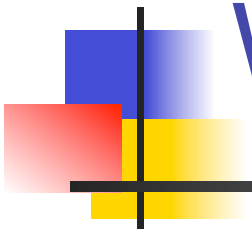
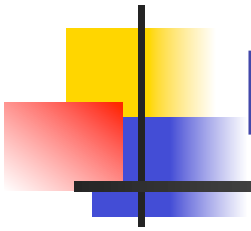


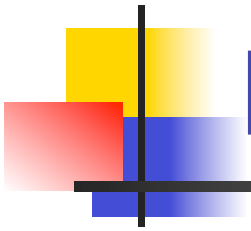
Welcome to Physics 4L!

Pick up handouts in back



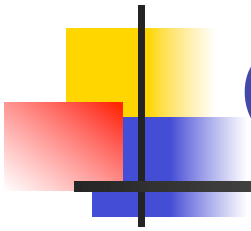
First lab next week:

- Bring lab materials (distributed Tuesday) in a 3-ring binder, or buy a binder ($2) in lab
- Do lab preparation before next week's lab
- Ray tracing exercises at end of first lab can also be done outside of lab with a study group
- Remainder of lab manual will be distributed in lab next week



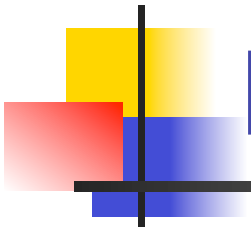
Problem sets

- First problem set due Tuesday in class
- Problem sessions tonight, Sunday, and Monday, 7:30 – 9 Science Center 128
- Solution guidelines posted; your solutions need to indicate your reasoning as well as your answer



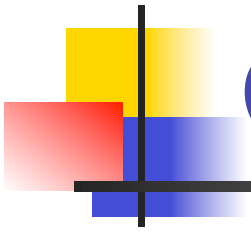
Class notes on web site

- Some time after class my complete notes appear on the corresponding “lecture” page
- Sometimes I add to them based on questions I get afterward
- Most important is for you to think about the material; consult notes judiciously!



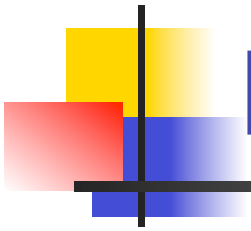
Readings listed on web site

- Don’t worry about web site saying “Not completed” after each past reading assignment
- In Ch. 30, skip polarization paragraph and references to wave nature of light, wavefronts, etc; we’ll get to those in April ....
- We will only consider curved mirrors qualitatively (with ray diagrams)



Crossing slab example

- Same problem as Wolfson Ex. 30.1
- Handout: my solution, more careful approach to notation
- Read at your convenience
- Use descriptive subscripts in your own solutions!



Key ideas from last time

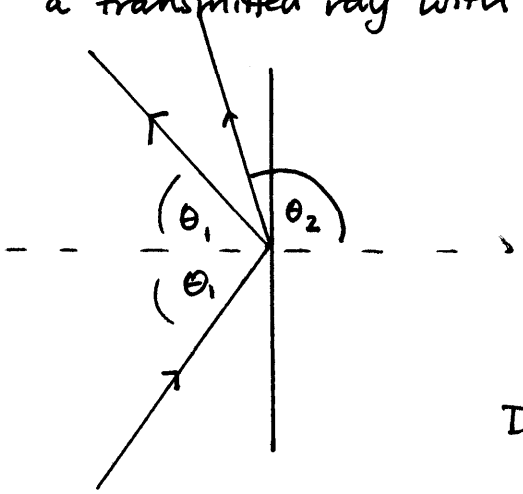
- Light is emitted in all directions from every point on a bright object
- Light rays travel in straight lines until reaching a surface
- At surfaces, rays are reflected with $\theta_i = \theta_r$ and transmitted (refracted) with $n_1 \sin\theta_1 = n_2 \sin\theta_2$; angles are measured from the normal to the surface
- Index of refraction n is a property of the material, generally increases with density, $n \geq 1$
- Total internal reflection (no transmission) occurs if the angle of the transmitted ray would exceed 90°

JJ.

1/21/2010

TIR quantitatively

Why do we get only reflection — why don't we also get a transmitted ray with $\theta > 90°$?



Reason: look at mathematics

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

When $\theta_2 = 90°$ we have

$$n_1 \sin\theta_1 = n_2 (1) \quad \text{b/c } \sin 90° = 1$$

Increasing θ_1 further would require not just θ_2 but $\sin\theta_2$ to increase in order to satisfy this eq. $\sin\theta$ is always ≤ 1. So just can't do it.

Why? Comes from using wave nature of light — we'll get to at the end

~~θ_1 at which we get $\theta_2 = 90°$~~ the critical angle:

Use $n_1 \sin\theta_1 = n_2 \sin 90°$ to define

$$n_1 \sin\theta_c = n_2 \Rightarrow \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

We call the value of θ_1 at which we get $\theta_2 = 90°$ the critical angle θ_c:

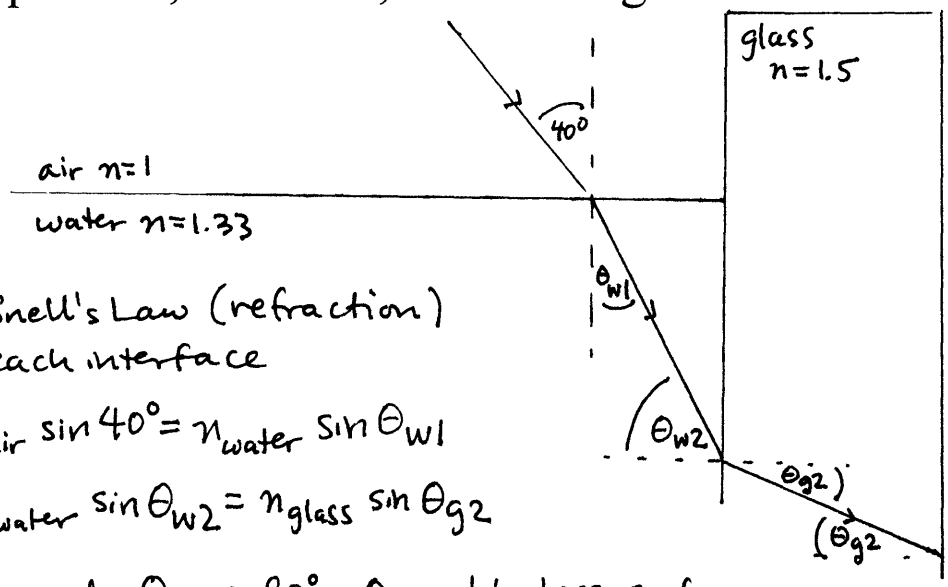
$$n_1 \sin\theta_c = n_2 \sin 90°$$

$$\Rightarrow \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

(This eq also shows we only get TIR if $n_1 > n_2$; θ_c not defined if $n_2 > n_1$ and thus $\frac{n_2}{n_1} > 1$!)

Always think through this, don't just blindly apply formula! Can get which medium is which confused....

You shine a laser pointer into a filled aquarium from above; the laser beam strikes the surface of the water at 40° from the normal and then reaches the glass side wall of the aquarium. Does the laser beam exit that wall of the aquarium, and if so, at what angle to the wall?



Use Snell's Law (refraction) at each interface

(1) $n_{air} \sin 40° = n_{water} \sin\theta_{w1}$

(2) $n_{water} \sin\theta_{w2} = n_{glass} \sin\theta_{g2}$

and $\theta_{w2} = 90° - \theta_{w1}$ b/c glass surface is perpendicular to air-water interface

Also: both angles in glass are equal because sides of glass wall are parallel, so label both θ_{g2}

(3) $n_{glass} \sin\theta_{g2} \stackrel{?}{=} n_{air} \sin\theta_{air}$

Does a θ_{air} exist that can satisfy this condition?

Combine (2) and (3):

$$n_{water} \sin\theta_{w2} \stackrel{?}{=} n_{air} \sin\theta_{air}$$

Now need to find θ_{w2}: use (1), substitute values

$$\sin\theta_{w1} = \frac{n_{air} \sin 40°}{n_{water}} \Rightarrow \theta_{w1} = \sin^{-1}\left(\frac{0.64}{1.33}\right) = 29°$$

$$\theta_{w2} = 90° - \theta_{w1} = 61°$$

Substitute into combined (2) & (3)

$$n_{water} \sin\theta_{w2} \stackrel{?}{=} n_{air} \sin\theta_{air}$$

$$(1.33)(\sin 61°) \stackrel{?}{=} (1) \sin\theta_{air}$$

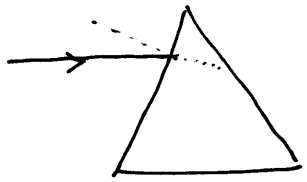
$$1.16 \stackrel{?}{=} \sin\theta_{air}$$

Not possible!
So no θ_{air} exists
Beam is totally internally reflected, does not exit

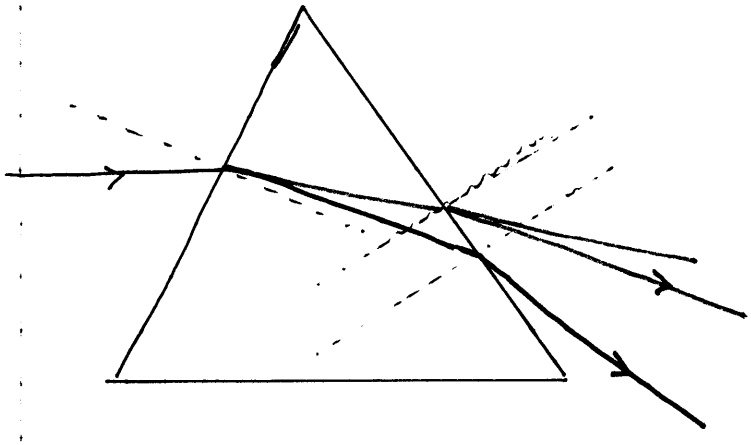
Dispersion

Why do prisms separate colors? B/C n depends slightly on wavelength / frequency of light
usually (for most mat'ls) $n_{violet} > n_{red}$

CT Which color comes out of the prism at the top?

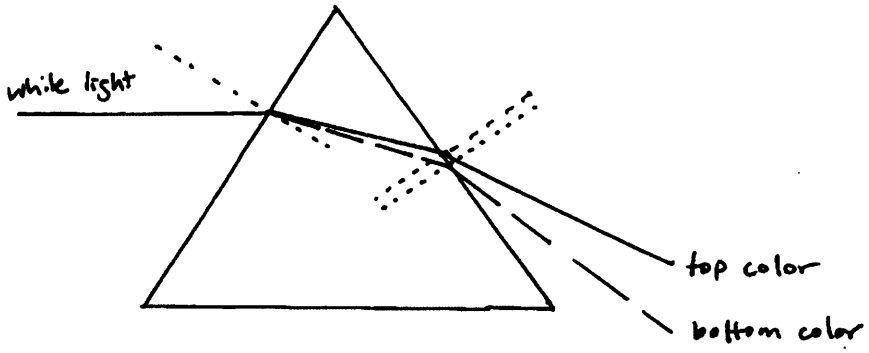


red:
if n_{red} is less, it bends less
if n_{violet} is more, it is bent more



(Basis of chromatic aberration in lenses)

White light enters a prism and emerges as a band of colors as shown below. How are the colors arranged in the band?



1. red at the top, violet at the bottom
2. violet at the top, red at the bottom
3. Need more information

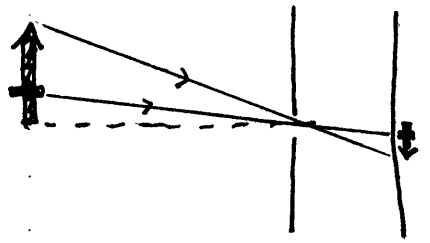
(skipped for lack of time.
Answer: (1))

TIR Problem

Forming images

Image: pattern of light that is a copy of light coming from a bright object

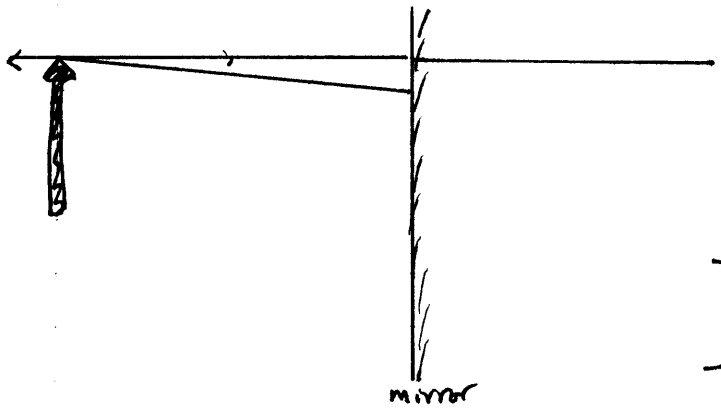
- light from each point on object ⇒ image of that point
- image of entire object = images of all points



Pinhole images are "real images": light from object actually gets to image location
Can cast on a screen/sense w/ digital camera

Saw Tues with fish question that light can appear to come from somewhere it doesn't actually pass through

"Virtual image" – most familiar is image w/ flat mirrors



(show image from Wolfson)

~~rays appear to come from image location but don't actually~~

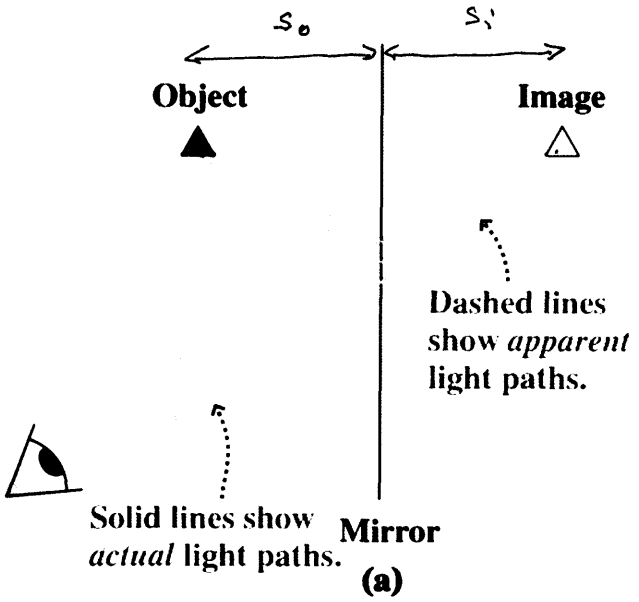
- rays only appear to come from image location
- cannot cast on a screen – no light behind the mirror!
- requires your eye/brain to observe!

12:00 CT What if mirror is short?

CT What if observer was in a different place? (sketch on figure) Different rays reach observer – we only draw some
(Move observer to where can't see image)

Virtual images

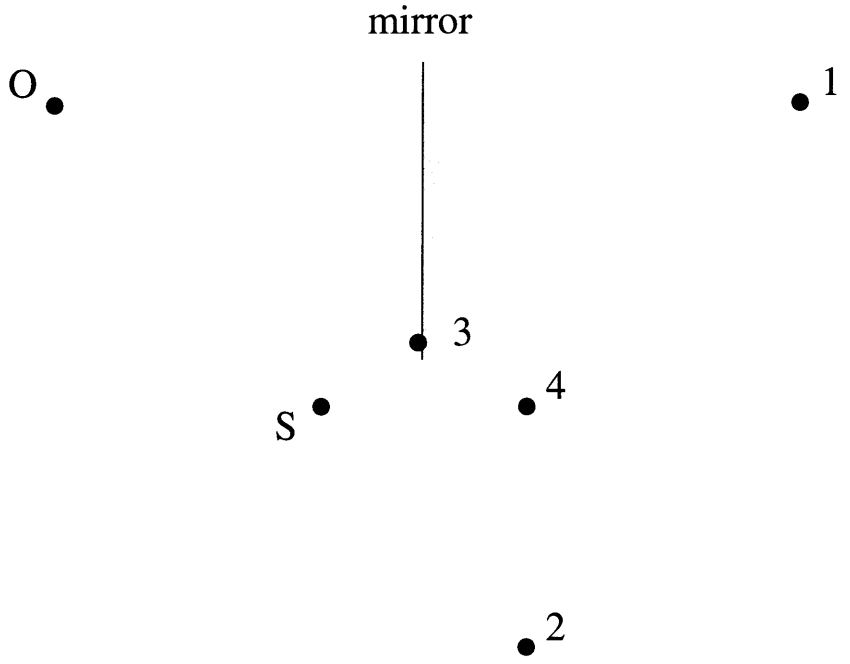
Rays reflect from mirror according to $\theta_i = \theta_r$



flat mirror: image appears directly behind object at same distance

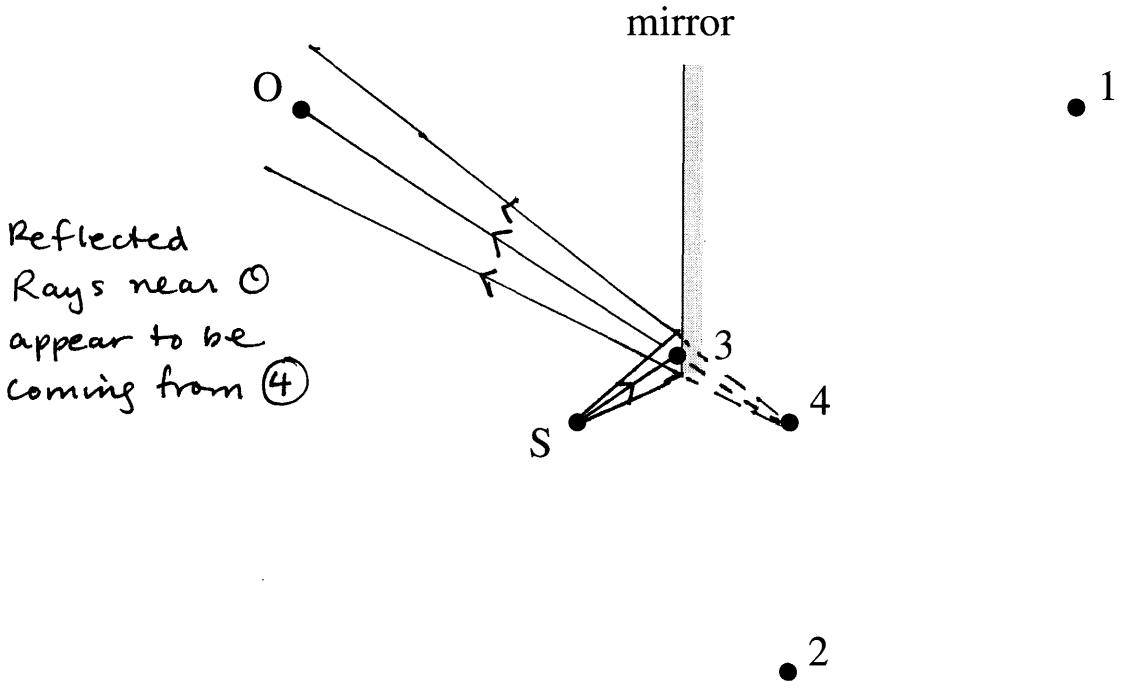
$s_o = s_i$

An observer *O*, facing a mirror, observes a light source *S*. Where does *O* perceive the mirror image of *S* to be located?



1. 1
2. 2
3. 3
4. 4
5. Some other location.
6. The image of *S* cannot be seen by *O* when *O* and *S* are located as shown.

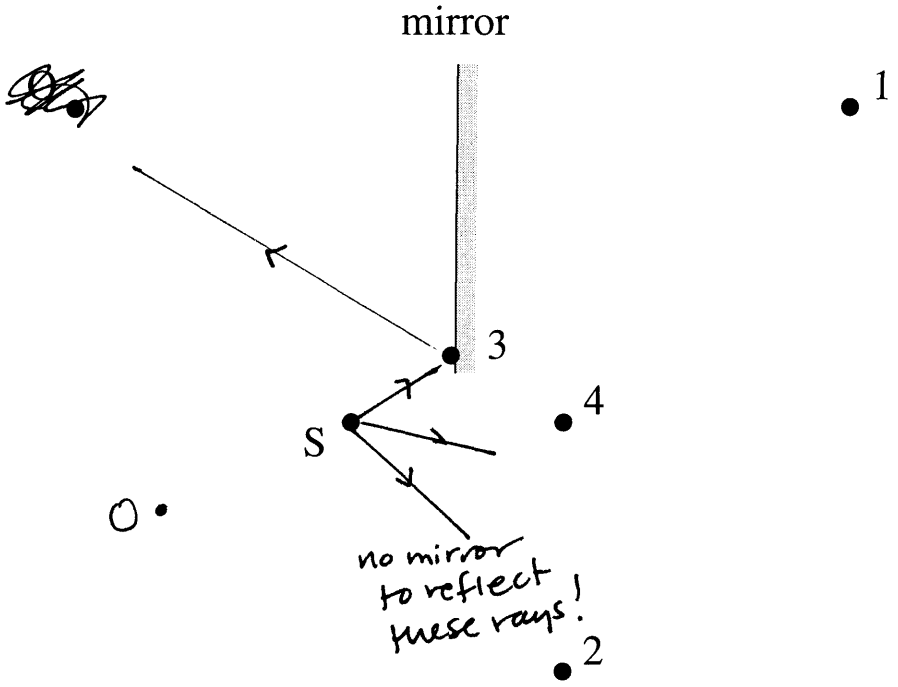
An observer O, facing a mirror, observes a light source S. Where does O perceive the mirror image of S to be located?



1. 1
2. 2
3. 3
4. 4
5. Some other location.
6. The image of S cannot be seen by O when O and S are located as shown.

If we move the observer as shown below the mirror edge

An observer O, facing a mirror, observes a light source S. Where does O perceive the mirror image of S to be located?



1. 1
2. 2
3. 3
4. 4
5. Some other location.
6. The image of S cannot be seen by O when O and S are located as shown.

Now rays from S cannot reflect off mirror toward O — no mirror in place to do that

Key ideas from these questions

- We draw only some of the rays to find the image
- Only some rays make it to the observer — as long as some can get there, observer can see image

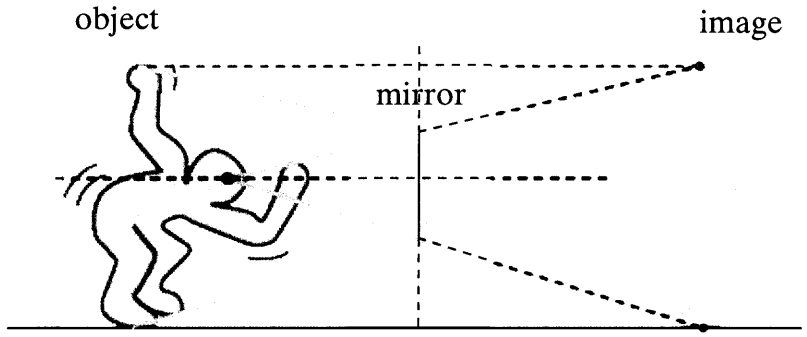
CT Mirror height (Explanation: use figure from Mazur)

You are standing in front of a mirror. If the mirror is flat on the wall, what minimum length must the mirror be in order for you to see your entire body in the mirror?

1. About your full height.
2. About three quarters of your height.
3. About half your height.
4. About one quarter of your height.

(skipped)

About half your height.



Curved mirrors

images also form when mirror is not flat

find image by:

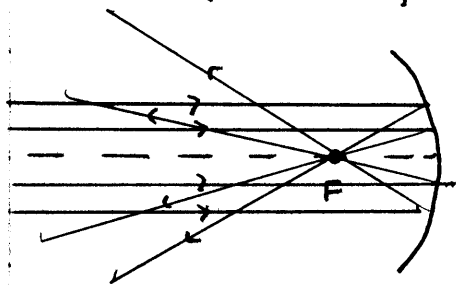
draw rays coming from a point

construct reflected rays

find where reflected rays meet or appear to come from

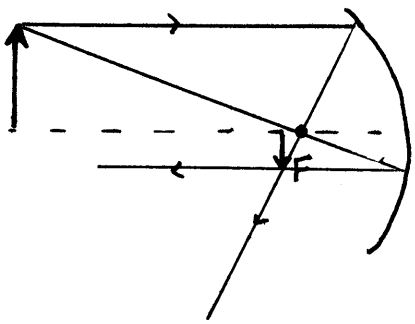
Reflected rays follow $\theta_i = \theta_r$ — but we have an easier strategy to construct them accurately

Converging (concave) mirror: designed so that parallel rays reflect to focal point F on axis



Because optical paths are reversible, rays through F reflect parallel to axis

So: to find image of a point, use just two rays, find where meet



(1) Ray from object ∥ to axis
(2) Ray from object through F
(W defines two other rays, not as simple)

Other rays follow paths that are less simple to draw but also give an image in the same location!

Is this image real or virtual? Real

Four things we always want to know about images:

(1) Real or virtual
(2) Location
(3) Size (enlarged or reduced)
(4) Upright or inverted

} can answer all of these qualitatively with ray diagrams

This image is inverted, reduced, real

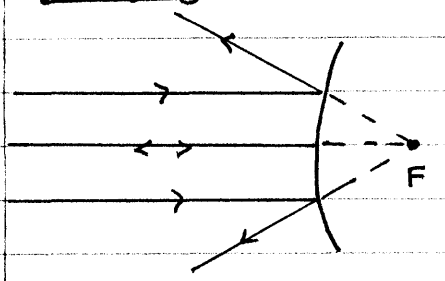
Bot demo CT : moving object slightly closer to mirror
→ image gets slightly bigger, moves further back

Converging mirrors can produce very different types of images depending on where the object is!

Bot demo - show switching from distant to near object
Show Wolfson Fig 31.6
Webcam has autofocus & a lens so it can record virtual images just as your brain does

Show lens/mirror applet

Diverging mirror (convex)

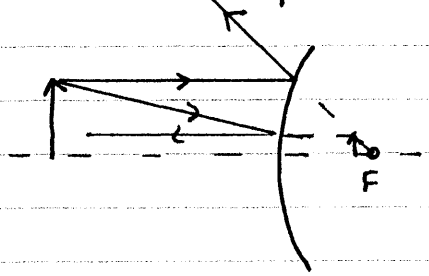


parallel rays spread out as they reflect
appear to come from a point behind the mirror – "virtual focus"

Form only virtual images – can't bring light together!

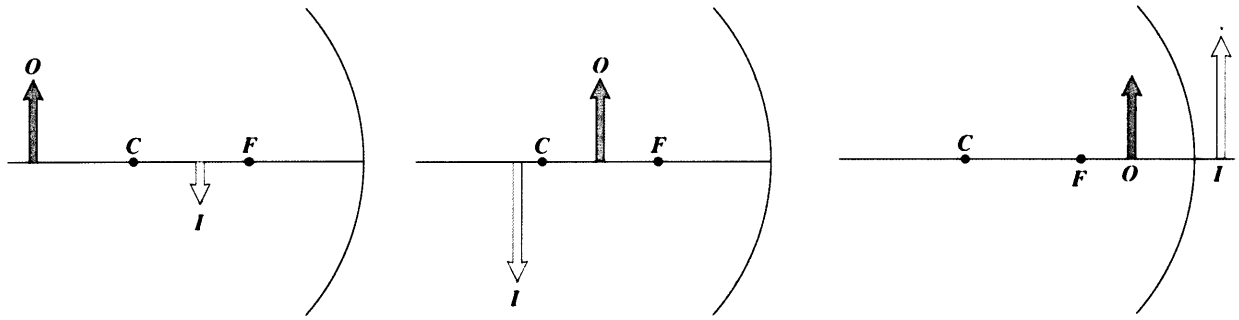
Principal rays:
(1) Ray parallel is reflected along line through focus
(2) Ray along line through focus is reflected parallel

Take time on your own to explore these images.



Moving the object slightly closer to the mirror will make the image

1. Closer to the mirror and smaller.
2. Closer to the mirror and bigger.
3. Farther from the mirror and smaller.
4. Farther from the mirror and bigger.



Wolfson Figure 31.6

Lens and mirror applet is linked to the web site, can Google "Thin Lens Applet"