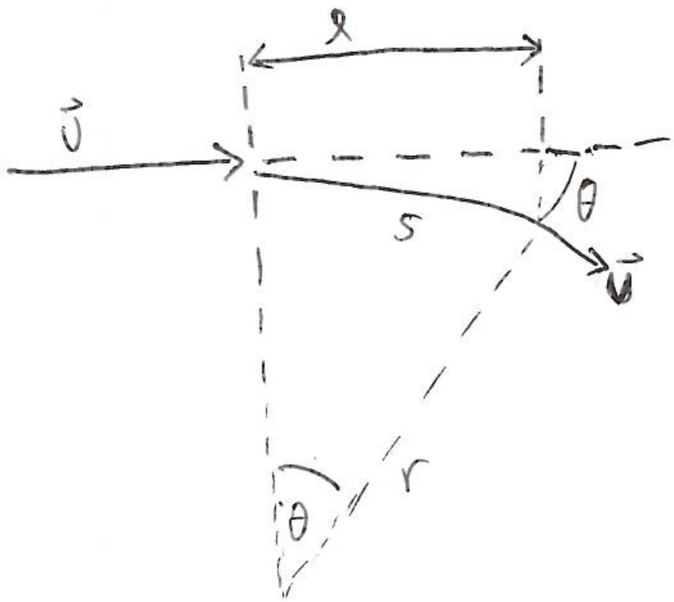
# MODERN PHYSICS

## HOMEWORK 3 SOLUTION

3-2




For small values of $\theta$, $s \approx \ell$

$$\theta = \frac{s}{r} = \frac{\ell}{r}$$

$$evB = \frac{mv^2}{r}$$

$$r = \frac{mv}{eB} \quad \therefore \theta \approx \frac{\ell}{mv/eB} = \frac{eB\ell}{mv}$$

3-6 (a) $E_k = \frac{1}{2} m v^2$

$$v = \sqrt{\frac{2E_k}{m}}$$

$$= \sqrt{\left(\frac{2E_k}{e}\right)\left(\frac{e}{m}\right)}$$

$$= \sqrt{(2)\,\frac{(2000\,eV)}{e}\,(1.76 \times 10^{11}\,C/kg)}$$

$$= 2.65 \times 10^{7}\,m/s$$

(b) $\Delta t = \frac{x}{v} = \frac{0.05\,m}{2.65 \times 10^{7}\,m/s} = 1.89 \times 10^{-9}\,s$

$$= 1.89\,ns$$

(c) $m v_y = F \Delta t = e E \Delta t$

$$v_y = \left(\frac{e}{m}\right) E \Delta t_1 = (1.76 \times 10^{11}\,C/kg)\,(3.33 \times 10^{3}\,V/m)\,(1.89 \times 10^{-9}\,s) = 1.11 \times 10^{6}\,m/s$$

3-8 $Q_1 - Q_2 = (25.41 - 20.64) \times 10^{-19} C$

$= 4.47 \times 10^{-19} C$

$= (n_1 - n_2)e$

$Q_2 - Q_3 = (20.64 - 17.47) \times 10^{-19} C$

$= 3.17 \times 10^{-19} C = (n_2 - n_3) e$

$Q_4 - Q_3 = (19.06 - 17.47) \times 10^{-19} C$

$= 1.59 \times 10^{-19} C = (n_4 - n_3) e$

$Q_4 - Q_5 = (19.06 - 12.70) \times 10^{-19} C$

$= 6.36 \times 10^{-19} C = (n_4 - n_5) e$

$Q_6 - Q_5 = (14.29 - 12.70) \times 10^{-19} C$

$= 1.59 \times 10^{-19} C = (n_6 - n_5) e$

where the $n_i$ are integers. Assuming the smallest $\Delta n = 1$, then $\Delta n_{12} = 3.0$, $\Delta n_{23} = 2.0$, $\Delta n_{43} = 1.0$ $\Delta n_{45} = 4.0$, and $\Delta n_{65} = 1.0$

The assumption is valid and the fundamental charge implied is $1.59 \times 10^{-19} C$

3-9 For the rise time to equal the field-free fall time, the net upward force must equal the weight.

$$qE - mg = mg$$

$$E = \frac{2mg}{q}$$

3-12 $\lambda_m T = 2.898 \times 10^{-3}$ m.K

(a) $\lambda_m = \dfrac{2.898 \times 10^{-3} \text{ mK}}{3 \text{ K}}$

$= 9.66 \times 10^{-4}$ m $= 0.966$ mm

(b) $\lambda_m = \dfrac{2.898 \times 10^{-3} \text{ mK}}{300 \text{ K}} = 9.66 \times 10^{-6}$ m

$= 9.66$ μm

(c) $\lambda_m = \dfrac{2.898 \times 10^{-3} \text{ mK}}{3000 \text{ K}} = 9.66 \times 10^{-7}$ m

$= 966$ nm

3-17 $R_1 = \sigma T_1^4$

$$T_2 = 2T_1$$

$$R_2 = \sigma T_2^4$$
$$= \sigma (2T_1)^4$$
$$= 16 \sigma T_1^4$$
$$= 16 R_1$$

3-18 (a) $$\bar{E} = \frac{hc/\lambda}{e^{hc/\lambda kT} - 1} = \frac{hc/(10hc/kT)}{e^{(hc/kT)/(10hc/kT)} - 1}$$

$$= \frac{0.1\,kT}{e^{0.1} - 1} = 0.951\,kT$$

(b) $$\bar{E} = \frac{hc/\lambda}{e^{hc/\lambda kT} - 1} = \frac{hc/(0.1\,hc/kT)}{e^{(hc/kT)/(0.1hc/kT)} - 1}$$

$$= \frac{10\,kT}{e^{10} - 1} = 4.59 \times 10^{-4}\,kT$$

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

3-31 $$E = n\frac{hc}{\lambda} = \frac{60\ (6.63\times10^{-34}\,J.s)\ (3.\times10^{8}\,m/s)}{550\times10^{-9}\,m}$$

$$= 2.17\times10^{-17}\,J$$

3-33 $$\lambda_2 - \lambda_1 = \Delta\lambda = \frac{h}{mc}(1-\cos\theta)$$

$$\Delta\lambda = \frac{(6.63\times10^{-34}\,J.s)\ (1-\cos(135^\circ))}{(9.11\times10^{-31}\,kg)\ (3.00\times10^{8}\,m/s)}$$

$$= 4.14\times10^{-12}\,m$$

$$= 4.14\times10^{-3}\,nm$$

$$\frac{\Delta\lambda}{\lambda_1}\times100 = \frac{4.14\times10^{-3}\,nm}{0.0711\,nm}\times100 = 5.8\%$$

3-42 (a) $eV_0 = hf - \phi$

$$= \frac{hc}{\lambda} - \phi$$

$$e(0.52\,V) = \left(\frac{hc}{450\,nm}\right) - \phi \quad \cdots \text{(i)}$$

$$e(1.90\,V) = \left(\frac{hc}{300\,nm}\right) - \phi \quad \cdots \text{(ii)}$$

Multiplying (i) by 450 nm/e and (ii) by 300nm/e,

then subtracting (ii) from (i) and rearranging gives:

$$\frac{\phi}{e} = \frac{[(300nm)(1.90V) - (450\,nm)(0.52V)]}{150\ nm} = 2.24\,eV$$

(b) $$\frac{hc}{e(300\ nm)} = 1.90 + 2.24$$

$$\rightarrow h = \frac{e\,(300 \times 10^{-9}\ m)\,(4.14\,V)}{(3.00 \times 10^{8}\ m/s)}$$

$$= 6.63 \times 10^{-34}\ J.s$$

3-47 Bragg condition: $m\lambda = 2d \sin\theta$

$$\lambda = (2)(0.28\ nm)(\sin 20°) = 1.92 \times 10^{-10} m$$
$$= 0.192\ nm$$

This is the minimum wavelength $\lambda_m$ that must be produced by the X ray tube.

$$\lambda_m = \frac{1.24 \times 10^3}{V}\ nm \quad \text{or} \quad V = \frac{1.24 \times 10^3}{0.192}$$
$$= 6.47 \times 10^3\ V$$
$$= 6.47\ kV$$

3-48 (a) $E = (100\ W)(10^4 s)$

$= (100\ J/s)(10^4 s) = 10^6\ J$

The momentum p absorbed is $p = \frac{E}{c}$

$$= \frac{10^6\ J}{(3.00 \times 10^8\ m/s)} = 3.33 \times 10^{-3}\ J.s/m$$

(b) $\Delta p = m(v_f - v_i) = (2 \times 10^{-3}\ kg)(v_f - 0)$

$= 3.3 \times 10^{-3}\ J\ s/m$

$$\therefore v = \frac{3.33 \times 10^{-3}\ J\ s/m}{2 \times 10^{-3}\ kg} = 1.67\ m/s$$

(c) $$E = \frac{1}{2} m v_f^2 = \frac{(2 \times 10^{-3}\ kg)(1.67\ m/s)^2}{2}$$

$= 2.78 \times 10^{-3}\ J$

The difference in energy has been used to increase the object's temperature and radiated into space by the blackbody.