08 – Electromagnetic Waves (Ch. 33)

$c = 3 \cdot 10^8$ m/s; $\varepsilon_0 = 8.854 \cdot 10^{-12}$ F/m; $\mu_0 = 1.257 \cdot 10^{-6}$ N/A^2

7) What is the intensity of a traveling plane electromagnetic wave if B_m is 1.0×10^{-4} T?

7. The intensity is the average of the Poynting vector:

$$I = S_{\text{avg}} = \frac{cB_m^2}{2\mu_0} = \frac{(3.0 \times 10^8 \text{ m/s})(1.0 \times 10^{-4} \text{ T})^2}{2(1.26 \times 10^{-6} \text{ H/m})} = 1.2 \times 10^6 \text{ W/m}^2.$$

Electromagnetic wave in vacuum

$$S = \frac{1}{\mu_0} E_0 B_0 \sin^2(kx - \omega t)$$

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

19) High-power lasers are used to compress a plasma (a gas of charged particles) by radiation pressure. A laser generating radiation pulses with peak power 1.5×10^3 MW is focused onto 1.0 mm^2 of high-electron-density plasma. Find the pressure exerted on the plasma if the plasma reflects all the light beams directly back along their paths.

19. **THINK** The plasma completely reflects all the energy incident on it, so the radiation pressure is given by $p_r = 2I/c$, where I is the intensity.

EXPRESS The intensity is $I = P/A$, where P is the power and A is the area intercepted by the radiation.

ANALYZE Thus, the radiation pressure is

$$p_r = \frac{2I}{c} = \frac{2P}{Ac} = \frac{2(1.5 \times 10^9 \text{ W})}{(1.00 \times 10^{-6} \text{m}^2)(2.998 \times 10^8 \text{ m/s})} = 1.0 \times 10^7 \text{ Pa}.$$

LEARN In the case of total absorption, the radiation pressure would be $p_r = I/c$, a factor of 2 smaller than the case of total reflection.

20) Radiation from the Sun reaching Earth (just outside the atmosphere) has an intensity of 1.4 kW/m^2. (a) Assuming that Earth (and its atmosphere) behaves like a flat disk perpendicular to the Sun's rays and that all the incident energy is absorbed, calculate the force on Earth due to radiation pressure. (b) For comparison, calculate the force due to the Sun's gravitational attraction.

20. (a) The radiation pressure produces a force equal to

$$F_r = p_r\left(\pi R_e^2\right) = \left(\frac{I}{c}\right)\left(\pi R_e^2\right) = \frac{\pi\left(1.4\times10^3\ \mathrm{W/m^2}\right)\left(6.37\times10^6\ \mathrm{m}\right)^2}{2.998\times10^8\ \mathrm{m/s}} = 6.0\times10^8\ \mathrm{N}.$$

(b) The gravitational pull of the Sun on the Earth is

$$F_{\text{grav}} = \frac{GM_sM_e}{d_{es}^2} = \frac{\left(6.67\times10^{-11}\ \mathrm{N\cdot m^2/kg^2}\right)\left(2.0\times10^{30}\ \mathrm{kg}\right)\left(5.98\times10^{24}\ \mathrm{kg}\right)}{\left(1.5\times10^{11}\ \mathrm{m}\right)^2}$$

$$= 3.6\times10^{22}\ \mathrm{N},$$