Chapter 34 Problem 43 [†]

Solution

a) Find the rate of photon production for a 1.0 kW radio antenna transmitting at 89.5 MHz.

First find the energy per photon

$$E = hf = (6.63 \times 10^{-34}\ J \cdot s)(89.5 \times 10^{6}\ Hz) = 5.93 \times 10^{-26}\ J$$

Now use this value as a conversion factor between joules and photons. A watt is a joule per second. Therefore, the photon production rate is

$$P = 1.0\ kW = \frac{1000\ J}{s}\left(\frac{1\ photon}{5.93 \times 10^{-26}\ J}\right) = 1.69 \times 10^{28}\ photons/s$$

b) Find the rate of photon production for a 1.0 mW laser transmitting at 633 nm.

First find the energy per photon

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\ J \cdot s)(3.0 \times 10^{8}\ m/s)}{633 \times 10^{-9}\ m} = 3.14 \times 10^{-19}\ J$$

Now use this value as a conversion factor between joules and photons. The photon production rate is

$$P = 1.0\ mW = \frac{0.0010\ J}{s}\left(\frac{1\ photon}{3.14 \times 10^{-19}\ J}\right) = 3.18 \times 10^{15}\ photons/s$$

c) Find the rate of photon production for a 2.5 kW X-ray machine transmitting at 0.10 nm.

First find the energy per photon

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\ J \cdot s)(3.0 \times 10^{8}\ m/s)}{0.10 \times 10^{-9}\ m} = 1.99 \times 10^{-15}\ J$$

Now use this value as a conversion factor between joules and photons. The photon production rate is

$$P = 2.5\ kW = \frac{2500\ J}{s}\left(\frac{1\ photon}{1.99 \times 10^{-15}\ J}\right) = 1.26 \times 10^{18}\ photons/s$$

[†]Problem from Essential University Physics, Wolfson