PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 10: SPACE

ASTRONOMICAL DISTANCES AND STARS

SCORE	PERCENTAGE
/180	%

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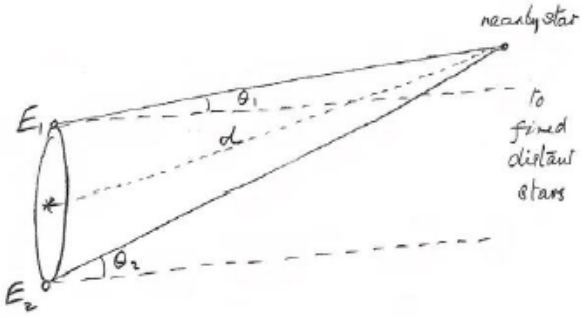
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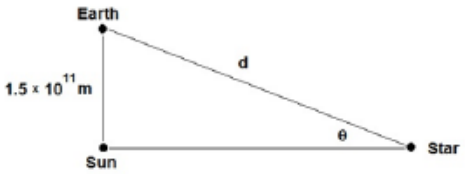
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Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• The star is viewed from two positions at 6 month intervals (1) **Or** The star is viewed from opposite ends of its orbit diameter about the Sun • The change in angle/position of the star against backdrop of fixed stars is measured (1) • Trigonometry is used to calculate the distance to the star [Do not accept Pythagoras] (1) **Or** The diameter/radius of the Earth's orbit about the Sun must be known	Marks may be obtained from suitably annotated diagrams e.g MP1 and MP2:  	3

Q2.

Question Number	Answer		Mark
(a)	**Max 6** The young star cluster consists (mainly) of main sequence stars	(1)	
	The old star cluster has a truncated main sequence	(1)	
	The old star cluster has lost its heaviest main sequence stars	(1)	
	The old star cluster has (many) red giant stars	(1)	
	The old star cluster has (some) white dwarf stars	(1)	
	Massive main sequence stars are the first stars (to deplete sufficient hydrogen in their core) to evolve into red giant stars.	(1)	
	Some red giant stars have evolved into white dwarf stars in the old cluster	(1)	**6**
(b)(i)	Star A is closer to Earth than Star B	(1)	**1**
(b)(ii)	 Use of appropriate trigonometric relationship	(1)	
	$d = 4.0 \times 10^{16}$ m	(1)	**2**
	Example of calculation: $\sin\theta = \frac{1.5\times10^{11}\text{m}}{d}$ $d = 4.01 \times 10^{16}$ m		

(c)	$\lambda_{max} = 1.0 \times 10^{-6}$ m	(1)	
	Use of $\lambda_{max} T = 2.9 \times 10^{-3}$	(1)	
	$T = 2900$ K	(1)	**3**
	Example of calculation: $T = 2.9 \times 10^{-3}$ m K/1.0×10^{-6} m = 2900 K		
	Total for question		**12**

Q3.

Question Number	Answer	Additional guidance	Mark
	D	(4*V*)	**(1)**

Q4.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is **C** because the correct method for a nearby star is parallax, for a nearby galaxy is standard candle and for a very distant galaxy is red shift A is not correct because only the nearby star method is correct B is not correct because only the nearby galaxy method is correct D is not correct because none of the methods are correct	1

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: **(1)** • Hubble is for cosmological distances **(1)** • is not suitable since S2 is in our galaxy **(1)** • trigonometrical parallax is suitable for local stars because the parallax angles produced are large enough to measure accurately	e.g. to distant galaxies	3

Q6.

Question Number	Acceptable answers	Additional guidance	
(a)	• Object of known luminosity **(1)**		1

Question Number	Acceptable answers	Additional guidance	
(b)	• The (parallax) angle becomes very small **(1)** **Or** the diameter of the Earth's orbit is very small • Giving a (very) large percentage uncertainty **(1)**		2

Question Number	Acceptable answers		Additional guidance	
(c)	• Measure change in wavelength / frequency	(1)		
	• Determine relative velocity using redshift formula	(1)		
	• Then apply $v = H_0 d$	(1)		3

Mark Scheme

Q1.

Question Number	Answers	Mark
	The only correct answer is B *A is incorrect because a red giant star has larger surface area but a lower surface temperature than the Sun* *C is incorrect because a red giant star has larger surface area but a lower surface temperature than the Sun* *D is incorrect because a red giant star has larger surface area but a lower surface temperature than the Sun*	1

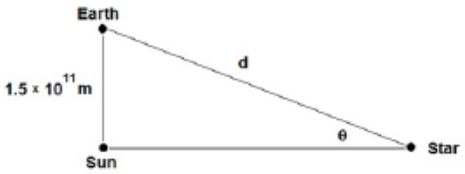
Q2.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is **C**: main sequence – red giant – white dwarf A is not correct because it is white dwarf – red giant – main sequence B is not correct because it moves along the main sequence from large to small D is not correct because it moves along the main sequence from small to large	**1**

Q3.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• use of $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • use of $F = Gm_1m_2/r^2$ **(1)** • Expresses forces as a ratio **(1)** **OR** calculates the individual forces $F_e = 8.1 \times 10^{-8}$ N $F_g =$ • 3.6×10^{-47} N **(1)** • Ratio = 2×10^{39} or 5×10^{-40} and identifies gravitational force as insignificant **(1)**		**4**
(ii)	• use of $F = mv^2/r$ and $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • to derive $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ **(1)** • velocity = 2.2×10^6 m s^{-1} **(1)**	Example of calculation: $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ $v = \sqrt{\frac{1.6\times10^{-19}\text{ C}\times1.6\times10^{-19}\text{ C}}{4\pi\times8.85^{-12}\text{ Fm}^{-1}\times5.3\times10^{-11}\text{m}\times9.1\times10^{-31}\text{ kg}}}$ $v = 2.185 \times 10^6$ m s^{-1}	**3**

Q4.

Question Number	Answer	Mark
(a)	**Max 6** The young star cluster consists (mainly) of main sequence stars (1) The old star cluster has a truncated main sequence (1) The old star cluster has lost its heaviest main sequence stars (1) The old star cluster has (many) red giant stars (1) The old star cluster has (some) white dwarf stars (1) Massive main sequence stars are the first stars (to deplete sufficient hydrogen in their core) to evolve into red giant stars. (1) Some red giant stars have evolved into white dwarf stars in the old cluster (1)	6
(b)(i)	Star A is closer to Earth than Star B (1)	1
(b)(ii)	 Use of appropriate trigonometric relationship (1) $d = 4.0 \times 10^{16}$ m (1) Example of calculation: $\sin\theta = \frac{1.5\times10^{11}\text{m}}{d}$ $d = 4.01 \times 10^{16}$ m	2

(c)	$\lambda_{max} = 1.0 \times 10^{-6}$ m (1) Use of $\lambda_{max} T = 2.9 \times 10^{-3}$ (1) $T = 2900$ K (1) Example of calculation: $T = 2.9 \times 10^{-3}$ m K/1.0×10^{-6} m = 2900 K	3
	Total for question	12

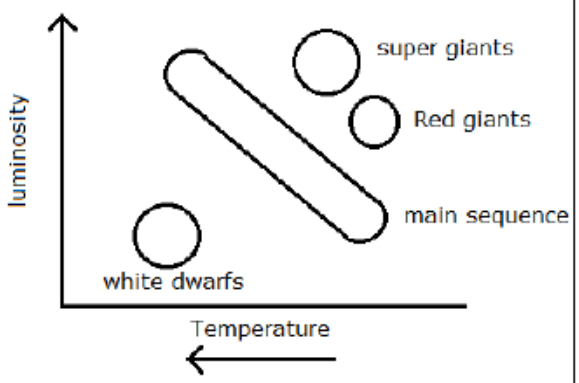
Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• All the stars are in the main sequence (1) • In an older cluster there would be red giant stars (1)		2
(ii)	**MAX 4** • The most massive stars experience much greater gravitational forces (1) • So core temperature and density is greatest (1) • The rate of fusion in the core is greatest (1) **Or** the power generated in the core is greatest (1) • The (surface) temperature is greatest • The surface area of these stars is greatest • So according to Stefan's Law the power radiated from these massive stars is greatest		4

Q6.

Question Number	Answer	Mark
	B – (point on graph with luminosity $\neq L_{\odot}$)	1
	Incorrect Answers: A – luminosity $\neq L_{\odot}$ C – luminosity $\neq L_{\odot}$ D – luminosity $\neq L_{\odot}$	

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• *y* axis: luminosity (/ luminosity of Sun) (1) • *x* axis: (surface) temperature, with indication of decreasing temperature (1) • 2 or 3 correct regions (1) • 4 correct regions (1)	Example of graph:  	(4)

Q8.

Question number	Acceptable answers	Additional guidance	Mark
(i)	**Either** • When x = R_0, F = GMm/R_0^2 **(1)** • F = $GMmR_0/R_0^3$ so k = $m\omega^2 = GMm/R_0^3$ **(1)** • Use of $T=2\pi/\omega$ **(1)** • $T^2 = 4\pi^2/\omega^2 = 4\pi^2 R_0^3/GM$ So $T = 2\pi\sqrt{(R_o^3/GM)}$ **(1)** **OR** • From graph F=-(g/R_o)r **(1)** • From which $\omega = \sqrt{(g/R_0)}$ **(1)** • Use of $T=2\pi/\omega$ **(1)** • So $T = 2\pi\sqrt{(R_o^3/g)}$ **(1)**		**4**

Question number	Acceptable answers	Additional guidance	Mark
(ii)	**Either** Centripetal force = $mv^2/R_0 = GMm/R_0^2$ **(1)** • $4\pi^2 R_0^2/ T^2R_0 = GM/R_0^2$ **(1)** • $T^2 = 4\pi^2/\omega^2 = 4\pi^2 R_0^3/GM$ So $T = 2\pi\sqrt{(R_o^3/GM)}$ **(1)** **OR** • $mg = mv^2/R_0 = m\omega^2R_0$ **(1)** • So $\omega = \sqrt{(g/R_0)}$ **(1)** • $T = 2\pi/\omega = 2\pi\sqrt{(R_0/g)}$ **(1)**		**3**

Q9.

Question Number	Answer	Mark
	B	1

Q10.

Question Number	Answer	Mark
	A	1

Mark Scheme

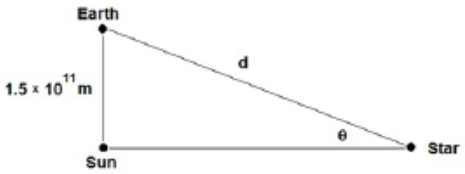
Q1.

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

Q2.

Question Number	Answer	Mark
(i)	A standard candle is a (stellar) object of known luminosity	1
*(ii)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Standard candle's flux/ brightness (on Earth) is measured/determined (1) Use inverse square law [Reference to $F=L/4\pi d^2$ with symbols defined] (1) (Hence) distance to standard candle is calculated/determined (1) [do not accept "measure" or "find" for "calculate"] [accept star/cluster for standard candle] [accept a re-arrangement of $F=L/4\pi d^2$ with d as subject as indication that d is calculated]	3
(iii)	Idea that trigonometric parallax is the change in position of a star against the background of more distant stars **Or** parallax angle is the angle subtended at the star by the radius of the Earth's orbit (1) [Mark can be obtained from a fully labelled diagram] If star is too distant the angle is too small to measure (1)	2
	Total for Question	12

Q3.

Question Number	Answer	Mark
(a)	**Max 6** The young star cluster consists (mainly) of main sequence stars (1) The old star cluster has a truncated main sequence (1) The old star cluster has lost its heaviest main sequence stars (1) The old star cluster has (many) red giant stars (1) The old star cluster has (some) white dwarf stars (1) Massive main sequence stars are the first stars (to deplete sufficient hydrogen in their core) to evolve into red giant stars. (1) Some red giant stars have evolved into white dwarf stars in the old cluster (1)	6
(b)(i)	Star A is closer to Earth than Star B (1)	1
(b)(ii)	 Use of appropriate trigonometric relationship (1) $d = 4.0 \times 10^{16}$ m (1) Example of calculation: $\sin\theta = \frac{1.5\times10^{11}\text{m}}{d}$ $d = 4.01 \times 10^{16}$ m	2

(c)	$\lambda_{max} = 1.0 \times 10^{-6}$ m (1) Use of $\lambda_{max} T = 2.9 \times 10^{-3}$ (1) $T = 2900$ K (1) Example of calculation: $T = 2.9 \times 10^{-3}$ m K/1.0×10^{-6} m = 2900 K	3
	Total for question	12

Q4.

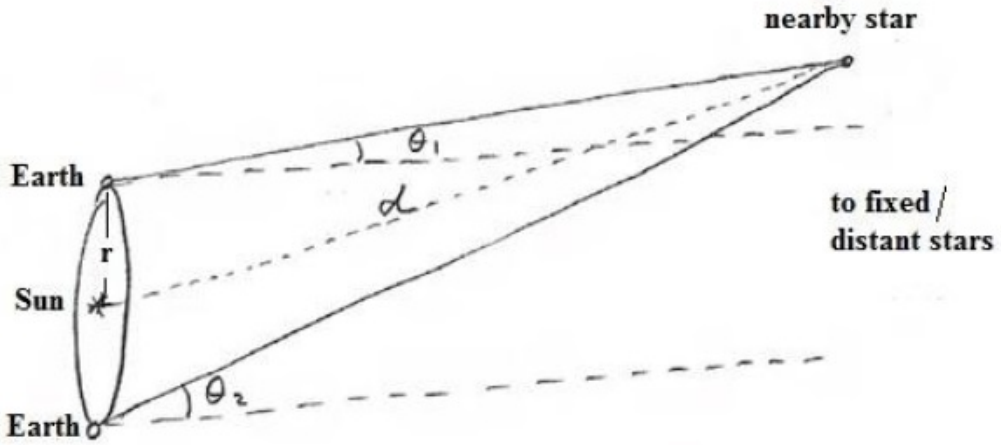
Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is C because the correct method for a nearby star is parallax, for a nearby galaxy is standard candle and for a very distant galaxy is red shift A is not correct because only the nearby star method is correct B is not correct because only the nearby galaxy method is correct D is not correct because none of the methods are correct	1

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Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	D		1

Q6.

Question Number	Answer	Mark
	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate **Parallax:** The star is viewed from two positions at 6 month intervals **Or** the star is viewed from opposite ends of its orbit diameter about the Sun (1) The (change in) angular position of the star relative to fixed/distant stars is measured (1) The diameter/radius of the Earth's orbit about the Sun must be known and trigonometry is used (to calculate the distance to the star) [Do not accept Pythagoras] (1) [the marks above may be obtained with the aid of a suitably annotated diagram] e.g  [Accept the symmetrical diagram seen in many text books] **Standard candle:** Flux/brightness/intensity of standard candle is measured (1) (1) Luminosity of standard candle is known [accept reference to absolute magnitude **Or** total power output of star] (1) Inverse square law is used (to calculate distance to standard candle)	**6**
	Total for question	**6**

Q7.

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Question Number	Answer		Mark
(a)(i)	Redshift is the (fractional) increase in wavelength received (by an observer)	(1)	
	Due to source and observer receding (from each other)	(1)	2
6(a)(ii)	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate**		
	Measure frequency/wavelength of light (from the galaxy)	(1)	
	Compare (measured) frequency/wavelength to the frequency/wavelength for a source on the Earth	(1)	
	States appropriate Doppler formula (consistent with mp1/mp2) and how it is used to calculate velocity	(1)	3
(b)	(Standard candles are stellar) objects of known luminosity	(1)	1
(c)	See $v = H_0 d$ and $v = d/t$	(1)	
	Therefore $t = 1/H_0$ (dependent mark)	(1)	2
(d)(i)	If density less than critical value, expansion would continue for ever	(1)	
	If density greater than critical, expansion would stop and universe would contract again	(1)	
	If density equals critical value, expansion rate would decrease to zero but universe would not contract again	(1)	3
(d)(ii)	The mass of the universe is uncertain because of the amount of dark matter is uncertain	(1)	
	The value of the Hubble constant is uncertain	(1)	
	Or		
	The amount of dark matter (in the universe) is uncertain	(1)	
	Since dark matter doesn't interact via the electromagnetic interaction	(1)	
	Or		
	The value of the Hubble constant is uncertain		
	Since measurements of distances to distant galaxies are uncertain	(1)	
		(1)	2
	Total for question		**13**

Q8.

Question Number	Answer		Mark
(a)(i)	(A standard candle is) an object of known luminosity	**(1)**	**1**
(a)(ii)	Flux/brightness/intensity of standard candle is measured Inverse square law used (to calculate distance to standard candle) [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]	**(1)** **(1)**	**2**
(b)(i)	An increase in the wavelength (of radiation) received from a receding source [accept in terms of a decrease in the frequency]	**(1)**	**1**
(b)(ii)	Use of $z = v/c$ and $v = H_0 d$ $[z = H_0 d/c]$ $d = 1.7 \times 10^{25}$ m <u>Example of calculation:</u> $v = zc = 0.12 \times 3\times10^{8}$ m s^{-1} = 3.6×10^{7} m s^{-1} $d = v/H = 3.6 \times10^{7}$ m s^{-1}/2.1×10^{-18} s^{-1} = 1.71×10^{25} m	**(1)** **(1)**	**2**
***(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] (Dark matter proposed when) observations of galaxies indicated that they must contain more matter than could be seen. The existence of dark matter will increase the (average) density of the universe This may make it more likely that the universe is closed [accept will contract **Or** end with a "Big Crunch"] **Or** Idea that this may make the ultimate fate of the Universe less certain	**(1)** **(1)** **(1)** **(1)**	**3**
(d)	**Max 2** The universe started from a small initial point [accept Big Bang] Idea that universe has a finite age 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)** **(1)** **(1)**	**2**
	Total for question		**11**

Q9.

Question Number	Acceptable answers	Additional guidance	
(a)	• Object of known luminosity **(1)**		1

Question Number	Acceptable answers	Additional guidance	
(b)	• The (parallax) angle becomes very small **(1)** **Or** the diameter of the Earth's orbit is very small • Giving a (very) large percentage uncertainty **(1)**		2

Question Number	Acceptable answers	Additional guidance	
(c)	• Measure change in wavelength / frequency **(1)** • Determine relative velocity using redshift formula **(1)** • Then apply $v = H_0 d$ **(1)**		3

☒ **D**

(Total for question = 1 marks)

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	A description that makes reference to the following: • (main sequence) stars are (primarily) converting hydrogen to helium in their core (1) • stars on main sequence maintain a constant luminosity (for most of their lifetime) (1)		**(2)**

Q2.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is **C**: main sequence – red giant – white dwarf A is not correct because it is white dwarf – red giant – main sequence B is not correct because it moves along the main sequence from large to small D is not correct because it moves along the main sequence from small to large	1

Q3.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• use of $F = Q_1Q_2/4\pi\varepsilon_0r^2$ **(1)** • use of $F = Gm_1m_2/r^2$ **(1)** • Expresses forces as a ratio **(1)** **OR** calculates the individual forces F_e=8.1 x 10^{-8} N F_g = • 3.6 x 10^{-47} N **(1)** • Ratio = 2 x 10^{39} or 5 x 10^{-40} and identifies gravitational force as insignificant **(1)**		**4**
(ii)	• use of $F = mv^2/r$ and $F = Q_1Q_2/4\pi\varepsilon_0r^2$ **(1)** • to derive $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ **(1)** • velocity = 2.2× 10^6 m s^{-1} **(1)**	Example of calculation: $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ $v = \sqrt{\frac{1.6\times10^{-19}\text{ C}\times1.6\times10^{-19}\text{ C}}{4\pi\times8.85^{-12}\text{ Fm}^{-1}\times5.3\times10^{-11}\text{m}\times9.1\times10^{-31}\text{ kg}}}$ $v = 2.185 \times 10^6$ m s^{-1}	**3**

Q4.

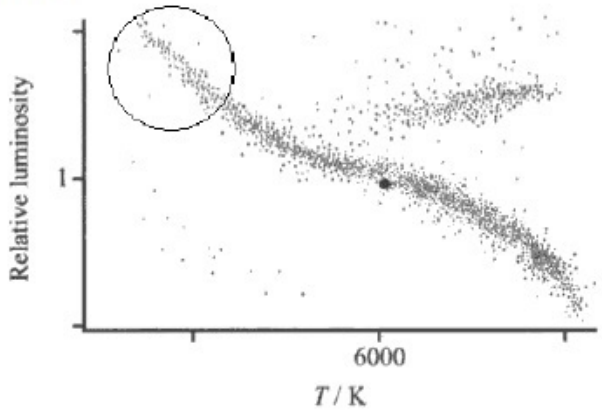
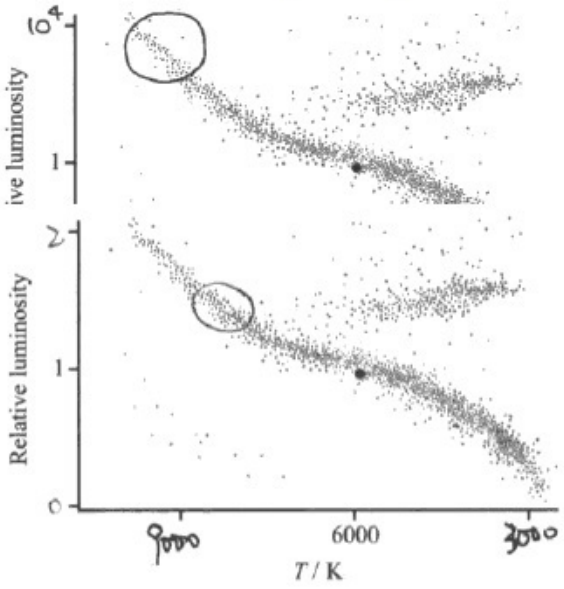
Question Number	Answer		Mark
(a)(i)	Reverse direction for temperature [at least 2 values seen]	(1)	
	Logarithmic/power temperature variation [at least 3 realistic values seen increasing by the same factor]	(1)	**2**
(a)(ii)	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate		
	Area 1: Max 2		
	The Sun is fusing/burning hydrogen (into helium in its core)	(1)	
	When (hydrogen) fusion/burning ceases the core of the Sun cools [accept radiation pressure drops when fusion/burning ceases in the core]	(1)	
	The core collapses/contracts (under gravitational forces)	(1)	
	Area 2: Max 2	(1)	
	The Sun expands and becomes a red giant	(1)	
	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)	(1)	
	Area 3: Max 2	(1)	
	Idea that outer layers of Sun are ejected into space	(1)	**6**
	The temperature doesn't rise enough for further fusion to begin	(1)	
	The core/Sun becomes a (white) dwarf star		

(b)(i)	Idea of a very high temperature [accept value of about 10^7 K] (1) 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 (1) Idea of a very high density [accept pressure] to give a sufficient collision rate (1)	**3**
(b)(ii)	Attempt at calculation of mass deficit (1) (1) Use of $\Delta E = c^2 \Delta m$ (1) Attempt at conversion from J to (M)eV (1) $\Delta E = 12.9$ (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> $\Delta m = ((5.008238 \times 2) - 6.646483 - (1.673534 \times 2)) \times 10^{-27}\,\text{kg}$	**4**
	$\Delta m = 2.2925 \times 10^{-29}$ kg $\Delta E = (3.00 \times 10^8\,\text{ms}^{-1})^2 \times 2.2925 \times 10^{-29}\,\text{kg} = 2.063 \times 10^{-12}$ J $\Delta E = \frac{2.063 \times 10^{-12}\,\text{J}}{1.60 \times 10^{-13}\,\text{J MeV}^{-1}} = 12.9\,\text{MeV}$	
	Total for question	**15**

Q5.

Question Number	Answer	Mark
	D	**1**

Q6.

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

	Total for question	**6**

Q7.

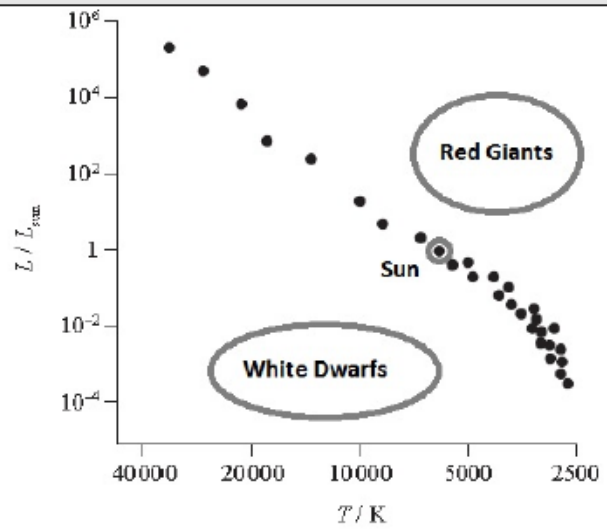
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Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• All the stars are in the main sequence (1) • In an older cluster there would be red giant stars (1)		2
(ii)	**MAX 4** • The most massive stars experience much greater gravitational forces (1) • So core temperature and density is greatest (1) • The rate of fusion in the core is greatest (1) **Or** the power generated in the core is greatest (1) • The (surface) temperature is greatest • The surface area of these stars is greatest • So according to Stefan's Law the power radiated from these massive stars is greatest		4

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q9.

Question Number	Answer	Mark
		
(i)	Sun's position identified [single point identified] (1)	
(ii)	White dwarf region (1) Red giant region (1)	3
*(iii)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) White dwarf stars have: high temperature T (because λ_{max} is small) (1) low luminosity L (1) $L = \sigma A T^4$ linked to a determination of the surface area (1)	3

Q10.

Question Number	Answer	Mark
	D	1