A 15.0 Cm Object Is 12.0 Cm From A Convex Mirror That Has A Focal Length Of -6.0 Cm. What Is The Height

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Understanding the principles of optics is essential when analyzing how images form in mirrors and lenses. In this article, we delve into the specifics of a convex mirror scenario, exploring how to determine the height of an object based on given parameters such as object size, distance from the mirror, and focal length. Whether you're a student preparing for exams or an enthusiast keen on optics, this comprehensive guide will walk you through the process step-by-step.

Introduction to Convex Mirrors

Convex mirrors are curved mirrors that bulge outward, causing light rays to diverge upon reflection. They are commonly used in vehicle side mirrors, security mirrors, and decorative applications. The key characteristics of convex mirrors include:

- Focal Length (f): Negative for convex mirrors, indicating diverging rays.
- Image Formation: Produces virtual, erect, and diminished images.
- Applications: Safety and security due to wide field of view.

Understanding the behavior of light in convex mirrors involves the mirror equation and magnification formula, which help determine the properties of the resulting image.

Understanding the Given Data

Let's review the provided information:

- Object Height (H_o): 15.0 cm
- Object Distance from Mirror (d_o): 12.0 cm
- Focal Length of Mirror (f): -6.0 cm

Our goal is to find the height of the image (H_i), which involves calculating the image distance (d_i) first, then applying the magnification concept.

The Mirror Equation and Its Application

The fundamental formula in mirror optics is:

$$ \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} $$

Where:

- f is the focal length
- d_o is the object distance
- d_i is the image distance

Since we're dealing with a convex mirror, f is negative, and for real objects, d_o is positive by convention.

Step 1: Rearrange the mirror equation to solve for d_i:

$$ \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} $$

Step 2: Substitute known values:

$$ \frac{1}{d_i} = \frac{1}{-6.0\,cm} - \frac{1}{12.0\,cm} $$

Calculate each term:

$$ \frac{1}{-6.0} = -\frac{1}{6} \approx -0.1667\,cm^{-1} $$

$$ \frac{1}{12.0} \approx 0.0833\,cm^{-1} $$

Now, compute:

$$ \frac{1}{d_i} = -0.1667 - 0.0833 = -0.25\,cm^{-1} $$

Step 3: Find d_i:

$$ d_i = \frac{1}{-0.25} = -4.0\,cm $$

The negative sign indicates that the image is virtual and located on the same side of the mirror as the object.

Calculating the Magnification

Magnification (M) relates the image height to the object height:

$$ M = \frac{H_i}{H_o} = -\frac{d_i}{d_o} $$

Note: The negative sign here indicates the orientation of the image relative to the object.

Step 1: Substitute known values:

$$ M = -\frac{-4.0\,cm}{12.0\,cm} = \frac{4.0}{12.0} = 0.333 $$

Step 2: Determine the image height:

$$H_i = M \times H_o = 0.333 \times 15.0\,cm \approx 5.0\,cm$$

This means the image height is approximately 5.0 cm, and since the magnification is positive, the image is erect.

Summary of Key Results

Parameter	Value	Explanation
Image Distance (d_i)	-4.0 cm	Virtual image, on same side as the object
Magnification (M)	0.333	Image is reduced in size
Image Height (H_i)	5.0 cm	Height of the virtual, erect image

Understanding the Significance of These Results

The calculations highlight several important concepts in convex mirror optics:

- Image Location: The virtual image is located 4.0 cm behind the mirror.
- Size of the Image: The image is smaller than the actual object, with a third of its height.
- Orientation: The positive magnification indicates an erect image, typical for convex mirrors.

This understanding is vital for designing optical systems and interpreting how objects appear when viewed through different types of mirrors.

Applications of Convex Mirror Calculations

Knowing how to calculate image properties has practical applications such as:

- Safety Mirror Design: Ensuring the image is sufficiently large for visibility.
- Security Camera Placement: Determining optimal distances for clear imaging.
- Optical Instrument Calibration: Fine-tuning focal lengths and object distances.

By mastering these calculations, engineers and designers can optimize the functionality of optical devices and enhance safety features.

Additional Considerations in Mirror Optics

While the calculations above provide a clear picture, real-world scenarios may involve additional factors:

- Mirror Surface Quality: Imperfections can distort images.

- Object and Image Distances: Larger distances may require more complex calculations.
- Material Properties: The reflective surface's quality impacts image clarity.

Understanding these factors ensures accurate application of theoretical principles in practical situations.

Conclusion

In summary, given the object height of 15.0 cm, object distance of 12.0 cm, and a convex mirror with a focal length of -6.0 cm, the image formed is approximately 5.0 cm tall, erect, virtual, and located 4.0 cm behind the mirror. These calculations demonstrate the effectiveness of the mirror equation and magnification formula in predicting optical image characteristics. Whether for academic purposes or practical applications, mastering these concepts is essential for working effectively with optical systems.

Key Takeaways

- The mirror equation is fundamental for analyzing image formation.
- Convex mirrors produce virtual, erect, and diminished images.
- Calculations involve careful attention to sign conventions.
- Practical applications span safety, security, and optical device design.

By understanding and applying these principles, you can confidently analyze various mirror and lens systems, enhancing your knowledge of optics and improving your ability to solve real-world problems.

Frequently Asked Questions

What is the formula to find the image distance in a convex mirror?

The formula is 1/f = 1/do + 1/di, where f is the focal length, do is the object distance, and di is the image distance.

How do you determine the magnification in a convex mirror?

Magnification (m) is given by m = -di / do, which also equals the ratio of the image height to the object height.

What is the significance of the negative focal length in convex mirrors?

A negative focal length indicates that the mirror is convex, causing the reflected rays to diverge.

How do you calculate the height of the image in this problem?

First, find the image height using magnification: image height = magnification × object height, where magnification is found from di and do.

Given the object height is 15.0 cm, object distance is 12.0 cm, and focal length is -6.0 cm, what is the first step to find the image distance?

Use the mirror equation: 1/f = 1/do + 1/di, plug in the known values, and solve for di.

What is the calculated image distance (di) for this convex mirror problem?

di ≈ 4.0 cm (positive, indicating a virtual image located behind the mirror).

What is the magnification of the image in this scenario?

Magnification ≈ 0.33, meaning the image is about one-third the size of the object and upright.

What is the height of the image formed by the convex mirror?

The image height is approximately 5.0 cm (positive, indicating an upright virtual image).

Why is the image in a convex mirror always virtual and erect?

Because convex mirrors diverge light rays, forming a virtual, upright, and reduced image behind the mirror.

Additional Resources

Understanding the behavior of convex mirrors and the calculation of an object's height based on image formation principles is fundamental in optics. This article delves into the specifics of a scenario involving a convex mirror with given parameters, exploring how to determine the height of an object using the mirror

equation and magnification concepts. By examining the problem in detail, we aim to clarify the underlying physics and mathematical steps involved, providing a comprehensive guide for students, educators, and enthusiasts interested in optical phenomena.

Introduction to Convex Mirrors and Image Formation

Convex mirrors are widely used in everyday applications such as vehicle side mirrors, security surveillance, and architectural design due to their unique optical properties. Unlike concave mirrors, convex mirrors bulge outward, causing incident light rays to diverge upon reflection. This divergence results in virtual, diminished, and upright images that appear to be behind the mirror.

Key Characteristics of Convex Mirrors:

- Focal Length (f): Negative in sign, indicating the mirror's convex nature.
- Image Type: Virtual, erect, and diminished.
- Image Location: Behind the mirror, where the diverging rays seem to originate.
- Applications: Enhanced field of view, safety, and security.

Understanding how these properties influence image formation is critical when analyzing real-world scenarios involving convex mirrors.

Problem Overview and Given Data

The problem involves the following data points:

- Object Height (h_o): 15.0 cm
- Object Distance from Mirror (u): 12.0 cm (positive, since object is in front of the mirror)
- Focal Length of Mirror (f): -6.0 cm (negative, characteristic of convex mirrors)

The goal is to determine the height of the object based on the provided data, which at first glance appears to be directly given. However, given the context and typical physics problems, it is more plausible that the problem intends to analyze the image height or to understand the relationship between object size and image size, possibly involving the calculation of magnification.

Note: The problem statement as provided is somewhat ambiguous because it states "What is the height" without explicitly specifying whether it refers to the object, the image, or something else. For the purpose of this comprehensive analysis, we will interpret it as calculating the image height or verifying the given object height based on image data, following typical optics problem patterns.

Fundamental Concepts in Optical Calculations

Before diving into calculations, it’s essential to review the core principles involved in image formation with mirrors:

1. Mirror Equation

The mirror equation relates the focal length (f), the object distance (u), and the image distance (v):

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

- f: focal length of the mirror (for convex mirrors, $f < 0$)
- u: object distance from the mirror (positive if object is in front of mirror)
- v: image distance from the mirror

Rearranging:

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

---

2. Magnification (M)

Magnification relates the heights and distances:

$$
M = \frac{\text{Image Height } (h_i)}{\text{Object Height } (h_0)} = \frac{v}{u}
$$

- For convex mirrors, the magnification is positive, indicating an upright image.

Calculating the Image Distance (v)

Applying the mirror equation with the given data:

$$
f = -6.0\, \text{cm}
$$

\]
\[
u = +12.0\, \text{cm}
\]

Rearranged:

\[
\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-6} - \frac{1}{12}
\]

Calculating:

\[
\frac{1}{v} = -\frac{1}{6} - \frac{1}{12} = -\frac{2}{12} - \frac{1}{12} = -\frac{3}{12} = -\frac{1}{4}
\]

Therefore:

\[
v = -4\, \text{cm}
\]

Interpreting the Image Distance and Magnification

The negative value of v indicates that the image is virtual and located behind the mirror, consistent with convex mirror behavior.

Calculating magnification:

\[
M = \frac{v}{u} = \frac{-4}{12} = -\frac{1}{3}
\]

The negative sign here suggests an inverted image, but in the case of convex mirrors, images are upright. Since the mirror equation yields a negative v, and the physics of convex mirrors produce upright images, the magnitude of magnification is positive:

\[
M = \left| \frac{v}{u} \right| = \frac{4}{12} = \frac{1}{3}
\]

This signifies that the image is one-third the height of the object and erect.

Determining the Image Height

Given the object height $h_0 = 15.0\, \text{cm}$, and the magnification:

$$
h_i = M \times h_0 = \frac{1}{3} \times 15.0\, \text{cm} = 5.0\, \text{cm}
$$

Result:

- The image height h_i is approximately 5.0 cm.
- The image is erect and diminished.
- The image appears behind the mirror at a distance of 4 cm.

Analysis and Implications of the Results

The calculations reveal several key insights:

1. Nature of the Image:

- The virtual image is upright and smaller than the object.
- Located approximately 4 cm behind the mirror, confirming typical convex mirror behavior.

2. Real-world Applications:

- Such size reduction and virtual image formation are essential in safety mirrors on vehicles, providing a wide field of view while minimizing distortions.
- The understanding of focal length and object distances allows engineers to design mirrors with precise image characteristics.

3. Limitations and Assumptions:

- The calculation assumes ideal conditions with no aberrations.
- The object is placed in a typical position relative to the mirror, with no external factors influencing the image.

Extended Considerations: Variations and Complexities

While the primary calculations provide a clear answer, real-world scenarios often involve additional factors:

- Object Position Variations: Moving the object closer or farther affects the image size and position.
- Focal Length Changes: Different convex mirrors have varying focal lengths, influencing the magnification.
- Multiple Reflections or Refractions: In complex optical systems, multiple elements can alter the image formation process.
- Measurement Accuracy: Precise measurements are critical—small errors in object distance or focal length can significantly impact the results.

Conclusion: Synthesis of Optical Principles in Practice

This detailed exploration underscores the importance of foundational physics in understanding optical systems. By applying the mirror equation and magnification principles, we determined that a convex mirror with a focal length of -6.0 cm, placed 12.0 cm from a 15.0 cm tall object, produces a virtual, upright, and diminished image approximately 4 cm behind the mirror, with a height of about 5.0 cm.

Educational and Practical Significance:

- The problem exemplifies how theoretical physics translates into real-world applications.
- It highlights the importance of sign conventions and careful analysis in optical calculations.
- The approach demonstrates how to interpret and solve problems involving convex mirrors systematically.

Final Reflection:

Understanding the interplay of object distance, focal length, and image formation is crucial for designing optical devices and interpreting visual phenomena. This case study not only clarifies how to compute the height of an image but also reinforces fundamental concepts that underpin much of modern optics. Whether for educational purposes or practical engineering, mastering these principles equips individuals to analyze and innovate within the field of optical science.

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