

PHAS1102 – Physics of the Universe

Practice Problem Sheet 1 – solutions – Oct. 2011

1.

If λ and λ_0 are the observed and emitted wavelengths respectively:

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

Thus the observed wavelength will be

$$\lambda = 550 \times (0.99933) \text{ nm} = 549.63 \text{ nm} \quad \text{in the first case (the velocity is negative because the star is travelling towards us), and} \quad 1$$

$$\lambda = 397.0 \times 1.1 \text{ nm} = 436.70 \text{ nm} \quad \text{(positive velocity because away from us).} \quad 1$$

Similarly for the cloud of H:

$$\lambda = 21 \times 1.00033 \text{ cm} = 21.007 \text{ cm, and}$$

$$v = \frac{c}{\lambda} = \frac{300,000 \times 10^5}{21.007} \text{ Hz} = 1.428 \times 10^9 \text{ Hz} = 1428 \text{ MHz} \quad 1$$

[4 marks total]

2.

$$E = h\nu = h \frac{c}{\lambda} = 6.63 \times 10^{-34} \frac{300,000 \times 10^3}{600 \times 10^{-9}} \text{ J} = 3.32 \times 10^{-19} \text{ J} = \frac{3.32 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} = 2.1 \text{ eV} \quad 2$$

[2 marks total]

3.

The energy of level $n=3$ for a H atom is 12.1 eV (from diagram shown in lectures), while the ionisation potential is 13.6 eV, so the photon must be of 1.5 eV energy, which corresponds to a wavelength of 1

$$\lambda = h \frac{c}{E} = 6.63 \times 10^{-34} \frac{300,000 \times 10^3}{1.5 \times 1.6 \times 10^{-19}} \text{ m} = 8.3 \times 10^{-7} \text{ m} = 830 \text{ nm} \quad 1$$

This correspond to the Infrared band. 1

[3 marks total]

4.

Assuming the two stars emit as blackbodies and have the same radius, using the Stefan-Boltzmann law, we know that the total energy flux from the stars is proportional to their temperature to the 4th power. Thus: 1

$$\frac{F_{20000}}{F_{5000}} = \left(\frac{2 \times 10^4}{5 \times 10^3} \right)^4 = 256 \quad 1$$

so the hotter star is emitting over two orders of magnitude more energy.

Wien's displacement law gives the wavelength of the blackbody peak:

$$\lambda_{\max} \approx \frac{3000}{T} \mu\text{m} \quad 1$$

So the hotter star's spectrum peaks at 0.15 μm , or 1500 angstroms, i.e. in the UV, and the cooler star's spectrum at 0.6 μm , or 6000 angstroms, i.e. in the visible band. 2

[5 marks total]