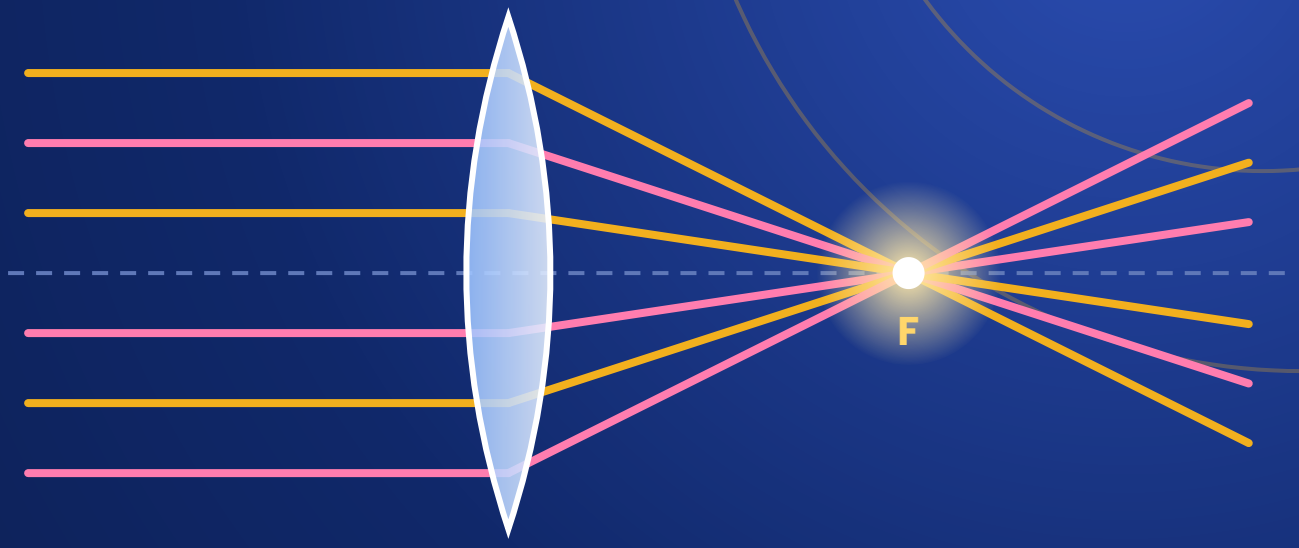
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Class 10 • Physics



CHAPTER 12

GEOMETRICAL OPTICS

Complete Exercise Solutions

10	25	10	12
MCQs	Review Questions	Conceptual	Numericals

A Multiple Choice Questions

Choose the correct answer from the given choices — 10 questions

i **Which of the following quantity is not changed during refraction of light?**

(a) its direction

(b) its speed

(c) **its frequency** ✓

(d) its wavelength

✓ Correct Answer: (c)

Explanation

When light travels from one medium to another, its speed and wavelength change, which causes it to bend (change direction). However, the frequency of the light depends only on the source and remains constant across boundaries.

ii **A converging mirror with a radius of 20 cm creates a real image 30 cm from the mirror. What is the object distance?**

(a) −5.0 cm

(b) −7.5 cm

(c) **−15 cm** ✓

(d) −20 cm

✓ Correct Answer: (c)

Explanation

For a converging (concave) mirror, f = R/2 = 20/2 = 10 cm. The image is real, so q = 30 cm. Using the mirror formula 1/f = 1/p + 1/q: 1/p = 1/10 − 1/30 = 3/30 − 1/30 = 2/30 = 1/15, so p = 15 cm. The negative sign in the options only shows that the object lies in front of the mirror (the textbook's way of writing it), so the answer is −15 cm.

iii **An object is placed at the centre of curvature of a concave mirror. The image produced by the mirror is located**

(a) out beyond the centre of curvature.

(b) **at the centre of curvature.** ✓

(c) between the centre of curvature and the focal point

(d) at the focal point

✓ **Correct Answer: (b)**

Explanation

When an object is placed at the centre of curvature (C) of a concave mirror, the reflected rays form an image that is also exactly at C. The image is real, inverted, and of the same size as the object.

iv **An object is 14 cm in front of a convex mirror. The image is 5.8 cm behind the mirror. What is the focal length of the mirror?**

(a) −4.1 cm

(b) −8.2 cm

(c) **−9.9 cm** ✓

(d) −20 cm

✓ **Correct Answer: (c)**

Explanation

The object is real, so p = 14 cm. The image is virtual (behind the mirror), so q = −5.8 cm. Using $1/f = 1/p + 1/q$: $1/f = 1/14 - 1/5.8 = 0.0714 - 0.1724 = -0.1010\ \text{cm}^{-1}$, so f = −9.9 cm. A negative focal length is the sign of a convex (diverging) mirror.

v **The index of refraction depends on**

(a) the focal length

(b) **the speed of light** ✓

(c) the image distance

(d) the object distance

✓ **Correct Answer: (b)**

Explanation

The refractive index (n) of a medium is the ratio of the speed of light in vacuum (c) to the speed of light in that medium (v): n = c/v. It therefore depends directly on the speed of light in the material.

vi **Which type of image is formed by a concave lens on a screen?**

(a) inverted and real

(b) inverted and virtual

(c) upright and real

(d) **upright and virtual** ✓

✓ **Correct Answer: (d)**

Explanation

A concave (diverging) lens always forms a virtual, upright and diminished image of a real object. Because the image is virtual, it cannot actually be caught on a screen; out of the given options, (d) describes the type of image the lens forms.

vii **Which type of image is produced by the converging lens of human eye if it views a distant object?**

(a) real, erect, same size

(b) **real, inverted, diminished** ✓

(c) virtual, erect, diminished

(d) virtual, inverted, magnified

✓ **Correct Answer: (b)**

Explanation

The eye's lens is a convex (converging) lens. For a distant object the object distance is effectively infinite, so the lens focuses the light to form a real, inverted and highly diminished image on the retina.

viii **Image formed by a camera is**

(a) **real, inverted, and diminished** ✓

(b) virtual, upright and diminished

(c) virtual, upright and magnified

(d) real, inverted and magnified

✓ **Correct Answer: (a)**

Explanation

A camera uses a convex lens. To record an image on the film or sensor, a real image must be formed. For objects at normal distances the image is real, inverted, and smaller than the object (diminished).

ix **If a ray of light in glass is incident on an air surface at an angle greater than the critical angle, the ray will**

(a) refract only

(b) **reflect only** ✓

(c) partially refract and partially reflect

(d) diffract only

✓ **Correct Answer: (b)**

Explanation

When light travels from a denser medium (glass) to a rarer medium (air) at an angle greater than the critical angle, Total Internal Reflection (TIR) occurs. The light does not refract into the air; it is entirely reflected back into the glass.

x **The critical angle for a beam of light passing from water into air is 48.8 degrees. This means that all light rays with an angle of incidence greater than this angle will be**

(a) absorbed

(b) **totally reflected** ✓

(c) partially reflected and partially transmitted

(d) totally transmitted

✓ **Correct Answer: (b)**

Explanation

This is the exact definition of Total Internal Reflection. If the angle of incidence exceeds the critical angle, no light is transmitted into the second medium; it is 100% reflected back into the original medium.

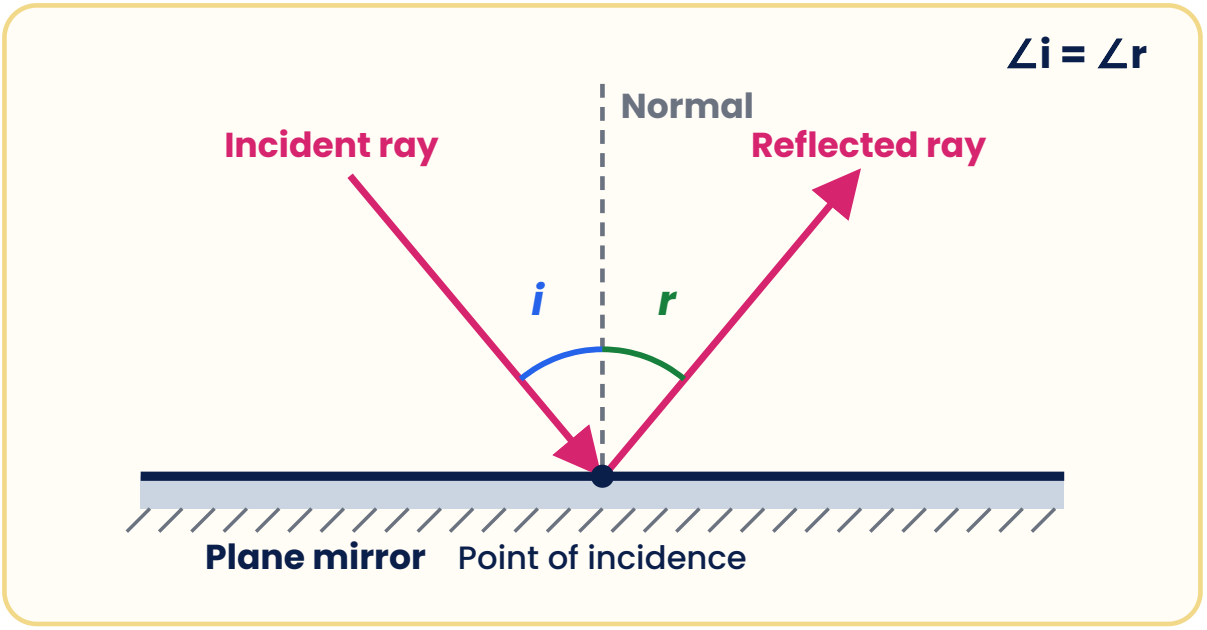
B Review Questions

Short and extensive questions 12.1 – 12.25 — 25 questions

12.1 What do you understand by reflection of light? Draw a diagram to illustrate reflection at a plane surface.

Answer

Reflection of light is the bouncing back of light rays into the same medium when they strike a smooth, polished surface (like a mirror). The surface reflects the light according to specific laws.



Reflection at a plane surface: the angle of incidence (i) equals the angle of reflection (r).

12.2 **Describe the following terms used in reflection: (i) normal (ii) angle of incidence (iii) angle of reflection**

Answer

1. **Normal:** An imaginary line drawn perpendicular to the reflecting surface at the point of incidence.
2. **Angle of incidence:** The angle between the incident ray and the normal.
3. **Angle of reflection:** The angle between the reflected ray and the normal.

12.3 **State laws of reflection. Describe how they can be verified graphically.**

Answer

Laws of reflection

- **First Law:** The incident ray, the normal, and the reflected ray all lie in the same plane.
- **Second Law:** The angle of incidence is equal to the angle of reflection ($\angle i = \angle r$).

Verification: These laws can be verified by drawing a normal to a plane mirror. By tracing incident and reflected rays, one can measure with a protractor that the angles are equal and confirm that all rays lie on the paper (the same plane).

12.4 **Define refraction of light. Describe the passage of light through parallel-sided transparent material.**

Answer

Refraction is the bending of light as it passes from one transparent medium to another due to a change in its speed.

When light passes through a parallel-sided glass slab, it bends **towards the normal** upon entering (rarer to denser) and **away from the normal** upon exiting (denser to rarer). The emergent ray is parallel to the incident ray, but laterally displaced.

12.5 **Define the following terms used in refraction: (i) angle of incidence (ii) angle of refraction**

Answer

1. **Angle of incidence:** The angle between the incident ray and the normal at the point of incidence.
2. **Angle of refraction:** The angle between the refracted ray and the normal at the point of refraction.

12.6 **What is meant by refractive index of a material? How would you determine the refractive index of a rectangular glass slab?**

Answer

Refractive index is the ratio of the speed of light in a vacuum to the speed of light in the material (n = c/v). It can also be found using Snell's Law: $n = \frac{\sin i}{\sin r}$.

Determination:

1. Place the glass slab on a sheet of paper and draw its outline.
2. Stick two pins on one side to form the incident ray.
3. Look through the opposite side and stick two more pins so that they appear in a straight line with the first two.
4. Remove the slab and draw the incident ray, the emergent ray and the normal.
5. Measure the angles i and r and calculate $n = \frac{\sin i}{\sin r}$.

12.7 **State the laws of refraction of light and show how they may be verified using rectangular glass slab and pins.**

Answer

Laws of refraction

- **First Law:** The incident ray, refracted ray, and normal all lie in the same plane.
- **Second Law (Snell's Law):** The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given pair of media: $\frac{\sin i}{\sin r} = n$.

Verification:

1. Use the pin method described in 12.6 and plot the incident and emergent rays.
2. Draw the normal at the point of incidence and measure i and r.
3. Repeat for different angles of incidence and calculate $\frac{\sin i}{\sin r}$ each time. The ratio remains constant, which verifies Snell's law.

12.8 **What is meant by the term total internal reflection?**

Answer

Total Internal Reflection (TIR) is the phenomenon where a light ray travelling from a denser medium to a rarer medium strikes the boundary at an angle greater than the critical angle and is completely reflected back into the denser medium.

12.9 **State the conditions for total internal reflection.**

Answer

1. Light must travel from a denser medium to a rarer medium.
2. The angle of incidence must be greater than the critical angle for that pair of media.

12.10 **What is critical angle? Derive a relationship between the critical angle and the refractive index of a substance.**

Answer

The critical angle is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is exactly 90°.

Derivation: By Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$. Let medium 1 be the denser substance (refractive index n) and medium 2 be air ($n \approx 1$). At the critical angle, $\theta_1 = \theta_c$ and $\theta_2 = 90°$.

$$n \sin\theta_c = 1 \times \sin 90°$$

$$n \sin\theta_c = 1 \times 1$$

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

12.11 **What are optical fibres? Describe how total internal reflection is used in light propagating through optical fibres.**

Answer

Optical fibres are thin, flexible strands of high-quality glass or plastic. They consist of a central **core** with a high refractive index surrounded by a **cladding** with a lower refractive index.

Light entering the fibre at a shallow angle hits the core–cladding boundary at an angle greater than the critical angle, causing Total Internal Reflection. The light bounces along the inside of the fibre with almost no loss, allowing data to be transmitted over long distances.

12.12 **Define the following terms applied to a lens: (i) principal axis (ii) optical centre (iii) focal length**

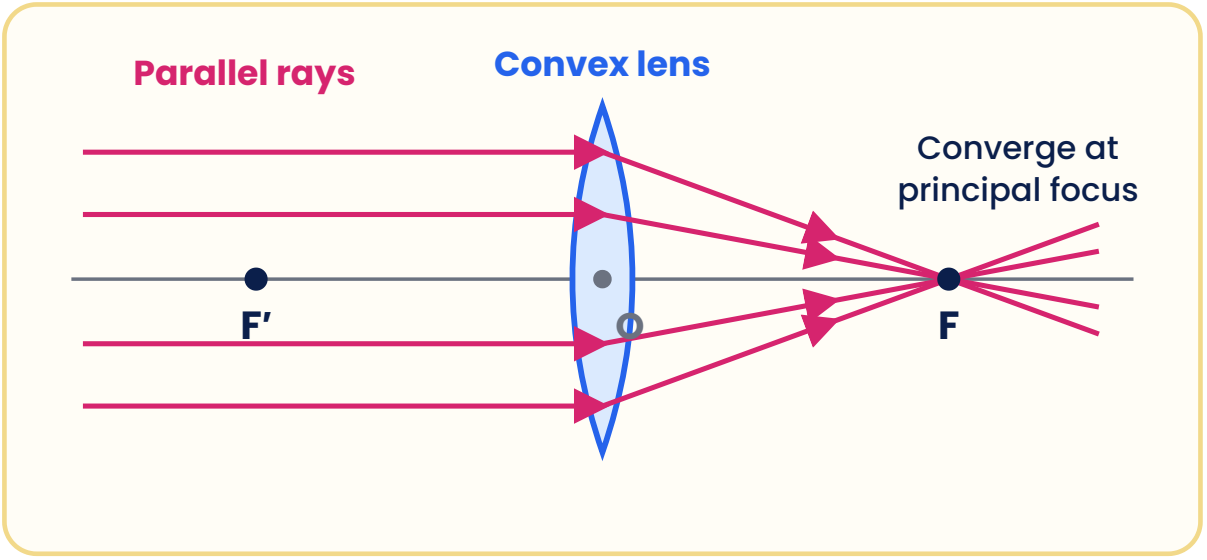
Answer

1. **Principal axis:** A straight line passing through the geometric centre of the lens and perpendicular to its surfaces.
2. **Optical centre:** The central point of a lens. A ray passing through it goes straight without deviation.
3. **Focal length:** The distance between the optical centre and the principal focus.

12.13 **What is meant by the principal focus of a (a) convex lens (b) concave lens? Illustrate your answer with ray diagrams.**

Answer

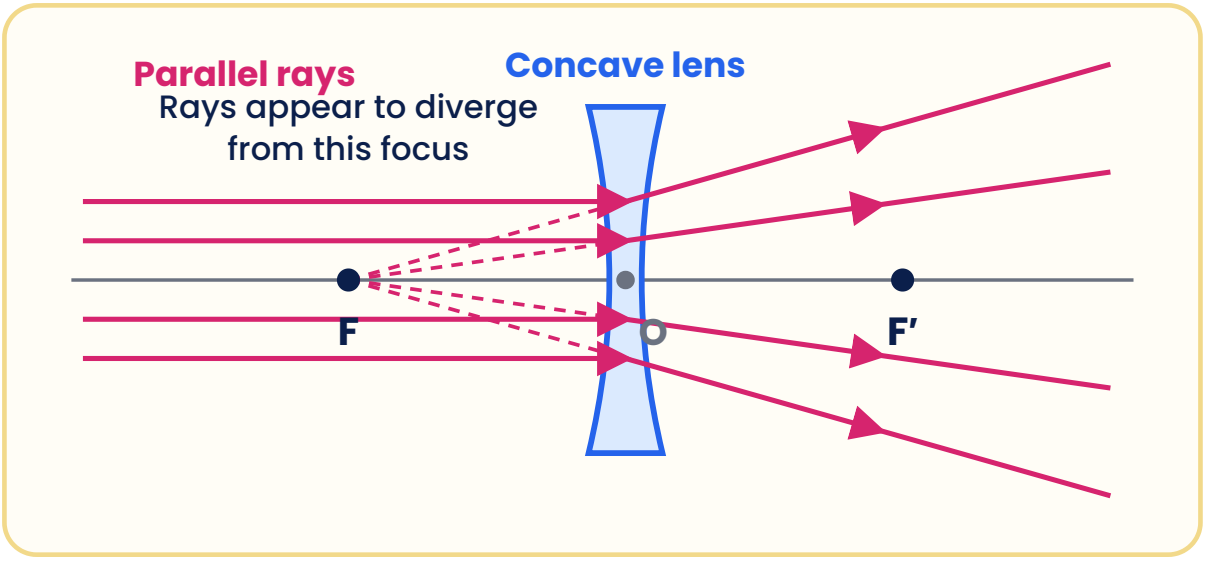
(a) Convex lens: The principal focus is a point on the principal axis where all rays parallel to the principal axis converge after passing through the lens.



Convex lens: parallel rays converge at the principal focus F.

Question 12.13 — continued

(b) Concave lens: The principal focus is a point on the principal axis from which parallel rays appear to diverge after passing through the lens.



Concave lens: parallel rays diverge as if coming from the principal focus F.

12.14 **Describe how light is refracted through convex lens.**

Answer

When light rays pass through a convex lens, they bend towards the principal axis. The three standard rays behave as follows:

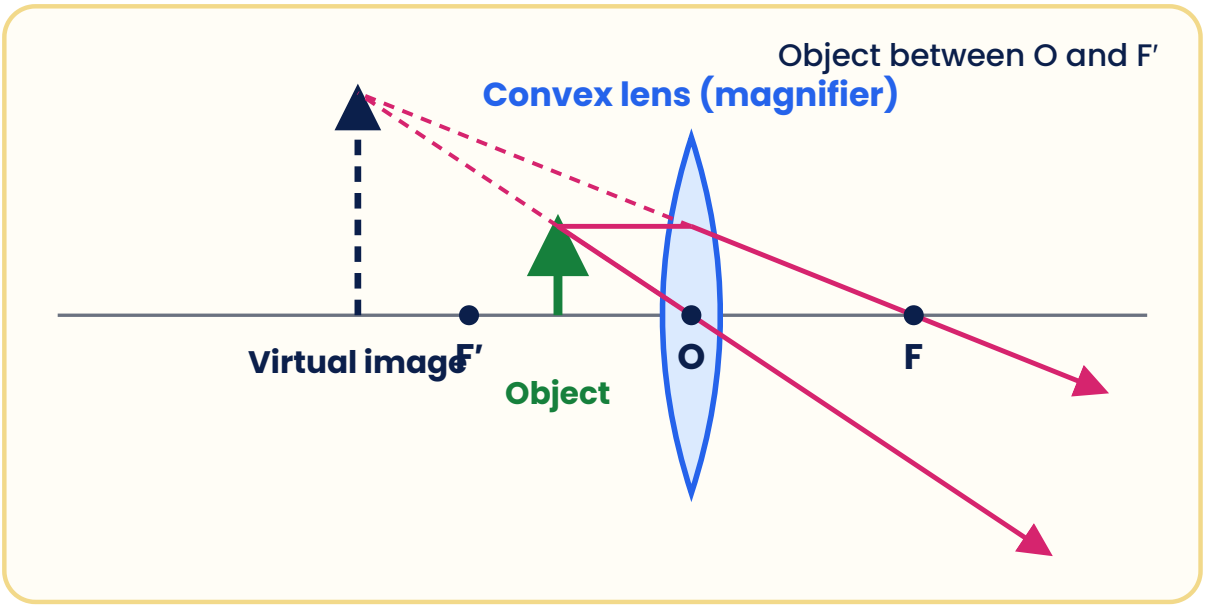
- A ray parallel to the principal axis passes through the focus after refraction.
- A ray passing through the focus emerges parallel to the principal axis.
- A ray passing through the optical centre goes straight without deviation.

The lens converges the light to form an image.

12.15 **With the help of a ray diagram, how can you show the use of thin converging lens as a magnifying glass.**

Answer

To use a convex lens as a magnifying glass, the object is placed between the optical centre and the principal focus (f). The rays diverge after passing through the lens, forming a **virtual, upright and enlarged** image on the same side as the object.



Convex lens as a magnifying glass: object between O and F′; image is virtual, upright and enlarged.

12.16 **A coin is placed at a focal point of a converging lens. Is an image formed? What is its nature?**

Answer

If the object (the coin) is exactly at the focal point, the refracted rays emerge **parallel** to each other. They never meet, and their backward extensions never meet either, so no image is formed at any finite distance. The image can only be said to lie at infinity, so it cannot be seen or caught on a screen.

12.17 What are the differences between real and virtual images?

Answer

Real image

- Formed when light rays actually meet at a point.
- Can be projected onto a screen.
- Is inverted (for a single lens or mirror).

Virtual image

- Formed when light rays only *appear* to meet (when extended backwards).
- Cannot be projected onto a screen.
- Is upright (for a single lens or mirror).

12.18 How does a converging lens form a virtual image of a real object? How does a diverging lens form a real image of a real object?

Answer

A converging lens forms a virtual image when the object is placed closer to the lens than its focal length (between O and F).

A diverging (concave) lens **cannot** form a real image of a real object. It always forms virtual, upright and diminished images.

12.19 Define power of a lens and its units.

Answer

Power of a lens is the measure of its ability to converge or diverge light. It is the reciprocal of the focal length in metres.

$$P = \frac{1}{f \text{ (in metres)}}$$

The SI unit of power is the **dioptre (D)**, where 1 D = 1 m^{-1}.

12.20 Describe the passage of light through a glass prism and measure the angle of deviation.

Answer

When a ray of light enters a prism, it bends towards the base (refracts). As it leaves the prism, it bends away from the normal, again towards the base. The total angle between the incident ray's original direction and the emergent ray is called the **angle of deviation (δ)**.

Measurement:

1. Place the prism on a sheet of paper and draw its outline.
2. Fix two pins on one side to mark the incident ray and look through the other face to fix two more pins in line with the images of the first two.
3. Remove the prism and join the pin marks to get the incident ray and the emergent ray.
4. Extend both rays until they meet. The angle between the extended incident ray and the emergent ray, measured with a protractor, is the angle of deviation.

12.21 Define the terms resolving power and magnifying power.

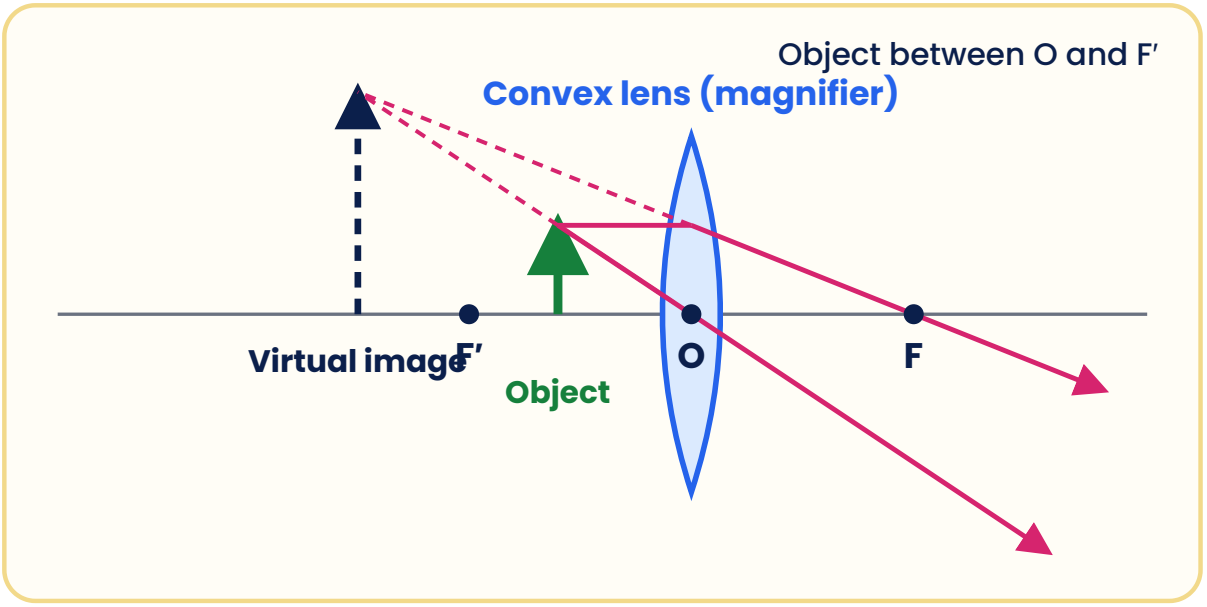
Answer

1. **Resolving power:** The ability of an optical instrument to produce distinctly separate images of two closely spaced objects.
2. **Magnifying power:** The ratio of the angle subtended by the image at the eye to the angle subtended by the object at the unaided eye.

12.22 Draw the ray diagrams of (i) simple microscope (ii) compound microscope (iii) refracting telescope

Answer

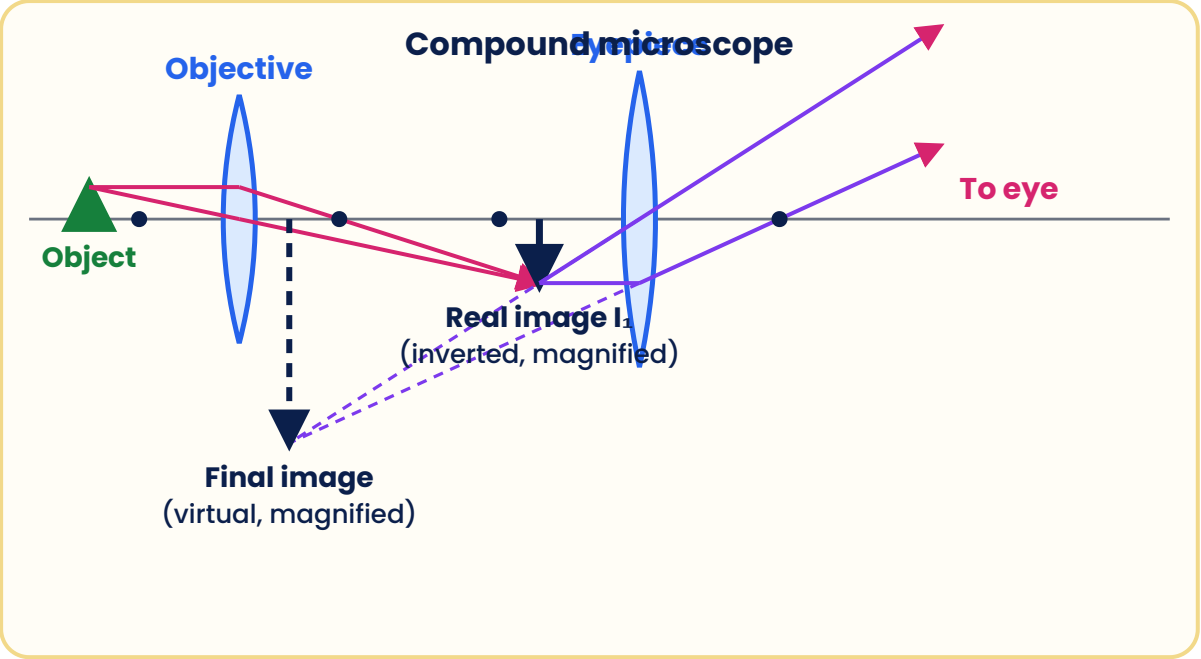
(i) Simple microscope: Object between O and F of a convex lens, forming a virtual, upright, magnified image.



Simple microscope (magnifying glass).

Question 12.22 — continued

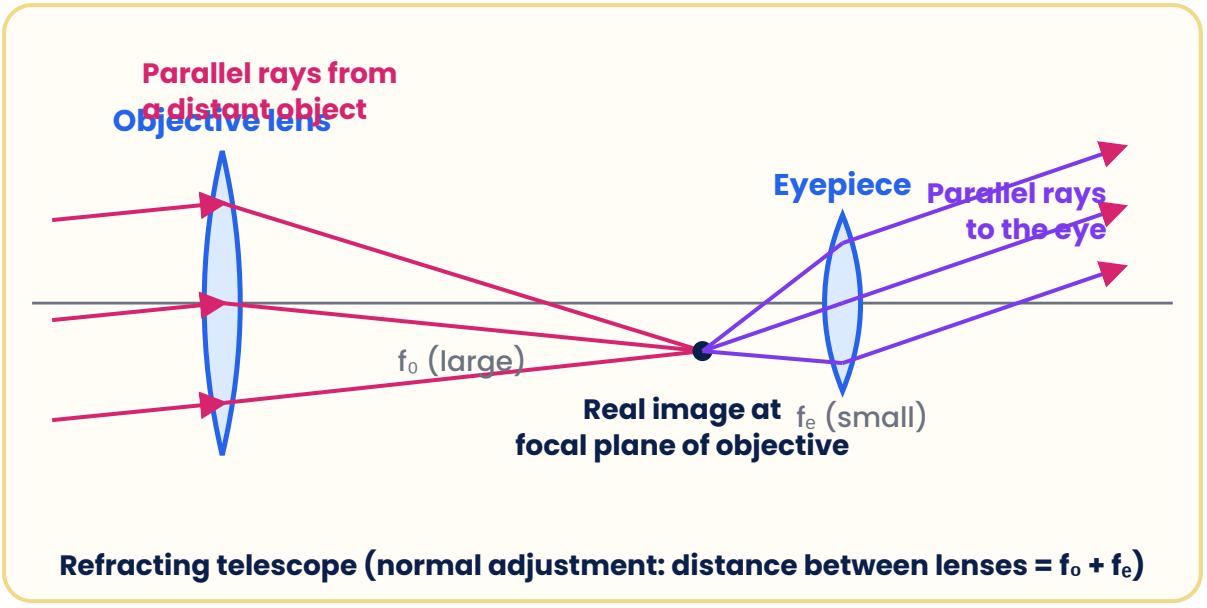
(ii) Compound microscope: Two convex lenses. The object is just outside F of the objective, forming a real, inverted, magnified image which acts as the object for the eyepiece (within its F) to form a final virtual, magnified image.



Compound microscope.

Question 12.22 — continued

(iii) Refracting telescope: The objective lens with a large focal length forms a real image of the distant object at its focal plane. The eyepiece acts as a magnifier.



Refracting telescope.

12.23 **Mention the magnifying powers of the following optical instruments: (i) simple microscope (ii) compound microscope (iii) refracting telescope**

Answer

1. **Simple microscope:** $M = 1 + \frac{D}{f}$ (for image at the near point).
2. **Compound microscope:** $M = M_o \times M_e$ (product of the magnifications of the objective and the eyepiece).
3. **Refracting telescope:** $M = \frac{f_o}{f_e}$ (ratio of the focal length of the objective to that of the eyepiece).

12.24 **Draw ray diagrams to show the formation of images in the normal human eye.**

Answer

The eye lens is a convex (converging) lens. It receives light rays from an object and converges them to a sharp point on the retina at the back of the eye.

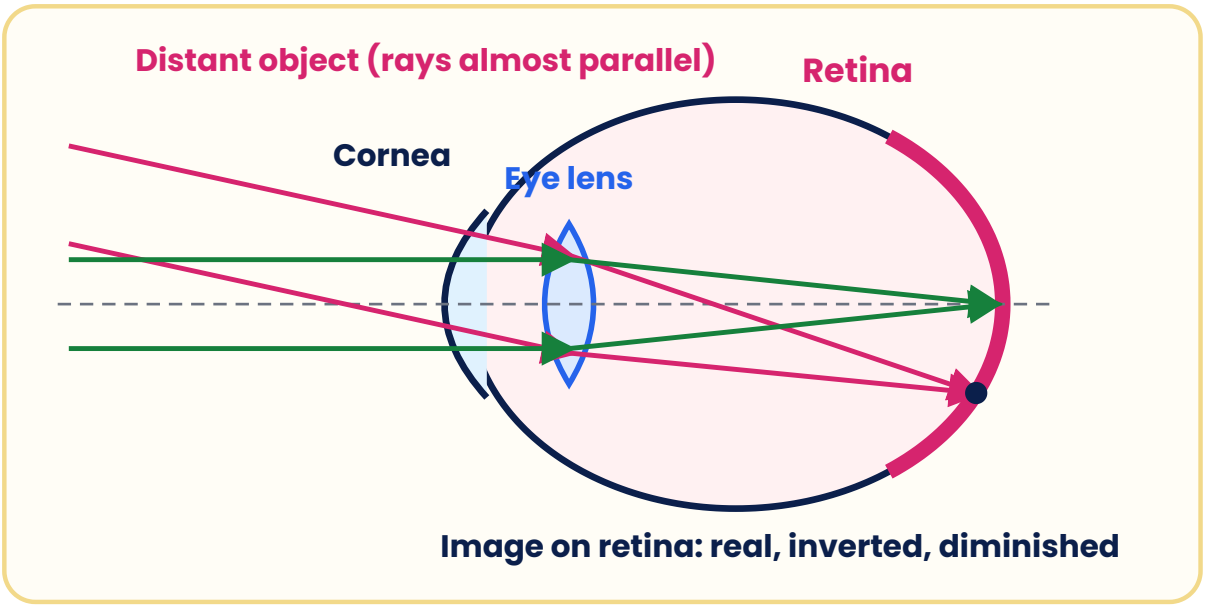


Image formation in the normal human eye.

12.25 **What is meant by the terms nearsightedness and farsightedness? How can these defects be corrected?**

Answer

Nearsightedness (Myopia): The eye can see nearby objects clearly but distant objects appear blurry because the image forms in front of the retina. It is corrected using a **concave (diverging) lens**.

Farsightedness (Hypermetropia): The eye can see distant objects clearly but nearby objects appear blurry because the image forms behind the retina. It is corrected using a **convex (converging) lens**.

C Conceptual Questions

Questions 12.1 – 12.10 — 10 questions

12.1 **A man raises his left hand in a plane mirror, the image facing him is raising his right hand. Explain why.**

Answer

A plane mirror forms an image as far behind the mirror as the object is in front of it, and the line joining every point of the object to its image is perpendicular to the mirror. So the mirror reverses only the front-to-back direction, which makes the image **face** the man.

The image of his left hand therefore appears behind the mirror on the same side as his left hand. But since the image is facing him, that same side is the image's own **right** side. This left–right reversal is called **lateral inversion**.

12.2 **In your own words, explain why light waves are refracted at a boundary between two materials.**

Answer

Light travels at different speeds in different materials. When it crosses a boundary at an angle, the part of the wavefront that enters the new material first slows down (or speeds up) before the rest of the wavefront does. This makes the wavefront change direction, which we observe as refraction.

12.3 **Explain why a fish under water appears to be at a different depth below the surface than it actually is. Does it appear deeper or shallower?**

Answer

Light from the fish travels from water (denser) to air (rarer) and bends away from the normal. When this light reaches our eyes, our brain traces the rays back in a straight line. The intersection of these extended rays forms a virtual image that is closer to the surface. Thus, the fish appears **shallower** than it actually is.

12.4 **Why or why not concave mirrors are suitable for makeup?**

Answer

They are very suitable. When a person's face is placed within the focal length of a concave mirror, it produces a virtual, upright and magnified image. This enlarged view helps in applying makeup accurately.

12.5 **Why is the driver's side mirror in many cars convex rather than plane or concave?**

Answer

A convex mirror always forms a diminished, upright, virtual image, which provides a much wider field of view than a plane mirror. This helps the driver see more traffic behind and beside the car, reducing blind spots.

12.6 **When an optician's testing room is small, he uses a mirror to help him test the eyesight of his patients. Explain why.**

Answer

The optician uses a **plane mirror**. The eye chart is hung behind the patient and the patient reads its image in the mirror. The image is as far behind the mirror as the chart is in front of it, so the patient sees the chart at a distance equal to the chart-to-mirror distance plus the mirror-to-patient distance.

This almost doubles the testing distance, so the standard test distance (about 6 m) can be obtained even in a small room.

12.7 **How does the thickness of a lens affect its focal length?**

Answer

A thicker lens (with more curvature) bends light more sharply. Therefore, a thicker lens has a shorter focal length and greater power. A thinner lens bends light less, resulting in a longer focal length.

12.8 **Under what conditions will a converging lens form a virtual image?**

Answer

A converging (convex) lens forms a virtual image when the object is placed between the optical centre and the principal focus (closer than the focal length).

12.9 **Under what conditions will a converging lens form a real image that is the same size as the object?**

Answer

A converging lens forms a real image of the same size as the object when the object is placed exactly at the centre of curvature, i.e. at a distance 2F from the lens. The image is then formed at 2F on the other side, and it is inverted.

12.10 **Why do we use refracting telescope with large objective lens of large focal length?**

Answer

A large objective lens gathers more light, making faint celestial objects visible. A large focal length gives a larger image of the object, and combined with a small eyepiece focal length, it produces a higher magnifying power ($M = \frac{f_o}{f_e}$).

D Numerical Problems

Problems 12.1 – 12.12 — 12 problems, fully solved

Sign convention used in the solutions: f is positive for a concave mirror / convex lens and negative for a convex mirror / concave lens; q is positive for a real image and negative for a virtual image; $1/f = 1/p + 1/q$ and $m = -q/p$.

12.1 An object 10.0 cm in front of a convex mirror forms an image 5.0 cm behind the mirror. What is the focal length of the mirror?

Given

Object distance	p = 10.0 cm (real object)
Image distance	q = −5.0 cm (virtual, behind mirror)
Focal length	f = ?

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Solution

$$\frac{1}{f} = \frac{1}{10.0} + \frac{1}{(-5.0)} = 0.1 - 0.2 = -0.1 \text{ cm}^{-1}$$

$$f = \frac{1}{-0.1} = -10 \text{ cm}$$

✓ **Answer:** f = −10 cm (the negative sign shows that the mirror is convex).

12.2 **An object 30 cm tall is located 10.5 cm from a concave mirror with focal length 16 cm. (a) Where is the image located? (b) How high is it?**

Given

Object height	$h_o = 30$ cm
Object distance	$p = 10.5$ cm
Focal length	$f = +16$ cm (concave)

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad m = -\frac{q}{p}, \quad h_i = m \times h_o$$

Solution

(a) $\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{16} - \frac{1}{10.5} = 0.0625 - 0.0952 = -0.0327$ cm^{-1}

$q = -30.54$ cm (negative: the image is virtual and lies 30.54 cm behind the mirror).

(b) $m = -\frac{q}{p} = -\frac{(-30.54)}{10.5} = +2.91$

$h_i = m \times h_o = 2.91 \times 30 = 87.27$ cm (upright).

✓ **Answer:** (a) 30.54 cm behind the mirror (virtual image); (b) 87.27 cm tall (≈ 87.3 cm).

Note: The object lies inside the focal length, so a virtual, upright and magnified image is formed.

12.3 **An object and its image in a concave mirror are of the same height, yet inverted, when the object is 20 cm from the mirror. What is the focal length of the mirror?**

Given

Object distance	$p = 20$ cm
Magnification	$m = -1$ (same size, inverted)
Focal length	$f = ?$

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad m = -\frac{q}{p}$$

Solution

$$-1 = -\frac{q}{20} \implies q = 20 \text{ cm (real image)}$$

$$\frac{1}{f} = \frac{1}{20} + \frac{1}{20} = \frac{2}{20} = \frac{1}{10}$$

$$f = 10 \text{ cm}$$

✓ **Answer:** $f = 10$ cm (the object is at the centre of curvature, so $R = 2f = 20$ cm).

12.4 **Find the focal length of a mirror that forms an image 5.66 cm behind the mirror of an object placed at 34.4 cm in front of the mirror. Is the mirror concave or convex?**

Given

Object distance	$p = 34.4$ cm
Image distance	$q = -5.66$ cm (virtual, behind mirror)
Focal length	$f = ?$

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Solution

$$\frac{1}{f} = \frac{1}{34.4} + \frac{1}{(-5.66)} = 0.02907 - 0.17668 = -0.14761 \text{ cm}^{-1}$$

$$f = \frac{1}{-0.14761} = -6.77 \text{ cm}$$

✓ **Answer:** $f = -6.77$ cm. Since f is negative, the mirror is **convex**.

12.5 **An image of a statue appears to be 11.5 cm behind a concave mirror with focal length 13.5 cm. Find the distance from the statue to the mirror.**

Given

Image distance	$q = -11.5$ cm (virtual, behind mirror)
Focal length	$f = +13.5$ cm (concave)
Object distance	$p = ?$

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Solution

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{13.5} - \frac{1}{(-11.5)} = \frac{1}{13.5} + \frac{1}{11.5}$$

$$= 0.07407 + 0.08696 = 0.16103 \text{ cm}^{-1}$$

$$p = \frac{1}{0.16103} = 6.21 \text{ cm}$$

✓ **Answer:** The statue is 6.21 cm in front of the mirror.

Note: A virtual image behind a concave mirror is formed only when the object lies inside the focal length (6.21 cm < 13.5 cm), which agrees with the answer.

12.6 **An image is produced by a concave mirror of focal length 8.7 cm. The object is 13.2 cm tall and at a distance 19.3 cm from the mirror. (a) Find the location and height of the image. (b) Find the height of the image produced by the mirror if the object is twice as far from the mirror.**

Given

Focal length	$f = +8.7$ cm (concave)
Object height	$h_o = 13.2$ cm
Object distance	$p = 19.3$ cm

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad m = -\frac{q}{p}, \quad h_i = m \times h_o$$

Solution

(a) $\frac{1}{q} = \frac{1}{8.7} - \frac{1}{19.3} = 0.11494 - 0.05181 = 0.06313\ \text{cm}^{-1} \implies q = 15.84$ cm (real, in front of the mirror)

$m = -\frac{15.84}{19.3} = -0.82 \implies h_i = -0.82 \times 13.2 = -10.83$ cm (inverted)

(b) Object twice as far: $p = 2 \times 19.3 = 38.6$ cm

$\frac{1}{q} = \frac{1}{8.7} - \frac{1}{38.6} = 0.11494 - 0.02591 = 0.08904\ \text{cm}^{-1} \implies q = 11.23$ cm

$m = -\frac{11.23}{38.6} = -0.29 \implies h_i = -0.29 \times 13.2 = -3.84$ cm (inverted)

✓ **Answer:** (a) $q = 15.84$ cm in front of the mirror, image height = 10.83 cm (real, inverted); (b) image height = 3.84 cm.

12.7 **Nabeela uses a concave mirror when applying makeup. The mirror has a radius of curvature of 38 cm. (a) What is the focal length of the mirror? (b) Nabeela is located 50 cm from the mirror. Where will her image appear? (c) Will the image be upright or inverted?**

Given

Radius of curvature	R = 38 cm
Object distance	p = 50 cm
Unknown	f, q and nature of image

Formula

$$f = \frac{R}{2} \qquad \frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Solution

(a) $f = \frac{R}{2} = \frac{38}{2} = 19$ cm

(b) $\frac{1}{q} = \frac{1}{19} - \frac{1}{50} = 0.05263 - 0.02 = 0.03263\ \text{cm}^{-1} \implies q =$ 30.65 cm (in front of the mirror)

(c) $m = -\frac{30.65}{50} = -0.61$. The negative sign shows that the image is **inverted** (it is also real and diminished).

✓ **Answer:** (a) f = 19 cm; (b) the image forms about 30.65 cm in front of the mirror; (c) the image is inverted.

Note: Nabeela stands beyond the focal length (50 cm > 19 cm), so the image is always real and inverted. She would see an upright magnified image only if she stood closer than 19 cm.

12.8 **An object 4 cm high is placed at a distance of 12 cm from a convex lens of focal length 8 cm. Calculate the position and size of the image. Also state the nature of the image.**

Given

Object height	$h_o = 4$ cm
Object distance	$p = 12$ cm
Focal length	$f = +8$ cm (convex lens)

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad m = -\frac{q}{p}, \quad h_i = m \times h_o$$

Solution

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{8} - \frac{1}{12} = \frac{3}{24} - \frac{2}{24} = \frac{1}{24}$$

$q = +24$ cm (the image is 24 cm behind the lens)

$$m = -\frac{q}{p} = -\frac{24}{12} = -2$$

$$h_i = m \times h_o = -2 \times 4 = -8 \text{ cm}$$

✓ **Answer:** Image distance = 24 cm, image height = 8 cm; the image is real, inverted and magnified.

12.9 **An object 10 cm high is placed at a distance of 20 cm from a concave lens of focal length 15 cm. Calculate the position and size of the image. Also, state the nature of the image.**

Given

Object height	$h_o = 10$ cm
Object distance	$p = 20$ cm
Focal length	$f = -15$ cm (concave lens)

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad m = -\frac{q}{p}, \quad h_i = m \times h_o$$

Solution

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{(-15)} - \frac{1}{20} = -\frac{4}{60} - \frac{3}{60} = -\frac{7}{60}$$

$q = -8.57$ cm (the image is 8.57 cm in front of the lens, on the same side as the object)

$$m = -\frac{q}{p} = -\frac{(-8.57)}{20} = +0.43$$

$$h_i = m \times h_o = 0.43 \times 10 \approx 4.29 \text{ cm}$$

✓ **Answer:** Image distance = −8.57 cm, image height ≈ 4.29 cm; the image is virtual, erect and diminished.

12.10 **A convex lens of focal length 6 cm is to be used to form a virtual image three times the size of the object. Where must the lens be placed?**

Given

Focal length	$f = +6$ cm
Magnification	$m = +3$ (virtual, erect, 3 times)
Object distance	$p = ?$

Formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad m = -\frac{q}{p}$$

Solution

$$3 = -\frac{q}{p} \implies q = -3p \text{ (virtual image)}$$

$$\frac{1}{6} = \frac{1}{p} + \frac{1}{(-3p)} = \frac{1}{p} - \frac{1}{3p} = \frac{2}{3p}$$

$$3p = 12 \implies p = 4 \text{ cm}$$

✓ **Answer:** The object must be placed 4 cm from the lens (inside the focal length).

12.11 **A ray of light from air is incident on a liquid surface at an angle of incidence 35°. Calculate the angle of refraction if the refractive index of the liquid is 1.25. Also calculate the critical angle between the liquid-air interface.**

Given

Angle of incidence	$i = 35°$
Refractive index	$n = 1.25$
Unknown	r and θ_c

Formula

$$n = \frac{\sin i}{\sin r} \qquad \sin \theta_c = \frac{1}{n}$$

Solution

$$\sin r = \frac{\sin 35°}{n} = \frac{0.5736}{1.25} = 0.4589$$

$$r = \sin^{-1}(0.4589) = 27.31°$$

$$\sin \theta_c = \frac{1}{1.25} = 0.8$$

$$\theta_c = \sin^{-1}(0.8) = 53.13°$$

✓ **Answer:** Angle of refraction = 27.31°; critical angle = 53.13°.

12.12 **The power of a convex lens is 5 D. At what distance the object should be placed from the lens so that its real and 2 times larger image is formed.**

Given

Power	$P = +5$ D
Magnification	$m = -2$ (real, inverted, 2 times)
Object distance	$p = ?$

Formula

$$f = \frac{1}{P} \qquad \frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad m = -\frac{q}{p}$$

Solution

$$f = \frac{1}{P} = \frac{1}{5}\ \text{m} = 0.2\ \text{m} = 20\ \text{cm}$$

$$-2 = -\frac{q}{p} \implies q = 2p$$

$$\frac{1}{20} = \frac{1}{p} + \frac{1}{2p} = \frac{3}{2p}$$

$$2p = 60 \implies p = 30\ \text{cm}$$

✓ **Answer:** The object should be placed 30 cm from the lens.

Thank You!

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