HW 1 Solutions

Physics 262 Spring 2013

32.17 a Since 5% of the 75 W used by the light bulb is converted to visible light, the visible-light power is 0.05 (75 W) = 3.75 W. The diameter of the bulb is 6.0 cm, so its radius is 3.0 cm and surface area is $4\,\pi\,(3.0\,\mathrm{cm})^2$. Then the visible-light intensity at the surface of the bulb is $\frac{3.75\,\mathrm{W}}{4\,\pi\,(0.030\,\mathrm{m})^2} = \boxed{332\,\mathrm{W/m^2}}$.

b As long as we aren't in the glass itself, we can use equations for electromagnetic waves in vacuum, so assume we are looking at a surface just inside or just outside the glass. From Eq. 32.29, the intensity $I = \frac{1}{2}\,\epsilon_0\,c\,E_{\mathrm{max}}^2$, so

$$\begin{aligned}E_{\mathrm{max}} &= \sqrt{\frac{2\,I}{\epsilon_0\,c}} = \sqrt{\frac{2\,(332\,\mathrm{W/m^2})}{(8.854\times10^{-12}\,\mathrm{C^2/N\cdot m^2})\,(2.998\times10^{8}\,\mathrm{m/s})}}\\ &= \sqrt{250,100\,\frac{\mathrm{N}\cdot\cancel{\mathrm{m}}/\cancel{\mathrm{s}}}{\cancel{\mathrm{m}^2}}\cdot\frac{\mathrm{N}\cdot\cancel{\mathrm{m}^2}}{\mathrm{C}^2}\cdot\frac{\cancel{\mathrm{s}}}{\cancel{\mathrm{m}}}} = \boxed{500.\,\mathrm{N/C}}.\end{aligned}$$

Also, Eq. 32.18 tells us that, in vacuum,

$$B_{\mathrm{max}} = \frac{E_{\mathrm{max}}}{c} = \frac{250.\,\mathrm{N/C}}{3.00\times10^{8}\,\mathrm{m/s}} = \boxed{1.67\times10^{-6}\,\mathrm{T}} = 1.67\,\mu\mathrm{T}.$$

32.47 From Eqs. 32.32 and 32.33, the radiation pressure is $p_{\text{rad},1} = \frac{I}{c}$ on the absorbing square and $p_{\text{rad},2} = \frac{2I}{c}$ on the reflecting square. The force on the absorbing square is $F_{\text{rad},1} = p_{\text{rad},1}\, A = \frac{I}{c}\,(1.50\,\text{cm})^2$, and the force on the reflecting square is twice as much. Each square is 0.500 m from the axis, and the radiation force is perpendicular to the rod, so the torque due to the absorbing square is $\tau_{\text{rad},1} = F_{\text{rad},1}\,(0.500\,\text{m})$ and the torque due to the reflecting square is twice as much. The torques are in opposite directions, so

$$\begin{aligned}\tau_{\text{net}} &= (F_{\text{rad},2} - F_{\text{rad},1})\,(0.500\,\text{m}) = (p_{\text{rad},2} - p_{\text{rad},1})\,(1.50\,\text{cm})^2\,(0.500\,\text{m}) \\ &= \left(\frac{2I}{c} - \frac{I}{c}\right)(1.50\,\text{cm})^2\,(0.500\,\text{m}) = \frac{I}{c}\,(1.50\,\text{cm})^2\,(0.500\,\text{m}).\end{aligned}$$

From Eq. 32.29, $I = \frac{1}{2}\,\epsilon_0\, c\, E_{\text{max}}^2$, so $\tau_{\text{net}} = \frac{1}{2}\,\epsilon_0\, E_{\text{max}}^2\,(1.50\,\text{cm})^2\,(0.500\,\text{m})$. In order to find the angular acceleration, we also need the moment of inertia, which I'll write I_{inert}. The mass of the rod is negligible, so the moment of inertia comes only from the two squares: $I_{\text{inert}} = \sum_i m_i\, r_i^2 = 2\,(4.00\,\text{g})\,(0.500\,\text{m})^2$. Now the angular acceleration is

$$\begin{aligned}\alpha &= \frac{\tau_{\text{net}}}{I_{\text{inert}}} = \frac{\frac{1}{2}\,\epsilon_0\, E_{\text{max}}^2\,(1.50\,\text{cm})^2\,(0.5\cancel{0}0\,\text{m})}{2\,(4.00\,\text{g})\,(0.500\,\text{m})^{\cancel{2}}} \\ &= \frac{(8.854\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2)\,(1.25\,\text{N/C})^2\,(0.0150\,\text{m})^2}{4\,(4.00\times10^{-3}\,\text{kg})\,(0.500\,\text{m})} \\ &= 3.89\times10^{-13}\,\frac{\cancel{\text{C}}^2}{\cancel{\text{N}}\cdot\cancel{\text{m}}^2}\cdot\frac{\text{N}^{\cancel{2}}}{\cancel{\text{C}}^2}\cdot\frac{\cancel{\text{m}}^2}{\text{kg}\cdot\text{m}} \\ &= \boxed{3.89\times10^{-13}\,\text{rad/s}^2} = 6.19\times10^{-14}\,\text{rev/s}^2 = 2.23\times10^{-11}\,\text{deg/s}^2.\end{aligned}$$