Physics 1C

Lecture 26C

"There are two kinds of light--the glow that illuminates, and the glare that obscures."

--James Thurber

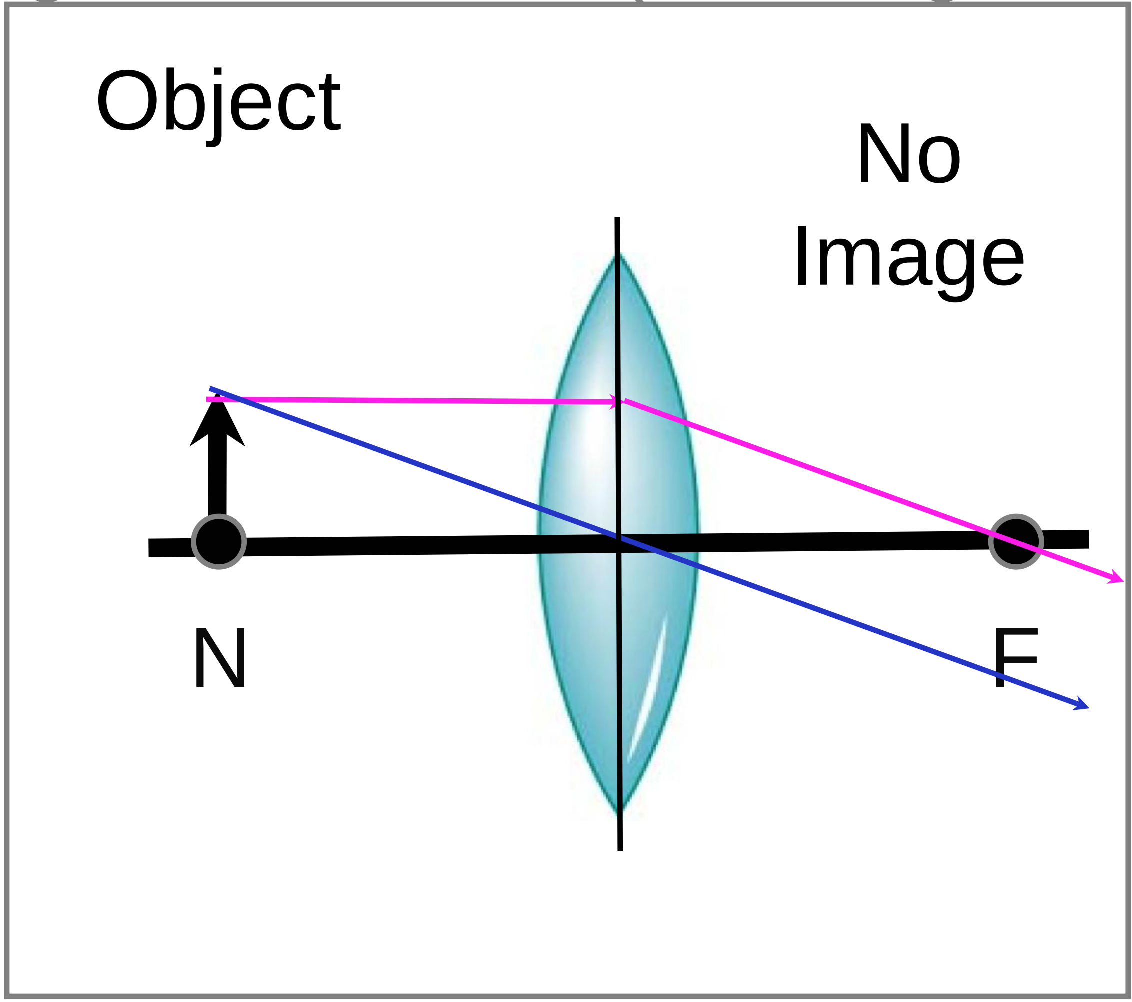
Outline

- Facebook
- Thin Lens equation
- Image formation summary
- The Eye
- Lenses in series

Thin Lens Equation

Example

An object is placed 10cm to the left of a converging lens that has a focal length of 10cm. Describe what the resulting image will look like (i.e. image distance, magnification...).



Answer

The coordinate system defined.

The center of the lens is the origin.

Thin Lens Equation

Answer

First, turn to the thin lens equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{10\text{cm}}-\frac{1}{10\text{cm}}=0$$

$$q=\infty$$

The image is at infinity. This means that there is no resulting image.

Thin Lens Equation

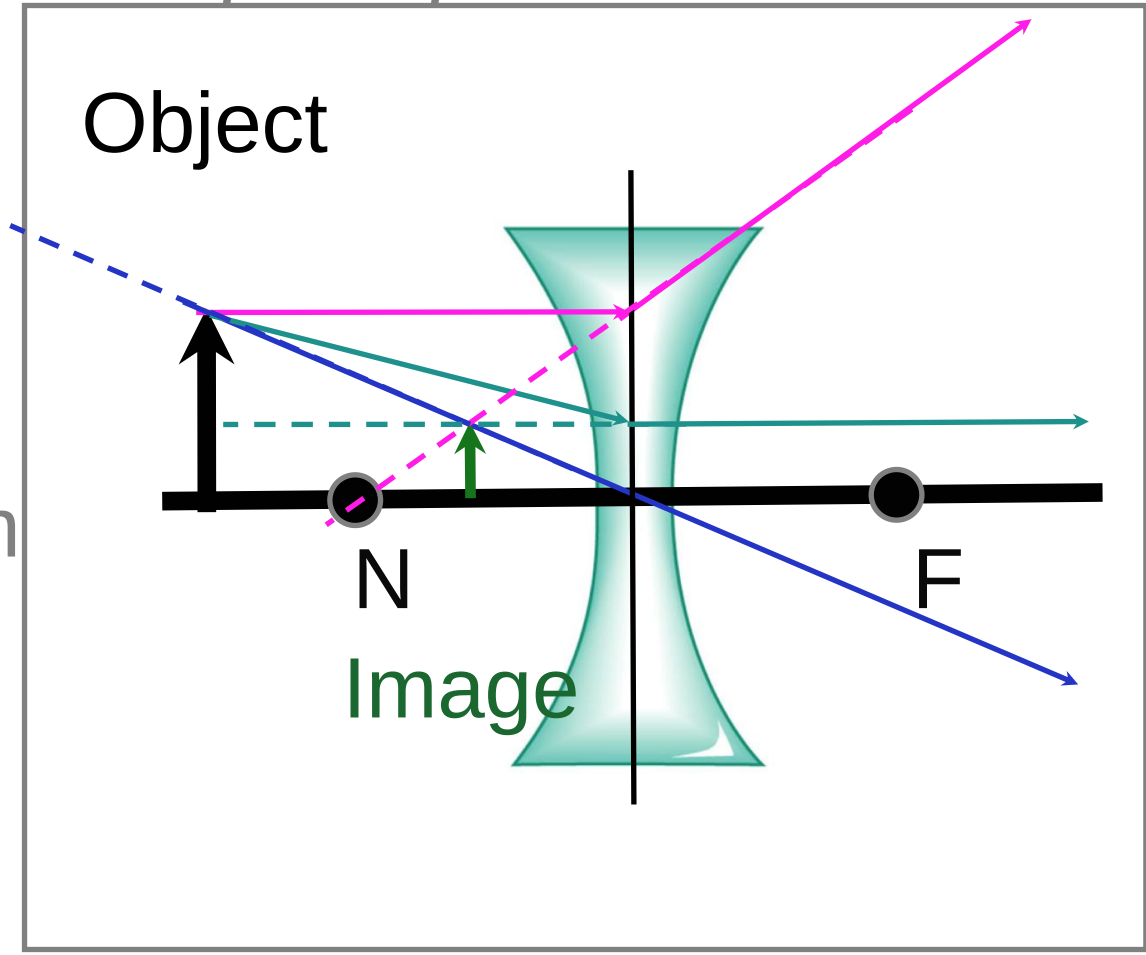
Example

An object is placed 15cm to the left of a diverging lens that has a focal length of 10cm. Describe what the resulting image will look like (i.e. image distance, magnification...).

Answer

The coordinate system defined.

The center of the lens is the origin.



Thin Lens Equation

Answer

First, turn to the thin lens equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{-10\text{cm}}-\frac{1}{15\text{cm}}$$

$$\frac{1}{q}=-\frac{3}{30\text{cm}}-\frac{2}{30\text{cm}}=-\frac{5}{30\text{cm}}$$

$$q=-\frac{30\text{cm}}{5}=-6.0\text{cm}$$

where the negative sign means that the image is on the same side of the lens as the object (i.e. the left side of the lens).

The magnification of the object will be:

$$M=-\frac{q}{p}=-\frac{-6.0\text{cm}}{15\text{cm}}=+0.40$$

Thin Lens Equation

Answer

From the thin lens and magnification equations we find that the image is:

Diminished ($|M| = 0.40 < 1$).

Upright ($M = +0.40 > 0$).

Virtual ($q = –6.0\text{cm} < 0$; same side as object).

Located about halfway between the near focal point and the lens ($q = –6.0\text{cm}$, $f = –10\text{cm}$).

Ray Diagrams

Let's check the answer by making a quick ray diagram of the situation:

Ray 1: parallel then away from near focal point.

Ray 2: straight through the center of the lens.

Ray 3: is intended to go through far focal point but goes parallel at lens.

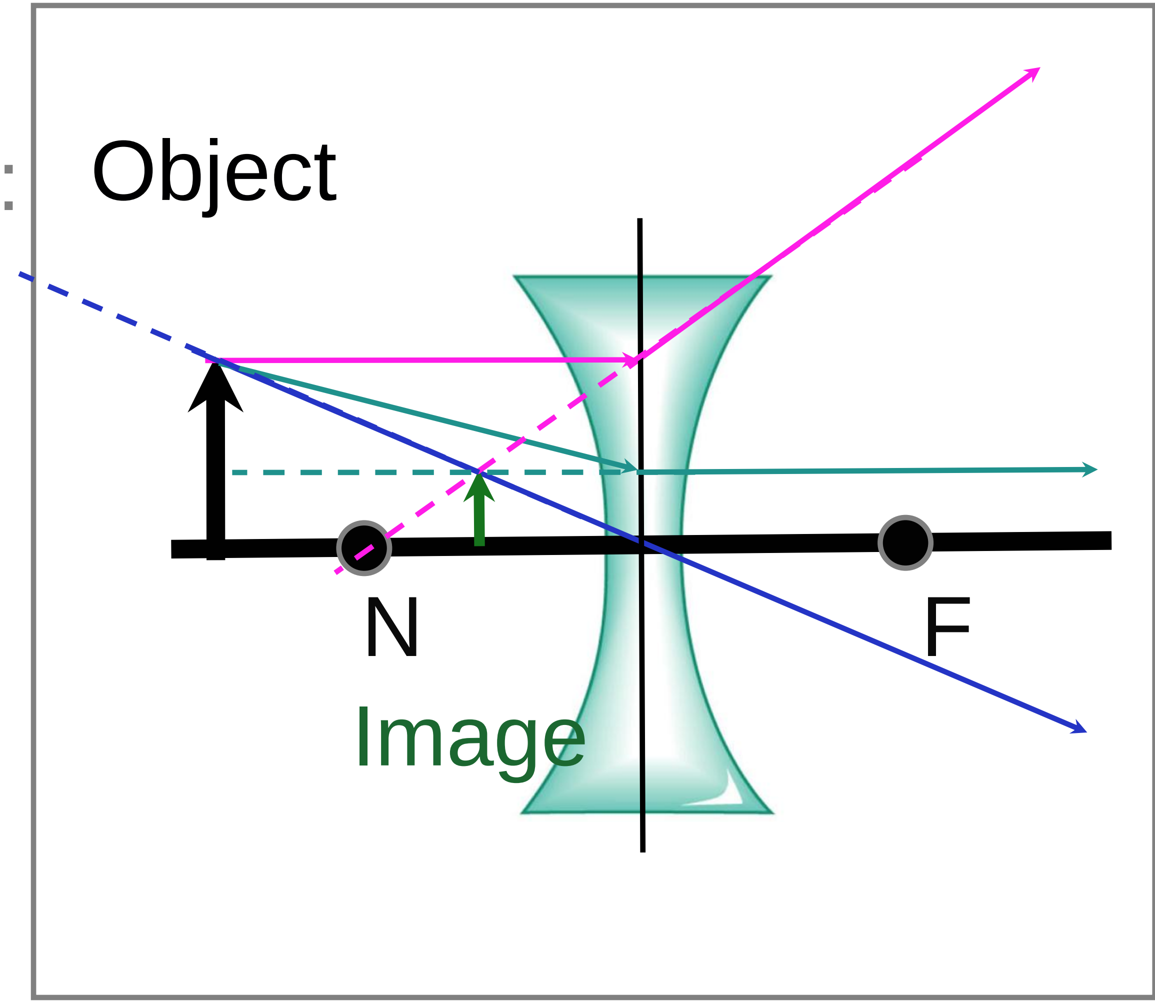


Image is **upright, diminished and virtual**.

Clicker Question 26C-1

An upright object placed outside the focal point of a converging lens will produce an image that is:

A) upright and virtual.

B) inverted and virtual.

C) upright and real.

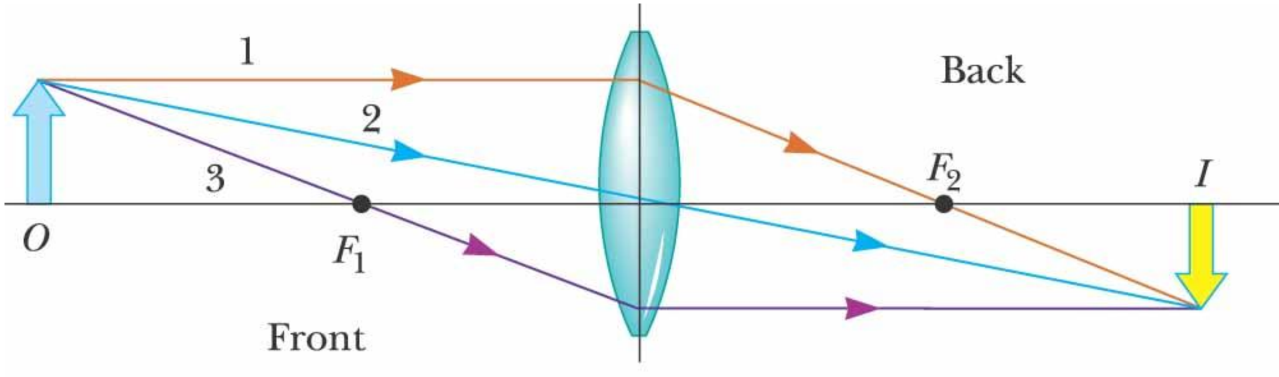
D) inverted and real.

E) will not exist.

Image Formation Summary

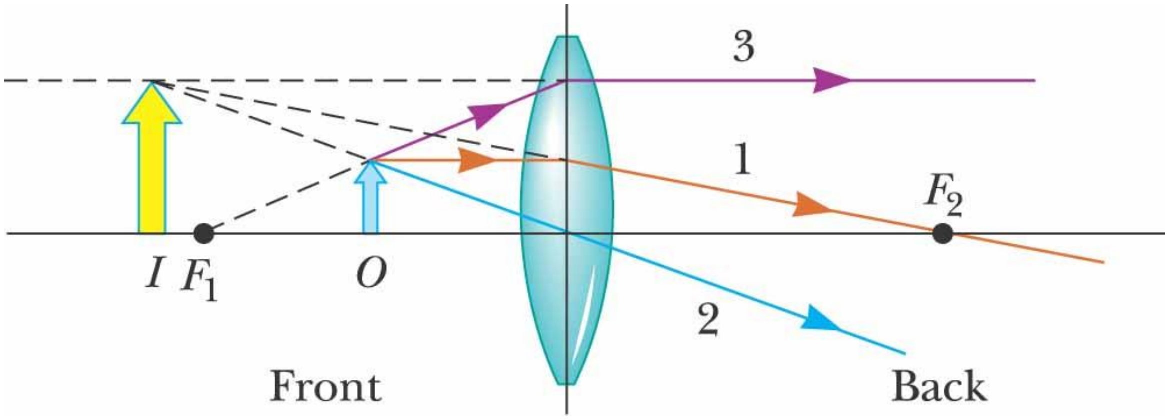
Converging Lens:

When the object distance is greater than the focal length (p > *f*)



the image is real and inverted

When the object is between the focal point and the lens (p < *f*)



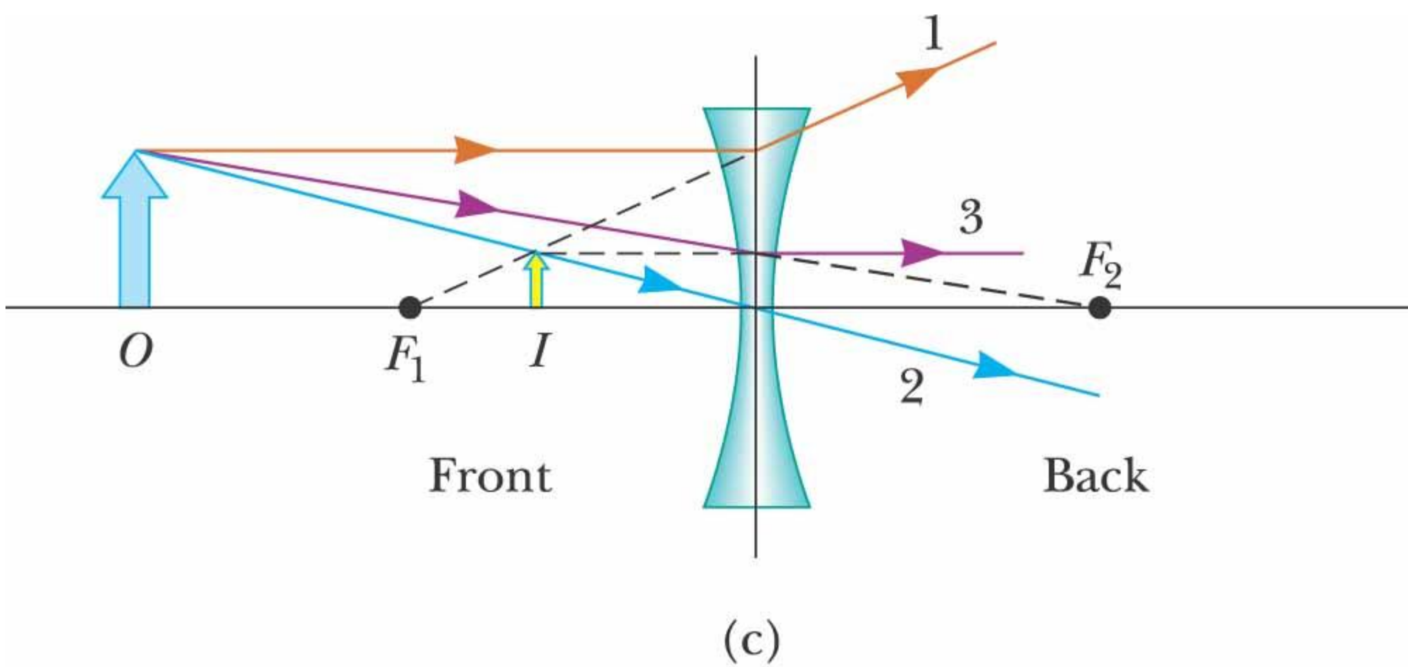
the image is virtual and upright

Image Formation Summary

Diverging Lens:

When the object distance is greater than the focal length ($p > |f|$)

the image is virtual and upright



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The Eye

The human eye is an organ that detects light

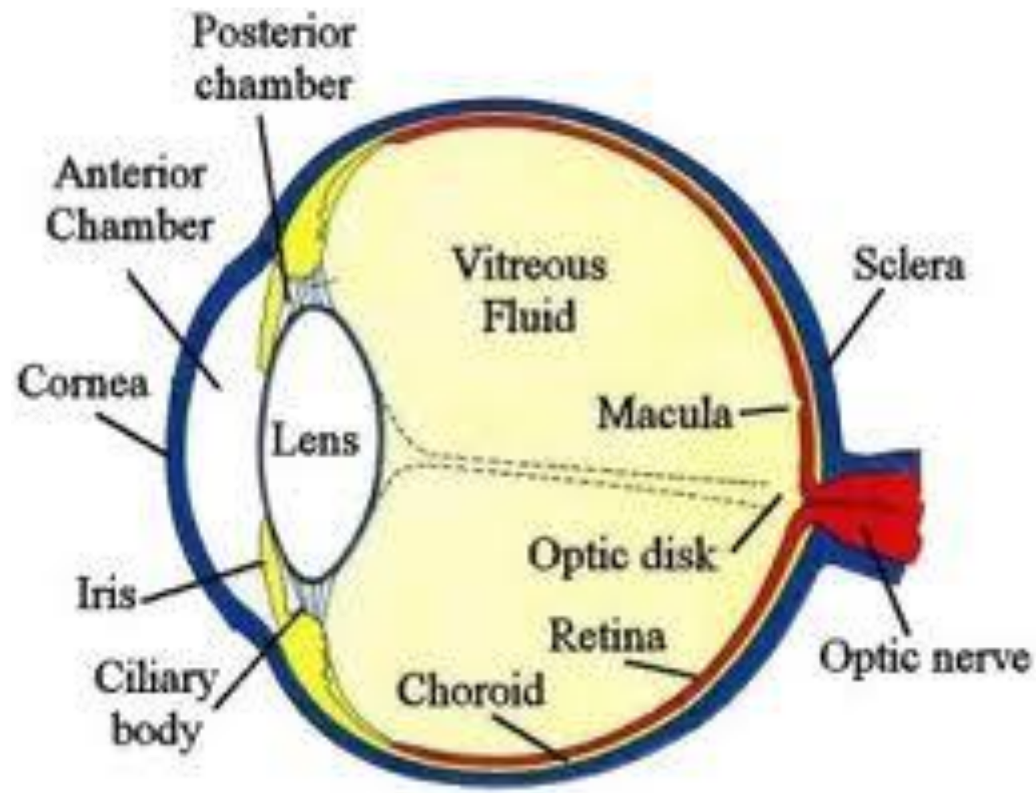
Composed of rods and cones that are light sensitive proteins

Our most important sense

Has a lens for focusing

Has limited ability to adjust the focal point of the built in lens

But not everyone has perfect vision.



Clicker Question 26C-2

Given what we know about the eye, the image that is observed is:

A) upright and virtual.

B) inverted and virtual.

C) upright and real.

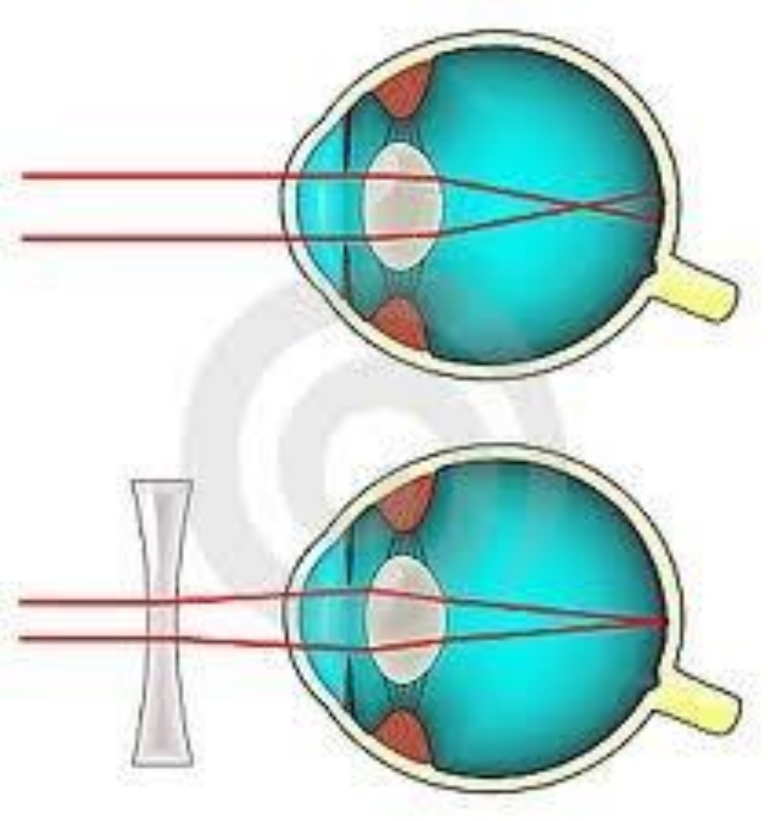
D) inverted and real.

E) will not exist.

Combination of Thin Lenses

If one wants to adjust the focal length of a lens system, can change the point of focus by adding another lens in series.

This is the basis of using glasses to adjust focal point for our natural lens in the eye



Consider this example of nearsightedness

Adding a diverging lens will

adjust the focal point to be closer to the retina which detect the light

Combination of Thin Lenses

When two lenses are placed next to each other, the light rays from the object will enter one lens then the other.

The image produced by the first lens is calculated as though the second lens is not present.

The light then approaches the second lens as if it had come from the image of the first lens.

The image of the first lens is treated as the object of the second lens!!!!!

The image formed by the second lens is the final image of the system.

Combination of Thin Lenses

If the image formed by the first lens lies on the back side of the second lens, then the image is treated as a **virtual object** for the second lens.

This means that the object distance, p, will have a negative value.

In a two lens system, there will be a magnification caused by the first lens, M_1, and a magnification caused by the second lens, M_2.

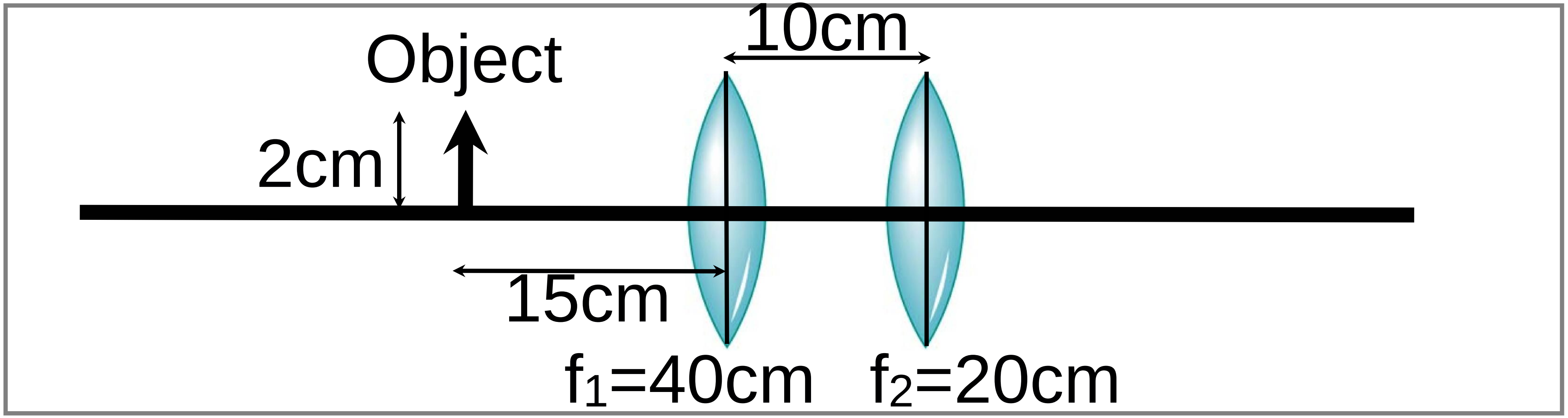
The overall magnification, M_{Tot}, is the product of the magnification of the separate lenses.

$$M_{Tot} = M_1 \times M_2$$

Two Lens System

Example

Two converging lenses with focal lengths of 40cm and 20cm are placed 10cm apart. A 2cm tall object is located 15cm from the 40cm focal length lens as shown in the figure. Fully describe the resulting image.



Answer

The center of the first lens is our origin.

Thin Lens Equation

Answer

First, turn to the thin lens equation for the first lens:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{q}=\frac{1}{f_1}-\frac{1}{p}=\frac{1}{40\text{cm}}-\frac{1}{15\text{cm}}$$

$$\frac{1}{q}=\frac{3}{120\text{cm}}-\frac{8}{120\text{cm}}=\frac{-5}{120\text{cm}}$$

$$q=\frac{120\text{cm}}{-5}=-24\text{cm}$$

where the negative sign means that the image is on the same side of the lens as the object (the left).

The magnification of the object from the first lens will be:

$$M_1=-\frac{q}{p}=-\frac{-24\text{cm}}{15\text{cm}}=+1.6$$

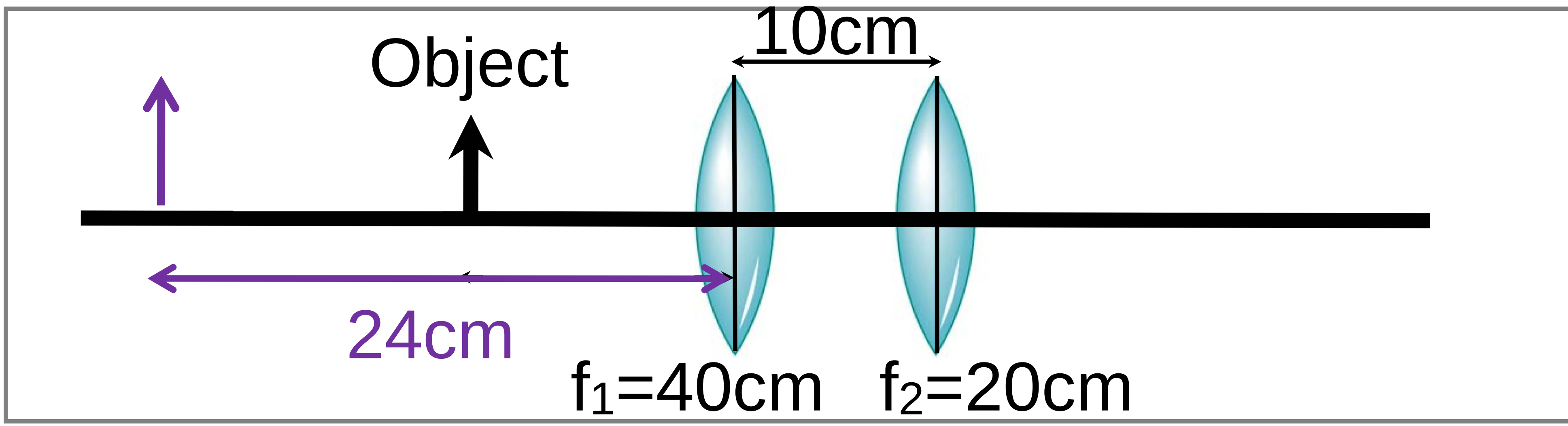
Thin Lens Equation

Answer

Next, turn to the thin lens equation for the second lens.

But now the object distance will be the distance from the image of the first lens to the second lens.

Since the image is 24cm to the left of the first lens and the two lenses are 10cm apart, this means that object distance to the second lens is 34cm.



Thin Lens Equation

Answer

The new object distance to the second lens is 34cm.

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{q}=\frac{1}{f_2}-\frac{1}{p}=\frac{1}{20\text{cm}}-\frac{1}{34\text{cm}}$$

$$\frac{1}{q}=\frac{17}{340\text{cm}}-\frac{10}{340\text{cm}}=\frac{7}{340\text{cm}}$$

$$q=\frac{340\text{cm}}{7}=48.6\text{cm}$$

The final image is to the right of the second lens.

Thin Lens Equation

Answer

The magnification of the object from the second lens will be:

$$M_2 = -\frac{q}{p} = -\frac{48.6\text{cm}}{34\text{cm}} = -1.43$$

The total magnification of the object through the two lens system will be:

$$M_{Tot} = M_1 \times M_2 = (1.6) \times (-1.43) = -2.3$$

So, the resulting image will be:

Magnified compared to the original object ($|M_{\text{Tot}}| = 2.3 > 1$).

A height of (2.3x2.0cm)=4.6cm.

Inverted compared to the original object ($M_{\text{Tot}} = -2.3 < 0$).

Real (q=+48.6cm).

Located (48.6cm+25cm)=73.6cm from the original object.

Two Lens System

Example

Two lenses with focal lengths of 10cm and –11.11cm are placed 10cm apart. A 2cm tall object is located 15cm to the left from the 10cm focal length lens. Fully describe the resulting image.

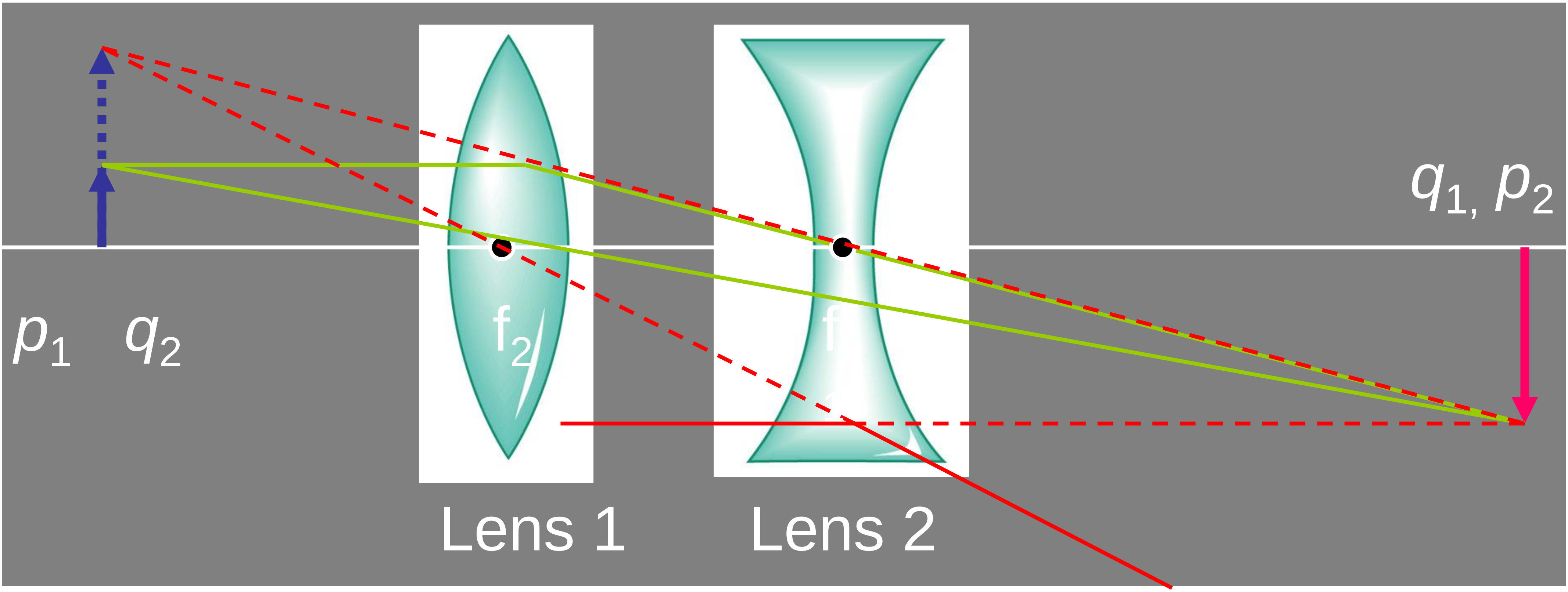
Answer

The center of the first lens is at the origin.

Ray Tracing

- **Answer**

p_1 = 15cm, f_1 = 10cm => q_1 = 30cm, M_1= –2



p_2 = –20cm, f_2 = –11.11cm => q_2 = –25cm, M_2= –1.25

Magnification of this system: M_{total} = M_1xM_2 = 2.5; h’=5cm

For Next Time (FNT)

Start reading Chapter 27

Finish working on the homework for Chapter 26