Problem 1-11

Calculate the number of photons in a 2.00 mJ light pulse at (a) 1.06 μm, (b) 537 nm, and (c) 266 nm.

Solution

The energy of one photon is

$$E = h\nu = \frac{hc}{\lambda}.$$

Part (a)

If $\lambda = 1.06\ \mu$m, then

$$E = \frac{(6.626 \times 10^{-34}\ \text{J} \cdot \cancel{\text{s}})\left(299\,792\,458\ \frac{\text{m}}{\cancel{\text{s}}}\right)}{1.06\ \cancel{\mu\text{m}} \times \frac{1\ \text{m}}{10^6\ \cancel{\mu\text{m}}}} \approx 1.87 \times 10^{-19}\ \text{J}.$$

The number of photons in a 2.00 mJ light pulse is then

$$n \approx \frac{2.00\ \cancel{\text{m}}\text{J} \times \frac{1\ \text{J}}{1000\ \cancel{\text{m}}\text{J}}}{1.87 \times 10^{-19}\ \frac{\text{J}}{\text{photon}}} \approx 1.07 \times 10^{16}\ \text{photons}.$$

Part (b)

If $\lambda = 537$ nm, then

$$E = \frac{(6.626 \times 10^{-34}\ \text{J} \cdot \cancel{\text{s}})\left(299\,792\,458\ \frac{\text{m}}{\cancel{\text{s}}}\right)}{537\ \cancel{\text{nm}} \times \frac{1\ \text{m}}{10^9\ \cancel{\text{nm}}}} \approx 3.70 \times 10^{-19}\ \text{J}.$$

The number of photons in a 2.00 mJ light pulse is then

$$n \approx \frac{2.00\ \cancel{\text{m}}\text{J} \times \frac{1\ \text{J}}{1000\ \cancel{\text{m}}\text{J}}}{3.70 \times 10^{-19}\ \frac{\text{J}}{\text{photon}}} \approx 5.41 \times 10^{15}\ \text{photons}.$$

Part (c)

If $\lambda = 266$ nm, then

$$E = \frac{(6.626 \times 10^{-34}\ \text{J} \cdot \cancel{\text{s}})\left(299\,792\,458\ \frac{\text{m}}{\cancel{\text{s}}}\right)}{266\ \cancel{\text{nm}} \times \frac{1\ \text{m}}{10^9\ \cancel{\text{nm}}}} \approx 7.47 \times 10^{-19}\ \text{J}.$$

The number of photons in a 2.00 mJ light pulse is then

$$n \approx \frac{2.00\ \cancel{\text{m}}\text{J} \times \frac{1\ \text{J}}{1000\ \cancel{\text{m}}\text{J}}}{7.47 \times 10^{-19}\ \frac{\text{J}}{\text{photon}}} \approx 2.68 \times 10^{15}\ \text{photons}.$$