Astro-practice-2 *[139 marks]*

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	$R = 13R_{\odot}$
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.

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

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

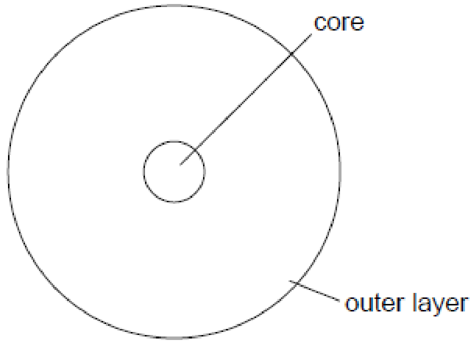
1c. The surface temperature of the Sun is about 6000 K. Estimate the surface temperature of Theta 1 Orionis. *[2 marks]*

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

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

1f. 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]*

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

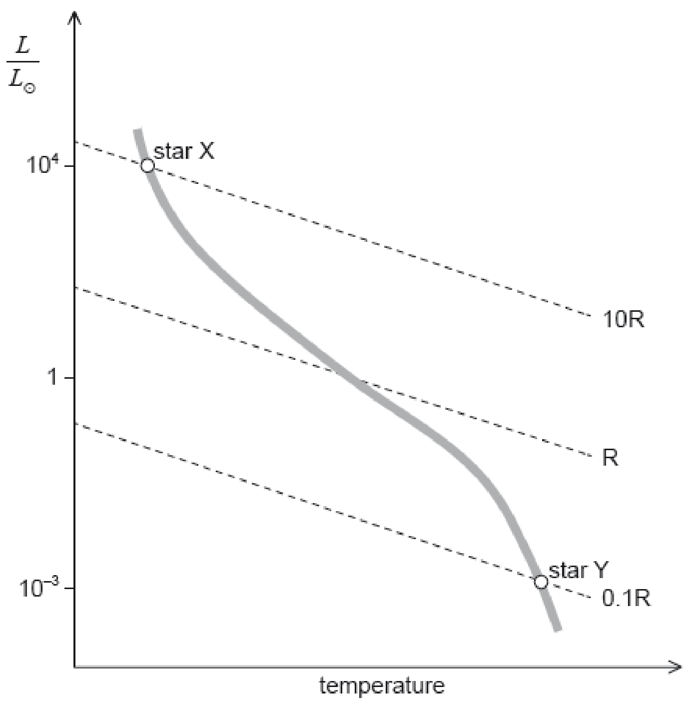


2a. State the most abundant element in the core and the most abundant element in the outer layer. *[2 marks]*

core: . . . .

outer layer: . . . .

2b. 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. *[3 marks]*



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

Star X is likely to evolve into a neutron star.

2c. On the HR diagram in (b), draw a line to indicate the evolutionary path of star X. *[1 mark]*

2d. Outline why the neutron star that is left after the supernova stage does not collapse under the action of gravitation. *[1 mark]*

2e. 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. *[2 marks]*

2f. Determine the region of the electromagnetic spectrum in which the neutron star in (c)(iii) emits most of its energy. *[2 marks]*

3a. Describe what is meant by the Big Bang model of the universe. *[2 marks]*

3b. State **two** features of the cosmic microwave background (CMB) radiation which are consistent with the Big Bang model. *[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}.

3c. Determine the distance to the galaxy in Mpc. *[2 marks]*

3d. Describe how type Ia supernovae could be used to measure the distance to this galaxy. *[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

4a. State what is meant by a binary star system. *[1 mark]*

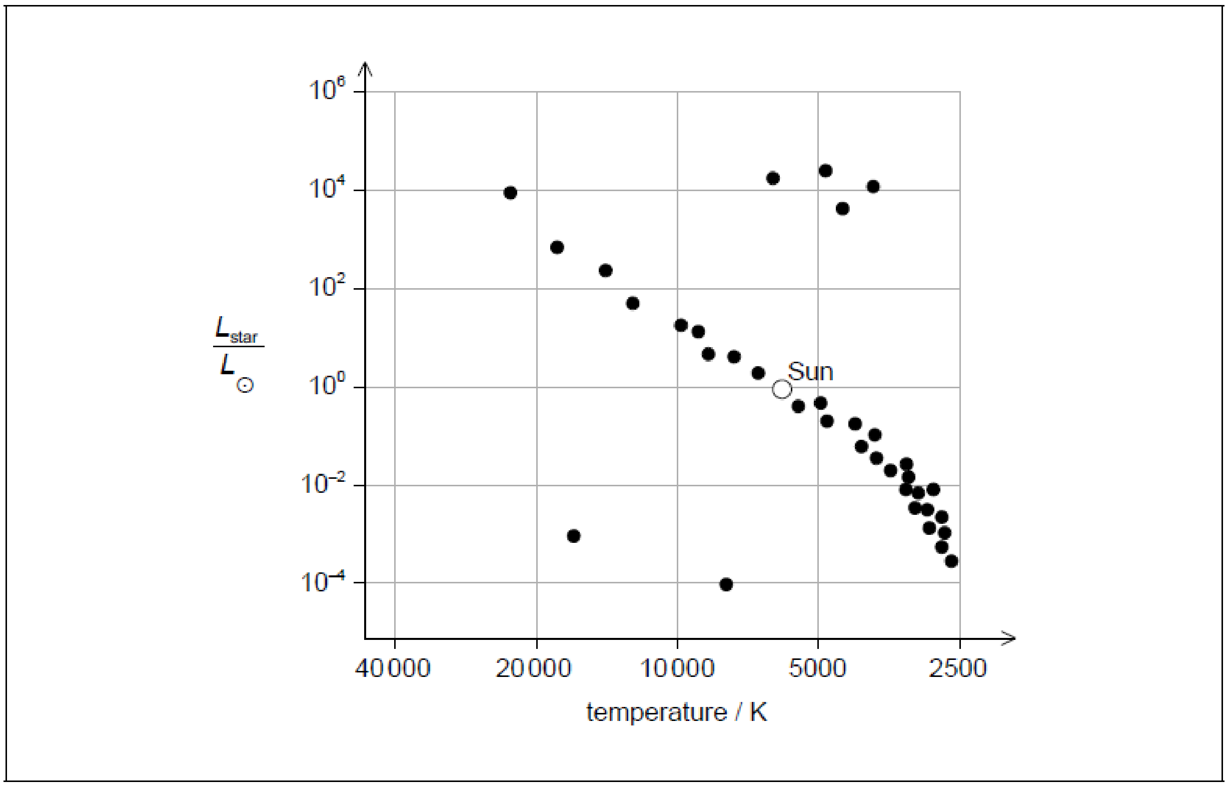
4b. (i) Calculate $\frac{b_A}{b_B} = \frac{\text{apparent brightness of Alpha Centauri A}}{\text{apparent brightness of Alpha Centauri B}}$. *[4 marks]*

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

4c. Show, without calculation, that the radius of Alpha Centauri B is smaller than the radius of Alpha Centauri A. *[2 marks]*

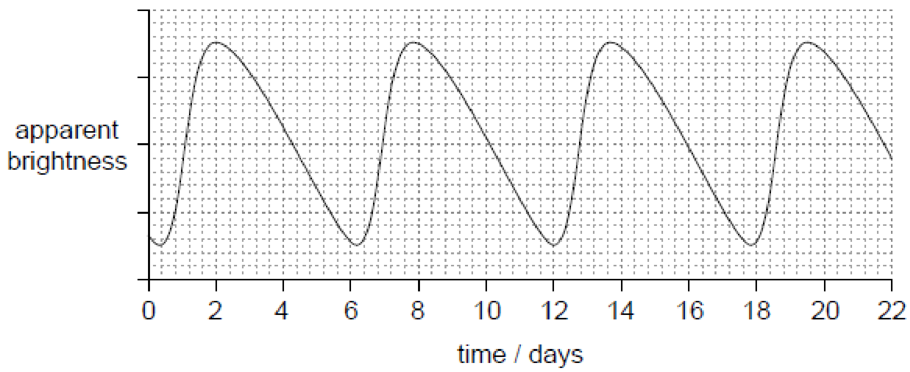
4d. Alpha Centauri A is in equilibrium at constant radius. Explain how this equilibrium is maintained. *[3 marks]*

4e. A standard Hertzsprung–Russell (HR) diagram is shown. *[2 marks]*

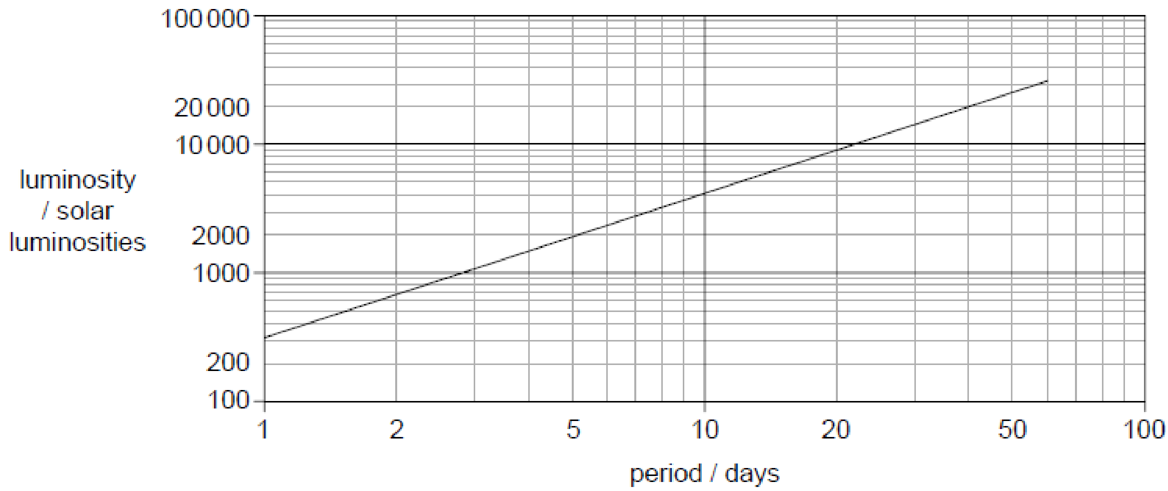


Using the HR diagram, draw the present position of Alpha Centauri A and its expected evolutionary path.

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.



5a. 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}. *[3 marks]*

5b. Explain why Cephids are used as standard candles. *[2 marks]*

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

6a. Identify **two** other characteristics of the CMB radiation that are predicted from the Hot Big Bang theory. *[2 marks]*

6b. 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. *[1 mark]*

7a. Describe **one** key characteristic of a nebula. *[1 mark]*

7b. 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]*

7c. Outline why astrophysicists use non-SI units for the measurement of astronomical distance. *[1 mark]*

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

8a. Show that the surface temperature of Aldebaran is about 4000 K. *[2 marks]*

8b. The radius of Aldebaran is 3.1×10^{10} m. Determine the luminosity of Aldebaran. *[2 marks]*

8c. Outline how the light from Aldebaran gives evidence of its composition. *[2 marks]*

8d. Identify the element that is fusing in Aldebaran’s core at this stage in its evolution. *[1 mark]*

8e. Predict the likely future evolution of Aldebaran. *[3 marks]*

9a. Light reaching Earth from quasar 3C273 has z=0.16. *[4 marks]*

(i) Outline what is meant by z.

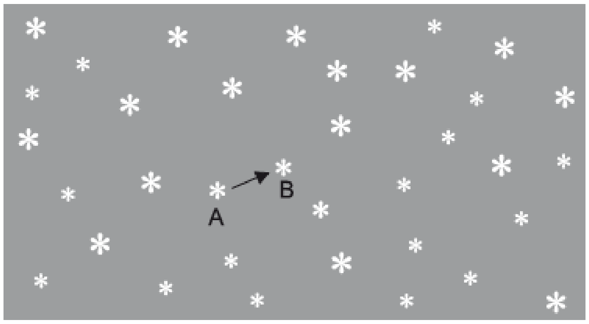
(ii) Calculate the ratio of the size of the universe when the light was emitted by the quasar to the present size of the universe.

(iii) Calculate the distance of 3C273 from Earth using H_0=68kms^{-1}Mpc^{-1}.

9b. Explain how cosmic microwave background (CMB) radiation provides support for the Hot Big Bang model. *[2 marks]*

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.



10a. Outline why the star appears to have shifted from position A to position B. *[1 mark]*

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.

10b. Draw a diagram showing d, D and θ. *[1 mark]*

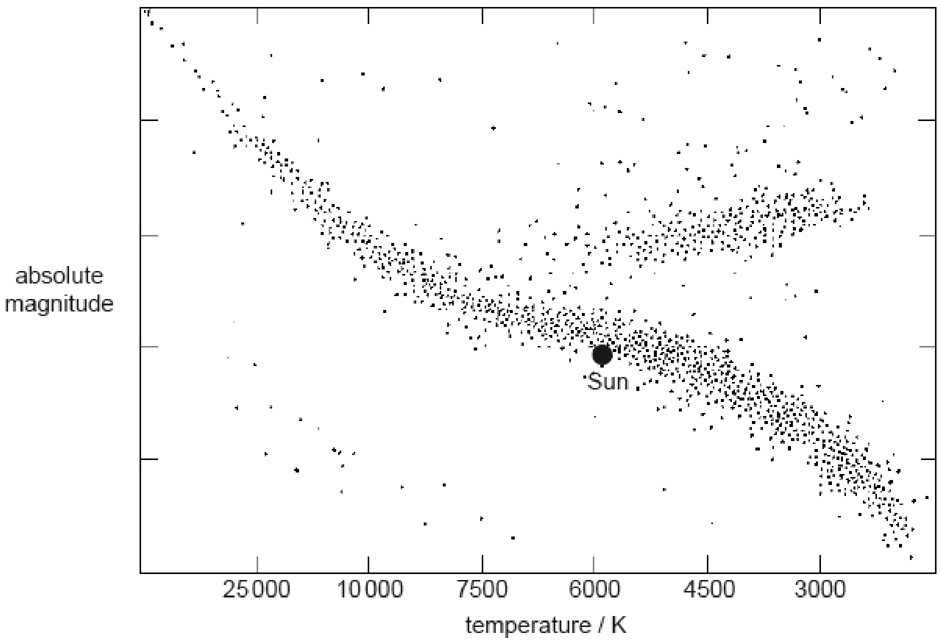
10c. Explain the relationship between d, D and θ. *[2 marks]*

10d. 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]*

10e. Suggest whether the distance from Earth to this star can be determined using spectroscopic parallax. *[1 mark]*

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

A Hertzsprung–Russell (HR) diagram is shown.



11a. The following data are given for the Sun and a star Vega. *[3 marks]*

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

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

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

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

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

11b. Outline how observers on Earth can determine experimentally the temperature of a distant star. *[3 marks]*

This question is about cosmic microwave background (CMB) radiation.

One of Newton’s assumptions was that the universe is static. The peak intensity of the cosmic microwave background (CMB) radiation has a wavelength of 1.06 mm.

12a. Show that this corresponds to a temperature around 3 K. *[2 marks]*

12b. Suggest how the discovery of the CMB in the microwave region contradicts Newton’s assumption of the static universe. *[2 marks]*

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.

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

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

13a. (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.

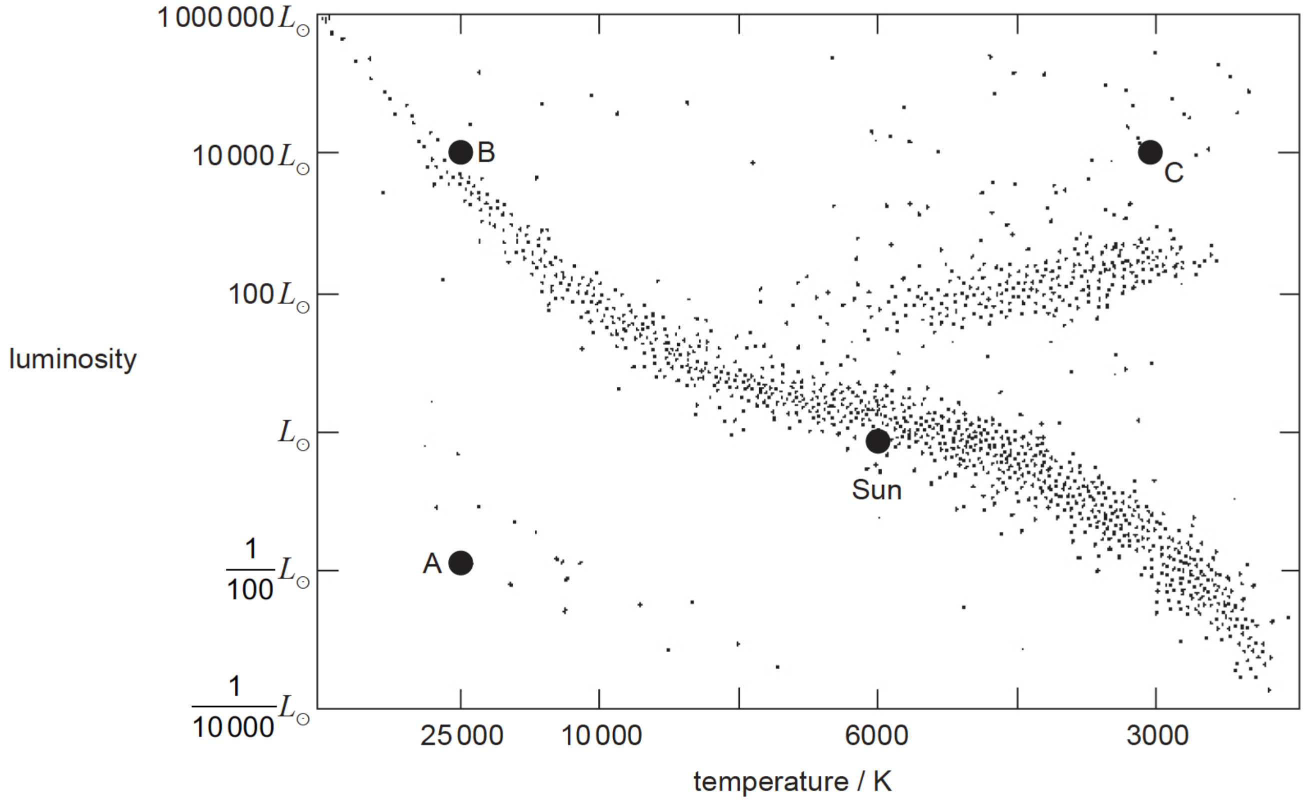
13b. (i) Determine, in astronomical units (AU), the distance between Earth and Barnard’s star. *[8 marks]*

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

(iii) Outline how the parallax angle is measured.

This question is about stars.

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



14a. State the star type for A, B and C. *[3 marks]*

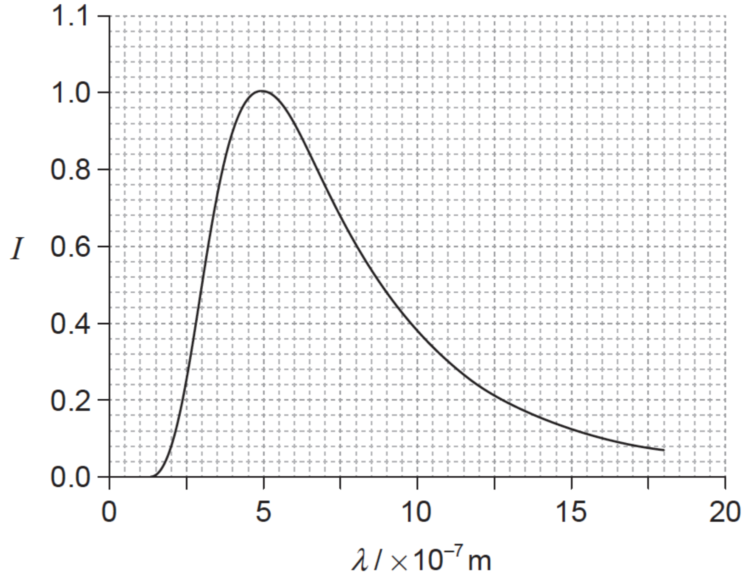
14b. The apparent brightness of C is 3.8×10^{-10} W m^{-2}. The luminosity of the Sun is 3.9×10^{26} W. *[4 marks]*

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

Apparent brightness:
Luminosity:

(ii) Determine the distance of C from Earth.

14c. 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 expanding universe.

Since 1929 it has been thought that the universe is expanding.

15a. State what is meant by the expansion of the universe. *[1 mark]*

15b. Red-shift of light from distant galaxies provides evidence for an expanding universe. *[4 marks]*

(i) State **one** other piece of evidence in support of an expanding universe.

(ii) Explain how your answer in (b)(i) is evidence for the Big Bang model of the universe.

This question is about the night sky.

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

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.

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

This question is about cosmology.

Newton assumed that the universe was infinite, uniform and static. The Big Bang model suggests space and time originated at one point around 14 billion years ago. At this time the temperature was very high.

18. In 1965, Penzias and Wilson discovered cosmic radiation with a wavelength that corresponded to a temperature of around 3 K. Outline how cosmic radiation in the microwave region is consistent with the Big Bang model. *[2 marks]*

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

Outline the nature of a comet.

20. This question is about the life history of stars. *[3 marks]*

Outline, with reference to pressure, how a star on the main sequence maintains its stability.

This question is about objects in the universe.

21a. State **one** difference between *[2 marks]*

(i) a main sequence star and a planet.

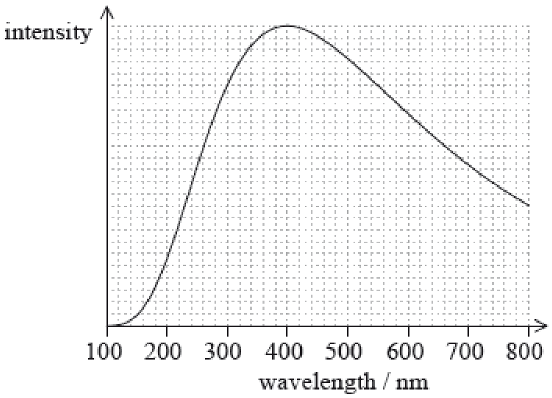
(ii) a stellar cluster and a constellation.

21b. 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.

21c. The graph shows the variation with wavelength of the intensity of a main sequence star. *[2 marks]*



Calculate the surface temperature of this star.

This question is about the cosmic microwave background (CMB) radiation.

22a. State **two** characteristics of the cosmic microwave background (CMB) radiation. *[2 marks]*

1.

2.

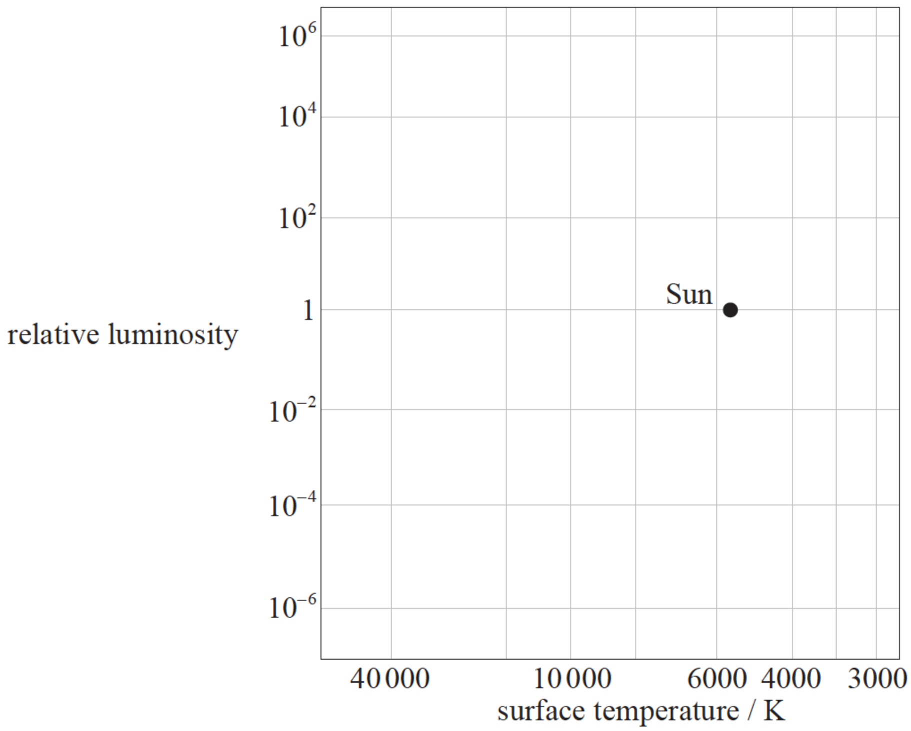
22b. Explain how CMB radiation is evidence for the Big Bang model of an expanding universe. *[2 marks]*

This question is about stars in the constellation Canis Minor.

23. Gomeisa, Luyten’s star and the Sun are main sequence stars. On the grid of the Hertzsprung–Russell (HR) diagram, identify the position of *[2 marks]*

(i) Gomeisa, with the letter G.

(ii) Luyten’s star, with the letter L.



This question is about the properties of a star.

24a. The peak in the radiation spectrum of a star X is at a wavelength of 300 nm. *[2 marks]*

Show that the surface temperature of star X is about 10000 K.

24b. On the Hertzsprung–Russell diagram, label the position of star X with the letter X. *[1 mark]*