8-3. $v_{rms} = \sqrt{\dfrac{3RT}{M}}$

(a) For O_2: $v_{rms} = \sqrt{\dfrac{3(8.31 J/K\ mol)(273K)}{32\times 10^{-3} kg/mol}} = 461 m/s$

(b) For H_2: $v_{rms} = \sqrt{\dfrac{3(8.31 J/K\ mol)(273K)}{2\times 10^{-3} kg/mol}} = 1840 m/s$

8-6. $\langle v^2 \rangle = \dfrac{1}{N}\int_0^\infty v^2 n\ v\ dv = 4\pi\left(\dfrac{m}{2\pi kT}\right)^{3/2}\int_0^\infty v^4 e^{-\lambda v^2} dv$ where $\lambda = m/2kT$

$\langle v^2 \rangle = 4\pi\left(\dfrac{m}{2\pi kT}\right)^{3/2} I_4$ where I_4 is given in Table B1-1.

$$I_4 = \frac{3}{8}\pi^{1/2}\lambda^{-5/2} = \frac{3}{8}\pi^{1/2}\ \ m/2kT^{\ -5/2}$$

$$\langle v^2 \rangle = 4\pi\left(\frac{m}{2\pi kT}\right)^{3/2}\left(\frac{3}{8}\right)\pi^{1/2}\left(\frac{2kT}{m}\right)^{5/2} = \frac{3kT}{m} = \frac{3RT}{mN_A} = \frac{3RT}{M}$$

$$v_{rms} = \sqrt{\langle v^2 \rangle} = \sqrt{\frac{3RT}{M}}$$

8-9. $n\ v\ dv = 4\pi N\left(\dfrac{m}{2\pi kT}\right)^{3/2} v^2 e^{-mv^2/2kT} dv$ (Equation 8-8)

$\dfrac{dn}{dv} = A\left[v^2\left(-\dfrac{2vm}{2kT}\right) + 2v\right]e^{-mv^2/2kT}$ The v for which $dn/dv = 0$ is v_m.

$$A\left[-\frac{2mv^3}{2kT} + 2v\right]e^{-mv^2/2kT} = 0$$

Because A = constant and the exponential term is only zero for $v \to \infty$, only the quantity in [] can be zero, so $-\dfrac{2mv^3}{2kT} + 2v = 0$

or $v^2 = \dfrac{2kT}{m} \to v_m = \sqrt{\dfrac{2kT}{m}}$ (Equation 8-9)

8-42. (a) $f(u)\,du = Ce^{-E/kT}du = Ce^{-Au^2/kT}du$ (from Equation 8-5)

$$1 = \int_{-\infty}^{+\infty} f(u)\,du = \int_{-\infty}^{+\infty} Ce^{-Au^2/kT}du = 2C\int_{-\infty}^{+\infty} e^{-Au^2/kT}du$$

$$= 2CI_0 = 2C\sqrt{\pi}\,\lambda^{-1/2}/2 \quad \text{where } \lambda = A/kT$$

$$= C\sqrt{\pi}\sqrt{kT/A} \rightarrow C = \sqrt{A/\pi kT}$$

(b) $$\langle E\rangle = \langle Au^2\rangle = \int_{-\infty}^{+\infty} Au^2 f(u)\,du = \int_{-\infty}^{+\infty} Au^2\sqrt{A/\pi kT}\,e^{-Au^2/kT}du$$

$$= A\sqrt{A/\pi kT}\,(2I_2) = A\sqrt{A/\pi kT}\,2\times\left(\sqrt{\pi}/4\right)\lambda^{-3/2} \quad \text{where } \lambda = A/kT$$

$$= \frac{1}{2}A\sqrt{A/kT}\,(kT/A)^{3/2} = \frac{1}{2}kT$$

3-5. (a) $$R = \frac{mu}{qB} = \frac{\left[(2E_k/e)(e/m)\right]^{1/2}}{(e/m)(B)}$$

$$= \frac{1}{B}\sqrt{\frac{2E_k/e}{e/m}} = \frac{1}{0.325T}\left[\frac{(2)(4.5\times10^4 eV/e)}{1.76\times10^{11}kg}\right]^{1/2} = 2.2\times10^{-3}m = 2.2mm$$

(b)

frequency $$f = \frac{u}{2\pi R} = \frac{\sqrt{(2E_k/e)(e/m)}}{2\pi R}$$

$$= \frac{\left[(2)(4.5\times10^4 eV/e)(1.76\times10^{11}C/kg)\right]^{1/2}}{2\pi(2.2\times10^{-3}m)} = 9.1\times10^9 Hz$$

period $T = 1/f = 1.1\times10^{-10}s$

3-6. (a) $1/2mu^2 = E_k$, so $u = \sqrt{(2E_k/e)(e/m)}$

$$\therefore \quad u = \left[(2)(2000eV/e)(1.76\times10^{11}C/kg)\right]^{1/2} = 2.65\times10^7 m/s$$

(b) $$\Delta t_1 = \frac{x_1}{u} = \frac{0.05m}{2.65\times10^7 m/s} = 1.89\times10^{-9}s = 1.89ns$$

(c) $mu_y = F\Delta t_1 = e\mathcal{E}\Delta t_1$

$\therefore \quad u_y = (e/m)\mathcal{E}\Delta t_1 = (1.76\times10^{11}C/kg)(3.33\times10^{3}V/m)(1.89\times10^{-9}s) = 1.11\times10^{6}m/s$

3-12. $\lambda_m T = 2.898\times10^{-3}m\cdot K$

(a) $\lambda_m = \dfrac{2.898\times10^{-3}m\cdot K}{3K} = 9.66\times10^{-4}m = 0.966mm$

(b) $\lambda_m = \dfrac{2.898\times10^{-3}m\cdot K}{300K} = 9.66\times10^{-6}m = 9.66\mu m$

(c) $\lambda_m = \dfrac{2.898\times10^{-3}m\cdot K}{3000K} = 9.66\times10^{-7}m = 966nm$

3-13. Equation 3-4: $R = \sigma T^4$. Equation 3-6: $R = \frac{1}{4}cU$.

From Example 3-4: $U = (8\pi^5 k^4 T^4)/(15h^3c^2)$

$$\sigma = \frac{R}{T^4} = \frac{(1/4)cU}{T^4} = \frac{1}{4}c(8\pi^5k^4T^4)/(15h^3c^2T^4)$$

$$= \frac{2\pi^5(1.38\times10^{-23}J/K)^4}{15(6.63\times10^{-34}J\cdot s)^3(3.00\times10^8m/s)^2} = 5.67\times10^{-8}W/m^2K^4$$

3-14. Equation 3-18: $u(\lambda)=\dfrac{8\pi hc\lambda^{-5}}{e^{hc/\lambda kT}-1}$

$$u(f)df=u(\lambda)d\lambda \quad \therefore \quad u(f)=u(f)\frac{d\lambda}{df} \text{ Because } c=f\lambda, \quad \left|\frac{d\lambda}{df}\right|=c/f^2$$

$$u(f)=\frac{8\pi hc(f/c)^5}{e^{hf/kT}-1}\left(\frac{c}{f^2}\right)=\frac{8\pi f^2}{c^3}\frac{hf}{e^{hf/kT}-1}$$

3-15.

(a) $\lambda_m T=2.898\times10^{-3}m\cdot K \quad \therefore \quad \lambda_m=\dfrac{2.898\times10^{-3}m\cdot K}{2.7K}=1.07\times10^{-3}m=1.07mm$

(b) $c=f\lambda \quad \therefore \quad f=\dfrac{c}{\lambda_m}=\dfrac{3.00\times10^{8}m/s}{1.07\times10^{-3}m}=2.80\times10^{11}Hz$

(c) Equation 3-6:

$$R=\frac{1}{4}cU=\frac{c}{4}\left(8\pi^5k^4T^4/15h^3c^3\right)$$
$$=\frac{(3.00\times10^8m/s)(8\pi^5)(1.38\times10^{-23}J/K)^4(2.7)^4}{(4)(15)(6.63\times10^{-34}J\cdot s)^3(3.00\times10^8m/s)^3}=3.01\times10^{-6}\,W/m^2$$

Area of Earth: $A=4\pi r_E^2=4\pi\left(6.38\times10^6m\right)^2$

Total power $=RA=\left(3.01\times10^{-6}W/m^2\right)(4\pi)\left(6.38\times10^6m\right)^2=1.54\times10^9W$

3-16. $\lambda_m T=2.898\times10^{-3}m\cdot K$

(a) $T=\dfrac{2.898\times10^{-3}m\cdot K}{700\times10^{-9}m}=4140K$

(b) $T=\dfrac{2.898\times10^{-3}m\cdot K}{3\times10^{-2}m}=9.66\times10^{-2}K$

(c) $T=\dfrac{2.898\times10^{-3}m\cdot K}{3m}=9.66\times10^{-4}K$

3-17. Equation 3-4: $R_1 = \sigma T_1^4$ $\qquad R_2 = \sigma T_2^4 = \sigma(2T_1)^4 = 16\sigma T_1^4 = 16R_1$

3-18. (a) Equation 3-17: $\bar{E} = \dfrac{hc/\lambda}{e^{hc/\lambda kT} - 1} = \dfrac{hc/(10hc/kT)}{e^{(hc/kT)/(10hc/kT)} - 1} = \dfrac{0.1kT}{e^{0.1} - 1} = 0.951kT$

(b) $\bar{E} = \dfrac{hc/\lambda}{e^{hc/\lambda kT} - 1} = \dfrac{hc/(0.1hc/kT)}{e^{(hc/kT)/(0.1hc/kT)} - 1} = \dfrac{10kT}{e^{10} - 1} = 4.59\times10^{-4}kT$

Equipartition theorem predicts $\bar{E} = kT$. The long wavelength value is very close to kT, but the short wavelength value is much smaller than the classical prediction.

3-19. (a) $\lambda_m T = 2.898\times10^{-3} m\cdot K \quad \therefore \quad T_1 = \dfrac{2.898\times10^{-3} m\cdot K}{27.0\times10^{-6} m} = 107K$

$R_1 = \sigma T_1^4$ and $R_2 = \sigma T_2^4 = 2R_1 = 2\sigma T_1^4$

$\therefore \quad T_2^4 = 2T_1^4$ or $T_2 = 2^{1/4}T_1 = (2^{1/4})(107K) = 128K$

(b) $\lambda_m = \dfrac{2.898\times10^{-3} m\cdot K}{128K} = 23\times10^{-6} m$

3-26. (a) $\lambda_t = \dfrac{hc}{\phi} = \dfrac{1240eV\cdot nm}{1.9ev} = 653nm, \quad f_t = \dfrac{\phi}{h} = \dfrac{1.9eV}{4.136\times10^{-15} eV\cdot s} = 4.59\times10^4 Hz$

(b) $V_0 = \dfrac{1}{e}\left(\dfrac{hc}{\lambda} - \phi\right) = \dfrac{1}{e}\left(\dfrac{1240eV\cdot nm}{300nm} - 1.9eV\right) = 2.23V$

(c) $V_0 = \dfrac{1}{e}\left(\dfrac{hc}{\lambda} - \phi\right) = \dfrac{1}{e}\left(\dfrac{1240eV\cdot nm}{400nm} - 1.9eV\right) = 1.20V$

3-27. (a) Choose λ =550nm for visible light. $nhf = E \rightarrow \frac{dn}{dt}hf = \frac{dE}{dt} = P$

$$\frac{dn}{dt} = \frac{P}{hf} = \frac{P\lambda}{hc} = \frac{(0.05\times 100W)(550\times 10^{-9}m)}{(6.63\times 10^{-34}J\cdot s)(3.00\times 10^{8}m/s)} = 1.38\times 10^{19}/s$$

(b) $$flux = \frac{number\ \ radiated\ /\ unit\ time}{area\ of\ the\ sphere} = \frac{1.38\times 10^{19}/s}{4\pi(2m)^2} = 2.75\times 10^{17}/m^2\cdot s$$

3-28. (a) $hf = \phi \quad \therefore \quad f_t = \frac{\phi}{h} = \frac{4.22eV}{4.14\times 10^{-15}eV\cdot s} = 1.02\times 10^{15}Hz$

(b) $f = c/\lambda = \frac{3.00\times 10^{8}m/s}{560\times 10^{-9}m} = 5.36\times 10^{14}Hz$ No.

Available energy/photon $hf = (4.14\times 10^{-15}eV\cdot s)(5.36\times 10^{14}Hz) = 2.22eV$.

This is less than ϕ.

3-32. (a) $\phi = \frac{hc}{\lambda} = \frac{1240eV\ nm}{653nm} = 1.90eV$

(b) $E_k = \frac{hc}{\lambda} - \phi = \frac{1240eV\ nm}{300nm} - 1.90eV = 2.23eV$