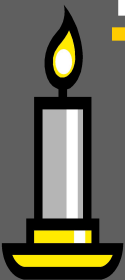


Images, Mirrors and Lenses Adapted from J.M. Gabrielse For Grade 11 Physics



Ray Diagrams



Objectives:

- To draw ray diagrams
- To see how real and virtual images are formed
- To use different object distances and focal lengths to create different sized images
- To gain a working knowledge of the terms: real image, virtual image, upright, inverted, magnified and diminished.

Real or Virtual Images

- Real Images are formed when light rays **do come together** to form an image.
- Virtual images are formed when light rays **seem to come together** to form an image.
- Sight lines are extensions of light rays needed to show the perceived virtual image.
- Sight lines are **dashed lines in ray diagrams**.

Symbols Used

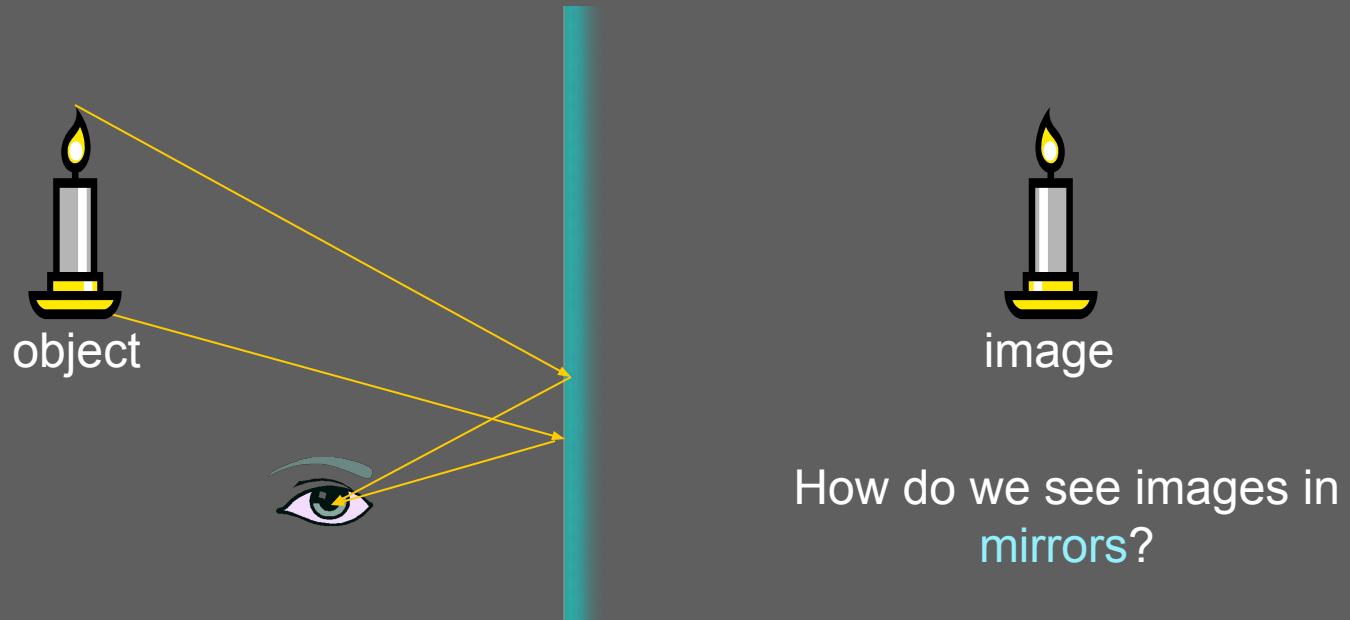
Designation	IB	British	Russian
Focal Length	d_f	f	F
Object distance	d_o	U	d
Image distance	d_i	V	f

Plane Mirrors (flat mirrors)



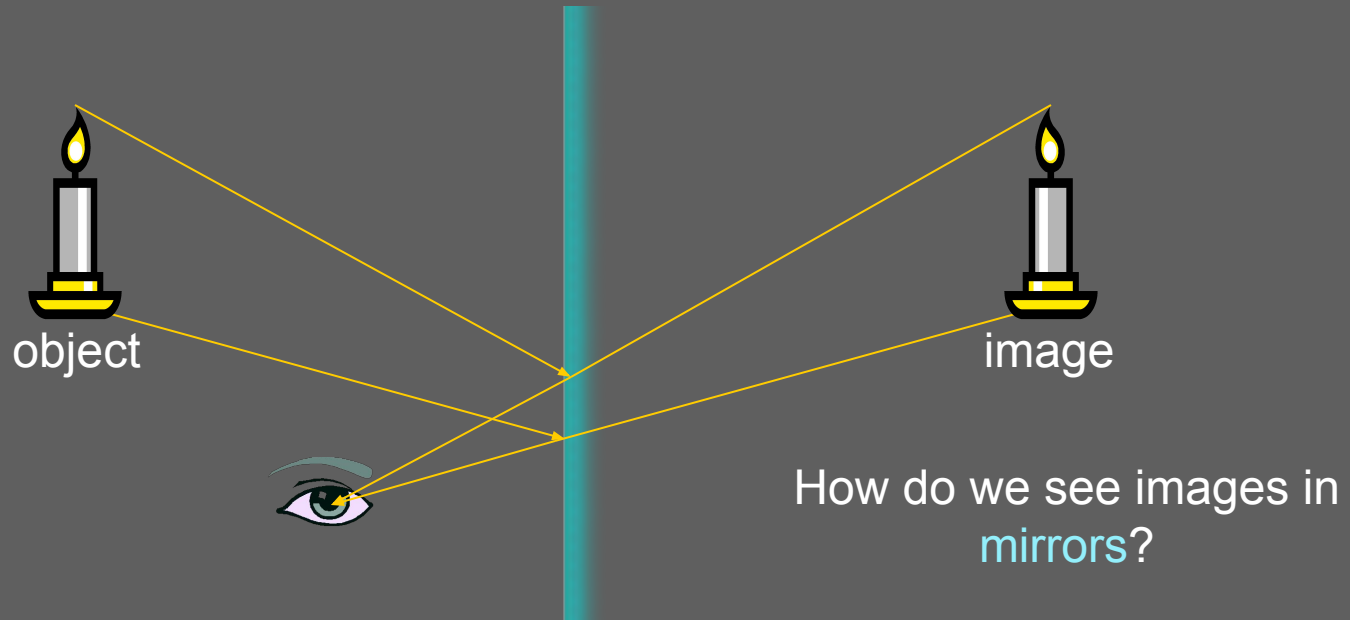
How do we see images in
mirrors?

Plane Mirrors (flat mirrors)



Light reflected off the mirror converges to form an image in the eye.

Plane Mirrors (flat mirrors)

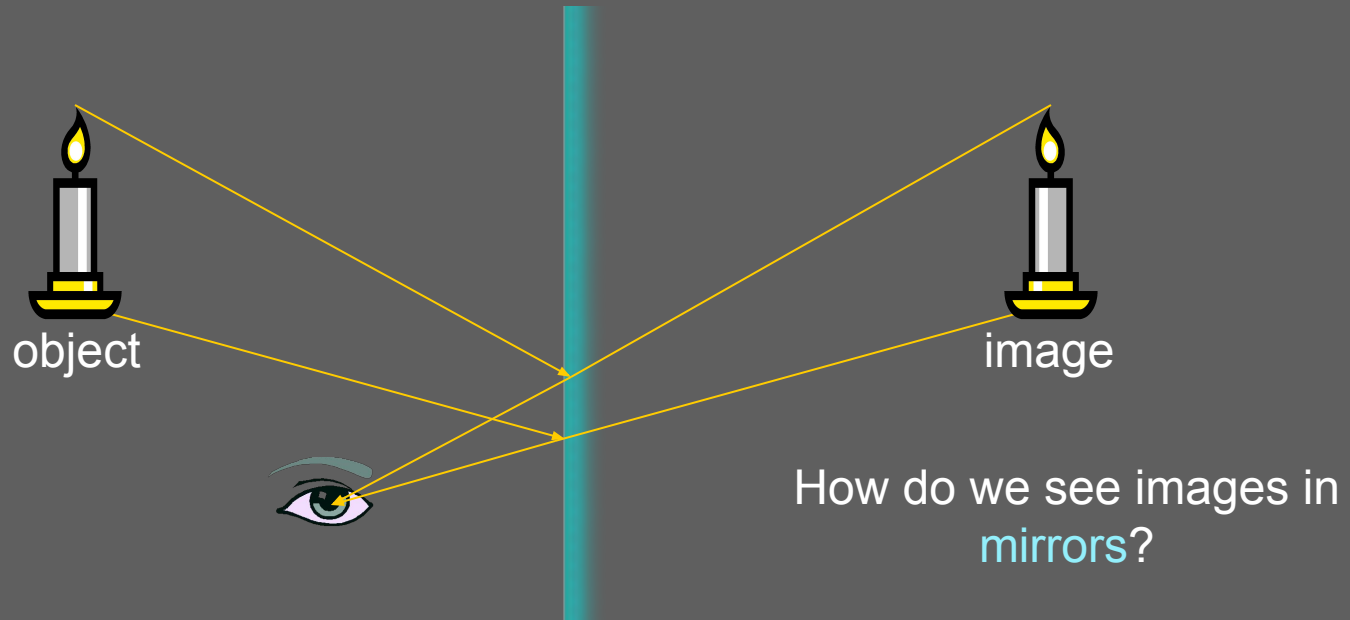


Light reflected off the mirror converges to form an image in the eye.

The eye perceives **light rays** as if they came through the **mirror**.

Imaginary **light rays** extended behind **mirrors** are called sight lines.

Plane Mirrors (flat mirrors)



Light reflected off the mirror converges to form an image in the eye.

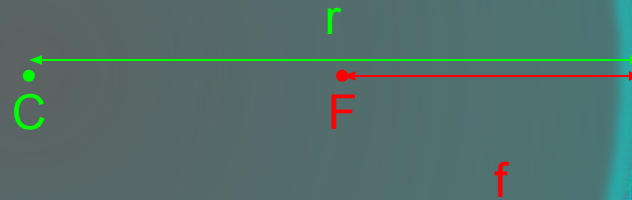
The eye perceives light rays as if they came through the mirror.

Imaginary light rays extended behind mirrors are called sight lines.

Image is virtual since it is formed by **imaginary sight lines, not real light rays.**

Spherical Mirrors (concave & convex)

Concave & Convex Mirrors are part of a sphere



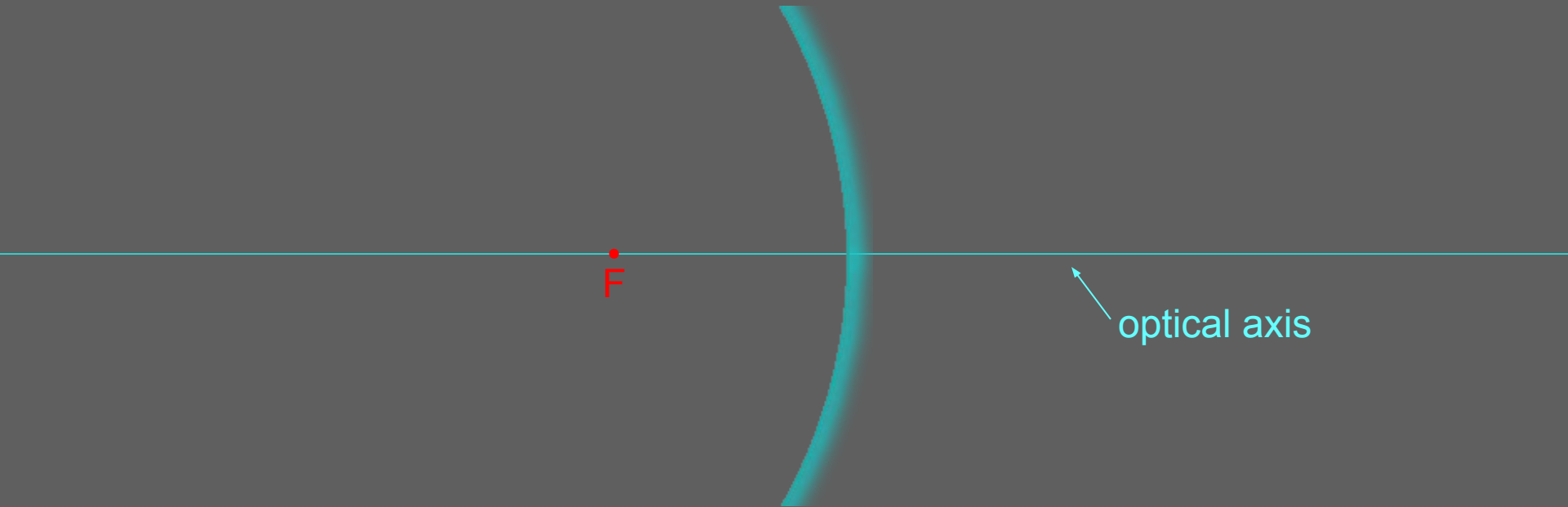
C: the center point of the sphere

r: radius of curvature = the radius of the sphere

F: focal point is halfway between C and the mirror

f: the focal distance, $f = r/2$

Concave Mirrors (caved in)



Light rays that come in parallel to the **optical axis** reflect through the **focal point**.

Concave Mirror (Object distance: $d_o > d_f$)



F



optical axis

Concave Mirror

(Object distance: $d_o > d_f$)



F

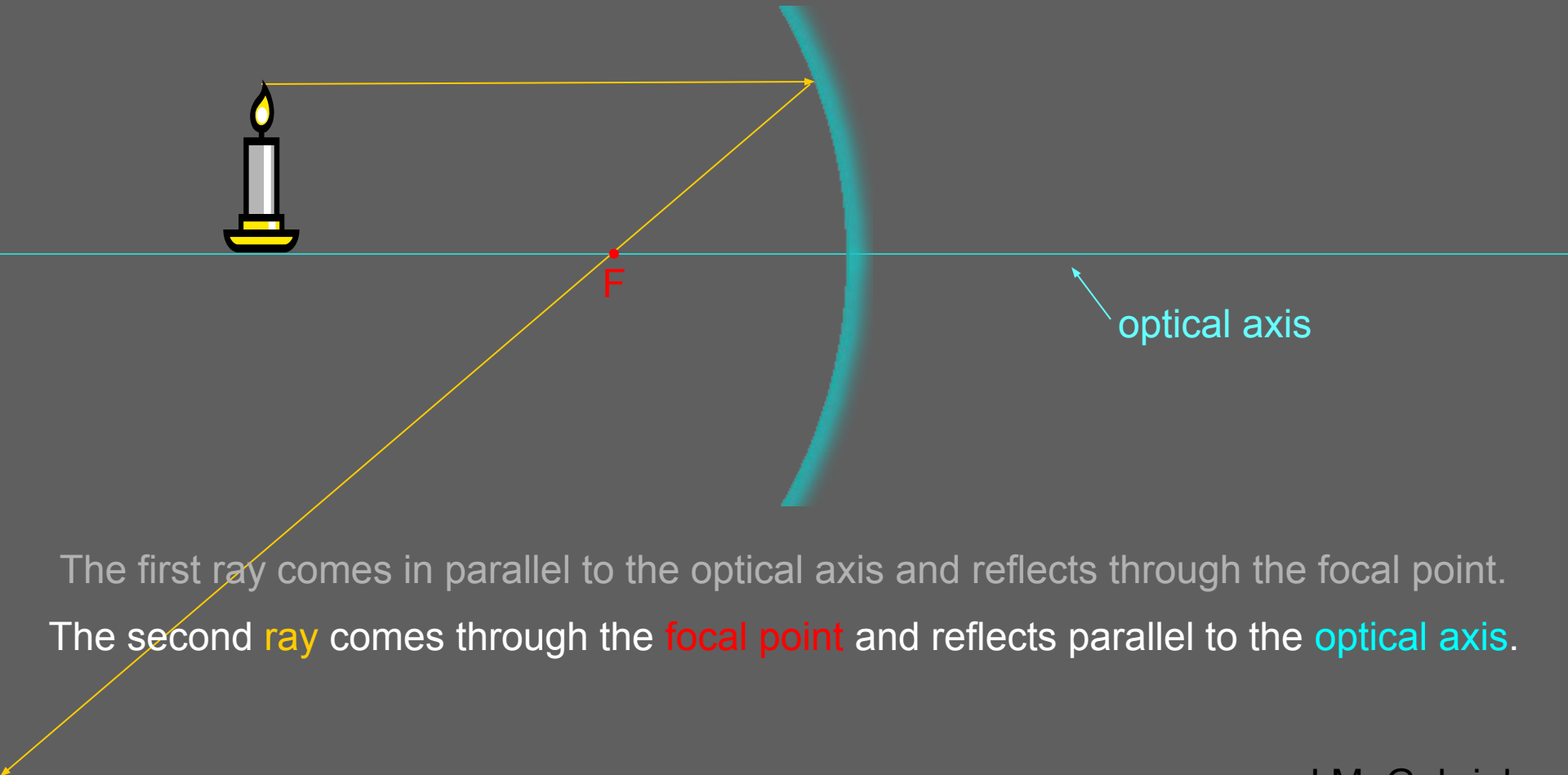


optical axis

The first ray comes in parallel to the optical axis and reflects through the focal point.

Concave Mirror

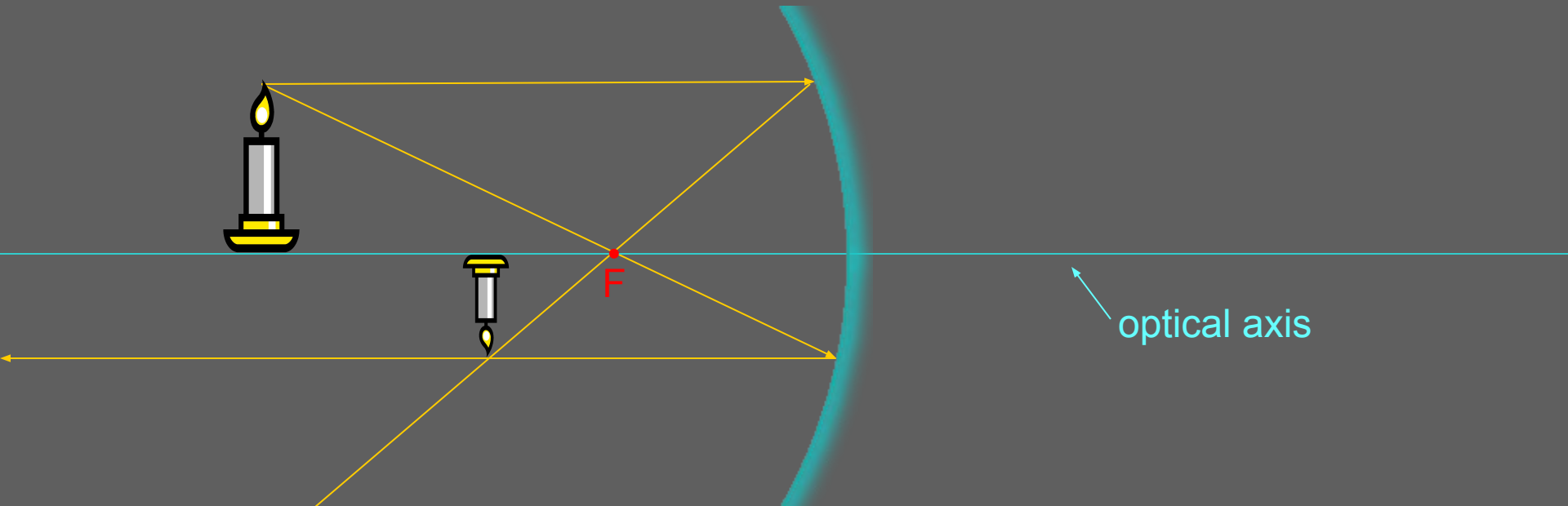
(Object distance: $d_o > d_f$)



The first ray comes in parallel to the optical axis and reflects through the focal point.
The second **ray** comes through the **focal point** and reflects parallel to the **optical axis**.

Concave Mirror

(Object distance: $d_o > d_f$)

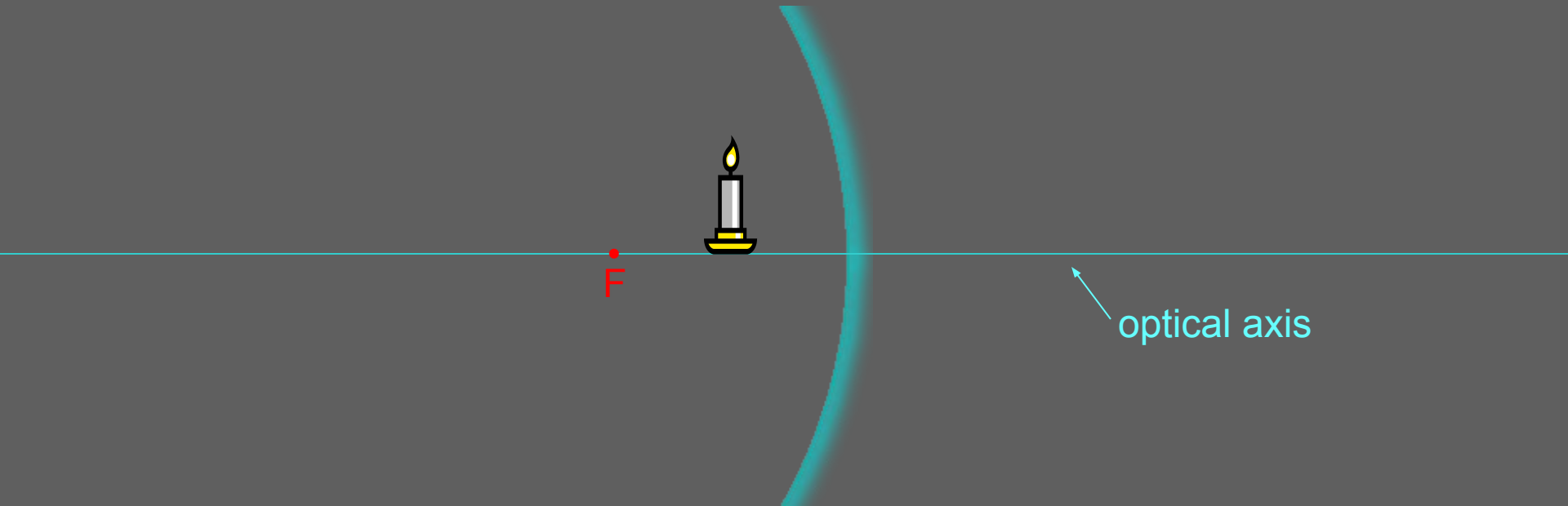


The first ray comes in parallel to the optical axis and reflects through the focal point.
The second ray comes through the focal point and reflects parallel to the optical axis.

A **real, inverted, diminished image** forms where the **light rays** converge.

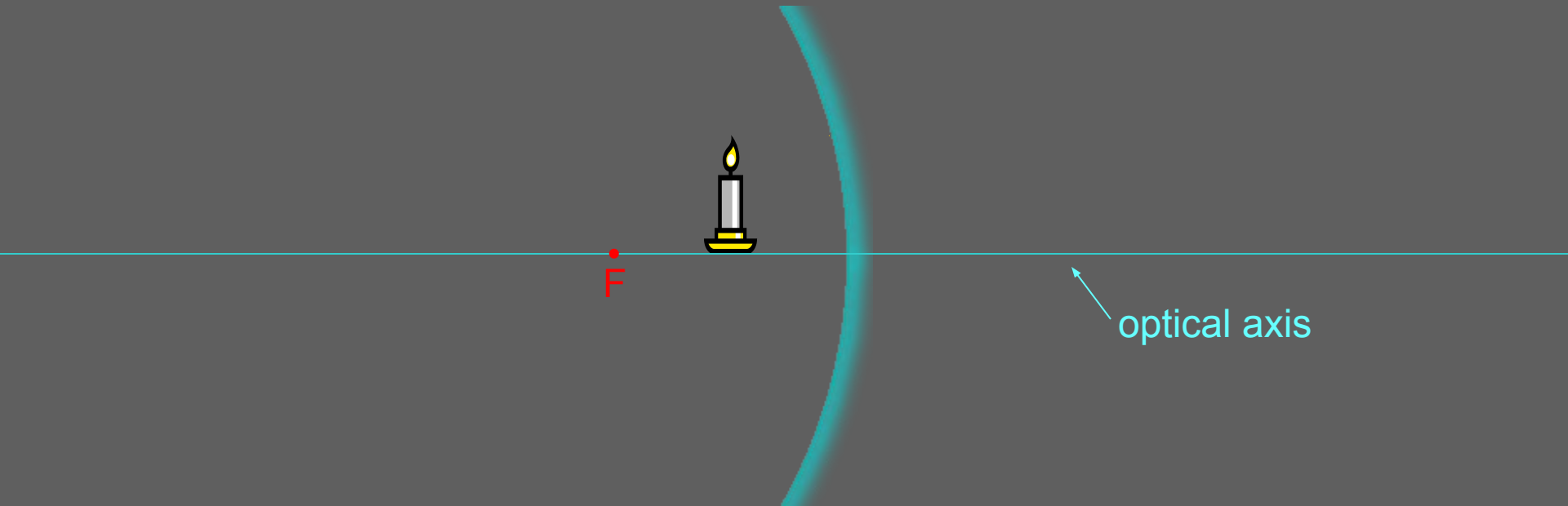
Concave Mirror

(Object distance: $d_o < d_f$)



Concave Mirror

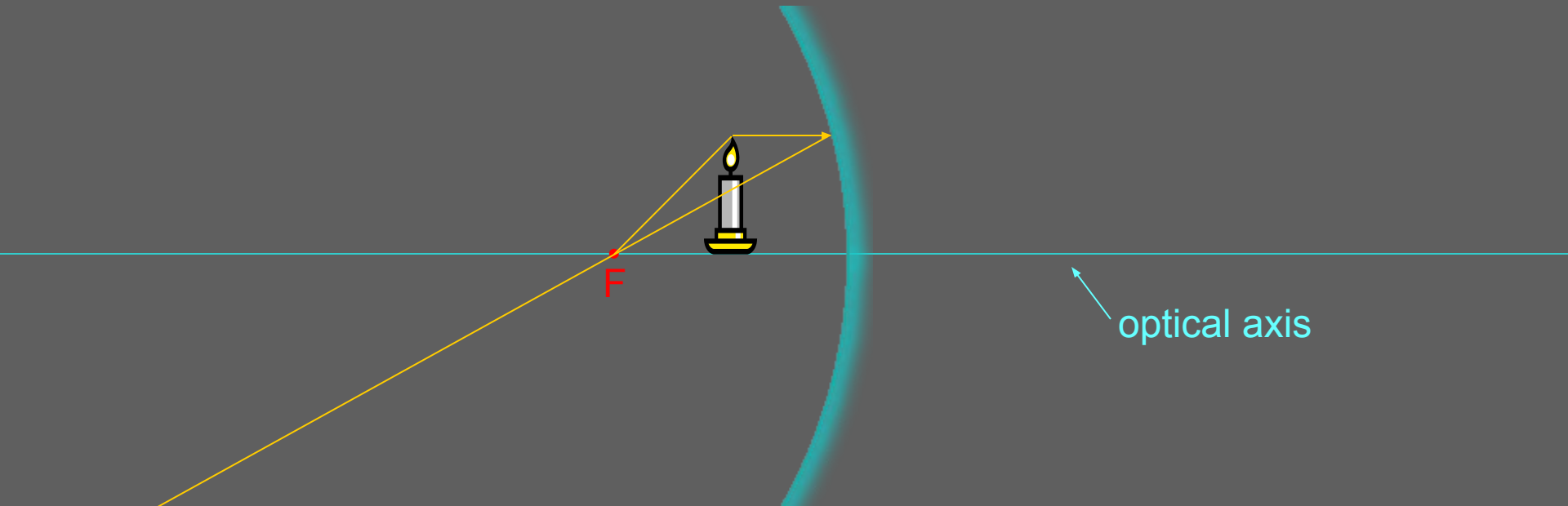
(Object distance: $d_o < d_f$)



The first **ray** comes in parallel to the **optical axis** and reflects through the **focal point**.

Concave Mirror

(Object distance: $d_o < d_f$)

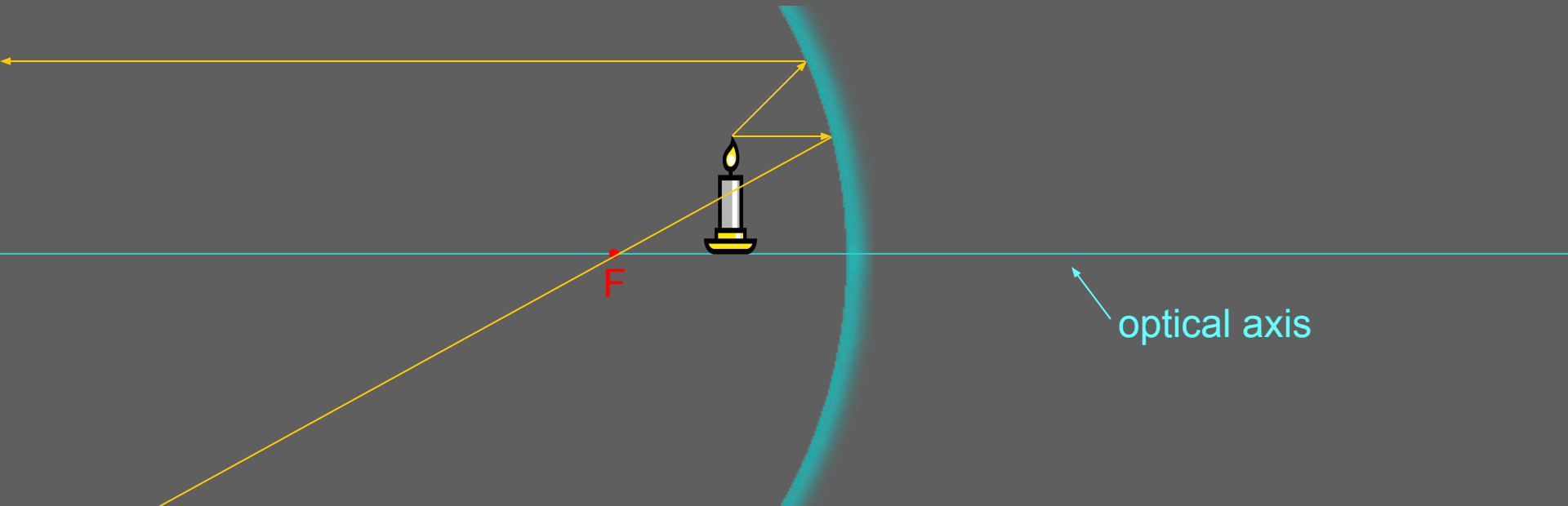


The first ray comes in parallel to the optical axis and reflects through the focal point.

The second ray comes through the focal point and reflects parallel to the optical axis.

Concave Mirror

(Object distance: $d_o < d_f$)



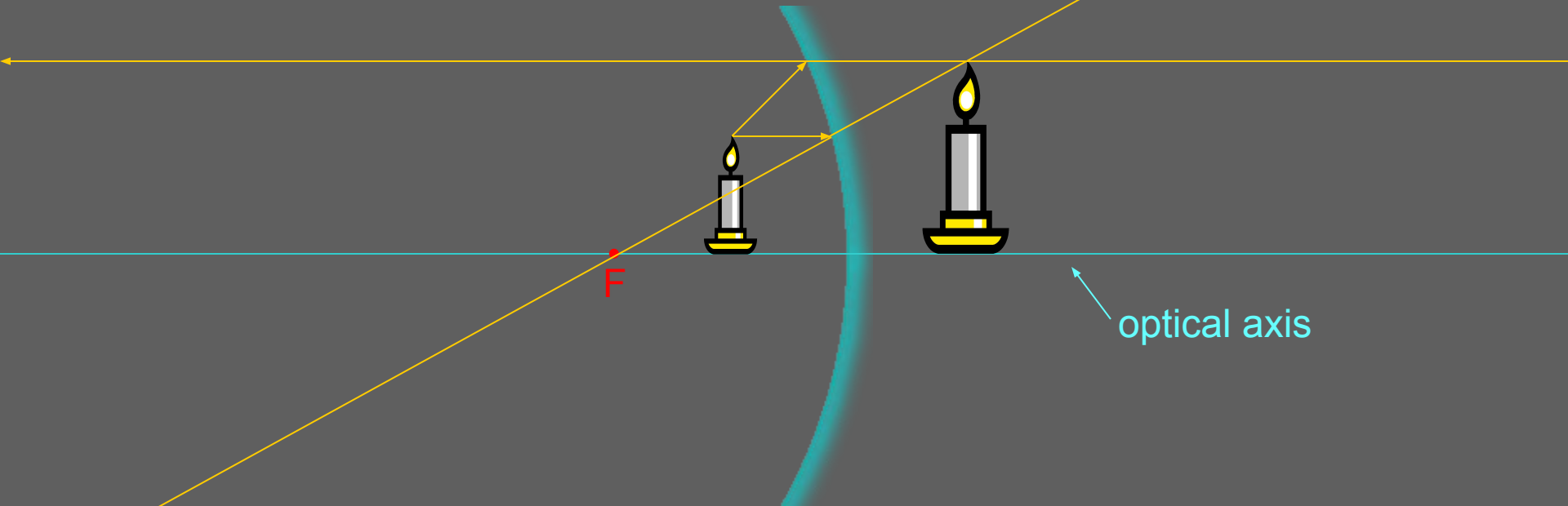
The first ray comes in parallel to the optical axis and reflects through the focal point.

The second ray comes through the focal point and reflects parallel to the optical axis.

The image forms where the **rays** converge. But they don't seem to converge.

Concave Mirror

Extend light rays with dashed sight lines



The first ray comes in parallel to the optical axis and reflects through the focal point.

The second ray comes through the focal point and reflects parallel to the optical axis.

A **virtual, upright, magnified image** forms where the sight rays converge.

Your Turn

(Object distance $d_o > 2d_f$)



object

F

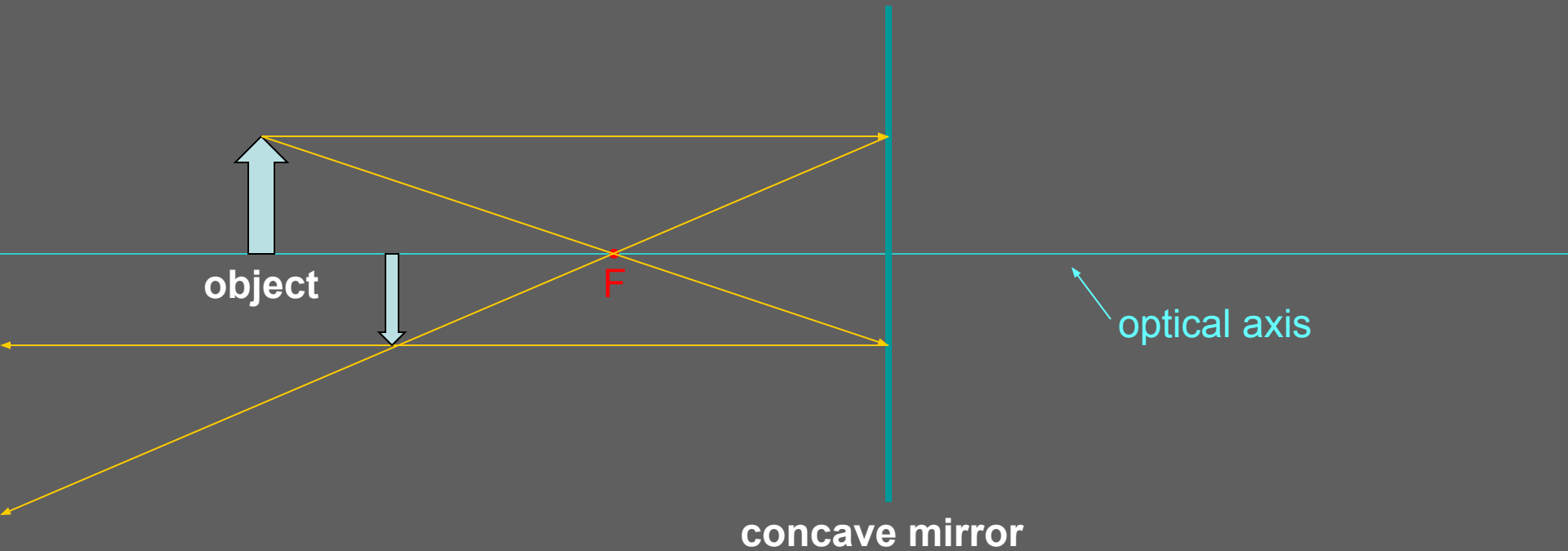
optical axis

concave mirror

- Note: mirrors are thin enough that you just draw a line to represent the mirror
- **Locate the image of the arrow**

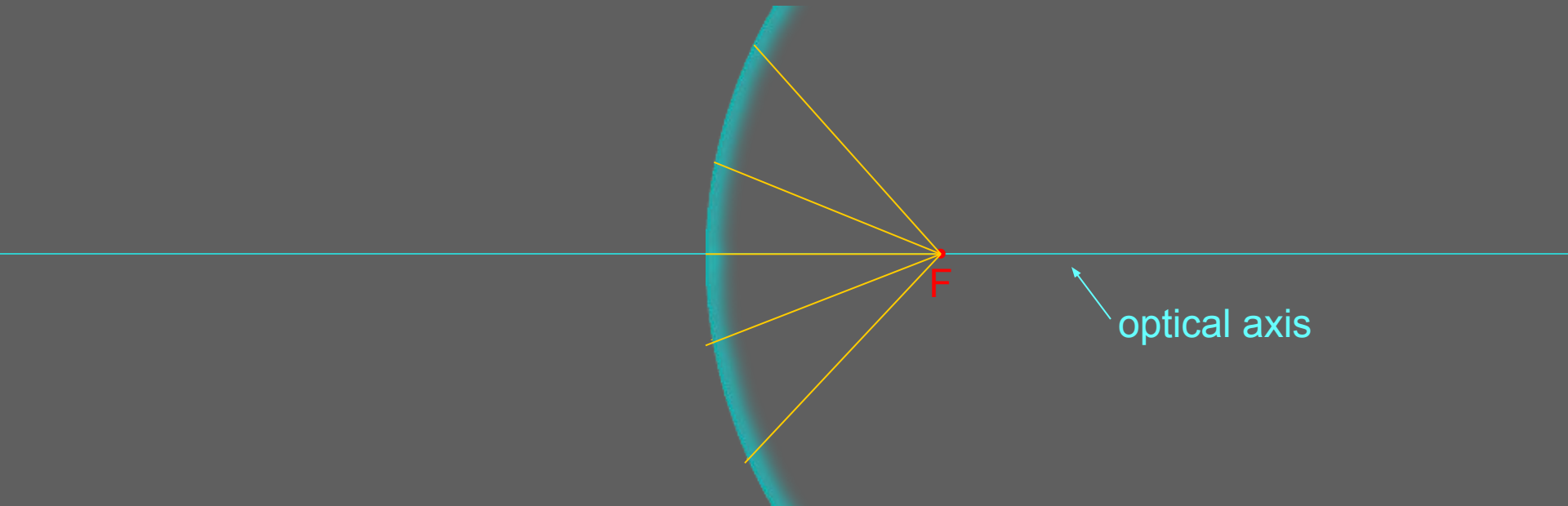
Your Turn

(Object distance: $d_o > 2d_f$)



- Note: mirrors are thin enough that you just draw a line to represent the mirror
- Locate the image of the arrow **A real, inverted same size image** is formed.

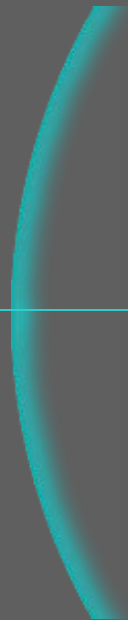
Convex Mirrors (curved out)



Light rays that come in parallel to the optical axis reflect from the focal point. The focal point is considered virtual since sight lines, not light rays, go through it.

Convex Mirror

(Object distance $d_o > 2d_f$)

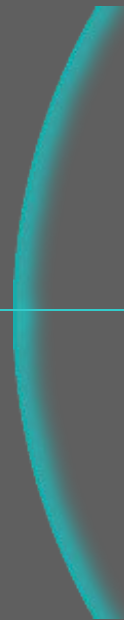


F

optical axis

Convex Mirror

(Object distance: $d_o > 2d_f$)



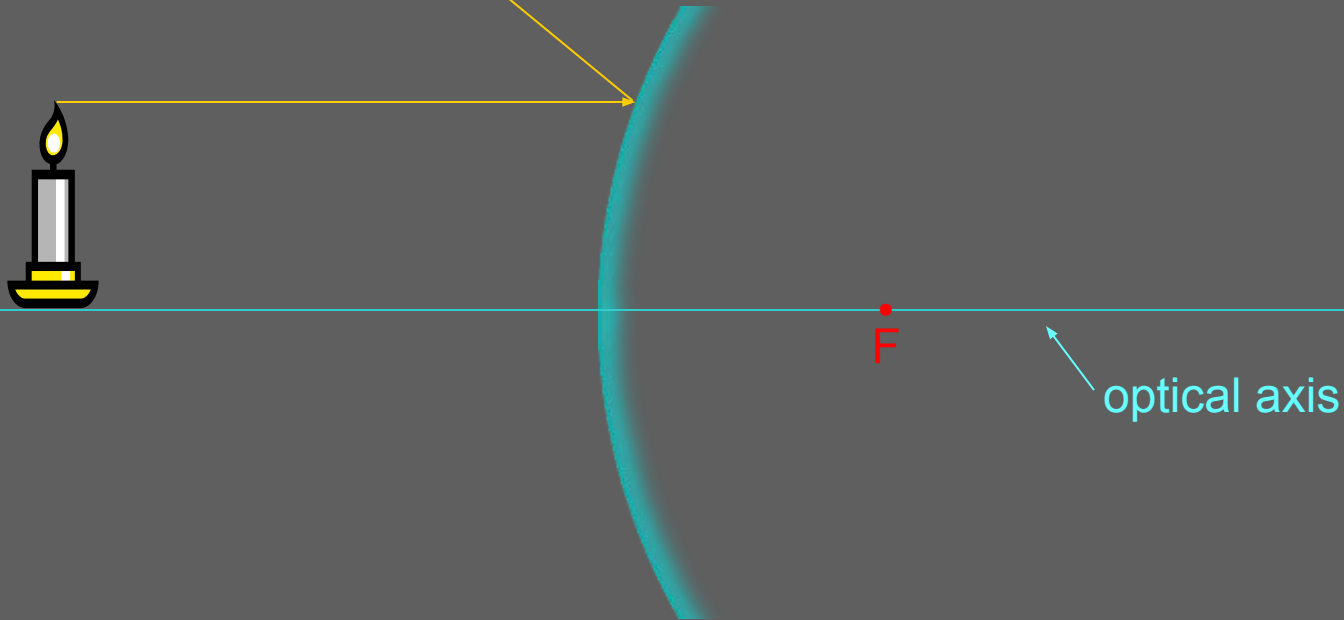
F

optical axis

The first **ray** comes in parallel to the **optical axis** and reflects through the **focal point**.

Convex Mirror

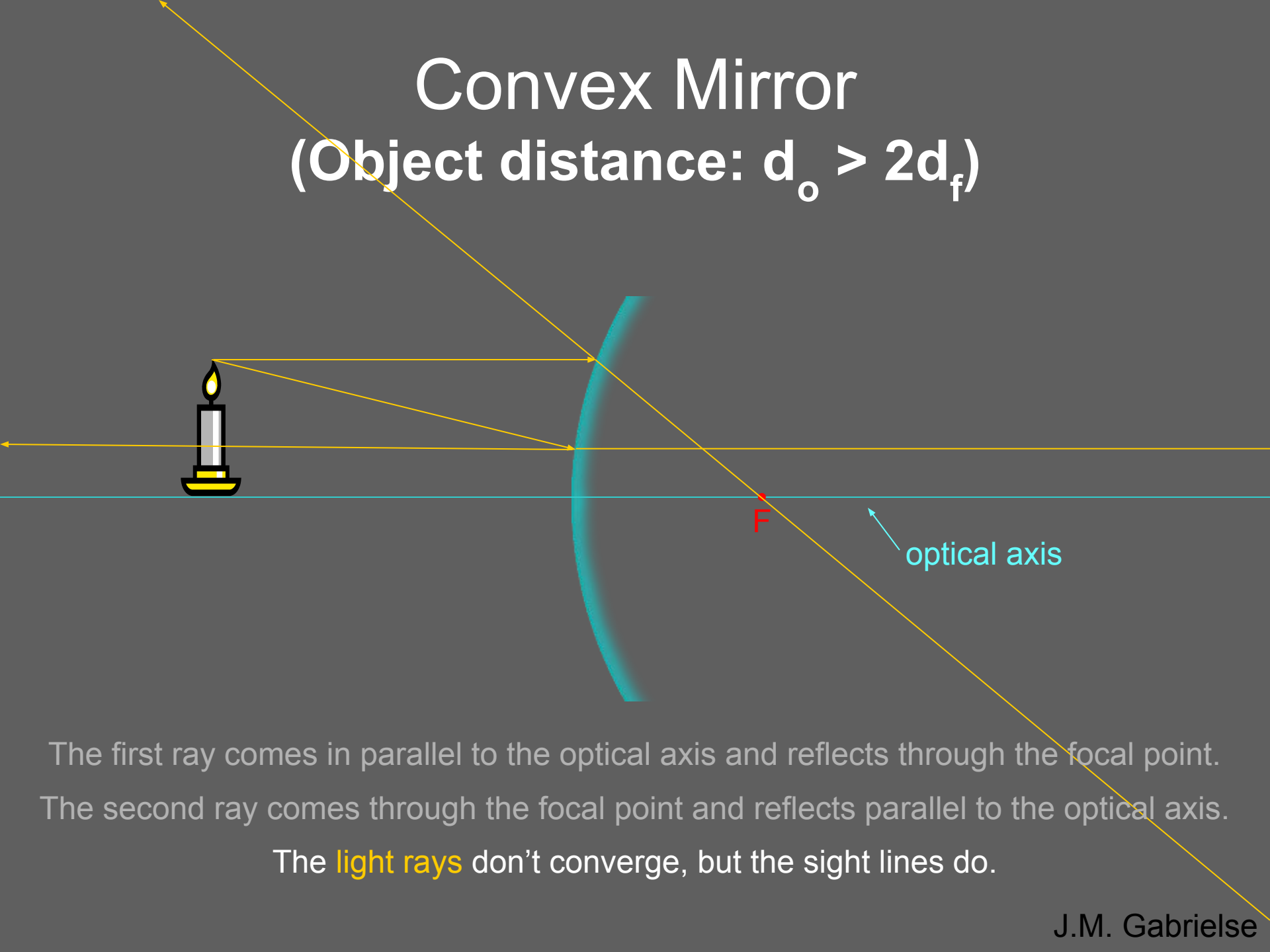
(Object distance: $d_o > 2d_f$)



The first ray comes in parallel to the optical axis and reflects through the focal point.
The second **ray** comes through the **focal point** and reflects parallel to the **optical axis**.

Convex Mirror

(Object distance: $d_o > 2d_f$)

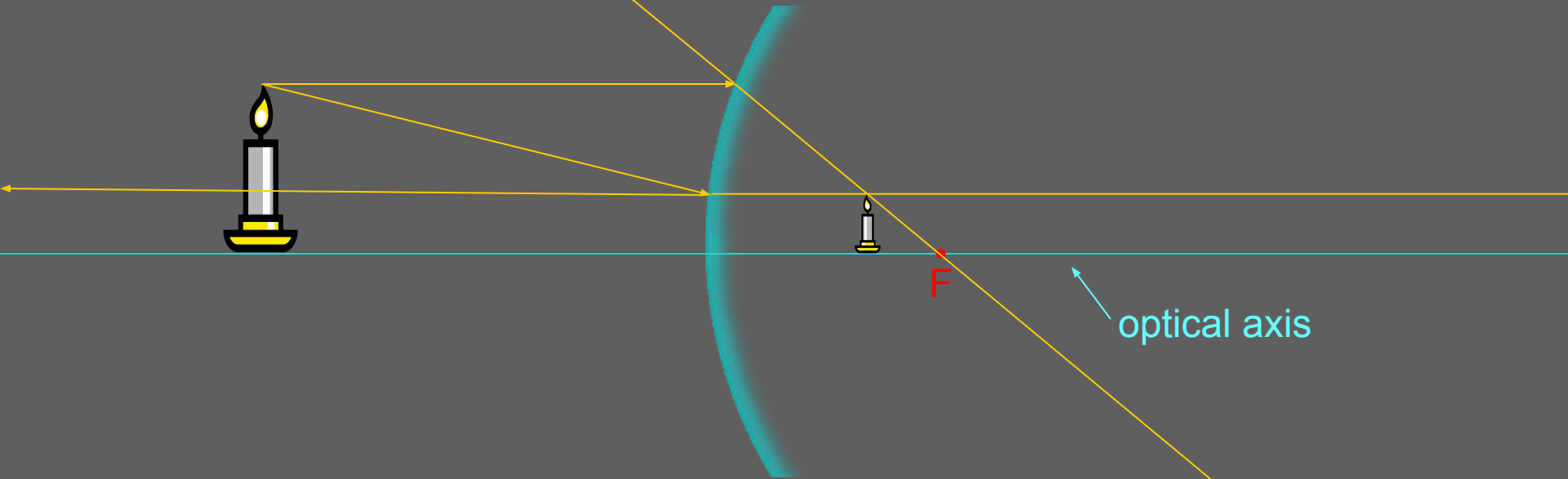


The first ray comes in parallel to the optical axis and reflects through the focal point. The second ray comes through the focal point and reflects parallel to the optical axis.

The **light rays** don't converge, but the sight lines do.

Convex Mirror

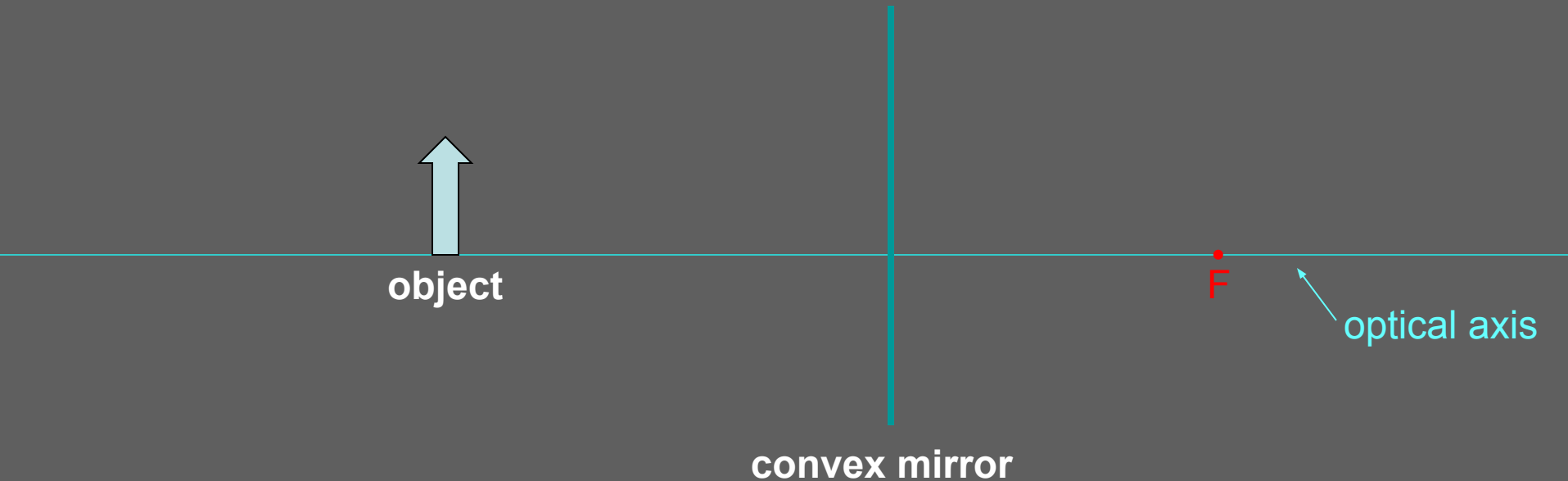
(Object distance: $d_o > 2d_f$)



The first ray comes in parallel to the optical axis and reflects through the focal point.
The second ray comes through the focal point and reflects parallel to the optical axis.
The light rays don't converge, but the sight lines do.

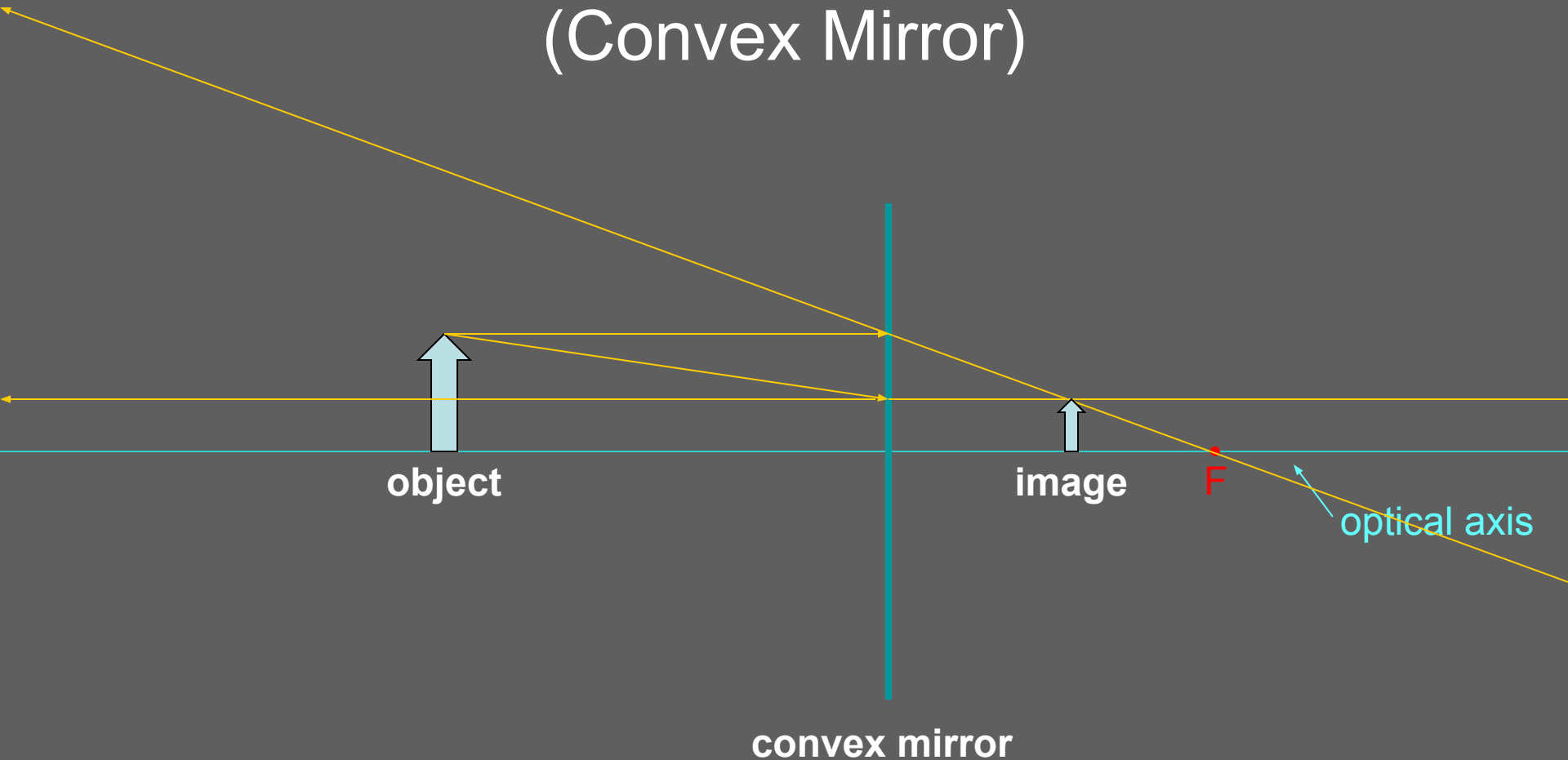
A **virtual, upright, diminished image** forms where the sight lines converge.

Your Turn (Convex Mirror)



- Note: mirrors are thin enough that you just draw a line to represent the mirror
- **Locate the image of the arrow**

Your Turn (Convex Mirror)



- Note: mirrors are thin enough that you just draw a line to represent the mirror
- **Locate the image of the arrow**



Lensmaker's Equation

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

f = focal length

d_o = object distance

d_i = image distance

if distance is negative the image is behind the mirror



Magnification Equation

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

m = magnification

h_i = image height

h_o = object height

If height is negative the image is upside down

if the magnification is negative
the image is inverted (upside down)

Refraction

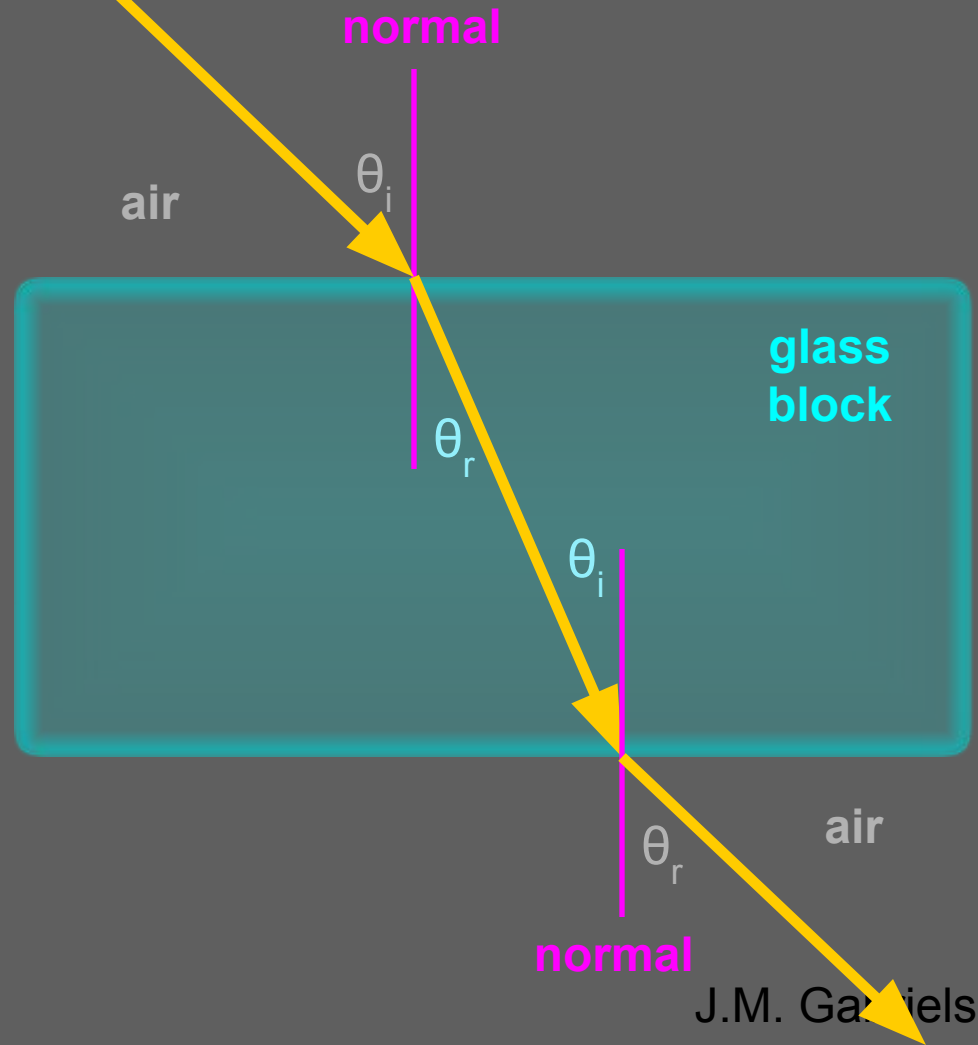
(bending **light**)

Refraction is when **light bends** as it passes from one medium into another.

When **light** traveling through air passes into the **glass** block it is **refracted** towards the **normal**.

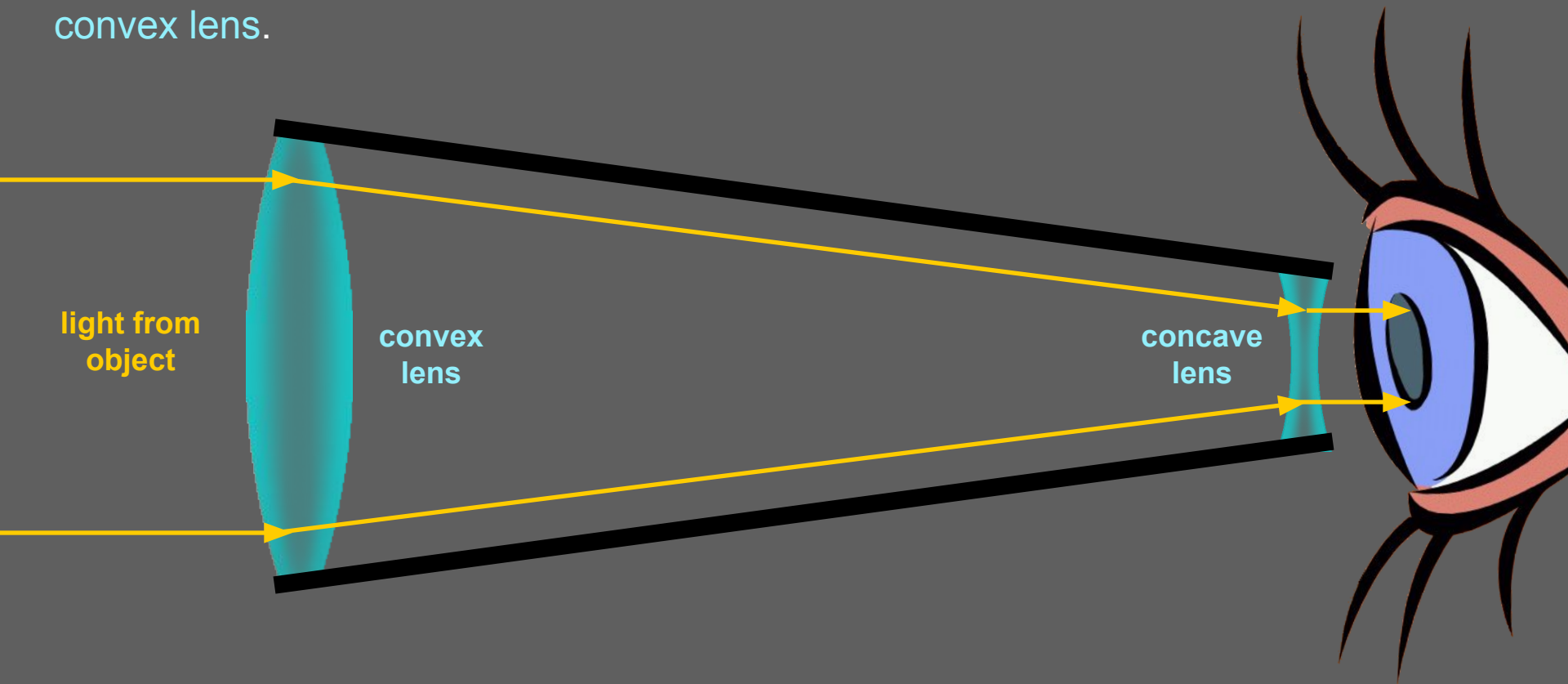
When **light** passes back out of the **glass** into the air, it is **refracted** away from the **normal**.

Since **light refracts** when it changes mediums it can be aimed. **Lenses** are shaped so **light** is aimed at a **focal point**.



Lenses

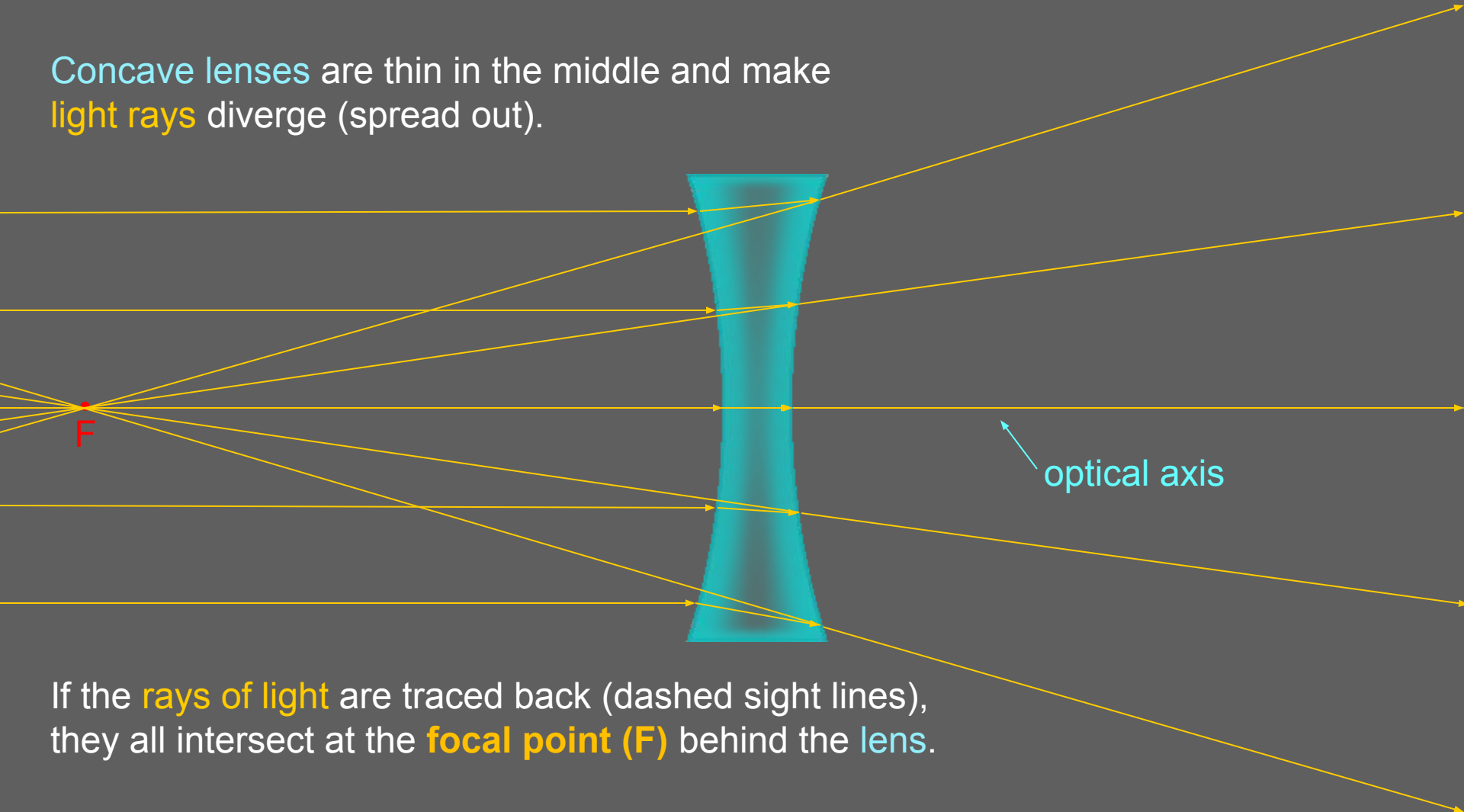
The first telescope, designed and built by Galileo, used **lenses** to focus **light** from faraway objects, into Galileo's eye. His telescope consisted of a **concave lens** and a **convex lens**.



Light rays are always refracted (bent) towards the thickest part of the **lens**.

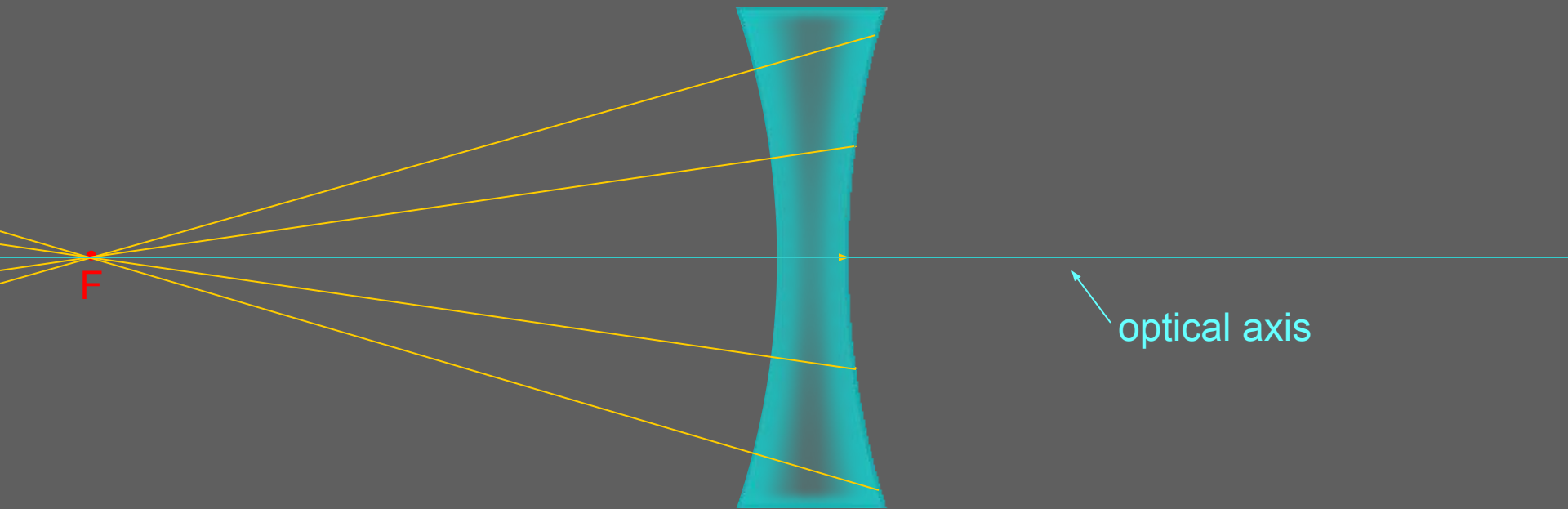
Concave Lenses

Concave lenses are thin in the middle and make light rays diverge (spread out).



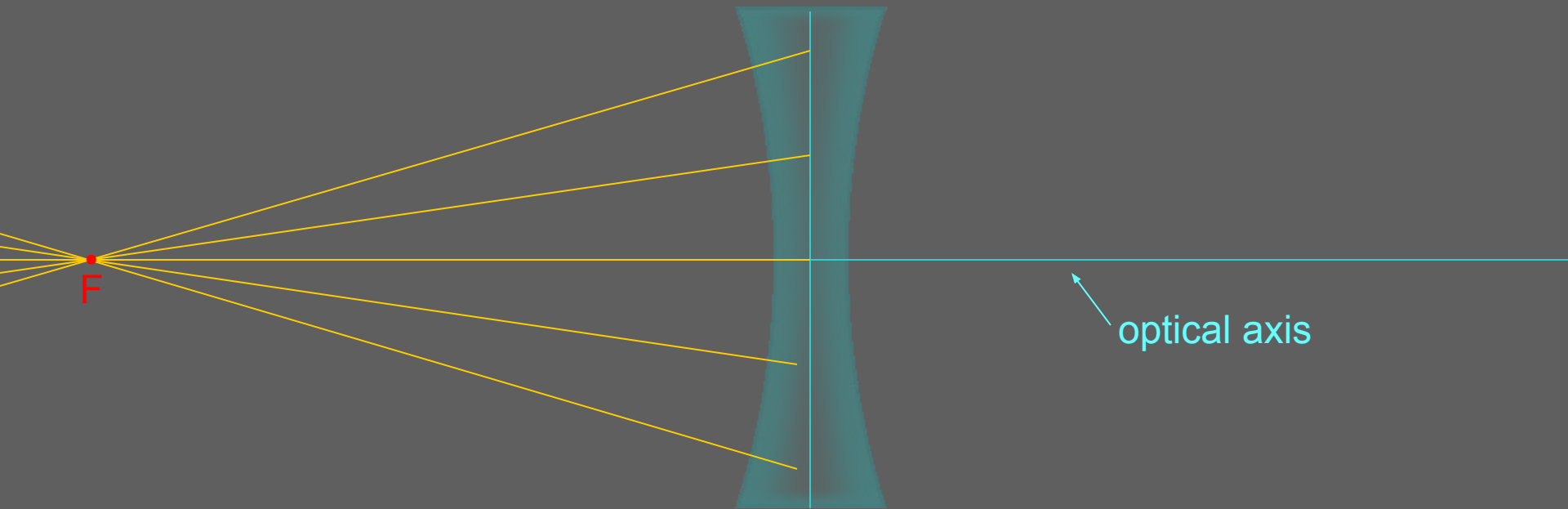
If the rays of light are traced back (dashed sight lines), they all intersect at the focal point (F) behind the lens.

Concave Lenses



The rays that behave parallel to the optical axis ignore the thickness of the lens.

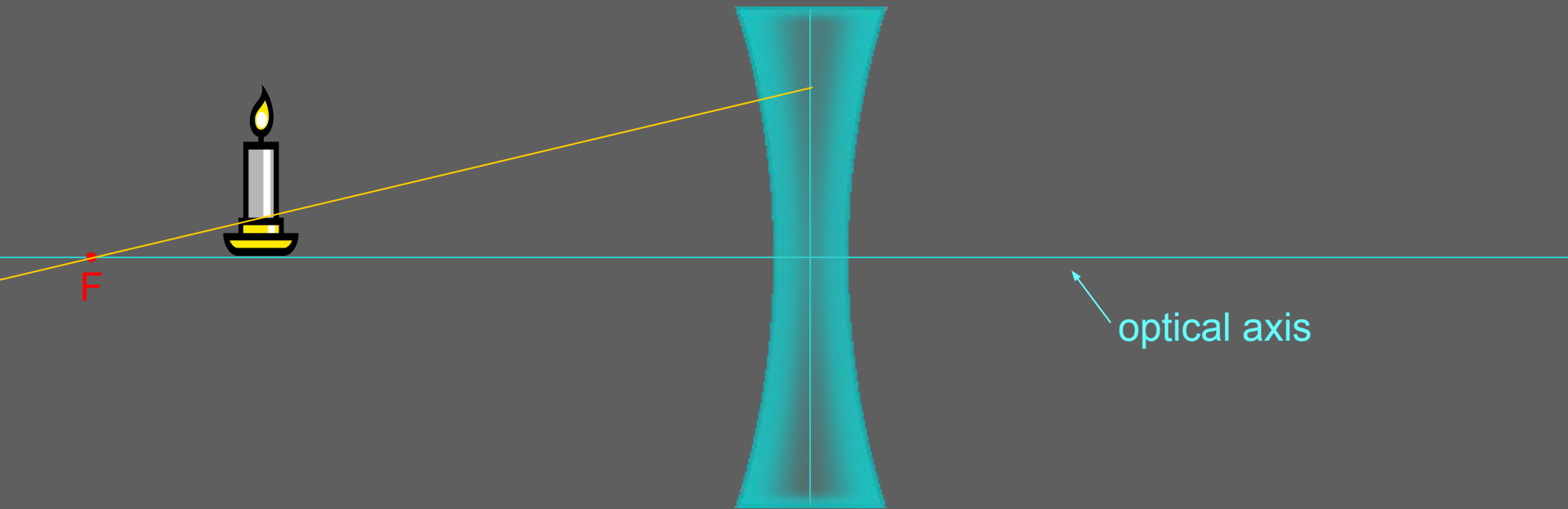
Concave Lenses



Light rays that come in parallel to the optical axis still diverge from the focal point.

Concave Lens

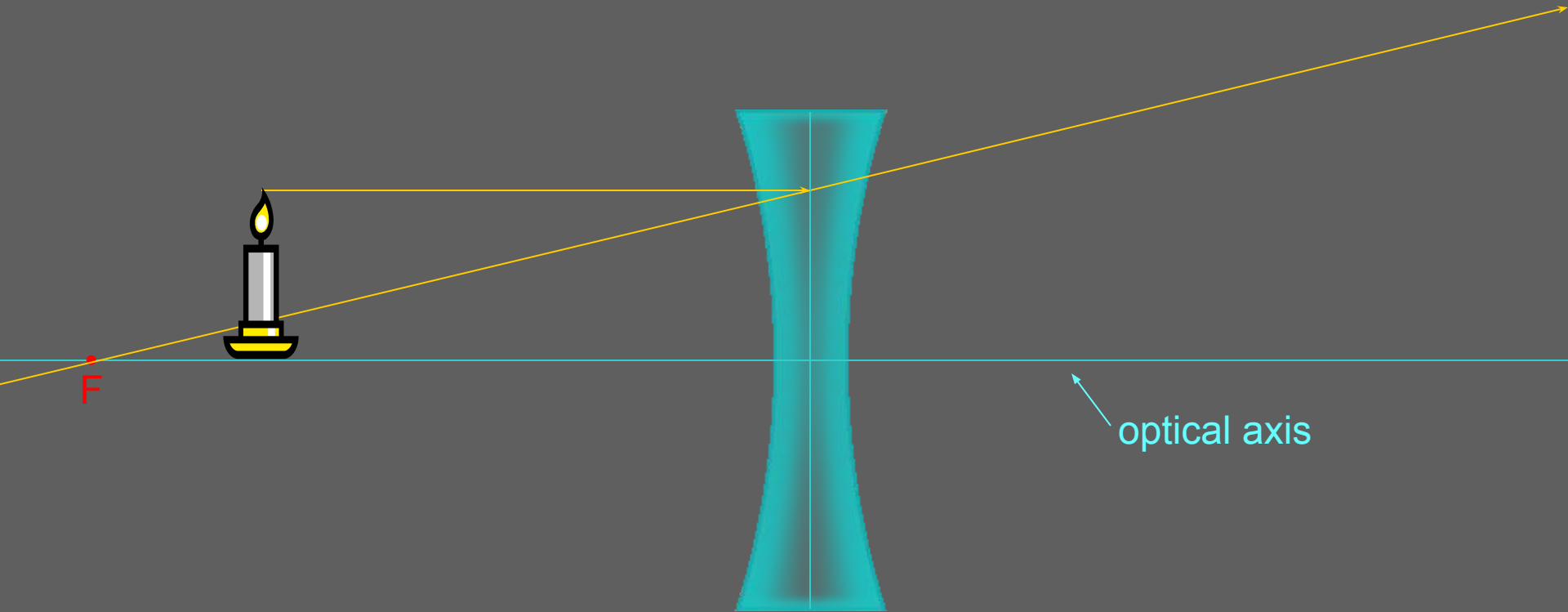
(Object distance: $d_o < d_f$)



The first **ray** comes in parallel to the **optical axis** and refracts from the **focal point**.

Concave Lens

(Object distance: $d_o < d_f$)

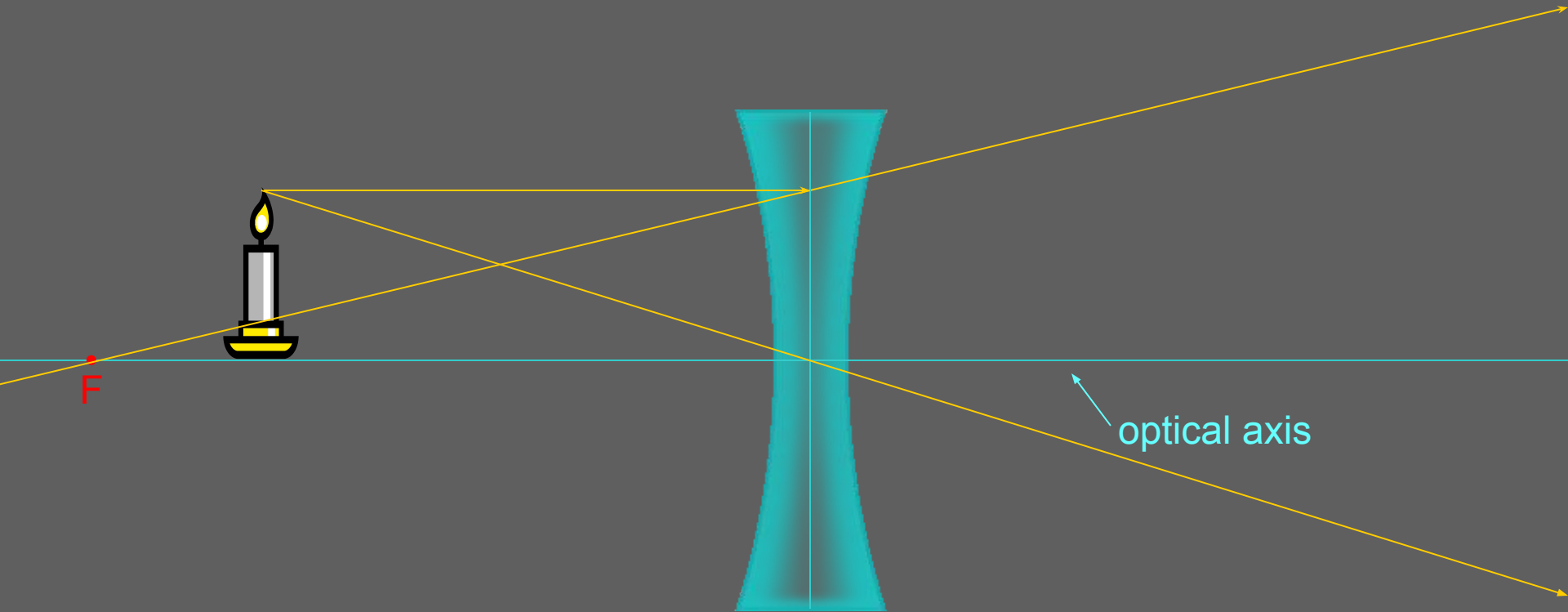


The first ray comes in parallel to the optical axis and refracts from the focal point.

The second ray goes straight through the center of the lens.

Concave Lens

(Object distance: $d_o < d_f$)



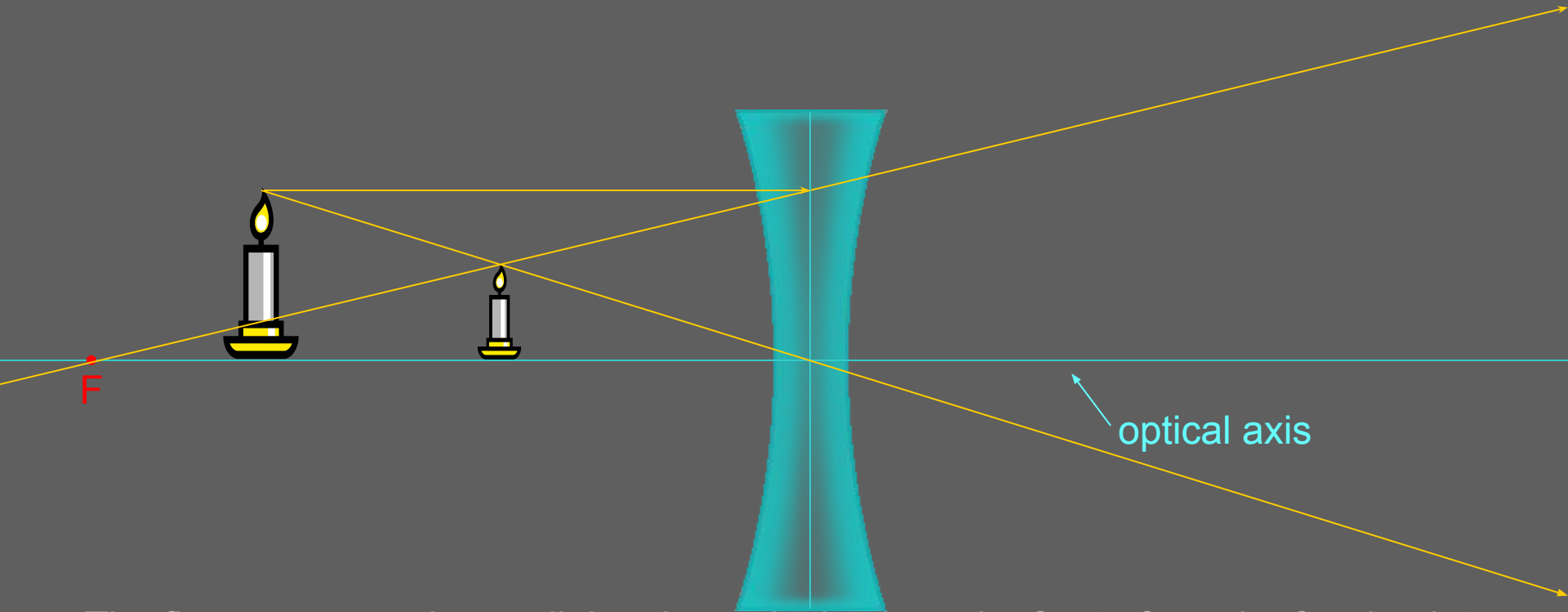
The first ray comes in parallel to the optical axis and refracts from the focal point.

The second ray goes straight through the center of the lens.

The **light rays** don't converge, but the sight lines do.

Concave Lens

(Object distance: $d_o < d_f$)



The first ray comes in parallel to the optical axis and refracts from the focal point.

The second ray goes straight through the center of the lens.

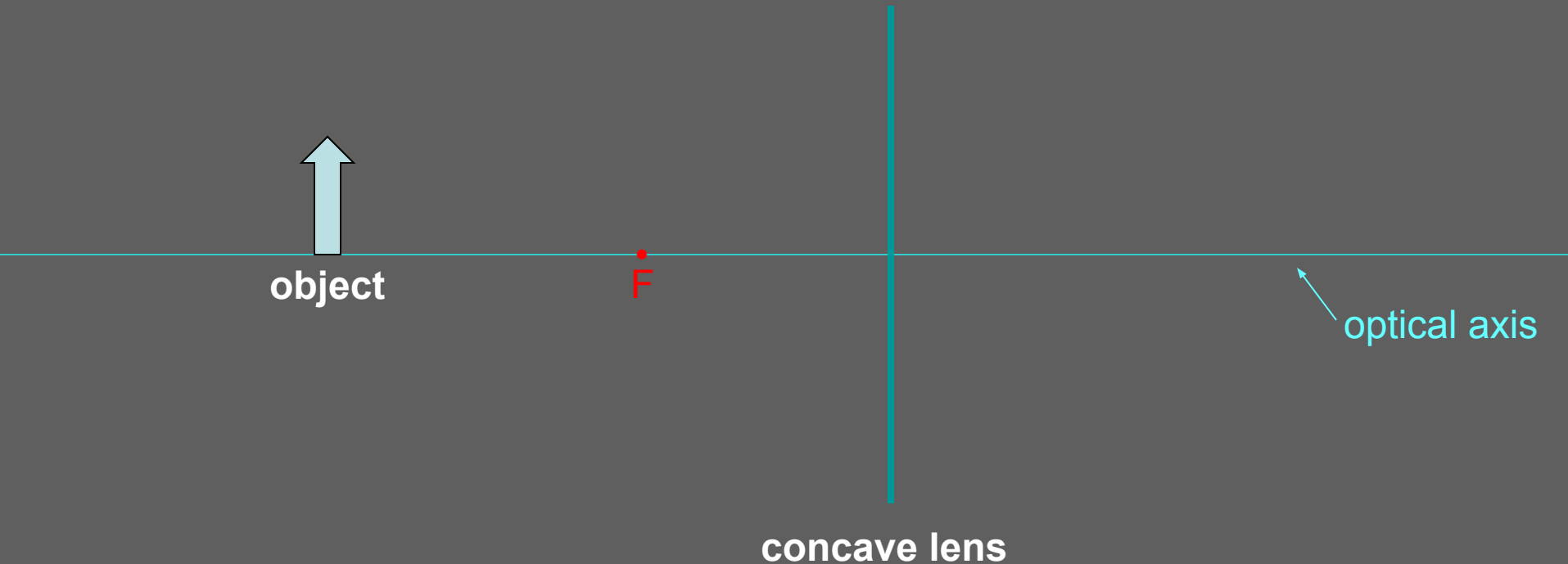
The light rays don't converge, but the sight lines do.

A **virtual, upright, diminished image** forms where the sight lines converge.

J.M. Gabrielse

Your Turn

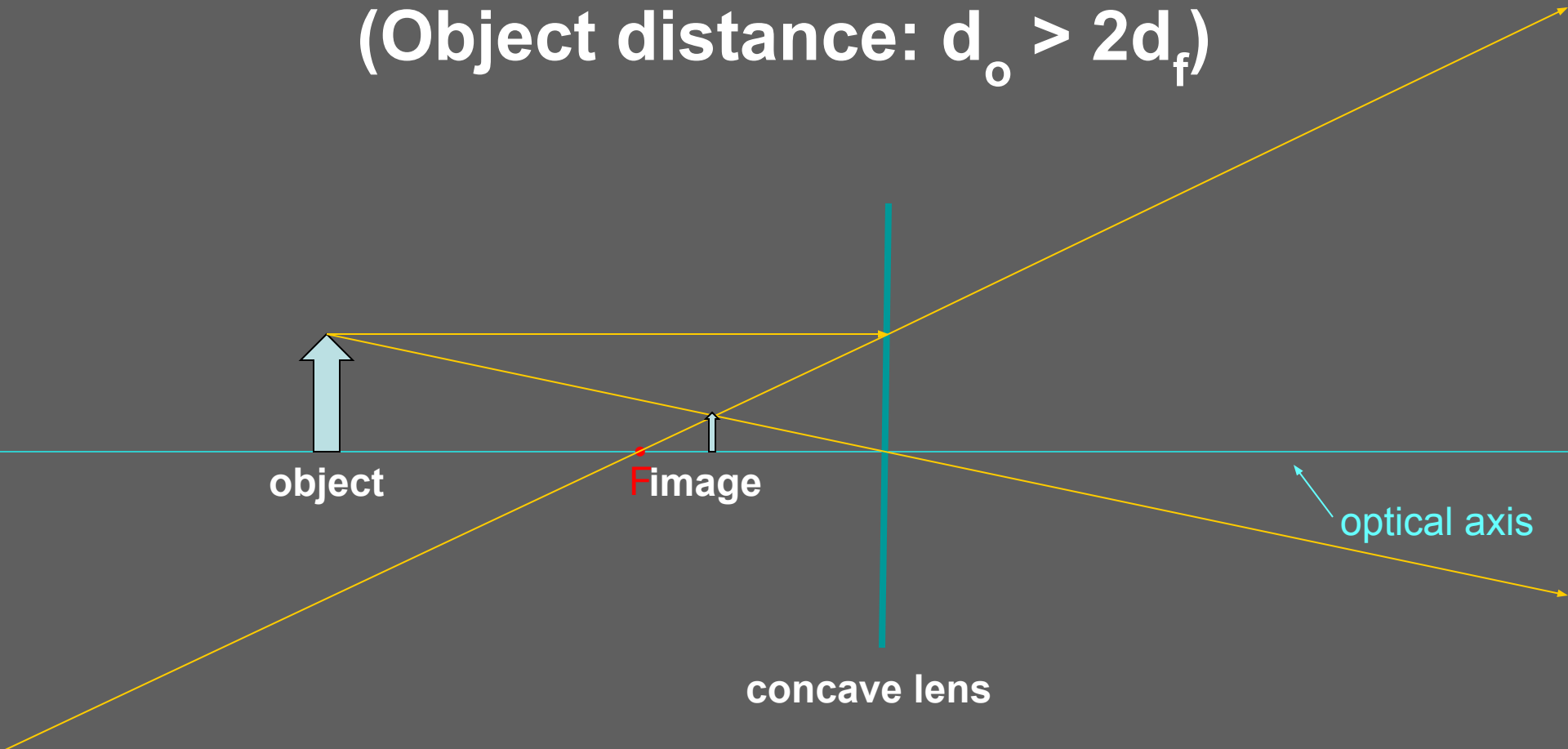
(Object distance: $d_o > 2d_f$)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- **Locate the image of the arrow.**

Your Turn

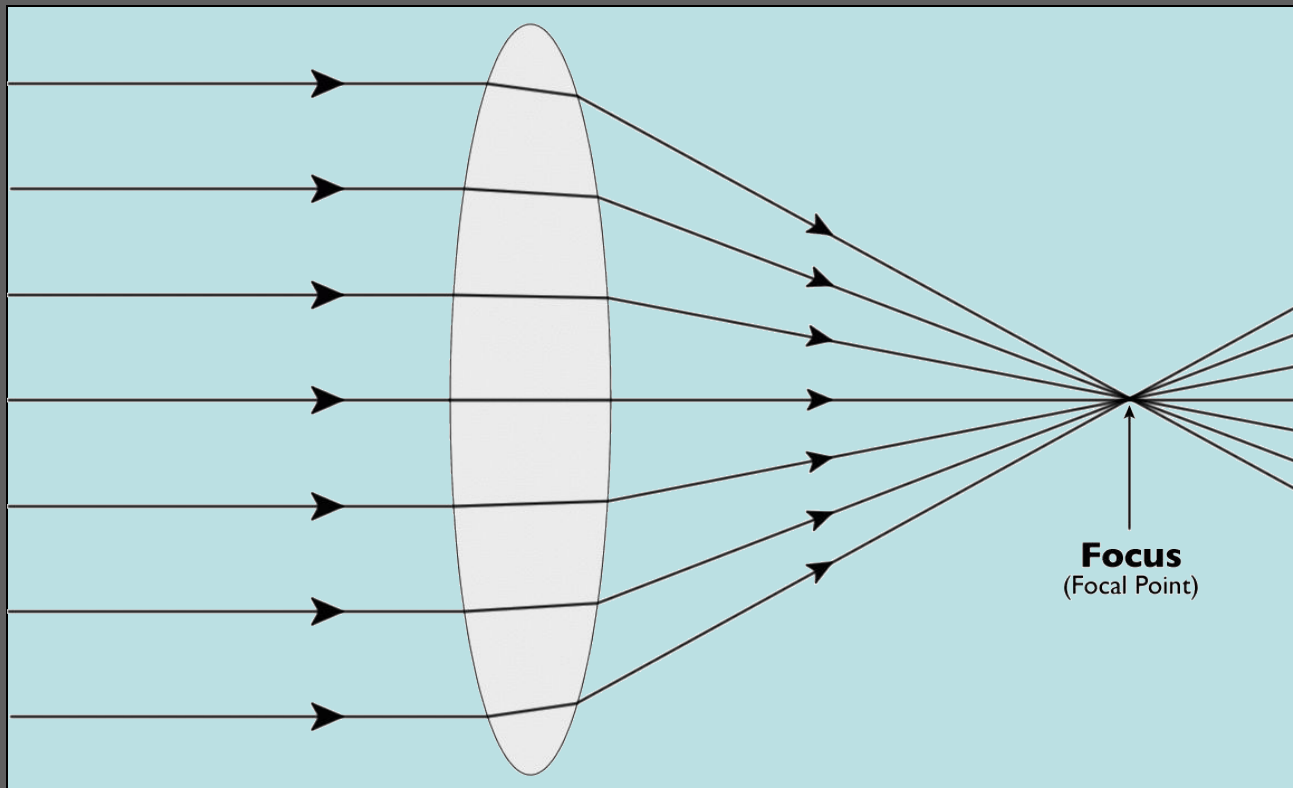
(Object distance: $d_o > 2d_f$)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- Locate the image of the arrow. A **virtual, upright, diminished image** forms where the sight lines converge.

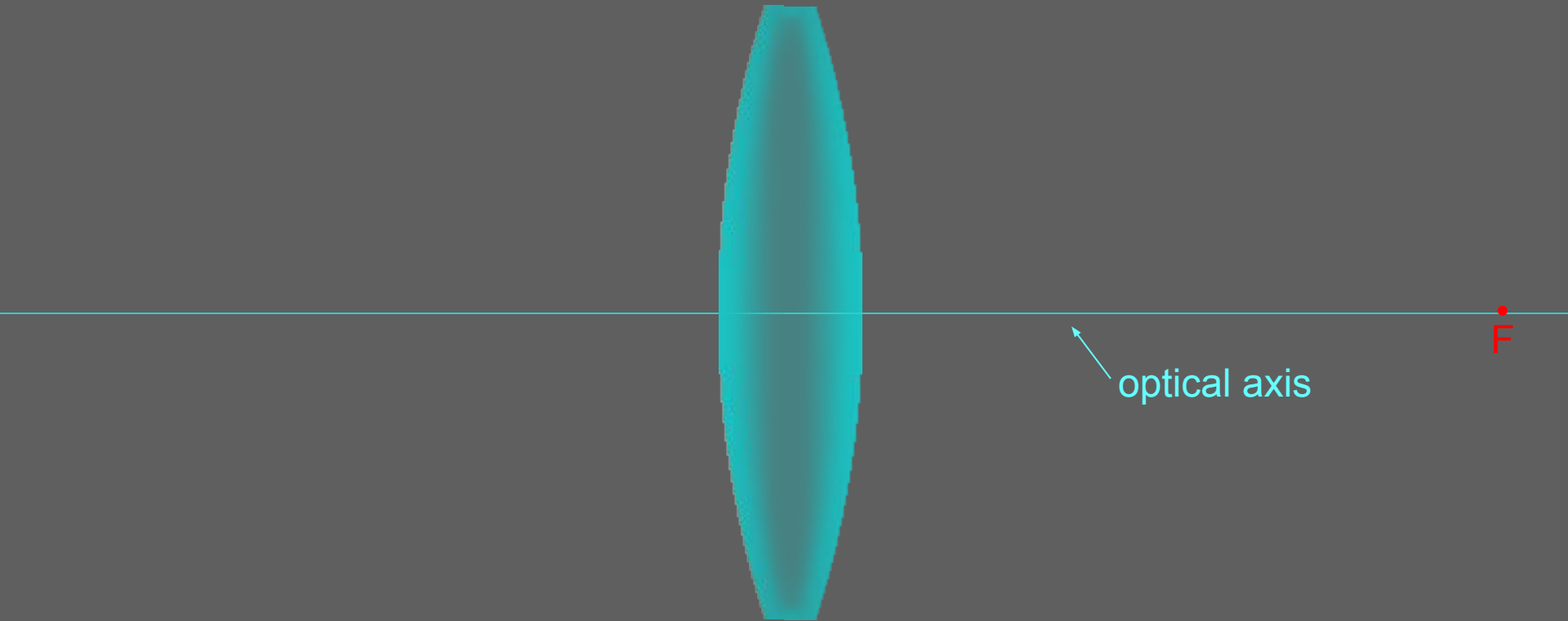
Convex Lenses

Convex lenses are thicker in the middle and focus light rays to a focal point in front of the lens.

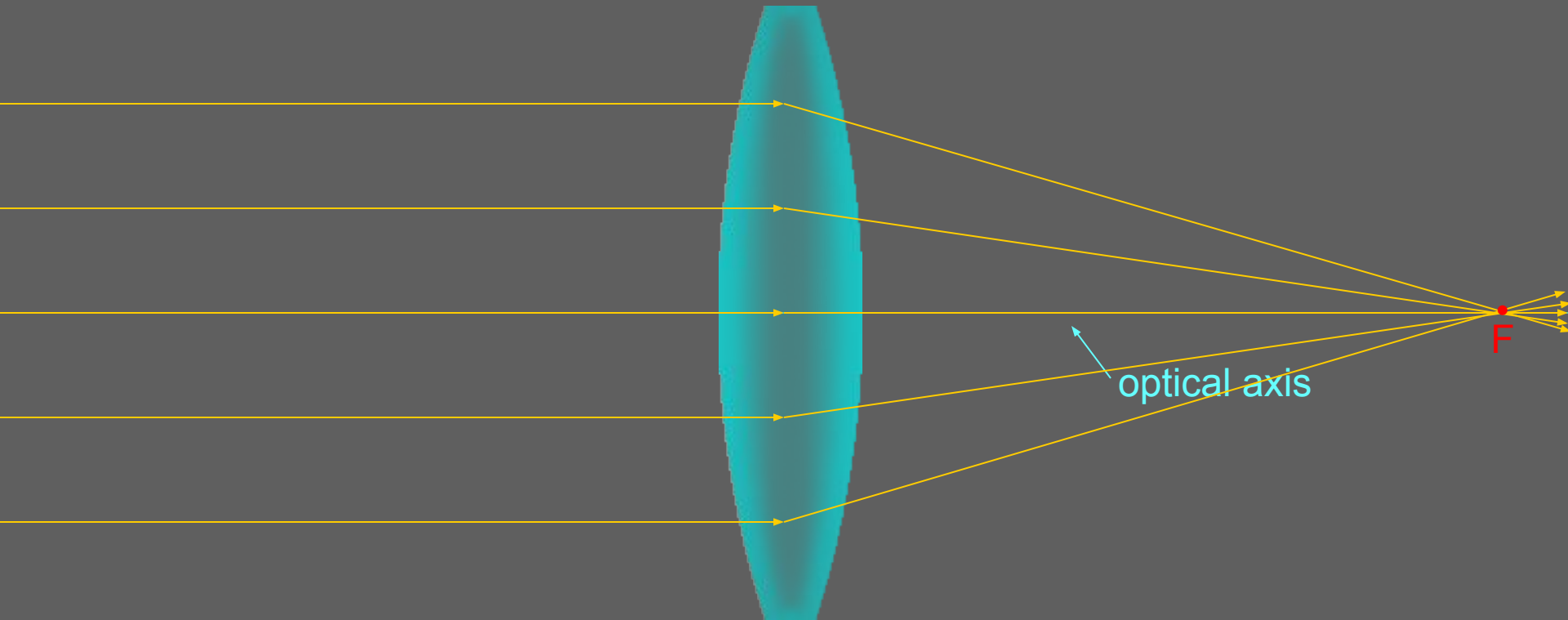


The focal length of the lens is the distance between the center of the lens and the point where the light rays are focused.

Convex Lenses



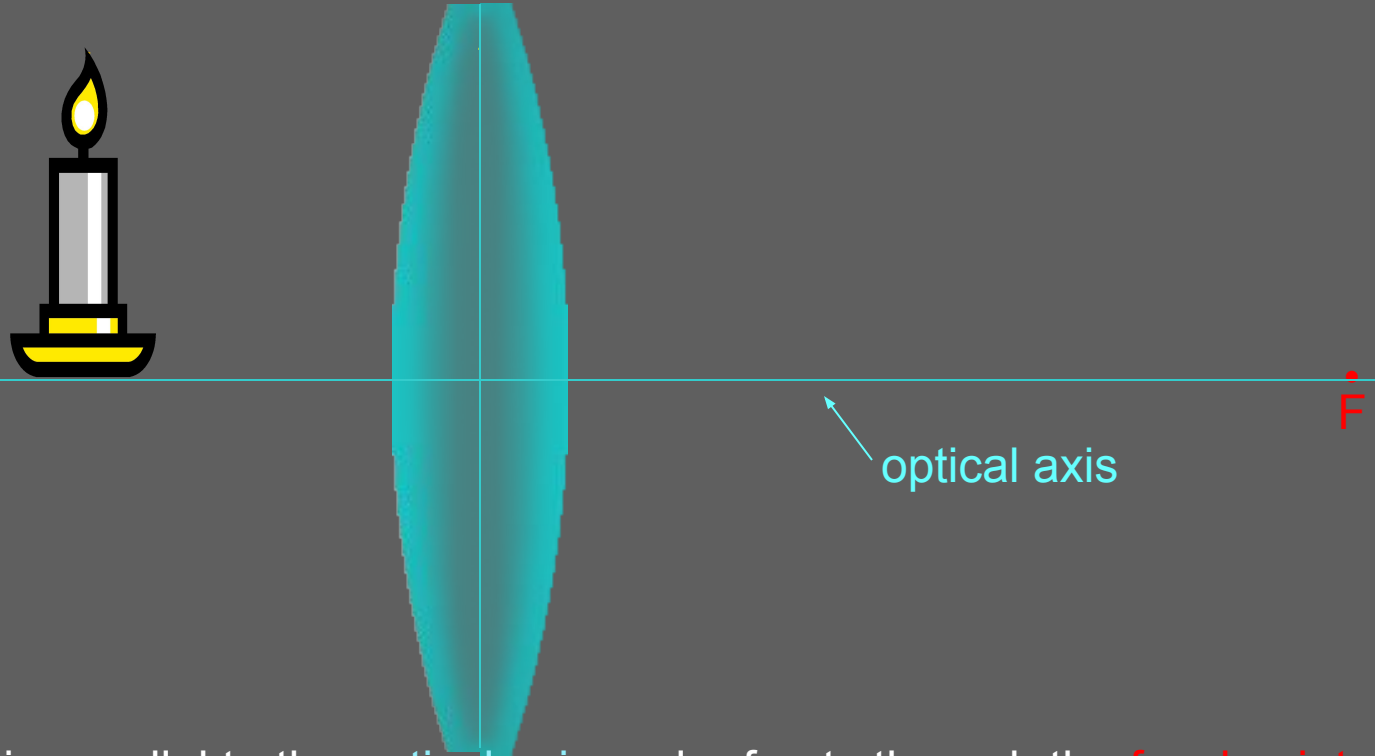
Convex Lenses



Light rays that come in parallel to the optical axis converge at the focal point.

Convex Lens

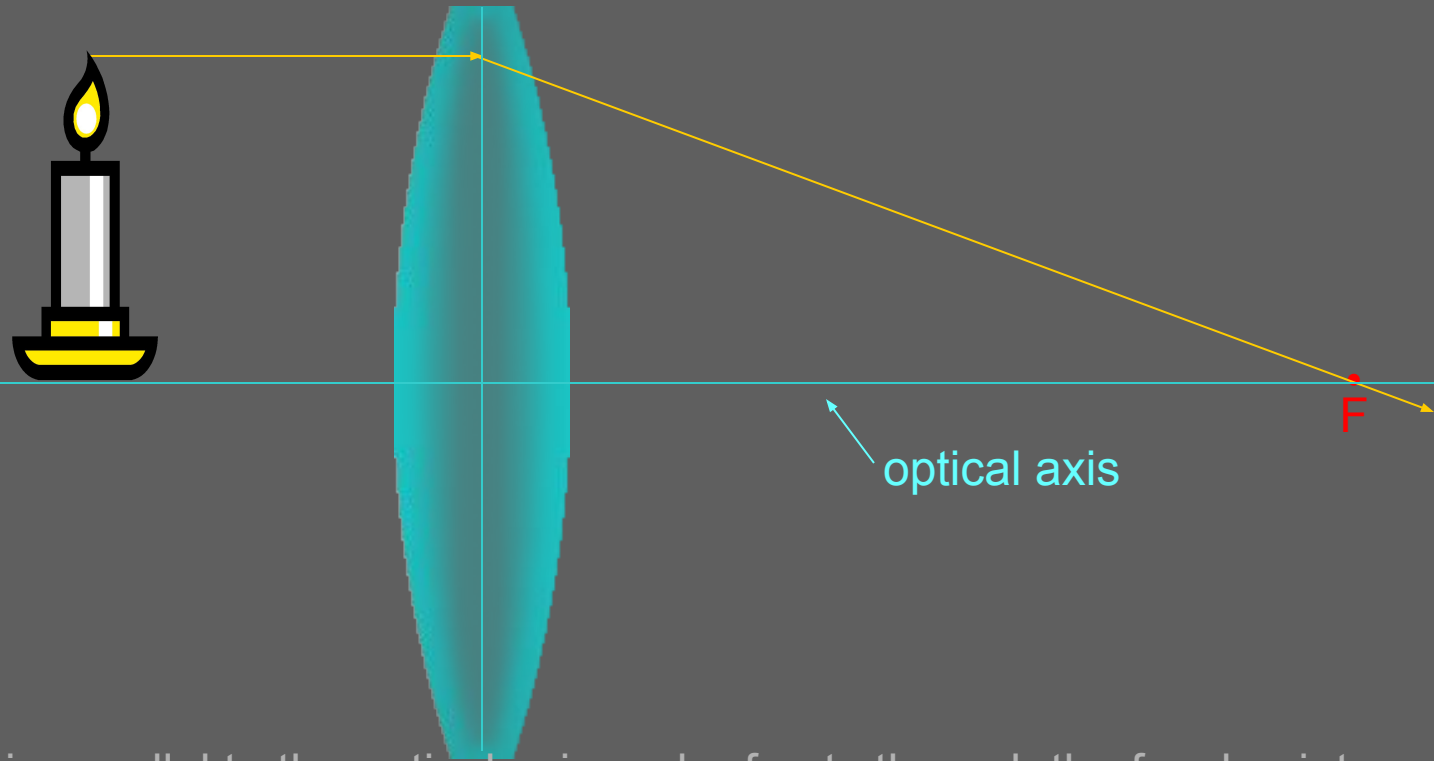
(Object distance: $d_o < d_f$)



The first **ray** comes in parallel to the **optical axis** and refracts through the **focal point**.

Convex Lens

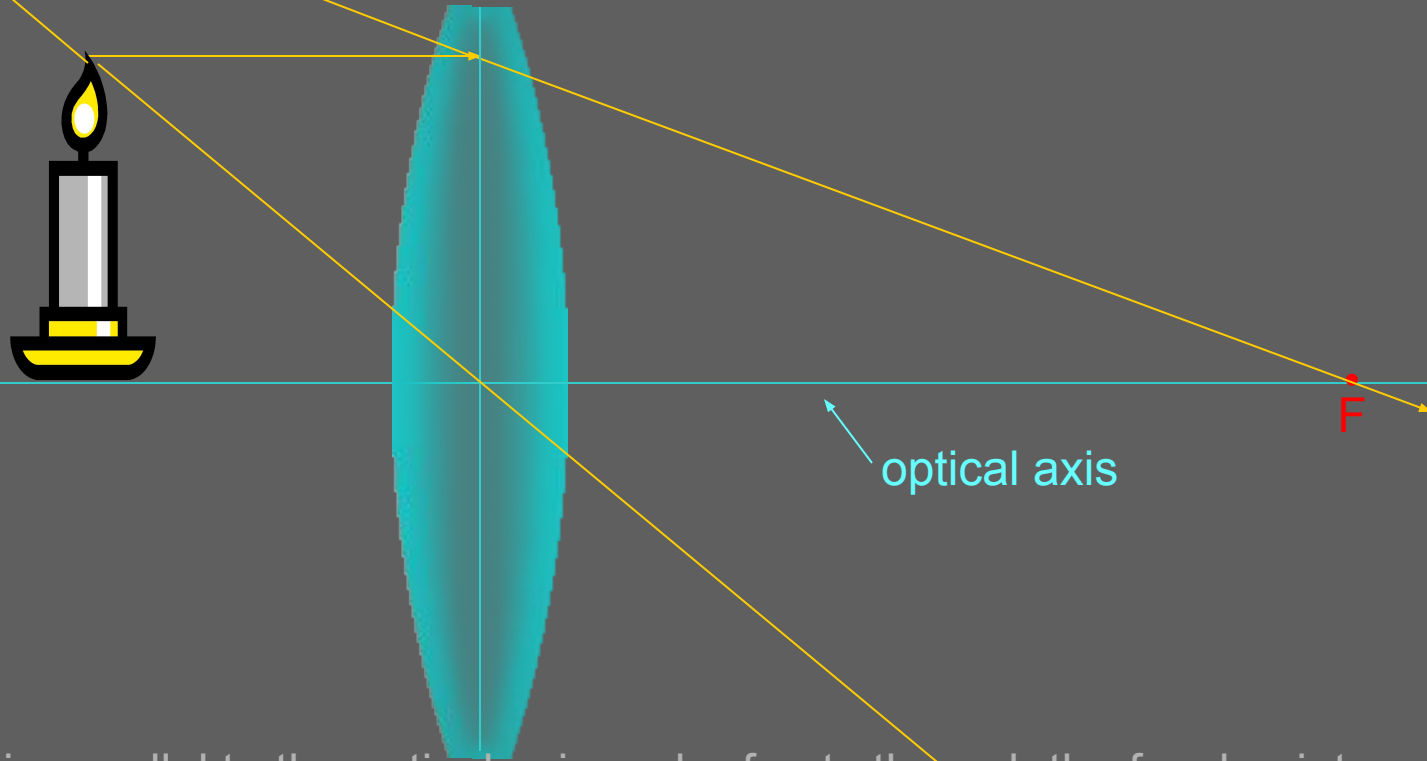
(Object distance: $d_o < d_f$)



The first ray comes in parallel to the optical axis and refracts through the focal point.

The second **ray** goes straight through the center of the **lens**.

Convex Lens (Object distance: $d_o < d_f$)

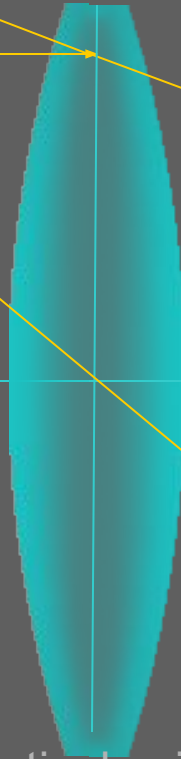
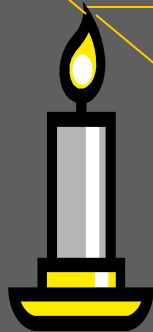
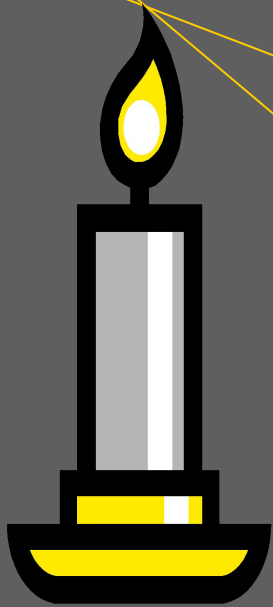


The first ray comes in parallel to the optical axis and refracts through the focal point.

The second ray goes straight through the center of the lens.

The **light rays** don't converge, but the sight lines do.

Convex Lens (Object distance: $d_o < d_f$)



optical axis

F

The first ray comes in parallel to the optical axis and refracts through the focal point.

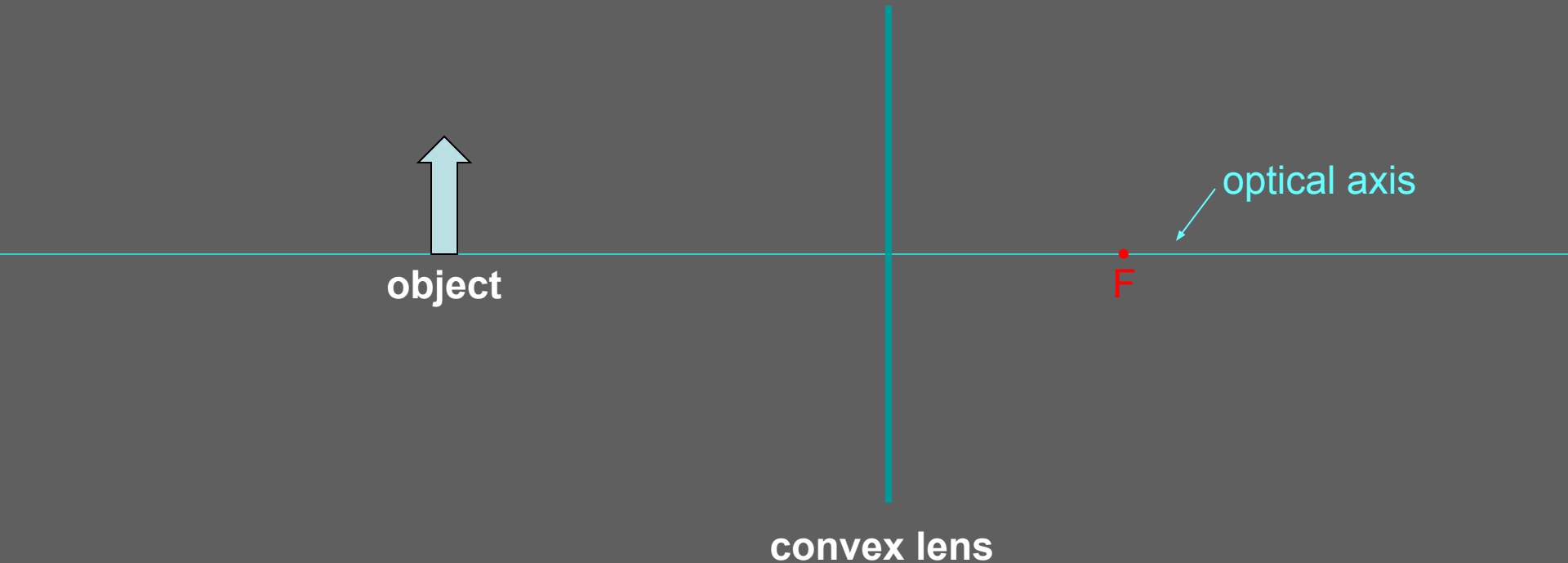
The second ray goes straight through the center of the lens.

The light rays don't converge, but the sight lines do.

A **virtual, upright, magnified image** forms where the sight lines converge.

Your Turn

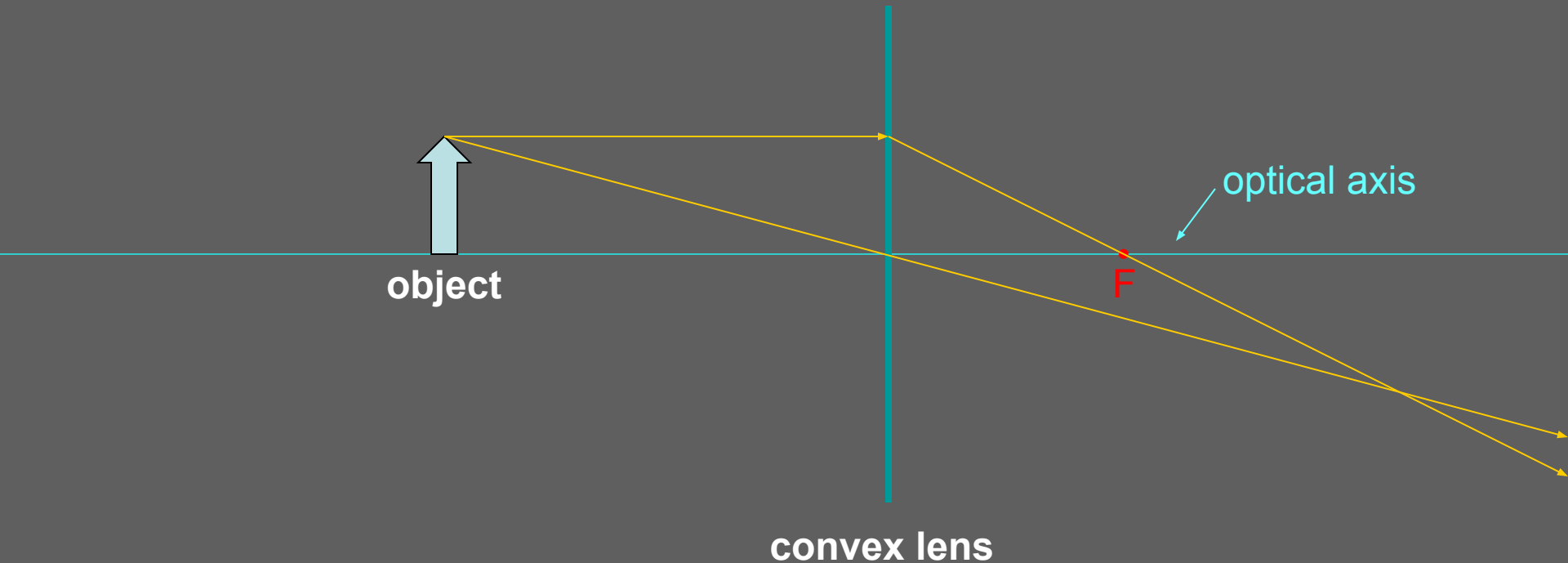
(Object distance: $d_o > 2d_f$)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- **Locate the image of the arrow.**

Your Turn

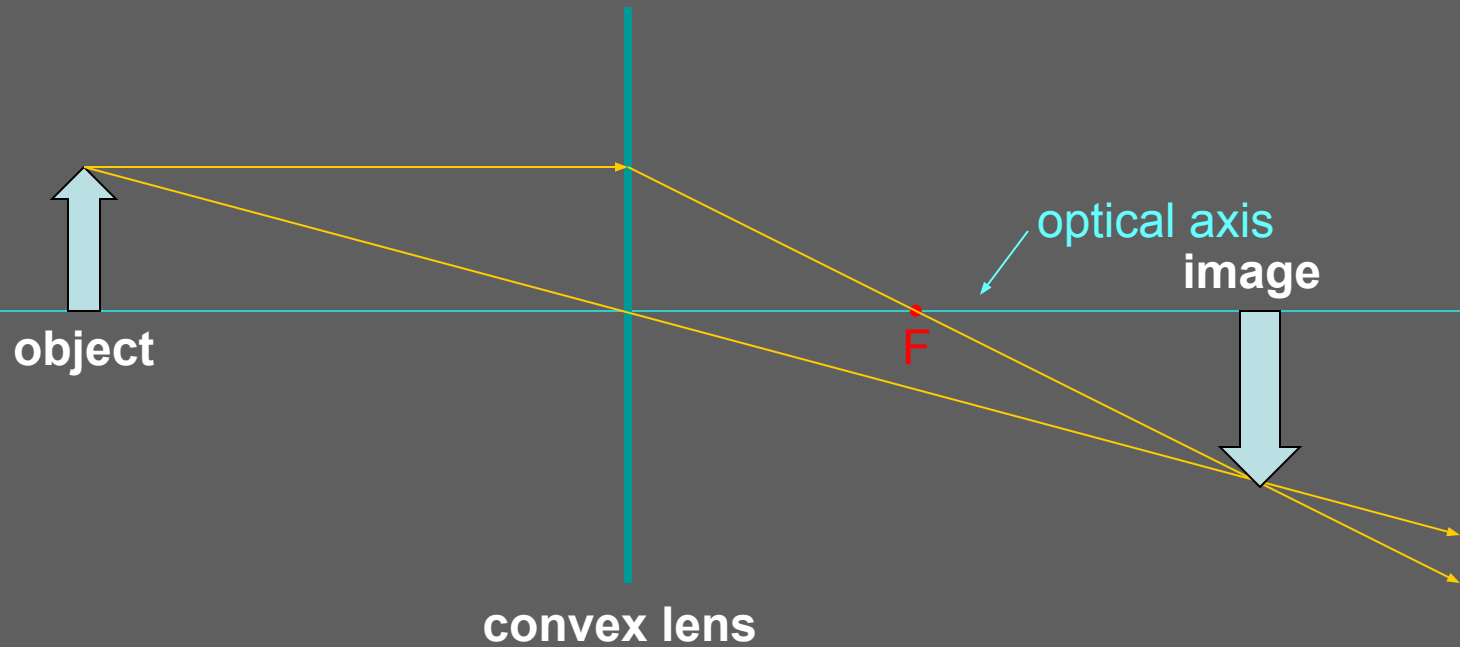
(Object distance: $d_o > 2d_f$)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- **Locate the image of the arrow.**

Your Turn

(Object distance: $d_o = 2d_f$)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- Locate the image of the arrow.

A **real, inverted, same size image** forms where the light rays converge.

Thanks/Further Info

- [Faulkes Telescope Project: Light & Optics](#) by Sarah Roberts
- [Fundamentals of Optics: An Introduction for Beginners](#) by Jenny Reinhard
- [PHET Geometric Optics \(Flash Simulator\)](#)
- [Thin Lens & Mirror \(Java Simulator\)](#) by Fu-Kwun Hwang