Astrophysics1 *[138 marks]*

1a. Distinguish between the solar system and a galaxy. *[1 mark]*

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1b. Distinguish between a planet and a comet. *[1 mark]*

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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.

2a. State what is meant by a main sequence star. *[1 mark]*

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2b. Show that the mass of Theta 1 Orionis is about 40 solar masses. *[1 mark]*

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2c. The surface temperature of the Sun is about 6000 K. Estimate the surface temperature of Theta 1 Orionis. *[2 marks]*

2d. Determine the distance of Theta 1 Orionis in AU. *[2 marks]*

2e. Discuss how Theta 1 Orionis does not collapse under its own weight. *[2 marks]*

2f. 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. *[3 marks]*

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

3a. State what is meant by a binary star system. *[1 mark]*

3b. (i) Calculate $\frac{b_A}{b_B} = \frac{\text{apparent brightness of Alpha Centauri A}}{\text{apparent brightness of Alpha Centauri B}}$. *[4 marks]*

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

3c. Show, without calculation, that the radius of Alpha Centauri B is smaller than the radius of Alpha Centauri A. *[2 marks]*

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3d. Alpha Centauri A is in equilibrium at constant radius. Explain how this equilibrium is maintained. *[3 marks]*

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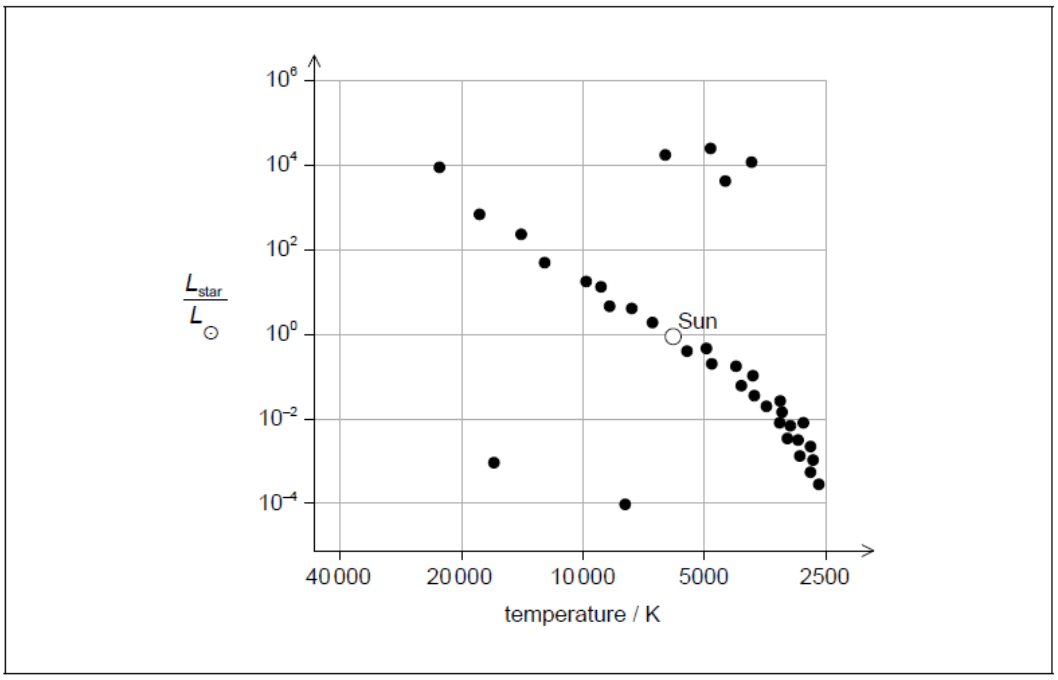
3e. A standard Hertzsprung–Russell (HR) diagram is shown. *[2 marks]*



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

4a. Describe **one** key characteristic of a nebula. *[1 mark]*

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4b. 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. *[2 marks]*

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4c. Outline why astrophysicists use non-SI units for the measurement of astronomical distance. *[1 mark]*

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

5a. Show that the surface temperature of Aldebaran is about 4000 K. *[2 marks]*

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5b. The radius of Aldebaran is 3.1×10^{10} m. Determine the luminosity of Aldebaran. *[2 marks]*

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5c. Outline how the light from Aldebaran gives evidence of its composition. *[2 marks]*

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5d. Identify the element that is fusing in Aldebaran's core at this stage in its evolution. *[1 mark]*

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5e. Predict the likely future evolution of Aldebaran. *[3 marks]*

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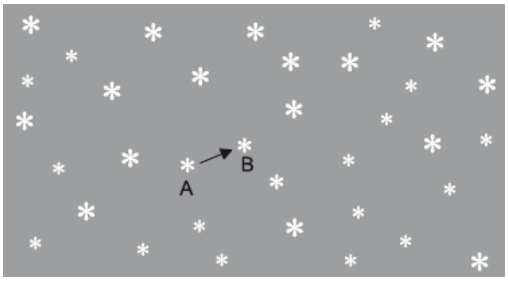
This question is about determining the distance to a nearby star.

Two photographs of the night sky are taken, one six months after the other. When the photographs are compared, one star appears to have shifted from position A to position B, relative to the other stars.



6a. Outline why the star appears to have shifted from position A to position B. *[1 mark]*

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The observed angular displacement of the star is θ and the diameter of the Earth's orbit is d. The distance from the Earth to the star is D.

6b. Draw a diagram showing d, D and θ. *[1 mark]*

6c. Explain the relationship between d, D and θ. *[2 marks]*

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6d. One consistent set of units for D and θ are parsecs and arc-seconds. State **one** other consistent set of units for this pair of quantities. *[1 mark]*

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6e. Suggest whether the distance from Earth to this star can be determined using spectroscopic parallax. *[1 mark]*

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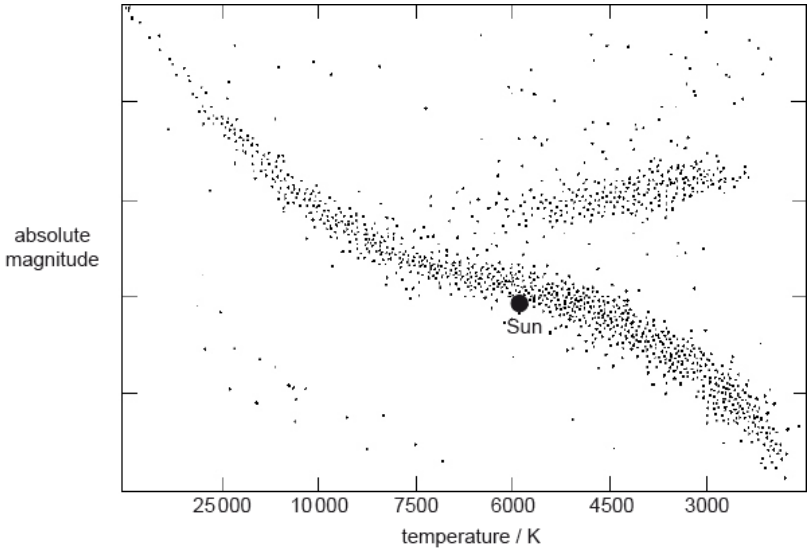
This question is about the Hertzsprung–Russell (HR) diagram and the Sun.

A Hertzsprung–Russell (HR) diagram is shown.



7a. The following data are given for the Sun and a star Vega. *[3 marks]*

Luminosity of the Sun $= 3.85 \times 10^{26}\ \text{W}$

Luminosity of Vega $= 1.54 \times 10^{28}\ \text{W}$

Surface temperature of the Sun $= 5800\ \text{K}$

Surface temperature of Vega $= 9600\ \text{K}$

Determine, using the data, the radius of Vega in terms of solar radii.

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7b. Outline how observers on Earth can determine experimentally the temperature of a distant star. *[3 marks]*

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This question is about a particular star called Barnard's star.

The peak wavelength in the spectrum of Barnard's star is 940 nm. The following data are available.

$$\frac{\text{apparent brightness of Barnard's star}}{\text{apparent brightness of the Sun}} = 2.5 \times 10^{-14}$$

$$\frac{\text{luminosity of Barnard's star}}{\text{luminosity of the Sun}} = 3.8 \times 10^{-3}$$

8a. (i) Show that the surface temperature of Barnard's star is about 3000 K. *[4 marks]*

(ii) Suggest why Barnard's star is not likely to be either a white dwarf or a red giant.

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8b. (i) Determine, in astronomical units (AU), the distance between Earth and Barnard's star. *[8 marks]*

(ii) Calculate the parallax angle for Barnard's star as observed from Earth.

(iii) Outline how the parallax angle is measured.

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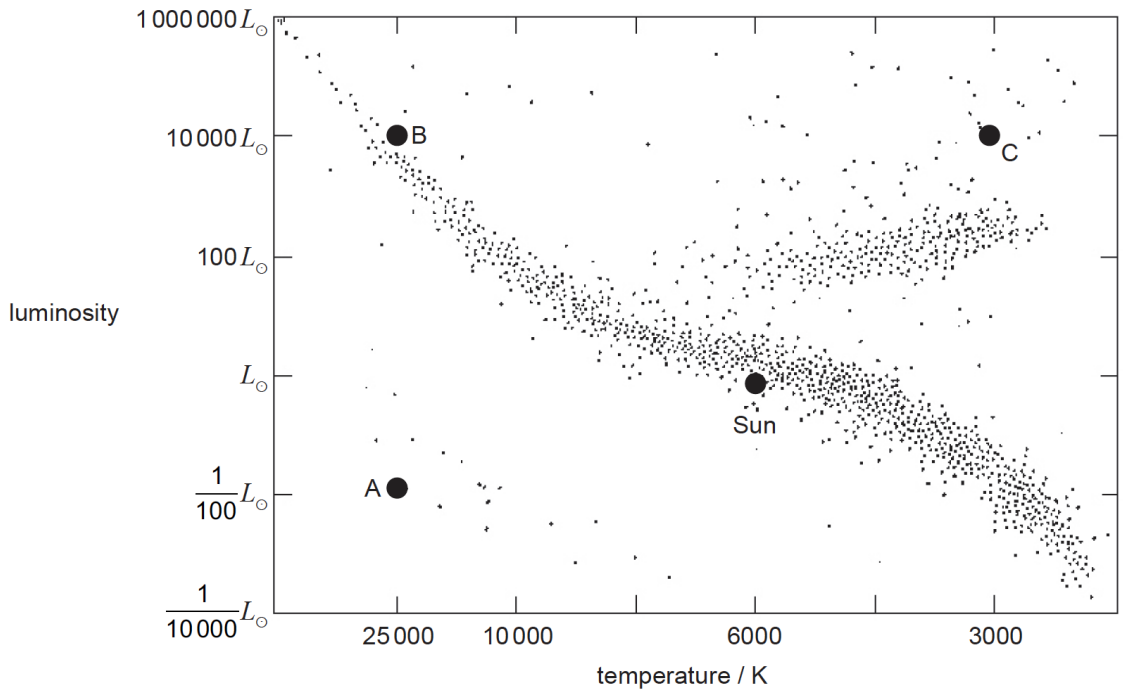
This question is about stars.

The Hertzsprung–Russell (HR) diagram shows the position of the Sun and three stars labelled A, B and C.



9a. State the star type for A, B and C. *[3 marks]*

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9b. The apparent brightness of C is 3.8 $\times$ 10^{-10} Wm^{-2}. The luminosity of the Sun is 3.9 $\times$ 10^{26} W. *[4 marks]*

(i) State what is meant by apparent brightness and luminosity.

Apparent brightness:
Luminosity:

(ii) Determine the distance of C from Earth.

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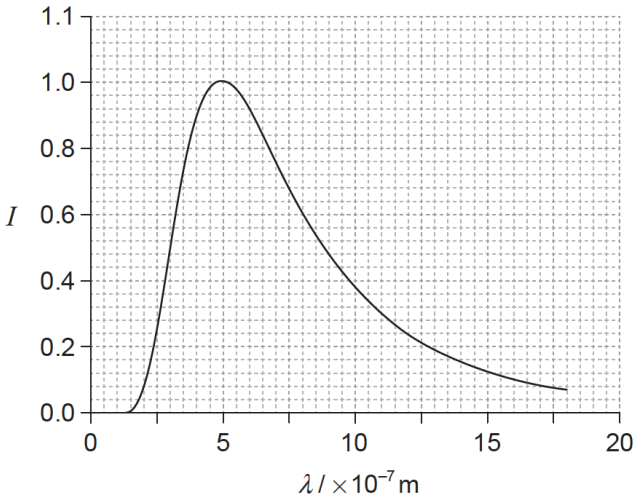
9c. The graph shows the variation with wavelength λ of the intensity I of the radiation emitted by 1.0m^2 of the surface of the Sun. The curve of the graph has been adjusted so that the maximum intensity is 1. *[2 marks]*



On the grid, draw a corresponding graph for star C. Your curve should have a maximum intensity of 1.

This question is about the night sky.

10. Distinguish between a stellar cluster and a constellation. *[2 marks]*

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This question is about stellar radiation and stellar types.

Alnilam and Bellatrix are two stars in the constellation of Orion. The table gives information on each of these stars. $L_\odot$ is the luminosity of the Sun and $R_\odot$ is the radius of the Sun.

	Apparent magnitude	Absolute magnitude	Surface temperature	Luminosity	Radius
Alnilam	+1.68	−6.37	27 000 K	$275\,000 L_\odot$	$24 R_\odot$
Bellatrix	+1.62	−2.37	T_B	$6400 L_\odot$	$6 R_\odot$

Using a telescope based on Earth, an observer estimates the distance to Alnilam using the stellar parallax method.

11. Describe the stellar parallax method. *[2 marks]*

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12. This question is about comets. *[2 marks]*

Outline the nature of a comet.

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This question is about objects in the universe.

13a. State **one** difference between *[2 marks]*

(i) a main sequence star and a planet.

(ii) a stellar cluster and a constellation.

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13b. State how *[2 marks]*

(i) it is known that main sequence stars are made predominantly of hydrogen.

(ii) a main sequence star remains in equilibrium despite it having a great mass.

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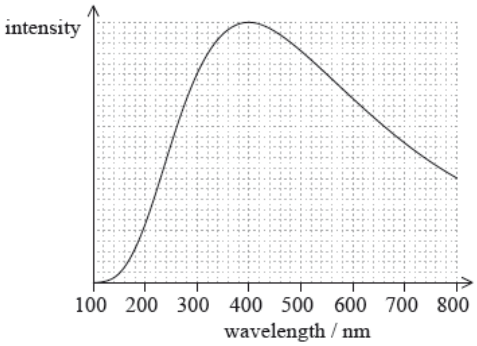
13c. The graph shows the variation with wavelength of the intensity of a main sequence star. *[2 marks]*



Calculate the surface temperature of this star.

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This question is about stellar distances.

14a. The star Sirius A is 3 pc from Earth. The apparent brightness of Sirius A is $1.2\times10^{-7}\,\text{Wm}^{-2}$. Determine the luminosity of Sirius A. *[2 marks]*

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14b. The luminosity of the Sun is 3.8×10^{26} W. Determine the mass of Sirius A relative to the mass of the Sun. (Assume that n=3.5 in the mass–luminosity relation.) *[2 marks]*

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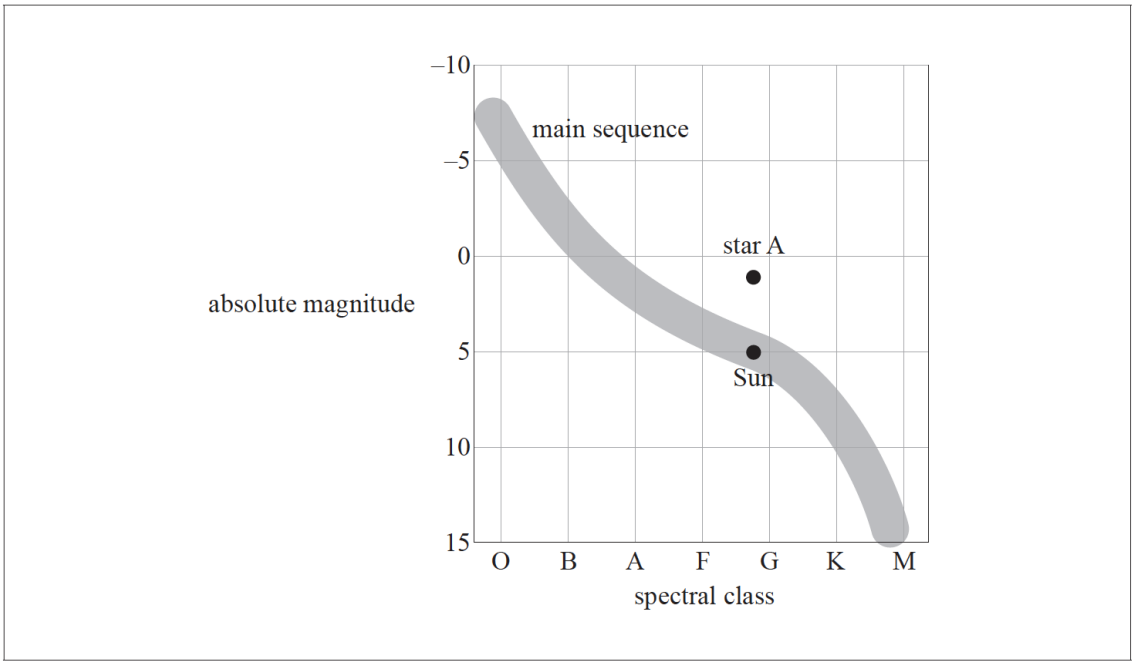
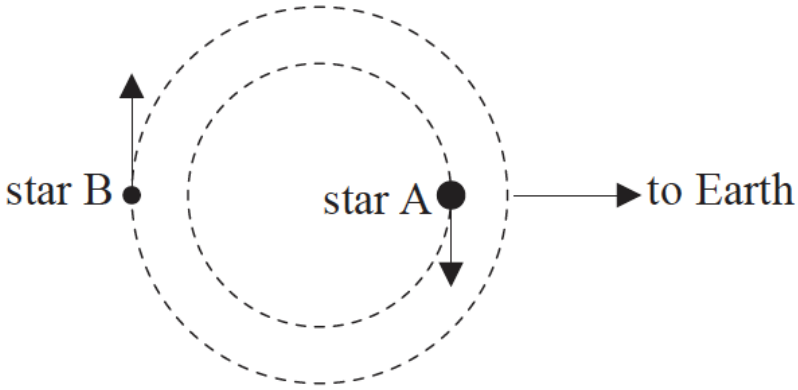
This question is about stars.

The Hertzsprung–Russell (HR) diagram shows the Sun, a star labelled A and the main sequence.



15a. Star A is part of a binary star system. The diagram shows the orbit of star A and the orbit of its companion, star B. *[2 marks]*



The temperature of star A is T_A, the temperature of star B is T_B and $\frac{T_A}{T_B} = 0.60$. The radius of star A is R_A, the radius of star B is R_B and $\frac{R_A}{R_B} = 270$.

Show that the luminosity of star A is 9.4×10^3 times greater than the luminosity of star B.

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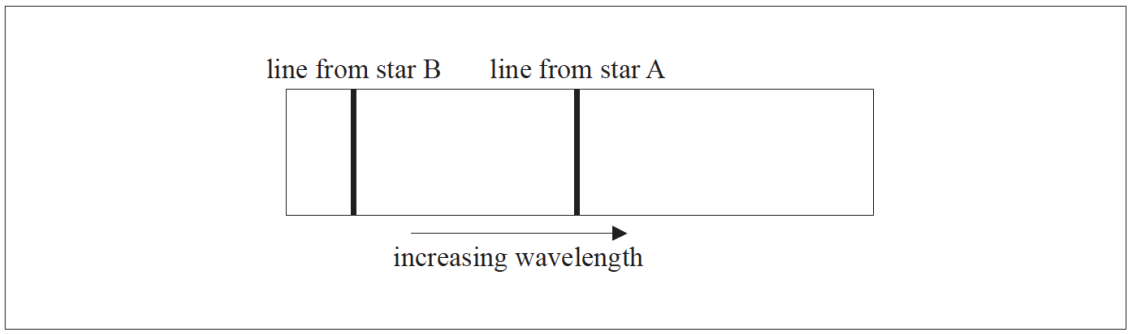
15b. The diagram below shows the spectrum of the stars as observed from Earth. The spectrum shows one line from star A and one line from star B, when the stars are in the position shown in the diagram (b). *[2 marks]*



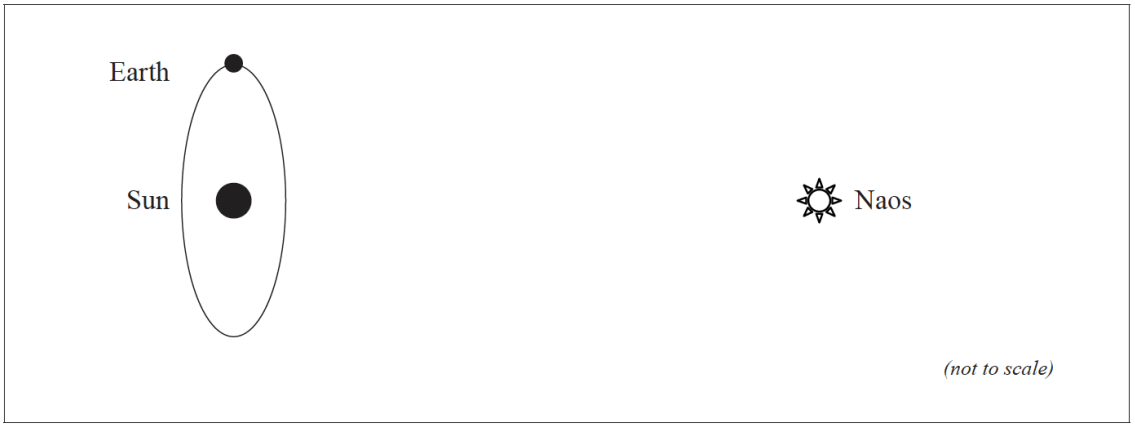
On the spectrum draw lines to show the approximate positions of these spectral lines after the stars have completed one quarter of a revolution.

This question is about the star Naos (Zeta Puppis).

The following data are available for the star Naos.

Surface temperature = 4.24×10^4K
Radius = 7.70×10^9m
Apparent magnitude = +2.21
Parallax angle = 3.36×10^{-3} arcseconds

16. The distance to Naos may be determined by the method of stellar parallax. The diagram shows the star Naos and the Earth in its orbit around the Sun. *[3 marks]*



(i) Draw lines on the diagram above in order to indicate the parallax angle of Naos.

(ii) Outline how the parallax angle of Naos may be measured.

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This question is about some of the properties of the star Aldebaran and also about galactic distances.

17a. Aldebaran is a red giant star in the constellation of Taurus. *[7 marks]*

(i) Describe the differences between a constellation and a stellar cluster.

(ii) Define the *luminosity* of a star.

(iii) The apparent brightness of Aldebaran is 3.3×10^{-8} W m^{-2} and the luminosity of the Sun is 3.9×10^{26} W. The luminosity of Aldebaran is 370 times that of the Sun. Show that Aldebaran is at a distance of 19 pc from Earth. (1 pc=3.1×10^{16} m)

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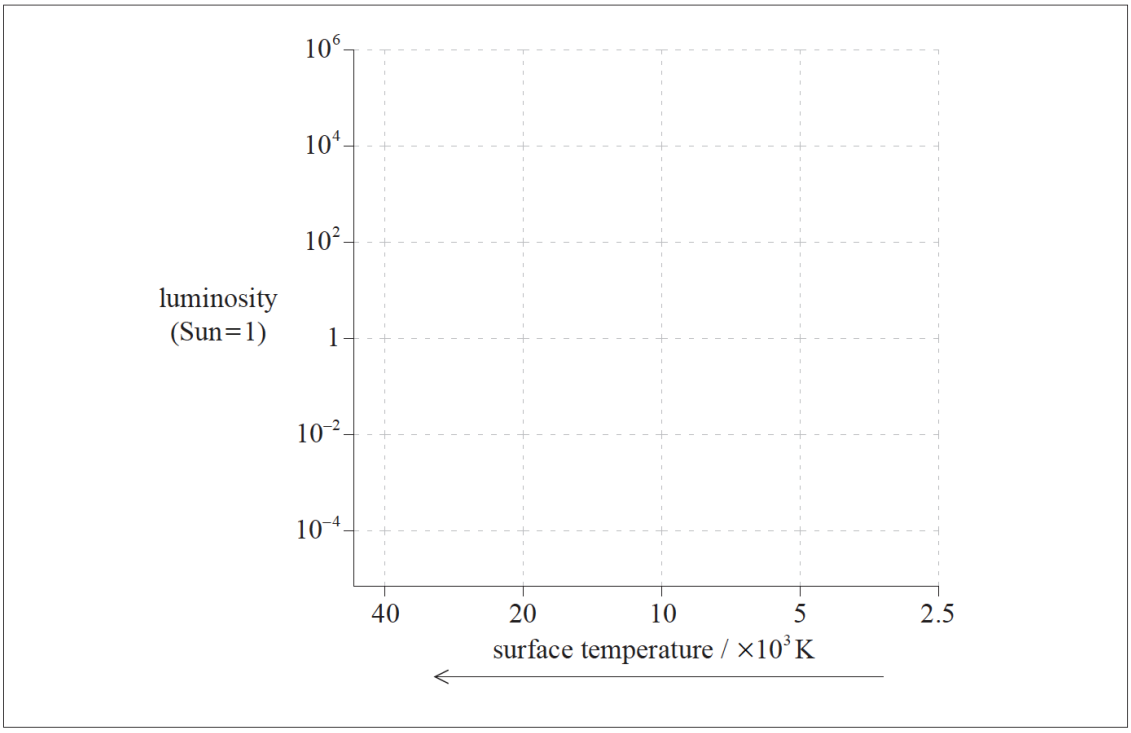
17b. Distances to galaxies may be determined by using Cepheid variable stars. *[5 marks]*

By considering the nature and properties of Cepheid variable stars, explain how such stars are used to determine galactic distances.

This question is about stellar distances and stellar properties.



18a. On the grid of the Hertzsprung–Russell (HR) diagram shown, draw a line to represent the approximate position of the main sequence. *[2 marks]*

18b. Barnard's star is a main sequence star that is 1.8 pc from Earth. *[2 marks]*

(i) Define the *parsec*.

(ii) Calculate the parallax angle of Barnard's star as measured from Earth.

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18c. Outline, using your answer to (b)(ii) and a labelled diagram, how the distance of Barnard's star from Earth is measured. *[3 marks]*

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18d. The apparent brightness of Barnard's star is $3.6\times10^{-12}\text{Wm}^{-2}$ and its surface temperature is 3800 K. *[6 marks]*

Given that 1 pc=3.1×10^{16}m, show for Barnard's star

(i) that its luminosity is of the order of 10^{23}W.

(ii) that its surface area is of the order of 10^{16}m^2.

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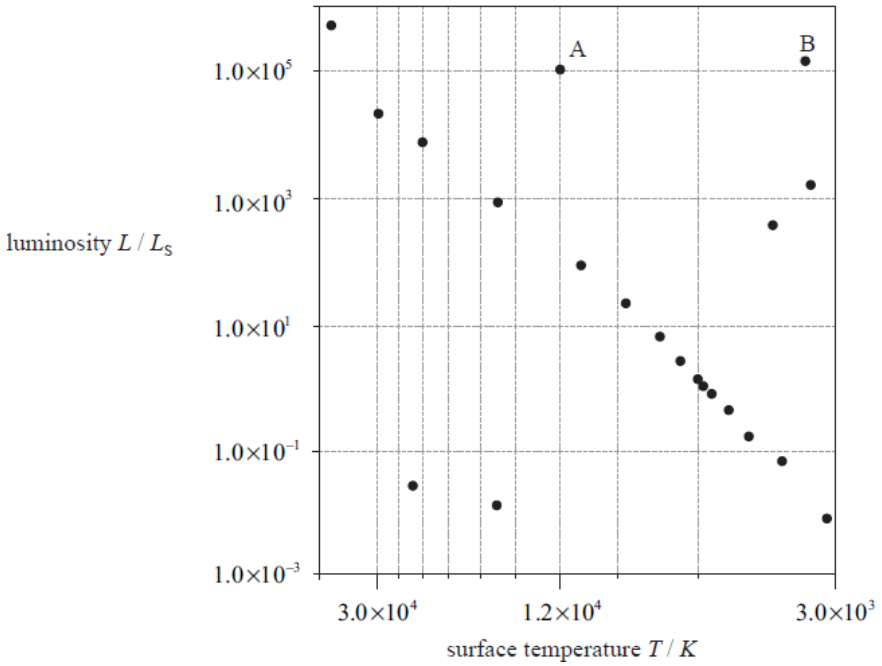
This question is about the Hertzsprung–Russell (HR) diagram and using it to determine some properties of stars.

The diagram below shows the grid of a HR diagram, on which the positions of selected stars are shown. (L_S = luminosity of the Sun.)



19a. (i) Draw a circle around the stars that are red giants. Label this circle R. *[3 marks]*

(ii) Draw a circle around the stars that are white dwarfs. Label this circle W.

(iii) Draw a line through the stars that are main sequence stars.

19b. Explain, without doing any calculation, how astronomers can deduce that star B has a larger diameter than star A. *[3 marks]*

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19c. Using the following data and information from the HR diagram, show that star A is at a distance of about 800 pc from Earth. *[4 marks]*

Apparent brightness of the Sun $= 1.4 \times 10^{3} \text{Wm}^{-2}$
Apparent brightness of star A $= 4.9 \times 10^{-9} \text{Wm}^{-2}$
Mean distance of Sun from Earth = 1.0 AU
1 pc $= 2.1 \times 10^{5}$ AU

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19d. Explain why the distance of star A from Earth cannot be determined by the method of stellar parallax. *[1 mark]*

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This question is about the properties of a star.

20a. Describe what is meant by a *[3 marks]*

(i) constellation.

(ii) stellar cluster.

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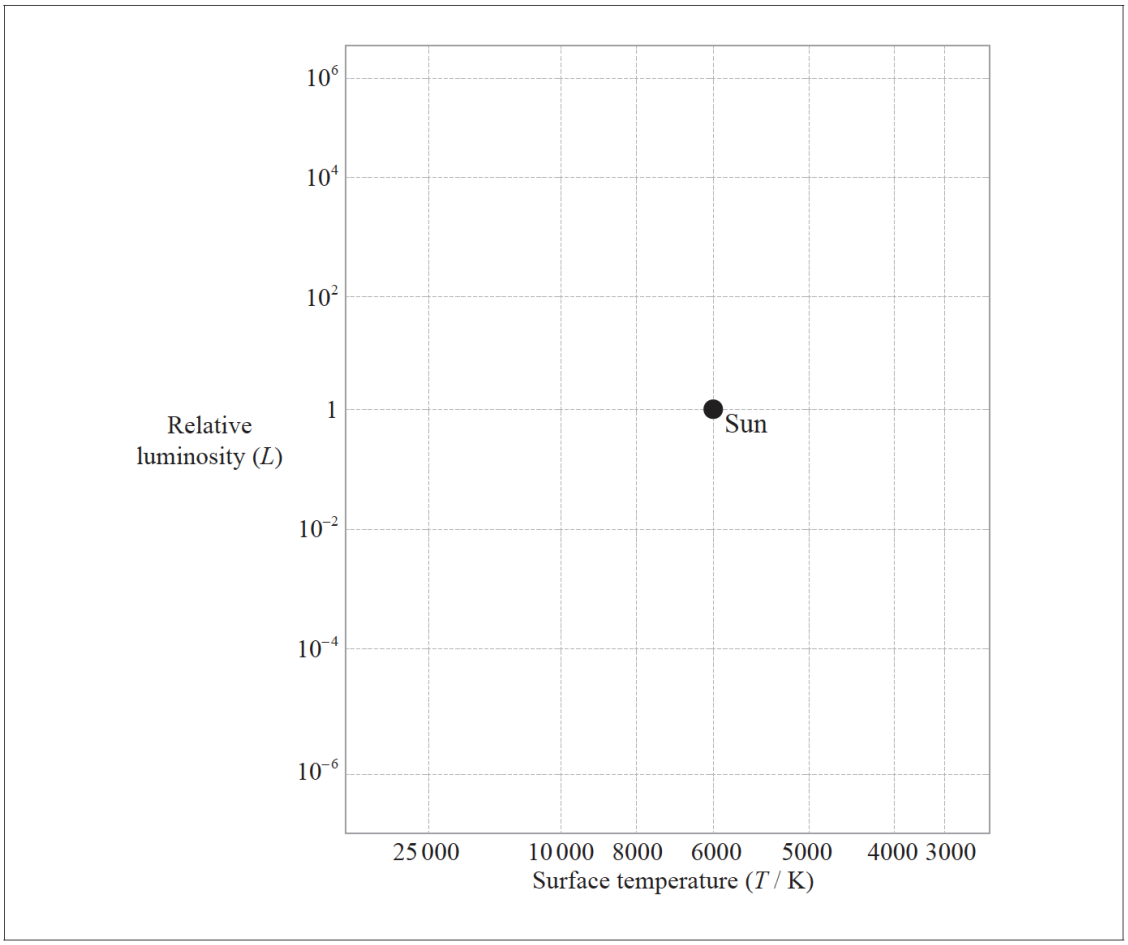
20b. *[2 marks]*



On the Hertzsprung–Russell diagram above,

(i) label the position of Betelgeuse with the letter B.

(ii) sketch the position of main sequence stars.

This question is about the characteristics of the stars Procyon A and Procyon B.

21. The stars Procyon A and Procyon B are both located in the same stellar cluster in the constellation Canis Minor. Distinguish between a constellation and a stellar cluster. *[2 marks]*

Constellation:

Stellar cluster:

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