PHYSICS 232 – CHAPTER 32: ELECTROMAGNETIC WAVES

For a plane wave in vacuum,

$$E = cB \quad , \quad c = \frac{1}{\sqrt{\epsilon_o \mu_o}}$$

$\vec{E} \perp \vec{B} \perp$ (direction of propagation).

Sinusoidal plane wave traveling in the +x direction,

$$E = E_{max} \sin(\omega t - kx), \quad B = B_{max} \sin(\omega t - kx),$$

Poynting vector: Energy flow rate (power per unit area),

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

Intensity (time average of Poynting vector)

$$I = \langle S \rangle = \frac{E_{max} B_{max}}{2\mu_o} = \frac{{E_{max}}^2}{2\mu_o c} = \frac{1}{2}\sqrt{\frac{\epsilon_o}{\mu_o}} E_{max}^2 = \frac{1}{2}\epsilon_o c E_{max}^2$$

Electromagnetic waves also carry momentum. The rate of transfer of momentum per unit cross-section area is

$$\frac{1}{A}\frac{dp}{dt} = \frac{S}{c} = \frac{EB}{\mu_o c}$$

Radiation pressure:

$$p_{rad} = I/c \quad \text{(absorbing surface)}$$

$$p_{rad} = 2I/c \quad \text{(reflecting surface)}$$