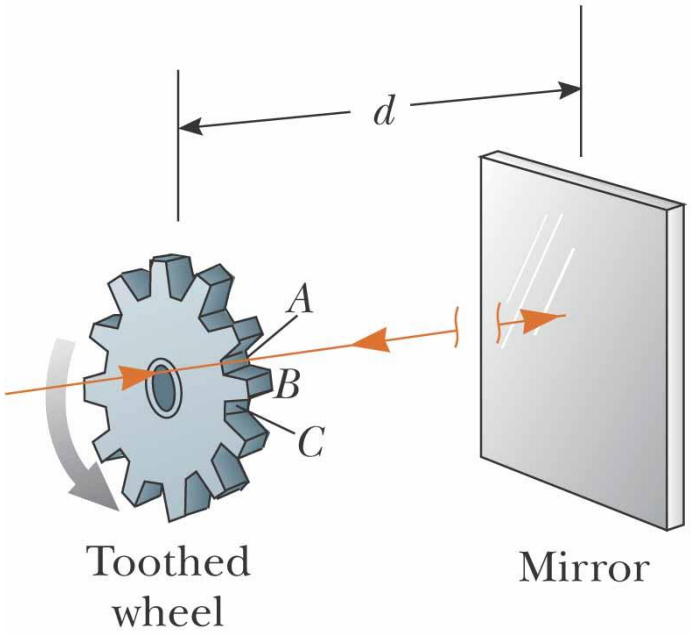
Nature of Light and Laws of Geometric Optics

- The nature of light
- Reflection
- Refraction
  - Index of refraction
- Huygens' Principle
- Dispersion and Prisms
- Total Internal Reflection

The Nature of Light

- Light as Particles
  - Tactile Theory (Ancient Greeks)
  - Emission Theory (al-Haitham)
  - Newton
- Light as Waves (ω, k)
  - Huygens
  - Maxwell
- Quantum Theory ($E = hf$)
  - Photons

Fizeau's Method for Speed of Light Measurement



$\omega = 27.5 rev/s$

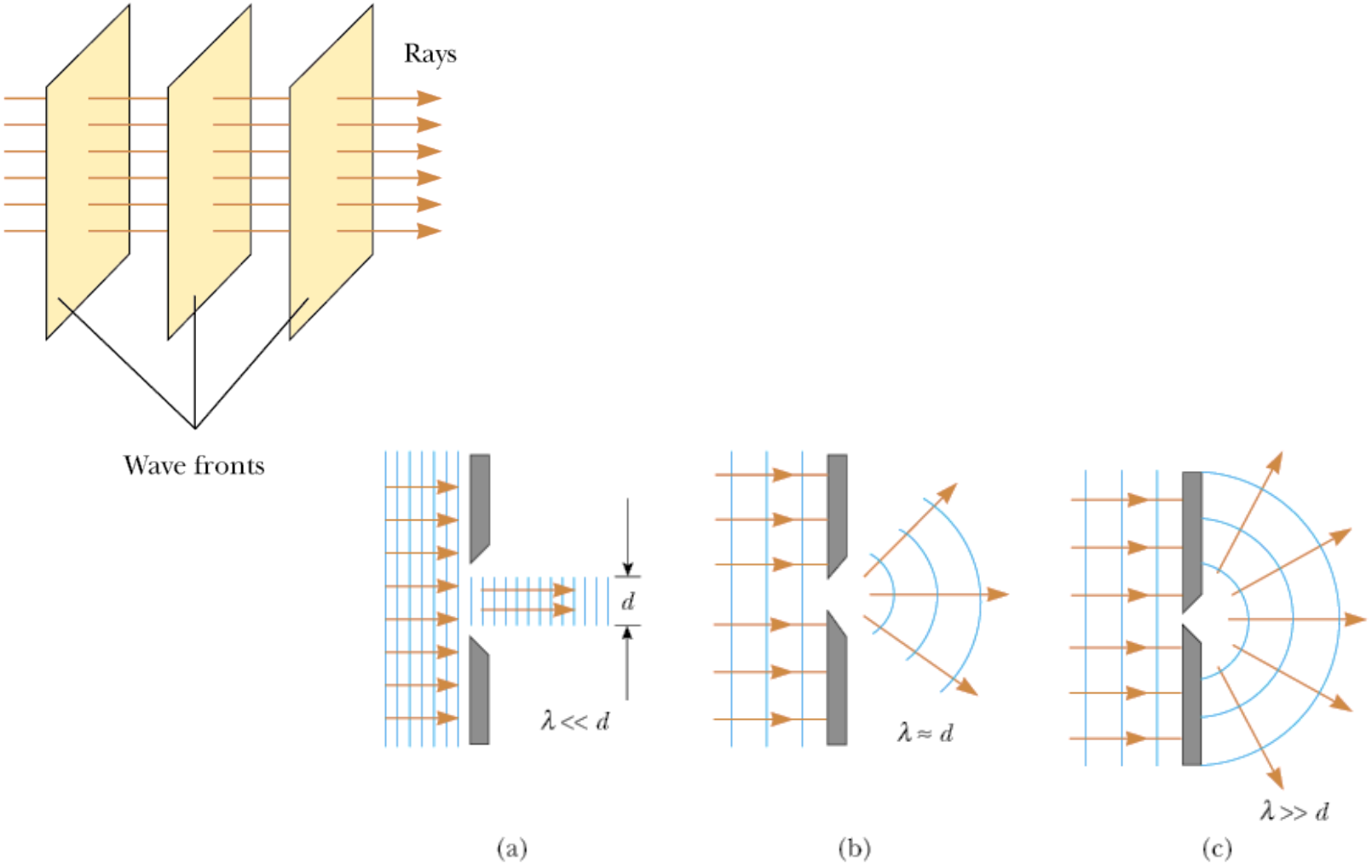
$N_{teeth} = 360$

$d = 7500m$

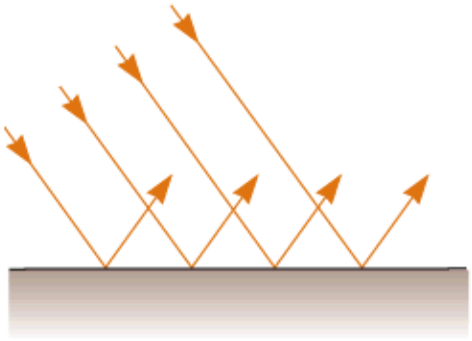
$$t = \frac{\theta}{\omega} = \frac{1/720}{27.5} = 5.05 \times 10^{-5} s$$

$$c = \frac{2d}{t} = \frac{2(7500m)}{5.05 \times 10^{-5} s} = 2.97 \times 10^{8} m/s$$

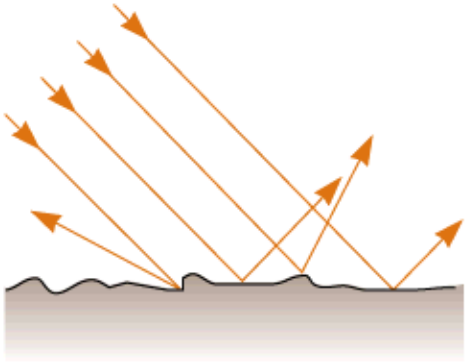
Ray Approximation in Geometric Optics



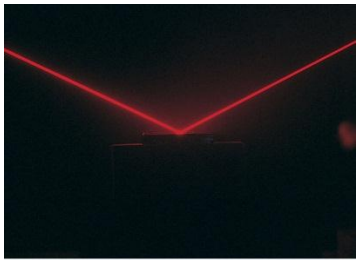
Reflection

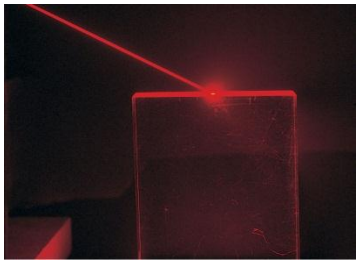


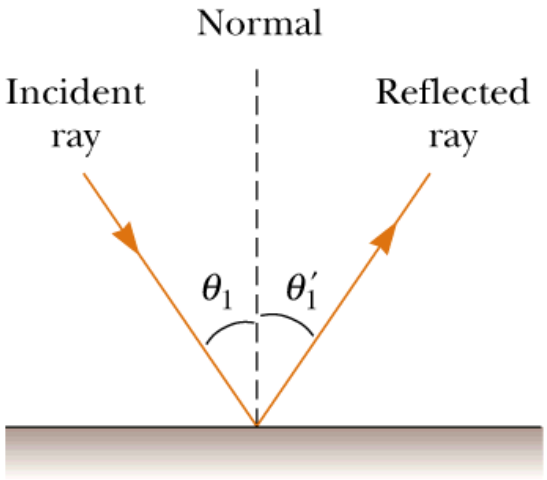
Specular Reflection



Diffuse Reflection

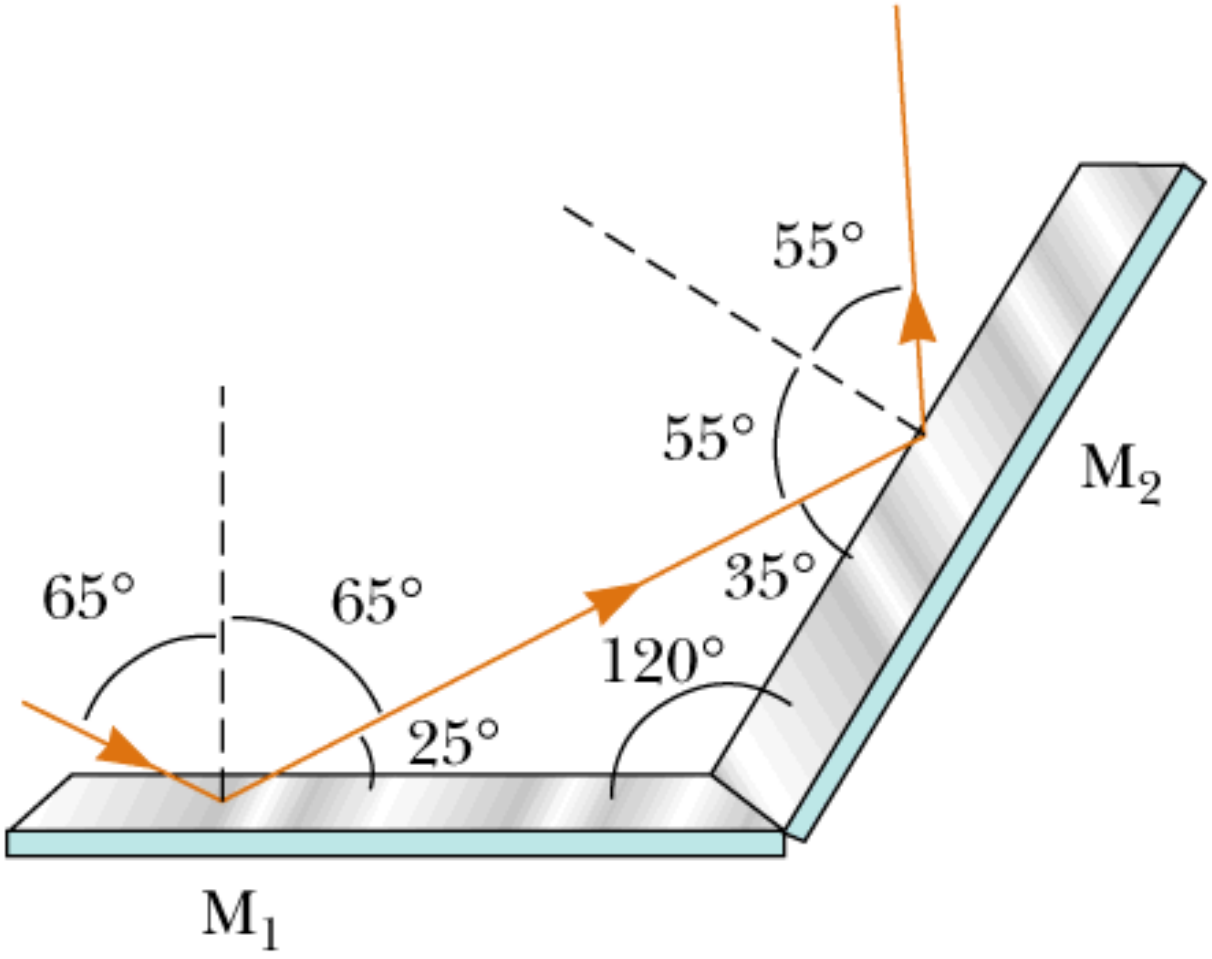




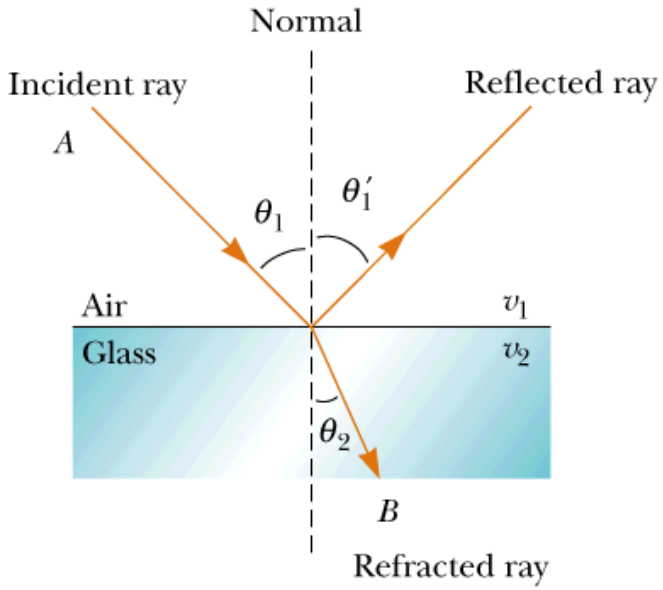


$$\theta_1' = \theta_1$$

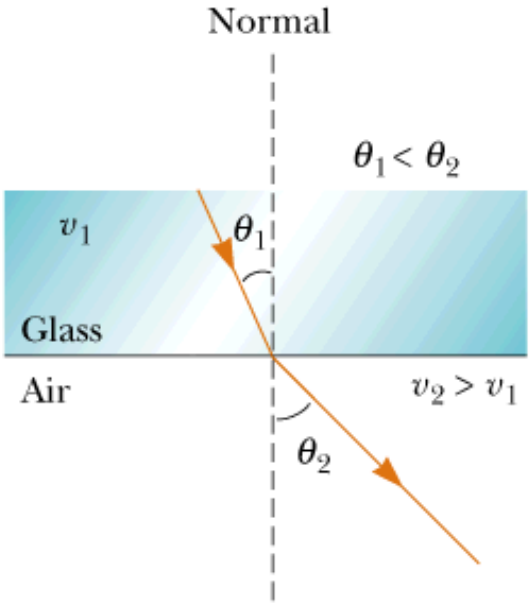
Double Reflection



Refraction

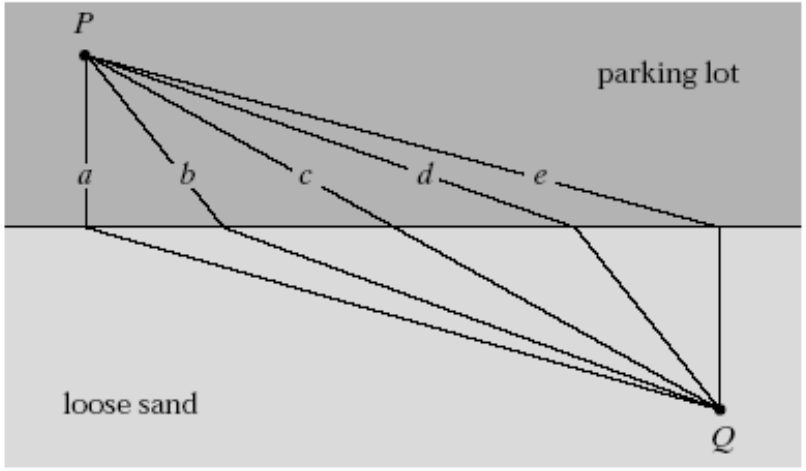


$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \text{constant}$$



Concept Question

Suppose the sprinters wish to get from point *Q* on the beach to point *P* on the parking lot as quickly as possible. Which path takes the least time?



1. a
2. b
3. c
4. d
5. e
6. All paths take the same amount of time.

Index of Refraction

$$n \equiv \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}} = \frac{c}{v}$$

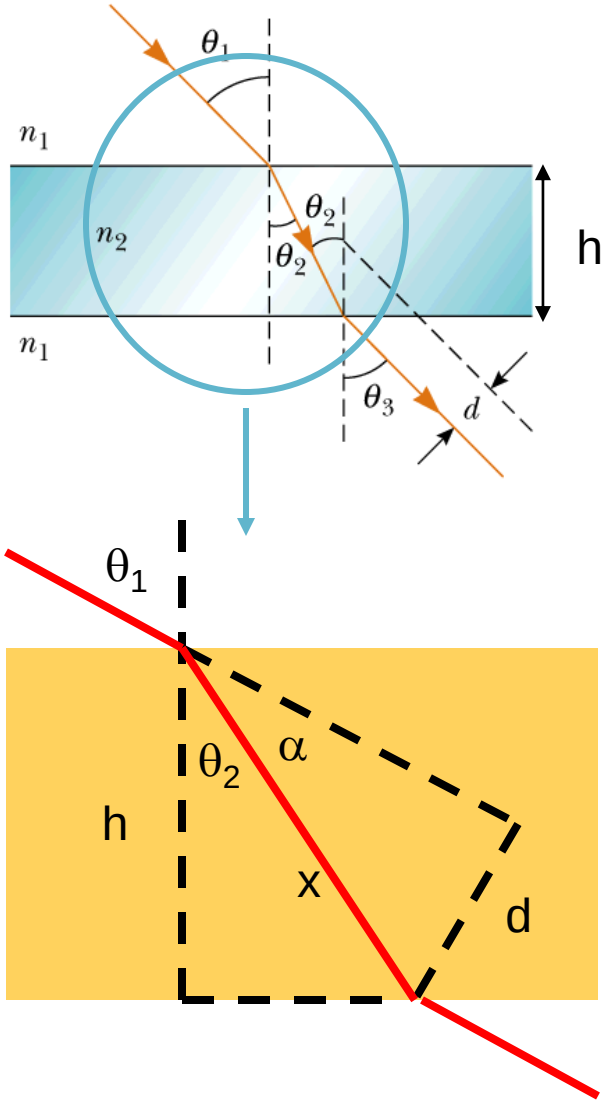
Going from one medium to another, the frequency of light does not change but its wavelength does.

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1}$$

If one of the medium's is vacuum (n=1), $n = \frac{\lambda}{\lambda_n}$

Snell's Law of Refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Light Propagation Through a Slab



$$\sin\theta_2 = \frac{n_1}{n_2}\sin\theta_1$$

$$\sin\theta_3 = \frac{n_2}{n_1}\sin\theta_2$$

$$\sin\theta_3 = \frac{n_2}{n_1}\frac{n_1}{n_2}\sin\theta_1 = \sin\theta_1$$

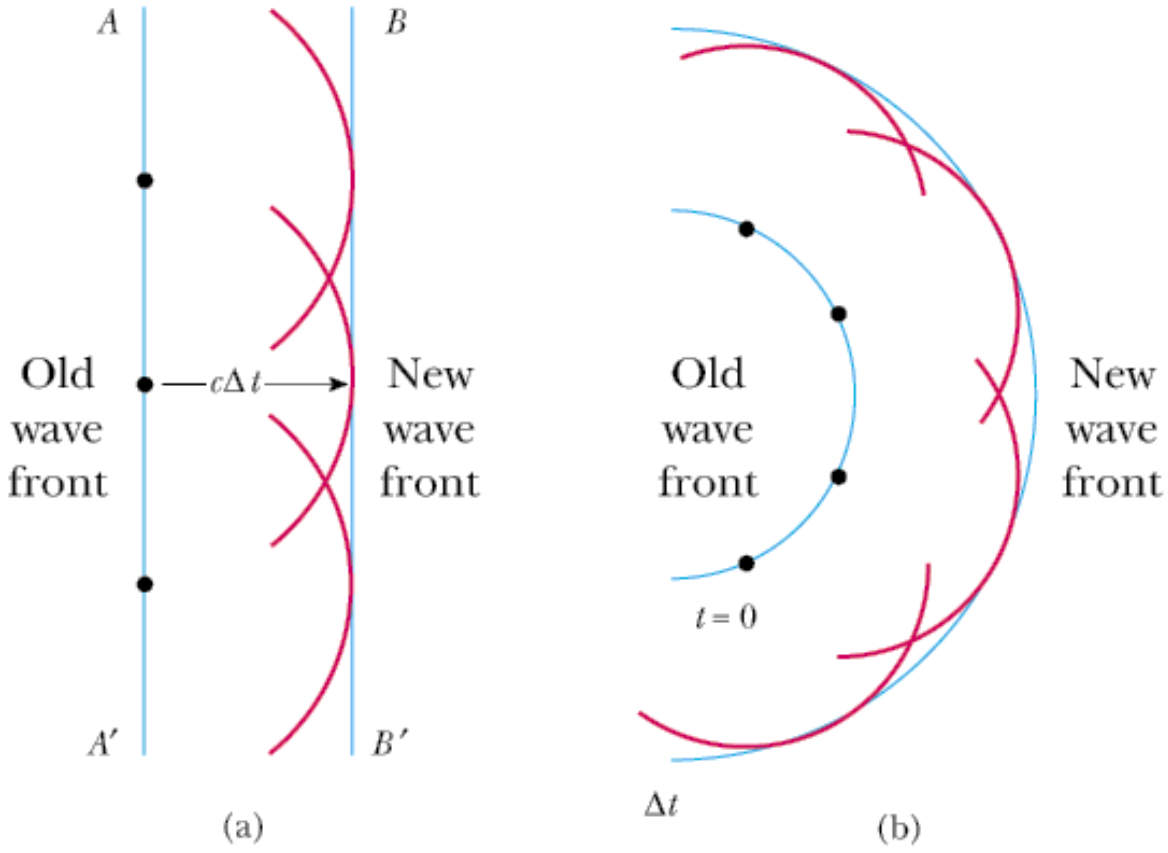
$$x = \frac{h}{\cos\theta_2}$$

$$d = x\sin\alpha$$

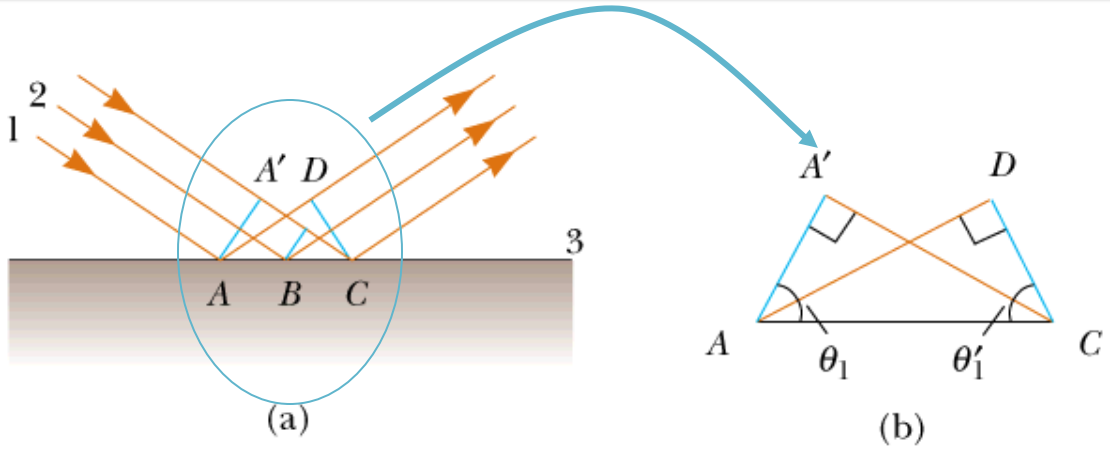
$$\alpha = \theta_1 - \theta_2$$

$$d = \frac{h}{\cos\theta_2}\sin(\theta_1 - \theta_2)$$

Huygens' Principle



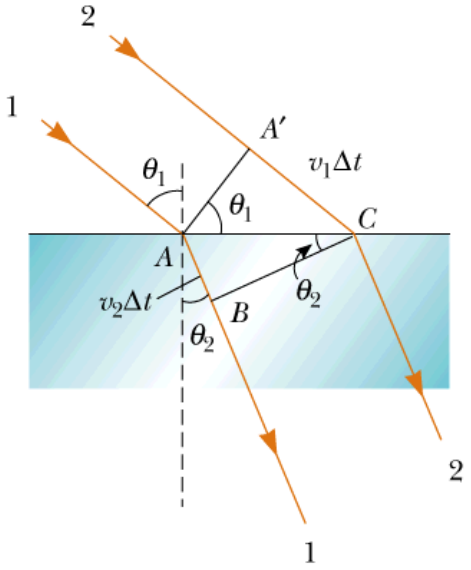
Huygens' Principle Applied to Reflection and Refraction



$$\sin\theta_1 = \frac{A'C}{AC} \qquad \sin\theta_1' = \frac{AD}{AC}$$

$$A'C = AD$$

$$\boxed{\theta_1 = \theta_1'}$$

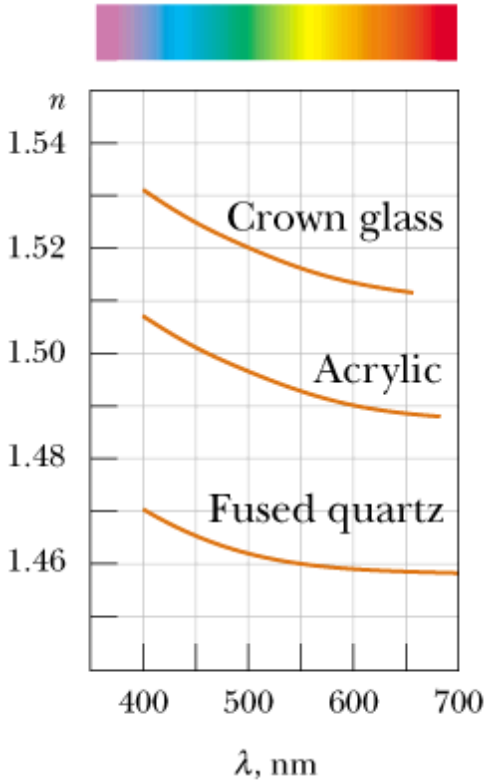


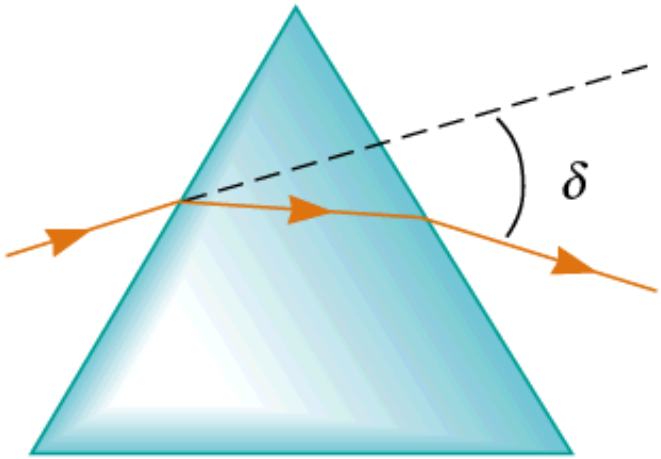
$$\sin\theta_1 = \frac{v_1\Delta t}{AC} \qquad \sin\theta_2 = \frac{v_2\Delta t}{AC}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2}$$

$$\boxed{n_1 \sin\theta_1 = n_2 \sin\theta_2}$$

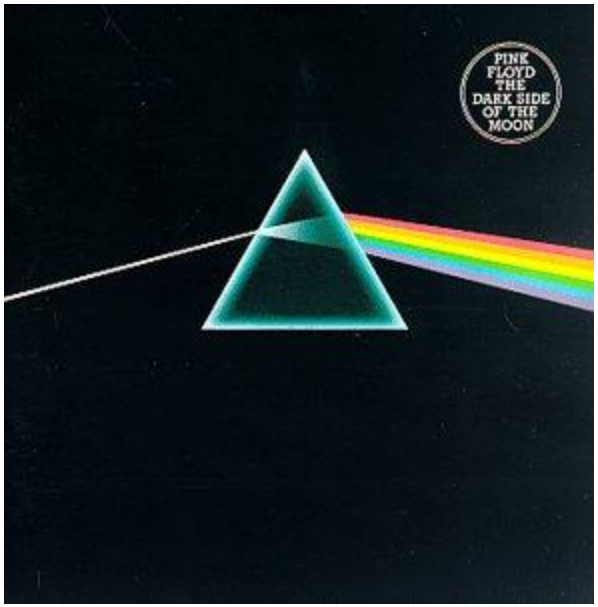
Dispersion and Prisms



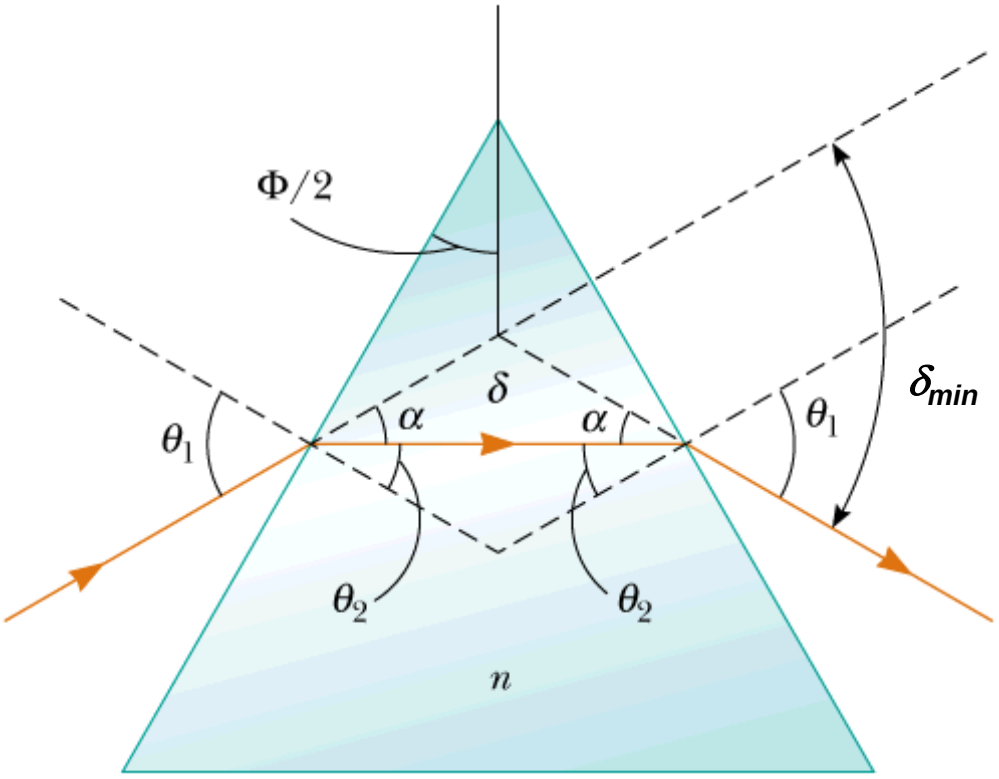


: angle of deviation

$$n = n(\lambda)$$



Measuring n Using a Prism



$$\theta_2 = \frac{\Phi}{2}$$

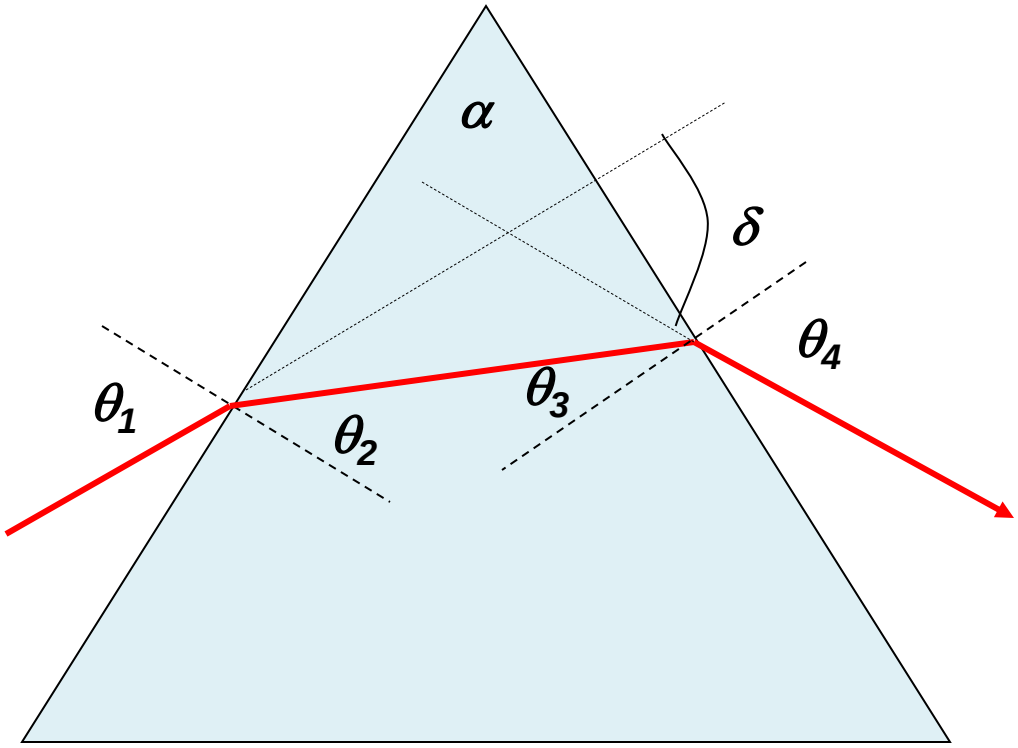
$$\theta_1 = \theta_2 + \alpha = \frac{\Phi}{2} + \frac{\delta_{\min}}{2}$$

$$\sin\theta_1 = n\sin\theta_2$$

$$\sin\left(\frac{\Phi + \delta_{\min}}{2}\right) = n\sin\left(\frac{\Phi}{2}\right)$$

$$n = \frac{\sin\left(\frac{\Phi + \delta_{\min}}{2}\right)}{\sin(\Phi/2)}$$

Angle of Deviation



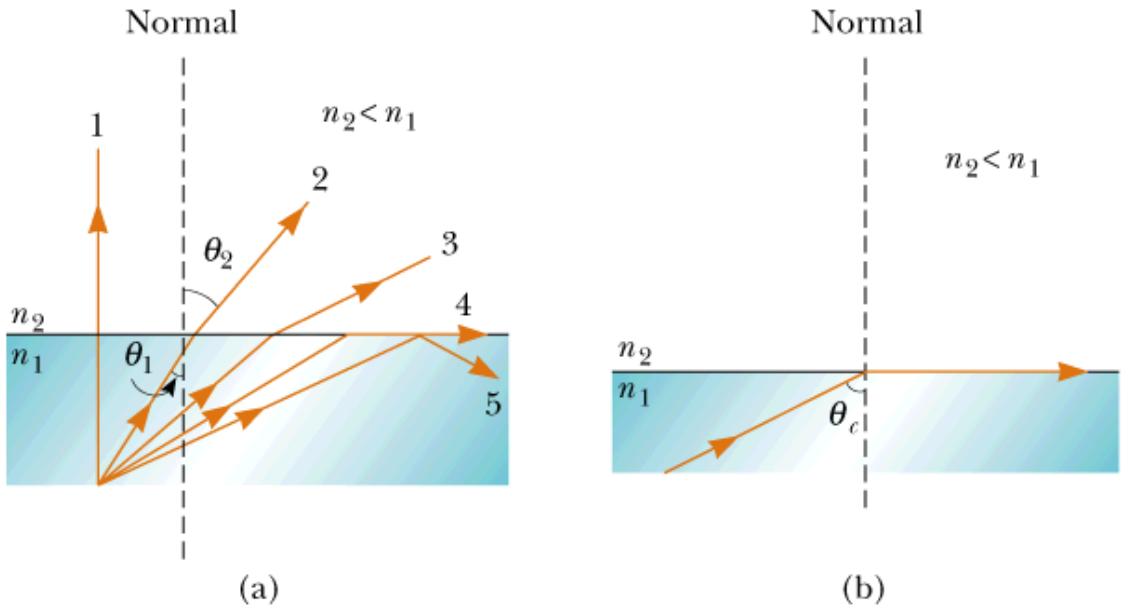
$$\delta = (\theta_1 - \theta_2) + (\theta_4 - \theta_3)$$

$$\delta = \theta_1 + \theta_4 - (\theta_2 + \theta_3)$$

$$\theta_2 + \theta_3 = \alpha$$

$$\delta = \theta_1 + \theta_4 - \alpha$$

Total Internal Reflection



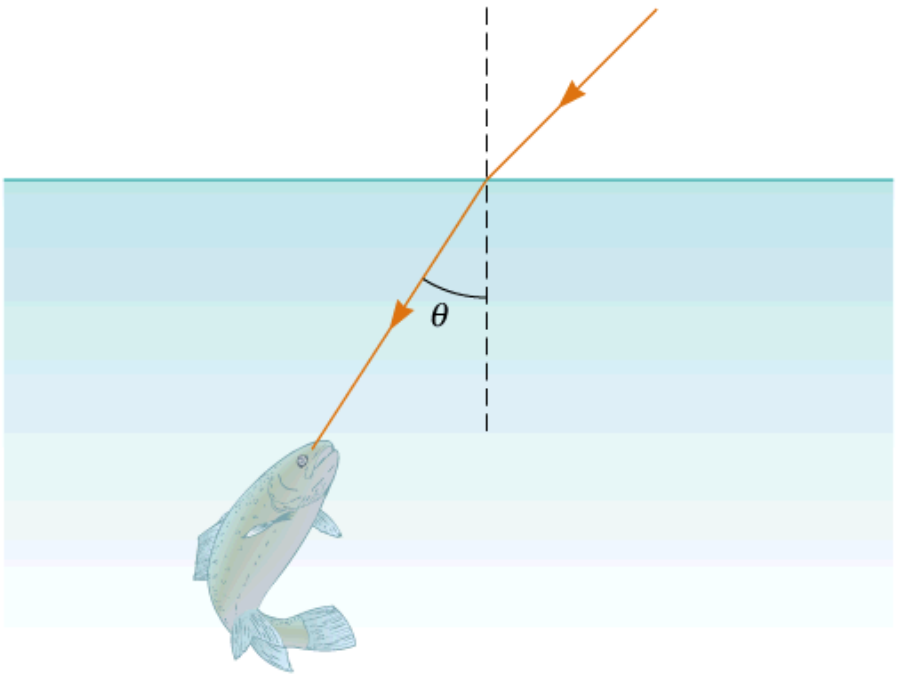
Critical Angle, θ_c

$$n_1 \sin\theta_c = n_2 \sin 90°$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

Only for $n_1 > n_2$

View From a Fish Eye



$$\sin\theta_c = \frac{n_2}{n_1} = \frac{1}{1.33} = 0.752$$

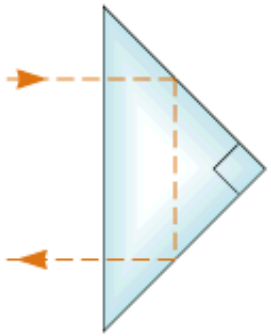
$$\theta_c = 48.8°$$

For $\theta < \theta_c$: The fish sees above the water

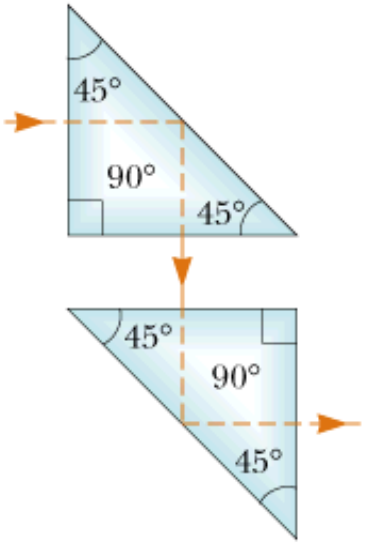
For $\theta = \theta_c$: The fish sees the shoreline

For $\theta > \theta_c$: The fish sees the pond bottom

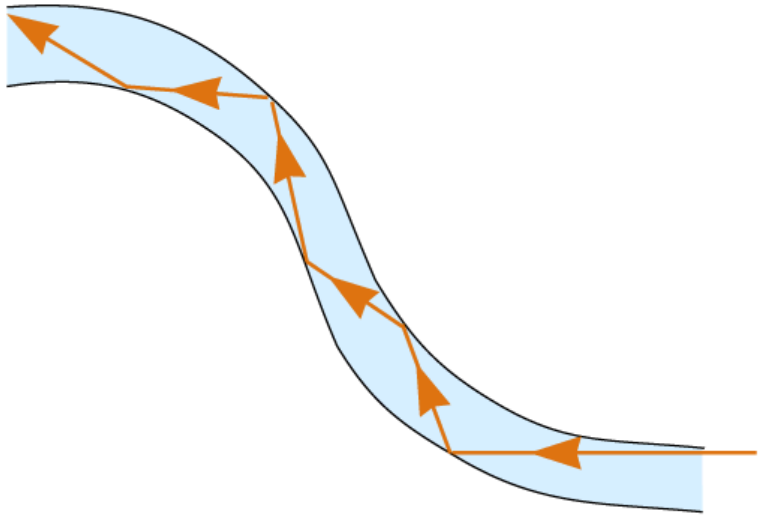
Applications of TIR



Retroreflector



Periscope



Fiber Optic Cable

For Next Class

- Reading Assignment
  - Chapter 36: Image Formation
- WebAssign: Assignment 13