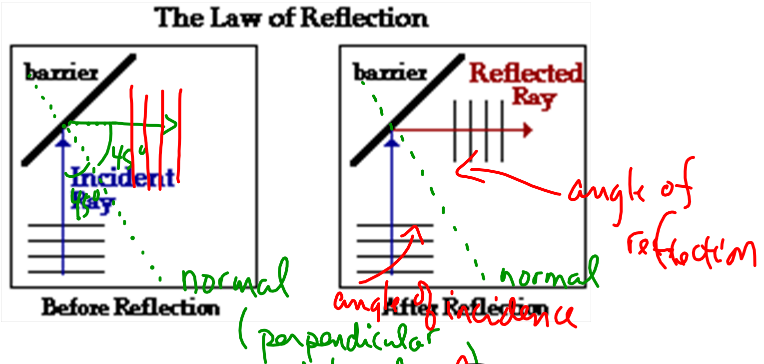
4.4 Wave Behaviour

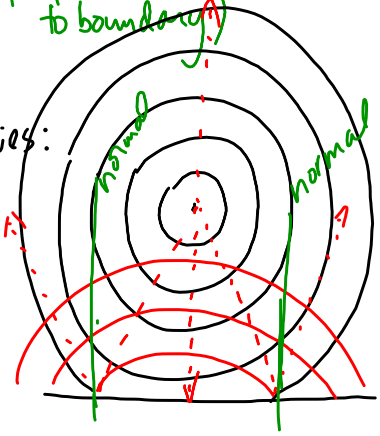
Waves in 2D (plane waves incident on a boundary)

Law of Reflection



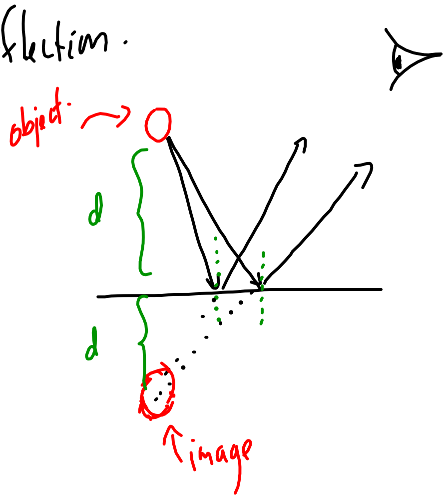
The angle of reflection is equal to the angle of incidence. (measured w.r.t. normal)

for circular waves:

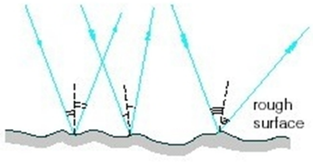


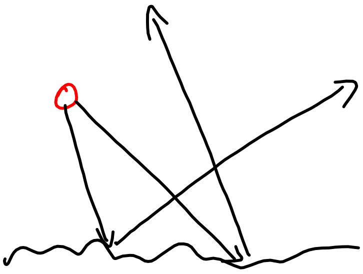
could be light, water ripples sound etc.

Specular Reflection.

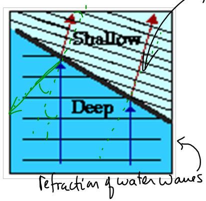


Diffuse Reflection.





Refraction



f is the same

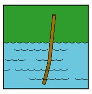
refraction of water waves

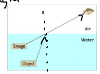
$\boxed{v} = \lambda f$ — changes; must change.

fast to slow ⇒ bend toward the normal

slow to fast ⇒ bend away from the normal.

refraction of light.

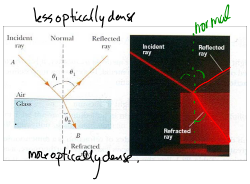




* ratio of the wavelengths is equal to the ratio of the speeds since the frequency is the same.

* 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:
$$\frac{\sin i}{\sin R} = \boxed{\text{constant}} = \frac{\lambda_1}{\lambda_2} = \frac{V_1}{V_2}$$

applies to all waves

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:
$$\boxed{\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{V_2}{V_1}}$$

$n_{air} = 1.00$

$n_{vacuum} = 1.00$

Example:

Yellow light of wavelength 500 $\overset{10^{-9}}{\text{n}}$m 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 ②
air -> glass

1.
$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$
$$\frac{1.00}{1.5} = \frac{\sin\theta_2}{\sin 30^\circ}$$
$$\sin\theta_2 = (\sin 30^\circ)\left(\frac{1.00}{1.5}\right)$$
$$\boxed{\theta_2 = 19^\circ}$$

2.
$$\frac{n_1}{n_2} = \frac{V_2}{V_1}$$
$$\frac{1.00}{1.5} = \frac{V_2}{3.00 \times 10^8\ m/s}$$
$$V_2 = (3.00 \times 10^8\ m/s)\left(\frac{1.00}{1.5}\right)$$
$$\boxed{V_2 = 2.0 \times 10^8\ m/s}$$

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

ⓄⓇ $\frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2}$

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1}$$
$$\frac{1.00}{1.5} = \frac{\lambda_2}{500\,nm}$$
$$\lambda = 500\,nm\left(\frac{1.00}{1.5}\right)$$
$$\boxed{\lambda = 3.3 \times 10^2\ nm}$$

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.

$$\underset{water}{①} \to \underset{acrylic}{②}$$

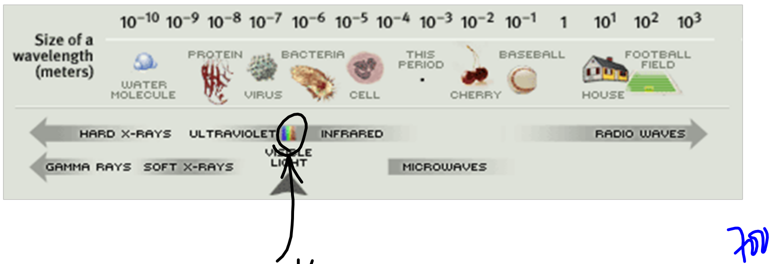
$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

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

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

$$\boxed{n_2 = 1.49}$$

The electromagnetic Spectrum

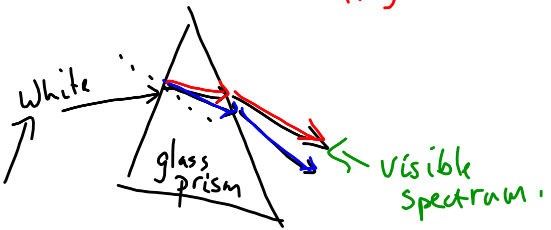


tiny.

eyes are sensitive.

700nm 400nm

ROYGBIV

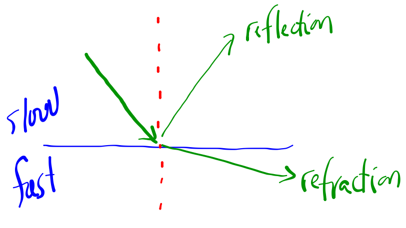


(all colours travel at sam speed)

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

Critical Angle & Total Internal Reflection

What happens when light travels from a more optically dense medium (high index of refraction / slow medium) to a less opticall dense medium (smaller index of refraction / fast medium)?



bends away from normal

As the angle of incidence gets bigger the angle of refraction approaches 90°

When the angle angle of refraction reaches 90°, the corresponding angle of incidence is called the critical angle.

This only occurs if going from more dense to less dense.

After the critical angle has been exceeded, the light is totallally reflected (total internal reflection)

Example:
The index of refraction for diamond is 2.42. Find the critical angle.

① diamond → ② air

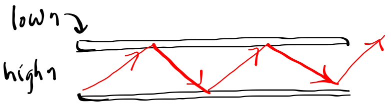
$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

$$\frac{2.42}{1.00} = \frac{\sin 90^\circ}{\sin\theta_1}$$ ← exactly

$$\sin\theta_1 = \frac{(1.00)\sin 90^\circ}{2.42}$$

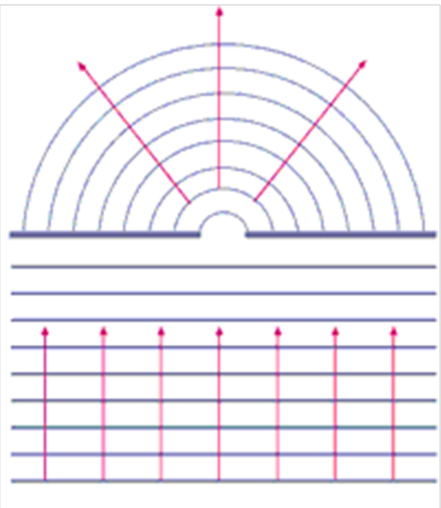
$$\boxed{\theta_1 = 24.4^\circ}$$

The critical angle for diamond is 24.4°. After this angle is surpassed there will be total internal reflection.

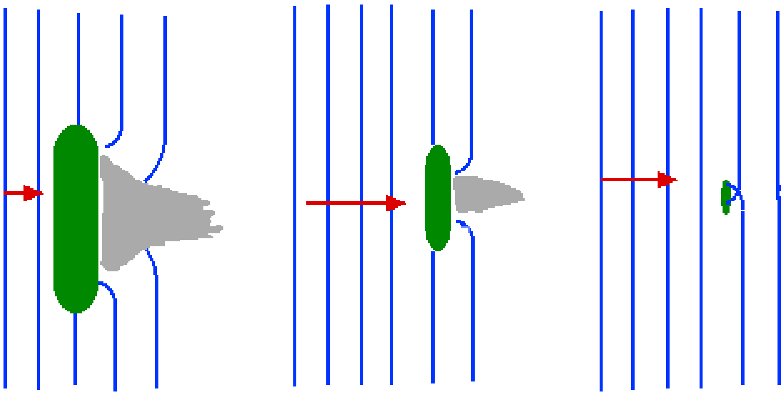


fibre optics.

Diffraction through a single-slit and around objects

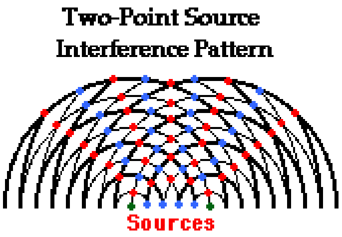


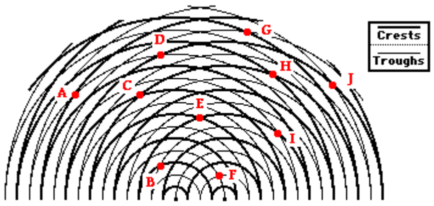
A wave is diffracted by an aperture.

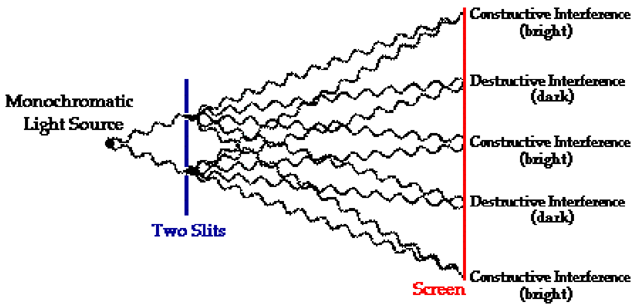


Very small objects cast no shadow, they do not register with the wave.

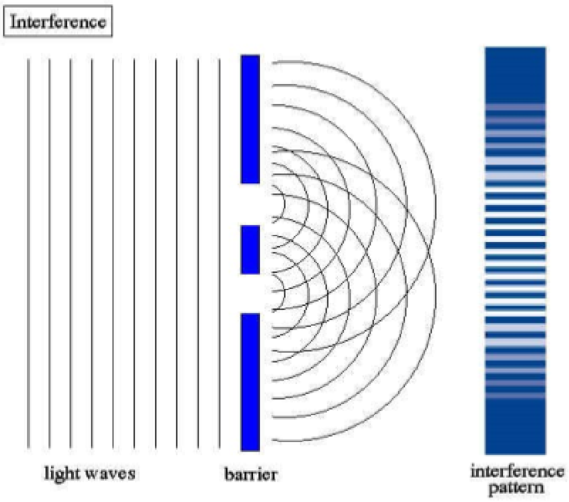
Interference Patterns

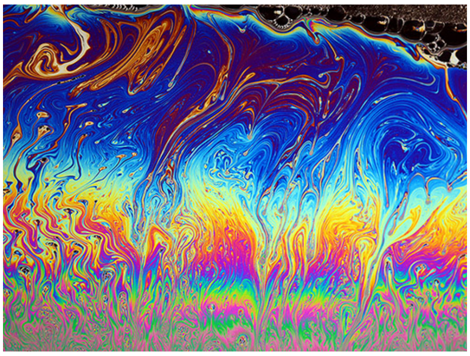




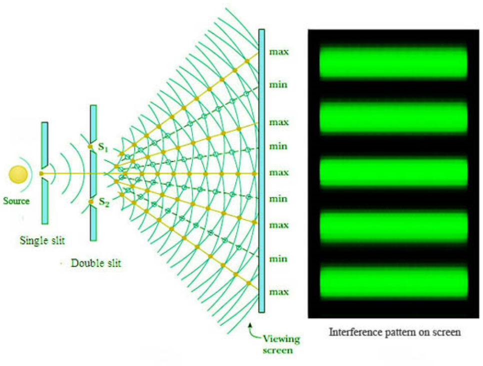


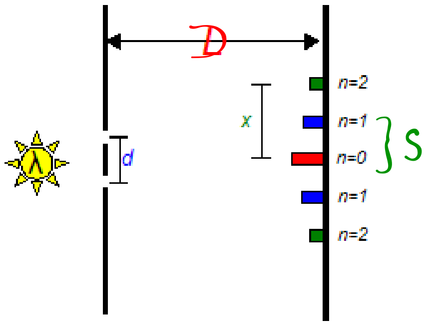
A two-point source interference pattern creates an alternating pattern of bright and dark lines when it is projected onto a screen.





Double-slit Interference & Path Difference





$$s = \frac{\lambda D}{d}$$

where s is the fringe spacing
λ is the wavelength
D is the distance from the screen
d is the distance between slits

constructive interference: $path \cdot difference = n\lambda$

destructive interference: $path \cdot difference = \left(n + \frac{1}{2}\right)\lambda$