Chapter 24

Maxwell's equs:

$$\oint \vec{E} \cdot d\vec{A} = Q_{in}/\epsilon_0$$ Gauss's law

$$\oint \vec{B} \cdot d\vec{A} = 0$$ " " for mag. field

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_m}{dt}$$ Faraday's law

$$\oint B \cdot d\vec{s} = \mu_0 I_{through} + \epsilon_0 \mu_0 \frac{d\Phi_e}{dt}$$

Ampère-Maxwell law

EM Waves

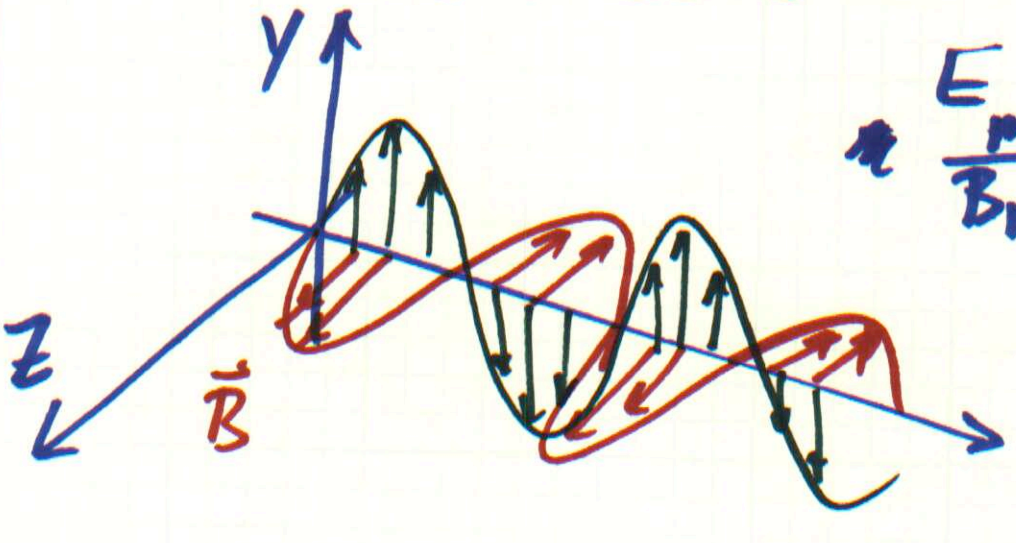
Maxwell's eqns:

$$\begin{cases} \dfrac{\partial^2 B}{\partial x^2} = (\epsilon_0 \mu_0) \dfrac{\partial^2 B}{\partial t^2} \\ \dfrac{\partial^2 E}{\partial x^2} = (\epsilon_0 \mu_0) \dfrac{\partial^2 E}{\partial t^2} \end{cases} \Rightarrow v_{EM} = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = c$$

light is an EM waves

$$E = E_{max} \sin(kx - \omega t)$$

$$B = B_{max} \sin(kx - \omega t)$$

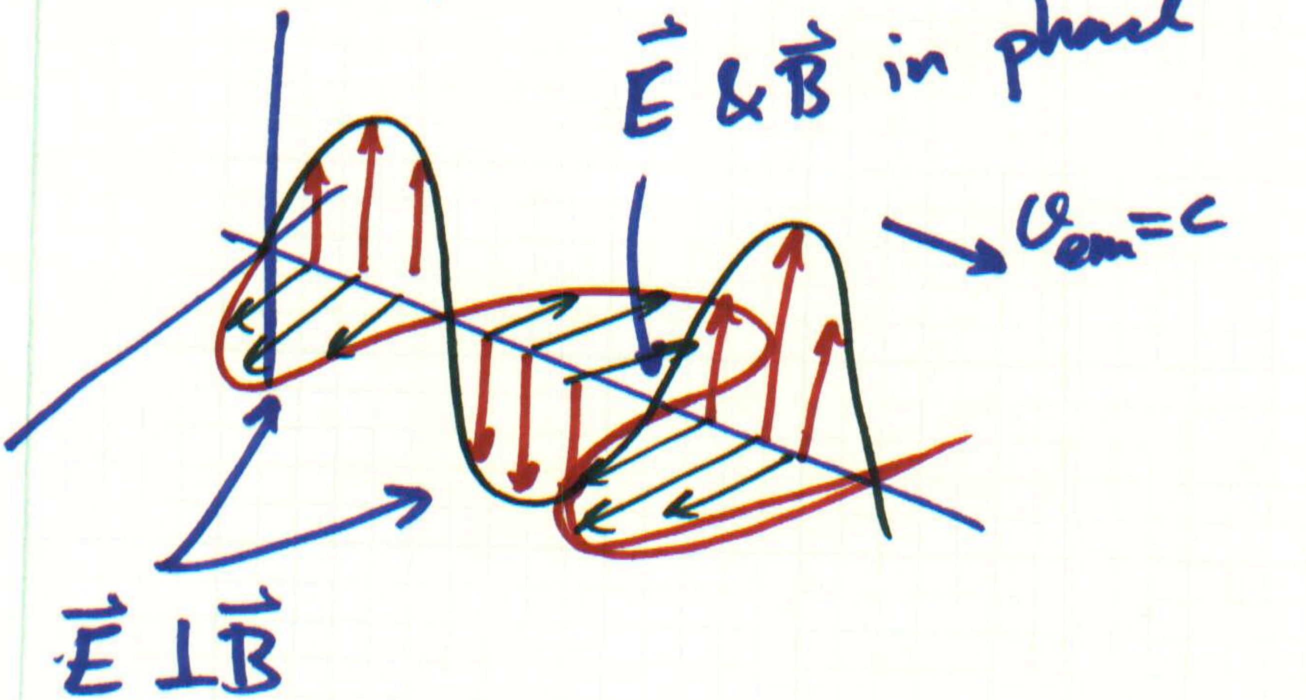


$$\frac{E_{max}}{B_{max}} = c$$

* EM waves can exist at any freq. (not only visible light) e.g. radio waves, ...

* All EM waves travel at speed 'c' in vacuum.

$$v_{em} = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3.00 \times 10^8 \text{ m/s} = c$$



1. $\vec{E}$ & $\vec{B}$ $\perp$ $\vec{v}_{em}$ (trans. wave)

2. $\vec{E} \perp \vec{B}$ in a way that:

$\vec{E} \times \vec{B}$ is in direction of v_{em}

3. $v_{em} = c$

4. $E = cB$ at any point

Energy of EM waves:

described by:

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

where

$$|S| = \frac{EB}{\mu_0} = \frac{E^2}{c\mu_0}$$

Intensity ~~upzz~~ when amplitude of E is E_0:

$$I = \frac{P}{A} = S_{avg} = \frac{1}{2c\mu_0} E_0^2 = \frac{c\epsilon_0}{2} E_0^2$$

$u_E \rightarrow$ energy / unit volume

$$\begin{cases} u_E = \frac{\epsilon_0}{2} E^2 \\ u_B = \frac{B^2}{2\mu_0} \end{cases}$$

$$u_B = \frac{(E/c)^2}{2\mu_0} = \frac{\epsilon_0 \mu_0}{2\mu_0} E^2 = \frac{1}{2} \epsilon_0 E^2$$

$$\Longrightarrow u_E = u_B$$

$$u = u_E + u_B = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$$

$$u_{ave} = \epsilon_0 (E^2)_{ave} = \frac{\epsilon_0 E_{max}^2}{2}$$

$$= \frac{B_{max}^2}{2\mu_0}$$

$$\Longrightarrow I = S_{ave} = c\, u_{ave}$$

Radiation Pressure

Pressure = force per unit area

$P_{rad} \longrightarrow$ radiation pressure

Black Body (absorbs all radiation):

$$p = \frac{U}{c} \leftarrow \text{momentum}$$

[illegible]

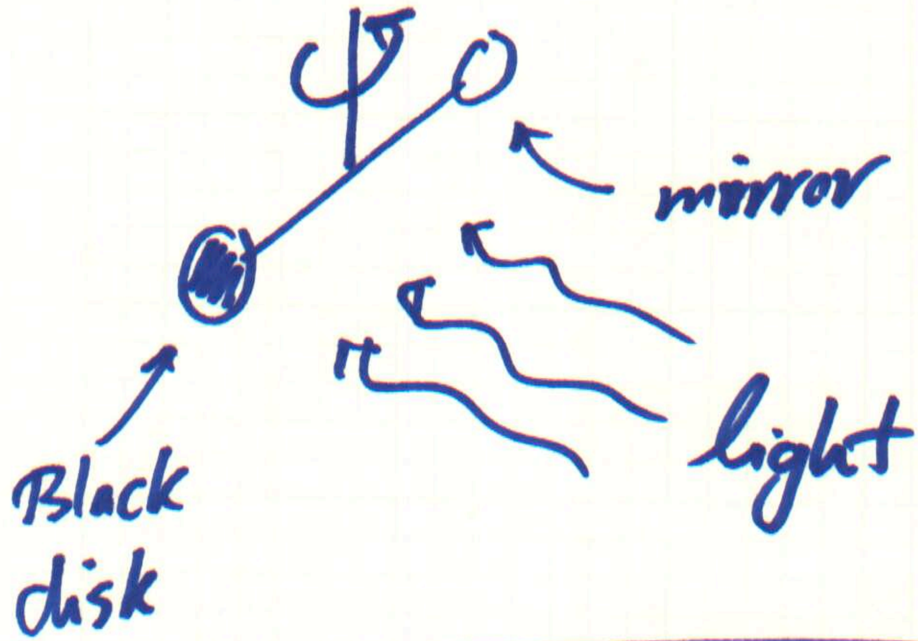
$$\Rightarrow P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt} = \frac{1}{c}\frac{dU/dt}{A}$$

mag. of Poynting vector: $\frac{dU/dt}{A}$

$$\Longrightarrow P = S/c$$

Perfectly Reflecting Surface:

$$P = 2U/c \Longrightarrow \mathcal{P} = 2S/c$$

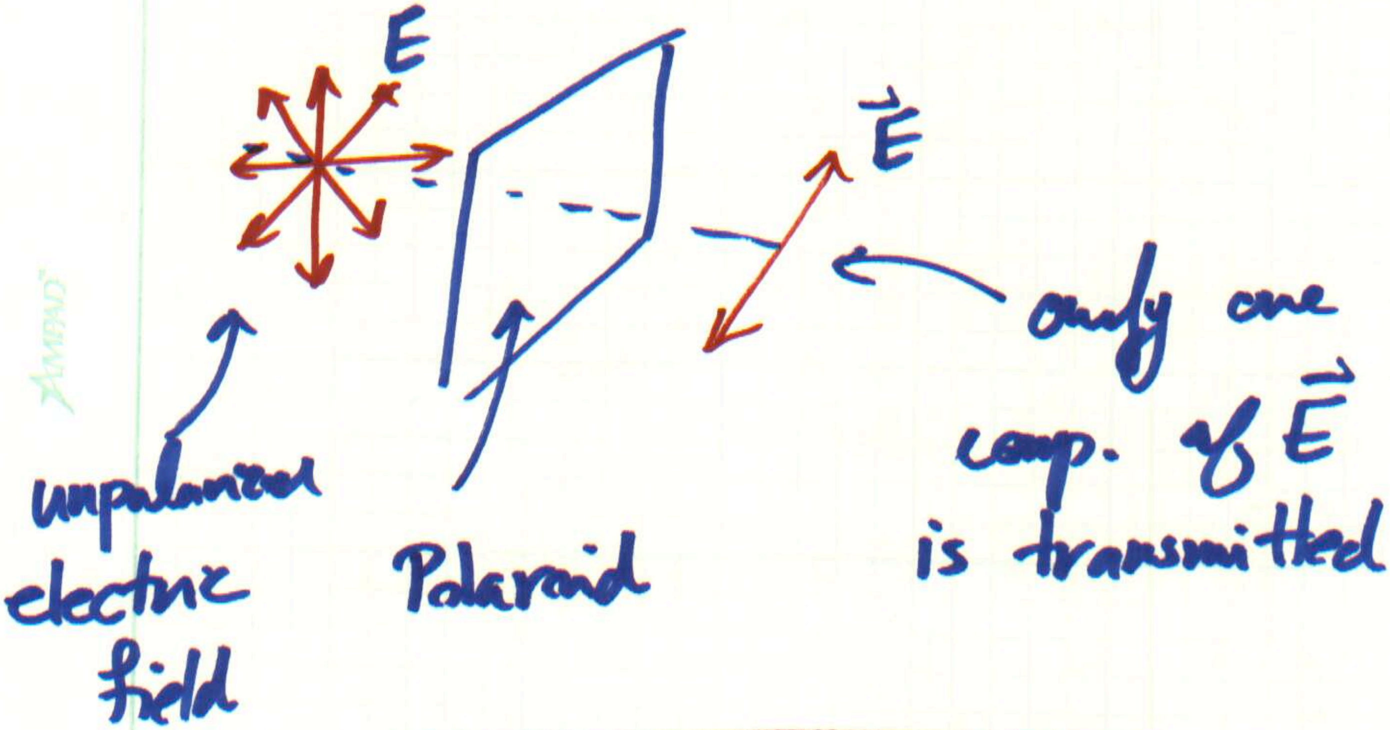


Space Sailing:

* very large sails to reflect light

*

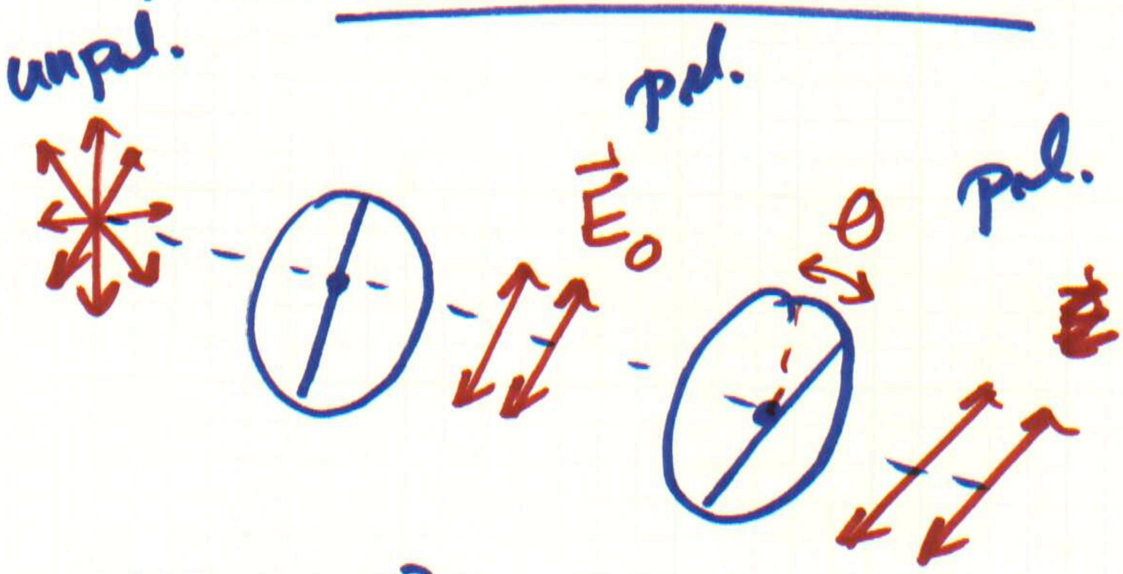
Polarization:



$\vec{E} \perp \vec{B}$ & $\vec{E}$ & $\vec{B} \perp \vec{S}$

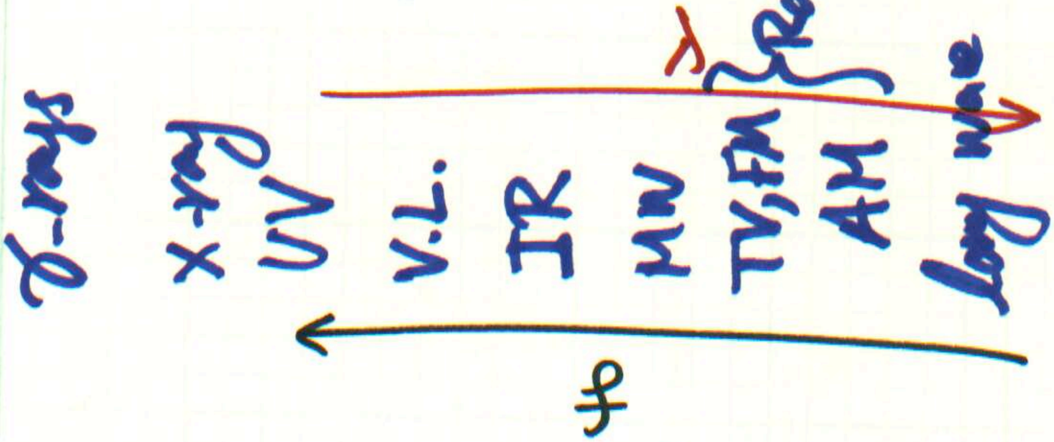
* Polarization specifies the direction of E-field & $\vec{B}$-field
* direction of pol. is defined as the direction of vibration of E-field

Linearly Polarized:



$$I = I_0 \cos^2\theta$$

EM Spectrum:



Radio Waves: $10^4 m > \lambda > 0.1 m$

M.W.: $0.3m > \lambda > 10^{-4} m$

radars, MW ovens

IR: $10^{-3} > \lambda > 7\times10^{-7}$

produced by hot obj.

V.L.: $\sim 5.5\times10^{-7} m$

diff λ → diff colors

U.V.: $4\times10^{-7} m > \lambda > 6\times10^{-10} m$

X-ray: $10^{-8} m > \lambda > 10^{-12} m$

γ-ray: $10^{-10} > \lambda > 10^{-14} m$