Physics 201 Day 23

Exam 2 "corrections" → new h.w.

Energy and Momentum of EM Waves

$$\frac{\text{Energy}}{\text{unit Volume}} = u = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$$

u ↑ energy density

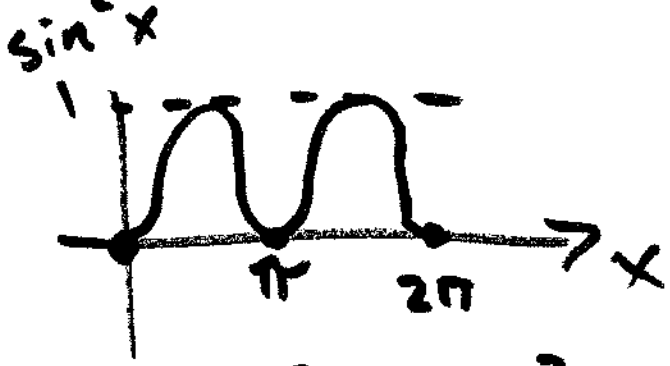
$\epsilon_0 E^2$: capacitor

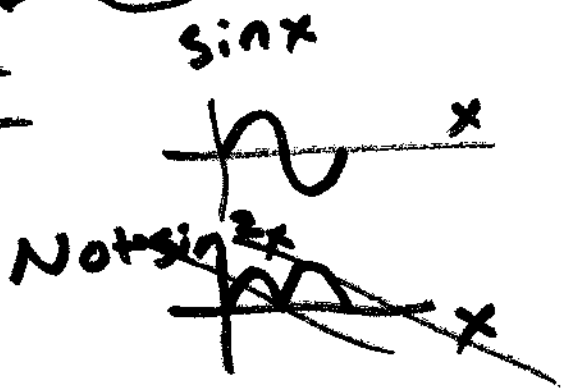
EM wave:

$$E(t) = E_0 \sin(kx \pm \omega t)$$

$$\bar{u} = \epsilon_0 \bar{E}^2 = \epsilon_0 E_0^2 \cdot \frac{1}{2}$$

$\overline{\sin^2(\ )} = \frac{1}{2}$





$$\sin^2 x + \cos^2 x = 1$$

$$\bar{u} = \frac{\epsilon_0 E_0^2}{2} = \frac{B_0^2}{2\mu_0} = \frac{E_0 B_0}{2\mu_0 c}$$

↑ Joules/m³

$$E_0 = \frac{B_0}{c}$$

P: Power = $\frac{\text{Watts}}{\text{unit}} = \frac{\text{Jolue}}{s}$

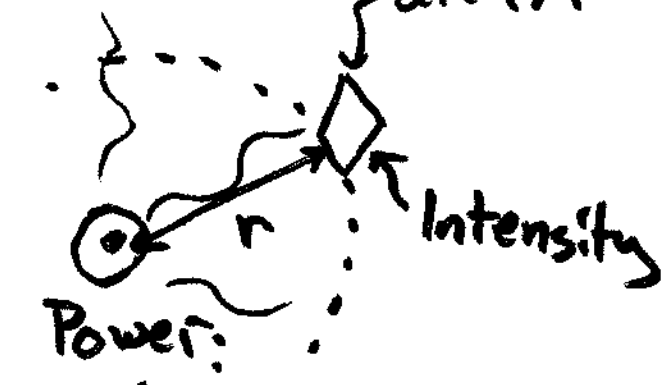
I: Intensity = $\frac{\text{Power}}{\text{Area}} = \frac{\text{Watts}}{m^2}$ ← brightness

side note:

decibels = $dB = 10 \cdot \log_{10}\left(\frac{I}{I_0}\right)$

$10^{-12} \frac{W}{m^2}$

Relate to $\vec{u}$, and then E_0, or B_0.



$I = \frac{P}{4\pi r^2}$ for a point source.

intensity Sun $\simeq 1300 \frac{\text{Watts}}{m^2}$ at Earth.

$P_{(sun)} = 1300 \frac{W}{m^2} \cdot 4\pi (1.5 \times 10^{11} m)^2$

$150 \times 10^6 \times 10^3 m = 1.5 \times 10^{11} m$

$P = 3.67 \times 10^{26}$ Watts (a lot)

Direction of EM waves:

in the $\vec{E} \times \vec{B}$ direction

and Poynting = $\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$ = Intensity (vector)

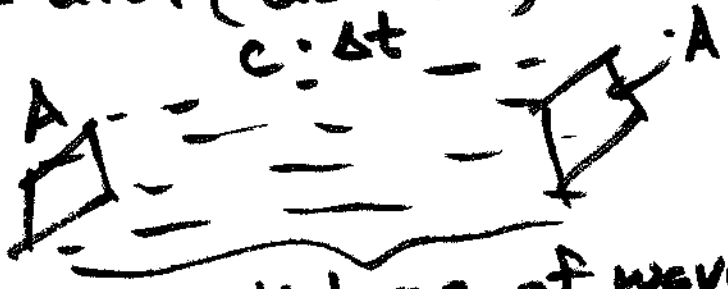
Power = $\bar{u} \cdot A \cdot \underbrace{\text{speed}}_{c}$

" = "

energy / time = energy / volume $\cdot$ volume of wave / time

c = speed of light

A = area (detector)



★ volume of wave passing per unit time

$$P = \bar{u} A c$$

intensity $I = \frac{P}{A} = \bar{u} \cdot c$

$$\bar{u} = \frac{E_0 B_0}{2 \mu_0 c}$$

$$I = \frac{E_0 B_0}{2 \mu_0}$$

↑ time average

momentum

$\vec{F} = \frac{d\vec{p}}{dt}$ $p = mv$

If EM waves carry P, they can push.

$$F = ma + \left(\frac{dm}{dt}\right) \cdot v$$

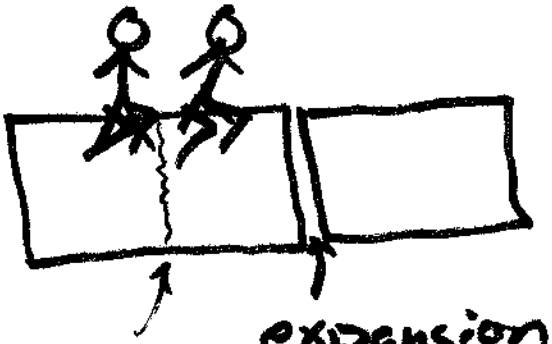
Can show (rated X) $p = \frac{U}{c}$ momentum

and Pressure $P = \frac{I}{c}$

Last time:

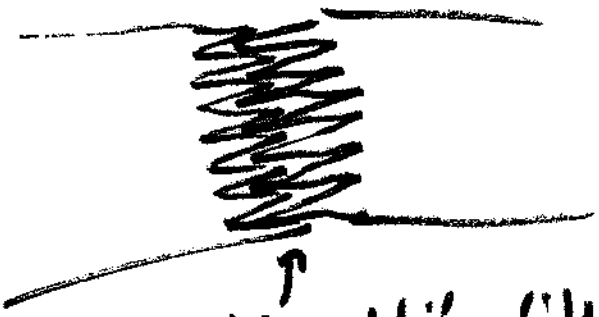
Thermal Expansion

$L(T) = L_0(1 + \alpha \Delta T)$



crack because too few gaps

expansion gap



"teeth" - like expansion gap (bridge)

α is bigger for liquids than solids.

$\alpha_{steel} = 12 \times 10^{-6} \frac{1}{^\circ C}$ for steel.

$\alpha_{mercury} = 60 \times 10^{-6} \frac{1}{^\circ C}$

$\alpha_{Quartz} = 0.59 \times 10^{-6} \frac{1}{^\circ C}$