PEARSON EDEXCEL IAL PHYSICS · YPH11

PHYSICS



EXAM QUESTION PACK

UNIT 5: ASTROPHYSICS AND COSMOLOGY

SCORE	PERCENTAGE
/83	%

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Q1.

Astronomers often use the unit megaparsec (Mpc) for astronomical distances. In a textbook a value for the Hubble constant is given as 72 km s^{-1} Mpc^{-1}.

(a)(i) Show that 72 km s^{-1} Mpc^{-1} is equivalent to a Hubble constant of about 2.3×10^{-18} s^{-1}.

1 Mpc = 3.09×10^{22} m

(2)

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(ii) Determine a value for the age of the universe in years.

1 year = 3.16×10^{7} s

(2)

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Age of universe = ... years

(b) In the 1950s, astronomers realised that they had made an error in their determination of distances to galaxies. Galaxies are twice as far away as astronomers had previously thought.

Explain how this changed the age of the universe as calculated by astronomers.

(2)

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(Total for question = 6 marks)

Q2.

In the 17th century, Kepler proposed his 'law of harmonies' for planetary motion. This law suggested that the ratio of the square of the orbital period T to the cube of the mean radius R has the same value for all the planets that orbit the Sun.

Mathematically his 'law of harmonies' can be written

$$T^2 = KR^3$$

where K is a constant.

(a) The table shows data for Earth and Mars.

Planet	T/s	R/m
Earth	3.16×10^7	1.50×10^{11}
Mars	5.93×10^7	2.28×10^{11}

Show that, for Earth and for Mars, K has a value of about 3.0 ×× 10^{-19} s^2 m^{-3}.

(3)

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(b) Kepler's law of harmonies was derived later by Newton. Newton applied his law of gravitation to a planet moving in an approximately circular orbit around the Sun.

Determine a value for K by applying Newton's law of gravitation to a planet of mass m moving in a circular orbit about the Sun.

mass of Sun = 1.99×10^{30} kg

(3)

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K = ... $s^2\ m^{-3}$

(c) Jupiter is the most massive planet in the solar system and has many moons. Kepler's law of harmonies applies to the orbiting moons. However, the value of K for the moons is not the same as the value that applies to planets orbiting the Sun.

Ganymede is Jupiter's largest moon. Ganymede has an orbital radius of 1.07×10^9 m and an orbital period of 172 hours.

Another moon, Io, has an orbital radius of 4.22×10^8 m.

Calculate the orbital period T_I of Io about Jupiter.

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T_I = ...

(Total for question = 8 marks)

Q3.

The astronomer Hertzsprung used parallax to determine the distances to some of the variable stars known as Cepheids.

(a) Using parallax measurements, astronomers can determine distances to all stars with a parallax angle
larger than 2.4×10^{-7} rad.

The variable star Alpha Cephei is 4.6×10^{17} m from the Earth.

Deduce whether the distance to Alpha Cephei could be determined from parallax measurements.

distance from Earth to Sun = 1.5×10^{11} m

(3)

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(b) Cepheids are a type of standard candle.

Describe how standard candles can be used to determine distances to stars.

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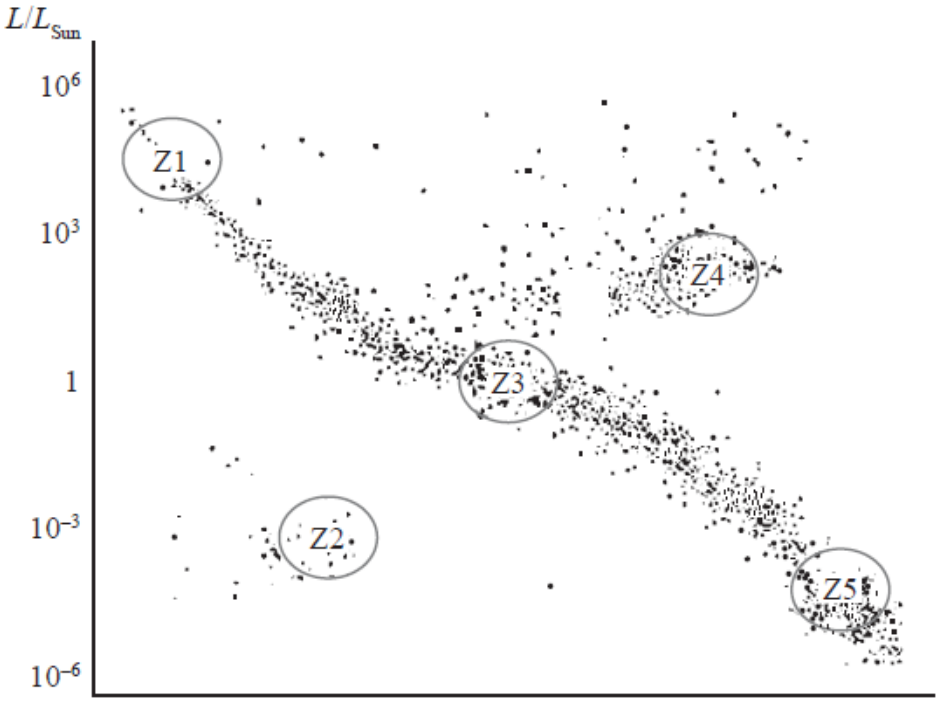
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(c) The Sun is a yellow star with a surface temperature of about 6000 K. In the 20th century, astronomers discovered a large variety of stars in our galaxy. Hertzsprung and Russell developed the Hertzsprung-Russell (HR) diagram as a way of classifying stars.

An HR diagram is shown below.



(i) Label the x-axis of the HR diagram. You should include approximate values.

(3)

(ii) There are five zones, Z1, Z2, Z3, Z4 and Z5, identified on the HR diagram.

Complete the following table. You should match one zone with each description.

(3)

Description	Zone
High mass hot stars	
Low mass cool stars	
Low mass hot stars	

*(iii) The position of a star on the HR diagram changes as the star evolves.

Explain how a star like the Sun evolves as it progresses from zone Z3 to its final position on the HR diagram.

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(Total for question = 18 marks)

Q4.

The spectrum of light emitted by the star Chi Lupi provides evidence of mercury atoms in the outer layers of the star. The light emitted from the star is compared with light emitted from a mercury lamp on Earth.

(a) The lamp contains 1.65×10^{19} mercury atoms in a volume of 1.50×10^{-5} m^3. The pressure of the mercury vapour is 4.25×10^4 Pa.

Calculate the mean kinetic energy of the mercury atoms.

(3)

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Mean kinetic energy of mercury atoms = ...

(b) One line in the spectrum of light from Chi Lupi has a wavelength of 576.933 nm.

The equivalent line in a mercury spectrum produced on Earth is 576.959 nm.

A student concluded from this data that Chi Lupi is moving towards the Earth, and that the relative velocity of Chi Lupi is about 1400 m s^{-1}.

Deduce whether the student's conclusions are correct.

(4)

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(c) The surface temperature of Chi Lupi is twice the surface temperature of the Sun.

The radius of Chi Lupi is three times the radius of the Sun.

State where Chi Lupi would be located on the Hertzsprung-Russell diagram.

(1)

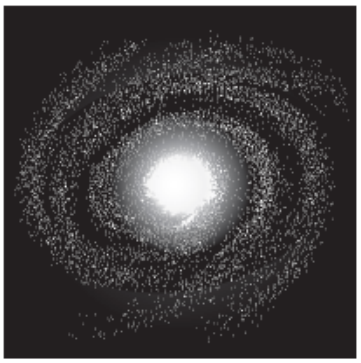
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(Total for question = 8 marks)

Q5.

The image shown is a representation of our galaxy, the Milky Way.



(Source: © daulon/Shutterstock)

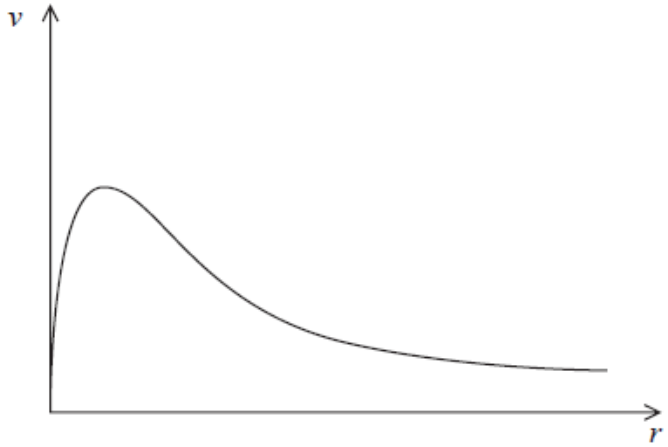
(a) Astronomers think that there is a very large concentration of stars in the central region of the galaxy. Outside this central region the concentration of stars is very much less. All stars in the galaxy are rotating about its centre.

It can be shown that the velocity v of a star a distance r from the centre of the galaxy is given by the expression

$$v = \sqrt{\frac{GM}{r}}$$

where M is the mass of the galaxy contained in a sphere of radius r.

(i) The graph shows how astronomers expect v to vary with r.



Explain how the expression gives the variation of v with r shown in the graph.

(3)

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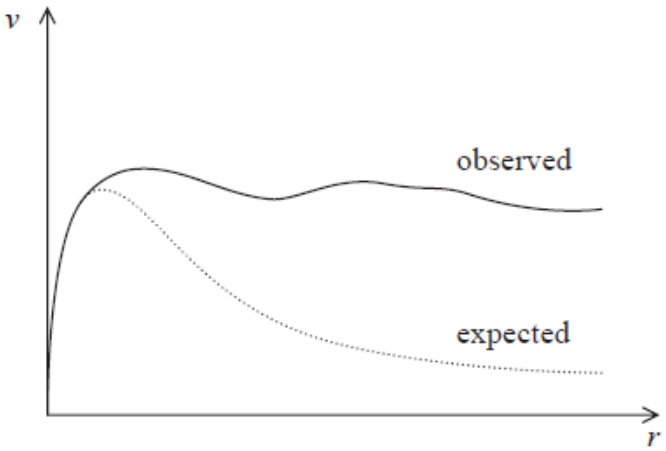
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(ii) The observed variation of v with r has been added to produce the graph below.



Suggest why the 'observed' velocity varies as shown.

(2)

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(b) The ultimate fate of the universe may be a closed universe, but astronomers cannot be sure what their current models predict.

Explain why astronomers cannot be sure that the universe is closed.

(2)

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(Total for question = 7 marks)

Q6.

The planets orbit the Sun in approximately circular orbits. The orbital time *T* of a planet is related to the average distance *r* of the planet from the Sun.

(a)(i) Show that T is related to r by the expression:

$$T^2 \propto r^3$$

(3)

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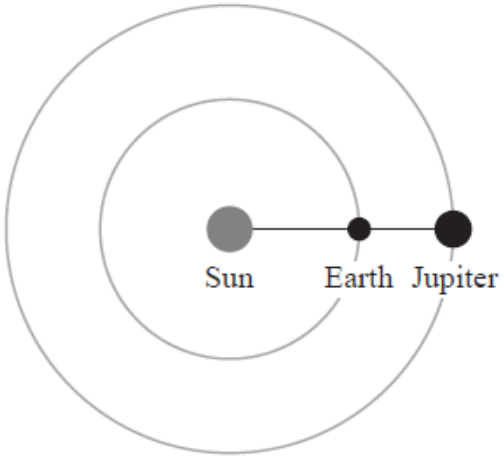
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(ii) When planets align as they orbit the Sun they are said to be 'in opposition'.

The diagram shows the Earth and Jupiter in opposition.



NOT TO SCALE

A website states that the Earth and Jupiter are in opposition every 13 months.

Deduce whether this statement is correct.

mean distance from Earth to Sun = 1.5×10^{11} m
mean distance from Jupiter to Sun = 7.8×10^{11} m
T_{Earth} = 12 months

(5)

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(b) The distance of Jupiter from the Sun varies from 7.4×10^{11} m to 8.2×10^{11} m.

Calculate the change in gravitational potential energy of Jupiter as it moves from its closest distance to its furthest distance from the Sun.

mass of Sun = 2.0×10^{30} kg
mass of Jupiter = 1.9×10^{27} kg

(3)

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Change in gravitational potential energy = ...

(Total for question = 11 marks)

Q7.

Wolf 359 is a red dwarf star. The distance of the star from Earth was first determined from parallax measurements made by the astronomer Max Wolf.

(a)(i) The parallax angle was 2.01×10^{-6} rad.

Calculate the distance, in metres, of Wolf 359 from Earth.

mean distance from Earth to Sun = 1.50×10^{11} m

(2)

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Distance of Wolf 359 from Earth = ... m

(ii) Explain why parallax measurements can only be used to determine the distances to a relatively small number of stars.

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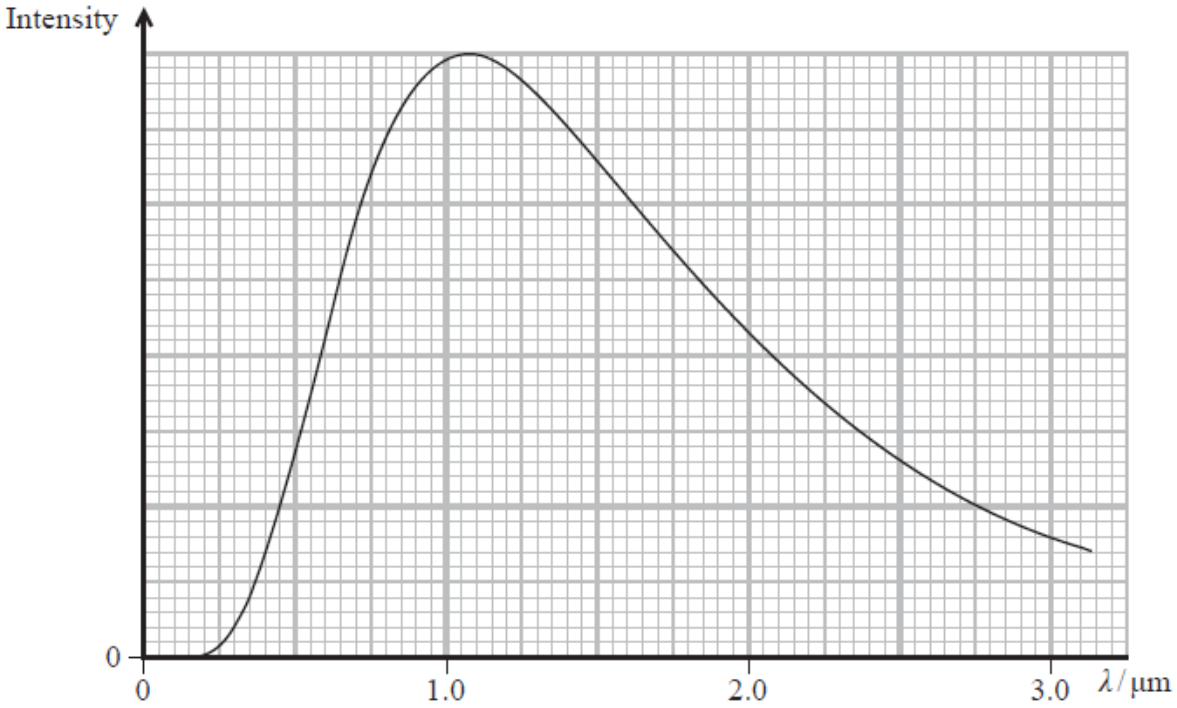
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(b) The graph shows how the intensity of radiation from the star Wolf 359 varies with wavelength.



(i) Show that the surface temperature of Wolf 359 is about 2700 K.

(3)

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(ii) The radius of the Sun is R_{Sun}. The radius of Wolf 359 is 0.16 R_{Sun}.

It is claimed that the luminosity of Wolf 359 is less than 0.1% of the luminosity of the Sun, L_{Sun}.

Deduce whether this claim is correct.

$R_{Sun} = 6.96 \times 10^8$ m
$L_{Sun} = 3.83 \times 10^{26}$ W
$T = 2700$ K

(3)

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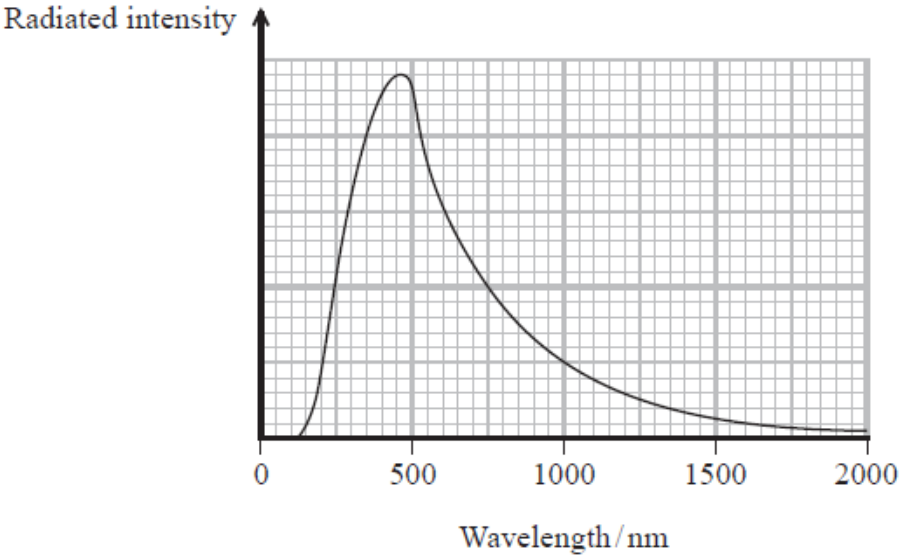
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(Total for question = 10 marks)

Q8.

Procyon is the brightest star in the constellation Canis Minor. The graph shows how the radiated intensity from Procyon varies with wavelength.



A website states that Procyon has twice the diameter of the Sun.

Assess the accuracy of this statement.

luminosity of Procyon = 2.65×10^{27} W
diameter of Sun = 6.96×10^{8} m

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(Total for question = 5 marks)

Q9.

A standard candle in the galaxy M81 has a luminosity 14 800 times the luminosity of the Sun. The intensity of radiation received from the standard candle, measured at the top of the Earth's

atmosphere, is 3.64×10^{-17} W m^{-2}.

$L_{Sun} = 3.83 \times 10^{26}$W

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Distance of M81 from Earth = ...

(Total for question = 3 marks)

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 ☒.

The gravitational field strength at the surface of the Earth is g.

Another planet has the same density as the Earth, but twice the radius of the Earth.

What is the gravitational field strength at the surface of this planet?

☐ **A** $4g$

☐ **B** $2g$

☐ **C** $\frac{g}{2}$

☐ **D** $\frac{g}{4}$

(Total for question = 1 mark)

Q11.

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 communications satellite has a mass of 935 kg. The satellite has an orbital radius four times the radius of the Earth.

☒ **A** 0 N

☒ **B** 570 N

☒ **C** 2300 N

☒ **D** 9200 N

(Total for question = 1 mark)

Q12.

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 ☒.

Which of the following does **not** have the base unit s^{-1}?

☒ **A** angular velocity

☒ **B** frequency

☒ **C** redshift

☒ **D** rate of decay

(Total for question = 1 mark)

Q13.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The spectrum of electromagnetic radiation from a galaxy is observed to have a redshift.

Which of the following is a correct statement about lines in this spectrum?

☐ **A** All the lines are in the red part of the spectrum.

☐ **B** All the lines are observed to have longer wavelengths than expected.

☐ **C** Lines with wavelengths at the red end of the spectrum are the most intense.

☐ **D** Light for all the lines was emitted with longer wavelengths than expected.

(Total for question = 1 mark)

Q14.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Sirius and α-Centauri are two of our closest stars. Sirius has a luminosity about 16 times greater than the luminosity of α-Centauri. Sirius is twice as far away from the Earth as α-Centauri.

The intensity of light from Sirius is I_s and the intensity of light from α-Centauri is I_α.

Which of the following is the value of $\frac{I_s}{I_\alpha}$?

☐ **A** $\frac{1}{4}$

☐ **B** 4

☐ **C** 8

☐ **D** 16

(Total for question = 1 mark)

Q15.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Current theory suggests that the universe is expanding.

Which of the following is evidence to support this theory?

☒ **A** All galaxies appear to be rotating in space.

☒ **B** Dark matter has been detected in the universe.

☒ **C** All distant stars are observed to be increasing in size.

☒ **D** The further a galaxy is from the Earth, the faster it recedes.

(Total for question = 1 mark)

Q16.

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 ☒.

The luminosity axis of a Hertzsprung-Russell diagram has a logarithmic scale.

Which of the following is the reason for this?

☒ **A** Stars all have very large luminosities.

☒ **B** The range of luminosities of stars is very large.

☒ **C** The range of distances to stars is very large.

☒ **D** The temperature axis has a logarithmic scale.

(Total for question = 1 mark)

Mark Scheme

Q1.

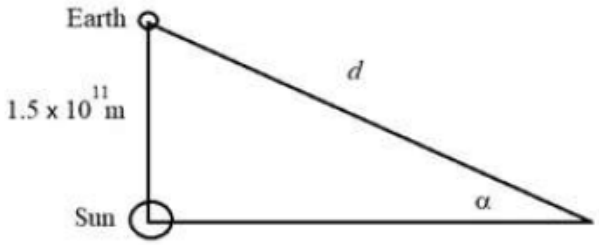
Question Number	Answer		Mark
(a)(i)	Use of $v = H_0 d$	(1)	
	$H_0 = 2.33 \times 10^{-1}$ (s^{-1})	(1)	2
	Example of calculation $H_0 = \frac{72 \times 10^3 \text{ m s}^{-1}}{3.09 \times 10^{22} \text{ m}} = 2.33 \times 10^{-18} \text{ s}^{-1}$		
(a)(ii)	Use of $t = \frac{1}{H_0}$	(1)	
	$t = 1.36 \times 10^{10}$ (years) ecf from (i)	(1)	2
	Example of calculation $t = \frac{1}{2.33 \times 10^{-1} \text{ s}^{-1}} = 4.29 \times 10^{17} \text{ s}$ $t = \frac{4.29 \times 10^{17} \text{ s}}{3.16 \times 10^7 \text{ s year}^{-1}} = 1.36 \times 10^{10} \text{ years}$		
(b)	H_0 is halved (for the same recessional velocity)	(1)	
	So the (calculated) age of the universe doubles (dependent upon MP1)	(1)	
	OR		
	The universe would have taken twice as long to expand to its current size (assuming it expanded at the same rate)	(1)	
	So the age of the universe is double what was previously thought (dependent upon MP1)	(1)	2
	Allow 1 mark max for H_0 is lower so universe is older than previously thought **Or** universe would have taken longer to expand to current size so it is older than previously thought.		
	Total for question		6

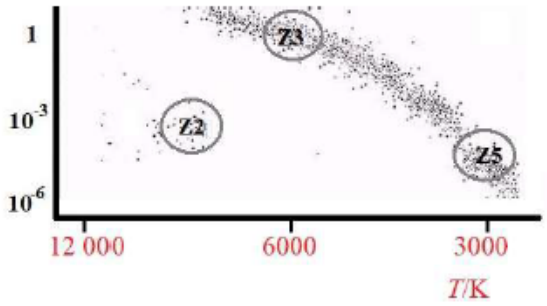
Q2.

Question Number	Answer		Mark
(a)	Use of $T^2 = KR^3$	(1)	
	K for Earth = 2.96×10^{-19} ($s^2\ m^{-3}$)	(1)	
	K for Mars = 2.97×10^{-1} ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation		
	$K = \frac{T^2}{R^3} = \frac{(3.16 \times 10^7 s)^2}{(1.50 \times 10^{11}\ m)^3} = 2.959 \times 10^{-19}\ s^2\ m^{-3}$		
	$K = \frac{T^2}{R^3} = \frac{(5.93 \times 10^7 s)^2}{(2.28 \times 10^{11}\ m)^3} = 2.967 \times 10^{-19}\ s^2\ m^{-3}$		
(b)	**Either**		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Re-arrangement with $v = \frac{2\pi r}{T}$ to identify K as $\frac{(2\pi)^2}{GM}$	(1)	
	$K = 2.97 \times 10^{-19}$ ($s^2\ m^{-3}$)	(1)	
	Or		
	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Re-arrangement with $\omega = \frac{2\pi}{T}$ to identify K as $\frac{(2\pi)^2}{GM}$	(1)	
	$K = 2.97 \times 10^{-19}$ ($s^2\ m^{-3}$)	(1)	**3**
	Example of calculation		
	$\frac{GMm}{r^2} = m\omega^2 r$		
	$\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$		
	$T^2 = \frac{(2\pi)^2}{GM} r^3$		
	$K = \left(\frac{4\pi^2}{6.67 \times 10^{-11}\ N\ m^2\ kg^{-2} \times 1.99 \times 10^{30}\ kg}\right) = 2.97 \times 10^{-1}\ s^2 m^{-3}$		

(c)	Use of $T^2 = KR^3$	(1)	
	T = 43 hours	(1)	**2**
	Example of calculation		
	$\left(\frac{T_I}{T_G}\right)^2 = \left(\frac{R_I}{R_G}\right)^3$		
	$T = \sqrt{\left(\frac{4.22 \times 10^8\ m}{1.07 \times 10^9\ m}\right)^3 \times (172\ hour)^2} = 42.6$ hours		
	Total for question		**8**

Q3.

Question Number	Answer		Mark
(a)	Use of trigonometry to calculate the parallax angle **Or** Use of trigonometry to calculate distance	(1)	
	(Smallest) parallax angle = 3.3×10^{-7} (rad) **Or** max distance = 6.25×10^{17} (m)	(1)	
	Comparison of calculated value with corresponding value in question with valid conclusion	(1)	**3**
	<u>Example of calculation</u> $\sin\alpha = \frac{1.5 \times 10^{11}\ \text{m}}{d}$ $\alpha = \sin^{-1}\left(\frac{1.5 \times 10^{11}\ \text{m}}{4.6 \times 10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad **Or** $\alpha = \left(\frac{1.5\times10^{11}\ \text{m}}{4.6\times10^{17}\ \text{m}}\right) = 3.26 \times 10^{-7}$ rad (small angle approximation)		
			
(b)	The intensity (of radiation from the candle) is measured	(1)	
	The luminosity of the standard candle is known	(1)	
	The inverse square law is used to determine the distance [Accept reference to $I=L/4\pi d^2$ with symbols defined]	(1)	**3**

(c)(i)	Axis labelled with T / K	(1)	
	Reverse logarithmic scale	(1)	
	6000 K in correct position on scale	(1)	3
	Example of graph labelling		
			
(c)(ii)			

Description	Zone		
High mass hot stars	Z1	(1)	
Low mass cool stars	Z5	(1)	
Low mass hot stars	Z2	(1)	3

(c)(iii)

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content

IC1 The star is fusing hydrogen in its core

IC2 When fusion ceases (the core of the star cools and) the core collapses/contracts (under gravitational forces)

IC3 The star (moves to Z4 as it expands and) becomes a red giant star

IC4 Temperature (in the core) is high enough for helium fusion to begin

IC5 Helium begins to run out and then fusion ceases

IC6 The star becomes a white dwarf (in Z2)

6

Total for question **18**

Q4.

Question Number	Answer		Mark
(a)	Use of $pV = NkT$	(1)	3
	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	(1)	
	$\frac{1}{2}m\langle c^2\rangle = 5.8 \times 10^{-20}$ J	(1)	
	Example of calculation $T = \frac{pV}{Nk} = \frac{4.25\times10^{4}\text{ Pa}\times1.50\times10^{-5}\text{ m}^3}{1.65\times10^{19}\times1.38\times10^{-23}\text{ J K}^{-1}} = 2800$ K $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}\times 1.38\times10^{-23}\text{ J K}^{-1}\times 2800\text{ K} = 5.80\times10^{-20}$ J		
(b)	Use of $\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ with wavelength measured on Earth in denominator	(1)	4
	v = 13500 m s^{-1}	(1)	
	The student is correct to say that the star is moving towards the Earth, as the measured wavelength is less than that from the lamp spectrum.	(1)	
	Comparison of calculated velocity with 1400 m s^{-1} and appropriate conclusion.	(1)	
	Example of calculation $v = \frac{\Delta\lambda}{\lambda}c = \frac{(576.933\text{-}576.959)\times10^{-9}\text{m}}{576.959\times10^{-9}\text{ m}}\times3.00\times10^{8}\text{ m s}^{-1} = (-)1.35\times10^{4}\text{ m s}^{-1}$ So the star's velocity is much larger than 1400 m s^{-1}		
(c)	On the main sequence, above the position of the Sun **Or** above and to the left of the position of the Sun	(1)	1
	Total for question		8

Q5.

Question Number	Answer		Mark
(a)(i)	$v \propto \sqrt{\frac{M}{r}}$	(1)	
	Within the central region M changes a lot (so v increases) **Or** Outside the central region M is approximately constant (so v decreases)		
	As r increases v reaches a peak value as shown on the graph	(1)	
	[A bald description of the graph having a peak value can score MP3]	(1)	**3**
(a)(ii)	There must be more mass (than we can observe) [Accept statement that there must be a greater gravitational force]	(1)	
	There is dark matter present (in the galaxy)	(1)	**2**
(b)	(For a closed universe) the density of the universe must be greater than the critical density	(1)	
	And the (average) density of the universe is uncertain **Or** the amount of dark matter is uncertain	(1)	**2**
	Total for question		7

Q6.

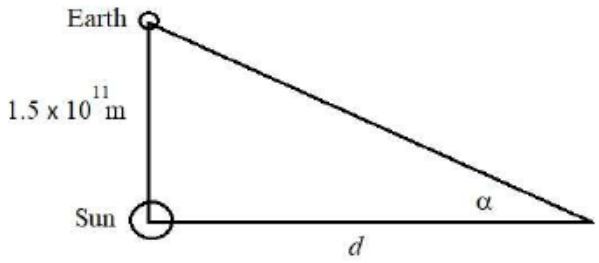
Question Number	Answer		Mark
(a)(i)	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Re-arrangement with $\omega = \frac{2\pi}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$	(1)	
	Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2)	(1)	
	OR		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Re-arrangement with $v = \frac{2\pi r}{T}$ to obtain $T^2 = \frac{(2\pi)^2}{GM} r^3$	(1)	
	Statement that G, M (and π) are constants, so $T^2 \propto r^3$ (dependent upon MP2)	(1)	3
	Example of calculation		
	$\frac{GMm}{r^2} = m\omega^2 r$		
	$\frac{GM}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$		
	$T^2 = \frac{(2\pi)^2}{GM} r^3$		
	$\therefore T^2 \propto r^3$		

(a)(ii)	Use of $T^2 \propto r^3$	(1)	
	T_J = 142 months (11.9 years)	(1)	
	Use of $\omega = \frac{\theta}{t}$ and $\omega = \frac{2\pi}{T}$	(1)	
	Calculation of time elapsed for planets to be in opposition	(1)	
	Time between opposition is 13.1 months, with an appropriate conclusion (dependent upon MP4)	(1)	5
	Example of calculation		
	$\left(\frac{T_J}{T_E}\right)^2 = \left(\frac{r_J}{r_E}\right)^3$		
	$\left(\frac{T_J}{1\text{ year}}\right)^2 = \left(\frac{7.8 \times 10^{11}\text{ m}}{1.5 \times 10^{11}\text{ m}}\right)^3$		
	$T_J = 12\text{ months} \times \sqrt{\left(\frac{7.8 \times 10^{11}\text{ m}}{1.5 \times 10^{11}\text{ m}}\right)^3} = 142\text{ months}$		
	At the next opposition Earth will have done one more orbit than Jupiter plus whatever fraction of an orbit Jupiter has completed.		
	If t is the time to next opposition, both planets will have the same angular displacement, so equating $\theta = 2\pi\, t/T$ for both planets where for Earth the time is $(t - 12)$.		
	$\frac{2\pi\text{ rad }(t-12)\text{ month}}{12\text{ month}} = \frac{2\pi\text{ rad }t}{142\text{ month}} \therefore t = 13.1\text{ month}$		

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(b)	Use of $V = (-)\frac{GM}{r}$	(1)	
	Use of $\Delta V \times m$	(1)	
	$\Delta E_{grav} = 3.3 \times 10^{34}$ J	(1)	**3**
	<u>Example of calculation</u> $\Delta V = -GM\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$ $\Delta V = -6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 2.0 \times 10^{30}\text{kg} \times \left(\frac{1}{8.2 \times 10^{11}\ \text{m}} - \frac{1}{7.4 \times 10^{11}\ \text{m}}\right)$ $\Delta V = 1.76 \times 10^{7}\ \text{J kg}^{-1}$ $\therefore \Delta E_{grav} = 1.76 \times 10^{7}\ \text{J kg}^{-1} \times 1.9 \times 10^{27}\ \text{kg} = 3.34 \times 10^{34}\ \text{J}$		
	Total for question		**11**

Q7.

Question Number	Answer		Mark
(a)(i)	Use of trigonometry to calculate distance **Or** use of small angle approximation to calculate distance	(1)	
	Distance to Wolf 359 = 7.5×10^{16} (m)	(1)	**2**
	<u>Example of calculation</u>  $\tan(2.01 \times 10^{-6}) = \frac{1.50 \times 10^{11}\ \text{m}}{d}$ $\therefore d = \frac{1.50 \times 10^{11}\ \text{m}}{2.01 \times 10^{-6}} = 7.46 \times 10^{16}\ \text{m}$		
(a)(ii)	Parallax angle decreases as distance from the Earth increases **Or** parallax is only suitable for (relatively) close stars	(1)	
	As parallax angle is too small to measure for distant stars	(1)	**2**

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(b)(i)	λ_{max} read from graph	(1)	
	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	(1)	
	$T = 2680$ (K) [accept 2635 K → 2760 K]	(1)	**3**
	Example of calculation $T = \frac{2.898 \times 10^{-3}\ \text{m K}}{1.08 \times 10^{-6}\ \text{m}} = 2683\ \text{K}$		
(b)(ii)	Use of $L = \sigma A T^4$	(1)	
	$L = 4.70 \times 10^{23}$ W (allow ecf from (b)(i))	(1)	
	Comparison of calculated value of L with L_{Sun} and appropriate conclusion **Or** comparison of calculated L/L_{Sun} percentage with 0.1% and appropriate conclusion	(1)	**3**
	Example of calculation $L = 4\pi\,(0.16 \times 6.96 \times 10^8\ \text{m})^2 \times 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}\ (2700\ \text{K})^4$ $L = 4.70 \times 10^{23}\ W$ $\frac{L}{L_{Sun}} \times 100\% = \frac{4.70 \times 10^{23}\ W}{3.83 \times 10^{26}\ W} \times 100\% = 0.12\%$		
	Total for question		**10**

Q8.

Question Number	Answer		Mark
	λ_{max} read from graph [450 nm → 500 nm]	(1)	
	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K	(1)	
	Use of $L = \sigma AT^4$	(1)	
	Use of $A = 4\pi r^2$	(1)	
	$D_P = 4.6 \times D_{Sun}$ so statement is incorrect Or $D_P = 3.2 \times 10^9$ m, which is more than twice Sun's diameter, so statement is incorrect	(1)	5
	Example of calculation $T = \frac{2.898 \times 10^{-3}\ \text{m K}}{470 \times 10^{-9}\ \text{nm}} = 6170\ \text{K}$ $A = \frac{2.65 \times 10^{27}\ \text{W}}{5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^4 \times (6170\ \text{K})^4} = 3.22 \times 10^{19}\ \text{m}^2$ $r = \sqrt{\frac{3.22 \times 10^{19}\ \text{m}^2}{4\pi}} = 1.60 \times 10^9\ \text{m}$ $\frac{D_P}{D_{Sun}} = \frac{2 \times 1.60 \times 10^9\ \text{m}}{6.96 \times 10^8\ \text{m}} = 4.6$		
	Total for question		5

Q9.

Question Number	Answer		Mark
	Use of $L = 14800\ L_{Sun}$	(1)	
	Use of $I = \frac{L}{4\pi d^2}$	(1)	
	$d = 1.1 \times 10^{23}$ m	(1)	3
	Example of calculation $L_{candle} = 14\,800 \times 3.83 \times 10^{26}\ \text{W} = 5.67 \times 10^{30}\ \text{W}$ $d = \sqrt{\frac{L}{4\pi I}} = \sqrt{\frac{5.67 \times 10^{30}\text{W}}{4\pi \times 3.64 \times 10^{-17}\ \text{W m}^{-2}}} = 1.11 \times 10^{23}\ \text{m}$		
	Total for question		3

Q10.

Question Number	Answer	Mark
	B is the correct answer, as $g = \frac{GM}{r^2}$ and $M = \frac{4}{3}\pi\rho r^3$	**(1)**

Q11.

Question Number	Answer	Mark
	B is the correct answer, as $F = \frac{GMm}{r^2}$	**(1)**

Q12.

Question Number	Answer	Mark
	C is the correct answer A is not the correct answer, as angular velocity has units (rad) s^{-1} B is not the correct answer, as frequency has units Hz = s^{-1} D is not the correct answer, as rate of decay has units Bq = s^{-1}	**(1)**

Q13.

Question Number	Answer	Mark
	B is the correct answer A is incorrect, as the lines may be shifted into any region of the spectrum C is incorrect, as the intensity of the lines is not related to the redshift D is incorrect, as the wavelengths of the emitted lines is not affected	**(1)**

Q14.

Question Number	Answer	Mark
	B is the correct answer, as $I = \frac{L}{4\pi d^2}$	**(1)**

Q15.

Question Number	Answer	Mark
	D is the correct answer, as this is a statement of Hubble's law	**(1)**

Q16.

Question Number	Answer	Mark
	B is the correct answer A is not the correct answer, as large values could fit on a linear scale C is not the correct answer, as distance from the star only affects the intensity D is not the correct answer, as the temperature and luminosity scales are independent	**(1)**