PHAS1102 – Physics of the Universe

21st October 2009

Assignment 1 – Model answers

[marks]

1.

$$E = h\nu = h\frac{c}{\lambda} = 6.63\times10^{-34}\,\frac{3.0\times10^{8}}{663\times10^{-9}}J = 3.0\times10^{-19}J$$

$$= \frac{3.0\times10^{-19}}{1.6\times10^{-19}}eV = 1.9\,eV$$ 2

[2 marks total]

2. The star distance is d = 1/0.02” = 50 pc. 1

The distance modulus will be m – M = 5$\log_{10}$d – 5 = 8.5– 5 = 3.5 1

The absolute magnitude is M = m – 3.5 = 2.5 mag 1

[3 marks total]

3. If λ and λ_o are the observed and emitted wavelengths respectively:

$$\frac{\lambda-\lambda_0}{\lambda_0} = \frac{v}{c} \quad \text{and} \quad \lambda = \lambda_0\left(1+\frac{v}{c}\right)$$

Thus the observed wavelength will be

(i) λ = 660.0 x (1–150/3.0x10^5) nm = 659.7 nm (because the star is travelling towards us) 1

(ii) λ = 4340 x (1+350/3.0x10^5) Å = 4345 Å 1

[2 marks total]

4. In the lectures the formula to compute the H energy levels was given:

$E(n) = -13.6\frac{1}{n^2}$ eV, thus for n = 2 (the first excited level above the ground level with n=1) we have E(1) = – 3.4 eV. 1

Thus the photon must have an energy,

E = 3.4 eV = 3.4 x 1.6 x 10^{-19} J = 5.44 x 10^{-19} J 1

This corresponds to a frequency,

$$\nu = \frac{E}{h} = \frac{5.44\times10^{-19}}{6.63\times10^{-34}}\text{Hz} = 8.2\times10^{14}\,\text{Hz}$$ 1

and a wavelength

$$\lambda = \frac{ch}{E} = \frac{3\times10^{8}\times6.63\times10^{-34}}{5.44\times10^{-19}}\text{m} = 3.7\times10^{-7}\,\text{m} = 370\,\text{nm}$$ 1

[4 marks total]

5. Let’s set: T_A = *18,000 K*, T_B = *6,000 K*, R_A = *2* R_B

Applying the Stefan-Boltzmann law, the luminosity of star A will be

$$L_A \propto T_A^{\,4} R_A^{\,2}$$

and that of star B $L_B \propto T_B^{\,4} R_B^{\,2}$ 1

Thus $\frac{L_A}{L_B} = \frac{T_A^4 R_A^2}{T_B^4 R_B^2} = \left(\frac{18000}{6000}\right)^4 \times (2)^2 = 324$ 1

[2 marks total]

6. (i) $(B–V) = 0.92$ 1

(ii) $E(B–V) = (B–V) – (B–V)_0$

We can use the Sun's $(B\text{-}V)_o = 0.62$ in the equation, since the star is of the same spectral type. Therefore, $E(B–V) = 0.3$. 1

(iii) $A_V = 3.1\ E(B–V) = 0.93$ 1

(iv) To derive the distance we use the distance modulus equation, using the absolute magnitude of the Sun for $M_V = 4.82$ (assuming that all G2 stars have the same properties): 1

$m_V – M_V = 5 \log_{10} d – 5 + A_V$

$9.55 – 4.82 = 5 \log_{10} d – 5 + 0.93$

$5 \log_{10} d = 8.8$

$d = 57.5$ pc 1

[5 marks total]

7. Let be $m_1 = 6.0$ and $m_2 = 8.5$. Then, $m_1 – m_2 = – 2.5 \log_{10}(F_1/F_2)$.

$\log_{10}(F_1/F_2) = 1.0$, i.e. $F_1/F_2 = 10.0$ or $F_1 = 10\ F_2$ 1

Thus the combination of the two stars will produce a flux

$F_{sum} = (1+10) \times F_2$ 1

Hence, $m_{sum} – m_2 = – 2.5 \log_{10}(F_{sum}/F_2) = – 2.5 \log_{10}(11\ F_2/F_2)$ and

$m_{sum} = – 2.5 \log_{10}(11) + 8.5 = 5.9$ 1

[3 marks total]

8. $V_1 = V_2 = 7.5$ and $B_1 = 8.0$, $B_2 = 8.9$

Thus $(B–V)_1 = 0.5$ and $(B–V)_2 = 1.4$ 1

Star 1 is bluer, because its blue magnitude is smaller than for star 2. 1

[2 marks total]