April 26, 2017 Physics 132 Prof. E. F. Redish

- **Theme Music:** **Janis Ian**
  Light a Light
- **Cartoon:** **Pat Brady**
  Rose is Rose

4/26/17 Physics 132 **1**

Outline

- Recap of Basic Principles of the Ray model
- Thin lenses
- The lens equation
- Examples

4/26/17 Physics 132 **2**

Foothold Ideas 1:
The Physics

- Certain objects (the sun, bulbs,…) give off light.
- Light can travel through a vacuum.
- In a vacuum light travels in straight lines (rays).
- Each point on a rough object scatters light, spraying it off in all directions.
- A polished surface reflects rays back again according to the rule: *The angle of incidence equals the angle of reflection*.
- When entering a transparent medium, a light ray changes its direction according to the rule $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- "n" is a property of the medium and we choose $n_{vac}=1$.

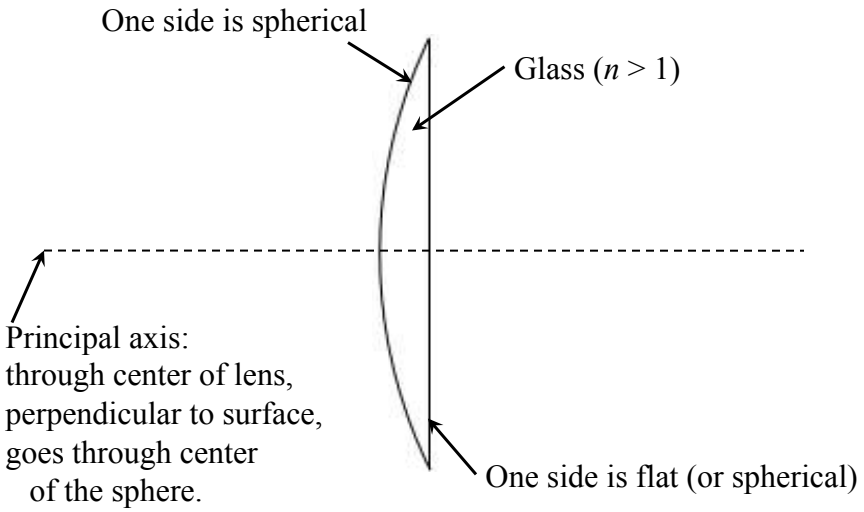
Foothold Ideas 2:
The Psycho-physiology

- We only see something when light coming from it enters our eyes.
- Our eyes identify a point as being on an object by many mechanisms:
  - By tracing rays back to see where they converge.
  - By how they change when we move.
  - By our experience with objects and the world.

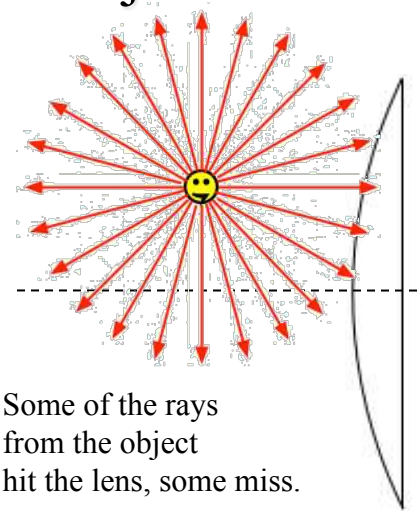
Kinds of Images

- Real
  - When the rays seen by the eye do meet, the image is called real.
  - If a screen is put at the real image, rays scatter in all directions and an image can be seen on the screen, just as if it were a real object.
- Virtual
  - When the rays seen by the eye extrapolate to a point but don't actually meet, the image is called virtual.

A thin lens



An object viewed through a thin lens



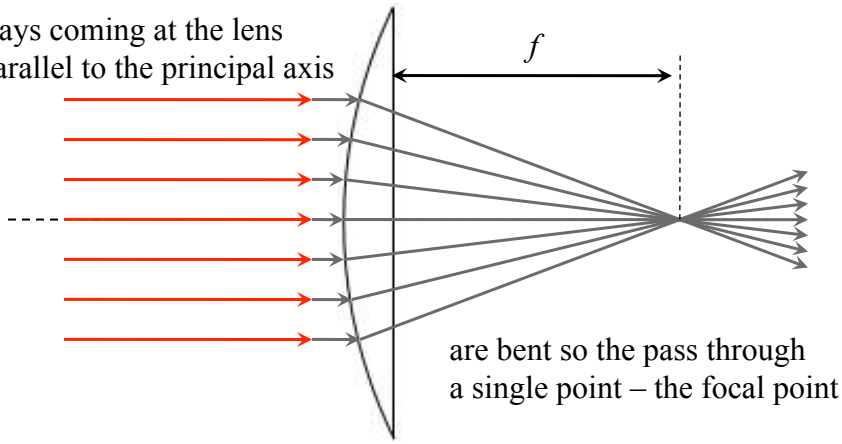
Light from the object sprays out in all directions.

Some of the rays from the object hit the lens, some miss.

Those that hit the lens may bend at the surface as it enters and leaves the glass.

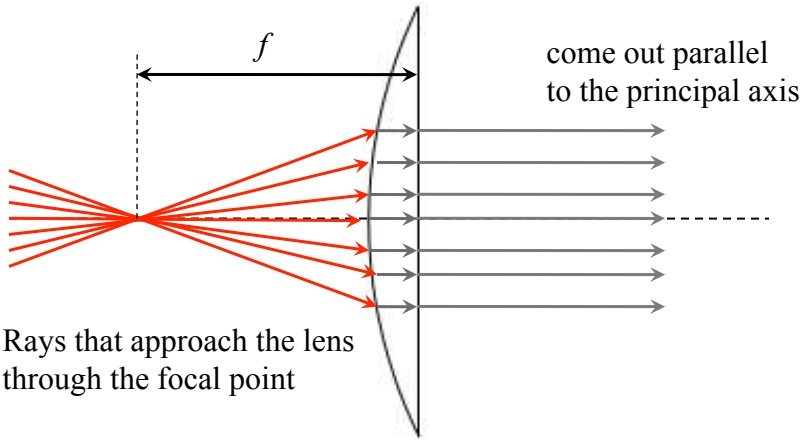
Easy-to-figure-out rays: focal point (far side)

Rays coming at the lens parallel to the principal axis

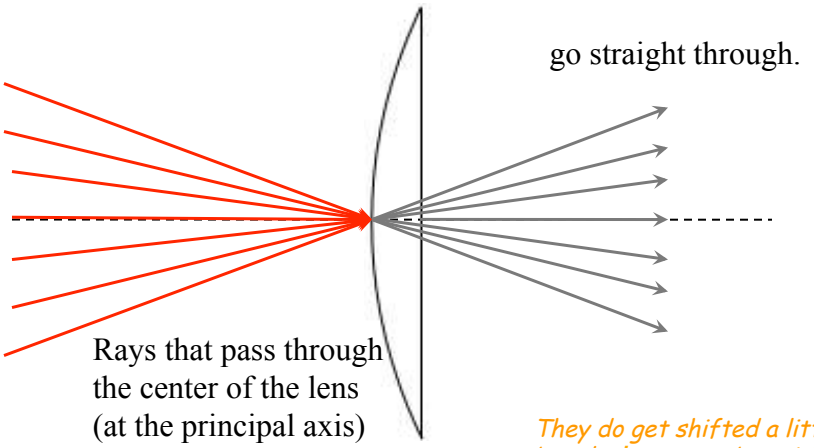


are bent so the pass through a single point – the focal point

Easy-to-figure-out rays: focal point (nearside)



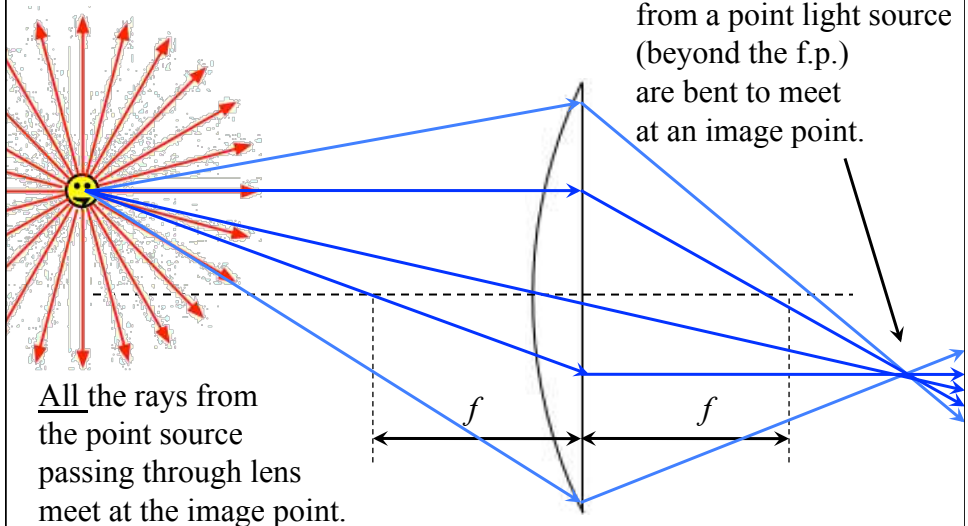
easy-to-figure-out rays: central



They do get shifted a little, but don't worry about it!

easy-to-figure-out rays

The principal rays from a point light source (beyond the f.p.) are bent to meet at an image point.

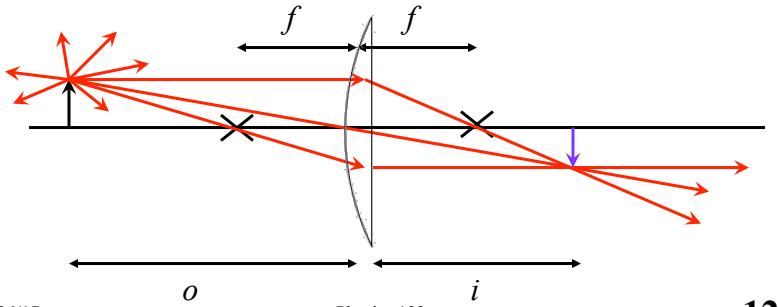


All the rays from the point source passing through lens meet at the image point.

The Lens Equation

- For a thin lens

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f} \qquad \frac{h'}{h}=\frac{i}{o}$$



Unifying Equation for Lenses

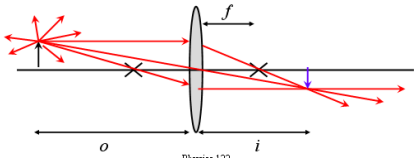
- If we treat our lens quantities as "signed" and let the signs carry directional information, we can unify all the situations in a single set of equations.

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i} \qquad \frac{h'}{h} = \frac{i}{o}$$

	$i < 0$, $o > 0$	$i > 0$, $o < 0$	
$h > 0$			$h' < 0$
$h < 0$			$h' > 0$

$f > 0$

$f < 0$



"standard" arrangement

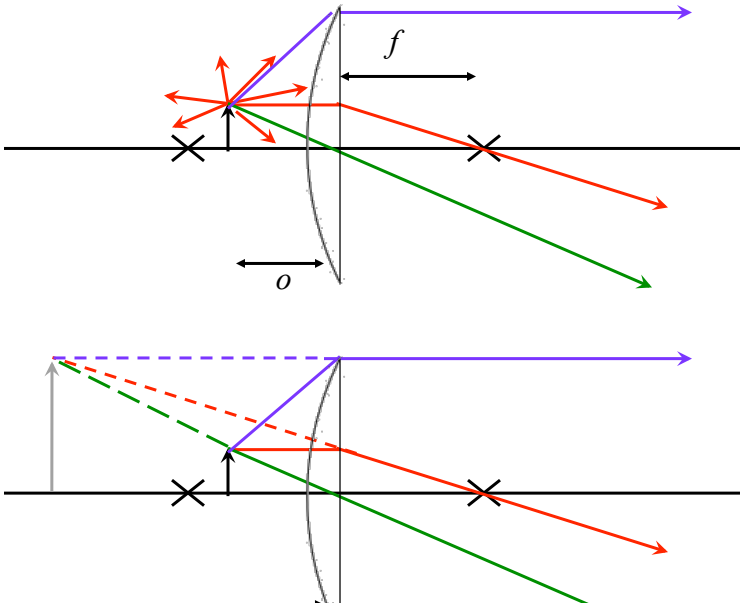
13

The Magnifying Glass

- What happens if the object is inside the focal point (closer to the lens)?

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \qquad \frac{h'}{h} = \frac{i}{o}$$

- If $o < f$ then $1/o > 1/f$.
  So $1/i = 1/f - 1/o < 0$.
- If $i < 0$, then $h' < 0$.
- The image is virtual and oriented upward.



Reading question

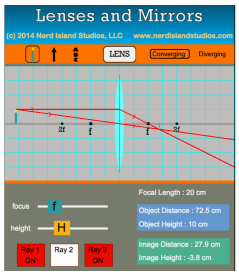
- What does it mean when you say negative focal point because technically you have two, one which is positive and the other negative, I know this was talked about with mirror, but because you technically have two focal points wouldn't one be a positive one?
- The thing that still bothers me is the part about the sign convention. How can a symbol be positive or negative regardless of the sign in front of it? When the focal length is positive, shouldn't there be a positive sign in front of it?

Reading questions

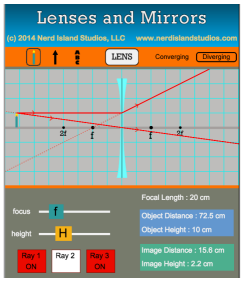
- I'm having trouble understanding what the difference is between a real image and a virtual image. What I'm getting so far is that a virtual image occurs when the object is within the focal length away from the mirror/lens, and a real image is when the object is past the focal length away from the mirror/lens. What I don't understand is why there's a distinction between the two. In the end, they are both just rays of light coming together to form an image.
- In the image at the bottom of the page. there are many greater than or less than signs and for the image height (for converging and diverging lens) they are the same on both sides. I thought everything on one side should be positive and everything on the other should be negative?

Exploring Lenses

- Converging



- Diverging



http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Optics-Bench/Optics-Bench-Refraction-Interactive