1 Betelgeuse is our nearest red giant. It has a luminosity of 4.49×10^{31} W and emits radiation with a peak energy emission occurring at a wavelength of 850 nm.

Show that Betelgeuse has a surface temperature of about 3000 K. Hence calculate the ratio of the radius of Betelgeuse, r_B to the radius of the Sun, r_S.

$r_S \quad 6.95 \times 10^8$ m

(5)

r_B/r_S .....

(Total for Question 5 marks)

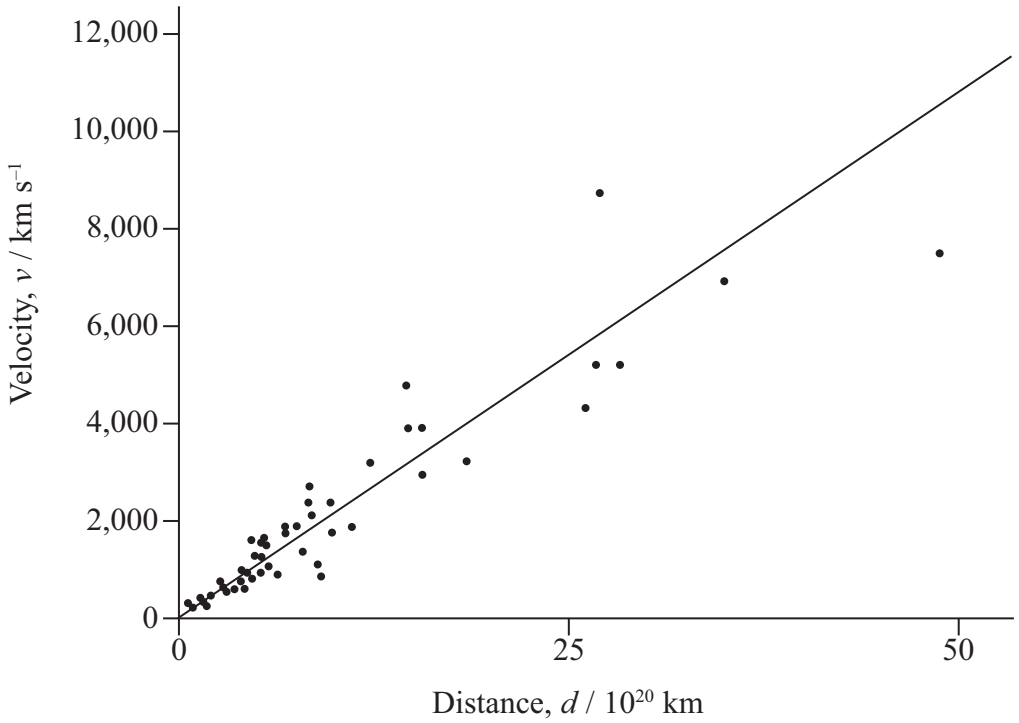
***2** Cepheid variable stars have long been seen as examples of standard candles. Recent measurements have indicated that the movement of the star through interstellar material might result in the formation of a layer of dust around the star. This affects how bright the star appears.

Explain how standard candles are used in astronomy, and suggest how the existence of a layer of dust around a Cepheid variable star might affect the conclusions drawn by astronomers.

(6)

(Total for Question 6 marks)

3 The graph shows how the velocity varies with distance for a number of distant galaxies. All the galaxies are receding from Earth, and there appears to be a linear relationship between the velocity of recession and the distance to the galaxy.



(a) Use the graph to estimate an age for the Universe.

(4)

Age of the Universe .....

*(b) Describe how astronomers would have determined the velocity of each galaxy.

(5)

*(c) Scientists are uncertain about the ultimate fate of the Universe.

Explain why.

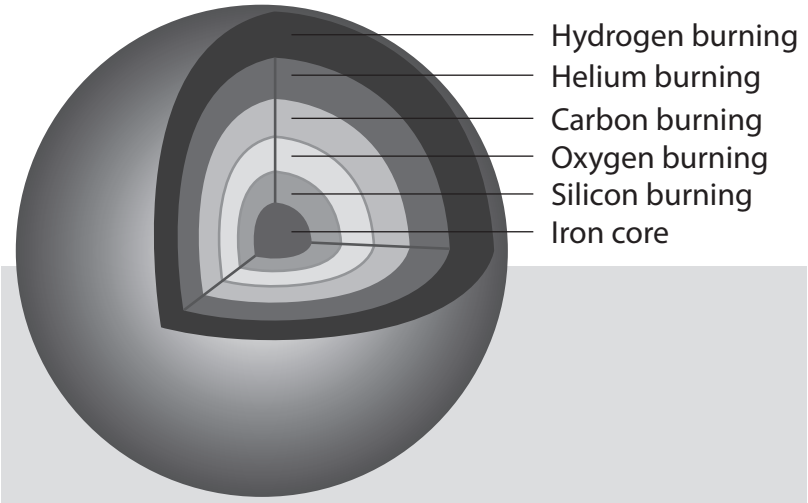
(3)

(Total for Question 12 marks)

4 The following passage is taken from a newspaper article.

Stars exist by fusing hydrogen within their cores. This process generates heat which pushes the star outwards. This outward pressure is matched by the gravitational forces pulling the star inwards. This maintains an equilibrium, allowing the star to radiate away vast amounts of energy for long periods of time. Our Sun has been in this state for about 4.5 billion years.

Eventually the star runs out of hydrogen to fuse, and so changes occur which allow fusion of helium to form heavier elements. Massive stars can produce elements up to iron in their cores by fusion.



Once a star's core has been converted into iron no further fusion can take place and the rapid collapse of the star results in a supernova explosion.

The remnant of the supernova may be a neutron star or black hole, depending upon the remnant's mass.

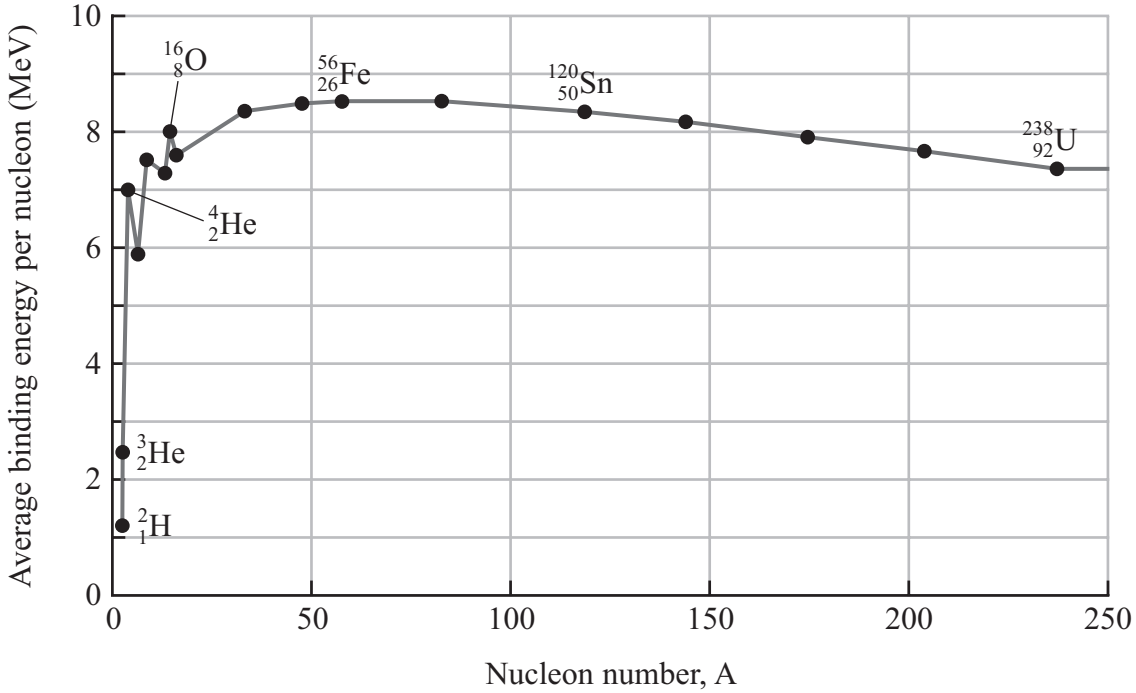
*(a) The conditions needed for fusion to occur make it difficult to replicate outside of a star.

State and explain:

- how the process of fusion is able to release energy
- the conditions necessary for fusion to occur
- why the conditions are difficult to replicate outside of a star.

(6)

(b) The graph shows the average binding energy per nucleon for a range of isotopes.



Massive stars can only produce elements up to iron (Fe) in their cores by fusion.
Use information from the graph to explain why.

(3)

A type 1a supernova occurs when a white dwarf star in a close binary system accumulates matter from its companion star. This eventually leads to a supernova outburst. Type 1a supernovae are used by astronomers as standard candles.

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

(1)

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(ii) A type 1a supernova is observed in a distant galaxy. Its flux at the Earth is measured to be 1.84×10^{-15} W m^{-2}. Theory predicts that it has a luminosity of 2.0×10^{36} W.

Show that the distance of the galaxy from the Earth is about 9×10^{24} m.

(2)

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(iii) The light from the galaxy is found to be red-shifted. State what this tells us about the galaxy.

(1)

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(iv) The redshift is measured to be 0.064. Calculate a value for the Hubble constant.

(3)

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Hubble constant .....

(Total for Question 16 marks)

5 A Cepheid variable star contracts and expands repeatedly and as it does, so its luminosity varies. By measuring the period of this variation, astronomers can determine the star's average luminosity.

(a) A Cepheid variable star is a type of standard candle. Discuss the use of standard candles in astronomy.

(4)

(b) As well as the variation in luminosity of the Cepheid, changes in the frequency of the detected radiation are also observed.

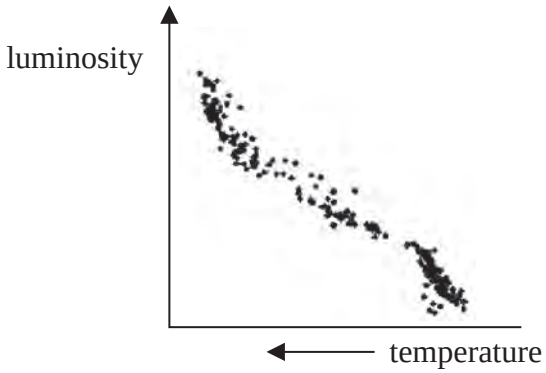
Suggest how the Doppler effect may account for these changes.

(2)

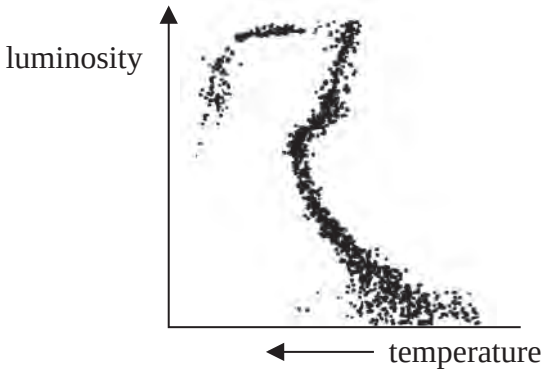
(Total for Question 6 marks)

6 (a) The Herzsprung-Russell (H-R) diagram is one of the most important tools in the study of stellar evolution.

The H-R diagrams below are for a young star cluster and an old star cluster.



Young star cluster



Old star cluster

Use the diagrams to describe and explain how the old star cluster is different from the young star cluster.

(6)

(b) Trigonometric parallax is one way in which stellar distances can be measured.

Astronomers measure the parallax angle for two nearby stars. The parallax angle for star A is 3.74×10^{-6} rad and that for star B is 1.84×10^{-7} rad.

(i) Without calculation, state what can be deduced from this data about the relative distances of the two stars.

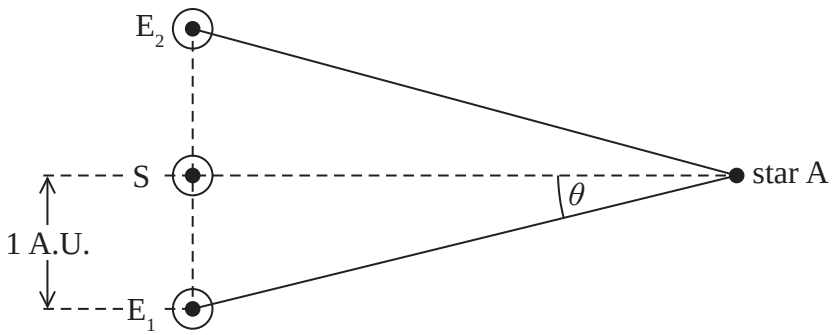
(1)

(ii) The diagram shows the parallax angle for star A.

Calculate the distance of star A from the Earth.

1 A.U. is 1.50×10^{11} m

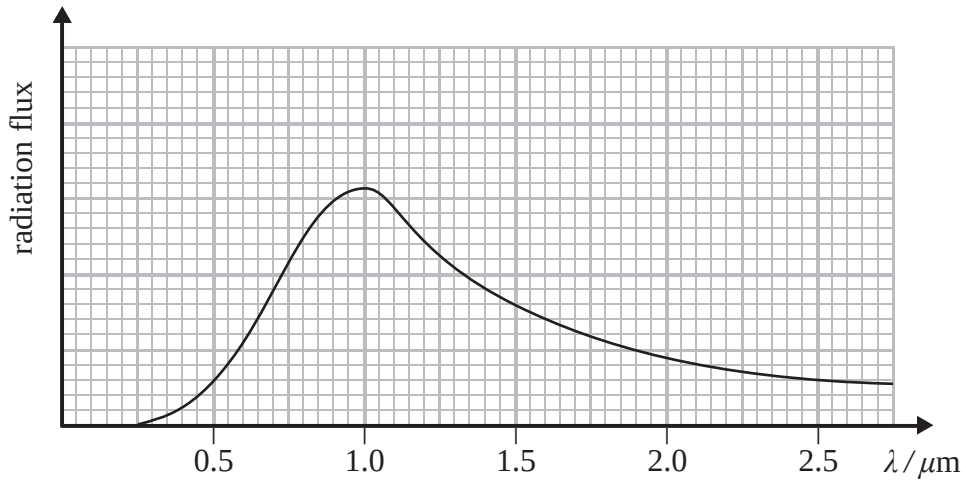
(2)



Distance =

(c) In addition to finding the distances to stars astronomers are interested in determining the temperatures of stars.

The spectrum of star A is shown below.



Use data from the graph to determine the surface temperature of star A.

(3)

Temperature =

(Total for Question = 12 marks)