1 The Pleiades star cluster is a prominent sight in the night sky. All the stars in the cluster were formed from the same gas cloud. Hence the stars have nearly identical ages and compositions, but vary in mass.

Earth-based parallax measurements have led to the conclusion that the Pleiades star cluster is about 435 light-years from Earth.

(a) (i) Explain how Earth-based parallax measurements can be used to determine the distance of the Pleiades star cluster from the Earth.

(3)

(ii) Suggest why this method of distance measurement is only suitable for the stars and star clusters closest to the Earth.

(1)

*(b) Since 1989 the Hipparcos satellite has been measuring the distances to a range of stars and star clusters. Using results from Hipparcos a more accurate distance of 392 light-years has been obtained for the Pleiades star cluster. This changed the luminosities of stars in the Pleiades star cluster as calculated by astronomers.

Explain how this variation in distance measurement has implications for our measurements of distance to the farthest galaxies.

(4)

(Total for Question = 8 marks)

2 The table shows the properties of three stars.

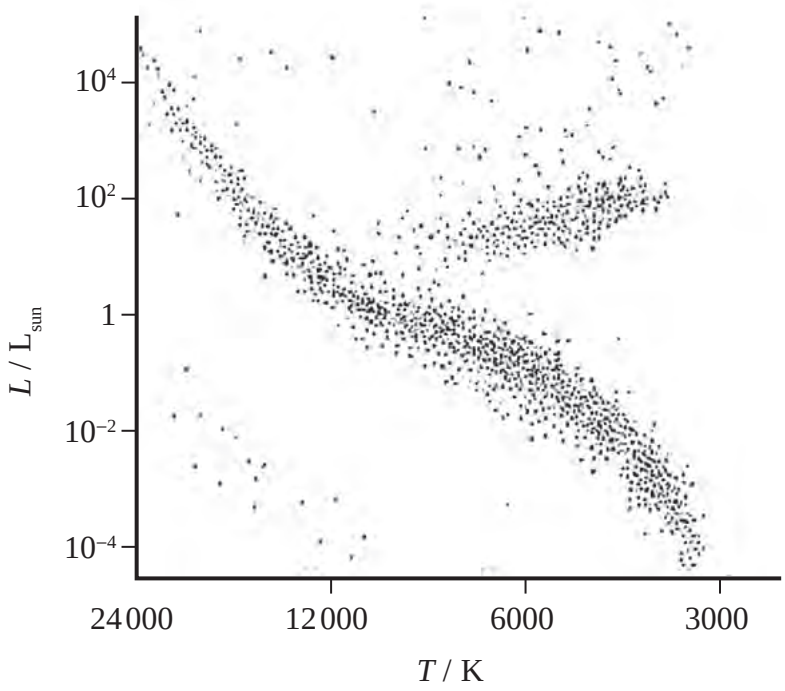
Star	Luminosity / L_{Sun}	Temperature / K	Type of star
Spica (S)	2.25×10^{3}	22,500	
Vega (V)	50.1	9,500	
Barnard's Star (B)	4.33×10^{-4}	3,000	Red Dwarf

(a) (i) Complete the table.

(2)

(ii) Use the letters S, V, and B to mark the approximate position of each star on the Hertzsprung-Russell diagram.

(1)



(b) By means of a calculation show that Barnard's Star would appear as a red star in the sky.

(3)

(c) Calculate the radius of Vega.

luminosity of the Sun = 3.85×10^{26} W

(2)

Radius of Vega =

(d) Vega appears to be much brighter than Spica in the night sky, although Spica has a much greater luminosity.

Explain why this is the case.

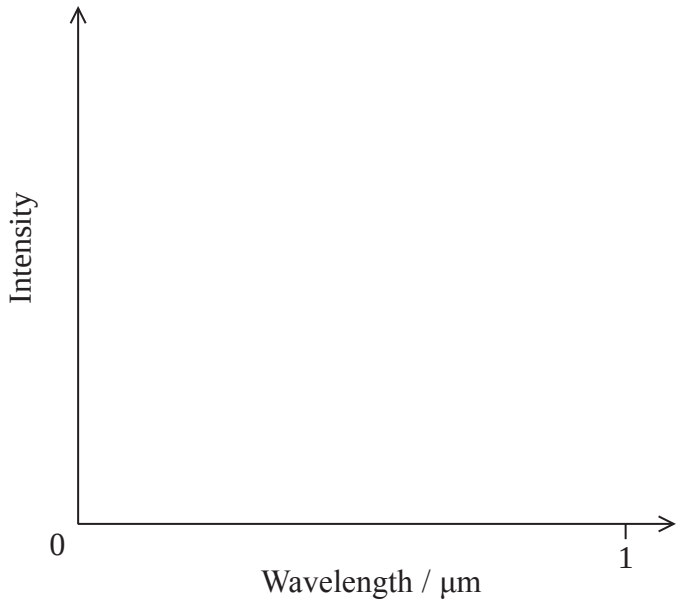
(3)

(Total for Question = 11 marks)

3 Rigel A in the constellation of Orion is one of the brightest stars in the sky. It is a massive blue variable star with an intensity peak at a wavelength λ_{max} of 0.25 μm.

(a) On the axes below, sketch a graph of the intensity of radiation emitted by Rigel A against the wavelength of that radiation.

(2)



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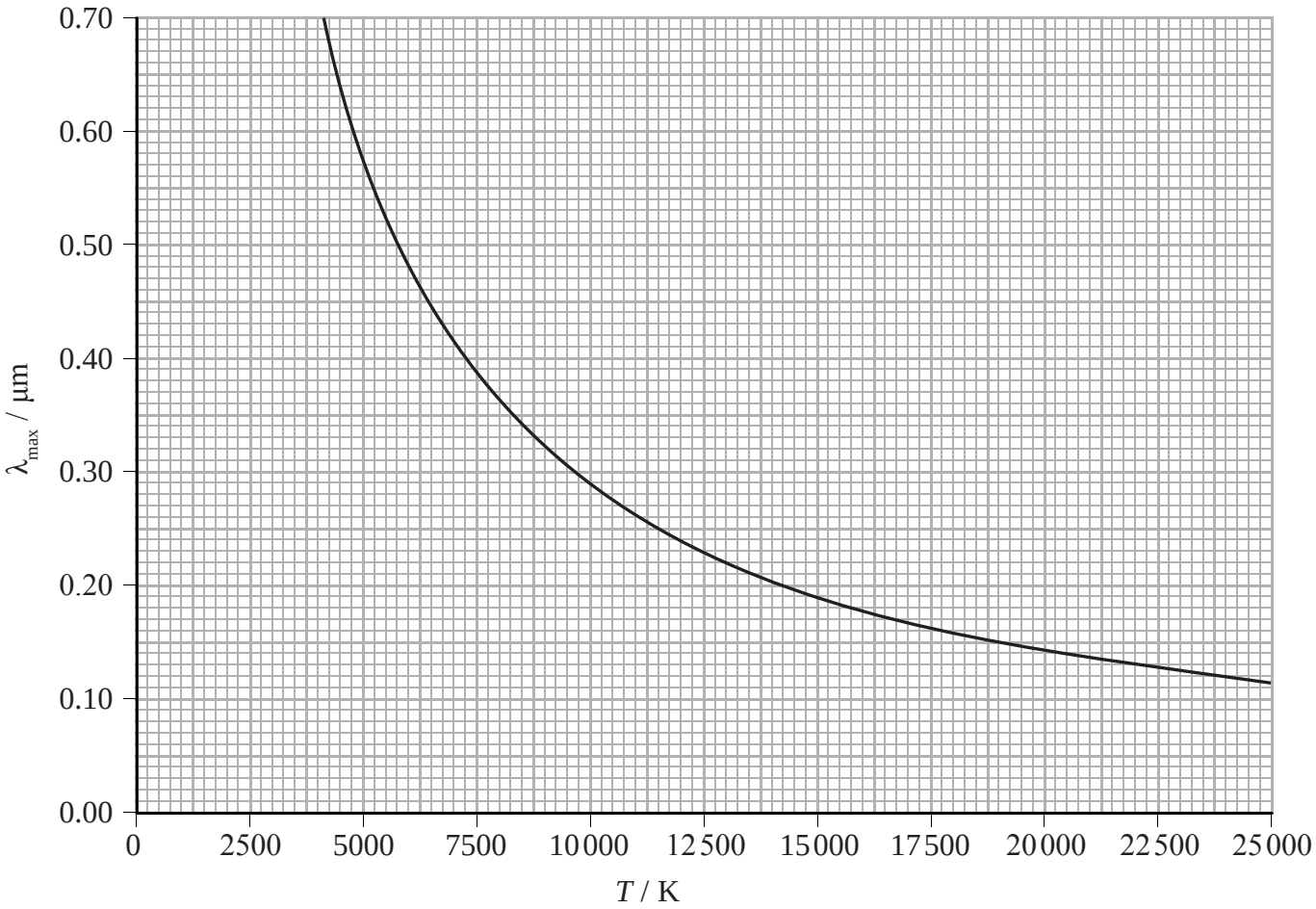
(b) The graph below shows how λ_{max} varies with temperature T for a black body radiator.



(i) Use the graph to estimate the surface temperature of Rigel A.

(1)

(ii) Show that the graph is consistent with Wien's law.

(3)

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(c) RR Lyrae stars are also variable stars. They are used by astronomers as standard candles, although none of them are close enough for trigonometric parallax to be useful.

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

(1)

*(ii) Describe how astronomers use standard candles.

(3)

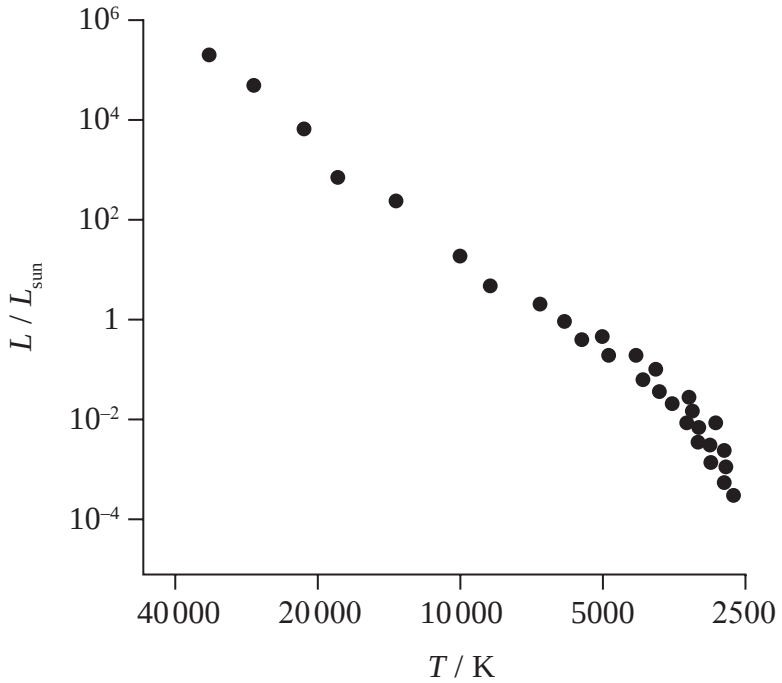
(iii) Explain why stars have to be within a certain distance from the Earth for trigonometric parallax to be useful.

(2)

(Total for Question = 12 marks)

4 The Hertzsprung-Russell (H-R) diagram is a plot of luminosity against temperature for a range of stars.

(a) The H-R diagram below shows a number of main sequence stars.



(i) Label the position of our Sun on the diagram.

(1)

(ii) Label on the diagram the regions in which white dwarf and red giant stars would be located.

(2)

*(iii) Stars known as white dwarf stars have small surface areas. Explain how astronomers have deduced this.

(3)

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(b) Most stars lie on the main sequence. In the early 20th century, it was thought that the main sequence represented different evolutionary stages of stars. According to this model, stars form with a high temperature and luminosity and so are located in the top left of the main sequence. As stars radiated energy they would move down the main sequence over time.

Scientists were unaware of fusion in the core of stars providing the energy for the star to shine.

Using this obsolete model explain why, in the absence of fusion, the luminosity of the star would decrease over time.

(3)

(c) In 1939 Hans Bethe published a paper describing the fusion processes in stars.

In the proton-proton cycle, hydrogen is converted to helium in stages. The nuclear equation below represents one of the stages.

$$^{7}_{3}\mathrm{Li} + \quad \mathrm{X} \rightarrow 2 \times {}^{4}_{2}\mathrm{He}$$

(i) Complete the equation and identify X.

(2)

X is

(ii) Calculate, in joules, the energy emitted in this stage of the cycle.

(3)

	Mass / MeV/c^2
Proton	938.3
Neutron	939.6
Helium	3727.4
Lithium	6533.8

Energy = J

(d) In 1967 Bethe re ved a Nobel Prize in Physics for his work on understanding the fusion processes in stars.

Explain why sustainable fusion has not yet been achieved for the generation of electrical power.

(4)

(Total for Question = 18 marks)

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5 The spectra below show dark absorption lines against a continuous visible spectrum.

light from a source in the laboratory

light from a distant galaxy

frequency

A particular line in the spectrum of light from a source in the laboratory has a frequency of 4.570×10^{14} Hz.
The same line in the spectrum of light from a distant galaxy has a frequency of 4.547×10^{14} Hz.

With the aid of a calculation state what should be concluded about the distant galaxy.

(3)

(Total for Question = 3 marks)

6 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)

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

(3)

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

(1)

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

(2)

(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.

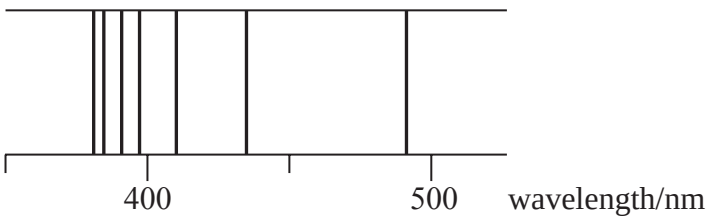
(3)

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

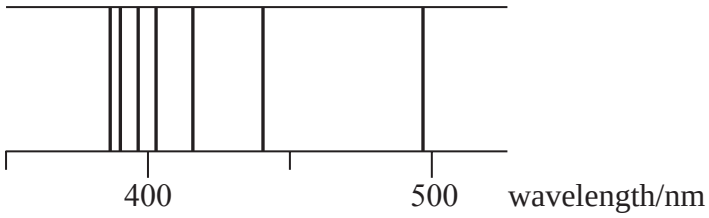
(2)

(Total for Question = 13 marks)

7 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)

(Total for Question = 2 marks)

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