An Object Is Placed 100 Cm In Front Of A Lens Of Focal Length Of 20 Cm. A Second Lens Is Placed 15 Cm

An Object Is Placed 100 Cm In Front Of A Lens Of Focal Length Of 20 Cm. A Second Lens Is Placed 15 Cm away from the first lens, creating an intriguing optical setup that warrants a detailed analysis. This arrangement involves understanding how light rays pass through multiple lenses, how images are formed, and the principles governing these phenomena. Such configurations are common in optical instruments like telescopes, microscopes, and camera systems, where multiple lenses are used to manipulate light for magnification, focusing, or image correction. In this article, we will explore the fundamental concepts involved, perform detailed calculations, and discuss practical implications of this two-lens system.

Understanding the Basic Principles of Lenses

What Is a Lens?

A lens is a transparent optical device that refracts light to converge or diverge rays, forming images of objects placed at various distances. Lenses are classified mainly into two types:
- Convex lenses (converging lenses): Cause light rays to converge to a focal point.
- Concave lenses (diverging lenses): Cause light rays to spread apart.

Most applications involving magnification or focusing use convex lenses, which is typical in our scenario.

Focal Length and Its Significance

The focal length (f) of a lens is the distance from the lens to the focal point, where parallel rays converge (for convex lenses). It is a measure of the lens's power to bend light:
- Shorter focal lengths mean stronger lenses with more bending.
- Longer focal lengths mean weaker lenses with less bending.

In our case, the first lens has a focal length of 20 cm, indicating a relatively moderate converging effect.

Analyzing the First Lens

Object Position and Image Formation

The object is placed 100 cm in front of the first lens, which has a focal length of 20 cm. To analyze the image formed by this lens, we use the lens formula:

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

Where:
- f is the focal length of the lens,
- v is the image distance from the lens,
- u is the object distance from the lens (taken as negative if object is on the same side as the incoming light).

Since the object is in front of the lens, $u = -100\,cm$.

Calculating the Image Distance (v):

$$
\frac{1}{20} = \frac{1}{v} - \frac{1}{-100}
$$
$$
\frac{1}{20} = \frac{1}{v} + \frac{1}{100}
$$
$$
\frac{1}{v} = \frac{1}{20} - \frac{1}{100}
$$
$$
\frac{1}{v} = \frac{5}{100} - \frac{1}{100} = \frac{4}{100} = \frac{1}{25}
$$
$$
v = 25\,cm
$$

Interpretation:
- The image formed by the first lens is real, because the image distance is positive.
- It is located 25 cm behind the first lens.

Image Magnification:

$$
M = \frac{v}{u} = \frac{25}{-100} = -0.25
$$

The negative sign indicates the image is inverted relative to the object, and the magnitude shows the image is reduced to 25% of the object size.

Summary of First Lens:
- Image position: 25 cm behind the lens.
- Image type: Real and inverted.
- Image size: Reduced.

Position of the Image Relative to the Second Lens

The second lens is placed 15 cm away from the first lens. To determine the position of the image relative to the second lens, consider the following:

- The image formed by the first lens is at 25 cm behind the first lens.
- The second lens is located 15 cm from the first lens, so the image's position relative to the second lens depends on whether the image is on the same or opposite side.

Scenario 1: The image is on the same side as the second lens

Since the image is 25 cm behind the first lens, and the second lens is 15 cm from the first, the position of the image relative to the second lens is:

$$
\text{Distance from second lens} = 25\,cm - 15\,cm = 10\,cm
$$

Because this value is positive, the image formed by the first lens is on the same side as the incoming light to the second lens, indicating the second lens sees a real object located 10 cm in front of it.

Analyzing the Second Lens

Object for the Second Lens

The second lens receives the image from the first lens as its object. The object distance for the second lens (u_2) is:

$$
u_2 = -10\,cm
$$

(negative because the object is on the same side as the incoming light).

Assuming the second lens is also a convex lens (common in such setups), and to proceed, we need its focal length. Since it's not specified, we can consider typical values or analyze generally.

For illustration, let's assume the second lens has a focal length of 20 cm as well.

Calculating the Image formed by the Second Lens:

$$
\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}
$$
$$
\frac{1}{20} = \frac{1}{v_2} - \frac{1}{-10}
$$
$$
\frac{1}{20} = \frac{1}{v_2} + \frac{1}{10}
$$
$$
\frac{1}{v_2} = \frac{1}{20} - \frac{1}{10} = \frac{1}{20} - \frac{2}{20} = -\frac{1}{20}
$$
$$
v_2 = -20\,cm
$$

Interpretation:
- The negative v_2 indicates the image is virtual and located 20 cm in front of the second lens.

Magnification for the second lens:

$$
M_2 = \frac{v_2}{u_2} = \frac{-20}{-10} = 2
$$

The positive magnification indicates the image erect relative to the object, and the size is twice that of the object.

Final Image Characteristics and Practical Implications

Position of the Final Image:

- Since the image by the second lens is virtual and on the same side as the incoming light, it appears 20 cm in front of the second lens.
- Relative to the original object, the total magnification is the product of individual magnifications:

$$
M_{total} = M_{1} \times M_{2} = (-0.25) \times (2) = -0.5
$$

- The negative sign indicates the final image is inverted relative to the original object.
- The size is 50% of the original object.

Implications in Optical Design:

This setup demonstrates how combining multiple lenses can manipulate image size, orientation, and

position. For example:
- Magnification control: Using lenses with specific focal lengths and placements to achieve desired magnification.
- Image correction: Correcting aberrations by combining lenses with complementary properties.
- Image transfer: Moving an image from one location to another, useful in microscopes and telescopes.

Practical considerations include:
- Precise alignment of lenses.
- Accounting for lens aberrations.
- Using appropriate focal lengths for desired magnification and image clarity.
- Ensuring the distances between lenses are optimized for the intended application.

Conclusion

Understanding the behavior of light through multiple lenses involves applying fundamental principles like the lens formula, magnification, and the sign conventions. In the given setup, the first lens creates a real, inverted, reduced image at 25 cm behind it, which then acts as an object for the second lens placed 15 cm away. Assuming typical focal lengths, the second lens forms a virtual, magnified, erect image in front of it. Such analyses are crucial in designing optical instruments, ensuring the correct placement of lenses to achieve desired imaging results. Mastery of these concepts enables engineers and scientists to manipulate light effectively, creating devices that serve a myriad of scientific and practical purposes.

Frequently Asked Questions

What is the nature of the image formed by the first lens when an object is placed 100 cm in front of a lens with a focal length of 20 cm?

Using the lens formula, the image distance is approximately 22.22 cm, and the image is real, inverted, and magnified.

How do you calculate the image position formed by the first lens in this setup?

Apply the lens formula: $1/f = 1/v - 1/u$, where $u = -100$ cm (object distance), $f = 20$ cm. Solving gives $v \approx 22.22$ cm.

What is the magnification produced by the first lens for the given object and focal length?

Magnification $M = v/u = 22.22 / (-100) \approx -0.222$, indicating an inverted image about 22.2% of the object size.

When a second lens is placed 15 cm from the first lens, how does it affect the overall image formation?

The second lens will act on the image formed by the first lens, potentially creating a new image depending on its position and focal length, which requires further calculation.

How do you determine the position of the second lens relative to the first image?

Calculate the position of the first image, then consider the distance between the first image and the second lens (placed 15 cm from the first), to analyze the subsequent image formation.

What factors influence the final image in a system with two lenses placed at different positions?

The focal lengths of both lenses, their relative positions, and the object and intermediate image distances all influence the size, position, and nature of the final image.

What are common applications of such multi-lens systems in optics?

Multi-lens systems are used in microscopes, telescopes, and camera lenses to achieve desired magnification, focus, and image clarity.

Additional Resources

An Object Is Placed 100 Cm In Front Of A Lens Of Focal Length Of 20 Cm. A Second Lens Is Placed 15 Cm

Understanding optical systems, especially those involving multiple lenses, is fundamental in both theoretical physics and practical applications like microscopes, telescopes, and camera systems. The scenario of an object placed at a certain distance in front of a lens, with a second lens positioned at a specific distance from the first, offers a rich ground for exploring image formation, magnification, and the principles governing lens combinations. This article provides an in-depth analysis of such a setup, focusing on the fundamental concepts, calculations, and implications involved.

Overview of the Setup

The problem involves two primary components:

- An object placed 100 cm in front of the first lens.
- The first lens with a focal length of 20 cm.

- A second lens positioned 15 cm from the first lens (the exact positioning relative to the object or the first lens is crucial).

This configuration is typical in optical experiments and devices where multiple lenses work in sequence to manipulate light paths for magnification, correction, or image projection.

Understanding the Optical Principles

Lens Formula and Sign Convention

The fundamental relation governing thin lenses is the lens formula:

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

where:
- f = focal length of the lens.
- u = object distance from the lens (taken as negative if the object is on the same side as the incoming light).
- v = image distance from the lens.

Sign conventions:
- Object distances (u) are negative if the object is on the same side as the incoming light (real object).
- Focal length (f) is positive for converging lenses and negative for diverging lenses.
- Image distances (v) are positive if the image is real and on the opposite side of the lens, negative if virtual and on the same side.

In our case, assuming a converging lens (focal length of 20 cm positive), the object at 100 cm in front of the lens means $u = -100$ cm.

Calculating the Image Formed by the First Lens

Applying the lens formula:

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

Given:
- $f_1 = 20$ cm
- $u_1 = -100$ cm

Calculating:

\[

$$
\frac{1}{20} = \frac{1}{v_1} - \frac{1}{-100}
$$

$$
\frac{1}{20} = \frac{1}{v_1} + \frac{1}{100}
$$

$$
\frac{1}{v_1} = \frac{1}{20} - \frac{1}{100}
$$

Finding common denominator:

$$
\frac{1}{v_1} = \frac{5}{100} - \frac{1}{100} = \frac{4}{100} = \frac{1}{25}
$$

Therefore:

$$
v_1 = 25 \text{ cm}
$$

Interpretation:

- The image formed by the first lens is real and located 25 cm on the opposite side of the lens (since v_1 is positive).
- The magnification M_1:

$$
M_1 = - \frac{v_1}{u_1} = - \frac{25}{-100} = 0.25
$$

- The negative sign indicates an inverted image.

- The size of the image is one-quarter the size of the object.

Positioning of the Second Lens and Its Effects

The second lens is placed 15 cm from the first lens. To analyze the entire system, we need to understand the relative positions:

- If the second lens is placed 15 cm downstream of the first (on the same side as the image formed by the first lens), then the inter-lens distance is 15 cm.
- The object for the second lens is the image produced by the first lens, which is located 25 cm on the other side of the first lens.

Assuming the second lens is placed along the same axis and the distance is measured from the first lens:

- The image from the first lens is at +25 cm from the first lens.
- The second lens is located 15 cm from the first lens, so the distance from the image to the second lens:

\[
d_{i2} = v_1 - 15\, \text{cm} = 25\, \text{cm} -

15\, \text{cm} = 10\, \text{cm}
\]

Since the image is beyond the second lens, it acts as a virtual object for the second lens, located 10 cm away from it.

Analyzing the Second Lens

Now, considering the second lens:

- Its position relative to the virtual object (the image from the first lens):
- The virtual object distance \(u_2 \) is:

\[
u_2 = - d_{i2} = -10\, \text{cm}
\]

(negative because the object for the second lens is on the same side as incoming light relative to that lens).

- Focal length of second lens:

The problem does not specify the focal length of the second lens, which is essential for further analysis. For illustration, let's assume the second lens is identical to the first, with \(f_2 = 20\,

cm.

Applying the lens formula for the second lens:

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

$$
\frac{1}{20} = \frac{1}{v_2} - \frac{1}{-10}
$$

$$
\frac{1}{20} = \frac{1}{v_2} + \frac{1}{10}
$$

$$
\frac{1}{v_2} = \frac{1}{20} - \frac{1}{10} = \frac{1}{20} - \frac{2}{20} = - \frac{1}{20}
$$

$$
v_2 = -20\, \text{cm}
$$

Interpretation:

- The negative v_2 indicates a virtual image formed on the same side as the incoming light.
- The magnification for the second lens:

$$
M_2 = - \frac{v_2}{u_2} = - \frac{-20}{-10} = - 2
$$

- The negative sign signifies that the image is inverted relative to the virtual object, which, in this context, results in an upright final image when considering the entire system.

Overall System Interpretation

The combined effect of both lenses results in an overall magnification:

$$
M_{total} = M_1 \times M_2 = 0.25 \times (-2) = -0.5
$$

This indicates:

- The final image is inverted relative to the original object.
- The final image is half the size of the original object.

The final image location:

- Since the second lens produces a virtual image at $v_2 = -20\, \text{cm}$, the image appears 20 cm on the same side as the incoming light for the second lens.

Features, Pros, and Cons of Such a System

Features:

- Magnification Control: Using multiple lenses allows precise control over image size and magnification.
- Image Inversion: The system inherently inverts the image, which can be useful or undesirable depending on the application.
- Adjustable Focal Lengths: By selecting different lens combinations, the system can be tailored for specific imaging requirements.

Pros:

- Can achieve high magnification or reduction effects.
- Useful in optical instruments like microscopes, where multiple lenses improve resolution.
- Flexibility in positioning allows for customized imaging setups.

Cons:

- Complexity increases with additional lenses, requiring precise alignment.
- Aberrations and distortions can occur, especially with simple thin lenses.
- Virtual images may be less intuitive to interpret and can complicate image analysis.

Practical Applications and Considerations

This type of multi-lens configuration is foundational in many optical devices:

- Microscopes: Use multiple lenses to magnify tiny objects.
- Telescopes: Combine objective and eyepiece lenses for distant object viewing.
- Cameras: Multiple lens elements correct aberrations and improve image quality.
- Optical Instruments: Used in projection systems, binoculars, and corrective lenses.

When designing such systems, it is crucial to consider:

- Precise measurement of lens positions.
-

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