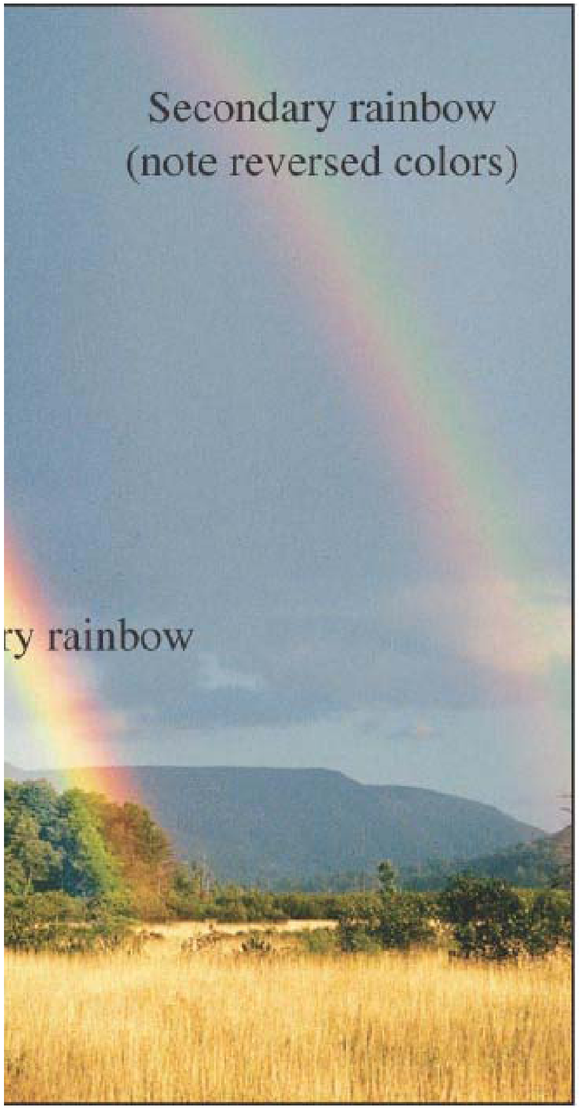
# Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Reminders:

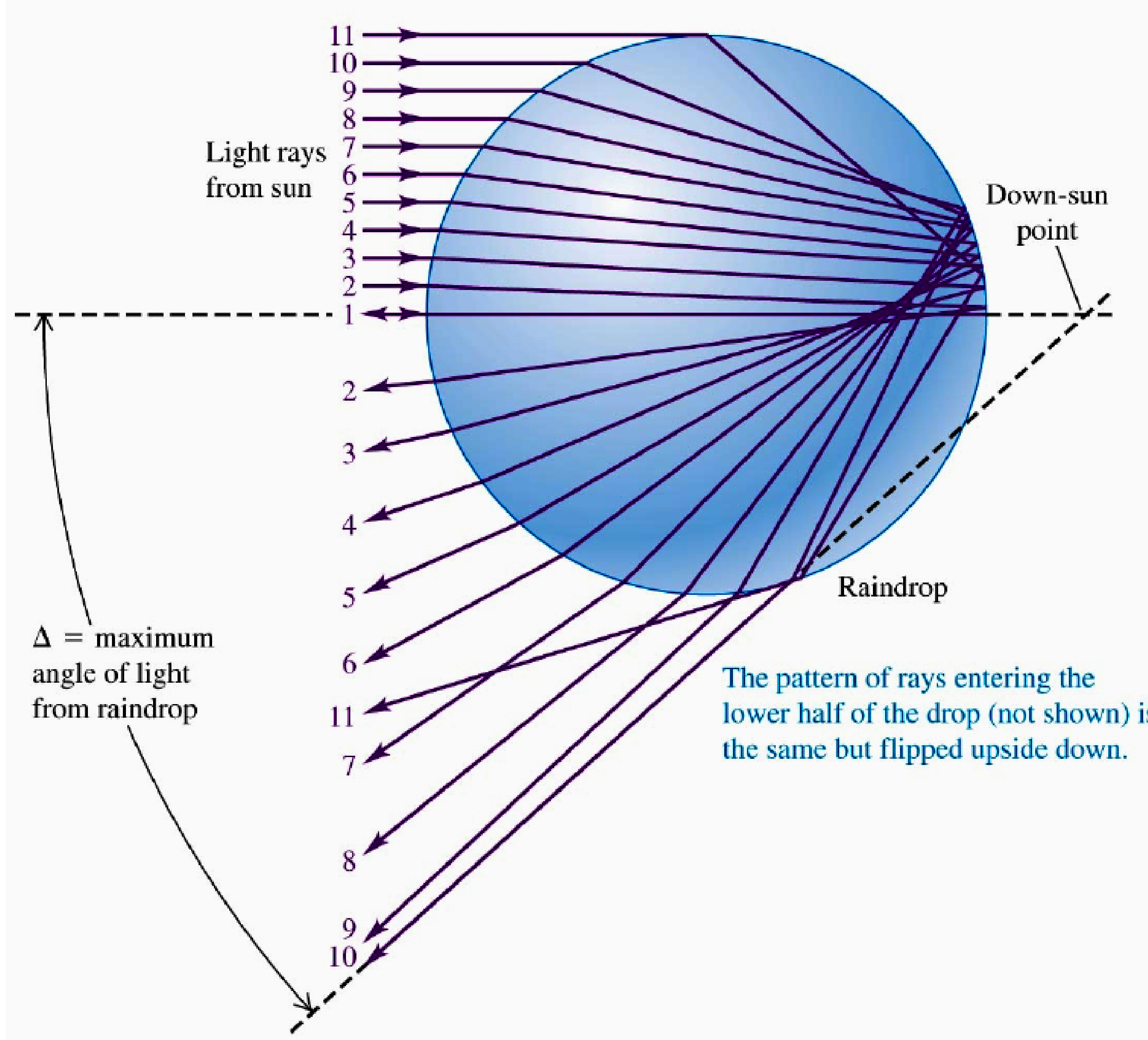
1) Assignment #13 → due Monday
2) Mirrors & Lenses
3) Review for Final: Wednesday, May 5th

# Rainbows (how they form)



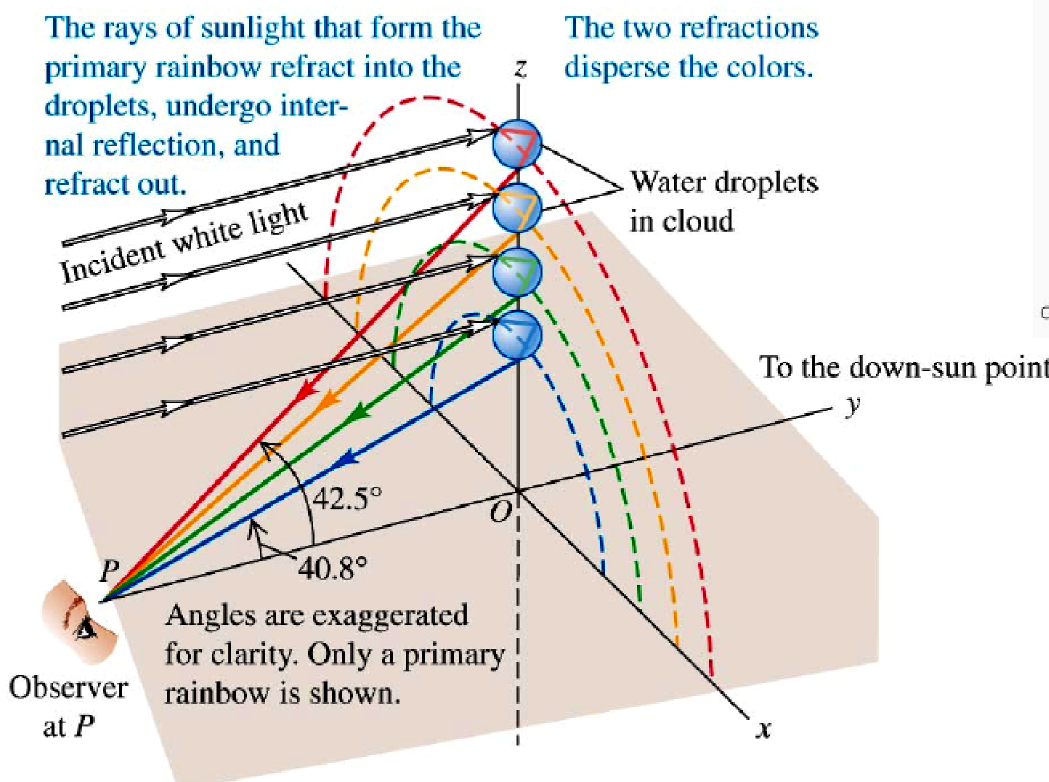



(b) The paths of light rays entering the upper half of a raindrop



# Rainbows

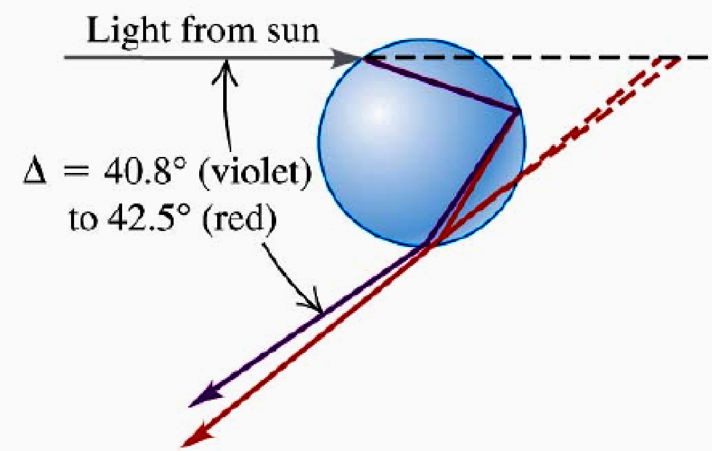
(c) Forming a rainbow. The sun in this illustration is directly behind the observer at $P$.





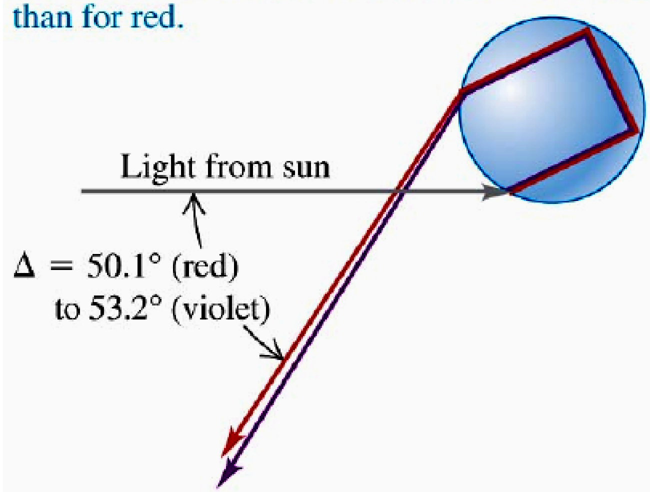

Hence we also see a faint secondary rainbow

(d) A primary rainbow is formed by rays that undergo two refractions and one internal reflection. The angle $\Delta$ is larger for red light than for violet.

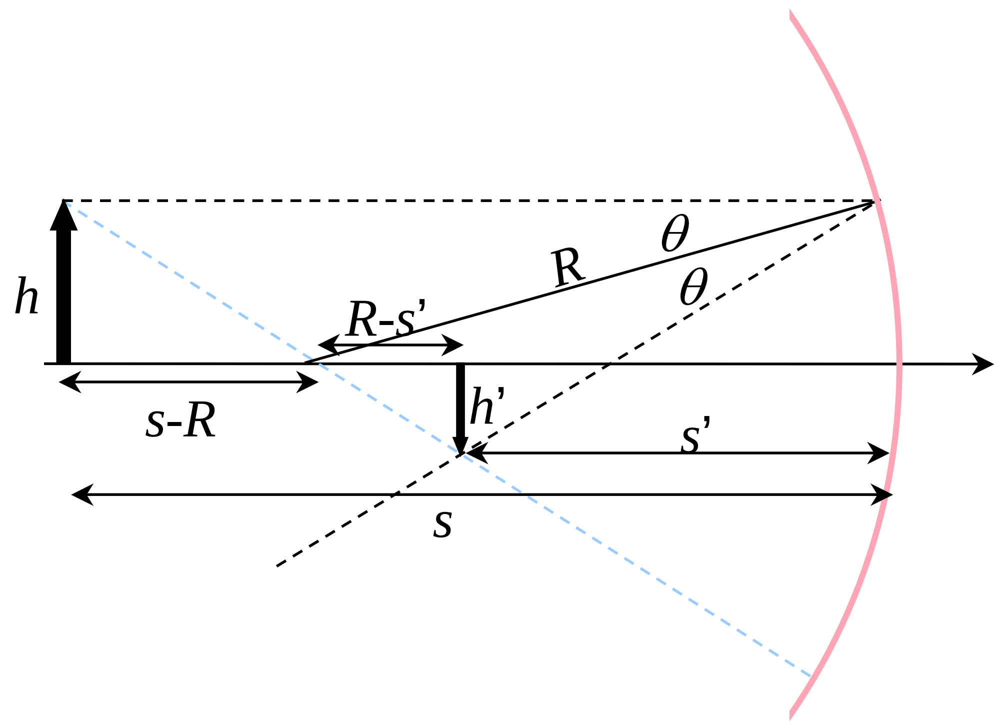





(e) A secondary rainbow is formed by rays that undergo two refractions and *two* internal reflections. The angle $\Delta$ is larger for violet light than for red.



# Mirrors

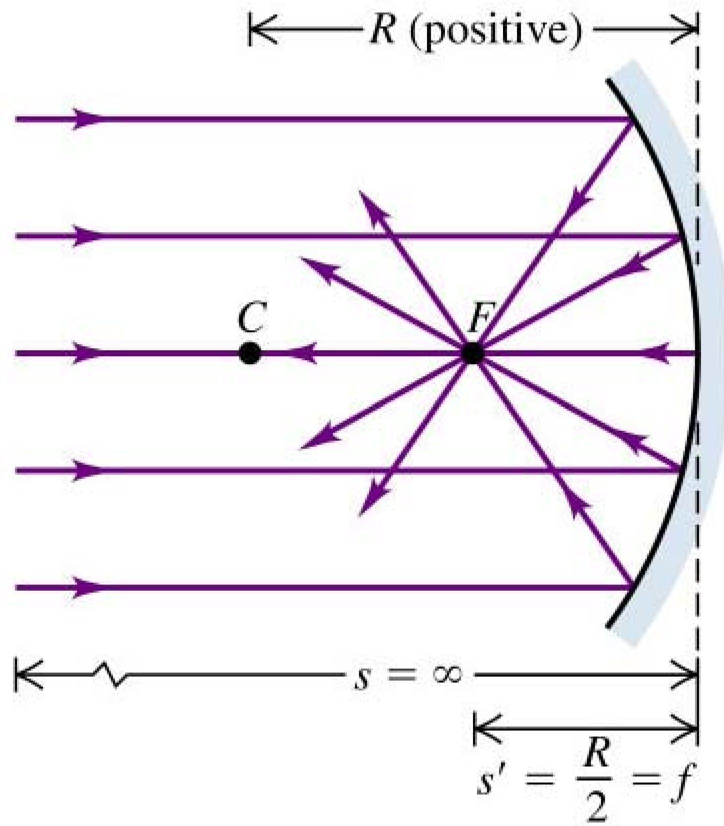


# Spherical Mirror

Equation $$\frac{1}{s}+\frac{1}{s'}=\frac{2}{R}$$

Infinite distance, s= ∞, s′=R/2 image appears at ½ radius of curvature.

$$\frac{1}{\infty}+\frac{1}{s'}=\frac{2}{R}$$

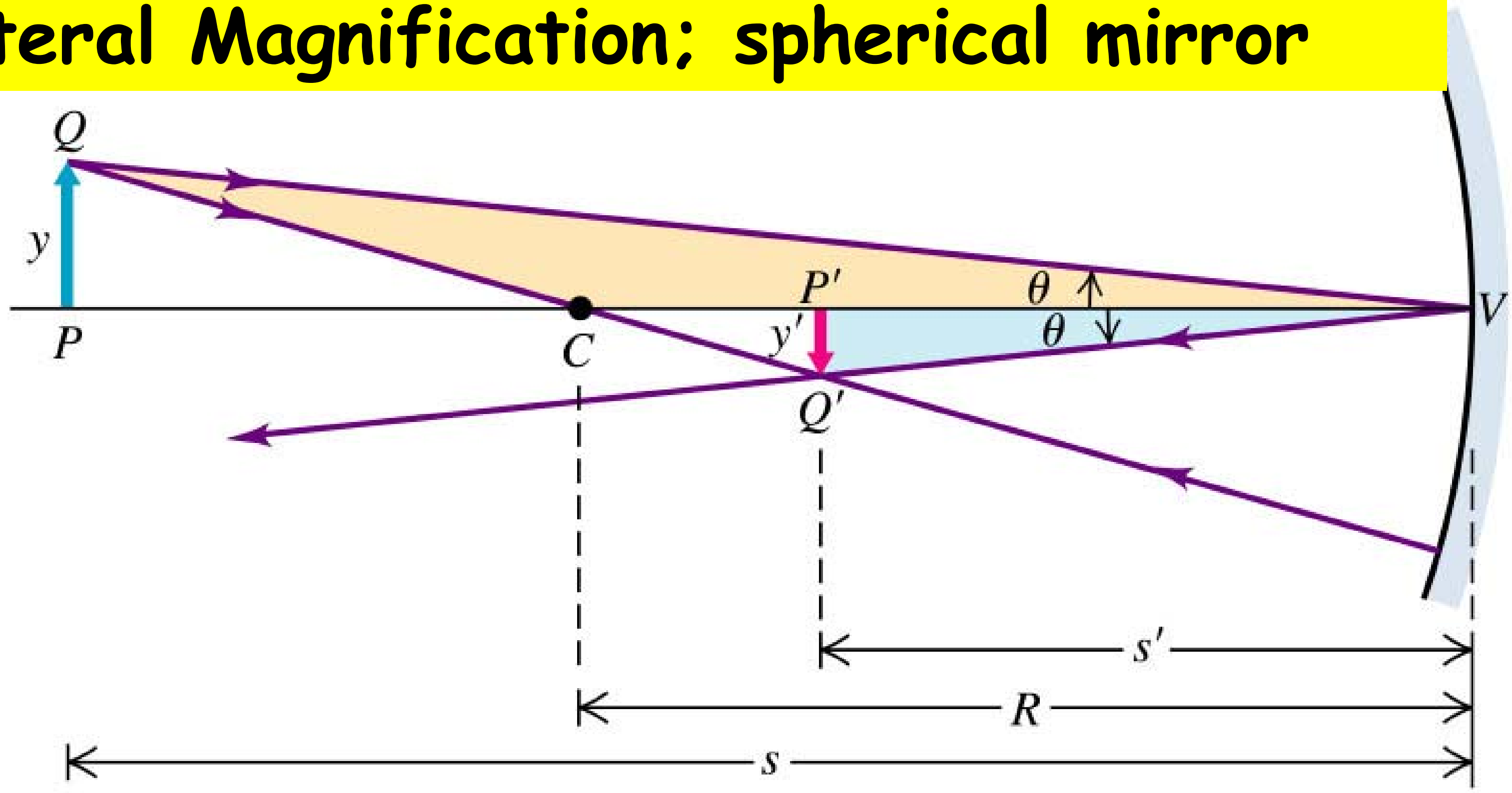



Nomenclature; focal length, f=R/2, is image length when object is at infinity.

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

Real image – formed by converging rays. Can be viewed on screen.
Virtual image – rays do not go through. Can not be shown on screen.
Concave mirror: can have real or virtual image.

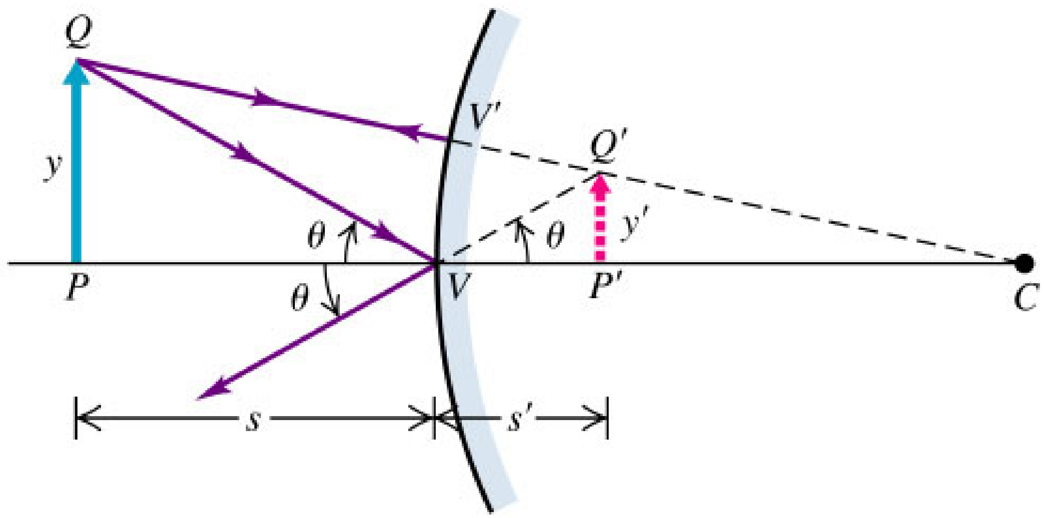
# Lateral Magnification; spherical mirror




Magnification = $\dfrac{y'}{y} = -\dfrac{s'}{s}$

Remarks; note that y′=-|y′|, since the arrow is upside down and that s, s′, and y are positive. So the magnification by this definition is negative, since y′ is upside down.

# Convex mirror




For a convex mirror, the radius of curvature is inside the mirror. We have another RULE, that when the curvature center C is on the same side of the outgoing ray, then the radius is positive. For the convex mirror we have NEGATIVE radius. Also from our rule for s', we observe this is negative in the above drawing. Using same recipe as we used for concave mirrors, we would find same formula:

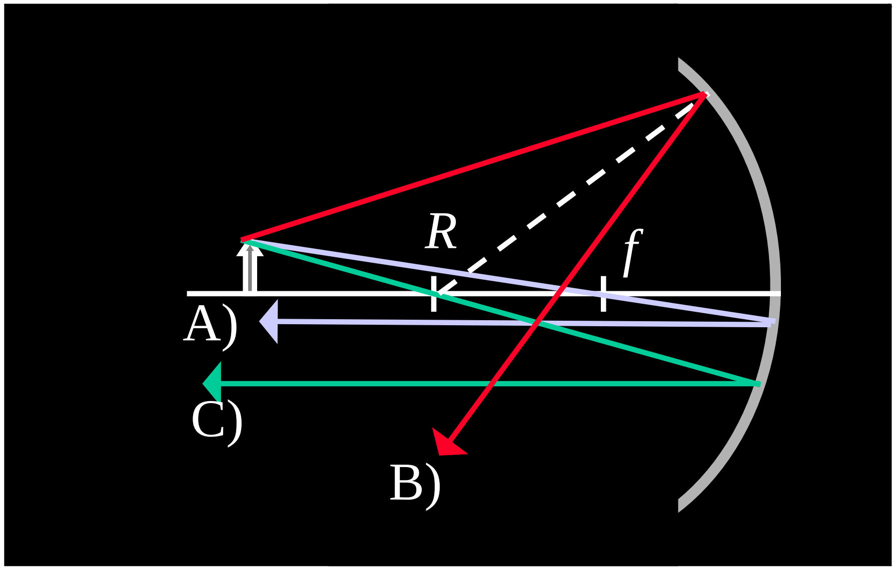
$$\frac{1}{s} + \frac{1}{s'} = \frac{2}{R}$$

Again, note s' and R are negative

Magnification = (this is positive) $\frac{y'}{y} = -\frac{s'}{s}$

# Question 1

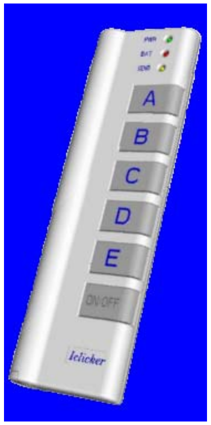
**The diagram below shows three light rays reflected off of a concave mirror. Which ray is NOT correct?**




A)

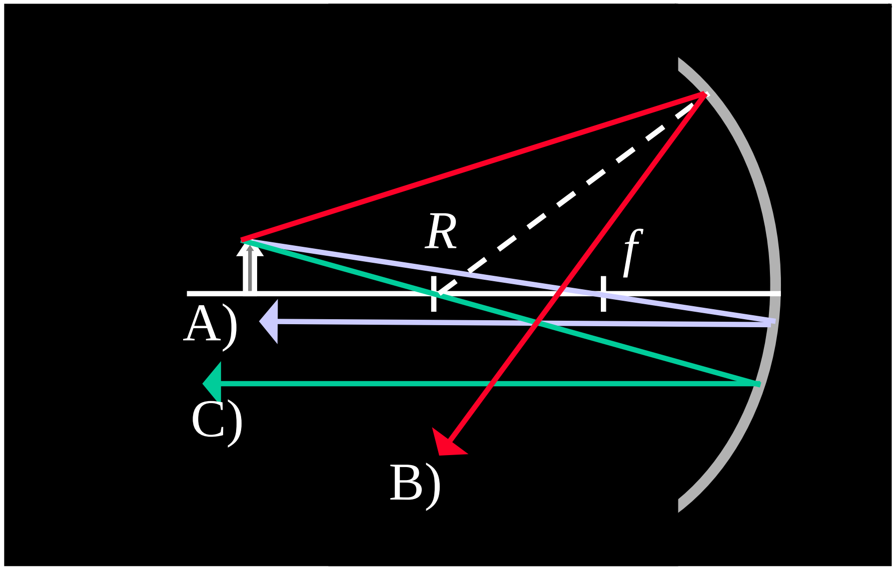
B)

C)



# Question 1

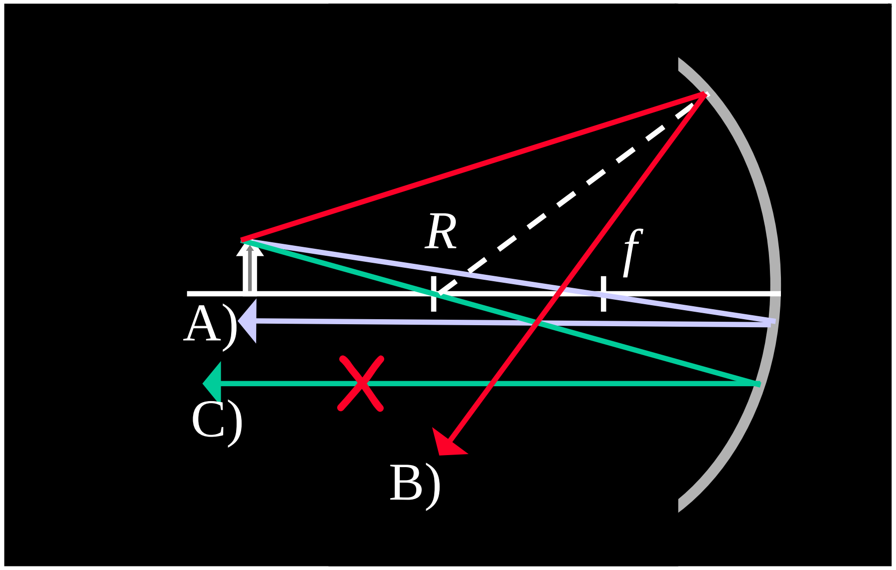
**The diagram below shows three light rays reflected off of a concave mirror. Which ray is NOT correct?**




A)

B)

C)




- Ray A goes through focal pt and is reflected parallel to the axis.
- Ray B has angle incidence = angle reflection
- Ray C goes through center of sphere.
  - Therefore it has normal incidence
  - Should be reflected straight back

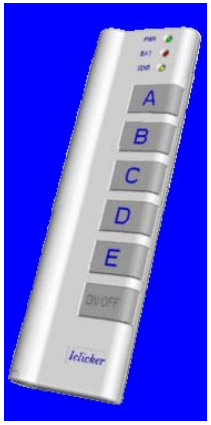
## Question 2

The image produced by a concave mirror of a real object is

a) always real.

b) always virtual.

c) sometimes real
and sometimes virtual.



## Question 2

The image produced by a concave mirror of a real object is

a) always real.

b) always virtual.

c) sometimes real
and sometimes virtual.

Is image of a real object from a concave mirror
real or virtual?

It depends on the position of the object relative to the focal point!

- Draw Rays or..
- $1/s' = 1/f - 1/s$ (concave implies $f > 0$)

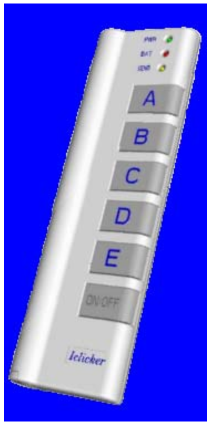
## Question 3

The image produced by a concave mirror of a real object is

a) always upright.

b) always inverted.

c) sometimes upright
and sometimes inverted.



## Question 3

The image produced by a concave mirror of a real object is

a) always upright.
b) always inverted.
c) sometimes upright
and sometimes inverted.

Is image of a real object from a concave mirror upright or inverted?

Once again, it depends on position relative to focal point!

- If $s' > 0$, real and inverted
- If $s' < 0$, virtual and upright

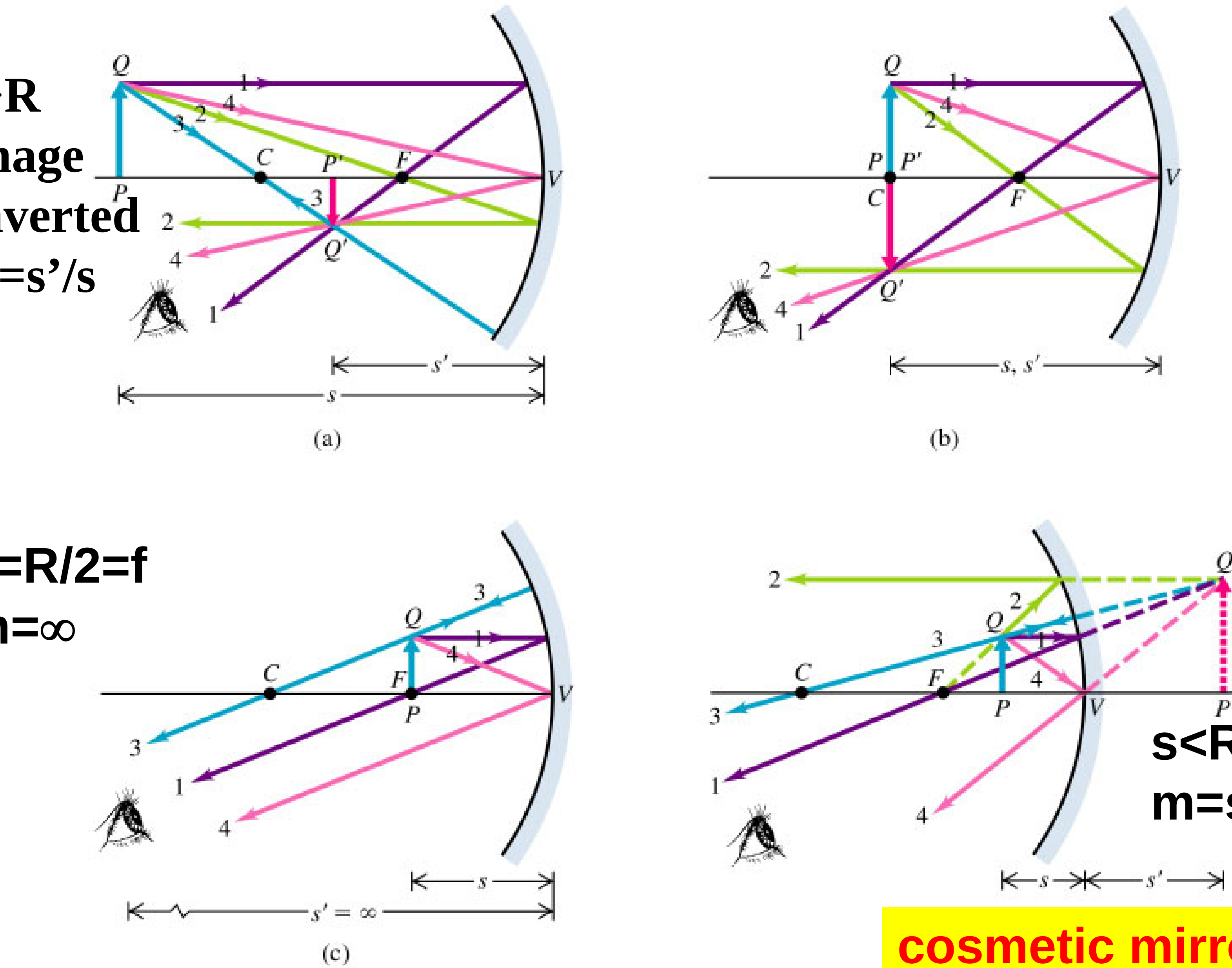
# Y&F Example 34.4

s>R
image
Inverted
m=s’/s

s=R
m=-1

s=R/2=f
m=∞

s<R/2
m=s’/s>1




cosmetic mirror

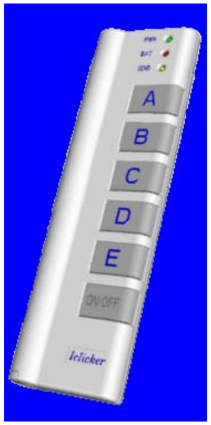
## Question 4

The image produced by a convex mirror of a real object is

a) always real.

b) always virtual.

c) sometimes real and sometimes virtual.



# Question 4

The image produced by a convex mirror of a real object is

a) always real.
b) always virtual.
c) sometimes real
and sometimes virtual.

Is image of a real object from a convex mirror
real or virtual?

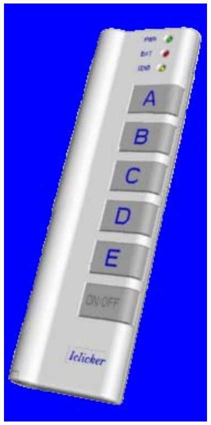
Same PROCEDURE as for concave mirrors we did earlier!

- Draw Rays or..
- $1/s' = 1/f - 1/s$ (convex implies $f < 0$)

# Question 5

The image produced by a convex mirror of a real object is

a) always upright.
b) always inverted.
c) sometimes upright



## Question 5

The image produced by a convex mirror of a real object is

a) always upright.
b) always inverted.
c) sometimes upright

Is image of a real object from a convex mirror upright or inverted?

Once again, depends on sign of s' (real/inverted or virtual/upright)

- Here s' < 0 ALWAYS... therefore virtual and upright

# Question 6

- In order for a real object to create a real, inverted enlarged image,

a) **we must use a concave mirror.**

b) **we must use a convex mirror.**

c) **neither a concave nor a convex mirror can produce this image.**

# Question 6

- In order for a real object to create a real, inverted enlarged image,

a) **we must use a concave mirror.**

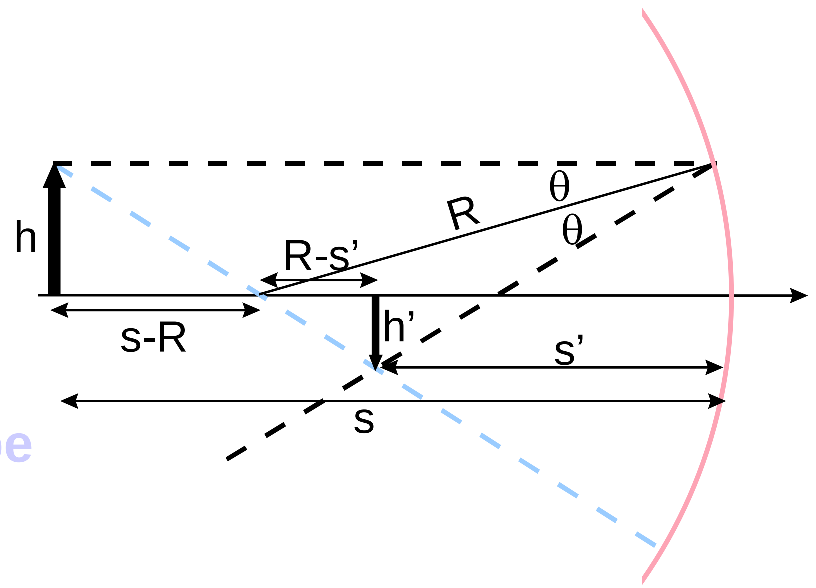
b) **we must use a convex mirror.**

c) **neither a concave nor a convex mirror can produce this image.**

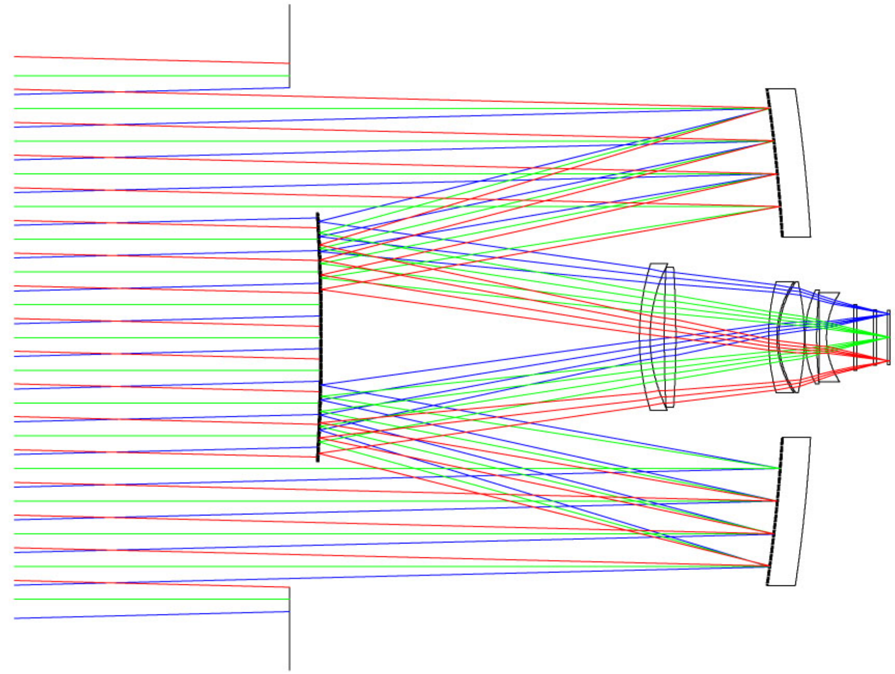
- A convex mirror can only produce a virtual image since all reflected rays will diverge. Therefore, **b)** is false.
- To create a real image with a concave mirror, the object must be outside the focal point.

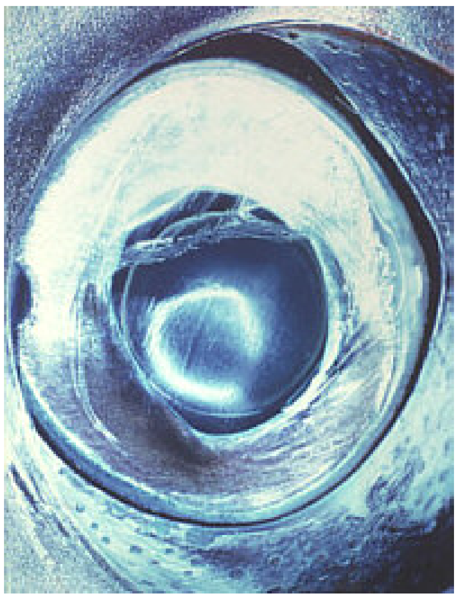
- The example we just did gave a real, inverted reduced image.
- Is it possible to choose the parameters such that the image is enlarged??

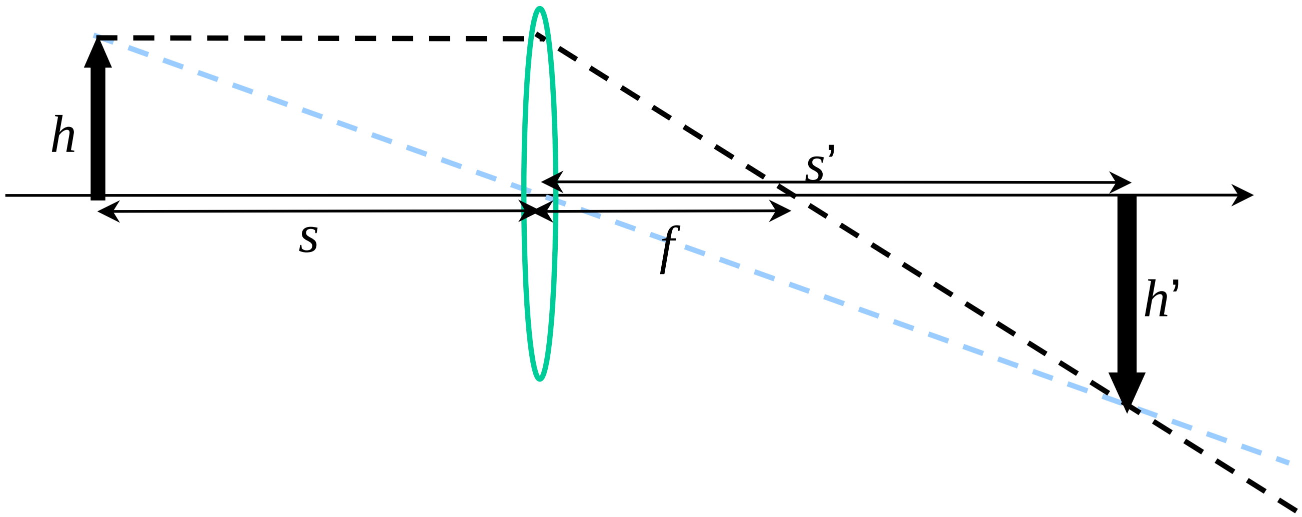
The answer:
- ***h'*** is a real image.
- Therefore consider the OBJECT to be ***h'***. The IMAGE will be ***h***



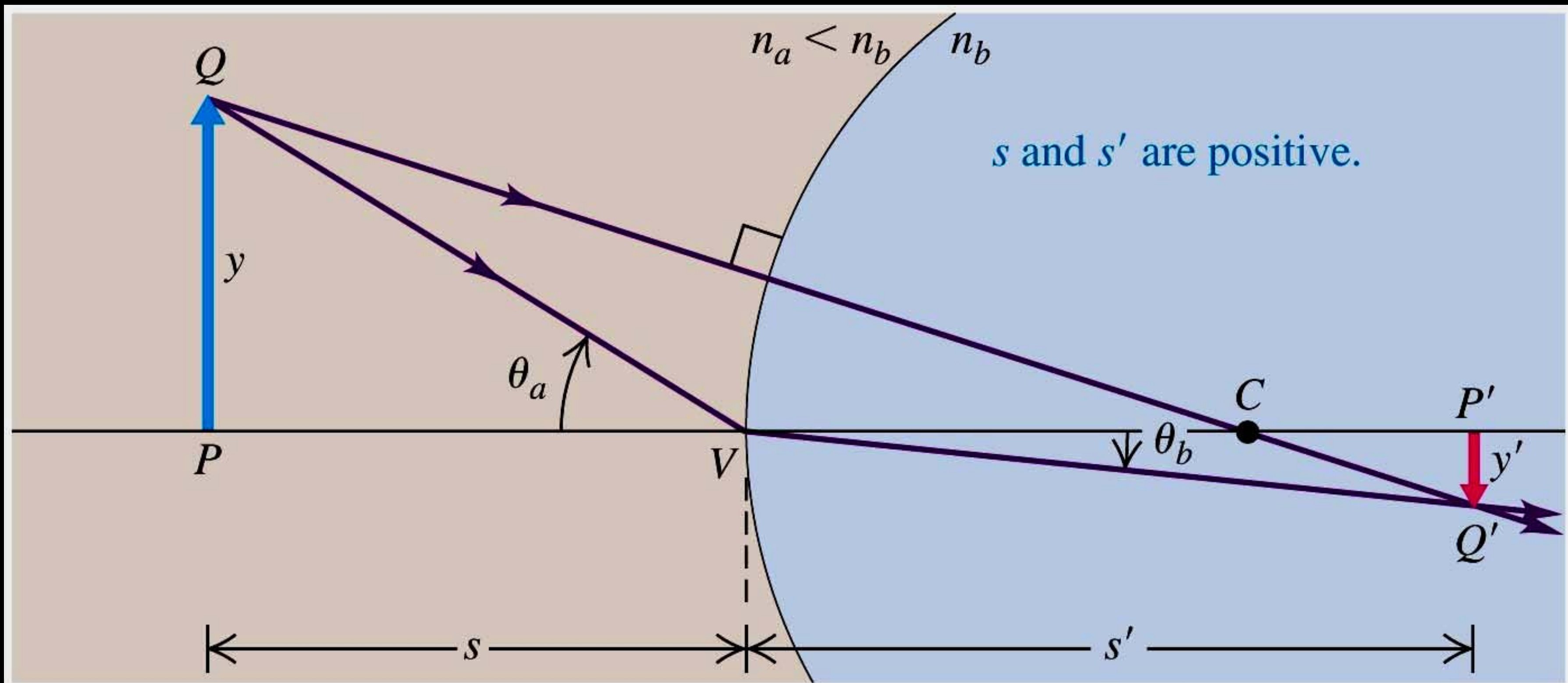
# LENSES







# Refraction on Spherical Surface

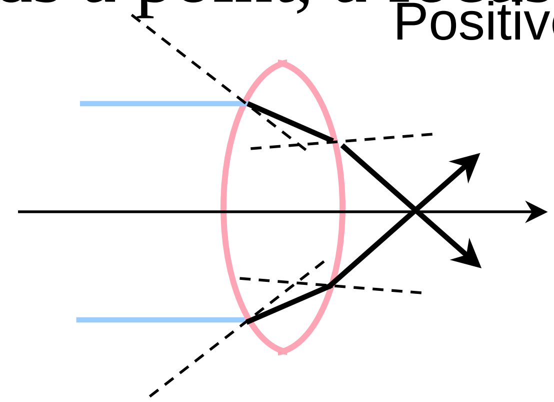


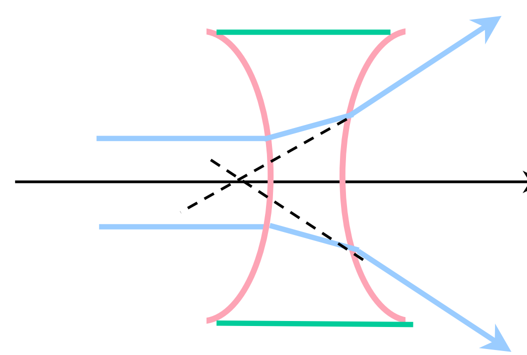



For small angles

# Lenses

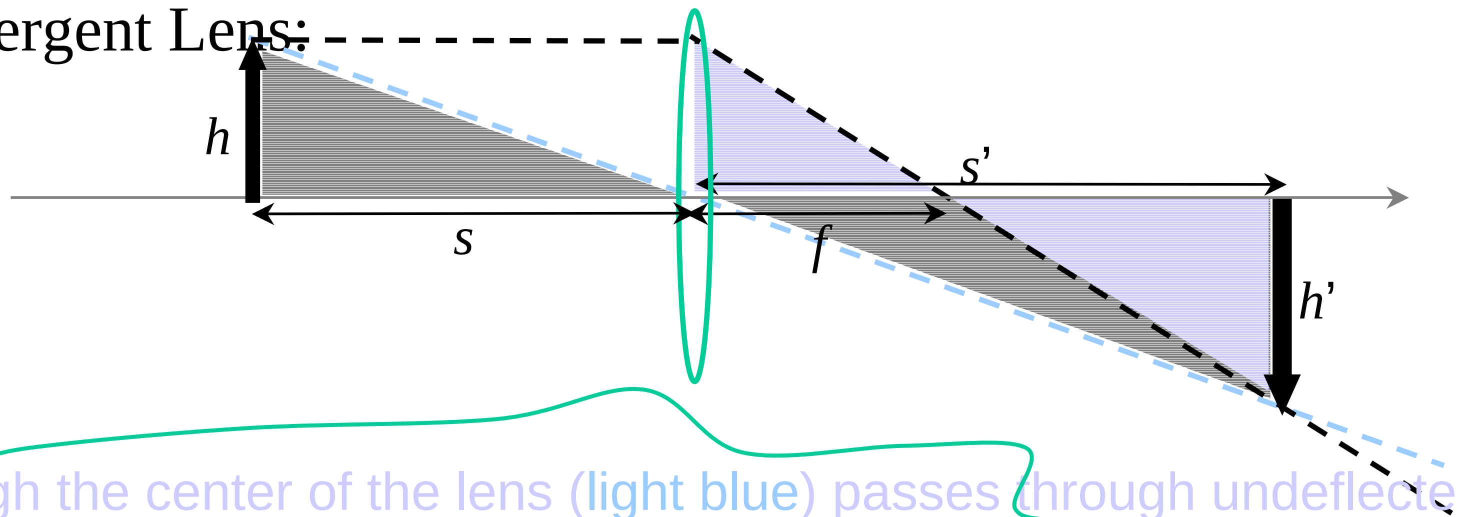
- A lens is a piece of transparent material shaped such that parallel light rays are refracted towards a point, a focus:
  - Convergent Lens
    - light moving from air into glass will move toward the normal
    - light moving from glass back into air will move away from the normal
    - real focus
  - Divergent Lens
    - light moving from air into glass will move toward the normal
    - light moving from glass back into air will move away from the normal
    - virtual focus



# The Lens Equation

- We now derive the lens equation which determines the image distance in terms of the object distance and the focal length.
  - Convergent Lens:




Ray Trace:

- Ray through the center of the lens (light blue) passes through undeflected.
- Ray parallel to axis (white) passes through focal point $f$.

These are principal rays!!!

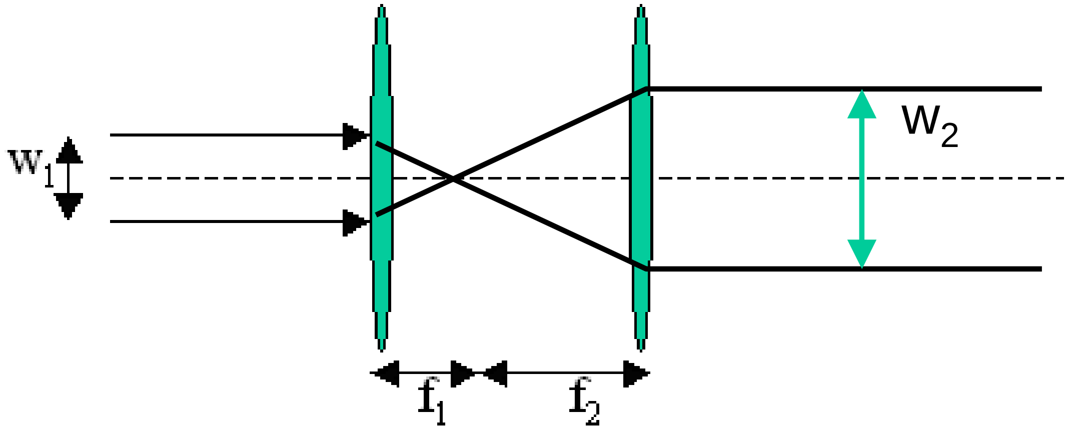
two sets of similar triangles: $\frac{h'}{h} = \frac{s'}{s}$ $\frac{h'}{s'-f} = \frac{h}{f}$

eliminating $h'/h$: $\frac{s'}{s} = \frac{s'-f}{f}$ → $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ → same as mirror eqn if we define $s' > 0$ $f > 0$

magnification: also same as mirror eqn!! → $M = -\frac{s'}{s}$

$M < 0$ for inverted image.

A parallel laser beam of width $w_1$ is incident on a two lens system as shown below



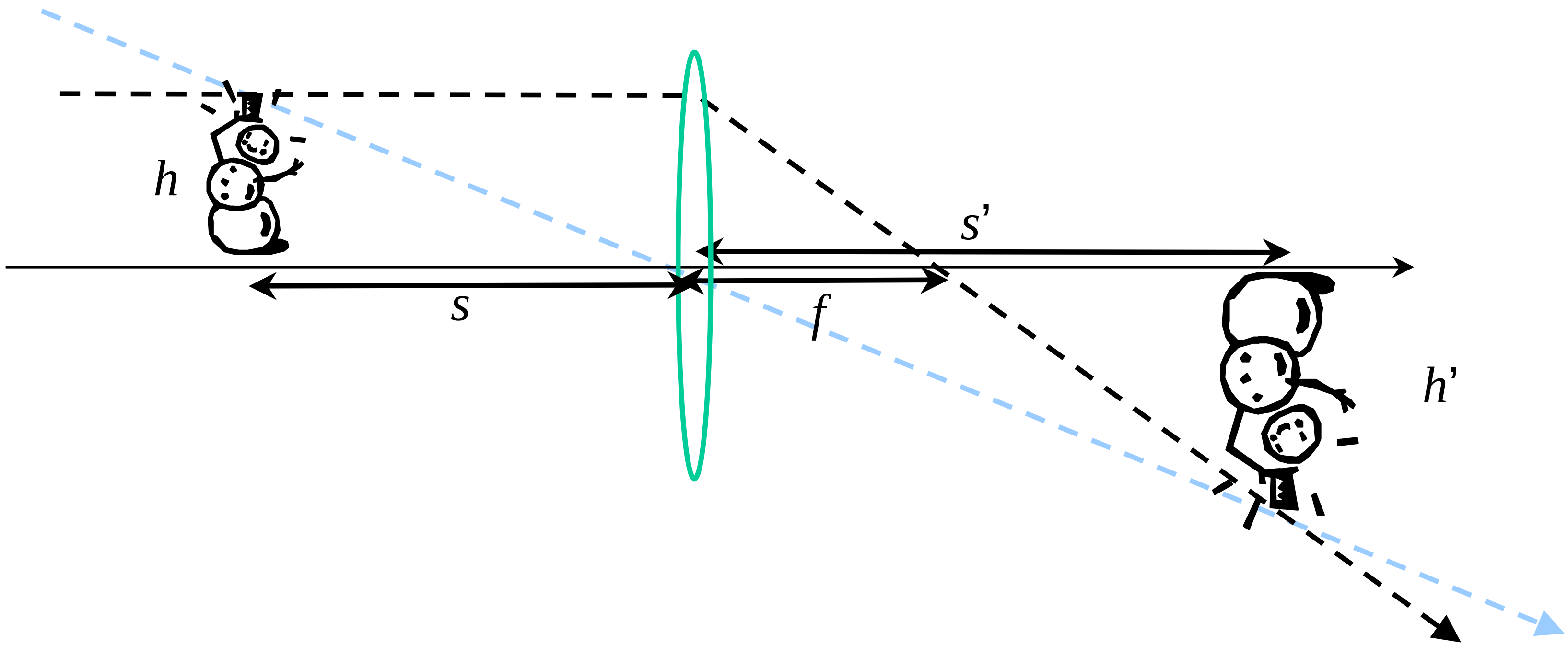

Each lens is converging. The second lens has a larger focal length than the first ($f_2 > f_1$).

What does the beam look like when it emerges from the second lens?

a) The beam is converging
b) The beam is diverging
c) The beam is parallel to the axis with a width < $w_1$
d) The beam is parallel to the axis with a width = $w_1$
e) The beam is parallel to the axis with a width > $w_1$

# Lens Equation summary

- *Draw some ray diagrams:* convergent lens example




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

$$s' = \frac{fs}{s - f}$$

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

The lens in your eye

a) is always a positive (i.e., converging) lens

b) is always a negative (i.e., diverging) lens

c) is sometimes positive, and sometimes negative, depending on whether you are looking at an object near or far away

d) is positive if you are near-sighted and negative if you are far-sighted

The image on the back of your retina is

a) inverted

b) noninverted

The image on the back of your retina is

a) real

b) virtual

The image on the back of your retina is

a) enlarged

b) reduced

# Summary of Lenses and Mirrors

- We have derived, in the paraxial (and thin lens) approximation, the same equations for mirrors and lenses:

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

$$M = -\frac{s'}{s}$$

when the following sign conventions are used:

| Variable | Mirror | Lens |
|---|---|---|
| $f > 0$<br>$f < 0$ | concave<br>convex | converging<br>diverging |
| $s > 0$<br>$s < 0$ | real (front)<br>~~virtual (back)~~ | real (front)<br>~~virtual (back)~~ |
| $s' > 0$<br>$s' < 0$ | real (front)<br>virtual (back) | real (back)<br>virtual (front) |

Principal rays "*connect*" object and image

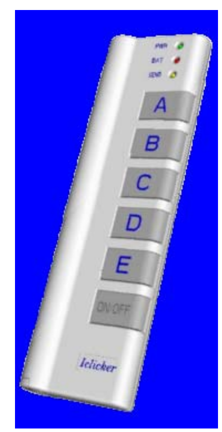
one goes through the center of the lens or mirror

the other goes parallel to the optic axis and then is refracted or reflected through a focal point

the third one is like the second one….

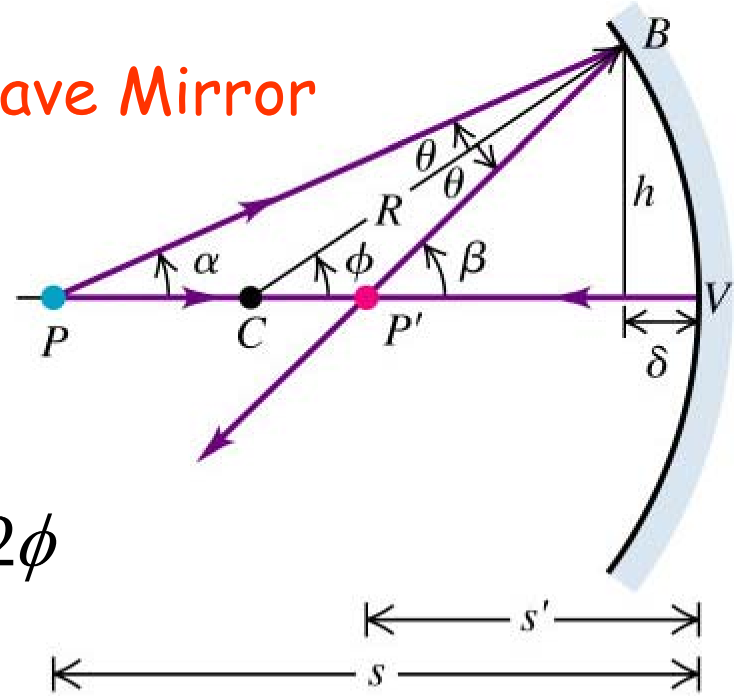
# For next time

- Homework #13 → due Monday
- One more lecture: optics/optical phenomenon
- Last quiz now!



# Spherical Mirror

Concave Mirror




Point C, center of curvature.
Suppose object at P, then out
Going ray passes through P′.

$$\alpha + \theta = \phi \;;\; \phi + \theta = \beta \;\Rightarrow \alpha + \beta = 2\phi$$

$$\tan\alpha = \frac{h}{s-\delta} \;;\; \tan\beta = \frac{h}{s'-\delta} \;;\; \tan\phi = \frac{h}{R-\delta}$$

Assume, angles small, $\delta \cong 0$,
paraxial rays, approx. parallel
to axis. Note s and s′ positive.

$$\alpha \cong \frac{h}{s} \;;\; \beta \cong \frac{h}{s'} \;;\; \phi \cong \frac{h}{R}$$

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