Item 5Two Concave Lenses, Each With F = -13 Cm, Are Separated By 4.2 Cm. An Object Is Placed 25 Cm In

Item 5Two Concave Lenses, Each With F = -13 Cm, Are Separated By 4.2 Cm. An Object Is Placed 25 Cm In

Understanding the behavior of concave lenses and their optical properties is fundamental in physics and optical engineering. In this article, we explore a specific problem involving two concave lenses with given focal lengths and separation, and analyze the image formation for an object placed at a certain distance. We will delve into the principles of lens optics, the calculations involved, and the practical applications of such optical systems.

Introduction to Concave Lenses and Optical Principles

What Are Concave Lenses?

Concave lenses, also known as diverging lenses, are optical devices that bend light rays outward. They are thinner at the center than at the edges and are commonly used in applications such as eyeglasses for nearsightedness, optical instruments, and laser systems.

Key features of concave lenses:
- Diverge incoming light rays.
- Form virtual, upright, and reduced images.
- Have negative focal lengths ($F < 0$).

Fundamental Concepts in Lens Optics

Understanding how lenses form images requires familiarity with several concepts:
- Focal Length (F): The distance from the lens to the focal point; negative for concave lenses.
- Object Distance (u): The distance from the object to the lens.
- Image Distance (v): The distance from the lens to the formed image.
- Lens Formula: \(\frac{1}{f} = \frac{1}{v} - \frac{1}{u}\), where \(f\) is the focal length.
- Magnification (m): \(\frac{v}{u}\), indicating the size relationship between the image and object.

Analyzing the System: Two Concave Lenses in Sequence

Given Data

- Focal length of each lens: $F_1 = F_2 = -13\,cm$
- Separation between lenses: $d = 4.2\,cm$
- Object distance from the first lens: $u_1 = -25\,cm$ (assuming the object is on the same side as the incoming light, conventionally negative)

Step-by-Step Approach to Image Formation

1. Calculate the image formed by the first lens.
2. Determine the position of this image relative to the second lens.
3. Use the image from the first lens as the object for the second lens.
4. Calculate the final image position and size.

Calculations for the First Concave Lens

Applying the Lens Formula

$$
\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}
$$

$$
\Rightarrow \frac{1}{-13} = \frac{1}{v_1} - \frac{1}{-25}
$$

$$
\Rightarrow \frac{1}{-13} = \frac{1}{v_1} + \frac{1}{25}
$$

$$
\Rightarrow \frac{1}{v_1} = \frac{1}{-13} - \frac{1}{25}
$$

Calculating:

$$
\frac{1}{v_1} = -\frac{1}{13} - \frac{1}{25} = -\frac{25}{325} - \frac{13}{325} = -\frac{38}{325}
$$

\[

$$
v_1 = -\frac{325}{38} \approx -8.55\,cm
$$

Interpretation:
- The negative sign indicates the image is virtual and located on the same side as the object, approximately 8.55 cm from the lens.

Magnification by First Lens

$$
m_1 = \frac{v_1}{u_1} = \frac{-8.55}{-25} \approx 0.342
$$

- The image is upright and about 34.2% the size of the object.

Position of the First Image Relative to the Second Lens

Distance Between the First Image and the Second Lens

- The object for the second lens is the first image.
- The second lens is located 4.2 cm from the first lens.
- Since the first image is 8.55 cm on the same side as the object, its position relative to the second lens depends on the initial setup.

Assuming the object is on the same side of the first lens and the lenses are aligned along a common axis:

- The first image forms 8.55 cm from the first lens, on the same side as the object.
- The second lens is separated by 4.2 cm from the first lens.
- Therefore, the distance from the second lens to the first image:

$$
u_2 = v_1 + d = -8.55\,cm + 4.2\,cm = -4.35\,cm
$$

- The negative sign indicates that the image (serving as object for the second lens) is on the same side as the incoming light relative to the second lens, making it a virtual object.

Calculations for the Second Concave Lens

Applying the Lens Formula

$$
\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}
$$

$$
\Rightarrow \frac{1}{-13} = \frac{1}{v_2} - \frac{1}{-4.35}
$$

$$
\Rightarrow -\frac{1}{13} = \frac{1}{v_2} + \frac{1}{4.35}
$$

$$
\Rightarrow \frac{1}{v_2} = -\frac{1}{13} - \frac{1}{4.35}
$$

Calculating:

$$
-\frac{1}{13} \approx -0.0769
$$

$$
-\frac{1}{4.35} \approx -0.2299
$$

$$
\Rightarrow \frac{1}{v_2} = -0.0769 - 0.2299 = -0.3068
$$

$$
v_2 \approx -3.26\,cm
$$

Interpretation:
- The negative v_2 indicates the final image is virtual and located approximately 3.26 cm on the same side as the incoming light to the second lens.

Final Image Magnification

$$
m_2 = \frac{v_2}{u_2} = \frac{-3.26}{-4.35} \approx 0.75
$$

- The final image is upright and about 75% the size of the original object.

Summary of Results

- The first lens creates a virtual, upright image located approximately 8.55 cm on the same side as the object.
- This image acts as a virtual object for the second lens, positioned approximately 4.35 cm on the same side as the incoming light.
- The second lens further diverges the rays, resulting in a virtual, upright, and reduced final image located about 3.26 cm from the second lens.

Practical Applications of Concave Lens Systems

Optical Devices Using Multiple Lenses

Concave lens systems, like the one analyzed here, have various practical applications:
- Eyeglasses: Correcting myopia by diverging light before it reaches the eye.
- Optical Instruments: Enhancing magnification and image correction in microscopes and telescopes.
- Laser Systems: Managing beam divergence and shaping.

Advantages of Multi-Lens Systems

- Improved control over image size, position, and clarity.
- Ability to correct aberrations and distortions.
- Compact designs for practical devices.

Conclusion

This comprehensive analysis demonstrates the principles of optical physics involved in systems with multiple concave lenses. By applying the lens formula, understanding virtual image formation, and calculating magnifications, we gain insight into how complex optical systems manipulate light to produce desired images. Whether in designing eyeglasses, microscopes, or other optical instruments, mastering these concepts is essential for engineers and physicists alike.

Key Takeaways

- Concave lenses produce virtual, upright, and reduced images.
- The position and size of images depend on the focal length, object distance, and lens arrangement.
- Multiple lens systems require sequential calculations, considering the image from one lens as the object for the next.
- Practical applications of concave lenses are widespread, from corrective eyewear to sophisticated optical devices.

If you want to deepen your understanding of optical systems, consider exploring topics such as lens aberrations, ray diagrams, and the design of compound lens systems for specific applications.

Frequently Asked Questions

What is the focal length of each concave lens in the setup?

Each concave lens has a focal length of -13 cm.

How are the two concave lenses positioned relative to each other?

They are separated by a distance of 4.2 cm.

Where is the object placed in relation to the first lens?

The object is placed 25 cm in front of the first lens.

How can I determine the overall image formed by the two concave lenses?

You can find the image formed by the first lens using the lens formula, then treat that image as the object for the second lens, and apply the lens formula again to find the final image.

What is the lens formula used to find the image position?

The lens formula is $1/f = 1/v - 1/u$, where f is the focal length, v is the image distance, and u is the object distance.

How does the separation between the lenses affect the final image?

The separation influences the intermediate image position; a smaller separation means the second lens acts on a closer or already formed image, affecting the final image's position and nature.

What is the significance of the negative focal length for these lenses?

A negative focal length indicates that the lenses are concave, diverging lenses, which cause incident rays to spread out and form virtual images.

Additional Resources

Understanding the Behavior of Two Concave Lenses with F = -13 cm Separated by 4.2 cm and an Object Placed 25 cm In

When exploring optical systems, the interaction of multiple lenses can produce intriguing results, especially when these lenses are concave with negative focal lengths. In this analysis, we delve into the scenario involving two concave lenses, each with a focal length of F = -13 cm, separated by 4.2 cm, and an object positioned 25 cm in front of the system. This configuration is rich with concepts such as image formation, lens combinations, and optical principles that underpin many practical applications in imaging systems, telescopes, and microscopes.

Introduction to Concave Lenses and Their Optical Properties

What Is a Concave Lens?

A concave lens is a diverging lens that causes light rays passing through it to spread apart. Unlike convex lenses that converge light rays to a real focus, concave lenses have a negative focal length (F < 0), indicating their diverging nature.

Key Characteristics of Concave Lenses

- Negative focal length (F < 0): Indicates diverging behavior.
- Virtual focus: Light rays appear to diverge from a point on the same side of the lens as the object.
- Image properties:
- Always virtual
- Upright
- Reduced in size relative to the object

Given the focal length of -13 cm, each lens individually diverges light rays, creating a virtual image located on the same side as the object.

System Overview: Two Concave Lenses in Series

Configuration Details

- Focal length of each lens: $F_1 = F_2 = -13$ cm
- Separation between lenses: $d = 4.2$ cm
- Object distance from the first lens: $u_1 = -25$ cm (assuming object is on the same side as incoming light, conventionally negative)

This setup involves a series of two diverging lenses, which modifies the path of light in a way that depends on the positions and focal lengths.

Step-by-Step Analysis

1. Determining the Image Formed by the First Lens

The initial step involves calculating the image produced by the first concave lens when the object is placed in front of it.

Lens Formula

The relationship between object distance (u), image distance (v), and focal length (F):

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

Note: Conventionally, distances are positive if they are measured in the direction of the incident light (toward the lens), and negative if measured against.

Assumptions:

- Object is on the same side as incoming light: $u_1 = -25$ cm
- Focal length: $F_1 = -13$ cm

Calculation for the First Lens

$$
\frac{1}{-13} = \frac{1}{v_1} - \frac{1}{-25}
$$

$$
\frac{1}{v_1} = \frac{1}{-13} + \frac{1}{25}
$$

Calculating:

$$
\frac{1}{v_1} = -\frac{1}{13} + \frac{1}{25}
$$

Find common denominator (13 25 = 325):

$$
\frac{1}{v_1} = -\frac{25}{325} + \frac{13}{325} = -\frac{25 - 13}{325} = -\frac{12}{325}
$$

Therefore,

$$
v_1 = -\frac{325}{12} \approx -27.08 \text{ cm}
$$

Interpretation:

- The negative sign indicates the image is virtual and on the same side as the object.
- The virtual image is approximately 27.08 cm in front of the first lens.

---

2. Locating the Virtual Image Relative to the Second Lens

The virtual image from the first lens serves as the object for the second lens.

Distance from the first lens to the second lens:

$$
d = 4.2 \text{ cm}
$$

Since the virtual image is located 27.08 cm in front of the first lens, the position of this virtual image relative to the second lens is:

$$
u_2 = v_1 + d = -27.08 + 4.2 = -22.88 \text{ cm}
$$

Note: The negative sign indicates that this "object" for the second lens is on the same side as the incoming light (the object appears to be 22.88 cm in front of the second lens).

---

3. Calculating the Image Formed by the Second Lens

Applying the lens formula again:

$$
\frac{1}{F_2} = \frac{1}{v_2} - \frac{1}{u_2}
$$

$$
\frac{1}{-13} = \frac{1}{v_2} - \frac{1}{-22.88}
$$

$$
\frac{1}{v_2} = \frac{1}{-13} + \frac{1}{22.88}
$$

Calculating:

$$
\frac{1}{v_2} = -\frac{1}{13} + \frac{1}{22.88}
$$

Expressed with common denominators:

- 13 22.88 ≈ 13 22.88 ≈ 297.44

$$
\frac{1}{v_2} = -\frac{22.88}{297.44} + \frac{13}{297.44} = -\frac{22.88 - 13}{297.44} = -\frac{9.88}{297.44}
$$

Thus,

$$
v_2 = -\frac{297.44}{9.88} \approx -30.1 \text{ cm}
$$

Interpretation:

- The negative value indicates a virtual image formed on the same side as the incoming light.
- Position: approximately 30.1 cm in front of the second lens.

Key Findings and Summary

- The first concave lens creates a virtual, upright, reduced image approximately 27.08 cm in front of it.
- This virtual image becomes the object for the second lens, located roughly 22.88 cm in front of the second lens.

- The second concave lens then produces a virtual image approximately 30.1 cm in front of itself.
- The entire system results in a series of virtual images, each influenced by the diverging nature of the concave lenses.

Visualizing the Ray Diagrams

Why Ray Diagrams Matter

Constructing accurate ray diagrams helps understand the behavior of complex lens systems and verify calculations. For this configuration:

- Draw the principal axes and position the lenses at their separation.
- Trace rays from the object passing through the first lens:
- Ray parallel to the axis diverges through the focal point.
- Ray passing through the center of the lens continues straight.
- Locate the virtual image formed by the first lens.
- Use this virtual image as the object for the second lens, repeating the process.

Significance of Virtual Images

In diverging lens systems, virtual images are critical because they often serve as the basis for further optical processing, such as in optical instruments or corrective lenses.

Practical Applications and Implications

Understanding the behavior of multiple concave lenses separated by a specific distance has practical implications in:

- Optical devices: such as eyeglasses, microscopes, and telescopes.
- Image processing: in systems where virtual images are manipulated.
- Design considerations: for minimizing aberrations or optimizing magnification.

Final Thoughts and Takeaways

- The combination of two concave lenses results in complex image formations that depend heavily on object positioning, focal lengths, and lens separation.
- Applying the lens formula at each stage allows precise calculation of image locations.
- Virtual images formed by diverging lenses are always upright, reduced, and located on the same side as the incoming light.

- Accurate visualization through ray diagrams enhances understanding and verification of analytical results.

Summary of Key Steps

1. Calculate the image formed by the first lens using object distance and focal length.
2. Identify the virtual object for the second lens based on the first image's position.
3. Calculate the second image's position considering the second lens's focal length and the virtual object.
4. Interpret the signs of the image distances based on the conventions for magnitudes and directions.
5. Visualize the system with ray diagrams to reinforce understanding.

By mastering these principles, optical engineers and enthusiasts can design and analyze complex lens systems to achieve desired imaging outcomes, whether for scientific research, medical devices, or consumer optics.

Note: Always verify your calculations with diagrammatic sketches, especially in complex multi-lens systems, to ensure physical intuition aligns with mathematical results.

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