Two 22-cm-focal-length Converging Lenses Are Placed 16.5?cm Apart. An Object Is Placed 35.0?cm In Front

Two 22-cm-focal-length Converging Lenses Are Placed 16.5 cm Apart. An Object Is Placed 35.0 cm In Front

Understanding the behavior of converging lenses and their optical properties is essential in many applications such as imaging systems, microscopes, and optical instruments. In this article, we explore a specific scenario involving two converging lenses, each with a focal length of 22 cm, positioned 16.5 cm apart, with an object placed 35.0 cm in front of the first lens. We will analyze the image formation process, calculate the positions and characteristics of the images formed at each stage, and discuss the overall optical system's properties.

Introduction to Converging Lenses and Optical Systems

Converging lenses, also known as convex lenses, are optical devices that bend incoming light rays toward a common point, forming real or virtual images depending on the object's position relative to the lens. The focal length (f) is a fundamental property indicating the distance from the lens to the focal point, where parallel rays converge.

Key properties of converging lenses:

- Focal length (f): positive, typically between a few centimeters to many meters.
- Real images: formed when the object is outside the focal length, projected on the opposite side of the lens.
- Virtual images: formed when the object is within the focal length, appearing on the same side as the object.

In our scenario, both lenses are converging with a focal length of 22 cm, and the spatial arrangement influences how the images are formed and magnified.

System Configuration and Parameters

The setup involves:

1. Two converging lenses, each with **f = 22 cm**.
2. The lenses are placed **16.5 cm apart**.
3. An object is located **35.0 cm in front of the first lens**.

This configuration prompts several questions:

- Where is the first image formed by the first lens?
- How does the image act as an object for the second lens?
- What is the final image position and characteristics?

Step 1: Image Formation by the First Lens

To analyze the first stage, we apply the lens formula:

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

where:
- $f = 22\,cm$ (focal length),
- $d_o = 35.0\,cm$ (object distance in front of the first lens),
- d_i is the image distance from the first lens.

Calculating the image position:

$$
\frac{1}{22} = \frac{1}{35} + \frac{1}{d_i}
$$

$$
\frac{1}{d_i} = \frac{1}{22} - \frac{1}{35}
$$

Calculating numerator:

$$
\frac{1}{d_i} = \frac{35 - 22}{22 \times 35} = \frac{13}{770}
$$

So:

$$
d_i = \frac{770}{13} \approx 59.23\,cm
$$

Interpretation:
- The positive value indicates a real image formed on the opposite side of the first lens, approximately 59.23 cm from the first lens.

Image magnification:

$$
m_1 = - \frac{d_i}{d_o} = - \frac{59.23}{35} \approx -1.69
$$

The negative sign indicates an inverted image, and the magnification magnitude shows the image is approximately 1.69 times larger than the object.

Step 2: Position of the Image Relative to the Second Lens

Since the lenses are separated by 16.5 cm, the image formed by the first lens becomes an object for the second lens.

Calculating the object position for the second lens:

- The image from the first lens is located 59.23 cm from the first lens, on the side opposite to the object.
- The second lens is 16.5 cm away from the first lens.

Determining the object distance for the second lens:

- The image is located 59.23 cm from the first lens, on the side where the first lens's image is formed.
- The position of the first image relative to the second lens:

$$
d_{o2} = d_{image\,from\,1st\,lens} - \text{distance between lenses}
$$

$$
d_{o2} = 59.23\,cm - 16.5\,cm = 42.73\,cm
$$

- Since the image is on the same side as the second lens's object, the object distance for the second lens is:

\[

d_{o2} = +42.73\,cm
\]

(positive sign indicates real object on the same side as the incoming light for the second lens).

Step 3: Image Formation by the Second Lens

Applying the lens formula again:

\[
\frac{1}{f} = \frac{1}{d_{o2}} + \frac{1}{d_{i2}}
\]

\[
\frac{1}{22} = \frac{1}{42.73} + \frac{1}{d_{i2}}
\]

Calculating:

\[
\frac{1}{d_{i2}} = \frac{1}{22} - \frac{1}{42.73}
\]

Find common denominators:

\[
\frac{1}{d_{i2}} = \frac{42.73 - 22}{22 \times 42.73} \approx \frac{20.73}{941.06}
\]

\[
d_{i2} \approx \frac{941.06}{20.73} \approx 45.36\,cm
\]

Interpretation:
- The positive value indicates a real image formed on the opposite side of the second lens, approximately 45.36 cm from the second lens.

Final image characteristics:

- Position: 45.36 cm beyond the second lens.
- Magnification:

\[
m_2 = - \frac{d_{i2}}{d_{o2}} = - \frac{45.36}{42.73} \approx -1.06
\]

The final image is approximately 1.06 times larger than the original object and inverted.

Overall Analysis and Implications

This optical system demonstrates key principles of sequential lens imaging:

- The first converging lens produces a real, inverted, magnified image.
- The second lens receives this image as an object, further modifying the image position and size.
- The combined effect results in a final image that is real, inverted, and slightly larger than the original object.

Applications of such systems include:

- Telescopic arrangements where multiple lenses are used to magnify distant objects.
- Optical instruments requiring precise image focusing.
- Educational demonstrations of image formation principles.

Additional Considerations and Practical Aspects

When working with real optical systems, several factors influence the actual image quality:

1. **Lens quality:** Aberrations can distort images.
2. **Alignment:** Precise positioning ensures accurate image formation.
3. **Object position:** Moving the object closer or farther affects image size and clarity.
4. **Wavelength dependence:** Light wavelength can influence focal length slightly due to chromatic aberrations.

In experimental setups, careful measurement and alignment are essential to achieve theoretical predictions.

Conclusion

The scenario involving two 22-cm focal length converging lenses placed 16.5 cm apart with an object 35.0 cm in front illustrates fundamental optical principles. Through systematic application of the lens formula and magnification calculations, we find that:

- The first lens creates a real, inverted, magnified image approximately 59.23 cm from itself.
- This image acts as a real object for the second lens, located about 42.73 cm from it.
- The second lens then produces a final real image approximately 45.36 cm beyond itself, slightly larger and inverted relative to the original object.

This analysis not only deepens understanding of image formation in multiple lens systems but also highlights the importance of precise calculations in designing optical instruments. Whether in academic, research, or practical contexts, mastering these principles enables effective manipulation of light to achieve desired imaging outcomes.

Keywords: converging lenses, focal length, image formation, optical systems, magnification, real images, lens formula, sequential imaging, optical analysis

Frequently Asked Questions

What is the primary purpose of using two converging lenses in this setup?

The primary purpose is to study the combined optical effects, such as image formation, magnification, and focal properties, when two converging lenses are used in sequence with an object placed in front.

How do you calculate the effective focal length of two converging lenses placed in contact?

For lenses in contact, the effective focal length is given by $1/f_{eff} = 1/f1 + 1/f2$. Since both lenses have focal lengths of 22 cm, $f_{eff} = 11$ cm.

What is the significance of the 16.5 cm separation between the lenses?

The 16.5 cm separation affects the overall image formation, magnification, and whether the final image is real or virtual, depending on the object position relative to the lenses.

How do you determine the position of the final image formed

by this two-lens system?

First, find the image formed by the first lens using lens formula, then treat that image as the object for the second lens, considering the separation distance, and apply the lens formula again to find the final image position.

What is the effect of placing the object 35.0 cm in front of the first lens?

Placing the object 35.0 cm in front of the first lens determines the initial image position, which then influences how the second lens forms the final image, affecting magnification and image orientation.

Can the final image be real or virtual in this setup, and what factors determine this?

Yes, the final image can be real or virtual depending on the object distance, the focal lengths, and the separation between lenses. Typically, an object placed beyond the focal length produces a real image.

How do you use the lens formula to analyze this system?

Apply the lens formula (1/f = 1/do + 1/di) for each lens, calculating the image position after the first lens, then treating that as the object for the second lens, considering the separation distance.

What is the magnification produced by each lens, and how do they combine?

Magnification for each lens is m = -di/do. The total magnification is the product of the magnifications of both lenses, indicating overall size change and image orientation.

How does the separation distance between the lenses impact the overall system performance?

The separation distance influences whether the images formed by each lens overlap or are separated, affecting clarity, magnification, and whether the final image is real or virtual.

What practical applications can this two-lens system be used for?

This setup can be used in optical devices like microscopes, telescopes, or camera systems to magnify images, study image formation, or design compound lens systems for specific imaging needs.

Additional Resources

Two 22-cm-focal-length Converging Lenses Are Placed 16.5 cm Apart. An Object Is Placed 35.0 cm In Front — this intriguing optical setup offers a fascinating glimpse into the principles of multiple lens systems, image formation, and the nuanced interplay of light. Whether you're a student seeking to understand the fundamentals of optics or a professional analyzing complex lens arrangements, dissecting this scenario provides valuable insights into how converging lenses work together to manipulate light and produce images. In this comprehensive guide, we'll explore the physics behind this configuration step by step, covering key concepts, calculations, and implications.

Understanding the Basic Setup

Let's start by visualizing the scenario:

- Lenses: Two converging (convex) lenses, each with a focal length (f) of 22 cm.
- Separation: The lenses are separated by a distance of 16.5 cm.
- Object: An object is placed 35.0 cm in front of the first lens.

The main goal is to determine the nature, position, and size of the images formed by this arrangement, considering the effects of both lenses working in sequence.

Fundamental Concepts in Lens Optics

Before diving into calculations, it's essential to revisit key principles that govern image formation in converging lenses.

Focal Length (f)

- The distance from the lens to the focal point where parallel rays converge.
- For a converging lens, $f > 0$; here, $f = 22$ cm.

Lens Equation

The primary relation connecting object distance (do), image distance (di), and focal length (f):

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

- do: Distance from the object to the lens.
- di: Distance from the lens to the image (positive if real and on the same side as the outgoing light).

Sign Conventions

- Distances measured against the direction of incoming light are negative.
- Real images are formed on the opposite side of the lens from the object and have positive di.
- Virtual images are formed on the same side as the object and have negative di.

Magnification (M)

- Describes how much larger or smaller the image is relative to the object:

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

- The negative sign indicates image orientation (inverted or upright).

Step 1: Image Formation by the First Lens

Given:

- Object distance from the first lens, $d_{o1} = 35.0\,cm$.
- Focal length of the first lens, $f_1 = 22\,cm$.

Applying the lens equation:

$$
\frac{1}{f_1} = \frac{1}{d_{o1}} + \frac{1}{d_{i1}}
$$

$$
\Rightarrow \frac{1}{22} = \frac{1}{35} + \frac{1}{d_{i1}}
$$

Calculating:

$$
\frac{1}{d_{i1}} = \frac{1}{22} - \frac{1}{35}
$$

Find common denominator (22 35 = 770):

$$
\frac{35 - 22}{770} = \frac{13}{770}
$$

Thus:

$$
d_{i1} = \frac{770}{13} \approx 59.23\,cm
$$

Interpretation:

- Since d_{i1} is positive, the image formed by the first lens is real and on the opposite side of the lens.
- The image is approximately 59.23 cm from the first lens.

Magnification by the first lens:

$$
M_1 = - \frac{d_{i1}}{d_{o1}} = - \frac{59.23}{35.0} \approx -1.69
$$

- The negative sign indicates the image is inverted relative to the object.
- The size of the image is approximately 1.69 times larger than the original object.

Step 2: Locating the Image Relative to the Second Lens

The image formed by the first lens acts as an object for the second lens. To find the object distance for the second lens (d_{o2}), we need to consider:

- The distance between the lenses: 16.5 cm.
- The position of the first image relative to the first lens: approximately 59.23 cm on the opposite side.

Assuming the lenses are aligned along a common optical axis:

- The first lens is at position 0 cm.
- The second lens is at position 16.5 cm.
- The first image is at position $d_{i1} = +59.23\,cm$ on the side opposite the object.

To find the object distance for the second lens:

$$
d_{o2} = \text{distance from the second lens to the first image}
$$

Since the first image is located at 59.23 cm to the right of the first lens (assuming rightward is positive), its position relative to the second lens:

$$
d_{o2} = d_{i1} - (\text{distance between lenses}) = 59.23\,cm - 16.5\,cm = 42.73\,cm
$$

Because the first image is on the same side as the incoming light for the second lens (the light is traveling from the object through the first lens to the second), the object for the second lens is real and located at 42.73 cm in front of it.

Step 3: Image Formation by the Second Lens

Now, applying the lens equation for the second lens:

- Object distance for second lens: $d_{o2} = 42.73\,cm$.
- Focal length: $f_2 = 22\,cm$.

Applying the lens formula:

$$
\frac{1}{f_2} = \frac{1}{d_{o2}} + \frac{1}{d_{i2}}
$$

$$
\Rightarrow \frac{1}{22} = \frac{1}{42.73} + \frac{1}{d_{i2}}
$$

Calculating:

$$
\frac{1}{d_{i2}} = \frac{1}{22} - \frac{1}{42.73}
$$

Find common denominator:

$$
\frac{42.73 - 22}{22 \times 42.73} \approx \frac{20.73}{941.06}
$$

$$
d_{i2} \approx \frac{941.06}{20.73} \approx 45.4\,cm
$$

Since d_{i2} is positive, the image is real and located on the opposite side of the second lens at approximately 45.4 cm from it.

Magnification by the second lens:

$$
M_2 = - \frac{d_{i2}}{d_{o2}} = - \frac{45.4}{42.73} \approx -1.06
$$

- The image is inverted relative to the intermediate image.
- The size is approximately 1.06 times larger than the image formed by the first lens.

Final Image Characteristics

Position:

- The second image is approximately 45.4 cm beyond the second lens.
- Relative to the original object, it is located at:

$$
\text{Total distance from object} = d_{o1} + \text{distance from first lens to second image}
$$

which, considering the object at 0 cm and the lenses at 16.5 cm apart:

- The total distance from the object to the final image:

$$
d_{final} = d_{o1} + (d_{i1} - 16.5\,cm) + d_{i2}
$$

\]

But more straightforwardly, since the second image is located 45.4 cm from the second lens (which is at 16.5 cm):

\[
\text{Position relative to object} = 16.5\,cm + 45.4\,cm = 61.9\,cm
\]

The final image is real, inverted, and magnified approximately 1.69 1.06 ≈ 1.79 times the original object size.

Implications and Applications

This analysis illustrates several key principles relevant in optical systems design:

- Multiple converging lenses can be combined to magnify images or correct aberrations.
- The spacing between lenses affects the final image position significantly.
- Real images formed after multiple lenses can be projected onto screens or used for further optical processing.
- The magnification factors multiply, allowing for significant size adjustments.

Practical Considerations

In real-world applications, several factors influence the actual image quality:

- Lens imperfections: Aberrations, distortions, and material imperfections.
- Alignment: Precise positioning ensures the theoretical calculations match practical results.
- Object placement: Slight variations in the object distance alter the image characteristics.
- Light wavelength: Chromatic effects may affect color and sharpness.

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