Essential Physics I

英語で物理学の

エッセンス I

Lecture 13: 11-07-16

Reminders

No lecture: Monday 18th July (holiday)

Essay due: Monday 25th July, 4:30 pm

月曜日２５日７月１６：３０

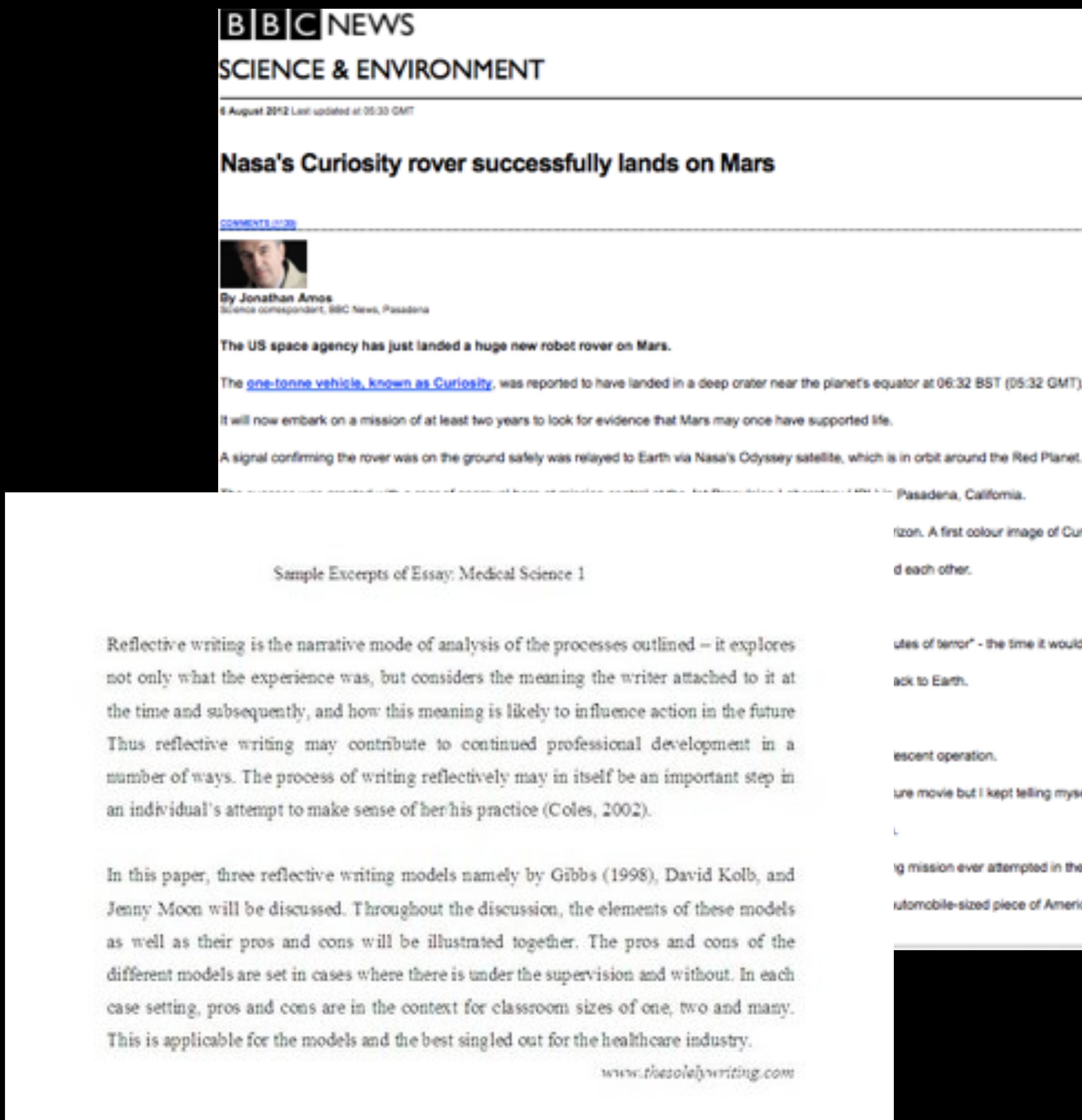
2 weeks!!

Exam: Monday 1st August, 4:30 pm

月曜日１日８月１６：３０

Announcements

<u>250 word essay</u>



BBC NEWS

SCIENCE & ENVIRONMENT

6 August 2012 Last updated at 05:30 GMT

Nasa's Curiosity rover successfully lands on Mars

By Jonathan Amos
Science correspondent, BBC News, Pasadena

The US space agency has just landed a huge new robot rover on Mars.

The one-tonne vehicle, known as Curiosity, was reported to have landed in a deep crater near the planet's equator at 06:32 BST (05:32 GMT).

It will now embark on a mission of at least two years to look for evidence that Mars may once have supported life.

A signal confirming the rover was on the ground safely was relayed to Earth via Nasa's Odyssey satellite, which is in orbit around the Red Planet.

Pasadena, California.

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Sample Excerpts of Essay: Medical Science 1

Reflective writing is the narrative mode of analysis of the processes outlined – it explores not only what the experience was, but considers the meaning the writer attached to it at the time and subsequently, and how this meaning is likely to influence action in the future. Thus reflective writing may contribute to continued professional development in a number of ways. The process of writing reflectively may in itself be an important step in an individual's attempt to make sense of her/his practice (Coles, 2002).

In this paper, three reflective writing models namely by Gibbs (1998), David Kolb, and Jenny Moon will be discussed. Throughout the discussion, the elements of these models as well as their pros and cons will be illustrated together. The pros and cons of the different models are set in cases where there is under the supervision and without. In each case setting, pros and cons are in the context for classroom sizes of one, two and many. This is applicable for the models and the best singled out for the healthcare industry.

www.thesolelywriting.com

Read a physics article (in English) on a topic that interests you

This can be one we have covered in class, or a new one.

Describe its main points in 250 words.

Hand in BOTH essay and article

Use your OWN WORDS

Due 2016/7/25

(NO EXTENSIONS)

Exam

10 multiple choice questions

(A) .....

(B) .....

(C) .....

(D) .....

- ~6 classical mechanics
- ~2 oscillations, waves & fluids
- ~2 optics

Homework	40 %
Attendance / clickers	20 %
Exam	40 %
Total	100 %

Pass > 60 %

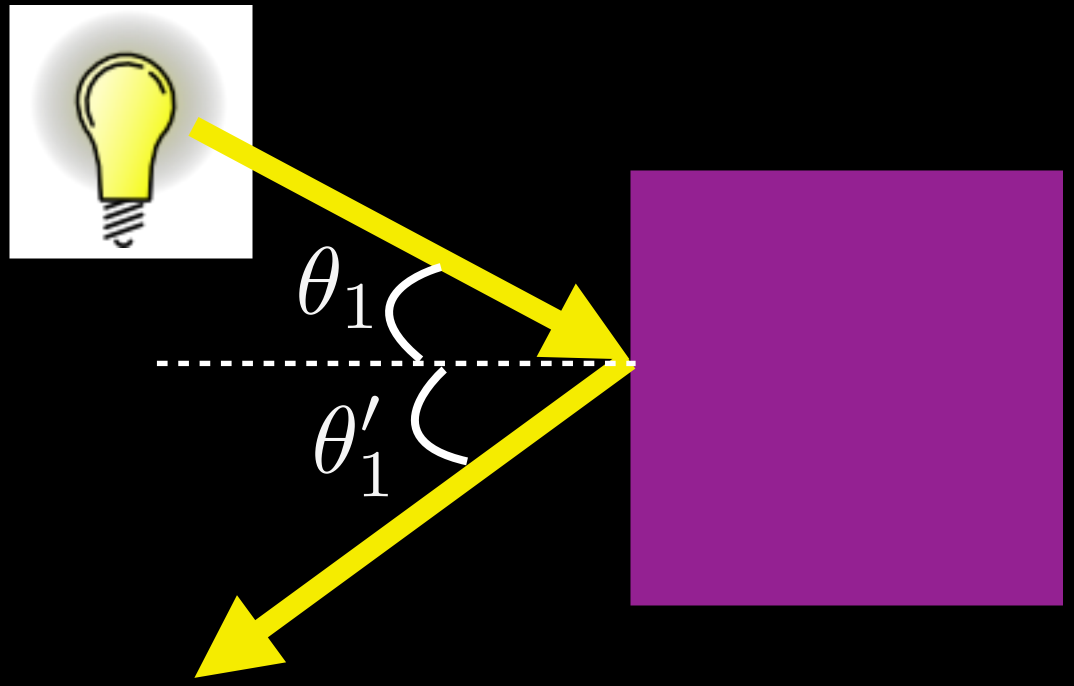
Last week: Reflection & Refraction

Reflection:

Light ray hits surface

Ray moves away from surface

$\theta_1' = \theta_1$

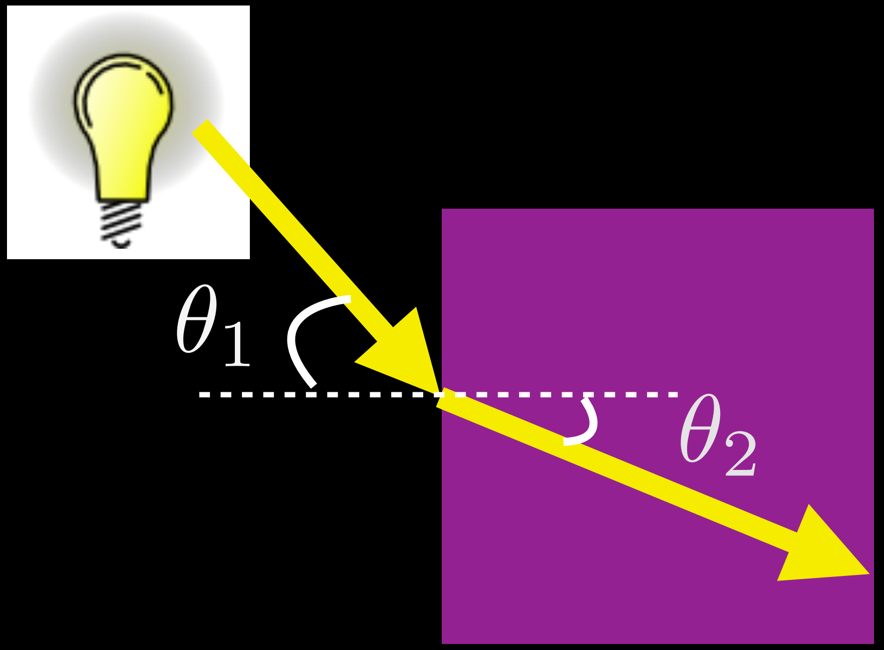


Refraction:

Light ray hits surface

Ray enters object and changes speed & direction.

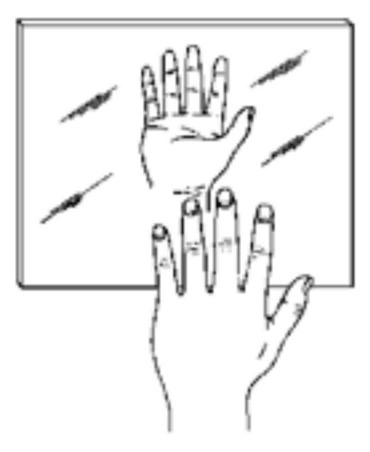
$n_1 \sin \theta_1 = n_2 \sin \theta_2$



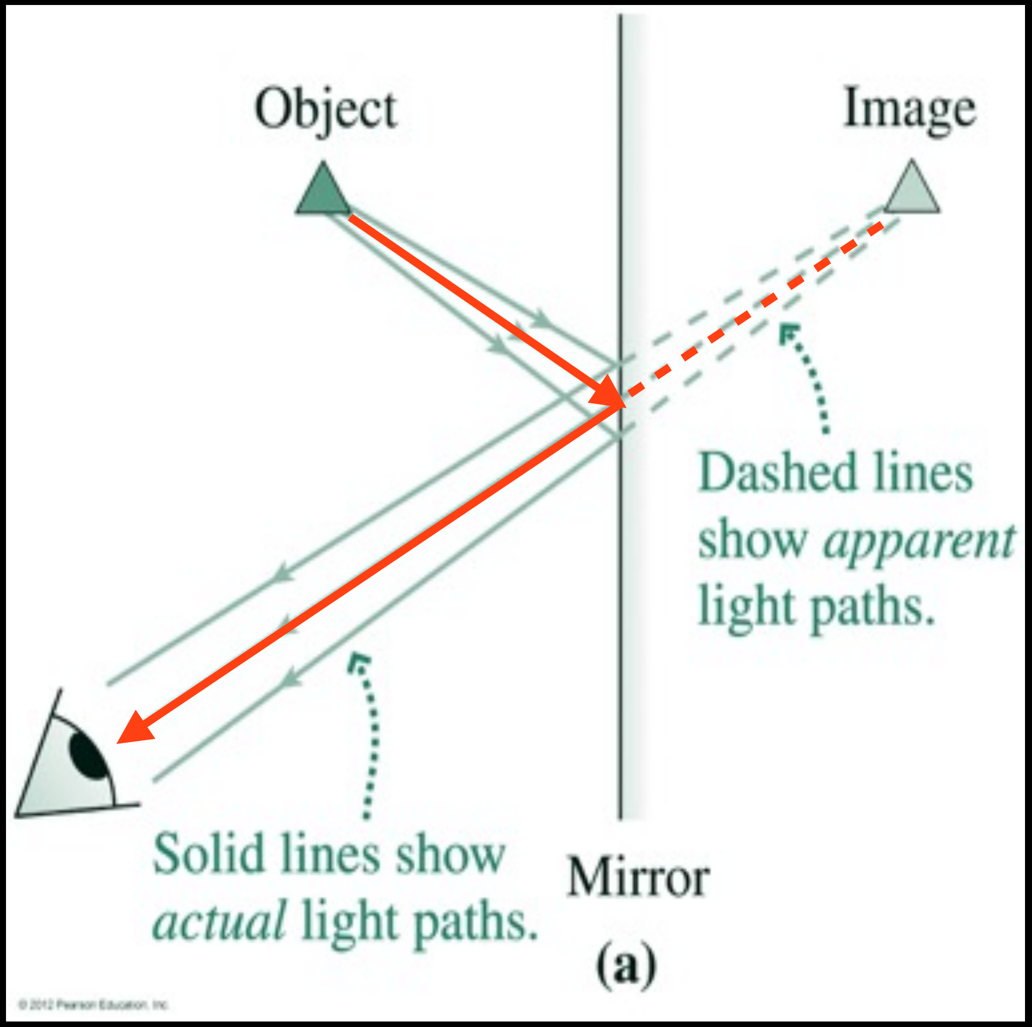
Optics

Mirrors and lenses

Plane (flat) Mirrors



Light from the triangle reflects off the mirror to the eye.



Eye assumes light rays are straight

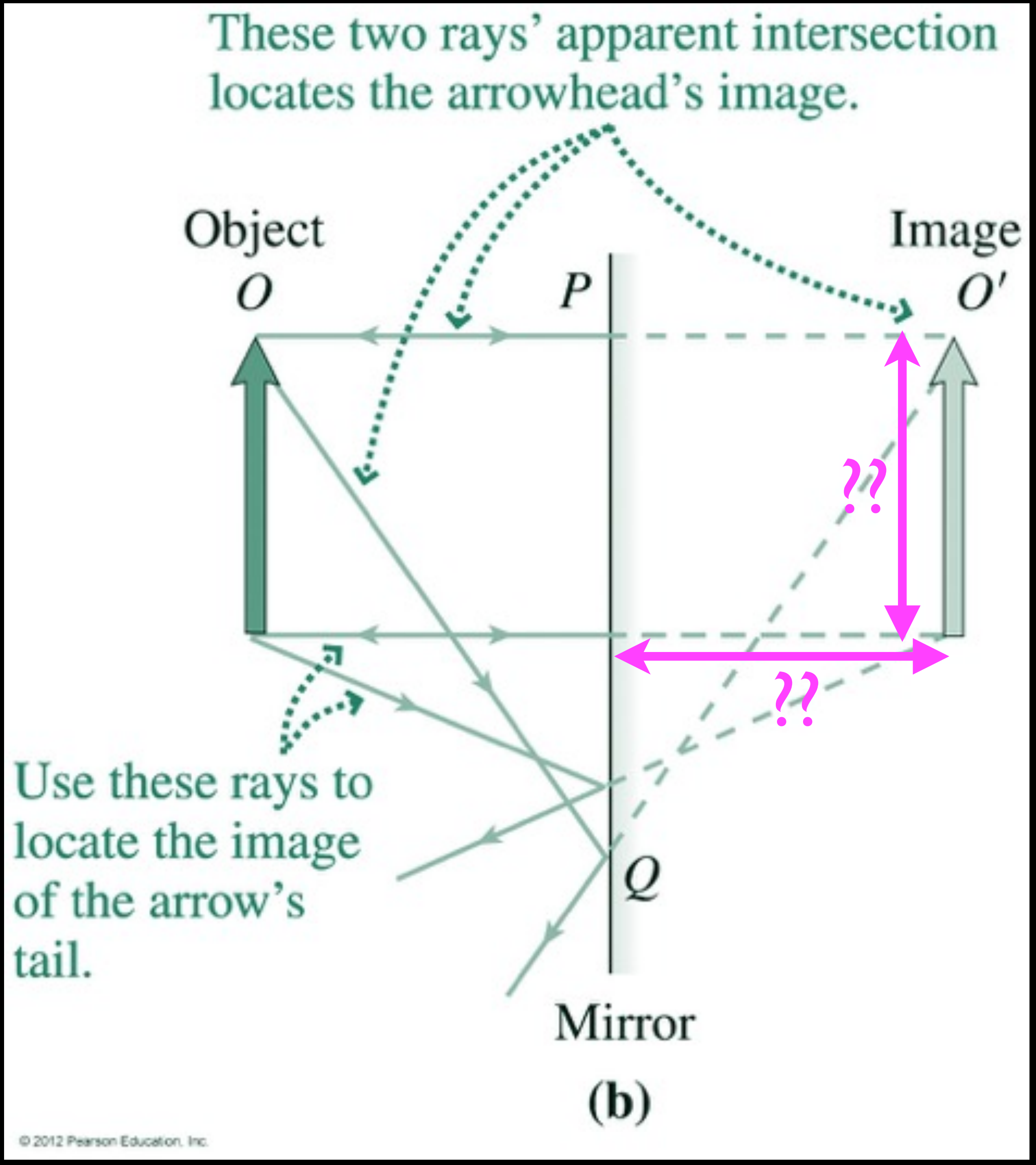
'Sees' the triangle behind the mirror.

Image is virtual : no light actually comes from behind the mirror.

Plane Mirrors

Where is the image?

- Distance from mirror?
- Height?

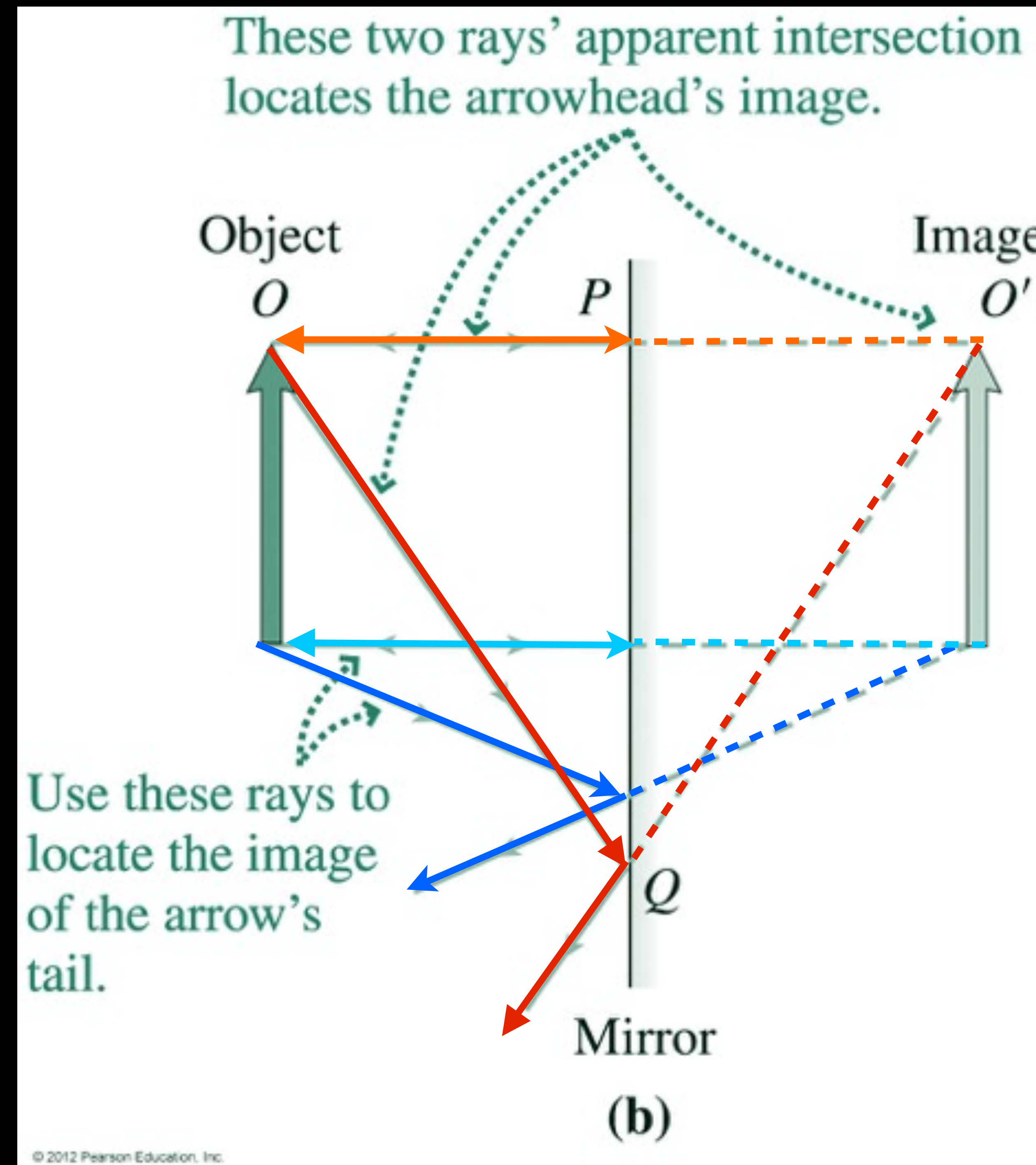


Plane Mirrors

2 light rays needed to locate each point in the mirror.

locate arrow top

locate arrow bottom



Plane Mirrors

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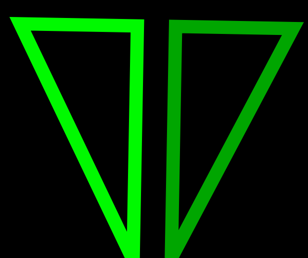
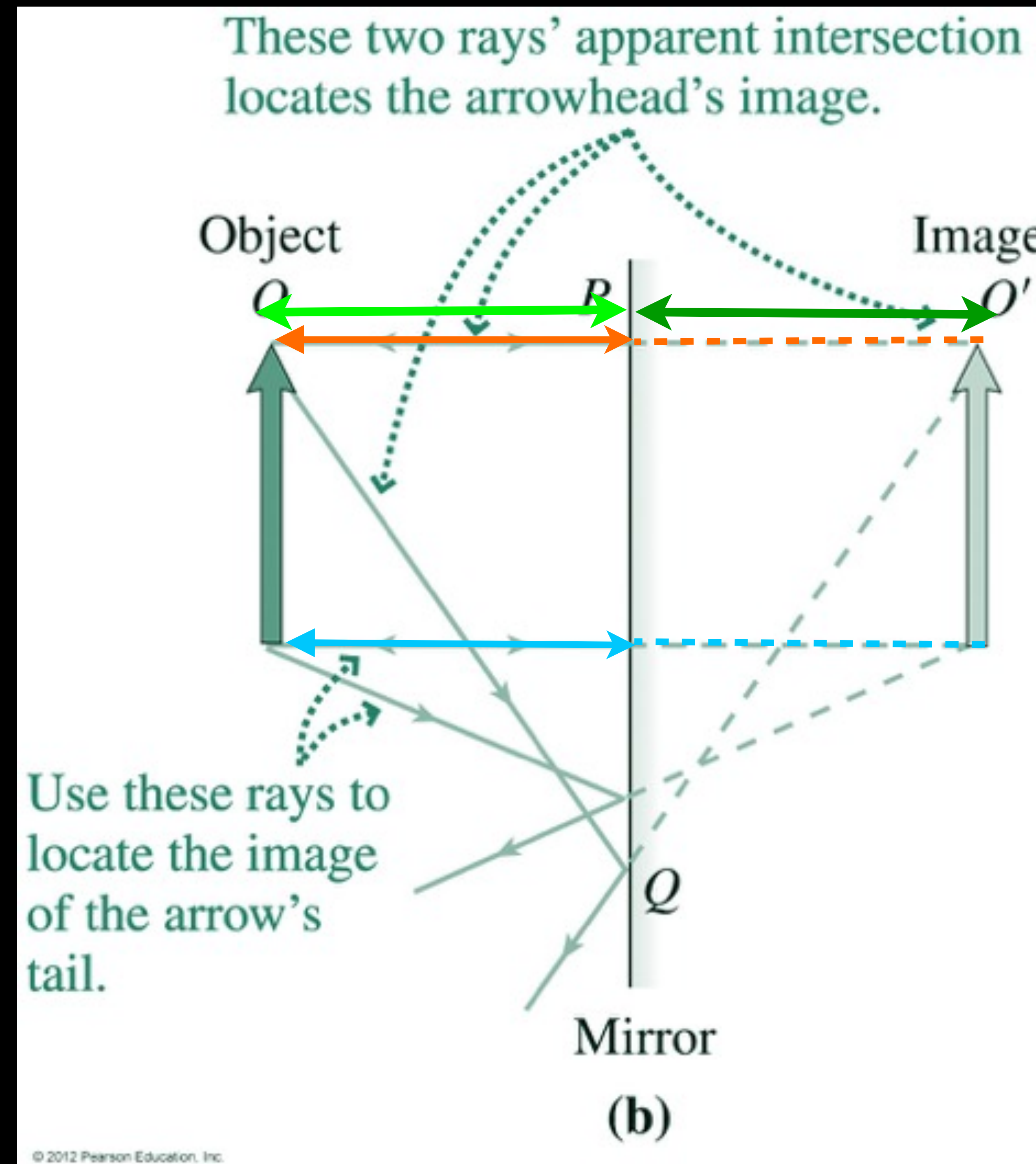


congruent triangles

(sides & angles equal)

arrow to mirror distance = image to mirror distance



Rays top and bottom of arrow are normal to mirror and parallel

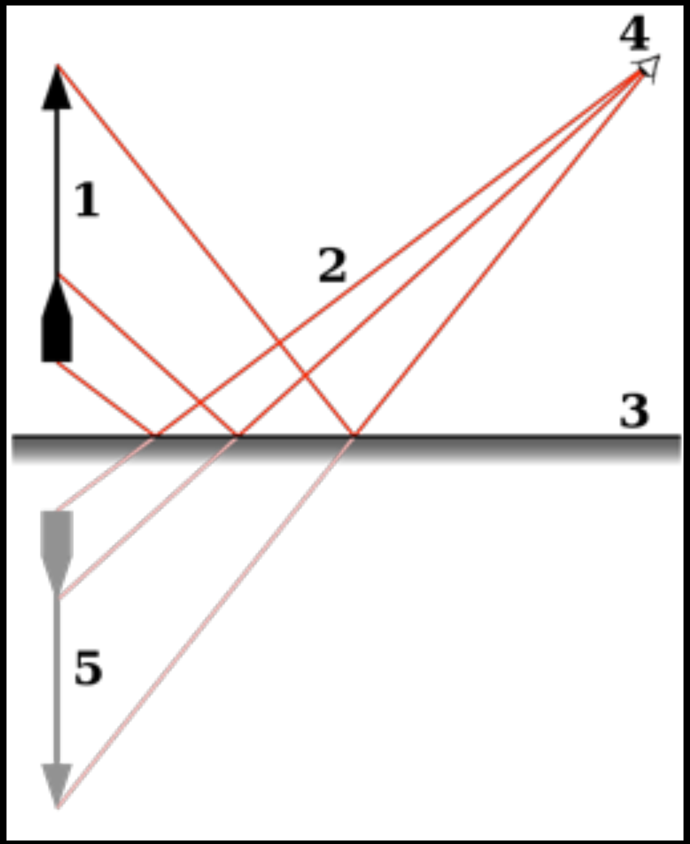
image is same height as arrow

Plane Mirrors

Plane mirror image has same length and orientation (not upside down) as object.

But reverse the object front-to-back.

Your right hand looks like your left hand.



Plane Mirrors

You stand in front of a plane mirror whose top is the same height as the top of your height.

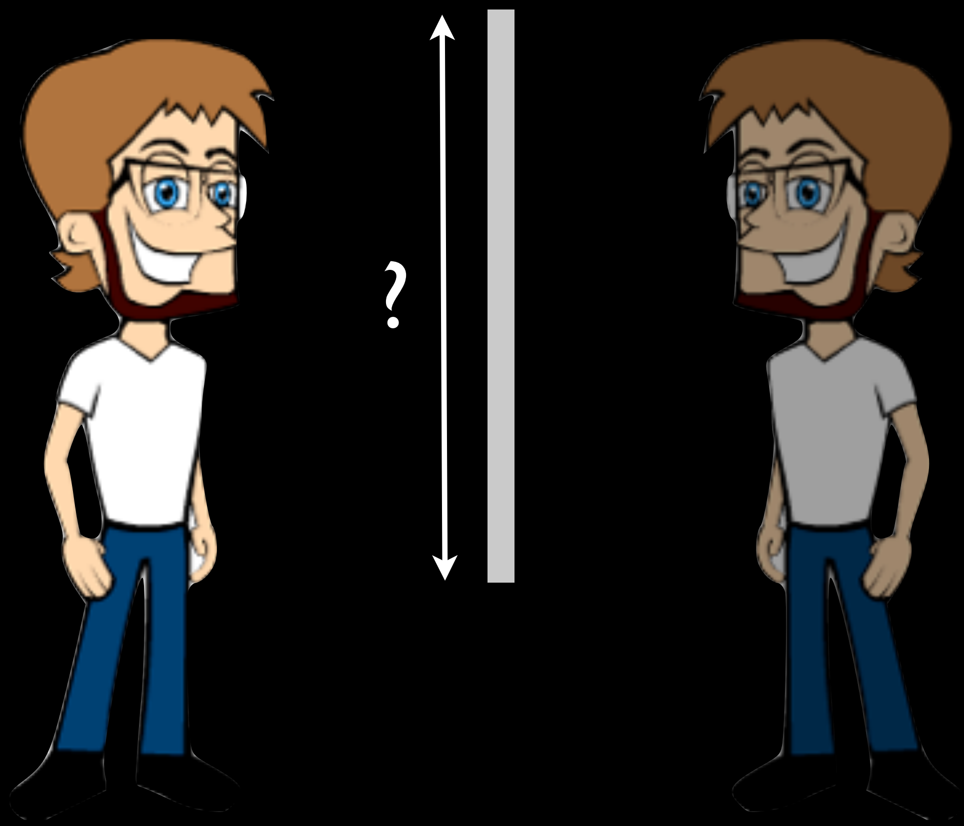
Approximately how far down must the mirror extend for you to see your full image?

(A) To ground where you are standing

(B) ~ 3/4 of the way to the ground

(C) ~ 1/2 of the way to the ground

(D) ~ 1/4 of the way to the ground

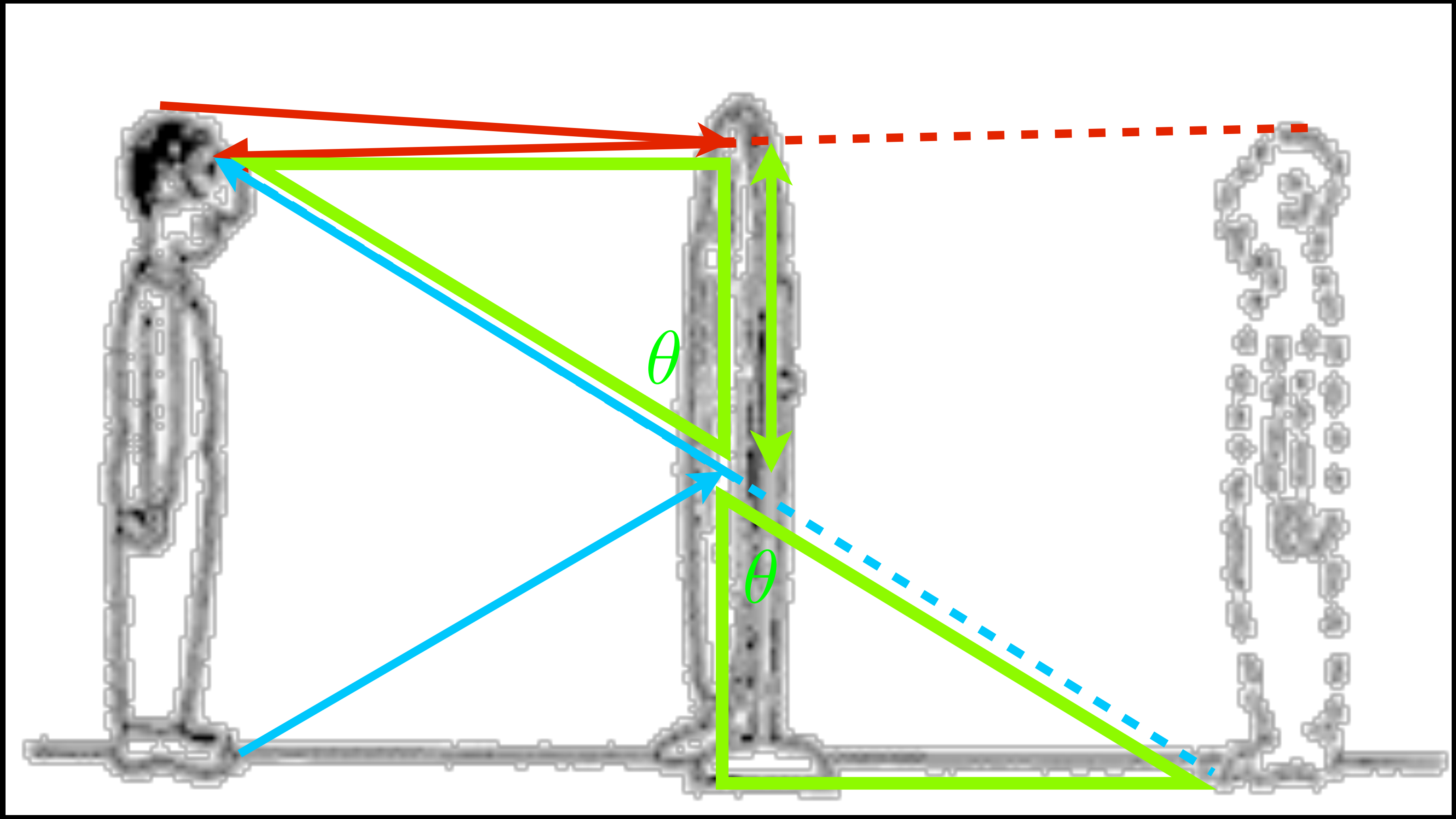


(Hint: draw rays)

Plane Mirrors

You stand in front of a plane mirror whose top is the same height as the top of your height.

Approximately how far down must the mirror extend for you to see your full image?



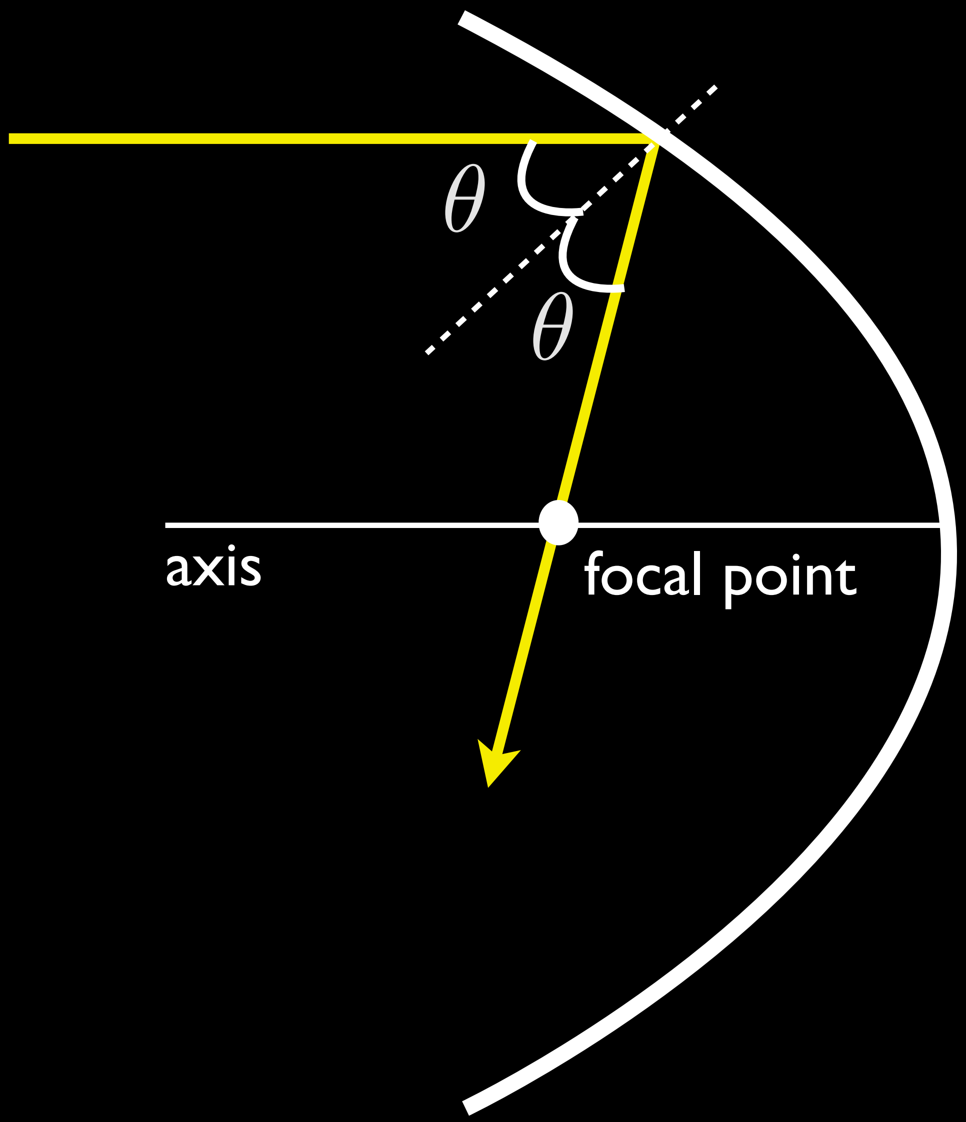
Curved Mirrors

Parabolic curved mirror:

If ray is parallel to axis,

it will be reflected through the focal point.

angle with normal = angle with line to focal point



Can concentrate light at the focal point

or put light source at the focal point and get parallel rays

Curved Mirrors

Parabolic curved mirror:

If ray is parallel to axis,

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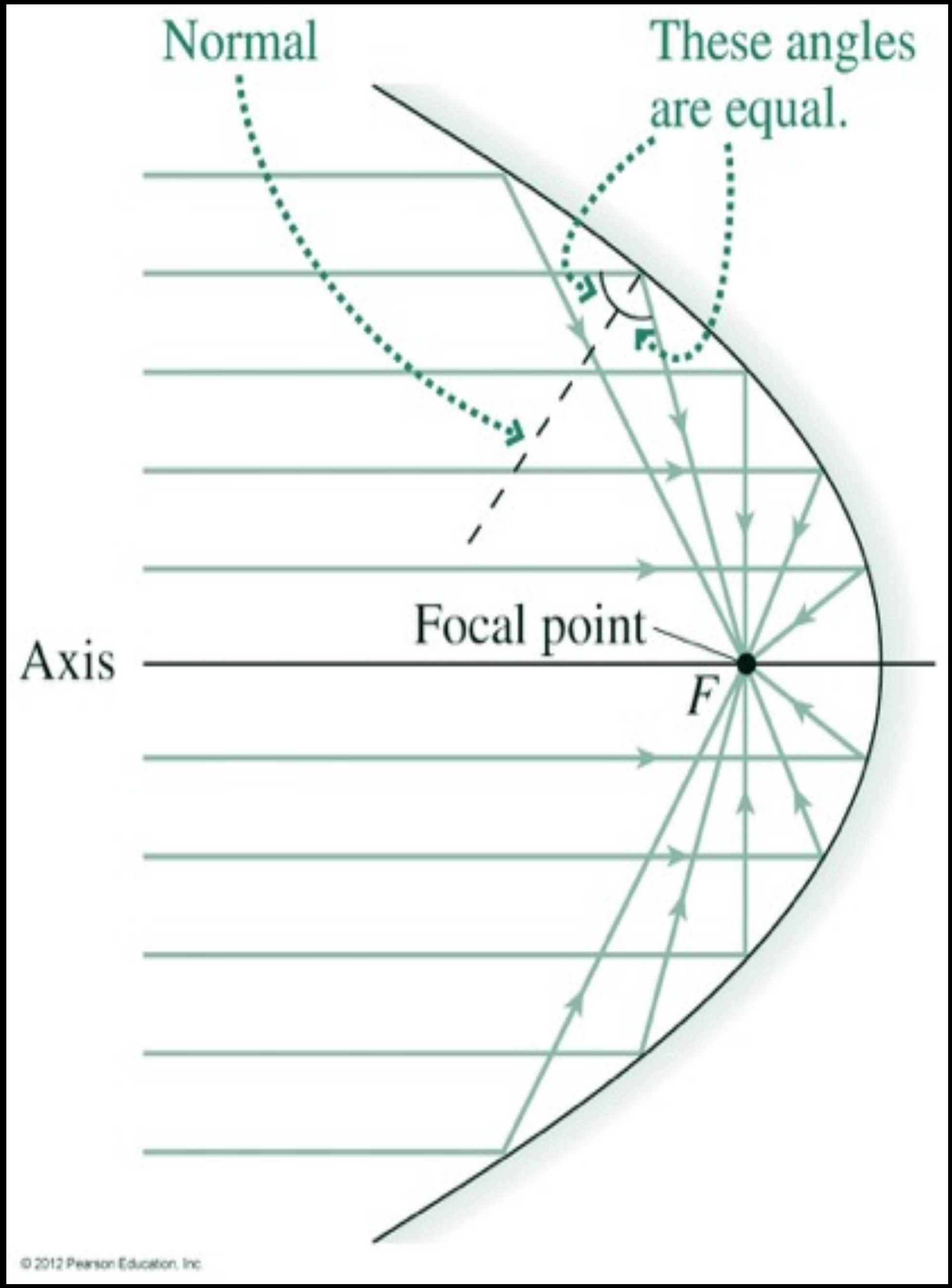
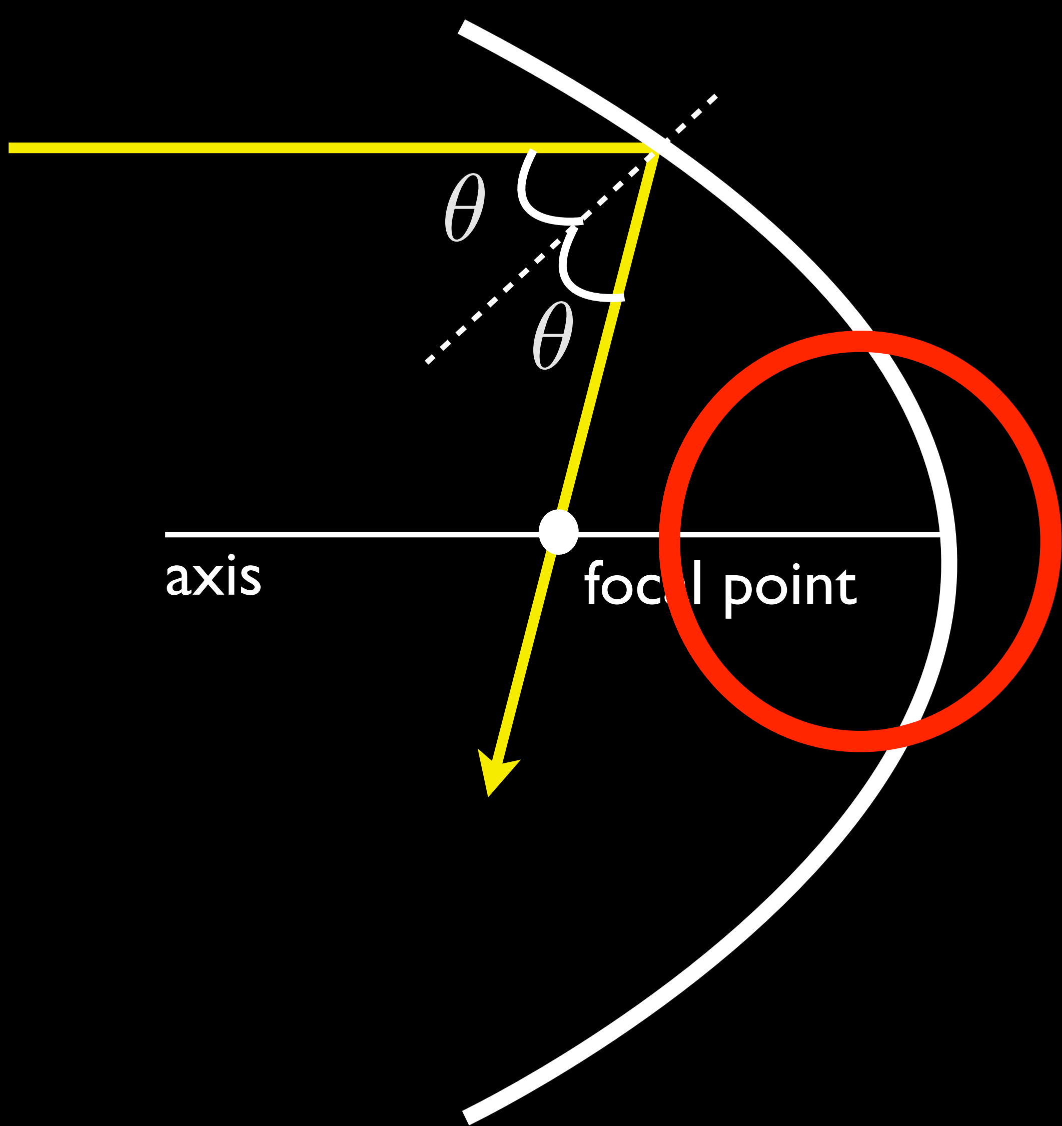


Can concentrate light at focal point

or put light source at focal point and get parallel rays

Curved Mirrors



Close to apex, mirror looks spherical.

Easier to make spherical mirrors

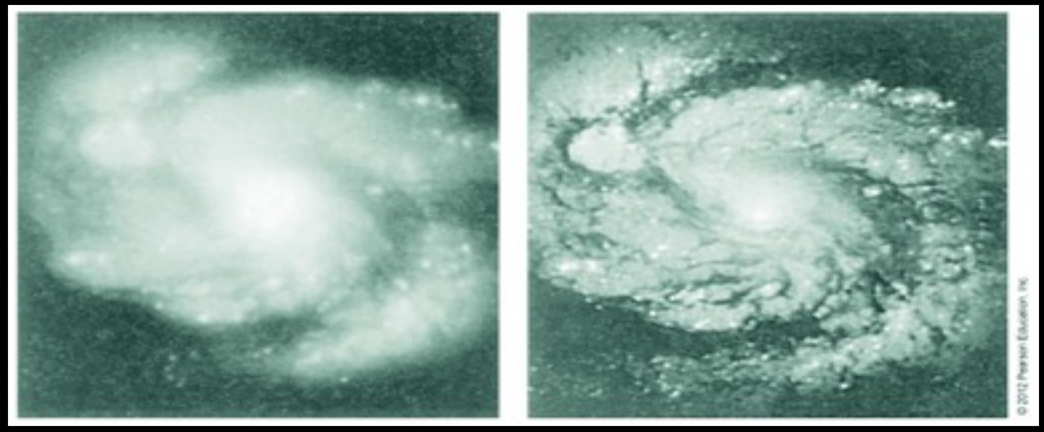
⬇

most focussing mirrors are spherical.

⬇

slight image distortion:

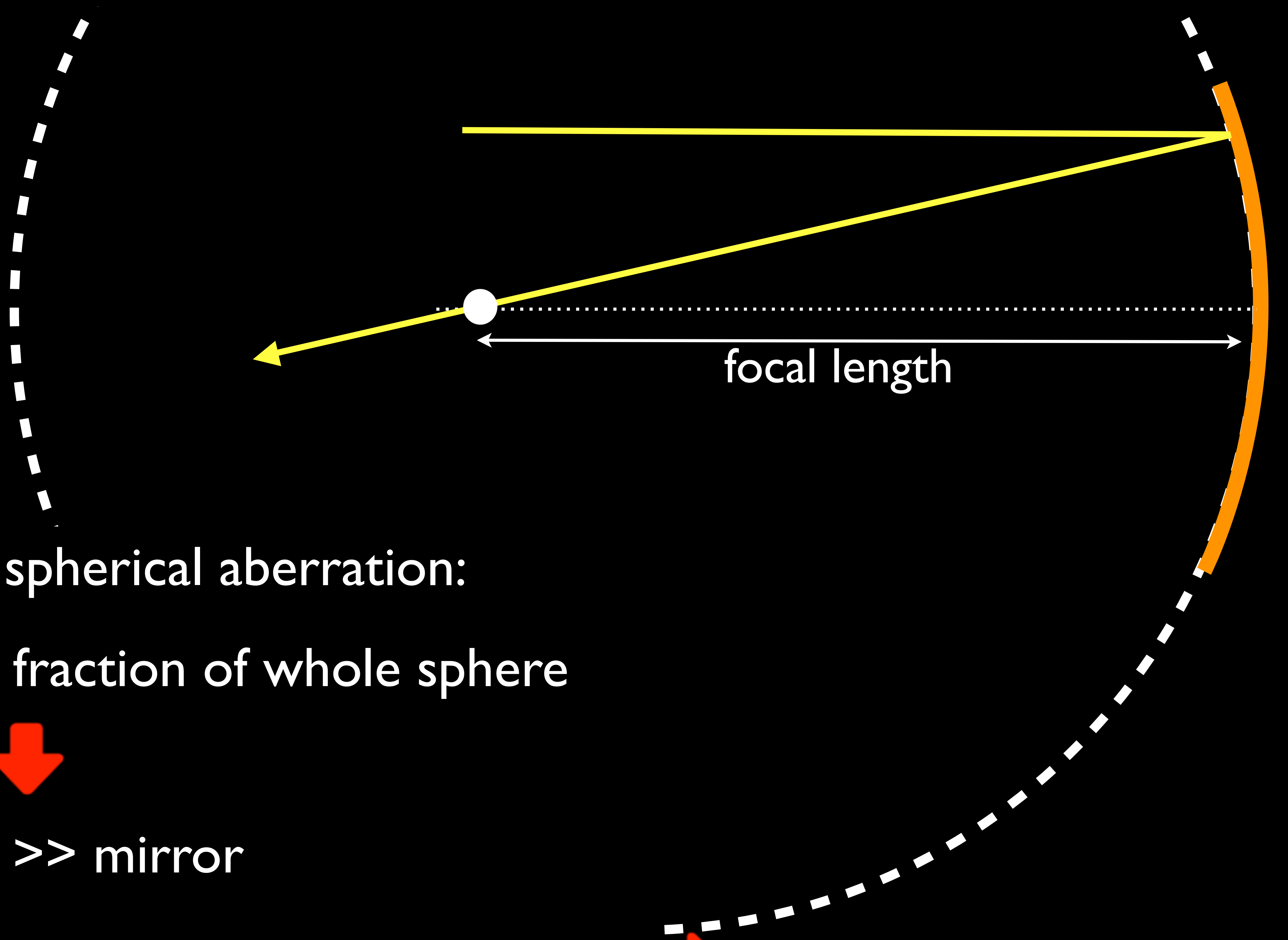
spherical aberration



Famous example: Hubble Space Telescope

Mirror made with wrong curve, big spherical aberration.

Curved Mirrors



To minimise spherical aberration:

Mirror small fraction of whole sphere

Focal length >> mirror

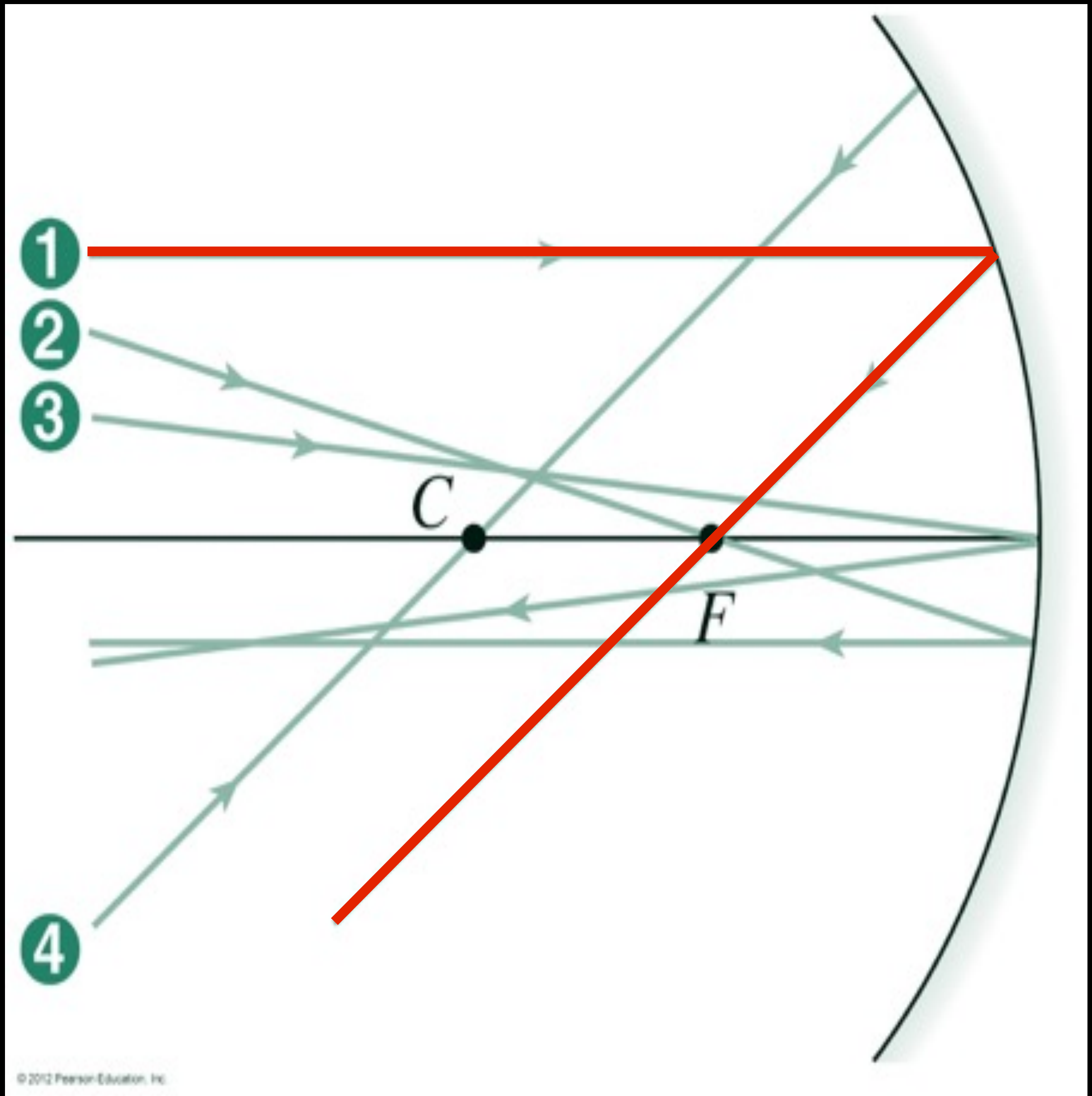
Rays strike the mirror ~ parallel to axis ➡ paraxial approximation

Curved Mirrors

To find image draw 2 rays from different points on the object.

Any ray possible, but these are simplest:

(1) A ray parallel to the mirror axis reflects through the focal point.



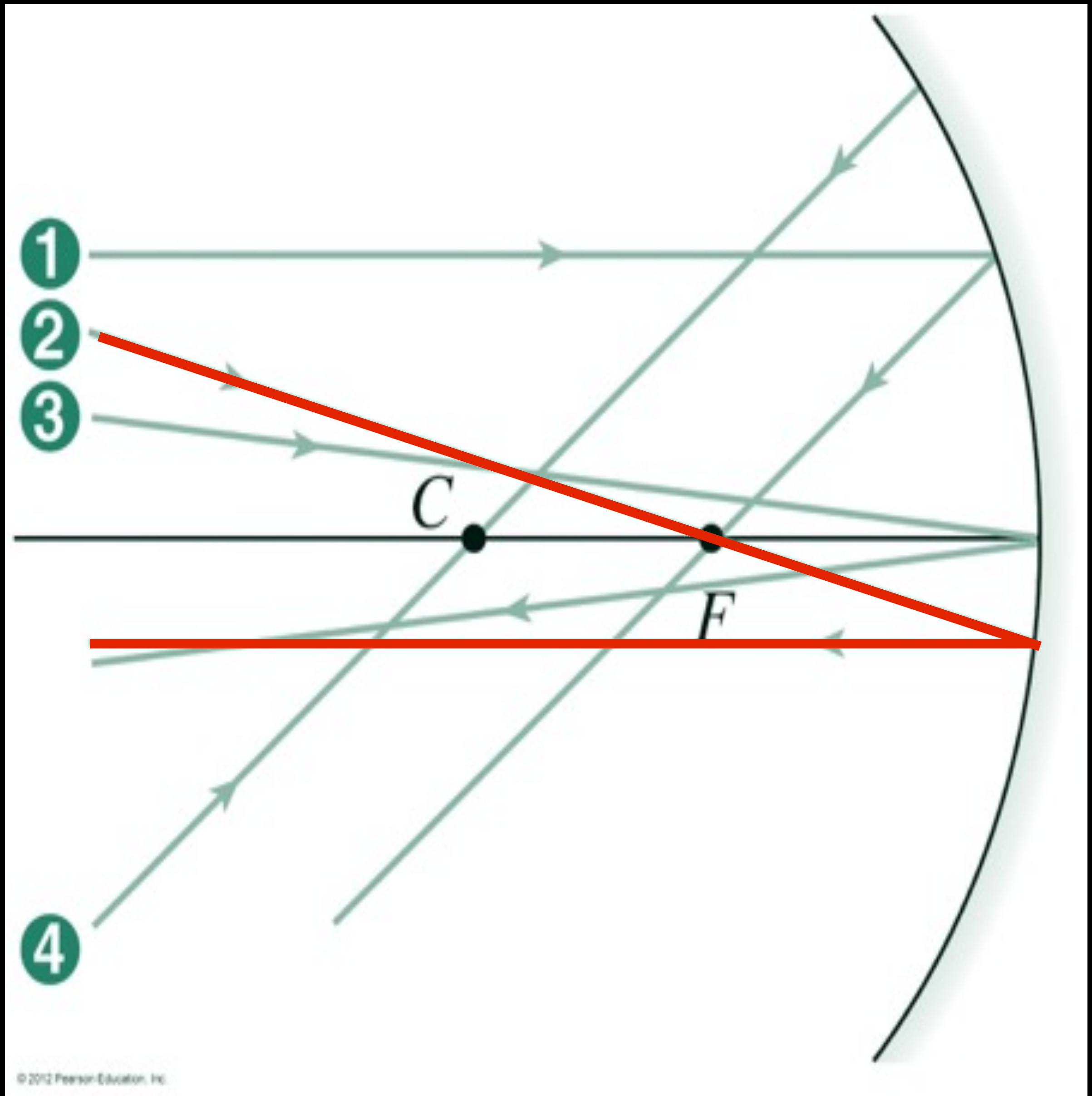
Curved Mirrors

To find image draw 2 rays from different points on the object.

Any ray possible, but these are simplest:

(1) A ray parallel to the mirror axis reflects through the focal point.

(2) A ray passing through the focal point reflects parallel to the axis.



Curved Mirrors

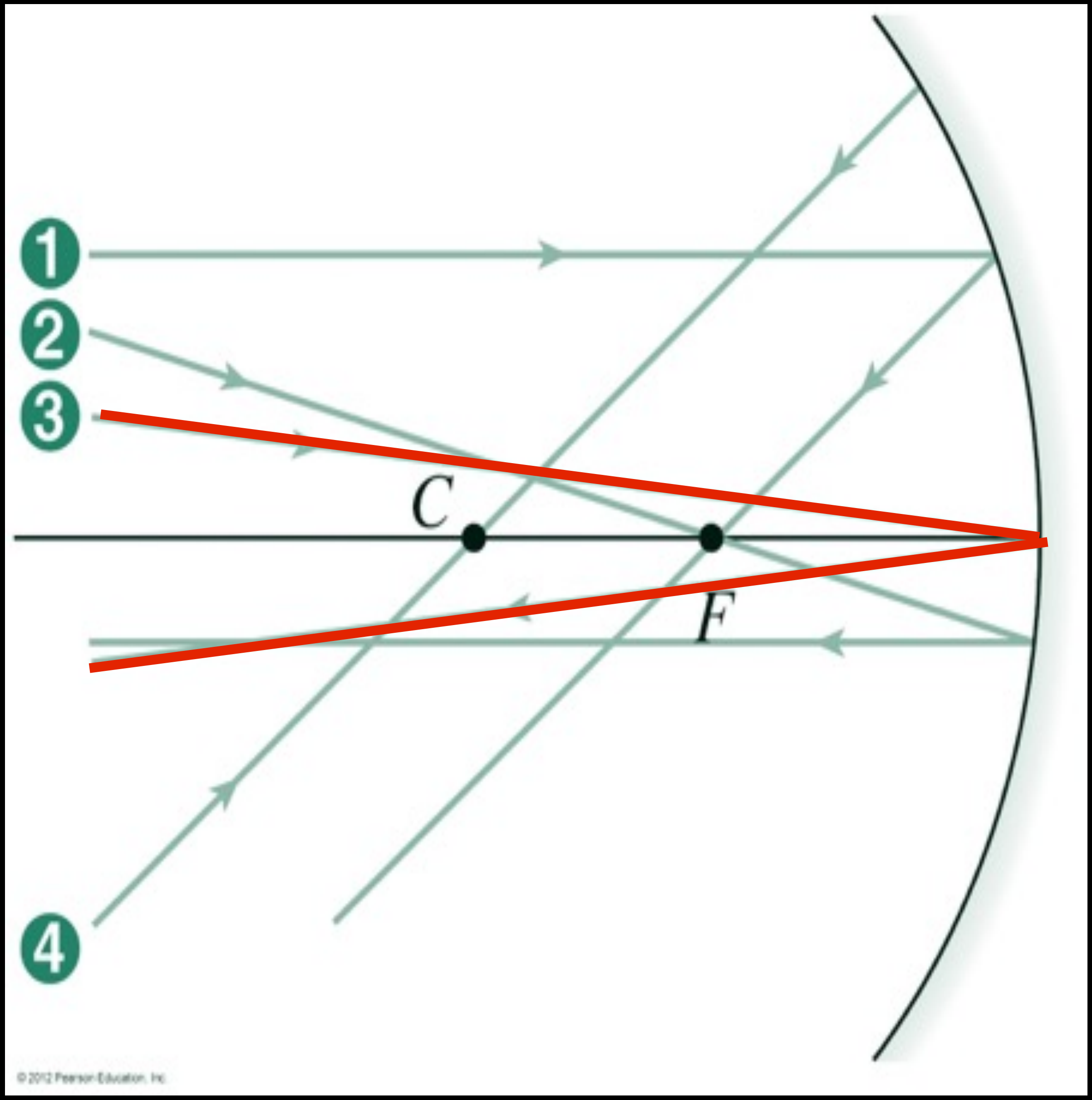
To find image draw 2 rays from different points on the object.

Any ray possible, but these are simplest:

(1) A ray parallel to the mirror axis reflects through the focal point.

(2) A ray passing through the focal point reflects parallel to the axis.

(3) A ray striking the center of the mirror reflects symmetrically about the mirror axis.



Curved Mirrors

To find image draw 2 rays from different points on the object.

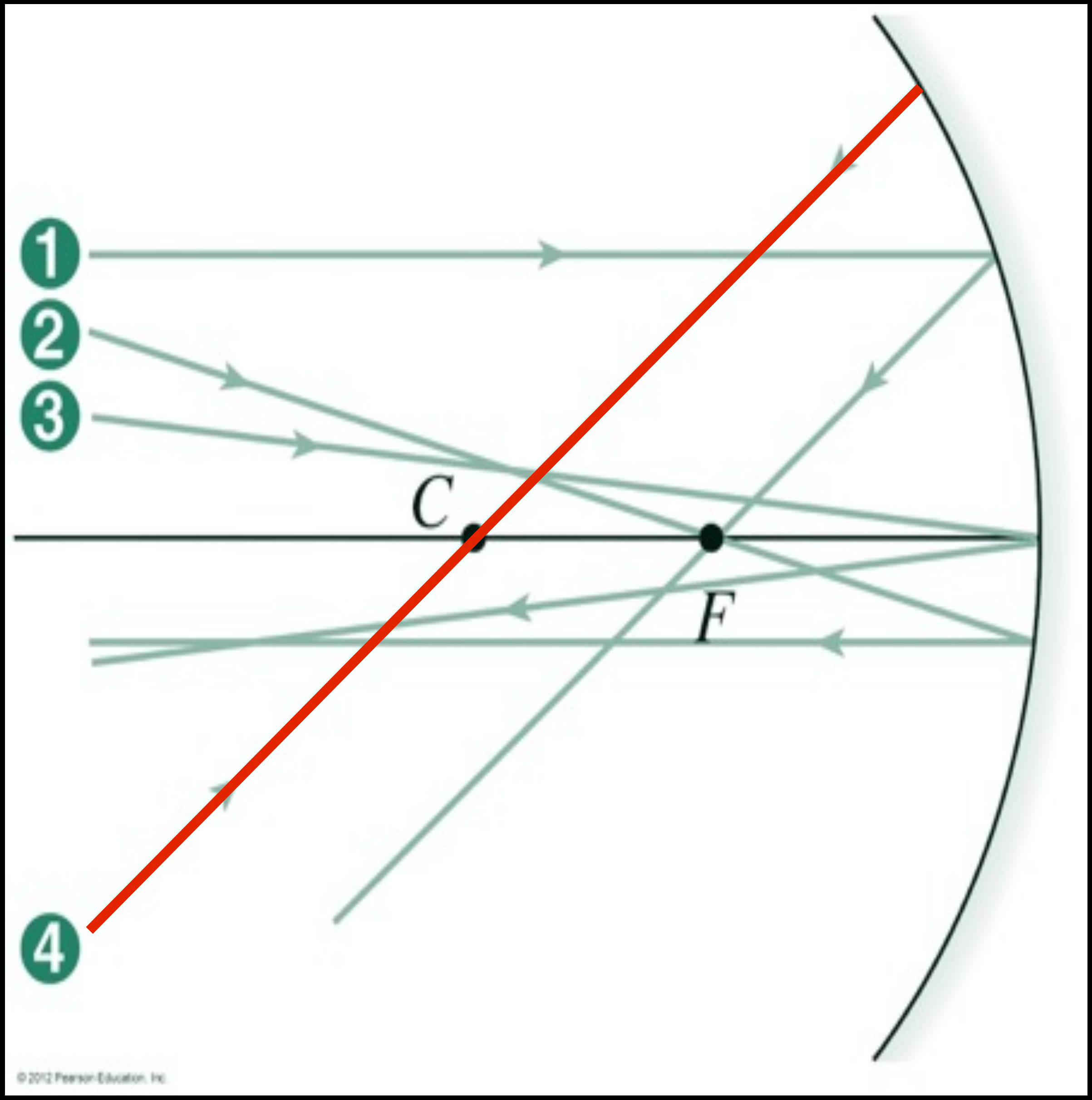
Any ray possible, but these are simplest:

(1) A ray parallel to the mirror axis reflects through the focal point.

(2) A ray passing through the focal point reflects parallel to the axis.

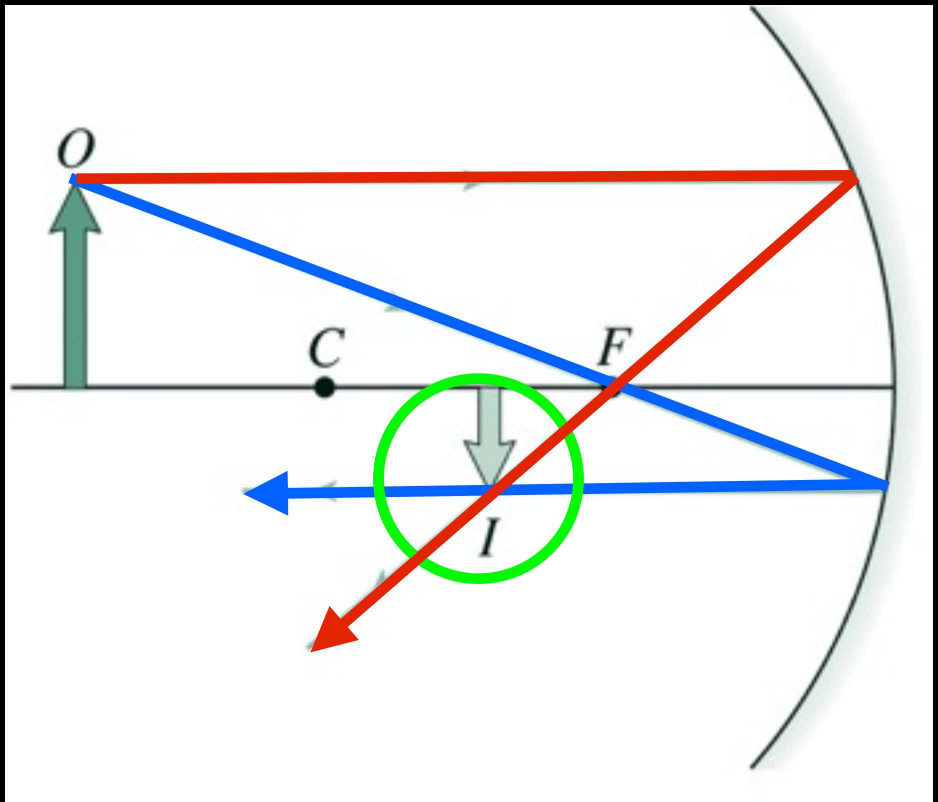
(3) A ray striking the center of the mirror reflects symmetrically about the mirror axis.

(4) A ray through the centre of curvature of the mirror returns on itself.



Curved Mirrors

Examples:



Real, inverted, reduced image

Locate image top with 2 rays

(types 1 & 2)

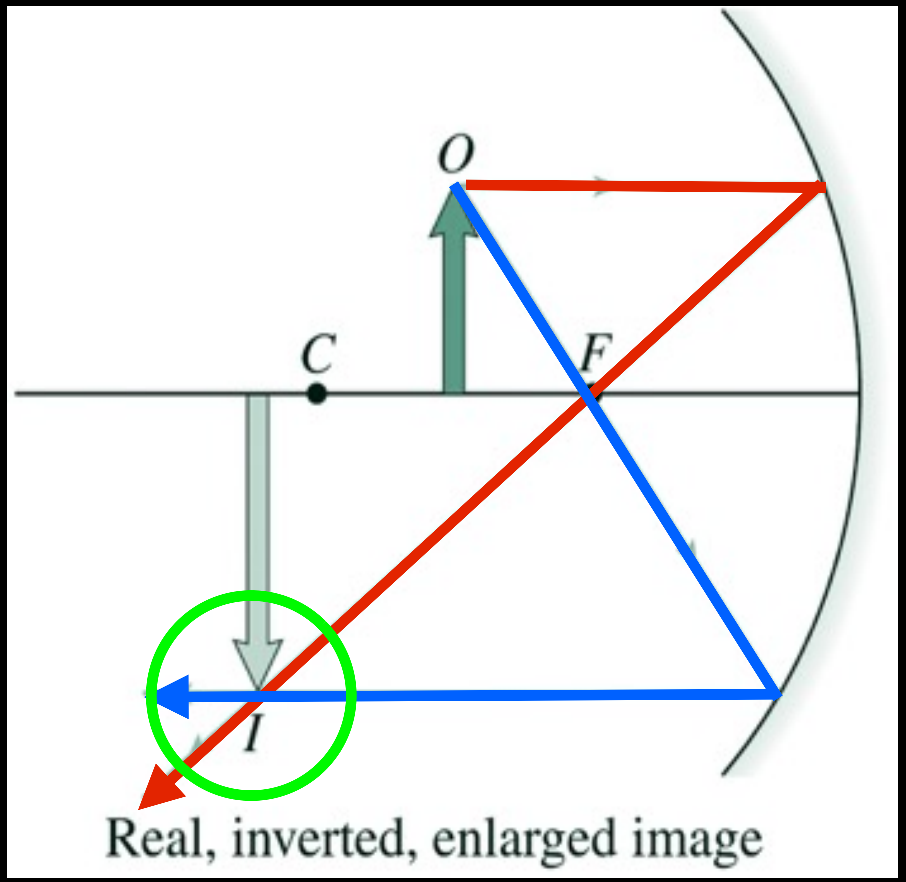
From symmetry, bottom of image is on the axis.

(also, ray along axis is reflected straight back, type 4)

Light rays come from the image: real image

Curved Mirrors

Examples: move object closer to mirror



Locate image top with 2 rays

(types 1 & 2)

From symmetry, bottom of image is on the axis.

(also, ray along axis is reflected straight back, type 4)

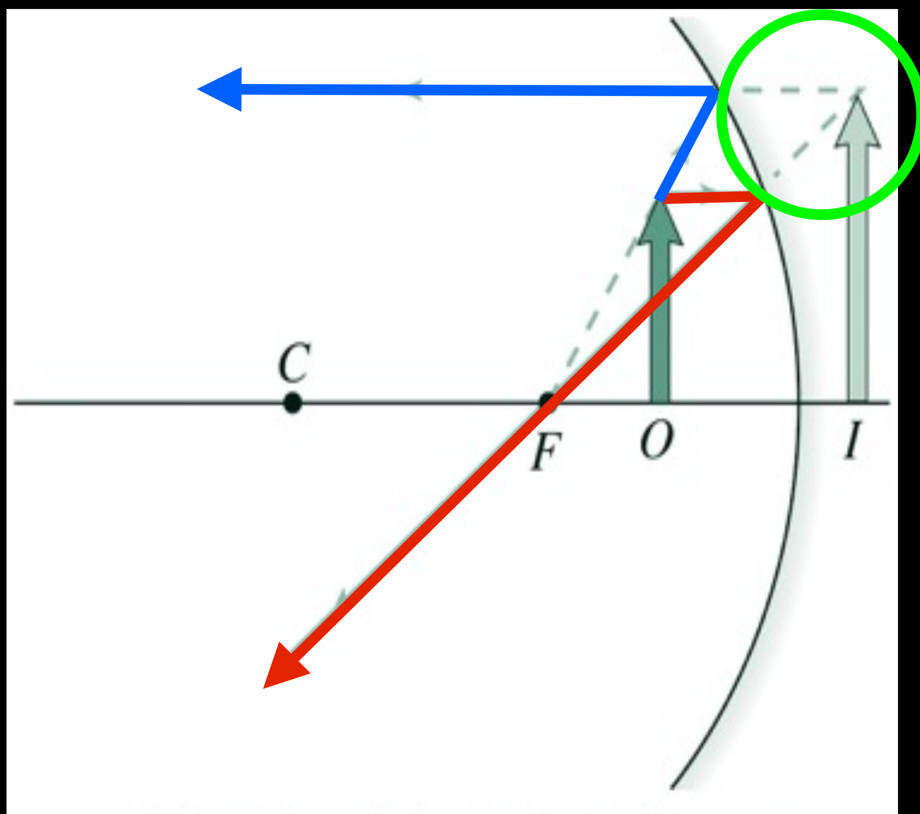
Light rays come from the image: real image

As object gets closer to mirror, image size increases.

When object is between mirror centre (C) and focus point (F), image is larger than object and further away.

Curved Mirrors

Examples: move object closer to mirror



Virtual, upright, enlarged image

Locate image top with 2 rays

(types 1 & 2)

From symmetry, bottom of image is on the axis.

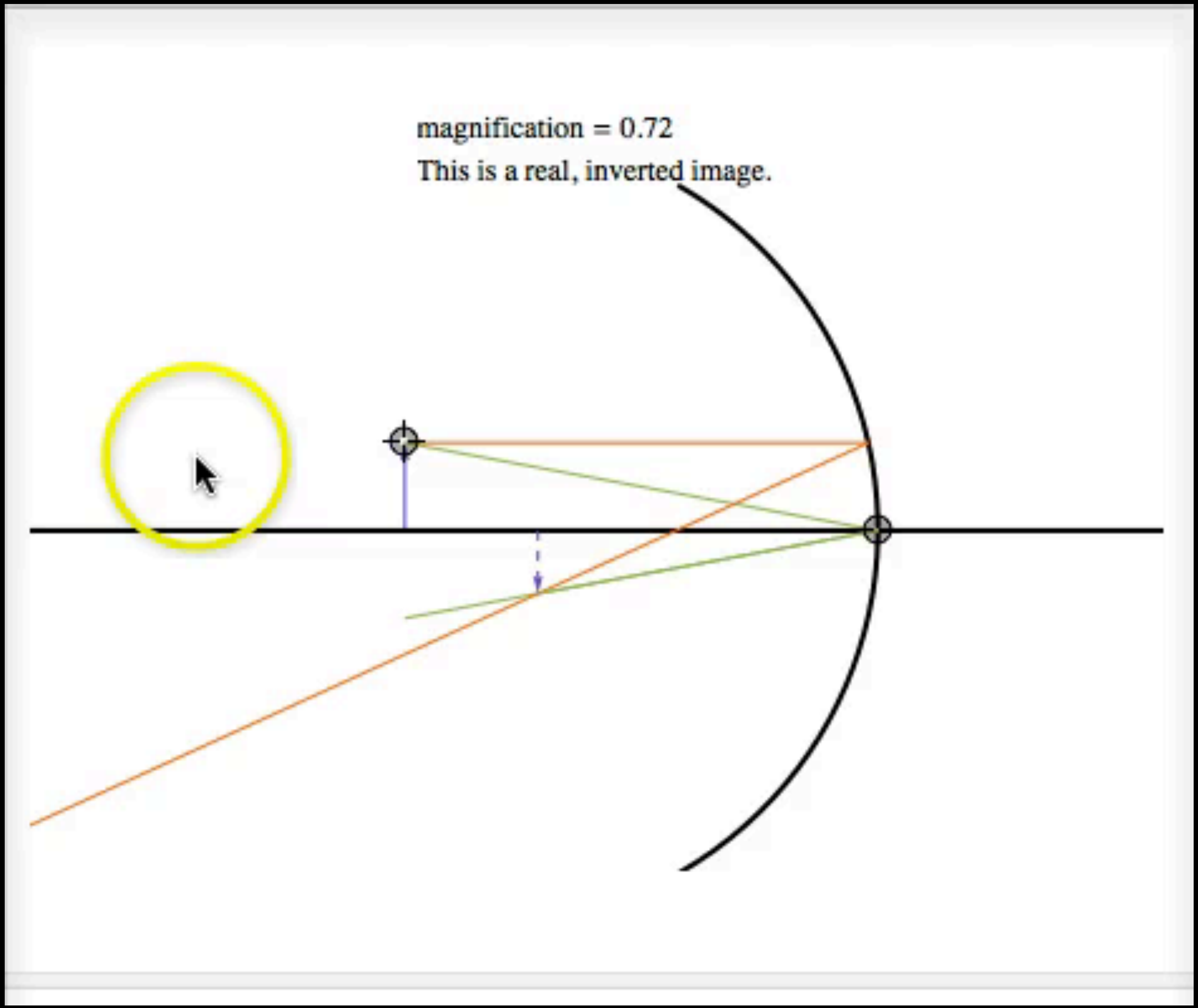
Rays diverge (go apart) after reflection.

Appear to cross behind the mirror

Light rays do not come from the image: virtual image

Image is upright and enlarged.

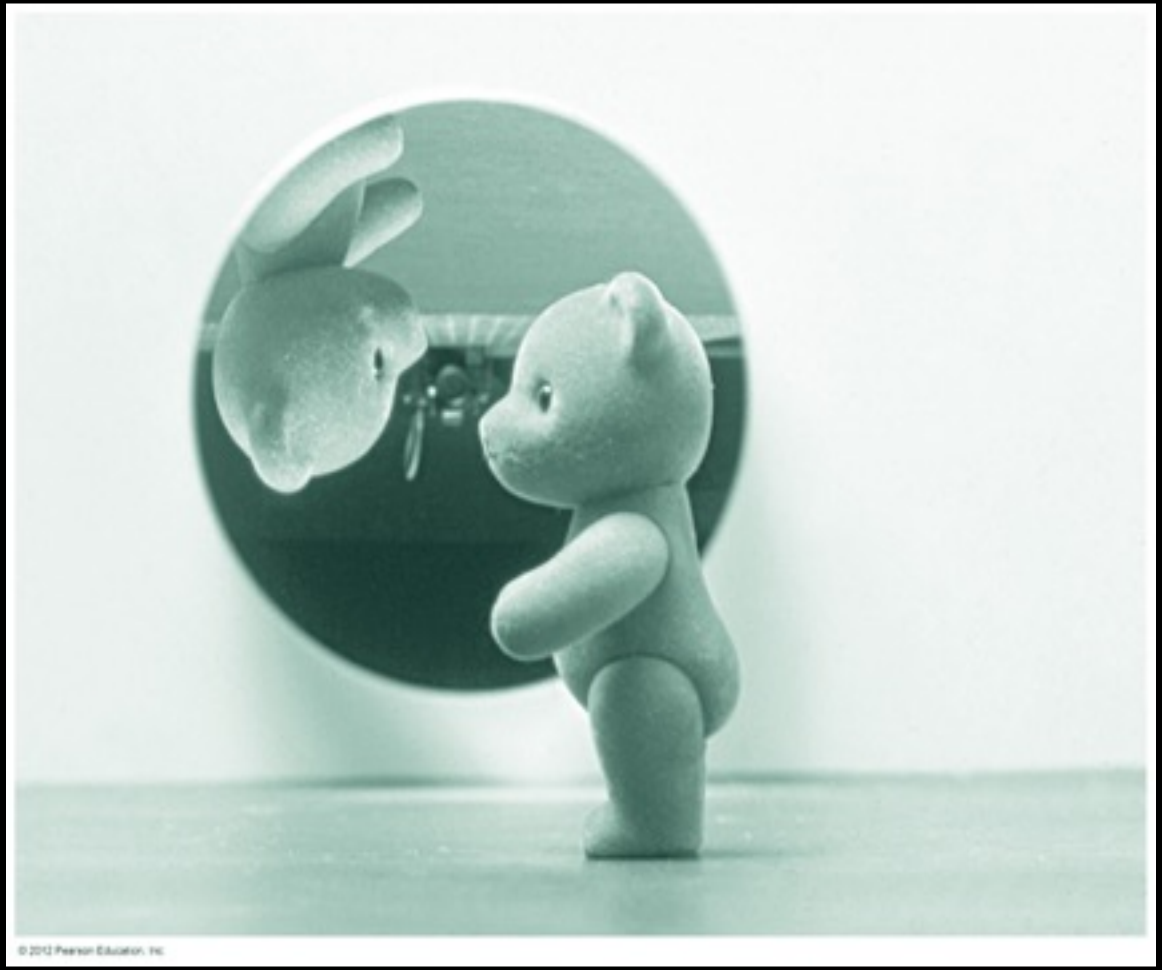
Curved Mirrors



Curved Mirrors

Quiz

Where would you place an object so its real image is the same size as the object?



(A) At the mirror's centre of curvature (C)

(B) At the mirror's focal length (F)

(C) At twice the mirror's centre of curvature (2 x C)

(D) Not possible

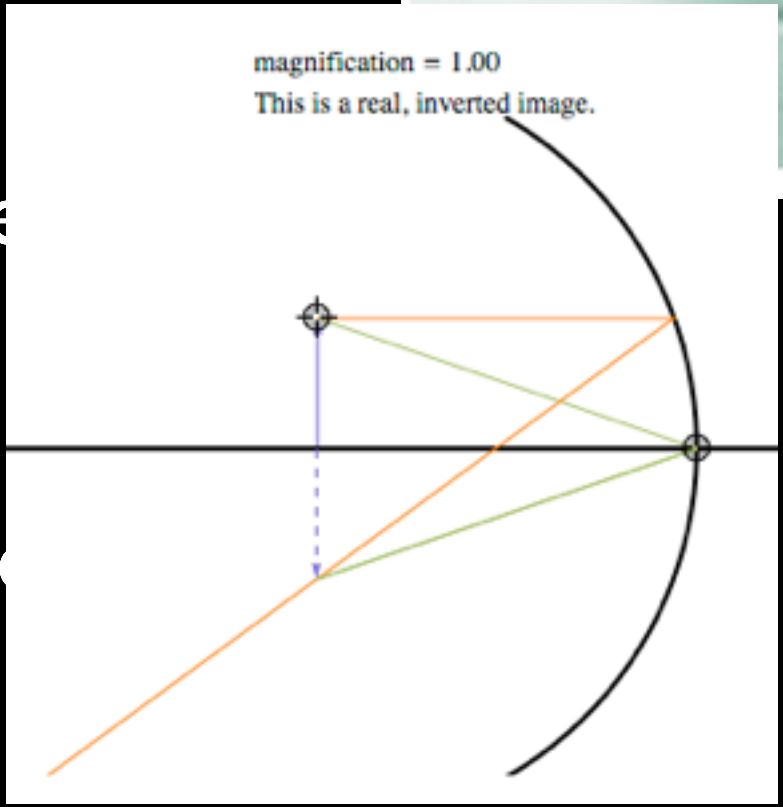
Curved Mirrors

Quiz

Where would you place an object so its real image is the same size as the object?

(A) At the mirror's centre of curvature (C)

(B) At the mirror's focal le



(C) At twice the mirror's c (2 x C)

(D) Not possible

Curved Mirrors

Where would you place an object so there is no reflected image?

(A) At the mirror's centre of curvature (C)

(B) At the mirror's focal length (F)

(C) At twice the mirror's centre of curvature (2 x C)

(D) Not possible

Curved Mirrors

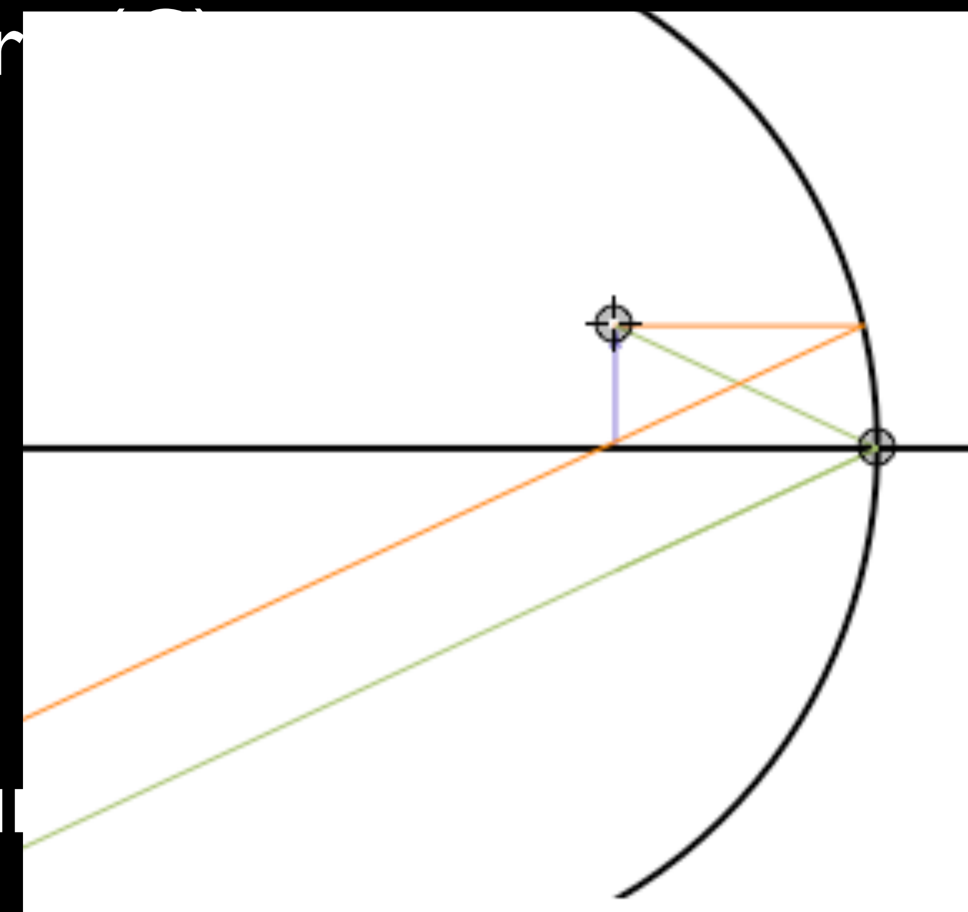
Where would you place an object so there is no reflected image?

(A) At the mirror’s centre of curvatur

(B) At the mirror’s focal length (F)

(C) At twice the mirror’s centre of cu

(D) Not possible



Rays are parallel:
never cross

Curved Mirrors

Convex mirrors

Reflected rays diverge

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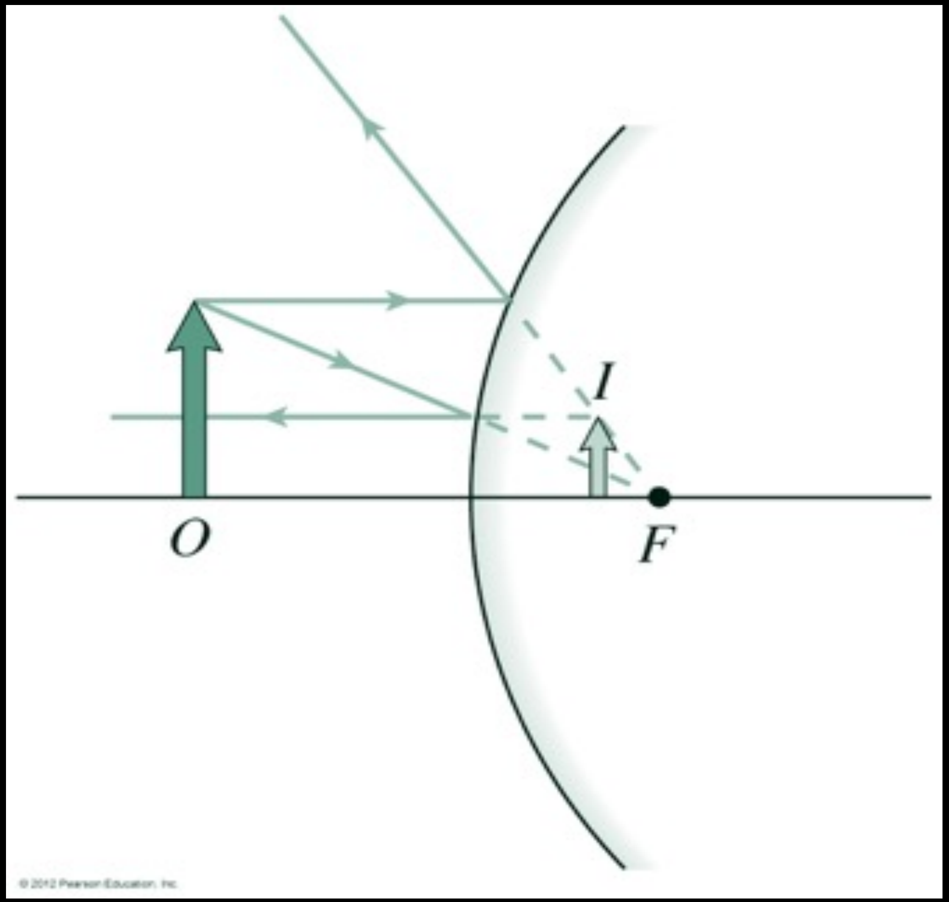
Only forms virtual images

Reflected parallel rays appear to come from the focal point behind the mirror, F

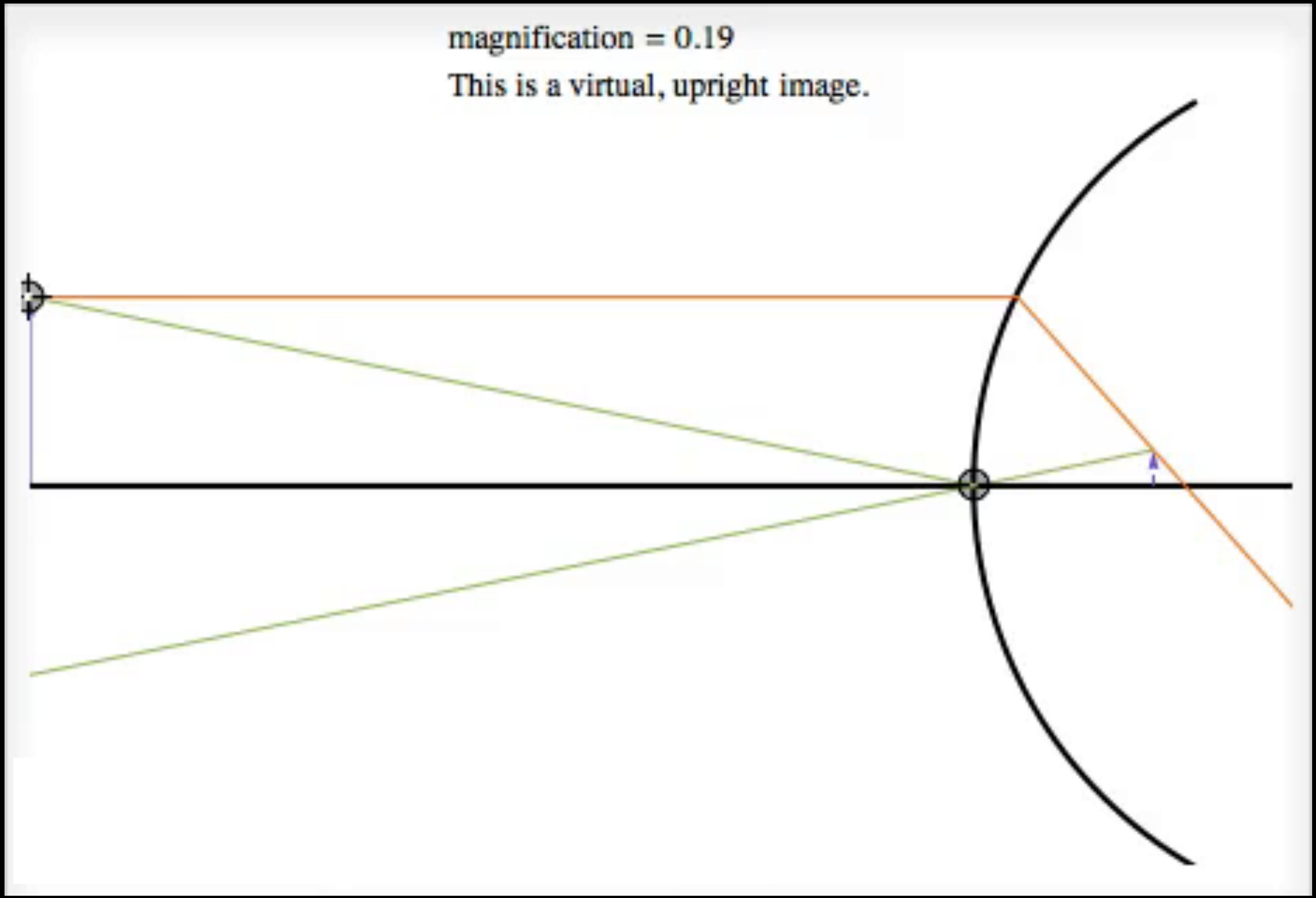
Image is always upright (not inverted) and smaller.

Used to image large area in small space (wide angle view)



Curved Mirrors

Convex mirrors

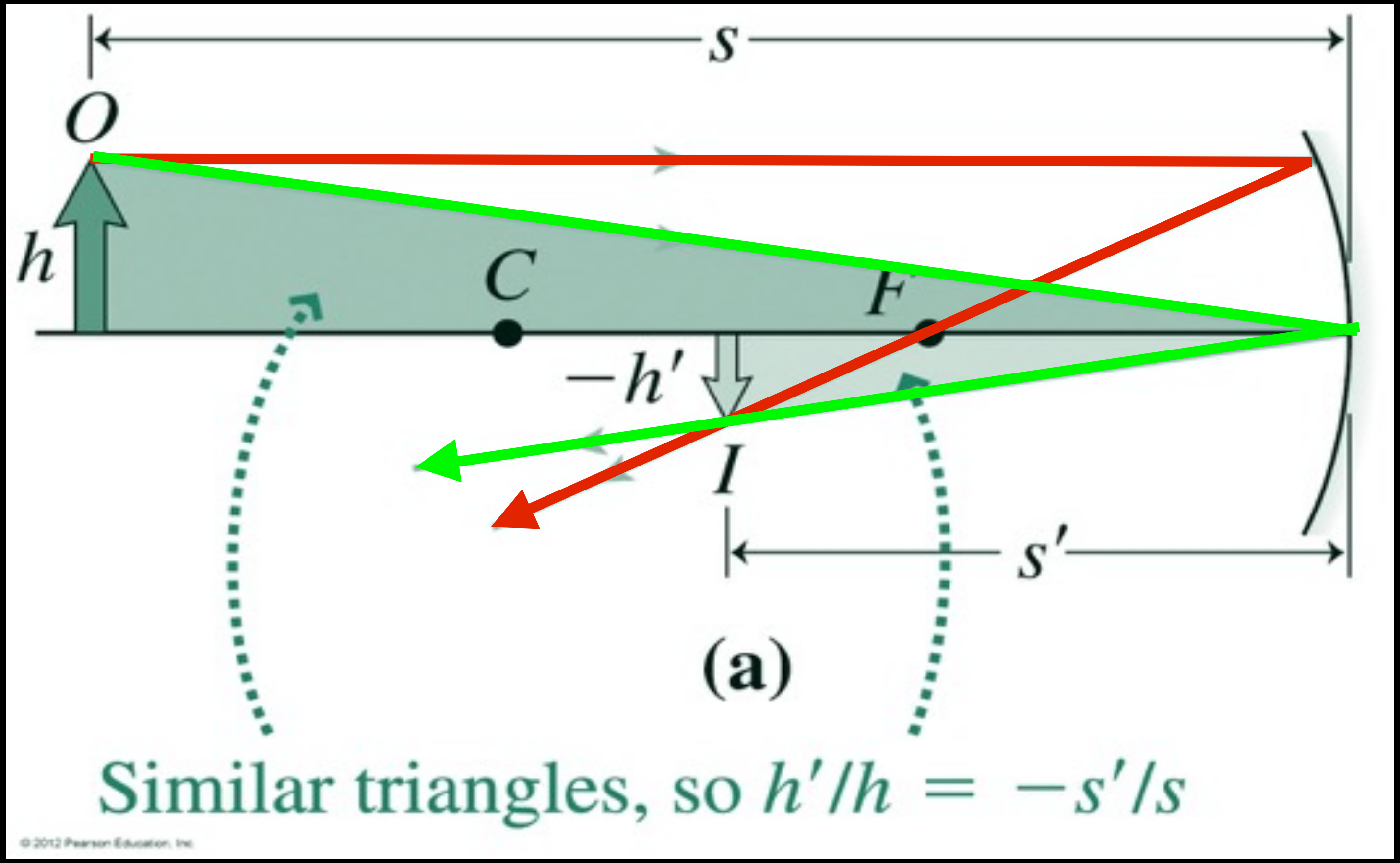


Mirror Equation

Drawing rays works....

... but can we be more accurate?

2 rays (type 1 & 3)



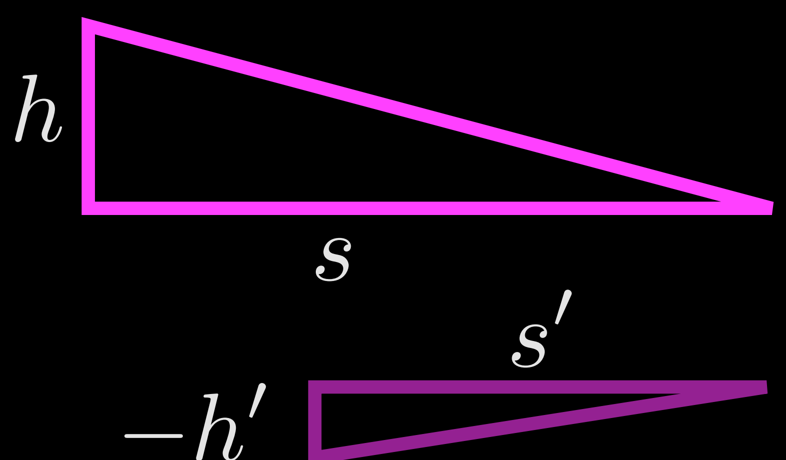
Mirror Equation

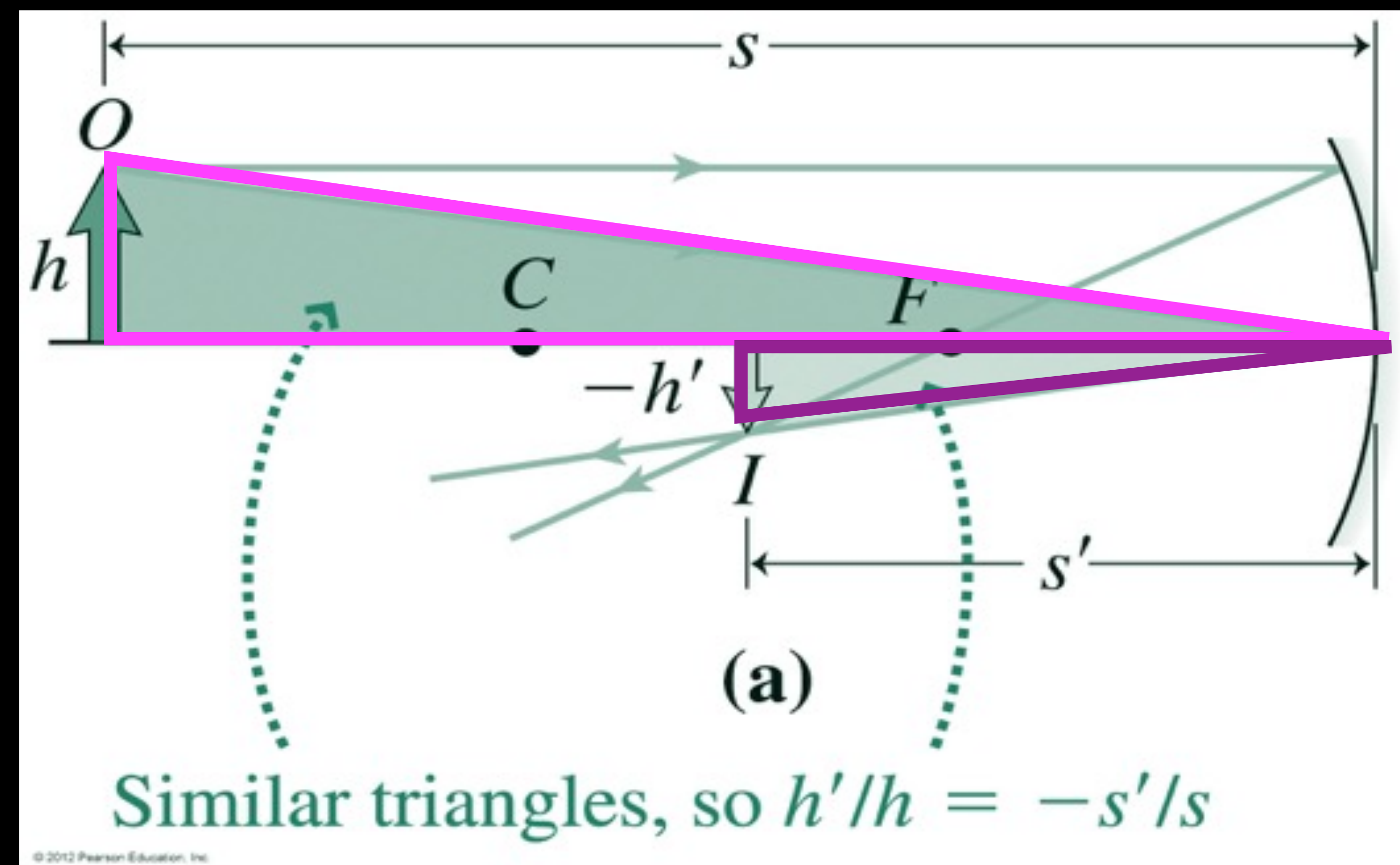
Drawing rays works....

... but can we be more accurate?

2 rays (type 1 & 3)

Similar triangles:





$$M = \frac{h'}{h} = -\frac{s'}{s}$$ (magnification)

inverted image: negative h’

(virtual image: negative s’)

Here, $|M| < 1$ because image is smaller and negative, because image is inverted

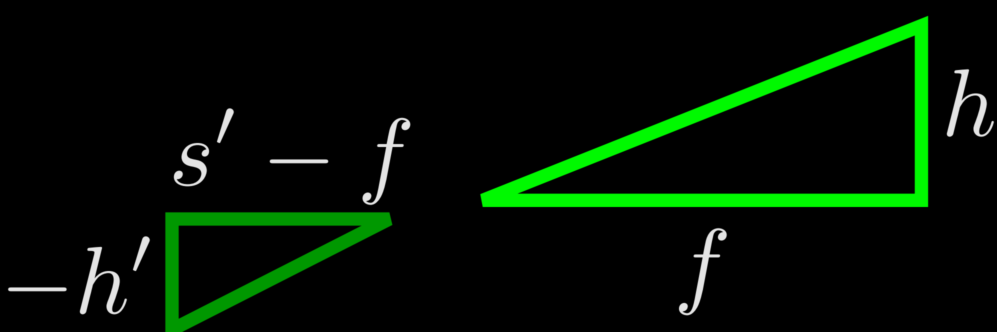
Mirror Equation

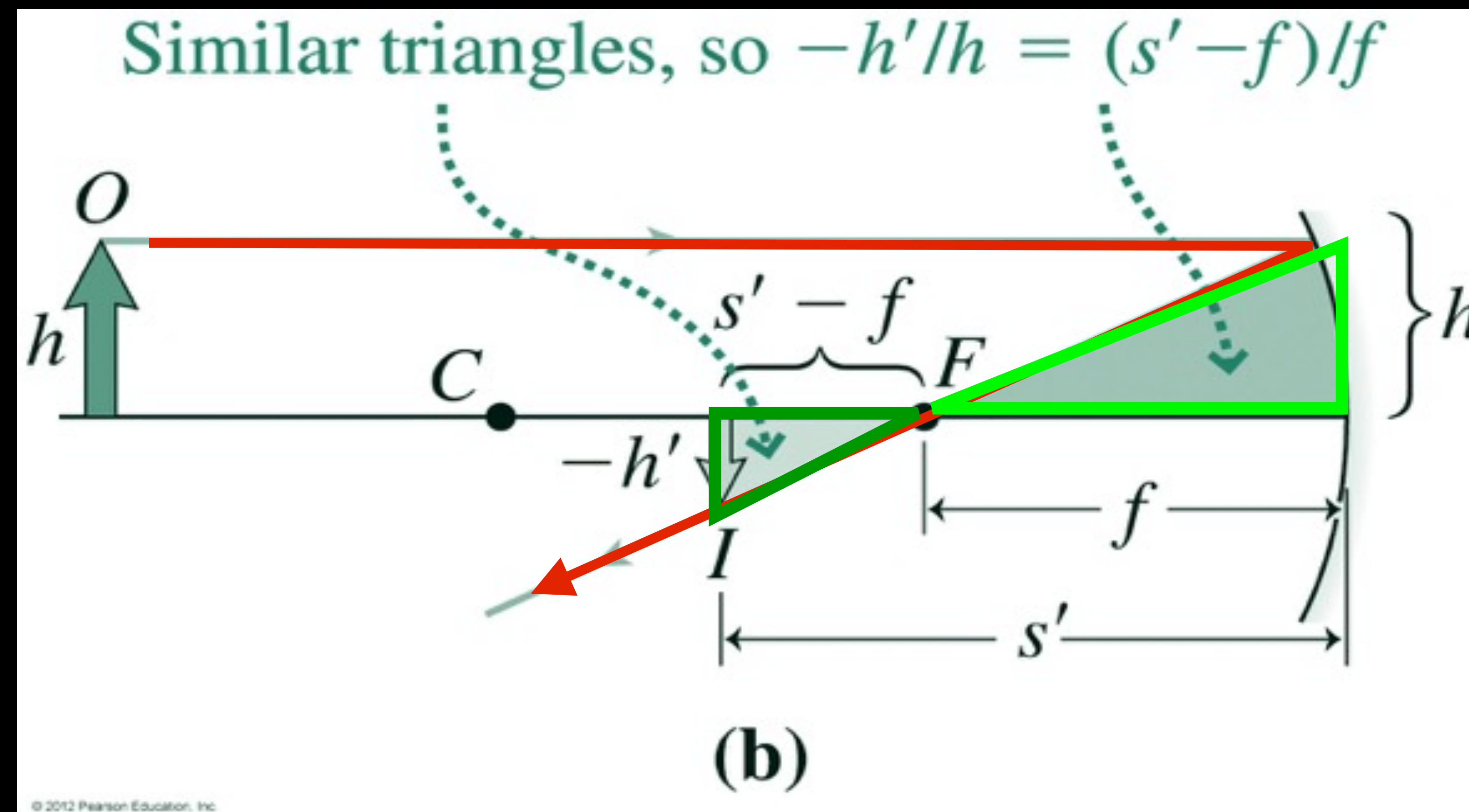
Drawing rays works....

... but can we be more accurate?

2 rays (type 1 & 3)

Similar triangles #2 :





$$-\frac{h'}{h} = \frac{(s'-f)}{f}$$

$M = h'/h = -s'/s$

$$\frac{s'}{s} = \frac{(s'-f)}{f}$$

$$\boxed{\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}}$$

mirror equation

Mirror Equation

Quiz

By drawing a ray through the centre of curvature (C), type 4

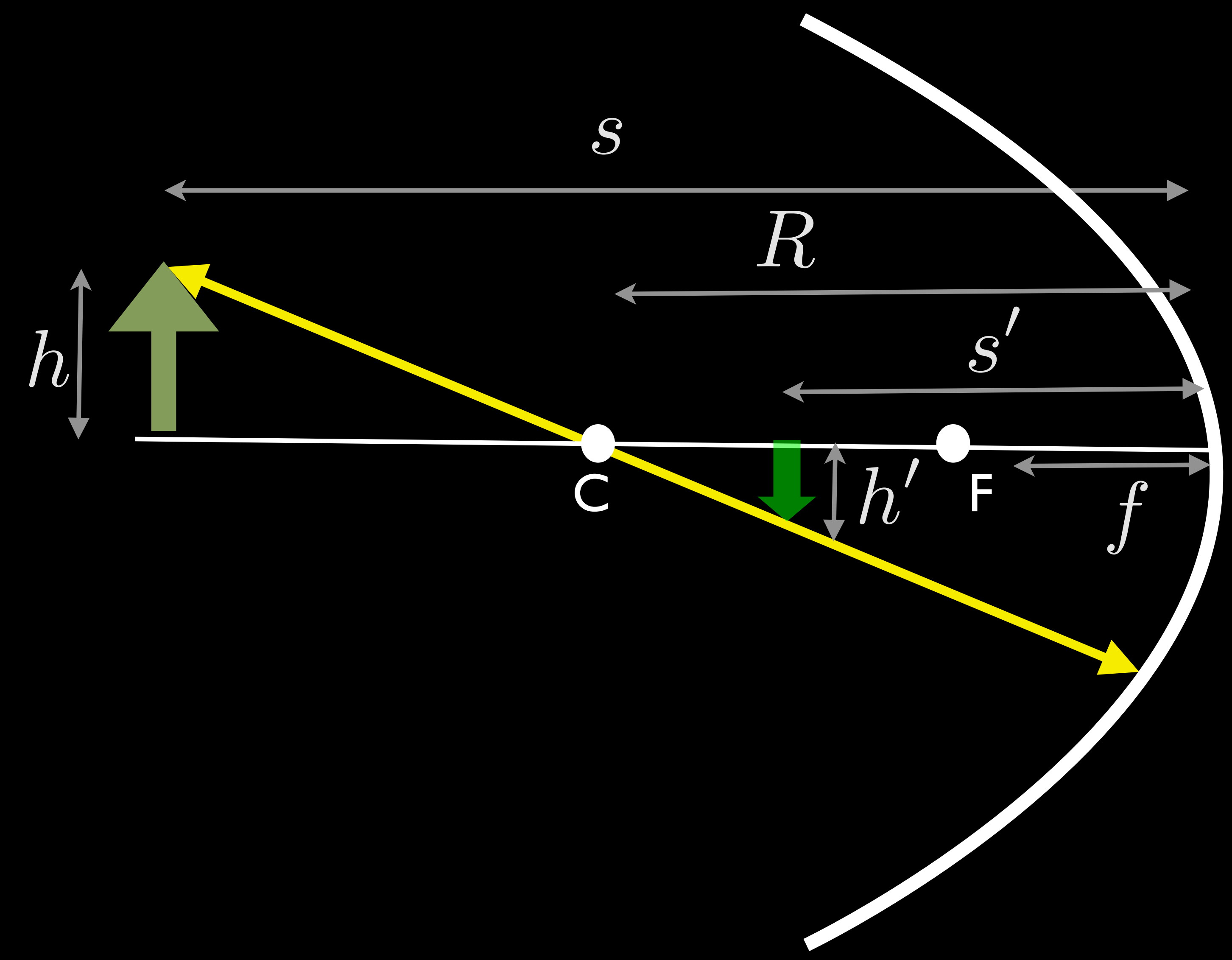
Find 3rd set of similar triangles and show:

(A) $|f| = \frac{R}{4}$

(B) $|f| = \frac{R}{2}$

(C) $|f| = R$

(D) $|f| = \frac{2R}{3}$

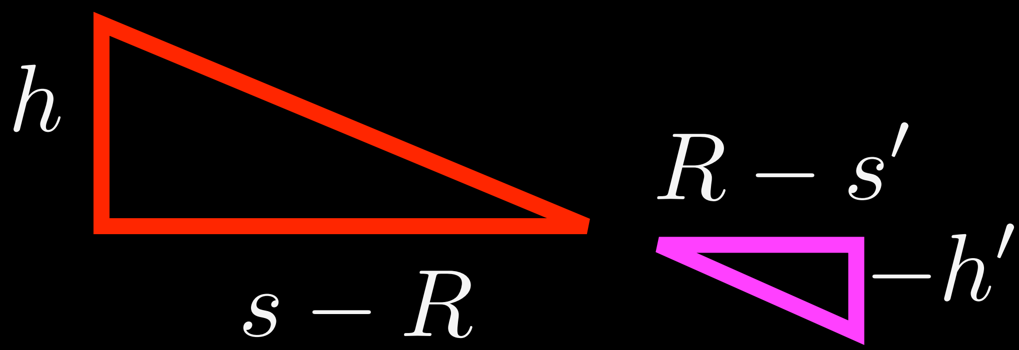


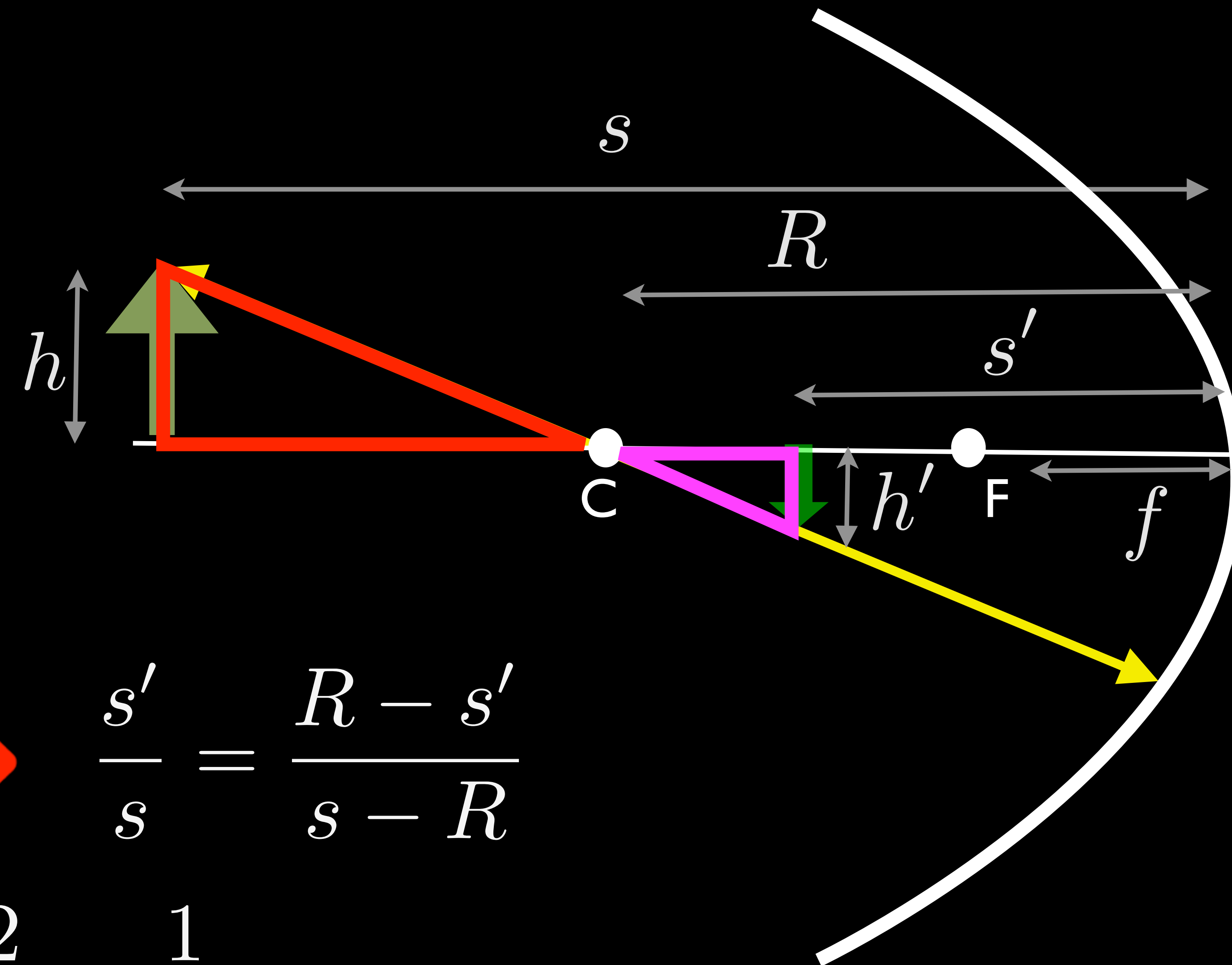
Mirror Equation

Quiz

By drawing a ray through the centre of curvature (C), type 4

Find 3rd set of similar triangles and show:





$$-\frac{h'}{h} = \frac{R - s'}{s - R}$$

since: $M = h'/h = -s'/s$ ➔ $\frac{s'}{s} = \frac{R - s'}{s - R}$

$$\frac{s - R}{s} = \frac{R - s'}{s'}$$ ➔ $$\frac{1}{s} = \frac{2}{R} - \frac{1}{s'}$$

Mirror Equation

By drawing a ray through the centre of curvature (C), type 4

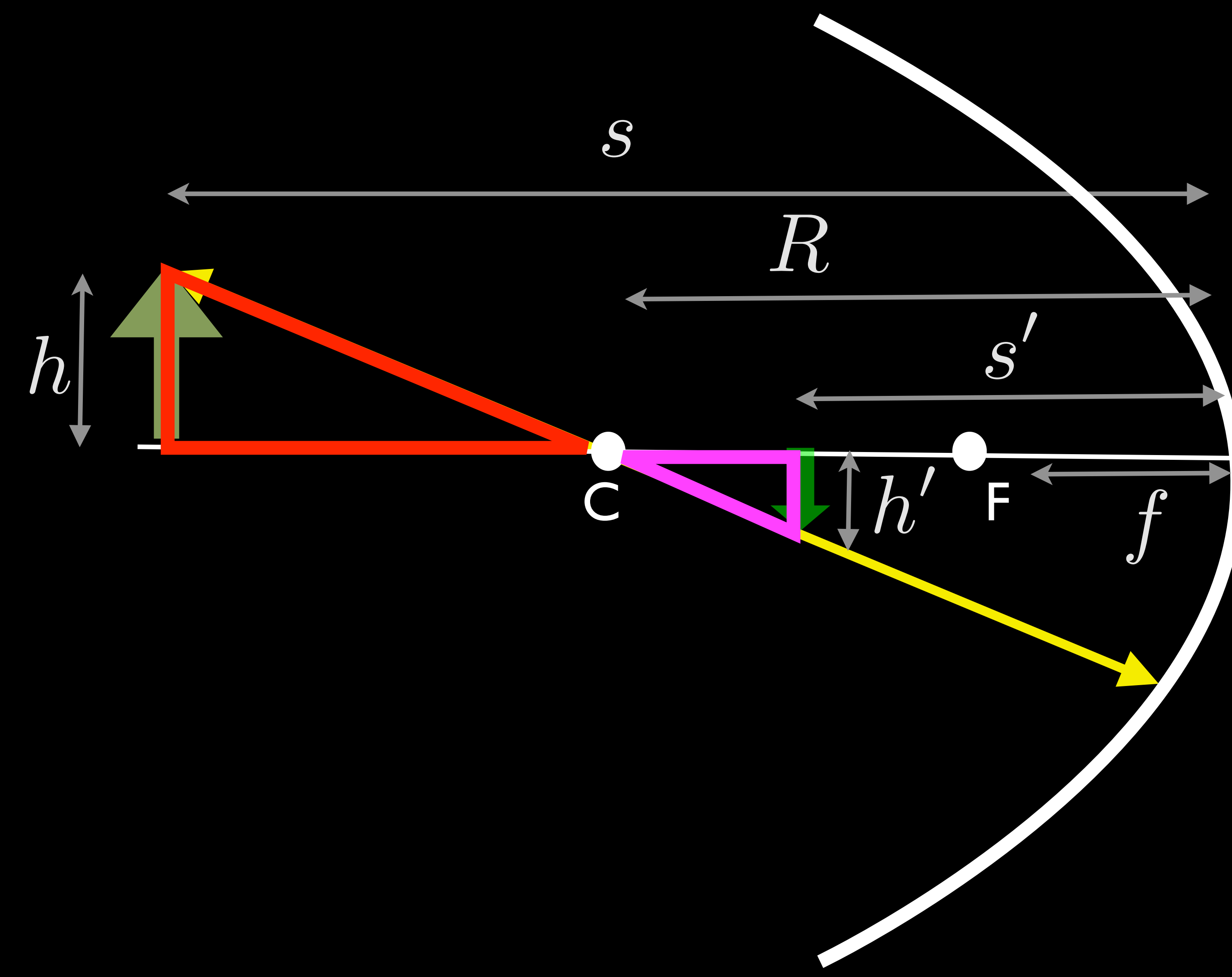
Find 3rd set of similar triangles and show:

$$\frac{1}{s} = \frac{2}{R} - \frac{1}{s'}$$

since: $$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$\left(\frac{2}{R} - \frac{1}{s'}\right) + \frac{1}{s'} = \frac{1}{f}$$

$$f = \frac{R}{2}$$

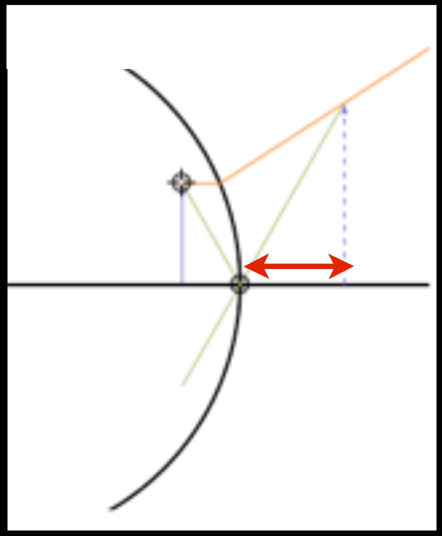


Mirror Equation

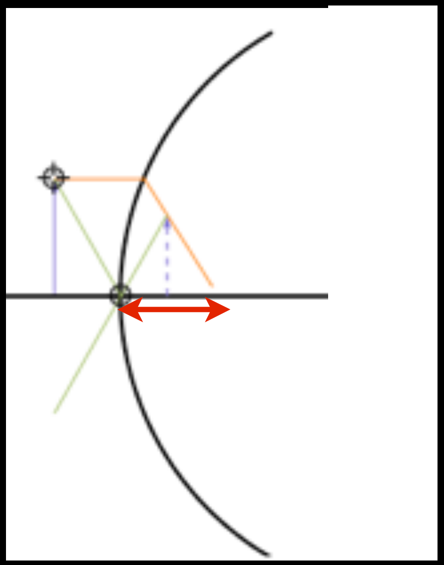
$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

If image is virtual: $s' < 0$

image distance is negative



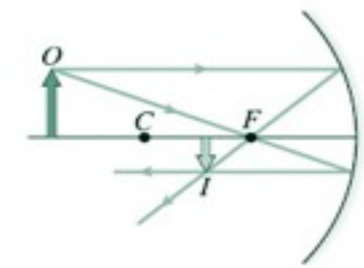
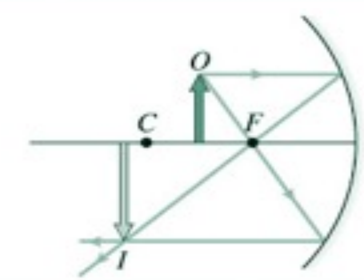
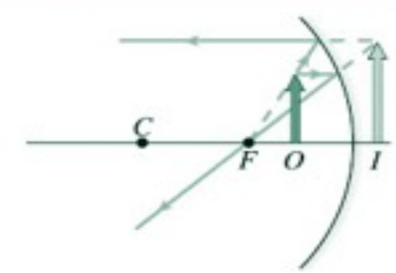
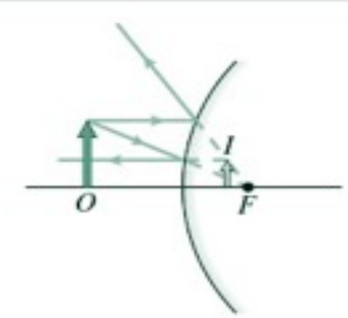
If mirror is convex: $f < 0$



Mirror Equation

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Table 31.1 Image Formation with Mirrors: Sign Conventions

Focal Length, f	Object Distance, s	Image Distance, s'	Type of Image	Ray Diagram
+ (concave)	+ (in front of mirror) $s > 2f$	+ (in front of mirror) $s' < 2f$	Real, inverted, reduced	
+ (concave)	+ (in front of mirror) $2f > s > f$	+ (in front of mirror) $s' > 2f$	Real, inverted, enlarged	
+ (concave)	+ (in front of mirror) $s < f$	− (behind mirror)	Virtual, upright, enlarged	
− (convex)	+ (in front of mirror)	− (behind mirror)	Virtual, upright, reduced	

Mirror Equation

A negative magnification for a mirror means that:

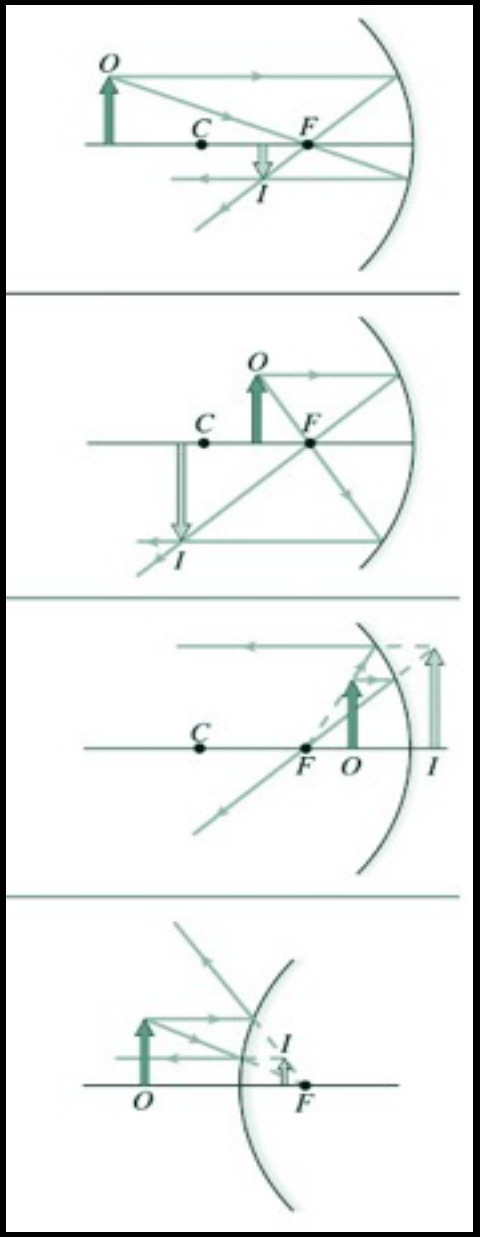
(A) the image is inverted, and the mirror is concave.

(B) the image is inverted, and the mirror is convex.

(C) the image is inverted, and the mirror may be convex or concave.

(D) the image is upright, and the mirror may be convex or concave.

(E) the image is upright, and the mirror is convex.



Mirror Equation

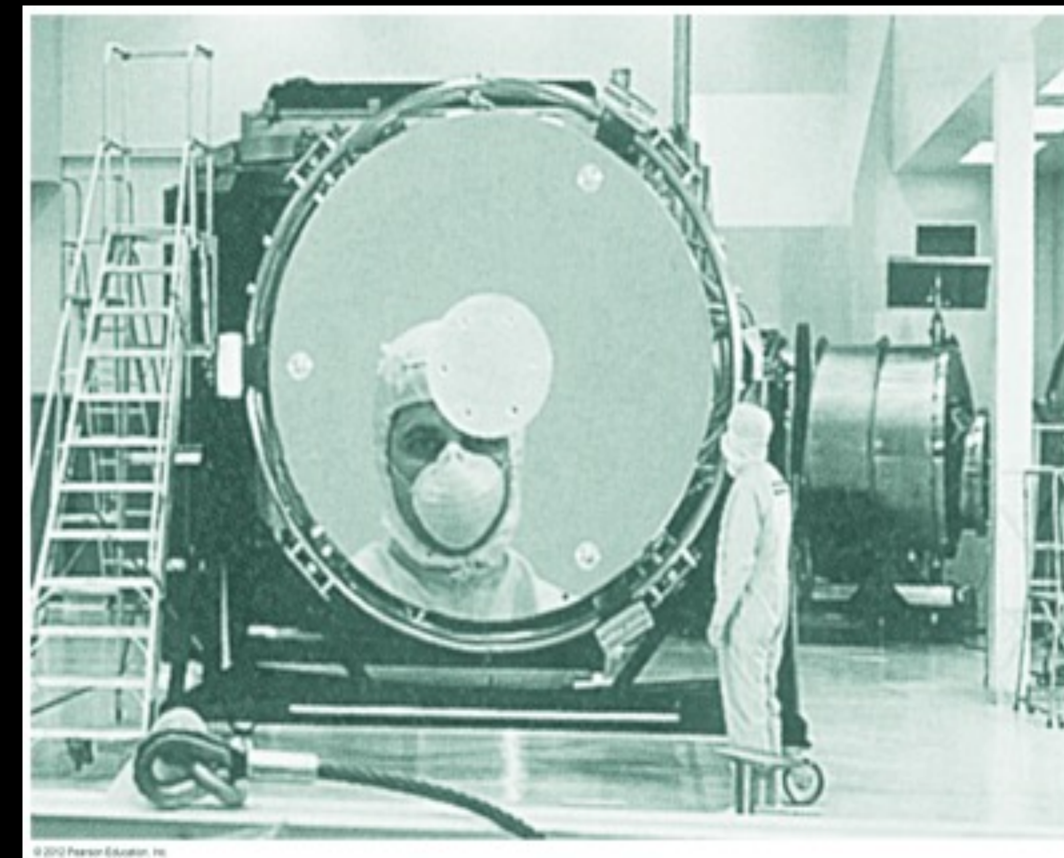
Example

The Hubble Space Telescope has a mirror with 5.52 m focal length.

A man stands 3.85 m in front of the mirror.

What is the (a) location

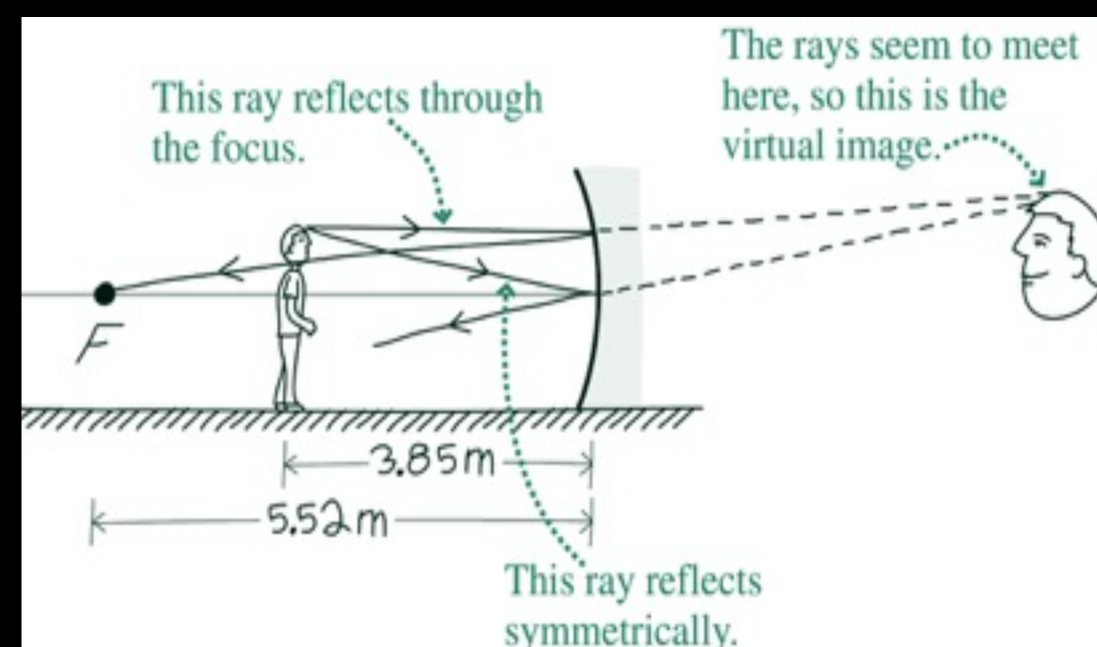
(b) magnification of the image?



mirror equation: $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

$$s' = \frac{fs}{s-f} = \frac{(5.52\text{m})(3.85\text{m})}{3.85\text{m} - 5.52\text{m}}$$

$$= -12.7\text{m}$$



Mirror Equation

Example

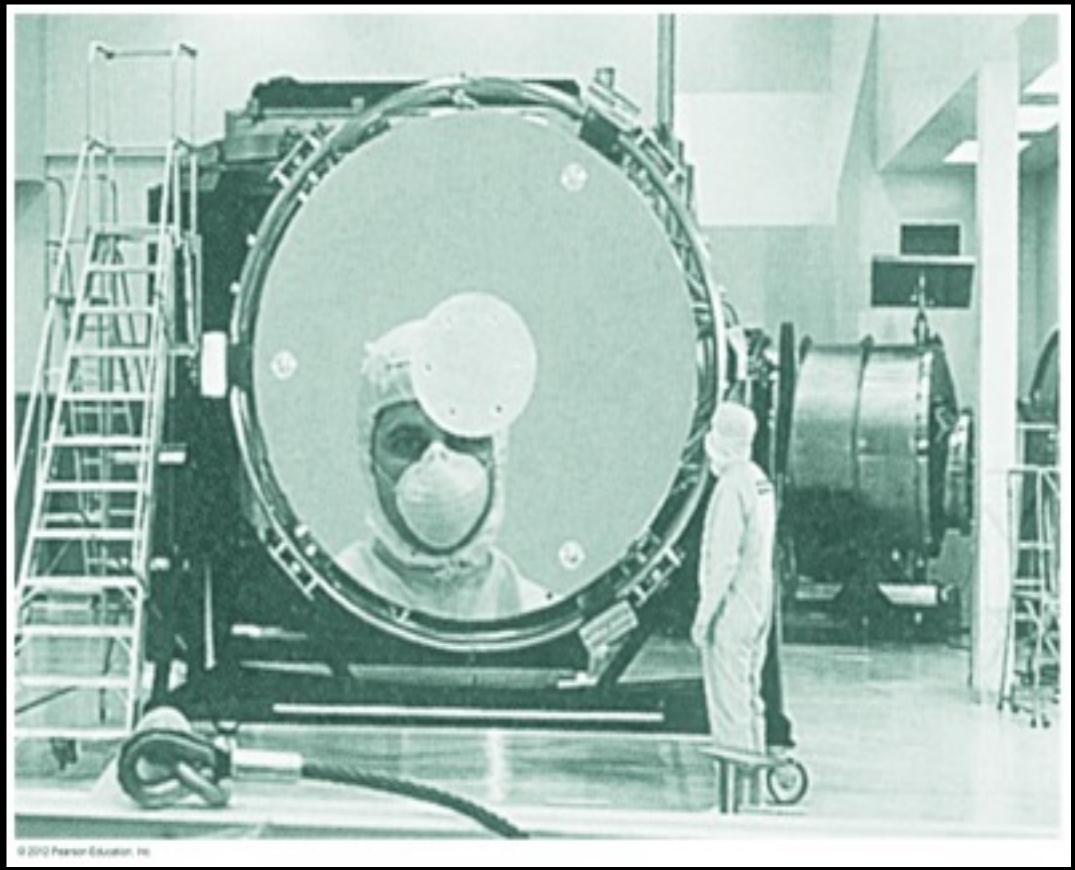
The Hubble Space Telescope has a mirror with 5.52 m focal length.

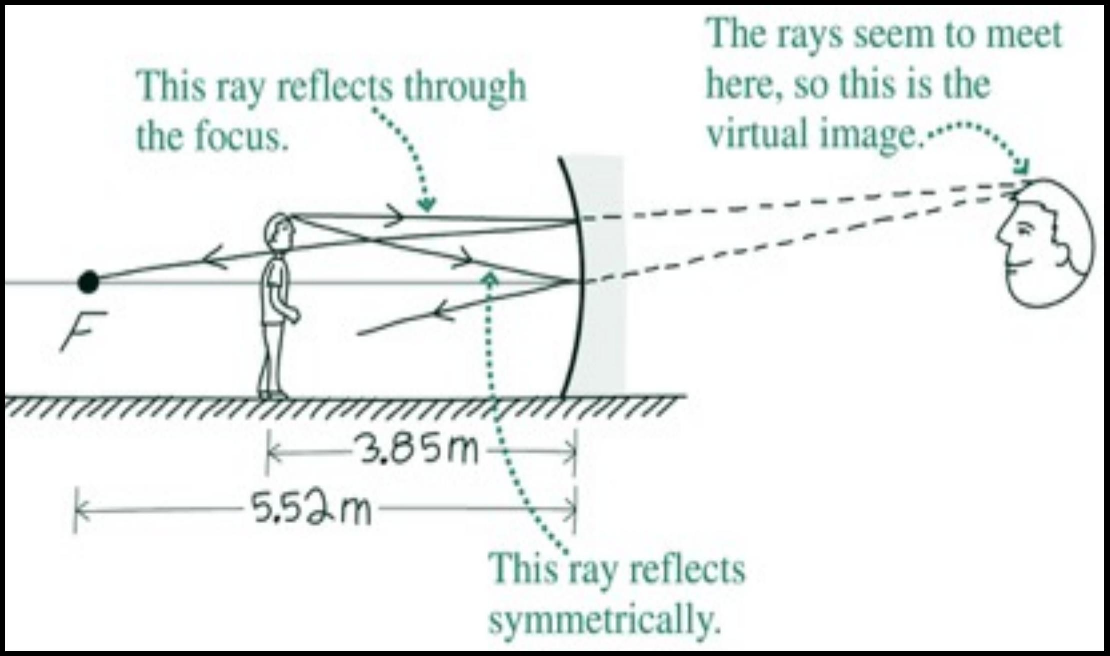
A man stands 3.85 m in front of the mirror.

What is the (a) location

(b) magnification of the image?

$$M = -\frac{s'}{s} = -\frac{-12.7\text{m}}{3.85\text{m}} = 3.30$$





Mirror Equation

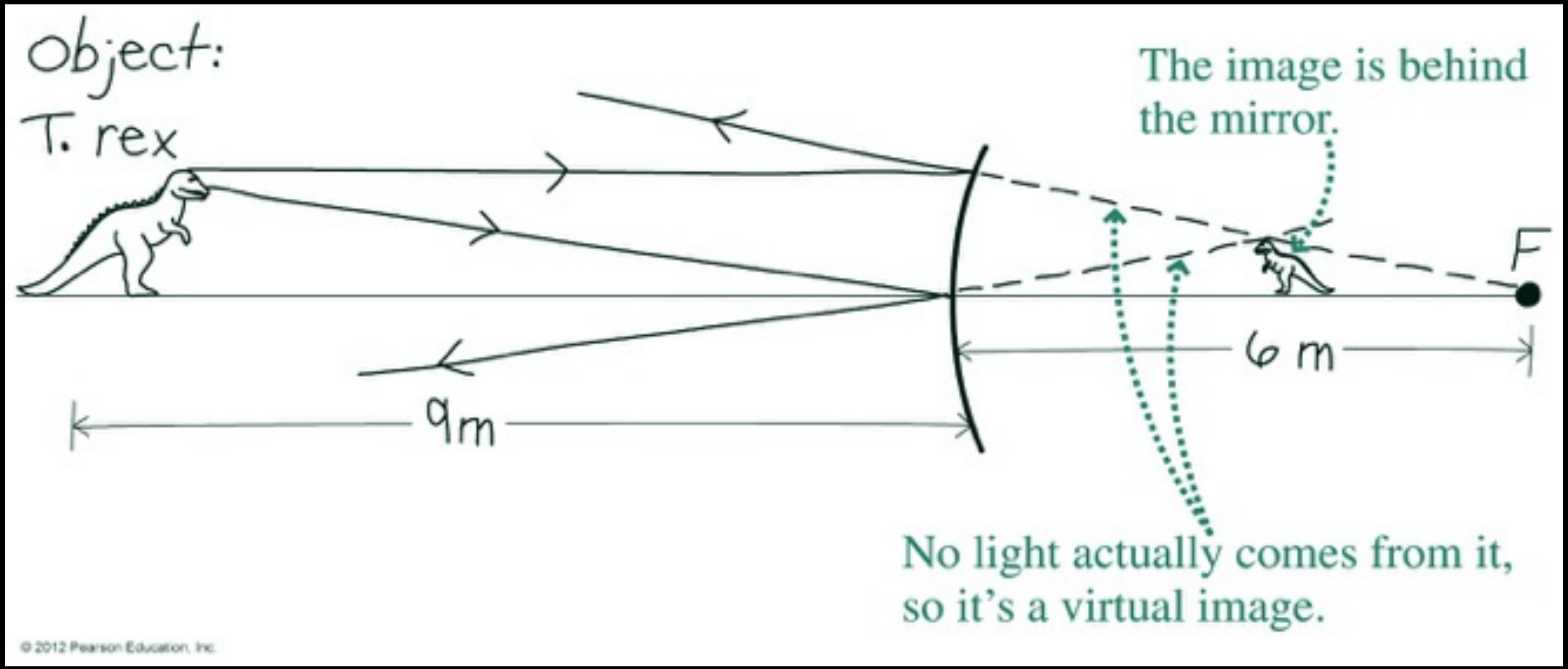
Example

Jurassic Park

OBJECTS IN MIRROR ARE CLOSER THAN THEY SEEM.

Mirror Equation

Example



If the mirror's curvature radius is 12 m and the T. rex is 9.0 m away, what is its magnification?

mirror equation: $$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad \Rightarrow \quad s' = \frac{fs}{s-f}$$

$$M = -\frac{s'}{s} = -\frac{fs/(s-f)}{s} = -\frac{f}{s-f}$$ and $$|f| = R/2 = -6.0\text{m}$$

$$= -\frac{(-6.0\text{m})}{9.0\text{m} - (-6.0\text{m})} = 0.4$$

40% of actual size, so seems to be further away.

Mirror Equation

Quiz

A virtual image is located 40 cm behind a concave (parabolic) mirror with focal length 18 cm.

Where is the object?

(A) 22cm

(B) -22cm

(C) 12cm

(D) -12cm

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$s = \frac{f\,s'}{(s' - f)} = \frac{(18\text{cm})(-40\text{cm})}{-58\text{cm}} = 12\text{cm}$$

Mirror Equation

A virtual image is located 40 cm behind a concave (parabolic) mirror with focal length 18 cm.

By how much is it magnified?

(A) 2.2

(B) 1.5

(C) 0.3

(D) 3.3

$$s = \frac{fs'}{(s' - f)} = \frac{(18\text{cm})(-40\text{cm})}{-58\text{cm}} = 12\text{cm}$$

$$M = -\frac{s'}{s} = \frac{40\text{cm}}{12\text{cm}} = 3.3$$

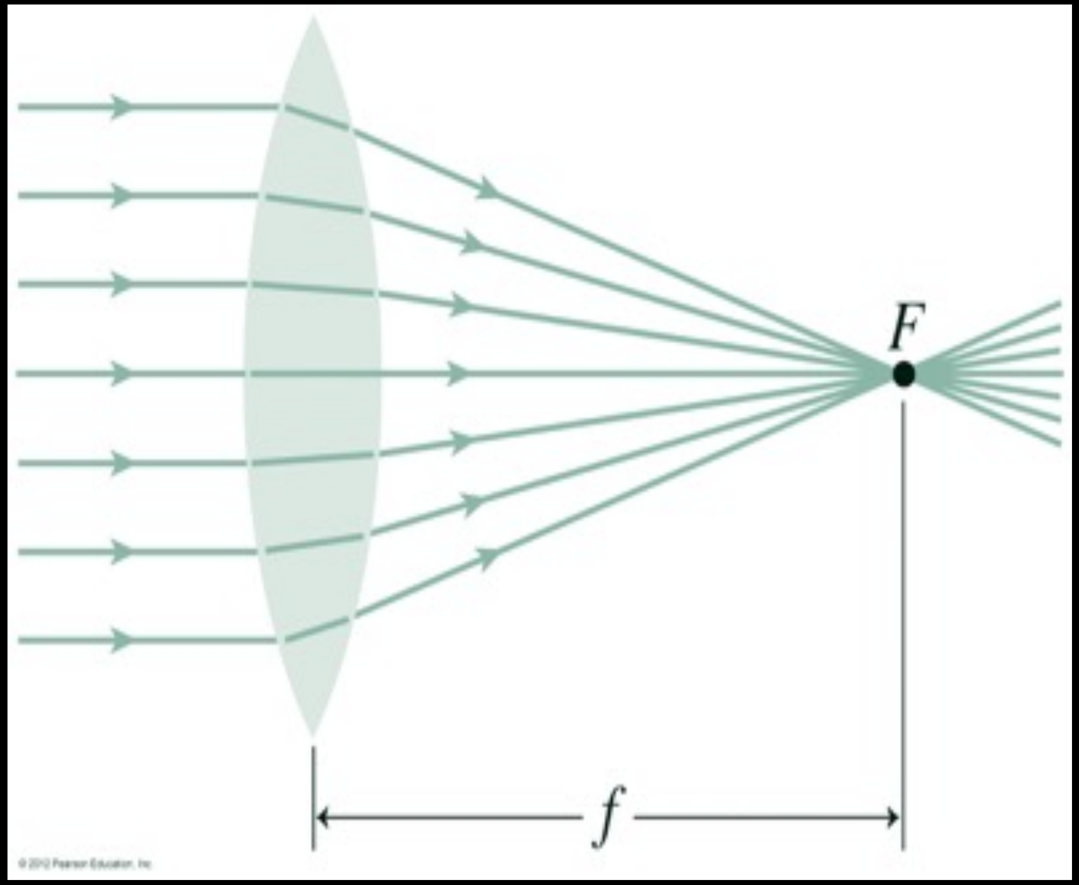
Lenses

Lenses

A lens uses refraction to form images.

Converging lens

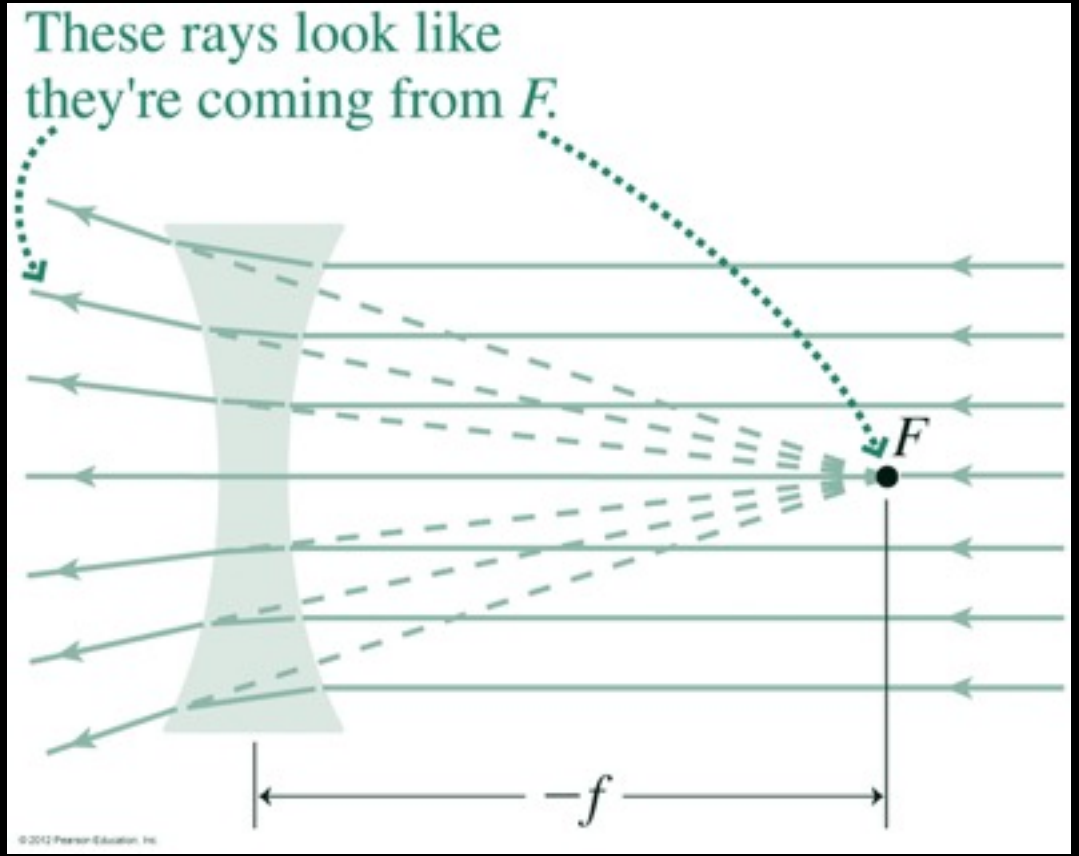
Convex lens that focusses parallel rays to the focal point



Diverging lens

Concave lens: parallel rays seem to move away from a common focus.

Only forms virtual images.



Because lenses refract, not reflect, this is *opposite* to mirrors.

Lenses

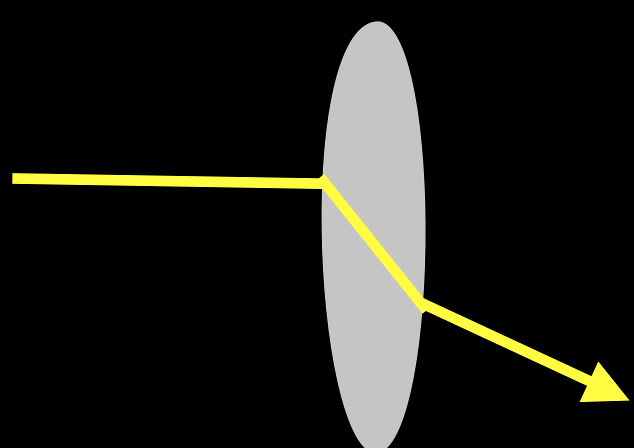
Thin lens approximation

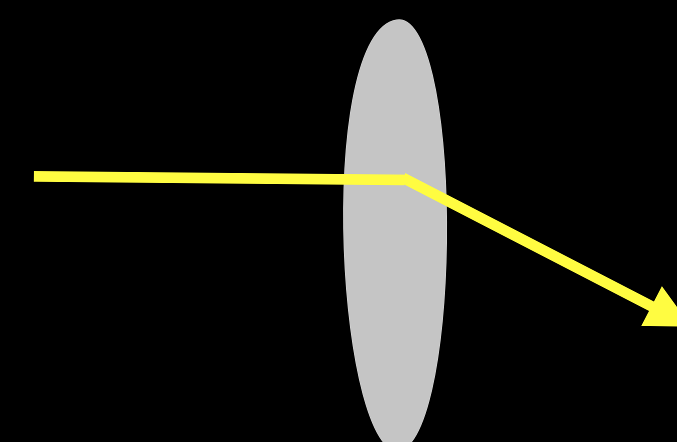
Thickness << curvature radius

Although the ray refracts twice
(as it enters lens and as it exits)

thin lens

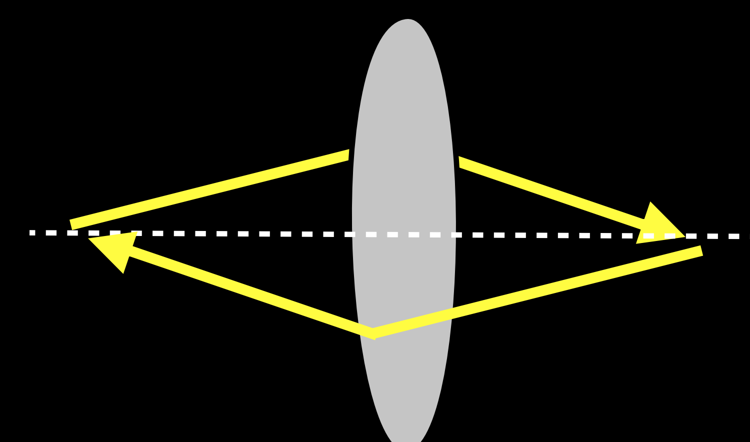
single refraction





Rays can pass through a lens in 2 directions

Focal length is the same both sides.

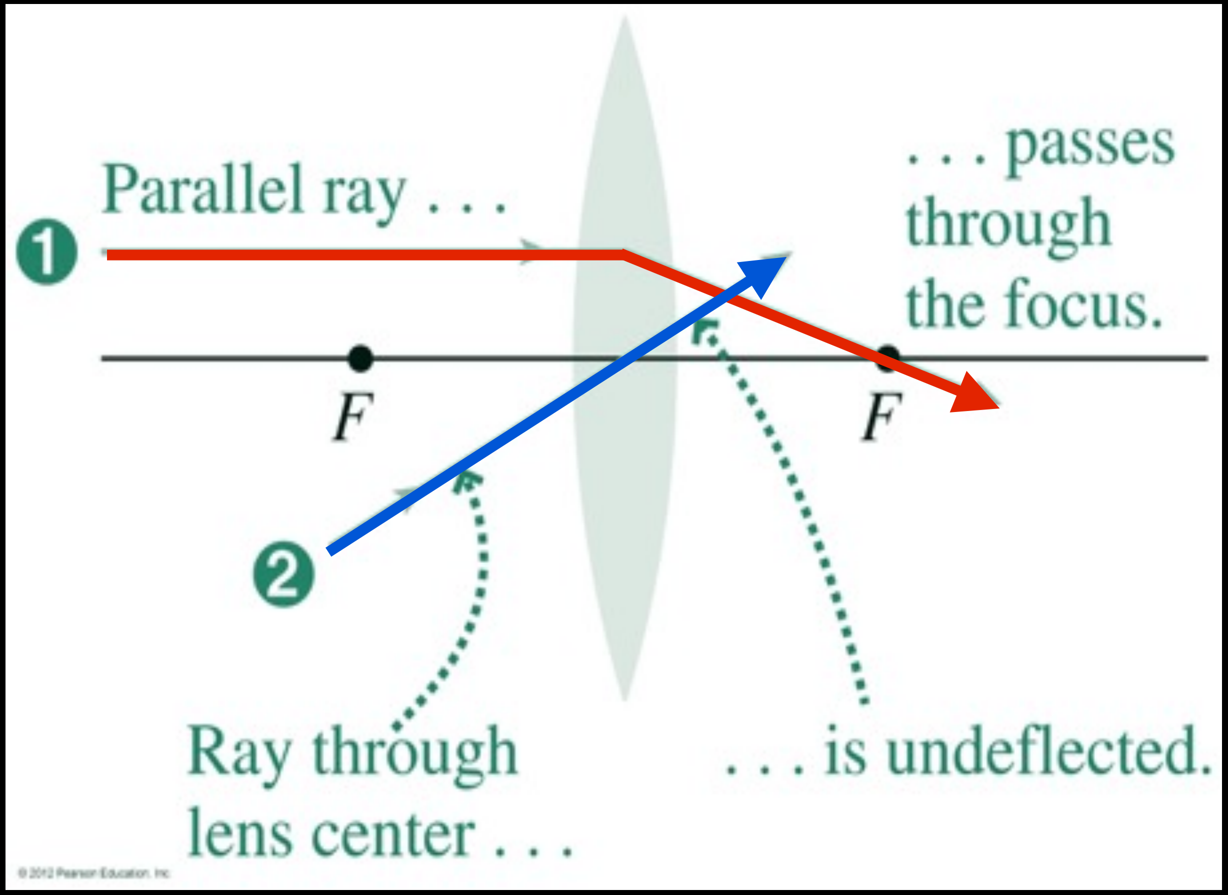


Lenses

Ray through lenses

(1) Ray parallel to lens axis reflects through the focal point.

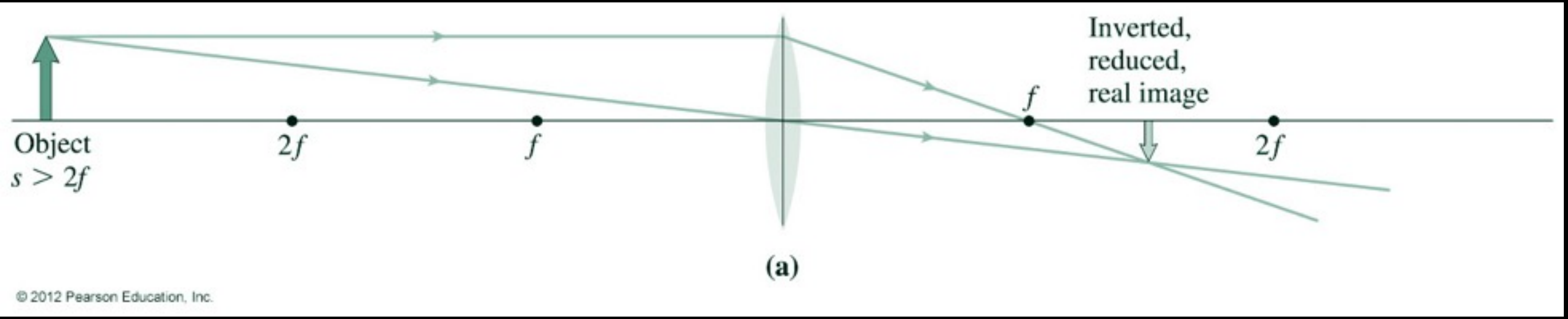
(2) Ray passing through the centre travels straight.



Use these two rays to find images formed with lenses.

Lenses

Examples



Object further than two focal lengths, $s > 2f$

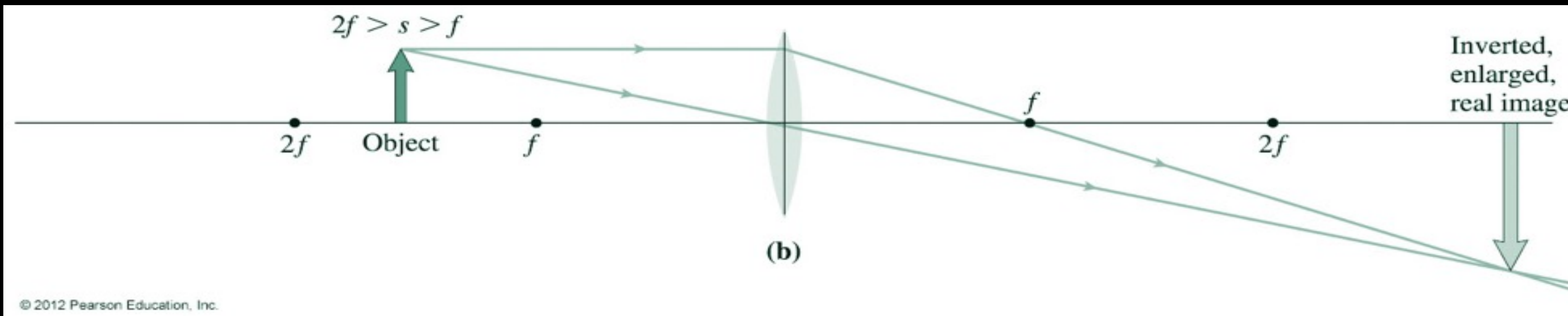
Image smaller and inverted.

Light rays come from the image: real image

(do not need to look through lens to see images)

Lenses

Examples: approach the lens

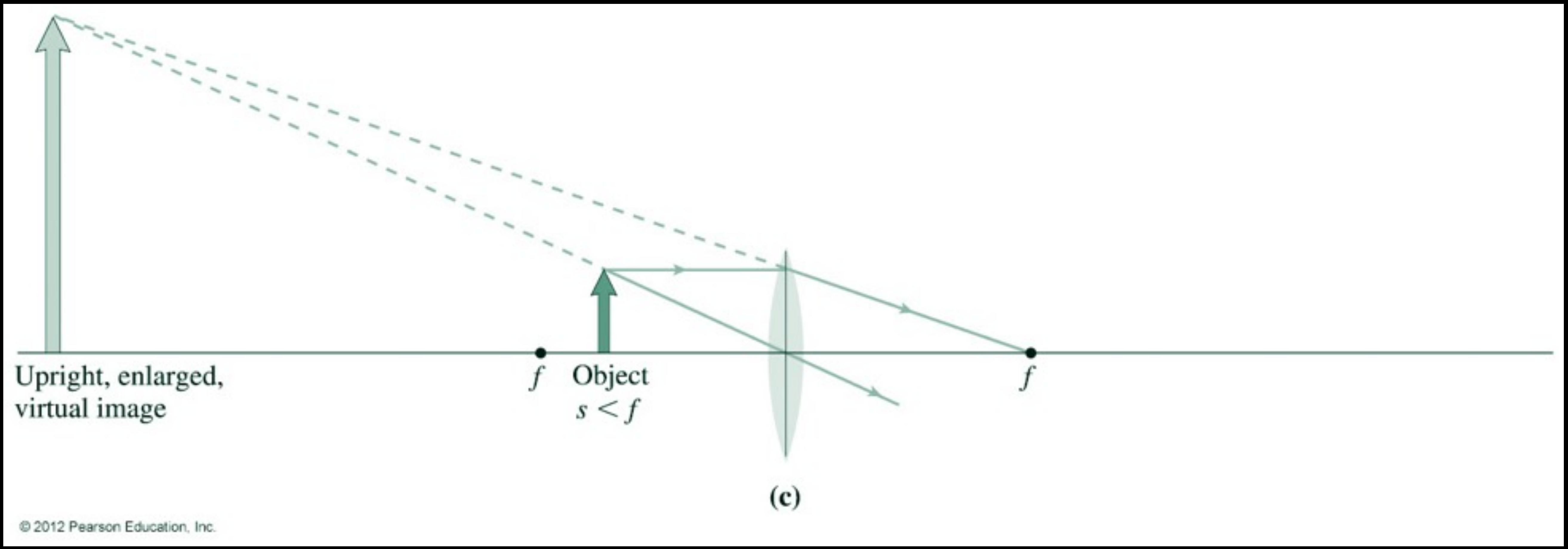


Distance to image gets larger.

Image becomes larger.

Lenses

Examples: approach the lens

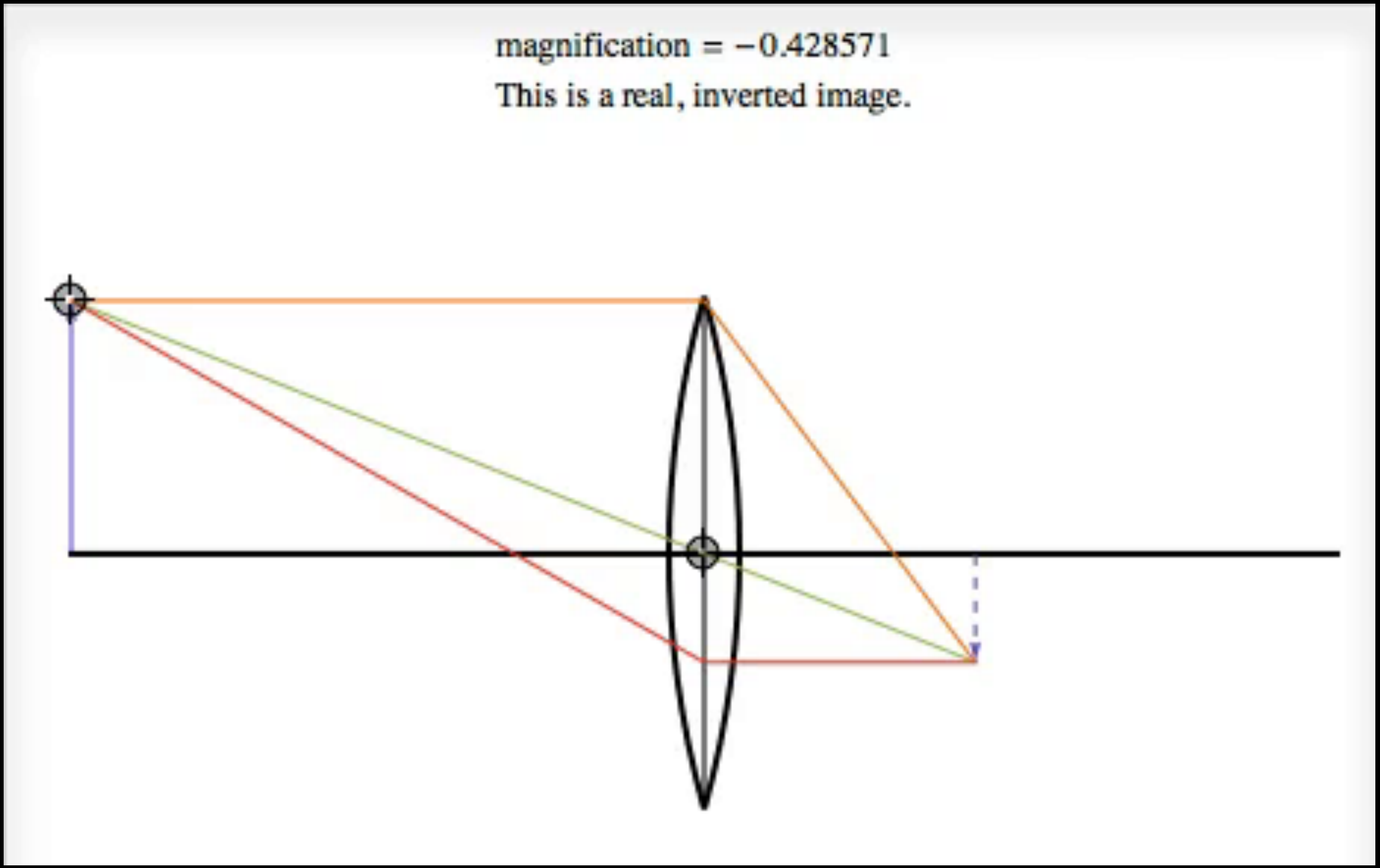


Object closer than focal length, $s < f$

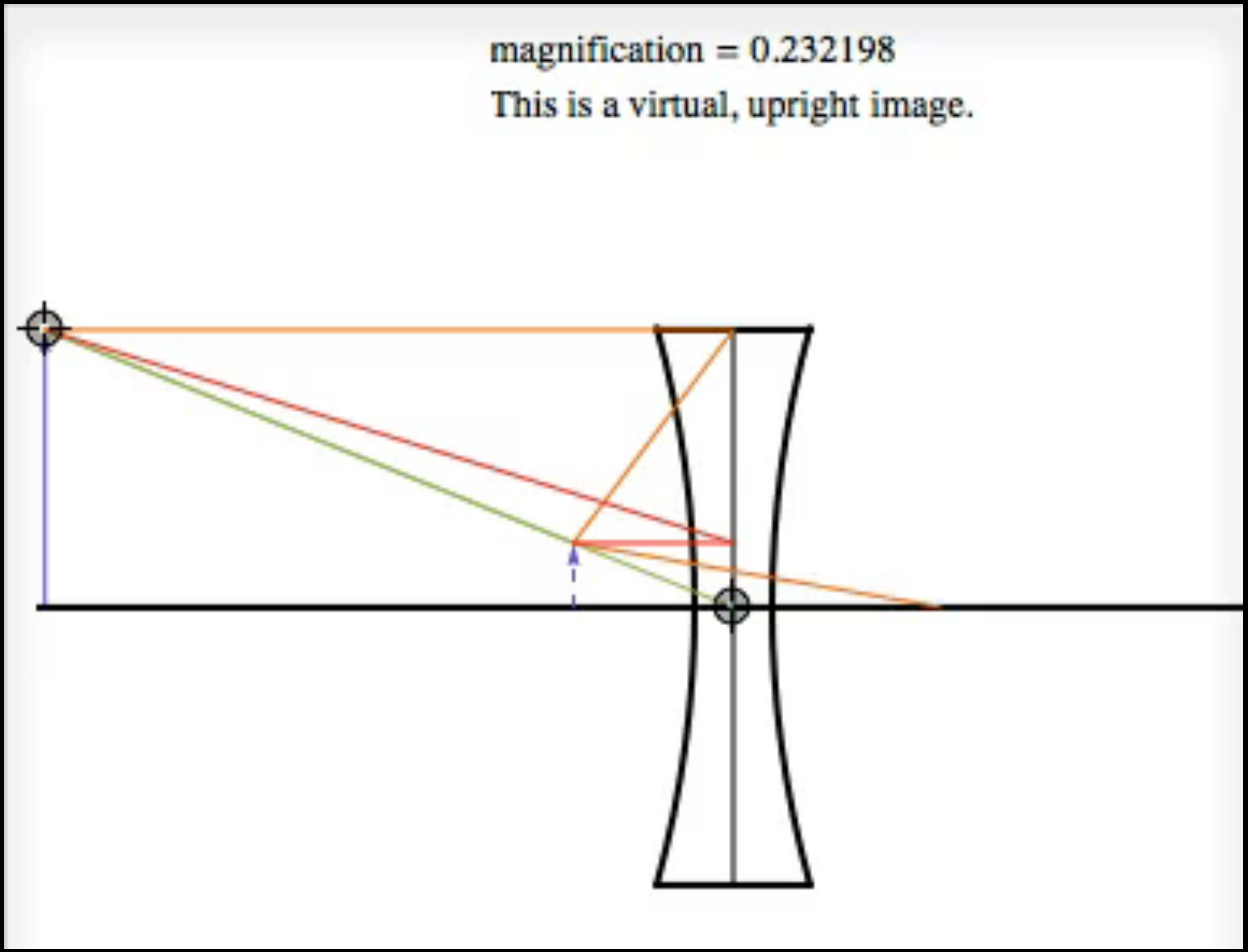
Image large and *virtual*: rays do not come from image

Can only be seen looking *through* the lens.

Lenses



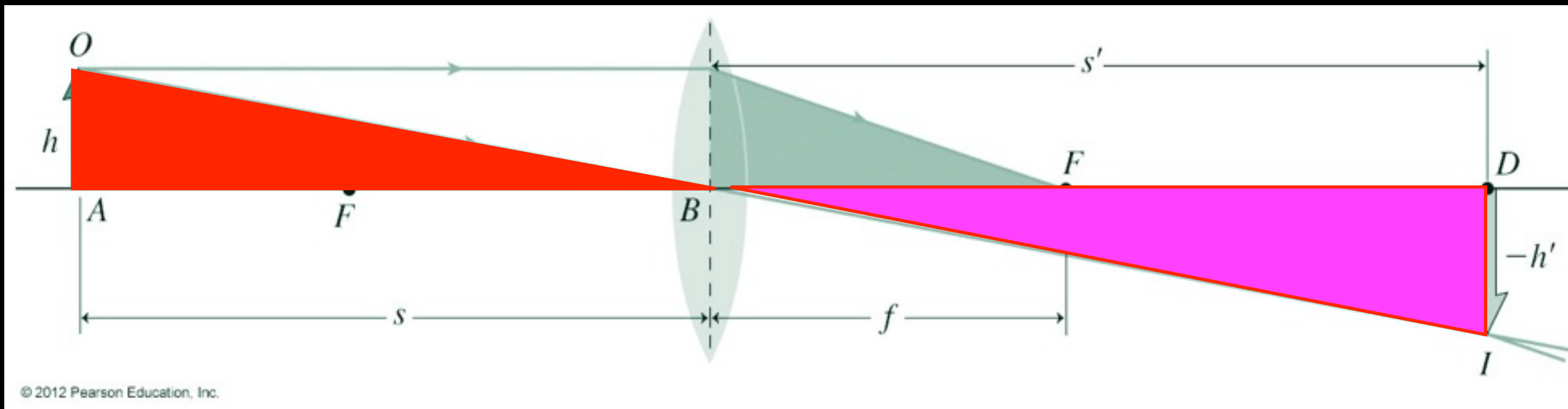
Lenses

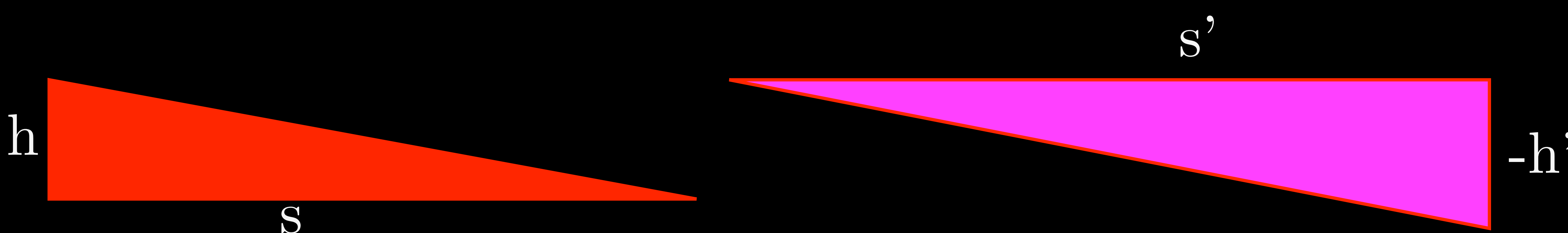


Concave (diverging) lens always forms a smaller, upright image.

Only visible through the lens.

The lens equation

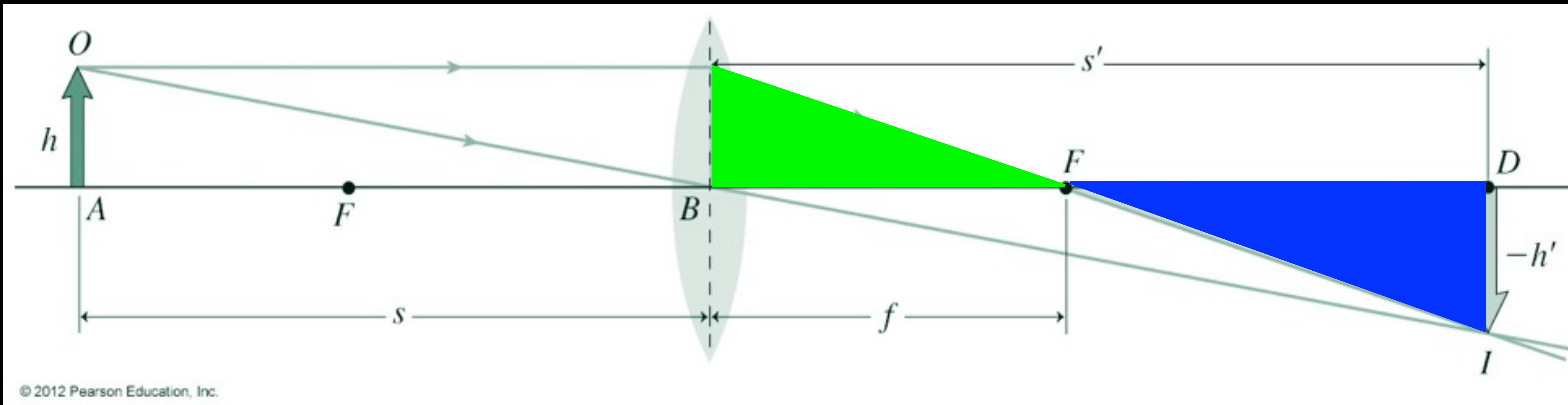


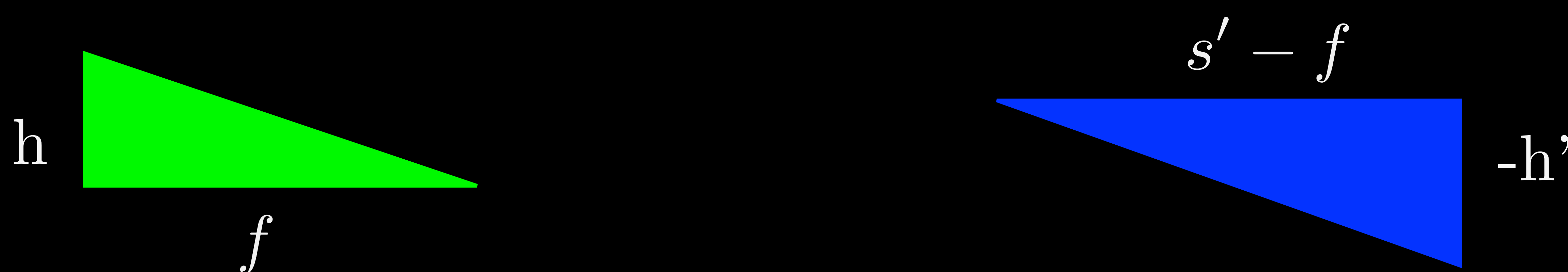


Similar triangles: $M = \frac{h'}{h} = -\frac{s'}{s}$ Magnification

(same as mirrors)

The lens equation



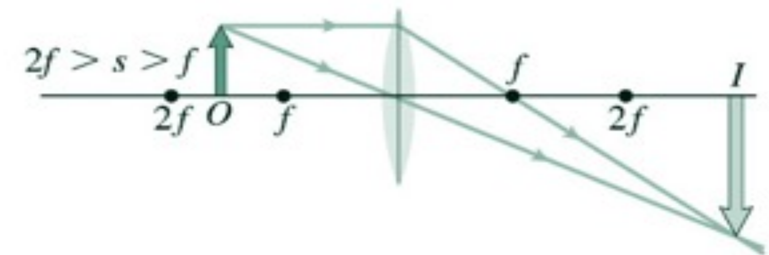
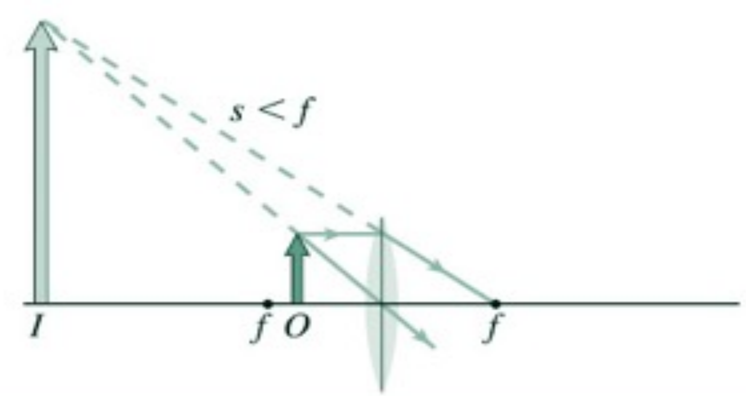


Similar triangles #2: $$\frac{-h'}{s'-f} = \frac{h}{f}$$

$$\boxed{\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}}$$ lens equation (same as mirror equation)

The lens equation

Table 31.2 Image Formation with Lenses: Sign Conventions

Focal Length, f	Object Distance, s	Image Distance, s'	Type of Image	Ray Diagram
+ (convex)	+ $s > 2f$	+ (opposite side of lens) $2f > s' > f$	Real, inverted, reduced	
+ (convex)	+ $2f > s > f$	+ (opposite side of lens) $s' > 2f$	Real, inverted, enlarged	
+ (convex)	+ $s < f$	− (same side of lens)	Virtual, upright, enlarged	
− (concave)	+	− (same side of lens)	Virtual, upright, reduced	

The lens equation

Quiz

You look through a lens at a page and see the words enlarged and right side up. Is the image and lens:

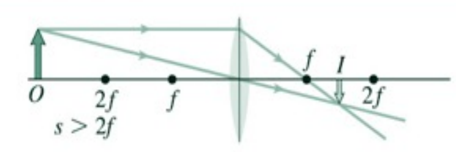
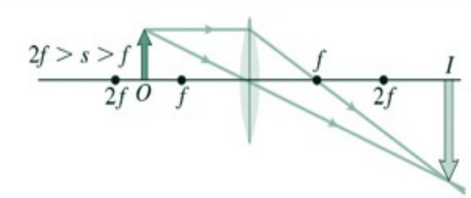
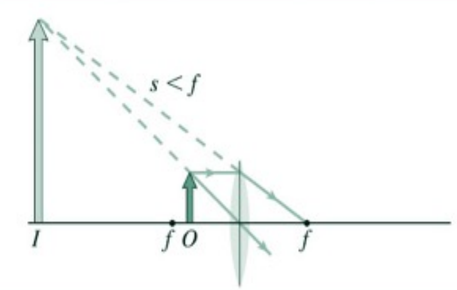
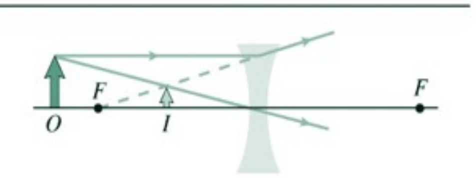
(A) real, concave

(B) real, convex

(C) virtual, concave

(D) virtual, convex

Table 31.2 Image Formation with Lenses: Sign Conventions

Focal Length, f	Object Distance, s	Image Distance, s'	Type of Image	Ray Diagram
+ (convex)	+ $s > 2f$	+ (opposite side of lens) $2f > s' > f$	Real, inverted, reduced	
+ (convex)	+ $2f > s > f$	+ (opposite side of lens) $s' > 2f$	Real, inverted, enlarged	
+ (convex)	+ $s < f$	− (same side of lens)	Virtual, upright, enlarged	
− (concave)	+	− (same side of lens)	Virtual, upright, reduced	

The lens equation

Example

You use a magnifying glass with a 30-cm focal length to read.

How far from the page should you hold the lens to see the print enlarge 3 x?

$$M = -\frac{s'}{s} = 3 \quad \Rightarrow \quad s' = -3s$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{s} - \frac{1}{3s} = \frac{2}{3s} = \frac{1}{f} = \frac{1}{30\text{cm}}$$

$$s = \frac{(2)(30\text{cm})}{3} = 20\text{cm}$$

The lens equation

A lightbulb is 56 cm from a convex lens. Its image appears on the screen 31 cm from the lens, on the opposite side.

What is the lens's focal length?

(A) 0.05cm

$$f^{-1} = s^{-1} + s'^{-1} = (56\text{cm})^{-1} + (31\text{cm})^{-1}$$

(B) 87cm

(C) 20cm

(D) 40cm

The lens equation

A real image is 4 x as far from the lens as the object is from the lens.

What's the object's distance?

(A) $s = \frac{5f}{4}$

(B) $s = \frac{4}{f}$

(C) $s = \frac{1}{4f}$

(D) $s = \frac{1f}{5}$

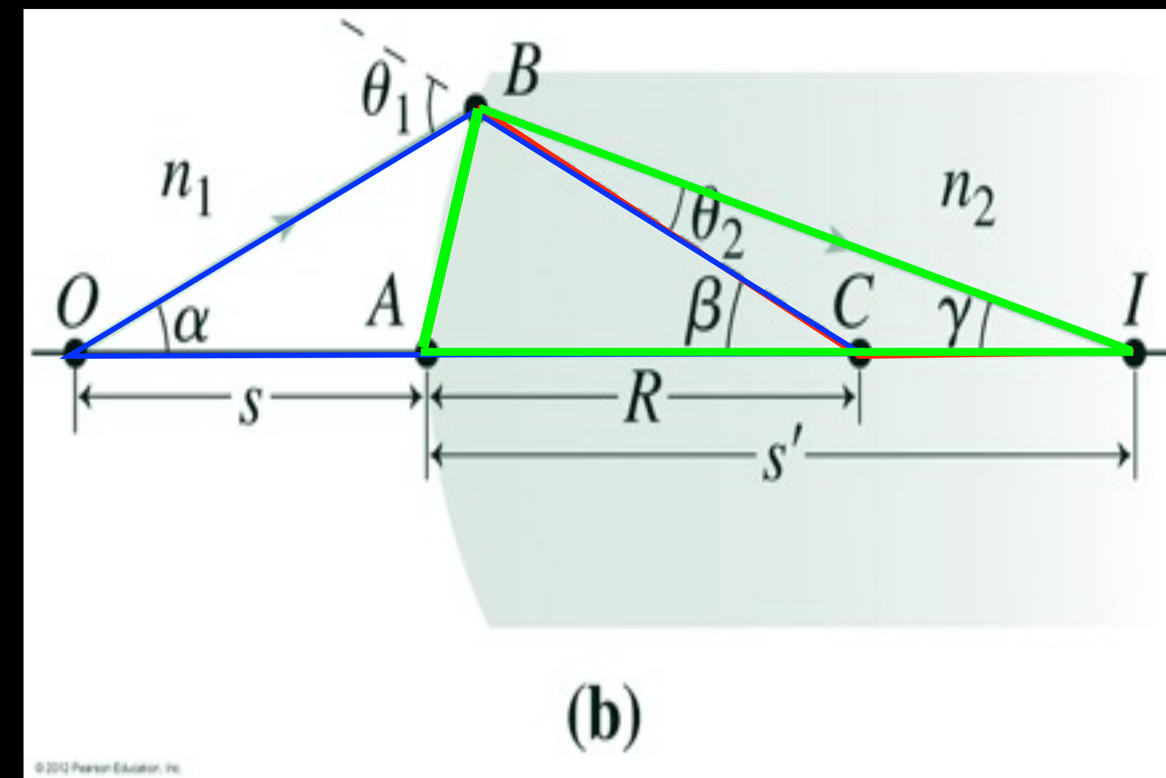
$$\frac{1}{f} = \frac{1}{s} + \frac{1}{4s} = \frac{5}{4s}$$

$$s = \frac{5f}{4}$$

Refraction in Lenses

What is the lens isn't 'thin'?

Path of a single ray



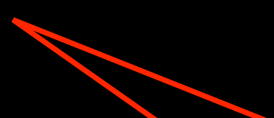
(b)

Assume rays make small angles with axis

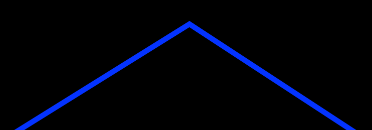
$$\sin x \simeq \tan x \simeq x$$

(paraxial approximation)

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \Rightarrow n_1\theta_1 = n_2\theta_2$$



$$\theta_2 = \beta - \gamma$$



$$\theta_1 = \alpha + \beta$$

$$n_1(\alpha + \beta) = n_2(\beta - \gamma)$$

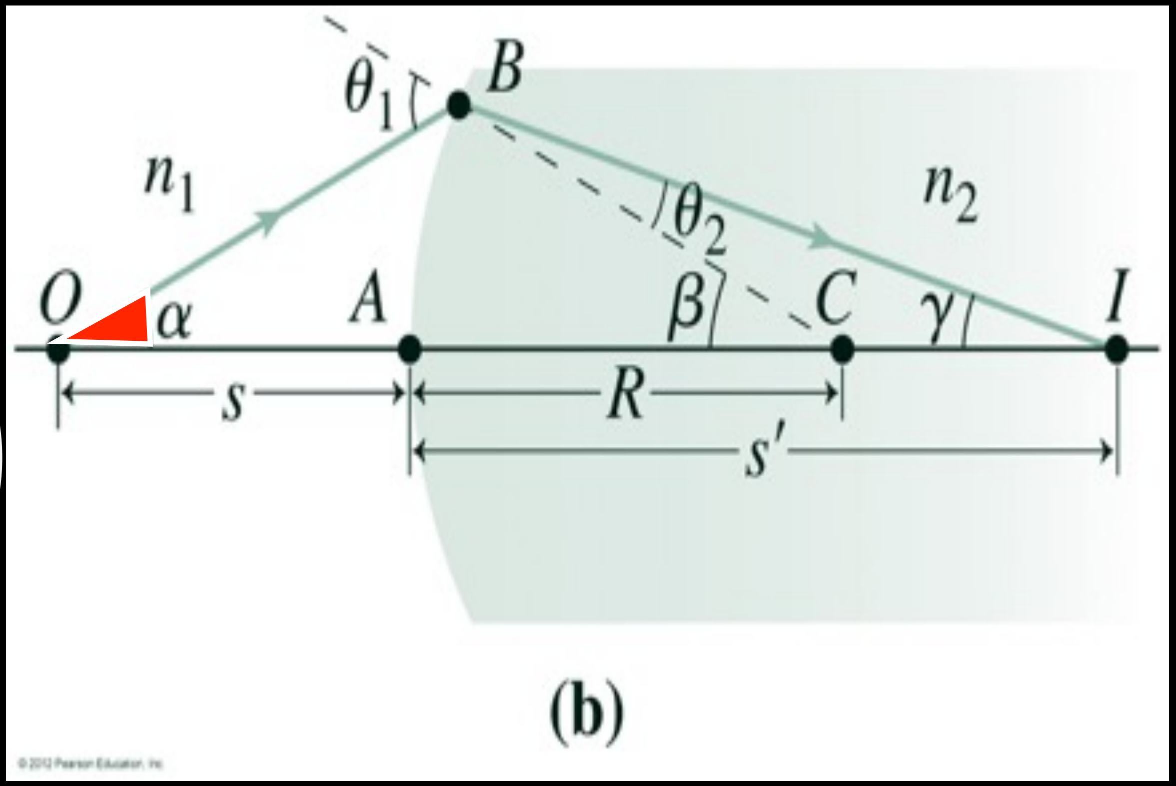
B A ~ straight line: $\alpha \simeq \tan\alpha \simeq BA/s$ and $\beta \simeq BA/R$

$\gamma \simeq BA/s'$

Refraction in Lenses

$$n_1(\alpha+\beta) = n_2(\beta-\gamma)$$

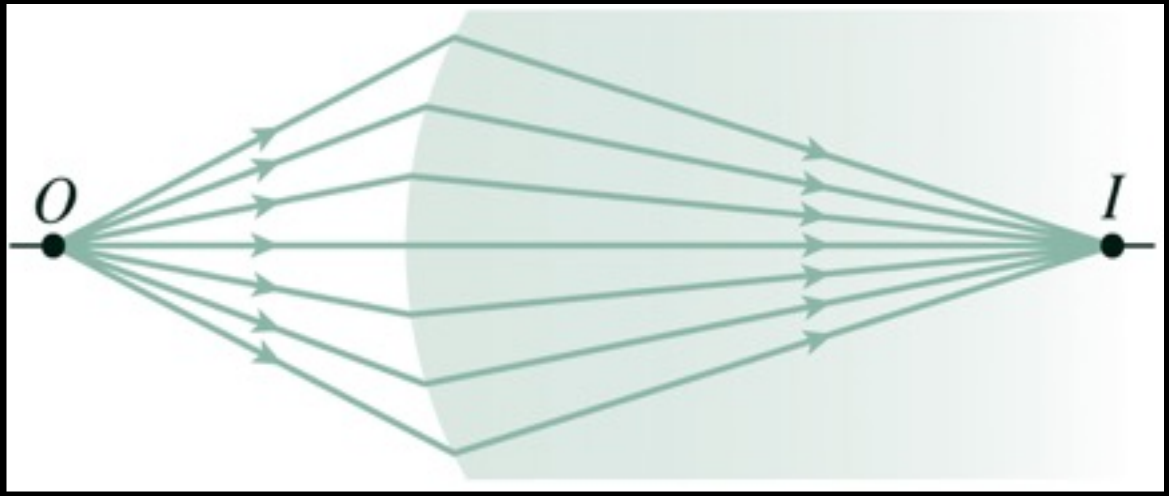
$$n_1\left(\frac{BA}{s}+\frac{BA}{R}\right) = n_2\left(\frac{BA}{R}-\frac{BA}{s'}\right)$$



Rearranging: $$\frac{n_1}{s}+\frac{n_2}{s'} = \frac{n_2-n_1}{R}$$

Angle of ray α , not in equation

True for ALL rays.



All rays from object focus onto a single point, I.

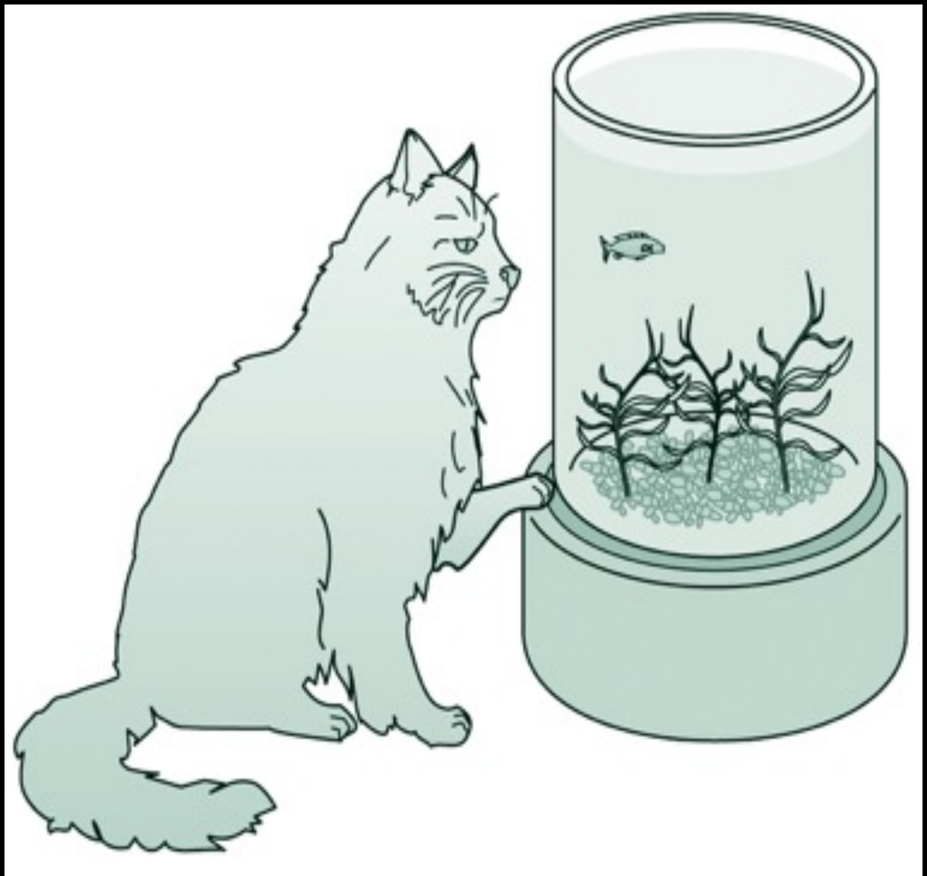
Refraction in Lenses

Example

A fish tank is a thin-walled plastic tube, 70 cm in diameter.

(cylinder of water = thick lens)

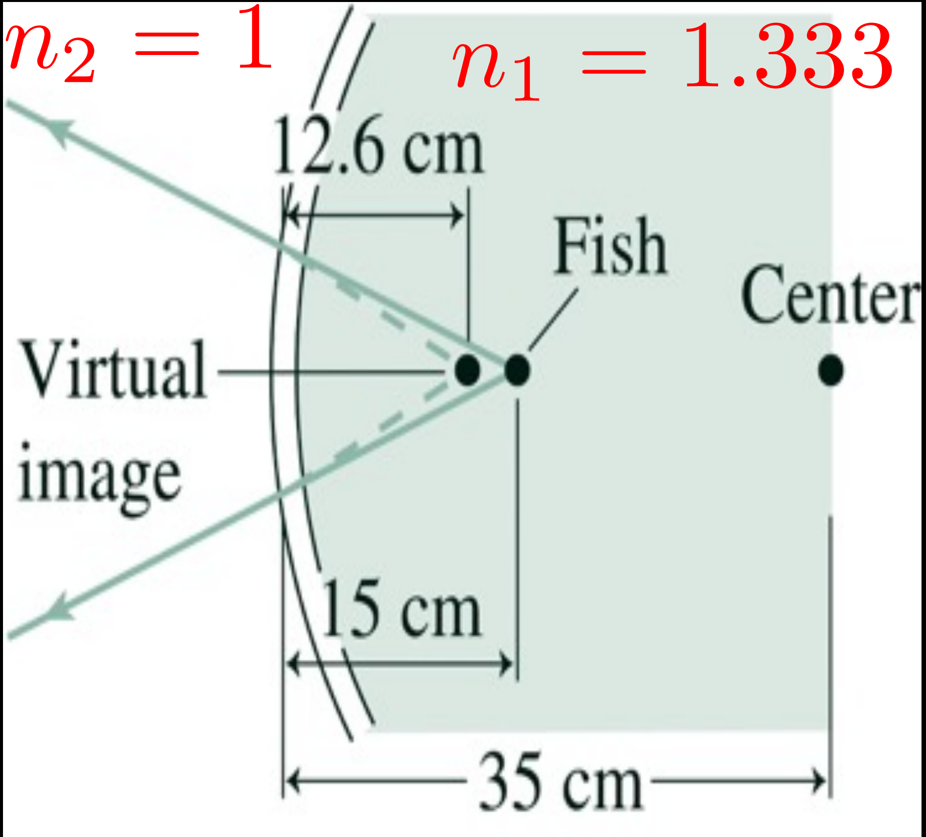
A cat looks directly at the fish. What is the apparent distance to fish 15 cm from the tank wall?



$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

s: 15cm R: −35cm

$$s' = n_2 \left(\frac{n_2 - n_1}{R} - \frac{n_1}{s} \right)^{-1} = -12.6\text{cm}$$



Refraction in Lenses

Quiz

The bottom of a swimming pool looks to be 1.5 m below the surface. Find the pool's actual depth.

[Hint: radius of curvature = radius of Earth ~ infinite]

n water = 1.33

(A) 2.0m

(B) 4.0m

(C) 6.0m

(D) 1.0m

Refraction in Lenses

The bottom of a swimming pool looks to be 1.5 m below the surface. Find the pool's actual depth.

[Hint: radius of curvature = radius of Earth ~ infinite]

(A) 2.0m

(B) 4.0m

(C) 6.0m

(D) 1.0m

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

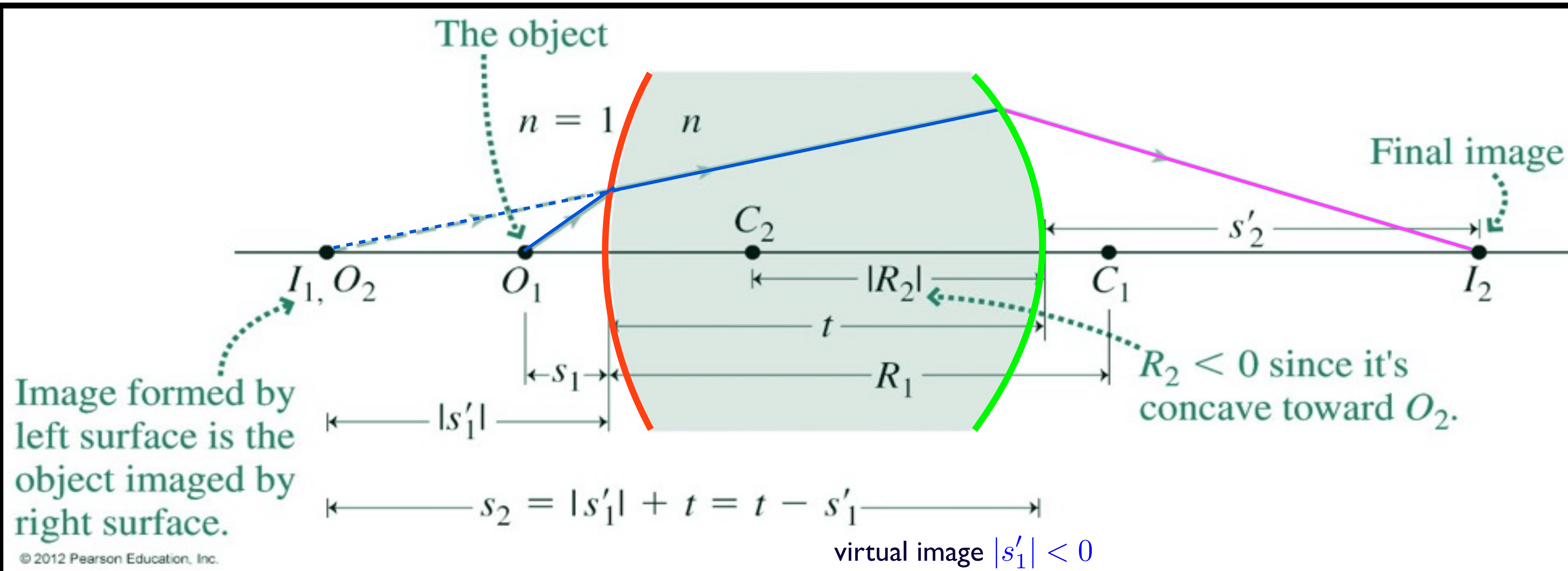
$R \to \infty$

$$= 0$$

$$\frac{n_1}{s} = -\frac{n_2}{s'}$$

$$s = -s' \frac{n_1}{n_2} = -(-1.5\text{m}) \frac{1.333}{1.0} = 2.0\text{m}$$

Thick and thin lenses



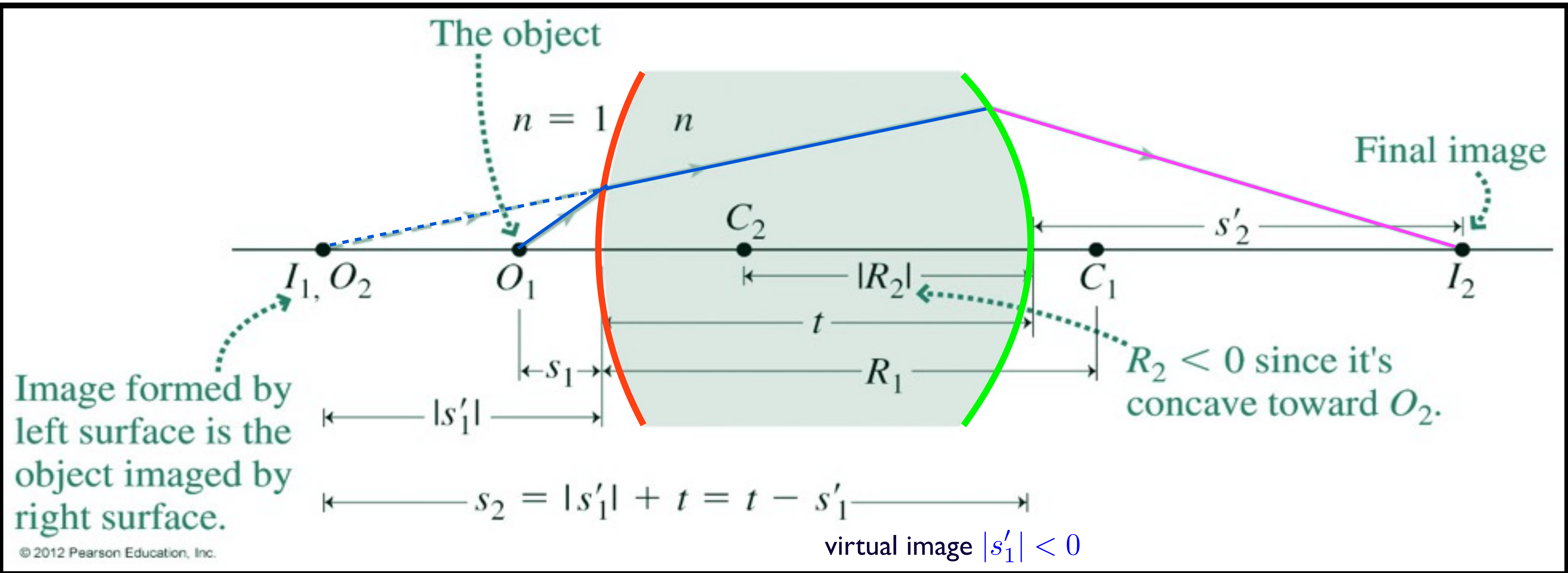
Left-hand side: convex surface, object O_1, virtual image I_1.

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R} \quad \Rightarrow \quad \frac{1}{s_1} + \frac{n}{s'_1} = \frac{n-1}{R_1}$$

Right-hand side: concave surface, object O_2, real image I_2.

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R} \quad \Rightarrow \quad \frac{n}{t - s'_1} + \frac{1}{s'_2} = \frac{1-n}{R_2}$$

Thick and thin lenses



Let lens become thin, $t \to 0$

$$\frac{1}{s_1} + \frac{n}{s_1'} = \frac{n-1}{R_1} \quad + \quad \frac{n}{t - s_1'} + \frac{1}{s_2'} = \frac{1-n}{R_2}$$

$$\frac{1}{s} + \frac{1}{s'} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

(subscripts dropped)

Thick and thin lenses

same left-hand side

$$\frac{1}{s} + \frac{1}{s'} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Therefore:

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

lensmaker's formula

left-hand surface is convex towards object

$R_1 > 0$

right-hand surface is concave towards object

$R_2 < 0$

Thick and thin lenses

Find an expression for the focal length of a plano-convex lens.

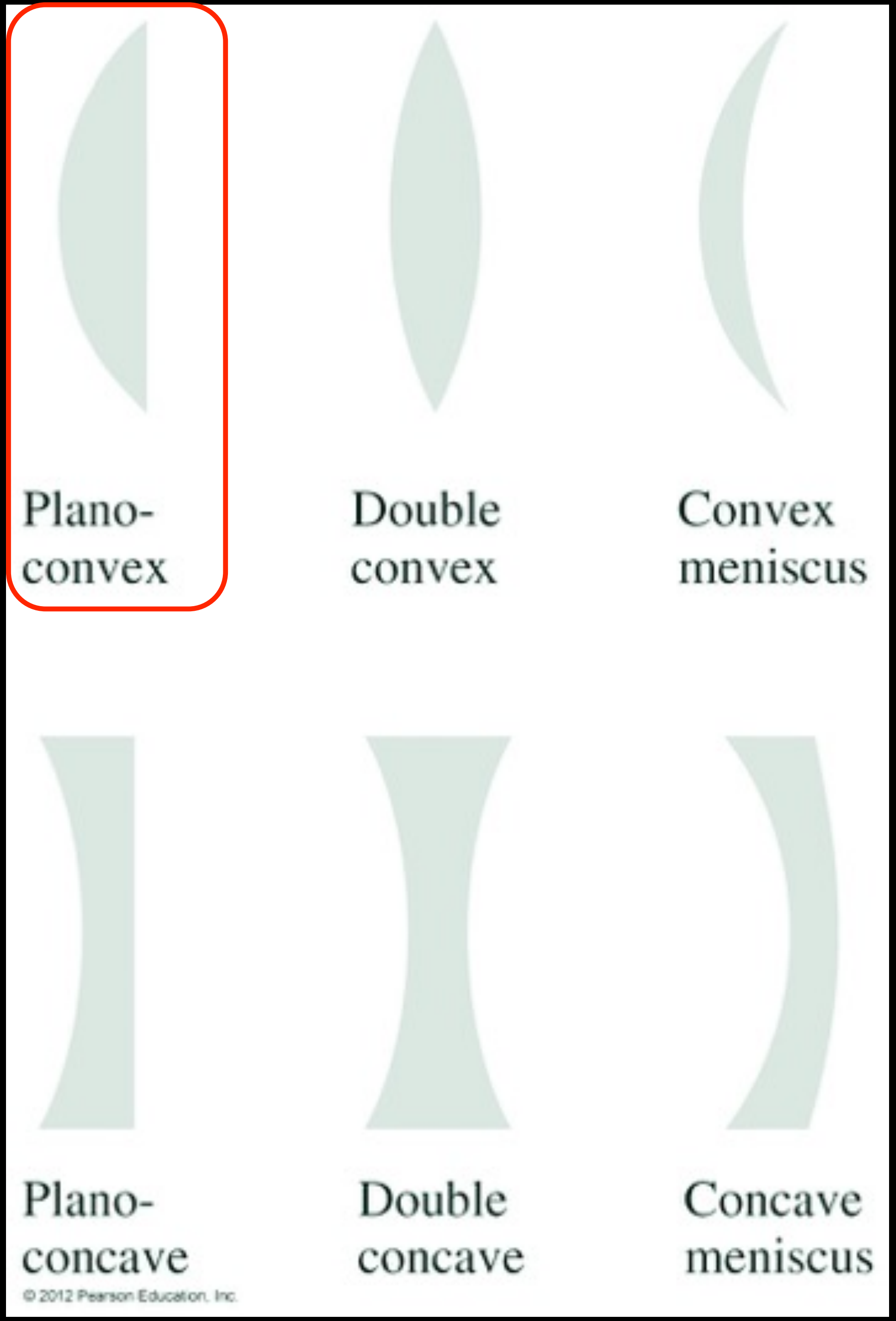
Refractive index n.

One curved surface: $R_1 = R$

One flat surface: $R_2 = \infty$

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$f = \left[(n-1)\left(\frac{1}{R} - \frac{1}{\infty}\right)\right]^{-1} = \frac{R}{n-1}$$



Final note: aberrations

If small angle approximation fails

(rays make bigger angle with axis)

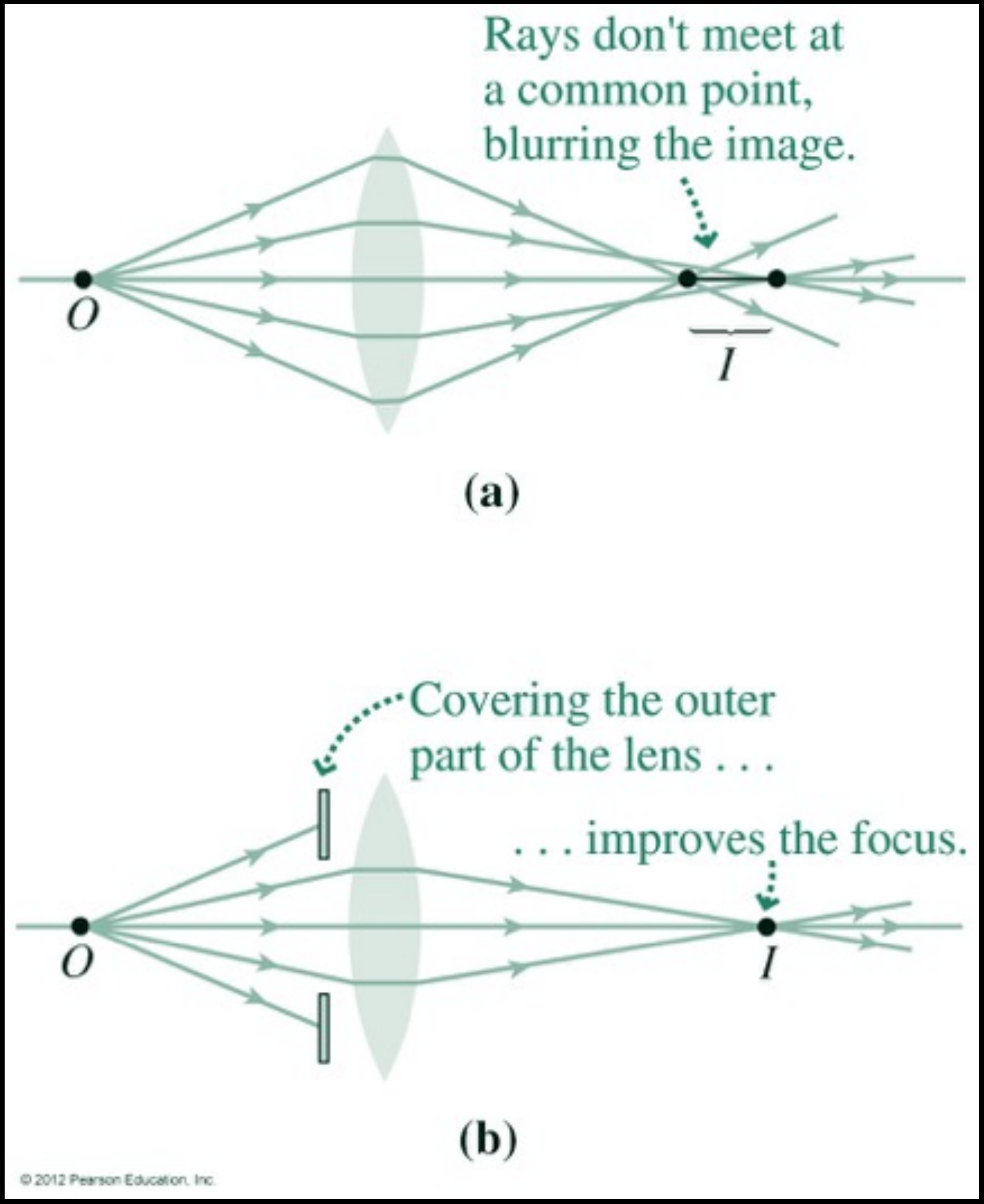
⬇

not all rays share a same focus

⬇

spherical aberration.

Using only centre of lens helps remove rays with big angles.



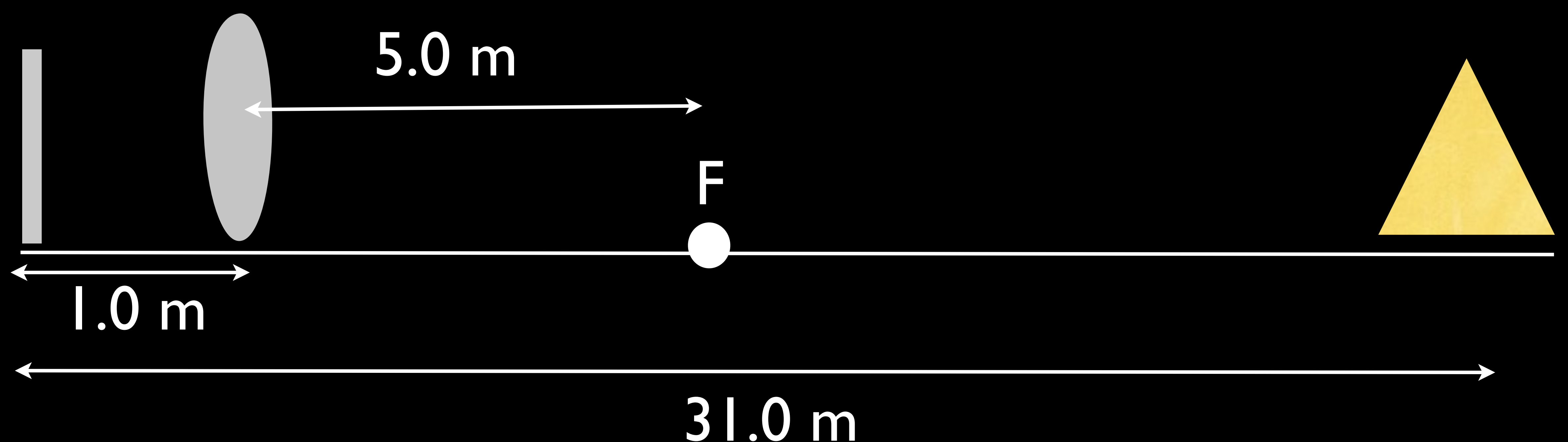
Lenses + Mirrors

A plane mirror is located at the origin.

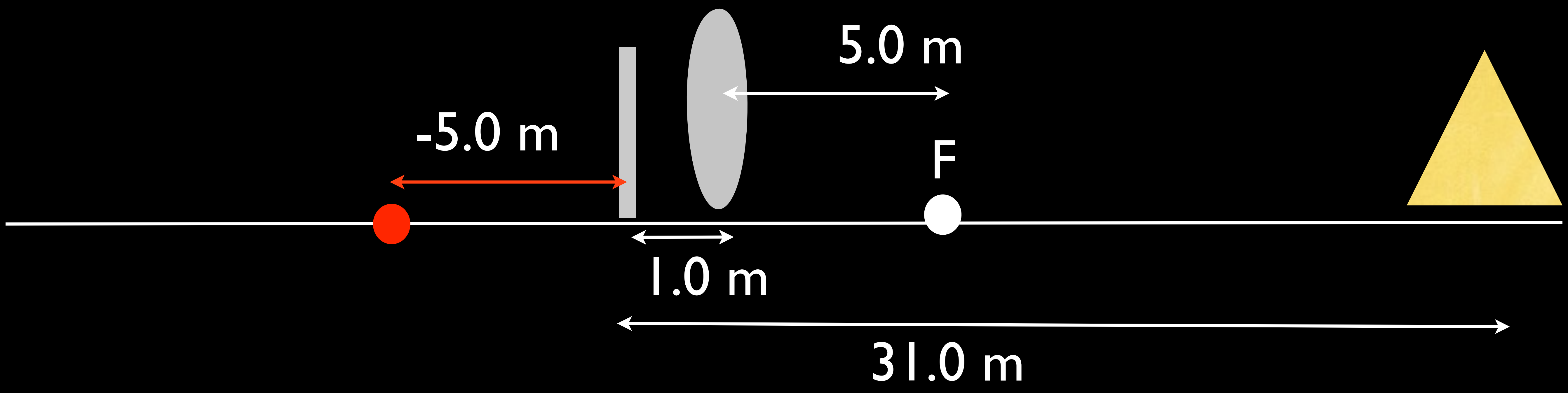
A converging lens with focal length 5.0 m is located at x = 1.0 m.

An object is places at x = 31.0 m.

What is the location of the final image, seen by looking through the lens?



Lenses + Mirrors



Step 1: Location of image produced by lens?

(A) 4.2 m

(B) -6 m

(C) -5 m

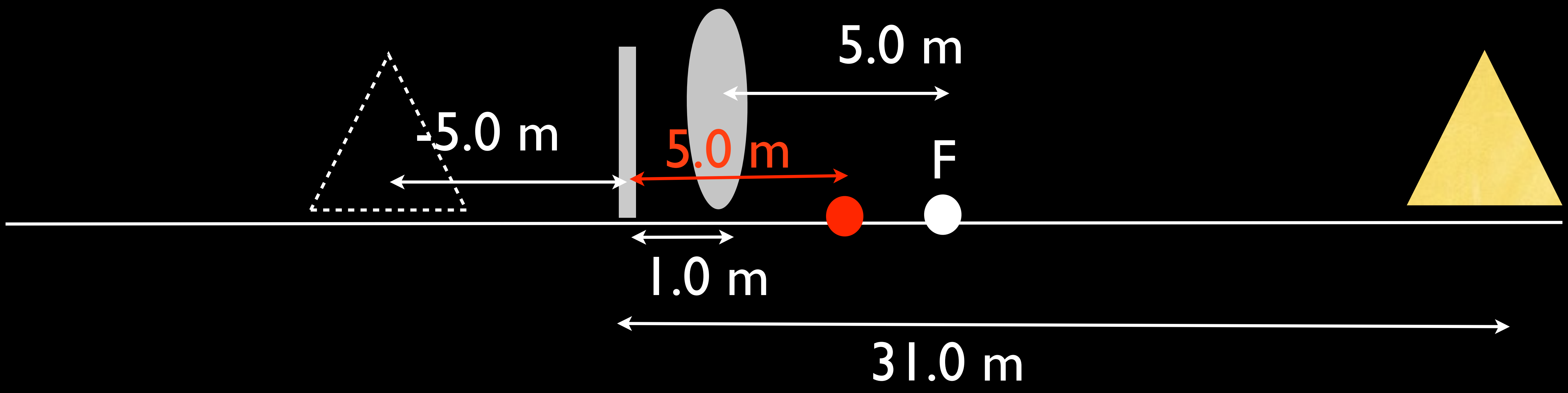
(D) 3 m

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{s'} = \frac{1}{5.0} - \frac{1}{30}$$

$s = 6.0\text{m}$ behind lens

x = -5 m

Lenses + Mirrors



This is on virtual side of mirror: virtual object.

Step 2: Location of image produced by mirror?

(A) 2.5 m

(B) 5 m

(C) -2.5 m

(D) 10 m

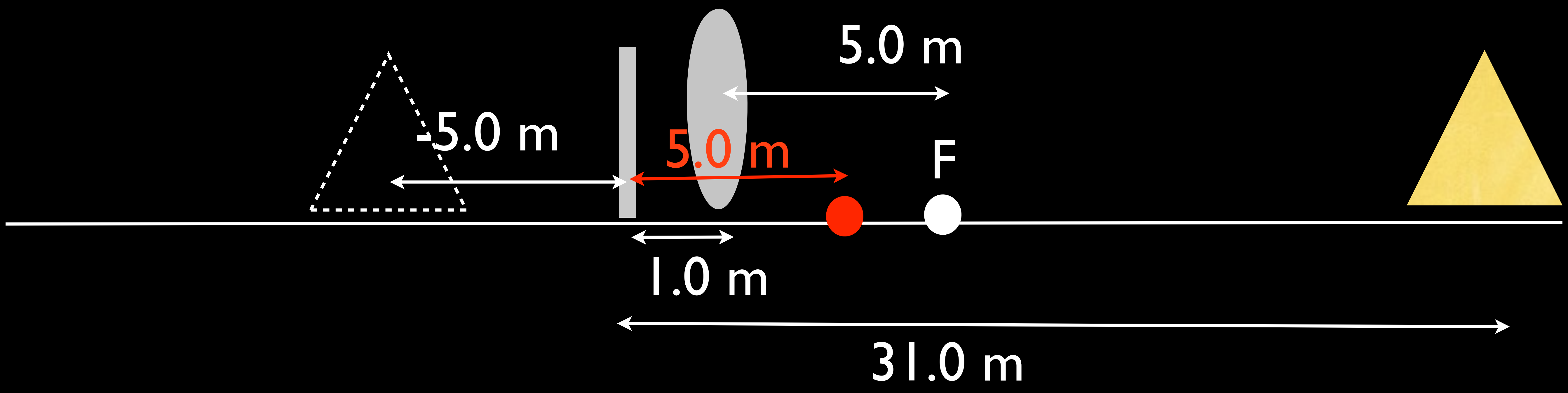
Plane mirror:

distance from mirror to object =

distance from object to mirror

Light passes back through lens!

Lenses + Mirrors



Step 3: Location of image produced by lens (after reflection) ?

(A) -4.3 m

(B) 5.1 m

(C) -3.9 m

(D) 3.2 m

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$s = -4\text{m}$$

virtual image

$$\frac{1}{s'} = \frac{1}{5} - \frac{1}{-4}$$

$$s' = 2.2\text{m} \qquad x = s' + 1 = 3.2\text{m}$$

This week

REMEMBER!

Essay next lecture.

Monday 25th July, 4:30 pm

月曜日２５日7月１６：３０