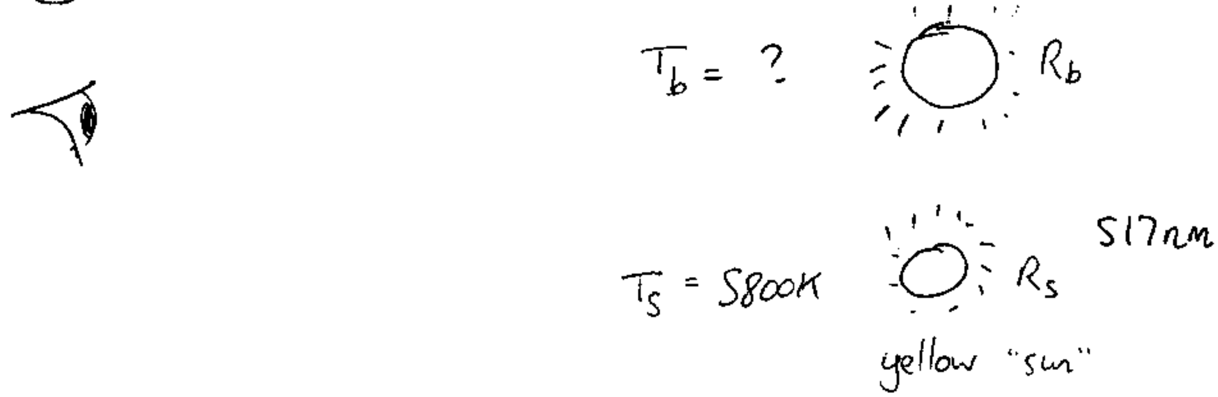
Physics 1C Quiz 4 Solutions

1.



a) From Wien's law, $\lambda_{max} T = \text{const.}$, i.e. $T \propto \frac{1}{\lambda_{max}}$

So $$\frac{T_b}{T_s} = \frac{(\lambda_{max})_s}{(\lambda_{max})_b} = \frac{517\,nm}{300\,nm}$$

$$\Rightarrow T_b = T_s \times \frac{517}{300} = 5800 \times \frac{517}{300} = \underline{9995.3\,K}$$

b) For each star, irradiance $I = \frac{P}{4\pi d^2}$, same distance d for both

and Stefan's law $\rightarrow$ power $P = A\sigma T^4 = 4\pi R^2 \sigma T^4$

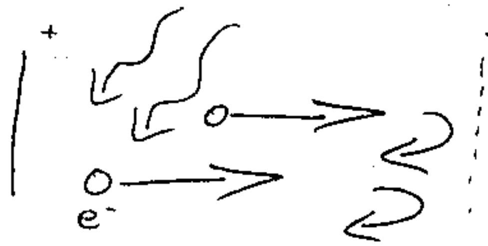
$$\therefore \text{ratio } \frac{I_b}{I_s} = \frac{P_b}{P_s} = \frac{\cancel{4\pi\sigma}\, R_b^2 T_b^4}{\cancel{4\pi\sigma}\, R_s^2 T_s^4} = 60 \text{ (given)}$$

$$\therefore \frac{R_b}{R_s} = \sqrt{60}\,\frac{T_s^2}{T_b^2}.$$

$$\frac{R_b}{R_s} = \sqrt{60} \times \left(\frac{9995.3K}{5800K}\right)^2 = 23.00$$

So the blue star has 23 times the radius of the sun.

2.



From energy conservation, E_{in} = work function + k.e.

$$hf = \frac{hc}{\lambda} = \frac{1}{2} m_e v^2 + \varphi$$

By definition, stopping potential $eV_s = \frac{1}{2} m_e v^2$

$$\frac{hc}{\lambda} = eV_s + \varphi$$

a) For $\lambda = 380\,nm$, find $V_s = 0.5\,V$

Photon energy $= \frac{hc}{\lambda}$ (J) $= \left(\frac{hc}{e}\right)\frac{1}{\lambda}$ (eV)

$$= \frac{1.2375 \times 10^{-6}}{380 \times 10^{-9}} = 3.2566\,eV$$

$\therefore$ Work function $\varphi = 3.2566\,eV - 0.5\,eV = 2.7566\,eV$
$(2.757\,eV)$.

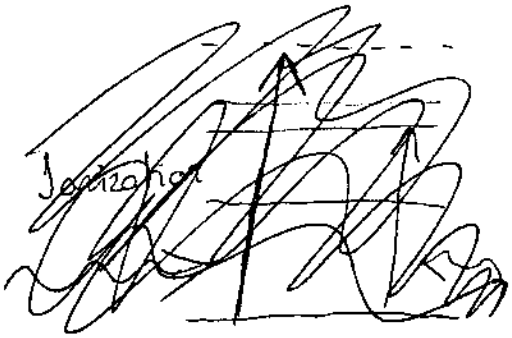
b) By definition, cutoff λ is where $V_s = 0$

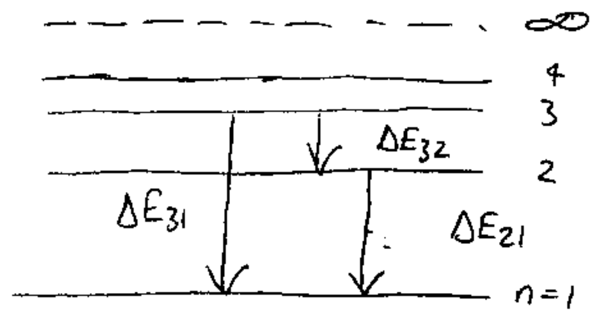
i.e. $\frac{hc}{\lambda_c} = \varphi \Rightarrow \lambda_c = \frac{hc}{\varphi}$

Here $\lambda_c = \frac{hc}{e \times 2.757} = \left(\frac{hc}{e}\right)\frac{1}{2.757}$

$$= 448.86\,nm$$

3 $\quad E_n = -13.6\,\text{eV}\,\dfrac{Z^2}{n^2}$





a) For $Z=2$, ionization energy $= |E_\infty - E_1|$ from ground state

$$= 13.6\,\text{eV} \times 2^2 = 54.4\,\text{eV}$$

b) For absorption $n=1$ to $n=3$, energy of photon

$$\Delta E = \frac{hc}{\lambda} = -13.6\,\text{eV} \times 2^2 \left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 48.355\,\text{eV}$$

$$\Rightarrow \text{wavelength } \lambda = \frac{hc}{(e \times 48.355)} = \frac{1.2375 \times 10^{-6}}{48.355\,\text{eV}} = 25.59$$

c) Emission lines from $n=3$ to $n=1$

$$\lambda_{3\to 1} = 25.59\,\text{nm}$$

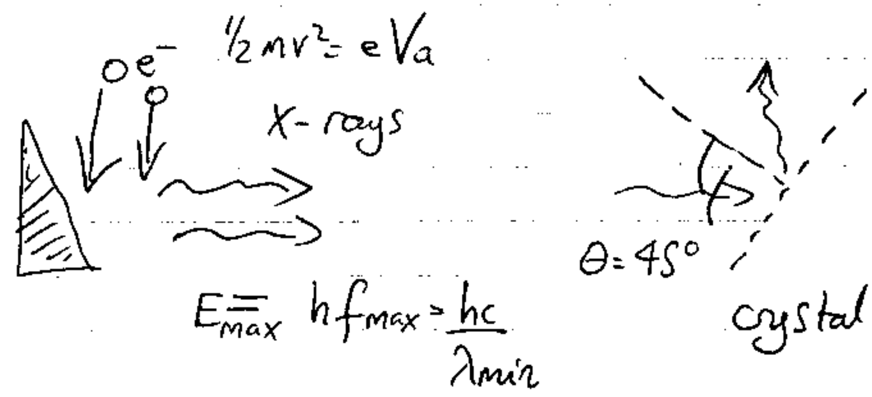
$\lambda_{3\to 2}$ given by $\Delta E_{32} = -13.6\,\text{eV} \times 2^2 \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

i.e. $\Delta E_{32} = 7.55\,\text{eV} \Rightarrow \lambda_{32} = 163.8\,\text{nm}$

followed by λ_{21} where $\Delta E_{21} = \dfrac{hc}{\lambda_{21}} = -13.6\,\text{eV} \times 2^2 \left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

$\Rightarrow \lambda_{21} = 30.33\,\text{nm}$

4.



a) Most energetic X-ray photons have E_{max} = K.e. of electron

$$\text{i.e. } \frac{hc}{\lambda_{min}} = \tfrac{1}{2}mv^2 = eV_a \quad \text{with } V_a = 22\times10^3\,V$$

$$\text{i.e. } \lambda_{min} = \frac{hc}{eV_a} = \frac{1.2375\times10^{-6}}{22\times10^3} = \underline{0.05625\,nm}$$

b) For Bragg diffraction

$$m\lambda = 2d\cos\theta \Rightarrow \lambda_m = \frac{2d\cos\theta}{m}$$

$$\text{i.e. } \lambda_m = \frac{2\times0.11\times\cos 45}{m} = \frac{0.1555\,nm}{m}$$

$$\left.\begin{aligned} m=1 &\Rightarrow \lambda_1 = 0.1555\,nm \\ m=2 &\Rightarrow \lambda_2 = \frac{0.1555}{2} = 0.0778\,nm \end{aligned}\right\} \text{present in input X-ray spectrum}$$

$m=3 \Rightarrow \lambda_3 = \frac{0.1555}{3} = 0.05185\,nm$, not present in X-ray spectrum ($\lambda > \lambda_{min} = 0.05625\,nm$)

So 2 X-ray wavelengths are produced at this angle.
(Can use a 2nd crystal to separate them).