OptionD-SL-Astro-2018

1a. *[2 marks]*

A distinctive feature of the constellation Orion is the Trapezium, an open cluster of stars within Orion.

Distinguish between a constellation and an open cluster.

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1b. *[1 mark]*

Mintaka is one of the stars in Orion.

The parallax angle of Mintaka measured from Earth is 3.64×10^{-3} arc-second. Calculate, in parsec, the approximate distance of Mintaka from Earth.

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1c. *[1 mark]*

State why there is a maximum distance that astronomers can measure using stellar parallax.

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2a. *[1 mark]*

The surface temperature of the star Epsilon Indi is 4600 K.

Determine the peak wavelength of the radiation emitted by Epsilon Indi.

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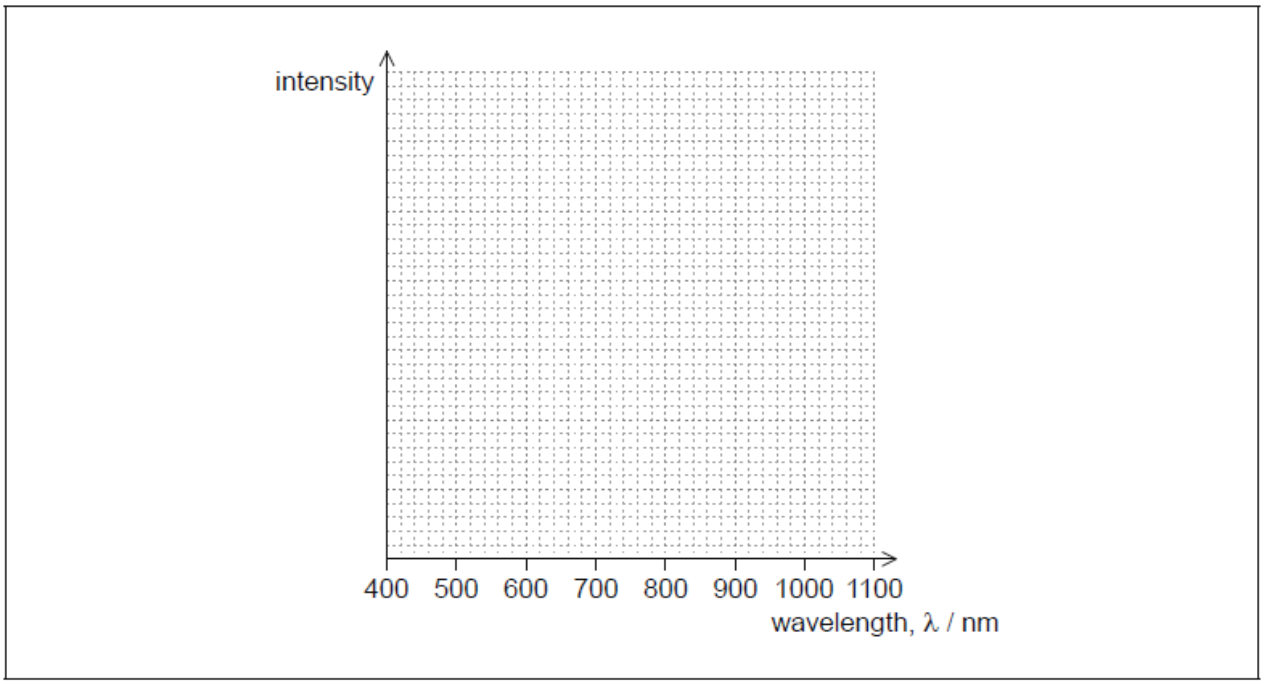
2b. *[2 marks]*

Using the axis, draw the variation with wavelength of the intensity of the radiation emitted by Epsilon Indi.



2c. *[2 marks]*

The following data are available for the Sun.

Surface temperature = 5800 K

Luminosity = $L_\odot$

Mass = $M_\odot$

Radius = $R_\odot$

Epsilon Indi has a radius of 0.73 $R_\odot$. Show that the luminosity of Epsilon Indi is 0.2 $L_\odot$.

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2d. *[1 mark]*

Epsilon Indi is a main sequence star. Show that the mass of Epsilon Indi is 0.64 $M_\odot$.

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2e. *[2 marks]*

Describe how the chemical composition of a star may be determined.

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2f. *[3 marks]*

Describe the stages in the evolution of Epsilon Indi from the point when it leaves the main sequence until its final stable state.

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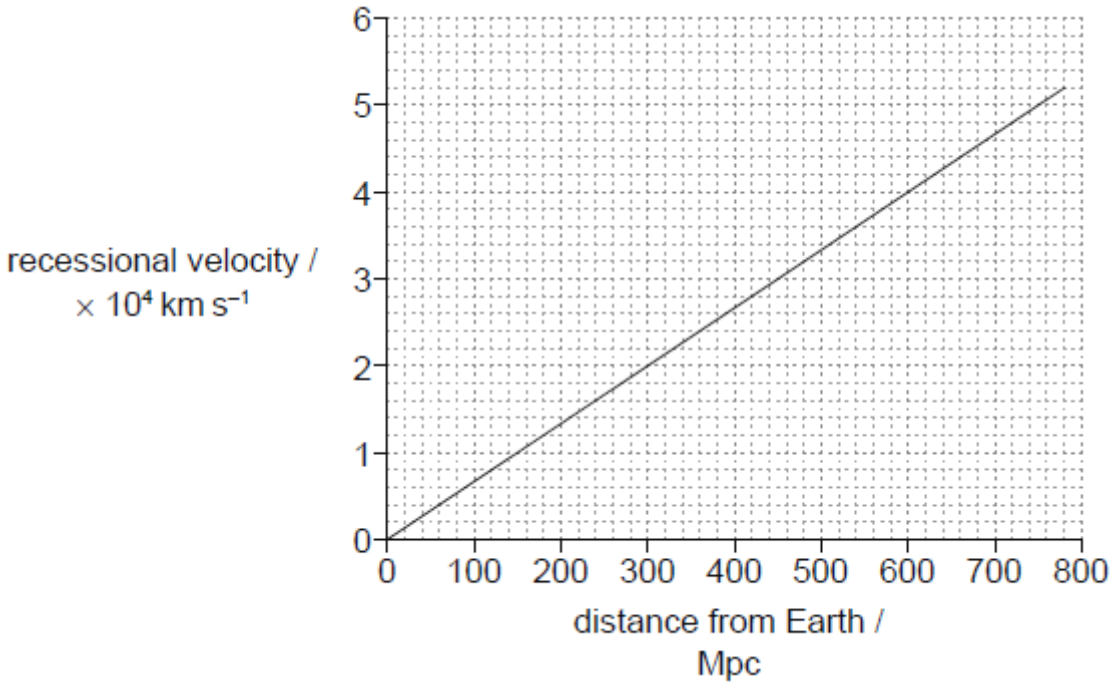
3a. *[2 marks]*

The graph shows the variation with distance from the Earth of the recessional velocities of distant galaxies.



Outline how Hubble measured the recessional velocities of galaxies.

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3b. *[3 marks]*

Using the graph, determine in s, the age of the universe.

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4a. *[2 marks]*

Distinguish between a constellation and an open cluster.

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4b. *[1 mark]*

The parallax angle of Mintaka measured from Earth is 3.64×10^{-3} arc-second. Calculate, in parsec, the approximate distance of Mintaka from Earth.

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4c. *[1 mark]*

State why there is a maximum distance that astronomers can measure using stellar parallax.

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4d. *[2 marks]*

The Great Nebula is located in Orion. Describe, using the Jeans criterion, the necessary condition for a nebula to form a star.

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5a. *[1 mark]*

Determine the peak wavelength of the radiation emitted by Epsilon Indi.

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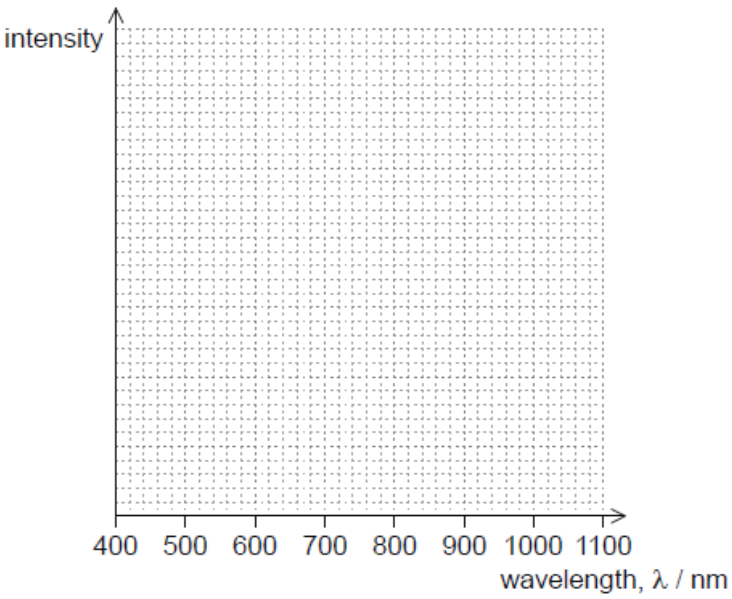
5b. *[2 marks]*

Using the axis, draw the variation with wavelength of the intensity of the radiation emitted by Epsilon Indi.



5c. *[2 marks]*

The following data are available for the Sun.

Surface temperature = 5800 K

Luminosity = $L_\odot$

Mass = $M_\odot$

Radius = $R_\odot$

Epsilon Indi has a radius of 0.73 $R_\odot$. Show that the luminosity of Epsilon Indi is 0.2 $L_\odot$.

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5d. *[1 mark]*

Epsilon Indi is a main sequence star. Show that the mass of Epsilon Indi is 0.64 $M_{\odot}$.

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5e. *[2 marks]*

The Sun will spend about nine billion years on the main sequence. Calculate how long Epsilon Indi will spend on the main sequence.

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5f. *[3 marks]*

Describe the stages in the evolution of Epsilon Indi from the point when it leaves the main sequence until its final stable state.

6a. *[2 marks]*

Outline how Hubble measured the recessional velocities of galaxies.

6b. *[3 marks]*

Use the graph to determine the age of the universe in s.

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7a. *[1 mark]*

Distinguish between the solar system and a galaxy.

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7b. *[1 mark]*

Distinguish between a planet and a comet.

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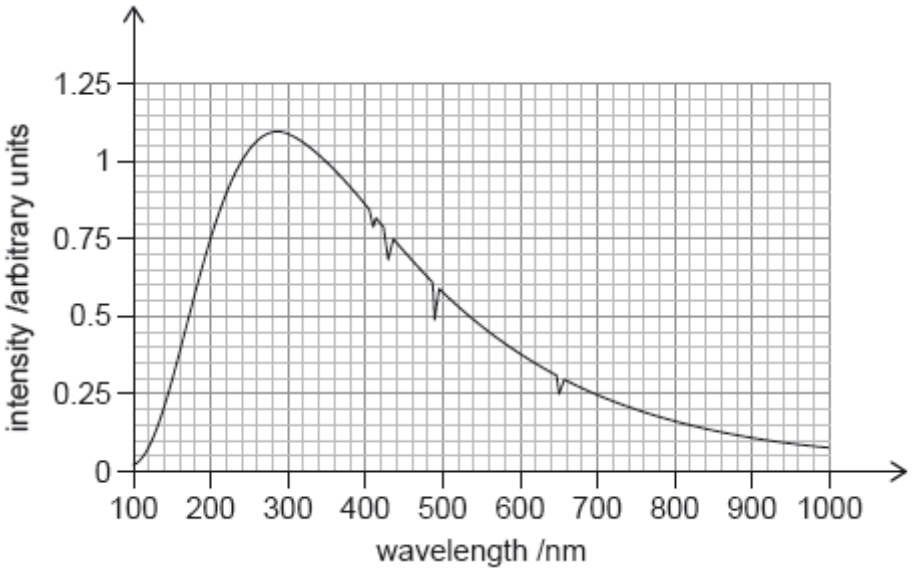
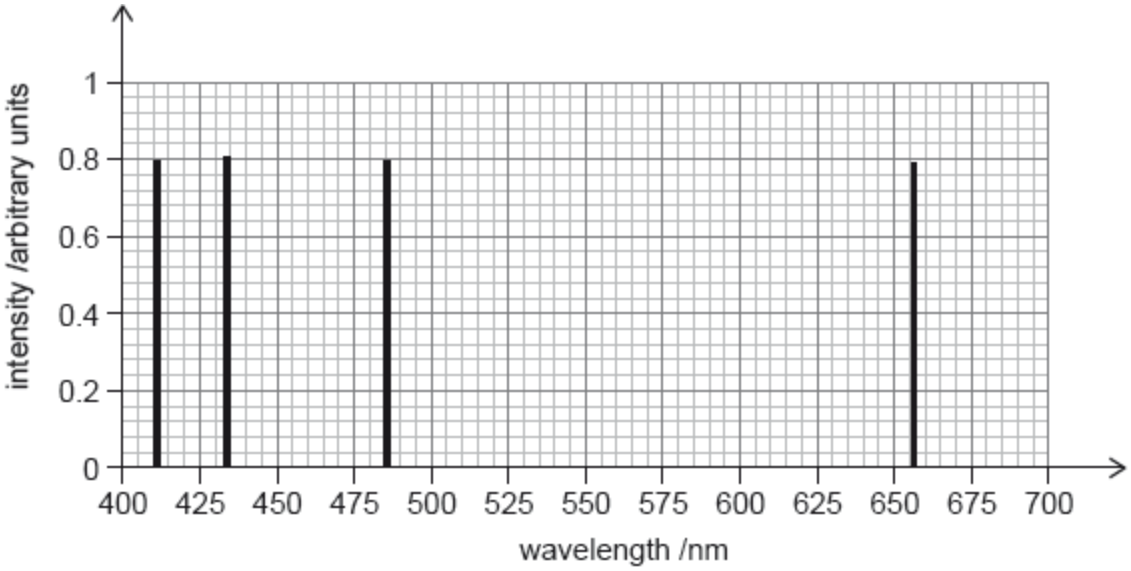
8a. *[2 marks]*

The graph shows the observed spectrum from star X.



The second graph shows the hydrogen emission spectrum in the visible range.



Suggest, using the graphs, why star X is most likely to be a main sequence star.

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8b. *[2 marks]*

Show that the temperature of star X is approximately 10 000 K.

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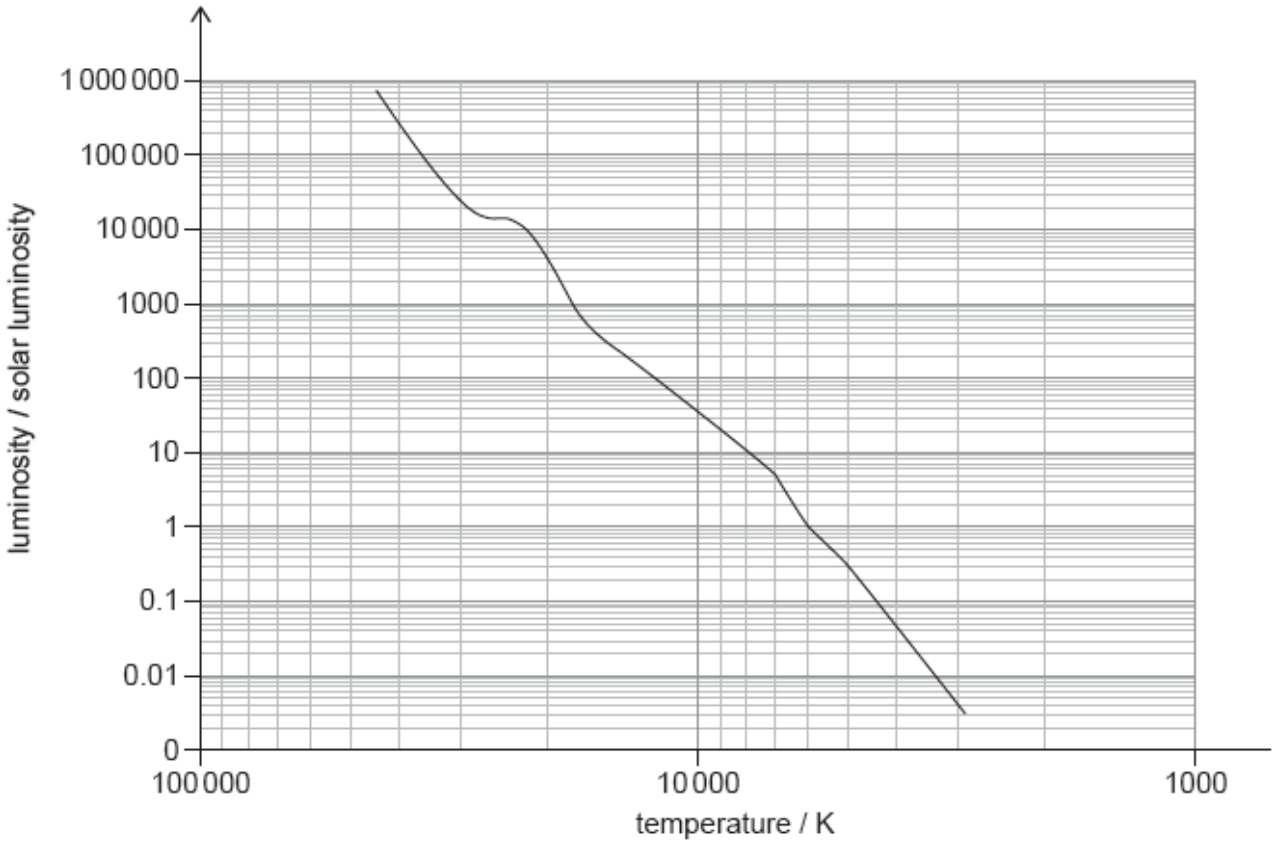
8c. *[1 mark]*

The following diagram shows the main sequence.



Write down the luminosity of star X (L_X) in terms of the luminosity of the Sun (L_s).

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8d. *[3 marks]*

Determine the radius of star X (R_X) in terms of the radius of the Sun (R_s).

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8e. *[2 marks]*

Estimate the mass of star X (M_X) in terms of the mass of the Sun (M_s).

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8f. *[2 marks]*

Star X is likely to evolve into a stable white dwarf star.

Outline why the radius of a white dwarf star reaches a stable value.

9a. *[1 mark]*

The Hubble constant is accepted to be 70 km s^{-1} Mpc^{-1}. This value of the Hubble constant gives an age for the universe of 14.0 billion years.

The accepted value of the Hubble constant has changed over the past decades.

Explain how international collaboration has helped to refine this value.

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9b. *[2 marks]*

The redshift of a galaxy is measured to be $z = 0.19$.

Estimate, in Mpc, the distance between the galaxy and the Earth.

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9c. *[3 marks]*

Determine, in years, the approximate age of the universe at the instant when the detected light from the distant galaxy was emitted.

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10a. *[2 marks]*

Main sequence stars are in equilibrium under the action of forces. Outline how this equilibrium is achieved.

10b. *[1 mark]*

A main sequence star P, is 1.3 times the mass of the Sun. Calculate the luminosity of P relative to the Sun.

10c. *[3 marks]*

The following data apply to the star Gacrux.

$$\begin{aligned} \text{Radius} &= 58.5 \times 10^9 \text{ m} \\ \text{Temperature} &= 3600 \text{ K} \\ \text{Distance} &= 88 \text{ ly} \end{aligned}$$

The luminosity of the Sun $L_\odot$ is 3.85×10^{26} W. Determine the luminosity of Gacrux relative to the Sun.

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10d. *[1 mark]*

The distance to Gacrux can be determined using stellar parallax. Outline why this method is not suitable for all stars.

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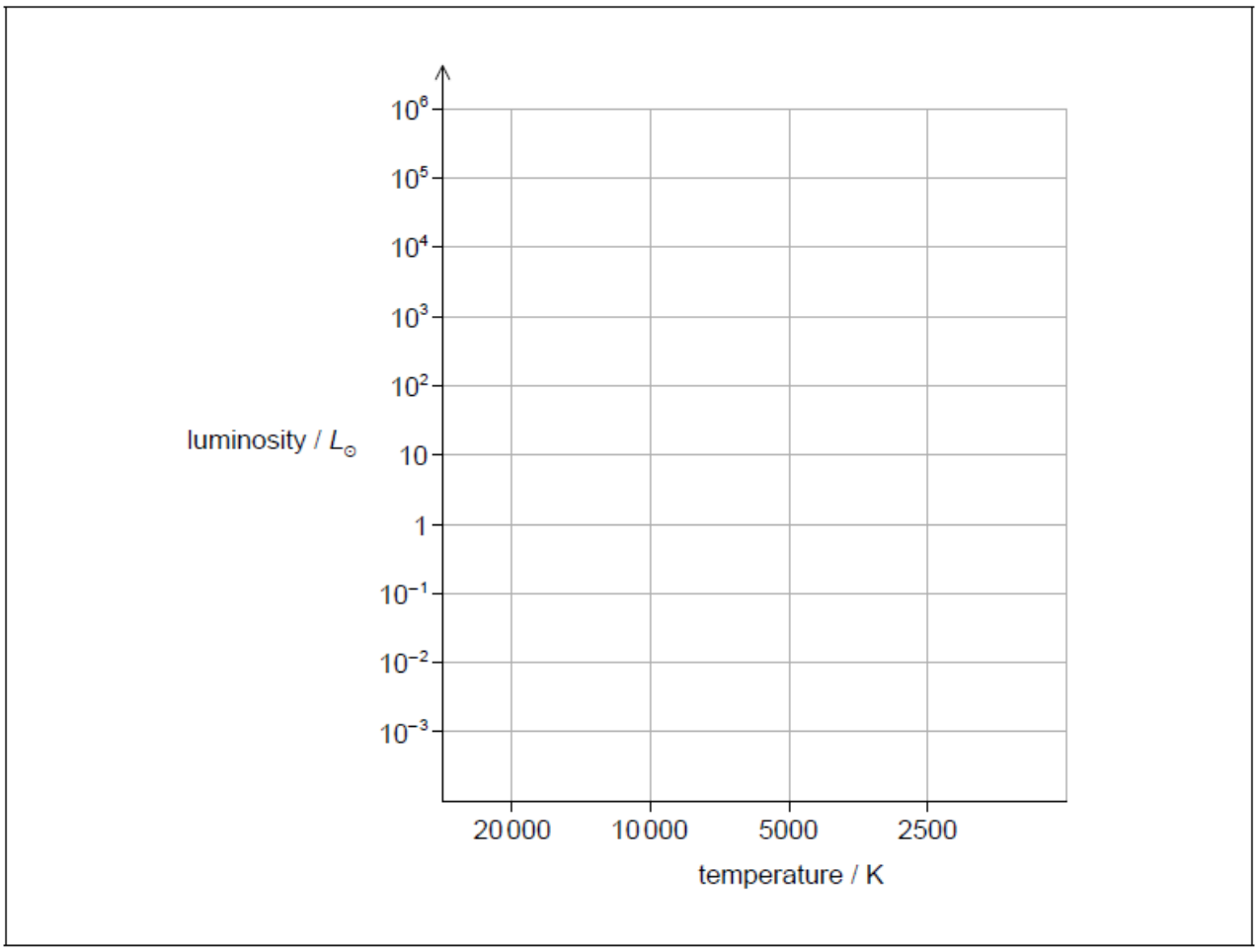
10e. *[1 mark]*

A Hertzsprung–Russell (HR) diagram is shown.



On the HR diagram,

draw the main sequence.

10f. *[1 mark]*

plot the position, using the letter P, of the main sequence star P you calculated in (b).

10g. *[1 mark]*

plot the position, using the letter G, of Gacrux.

10h. *[3 marks]*

Discuss, with reference to its change in mass, the evolution of star P from the main sequence until its final stable phase.

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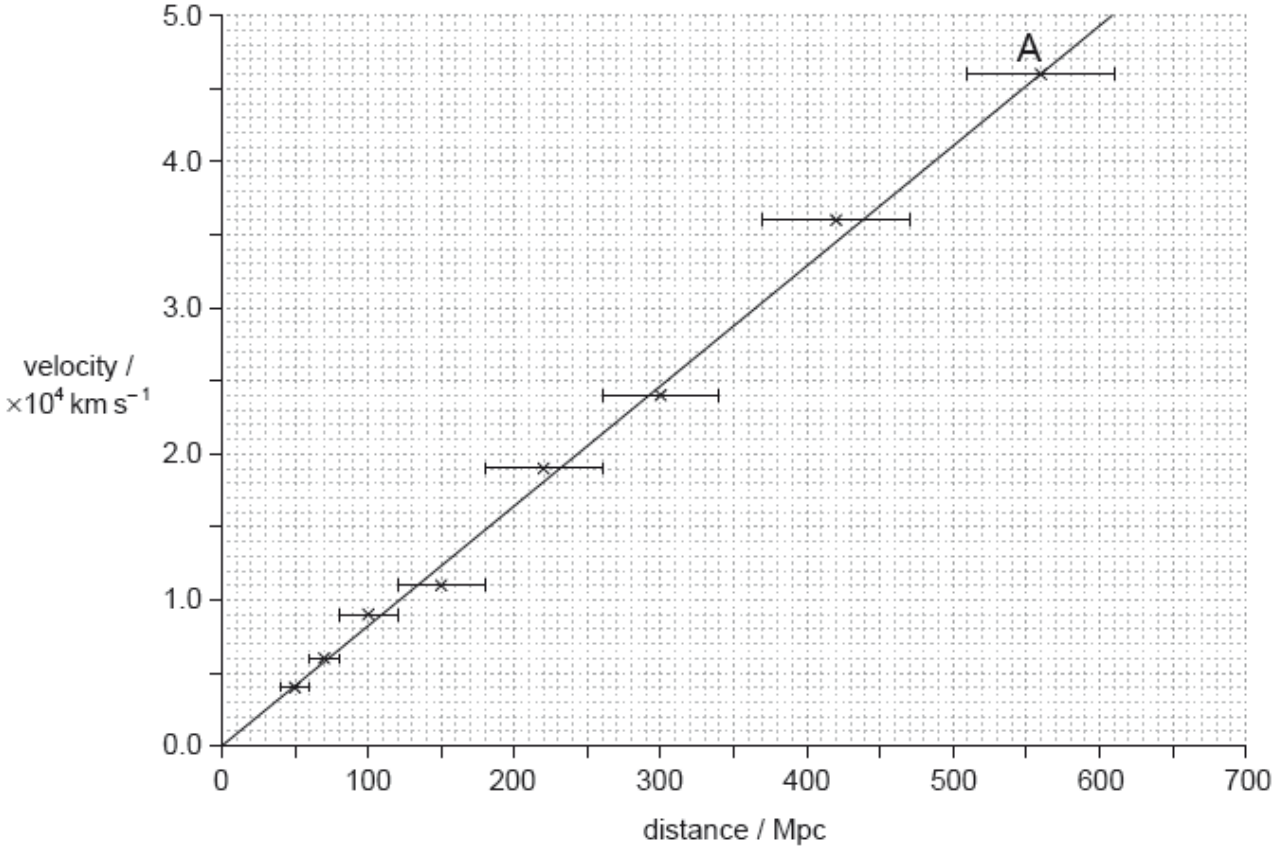
11a. *[3 marks]*

Data from distant galaxies are shown on the graph.



Estimate, using the data, the age of the universe. Give your answer in seconds.

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11b. *[1 mark]*

Identify the assumption that you made in your answer to (a).

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11c. *[3 marks]*

On the graph, one galaxy is labelled A. Determine the size of the universe, relative to its present size, when light from the galaxy labelled A was emitted.

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12a. *[1 mark]*

Sirius is a binary star. It is composed of two stars, Sirius A and Sirius B. Sirius A is a main sequence star.

State what is meant by a binary star.

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12b. *[1 mark]*

The peak spectral line of Sirius B has a measured wavelength of 115 nm. Show that the surface temperature of Sirius B is about 25 000 K.

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12c. *[2 marks]*

The mass of Sirius B is about the same mass as the Sun. The luminosity of Sirius B is 2.5 % of the luminosity of the Sun. Show, with a calculation, that Sirius B is **not** a main sequence star.

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12d. *[2 marks]*

The Sun's surface temperature is about 5800 K.

Determine the radius of Sirius B in terms of the radius of the Sun.

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12e. *[1 mark]*

Identify the star type of Sirius B.

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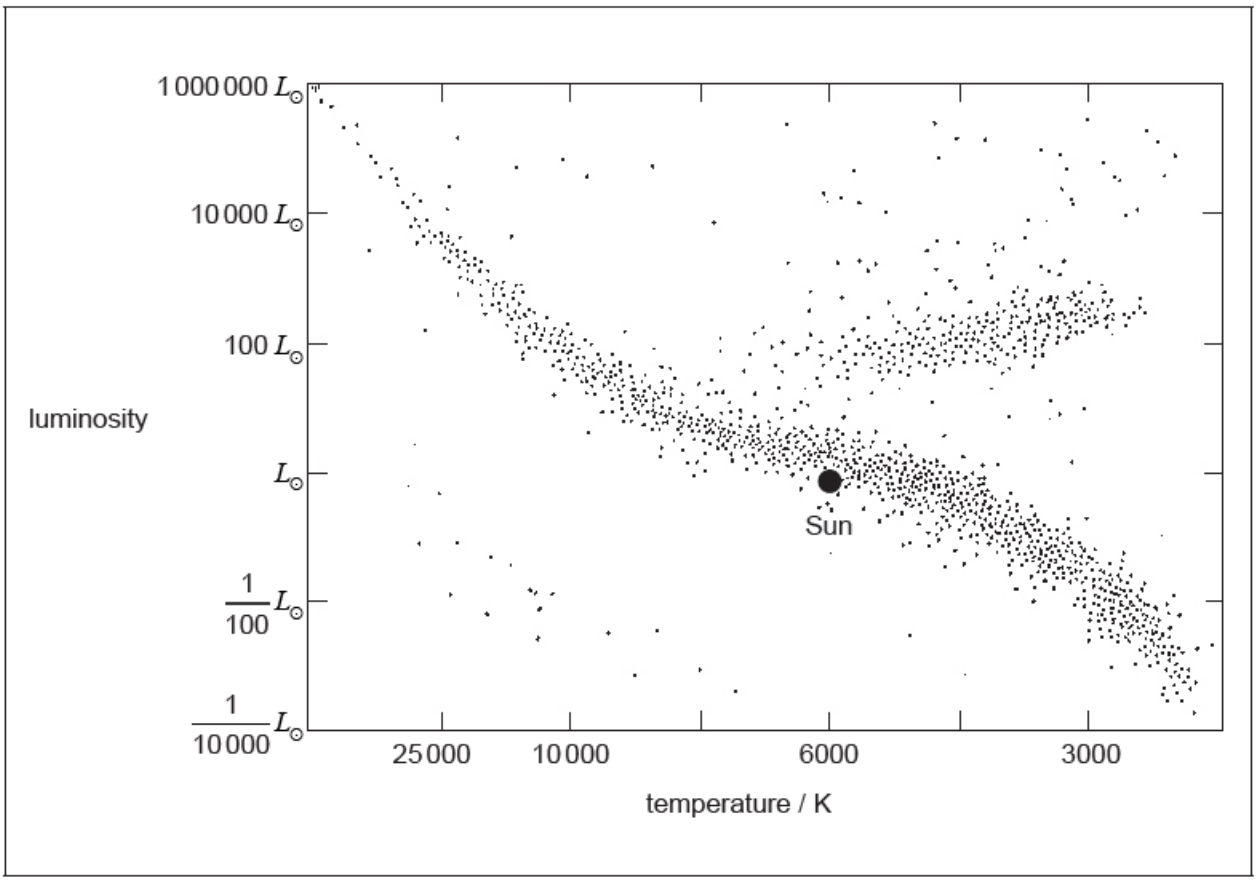
12f. *[1 mark]*

The image shows a Hertzsprung–Russell (HR) diagram.



The mass of Sirius A is twice the mass of the Sun. Using the Hertzsprung–Russell (HR) diagram, draw the approximate positions of Sirius A, labelled A and Sirius B, labelled B.

12g. *[1 mark]*

sketch the expected evolutionary path for Sirius A.

13a. *[1 mark]*

The collision of two galaxies is being studied. The wavelength of a particular spectral line from the galaxy measured from Earth is 116.04 nm. The spectral line when measured from a source on Earth is 115.00 nm.

Outline **one** reason for the difference in wavelength.

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13b. *[2 marks]*

Determine the velocity of the galaxy relative to Earth.

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14a. *[2 marks]*

State **two** characteristics of the cosmic microwave background (CMB) radiation.

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14b. *[1 mark]*

The present temperature of the CMB is 2.8 K. Calculate the peak wavelength of the CMB.

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14c. *[2 marks]*

Describe how the CMB provides evidence for the Hot Big Bang model of the universe.

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14d. *[2 marks]*

A spectral line in the light received from a distant galaxy shows a redshift of $z = 0.16$.

Determine the distance to this galaxy using a value for the Hubble constant of $H_0 = 68$ km s^{-1} Mpc^{-1}.

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14e. *[2 marks]*

Estimate the size of the Universe relative to its present size when the light was emitted by the galaxy in (c).

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15a. *[1 mark]*

Theta 1 Orionis is a main sequence star. The following data for Theta 1 Orionis are available.

Luminosity	$L = 4 \times 10^{5} L_{\odot}$
Radius	$R = 13 R_{\odot}$
Apparent brightness	$b = 4 \times 10^{-11} b_{\odot}$

where $L_\odot$, $R_\odot$ and $b_\odot$ are the luminosity, radius and apparent brightness of the Sun.

State what is meant by a main sequence star.

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15b. *[1 mark]*

Show that the mass of Theta 1 Orionis is about 40 solar masses.

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15c. *[2 marks]*

The surface temperature of the Sun is about 6000 K. Estimate the surface temperature of Theta 1 Orionis.

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15d. *[2 marks]*

Determine the distance of Theta 1 Orionis in AU.

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15e. *[2 marks]*

Discuss how Theta 1 Orionis does not collapse under its own weight.

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15f. *[3 marks]*

The Sun and Theta 1 Orionis will eventually leave the main sequence. Compare and contrast the different stages in the evolution of the two stars.

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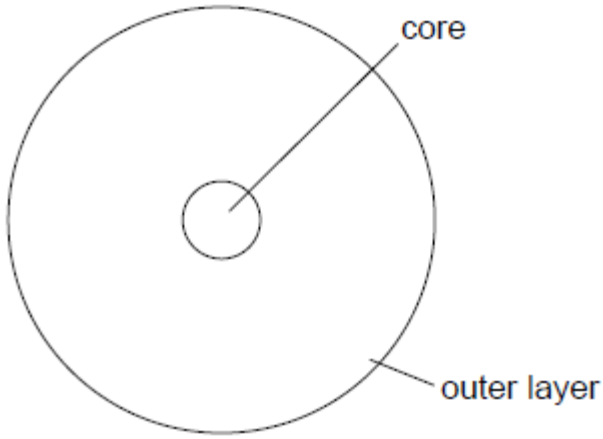
16a. *[2 marks]*

The diagram shows the structure of a typical main sequence star.



State the most abundant element in the core and the most abundant element in the outer layer.

core: . . . . . .

outer layer: . . . . . .

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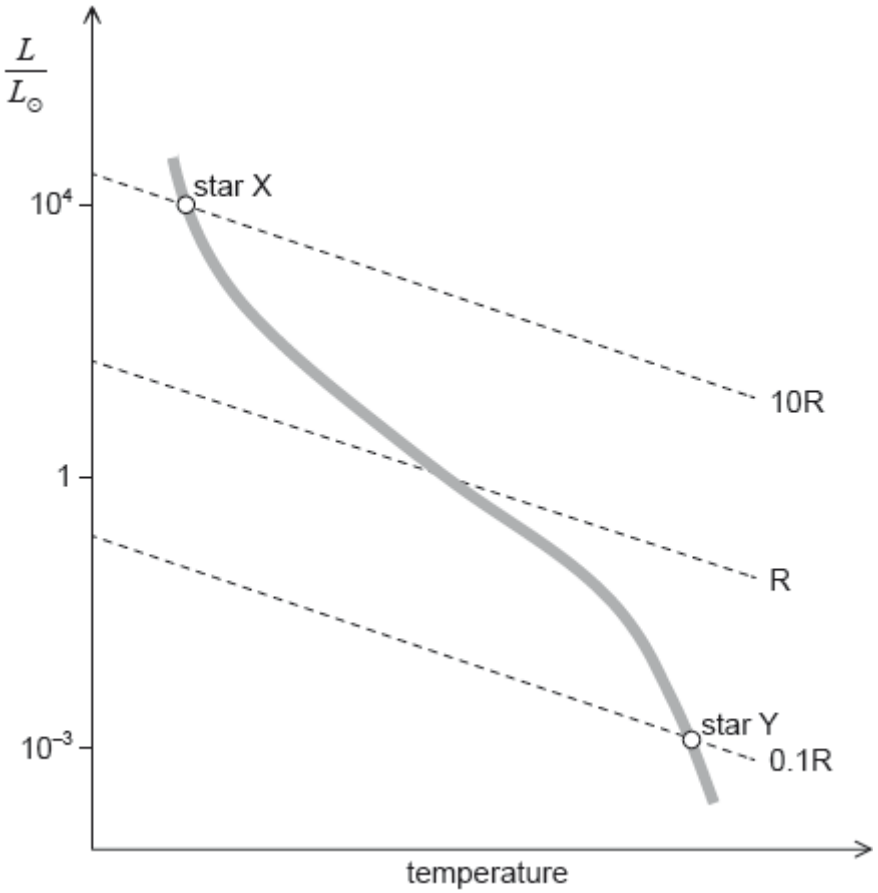
16b. *[3 marks]*

The Hertzsprung–Russell (HR) diagram shows two main sequence stars X and Y and includes lines of constant radius. *R* is the radius of the Sun.



Using the mass–luminosity relation and information from the graph, determine the ratio $\frac{\text{density of star X}}{\text{density of star Y}}$

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16c. *[1 mark]*

Star X is likely to evolve into a neutron star.

On the HR diagram in (b), draw a line to indicate the evolutionary path of star X.

16d. *[1 mark]*

Outline why the neutron star that is left after the supernova stage does not collapse under the action of gravitation.

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16e. *[2 marks]*

The radius of a typical neutron star is 20 km and its surface temperature is 10^6 K. Determine the luminosity of this neutron star.

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16f. *[2 marks]*

Determine the region of the electromagnetic spectrum in which the neutron star in (c)(iii) emits most of its energy.

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17a. *[2 marks]*

Describe what is meant by the Big Bang model of the universe.

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17b. *[2 marks]*

State **two** features of the cosmic microwave background (CMB) radiation which are consistent with the Big Bang model.

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17c. *[2 marks]*

A particular emission line in a distant galaxy shows a redshift $z = 0.084$.

The Hubble constant is $H_0 = 68$ km s^{-1} Mpc^{-1}.

Determine the distance to the galaxy in Mpc.

17d. *[3 marks]*

Describe how type Ia supernovae could be used to measure the distance to this galaxy.

18a. *[1 mark]*

Alpha Centauri A and B is a binary star system in the main sequence.

	Alpha Centauri A	Alpha Centauri B
Luminosity	$1.5L_{\odot}$	$0.5L_{\odot}$
Surface temperature / K	5800	5300

State what is meant by a binary star system.

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18b. *[4 marks]*

(i) Calculate $\frac{b_{\mathrm{A}}}{b_{\mathrm{B}}} = \frac{\text{apparent brightness of Alpha Centauri A}}{\text{apparent brightness of Alpha Centauri B}}$.

(ii) The luminosity of the Sun is 3.8×10^{26} W. Calculate the radius of Alpha Centauri A.

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18c. *[2 marks]*

Show, without calculation, that the radius of Alpha Centauri B is smaller than the radius of Alpha Centauri A.

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18d. *[3 marks]*

Alpha Centauri A is in equilibrium at constant radius. Explain how this equilibrium is maintained.

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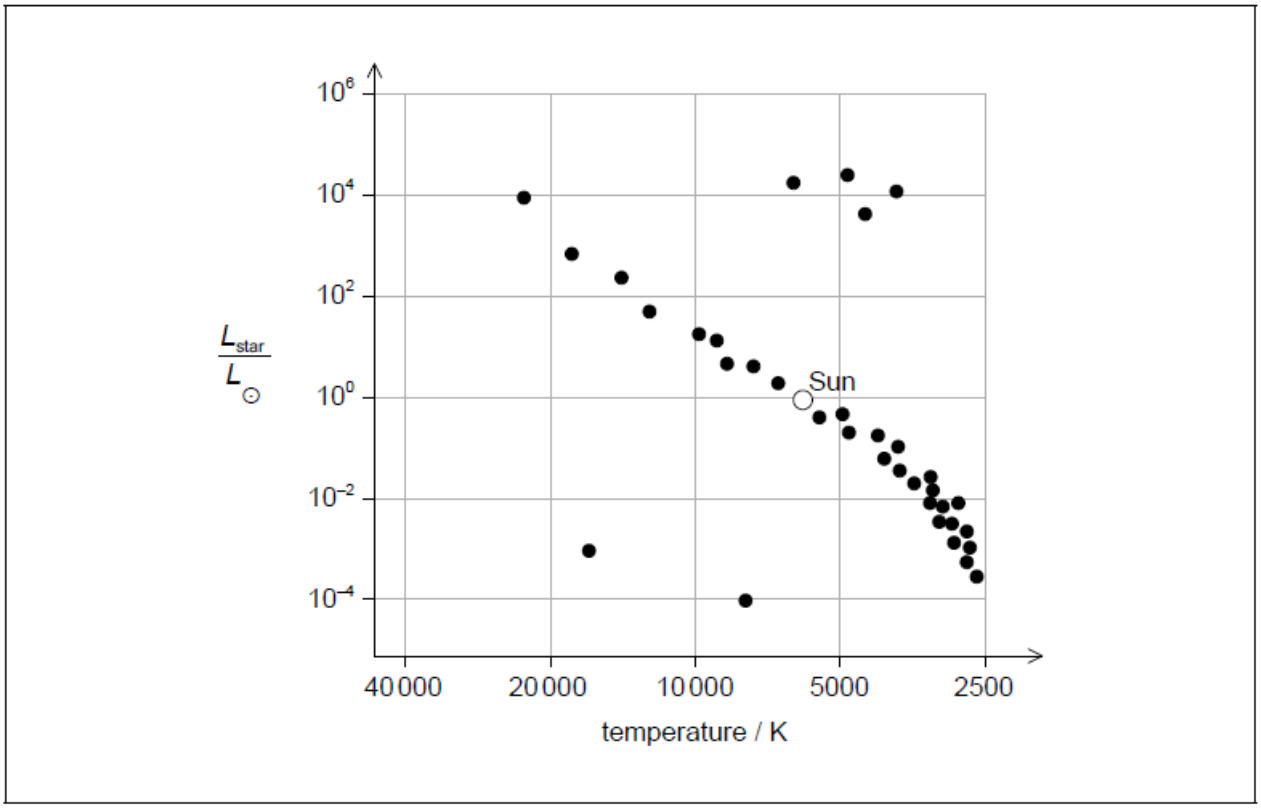
18e. *[2 marks]*

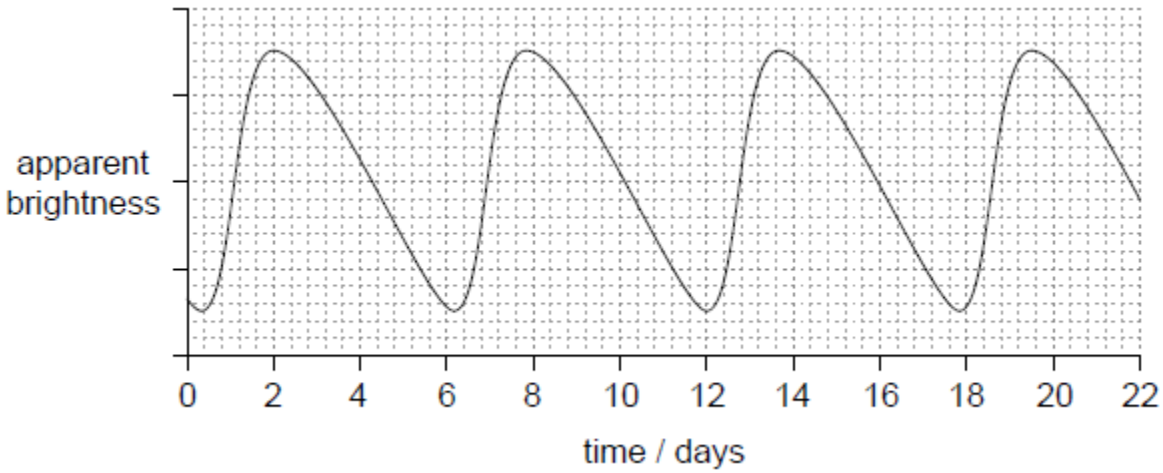
A standard Hertzsprung–Russell (HR) diagram is shown.



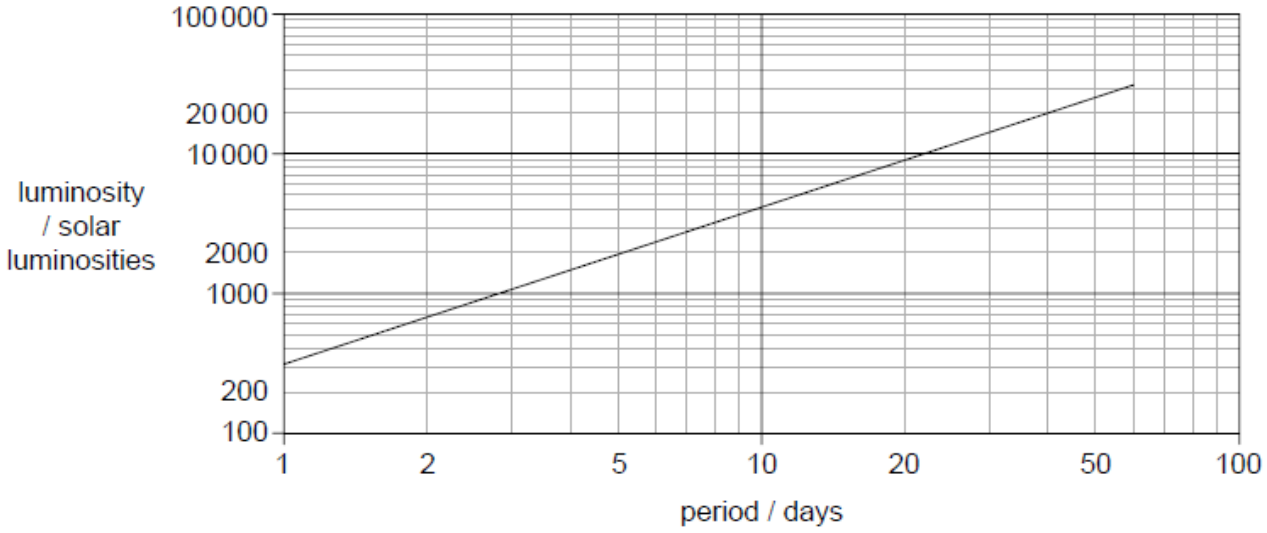
Using the HR diagram, draw the present position of Alpha Centauri A and its expected evolutionary path.

19a. *[3 marks]*

The first graph shows the variation of apparent brightness of a Cepheid star with time.



The second graph shows the average luminosity with period for Cepheid stars.



Determine the distance from Earth to the Cepheid star in parsecs. The luminosity of the Sun is 3.8×10^{26} W. The average apparent brightness of the Cepheid star is 1.1×10^{-9} W m^{-2}.

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19b. *[2 marks]*

Explain why Cephids are used as standard candles.

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20a. *[2 marks]*

The peak wavelength of the cosmic microwave background (CMB) radiation spectrum corresponds to a temperature of 2.76 K.

Identify **two** other characteristics of the CMB radiation that are predicted from the Hot Big Bang theory.

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20b. *[1 mark]*

A spectral line in the hydrogen spectrum measured in the laboratory today has a wavelength of 21cm. Since the emission of the CMB radiation, the cosmic scale factor has changed by a factor of 1100. Determine the wavelength of the 21cm spectral line in the CMB radiation when it is observed today.

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21a. *[1 mark]*

Describe **one** key characteristic of a nebula.

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21b. *[2 marks]*

Beta Centauri is a star in the southern skies with a parallax angle of 8.32×10^{-3} arc-seconds. Calculate, in metres, the distance of this star from Earth.

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21c. *[1 mark]*

Outline why astrophysicists use non-SI units for the measurement of astronomical distance.

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22a. *[2 marks]*

Aldebaran is a red giant star with a peak wavelength of 740 nm and a mass of 1.7 solar masses.

Show that the surface temperature of Aldebaran is about 4000 K.

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22b. *[2 marks]*

The radius of Aldebaran is 3.1×10^{10} m. Determine the luminosity of Aldebaran.

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22c. *[2 marks]*

Outline how the light from Aldebaran gives evidence of its composition.

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22d. *[1 mark]*

Identify the element that is fusing in Aldebaran's core at this stage in its evolution.

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22e. *[3 marks]*

Predict the likely future evolution of Aldebaran.

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23a. *[4 marks]*

Light reaching Earth from quasar 3C273 has z=0.16.

(i) Outline what is meant by z.

(ii) Calculate the ratio of the size of the universe when the light was emitted by the quasar to the present size of the universe.

(iii) Calculate the distance of 3C273 from Earth using H_o=68kms^{-1}Mpc^{-1}.

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23b. *[2 marks]*

Explain how cosmic microwave background (CMB) radiation provides support for the Hot Big Bang model.

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24a. *[2 marks]*

Beta Centauri is a star in the southern skies with a parallax angle of 8.32×10^{-3} arc-seconds. Calculate, in metres, the distance of this star from Earth.

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24b. *[1 mark]*

Outline why astrophysicists use non-SI units for the measurement of astronomical distance.

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