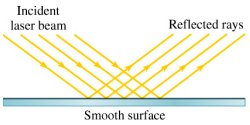
Chapter 23

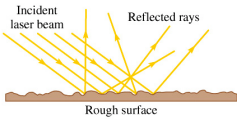
Reflection and Refraction of Light

Reflection: Two types

- Specular

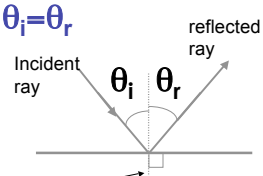


- Diffuse



Law of Reflection

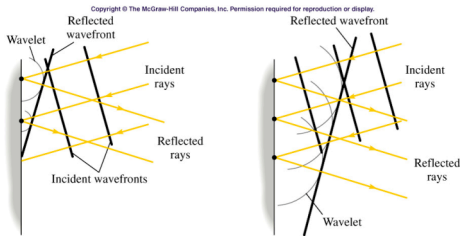
- The angle of incidence is equal to the angle of reflection
- $\theta_i = \theta_r$



Plane of incidence-- The incident and reflected rays and the normal all lie in a plane

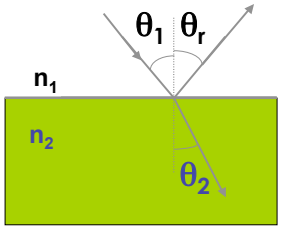
Normal--a line perpendicular to the surface where the incident ray touches

Reflection: plane waves



Refraction: Snell's Law

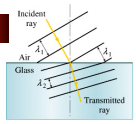
- $n_1 \sin \theta_1 = n_2 \sin \theta_2$

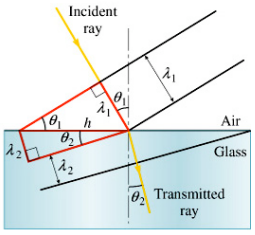


$n_2 > n_1$

Note the light bends towards the normal in the higher index medium

Snell's Law: Derivation





$$\sin\theta_1 = \frac{\lambda_1}{h} \text{ and } \sin\theta_2 = \frac{\lambda_2}{h}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2}$$

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

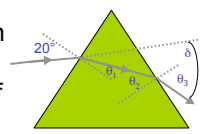
$n_1 \sin \theta_1 = n_2 \sin \theta_2$

Snell's Law example

- Light is incident on a material at an angle of incidence of 25°. The light in the material is observed to have an angle of transmission of 15°.
- What is the index of refraction of the material assuming it is in air?
- What is the angle of the transmitted ray if the material is under water (n=1.3) where the light has the same angle of incidence?

Snell's Law: Example

- A ray of light is incident on an equilateral prism of index n=1.5 at an angle of incidence of 35°. At what angle with respect to the normal does the ray leave the prism? What is the angle of deviation, δ?



Prism Refraction

$\sin\theta_0 = n \sin\theta_1$

$n \sin\theta_2 = \sin\theta_3$

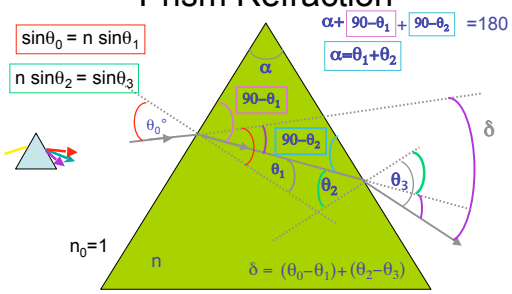
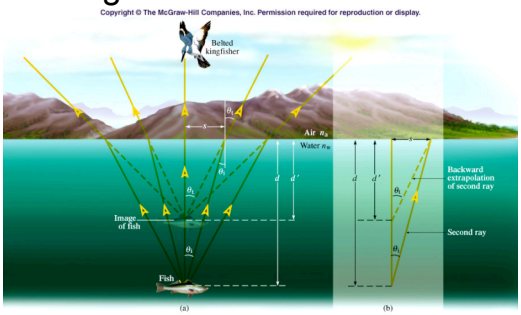
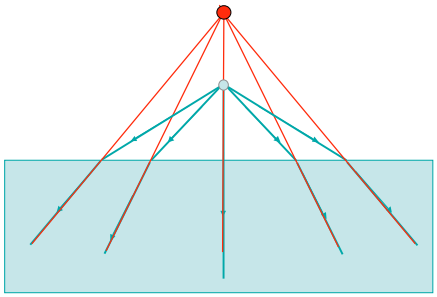


Image formation: refraction



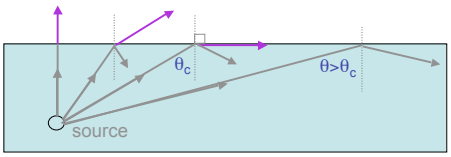
Where does the fish see the bird?



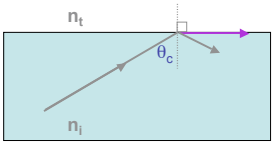
Total Internal Reflection:

Critical Angle

- When a ray of light travels from a higher index material to a lower index material there is an angle of incidence above which no light is transmitted.



Critical Angle: Derivation



$$n_i \sin\theta_i = n_t \sin\theta_t$$

when $\theta_t = 90,\ \theta_i = \theta_c$

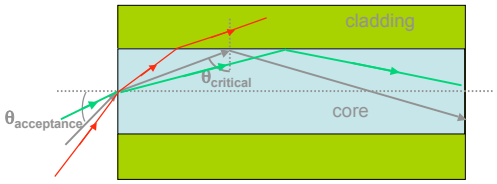
$$n_i \sin\theta_c = n_t$$

$$\boxed{\theta_c = \sin^{-1}\left(n_t / n_i\right)}$$

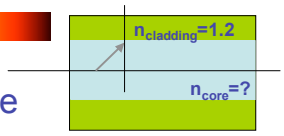
$n_i > n_t$

Optical Fibers

$n_{core} > n_{cladding}$



TIR: Example

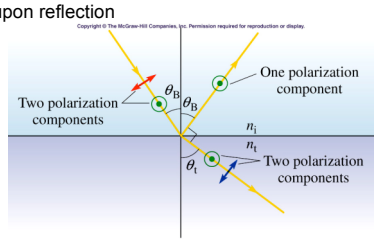


- What is the index of refraction of the core of an optical fiber is the cladding has n=1.20 and the critical angle at the core cladding boundary is 67°?
- What is the acceptance angle?

Brewster's Angle:

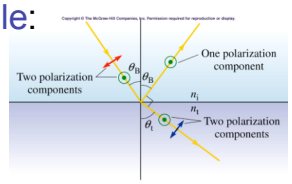
polarization of light due to reflection

- When the reflected ray is perpendicular to the transmitted ray the light is completely polarized upon reflection



Brewster's Angle:

derivation



$$n_i \sin\theta_B = n_t \sin\theta_t$$

but $\theta_t + \theta_B = 90$, so $\theta_t = 90 - \theta_B$

$$n_i \sin\theta_B = n_t \sin(90 - \theta_B) = n_t \cos\theta_B$$

$$\frac{\sin\theta_B}{\cos\theta_B} = \tan\theta_B = \frac{n_t}{n_i} \quad \rightarrow \quad \boxed{\theta_B = \tan^{-1}\left(n_t / n_i\right)}$$

Brewster's Angle:example

- What is Brewster's angle going from an air to glass (n=1.5) interface?
- What is Brewster's angle going from a glass to air interface?