SUMMER VACATION HOMEWORK

Sub: Physics • Class X • Worksheet-05: Spherical Mirrors

Important Sign Conventions & Key Formulas

- Object distance (u): Always negative (−)
- Concave mirror focal length (f): Negative (−)
- Convex mirror focal length (f): Positive (+)
- Real & Inverted image: m is (−), v is (−)
- Virtual & Erect image: m is (+), v is (+)
- Mirror Formula: $1/f = 1/v + 1/u$

Q1. An object is placed in front of a concave mirror of focal length 20 cm. The image formed is 3 times the size of the object. Calculate two possible distances of the object from the mirror.

Given: Focal length, $f = -20$ cm. Since the nature of the image is not specified, we must consider both real and virtual cases.

<u>**Case 1: Image is Real and Inverted (m = –3)**</u>

$$m = -(v / u) \Rightarrow -3 = -(v / u) \Rightarrow v = 3u$$

Applying the mirror formula:

$$1/f = 1/v + 1/u$$

$$1/(-20) = 1/(3u) + 1/u \Rightarrow -1/20 = (1 + 3) / 3u \Rightarrow -1/20 = 4 / 3u$$

$$3u = -80 \Rightarrow u = -80/3 \text{ cm} \approx -26.67 \text{ cm}$$

<u>**Case 2: Image is Virtual and Erect (m = +3)**</u>

$$m = -(v / u) \Rightarrow 3 = -(v / u) \Rightarrow v = -3u$$

Applying the mirror formula:

$$1/(-20) = 1/(-3u) + 1/u \Rightarrow -1/20 = (-1 + 3) / 3u \Rightarrow -1/20 = 2 / 3u$$

$$3u = -40 \Rightarrow u = -40/3 \text{ cm} \approx -13.33 \text{ cm}$$

Answer: The two possible object distances are 26.67 cm and 13.33 cm in front of the mirror.

Q2. A concave mirror produces a real image 10 mm tall, of an object 2.5 mm tall placed at 5 cm from the mirror. Calculate focal length of the mirror and the position of the image.

Given:

- Height of object, $h_o = +2.5\ mm$
- Height of real image, $h_i = -10\ mm$ (negative because real images are inverted)
- Object distance, $u = -5\ cm$

Step 1: Find the image position (v)

$$m = h_i / h_o = -v / u$$

$$(-10) / 2.5 = -v / (-5) \;\Rightarrow\; -4 = v / 5 \;\Rightarrow\; v = -20\ cm$$

Step 2: Find the focal length (f)

$$1/f = 1/v + 1/u$$

$$1/f = 1/(-20) + 1/(-5) = (-1 - 4) / 20 = -5 / 20 = -1 / 4$$

$$f = -4\ cm$$

Answer: The position of the image is 20 cm in front of the mirror (v = –20 cm), and the focal length is –4 cm.

Q3. When an object is placed at a distance of 60 cm from a convex mirror, the magnification produced is 1/2. Where should the object be placed to get a magnification of 1/3?

Case 1: $u_1 = -60\ cm$, $m_1 = +1/2$ (convex mirrors always form virtual, erect images).

$$m_1 = -v_1 / u_1 \;\Rightarrow\; 1/2 = -v_1 / (-60) \;\Rightarrow\; v_1 = 30\ cm$$

Using mirror formula to find f:

$$1/f = 1/v_1 + 1/u_1 = 1/30 + 1/(-60) = (2 - 1) / 60 = 1 / 60 \;\Rightarrow\; f = +60\ cm$$

Case 2: New magnification required, $m_2 = +1/3$.

$$m_2 = -v_2 / u_2 \;\Rightarrow\; 1/3 = -v_2 / u_2 \;\Rightarrow\; v_2 = -u_2 / 3$$

Using mirror formula with $f = +60\ cm$:

$$1/60 = 1 / (-u_2 / 3) + 1 / u_2 \;\Rightarrow\; 1/60 = -3 / u_2 + 1 / u_2$$

$$1/60 = -2 / u_2 \;\Rightarrow\; u_2 = -120\ cm$$

Answer: The object should be placed at a distance of 120 cm in front of the mirror.

Q4. An object is placed 18 cm in front of a mirror. If the image is formed at 4 cm to the right of the mirror, calculate its focal length. Is the mirror convex or concave? What is the nature of the image? What is the radius of curvature of the mirror?

Given: Object distance $u = -18\ cm$, Image distance $v = +4\ cm$ (positive since it is to the right).

$$1/f = 1/v + 1/u \;\Rightarrow\; 1/f = 1/4 + 1/(-18) = (9 - 2) / 36 = 7 / 36$$

$$f = 36/7\ cm \;\approx\; +5.14\ cm$$

Analysis:

- Since focal length f is **positive**, the mirror is **Convex**.
- Since it is a convex mirror and the image is behind it, the nature is **Virtual and Erect**.
- Radius of Curvature: $R = 2f = 2 \times (36/7) = 72/7\ cm \;\approx\; 10.29\ cm$.

Answer: f = +5.14 cm, Mirror: Convex, Nature: Virtual and Erect, R = 10.29 cm.

Q5. A convex mirror used for rear view on an automobile has a radius of curvature of 3 m. If a bus is located at 5 m from this mirror, find the position, nature and magnification of the image.

Given: Radius of curvature $R = +3\ m \;\Rightarrow\; f = R/2 = +1.5\ m$. Object distance $u = -5\ m$.

$$1/v = 1/f - 1/u \;\Rightarrow\; 1/v = 1/1.5 - 1/(-5) = 10/15 + 1/5 = 2/3 + 1/5$$

$$1/v = (10 + 3) / 15 = 13 / 15 \;\Rightarrow\; v = 15/13\ m \;\approx\; +1.15\ m$$

Magnification:

$$m = -v / u = -(15/13) / (-5) = +3/13 \;\approx\; +0.23$$

Answer: The image is at a distance of 1.15 m behind the mirror. Nature is Virtual, Erect and Diminished (m = +0.23).

Q6. An object 3 cm high is held at a distance of 50 cm from a diverging mirror of focal length 25 cm. Find the nature, position and size of the image formed.

Given: Height of object $h_o = +3\ cm$, Object distance $u = -50\ cm$, Focal length of diverging (convex) mirror $f = +25\ cm$.

$$1/v = 1/f - 1/u \;\Rightarrow\; 1/v = 1/25 - 1/(-50) = (2 + 1) / 50 = 3 / 50$$

$$v = 50/3\ cm \;\approx\; +16.67\ cm$$

Size of image (h_i):

$$h_i / h_o = -v / u \;\Rightarrow\; h_i / 3 = -(50/3) / (-50) = 1/3$$

$$h_i = 3 \times (1/3) = +1\ cm$$

Answer: Position: 16.67 cm behind the mirror; Nature: Virtual and Erect; Size: 1 cm tall.

Q7. A converging mirror of focal length 20 cm forms an image which is two times the size of the object. Calculate two possible distances of the object from the mirror.

Given: Focal length of converging (concave) mirror, $f = -20\ cm$.

Case 1: Image is Real and Inverted (m = –2)

$$v = 2u \Rightarrow 1/(-20) = 1/(2u) + 1/u = 3 / 2u \Rightarrow 2u = -60 \Rightarrow u = -30\ cm$$

Case 2: Image is Virtual and Erect (m = +2)

$$v = -2u \Rightarrow 1/(-20) = 1/(-2u) + 1/u = 1 / 2u \Rightarrow 2u = -20 \Rightarrow u = -10\ cm$$

Answer: The two possible object distances are 30 cm and 10 cm in front of the mirror.

Q8. The linear magnification of a convex mirror of focal length 15 cm is 1/3. What is the distance of the object from the focus of the mirror?

Given: $f = +15\ cm$, Magnification $m = +1/3$ (convex mirror).

$$m = -v / u \Rightarrow 1/3 = -v / u \Rightarrow v = -u / 3$$

Applying mirror formula:

$$1/15 = 1 / (-u / 3) + 1 / u = -3 / u + 1 / u = -2 / u \Rightarrow u = -30\ cm$$

Distance from focus: For a convex mirror, the focus lies 15 cm behind the mirror, while the object is 30 cm in front of it.

$$ext\{Distance\ from\ focus\} = |u| + f = 30 + 15 = 45\ cm$$

Answer: The object is at a distance of 45 cm from the focus of the mirror.

Q9. The focal length of a convex mirror is 12.5 cm. How far is its center of curvature (i) from the pole (ii) from the focus?

Given: Focal length $f = 12.5\ cm$.
Radius of curvature, $R = 2f = 2 \times 12.5 = 25\ cm$.

- **(i) From the pole:** The center of curvature is at a distance equal to the radius of curvature (R) from the pole. Thus, distance = **25 cm**.

- **(ii) From the focus:** The focus lies midway between the pole and the center of curvature. Thus, the distance from focus to center of curvature is equal to the focal length (f) = **12.5 cm**.

Answer: (i) 25 cm from the pole, (ii) 12.5 cm from the focus.

Q10. Find the focal length of a concave mirror that produces a four times larger real image of an object held at 5 cm from the mirror.

Given: Object distance $u = -5\ cm$, Magnification $m = -4$ (negative for a real image).

$$m = -v / u \ \Rightarrow\ -4 = -v / (-5) \ \Rightarrow\ v = -20\ cm$$

Applying mirror formula:

$$1/f = 1/v + 1/u \ \Rightarrow\ 1/f = 1/(-20) + 1/(-5) = (-1 - 4) / 20 = -5 / 20 = -1 / 4$$

$$f = -4\ cm$$

Answer: The focal length of the concave mirror is –4 cm.

Q11. An object is held at 30 cm in front of a convex mirror of focal length 15 cm. At what distance from the convex mirror should a plane mirror be held so that images in the two mirrors coincide with each other?

Step 1: Find the position of the image formed by the convex mirror
Given: $u = -30\ cm$, $f = +15\ cm$.

$$1/v = 1/f - 1/u = 1/15 - 1/(-30) = (2 + 1) / 30 = 3 / 30 = 1 / 10 \ \Rightarrow\ v = +10\ cm$$

The virtual image is formed 10 cm behind the convex mirror.
Step 2: Position the plane mirror
Let the plane mirror be held at a distance x in front of the object.

- Distance of object from plane mirror = x.
- Distance of plane mirror's image behind it = x.
- Total distance from object to the coinciding images = $2x$.

The total distance from the object to the convex mirror's image is:

$$ext\{Total\ Distance\} = |u| + v = 30 + 10 = 40\ cm$$

Since the images coincide:

$$2x = 40\ cm \ \Rightarrow\ x = 20\ cm\ ext\{\ (from\ the\ object)\}$$

Step 3: Calculate distance from the convex mirror

Since the object is 30 cm away from the convex mirror, the plane mirror's position relative to the convex mirror is:

$$30\ cm - 20\ cm = 10\ cm$$

Answer: The plane mirror should be held at a distance of 10 cm in front of the convex mirror.

Q12. Draw any three ray diagrams to show how the size and nature of the image of an object change when it moves from the centre of curvature of a concave mirror towards the pole of the mirror.

As an object moves from the Centre of Curvature (C) toward the Pole (P) of a concave mirror, its image transitions from being real and inverted to virtual and erect. The three standard progressive ray diagram configurations are described below:

1. **Object between C and F:**
   - *Position of Image:* Beyond C
   - *Nature:* Real and Inverted
   - *Size:* Magnified (Enlarged)
2. **Object exactly at Focus (F):**
   - *Position of Image:* At Infinity
   - *Nature:* Real and Inverted
   - *Size:* Highly Magnified (Infinitely large)
3. **Object between Focus (F) and Pole (P):**
   - *Position of Image:* Behind the mirror
   - *Nature:* Virtual and Erect
   - *Size:* Magnified (Enlarged)