Name: _____

Topic 10: Space Part 1

Date:

Time:

Total marks available:

Total marks achieved: _____

Questions

Q1.

The wavelength of a line in the spectrum produced by a distant star is found to be shorter than the wavelength of the corresponding line in the spectrum produced by the Sun.

This is because the distant star is

☒ **A** cooler than the Sun.

☒ **B** hotter than the Sun.

☒ **C** moving away from the Earth.

☒ **D** moving towards the Earth.

(Total for question = 1 mark)

Q2.

The distance to astronomical objects relatively close to the Sun is determined using trigonometric parallax. For objects beyond a certain distance standard candles are used.

(a) State what is meant by a standard candle.

(1)

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(b) Explain why trigonometric parallax is not used beyond a certain distance.

(2)

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(c) Describe how distances too large for the use of standard candles can be determined.

(3)

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(Total for question = 6 marks)

Q3.

Astronomers observing stars at the centre of our galaxy have suggested that many of them are orbiting a supermassive black hole. The mass of this black hole is 9.2×10^{36} kg.

Trigonometric parallax and Hubble's law are two methods used to determine astronomical distances.
Explain whether either of these methods is suitable to determine the distance to S0-2.

(3)

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(Total for question = 3 marks)

Q4.

One of the largest stars in our galaxy is VY Canis Majoris. This star's radius is 1420 times the radius of the Sun. The luminosity of this star is 270 000 times the luminosity of the Sun.

A student states that the surface temperature of VY Canis Majoris must be much greater than

the surface temperature of the Sun.

(a) Determine whether the student's statement is correct.

surface temperature of Sun = 5780 K
luminosity of Sun = 3.85×10^{26} W
radius of Sun = 6.96×10^{8} m

(3)

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(b) Calculate the wavelength with maximum intensity in the black body radiation spectrum of VY Canis Majoris.

(2)

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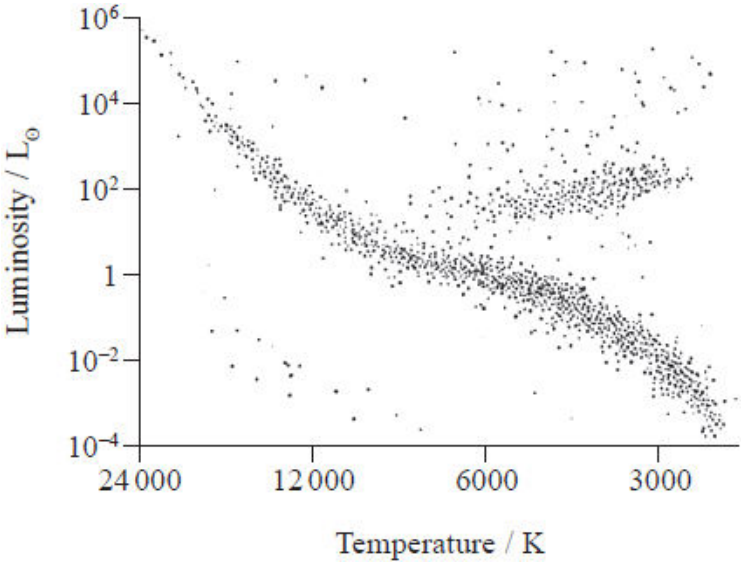
Wavelength = ...

(c) Add the position of VY Canis Majoris to the Hertzsprung Russell diagram to determine which type of star it is.

(2)



Type of star .....

(Total for question = 7 marks)

Q5.

According to astronomers in Denmark and Australia a common type of active galactic nucleus (AGN) could be used as an accurate "standard candle" for measuring cosmic distances. The technique has been used to measure distances corresponding to redshifts significantly larger than was previously possible.

(a) (i) State what is meant by a standard candle.

(1)

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(ii) Explain how a standard candle is used to measure cosmic distances.

(2)

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(b) (i) State what is meant by redshift.

(1)

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(ii) Calculate the distance to a galaxy with a redshift $z = 0.12$

$H_0 = 2.1 \times 10^{-18}\ s^{-1}$

(2)

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Distance to galaxy = ...

*(c) Discuss how astronomers were led to propose the existence of dark matter and the consequences of its existence for the ultimate fate of the universe.

(3)

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(d) Explain why the observable universe has a finite size.

(2)

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(Total for Question = 11 marks)

Q6.

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 diagram shows a source of sound waves and an observer.

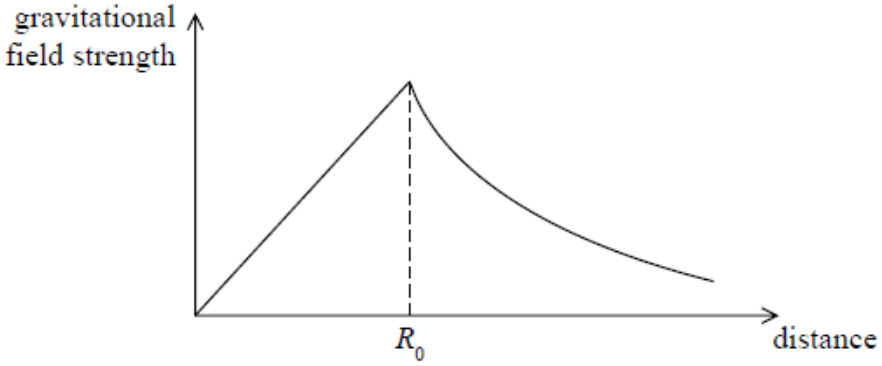
Which row of the table shows a situation which would result in a decrease in the frequency of sound observed?

		Source	Observer
☒	**A**	moves to the right at $20\,m\,s^{-1}$	moves to the left at $20\,m\,s^{-1}$
☒	**B**	moves to the right at $20\,m\,s^{-1}$	moves to the right at $20\,m\,s^{-1}$
☒	**C**	moves to the right at $20\,m\,s^{-1}$	stationary
☒	**D**	stationary	moves to the right at $20\,m\,s^{-1}$

(Total for question = 1 mark)

Q7.

The graph shows the variation of the gravitational field strength with distance from the centre of the Earth. R_0 is the radius of the Earth.



A scientist suggests the following:

"If a tunnel were made through the centre of the Earth, an object dropped at one end would accelerate downwards until it reached the centre. It would then decrease in speed until it reached the other end of the tunnel with a speed of zero. The object would then return the other way, undergoing simple harmonic motion."

Using the graph between 0 and R_0, determine whether simple harmonic motion would occur.

(4)

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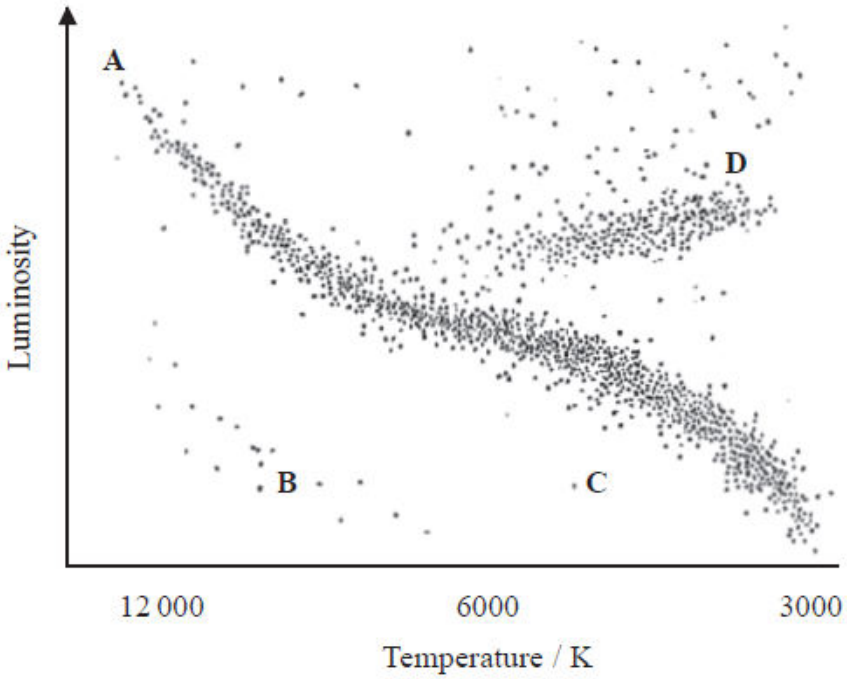
(Total for question = 4 marks)

Q8.

This question refers to the Hertzsprung-Russell diagram below.



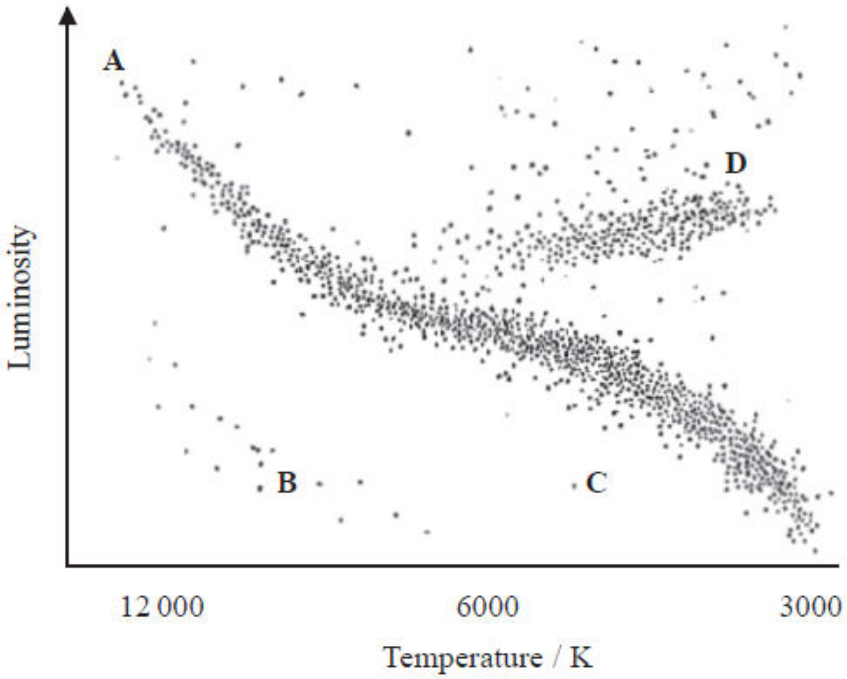
Which letter, **A**, **B**, **C** or **D**, indicates the region where a blue giant star would be shown?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for question = 1 mark)

Q9.

This question refers to the Hertzsprung-Russell diagram below.

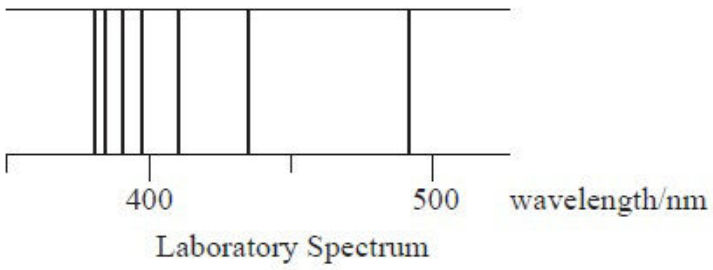


Which letter, **A**, **B**, **C** or **D**, indicates the region where a white dwarf star would be shown?

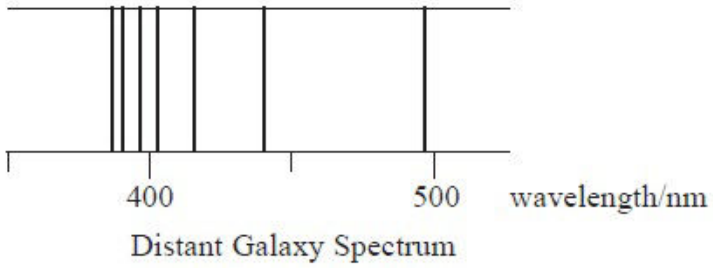
- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for question = 1 mark)

Q10. The diagram shows part of the hydrogen line spectra obtained for radiation emitted from hydrogen in the laboratory and received from hydrogen in a distant galaxy.



Laboratory Spectrum



Distant Galaxy Spectrum

The lines in the distant galaxy spectrum are all shifted in wavelength compared to the lines in the laboratory spectrum.

State why the lines are shifted and what we can conclude about this distant galaxy.

(2)

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(Total for Question = 2 marks)

Q11.

Almost a century ago Edwin Hubble was investigating the light spectra emitted from a large number of galaxies. He used redshift values obtained from these spectra to determine the velocity of the galaxies relative to the Earth. He also measured the distances to each galaxy using Cepheid variable stars, which are a type of standard candle. From these measurements Hubble was able to formulate a law linking the velocity of distant galaxies to their distance from the Earth.

(a) (i) Explain what is meant by redshift.

(2)

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*(ii) Explain how redshift can be used to determine the velocity of a galaxy relative to the Earth.

(3)

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(b) State what is meant by a standard candle.

(1)

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(c) Explain how Hubble's law can be used to find a value for the age of the universe.

(2)

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(d) Hubble's law is seen as one piece of evidence supporting the Big Bang theory of the origin of the universe. In this theory the universe has been expanding ever since it was created 14 billion years ago.

(i) Describe how you would expect the average density of matter in the universe to affect its ultimate fate.

(3)

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(ii) It is difficult for scientists to estimate the average density of the universe reliably. Explain why.

(2)

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(Total for question = 13 marks)

Q12.

When light from the galaxy in Andromeda is analysed, it is found that the wavelengths are shorter than expected.
This tells us that the galaxy is

☒ **A** moving towards us.

☒ **B** moving away from us.

☒ **C** a very distant galaxy.

☒ **D** rotating on an axis.

(Total for question = 1 mark)

Q13.

A student is constructing a spreadsheet to calculate the radius R of some stars. To obtain the radius, the surface temperature T of the star must first be calculated. She is given values for the stars' luminosities L and the wavelengths λ_{max} at which peak energy emission occurs. Part of the spreadsheet is shown, A is the surface area of the star.

	A	B	C	D	E
1	λ_{max} / 10^{-7} m	T / 10^{3} K	L / 10^{27} W	A / 10^{19} m^2	R / 10^{9} m
2	6.85	4.23	0.039		0.41
3	5.74	5.05	0.384	1.04	0.91
4	3.56	8.14	3.385	1.36	1.04
5					

(a) Write an equation to show how the value in B2 is calculated.

(1)

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(b) Show that the value in D2 is about 0.2

(2)

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(c) The student was given the luminosity values to enter into column C.

Describe how astronomers could determine the luminosity of a star.

(2)

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(Total for Question = 5 marks)

Q14. * Parallax measurements are used to determine the distance to nearby stars, but this method is unsuitable for more distant objects.

Outline how parallax measurements are used to determine the distance to nearby stars and explain how the use of a standard candle enables the distance to more distant objects to be determined.

(6)

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(Total for Question = 6 marks)

Q15.

Standard candles are used by astronomers to determine the distances to distant star clusters.

A standard candle has a

☒ **A** constant brightness.

☒ **B** constant luminosity.

☒ **C** known brightness.

☒ **D** known luminosity.

(Total for question = 1 mark)

Q16.

At the Culham Centre for Fusion Energy (CCFE) experiments are carried out to investigate nuclear fusion and the properties of plasmas. A plasma consists of ionised gas, containing positive ions and electrons.

In a plasma experiment 5.0 mg of deuterium, an isotope of hydrogen, occupies a volume of 98 m^3. The temperature of deuterium is raised to 1.3×10^8 K. In this experiment, the deuterium behaves as an ideal gas.

(i) Calculate the pressure due to the deuterium ions.

mass of deuterium ion = 3.3×10^{-27} kg

(3)

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Pressure = ...

(ii) Calculate the root mean square speed of the deuterium ions at this temperature.

(2)

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Root mean square speed = ...

(iii) The temperature of the plasma is monitored using the Doppler effect. Light from a laser is directed into the plasma and the wavelength of the light reflected is measured.

The Doppler shift observed when light is reflected by a deuterium ion is twice the Doppler shift that would be observed for a source of light moving at the same speed as the deuterium ion.

Calculate the maximum wavelength of light that would be detected after reflection from a deuterium ion moving at $1.5 \times 106\ m\ s^{-1}$.

wavelength of laser light = 1064 nm

(3)

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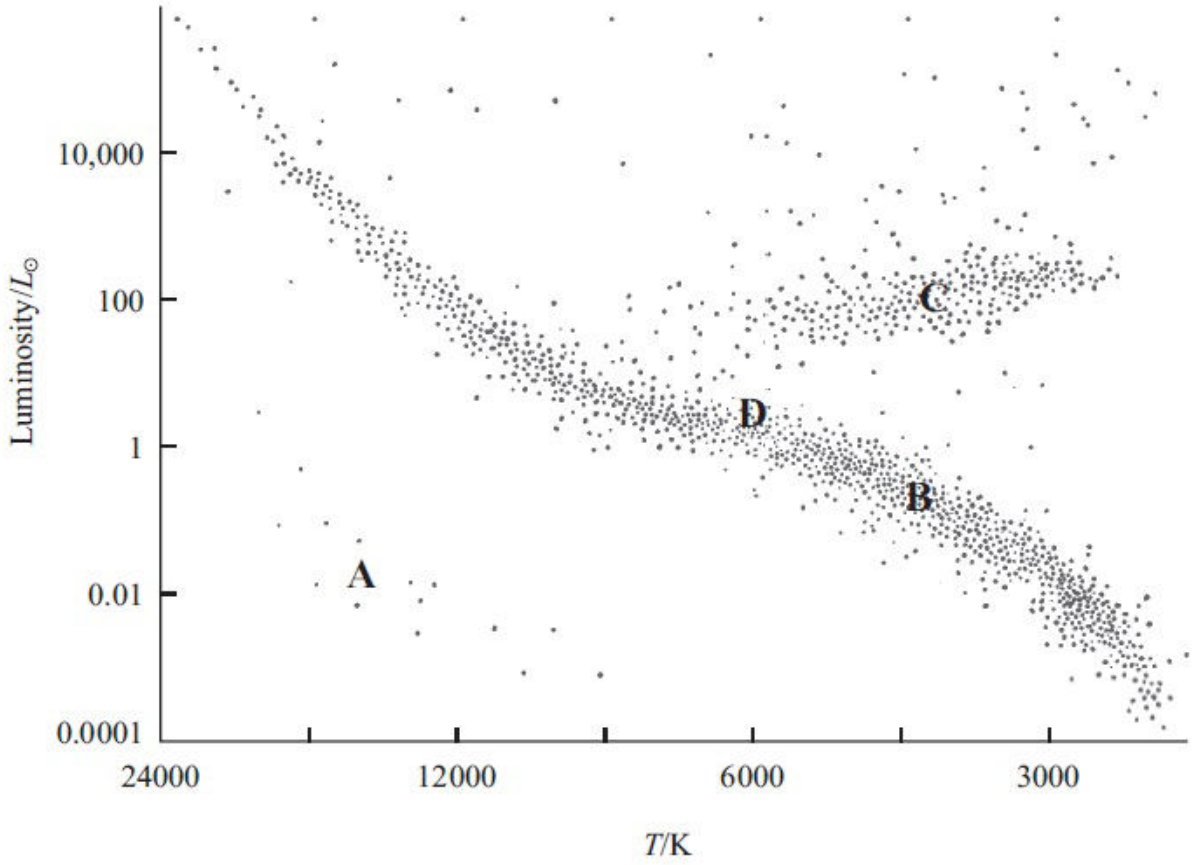
Maximum wavelength detected = ...

(Total for question = 8 marks)

Q17.



Which letter A, B, C or D represents the region on the diagram where a white dwarf star would be shown?

☒ **A**

☒ **B**

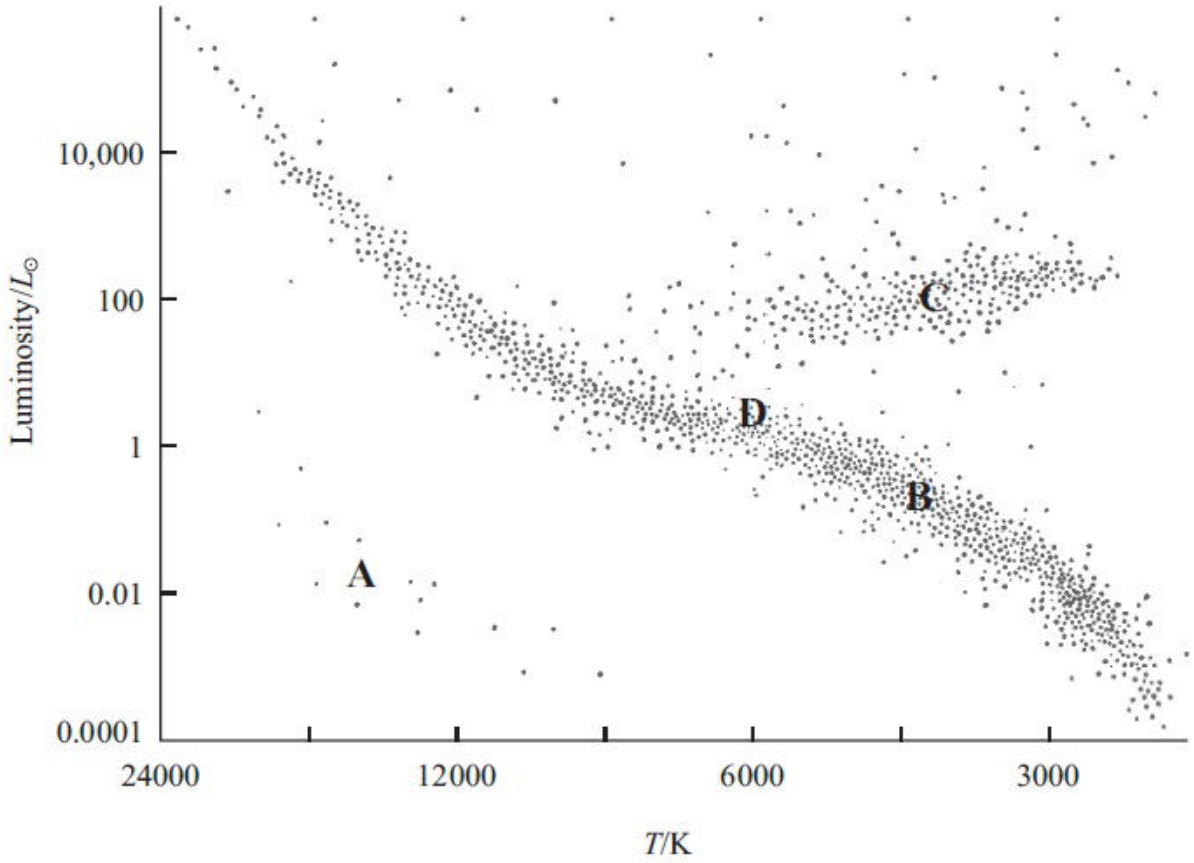
☒

C

D

(Total for question = 1 marks)

Q18.



Which letter A, B, C or D represents the region on the diagram where our Sun would be shown?

A

B

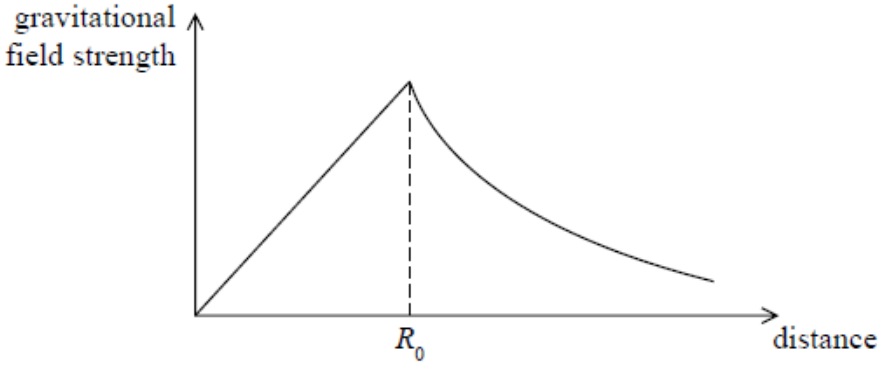
C

D

(Total for question = 1 marks)

Q19.

The graph shows the variation of the gravitational field strength with distance from the centre of the Earth. R_0 is the radius of the Earth.



A scientist suggests that the period of oscillation for a body dropped through the tunnel would be the same as the orbital period for a body orbiting just above the surface of the Earth. Its radius of orbit is assumed to be R_0.

(i) Derive an expression for the period of oscillation of the body dropped through the tunnel.

(4)

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(ii) Derive an expression for the orbital period for a body that is orbiting the Earth with radius R_0.

(3)

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(Total for question = 7 marks)

Q20.

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 ☒.

There are several different methods that can be used to determine the distance from our solar system to astronomical objects. These include the measurement of red shift, trigonometrical parallax and the use of standard candles.

Which row of the table shows a suitable method for each of the objects named?

		Nearby star	Nearby galaxy	Very distant galaxy
☒	**A**	parallax	red shift	standard candle
☒	**B**	red shift	standard candle	parallax
☒	**C**	parallax	standard candle	red shift
☒	**D**	red shift	parallax	standard candle

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer	Mark
	D	1

Q2.

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

Q3.

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

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Use of $L = 4\pi r^2 \sigma T^4$ • With 270 000 or 1420 • $T = 3494$ K which is smaller than the temperature of the Sun, so it is not correct • **Or** $T = 0.605\ T_{Sun}$ which is smaller than the temperature of the Sun, so it is not correct	(1) (1) (1)	Example of calculation 3.85×10^{26} W $\times$ 270 000 $= 4 \times \pi \times 5.67 \times 10^{-8} \times (1420 \times 6.96 \times 10^{8}\ \text{m})^2 \times T^4$ $T = 3494$ K	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Use of $\lambda_{max}\ T = 2.898 \times 10^{-3}$ m K • $\lambda_{max} = 8.29 \times 10^{-7}$ m (ecf for T from (a))	(1) (1)	Example of calculation $\lambda_{max} \times 3494\ \text{K} = 2.898 \times 10^{-3}$ m K $\lambda_{max} = 8.29 \times 10^{-7}$ m	2

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Add to top right • Red giant/supergiant	(1) (1)	Consistent with the answer from (a) for both marking points Accept hypergiant	2

Q5.

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**

Q6.

Question Number	Answer	Mark
	The only correct answer is D because there is relative motion of the objects away from each other so the wavelength is increased by the Doppler effect so the observed frequency is decreased A there is relative motion of the objects towards each other so the wavelength is decreased by the Doppler effect so the observed frequency is increased B there is no relative motion for the objects so there is no observed change in wavelength or frequency C there is relative motion of the objects towards each other so the wavelength is decreased by the Doppler effect so the observed frequency is increased	**1**

Q7.

Question number	Acceptable answers	Additional guidance	Mark
	• Force on object = mg (local g) **(1)** • Force is proportional to displacement **(1)** • Force acts in the opposite direction to the displacement **(1)** • Therefore we can say $F = -kx$, so the condition for SHM is met and the prediction is correct **(1)**		**4**

Q8.

Question Number	Answer	Mark
	A	1

Q9.

Question Number	Answer	Mark
	B	1

Q10.

Question Number	Answer		Mark
	There is a red shift [accept Doppler shift] The galaxy is receding **Or** the galaxy is moving away from us [Do not accept "the universe is expanding"]	(1) (1)	**2**
	Total for question		**2**

Q11.

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

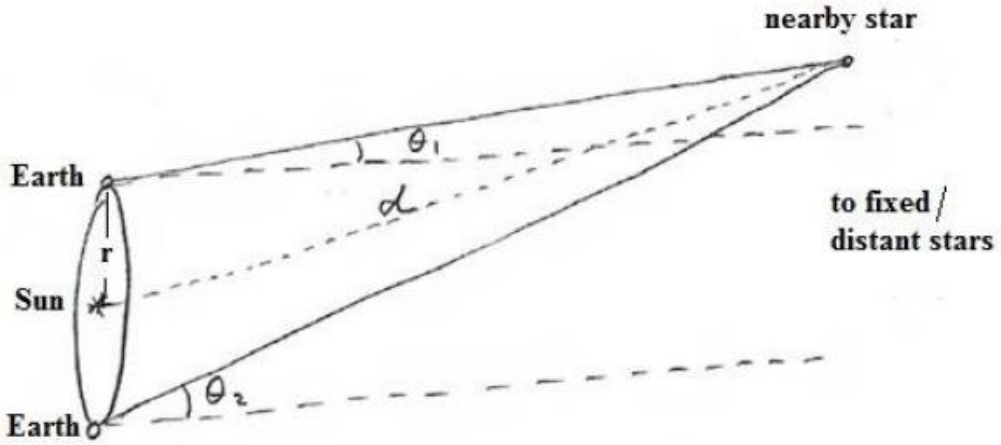
Q12.

Question Number	Answer	Mark
	A	1

Q13.

Question Number	Answer		Mark
(a)	(B2 =) 2.9×10^{-3}/A2 **Or** (B2 =) $2.9 \times 10^{-3}/\lambda_{max}$ **Or** (B2=) $2.9 \times 10^{-3}/6.85 \times 10^{-7}$ [Ignore incorrect powers of 10]	**(1)**	**1**
(b)	Use of $L = \sigma T^4 A$ $A = 0.21(48) \times 10^{19}$ (m^2) For max 1 Use of $A = 4\pi R^2$ to give $A = 2.1(1) \times 10^{18}$ (m^2) <u>Example of calculation:</u> $A = \frac{0.392 \times 10^{26}\ \text{W m}^{-2}}{5.67 \times 10^{-8}\ \text{W m}^{-4}\ \text{K}^{-4} \times (4230\ \text{K})^4} = 2.148 \times 10^{18}\ \text{m}^2$	**(1)** **(1)**	**2**
(c)	Flux/brightness/intensity measured and distance to star determined (Luminosity calculated using) L= $4\pi d^2 F$ **Alternative mark scheme:** Temperature and type of star identified [e.g. main sequence]	**(1)** **(1)** **(1)**	
	Hertzsprung-Russell diagram used to find luminosity	**(1)**	**2**
	Total for question		**5**

Q14.

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) 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) (1)	**6**
	Total for question	**6**

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	D		**1**

Q16.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use total mass / mass of D ion • Use of $pV = NkT$ • $p = 2.8 \times 10^4$ Pa	(1) (1) (1)	Example of calculation $N = 5.0 \times 10^{-6}$ kg / 3.3×10^{-27} kg = 1.5×10^{21} $p = 1.5 \times 10^{21} \times 1.38 \times 10^{-23}$ J K^{-1} × 130 000 000 K / 98 m^3 = 2.77×10^4 Pa	3
(ii)	• Use of ½ m $<c^2>$ = 3/2 kT **Or** pV = 1/3 ($Nm<c^2>$) (ecf for N and p from (i)) • $\sqrt{<c^2>} = 1.3 \times 10^6$ m s^{-1}	(1) (1)	Example of calculation ½ m $<c^2>$ = 3/2 kT ½ × (3.3×10^{-27} kg) × $<c^2>$ = 3/2 × 1.38 × 10^{-23} J K^{-1} × 130 000 000 K $<c^2> = 1.6 \times 10^{12}$ m^2 s^{-2} $\sqrt{<c^2>} = 1.28 \times 10^6$ m s^{-1}	2
(iii)	• Use of $\Delta\lambda / \lambda = v/c$ to determine $\Delta\lambda$ • Adds shift to original wavelength • 1.075×10^{-6} m	(1) (1) (1)	Example of calculation $\Delta\lambda / 1.064 \times 10^{-6}$ m = 15×10^6 m s^{-1}/3.00×10^8 m s^{-1} $\Delta\lambda = 5.3 \times 10^{-9}$ m $\lambda + 2\Delta\lambda = 1.075 \times 10^{-6}$ m	3

Q17.

Question Number	Answer	Mark
	A	1

Q18.

Question Number	Answer	Mark
	D	1

Q19.

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**

Q20.

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**