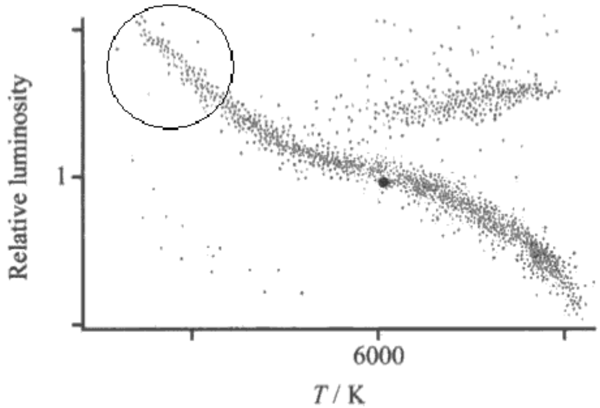
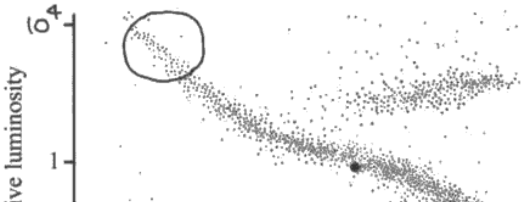
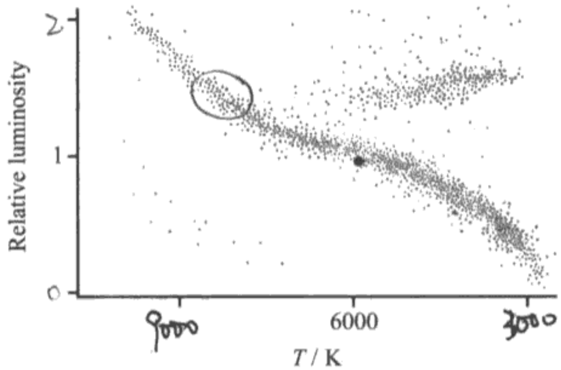
Question Number	Answer	Mark
1	Galaxies are receding **(1)** **O**r galaxies are moving away (from us and from each other) **(1)** **T**he greater the distance the greater the velocity **(1)** The universe is expanding	**3**
	Total for question	**3**

Question Number	Answer		Mark
2(a)	Luminosity scale: Log scale [$10^{3} \rightarrow 10^{6}$ (top) and $10^{-3} \rightarrow 10^{-6}$ (bottom)] Temperature scale: reverse log/power scale [e.g. 12,000 (left) and 3000 (right)]	**(1)** **(1)**	**2**
2(b)(i)	(Fusion of) hydrogen into helium [accept symbols]	**(1)**	
2(b)(ii)	Circle around stars top left of main sequence [included in the area indicated below]  **Max 2** They have the highest temperatures **Or** they are the most luminous [accept brightest] (Because) they fuse H (into He) at the highest/higher rate (Because) they have the largest/larger gravitational forces [Max 1 mark if no comparative]  Both scale marks and correct area identified  Neither scale mark and area too low	**(1)** **(1)** **(1)** **(1)**	**3**
	Total for question		**6**

Question Number	Answer	Mark
3(a)(i)	(A standard candle is) an object of known luminosity **(1)**	
3(a)(ii)	Flux/brightness/intensity of standard candle is measured **(1)** Inverse square law used (to calculate distance to standard candle) **(1)** [Reference to measurement of apparent magnitude of star, m, and distance calculated using $m - M = 5\log(d/10\text{ pc})$ can score 2 marks]	**2**
3(b)(i)	An increase in the wavelength (of radiation) received from a receding source **(1)** [accept in terms of a decrease in the frequency]	**1**
3(b)(ii)	Use of $z = v/c$ and $v = H_0 d$ [$z = H_0 d/c$] **(1)** $d = 1.7 \times 10^{25}$ m **(1)** <u>Example of calculation:</u> $v = zc = 0.12 \times 3{\times}10^{8}\text{ m s}^{-1} = 3.6 \times 10^{7}\text{ m s}^{-1}$ $d = v/H = 3.6 \times 10^{7}\text{ m s}^{-1}/2.1 \times 10^{-18}\text{ s}^{-1} = 1.71 \times 10^{25}\text{ m}$	**2**
***3(c**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 3** Dark matter has mass but does not emit e-m radiation [accept light] **(1)** (Dark matter proposed when) observations of galaxies indicated that they must contain more matter than could be seen. **(1)** The existence of dark matter will increase the (average) density of the universe **(1)** This may make it more likely that the universe is closed [accept will contract **Or** end with a "Big Crunch"] **(1)** **Or** Idea that this may make the ultimate fate of the Universe less certain	**3**
3(d)	**2** The universe started from a small initial point [accept Big Bang] **(1)** Idea that universe has a finite age **(1)** Idea that (observable universe is finite because) we can only see as far as (speed of light) × (age of universe) **Or** light reaching us must have travelled a finite distance since the Big Bang **Or** some parts of the universe are so distant, light has not had time to reach us yet **(1)**	**2**
	Total for question	**11**

Question Number	Answer		Mark
4(a)	Use of $F = \frac{G m_1 m_2}{r^2}$ G = 6.6 × 10^{-11} (N m^2 kg^{-2}) [must see 6.6 × 10^{-11} when rounded to 2 sf] <u>Example of calculation</u> $G = \frac{1.5\times10^{-7}\text{ N}\times(0.23\text{m})^2}{160\text{kg}\times0.75\text{kg}} = 6.61\times10^{-11}\text{ N m}^2\text{ kg}^{-2}$	(1) (1)	**2**
4(b)(i)	Read (peak) times from graph for at least 3 cycles T = 6.4 min (±0.2 min) [T = (380 ±12) s] [max 1 mark if correct answer shown without working] <u>Example of calculation</u> $T = \frac{(28.0-2.5)\text{min}}{4} = 6.38\text{min}$	(1) (1)	**2**
4(b)(ii)	Air resistance acts on the sphere [accept frictional forces **Or** (viscous) drag for air resistance] Energy is removed from the oscillation/system **Or** the oscillation/system is damped [For mp 2 do not credit 'energy is lost' but accept 'energy is dissipated'; answer must indicate idea of transfer of energy]	(1) (1)	**2**
4(b)(iii)	Evidence of values of at least 3 consecutive peaks read from graph [accept values of 3 points separated by equal time intervals] Attempt to obtain amplitudes, by subtracting 0.75 Calculation of two values of A_{n+1}/A_n with corresponding conclusion **Or** Calculation of two values of difference of ln A_{n+1} and ln A_n with corresponding conclusion **Or** Use peaks of graph to sketch curve Use curve to determine "half-life" [accept other ratio] Calculation of two values of "half-life" with corresponding conclusion <u>Example of calculation</u> A_0 = 1.45-0.75 = 0.7, A_1 = 0.75-0.25 = 0.5, A_2 = 1.1-0.75 = 0.35, A_4 = 0.75 – 0.5 = 0.2	(1) (1) (1) (1) (1) (1)	**3**

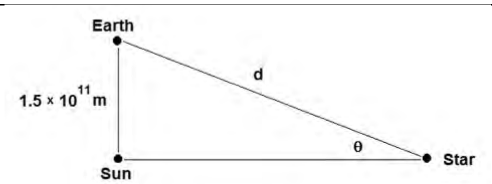
	$\frac{A_1}{A_0} = \frac{0.50}{0.70} = 0.71$ $\frac{A_2}{A_1} = \frac{0.35}{0.50} = 0.70$ $\frac{A_3}{A_2} = \frac{0.25}{0.35} = 0.71$	
	Total for question	**9**

Question Number	Answer		Mark
5(a)(i)	Reverse direction for temperature [at least 2 values seen] Logarithmic/power temperature variation [at least 3 realistic values seen increasing by the same factor]	(1) (1)	**2**
5(a)(ii)	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate **Area 1: Max 2** The Sun is fusing/burning hydrogen (into helium in its core) When (hydrogen) fusion/burning ceases the core of the Sun cools [accept radiation pressure drops when fusion/burning ceases in the core] The core collapses/contracts (under gravitational forces) **Area 2: Max 2** The Sun expands and becomes a red giant The core becomes hot enough for helium fusion/burning to begin (in the core) Helium begins to run out and the core collapses again (under gravitational forces) **Area 3: Max 2** Idea that outer layers of Sun are ejected into space The temperature doesn't rise enough for further fusion to begin The core/Sun becomes a (white) dwarf star	 (1) (1) (1) (1) (1) (1) (1) (1) (1)	**6**
5(b)(i)	Idea of a very high temperature [accept value of about 10^7 K] To overcome repulsive/electrostatic forces between protons/nuclei **Or** so that protons/nuclei get close enough together for the strong (nuclear) force to act **Or** so that protons/nuclei get close enough to fuse Idea of a very high density [accept pressure] to give a sufficient collision rate	(1) (1) (1)	**3**
5(b)(ii)	Attempt at calculation of mass deficit Use of $\Delta E = c^2 \Delta m$ Attempt at conversion from J to (M)eV $\Delta E = 12.9$ (MeV) [If correct mass defect in kg is converted into u and then 1u = 931 Mev used, then full marks may be awarded] <u>Example of calculation</u> $\Delta m = ((5.008238 \times 2) - 6.646483 - (1.673534 \times 2)) \times 10^{-27}$ kg	(1) (1) (1) (1)	**4**

PhysicsAndMathsTutor.com

	$\Delta m = 2.2925 \times 10^{-29}$ kg $\Delta E = (3.00 \times 10^{8}\,\text{ms}^{-1})^2 \times 2.2925 \times 10^{-29}\,\text{kg} = 2.063 \times 10^{-12}\,\text{J}$ $\Delta E = \dfrac{2.063 \times 10^{-12}\,\text{J}}{1.60 \times 10^{-13}\,\text{J MeV}^{-1}} = 12.9\,\text{MeV}$	
	Total for question	**15**

Question Number	Answer	Mark
6(a)(i)	16 μm [accept ±1μm] **(1)**	
6(a)(ii)	Use of $\lambda_{max} T = 2.898 \times 10^{-3}$ **(1)** Temperature = 180 K (ecf from (a)(i)) **(1)** [161 K for 18 μm, 170 K for 17 μm, 193 K for 15 μm, 207 K for 14 μm] <u>Example of calculation</u> $T = \dfrac{2.898 \times 10^{-3}\,\text{mK}}{16 \times 10^{-6}\,\text{m}} = 181\,\text{K}$	**2**
6(b)	Mass of the Sun **(1)** G **Or** gravitational constant **Or** 6.67×10^{-11} (N m^2 kg^{-2}) **(1)** [can be next to either answer prompt]	**2**
6(c)	Use of $g = \dfrac{GM}{r^2}$ **(1)** Field strength = 5.6×10^{-6} N kg^{-1} [accept m s^{-2}] **(1)** <u>Example of calculation</u> $g = \dfrac{6.67 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2} \times 1.9 \times 10^{27}\,\text{kg}}{(1.5 \times 10^{11}\,\text{m})^2} = 5.63 \times 10^{-6}\,\text{N kg}^{-1}$	**2**
	Total for question	**7**

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 Example of calculation: $\sin\theta = \frac{1.5\times10^{11}\,\text{m}}{d}$ $d = 4.01 \times 10^{16}$ 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 Example of calculation: $T = 2.9 \times 10^{-3}$ m K/1.0×10^{-6} m = 2900 K	**(1)** **(1)** **(1)**	**3**
	Total for question		**12**