Physics 2D　　Quiz 2 Solutions　　Winter 2011

Problem 1

(a) First find the temperature from Wien's law:

$$\lambda_m T = \frac{hc}{4.96 k_B} \; ; \; \lambda_m = 8{,}000\,\text{Å}, \; hc = 12{,}400\,\text{eVÅ}, \; k_B = \frac{1}{11{,}600}\frac{\text{eV}}{\text{K}}$$

$$T = \frac{hc}{\lambda_m \cdot 4.96 k_B} = \frac{12{,}400 \times 11{,}600}{8{,}000 \times 4.96}\,°\text{K} \Rightarrow \boxed{T = 3625°\text{K}}$$

$$P = e_{tot} \times \text{Area}, \quad e_{tot} = \sigma T^4 \Rightarrow \text{given that } P = 10\,\text{W}$$

$$\text{Area} = \frac{P}{\sigma T^4} = \frac{10\,\text{W}}{5.67\times10^{-8}\,\text{W}}\frac{\text{m}^2\,\text{K}^4}{3625^4\,\text{K}^4} = 1.02\times10^{-6}\,\text{m}^2 \Rightarrow$$

$$\boxed{\text{Area} = 1.02\,\text{mm}^2}$$

(b) V increases by factor of 2 ⇒ power dissipated increases by factor 4

$$\Rightarrow \sigma T'^4 = 4\sigma T^4 \Rightarrow T' = 4^{1/4} T = \sqrt{2}\,T$$

$$\Rightarrow \boxed{T' = 1.414\,T = 5126°\text{K}} \text{ is larger}$$

(c) The classical approximation is:

$$u_\lambda = \frac{8\pi}{\lambda^4}\frac{hc}{\lambda}\frac{1}{e^{hc/\lambda kT}-1} \longrightarrow \boxed{\frac{8\pi}{\lambda^4}} \quad \text{for } \frac{hc}{\lambda kT} \ll 1.$$

Here, for $T = 5126°\text{K}$, $\lambda = 200{,}000\,\text{Å}$, $\frac{hc}{\lambda kT} = 0.14$, quite small

⇒ use classical approximation. So if λ increases by factor of 2 (200,000 Å to 400,000 Å), power decreases by factor

$$\boxed{\text{of } 2^4 = 16}$$

Problem 2

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

Maximum kinetic energy results from smallest λ

$$\Rightarrow \quad 2eV = \frac{hc}{2{,}500\,A} - \phi \Rightarrow \phi = \frac{12{,}400}{2{,}500}\,eV - 2eV$$

$$\Rightarrow \boxed{\phi = 2.96\,eV}$$

(a) If minimum wavelength is $\lambda = 5000\,\mathring{A}$:

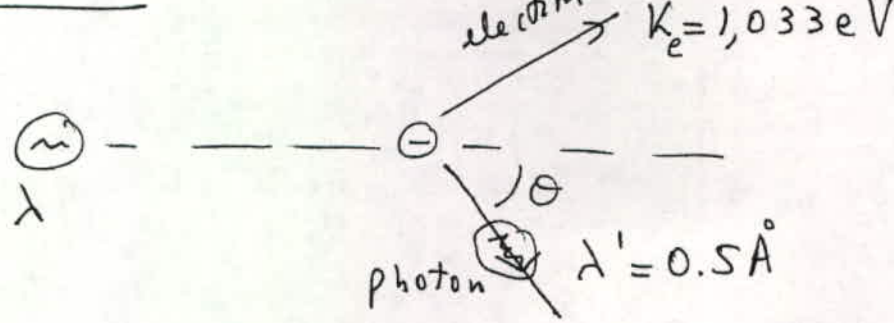
$$K_{max} = \frac{hc}{5{,}000\,\mathring{A}} - \phi = 2.48eV - 2.96\,eV < 0$$

This means that no electrons are emitted

(b) For light in the range $2{,}500\,\mathring{A}$ to $5{,}000\,\mathring{A}$, maximum kinetic energy is same as before, $\boxed{2eV}$

(c) $\boxed{\phi = 2.96\,eV}$

Problem 3



$E = \frac{hc}{\lambda}$, $E' = \frac{hc}{\lambda'}$ are energies of incident and scattered photons

$E_e = E - E' + m_e c^2$, or $K_e = E - E'$ by energy

conservation, with $K_e =$ electron kinetic energy $= 1033\,eV$

$$\Rightarrow E' = E' + K_e \Rightarrow \frac{hc}{\lambda'} = \frac{hc}{\lambda'} + K_e \Rightarrow \frac{1}{\lambda'} = \frac{1}{\lambda'} + \frac{K_e}{hc}$$

$$\Rightarrow \frac{1}{\lambda} = \frac{1}{0.5\,\mathring{A}} + \frac{1{,}033\,eV}{12{,}400\,eV\mathring{A}} = \frac{2.0833}{\mathring{A}} \Rightarrow \boxed{\lambda = 0.48\,\mathring{A}}$$

(b) $\lambda' - \lambda = \lambda_c(1 - \cos\theta) \Rightarrow 1 - \cos\theta = \frac{\lambda' - \lambda}{\lambda_c} \Rightarrow$

$$\cos\theta = 1 - \frac{\lambda' - \lambda}{\lambda_c} = 1 - \frac{0.02}{0.0243} = 0.17695 \Rightarrow$$

$$\Rightarrow \boxed{\theta = 79.8^\circ}$$

(c) Conservation of y-momentum $\Rightarrow p_{e,y} = p' \sin\theta$

with $p' = \frac{h}{\lambda'}$ = momentum of scattered photon $\Rightarrow$

$$p_{e,y} = \frac{h}{\lambda'} \sin\theta = \frac{hc}{c\lambda'} \sin\theta = \frac{12{,}400\,eV}{c \cdot 0.5} \cdot \sin(79.8^\circ) = 24{,}408\,\frac{eV}{c}$$

$$\boxed{p_{e,y} = 24{,}408\,eV/c}$$