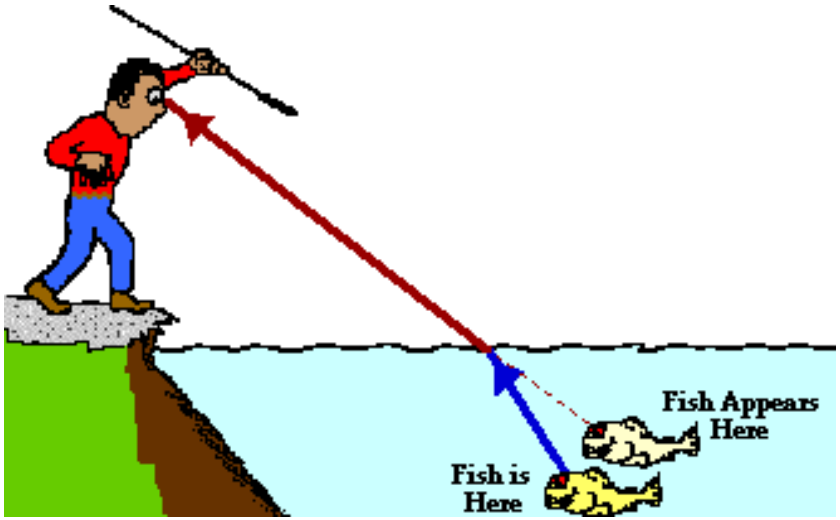
Refraction

How to Find Images Using Ray Diagrams

- It's easy to see how an image can be distorted.
- Reflected light off the shirt is refracted in the more optically dense material.
- Shouldn't the red stripes appear black through the Jell-O?

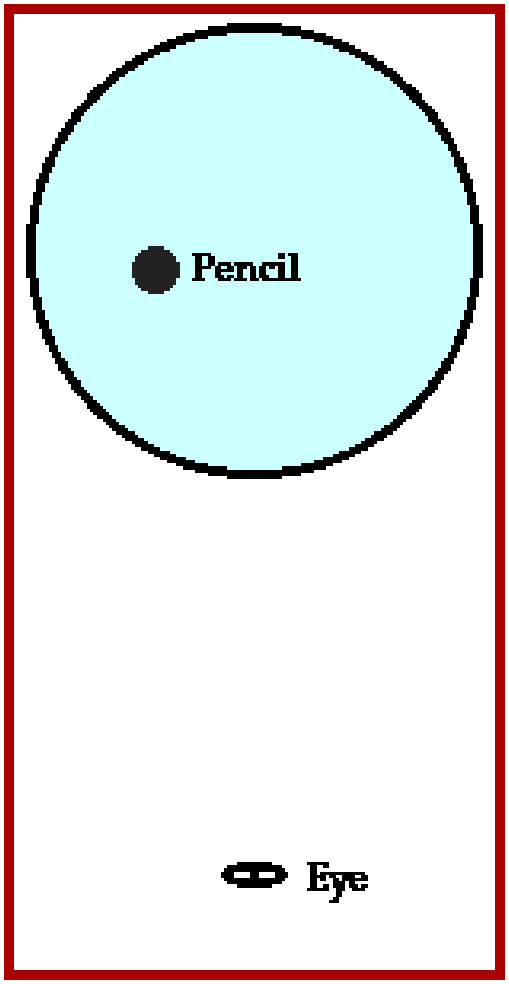
Practical Applications

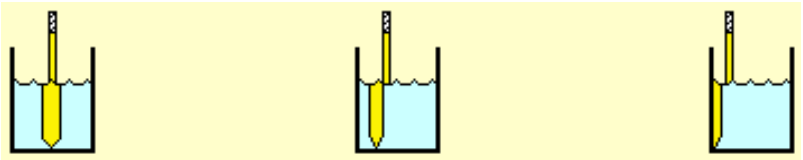
- Survival



- Light reflecting off fish bends before entering the eye.
- Makes spear fishing hard.
- Must aim at where fish is not at.
- Cows are less deceptive!

The "Broken?" Pencil

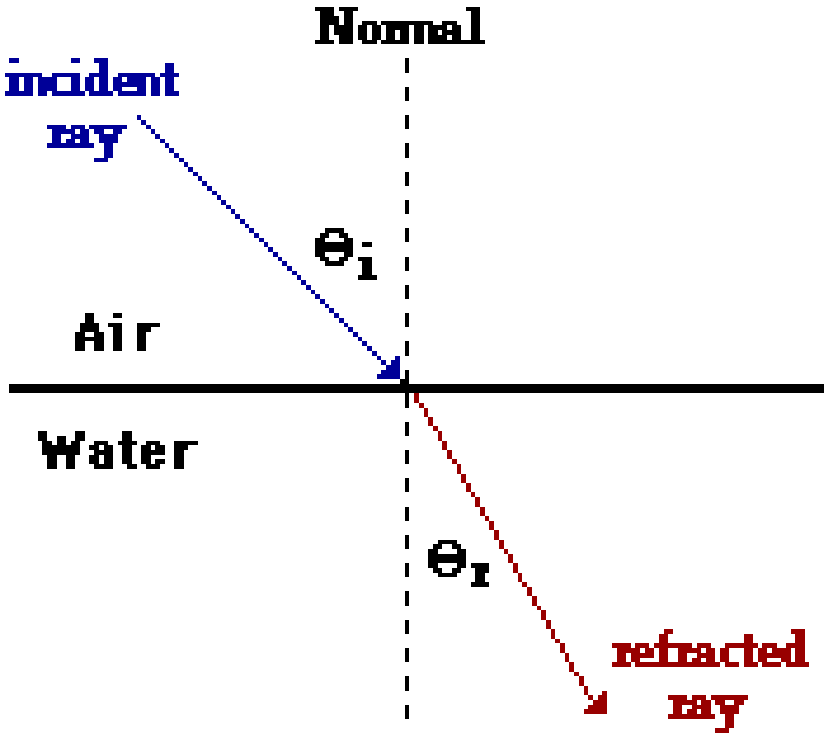




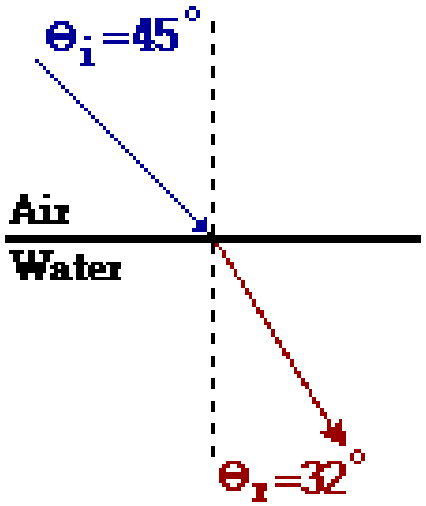
- Light rays bend as they leave water.
- Travel to eye.
- Follow bent rays back to see where object appears to be.

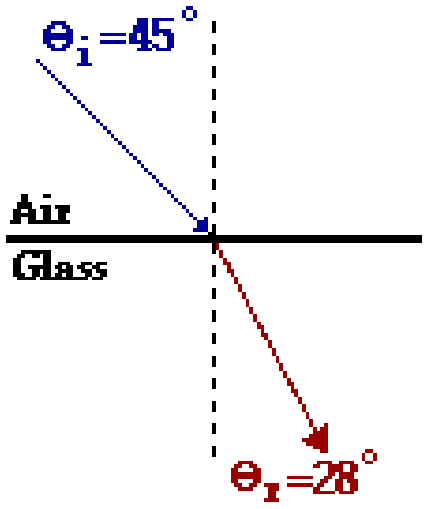
Refraction

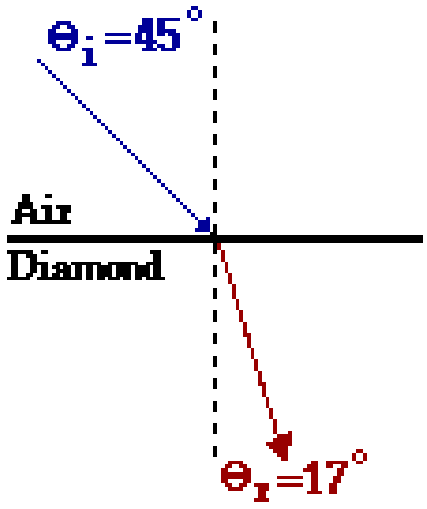
Ray Diagrams



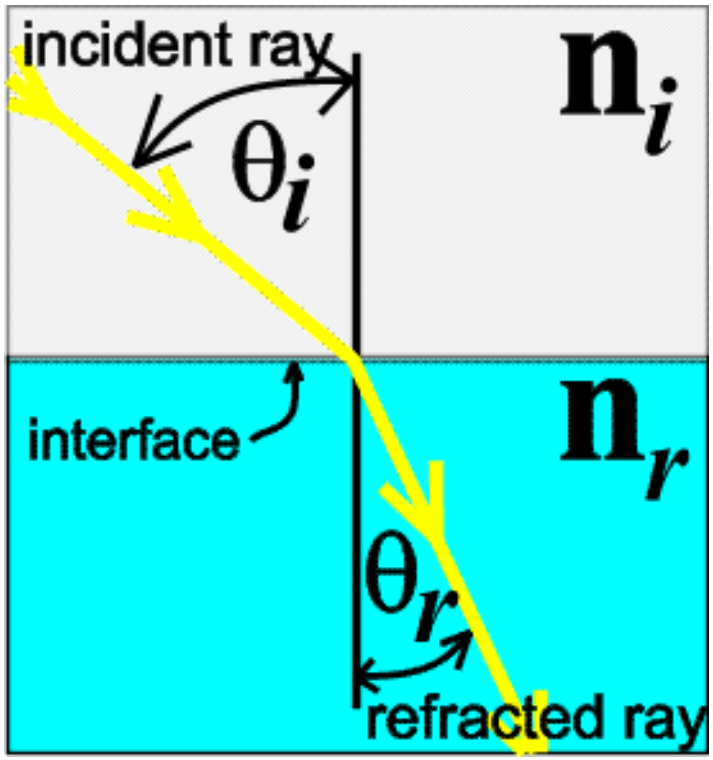
- Index of refraction (***n***) changes θ_r
- The bigger n_r is the smaller θ_r becomes







Determining the Angle



Snell's Law

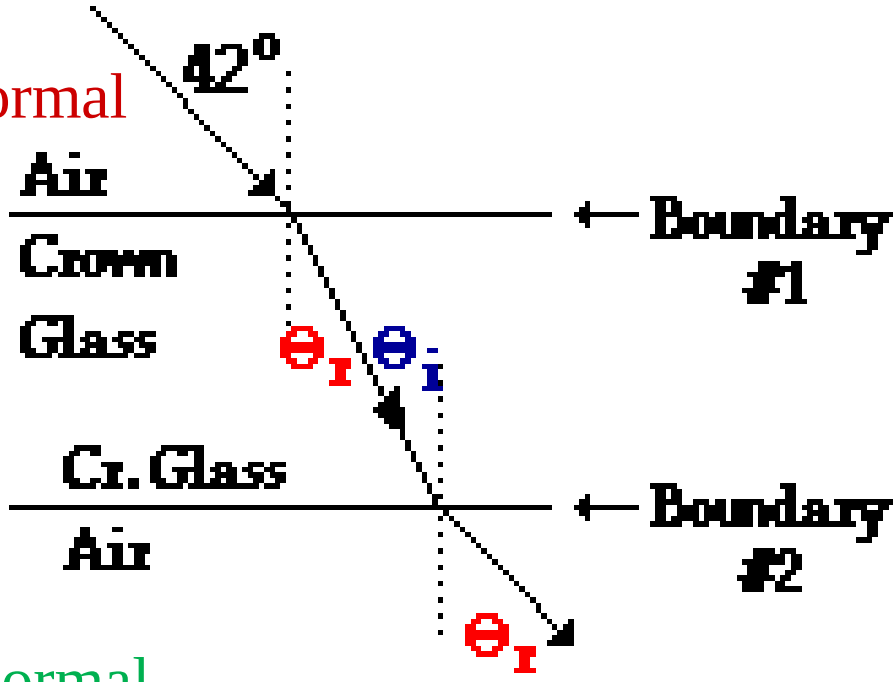
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_i \sin\theta_i = n_r \sin\theta_r$$

Refraction

Rules

- If the $n_i < n_r$ then the $\theta_i > \theta_r$
  - It would bend TOWARDS the normal
  - Example air to glass

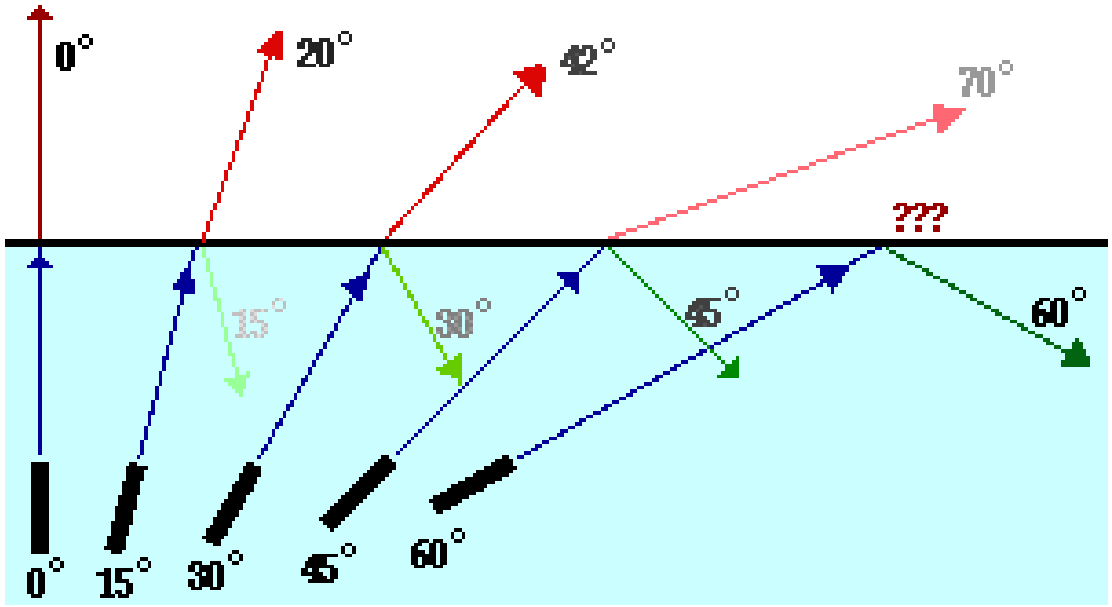


- If the $n_i > n_r$ then the $\theta_i < \theta_r$
  - It would bend AWAY from the normal
  - Example glass to air

Internal Reflection

What happens when you vary the incident angle (θ_i) from a more optically dense material?

As the angle of incidence increases from 0 to greater angles ...

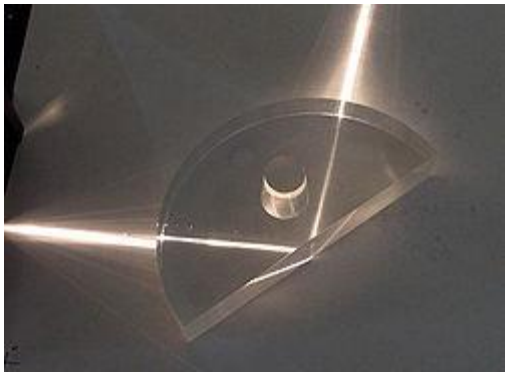


...the refracted ray becomes dimmer (there is less refraction)

...the reflected ray becomes brighter (there is more reflection)

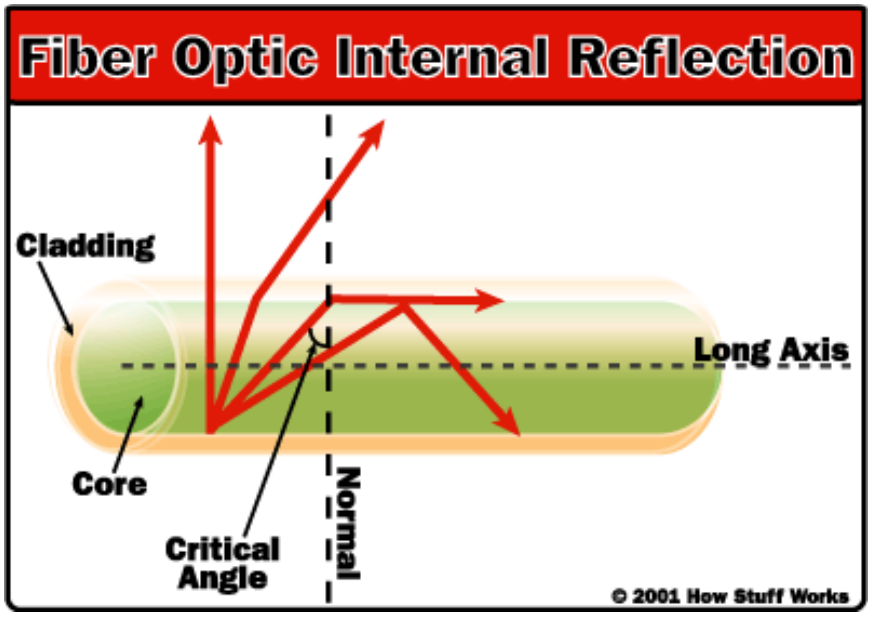
...the angle of refraction approaches 90 degrees until finally a refracted ray can no longer be seen.

Total Internal Reflection



- Happens at a specific angle and anything larger than that!
- Specific angle = θ_c
- Sin (θ_c) = n_r/n_i
- Must go from a larger index of refraction to a smaller index of refraction

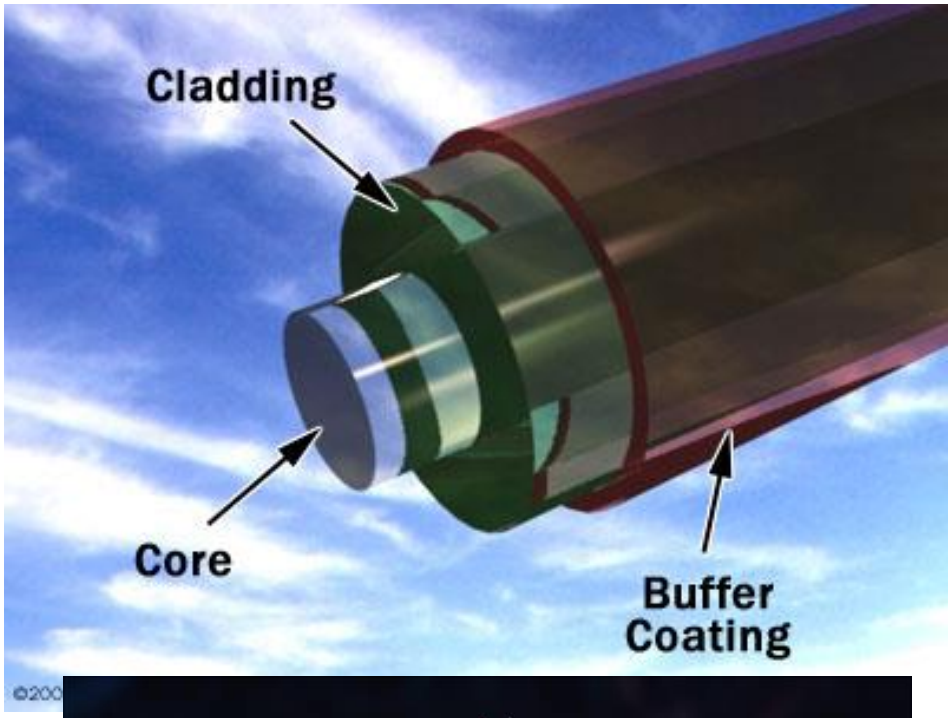
Fiber Optics



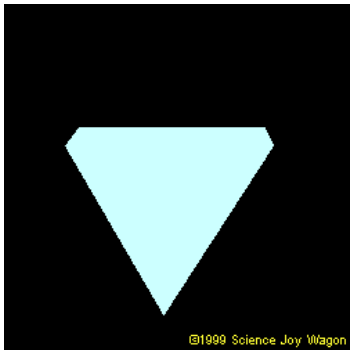
- Fiber optics makes use of internal reflection.
- Light travels long distances at **very** high speeds.
- Digital information.

Fibers

- Core is more optically dense then the surrounding cladding.
- Only need a thin fiber to transmit information.

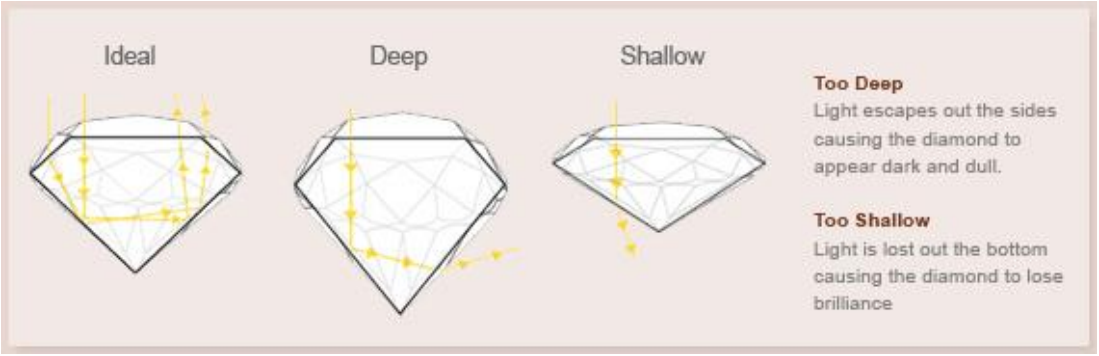


Diamonds paired with physics!

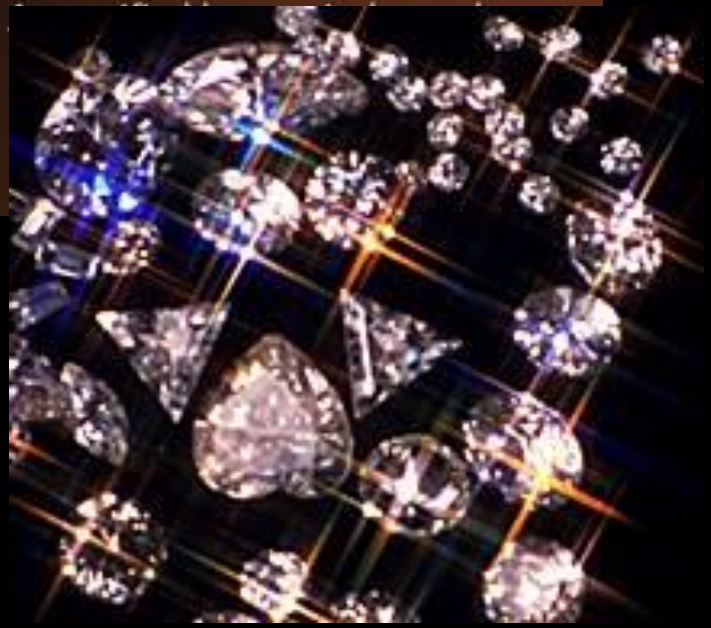


- The way a diamond is cut can optimize the amount of total internal reflection…

  optimizing the amount of sparkle!



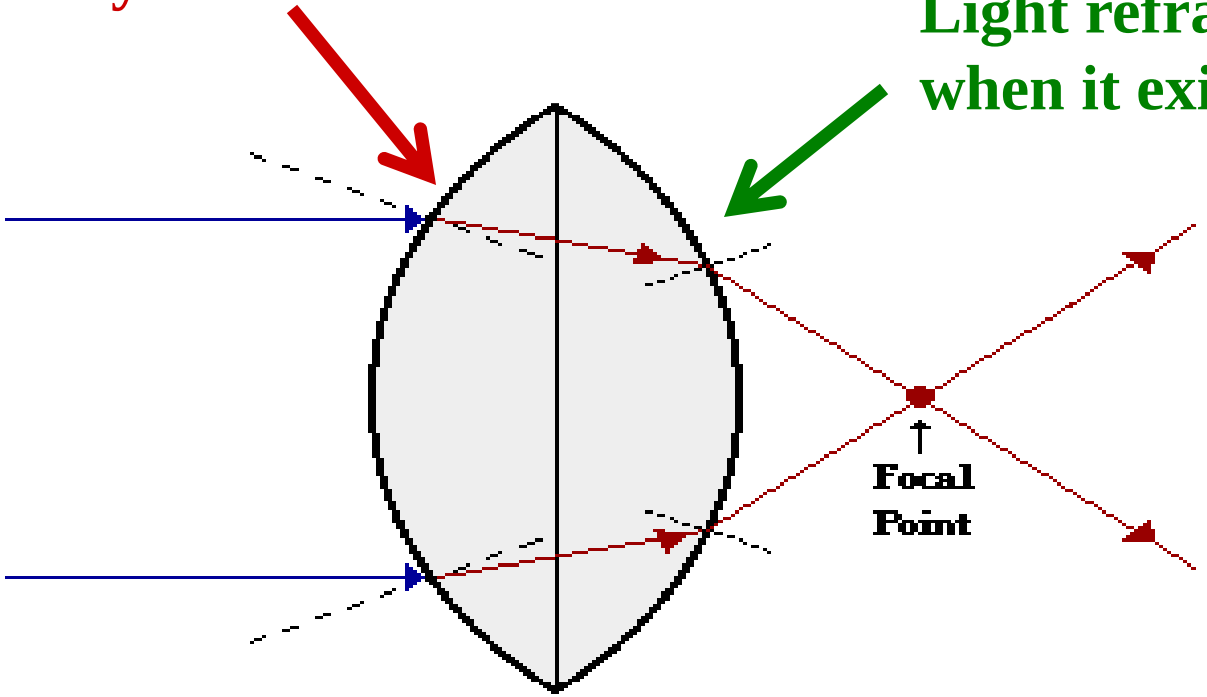
Diamond Examples



Refraction by a Converging Lens

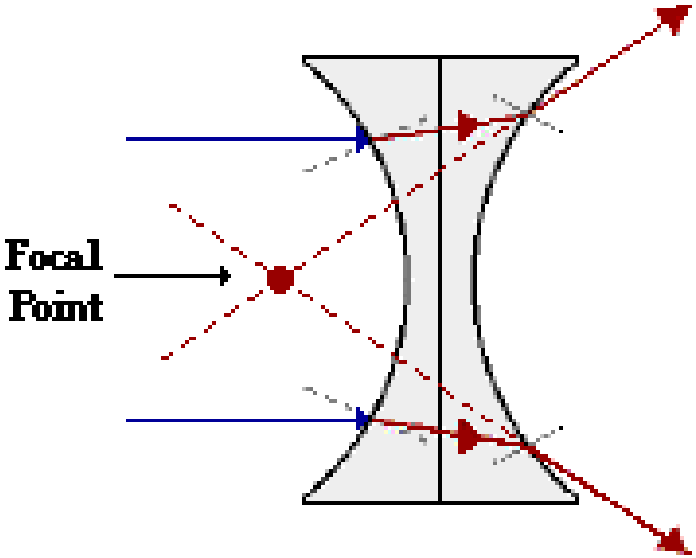
Light bends (refracts) as it enters more optically dense material.

Light refracts again when it exits lens.



Incident rays which travel parallel to the principal axis will refract through the lens and converge to a point.

Refraction by a Diverging Lens

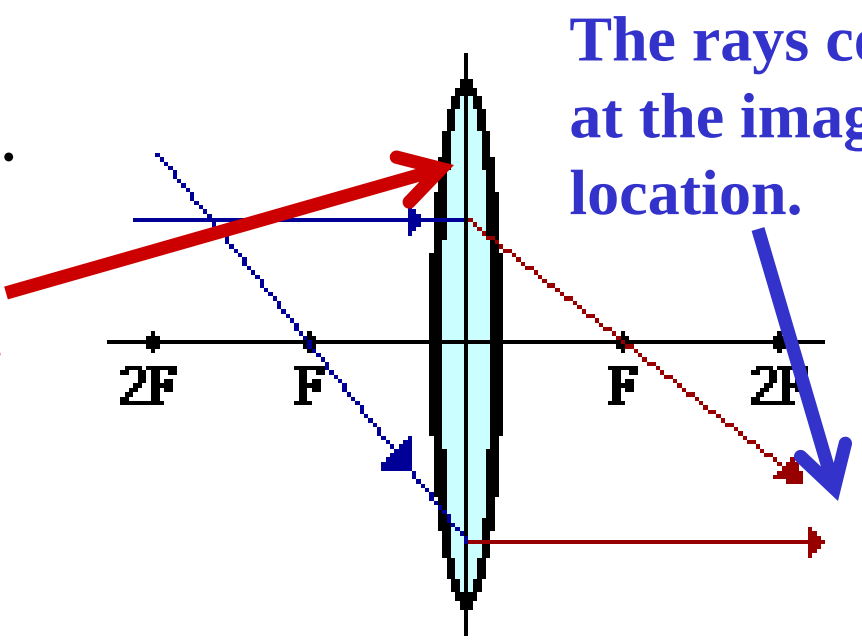


A diverging lens is said to have a negative focal length since rays which enter the lens traveling parallel to the principal axis diverge.

- The same applies for a diverging lens.
- Refracted rays don't converge
- Follow back diverging rays to find focal point.

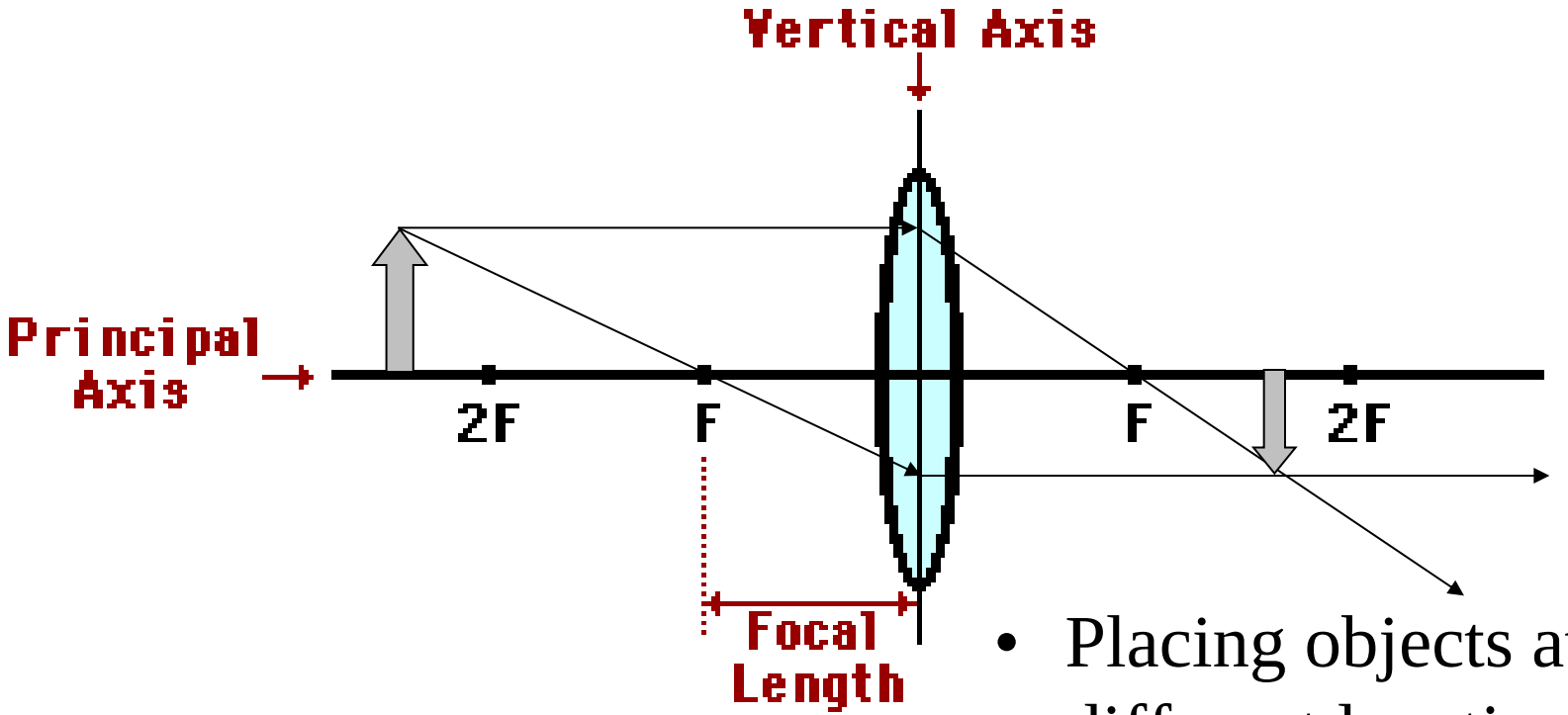
Thin Lens Approximation

- Hard to draw all refractions inside lens.
- Approximate using vertical bisecting line.
- Parallel to principal axis, through focal point.
- This time the rays go through instead of reflecting.



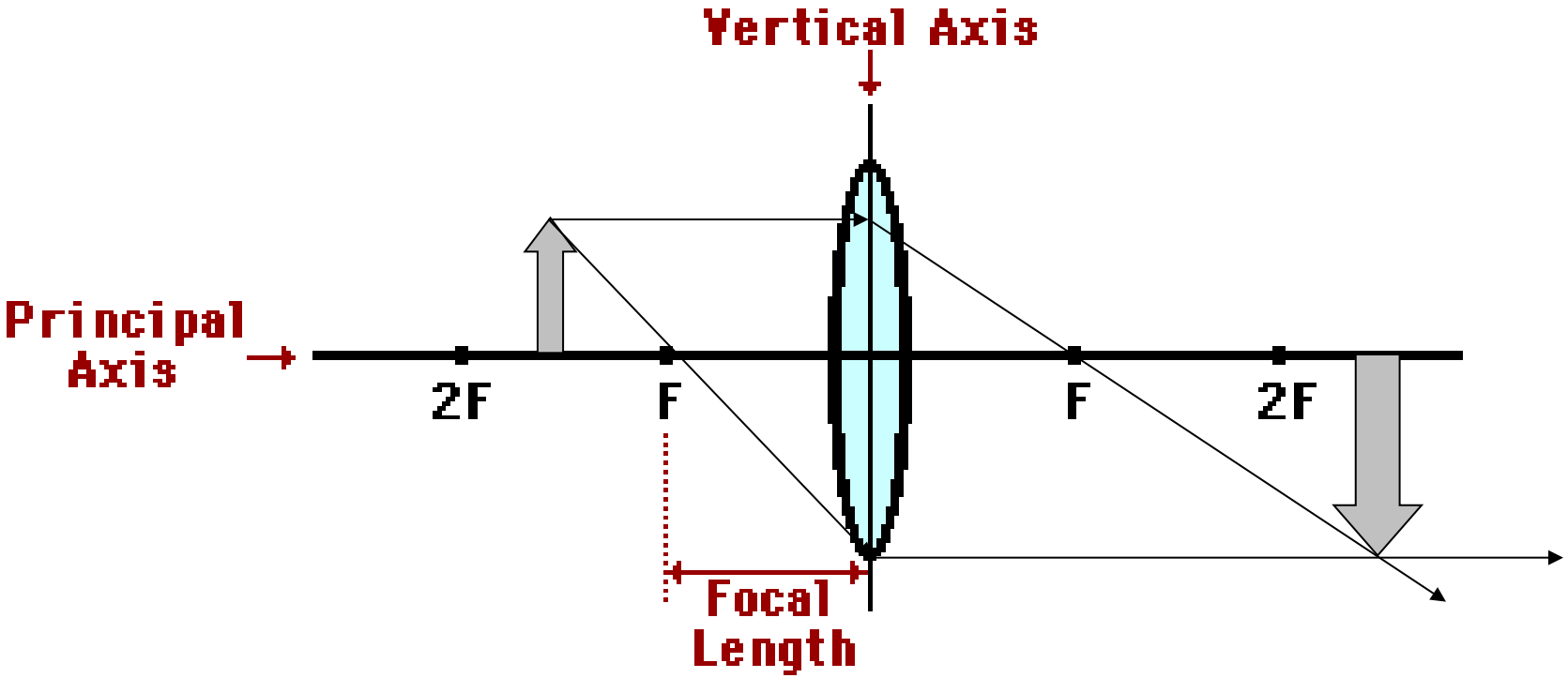
In the construction of incident and refracted rays, the light can merely be bent at the vertical axis. This creates the same result as refracting the light rays twice.

Finding Image Locations

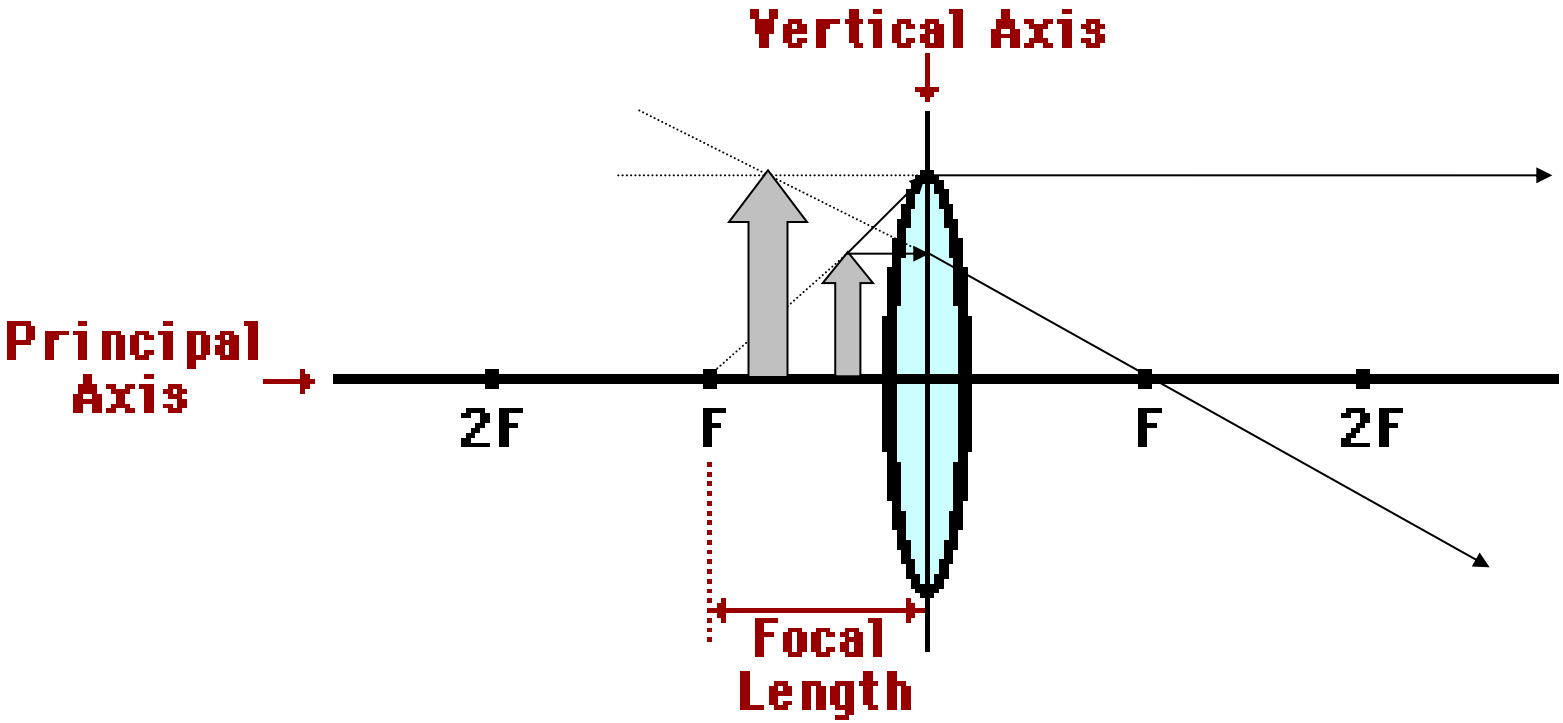


- Placing objects at different locations produces images of varying sizes and locations.

Finding Image Locations



Finding Image Locations



Diverging Lens