

15. (a) We assume all the power results in photon production at the wavelength $\lambda = 589 \text{ nm}$. Let R be the rate of photon production and E be the energy of a single photon. Then, $P = RE = Rhc/\lambda$, where $E = hf$ and $f = c/\lambda$ are used. Here h is the Planck constant, f is the frequency of the emitted light, and λ is its wavelength. Thus,

$$R = \frac{\lambda P}{hc} = \frac{(589 \times 10^{-9} \text{ m})(100 \text{ W})}{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})} = 2.96 \times 10^{20} \text{ photon/s} .$$

- (b) Let I be the photon flux a distance r from the source. Since photons are emitted uniformly in all directions, $R = 4\pi r^2 I$ and

$$r = \sqrt{\frac{R}{4\pi I}} = \sqrt{\frac{2.96 \times 10^{20} \text{ photon/s}}{4\pi(1.00 \times 10^4 \text{ photon/m}^2 \cdot \text{s})}} = 4.85 \times 10^7 \text{ m} .$$

- (c) The photon flux is

$$I = \frac{R}{4\pi r^2} = \frac{2.96 \times 10^{20} \text{ photon/s}}{4\pi(2.00 \text{ m})^2} = 5.89 \times 10^{18} \frac{\text{photon}}{\text{m}^2 \cdot \text{s}} .$$