Hwk 9 Solutions PHYS 142 Summer '09 Dr. Jenkins

Question 34.9

for all 5 properties (i) - (v), the answer is (c) stay constant. the only non-constant components of a plane wave are its position (x-direction in this case) and the actual oscillation of the wave.

Question 34.12

(i) the E and B-fields must have proportional amplitudes to guarantee they are carrying the same energy; so if $|E|$ is doubled, then $|B|$ is also, answer (b).

(ii) intensity is proportional to E^2, so if $|E|$ doubles, then I increases by a factor of 4, answer (a).

Question 34.14

just like with conservation of momentum in 141, you need double the impulse to stop something and rebound it with the same momentum in the opposite direction as you do just to stop it; the photons have to be stopped and turned around by a reflecting surface; since ~~since~~ change in momentum and pressure are both proportional to force, the same argument holds.

Question 34.16

the incoming waves impart excitations of elections in the antenna to mimic the E-field of the wave; these excitations constitute vibrations in the elections that match the EM wave according to amplitude (AM) or frequency (FM) to transmit a copy of the signal to your receiver almost exactly.

Problem 34.3

using the new version of Ampere's law:

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

where

$$\frac{d\Phi_E}{dt} = A \frac{dE}{dt}$$

note A is the area of the smaller circle because the field is zero in the rest of the bigger circle. we do, though, use the larger radius for the path in the loop integral since that is where we need the field strength:

$$B(2\pi R) = \mu_0 \epsilon_0 \pi \left(\frac{d}{2}\right)^2 \frac{dE}{dt}$$

$$\Rightarrow B = \frac{\mu_0 \epsilon_0}{8R} d^2 \frac{dE}{dt} = \frac{(4\pi \times 10^{-7})(8.85 \times 10^{-12})(0.10\,m)^2 (20.0\,V/m \cdot s)}{8(0.15\,m)}$$

$$B = 1.85 \times 10^{-18}\,T$$

flux change is out of page for a (+) rate of change, so B is CCW by RHR, and is therefore upward at P.

Problem 34.7

(a) $d = ct \Rightarrow t = \frac{d}{c} = \frac{6.44 \times 10^{18}\,m}{3.0 \times 10^8\,m/s} = 2.15 \times 10^{10}\,s$

this is $2.15 \times 10^{10}\,s \left(\frac{hr}{3600\,s}\right)\left(\frac{day}{24\,hr}\right)\left(\frac{year}{365.25\,dy}\right) = 681$ years

so we would see it disappear in 2690 AD

(b) distance to the sun is $d = 1.496 \times 10^{11}\,m$

$\Rightarrow t = \frac{1.496 \times 10^{11}\,m}{3.00 \times 10^8\,m/s} = 499\,s = 8.31\,min$

(Prob 34.7) cont.

(c) distance to the moon $d = 3.84\times10^{8}\,m$ (384,000 km ≈ 240,000 mi).

$$t = \frac{2d}{c} = \frac{2(3.84\times10^{8}\,m)}{3.00\times10^{8}\,m/s} = 2.56\,s$$

(d) radius of earth is $6.37\times10^{6}\,m$

$$t = \frac{2\pi(6.37\times10^{6}\,m)}{3.0\times10^{8}\,m/s} = 0.133\,s$$

(e) $$t = \frac{1.0\times10^{4}\,m}{3.0\times10^{8}\,m/s} = 3.33\times10^{-5}\,s = 33.3\,\mu s$$

Problem 34.8

$$c' = \frac{1}{\sqrt{K\mu_0\epsilon_0}} \Rightarrow c_{water} = \left[1.78(4\pi\times10^{-7})(8.85\times10^{-12})\right]^{-1/2}$$

$$c_{water} = 2.25\times10^{8}\,m/s = 0.75\,c$$

Problem 34.9

(a) $$f = \frac{c}{\lambda} = \frac{3.0\times10^{8}\,m/s}{50.0\,m} = 6.0\times10^{6}/s = 6.0\,MHz$$

(b) traveling in $\hat{x}$-direction, $\vec{E}$ in $(-\hat{y})$ direction, RHR gives $\vec{B}$ in $(-\hat{z})$ direction

$$B_0 = \frac{E_0}{c} = \frac{22.0\,V/m}{3.0\times10^{-8}\,m/s} = 7.33\times10^{-8}\,T$$

$$\Rightarrow \vec{B}_0 = -73.3\,\hat{z}\,nT$$

(c) $$k = \frac{2\pi}{\lambda} = \frac{2\pi}{50.0\,m} = 0.126/m$$

$$\omega = 2\pi f = 2\pi(6.0\times10^{6}\,Hz) = 3.77\times10^{7}\,rad/s$$

$$\Rightarrow \vec{B} = \vec{B}_0\cos(kx-\omega t) = -73.3\cos(0.126x - 3.77\times10^{7}t)\,\hat{z}\,nT$$

Problem 34.12

$$E = E_0 \cos(kx - \omega t)$$

$$\Rightarrow \frac{\partial E}{\partial x} = -kE_0 \sin(kx - \omega t) \Rightarrow \frac{\partial^2 E}{\partial x^2} = -k^2 E_0 \cos(kx - \omega t)$$

and $$\frac{\partial E}{\partial t} = \omega E_0 \sin(kx - \omega t) \Rightarrow \frac{\partial^2 E}{\partial t^2} = -\omega^2 E_0 \cos(kx - \omega t)$$

now, $$\frac{\partial^2 E}{\partial x^2} = \mu_0 \epsilon_0 \frac{\partial^2 E}{\partial t^2} = \frac{1}{c^2} \frac{\partial^2 E}{\partial t^2}$$

recall that

$$c = \frac{\omega}{k} \Rightarrow \frac{1}{c^2} = \frac{k^2}{\omega^2}$$

plugging in:

$$\Rightarrow -k^2 E_0 \cos(kx - \omega t) = \frac{k^2}{\cancel{\omega^2}} \left(-\cancel{\omega^2} E_0 \cos(kx - \omega t)\right)$$

$\therefore$ The wave eqn is satisfied.

The proof for B is exactly the same.

Problem 34.15

we are given intensity I

we want energy per unit volume $u = \frac{U}{V}$

intensity is power per area $I = \frac{P}{A}$

so we are lacking a third dimension; we can get this (and get from power to energy) by using $P = \frac{E}{t}$ and $t = \frac{d}{v}$, where d is distance (which would be our depth we need) and $v = c$ is wave speed

$$\Rightarrow I = \frac{P}{A} = \frac{E}{At} = \frac{Ec}{Ad} = \frac{Ec}{Vol} \Rightarrow \frac{E}{V} = \frac{I}{c}$$

$$\frac{E}{V} = \frac{1.0 \times 10^3 \ W/m^2}{3.0 \times 10^8 \ m/s} = 3.33 \times 10^{-6} \ J/m^3$$

Problem 34.28

(a) use radiation pressure to get the force:

$$P = \frac{2S}{c} = \frac{2I}{c} \quad \text{(for reflective surface)}$$

$$P = \frac{2(1370\ W/m^2)}{3.0\times 10^8\ m/s} = 9.13\times 10^{-6}\ N/m^2$$

$$\Rightarrow F = PA = (9.13\times 10^{-6}\ N/m^2)(6.0\times 10^5\ m^2) = 5.48\,N$$

(b) from Newton's law:

$$a = \frac{F}{m} = \frac{5.48\,N}{6000\,kg} = 9.13\times 10^{-4}\ m/s^2$$

(c) using kinematics:

$$d = \frac{1}{2}at^2 \Rightarrow t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2(3.84\times 10^8\,m)}{9.13\times 10^{-4}\ m/s^2}}$$

$$t = 9.17\times 10^5\,s = 10.6 \text{ days}$$

so even with all the simplifications (which are major), this is very slow.