Light

Electromagnetic wave with wave-like nature

- Refraction
- Interference
- Diffraction

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- Interference
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Photons with particle-like nature

- Momentum
- Quantization
- Scattering

Geometric Optics

Study of light propagation using ray diagrams and related calculations

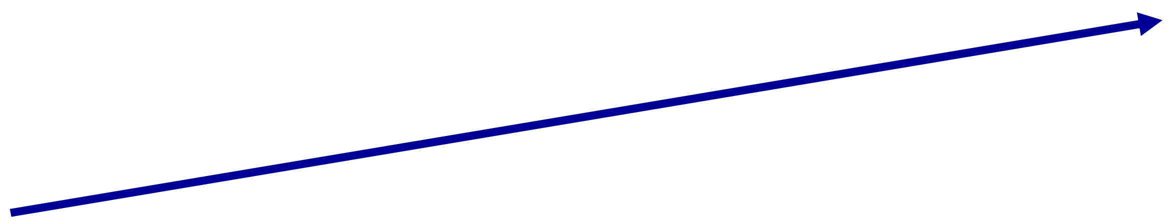
Diagrams and calculations are consistent with more rigorous calculations derived from solving Maxwell's equations in the presence of various media.

(i.e. light reflecting off a mirror, light passing through a window or light being absorbed by a wall.)

Light Interactions

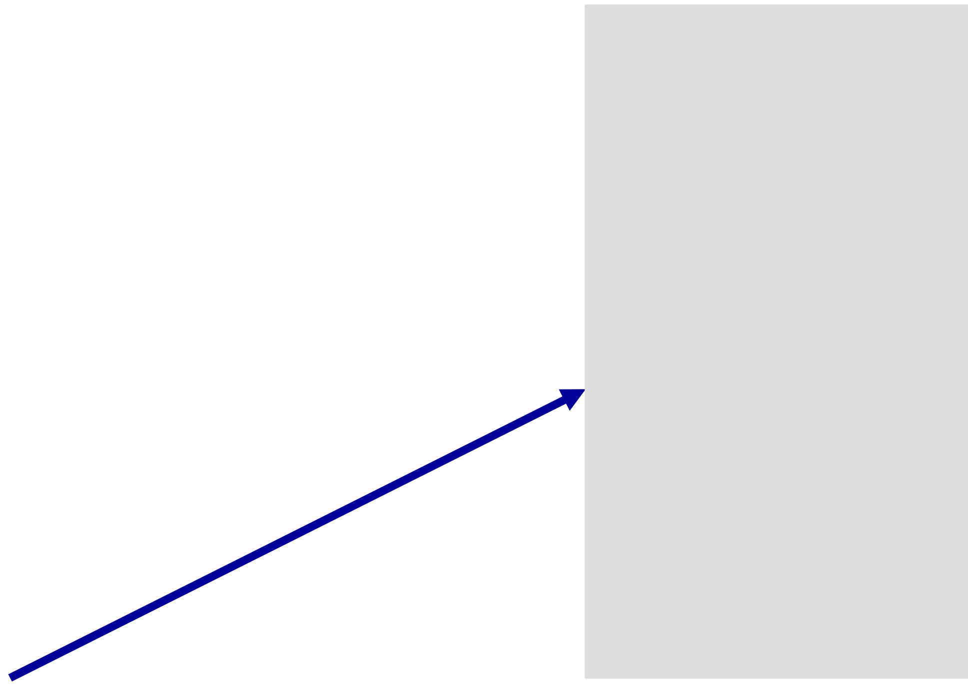
Light travels in a straight line in a vacuum with speed, *c*. (Approximately true for light in air.)

Path of light represented by a ray.



Light Interactions

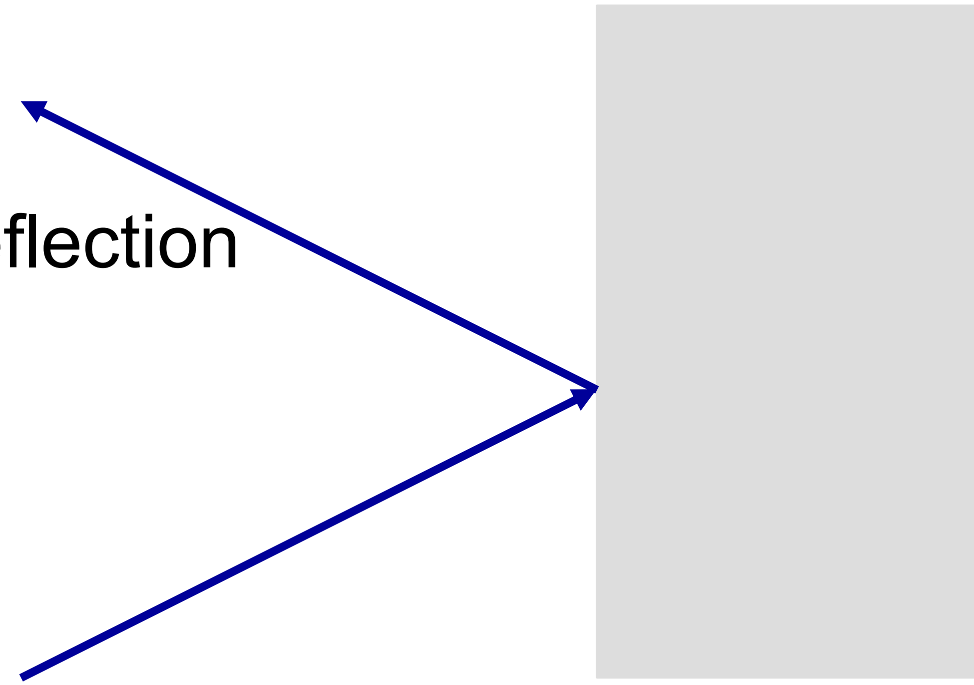
Consider light impinging on a surface.



Light Interactions

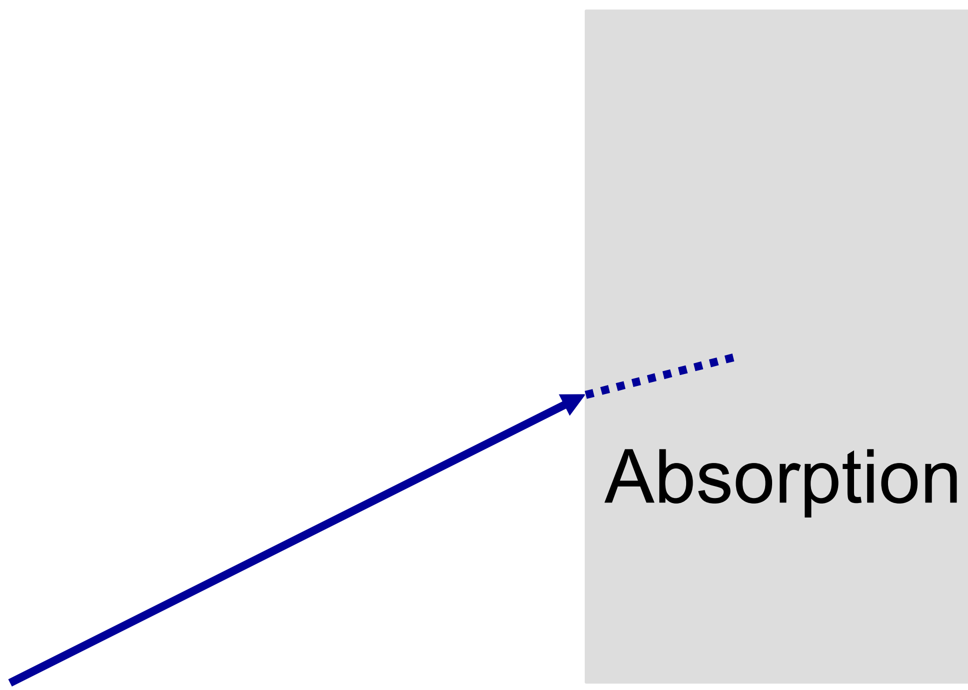
Consider light impinging on a surface. It may reflect off the surface.

Reflection



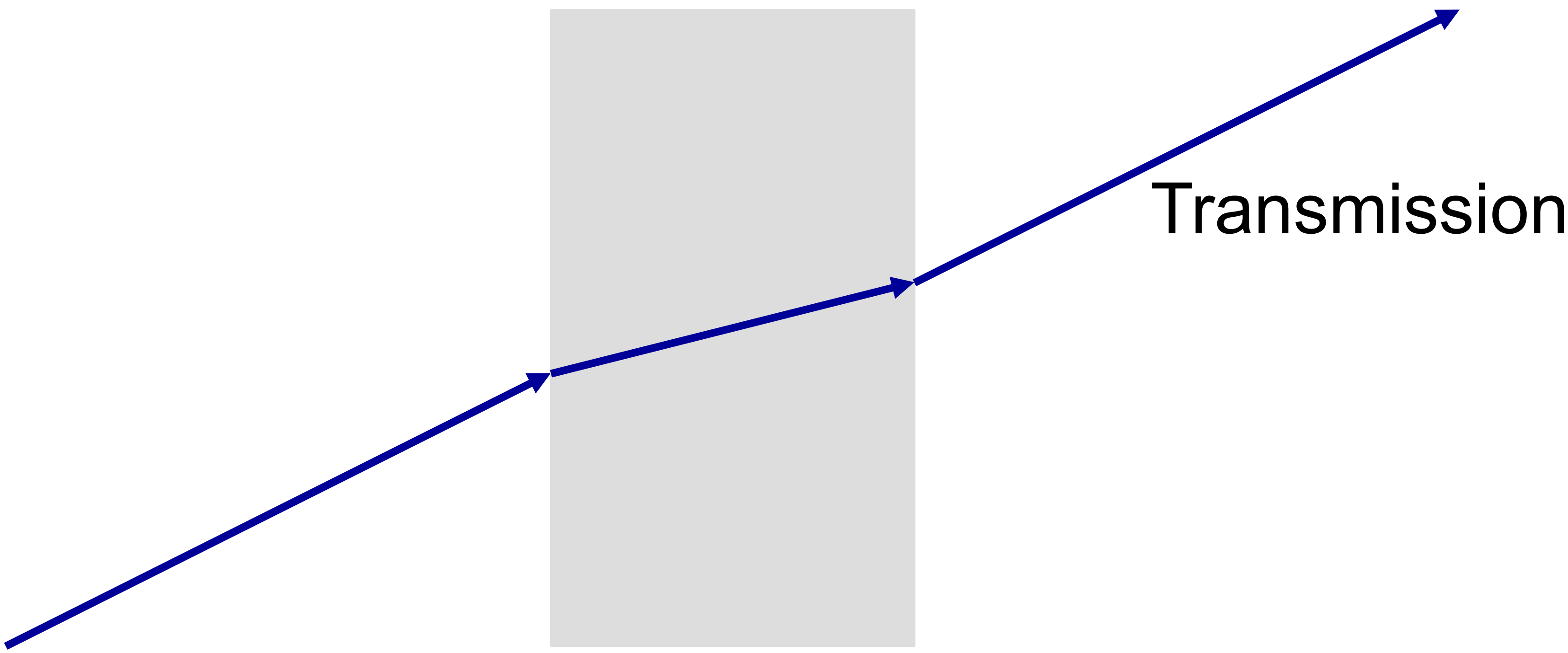
Light Interactions

Consider light impinging on a surface. It may be absorbed in the object.



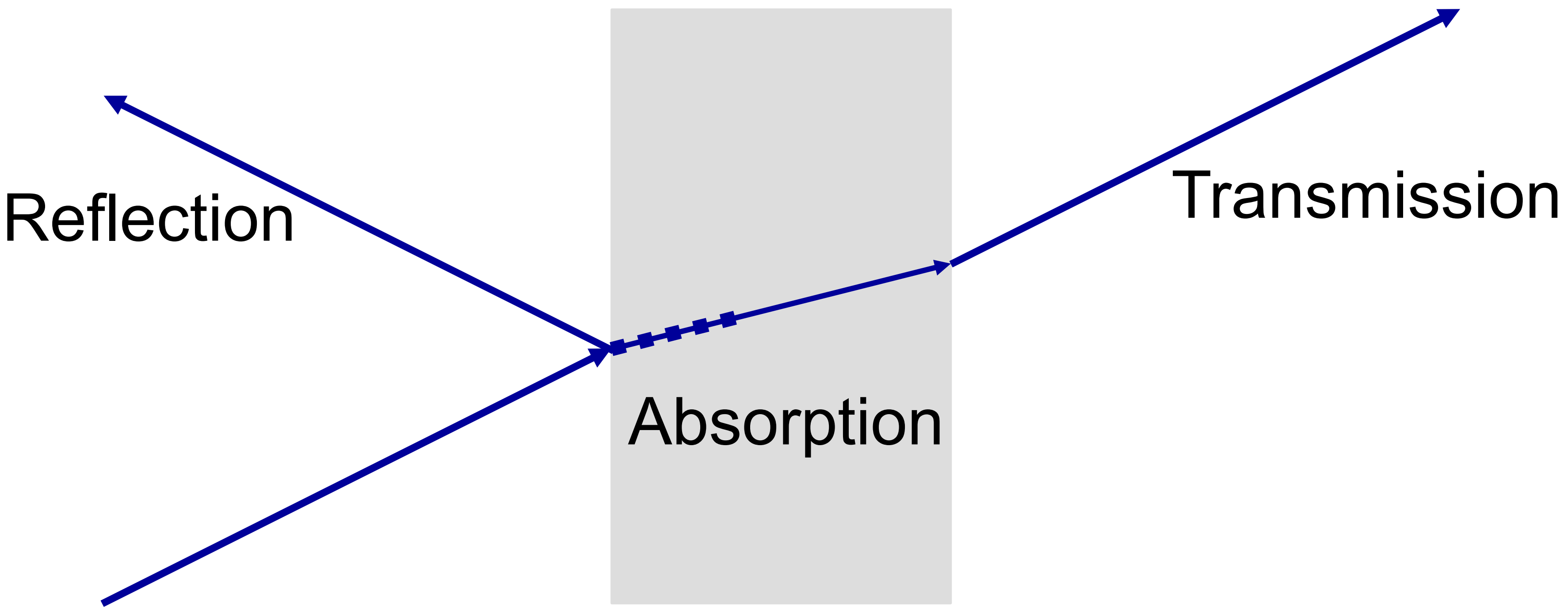
Light Interactions

Consider light impinging on a surface. It may be transmitted through the object.



Light Interactions

Consider light impinging on a surface. It may experience a combination of these.



Light and Sight

- Light of many colors (white) shines on objects.
- Some light is reflected off the objects.
- Light coming to our eyes is transmitted through our lenses.
- Light is absorbed in the back of our eyes.

The color of an object is due to the weighted average of the light reflected off of the object.

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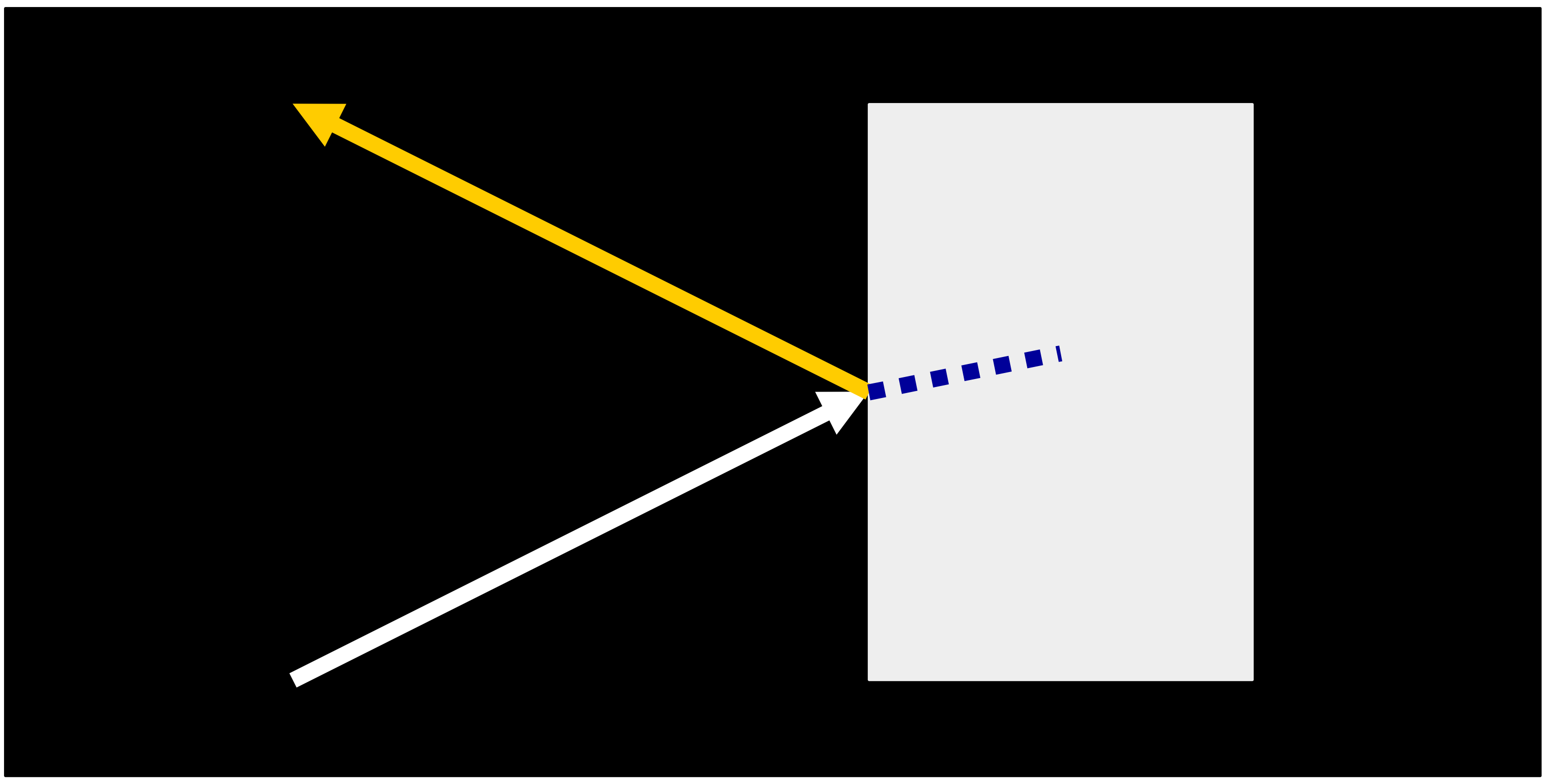
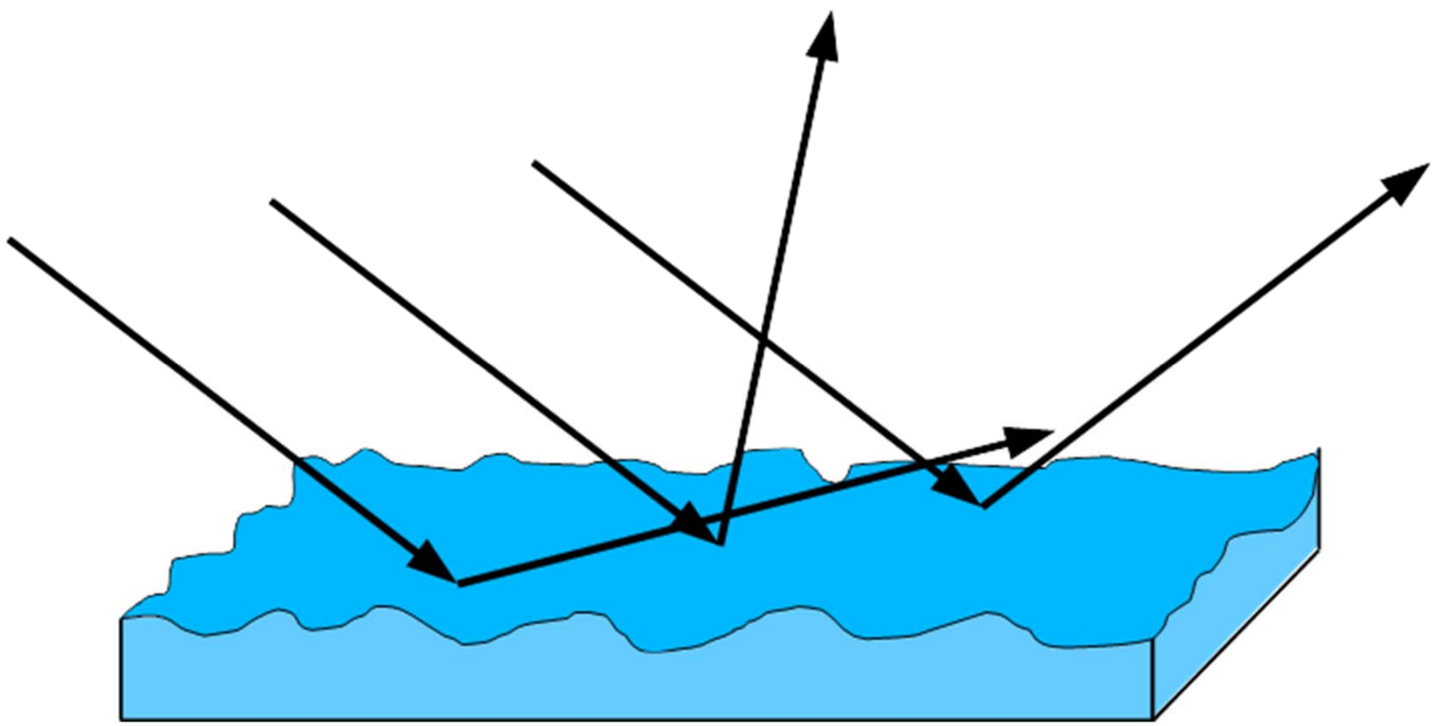


Reflection

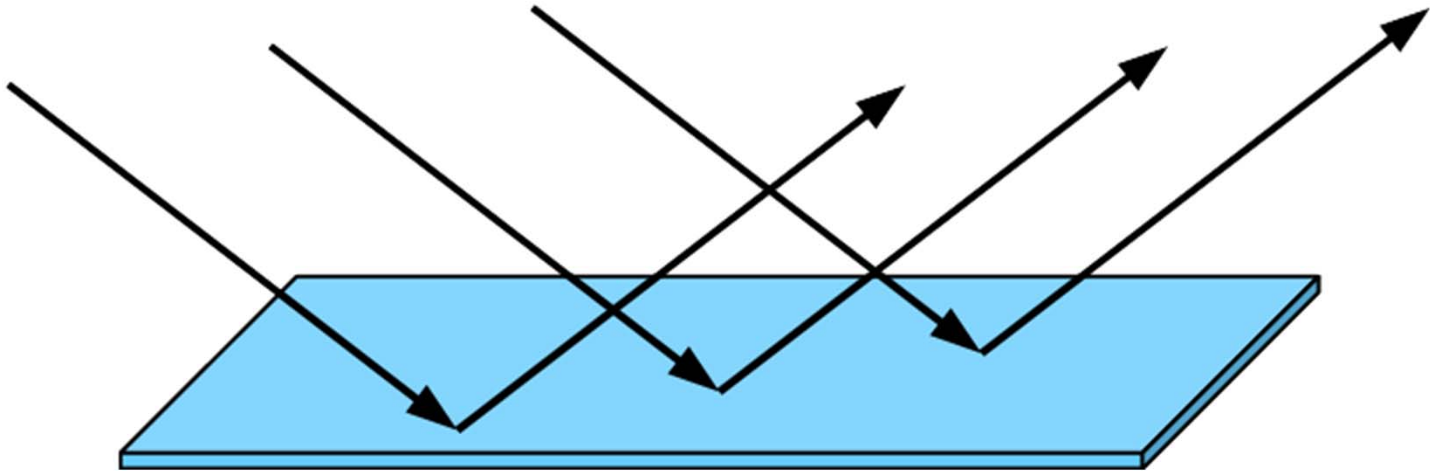
Diffuse Reflection, reflection off a rough surface



(Example: whiteboard)

Reflection

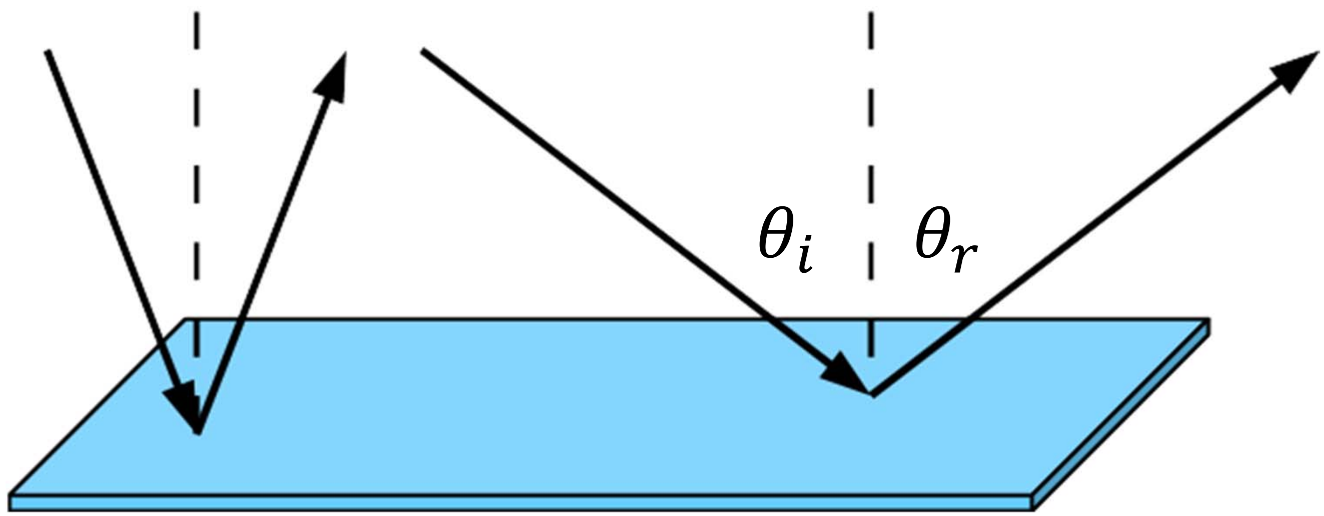
Specular Reflection, reflection off a smooth surface



(Example: mirror)

Reflection

Specular Reflection, reflection off a smooth surface

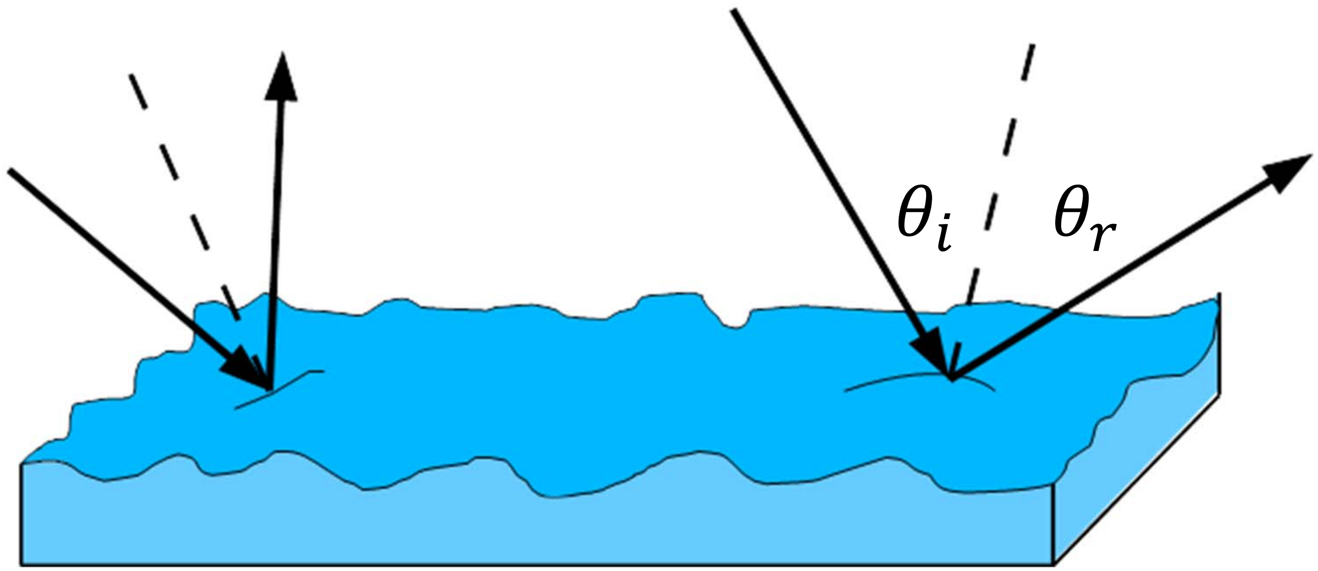


Angle of incidence equals angle of reflection.

$$\theta_i = \theta_r$$

Reflection

Diffuse Reflection, reflection off a rough surface

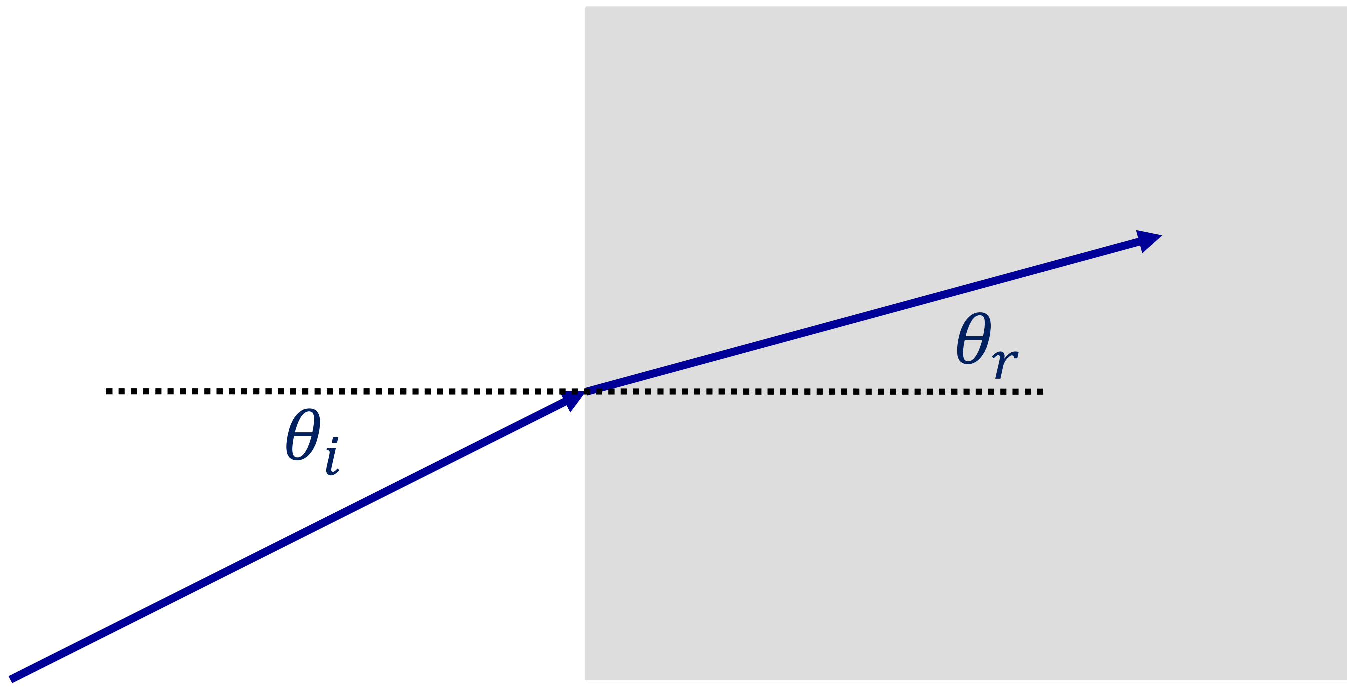


Angle of incidence equals angle of reflection.

(Must measure normal relative to local surface.)

Refraction

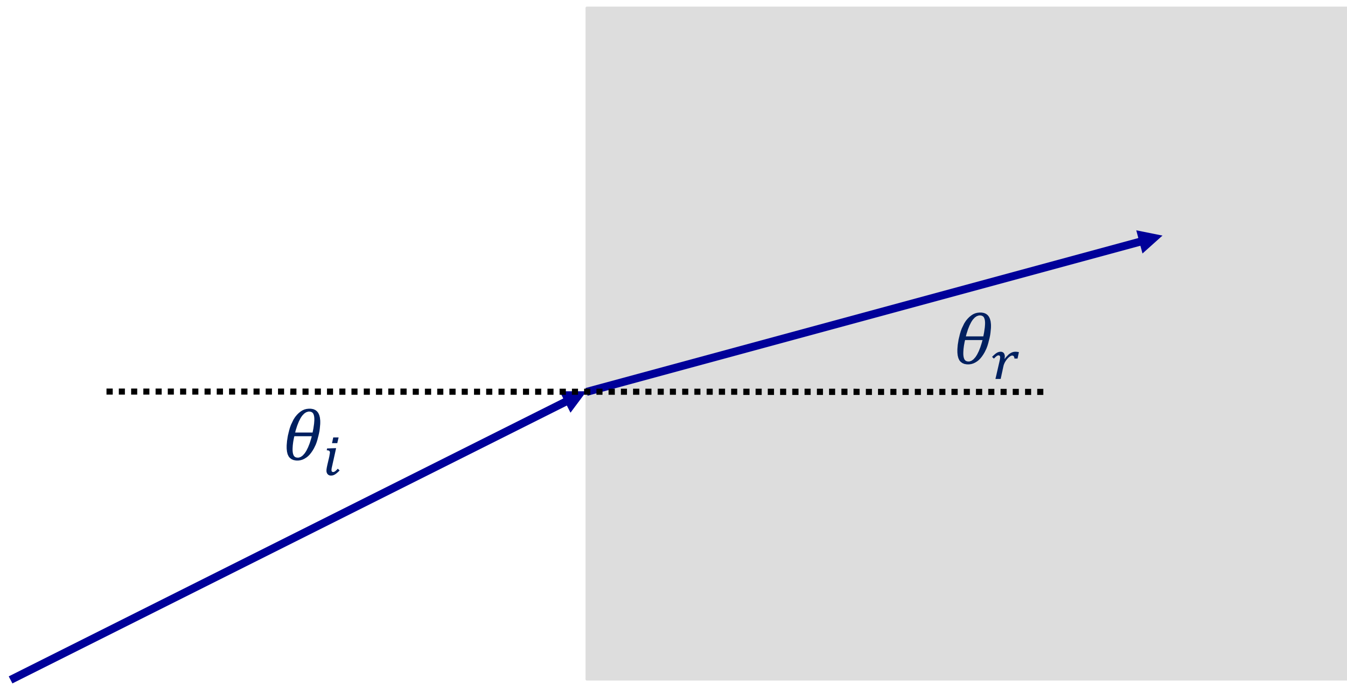
Light path can “bend” upon moving from one medium to another.



Bend is due to speed difference between media.

Refraction

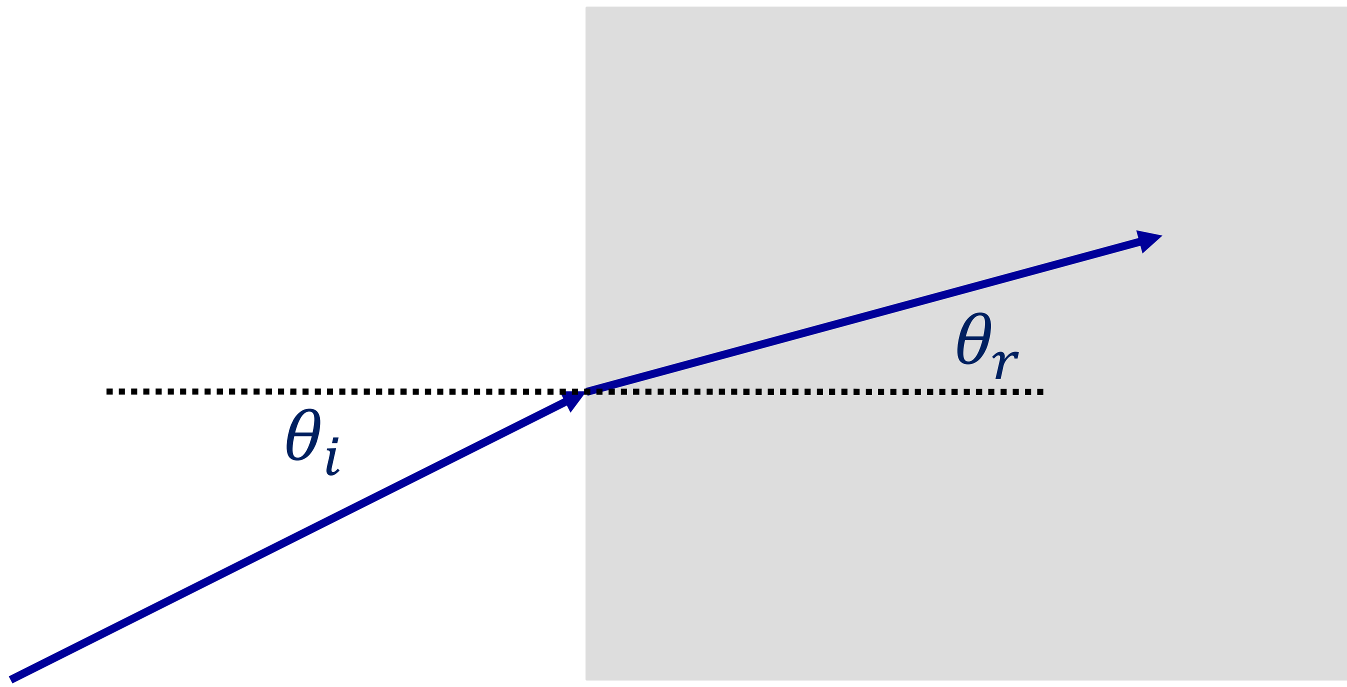
Speed in medium is characterized relative to speed in vacuum.



Index of Refraction, $n = \frac{c}{v} = \frac{\text{Speed in Vacuum}}{\text{Speed in Medium}}$

Refraction

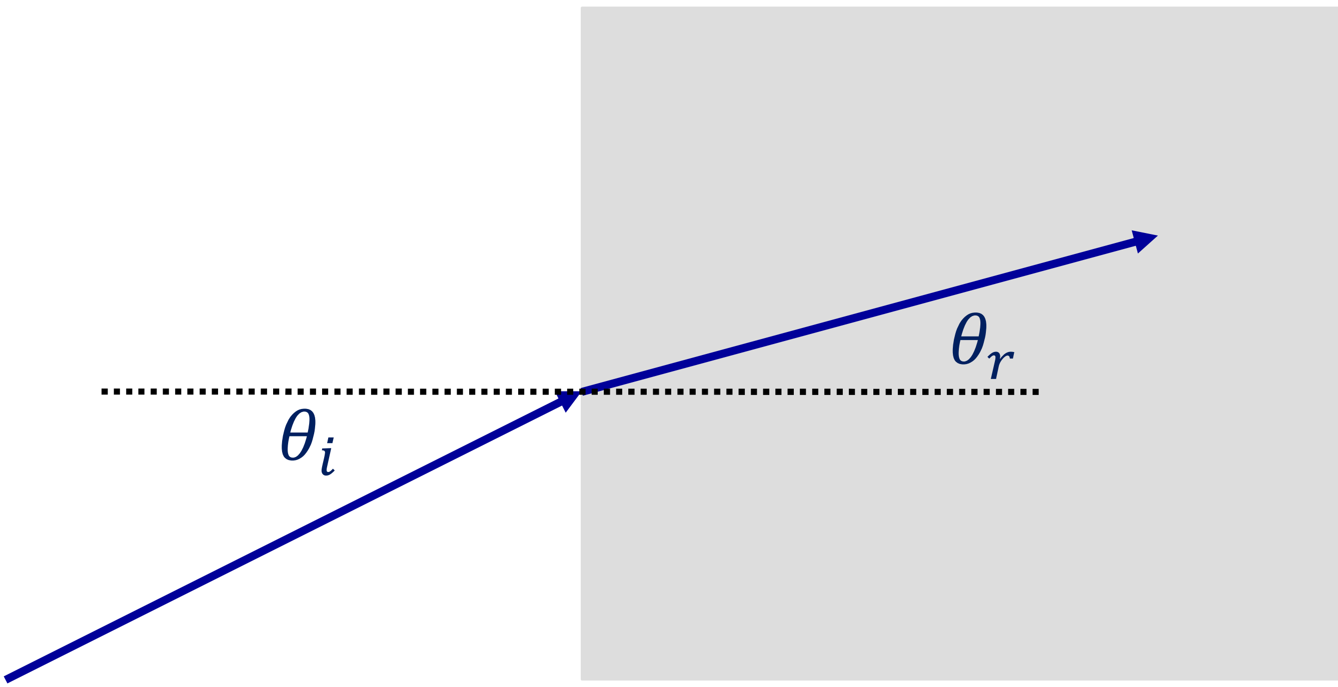
Frequency is constant.
Wavelength changes with speed.



$$n = \frac{c}{v} = \frac{\lambda f}{\lambda_n f_n} = \frac{\lambda f}{\lambda_n f} = \frac{\lambda}{\lambda_n}$$

Refraction
Snell's Law

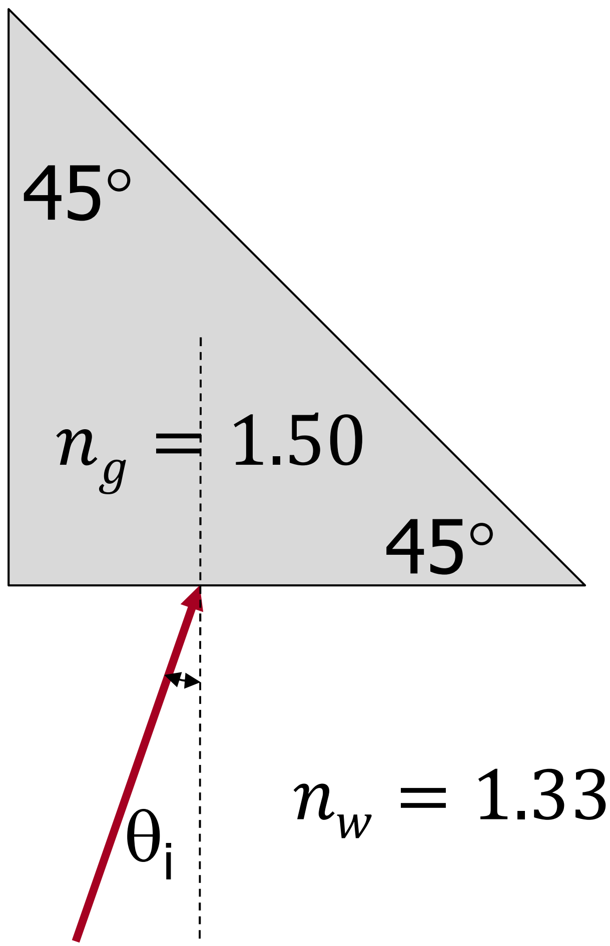
$$n_i \sin\theta_i = n_r \sin\theta_r$$



$$n = \frac{c}{v} = \frac{\lambda f}{\lambda_n f_n} = \frac{\lambda f}{\lambda_n f} = \frac{\lambda}{\lambda_n}$$

Example: calculate the speed of light in diamond ($n = 2.42$).

Example: a $45° - 45° - 90°$ glass ($n = 1.50$) prism is surrounded by water ($n = 1.33$). Light is incident at a $23°$ angle, as shown in the diagram. What angle does the light make when it exits the prism?



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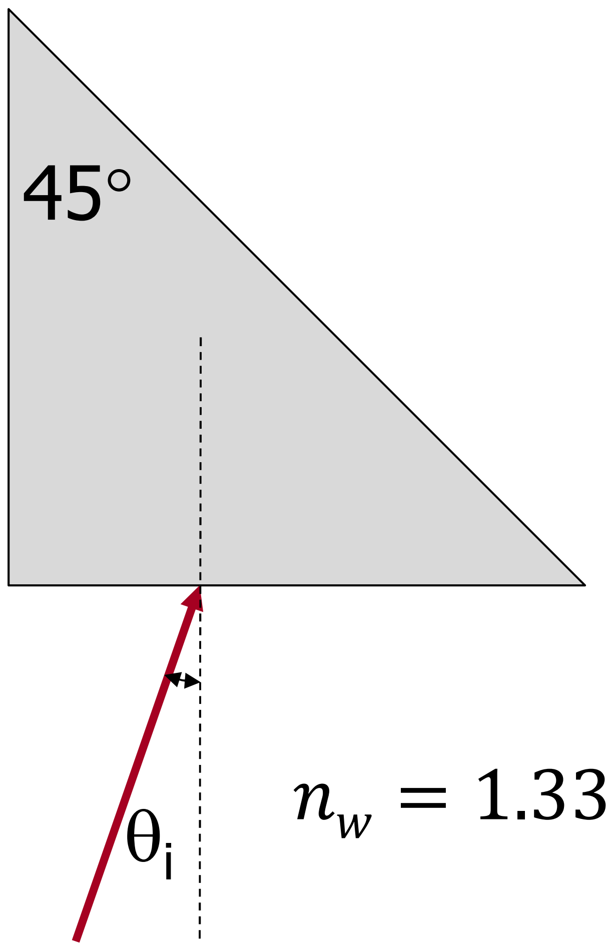
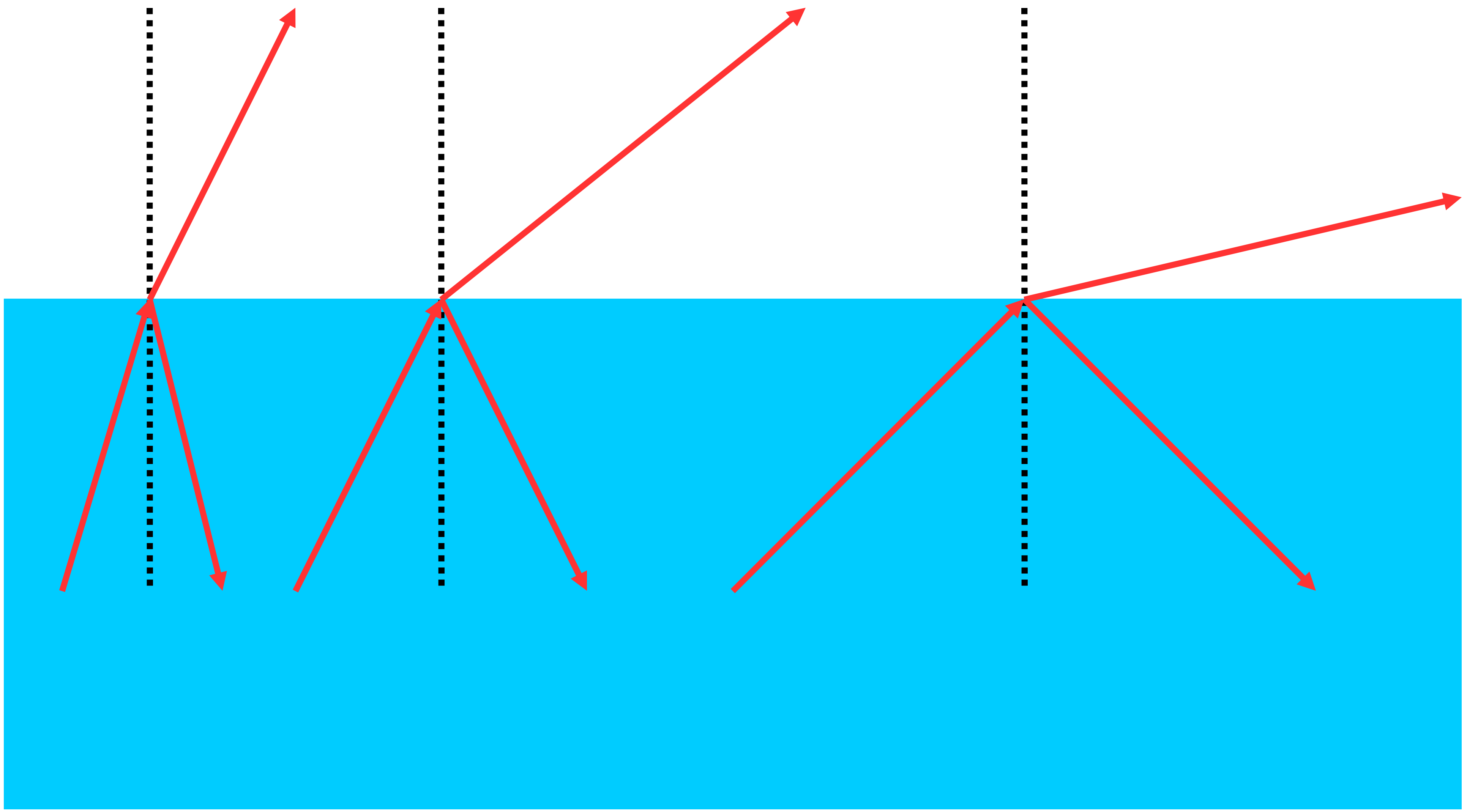


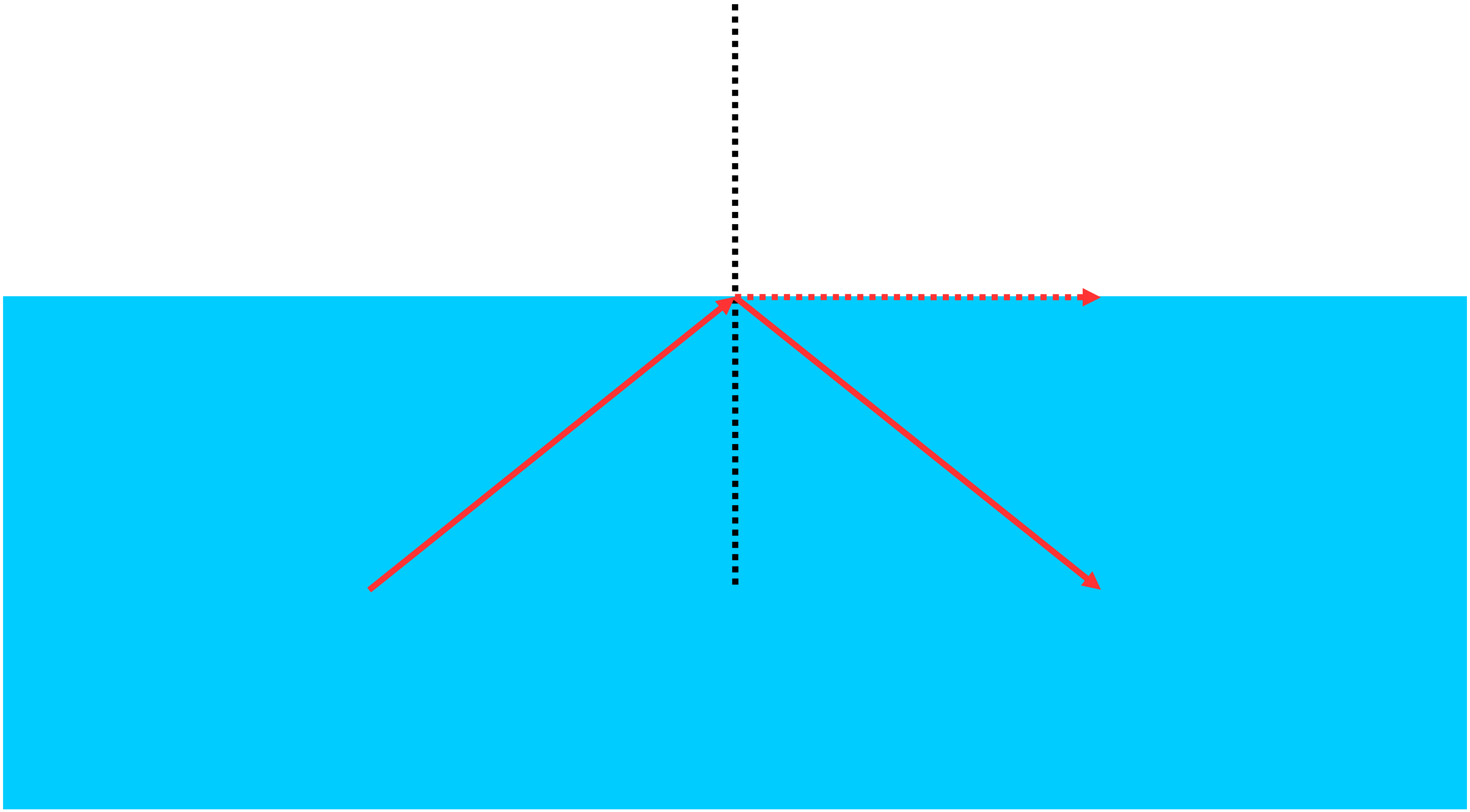
Refraction vs. Angle

$$n_a \sin\theta_a = n_b \sin\theta_b$$



Total Internal Reflection

$$n_a \sin\theta_a = n_b \sin\theta_b$$

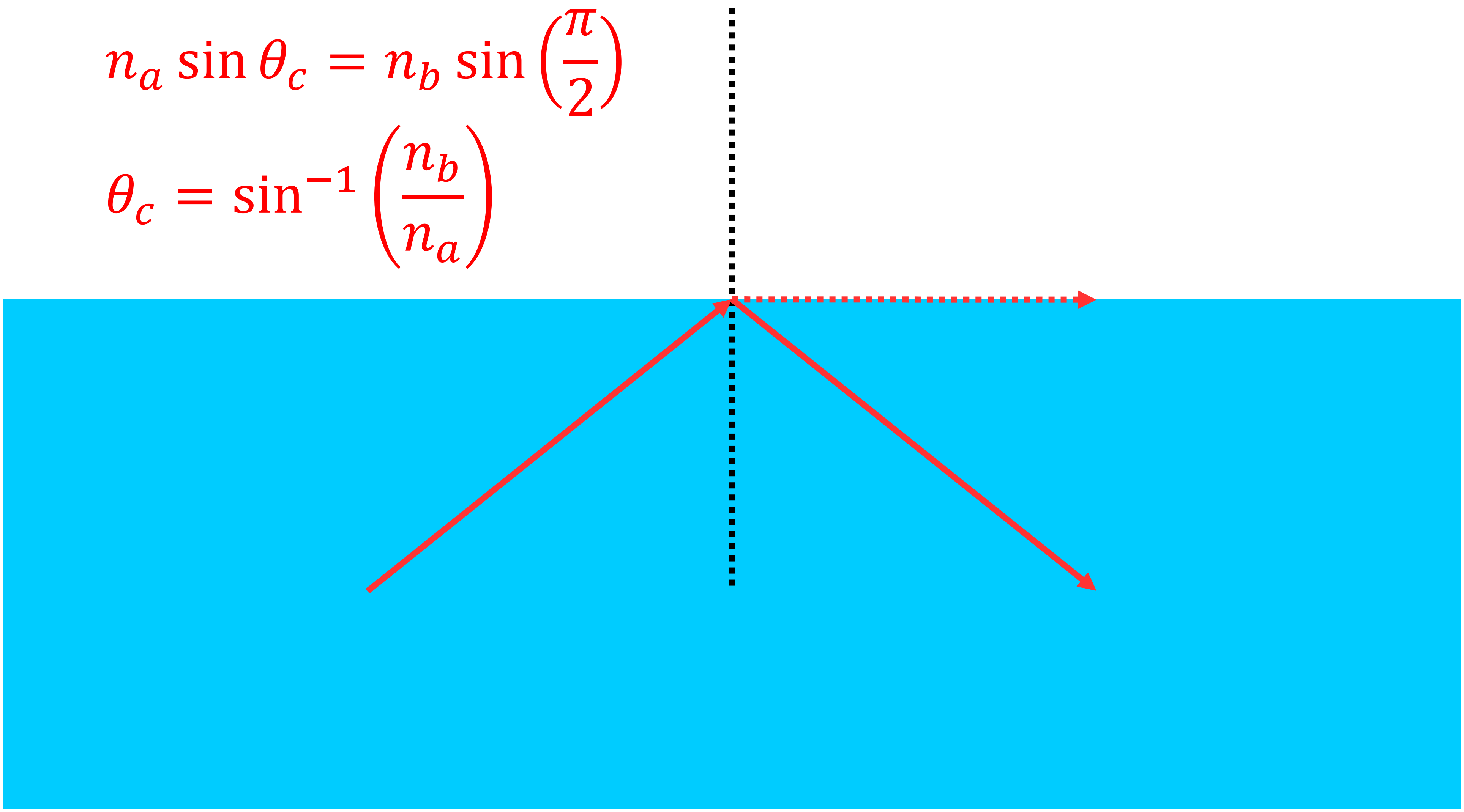


Total Internal Reflection

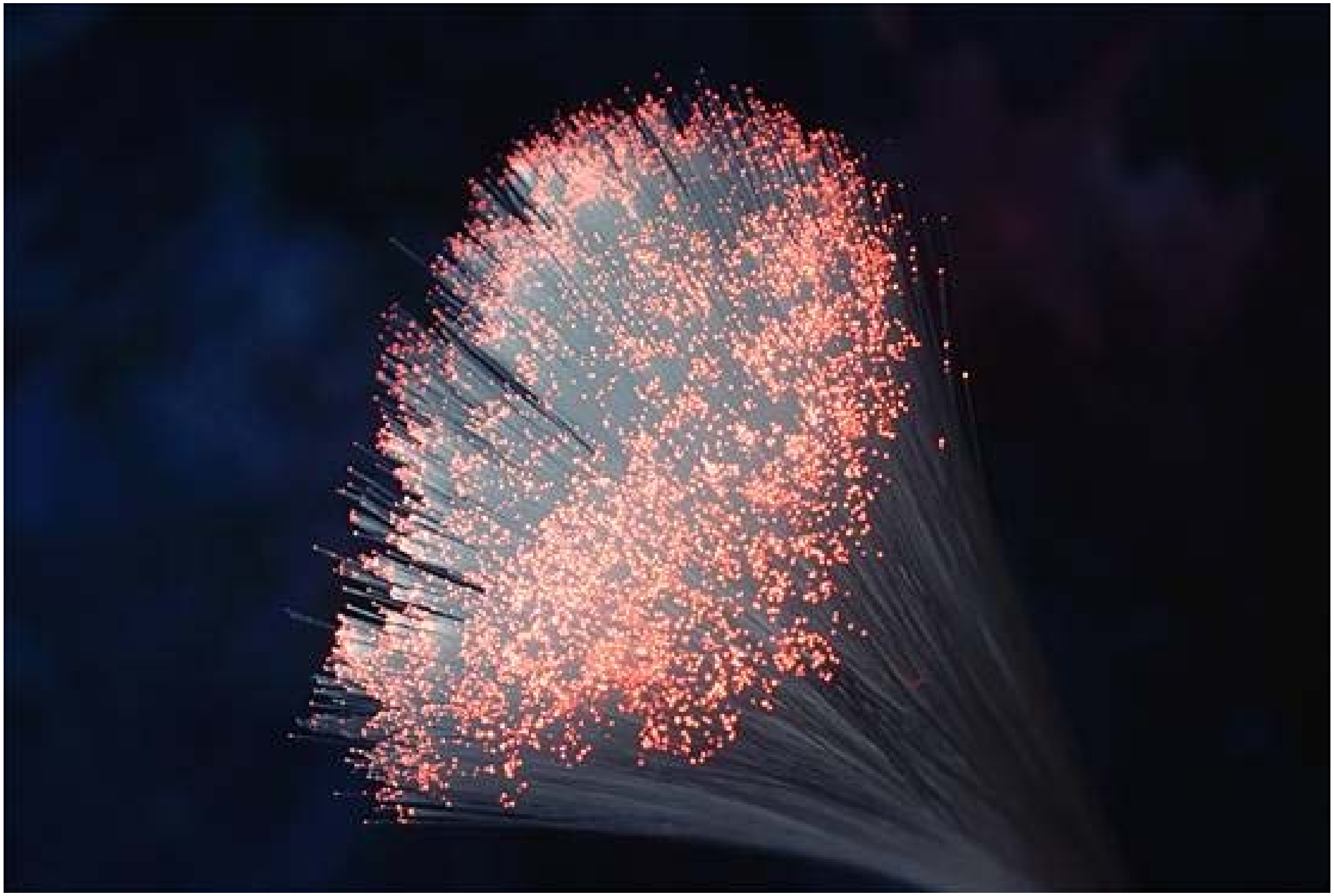
$$n_a \sin\theta_a = n_b \sin\theta_b$$

$$n_a \sin\theta_c = n_b \sin\left(\frac{\pi}{2}\right)$$

$$\theta_c = \sin^{-1}\left(\frac{n_b}{n_a}\right)$$

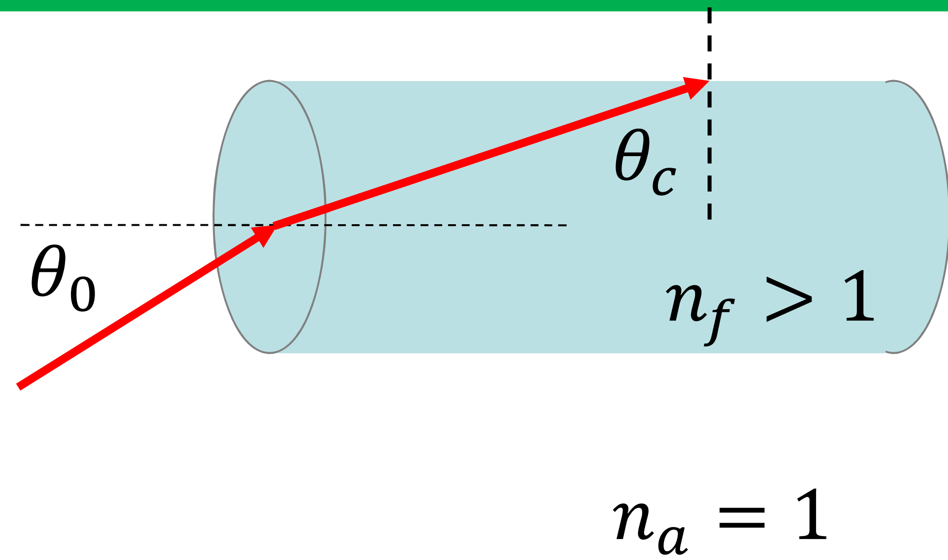


Total Internal Reflection

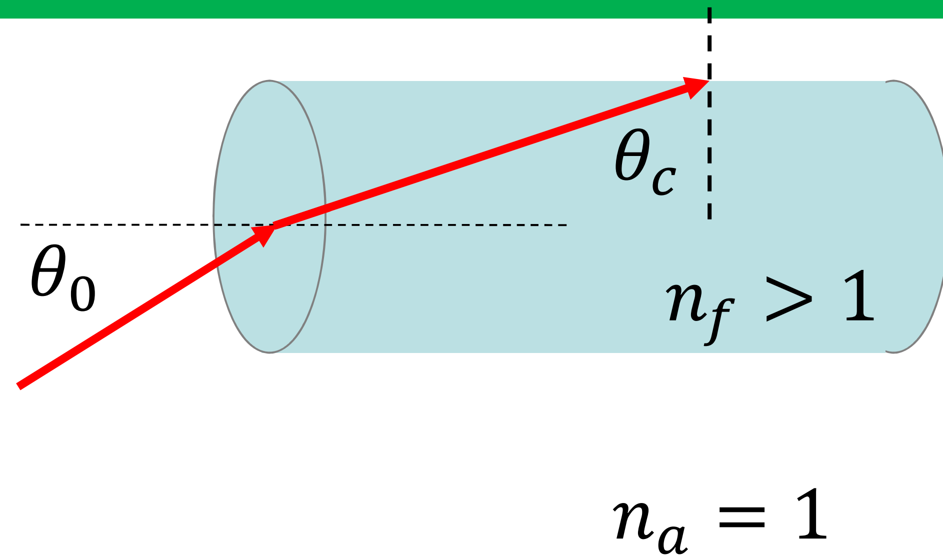


http://laser.physics.sunysb.edu/~wise/wise187/janfeb2001/reports/andrea/report.html

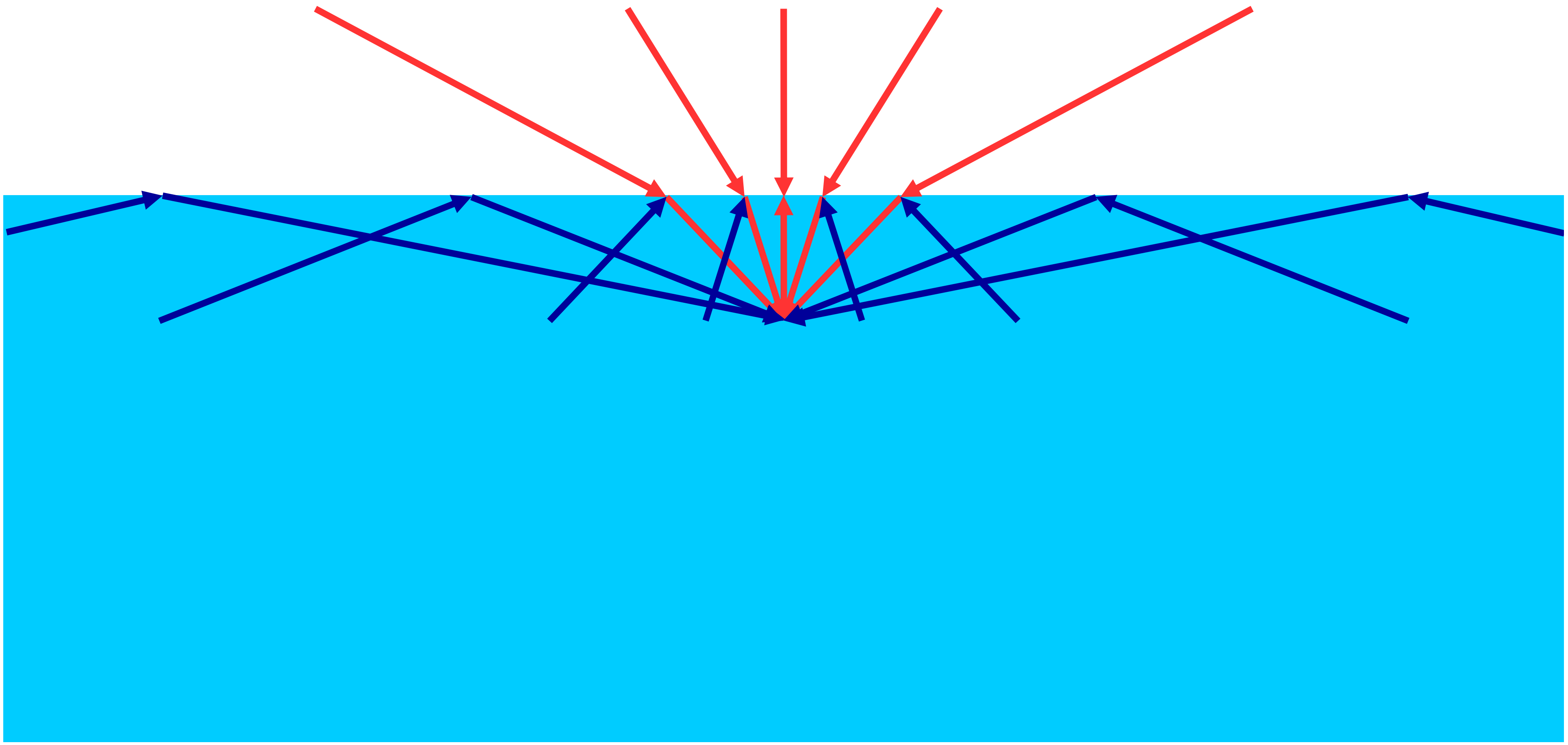
Example: determine the incident angle θ_0 for which light strikes the inner surface of a fiber optic cable at the critical angle.



Example: determine the incident angle θ_0 for which light strikes the inner surface of a fiber optic cable at the critical angle. Let $n_f = 1.4$.

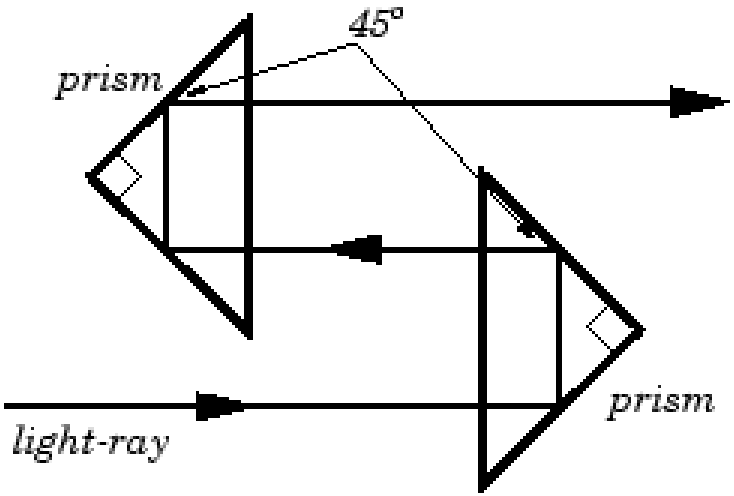


The View from the Pool

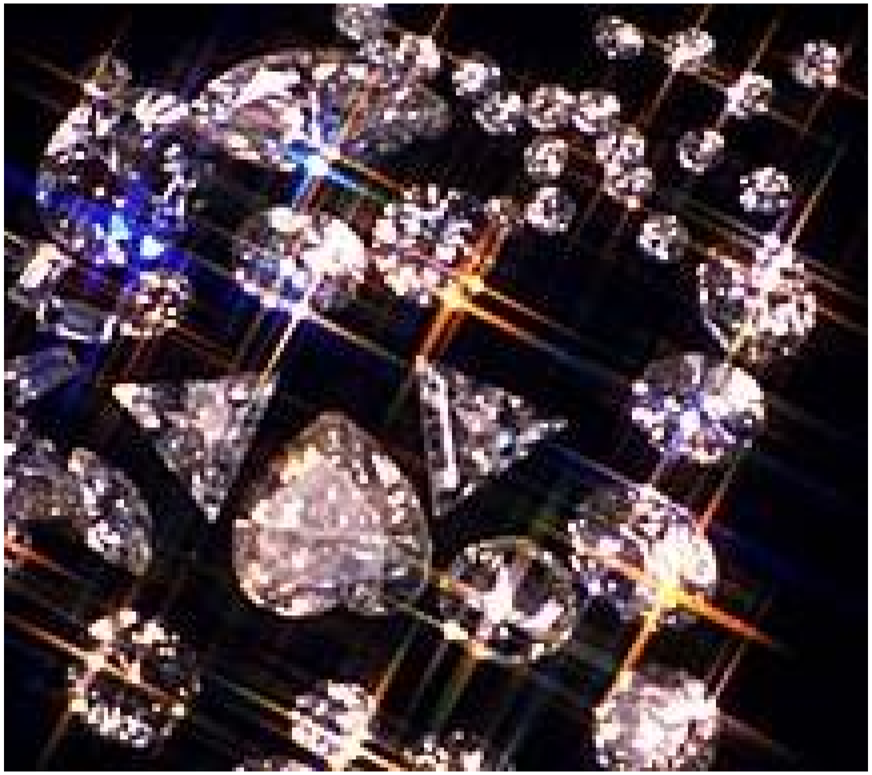


Total Internal Reflection

Binoculars

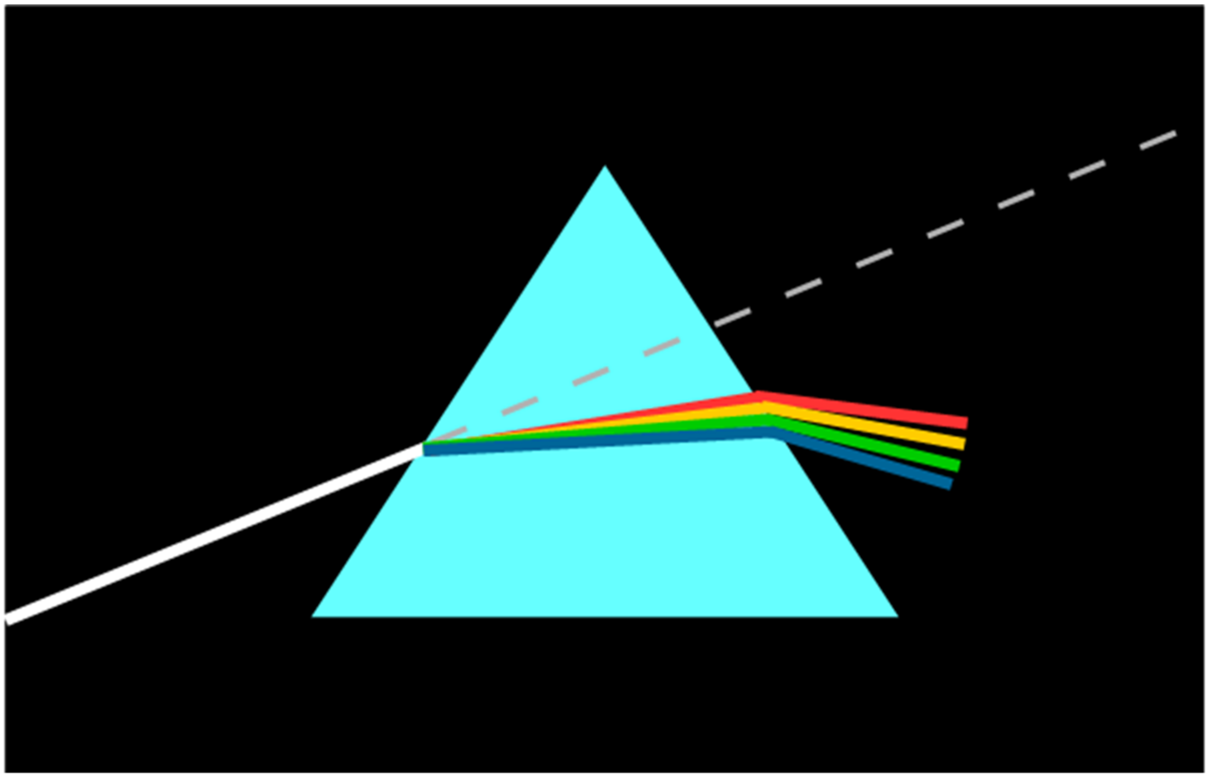


Gems



Dispersion

$$n_{\text{blue}} > n_{\text{green}} > n_{\text{yellow}} > n_{\text{red}}$$



Differing n's results in dispersion

Summary

Light impinging on a surface may be

- reflected ($\theta_i = \theta_r$),
- transmitted with refraction at each surface ($n_i \sin\theta_i = n_r \sin\theta_r$),
- absorbed or
- a combination of the above options.