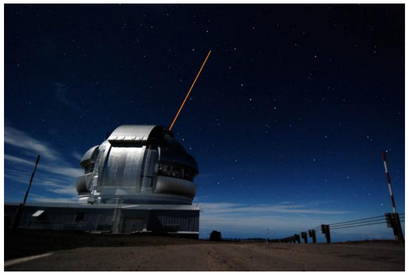
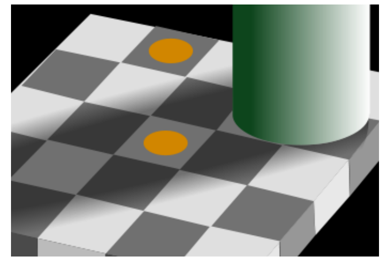
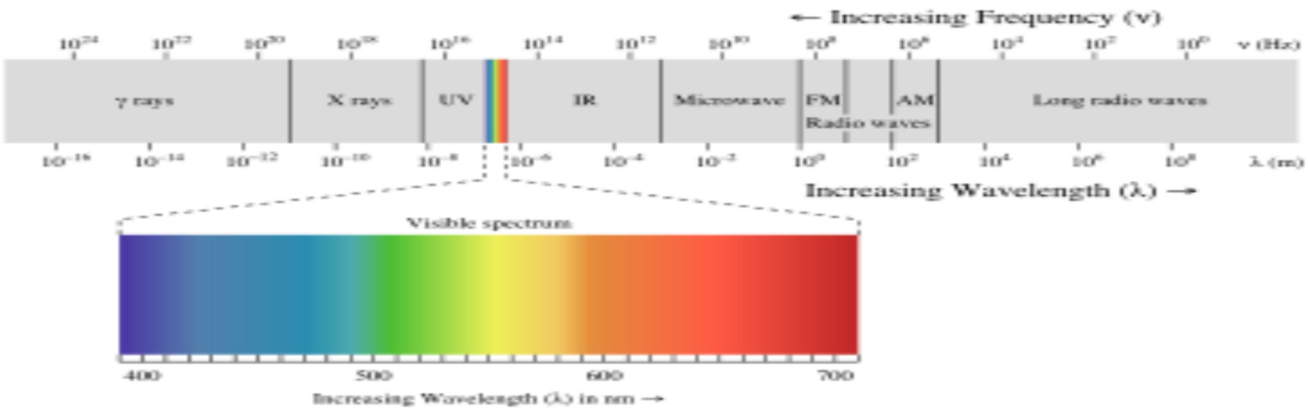
Physics 1230: Light and Color



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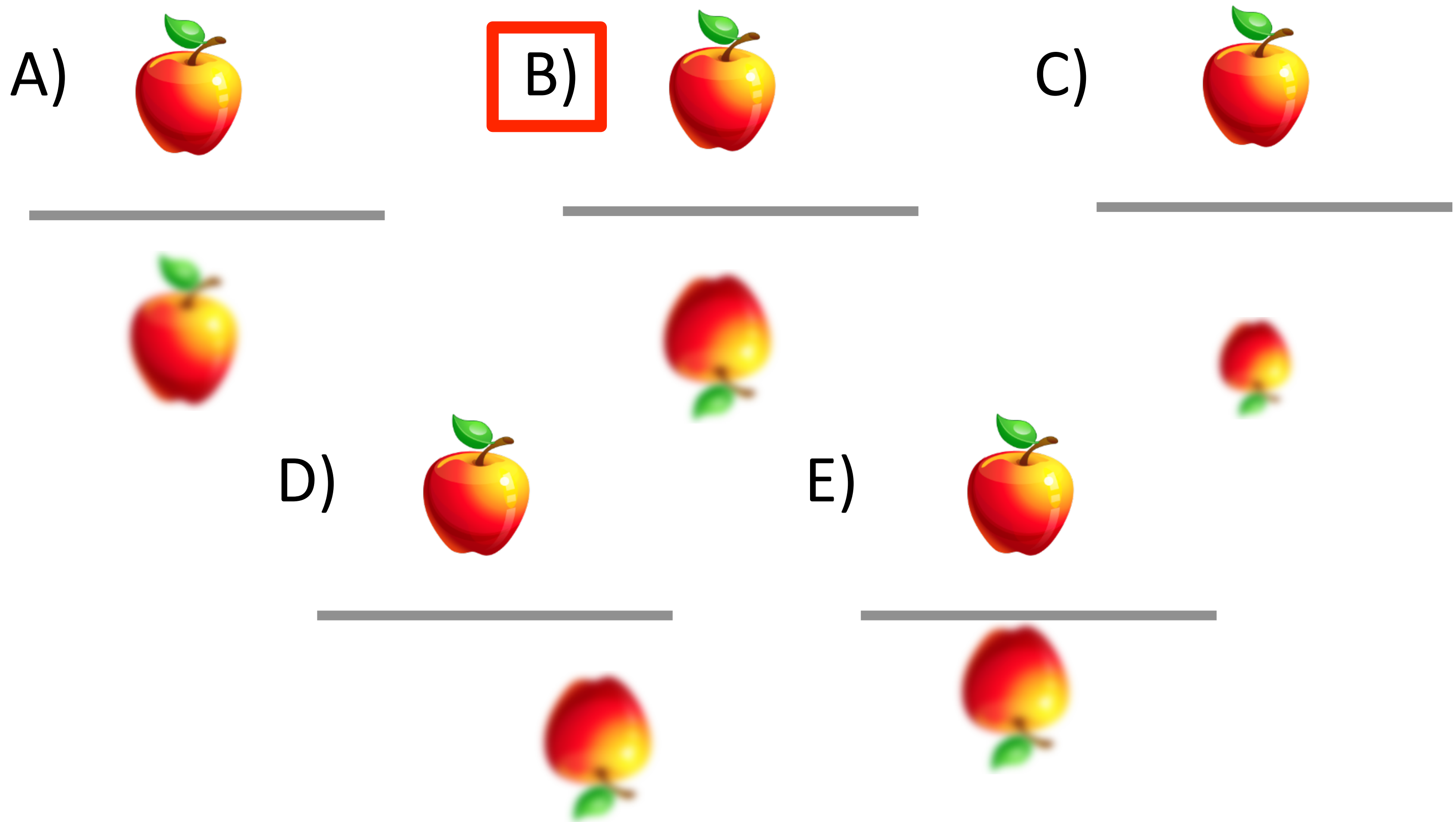
http://www.colorado.edu/physics/phys1230/

clicker question

Flat mirror reflection

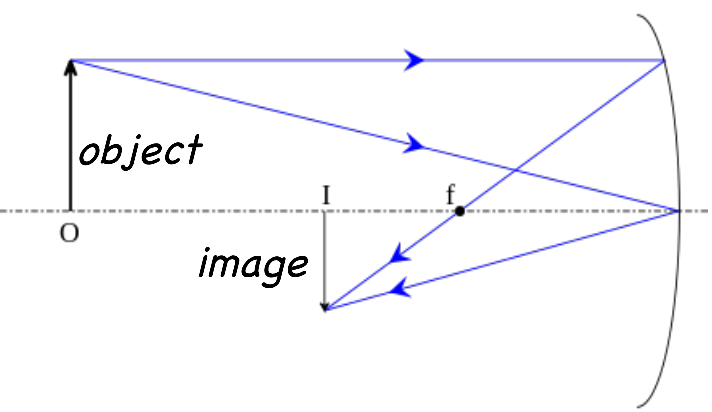
Which shows the correct location, orientation, and size for the image?



Spherical mirrors

Announcements:

- lectures 5 is posted on the class website
- midterm 1 solutions are posted
- homework 5 is posted on D2L
  - due Thurs, March 6 in homework box in Help Room
  - solutions will be posted on D2L
- reading for this week is:
  - Ch. 3 in SL



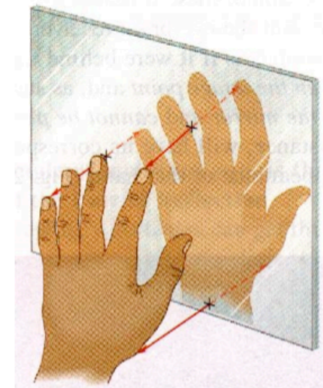
Concave solar concentrator

Convex traffic safety mirror

Recall

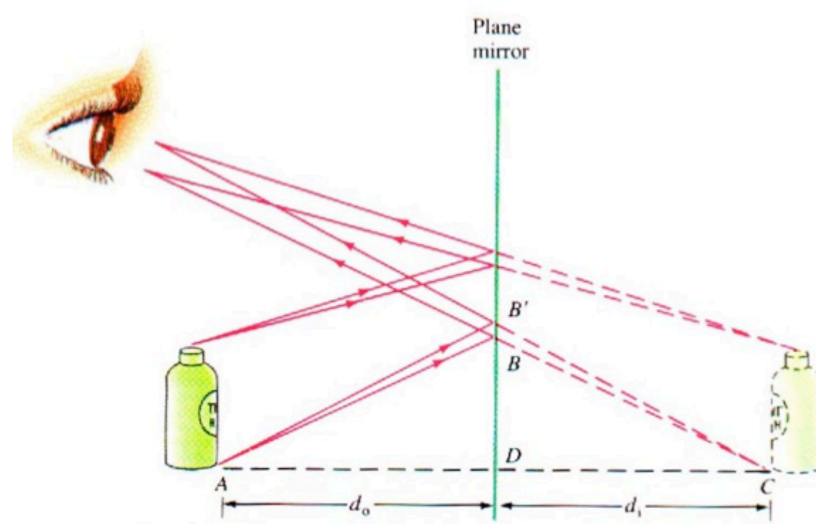
Last time

recall lecture 5: Image formation: mirrors & mirages



- real and virtual images
- image due to reflection: plane mirror
- image due to refraction: mirage, rainbow, sun columns
- optical illusions

How we see an image



Today

Spherical mirrors

- convex and concave mirrors
  - ray tracing
  - image formation
  - applications

Concave solar concentrator

Convex traffic safety mirror

Mirrors everywhere

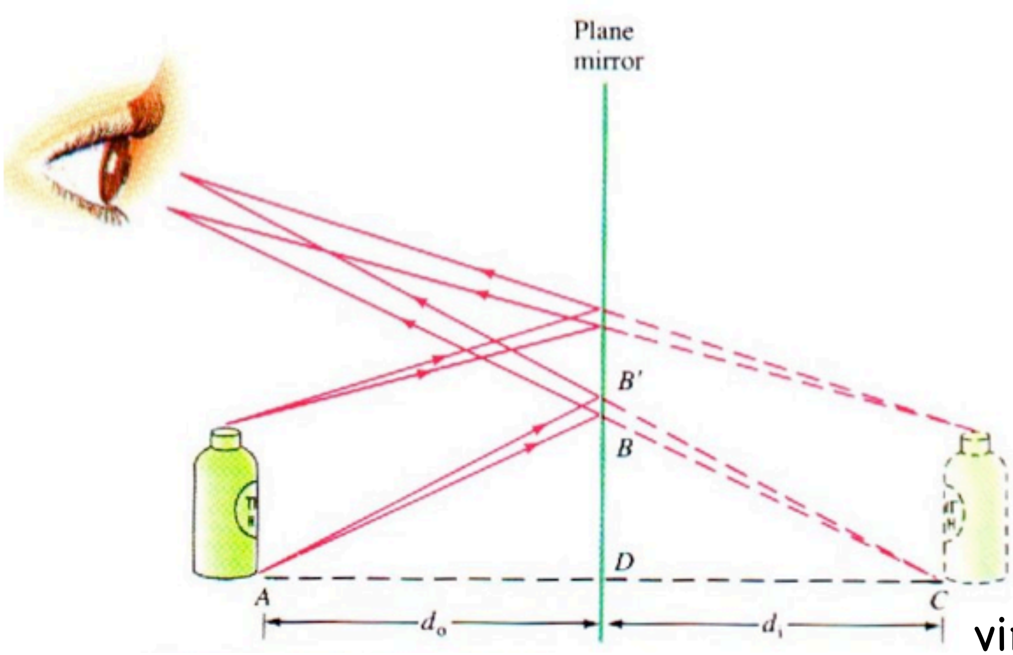
Concave solar concentrator

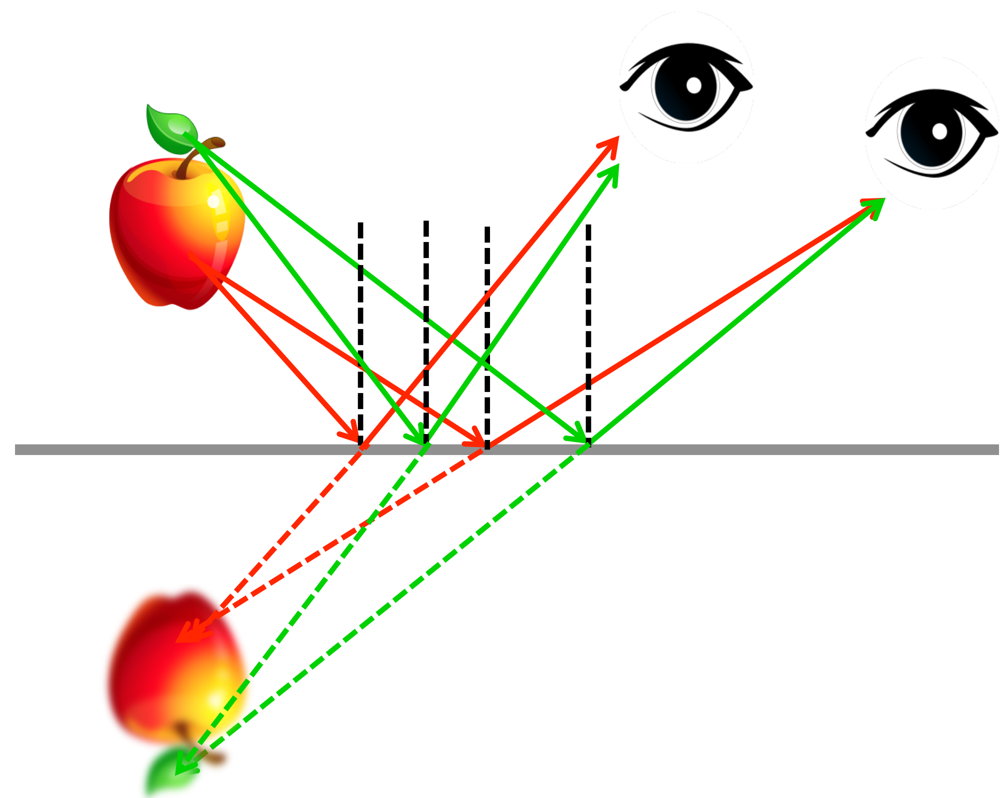
Convex traffic safety mirror

Flat mirrors review

- Recall ray tracing of a flat mirror: *normal* and law of *reflection*
- There are "special" rays that are sufficient for locating the image
- The *virtual* image is in the same place regardless of the location of the viewer
- The image is called *virtual* because no real rays reach the image, and it cannot be seen by putting a screen at its position

How we see an image

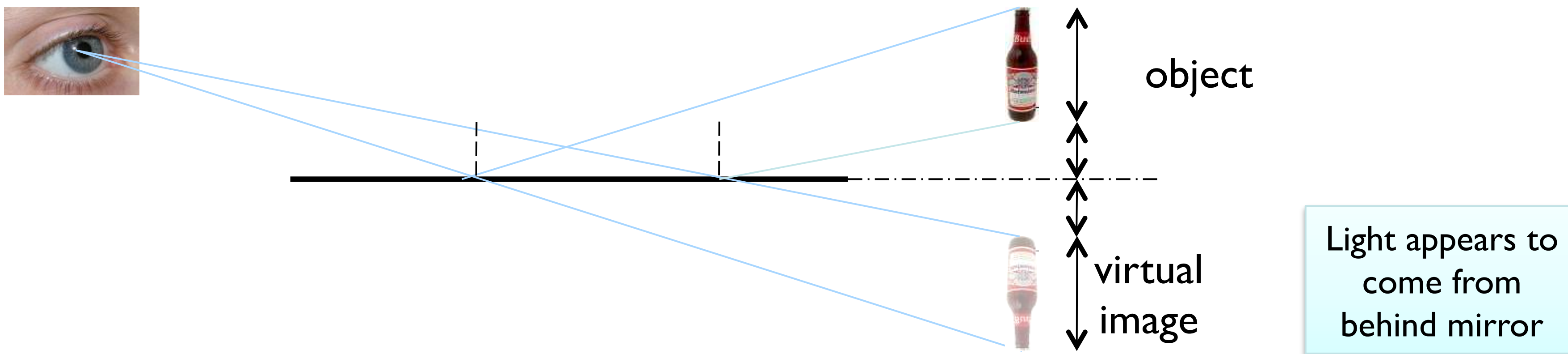




Virtual vs real image

Virtual image:

The light appears to come from the virtual image, but in fact does not come from there.



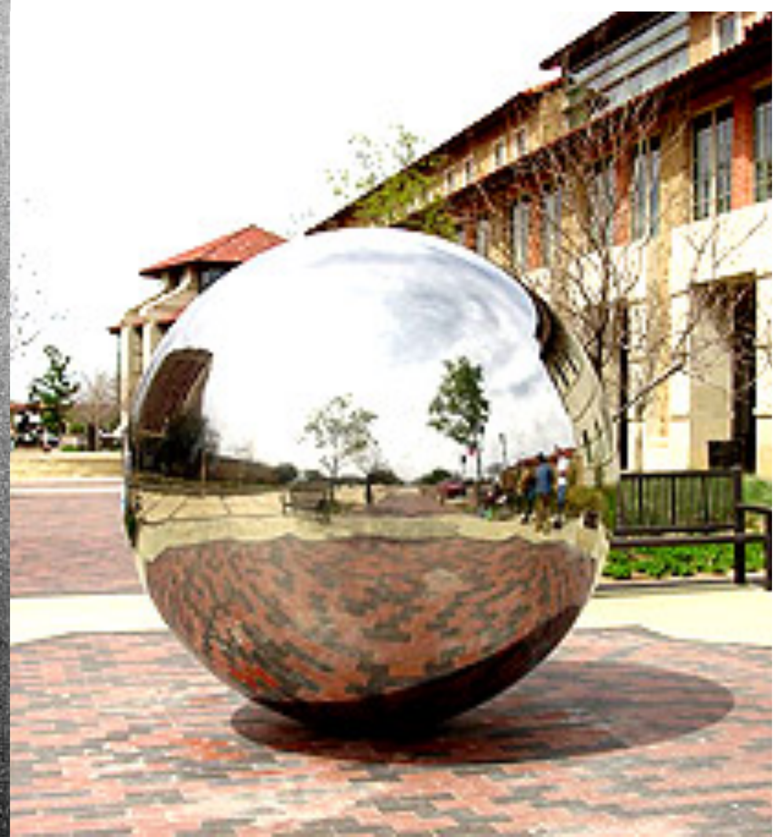
Real image:

The light comes from the image (rather than appearing to come from there). You may need a screen to see it.

a real image:

Spherical mirrors

Concave solar concentrator

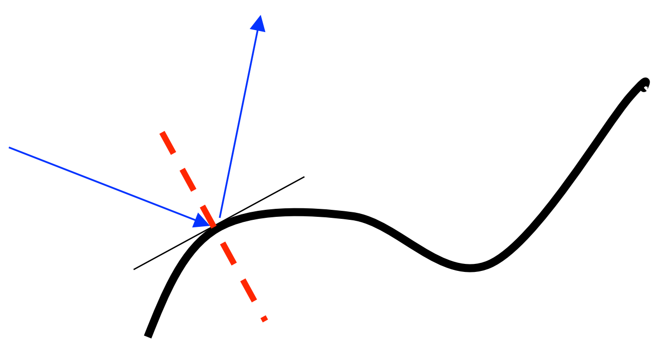


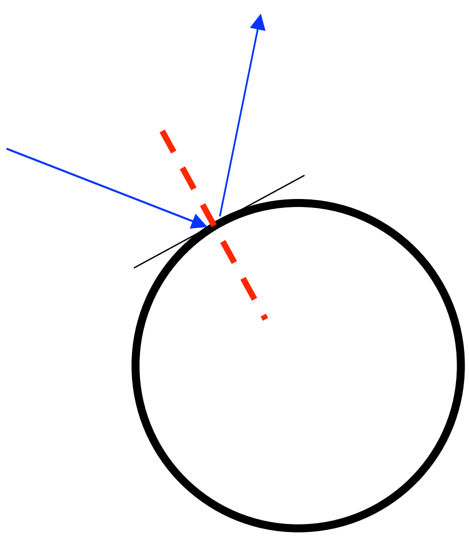
Convex traffic safety mirror

Normal to a surface

What is the *normal* to a *curved* surface and how is it used to find reflected rays?

- draw a tangent line to the curve (tangent plane to the surface)
- the normal is perpendicular to that line at the point
- with normal in place reflected and refracted rays are given as for the flat interface





Convex vs concave spherical mirrors

Metal bowls have both a convex and a concave mirror
(though not very good ones)

Convex traffic safety mirror

Concave solar concentrator

Convex:

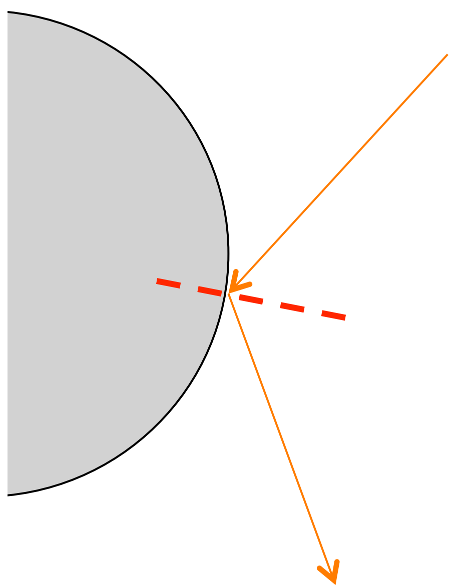
- make something *smaller*
- looks *far* away
- lets you see a *wide angle*
- bike mirrors, car mirrors

Concave:

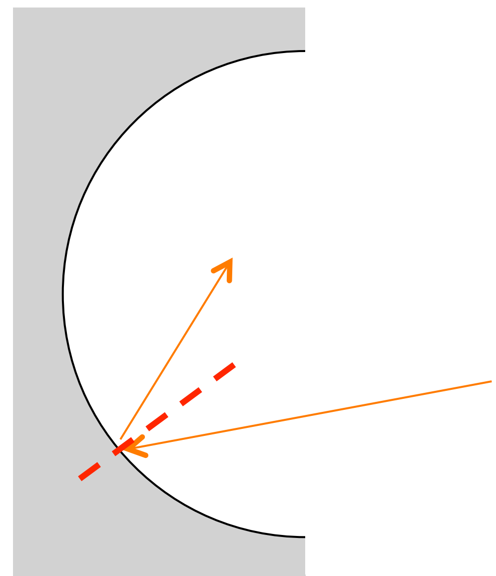
- make something *bigger*
- looks *closer*
- you can't see much around you
- makeup mirrors

Convex vs concave spherical mirrors

- Spherical mirrors are drawn in two dimensions, so you have to imagine the 3D mirror that this line represents
- Both convex and concave mirrors obey the same law of reflection, but they make different kinds of images

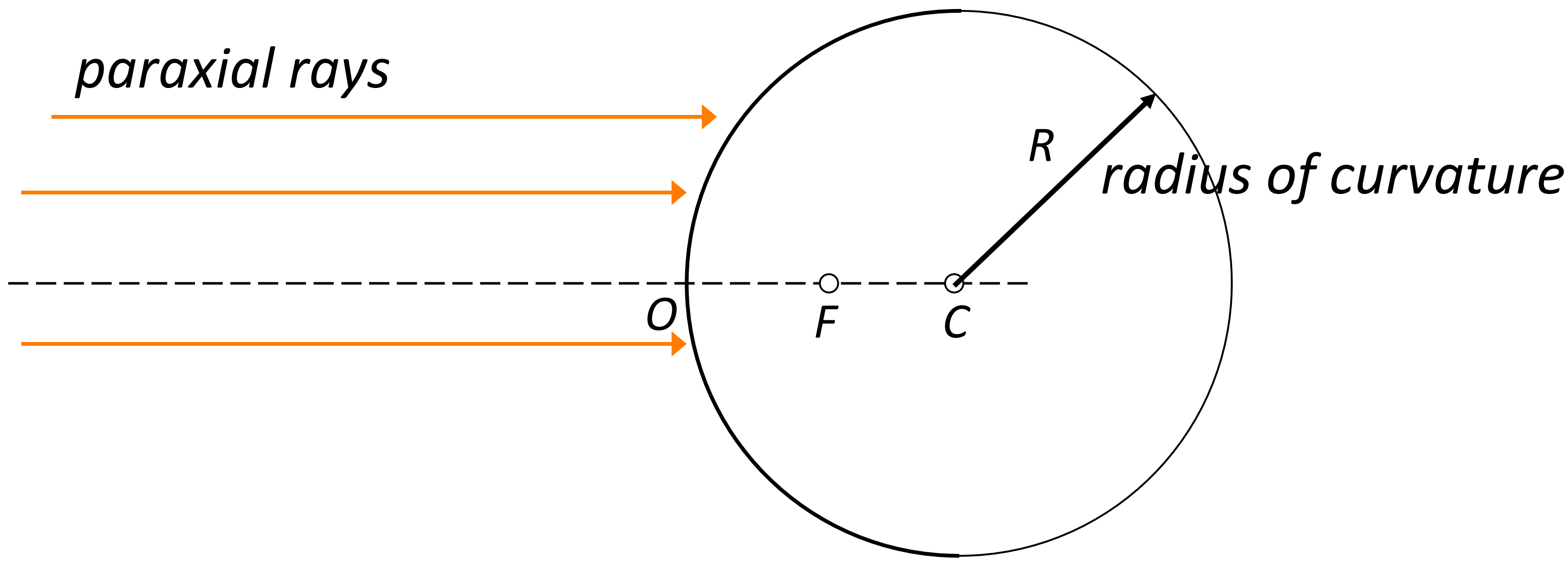


Convex



Concave

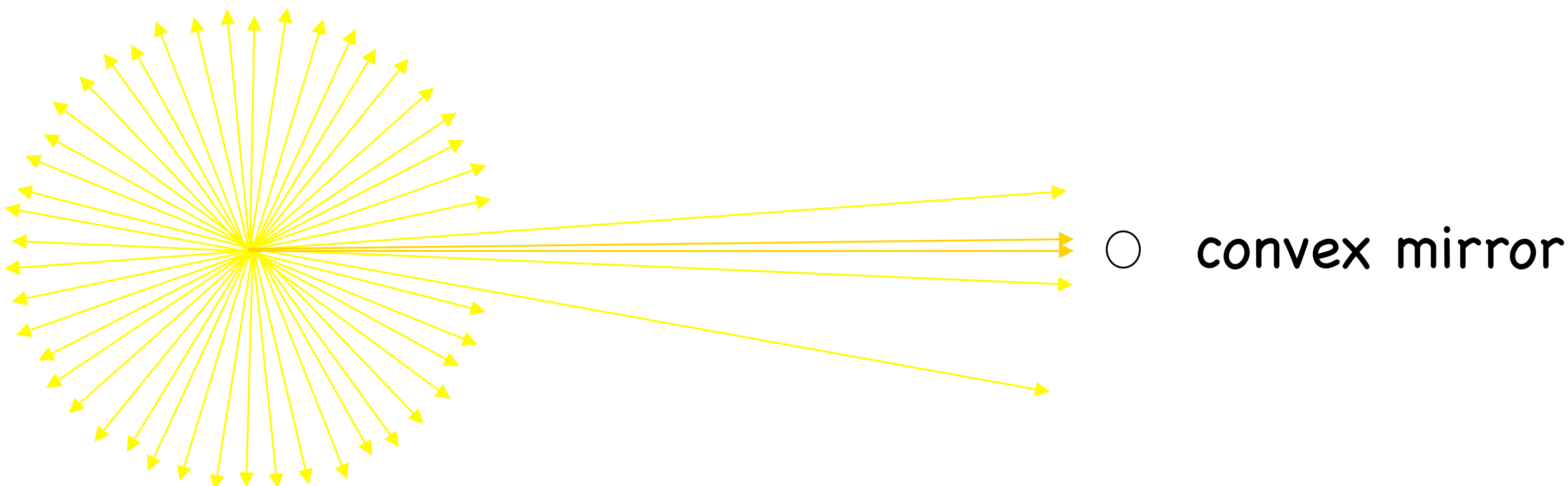
Ray tracing for spherical mirrors



- radius of curvature (R): radius of the sphere the mirror is "cut from"
- center of curvature (C): center of the sphere
- focal point (F): point where rays from a distance appear to converge; half way between the surface and the center of curvature
- paraxial rays: rays coming onto the mirror close to the axis
- $f = OF = \frac{1}{2}\, OC$: focal length

Sources of paraxial rays

- The rays coming from a distance source can be considered approximately paraxial (parallel, close to axis) when they reach a mirror



- The rays from a nearby source, such as a candle or bare light bulb, cannot be considered paraxial

Convex mirrors

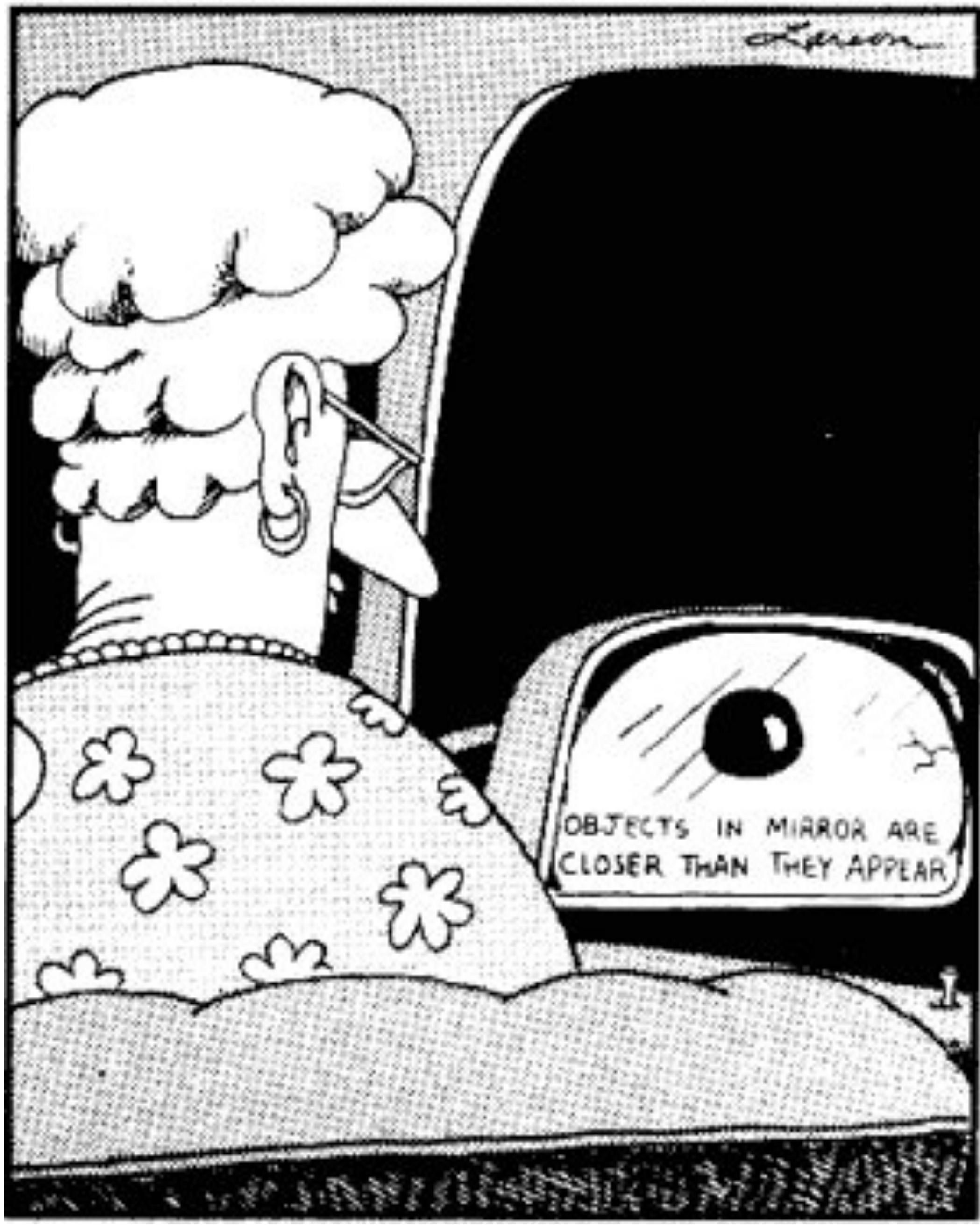
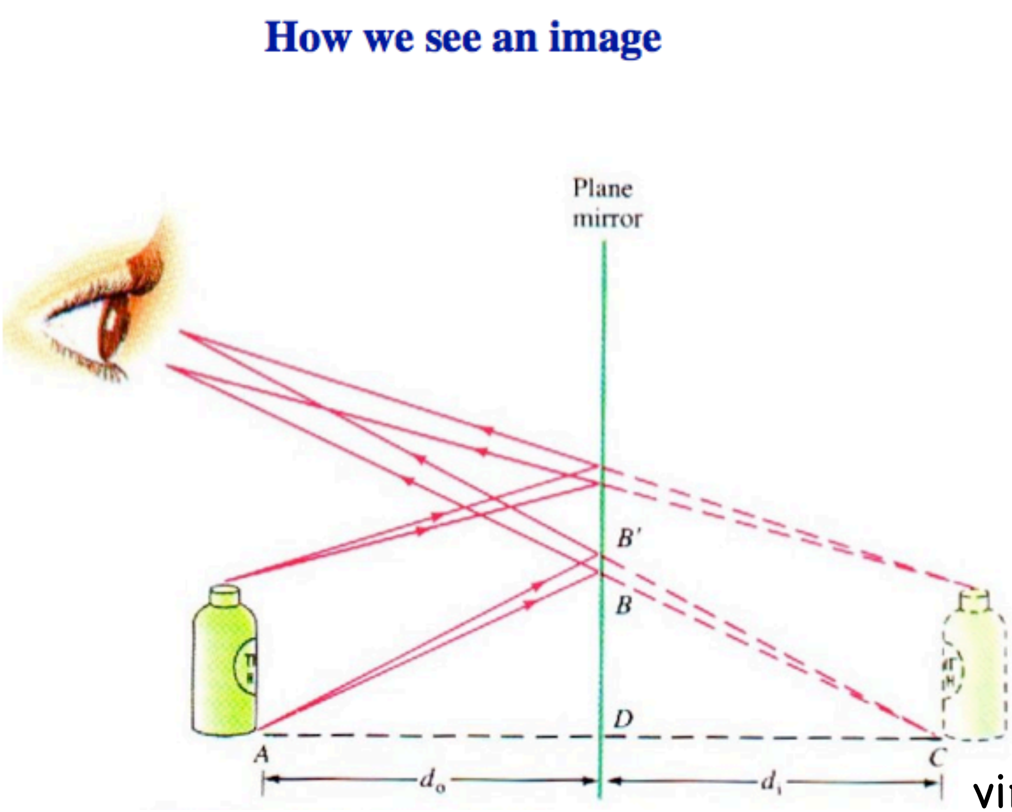
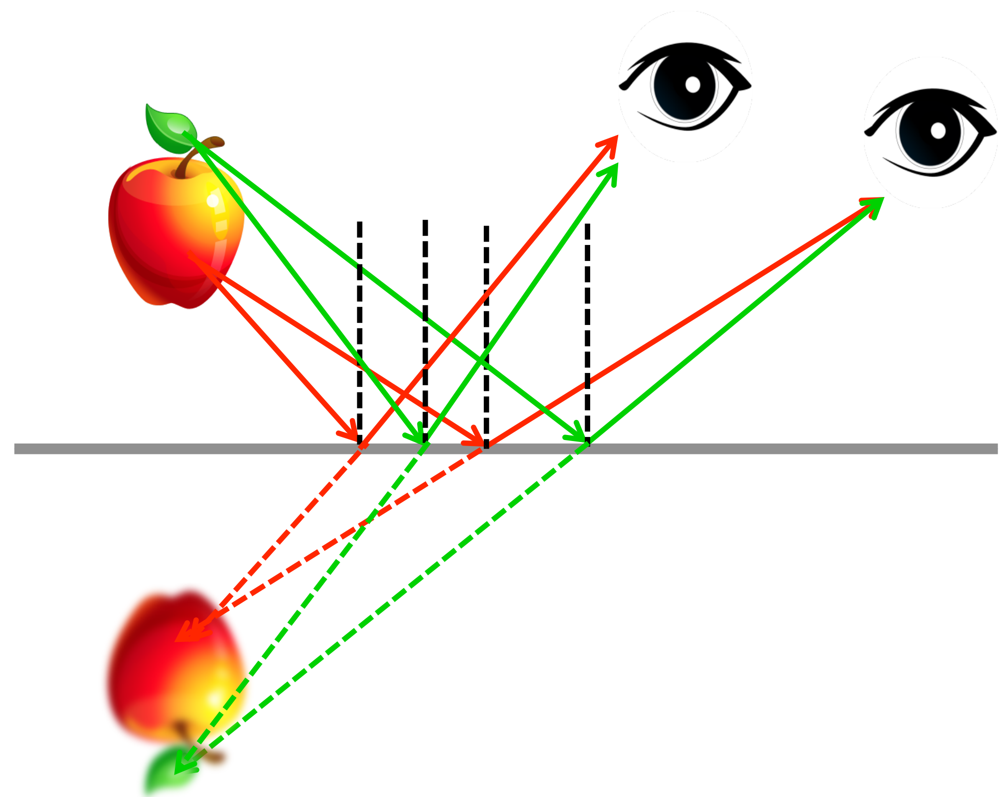


Image formation in spherical mirrors

recall plane mirror:

- reflected rays extrapolated behind mirror
- intersection found to locate image

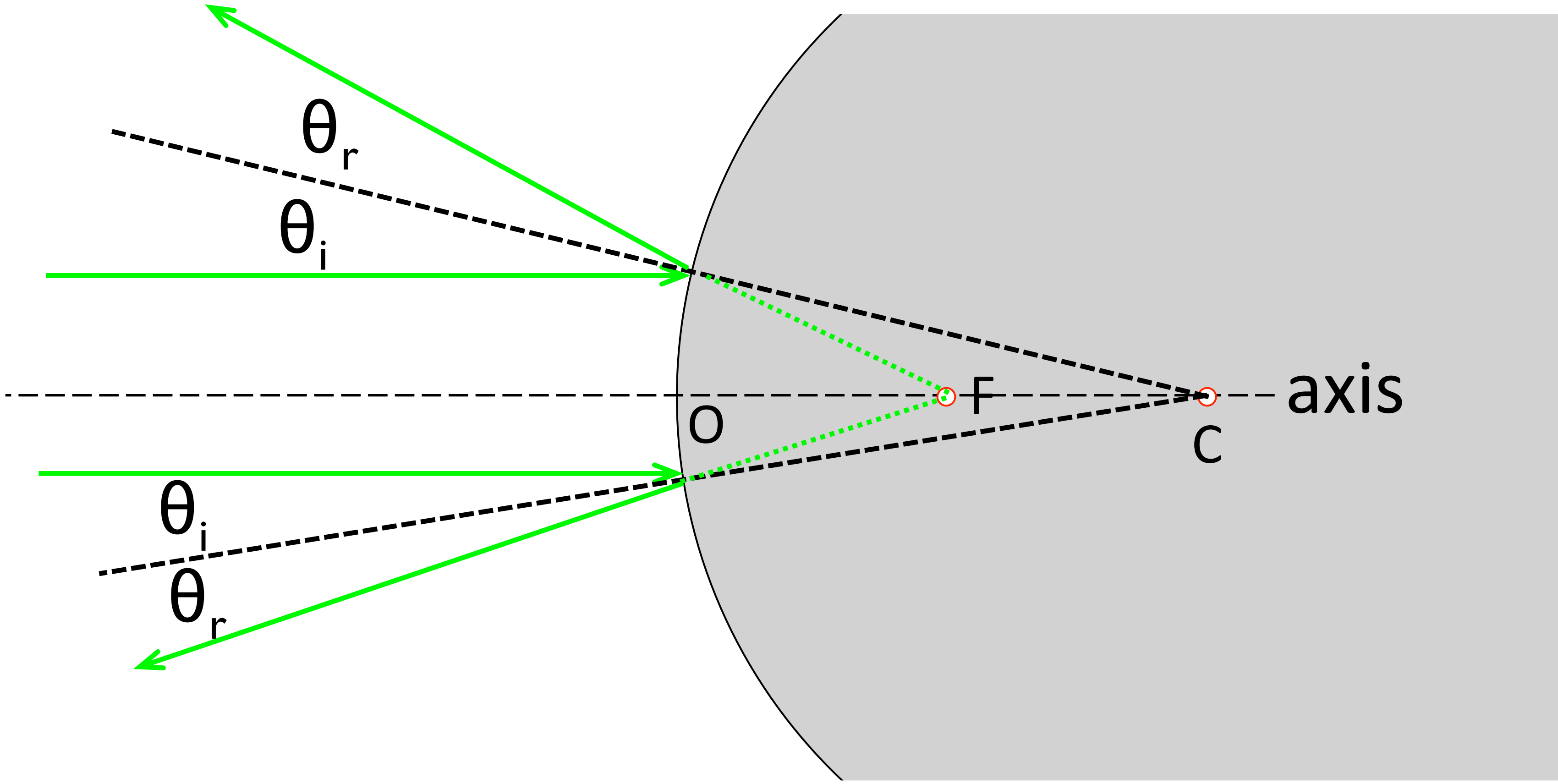




virtual image

Special rays: convex mirror

f = OF = ½ OC > 0

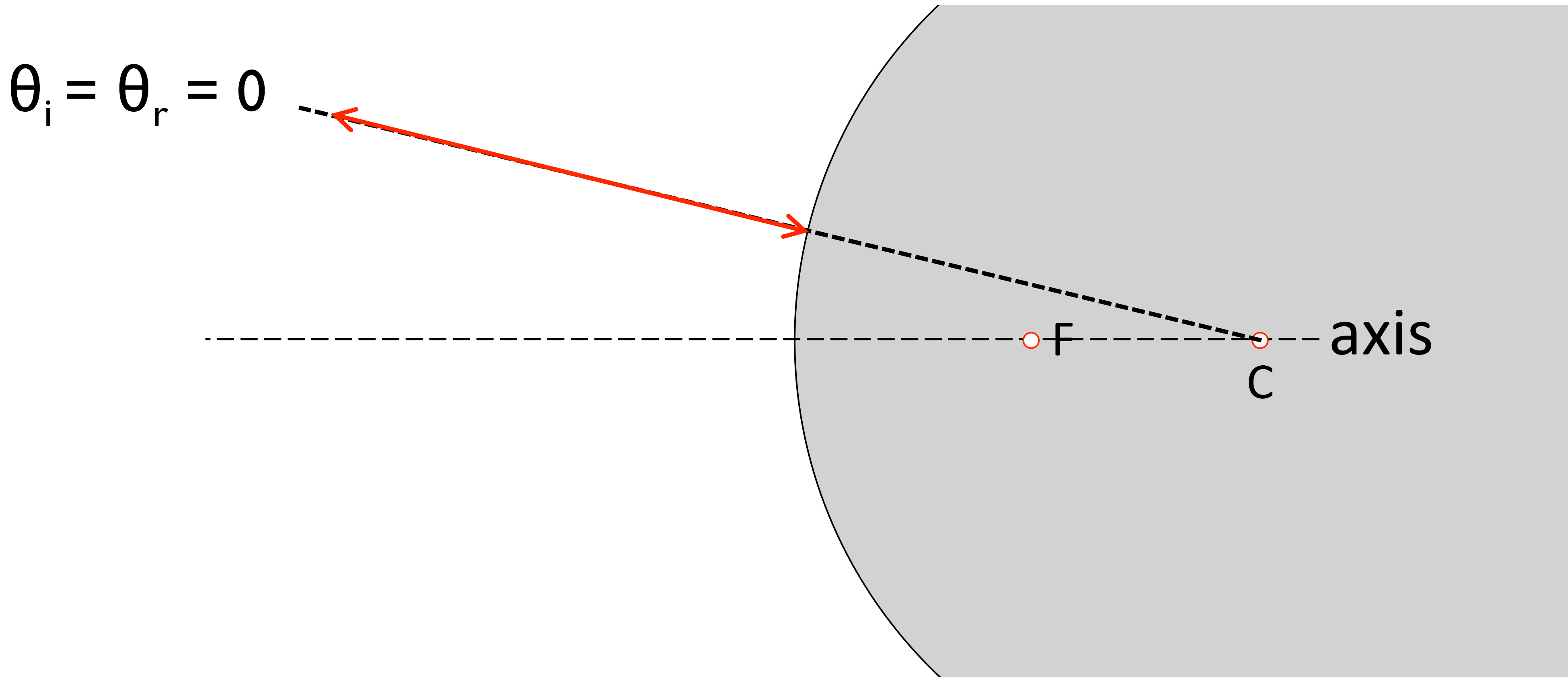


Rule 1:

All rays incident parallel to the axis are reflected so that they appear to be coming from the focal point, F.

Special rays: convex mirror

$f = OF = \frac{1}{2} OC > 0$

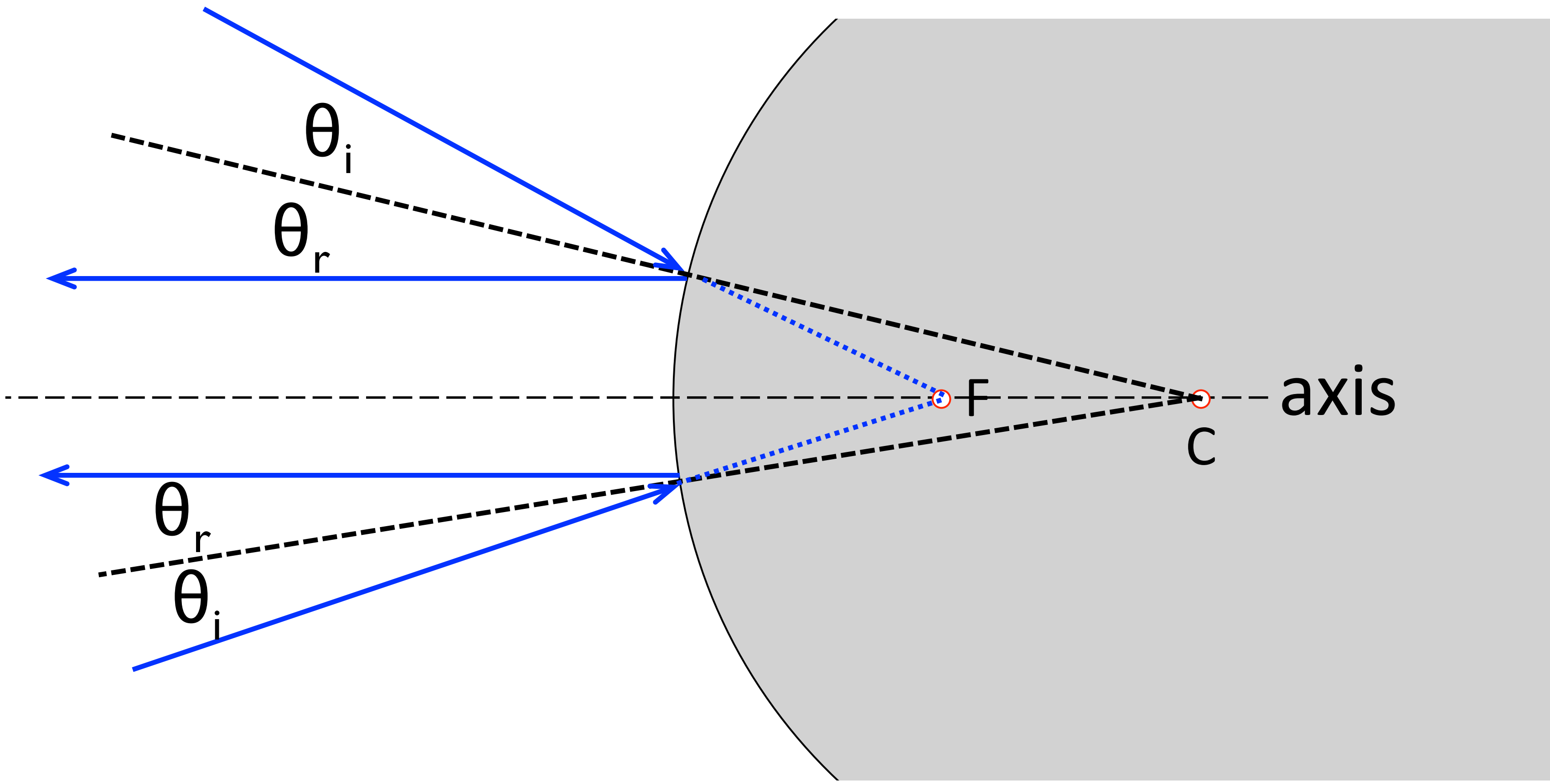


Rule 2:

All rays that (when extended) pass through C are reflected back on themselves

Special rays: convex mirror

$f = OF = \frac{1}{2} OC > 0$



Rule 3:

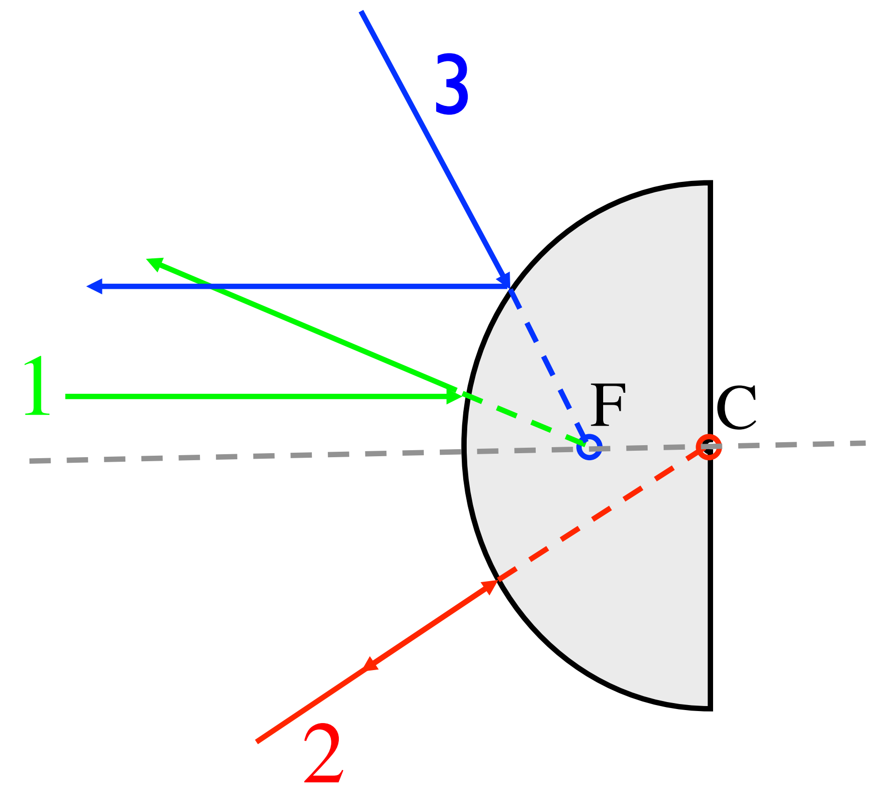
All rays that (when extended) pass through F are reflected back parallel to the axis

Three rules of ray tracing: convex mirror

Ray 1 rule:
All rays incident *parallel* to the axis (line connecting C and F) are reflected so that they appear to be coming from the focal point, F.

Rule 2:
All rays aimed at the *center point*, C are reflected back on themselves

Rule 3:
All rays aimed at the *focal point*, F are reflected back parallel to the axis (line connecting C and F)



(use a ruler)

strictly valid only for paraxial rays; others cause blurring

Locating an image: convex mirror

What does the observer see in the mirror?

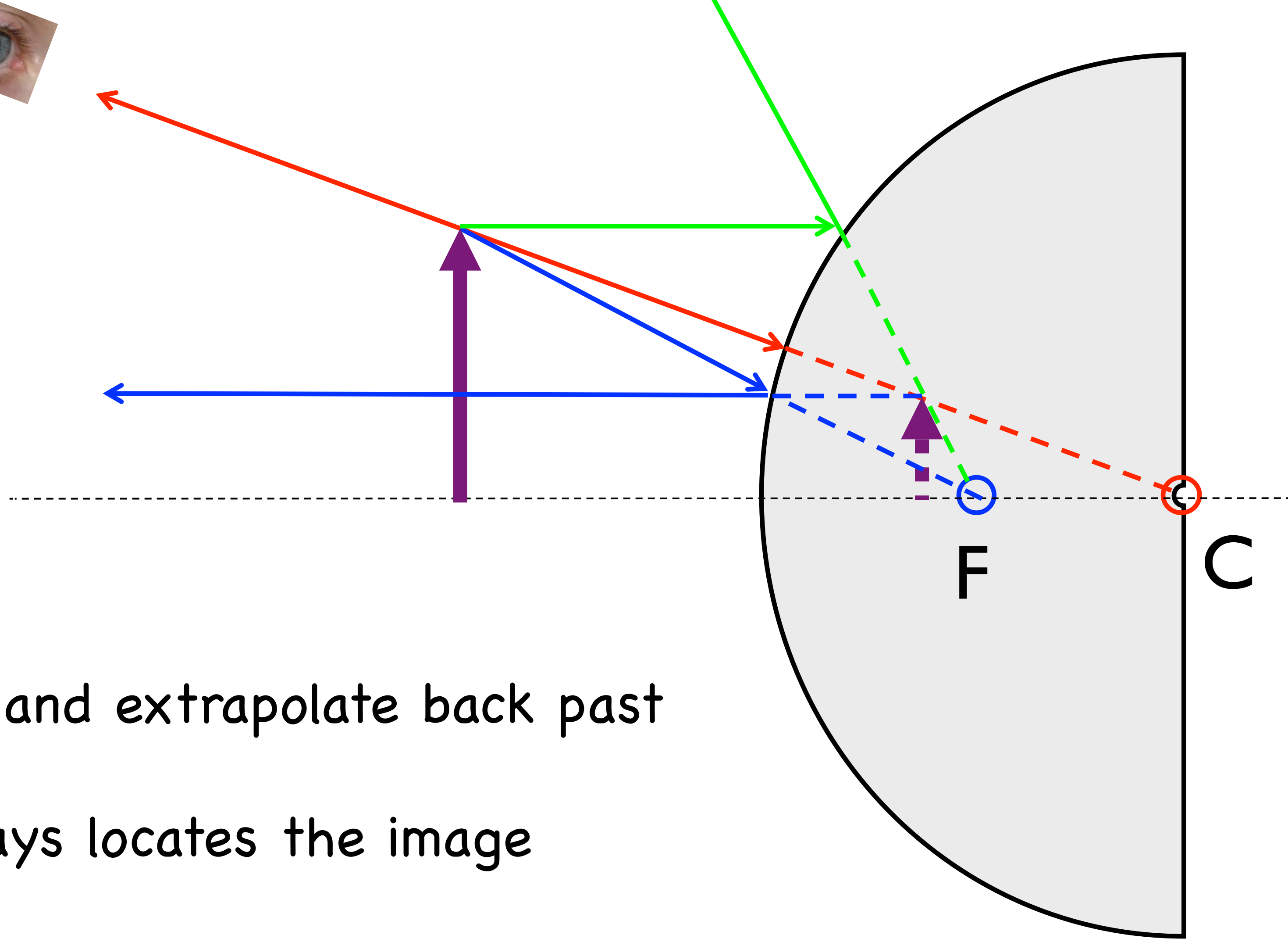


Image properties:

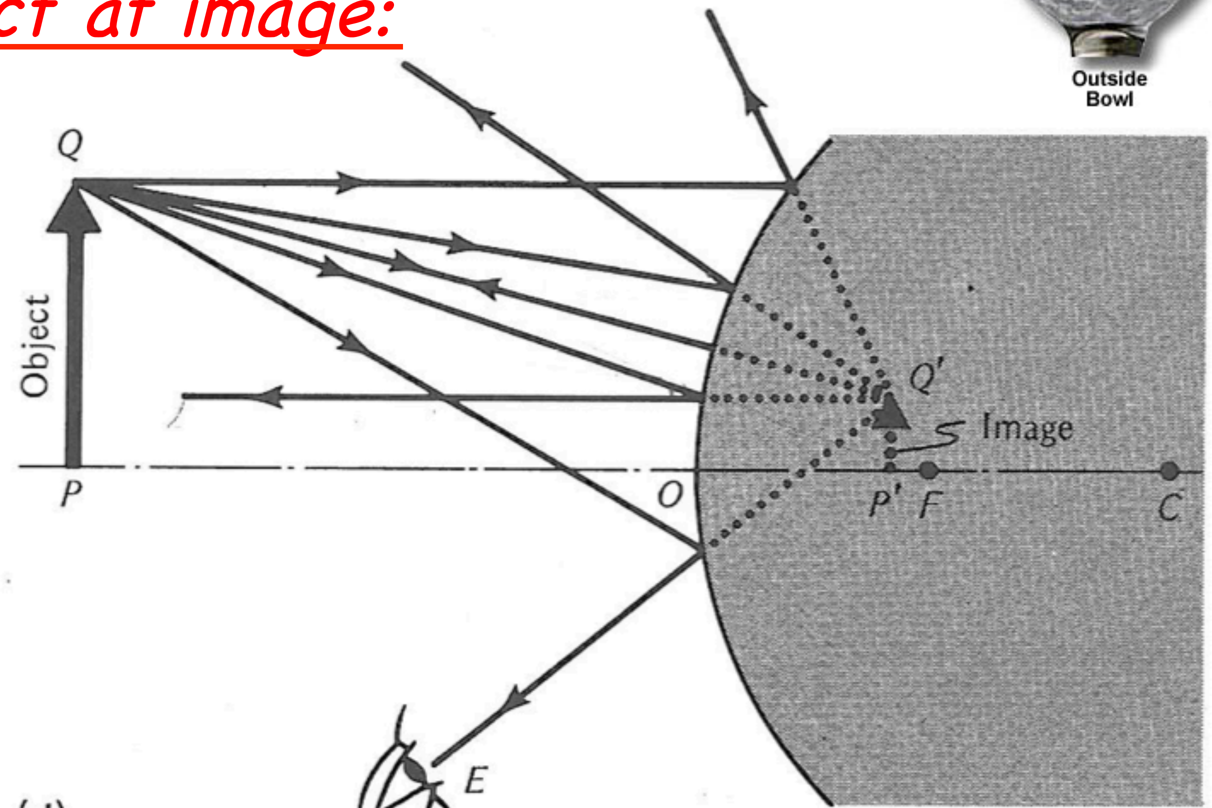
- virtual
- right-side up
- closer to the mirror than object
- smaller than the object

- Draw in the rays and extrapolate back past the mirror
- Intersection of rays locates the image

Locating an image: convex mirror

What does the observer see in the mirror?

All other rays intersect at image:



(d)

Image properties:

- virtual
- right-side up
- closer to the mirror than object
- smaller than the object

- Draw in the rays and extrapolate back past the mirror
- Intersection of rays locates the image

Locating an image: convex mirror

What does the observer see in the mirror?

object Q (star) at "infinity" imaged at F:

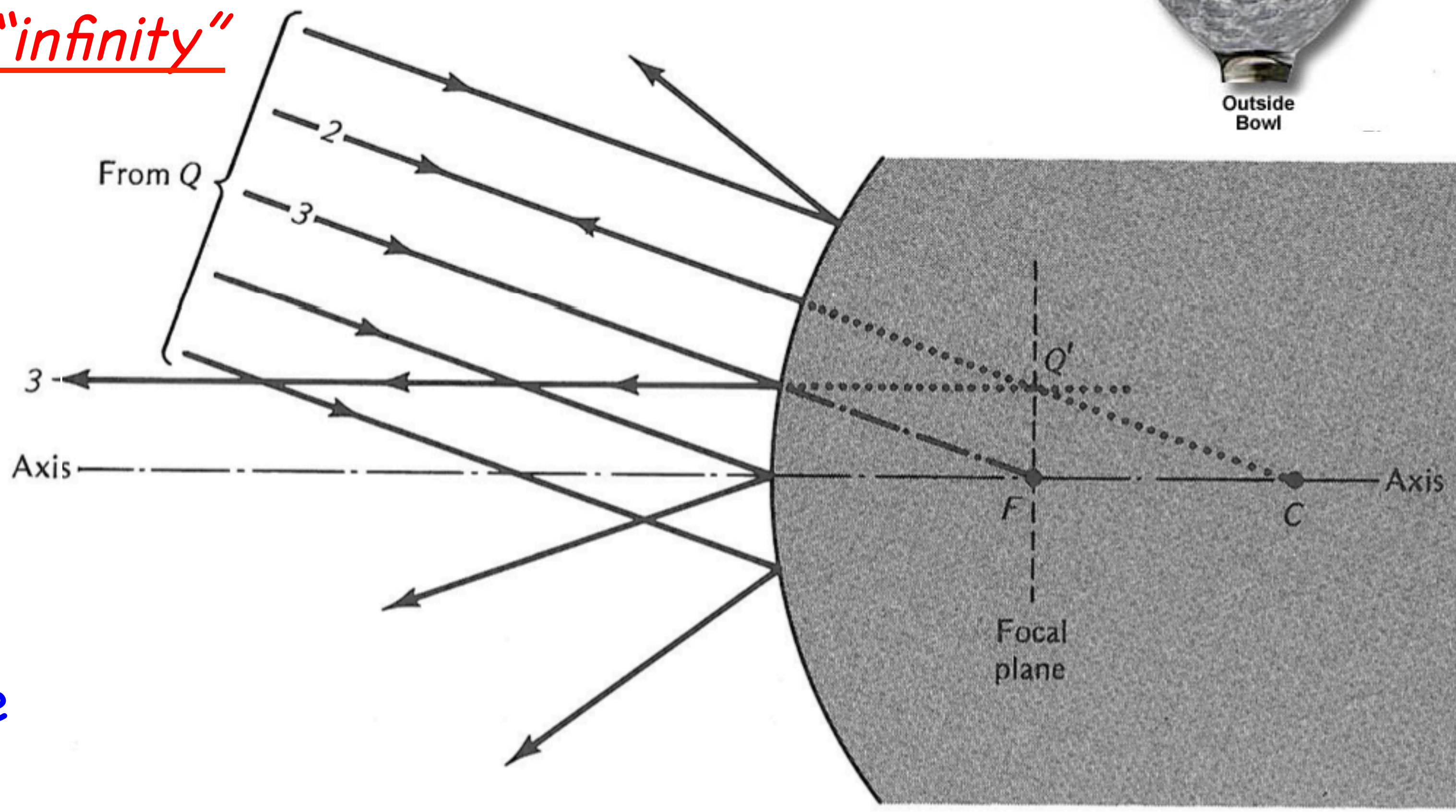


Image properties:

- virtual
- right-side up
- closer to the mirror than object
- smaller than the object

- Draw in the rays and extrapolate back past the mirror
- Intersection of rays locates the image

Compare to flat mirror

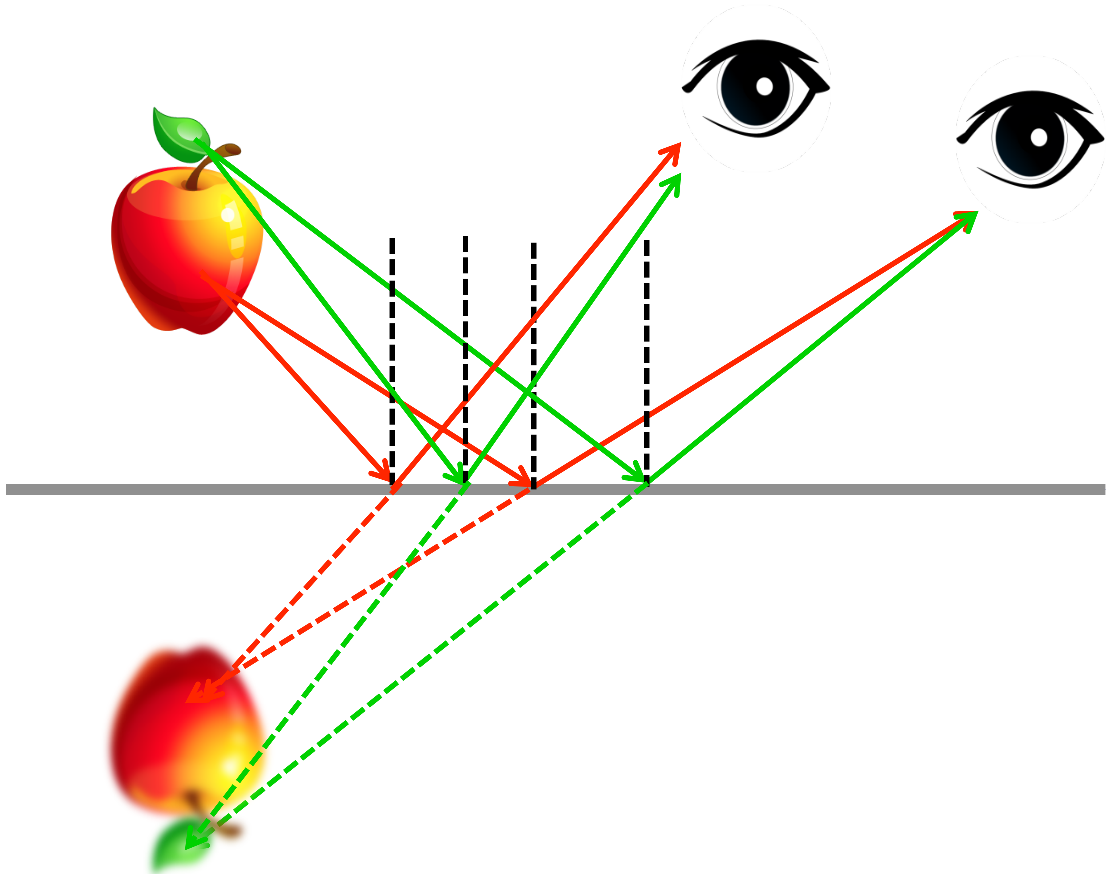


Image properties:

- virtual
- upside down
- the same distance from to the mirror as the object
- the same size as the object

clicker question

Image of a convex mirror

Q: The image formed in a convex mirror is smaller than the object. This would make a convex mirror useful for which application?

a) Makeup or shaving mirror

b) Wide-angle mirror, on a car or at a blind intersection

c) A mirror in a clothing store dressing room

Because the image is smaller than the object, convex mirrors reflect from wider angles than flat mirrors

Convex mirror art

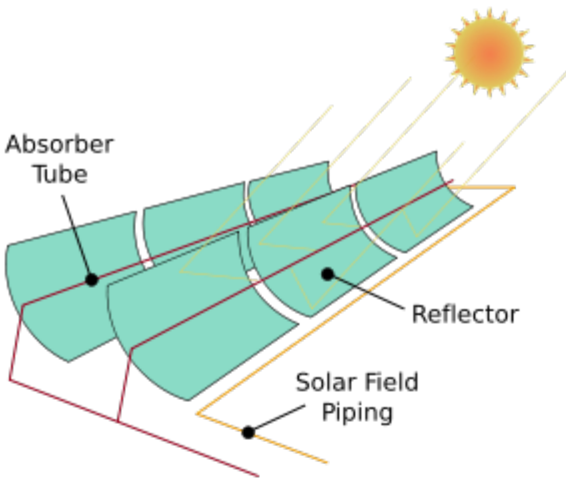
anamorphic art

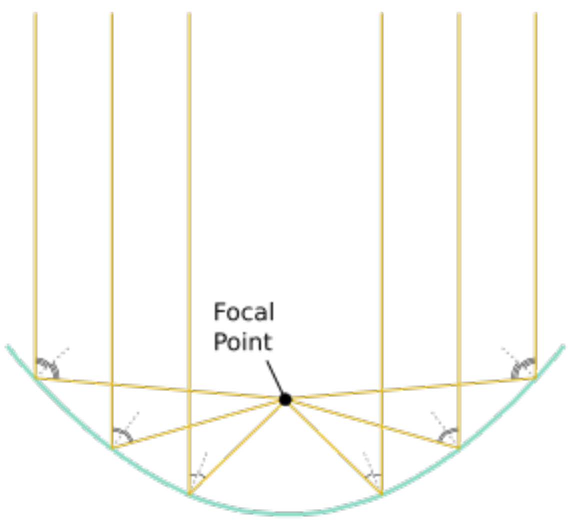
M.C. Escher's "Hand with reflecting globe"

Concave mirrors

Archimedes' idea
(see pg.104-105 SL text)

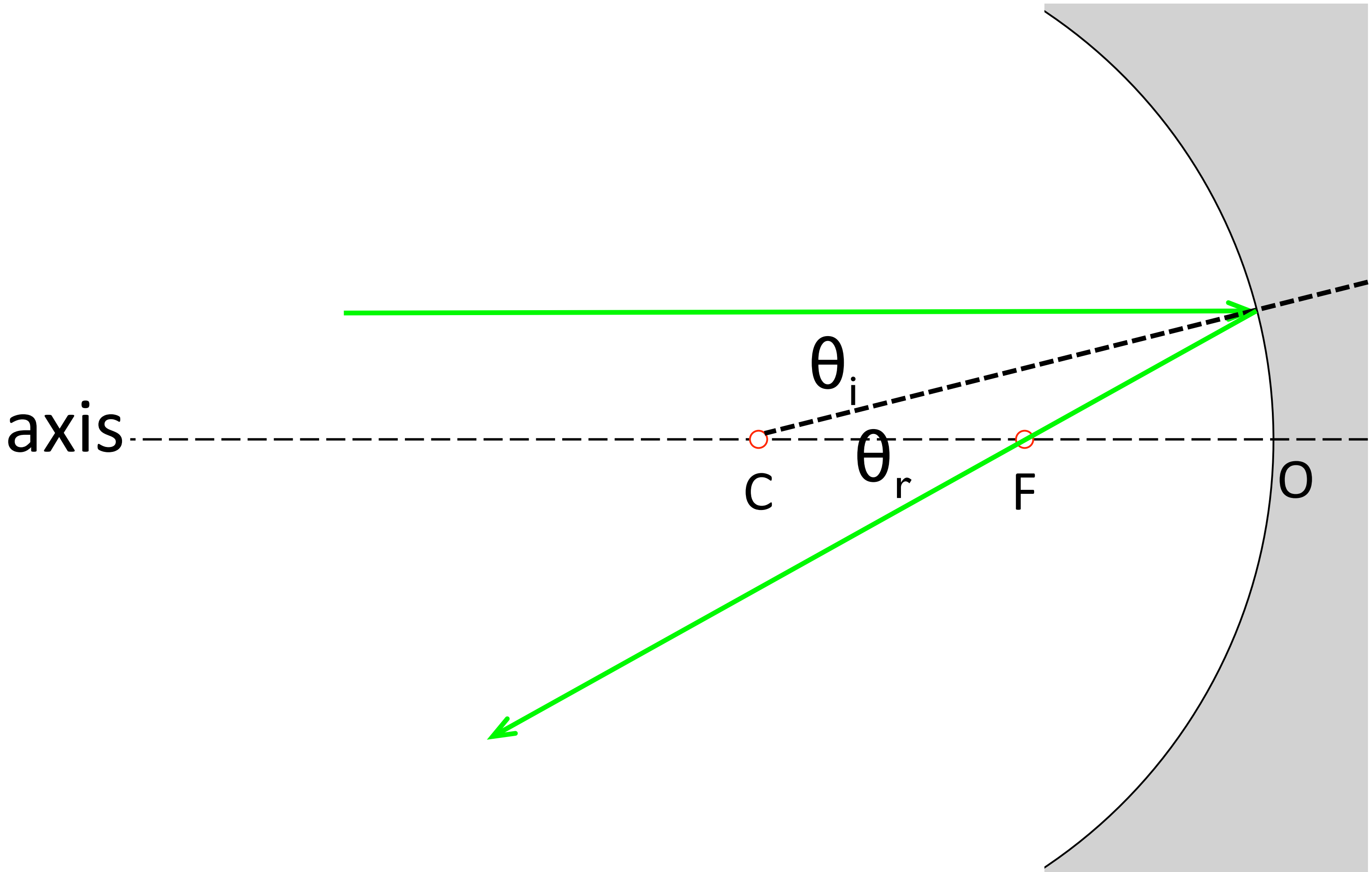
power from Sun:
1 kilowatt/meter^2





Special rays: concave mirror

$f = OF = \frac{1}{2}\,OC < 0$

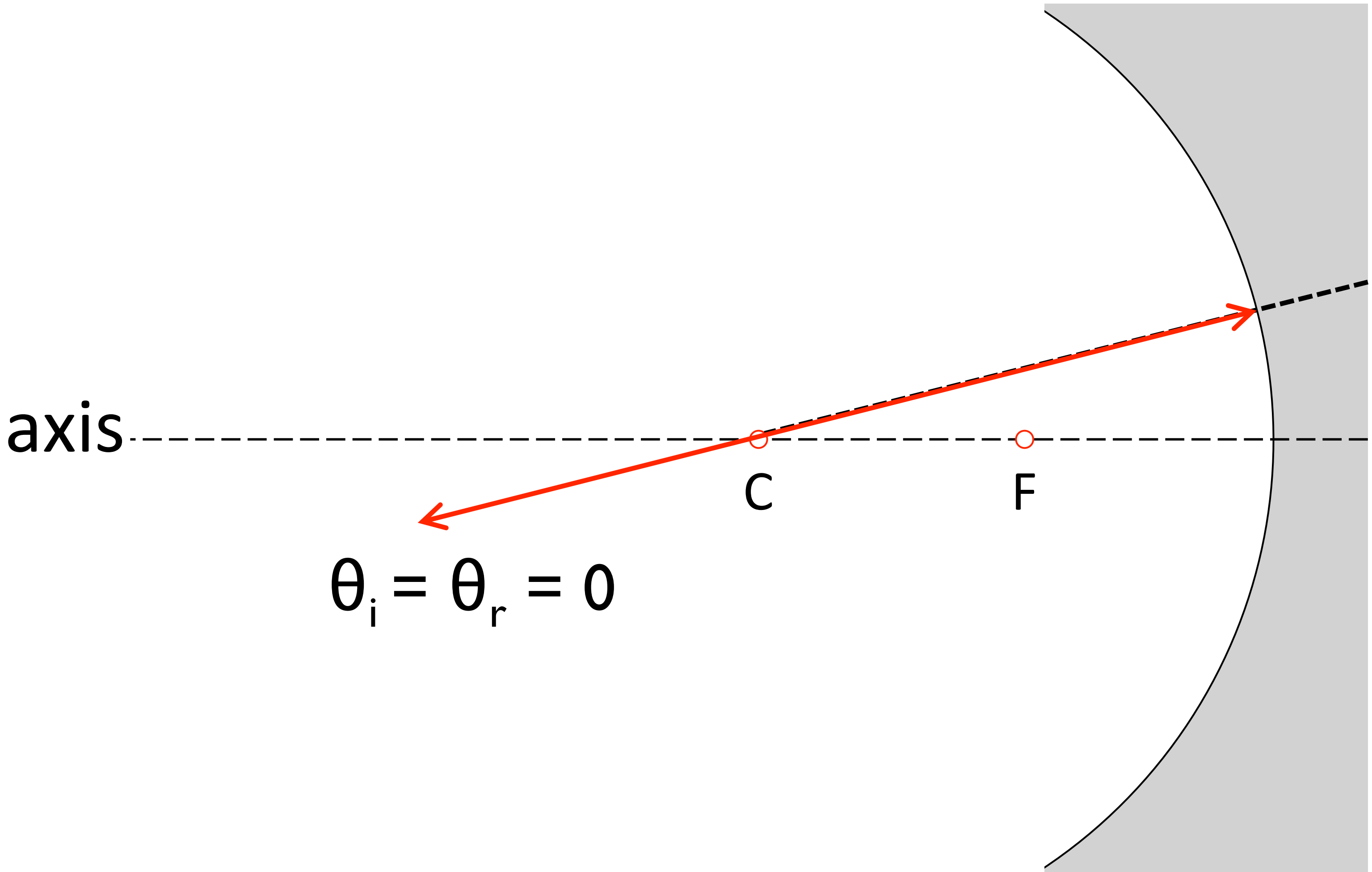


Rule 1:

All rays incident parallel to the axis are reflected so that they pass through the focal point, F.

Special rays: concave mirror

$f = OF = ½ OC < 0$

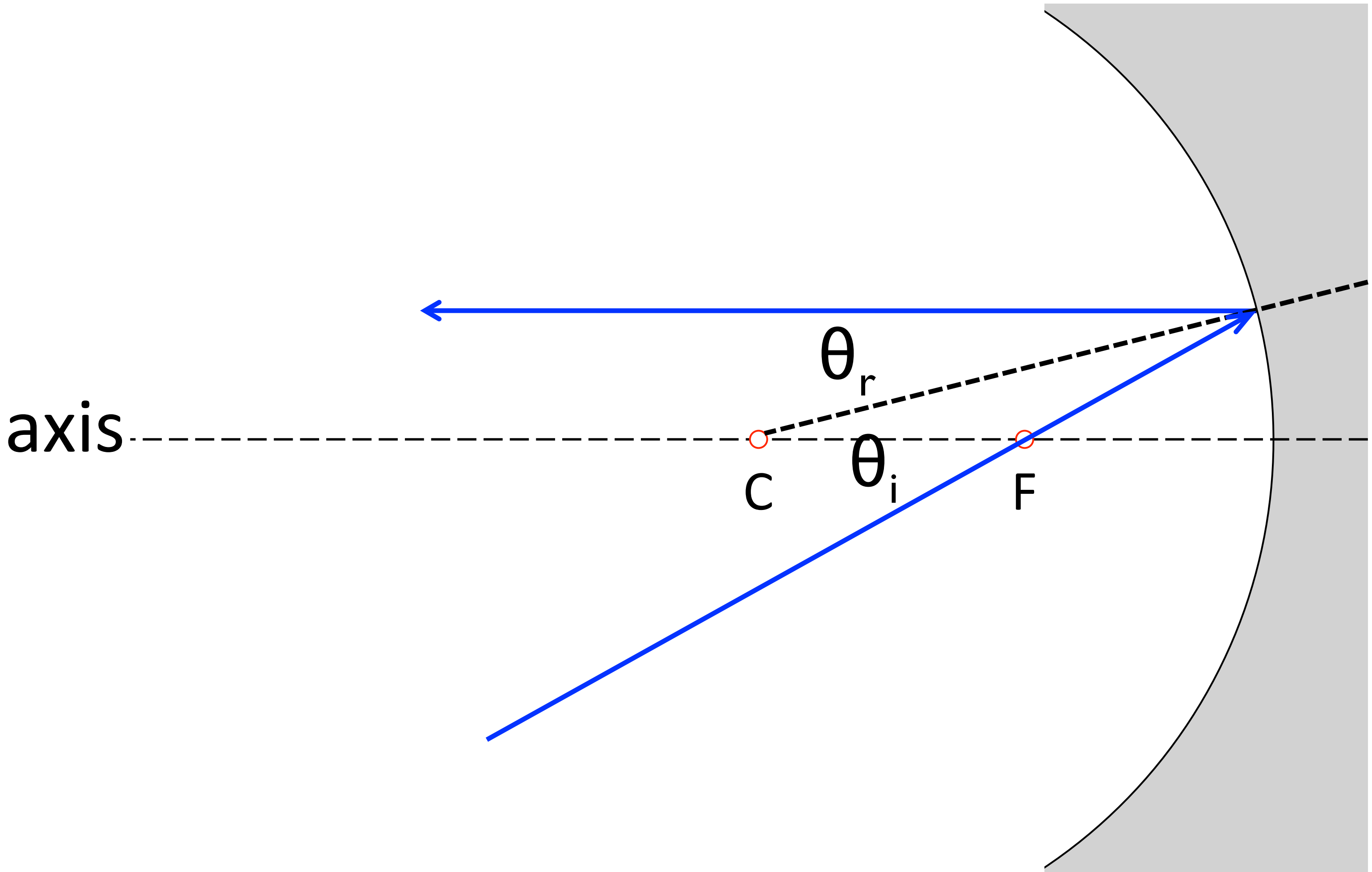


Rule 2:

All rays that pass through C are reflected back on themselves.

Special rays: concave mirror

$f = OF = \frac{1}{2} OC < 0$



Rule 3:

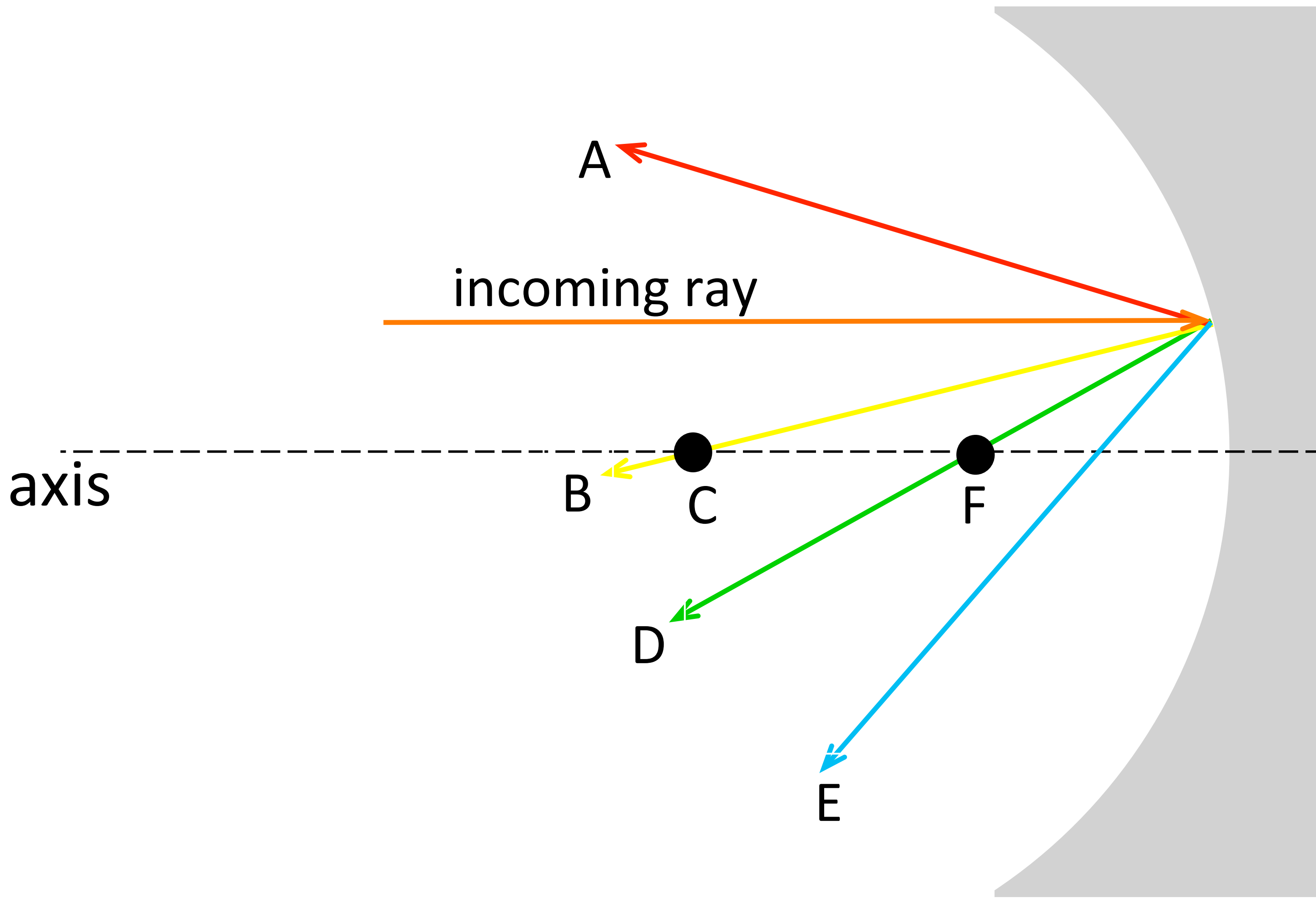
All rays that pass through F are reflected back parallel to the axis.

clicker question

Concave mirror reflection

Q: Using ray tracing rules, which is the correct reflected ray for the incoming ray parallel to the axis?

a) ray A
b) ray B
c) ray C
d) ray D
e) ray E



Locating an image: concave mirror

case 1: *object between focus F and mirror*

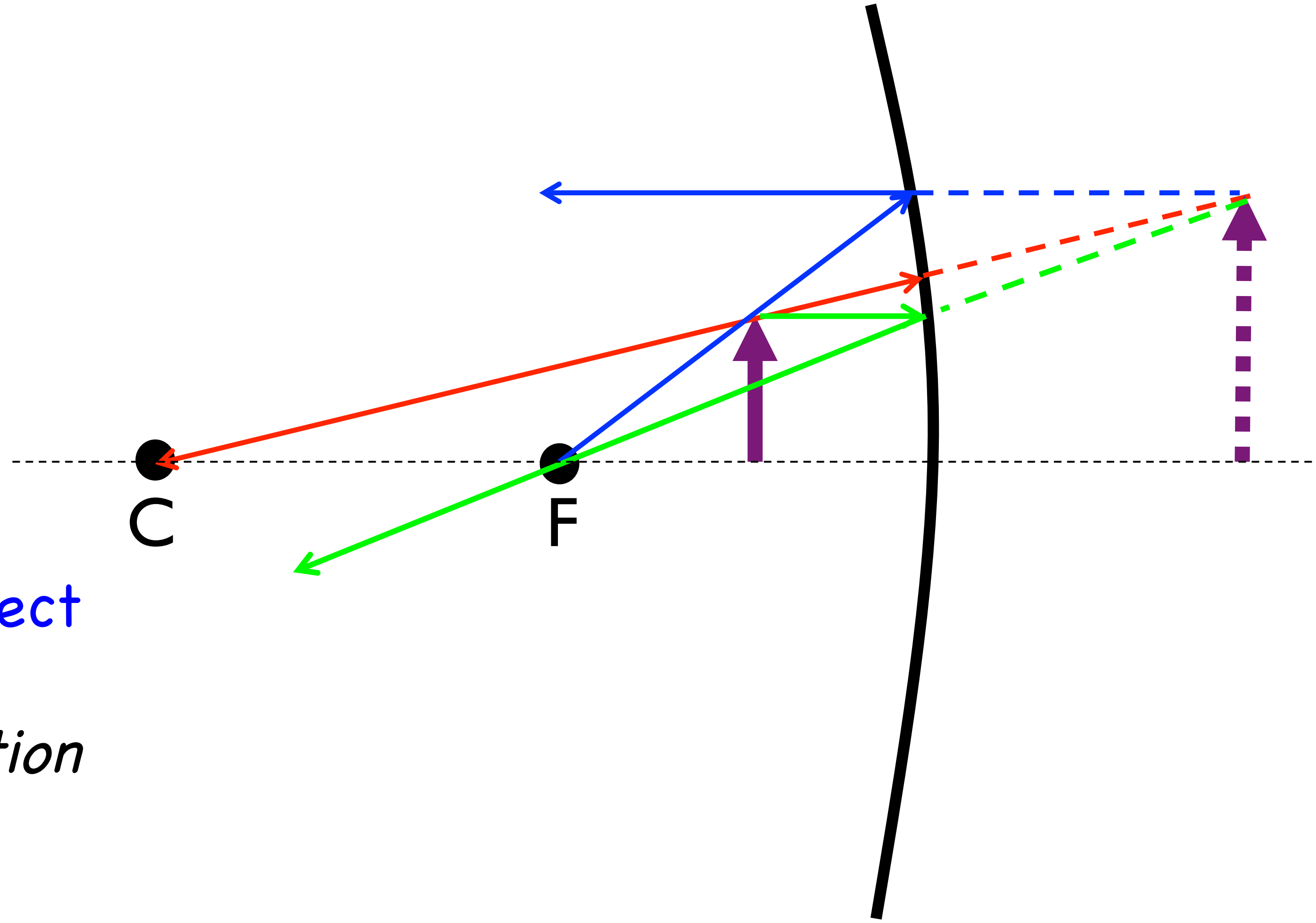


Image properties:

- virtual
- right-side up
- further from the mirror than the object
- larger than the object -> *magnification*

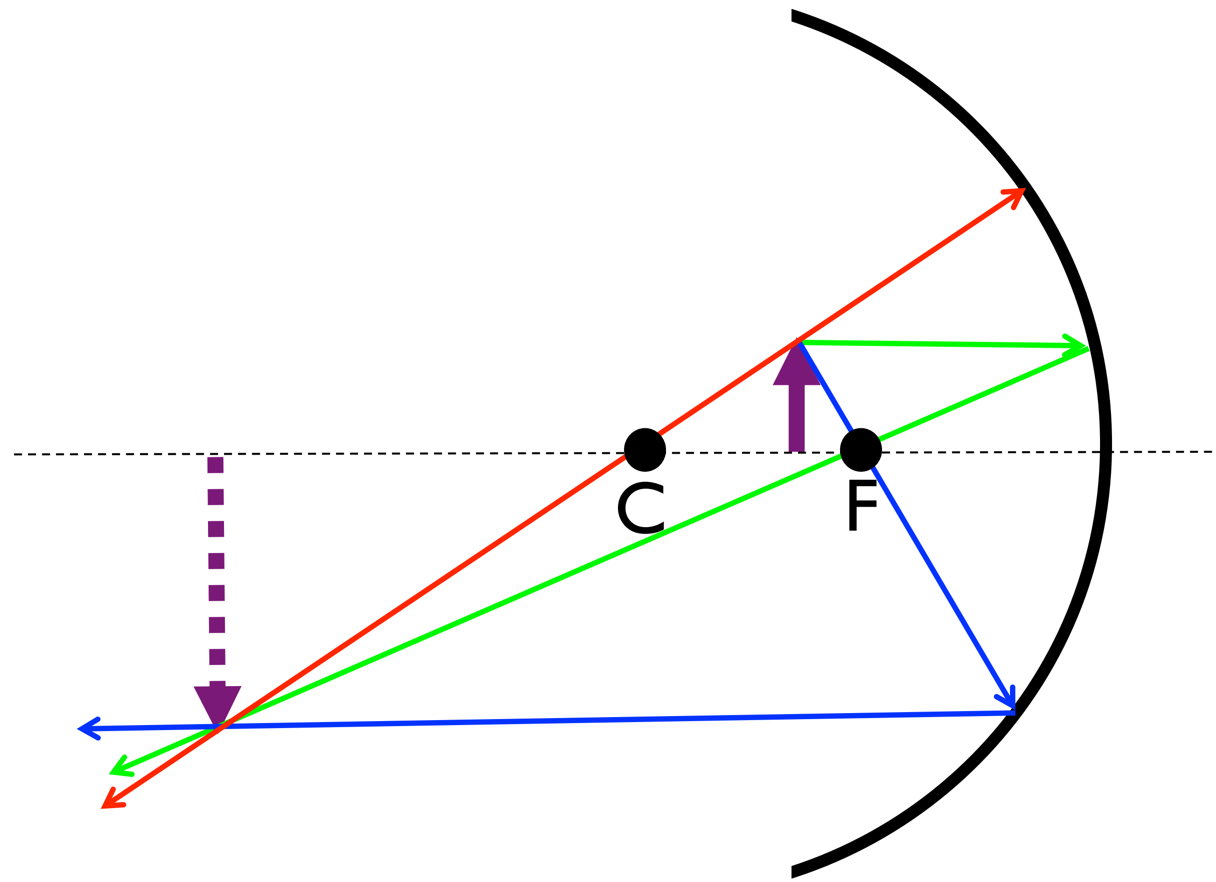
- Draw in the rays and extrapolate back past the mirror
- Intersection of rays locates the image

Locating an image: concave mirror

case 2: *object between focus F and center of curvature C*

Image properties:

- real
- upside down
- further from the mirror than the object
- larger than the object -> *magnification*



- Draw in the rays and extrapolate back past the mirror
- Intersection of rays locates the image

Locating an image: concave mirror

case 3: *object past the center of curvature C*

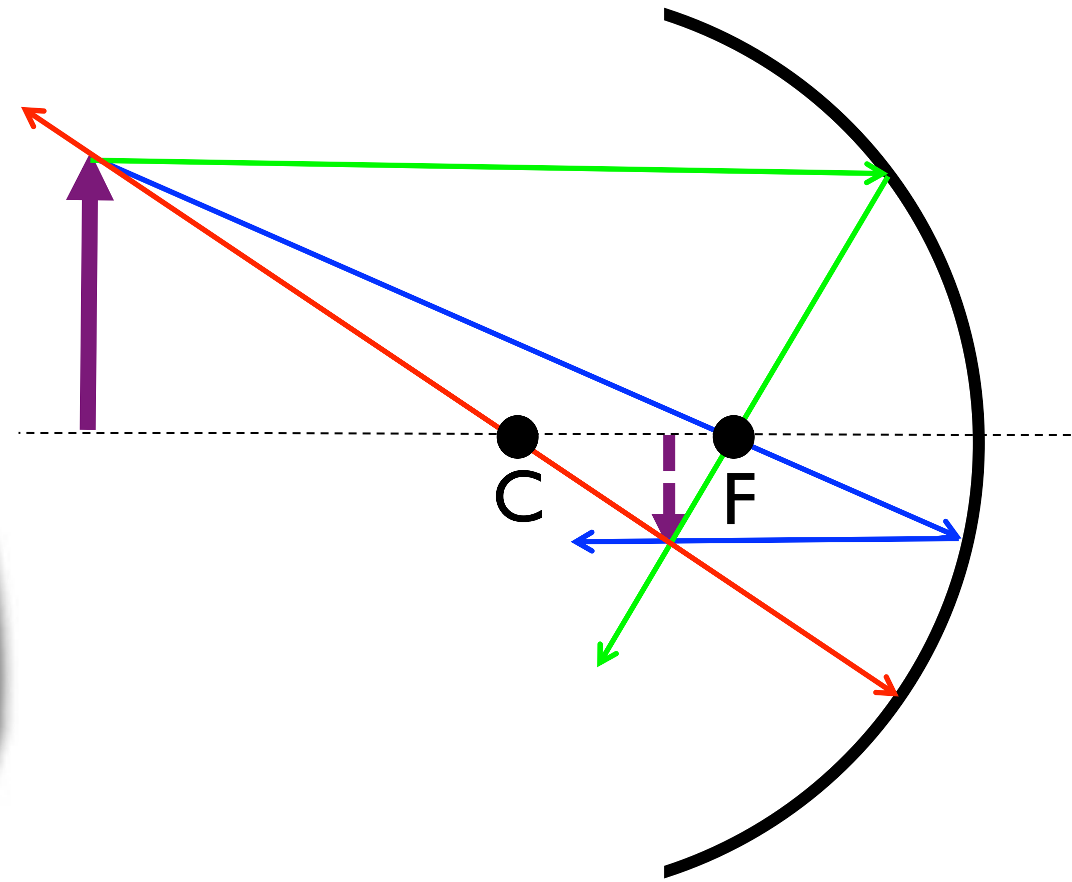


Image properties:

- real
- upside down
- closer to the mirror than the object
- smaller than the object

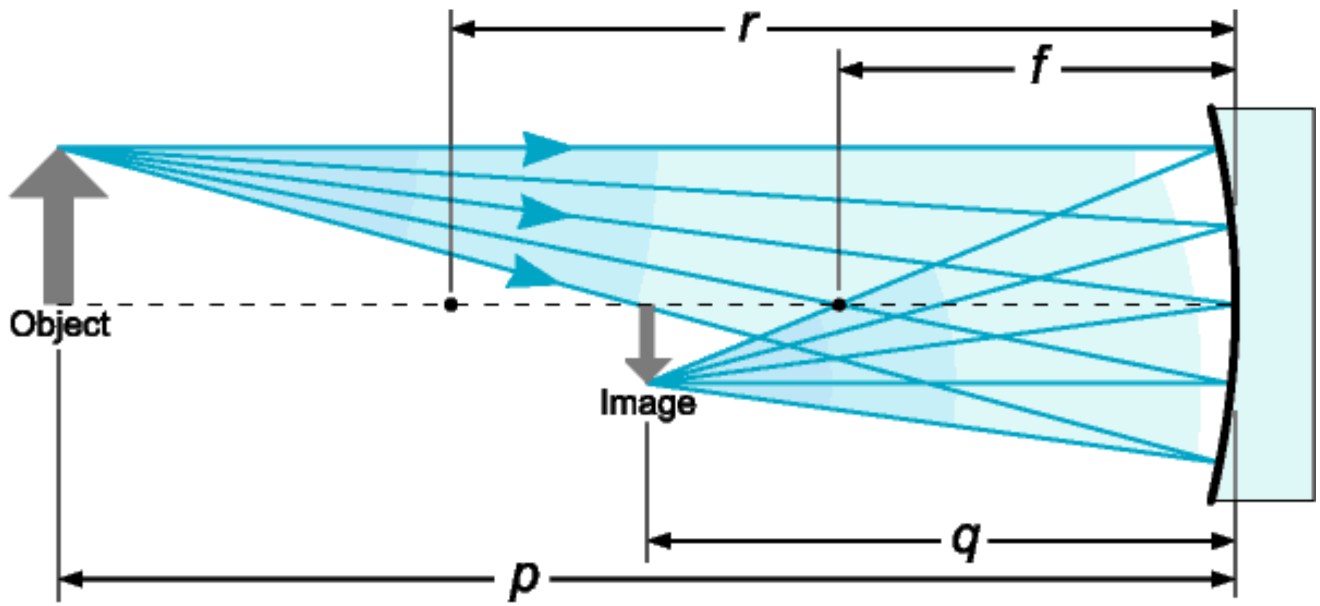
- Draw in the rays and extrapolate back past the mirror
- Intersection of rays locates the image

Locating an image: concave mirror

case 3: *object past the center of curvature C*

Image properties:

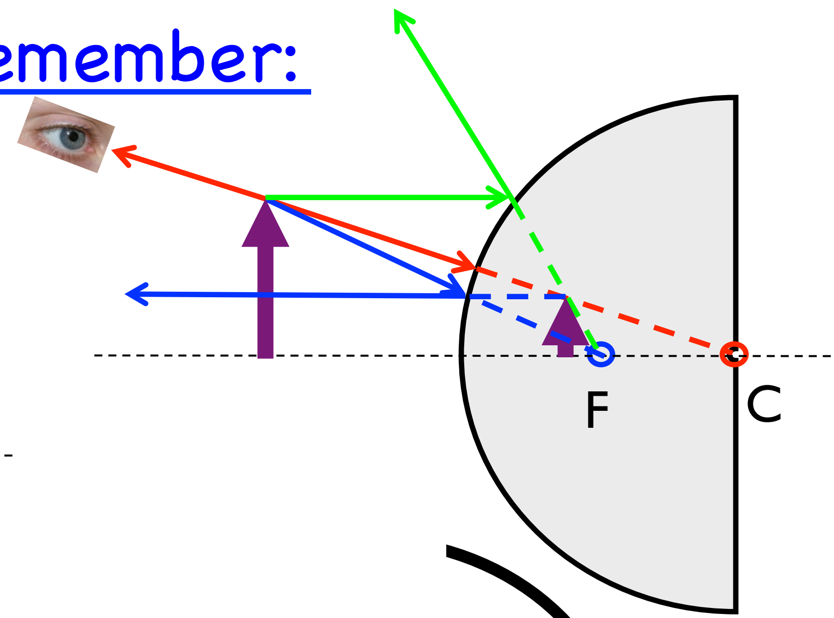
- real
- upside down
- closer to the mirror than the object
- smaller than the the object



- Draw in the rays and extrapolate back past the mirror
- Intersection of rays locates the image

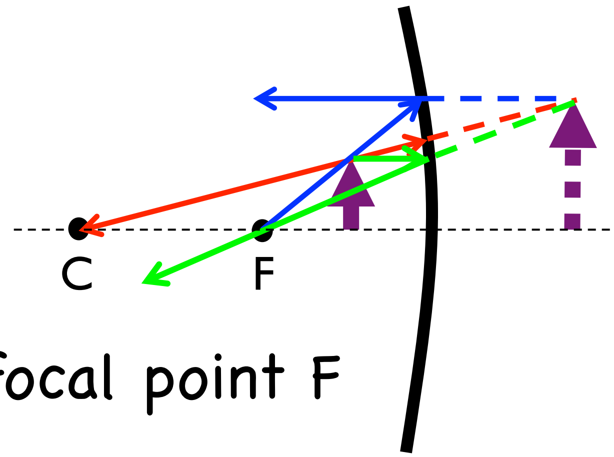
Summary of spherical mirrors

4 distict cases to understand and remember:

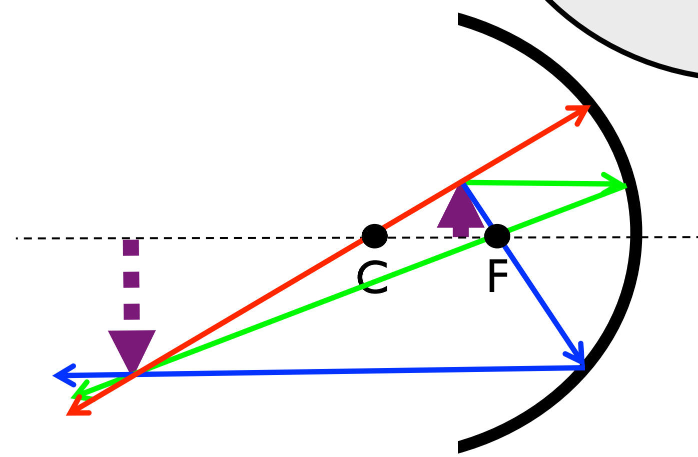


1. Convex mirror

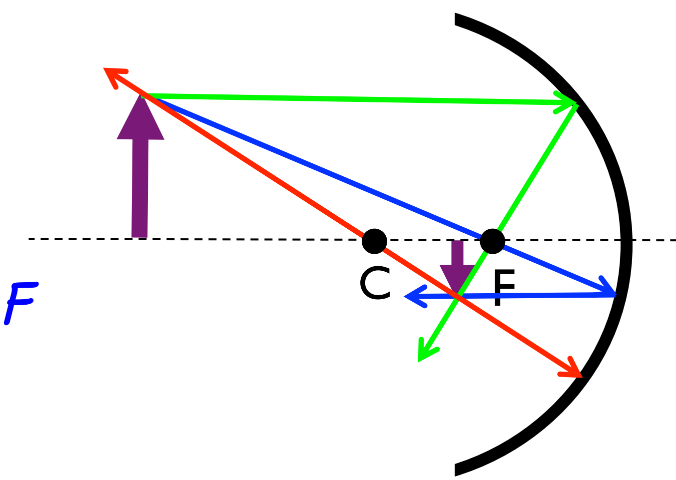
2. Concave mirror



a. object between focal point F and mirror



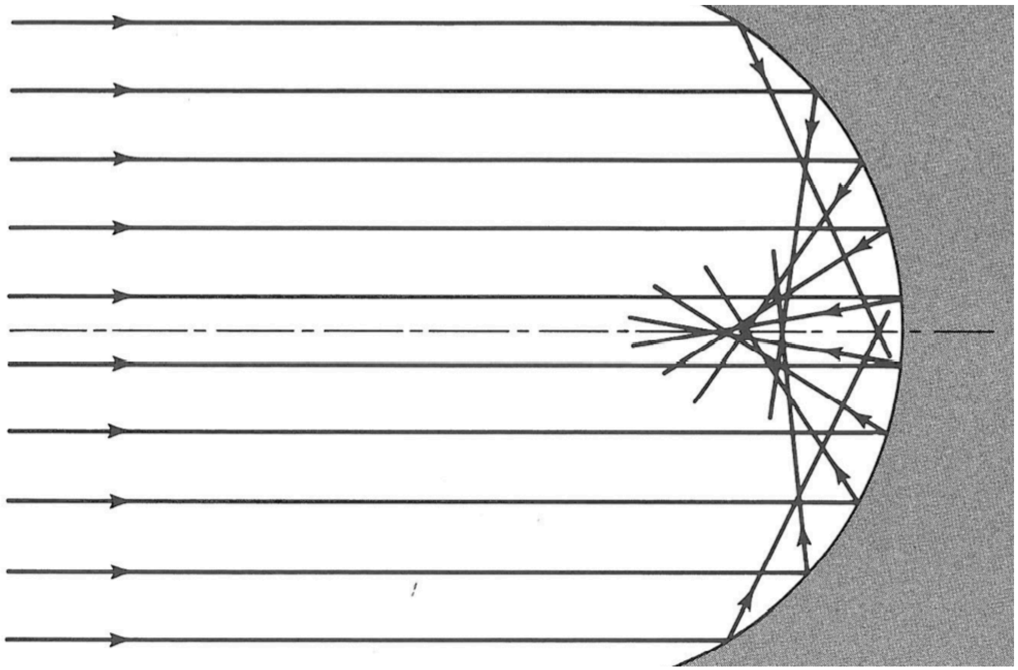
b. object between focal point F and center of curvature point C
moving object to F, moves images out to infinity



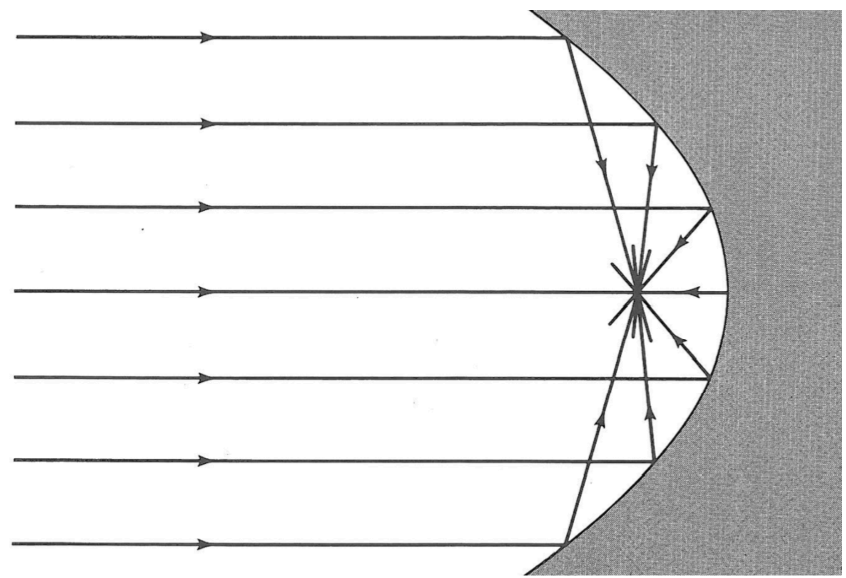
c. object outside center of curvature point C
moving object to infinity, moves image to F

Spherical aberration

- The nonparaxial (outer) rays have different focal point than the paraxial (inner) rays, leading to a blurry image

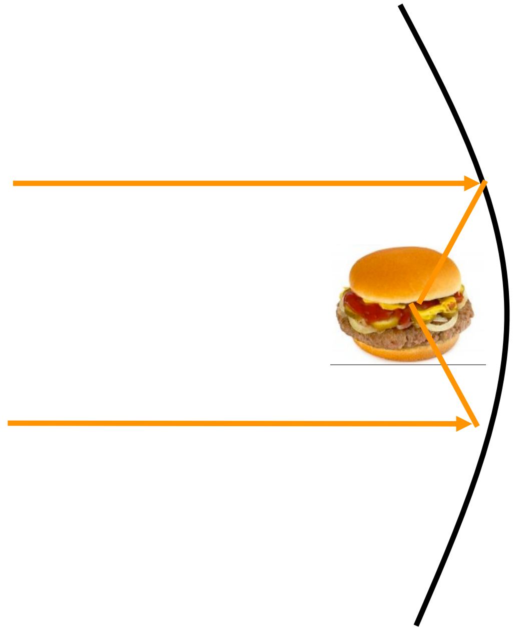


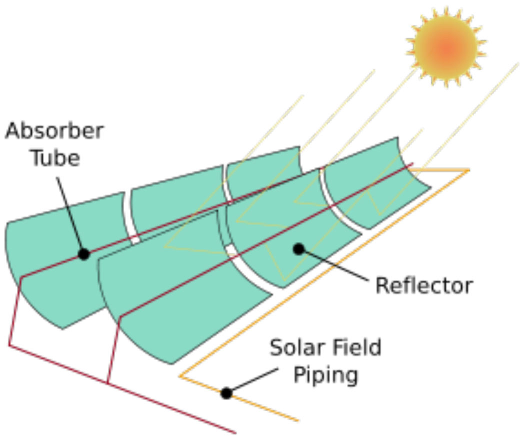
- *Parabolic* mirror has no spherical aberration

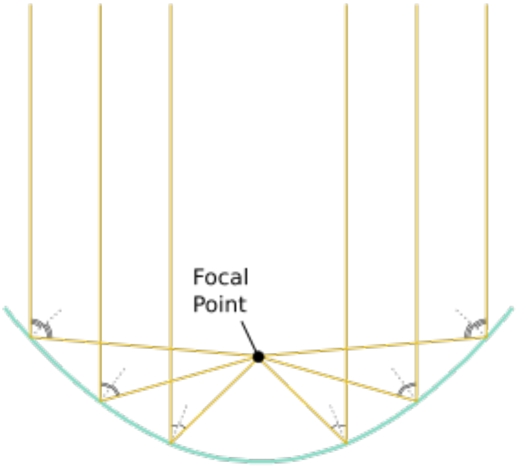


Application of concave mirrors

focus sun's rays at a focal point F to convert into heat

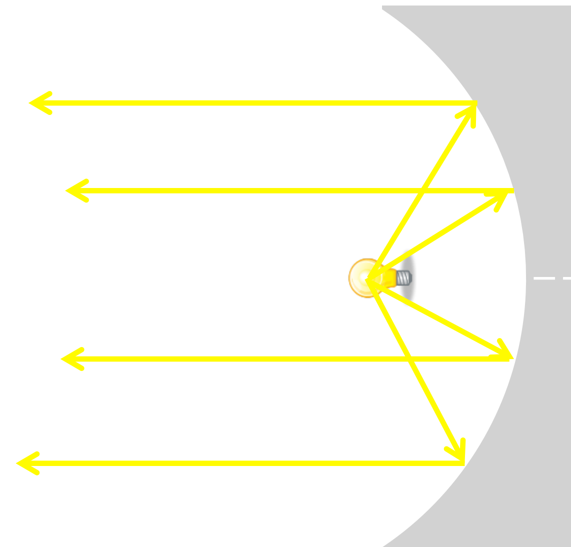




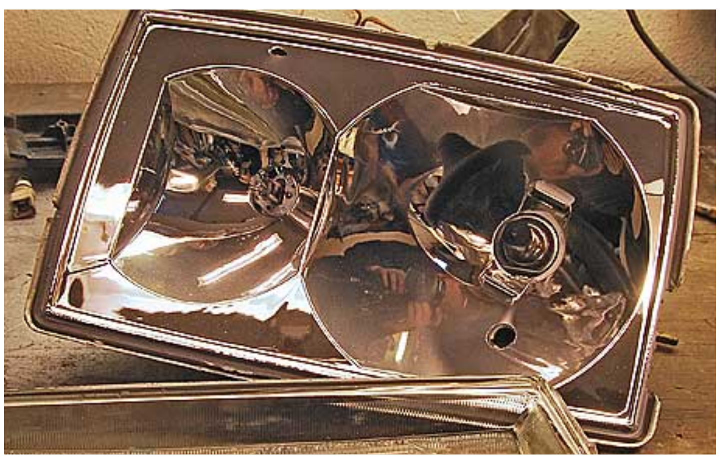


Application of concave mirrors

light beam emitter *(flashlight)* -> produces collimated light



- What if we put a light source at the focal point of a concave mirror?
- All the rays emitted go through the focal point, and are therefore reflected parallel to the axis of the mirror -> *flashlight*



Application of concave mirrors

radio telescope antennas

Parallel rays from a distance source are reflected from a large dish and focused onto a receiver at the focal point

clicker question

Concave mirror reflection

Q: The inside of a spoon bowl is a concave surface with a radius of curvature of a couple of inches. If you hold it about a foot from your face, what will your face look like?

a) Normal size, upside down

b) Normal size, right side up

c) Smaller, upside down

d) Smaller, right side up