Physics 111 Homework Solutions Week #7 - Wednesday

Friday, February 14, 2014

None due to exam 2.

Monday, February 17, 2014
Chapter 19
Questions

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.

19.10 The polarizer must be oriented with its transmission axis horizontal.

19.11 Starting with unpolarized light of intensity S_o and passing this light through a polarizer with its transmission axis oriented say vertically, transmits ½ of the initial intensity. This light is polarized vertically, say and when this light passes strikes the 2nd polarizer with its transmission axis at a 45^o to the vertical, the intensity that emerges is $S_{out} = S_{in}\cos^2\theta = \frac{S_0}{2}\cos^2 45 = \frac{S_0}{4}$

Multiple-Choice

19.7 B
19.8 B
19.9 C
19.10 C
19.14 D
19.15 B

Problems

19.6 A vertically polarized beam of light is passed through a Polaroid with its transmission axis at 30^o 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 $I_2 = \frac{1}{2} I_0 \cos^2(30) = 0.375 I_0$. This light is incident on a 3rd polarizer oriented also at 30°, so the intensity of the light that emerges is $I_3 = 0.375 I_0 \cos^2(30) = 0.281 I_0 = 28.1\% I_0$. It is found that the intensity after the 3rd polarizer is *0.2 W/m²*, so the initial intensity of the beam is $I_3 = 0.281 I_0 \rightarrow 0.2 \frac{W}{m^2} = 0.281 I_o \rightarrow I_o = 0.71 \frac{W}{m^2}$.

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

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

19.12 A 50,000 Watt radio station

a. The wavelength is given by $\lambda = \frac{c}{f} = \frac{3 \times 10^8 \frac{m}{s}}{106.5 \times 10^6 s^{-1}} = 2.8m$.

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 $\bar{I} = \frac{P}{A} = \frac{50 \times 10^3 W}{4\pi(100m)^2} = 0.398 \frac{W}{m^2}$. Passing through the detector area given at *100m* is $\bar{I} = \frac{P}{A} \rightarrow P = \bar{I} A = 0.398 \frac{W}{m^2} \times 1.0 m^2 = 0.398W$.

c. The maximum electric field depends on the intensity through
$I = \frac{1}{2} c \varepsilon_o E_{\max}^2 \rightarrow 0.398 \frac{W}{m^2} = \frac{1}{2} \times 3 \times 10^8 \frac{m}{s} \times 8.85 \times 10^{-12} \frac{C^2}{Nm^2} E_{\max}^2 \rightarrow E_{\max} = 17.3 \frac{N}{C}$

d. The electric potential difference induced over the length of the wire is
$E = \frac{\Delta V}{\Delta x} \rightarrow \Delta V = E_{\max} L = 17.3 \frac{V}{m} \times 1m = 17.3V$

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 $A = \pi r^2 = \pi (1 \times 10^{-3} m)^2 = 3.14 \times 10^{-6} m^2$. Thus the radiation pressure is

$$P = \frac{Power}{A \times c} = \frac{3 \times 10^{-3} \frac{J}{s}}{3.14 \times 10^{-6} m^2 \times 3 \times 10^8 \frac{m}{s}} = 3.18 \times 10^{-6} \frac{N}{m^2}$$