4.5 Wave Properties

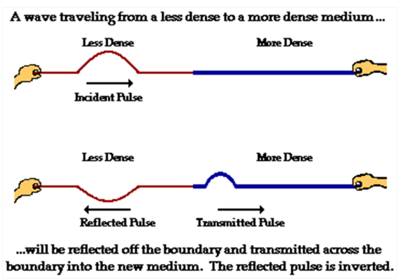
What happens to a wave when it encounters a boundary?

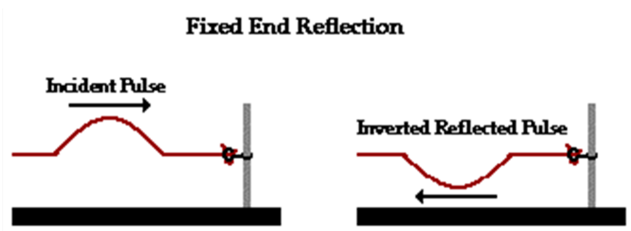
- the speed of the wave is dependent ONLY on the properties of the medium.
- the frequency of the wave remains the same

When the wave enters a new medium:

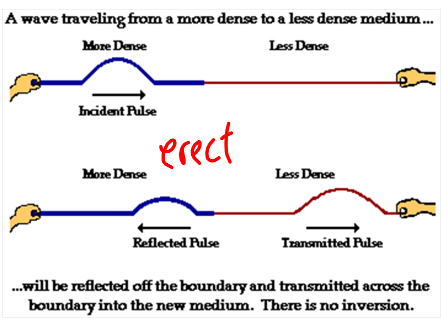
- some energy will be reflected + some is transmitted
- If the wave is going from a less dense medium (fast) to a more dense medium (slow), then the reflected wave will be inverted.

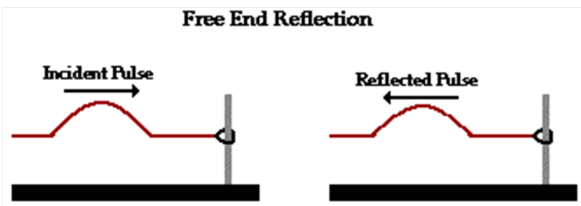
Waves encountering a boundary (1D)





Less dense -> More Dense.
(fast) (slow)

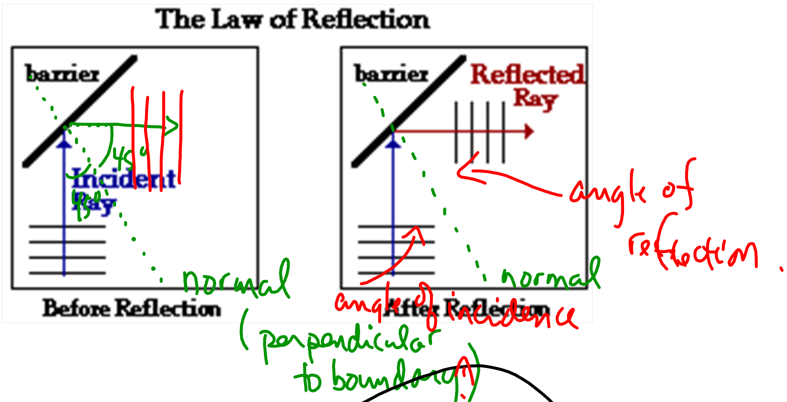




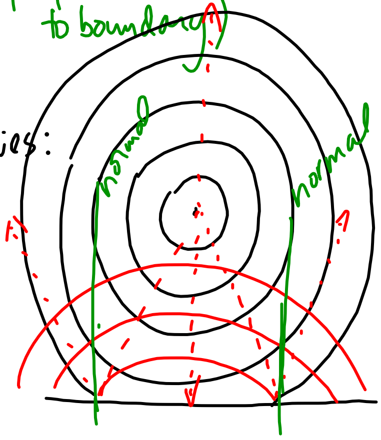
More Dense -> Less Dense
(slow) (fast)

Waves in 2D (plane waves incident on a boundary)

Law of Reflection

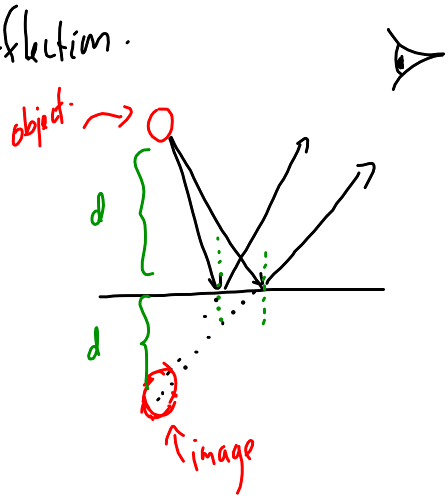


for circular waves:

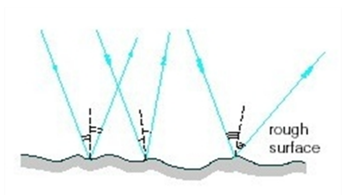


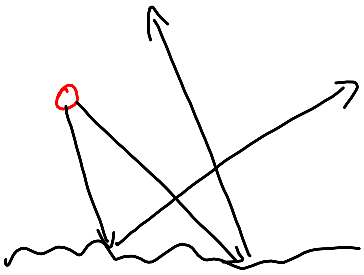
could be light, water ripples sound etc.

Specular Reflection.

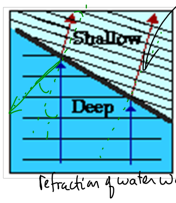


Diffuse Reflection.





Refraction



refraction of water waves

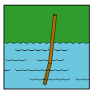
f is the same

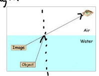
changes → $v = \lambda f$ ← must change.

fast to slow ⇒ bend toward the normal

slow to fast ⇒ bend away from the normal.

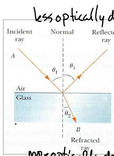
refraction of light.

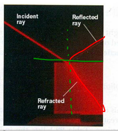




* ratio of the wavelengths is equal to the ratio of the speeds since the frequency is the same.
* ratio of the sines of the angles is the same as the ratio of the wavelengths

less optically dense





more optically dense.

Snell's Law:

$$\frac{\sin i}{\sin R} = \text{constant} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

applies to all waves (→ $\frac{\sin i}{\sin R}$)

constant: called the index of refraction (if going from air to ?) (vacuum)

for light: $n = \frac{c}{v}$

where n is the index of refraction

c is the speed of light in a vacuum ($3.00 \times 10^8\ ms^{-1}$)

v is the speed of light in a given medium.

Snell's Law in data booklet:

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

$n_{air} = 1.00$

$n_{vacuum} = 1.00$

Example:

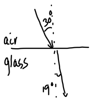
Yellow light of wavelength 500nm enters glass at an angle of incidence 30°. The refractive index for glass is 1.5

Determine:

1. the angle of refraction of the light as it enters the glass.
2. the speed of the yellow light in glass.
3. the wavelength of the yellow light in glass.

① air → ② glass

1.



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

$$\frac{1.00}{1.5} = \frac{\sin\theta_2}{\sin 30°}$$

$$\sin\theta_2 = (\sin 30°)\left(\frac{1.00}{1.5}\right)$$

$$\theta_2 = 19°$$

2.

$$\frac{n_1}{n_2} = \frac{v_2}{v_1}$$

$$\frac{1.00}{1.5} = \frac{v_2}{3.00 \times 10^8\ m/s}$$

$$v_2 = (3.00 \times 10^8\ m/s)\left(\frac{1.00}{1.5}\right)$$

$$v_2 = 2.0 \times 10^8\ m/s$$

3. ratio of the wavelengths is equal to the ratio of the speeds.

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} \quad \text{or} \quad \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

$$\frac{1.00}{1.5} = \frac{\lambda_2}{500nm}$$

$$\lambda = 500nm\left(\frac{1.00}{1.5}\right)$$

$$\lambda = 3.3 \times 10^2\ nm$$

Example

A ray of light in water meets a flat-sided block of acrylic with an angle of incidence of 55.0°. The angle of refraction in acrylic is 47.0°. The refractive index of water is 1.33. Determine the refractive index of acrylic.

① water -> ② acrylic

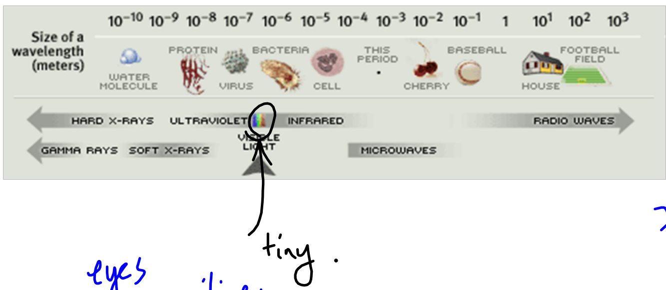
$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

$$\frac{1.33}{n_2} = \frac{\sin 47.0^\circ}{\sin 55.0^\circ}$$

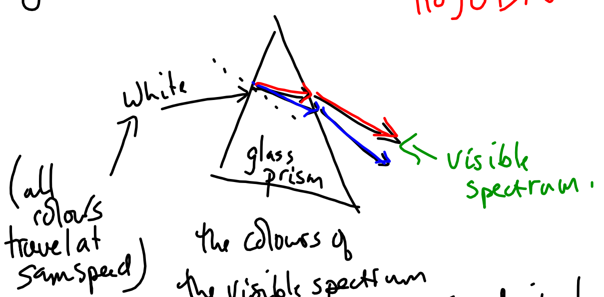
$$n_2 = \frac{(1.33)\sin 55.0^\circ}{\sin 47.0^\circ}$$

$$n_2 = 1.49$$

The electromagnetic Spectrum



700nm 400nm
ROYGBIV



the colours of the visible spectrum travel a different speeds in glass

Still to Do:
- Diffraction
- Constructive + Destructive Interference.
- Path Difference + Interference Patterns.