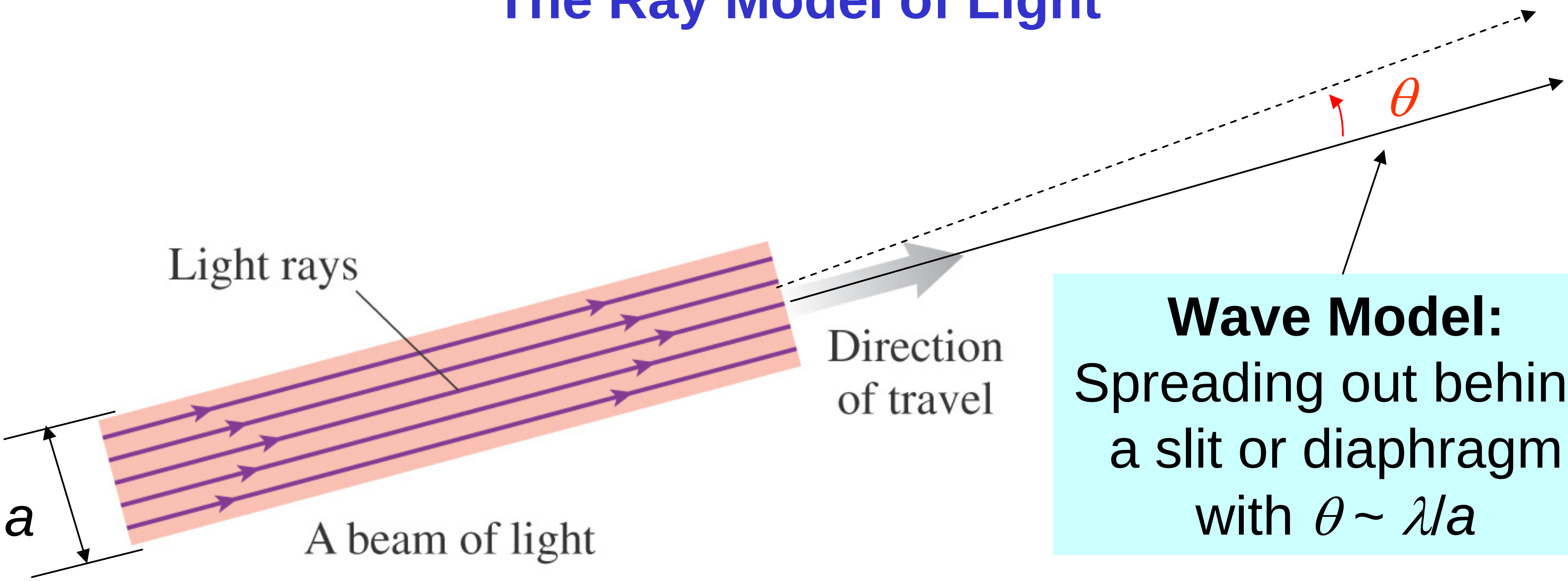
Lecture 22: Chapter 23, December 1 2005

The Ray Model of Light

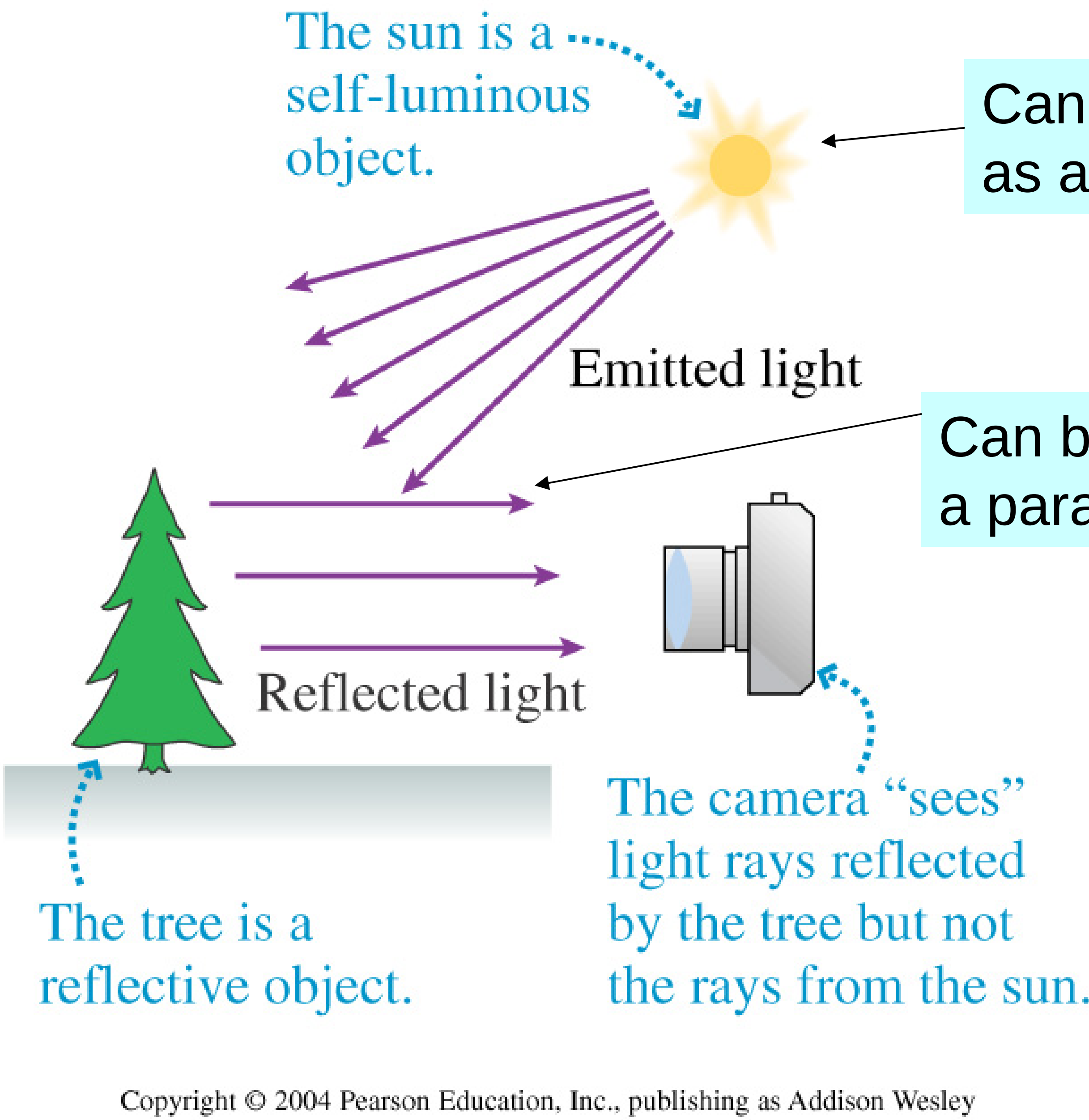


Wave Model:
Spreading out behind
a slit or diaphragm
with $\theta \sim \lambda/a$

- The ray model of light is valid as long as any apertures through which the light passes (lenses, mirrors, holes, etc.) are very large compared to $\lambda \Rightarrow \theta \sim 0$.

- A beam of light is modeled as a series of lines, rays of light, in the direction along which light energy is flowing.

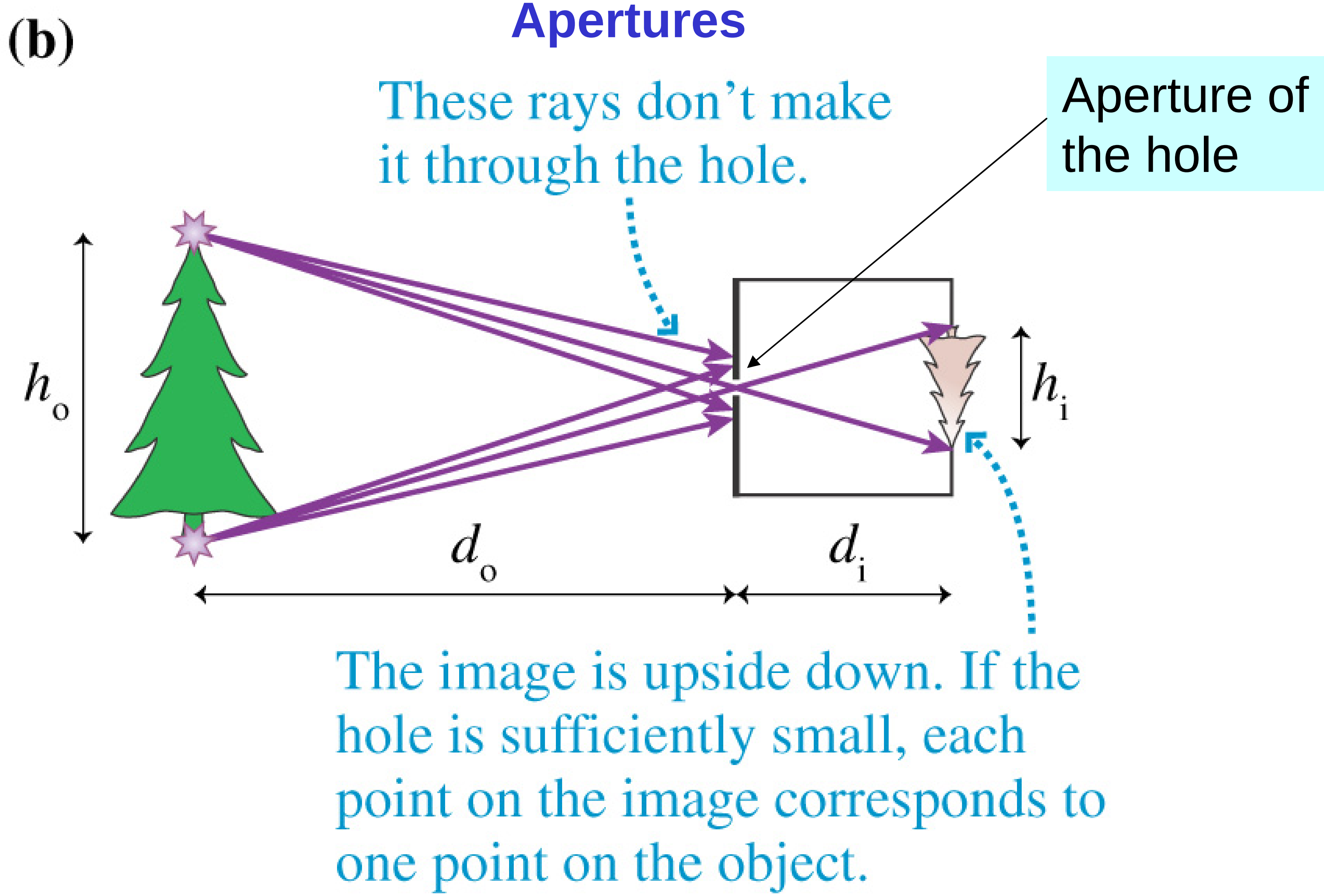
Objects



Can be modeled as a point source

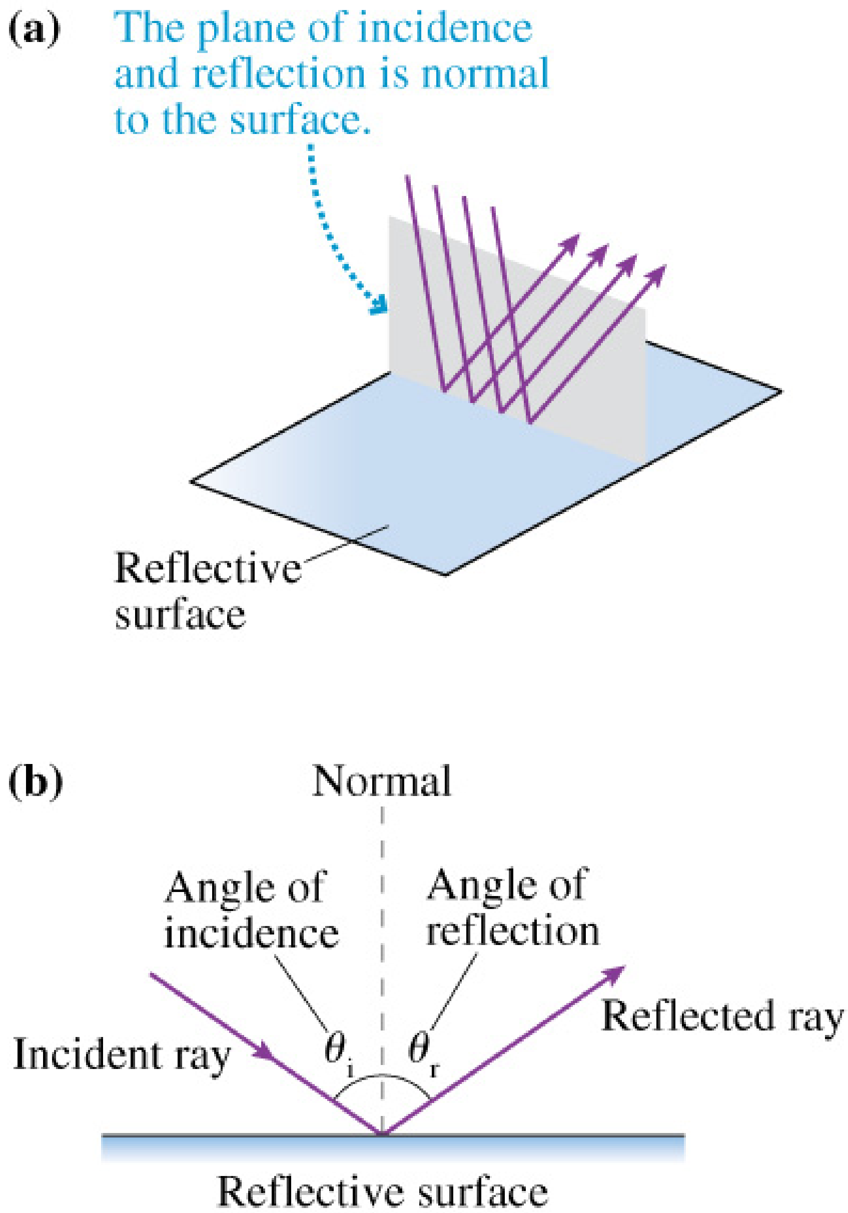
Can be modeled as a parallel bundle

Apertures



- For smaller holes the image gets sharper but weaker
- If aperture is very small the ray model breaks due to diffraction
- Magnification: $m = h_i/h_0 = d_i/d_0$

Reflection

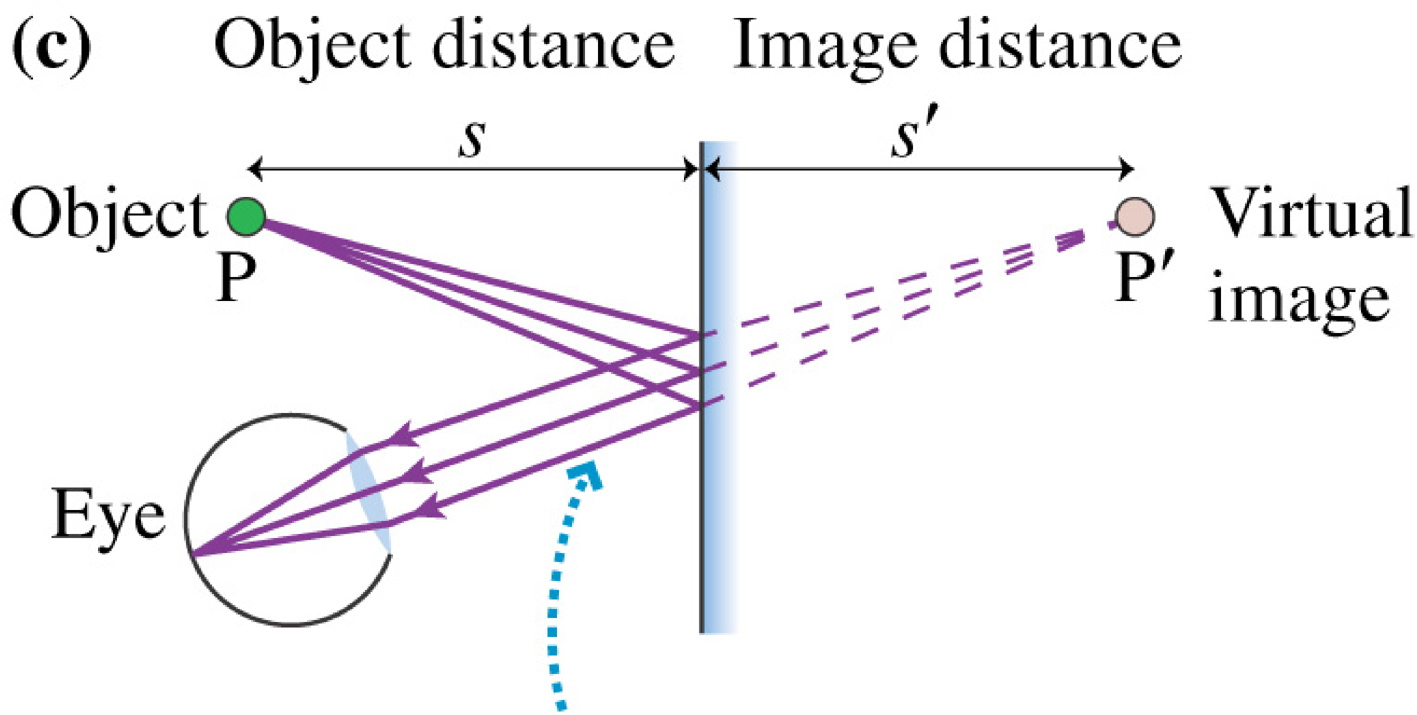


- The incident ray and the reflected ray are in the same plane normal to the surface

- The angle of reflection is equal to the angle of incidence:

$\theta_r = \theta_i$

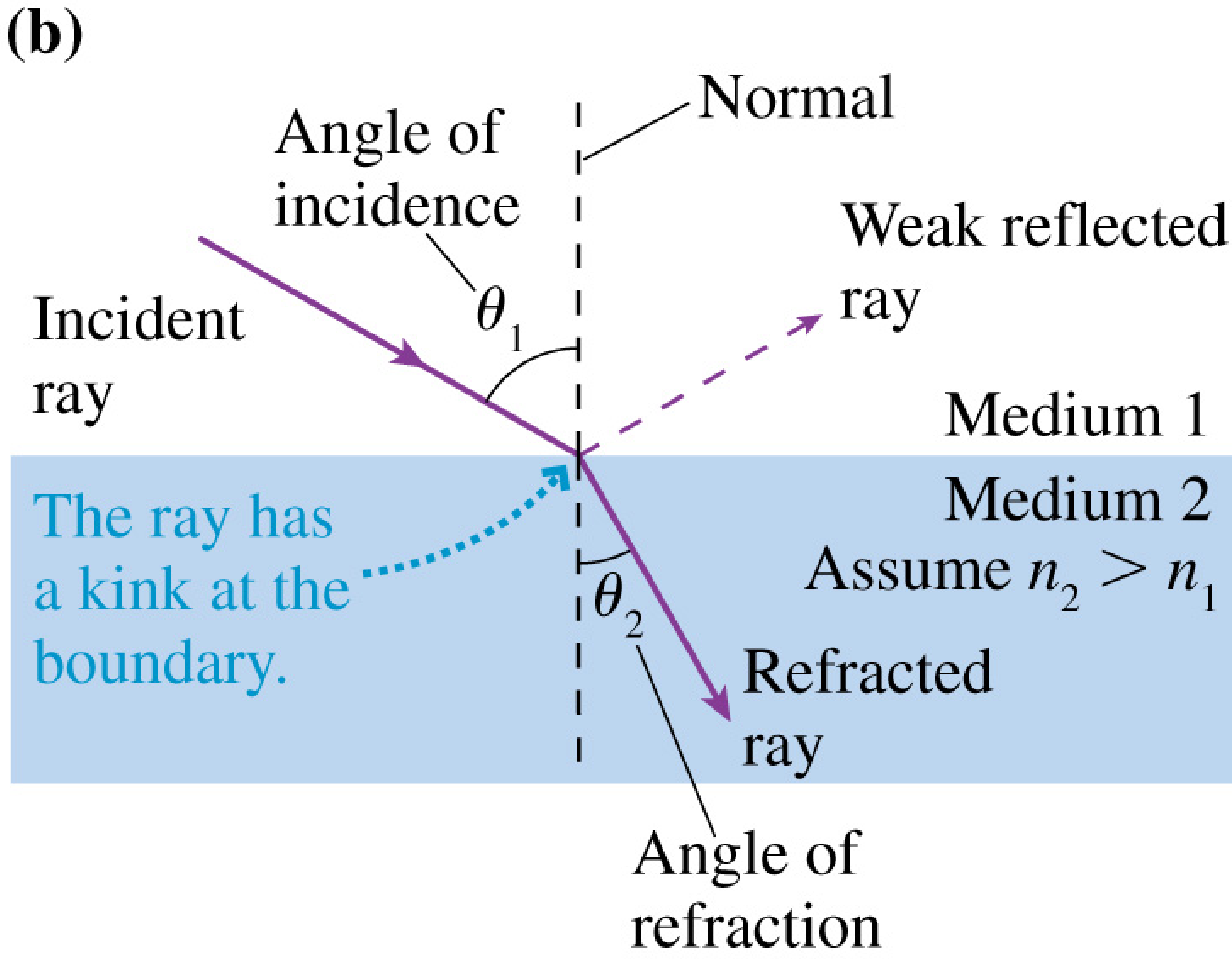
Virtual Image



The reflected rays *all* diverge from P′, which appears to be the source of the reflected rays. Your eye collects the bundle of diverging rays and "sees" the light coming from P′.

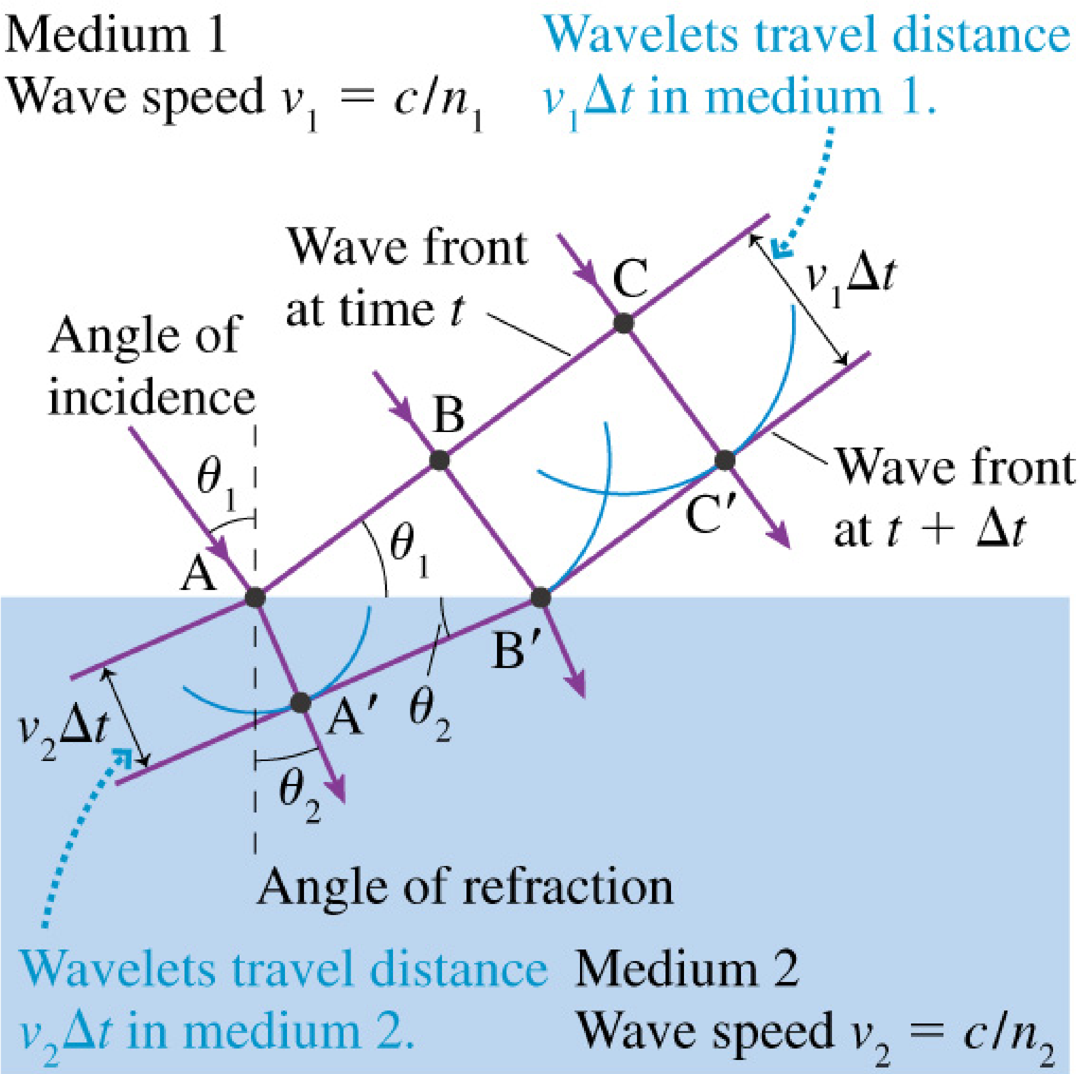
For a plane mirror: $s' = s$

Refraction



- Snell's law of refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

The Index of Refraction and Wave Model Interpretation



- Index of refraction:
  $n = c / v_{medium}$

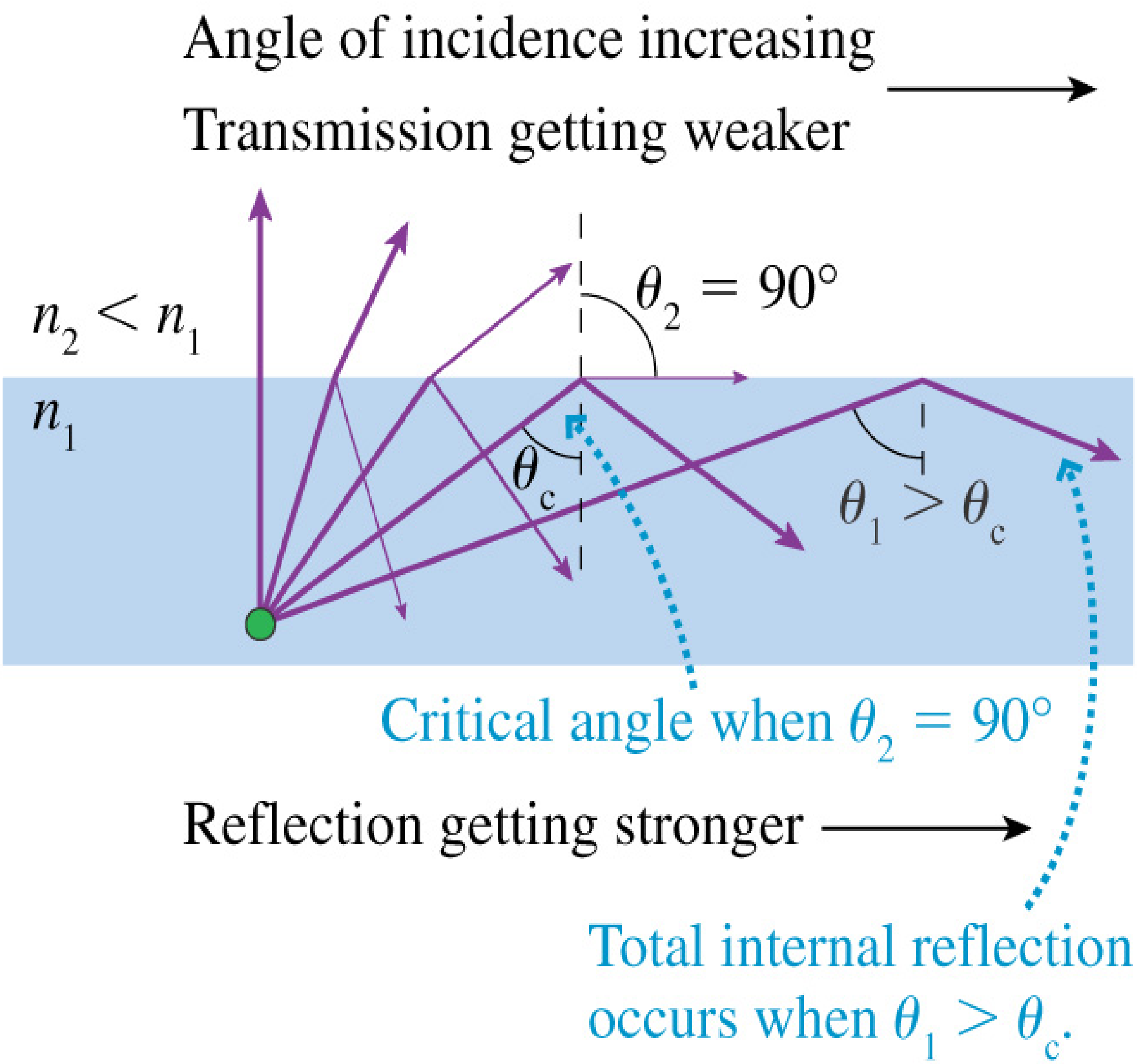
- **Huygen's principle**:
  Each point on the wave front is a source of secondary waves.

- The refracted wave front is tangent to all secondary waves fronts.

$$\frac{v_1 \Delta t}{\sin\theta_1} = \frac{v_2 \Delta t}{\sin\theta_2}$$

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

Total Internal Reflection



- Incidence from the medium with higher index n_1

- As θ_1 increases θ_2 approaches 90^0. The transmitted energy decreased.

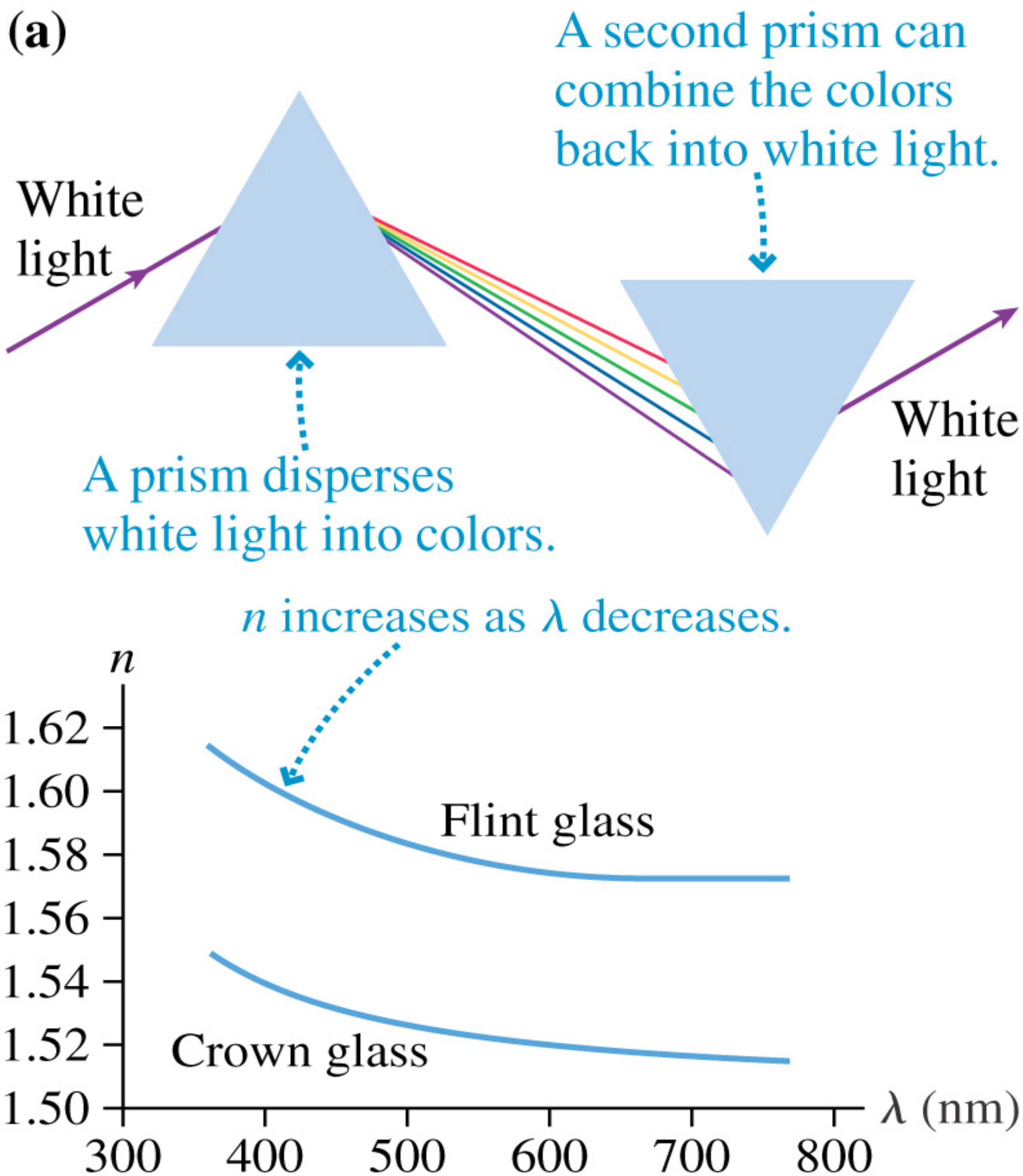
- A critical angle is reached when $\theta_2 = 90^0$:

$\theta_c = \sin^{-1}(n_2/n_1)$

For glass-air:
$\theta_c = 42^0$

Application: fiber optics and Internet

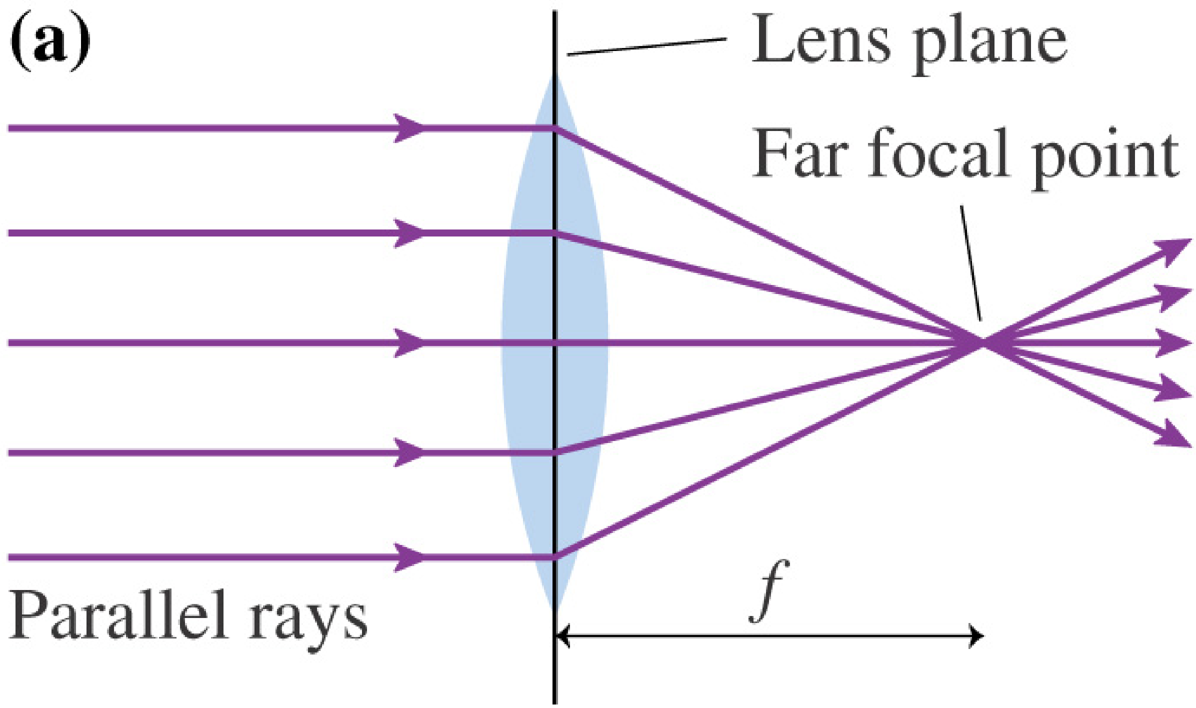
Color and Dispersion



- White light is a mixture of all colors.

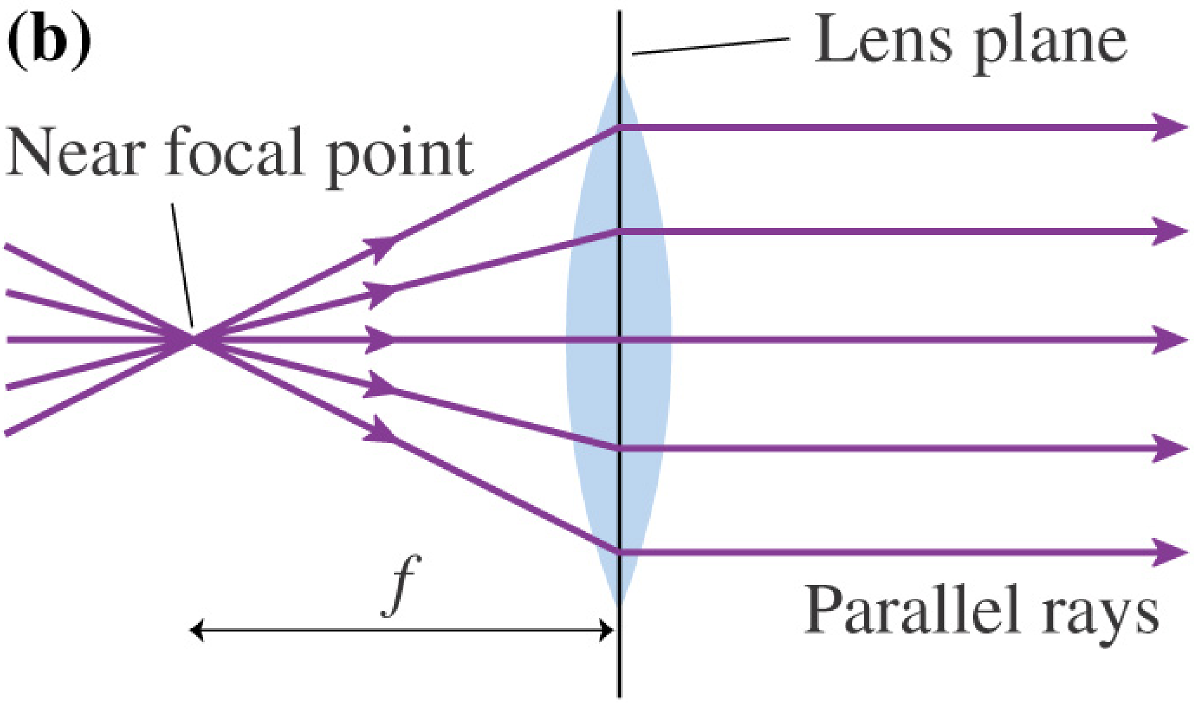
- The index of refraction of a glass differs for different colors.

Thin Lenses: Ray Tracing, Rule 1



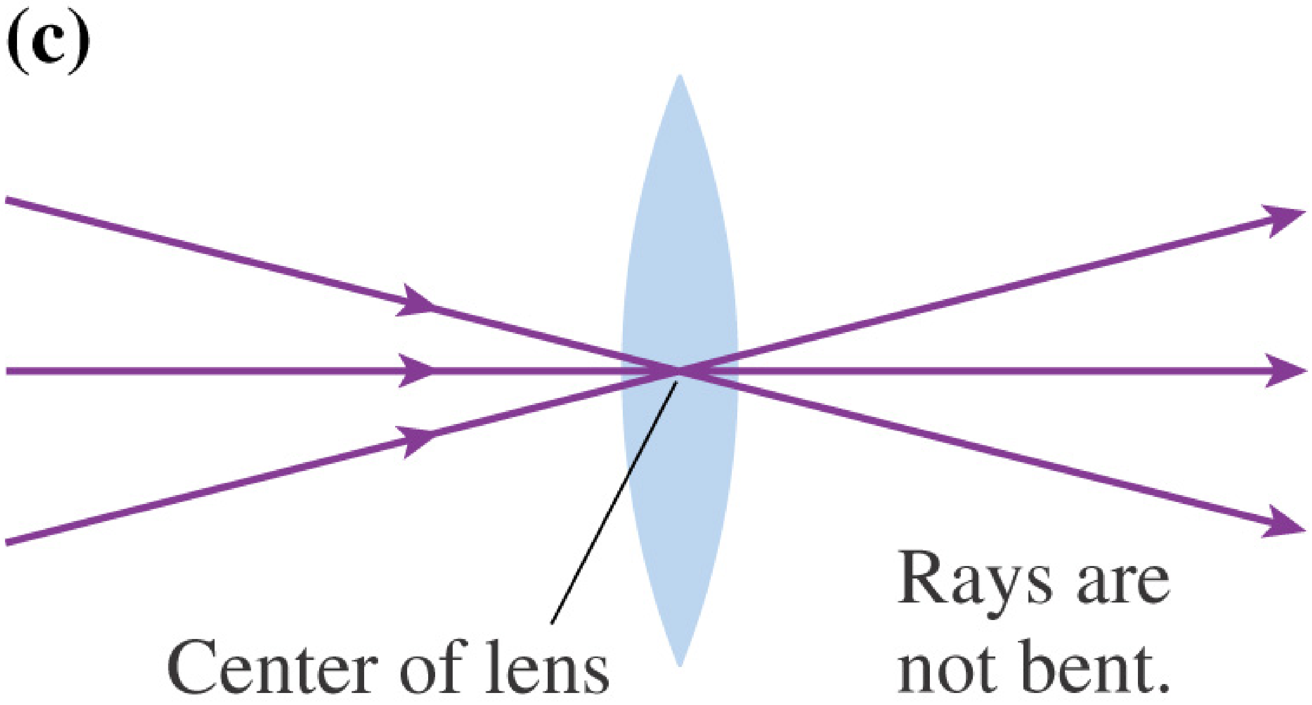
Any ray initially parallel to the optical axis will refract through the focal point on the far side of the lens.

Thin Lenses: Ray Tracing, Rule 2



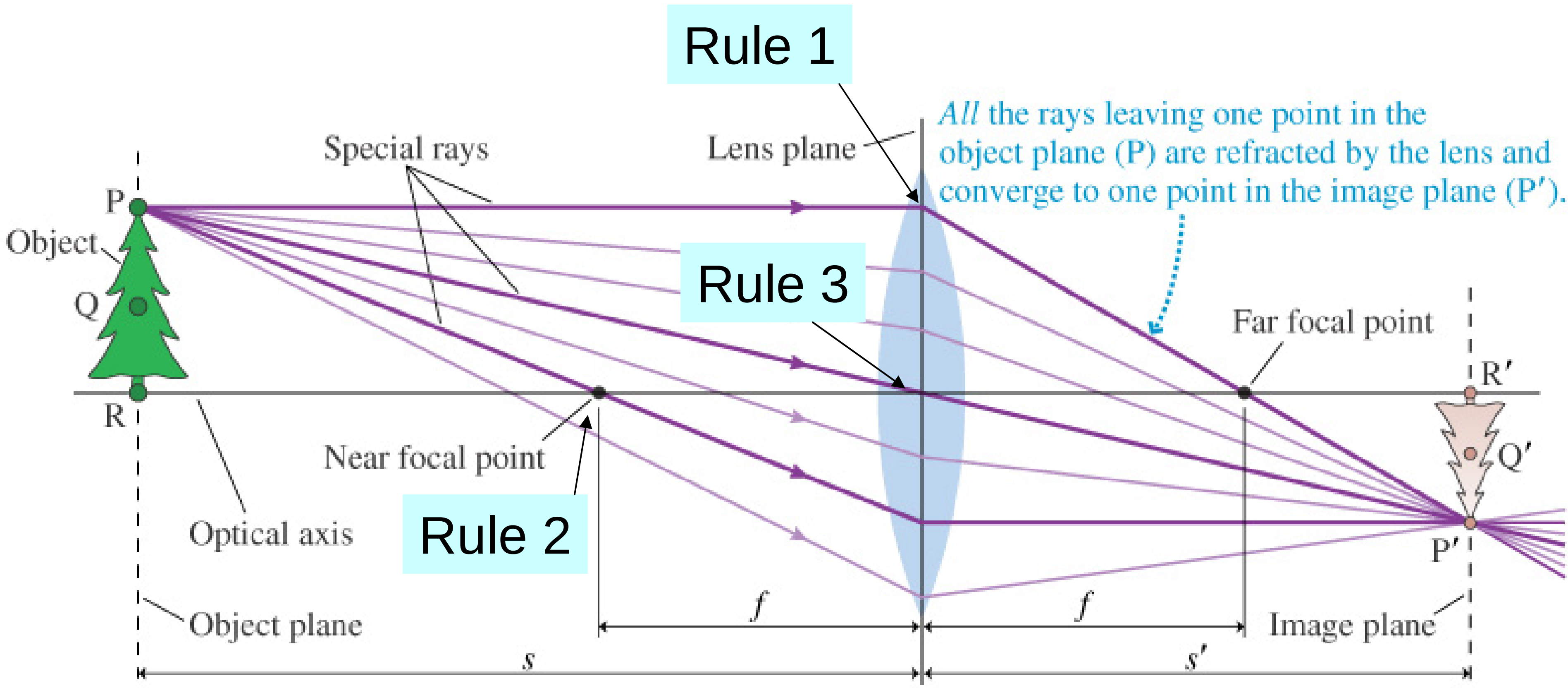
Any ray passing through the near focal point emerges from the lens parallel to the optical axis.

Thin Lenses: Ray Tracing, Rule 3



Any ray directed at the center of the lens passes through in a straight line.

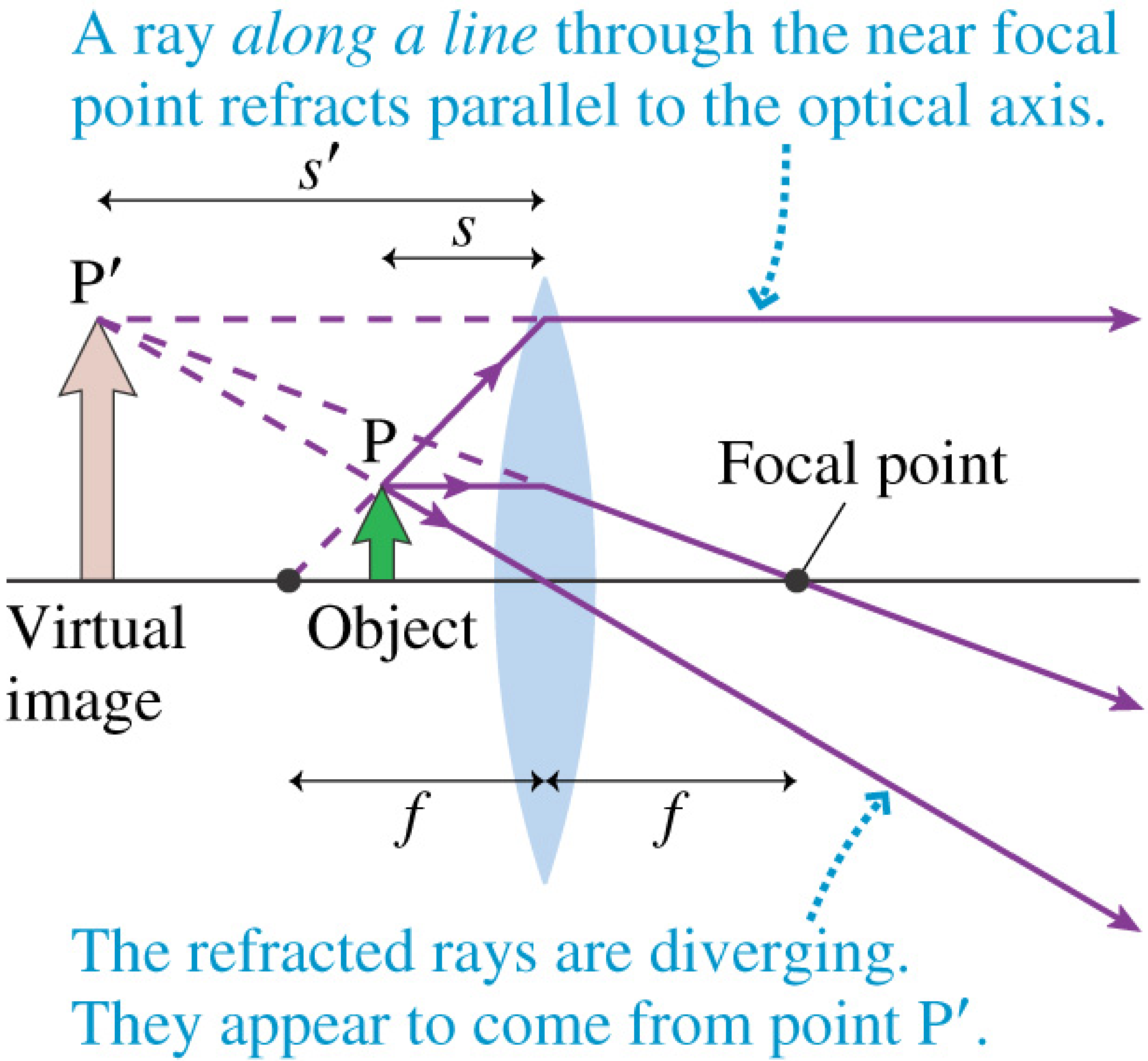
Real Images



Magnification: $M = - h'/h = - s'/s$

- Negative M indicates that the image is inverted
- The absolute value of M is given by the size ratio of the image and object

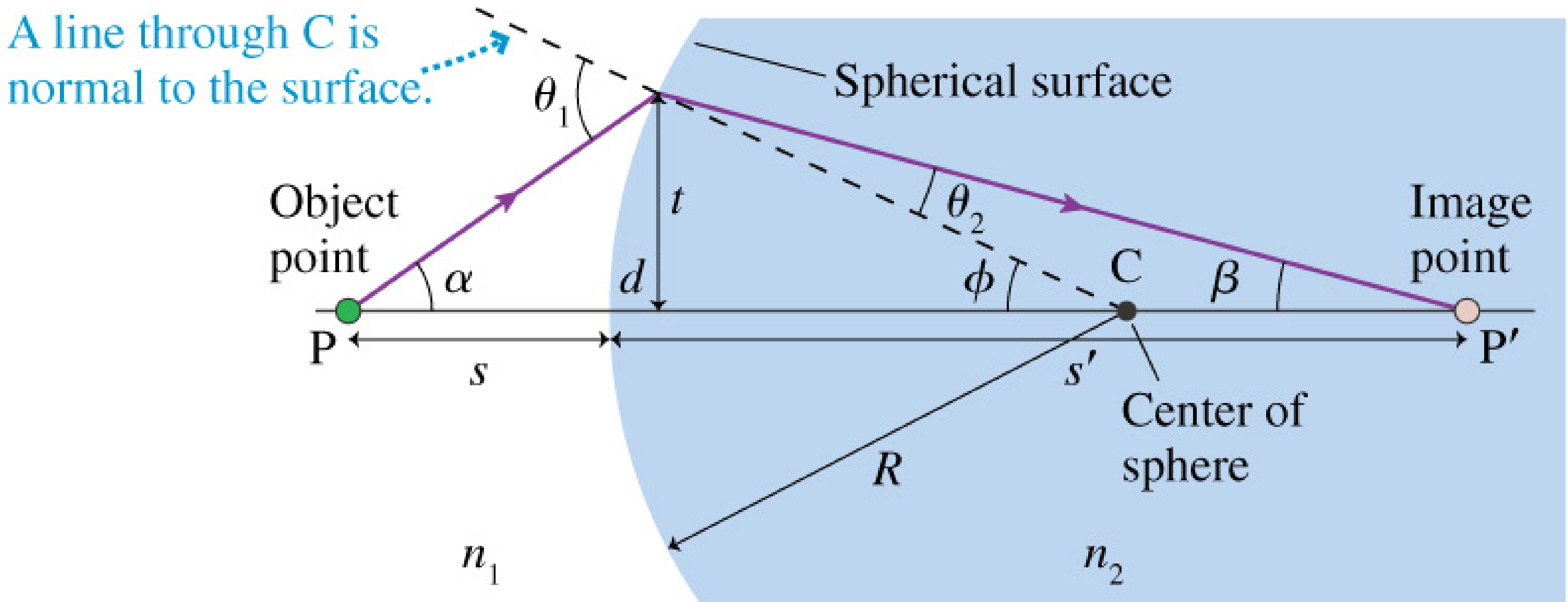
Virtual Images



- Case $s < f$
- Upright image
- By definition $s' < 0$
- $M > 0$

Thin Lenses: Refraction Theory

Single spherical boundary



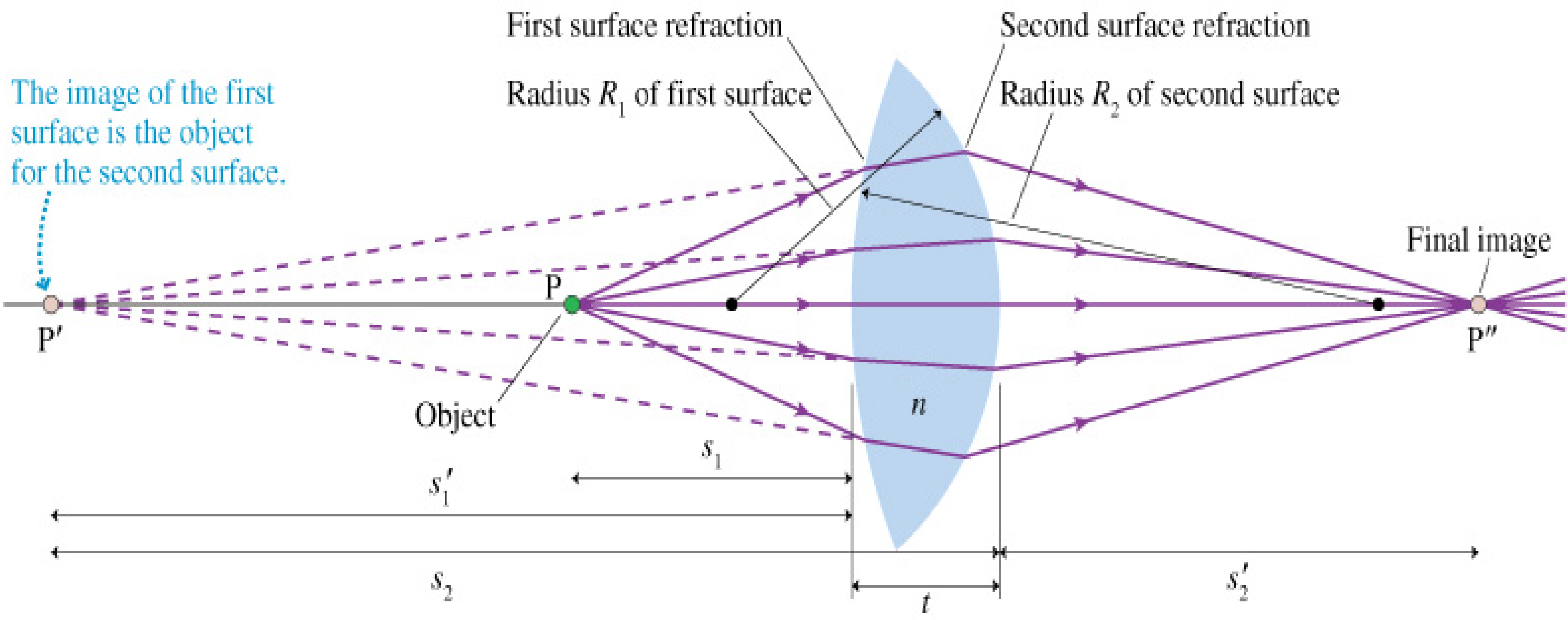
Snell's law in the small-angle approximation: $n_1\theta_1 = n_2\theta_2$

Geometry: $\theta_1 = \alpha + \phi$, $\theta_2 = \phi - \beta$

Leads to Equation:

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

Two spherical surfaces



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

Thin-lens equation

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

Lens maker's Equation (See derivation in the text)

End of Lecture 22

Reading: Chapter 23

HW for Chapter 22