A Lighted Candle Is Placed 36 Cmcm In Front Of A Converging Lens Of Focal Length 13 Cmcm , Which In Turn

A Lighted Candle Is Placed 36 Cmcm In Front Of A Converging Lens Of Focal Length 13 Cmcm , Which In Turn sets the stage for an intriguing exploration of optical principles, particularly how converging lenses form images of objects placed at various distances. This scenario is a classic problem in geometric optics, illustrating the fundamental concepts of image formation, magnification, and the nature of real and virtual images. Understanding these principles is essential not only for students studying physics but also for anyone interested in optical devices such as cameras, microscopes, and eyeglasses.

In this article, we will analyze the situation step by step, calculating the position, nature, and size of the image formed by the converging lens. We will also discuss the practical implications of these calculations and how they apply to real-world optical systems.

Understanding the Basic Concepts of Converging Lenses

What Is a Converging Lens?

A converging lens, also known as a convex lens, is a transparent optical device that bends (refracts) incoming parallel light rays so that they meet at a point called the focal point. These lenses are thicker at the center than at the edges and are commonly used in magnifying glasses, cameras, and corrective eyewear.

The Focal Length and Its Significance

The focal length (f) of a converging lens is the distance from the lens to its focal point, where parallel rays of light converge after passing through the lens. It is a critical parameter that determines how the lens forms images:
- Shorter focal lengths produce stronger convergence and larger magnification.
- Longer focal lengths produce less convergence and more distant images.

In our case, the focal length is given as 13 cm, indicating a converging lens with a reasonably strong convergence ability.

Analyzing the Object and Its Position

Given Data

- Object (candle) distance from the lens, $u = -36\, \text{cm}$ (the negative sign indicates that the object is in front of the lens).
- Focal length of the lens, $f = 13\, \text{cm}$.

Understanding the sign conventions is vital:
- Object distance u is negative if the object is on the same side as the incoming light (usual case for real objects).
- Focal length f is positive for converging lenses.

Sign Conventions and Their Importance

Using the Cartesian sign convention:
- Object distances (u) are negative if the object is on the same side as the incoming light.
- Image distances (v) are positive if the image is real and on the opposite side of the lens.
- Focal length (f) is positive for converging lenses.

Applying these conventions ensures consistent and accurate calculations in optical problems.

Calculating the Image Position Using the Lens Formula

The fundamental lens formula relates the object distance u, the image distance v, and the focal length f:

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

Rearranged to solve for v:

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

Substituting the known values:

$$
\frac{1}{v} = \frac{1}{13} + \frac{1}{-36}
$$

Calculating:

$$
\frac{1}{v} = \frac{1}{13} - \frac{1}{36}
$$

Find common denominator:

$$
\frac{1}{v} = \frac{36}{468} - \frac{13}{468} = \frac{23}{468}
$$

Thus,

$$
v = \frac{468}{23} \approx 20.35\, \text{cm}
$$

Since v is positive, the image is real and formed on the opposite side of the lens at approximately 20.35 cm from the lens.

Nature and Magnification of the Image

Nature of the Image

Given that v is positive, the image formed is:
- Real: the light rays actually converge at the image point.
- Inverted: typical for real images formed by converging lenses when the object is beyond the focal length.
- Magnified or Reduced: depending on the size ratio, which we can determine next.

Calculating the Magnification

Magnification (M) describes how much larger or smaller the image is compared to the object:

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

Substituting the values:

$$
M = \frac{20.35}{-36} \approx -0.565
$$

The negative sign indicates the image is inverted, and the magnitude shows the image is approximately 56.5% the size of the candle.

Image Characteristics and Practical Implications

Size and Orientation

- The image is inverted.
- The image is diminished in size, about 56.5% of the candle's size.
- Located approximately 20.35 cm from the lens on the opposite side.

Applications of Such Calculations

Understanding image formation is essential in:
- Designing optical devices like microscopes and telescopes.
- Correcting vision with appropriate lenses.
- Photography, to determine the focus and magnification.
- Scientific experiments involving precise measurements of images.

Real-World Considerations

- The actual size of the candle and the image can be compared for clarity.
- The distance from the lens affects the focus and sharpness.
- Adjustments to object distance or lens focal length can optimize image quality.

Additional Factors and Advanced Considerations

Effect of Changing Object Distance

- Moving the candle closer or farther from the lens will alter the image position and size.
- If the candle is placed at the focal point ($u = -13\, \text{cm}$), the image will form at infinity.
- If placed within the focal length ($|u| < 13\, \text{cm}$), the image becomes virtual and erect.

Limitations and Assumptions

- Assumes thin lens approximation.
- Ignores aberrations and other optical imperfections.
- Assumes ideal conditions with no distortions.

Conclusion

The placement of a lighted candle 36 cm in front of a converging lens with a focal length of 13 cm results in a real, inverted, diminished image formed approximately 20.35 cm on the opposite side of the lens. The calculations demonstrate the fundamental principles of geometric optics, illustrating how object distance, focal length, and lens properties determine the characteristics of the resulting image. These principles underpin many optical technologies and enhance our understanding of how light behaves in various systems.

Summary of Key Points

- Object distance $u = -36\, \text{cm}$.
- Focal length $f = 13\, \text{cm}$.
- Image distance $v \approx 20.35\, \text{cm}$.
- Image is real, inverted, and reduced in size.
- Magnification $M \approx -0.565$.

By mastering these concepts, students and professionals can better understand and manipulate optical systems for various applications, from simple magnifiers to complex imaging devices.

If you'd like further elaboration on related topics such as virtual images, lens formula derivations, or real-world optical device design, feel free to ask!

Frequently Asked Questions

What is the image position when a lighted candle is placed 36 cm in front of a converging lens with a focal length of 13 cm?

Using the lens formula 1/f = 1/v - 1/u, with u = -36 cm and f = 13 cm, the image distance v is approximately 17.2 cm on the same side as the object, indicating a real, inverted image formed between the lens and the focal point.

Is the image formed by the converging lens real or virtual when the candle is placed 36 cm away?

Since the object distance exceeds the focal length, the converging lens forms a real, inverted image on the opposite side of the lens.

How does changing the object distance from 36 cm affect the

size of the image formed by the converging lens?

Increasing the object distance moves the image closer to the focal point, making it smaller; decreasing the object distance moves the image farther away, enlarging the image, according to the lens formula.

What is the magnification of the image formed when the candle is placed 36 cm in front of the lens?

Magnification (M) = v/u. Using $v \approx 17.2$ cm and $u = -36$ cm, $M \approx -0.478$, indicating the image is roughly half the size of the object and inverted.

If the candle moves closer to the lens, say to 20 cm, how will the image change?

Reducing the object distance to 20 cm will produce a larger, real, inverted image located closer to the focal point, with increased magnification compared to the initial position.

Additional Resources

Understanding the Formation of Images by Converging Lenses: A Detailed Analysis of a Candle Placed in Front of a Convex Lens

When exploring the fascinating world of optics, the behavior of light as it interacts with lenses offers profound insights into the nature of vision and image formation. In particular, the scenario involving a lighted candle placed in front of a converging (convex) lens serves as an excellent case study, illustrating fundamental principles such as focal length, object distance, image characteristics, and the application of lens formulas. This comprehensive review delves into each aspect of this configuration, providing a thorough understanding of the underlying physics and practical implications.

Introduction to Converging (Convex) Lenses

A converging lens, commonly known as a convex lens, is characterized by its shape—bulging outward at the center—and its ability to bend (refract) incoming light rays toward a common point. This point is known as the focus or focal point. The principal features and properties include:

- Shape & Structure: Thicker at the center than at the edges.
- Focal Length (f): The distance from the lens to the focal point, where parallel rays converge.
- Image Formation: Depending on object position relative to the focal length, the lens can produce real or virtual images that are magnified or diminished.

Key Parameters of the Scenario

Before analyzing the image formation, it’s essential to specify the given parameters:

- Object: A lit candle, serving as the object.
- Object Distance (u): 36 cm in front of the lens (object placed on the same side as the incoming light).
- Focal Length (f): 13 cm for the convex lens.
- Lens Type: Converging (convex).

Understanding the Sign Conventions and Lens Formula

To analyze the image, we rely on the thin lens formula:

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

Where:

- f: Focal length of the lens. For a convex lens, f is positive.
- u: Object distance, measured from the lens to the object. Conventionally, u is negative if the object is on the same side as the incoming light.
- v: Image distance, positive if the image is real and on the opposite side of the object; negative if virtual and on the same side as the object.

Sign conventions:

- Object on the same side as incoming light: $u < 0$
- Real images: $v > 0$
- Virtual images: $v < 0$

Given the object is placed in front of the lens (on the same side as the light source), the object distance u should be taken as -36 cm.

Calculating the Image Position

Applying the lens formula with the provided data:

$$
f = +13\, \text{cm} \quad (\text{since convex lens})

\]
\[
u = -36\, \text{cm}
\]

Plugging into the formula:

\[
\frac{1}{13} = \frac{1}{v} - \frac{1}{-36}
\]
\[
\frac{1}{13} = \frac{1}{v} + \frac{1}{36}
\]

Rearranged to find \(\frac{1}{v} \):

\[
\frac{1}{v} = \frac{1}{13} - \frac{1}{36}
\]

Calculating the right side:

\[
\frac{1}{v} = \frac{36 - 13}{13 \times 36} = \frac{23}{468}
\]

Simplify:

\[
\frac{1}{v} = \frac{23}{468}
\]

Hence:

\[
v = \frac{468}{23} \approx 20.35\, \text{cm}
\]

Interpretation:

- Since \(v \) is positive, the image is real and formed on the opposite side of the lens.
- The image is approximately 20.35 cm from the lens.

Characteristics of the Image

With the image position determined, we now analyze the nature, size, and orientation of the image.

1. Magnification (m)

The magnification formula:

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

Substituting the known values:

$$
m = \frac{20.35}{-36} \approx -0.565
$$

Implications:

- The negative sign indicates that the image is inverted relative to the object.
- The magnitude (~0.565) indicates the image is diminished to approximately 56.5% of the object’s size.

2. Image Nature

- Real and Inverted: Because $v > 0$, the image is real and inverted.
- Size: Smaller than the actual candle, owing to the magnification being less than 1.
- Position: Approximately 20.35 cm beyond the lens on the opposite side.

3. Image Brightness and Illumination

- The candle's light intensity diminishes with distance; however, since the image is formed via real rays converging at a point, it can be projected onto a screen.
- The brightness depends on the candle’s luminous intensity and the size of the image. Given the reduction in size, the image will appear dimmer than the candle itself.

Practical Implications and Applications

Understanding how a candle’s image forms through a converging lens has both educational and practical significance.

1. Optical Experiments and Demonstrations

- Visualizing image formation helps students grasp concepts like real and virtual images, magnification, and the effect of object distance.
- The setup can be used to demonstrate how images vary with object placement relative to the focal length.

2. Imaging Devices

- Convex lenses are fundamental in devices such as cameras, microscopes, and telescopes.
- Knowing the image position and size aids in designing systems with desired magnification and focus.

3. Medical and Scientific Instruments

- Precise image formation is critical in optical instruments used for diagnosis and research.

Extended Analysis: Effect of Changing Object Distance

While the current scenario involves a candle placed at 36 cm, exploring how the image characteristics change with different object distances offers deeper insights.

1. Object Beyond 2f (more than twice the focal length)

- The image remains real, inverted, and diminished.
- As the object moves farther away, the image approaches the focal point and shrinks.

2. Object Between f and 2f (between 13 cm and 26 cm)

- The image is real, inverted, magnified, and located beyond 2f.
- The closer the object gets to the focal point, the larger and farther the image becomes.

3. Object at the Focal Point ($u = f$)

- Theoretically, the image forms at infinity, meaning rays are parallel, and the image is highly magnified.

4. Object Between Lens and Focus ($u < f$)

- The image is virtual, erect, and magnified, forming on the same side as the object.
- Useful in magnifying glasses.

Limitations and Assumptions in the Analysis

- Thin Lens Approximation: Assumes the lens thickness is negligible; real lenses may introduce aberrations.
- Paraxial Rays: The calculations presume small angles; large deviations may cause deviations.
- Ideal Conditions: No consideration of imperfections, chromatic aberrations, or environmental factors.

Conclusion

Placing a lighted candle 36 cm in front of a converging lens with a focal length of 13 cm results in the formation of a real, inverted, and diminished image approximately 20.35 cm on the other side of the lens. The magnification of about -0.565 indicates the image is roughly half the size of the candle, with the negative sign confirming inversion. This scenario exemplifies core principles of optics, illustrating how object distance relative to the focal length dictates the nature and position of the resulting image.

Understanding these concepts is crucial not only in theoretical physics but also in designing and optimizing optical devices and systems used in various scientific, medical, and technological applications. The analysis underscores the importance of sign conventions, the interplay between object and image distances, and the significance of focal length in defining the behavior of converging lenses.

Further Exploration: Students and enthusiasts are encouraged to experiment with varying object distances, lens focal lengths, or employing different types of lenses to deepen their grasp of optical phenomena, thereby bridging theoretical calculations with real-world observations.

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