49-1 Wien's Law

$\lambda_{max} T = 2898\ \mu m\text{-}K$

$$T = \frac{2898}{32} K = 90.6 K$$

49-6 $T = 273 + 500 = 773 K$

$$P = \underbrace{\varepsilon}_{0.9} \underbrace{I(T)}_{\sigma T^4} \underbrace{A}_{\text{area}}$$

$$= 0.9 \cdot \left(5.67 \cdot 10^{-8} \frac{W}{m^2 \cancel{K^4}} \cdot 773^4 \cancel{K^4}\right) \cdot 0.5 m^2$$

$P = 9{,}110\ W \simeq 9.1\ kW$

seems a fair amount higher than a light bulb (≈ few hundred Watts) which seems right

49-12 $I(T) = \sigma T^4$

(a) $\Delta I = 4 \sigma T^3 \Delta T$

$$\frac{\Delta I}{I} = 4 \cdot \frac{\Delta T}{T}$$

(b) $$\frac{\Delta I}{I} = 4 \cdot \frac{1.3}{273 + 34} = 0.017 \simeq 1.7\%$$

49-17

(a) $R(\lambda) = \dfrac{2\pi c^2 h}{\lambda^5} \dfrac{1}{e^{hc/\lambda kT} - 1}$

$x = \dfrac{hc}{\lambda kT}$ $\quad \lambda = 0,\ x = \infty$
$\quad \lambda = \infty,\ x = 0$

$dx = -\dfrac{hc}{\lambda^2 kT} d\lambda$

or $d\lambda = -\dfrac{\lambda^2 kT}{hc} dx$

$R(\lambda)\, d\lambda = -\dfrac{2\pi c^{\cancel{2}} h}{\lambda^5} \times \dfrac{\lambda^2 kT}{\cancel{hc}} \dfrac{dx}{e^x - 1}$

$= -\dfrac{2\pi c kT}{\lambda^3} \dfrac{dx}{e^x - 1}$

$\dfrac{1}{\lambda} = \dfrac{kT}{hc} x$

$R(\lambda)\, d\lambda = -2\pi c kT \cdot \dfrac{(kT)^3}{(hc)^3} \dfrac{x^3 dx}{e^x - 1}$

$= -\dfrac{2\pi k^4}{h^3 c^2} T^4 \dfrac{x^3 dx}{e^x - 1}$

$\int_0^\infty R(\lambda)\, d\lambda = -\int_\infty^0 \dfrac{2\pi k^4}{h^3 c^2} T^4 \dfrac{x^3 dx}{e^x - 1}$

$= \dfrac{2\pi k^4}{h^3 c^2} T^4 \left[\int_0^\infty \dfrac{x^3 dx}{e^x - 1} = \dfrac{\pi^4}{15}\right]$

$$I(T) = \int_0^\infty R(\lambda)\,d\lambda = \left(\frac{2\pi^5 k^4}{15h^3c^2}\right)T^4$$

(b) $k = 1.38\cdot 10^{-23}\ \text{J/K}$

$h = 6.63\cdot 10^{-34}\ \text{J}\cdot\text{s}$

$c = 3.00\cdot 10^{8}\ \text{m/s}$

$$\sigma = \frac{2\pi^5 k^4}{15h^3c^2} = \frac{2\cdot\pi^5\cdot(1.38\cdot 10^{-23})^4}{15(6.63\cdot 10^{-34})^3(3\cdot 10^8)^2}\ \frac{\text{J}^4/\text{K}^4}{\text{J}^3\text{s}^3\frac{\text{m}^2}{\text{s}^2}}$$

$$\sigma = 5.64\cdot 10^{-8}\ \frac{\text{J}}{\text{s m}^2}\ \frac{1}{\text{K}^4}$$

$$\boxed{\sigma = 5.64\cdot 10^{-8}\ \frac{\text{W}}{\text{m}^2\text{K}^4}}$$ close enough.

49-24 (a) $E_{int} = 3RT_E\left(\frac{1}{e^{T_E/T}-1}\right)$

$$= 3(8.31)\,290\ \frac{1}{e^{290/150}-1}$$

$$\boxed{E_{int} = 1644\ \frac{\text{J}}{\text{mole}}}$$

(b) $$\frac{dE_{int}}{dT} = 3RT_E\left\{-\left(\frac{1}{e^{T_E/T}-1}\right)^2 e^{T_E/T}\left(-\frac{T_E}{T^2}\right)\right\}$$

$$= 3R\left(\frac{T_E}{T}\right)^2 \frac{e^{T_E/T}}{(e^{T_E/T}-1)^2}$$

$$= 3\cdot(8.31)\left(\frac{290}{150}\right)^2 \times \frac{e^{290/150}}{(e^{290/150}-1)^2}$$

$$\boxed{\frac{dE_{int}}{dT} = 18.4 \text{ J/K mole}}$$

49-28 $E = h\nu_0 = \frac{hc}{\lambda}$

$$\lambda = \frac{hc}{E} = \frac{4.14\cdot 10^{-15} \cancel{eV}\cdot s \cdot 3\cdot 10^{8} \frac{m}{s}}{0.6\ \cancel{eV}}$$

$$\boxed{\lambda = 2.07\ \mu m}$$

$\Rightarrow$ infrared. p. 872

49-34 $\phi = 5.32\,eV \leq h\nu_0$

h: $4.14\cdot 10^{-15}\,eV\cdot s$

$$\nu_0 \geq \frac{5.32\ eV}{4.14\cdot 10^{-15}\ eV\cdot s}$$

$$\nu_0 \geq 1.29\cdot 10^{15}\ \frac{1}{s}$$

$$\lambda_0 = \frac{c}{\nu_0} \leq 234\ nm,\ UV$$

$\boxed{49\text{-}38}$ $E = h\nu_0 = \dfrac{hc}{\lambda_0} = \dfrac{4.14 \cdot 10^{-15} \cdot 3 \cdot 10^{8}}{200 \cdot 10^{-9}}$

$= 6.21\,eV$

(a) Fastest... $T_{max} = E - \phi$

$T_{max} = 6.21 - 4.2$

$\boxed{T_{max} = 2.01\ eV}$

(b) Slowest... $\boxed{T_{min} = 0}$

(c) Stopping potential... $eV_0 = T_{max}$

$\boxed{V_0 = 2.01\,V}$

(d) Cutoff wavelength

$4.2\,eV\ \phi = h\nu_0 = \dfrac{hc}{\lambda_0}$

$\lambda_0 = \dfrac{hc}{4.2\,eV} = \dfrac{4.14 \cdot 10^{-15} \cdot 3 \cdot 10^{8}}{4.2}$

$\boxed{\lambda_0 = 296\ nm}$

$\boxed{49-46}$ $E = h\nu_0 = \frac{hc}{\lambda_0}$

$$\lambda_0 = \frac{hc}{E} = \frac{4.14 \cdot 10^{-15} \cdot 3 \cdot 10^8}{20 \cdot 10^3}$$

(a) $\boxed{\lambda_0 = 0.062 \text{ nm}}$

(b) p. 872 x-ray

(c) The "work function" for the standard photoelectric effect is more of a collective effect in the metal... here it is the atomic binding energy. But I'd still call it a photoelectric effect

$\boxed{49-52}$ Electron mc^2:

$$mc^2 = (9.11 \cdot 10^{-31} \text{kg})(3 \cdot 10^8 \tfrac{m}{s})^2$$

$$= 8.20 \cdot 10^{-14} \text{ Joules}$$

$1.6 \cdot 10^{-19}$ J/eV

$$mc^2 = \frac{8.20 \cdot 10^{-14} \text{ J}}{1.6 \cdot 10^{-19} \text{ J/eV}} = 512{,}000 \text{ eV}$$

(a) $E = h\nu_0$, $\nu_0 = \frac{E}{h} = \frac{512{,}000 \text{ eV}}{4.14 \cdot 10^{-15} \text{ eV} \cdot s}$

$\boxed{\nu_0 = 1.24 \cdot 10^{20} \text{ 1/s}}$

(b) $\lambda_0 = \frac{c}{\nu_0} = \frac{3 \cdot 10^8 \ m/s}{1.24 \cdot 10^{20} \ 1/s}$

$\boxed{\lambda_0 = 2.43 \cdot 10^{-12} \ m}$ (note = $\frac{hc}{mc^2}$ = compton wavelengh)

(c) $p = \frac{h}{\lambda_0}$

$= \frac{6.63 \cdot 10^{-34} \ \frac{kg \, m^2}{s^2} \cdot s}{2.43 \cdot 10^{-12} \ m}$

$\boxed{p = 2.74 \cdot 10^{-22} \ \frac{kg \, m}{s}}$

49-54

(a) $\frac{h}{mc} = \frac{hc}{mc^2} = \frac{4.14 \cdot 10^{-15} \ eV \cdot s \cdot 3 \cdot 10^8 \ \frac{m}{s}}{512{,}000 \ eV}$

$\boxed{\lambda_c = 2.43 \cdot 10^{-12} \ m}$

proton: $\frac{m_p}{m_e} = \frac{1.67 \cdot 10^{-27}}{9.11 \cdot 10^{-31}} = 1833$

$\boxed{\lambda_{cp} = \frac{1}{1833} \cdot \lambda_{ce} = 1.32 \cdot 10^{-15} \ m}$

(b) $E = h\nu_0 = \frac{hc}{\lambda_c} = \frac{4.14 \cdot 10^{-15} \cdot 3 \cdot 10^8}{2.43 \cdot 10^{-12}}$

electron $\boxed{E = 512{,}000 \ eV}$

proton: $= 1833 \cdot 512{,}000$ eV

$$\boxed{E = 939 \cdot 10^{6}\ eV}$$

(c) $\lambda = \frac{h}{mc}$

$$E = h\nu = \frac{hc}{\lambda} = \frac{\cancel{h}c}{\left(\frac{\cancel{h}}{mc}\right)}$$

$$\boxed{E = mc^{2}}$$