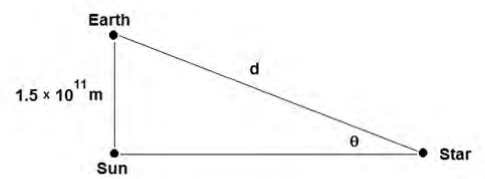
Question Number	Answer		Mark
1	Use of $\lambda_{max} T = 2.898 \times 10^{-3}$ m K T = 3400 (K) Use of $L = 4\pi r^2 \sigma T^4$ $r_B = 6.8 \times 10^{11}$ (m) [8.82×10^{11} m if T = 3000 K, 6.87×10^{11} m if T = 3400 K] r_B/r_S = 980 [1270 if T = 3000 K, 988 if T = 3400 K] <u>Example of calculation</u> $T = \frac{2.898 \times 10^{-3}\,\text{m K}}{850 \times 10^{-9}\,\text{m}} = 3410\,\text{K}$ $r_B = \sqrt{\frac{4.49 \times 10^{31}\,\text{W}}{4\pi \times 5.67 \times 10^{-8}\,\text{W m}^{-2}\text{K}^{-4} \times (3410\,\text{K})^4}} = 6.83 \times 10^{11}\,\text{m}$ $\frac{r_B}{r_S} = \frac{6.83 \times 10^{11}\,\text{m}}{6.95 \times 10^{8}\,\text{m}} = 983$	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	Total for question		**5**

Question Number	Answer		**Mark**
2	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate** Standard candles are (stellar) objects of known luminosity Standard candle's brightness on earth is measured/known/found [accept apparent magnitude or flux in place of brightness] [Do not accept 'used' in place of 'measured'] Use inverse square law [$F=L/4\pi d^2$] **Or** use distance modulus method [M – m = 5log(d/10)] (Hence) distance to standard candle is calculated Dust layer will reduce brightness /magnitude/flux of Cepheid Cepheid will appear to be further away than it is [accept "star" for "standard candle" or for "Cepheid" for MP2 to MP6]	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
	Total for question		**6**

Question Number	Answer		Mark
3(a)	Calculate gradient of line Identify gradient with H **Or** use of v = Hd for a point on the line Use of t = 1/H $t = 4.5 \times 10^{17}$ s (accept answers in range 4.2×10^{17} s to 4.8×10^{17} s) **Alternative method:** Pair of d, v values read from the line Values chosen from the upper end of the line Use of t = d/v $t = 4.5 \times 10^{17}$ s [$\pm 0.3 \times 10^{17}$ s] [$t = 1.4 \times 10^{10}$ yr [$\pm 0.1 \times 10^{10}$ yr] <u>Example of calculation</u> $H = \text{gradient} = \dfrac{(11000-0)\times 10^{3}\ \text{m s}^{-1}}{(50-0)\times 10^{23}\ \text{m}} = 2.2\times 10^{-18}\ \text{s}^{-1}$ $t = \dfrac{1}{H} = \dfrac{1}{2.2\times 10^{-18}\ \text{s}^{-1}} = 4.5\times 10^{17}\ \text{s}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **4**
3* (b)	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate** Measure wavelength of light (from the galaxy) Compare it to the wavelength for a source on the Earth Reference to spectral line **o**r line spectrum Reference to Doppler effect/shift **Or** redshift *v* is found from: fractional change in wavelength equals ratio of speed of source to speed of light **Or** see reference to $\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$ with terms defined **Or** see reference to $z = \dfrac{v}{c}$ with terms defined [accept answers in terms of frequency rather than wavelength]	 **(1)** **(1)** **(1)** **(1)** **(1)**	 **5**
3*(c)	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate** **Max 3** (Due to the) difficulty in making accurate measurements of distances to galaxies Hubble constant has a large uncertainty **Or** age = 1/H may not be valid as gravity is changing the expansion rate Because of the existence of dark matter Values of the (average) density/mass of the universe have a large uncertainty [accept not known] (Hence) measurements of the critical density of the Universe have a large uncertainty Dark energy may mean we don't understand gravity as well as we thought we did (so it's hard to predict how gravity will determine the ultimate fate)	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **3**
	Total for question		**12**

Question Number	Answer		Mark
***4 (a)**	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate **Process of fusion: Max 2** In nuclear fusion small <u>nuclei</u> fuse / join together to produce a larger <u>nucleus</u> Mass of the fused nucleus < total mass of initial nuclei (Energy is released as) $\Delta E = c^2 \Delta m$ **Or** B.E./nucleon increases (so energy is released) **Conditions: Max 3** A very high temperature To overcome the (electrostatic) repulsion between <u>nuclei</u> A (very) high pressure/density To maintain a high/sufficient collision rate **Difficult to replicate: Max 2** (Very high) temperatures lead to confinement problems Contact with container causes temperature to fall (and fusion to cease) Very strong magnetic fields are required	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**Max 6**
4 (b)	Idea that ^{56}Fe is the peak of the graph If nuclei were to be formed with A > 56, the B.E./nucleon would decrease This would require a net input of energy (and so does not occur)	**(1)** **(1)** **(1)**	**3**
4 (c)(i)	(A star/astronomical) object of known luminosity (due to some characteristic property of the star/object)	**(1)**	
4(c)(ii)	Use of $F = \frac{L}{4\pi d^2}$ Distance = 9.3×10^{24} m <u>Example of calculation</u> $d = \sqrt{\frac{2.0 \times 10^{36}\ \text{W}}{4\pi \times 10^{-15}\ \text{W m}^{-2}}} = 9.30 \times 10^{24}\ \text{m}$	**(1)** **(1)**	**2**
4(c)(iii)	The galaxy is receding / moving away from the Earth	**(1)**	
4(c)(iv)	Use of $Z=v/c$ Use of $v=\text{H}d$ Hubble constant = $2.1 \times 10^{-18}\ \text{s}^{-1}$ <u>Example of calculation</u> $v = Zc = 0.064 \times 3 \times 10^{8}\ \text{m s}^{-1} = 1.92 \times 10^{7}\ \text{m s}^{-1}$ $H = \frac{v}{d} = \frac{1.92 \times 10^{7}\ \text{m s}^{-1}}{9.30 \times 10^{24}\ \text{m}} = 2.06 \times 10^{-18}\ \text{s}^{-1}$	**(1)** **(1)** **(1)**	**3**
	Total for question		**16**

Question Number	Answer	Mark
5(a)	Object must have a standard/known luminosity OR luminous properties independent of its position (1) It can be used to calculate distances (1) Reference to any **two** of the following: ♦ Radiation/energy flux <u>measured</u> (1) ♦ Observed brightness compared with luminosity (1) ♦ Use of inverse square law [accept if equation quoted] (1) ♦ Object must be commonly found in the universe (1)	**Max 4**
5(b)	When star contracts (front of) star is moving away from observer OR explanation in terms of a rotating/binary star (1) Movement away from observer results in a decrease in the frequency of the radiation/red shift (1) Accept converse argument for an expanding star	**2**
	Total for question	**6**

Question Number	Answer		Mark
6(a)	**Max 6** The young star cluster consists (mainly) of main sequence stars The old star cluster has a truncated main sequence The old star cluster has lost its heaviest main sequence stars The old star cluster has (many) red giant stars The old star cluster has (some) white dwarf stars Massive main sequence stars are the first stars (to deplete sufficient hydrogen in their core) to evolve into red giant stars. Some red giant stars have evolved into white dwarf stars in the old cluster	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
6(b)(i)	Star A is closer to Earth than Star B	**(1)**	**1**
6(b)(ii)	 Use of appropriate trigonometric relationship $d = 4.0 \times 10^{16}$ m <u>Example of calculation:</u> $\sin\theta = \frac{1.5 \times 10^{11}\text{ m}}{d}$ $d = 4.01 \times 10^{16}$ m	**(1)** **(1)**	**2**
6(c)	$\lambda_{max} = 1.0 \times 10^{-6}$ m Use of $\lambda_{max} T = 2.9 \times 10^{-3}$ $T = 2900$ K <u>Example of calculation:</u> $T = 2.9 \times 10^{-3}$ m K/1.0×10^{-6} m = 2900 K	**(1)** **(1)** **(1)**	**3**
	Total for question		**12**