Key Concepts

Chapter 10

Lenses

$$\frac{1}{f}=\frac{1}{o}+\frac{1}{i}$$

$$m=-\frac{i}{o}$$

Takeaways

This question is posed in an unusual way—it does not ask for the object or image distance specifically. However, you should realize that on almost all quantitative lens (or mirror) problems, you will need to solve for the object or image distance or both. When in doubt, write the magnification formula and lens formula and try to combine them.

Ray diagrams, although helpful conceptually, cannot be used to find exact values. A thorough understanding of the mathematical basis for these problems is essential.

Converging Lens

A converging lens with a focal length of 30 cm is used to project an image that is 5 times as large as the object onto a screen. To produce this image, how far from the screen is the object?

1) Write the formula for magnification.

$$m=-\frac{i}{o}=-5$$

For a single-lens system, the magnification is always the negative of the image distance over the object distance. The image is cast onto a screen, meaning that it cannot be a virtual image; it must be a real image. Virtual images cannot be projected, which is why they are called virtual. Because a single lens can either create a virtual, erect image or a real, inverted image, the image must be real and inverted. This means that $m = -5$.

Remember: *A negative magnification indicates an inverted image.*

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2) Write the lens formula.

$$\frac{1}{f}=\frac{1}{o}+\frac{1}{i}$$

$$\frac{1}{30}=\frac{1}{o}+\frac{1}{i}$$

Understanding the sign conventions of this formula is the most important thing in this problem. Always make o, the distance from the object to the lens, a positive number; f is positive for converging lenses, negative for diverging lenses.

For a real (and thus inverted) image, i is always positive, and thus m is always negative (as long as you have taken o to be positive).For a virtual (and thus erect) image, i is always negative, and thus m is always positive.

If i is positive, the image is on the other side of the lens from the object. If i is negative, the image is on the same side as the object.

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3) Solve the magnification formula and substitute it into the lens formula.

$$-\frac{i}{o}=-5$$

$$i=5o$$

$$\frac{1}{30}=\frac{1}{o}+\frac{1}{5o}$$

$$\frac{1}{30} = \frac{6}{5o}$$

$$\frac{5o}{6} = 30$$

$$o = \frac{180}{5} = 36 \text{ cm}$$

Remember: *We know that we are looking for a positive object distance. If you get a negative number here, you have made an error somewhere along the line.*

MCAT Pitfall: *We are not done. The question asks for the distance between the object and the screen, not the object and the lens. We need to do more calculations to get the answer.*

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4) Solve for the image distance.

Use the expression for magnification from step 1 with the object distance we solved for in step 3.

$$m = -\frac{i}{o}$$

$$-5 = -\frac{i}{36}$$

$$i = 180 \text{ cm}$$

Remember: *We know that we have to get a positive image distance. If you get a negative number here, you have made an error somewhere along the line.*

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5) Add the image and object distance.

The question asks for the distance between the object and the screen or, in other words, the distance between the object and image location. This is simply $o + i$.

$$o + i = 36 + 180 = 216 \text{ cm}$$

Remember: *A real image always appears on the other side of the lens from the object. A virtual image appears on the same side as the object.*

Similar Questions

1) What is the focal length of a lens that produces a real, inverted image 45 cm away from the lens for an object placed 20 cm from the lens?
2) A 2 cm-tall slide is placed 10 cm in front of a diverging lens with a focal length of 20 cm. What are the location and size of the resulting image?
3) A lens produces an inverted image that is the same size as the object when the object is placed 20 cm away from the lens. What is the type and focal length of the lens?

Things to Watch Out For

The biggest mistake on this problem is sign errors caused by a misunderstanding of the sign convention for these formulas. Know it well. Practice!

Many test takers do not understand the physical difference between a real and virtual image: A virtual image cannot be projected. To project an image, we would have to place a screen where the outgoing light rays converge. For a virtual image, though, the outgoing light rays never converge—they only *appear* to converge at the image location.

Also, many test takers do not realize that a single lens cannot produce a virtual, inverted image, nor can it produce a real, erect image. Use these facts to your advantage.