2) E & M Wave $\mu_0 \varepsilon_0 = \frac{1}{c^2}$

$$\vec{E} = \vec{E}_0 \cos(\vec{k} \cdot r - \omega t)$$

$\vec{k} = \frac{2\pi}{\lambda}$, $\omega = 2\pi f = \frac{2\pi}{T}$

$\frac{\omega}{k} = c$ — phase velocity

$$\vec{B} = \frac{\hat{k}}{c} \times \vec{E}$$

} plane waves

- characterized by: $\hat{k}$, $|\vec{E}_0|$, dir of $\vec{E}_0$ (polarization), & ω

frequency

radio waves are the lowest wave of them all (because we dont have a label for anything lower)

How much we have covered in class

1 Hz ⟶ 0.5 PHz

How far can we go?

Radio, µwave, THz, infrared, light, UV, x-rays, gamma-rays

1 Hz → 0.5 PHz ⟶ 1 PHz − 10^{21} Hz

↑ visible

10^{15} Hz

Intensity from Sun ~ $\frac{1.3 \text{ kW}}{m^2}$

$$\sin^2 + \cos^2 = 1 \;\therefore\; \text{on average } \cos^2 = \frac{1}{2}$$

How it relates:

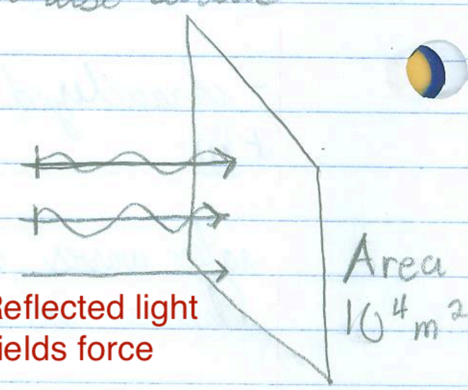
$$\frac{\Delta E}{\Delta V_{Volume}} = \frac{\varepsilon_0}{2}\vec{E}^2 + \frac{1}{2\mu_0}\vec{B}^2 \xrightarrow{P.W.} \frac{\varepsilon_0}{2}E_0^2\cos^2 + \underbrace{\frac{1}{2\mu_0}\frac{1}{c^2}}_{\frac{\varepsilon_0}{2}}E_0^2\cos^2$$

$$\frac{\Delta E}{\Delta area\,\Delta t} = \frac{\Delta E}{\Delta V_{Volume}} \cdot c$$

$$= \frac{c\varepsilon_0}{2}E_0^2 = \frac{1}{2\mu_0 c}E_0^2 = \frac{1}{2\mu_0}E_0 B_0 = S$$

Light not only carries energy it also carries momentum

$$\frac{S}{c} \simeq 433 \cdot 10^{-8} \; \frac{kg\,m}{s} \Big/ m^2 s$$



Radiation Pressure

$$= 2 \cdot 433 \cdot 10^{-4} \; \frac{kg\,m}{s^2}$$

$= 0.086$ N

Reflected light yields force

$$E = p \cdot c$$

3) Electromagnetic waves are made of Particles (photons)

$$E^2 = m^2c^4 + p^2c^2$$

? So how can something be a wave and a particle at the same time?

* Everything is a wave and a particle.

Black body: When matter is heated then gives of radiation
We have a direct relation of all the energy being ratiated