38.4 **IDENTIFY** and **SET UP:** $P_{av} = \dfrac{\text{energy}}{t}$. $1\text{ eV} = 1.60\times10^{-19}\text{ J}$. For a photon, $E = hf = \dfrac{hc}{\lambda}$. $h = 6.63\times10^{-34}\text{ J}\cdot\text{s}$.

EXECUTE: **(a)** $\text{energy} = P_{av}t = (0.600\text{ W})(20.0\times10^{-3}\text{ s}) = 1.20\times10^{-2}\text{ J} = 7.5\times10^{16}\text{ eV}$

(b) $E = \dfrac{hc}{\lambda} = \dfrac{(6.63\times10^{-34}\text{ J}\cdot\text{s})(3.00\times10^{8}\text{ m/s})}{652\times10^{-9}\text{ m}} = 3.05\times10^{-19}\text{ J} = 1.91\text{ eV}$

(c) The number of photons is the total energy in a pulse divided by the energy of one photon:

$\dfrac{1.20\times10^{-2}\text{ J}}{3.05\times10^{-19}\text{ J/photon}} = 3.93\times10^{16}\text{ photons}$.

EVALUATE: The number of photons in each pulse is very large.

38.43 **(a)** $H = Ae\sigma T^4$; $A = \pi r^2 l$

$$T = \left(\frac{H}{Ae\sigma}\right)^{1/4} = \left(\frac{100\text{ W}}{2\pi(0.20\times10^{-3}\text{ m})(0.30\text{ m})(0.26)(5.671\times10^{-8}\text{ W/m}^2\cdot\text{K}^4)}\right)^{1/4}$$

$T = 2.06\times10^{3}\text{ K}$

(b) $\lambda_m T = 2.90\times10^{-3}\text{ m}\cdot\text{K}$; $\lambda_m = 1410\text{ nm}$

Much of the emitted radiation is in the infrared.

38.48 **IDENTIFY:** Since the stars radiate as blackbodies, they obey the Stefan-Boltzmann law.

SET UP: The Stefan-Boltzmann law says that the intensity of the radiation is $I = \sigma T^4$, so the total radiated power is $P = \sigma A T^4$.

EXECUTE: **(a)** $I = \sigma T^4 = (5.67\times10^{-8}\text{ W/m}^2\cdot\text{K}^4)(24{,}000\text{ K})^4 = 1.9\times10^{10}\text{ W/m}^2$

(b) Wien's law gives $\lambda_m = (0.00290\text{ m}\cdot\text{K})/(24{,}000\text{ K}) = 1.2\times10^{-7}\text{ m} = 120\text{ nm}$

This is not visible since the wavelength is less than 400 nm.

(c) $P = AI \Rightarrow 4\pi R^2 = P/I = (1.00\times10^{25}\text{ W})/(1.9\times10^{10}\text{ W/m}^2)$

which gives $R_{Sirius} = 6.51\times10^6\text{ m} = 6510\text{ km}$.

$R_{Sirius}/R_{sun} = (6.51\times10^6\text{ m})/(6.96\times10^9\text{ m}) = 0.0093$, which gives

$$R_{Sirius} = 0.0093\,R_{sun} \approx 1\%\,R_{sun}$$

(d) Using the Stefan-Boltzmann law, we have

$$\frac{P_{sun}}{P_{Sirius}} = \frac{\sigma A_{sun}T_{sun}^4}{\sigma A_{Sirius}T_{Sirius}^4} = \frac{4\pi R_{sun}^2 T_{sun}^4}{4\pi R_{Sirius}^2 T_{Sirius}^4} = \left(\frac{R_{sun}}{R_{Sirius}}\right)^2\left(\frac{T_{sun}}{T_{Sirius}}\right)^4 \cdot \frac{P_{sun}}{P_{Sirius}} = \left(\frac{R_{sun}}{0.00935R_{sun}}\right)^2\left(\frac{5800\text{ K}}{24{,}000\text{ K}}\right)^4 = 39$$

EVALUATE: Even though the absolute surface temperature of Sirius B is about 4 times that of our sun, it radiates only 1/39 times as much energy per second as our sun because it is so small.

38.51 **IDENTIFY** and **SET UP:** Use $c = f\lambda$ to relate frequency and wavelength and use $E = hf$ to relate photon energy and frequency.

EXECUTE: **(a)** One photon dissociates one AgBr molecule, so we need to find the energy required to dissociate a single molecule. The problem states that it requires $1.00\times10^5\text{ J}$ to dissociate one mole of AgBr, and one mole contains Avogadro's number (6.02×10^{23}) of molecules, so the energy required to dissociate one AgBr is

$\dfrac{1.00\times10^5\text{ J/mol}}{6.02\times10^{23}\text{ molecules/mol}} = 1.66\times10^{-19}\text{ J/molecule}$.

The photon is to have this energy, so $E = 1.66\times10^{-19}\text{ J}(1\text{eV}/1.602\times10^{-19}\text{ J}) = 1.04\text{ eV}$.

(b) $E = \dfrac{hc}{\lambda}$ so $\lambda = \dfrac{hc}{E} = \dfrac{(6.626\times10^{-34}\text{ J}\cdot\text{s})(2.998\times10^8\text{ m/s})}{1.66\times10^{-19}\text{ J}} = 1.20\times10^{-6}\text{ m} = 1200\text{ nm}$

(c) $c = f\lambda$ so $f = \dfrac{c}{\lambda} = \dfrac{2.998\times10^8\text{ m/s}}{1.20\times10^{-6}\text{ m}} = 2.50\times10^{14}\text{ Hz}$

(d) $E = hf = (6.626\times10^{-34}\text{ J}\cdot\text{s})(100\times10^6\text{ Hz}) = 6.63\times10^{-26}\text{ J}$

$E = 6.63\times10^{-26}\text{ J}(1\text{ eV}/1.602\times10^{-19}\text{ J}) = 4.14\times10^{-7}\text{ eV}$

(e) EVALUATE: A photon with frequency $f = 100\text{ MHz}$ has too little energy, by a large factor, to dissociate a AgBr molecule. The photons in the visible light from a firefly do individually have enough energy to dissociate AgBr. The huge number of 100 MHz photons can't compensate for the fact that individually they have too little energy.

38.56. **IDENTIFY:** The photoelectric effect occurs, so the energy of the photon is used to eject an electron, with any excess energy going into kinetic energy of the electron.

SET UP: Conservation of energy gives $hf = hc/\lambda = K_{max} + \phi$.

EXECUTE: **(a)** Using $hc/\lambda = K_{max} + \phi$, we solve for the work function:

$$\phi = hc/\lambda - K_{max} = (4.136 \times 10^{-15}\ \text{eV} \cdot \text{s})(3.00 \times 10^{8}\ \text{m/s})/(124\ \text{nm}) - 4.16\ \text{eV} = 5.85\ \text{eV}$$

(b) The number N of photoelectrons per second is equal to the number of photons per second that strike the metal per second. $N \times$ (energy of a photon) = 2.50 W. $N(hc/\lambda) = 2.50$ W.

$N = (2.50\ \text{W})(124\ \text{nm})/[(6.626 \times 10^{-34}\ \text{J} \cdot \text{s})(3.00 \times 10^{8}\ \text{m/s})] = 1.56 \times 10^{18}$ electrons/s

(c) N is proportional to the power, so if the power is cut in half, so is N, which gives

$$N = (1.56 \times 10^{18}\ \text{el/s})/2 = 7.80 \times 10^{17}\ \text{el/s}$$

(d) If we cut the wavelength by half, the energy of each photon is doubled since $E = hc/\lambda$. To maintain the same power, the number of photons must be half of what they were in part (b), so N is cut in half to 7.80×10^{17} el/s. We could also see this from part (b), where N is proportional to λ. So if the wavelength is cut in half, so is N.

EVALUATE: In part (c), reducing the power does not reduce the maximum kinetic energy of the photons; it only reduces the number of ejected electrons. In part (d), reducing the wavelength *does* change the maximum kinetic energy of the photoelectrons because we have increased the energy of each photon.