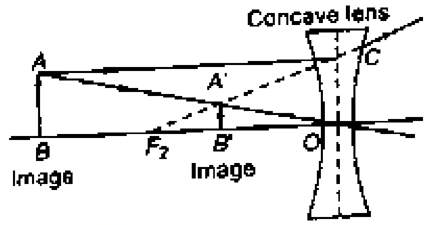


Image Formation by a Concave Lens

- **Object at infinity** The image formed is at F_2, erect, virtual and diminished.



- **Object anywhere between infinity and lens** The image formed is between F_2 and lens, erect, virtual and diminished.



Lens Formula

- If v is the image distance, u is the object distance and f is the focal length of a lens, then

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

Magnification $m = \frac{v}{u} = \frac{I}{O} = \frac{\text{Size of image}}{\text{Size of object}}$

- Power (P) of a lens is the reciprocal of focal length of lens

i.e., $P = \frac{1}{f}$

- SI unit of power is dioptre (D).
- If two or more lenses are combined, then
  (a) there is an increase in the magnification of image.
  (b) the final image is erect.
  (c) the spherical aberration is reduced.
- If m is the total magnification of two lenses in contact having magnification m_1 and m_2, then

$$m = m_1 \times m_2$$

- If P is power of two lenses in contact having powers P_1 and P_2, then

$$P = P_1 + P_2$$

or

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

- When lens is dipped in a liquid of higher refractive index the focal length increases and convex lens behaves as concave lens and *vice-versa*.
- An air bubble trapped in water or glass appears as convex but behaves as concave lens.

Dispersion of Light

- Sir Isaac Newton observed that when a narrow beam of light is incident on a prism, the emergent beam is not only deviated but at the same time splits up into a coloured band of seven colours. This phenomenon is called dispersion of light.
- The seven colours of band are Violet, Indigo, Blue, Green, Yellow, Orange and Red (can be memorised as VIBGYOR).
- The colour of an object is determined by the colour of the light reflected by it.
- Violet colour deviates through maximum angle and red colour deviates through the minimum angle.
- Scattering of light is maximum in case of violet colour and minimum in case of red colour of light.
- Blue colour of sky is due to scattering of light.

Primary Colours

- Red, green and blue are called primary colours or basic colours.

Mixing of Colours

Red + Green + Blue = White
Red + Blue = Magenta
Blue + Green = Peacock blue (or Cyan)
Red + Green = Yellow

- Magenta, Peacock Blue (or Cyan) and Yellow etc are called secondary colours.
- If all the colours of white light are reflected back from the object, then it appears white.
- If all the colours of white light are absorbed by the object, then it appears black.
- The natural colours of transparent objects are due to their selective transmission of light.

Human Eye

- Human eye is an optical instrument which forms real image of the objects.
- Least distance of distinct vision is 25 cm.
- Far point of normal eye is at infinity.

Defect of Human Eye

- **Myopia** A person suffering from myopia can see the near objects clearly while far objects are not clear concave lens is used for no move it .
- **Hypemetropia** A person suffering from hypermetropia can see the distant objects clearly but not the near objects. Convex lens is used to remove it.
- **Presbyopia** In the old age, the power of accomodation of the eye is so much lost that a person can neither see the near objets distinctly nor the distant objects. To correct this defect bifocal laws is used.
- **Astigmatism** In this defect, a person cannot distantly see the horizontal and vertical lines, simultaneously at a normal distance. To correct this defect, cylindrical lens is used.

Magnifying Optical Instruments

Microscope

- A simple microscope consists of a convex lens of short focal length.
- It is used to see the details of very small objects.
- The magnifying power of a simple microscope is given by $M=\left[1+\frac{D}{f}\right]$, D is least distance of distinct vision.
- For compound microscope $m=m_o \times m_e$ where m_o is magnification of objective lens and m_e is magnification of eye-piece.

Telescope

- Used to see the details of the distant objects.
- There are two types of telescopes
  (a) Astronomical telescope (invented by Kepler in 1611)
  (b) Galilean telescope (invented by Galileo in 1609)
- In an astronomical telescope, the objective lens is a convex lens of large focal length but eye-piece is a convex lens of short focal length.
- In Galilean telescope, the objective lens is a convex lens of large focal length but the eye-piece is a concave lens of short focal length.
- Magnifying power of telescope $m=\frac{f_o}{f_e}$ where f_o is focal length of objective of the telescope and where f_e is focal length of eye-piece of the telescope.
- Length of telescope tube in astronomical telescope is
  $$L=f_o+f_e$$
  In Galilean telescope the length of telescope, $L=f_o+f_e$

Periscope consists of two plane mirror inclined at an angle of 45°. The principle of working of periscope is based upon reflection and refraction.

Points to be Remember

- Vertex (pole) is the centre of the spherical surface.
- Centre of curvature is the geometric centre of the sphere whose part is the curved mirror.
- Radius of curvature (R) is the radius of the sphere whose part is the curved mirror.
- Focus (F) is a point on the principal axis where parallel beam of light after reflection from the mirror actually meets or appears to meet.
- Focal length (f) is distance between the vertex and the focus of the mirror.
- Principal axis is the line joining the centre of curvature and the vertex of the mirror.

$$f = \frac{R}{2}$$

- Number of images (n) of an object held between two plane mirrors inclined at an angle θ

$$n = \frac{360^\circ}{\theta} - 1$$

- The image in a plane mirror appear as far behind the mirror as the object is in front of it.
- The size of the image formed by a plane mirror is the same as the size of the object.
- The image formed by a plane mirror is always virtual.
- Minimum size of the plane mirror required to form full image of the object is half the linear size of the object.
- The line joining the object and the image is normal to the plane mirror.
- When a mirror is rotated through a certain angle, the reflected ray is rotated through twice that angle.
- Aperture of a lens is the diameter of the boundary of that lens.
- Principal axis of a lens is the line joining the two centres of curvature of the lens.
- Optical centre is the point within the lens through which ray of light passes undeviated.
- **Principal focus** When a beam of parallel rays of light falls on a lens, then after refraction from the lens, this beam either converges to a point (in convex lens) or appears to diverge from a point (in concave lens).
- This point is called as principal focus.
- Focal length is the distance of the focal point from the optical centre of a lens.
- Human eye is just like a TV camera than an ordinary camera.
- Colour blindness is due to improper functioning of any of the three types of cones.
- Colour blindness is a genetic disorder which occurs by inheritance.
- John Dalton was colour-blind (daltonism).
- A layer of kerosene oil over water surface appear coloured in the presence of light. It is an example of interference.
- The duration of day appears to be increased by nearly 4 min due to atmospheric refraction.
- Sky appears black to astronaut from space because, there is no atmosphere in space and therefore, no scattering of light take place.
- The eye lens is a conure lens made of a protigeneous jelly like material.
- Dangers signals are of red column because red colour of light scatter least and therefore, these signals can be sun from far away.
- A rose appears red when day light falls on it because it absorbs all the constituent colour of white light except red, which it reflects to us.

Exercise

1. Sun appears reddish during the rising and setting time, because
   (a) the atmosphere absorbs short wavelengths more than long wavelengths
   (b) red light is emitted in huge amount by it
   (c) the atmosphere absorbs long wavelength more than short wavelengths
   (d) light of shorter wavelengths are scattered to a greater extent than the longer wavelengths by the atmosphere

2. Dispersion produced by a prism depends on
   (a) its refracting angle
   (b) size of the prism
   (c) height of the prism
   (d) one of the angle at the base of the prism

3. Where should an object be placed so that a real and inverted image of the same size is obtained using a convex lens?
   (a) Between the lens and its axis
   (b) At the focus
   (c) At twice the focal length
   (d) At infinity

4. The colour of the sky is blue because of
   (a) combination of various lights producing blue colour
   (b) scattering of light by dust particles
   (c) diffraction of light
   (d) reflection of light by water droplets

5. The phenomenon of mirage is due to
   (a) change in refractive index of air with change in temperature
   (b) total internal reflection
   (c) absorption of light by air at high temperature
   (d) polarisation of light on reflection

6. To an observer on the lunar surface, during the day time, the sky will appear to be
   (a) light yellow (b) orange
   (c) blue (d) black

7. The magnifying power of the objective and eye-piece of a compound microscope are m_1 and m_2. The magnifying power of the microscope will be
   (a) $m_1 + m_2$ (b) $m_1 - m_2$
   (c) $m_1 m_2$ (d) m_1 / m_2

8. Panchromatic photographic film is sensitive to
   (a) light of yellow colour
   (b) light of red colour
   (c) light of violet colour
   (d) the entire region of the visible spectrum

9. When dispersion of white light takes place through a prism, the maximum deviation is suffered by which one of the following colour?
   (a) Red (b) Yellow
   (c) Green (d) Violet

10. We cannot see the details of a distant object because
(a) there is a defect in our eyes
(b) the light rays are absorbed and scattered in this way
(c) there is a limit of resolution for our eyes
(d) the objects are too far away

11. Which one of the following sets of colour combinations is added in colour vision in T V?
(a) Yellow, green and blue
(b) White, black, red and green
(c) Red, green and blue
(d) Orange, pink and blue

12. Which one of the following phenomenon cannot be attributed to the refraction of light?
(a) Twinkling of stars (b) Mirage
(c) Rainbow (d) Red shift

13. Match List I with List II and select the correct answer using the codes given below the lists.

List I	List II
A. Intensity of light	1. Properties of the medium
B. Colour of light	2. Refractive index of medium
C. Velocity of light	3. Amplitude of light
D. Propagation of light	4. Frequency of light

Codes

	A	B	C	D		A	B	C	D
(a)	3	4	2	1	(b)	2	4	1	3
(c)	3	1	2	4	(d)	4	2	3	1

14. The colour of an opaque object is due to the colour it
(a) absorbs (b) refracts
(c) reflects (d) scatters

15. The muscles of the iris control the
(a) focal length of the eye-lens
(b) opening of the pupil
(c) shape of the crystalline lens
(d) optic nerve

16. A double convex glass lens of focal length f and having a circular aperture is cut into two halves, each having a semicircular aperture. The focal length of each half is
(a) f (b) $2f$ (c) $\frac{f}{2}$ (d) $-f$

17. Distant objects can be seen with the help of
(a) cronometer (b) telescope
(c) microscope (d) telephone

18. The velocity of light was measured by
(a) Romer (b) Galileo
(c) Newton (d) Kepler

19. The principle of working of periscope is based on
(a) reflection only (b) refraction only
(c) reflection and interference (d) reflection and refraction

20. The mirror used in vehicles as rear view mirror is
(a) convex mirror (b) concave mirror
(c) plane mirror (d) plano-concave mirror

21. In the visible spectrum, the colour having the shortest wavelength is
(a) blue (b) yellow
(c) red (d) violet

22. The mirrors used in search light are
(a) concave (b) convex (c) parabolic (d) plane

23. For a telescope, the focal lengths of two lenses are 30 cm and 10 cm. One acts as objective and other as eye-piece. The length of the telescope is
(a) 40 cm (b) 3 cm (c) 200 cm (d) 30 cm

24. The wave theory of light cannot explain the phenomenon of
(a) reflection (b) polarisation
(c) scattering (d) Photoelectric effect

25. Which one of the following is not a primary colour?
(a) Blue (b) Yellow
(c) Red (d) Green

26. A thin lens has a focal length of –25 cm. Then, the nature of lens is
(a) concave lens of power 4 D
(b) convex lens of power 4 D
(c) convex lens of power 25 D
(d) convex lens of power $\frac{1}{4}$ D

27. Parallel light rays entering a convex lens always converge at
(a) centre of curvature
(b) the focal plane
(c) the principal focus
(d) a point on the principal axis

28. Mirror formula is true only when
(a) object is placed in front of the mirror
(b) aperture of the mirror is small
(c) rays of light are always parallel to the principal axis
(d) None of the above

29. We always get real image in a convex lens if object is situated beyond
(a) optical centre (b) focus
(c) centre of curvature (d) None of these

30. Quantity of light entering the eyes is controlled by
(a) retina (b) eye-lids
(c) iris (d) eye-lens

31. Two beams of light, one red and the other green, fall on the same spot on a white screen. The colour on the screen will appear to be
(a) magenta (b) blue (c) yellow (d) cyan

32. If the light moving in a straight line bends by a small but fixed angle it may be a case of
(a) diffraction (d) dispersion
(c) reflection (d) refraction and dispersion

33. Shadows are caused by things, which are
(a) light (b) heavy
(c) transparent (d) opaque

34. If a glass rod is immersed in a liquid of the same refractive index, then it will
(a) look longer (b) disappear
(c) look bent (d) None of these

35. Rainbow is formed due to a combination of
(a) refraction and scattering
(b) refraction and absorption
(c) dispersion and focussing
(d) total internal reflection and dispersion

36. The velocity of light in vacuum can be changed by changing
(a) wavelength (b) frequency
(c) amplitude (d) None of these

37. The power of a lens of focal length 80 cm is
(a) 80 D (b) 40 D (c) 12.5 D (d) 1.25 D

38. **Assertion (A)** The colour of the green flower seen through red glass appears to be dark.
Reason (R) Red glass transmits only red light.
(a) Both A and R are individually true and R is the correct explanation of A.
(b) Both A and R are individually true But R is not the correct explanation of A
(c) A is true R is false
(d) A is false But R is true

39. When a thin film of oil is spread over water at rest, coloured bands are observed. This is the result of the phenomenon of
(a) dispersion (b) interference
(c) polarisation (d) scattering

40. Viewfinders, used in automobiles to locate the position of the vehicles behind, are made of **(CDS 2011 I)**
(a) plane mirror (b) concave mirror
(c) convex mirror (d) parabolic mirror

41. The focal length of convex lens is **(CDS 2011 I)**
(a) the same for all colours
(b) shorter for blue light than for red
(c) shorter for red light than for blue
(d) maximum for yellow light

42. A diffraction pattern is obtained using a beam of red light. Which one among the following will be the outcome, if the red light is replaced by blue light?
(a) Bands disappear **(CDS 2010 II)**
(b) Diffraction pattern becomes broader and further apart
(c) Diffraction pattern becomes narrower and crowded together
(d) No change

43. Consider the following statements.
1. Clear sky appears blue due to poor scattering of blue wavelength of visible light.
2. Red part of light shows more scattering than blue light in the atmosphere.
3. In the absence of atmosphere, there would be no scattering of light and sky will look black.

Which of the statements given above is/are correct? **(CDS 2010 I)**
(a) 1 only (b) 1 and 2
(c) 3 only (d) 1, 2 and 3

44. As the sunlight passes through the atmosphere, the rays are scattered by tiny particles of dust, pollen, soot and other minute particulate matters present there. However, when we look up, the sky appears blue during mid-day because **(CDS 2010 II)**
(a) blue light is scattered most
(b) blue light is absorbed most
(c) blue light is reflected most
(d) ultraviolet and yellow component of sunlight combine

45. Why is it difficult to see through fog? **(CDS 2008 II)**
(a) Rays of light suffer total internal reflection from the fog droplets
(b) Rays of light are scattered by the fog droplets
(c) Fog droplets absorb light
(d) The refractive index of fog is extremely high

46. A coin immersed in water pond appears to be raised when viewed from the top. What is this due to?
(a) Total internal reflection of light **(CDS 2007 II)**
(b) Scattering of light
(c) Reflection of light
(d) Refraction of light

47. Efficient working of optical fibre is dependent on which one of the following? **(CDS 2007 I)**
(a) Reflection (b) Interference
(c) Diffraction (d) Total internal reflection

Answers

1. (d)	2. (a)	3. (c)	4. (b)	5. (a)	6. (d)	7. (c)	8. (d)	9. (d)	10. (b)
11. (c)	12. (d)	13. (a)	14. (c)	15. (b)	16. (a)	17. (b)	18. (a)	19. (d)	20. (a)
21. (d)	22. (c)	23. (a)	24. (d)	25. (b)	26. (a)	27. (c)	28. (b)	29. (b)	30. (c)
31. (c)	32. (d)	33. (d)	34. (b)	35. (d)	36. (a)	37. (d)	38. (a)	39. (b)	40. (c)
41. (b)	42. (a)	43. (c)	44. (a)	45. (b)	46. (d)	47. (d)			