Intro To Optics

Tuesday, July 29, 2014 12:55 PM

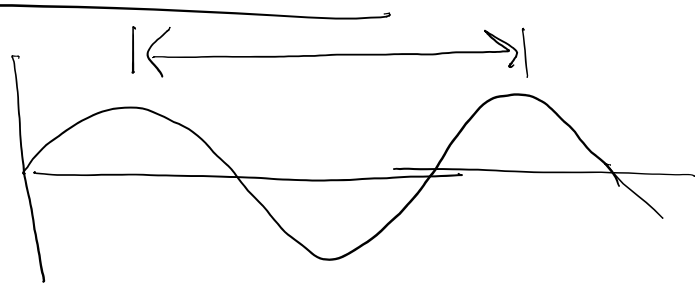
Oψ

Optics: study of electromagnetic radiation and its interaction with matter

particle model: photons

- ray = stream of photon

wave model:



λ = wavelength

$\lambda \approx 10^{-7} m = 100 nm$

use particle model when light interacts

w/ objects larger than its λ

Use wave model when light interacts with objects "about" the same size as λ

Intro to Geometric Optics

Tuesday, July 29, 2014 1:38 PM

Geometric Optics

treat like as a ray that moves with a constant velocity until it encounters a new medium

Speed of light $c = 3.00 \times 10^8 \text{ m/s}$

$(299,792,458 \text{ m/s})$

$= 186,000 \text{ mi/s}$

$= 1 \text{ ft/ns}$

7.5x in 1 s

Earth is 150,000,000 km from Sun

8.3 min

$v = d$

$\overline{t}$

$tv = d \Rightarrow t = \frac{d}{v}$

$t = \frac{150,000,000,000\,m}{3 \times 10^8\,m/s} = 500\,s$

$t = 8.3\,min$

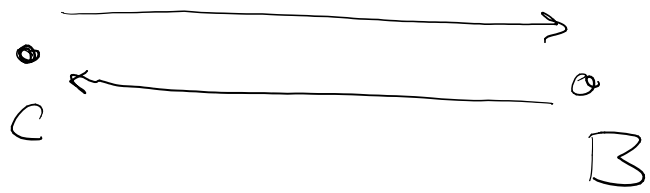
Suppose Alice and Bob shine a light on Chris. Chris sees Bob's light 1 microsecond after he sees Alice's light. How much farther from Chris is Bob compared to Alice?

$d = vt = (3 \times 10^8\,m/s)(10^{-6}\,s)$

$= 3 \times 10^2\,m = 300m$

$v = \frac{d}{t}$ or $t = \frac{d}{v}$

b)



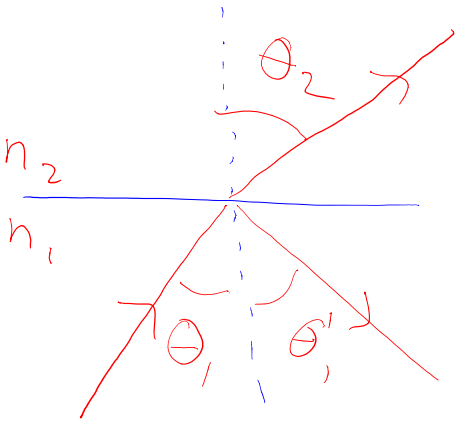
10 s

$d = vt = c(10s) \Rightarrow \frac{d}{2}$

$d = c(5s)$

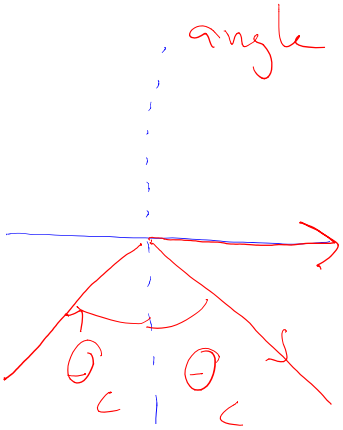
Total Internal Reflection

$n_1 > n_2$



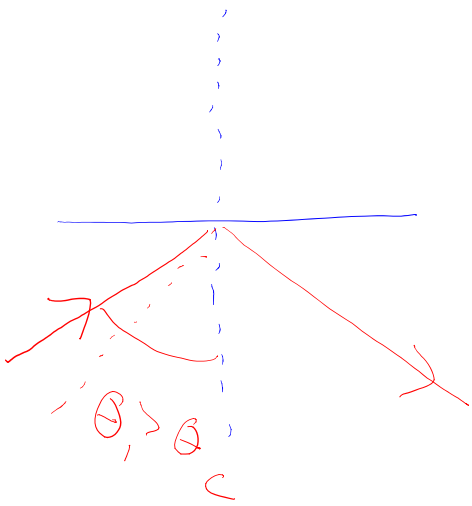
$\theta_2 > \theta_1$

critical angle



$\theta_1 = \theta_c$
refracted along boundary

$n_d = 2.4$



all light reflected back in medium

$\theta_2 = 90°$ when $\theta_1 = \theta_c$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad \sin 90 = 1$

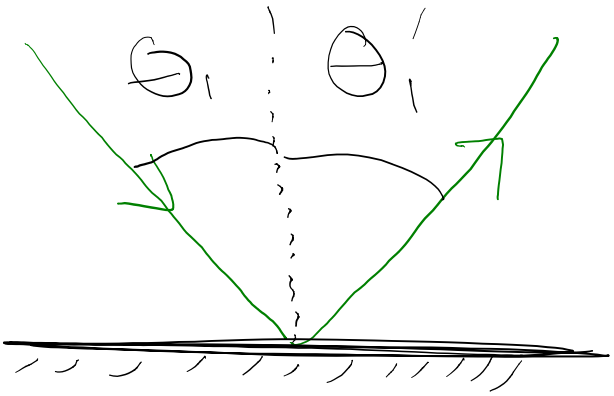
$$\sin\theta_c = \frac{n_2}{n_1}$$

diamond $n = 2.42$ air $\Rightarrow n = 1$ $\quad \theta_c = 24°$

Reflection and Refraction

Wednesday, July 30, 2014 2:00 PM

Law of Reflection

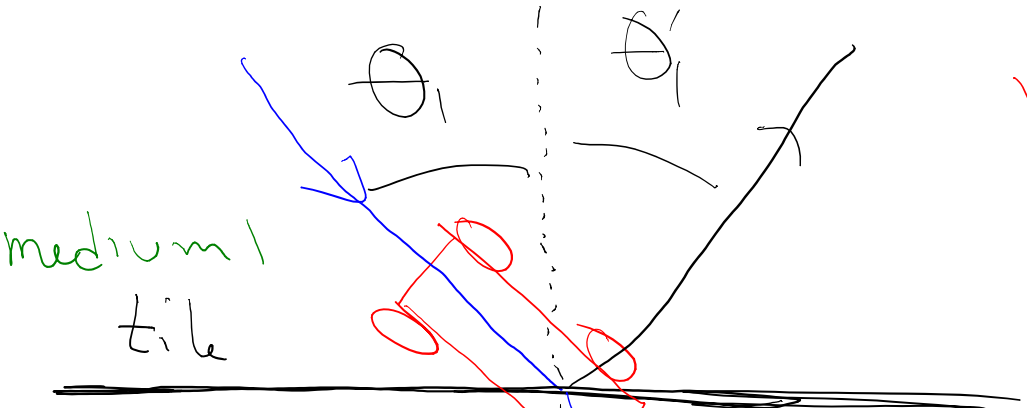


θ_1 = angle of incidence

θ_1' = angle of reflection

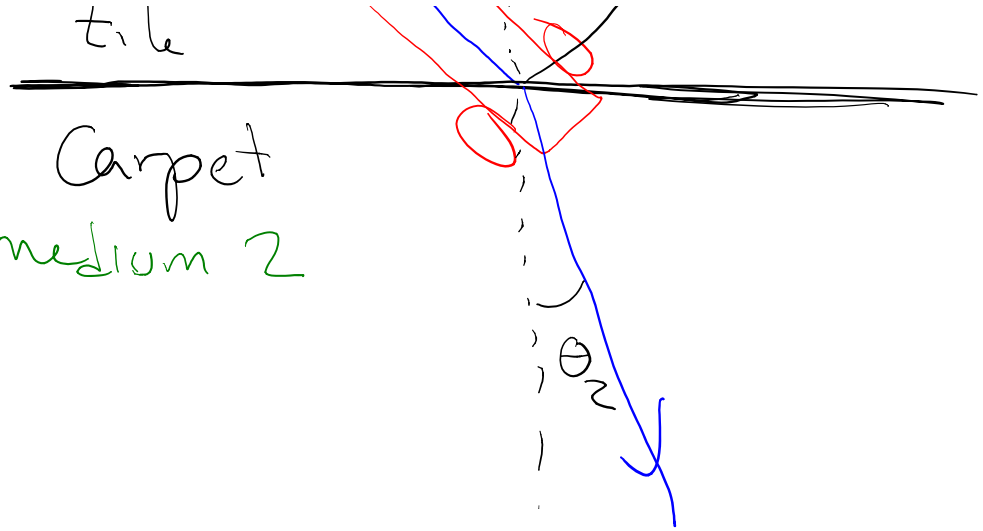
$$\theta_1 = \theta_1'$$

Refraction: change of direction of ray due to a change of speed as it enters a new medium



$v_c < v_t$

$v_1 < v_2$



$v_1 \quad v_2$

θ_2 = angle of refraction

if $v_1 < v_2$ $\theta_2 < \theta_1$ (light bends towards the normal)

$v_1 > v_2$ $\theta_2 > \theta_1$ (light bends away)

n = index of refraction

$$n = \frac{c}{v}$$ ← speed of light in medium

$v \leq c$

$n \geq 1$ $n_{vacuum} = 1$

$n_{air} = 1.00029$

$n_{water} = 1.33$

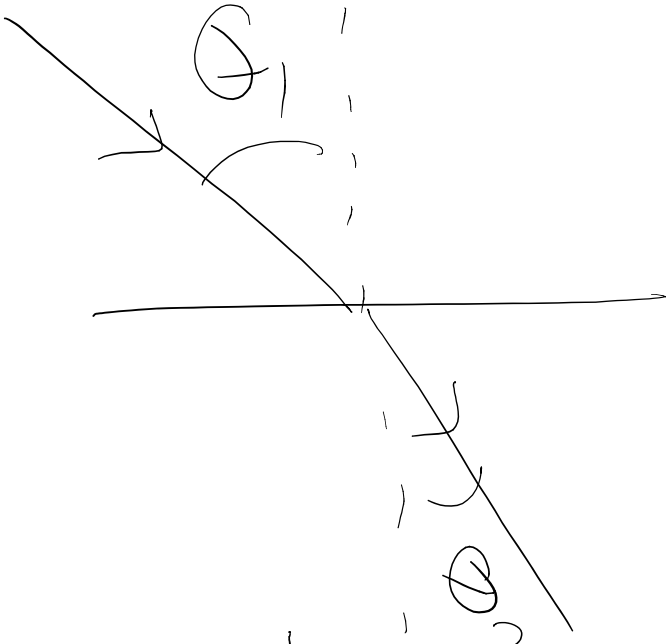
$n_{glass} = 1.5$

$n = 1.66$

n tells us how much light refracts

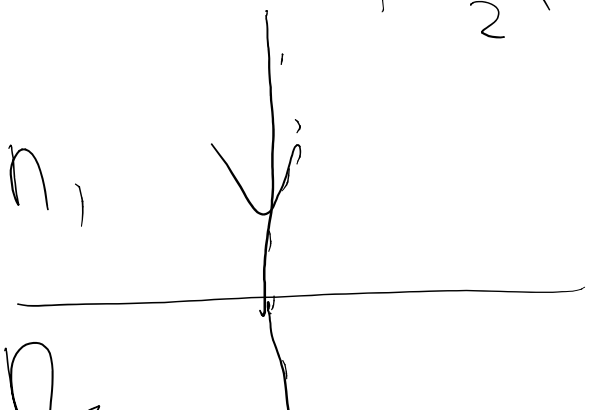
$n_1 > n_2$ $v_1 < v_2$ → bend away

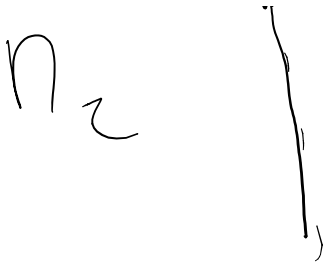
$n_1 < n_2$ $v_1 > v_2$ → bend towards



Snell's Law

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





$$v = f\lambda$$

When light enters a new medium its f doesn't change but λ does

n depends on λ

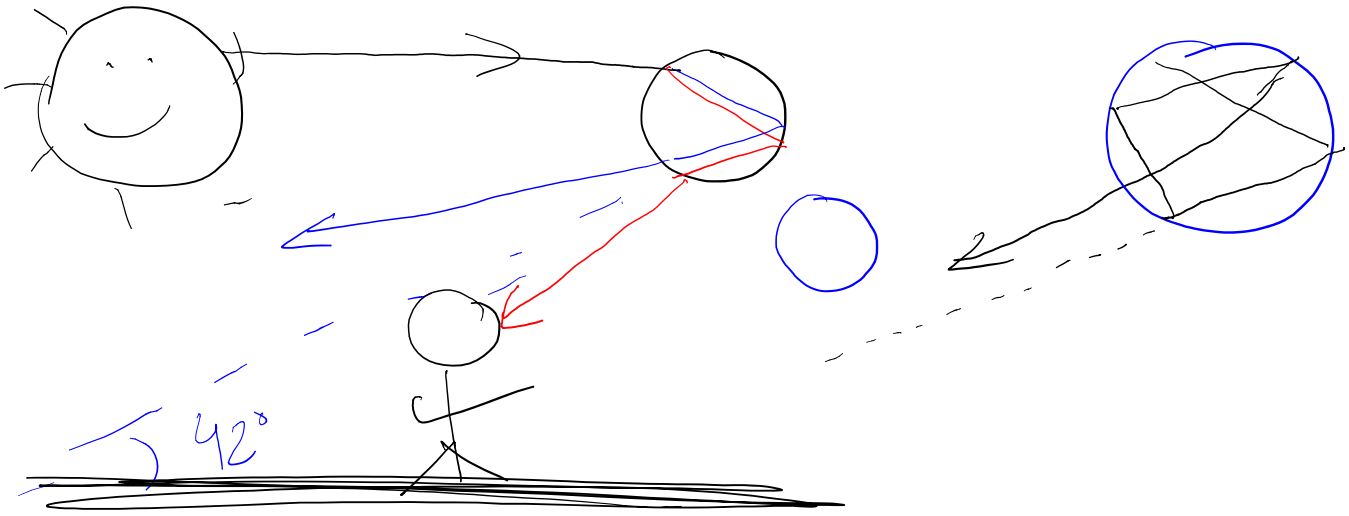
each color has own n so each color goes its own direction

$$n = \frac{c}{v} = \frac{f\lambda_v}{f\lambda}$$

← vacuum

← medium

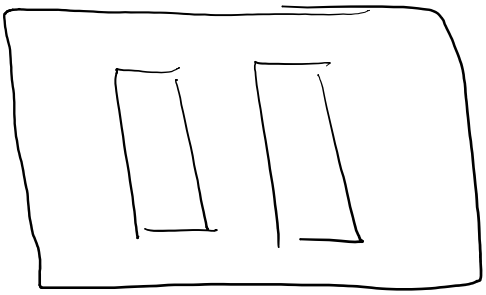
$$n = \frac{\lambda_v}{\lambda}$$



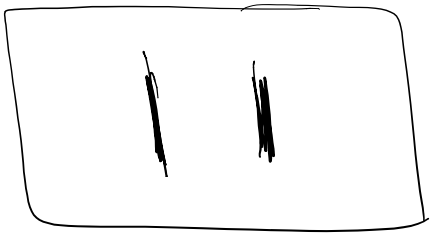
dispersion: different colors having different n

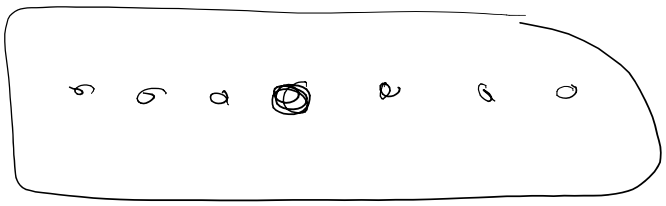
Young's Double Slit Experiment

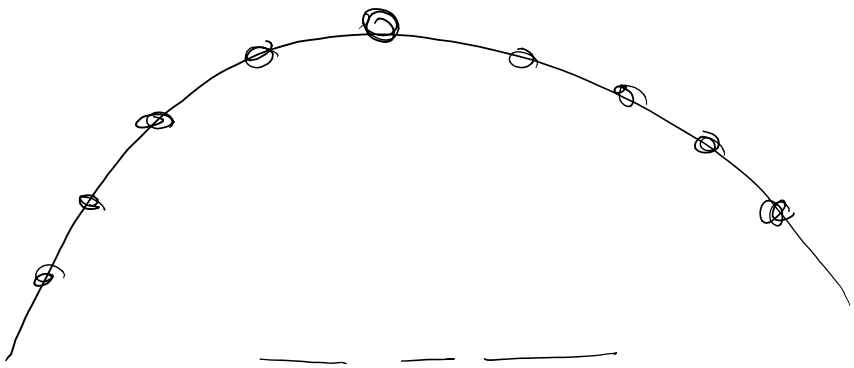
Wednesday, July 30, 2014 2:42 PM



if particle





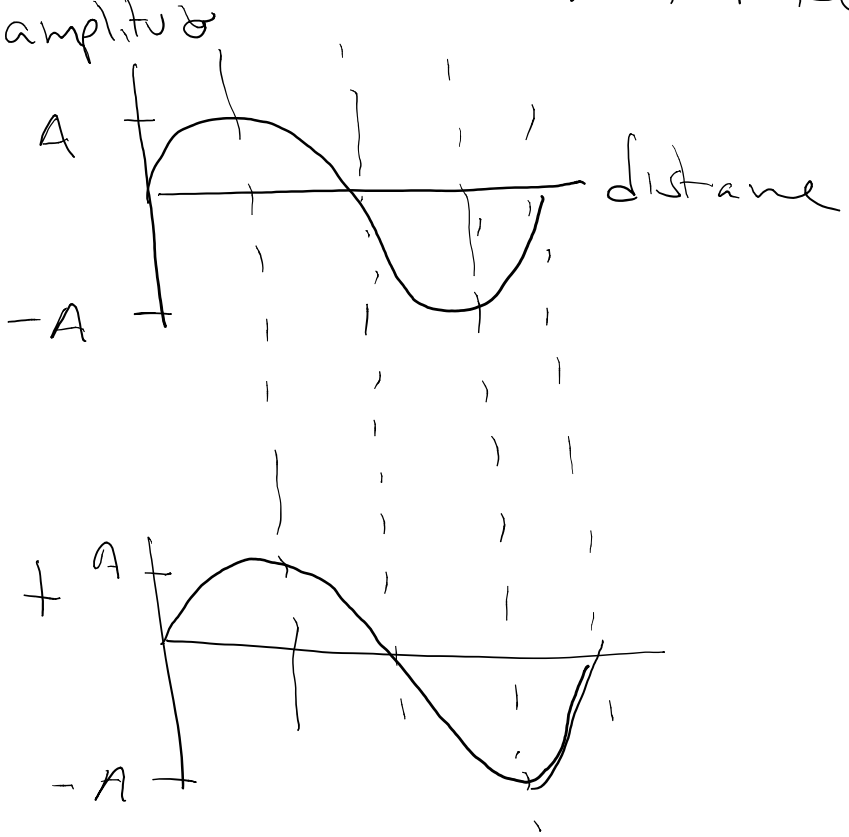


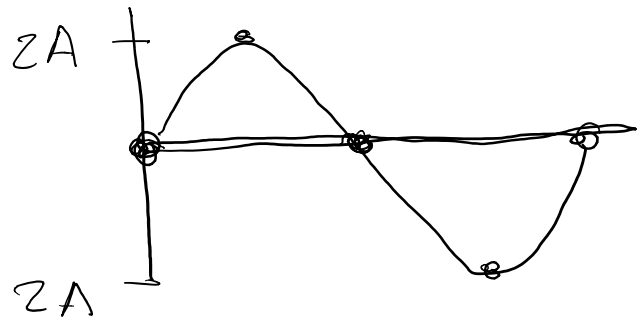
Young's Double Slit Experiment

evidence of wave nature

- each slit behaved like a point

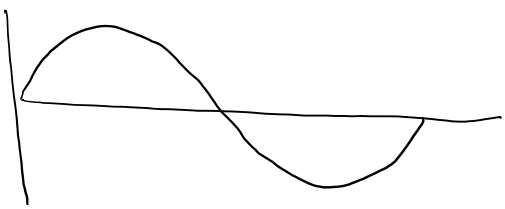
Source for light and pattern is a result of waves from each source interfering



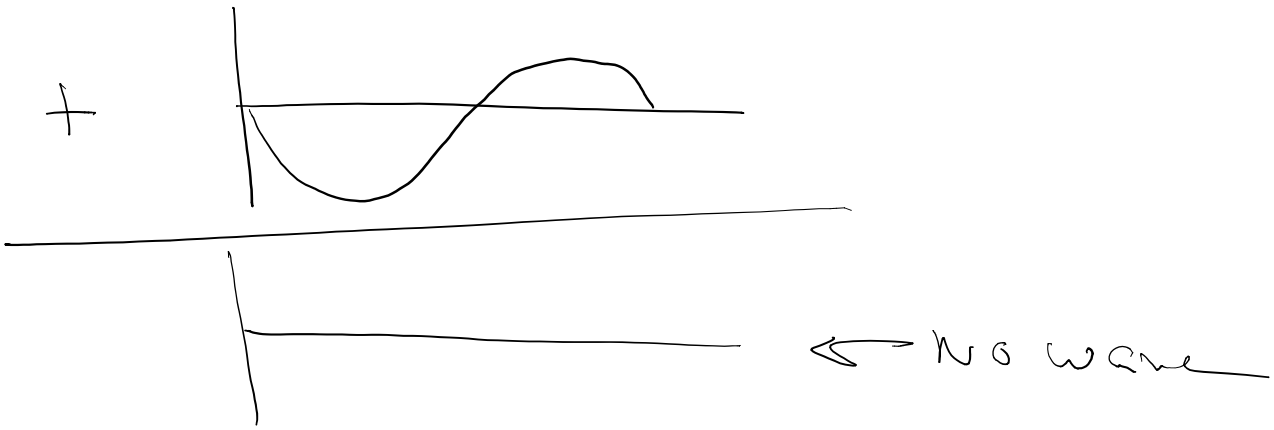


wave w/ a larger amplitude

constructive interference

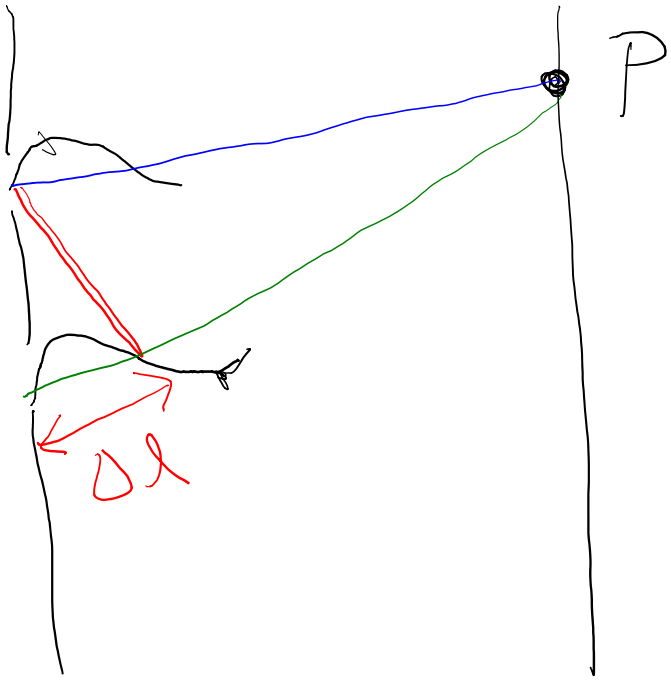


destructive interference


+
No wave

Diffraction

Wednesday, July 30, 2014 3:11 PM

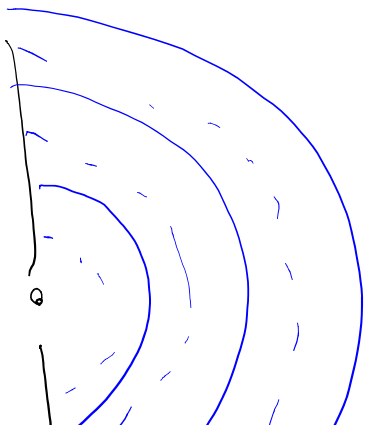


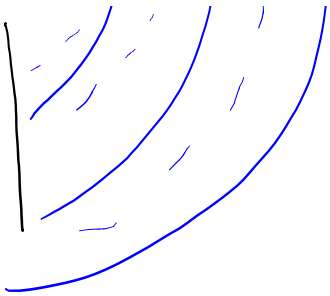
$\Delta l = m\lambda$ m integers

→ constructive interference

$\Delta l = (m + 1/2)\lambda$ destructive

diffraction – spreading out of a wave



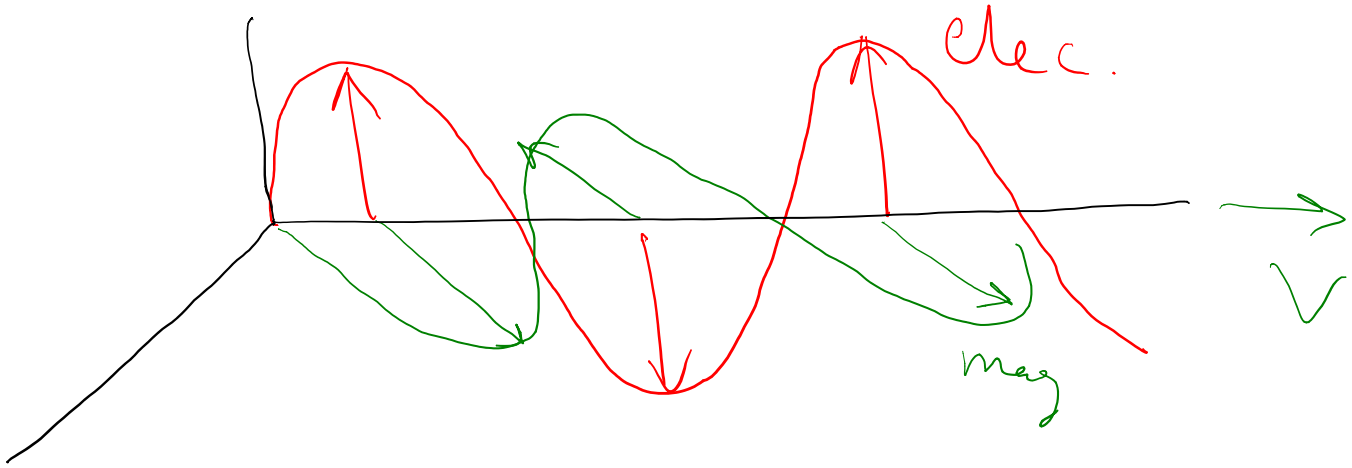


Electromagnetic Waves

Wednesday, July 30, 2014 3:24 PM

James Clerk Maxwell

- develops unified theory of electricity and magnetism
- electric fields and magnetic fields take the form of a wave



electromagnetic wave has a speed C in vacuum.

Electromagnetic Spectrum

Type	λ
Radio waves	10^{-3} ... 10^{8}

Radiowaves	10^{-2} m – 10^{8} m
Infrared	10^{-2} m – 10^{-6} m
visible	400nm – 700nm
	violet – red
UV	400nm – 1nm
Xray	1nm – 0.001
Gamma	< 0.001nm

$C = \lambda f$

frequency of green light (535nm)

$$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}\ m/s}{535 \times 10^{-9}\ m} = 5.6 \times 10^{14}\ Hz$$

$1\ Hz = 1/s$

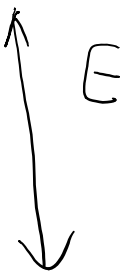
s

Polarization

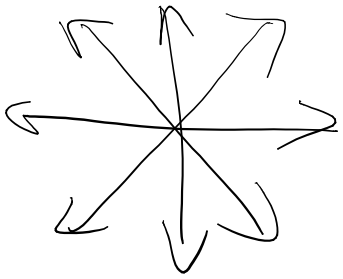
Wednesday, July 30, 2014 3:44 PM

Polarization

direction of the Electric field's oscillation

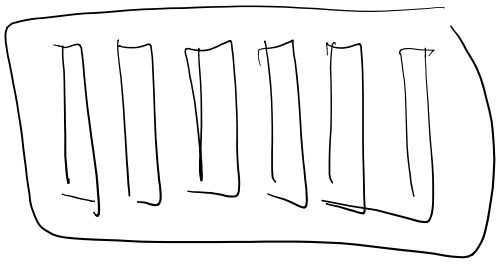


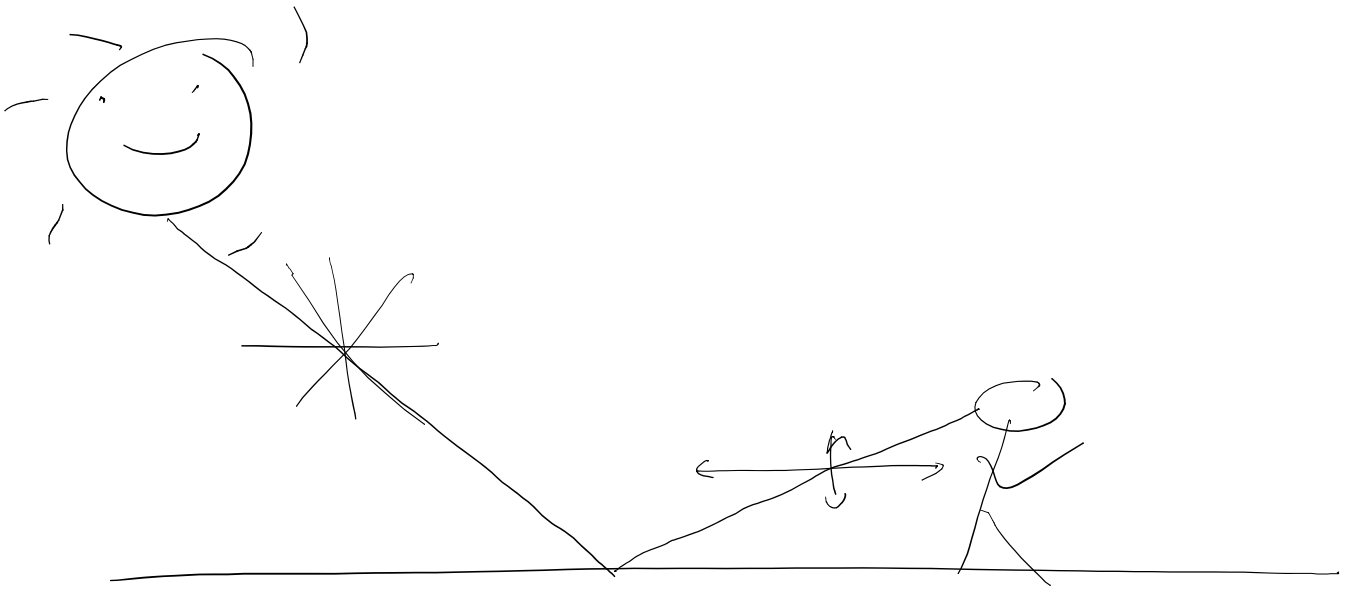
polarized



Unpolarized

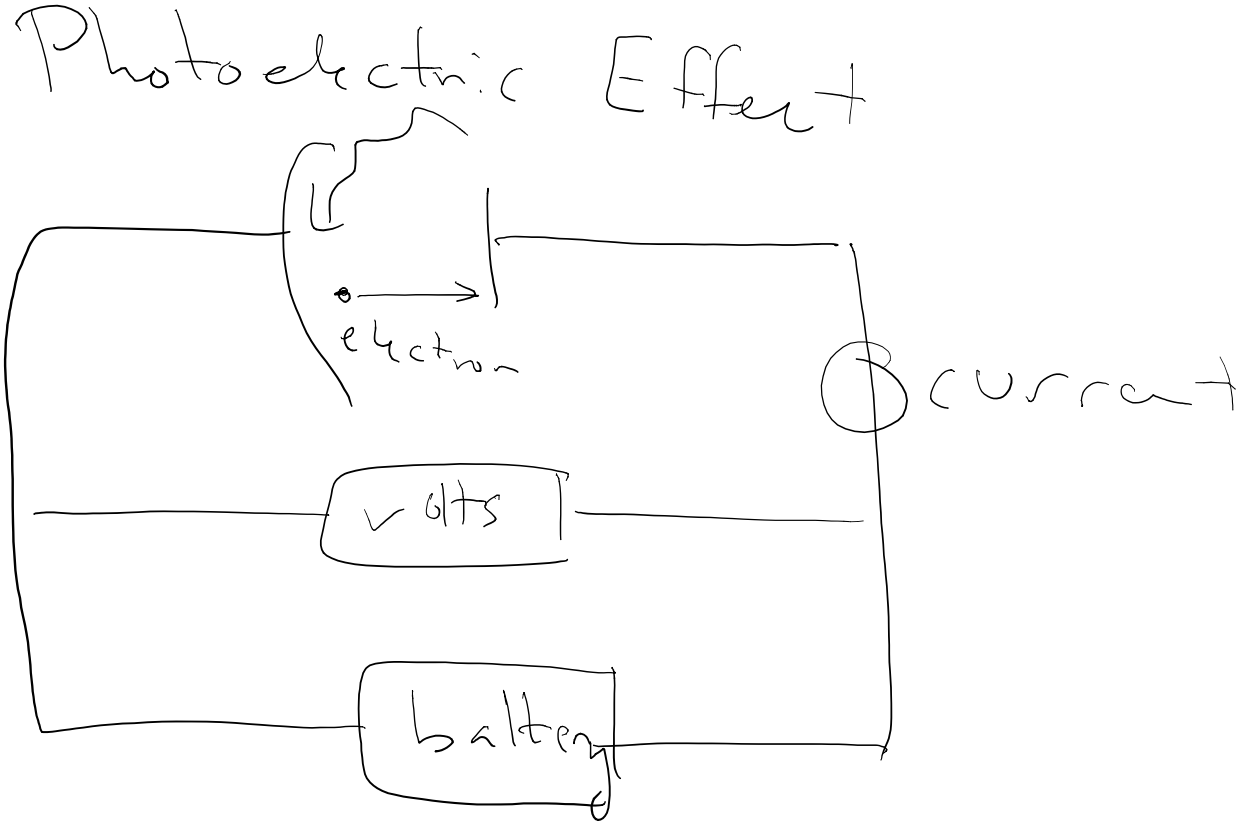
polarized filter





Photoelectric Effect

Thursday, July 31, 2014 9:10 AM



Wave theory says bright lights should cause more current

energy of photon = $E = hf$

freq. of light

h = Planck's Const 6.626×10^{-34} J·s