Name: _____

Topic 10: Space Part 2

Date:

Time:

Total marks available:

Total marks achieved: _____

Questions

Q1.

A sample of gas is contained within a sealed tube with a moveable piston at one end.
The gas occupies a volume V at pressure p and temperature T.

The temperature of the gas is increased to $2T$ and the volume of the cylinder changes.
The pressure decreases to $p/2$.

What will the new volume be?

☒ **A** $V/2$

☒ **B** V

☒ **C** $2V$

☒ **D** $4V$

(Total for question = 1 mark)

Q2.

A line in the hydrogen spectrum of a star in the Milky Way galaxy is observed to have a wavelength of 656.3 nm. In a laboratory on Earth this line has a wavelength of 654.9 nm.

Which of the following expressions gives the magnitude of the velocity of the star relative to Earth?

(1)

☒ **A** $\dfrac{656.3}{654.9} \times 3 \times 10^8 \, \mathrm{m s^{-1}}$

☒ **B** $\dfrac{654.9}{(656.3 - 654.9)} \times 3 \times 10^8 \, \mathrm{m s^{-1}}$

☒ **C** $\dfrac{654.9}{656.3} \times 3 \times 10^8 \, \mathrm{m s^{-1}}$

☒ **D** $\dfrac{(656.3 - 654.9)}{654.9} \times 3 \times 10^8 \, \mathrm{m s^{-1}}$

(Total for question = 1 mark)

Q3.

In 2016 the Breakthrough Starshot initiative was announced. This project intends to send a fleet of small probes to Proxima Centauri, the nearest star to the Sun. This journey would take about twenty years.

The radiation intensity at Earth from Proxima Centauri is 3.25×10^{-11} W m^{-2}. The luminosity of the Sun is $L_\odot$.

(i) Show that the luminosity of Proxima Centauri is about 0.002 $L_\odot$.

(3)

distance to Proxima Centauri = 4.00×10^{16} m
$L_\odot = 3.85 \times 10^{26}$ W

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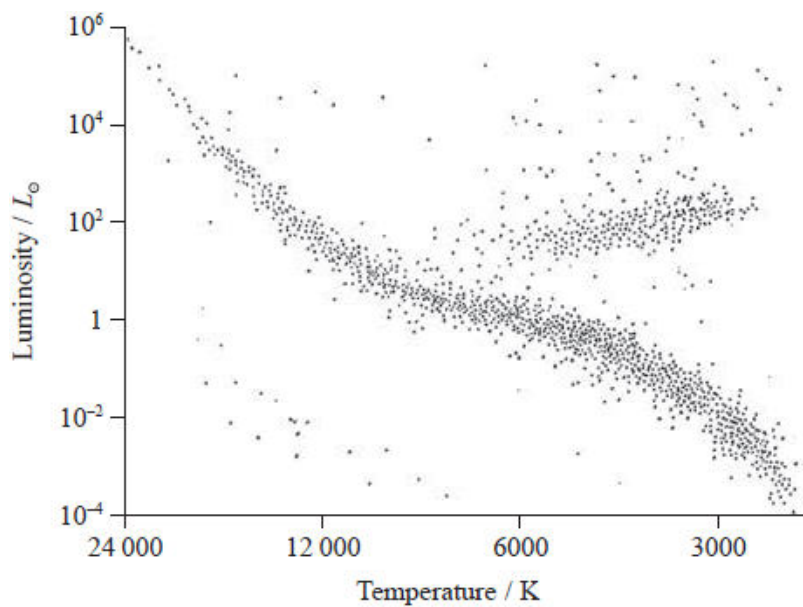
(ii) Proxima Centauri is described on a website as a main sequence star.

Determine whether the surface temperature of Proxima Centauri is consistent with a position on the main sequence of the Hertzsprung-Russell diagram.

(3)

radius of Proxima Centauri = 9.81×10^{7} m

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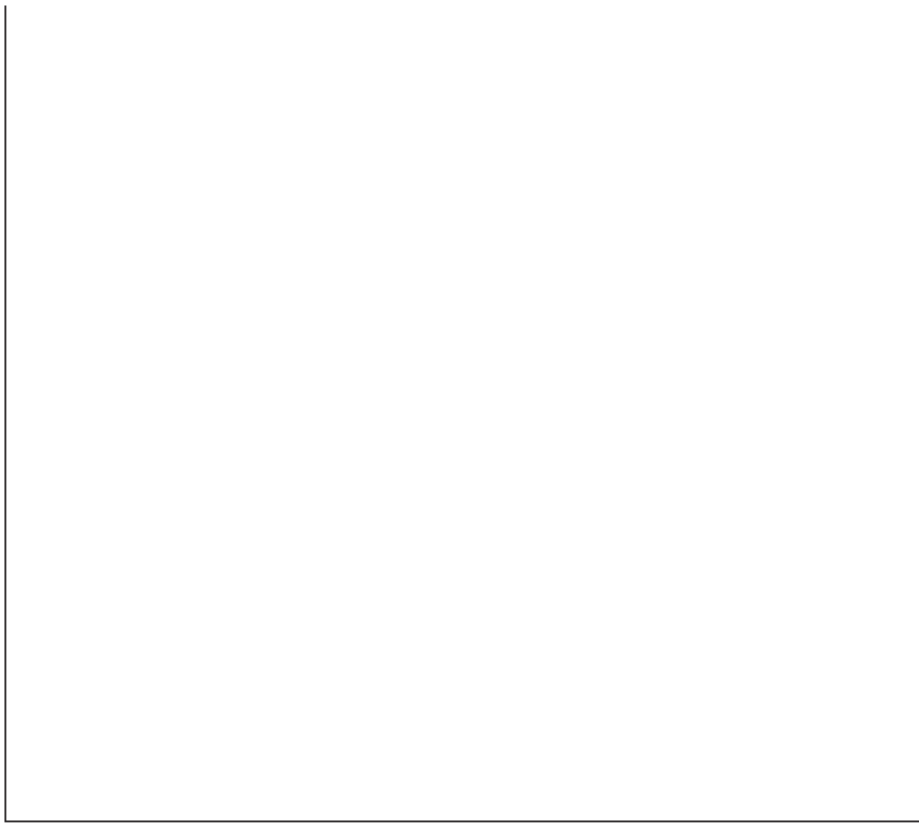
(Total for question = 3 marks)

Q4.

The Hertzsprung-Russell diagram is a diagram used by astronomers to illustrate the properties of stars.

Label the axes below and use them to sketch a Hertzsprung-Russell diagram.
Your diagram should include labelled regions where the following stars are found:

- main sequence
- red giants
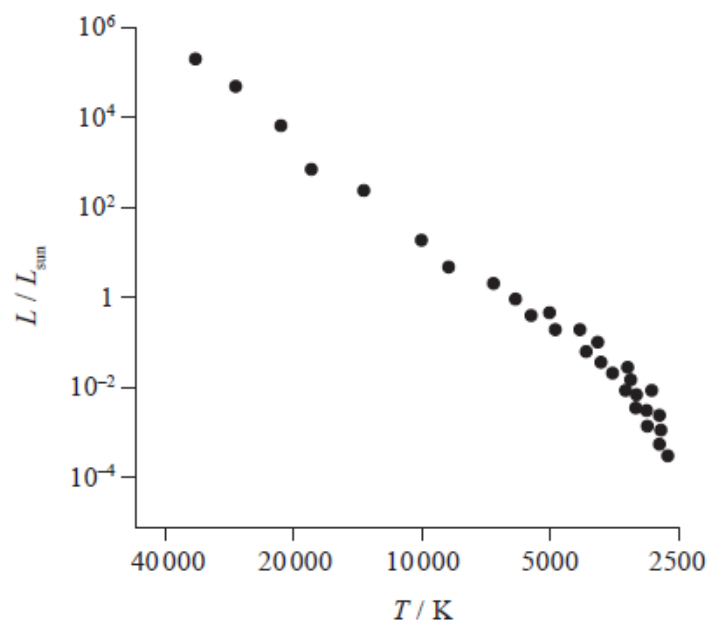- supergiants
- white dwarfs

(4)

Q5.

The Hertzsprung-Russell (H-R) diagram is a plot of luminosity against temperature for a range of stars.

The H-R diagram below shows a number of main sequence stars.

(i) Label the position of our Sun on the diagram.

(1)

(ii) Label on the diagram the regions in which white dwarf and red giant stars would be located.

(2)

*(iii) Stars known as white dwarf stars have small surface areas. Explain how astronomers have deduced this.

(3)

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(Total for question = 6 marks)

Q6.

Solar panels consisting of combinations of photovoltaic cells use energy in the radiation received from the Sun to generate electricity.

An advertisement for solar panels claims that the intensity of radiation from the Sun incident at the top of the Earth's atmosphere is more than $2\,\text{kW}\,\text{m}^{-2}$.

Assess the validity of this claim.

radius of Sun = $6.96 \times 10^8\,\text{m}$

surface temperature of Sun = $5790\,\text{K}$

distance from Sun to Earth = $1.50 \times 10^{11}\,\text{m}$

(4)

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(Total for question = 4 marks)

Q7.

Light from all distant galaxies is found to be shifted towards longer wavelengths. The more distant the galaxy, the greater the shift in wavelength.

State the conclusions that we can draw from this.

(3)

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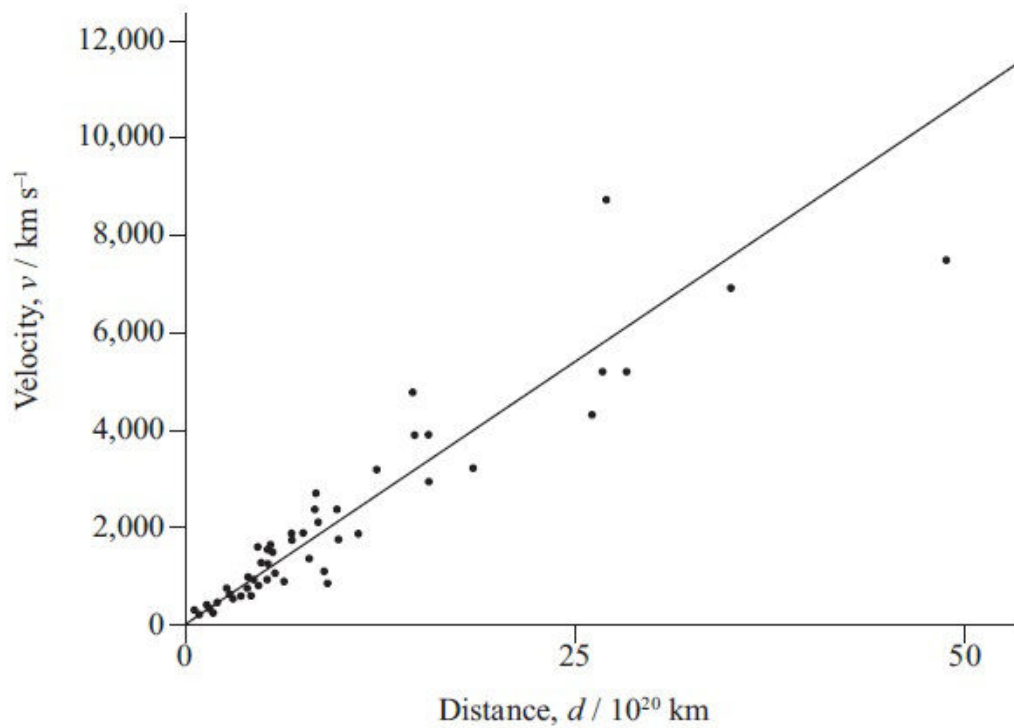..

(Total for Question = 3 marks)

Q8.

The graph shows how the velocity varies with distance for a number of distant galaxies. All the galaxies are receding from Earth, and there appears to be a linear relationship between the velocity of recession and the distance to the galaxy.

Velocity, v / km s^{-1} versus Distance, d / 10^{20} km

(a) Use the graph to estimate an age for the Universe

(4)

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Age of the Universe = ...

*(b) Describe how astronomers would have determined the velocity of each galaxy.

(5)

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*(c) Scientists are uncertain about the ultimate fate of the Universe.

Explain why.

(3)

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(Total for question = 12 marks)

Q9.

Hertzsprung-Russell diagrams are shown for three star clusters.

Choose the row that correctly identifies the relative ages of the three clusters.

	Youngest ———————→ Oldest		
☒ A	X	Z	Y
☒ B	Y	X	Z
☒ C	Y	Z	X
☒ D	Z	X	Y

(Total for question = 1 mark)

Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A student finds a Hertzsprung-Russell diagram in an old astronomy book and notices that the axes aren't the same as in her current textbook.
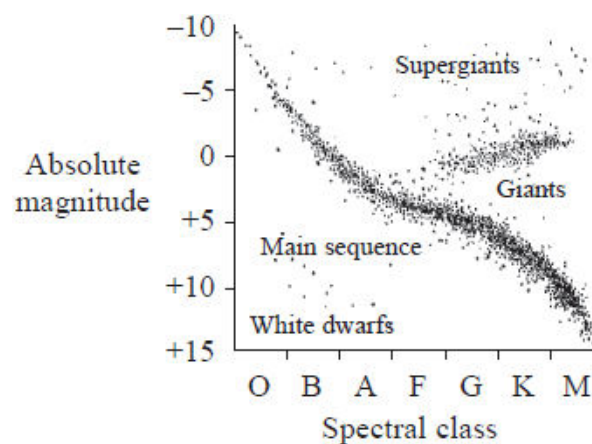
Which of the following graphs shows a correct alternative way to label the axes?
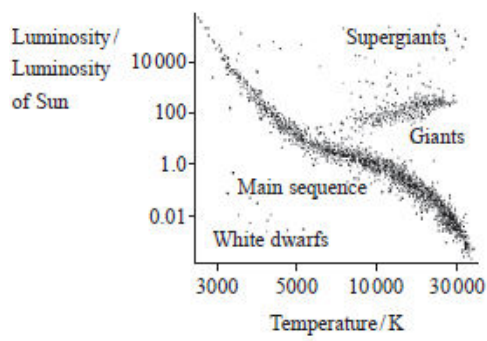
A
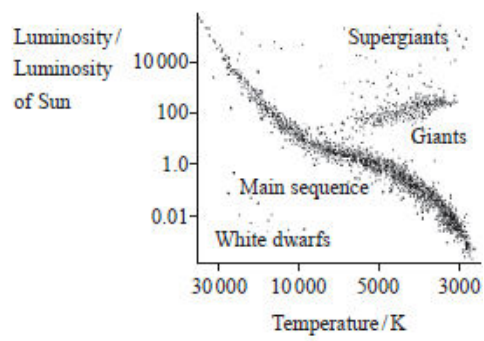
B
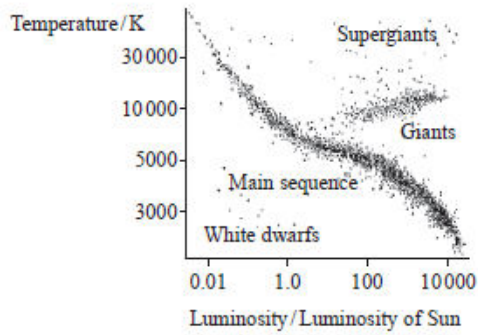
C
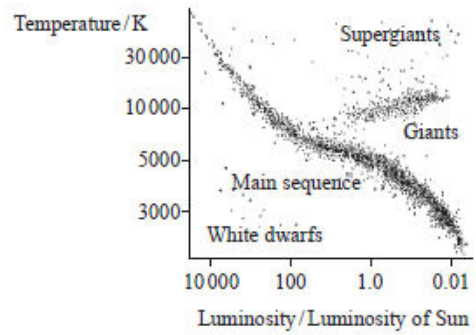
D

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q11.

Four regions **A**, **B**, **C** and **D** are labelled on the Hertzsprung-Russell diagram.
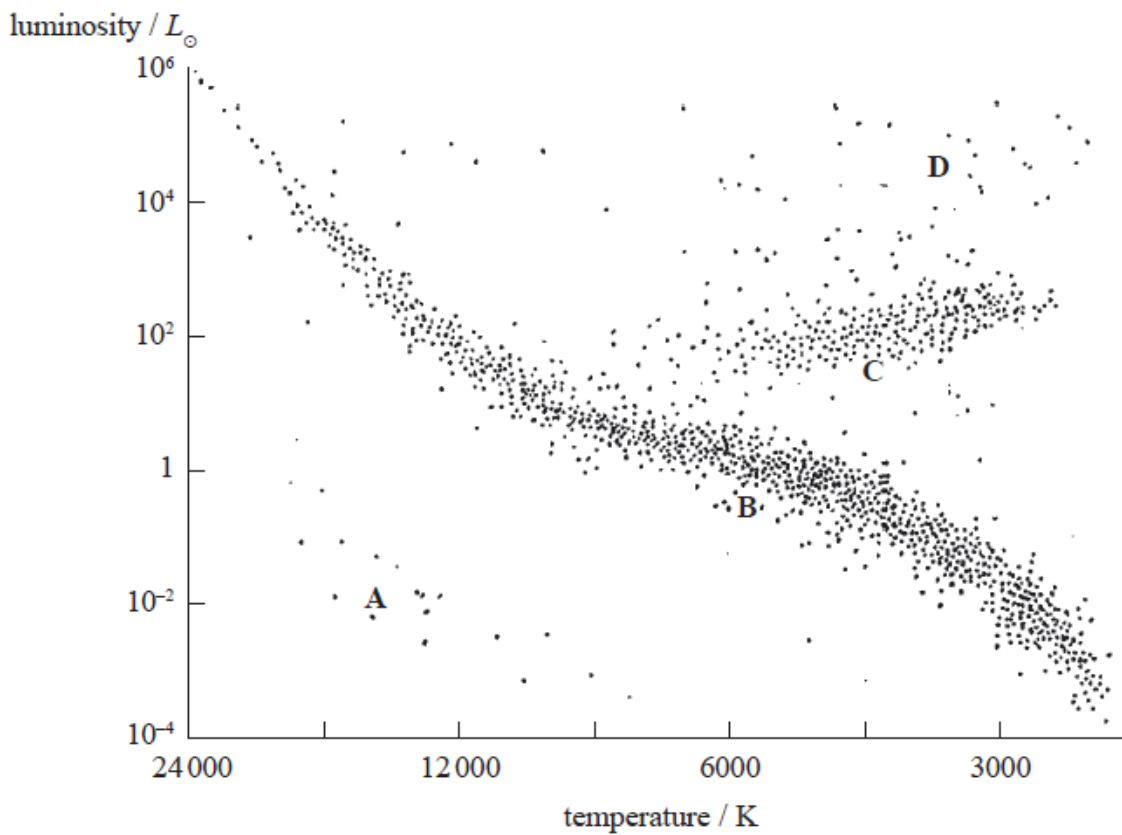
luminosity / $L_\odot$

Which region includes the position of the Sun?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q12.

A Hertzsprung-Russell (HR) diagram shows how the luminosity L depends on the surface temperature T for a group of stars.

The HR diagram below is for a young star cluster.
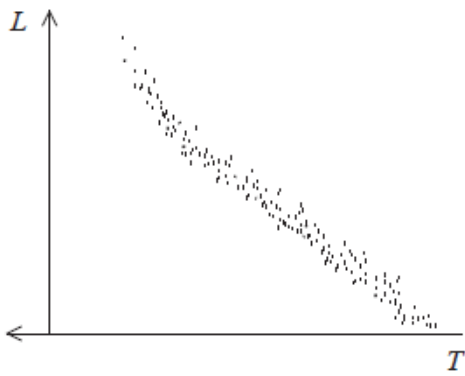
(i) Explain how we can tell that the young star cluster is in the early stages of its evolution.

(2)

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(ii) Explain why the most massive stars in the cluster have the greatest luminosities.

(4)

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(Total for question = 6 marks)

Q13.

(a) The Herzsprung-Russell (H-R) diagram is one of the most important tools in the study of stellar evolution.

The H-R diagrams below are for a young star cluster and an old star cluster.

Young star cluster   **Old star cluster**
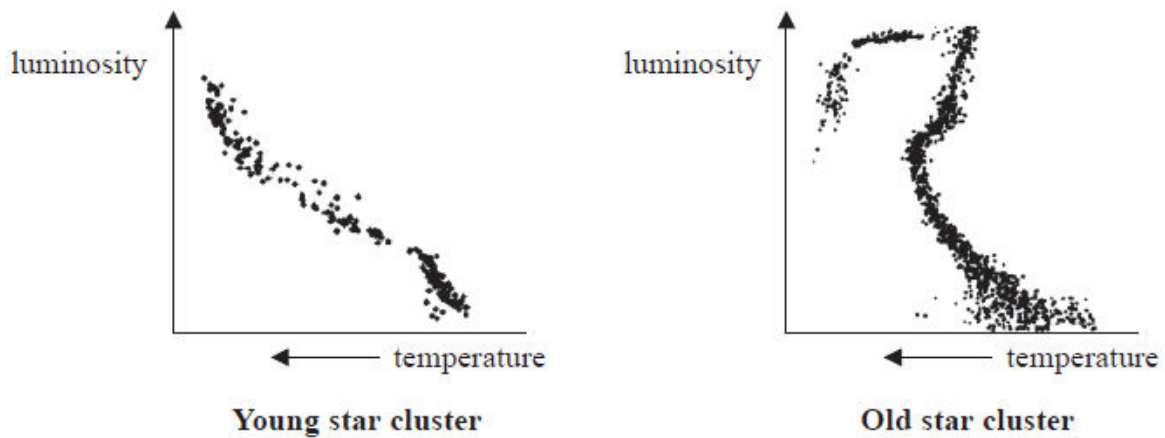
Use the diagrams to describe and explain how the old star cluster is different from the young star cluster.

(6)

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(b) Trigonometric parallax is one way in which stellar distances can be measured.

Astronomers measure the parallax angle for two nearby stars. The parallax angle for star A is 3.74×10^{-6} rad and that for star B is 1.84×10^{-7} rad.

(i) Without calculation, state what can be deduced from this data about the relative distances of the two stars.

(1)

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(ii) The diagram shows the parallax angle for star A.

Calculate the distance of star A from the Earth.

1 A.U. is 1.50×10^{11} m

(2)

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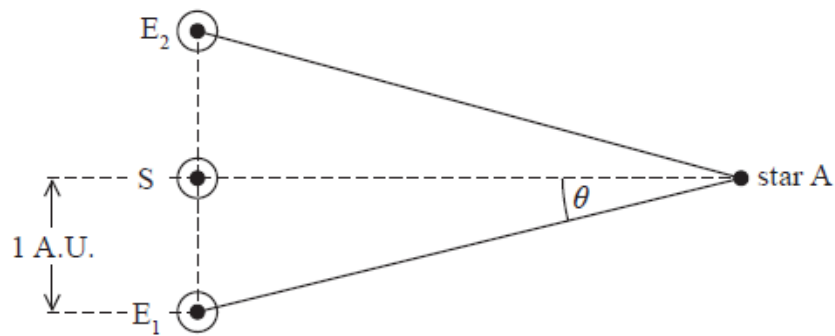
Distance = ...

(c) In addition to finding the distances to stars astronomers are interested in determining the temperatures of stars.

The spectrum of star A is shown below.
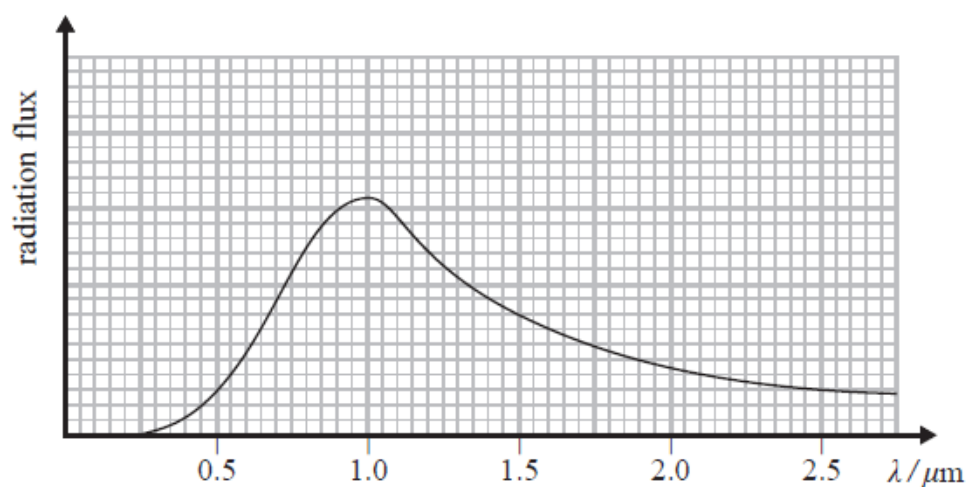
Use data from the graph to determine the surface temperature of star A.

(3)

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Temperature = ...

(Total for question = 12 marks)

Q14.

This Hertzsprung-Russell diagram is a plot of relative luminosity against temperature for a large number of stars.
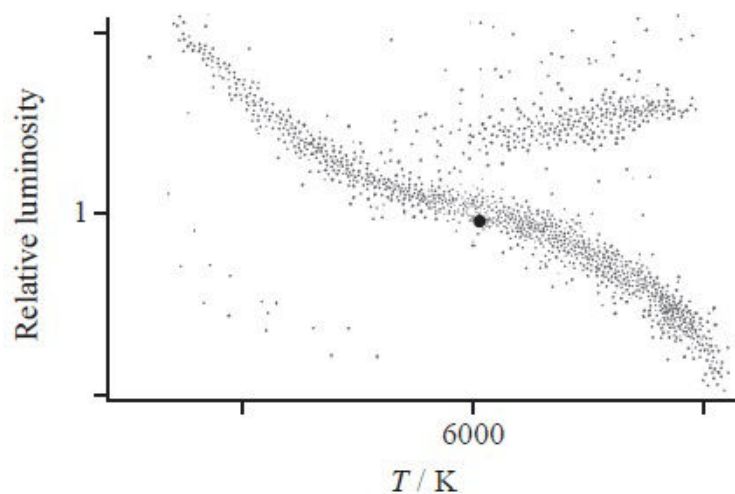
The position of the Sun, at a surface temperature of about 6000 K and a relative luminosity of 1, is marked on the diagram.

(a) Complete the temperature and relative luminosity scales by adding values at the positions shown.

(2)

(b) The Sun is an example of a main sequence star.

(i) State the fusion process taking place in the core of all main sequence stars.

(1)

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(ii) Draw a circle where the most massive main sequence stars are located on the diagram and explain why they are found in this position.

(3)

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(Total for Question = 6 marks)

Q15.

A star is estimated to have approximately the same surface temperature as the Sun, but less than 1% of the Sun's luminosity.

The star is best classified as a

☒ **A**   main sequence star.

☒ **B**   red dwarf star.

☒ **C**   red giant star.

☒ **D**   white dwarf star.

(Total for Question = 1 mark)

Mark Scheme

Q1.

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

Q2.

Question Number	Answer	Mark
	D – $$\frac{(656.3 - 654.9)}{654.9} \times 3 \times 10^8 \text{ m s}^{-1}$$	1
	Incorrect Answers: correct method: $$\frac{change\ in\ wavelength}{wavelength\ in\ laboratory} \times speed\ of\ light$$ A – uses $$\frac{wavelength\ from\ star}{wavelength\ in\ laboratory} \times speed\ of\ light$$ B – uses $$\frac{wavelength\ in\ laboratory}{change\ in\ wavelength} \times speed\ of\ light$$ C – uses $$\frac{wavelength\ in\ laboratory}{wavelength\ from\ star} \times speed\ of\ light$$	

Q3.

Question Number	Acceptable Answers		Additional Guidance	Mark
(i)	• use of $I = L / 4\pi d^2$	(1)	Example of calculation $3.25 \times 10^{-11} \text{ W m}^{-2} = L / 4\pi(4.00 \times 10^{16} \text{ m})^2$	
	• $L = 6.53 \times 10^{23} \text{ W}$	(1)	$L = 6.53 \times 10^{23} \text{ W}$	
	• $= 0.17\%$ of Sun	(1)	$6.53 \times 10^{23} \text{ W} / 3.85 \times 10^{26} \text{ W} = 0.17\%$	3
(ii)	• use of $L = \sigma A T^4$	(1)	Example of calculation $6.53 \times 10^{23} \text{ W} = 5.67 \times 10^{-8} \text{ W m}^{-2}\text{K}^{-4} \times 4\pi (9.81 \times 10^7 \text{ m})^2 \times T^4$	
	• $T = 3124$ (K)	(1)	$T = 3124 \text{ K}$	
	• Statement relating calculated values of T and L to main sequence on H-R diagram	(1)		3

Q4.

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

Q5.

Question Number	Answer	Mark
(i)	Sun's position identified [single point identified]	(1)
(ii)	White dwarf region Red giant region	(1) (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) low luminosity L $L = \sigma A T^4$ linked to a determination of the surface area	(1) (1) (1) 3

Q6.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $L = 4\pi r^2 \sigma T^4$	(1)	Example of calculation:	
	• Use of $I = \frac{L}{4\pi d^2}$	(1)	$L = 4\pi(6.96\times10^8 m)^2 \times 5.67\times10^{-8} W$	
	• $I = 1.37$ (kW m^{-2})	(1)	$L = 3.88 \times 10^{26}$ W	
	• This is less than 2 (kW m^{-2}) and so the claim is false.	(1)	$I = \dfrac{3.88\times10^{26} W}{4\pi(1.50\times10^{11} m)^2} = 1372$ W m^{-2}	4

Q7.

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

Q8.

Question Number	Answer		Mark
(a)	Calculate gradient of line	(1)	
	Identify gradient with H **Or** use of v = Hd for a point on the line	(1)	
	Use of t = 1/H	(1)	
	$t = 4.5 \times 10^{17}$ s (accept answers in range 4.2×10^{17} s to 4.8×10^{17} s)	(1)	
	Alternative method:		
	Pair of d, v values read from the line	(1)	
	Values chosen from the upper end of the line	(1)	
	Use of t = d/v	(1)	
	$t = 4.5 \times 10^{17}$ s [$\pm 0.3 \times 10^{17}$ s]	(1)	4
	[$t = 1.4 \times 10^{10}$ yr [$\pm 0.1 \times 10^{10}$ yr]		
	Example of calculation		
	$$H = \text{gradient} = \frac{(11000 - 0) \times 10^3 \, \text{m s}^{-1}}{(50 - 0) \times 10^{23} \, \text{m}} = 2.2 \times 10^{-18} \, \text{s}^{-1}$$		
	$$t = \frac{1}{H} = \frac{1}{2.2 \times 10^{-18} \, \text{s}^{-1}} = 4.5 \times 10^{17} \, \text{s}$$		
* (b)	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate**		
	Measure wavelength of light (from the galaxy)	(1)	
	Compare it to the wavelength for a source on the Earth	(1)	
	Reference to spectral line or line spectrum	(1)	
	Reference to Doppler effect/shift **Or** redshift	(1)	
	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	(1)	5
	[accept answers in terms of frequency rather than wavelength]		
*(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	(1)	
	Hubble constant has a large uncertainty		
	Or age = 1/H may not be valid as gravity is changing the expansion rate	(1)	
	Because of the existence of dark matter	(1)	
	Values of the (average) density/mass of the universe have a large uncertainty [accept not known]	(1)	
	(Hence) measurements of the critical density of the Universe have a large uncertainty	(1)	
	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)	3

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q10.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B** because the y axis is luminosity and the x axis shows temperature decreasing A is not the correct answer because the y axis is luminosity but the x axis shows temperature increasing C is not the correct answer because the x axis is luminosity and the y axis is luminosity D is not the correct answer because the x axis is luminosity and the y axis is luminosity	1
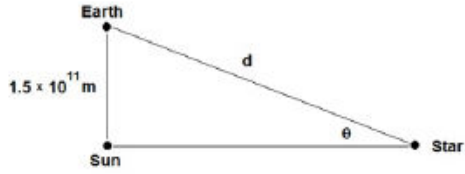
Q11.

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 $\neq L_\odot$	

Q12.
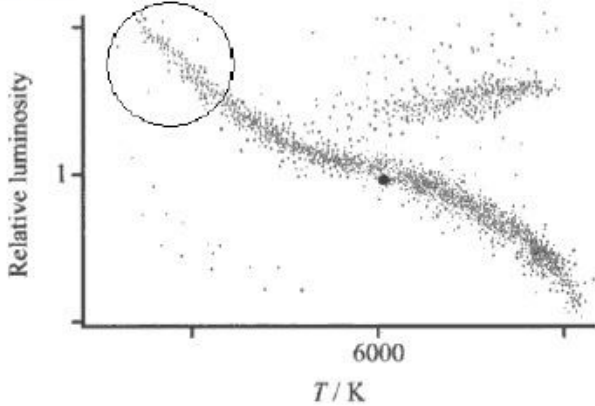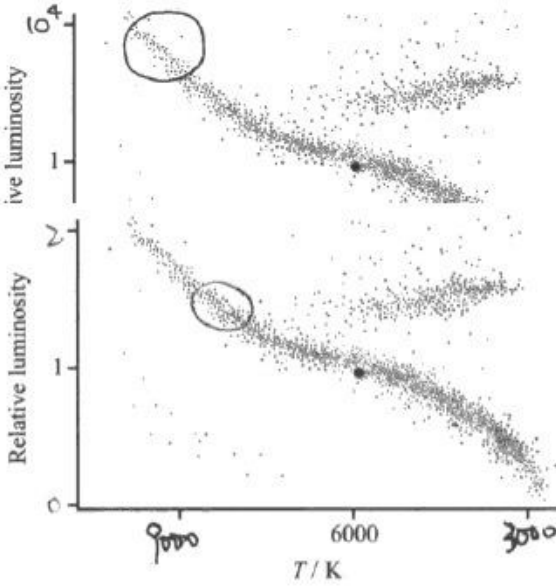
Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• All the stars are in the main sequence • In an older cluster there would be red giant stars	(1) (1)		2
(ii)	**MAX 4** • The most massive stars experience much greater gravitational forces • So core temperature and density is greatest • The rate of fusion in the core is greatest Or the power generated in the core is greatest • 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	(1) (1) (1) (1) (1) (1)		4

Q13.

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: $\sin \theta = \dfrac{1.5 \times 10^{11}\,\text{m}}{d}$ $d = 4.01 \times 10^{16}$ 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$/1.0 \times 10^{-6}$ m $= 2900$ K		
	Total for question		12

Q14.

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

Q15.

Question Number	Answer	Mark
	D	**1**