Physics 111 Homework Solutions Collected on Friday 2/13/15

Tuesday, February 10, 2015

Chapter 19

Questions

- none

Multiple-Choice

- none

Multiple-Choice

- none

Wednesday, February 11, 2015

Chapter 19

Questions

19.2 Electromagnetic waves and waves on a string are similar in that they both are transverse waves that travel with a speed that is dependent on the material through which the waves pass. They are different in that electromagnetic waves do not need a material to propagate unlike waves on a string.

19.3 See class notes for the solution

19.4 The intensity is the total amount of energy per unit time that flows across an area A. The Poynting vector gives the direction of the energy flow per unit time per unit area.

Multiple-Choice

19.1 D
19.2 D
19.3 C
19.4 D
19.7 B
19.8 B
19.9 C
19.10 C
19.14 D
19.15 B

Problems

19.1 The maximum electric and magnetic field amplitudes are related through $E_{\max} = cB_{\max} = 3\times10^{8}\,\tfrac{m}{s}\times2\times10^{-7}\,T = 60\,\tfrac{N}{C}$.

19.2. Since $E_{\max} = cB_{\max}$ then $B_{\max} = \frac{E_{\max}}{c} = \frac{2\times10^{-4}\ \frac{N}{C}}{3\times10^{8}\ \frac{m}{s}} = 6.67\times10^{-13}T$ in the z-direction.

19.3. The intensity is given as $I = \frac{cB^2}{2\mu_0} = \frac{\left(3\times10^{8}\ \frac{m}{s}\right)\left(5\times10^{-7}T\right)}{2\left(4\pi\times10^{-7}\ \frac{Tm}{A}\right)} = 29.8\frac{W}{m^2}$.

19.6 A vertically polarized beam of light is passed through a Polaroid with its transmission axis at 30° with respect to the vertical has $I_T = I_o\cos^2 30 = 0.75I_o = 75\%I_o$ transmitted. This transmitted beam is incident on a Polaroid whose transmission axis is aligned with the vertical. The transmitted intensity is given by the equation above with $I_T = 0.75I_o\cos^2 30 = 0.563I_o = 56.3\%I_o$.

19.7 Here we have unpolarized light passing through a Polaroid and this results in half of the light's intensity transmitted with and now the light is polarized with its axis along that of the Polaroid. Passing through the second Polaroid we have $I_T = 0.5I_o\cos^2 60 = 0.125I_o = 12.5\%I_o$. So the fraction of the initial unpolarized light passing the second Polaroid 12.5%.

19.8 For unpolarized light incident on the 1st polarizer, the intensity that emerges is ½ I_0. This light is incident on a 2nd polarizer oriented at 30°, so the intensity that emerges from the 2nd polarizer is $I_2 = \frac{1}{2}I_0\cos^2(30) = 0.375I_0$. This light is incident on a 3rd polarizer oriented also at 30°, so the intensity of the light that emerges is $I_3 = 0.375I_0\cos^2(30) = 0.281I_0 = 28.1\%I_0$. It is found that the intensity after the 3rd polarizer is *0.2 W/m²*, so the initial intensity of the beam is $I_3 = 0.281I_0 \rightarrow 0.2\frac{W}{m^2} = 0.281I_o \rightarrow I_o = 0.71\frac{W}{m^2}$.

19.10 The first polarizer transmits half of the incident intensity or 0.4 W/m^2. The second transmits $I_o\cos^2 45$ or another ½ of what is incident on it or 0.2 W/m^2. The final polarization direction is along the second polarizer transmission axis. If the two polarizers are reversed, the transmitted intensity does not change in this case, but the final polarization direction will be along the second polarizer's transmission axis again and will have changed.

19.11 The intensity is defined as the power radiated per unit area. Thus the intensity *4m* away in any direction from the light source is $\bar{I} = \frac{P}{A} = \frac{60W}{4\pi(4m)^2} = 0.298\,\frac{W}{m^2}$. The detector only occupies a small fraction of the total surface area of the sphere centered on the light source and further the detector is only 75% efficient. Thus the power at the detector is

$$P_D = 0.75\times\bar{I}A_D = 0.75\times 0.298\,\tfrac{W}{m^2}\left(10cm^2\times\frac{1m^2}{(100cm)^2}\right) = 2.2\times10^{-4}W$$

19.12 A 50,000 Watt radio station

a. The wavelength is given by $\lambda = \frac{c}{f} = \frac{3\times10^8\,\frac{m}{s}}{106.5\times10^6\,s^{-1}} = 2.8m$.

b. The intensity is defined as the power radiated per unit area. Thus the intensity *100m* away in any direction from the light source passing through the sphere centered on the radio source is $\bar{I} = \frac{P}{A} = \frac{50\times10^3 W}{4\pi(100m)^2} = 0.398\,\frac{W}{m^2}$. Passing through the detector area given at *100m* is $\bar{I} = \frac{P}{A} \to P = \bar{I}A = 0.398\,\frac{W}{m^2}\times1.0m^2 = 0.398W$.

c. The maximum electric field depends on the intensity through $I = \frac{1}{2}c\varepsilon_o E_{\max}^2 \to 0.398\,\frac{W}{m^2} = \frac{1}{2}\times3\times10^8\,\frac{m}{s}\times8.85\times10^{-12}\,\frac{C^2}{Nm^2}E_{\max}^2 \to E_{\max} = 17.3\,\frac{N}{C}$

d. The electric potential difference induced over the length of the wire is $E = \frac{\Delta V}{\Delta x} \to \Delta V = E_{\max}L = 17.3\,\frac{V}{m}\times1m = 17.3V$

19.15 The frequency is given as $f = \frac{c}{\lambda} = \frac{3\times10^8\,\frac{m}{s}}{5.5\times10^{-7}\,m} = 5.5\times10^{14}\,s^{-1}$.

19.16 The laser pointer is rated at *3mW* which is *3x10^{-3} J/s* and this energy (per second) is spread over the area of the beam spot. The area of the beam spot is $A = \pi r^2 = \pi(1\times10^{-3}m)^2 = 3.14\times10^{-6}m^2$. Thus the radiation pressure is

$$P = \frac{Power}{A\times c} = \frac{3\times10^{-3}\,\frac{J}{s}}{3.14\times10^{-6}m^2\times3\times10^8\,\frac{m}{s}} = 3.18\times10^{-6}\,\frac{N}{m^2}$$