Producing

Energy Carried by EM waves

- rate of flow: Energy per area per time in direction of motion of wave

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

(for a plane EM wave $S = EB/\mu_0$)

But we would like average S over many cycles:

$$S_{avg} = \frac{E_{max} B_{max}}{2\mu_0} = I \quad \text{"wave intensity"}$$

use $E_{rms} = \frac{E_{max}}{\sqrt{2}}$; $B_{rms} = \frac{B_{max}}{\sqrt{2}}$

Now consider instantaneous energy density (Energy per volume)

$$u_E = \frac{1}{2} \epsilon_0 E^2 \qquad \text{(recall } E = cB\text{)}$$

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

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

and average is $u_{avg} = \epsilon_0 E_{max}^2/2 = B_{max}^2/2\mu_0$

so

$$\underline{\underline{I}} = \frac{E_{max}^2}{2\mu_0 c} = \frac{cB^2}{2\mu_0} = \boxed{c u_{avg}}$$

Problem 11

How much energy density in sunlight? Intensity is $1 kW/m^2$.

use $I = c u_{avg}$

$$u_{avg} = I/c = \frac{(10^3 W/m^2)}{3 \times 10^8 m/s}$$

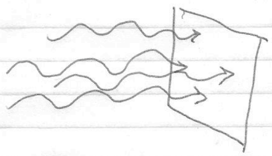
$$= \frac{1}{3} \times 10^{-5} \frac{W/m^2}{m/s}$$

$$= \boxed{3.33 \times 10^{-6} J/m^3}$$

(3)

Radiation Pressure

Light has energy. Consider a surface $\perp$ to direction of travel of wave



Momentum of light

Total energy transferred to surface in some time Δt, is U. The momentum transferred by radiation is

$$p = U/c \quad \text{(complete absorption)}$$

Pressure is exerted by this momentum transfer

$$P = F/A = \frac{1}{A}\frac{dp}{dt} = \frac{1}{A}\frac{d}{dt}\left(\frac{U}{c}\right)$$

$$= \frac{1}{cA}\frac{dU}{dt}$$

$\frac{dU}{dt}$ → magnitude of $\vec{S}$ (energy arriving at surface per unit time)

$P = S/c$ (100% absorption)

$P = 2S/c$ (perfect reflection)

1304/1404 220, p4

Prob 27

S = power/area = $25\ W/m^2$

surface area A

What is P?

$P = S/c$

$= \frac{25}{3\times10^8}\ N/m^2$

$= 8\times10^{-8}\ N/m^2$

Prob 31

$S = 750\ W/m^2$

$A = 50cm \times 100cm = 0.5\ m^2$

$P = 3S/2c = \frac{1}{cA}\frac{\Delta U}{\Delta t}$

$\Delta U = \frac{3S}{2c}(cA\Delta t)$

$= \frac{3}{4}(750\ W)(60\ s) = \frac{27}{80}(10^5\ J)$

$= 3.4\times10^4\ J = 34\ kJ$