Lenses

1

Lenses

Lenses are a practical application of refraction.

A converging lens creates an image of a long light-bulb filament on a glass plate.

Is the image real or virtual?

It must be real, because we can project it on a screen. The light rays diverge from the filament, and are then converged by the lens to create the image.

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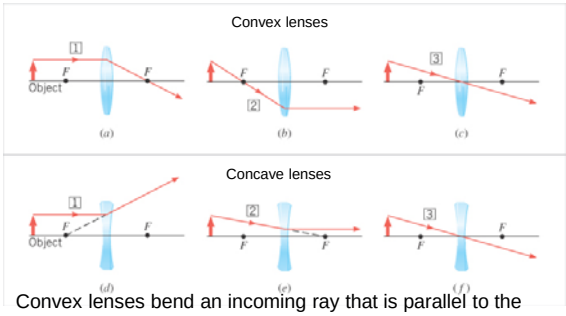
Convergent vs. Diverging Lenses



Convex lenses bend an incoming ray that is parallel to the principal axis toward the principal axis **after transmission** while concave lenses bend it away. Thus, convex lenses are convergent lenses and concave lenses are divergent lenses. Note that you get two focal points with lenses!

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Image formation with a convex (convergent) lens

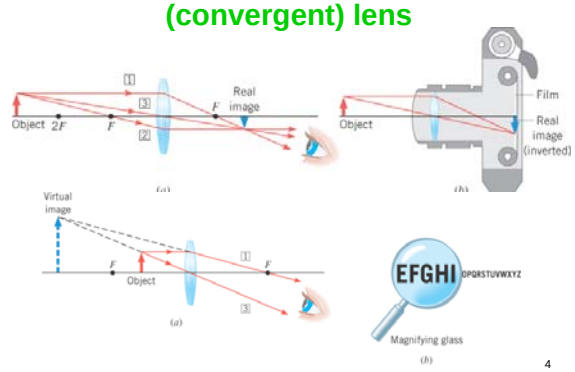

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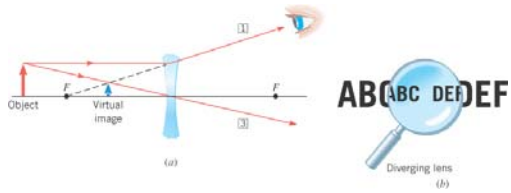
Image formation with a concave (divergent) lens



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Cover half the filament

A light filament is placed at a distance equal to +2f from a lens, where f is its focal length. What will happen to the image of the light filament if I cover up the top half of the filament?

1. The top half of the image will vanish.
2. The bottom half of the image will vanish.
3. The entire image will vanish.
4. The entire image will remain, but will be dimmer.
5. Nothing will change.
6. Something else will happen (you have to specify what!)

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Cover half the filament

If we cover the top half of the filament, the bottom half of the image disappears, because the image is _____.

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Cover half the lens

What will happen to the image if I cover up the top half of the lens, instead?

1. The top half of the image will vanish.
2. The bottom half of the image will vanish.
3. The entire image will vanish.
4. The entire image will remain, but will be dimmer.
5. Nothing will change.
6. Something else will happen (you have to specify what!)

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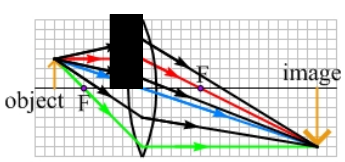
Cover half the lens

If we cover the top half of the lens, the image just gets dimmer. This tells us that light from all parts of the object goes through all of the lens and then forms the image, so we're losing about half the light from every part of the object when we block half the lens.



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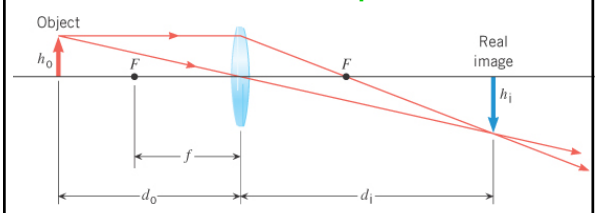
The thin-lens equation



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

Conveniently, it's the same equation we used for mirrors!

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Sign convention of the thin-lens equation

	The conventional side for the object (usually the l.h.s. of the lens)	The side opposite (usually the r.h.s. of the lens)
Object position	d_o is +	d_o is –
Image position	d_i is –	d_i is +
Focal point, F	f is -, applicable to diverging (concave) lens	f is +, applicable to converging (convex) lens

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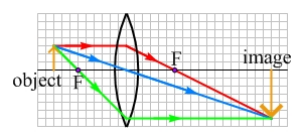
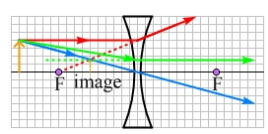
The sign convention

A negative *m* means that the image is inverted.



Positive *m* means an upright image.



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A method for analyzing lens problems

Solving a lens problem means determining where the image is, and determining what kind of image it is (real or virtual, upright or inverted).

1. Draw a ray diagram. The more careful you are in drawing it, the more accurately you will know where the image is.

2. Apply the thin-lens equation to determine the image distance. (Or to find the object distance, or the focal length, depending on what is given.)

3. Make sure steps 1 and 2 are consistent with each other.

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Example 1

A Star Wars action figure, 15 cm tall, is placed 60 cm in front of a diverging lens that has a focal length of -30 cm.

Where is the image?

How tall is the image?

What are the characteristics of the image?

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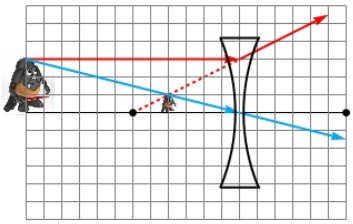
Example 1

First, sketch a ray diagram.

1 grid unit = 5 cm.



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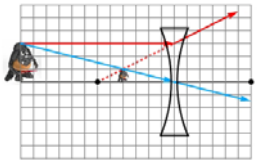
Example 1

A Star Wars action figure, 15 cm tall, is placed 60 cm in front of a diverging lens that has a focal length of -30 cm.

Where is the image?



$$d_o = 60 \text{ cm}, \; f = -30 \text{ cm}$$

$$d_i = \frac{d_o \times f}{d_o - f}$$

$$= \frac{(60 \text{ cm}) \times (-30 \text{ cm})}{(60 \text{ cm}) - (-30 \text{ cm})}$$

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

This agrees with the ray diagram

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Example 1

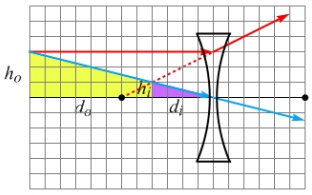
How tall is the image?

$$d_o = 60 \text{ cm}, \; d_i = -20 \text{ cm}, \; h_o = 15 \text{ cm}$$

Find the image height from the complete magnification equation.

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$h_i = 5 \text{ cm}$$



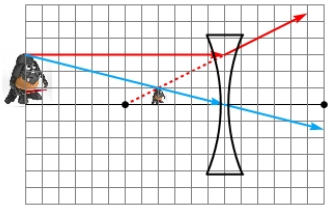
Example 1

A Star Wars action figure, 15 cm tall, is placed 60 cm in front of a diverging lens that has a focal length of -30 cm.

What are the image characteristics?

The image is:

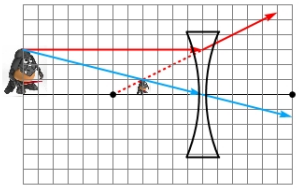
- virtual
- upright
- smaller than the object



Moving the object

If the object is moved a little closer to the lens, what happens to the image?

1. The image moves closer to the lens
2. The image moves farther from the lens
3. The image becomes taller
4. The image becomes shorter
5. 1 and 3
6. 1 and 4
7. 2 and 3
8. 2 and 4



Example 2

A Star Wars action figure, 15 cm tall, is placed 75 cm in front of a converging lens that has a focal length of +30 cm.

- Where is the image?
- How tall is the image?
- What are the characteristics of the image?

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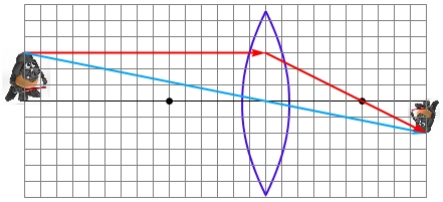
Example 2

First, sketch a ray diagram.

1 grid unit = 5 cm.



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Example 2

Where is the image? $d_o = 75\text{ cm},\ f = +30\text{ cm}$

$$d_i = \frac{d_o \times f}{d_o - f}$$

$$= \frac{(75\text{ cm}) \times (30\text{ cm})}{(75\text{ cm}) - (30\text{ cm})}$$

$$= +50\text{ cm}$$

This agrees with the ray diagram.

How tall is the image? $h_o = 15\text{ cm}$

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \quad \begin{matrix} \leftarrow +50\text{ cm} \\ \leftarrow +75\text{ cm} \end{matrix}$$

$$h_i = -10\text{ cm}$$

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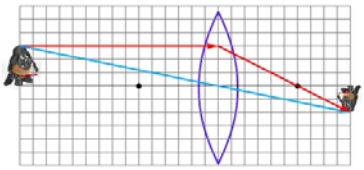
Example 2

A Star Wars action figure, 15 cm tall, is placed 75 cm in front of a converging lens that has a focal length of +30 cm.

What are the image characteristics?

The image is:

- real
- inverted
- the same size as
- the object



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Moving the object

If the object is moved a little closer to the lens, what happens to the image?

1. The image moves closer to the lens
2. The image moves farther from the lens
3. The image becomes taller
4. The image becomes shorter
5. 1 and 3
6. 1 and 4
7. 2 and 3
8. 2 and 4