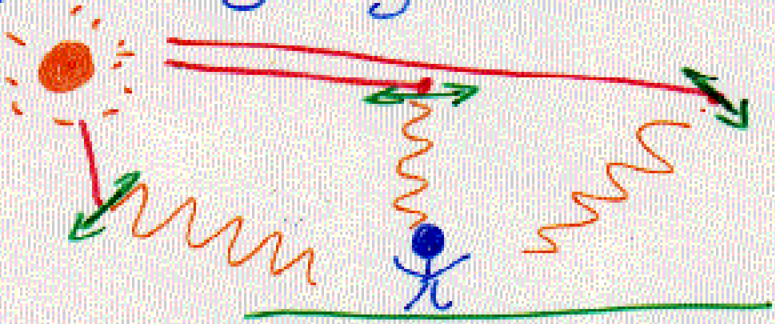
Polarization in Nature - Examples

1. Scattering of sunlight by molecules in atmosphere

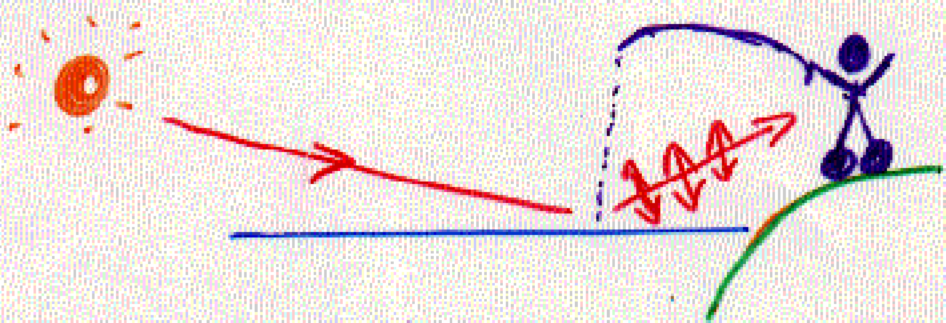


Molecules act as "antennas", scattering light with plane of polarization depending on direction

⇒ observer sees partially polarized light from (blue) sky

(homing pigeons can locate sun behind clouds)

2. Scattering by Reflection:

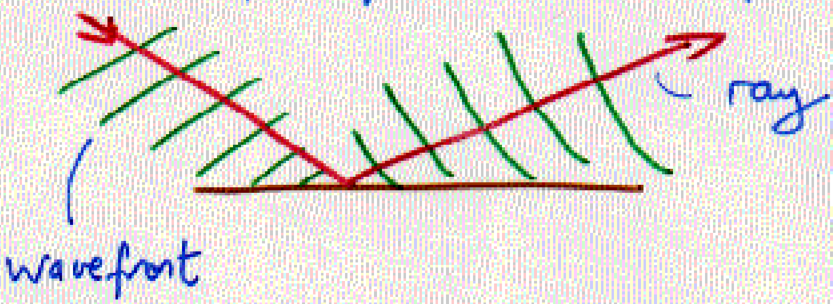


Reflected "glare" scattered with $\underline{E}$ polarized horizontally

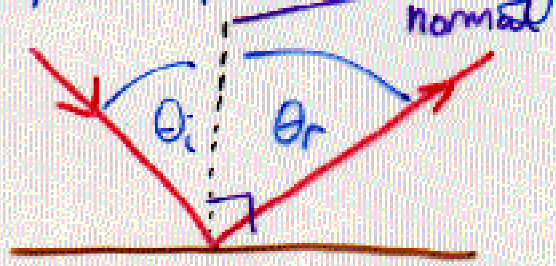
∴ use sunglasses with vertical axis to see below surface

Reflection of EM Waves at a Surface

EM waves can "bounce" of surface similar to particles



Reflection reverses component of wave velocity ⊥ to surface.



By symmetry of space/time (Maxwell's eqns) we find

① Angle of incidence θ_i = Angle of reflection θ_r

Note : θ measured relative to the normal, at 90° to surface

② Incident ray, normal and reflected ray lie in same plane.

True as long as atomic spacing << wavelength of light
(⇒ wave "sees" only smooth surface).

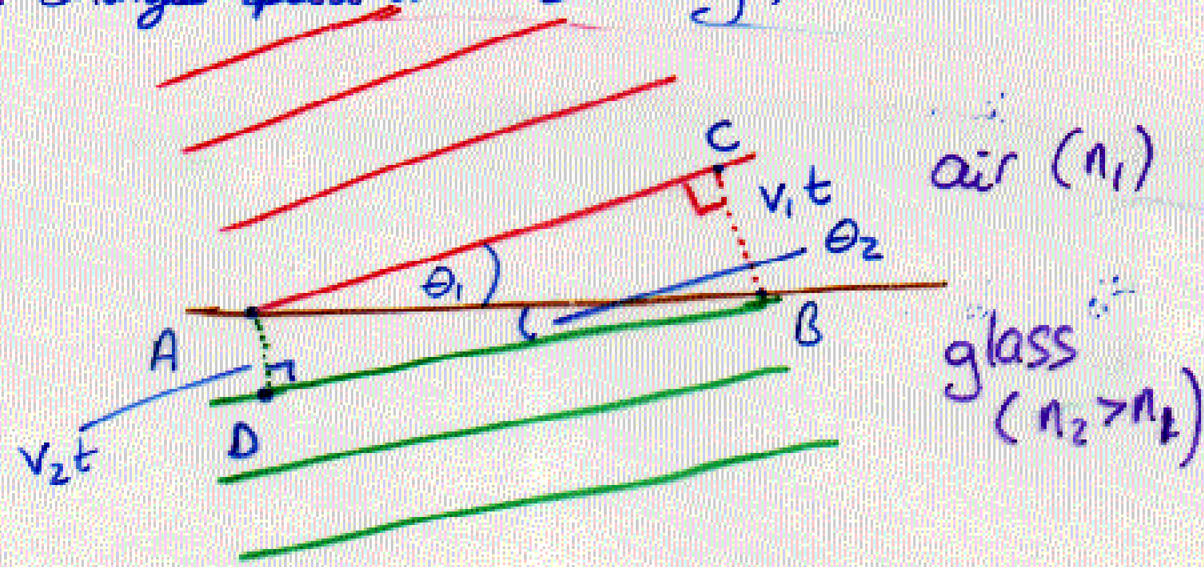
Specular reflection ("shiny")
Diffuse reflection (e.g. matte finish)

EM Waves in Transparent Media: Refraction

Speed of light in material $v = \frac{1}{\sqrt{\mu\epsilon}} < \frac{1}{\sqrt{\mu_0\epsilon_0}}$

Define refractive index $n \equiv \frac{c}{v} \geq 1$

When wave changes speed at a boundary, its direction is "bent":



In time t, incident wave travels $v_1 t$ so $BC = v_1 t$
transmitted " $v_2 t$ so $AD = v_2 t$

In both Δs ABC, ABD hypotenuse $AB = \frac{v_1 t}{\sin\theta_1} = \frac{v_2 t}{\sin\theta_2}$

Using $n_1 = \frac{c}{v_1}$ etc:

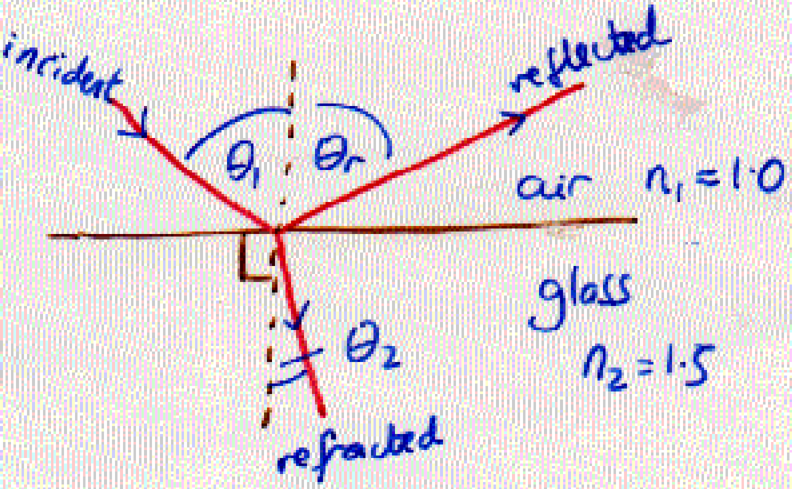
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Snell's Law of Refraction

Refraction cont'd...

Using rays:

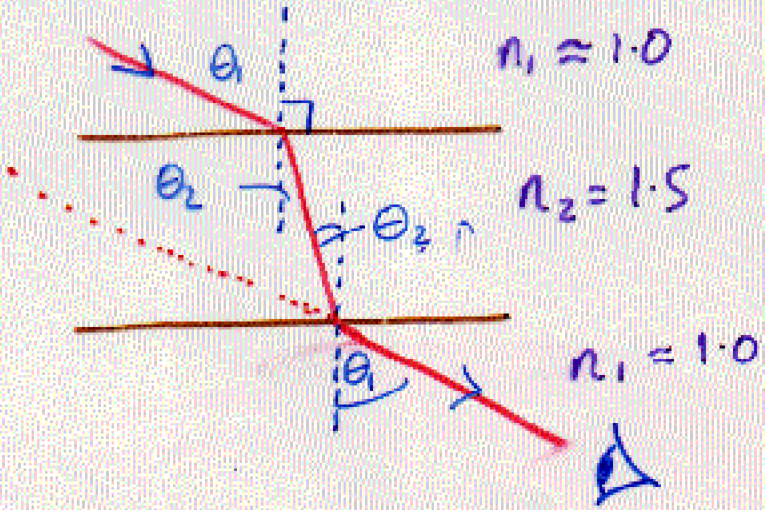
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



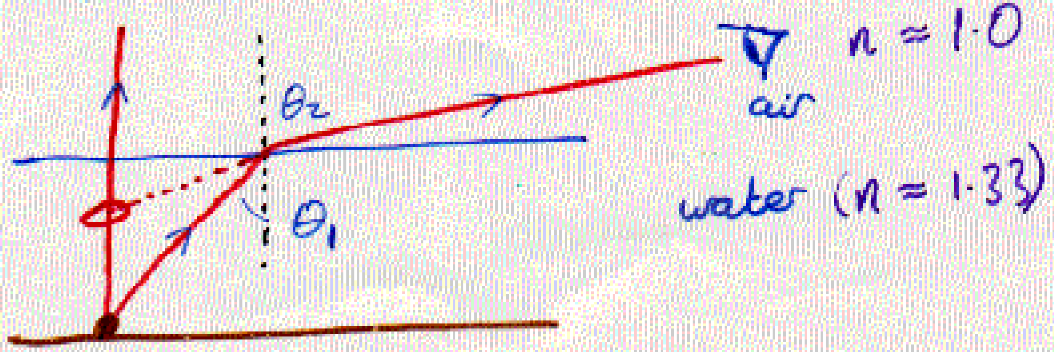
Note: If $n_2 > n_1$ ⇒ light bent towards normal ($\theta_2 < \theta_1$)

If $n_2 < n_1$ ⇒ " " away from normal. ($\theta_2 > \theta_1$)

e.g. A thick window displaces images of objects behind it:



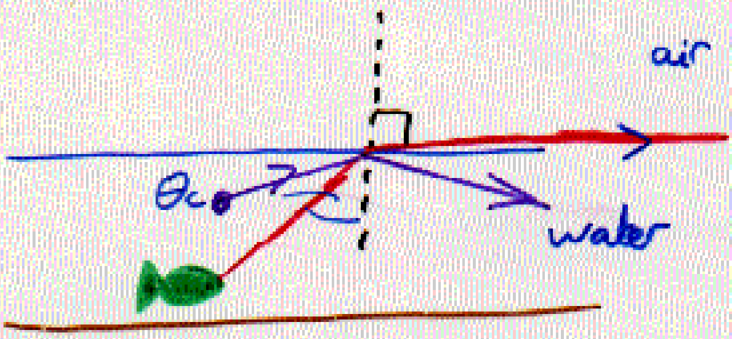
e.g. Apparent depth of pool < real depth:



Total Internal Reflection: Critical Angle (fig 34.24

When light travels from more dense → less dense medium,

$\theta_2 > \theta_1$



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

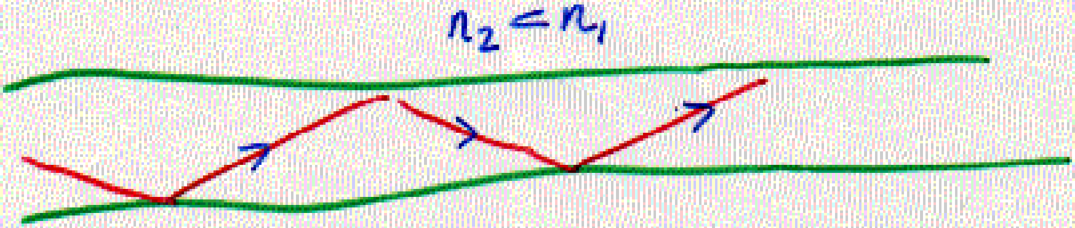
Increase θ_1. At some critical angle $\theta_1 \equiv \theta_c$,

$\sin\theta_2 = 1$, i.e. $\theta_2 = 90°$. Given by $\frac{n_1}{n_2}\sin\theta_c = 1$

For angles $\theta_1 > \theta_c$, no refraction can occur

⇒ total internal reflection (~100% efficient)

e.g. Optical fibers (endoscopy)



As long as $\theta_1 > \theta_c$, light is trapped inside fiber