Homework-10

Chapter 24

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22. ***REASONING AND SOLUTION*** According to Equation 16.8, we have

$$S = \frac{P}{A} = \frac{P}{\pi r^2} = \frac{1.2 \times 10^{-3}\ \text{W}}{\pi \left(1.0 \times 10^{-3}\ \text{m}\right)^2} = \boxed{3.8 \times 10^2\ \text{W/m}^2}$$

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24. ***REASONING*** The relationship between the intensity *S* of an electromagnetic wave and its electric field *E* is given by Equation 24.5b as $S = c\varepsilon_0 E^2$. For example, if the magnitude of the electric field triples, the intensity increases by a factor of $3^2 = 9$.

The magnitude of the magnetic field is given by Equation 24.3 as $B = E / c$. Even though the magnitude of the magnetic field is much smaller than that of the electric field, tripling the magnetic field also causes the intensity to increase by a factor of $3^2 = 9$. This can be seen by examining Equation 24.5c, $S = \frac{c}{\mu_0} B^2$.

SOLUTION

a. When the magnitude of the electric field is 315 N/C, the intensity of the electromagnetic wave is

$$S = c\varepsilon_0 E^2 \qquad (24.5b)$$

$$= \left(3.00 \times 10^8\ \text{m/s}\right)\left[8.85 \times 10^{-12}\ \text{C}^2 / \left(\text{N} \cdot \text{m}^2\right)\right](315\ \text{N/C})^2 = \boxed{263\ \text{W/m}^2}$$

When the magnitude of the electric field is 945 N/C, the intensity of the electromagnetic wave is

$$S = c\varepsilon_0 E^2 = \left(3.00\times10^{8}\text{ m/s}\right)\left[8.85\times10^{-12}\text{ C}^2/\left(\text{N}\cdot\text{m}^2\right)\right]\left(945\text{ N/C}\right)^2 = \boxed{2370\text{ W/m}^2}$$

b. The magnitudes of the magnetic fields associated with each electric field are

$$B = \frac{E}{c} = \frac{315\text{ N/C}}{3.00\times10^{8}\text{ m/s}} = \boxed{1.05\times10^{-6}\text{ T}} \qquad (24.3)$$

$$B = \frac{E}{c} = \frac{945\text{ N/C}}{3.00\times10^{8}\text{ m/s}} = \boxed{3.15\times10^{-6}\text{ T}}$$

c. The intensities of the waves associated with each value of the magnetic field are

$$S = \frac{c}{\mu_0}B^2 = \frac{3.00\times10^{8}\text{ m/s}}{4\pi\times10^{-7}\text{ T}\cdot\text{m/A}}\left(1.05\times10^{-6}\text{ T}\right)^2 = \boxed{263\text{ W/m}^2} \qquad (24.5c)$$

$$S = \frac{c}{\mu_0}B^2 = \frac{3.00\times10^{8}\text{ m/s}}{4\pi\times10^{-7}\text{ T}\cdot\text{m/A}}\left(3.15\times10^{-6}\text{ T}\right)^2 = \boxed{2370\text{ W/m}^2}$$

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27. SSM ***REASONING AND SOLUTION*** The energy is equal to the power *P* multiplied by the time *t*. The power, on the other hand, is equal to product of the intensity *S* of the wave and the area *A* through which the wave passes.

$$\text{Energy} = P\,t = (SA)t = (1390\text{ W/m}^2)(25\text{ m}\times45\text{ m})(3600\text{ s}) = \boxed{5.6\times10^{9}\text{ J}}$$

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35. ***REASONING*** The Doppler effect for electromagnetic radiation is given by Equation 24.6;

$$f_o = f_s\left(1\pm\frac{v_{rel}}{c}\right) \qquad \text{if } v_{rel} << c$$

where f_o is the observed frequency, f_s is the frequency emitted by the source, and v_{rel} is the speed of the source relative to the observer. As discussed in the text, the plus sign applies when the source and the observer are moving toward one another, while the minus sign applies when they are moving apart. According to Equation 16.1, the wavelength of these waves is $\lambda = c/f$. Therefore, the Doppler shift can be written in terms of wavelengths:

$$\frac{1}{\lambda_o} = \frac{1}{\lambda_s}\left(1 \pm \frac{v_{rel}}{c}\right) \qquad \text{if } v_{rel} << c$$

SOLUTION

a. The wavelength λ_o of the light observed on earth is greater than the wavelength λ_s of the light when it is emitted from the distant galaxy (the source). Therefore, the frequency of the light observed on earth is less than the frequency of the light when it is emitted from the distant galaxy. Thus, the quantity in the brackets in Equation 24.6 must be less than one; it must be equal to $\left[1-(v_{rel}/c)\right]$. Since the minus sign applies, we can conclude that

$$\boxed{\text{the galaxy must be receding from the earth}}\ .$$

b. We can find the speed of the galaxy relative to the earth by solving the wavelength version of Equation 24.6 for v_{rel}:

$$v_{rel} = c\left(1-\frac{\lambda_s}{\lambda_o}\right) = (3.0\times10^8 \text{ m/s})\left(1-\frac{434.1 \text{ nm}}{438.6 \text{ nm}}\right) = \boxed{3.1\times10^6 \text{ m/s}}$$

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39. ***REASONING AND SOLUTION***

a. The polarizer reduces the intensity of the light by a factor of two or to $\boxed{0.55 \text{ W/m}^2}$.

b. The intensity of the light leaving the analyzer is given by Malus' law.

$$S = (0.55 \text{ W/m}^2) \cos^2 75° = \boxed{3.7\times10^{-2} \text{ W/m}^2}$$

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43. ***REASONING*** If the intensity of the unpolarized light is I_0, the intensity of the polarized light leaving the polarizer is $\frac{1}{2}I_0$. By Malus' law, the intensity of the light leaving the insert is $\frac{1}{2}I_0\cos^2\theta$. From the results of Conceptual Example 8, the intensity of light leaving the analyzer is $\frac{1}{2}I_0\cos^2\theta\sin^2\theta$.

SOLUTION The intensity *I* of light that reaches the photocell is

$$I = \tfrac{1}{2}I_o\cos^2\theta\,\sin^2\theta = \tfrac{1}{2}(150\ \text{W/m}^2)\cos^2 30.0^\circ\,\sin^2 30.0^\circ = \boxed{14\ \text{W/m}^2}$$

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44. ***REASONING***

Drawing A The transmission axes of the polarizer and analyzer are parallel to each other, so all the light transmitted by the polarizer is completely transmitted by the analyzer.

Drawing B The transmission axes of the polarizer and analyzer are perpendicular to each other, so no light is transmitted through the analyzer.

Drawing C The transmission axes of the polarizer and analyzer make an angle of 30.0° with respect to each other. Thus, some of the light transmitted by the polarizer, but not all, is transmitted through the analyzer.

Therefore, we expect the transmitted intensities to be in the following decreasing order (largest first): A, C, B.

SOLUTION Since the incident light is unpolarized, the average intensity $\overline{S}_1$ of the light transmitted by the polarizer is one-half the average intensity $\overline{S}_0$ of the incident light, or $\overline{S}_1 = \frac{1}{2}\overline{S}_0 = \frac{1}{2}\left(48\ \text{W/m}^2\right) = 24\ \text{W/m}^2$. The average intensity $\overline{S}_2$ of the light transmitted by the analyzer is given by Malus' law, Equation 24.7, as $\overline{S}_2 = \overline{S}_1\cos^2\theta$, where θ is the angle between the direction of polarization and the transmission axis. The average intensity of the transmitted beams for each of the three cases is

A $$\bar{S}_2 = \bar{S}_1 \cos^2\theta = \left(24\ \text{W/m}^2\right)\cos^2 0° = \boxed{24\ \text{W/m}^2}$$

B $$\bar{S}_2 = \bar{S}_1 \cos^2\theta = \left(24\ \text{W/m}^2\right)\cos^2 90° = \boxed{0\ \text{W/m}^2}$$

C $$\bar{S}_2 = \bar{S}_1 \cos^2\theta = \left(24\ \text{W/m}^2\right)\cos^2 \left(60.0° - 30.0°\right) = \boxed{18\ \text{W/m}^2}$$

Chapter 25

9. ***REASONING AND SOLUTION***

a. After the mirror has been rotated, the new angle of incidence is θ_i = 45° + 15° = 60°. The angle of reflection, then, is also equal to 60°. The reflected ray which was originally 90° (45° + 45°) from the original angle of incidence, is now 120° (60° + 60°) from the incident ray's direction. Therefore, the reflected ray has been rotated through

$$\beta = 120° - 90° = \boxed{30°}$$

b. The angle through which the reflected ray is rotated depends only on the angle through which the mirror is rotated, and is independent of the angle of incidence. Therefore, $\boxed{\beta' = 30°}$.
