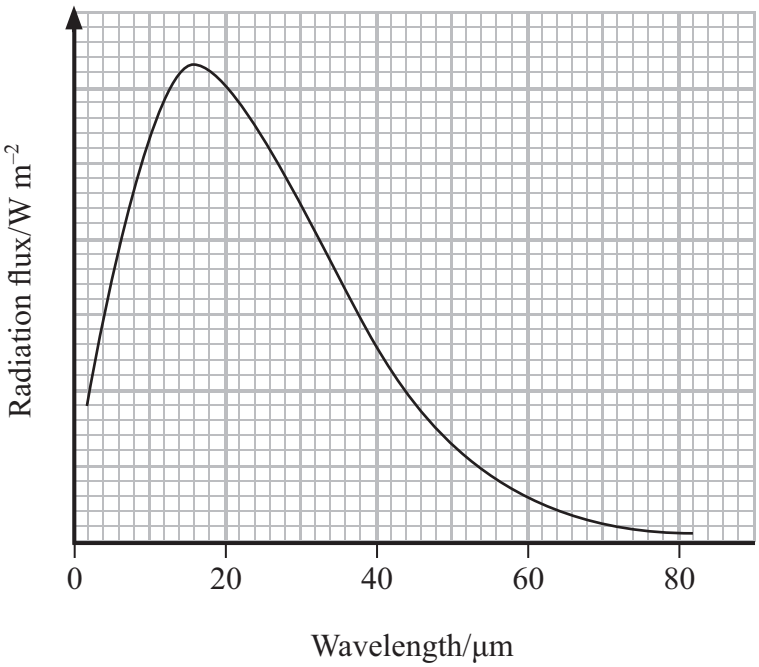
1 The radiation emitted from an asteroid is monitored and the following spectrum obtained.



(a) (i) State the wavelength at which the peak radiation flux from the asteroid occurs.

(1)

Wavelength of peak radiation flux .....

(ii) Use the data to estimate the temperature of the asteroid.

(2)

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Temperature of asteroid .....

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(b) The asteroid is in a circular orbit, of known radius, about the Sun. The average speed of the asteroid cannot be determined directly.

State the two extra data values that you would need in order to calculate the orbital period of the asteroid.

(2)

1 .....

2 .....

(c) This asteroid is about 1.5×10^{11} m from the planet Jupiter.

Calculate the magnitude of the gravitational field strength of Jupiter at this distance.

mass of Jupiter 1.9×10^{27} kg

(2)

.....

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Gravitational field strength of Jupiter .....

(Total for Question 7 marks)

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*2 The Sun behaves as an approximate black-body radiator with peak energy radiation occurring at a wavelength of 5.2×10^{-7} m.

(a) (i) Show that the Sun has a surface temperature of about 6000 K.

(2)

(ii) The radiation received from the Sun at the top of the atmosphere is 1.37 kW m^{-2}. Show the Sun's luminosity is about 4×10^{26} W.

Distance from the Sun to the Earth = 1.49×10^{11} m

(2)

(iii) Hence calculate the radius of the Sun.

(2)

Radius =

(b) The huge power output of the Sun is due to nuclear fusion reactions taking place within its core. State and explain the conditions necessary for fusion to occur.

(3)

(Total for Question = 9 marks)

3 The Earth can be considered to be a black body radiator at a temperature of 25 °C.

radius of Earth 6380 km

(a) Calculate the total power radiated from the Earth.

(2)

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Total power radiated .....

(b) Calculate the wavelength of the peak energy radiation for the Earth.

(2)

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Wavelength of the peak energy radiation .....

(c) State the region of the electromagnetic spectrum in which this wavelength is found.

(1)

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(Total for Question 5 marks)

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4 The planet Mars has a mean distance from the Sun of 2.3×10^{11} m compared with the Earth's mean distance from the Sun of 1.5×10^{11} m.

(a) Calculate the ratio $\frac{\text{Sun's radiation flux at distance of Mars}}{\text{Sun's radiation flux at distance of Earth}}$.

(2)

Ratio .....

(b) With reference to your answer in (a), comment on the suggestion that Mars could be capable of supporting life.

(2)

(Total for Question 4 marks)

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5 Records of people walking on fire have existed for thousands of years. Walking across hot coals without getting burned does seem impossible, especially when the coals are at a temperature of 1500 K. However, as long as they do not take too long to walk across the coals, firewalkers won't get burned.

The explanation may have something to do with the relatively small amount of thermal energy involved. Although the coals are hot, the total amount of thermal energy transferred to the soles of the walker's feet is small. This is a little like quenching a red hot metal bar in a trough of cold water. The metal bar cools rapidly, transferring thermal energy to the water, but the rise in temperature of the water is quite small because of the relatively large value for the specific heat capacity of the water.

(a) Describe an experiment you could carry out to measure the specific heat capacity of a metal, assuming that you have a number of metal washers which can be heated to a known temperature in a Bunsen flame and plunged into a container of water. State the measurements that you would need to make and give the theoretical basis of the calculation that you would carry out.

What assumption would you make in calculating the specific heat capacity of the metal?

(4)

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(b) Coals used for firewalking typically glow a dull red, with the peak energy emission taking place at a wavelength of about 2 μm.

(i) To which region of the electromagnetic spectrum does this wavelength belong?

(1)

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(ii) Show that a peak wavelength of 2.00 μm corresponds to a black-body temperature of about 1500 K.

(2)

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(iii) The coals have an average radius of 2.5 cm. Assuming that each coal behaves as a black-body radiator, calculate the rate at which energy is radiated from each coal at a temperature of 1500 K.

(3)

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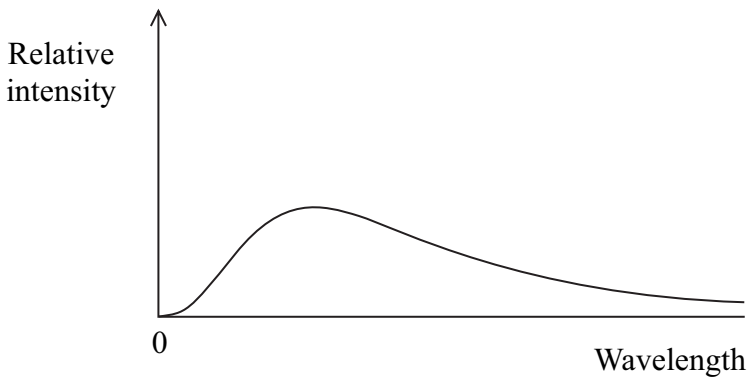
(iv) The graph shows the shape of the spectrum for radiation emitted from a black-body radiator at 1500 K. Add a second curve to show the shape of the spectrum for a temperature of 2000 K.

(2)



(Total for Question 12 marks)

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6 A student is constructing a spreadsheet to calculate the radius R of some stars.
To obtain the radius, the surface temperature T of the star must first be calculated. She is given values for the stars' luminosities L and the wavelengths λ_{max} at which peak energy emission occurs. Part of the spreadsheet is shown, A is the surface area of the star.

	A	B	C	D	E
1	λ_{max} / 10^{-7} m	T / 10^{3} K	L / 10^{27} W	A / 10^{19} m^2	R / 10^{9} m
2	6.85	4.23	0.039		0.41
3	5.74	5.05	0.384	1.04	0.91
4	3.56	8.14	3.385	1.36	1.04
5					

(a) Write an equation to show how the value in B2 is calculated.

(1)

(b) Show that the value in D2 is about 0.2

(2)

(c) The student was given the luminosity values to enter into column C.

Describe how astronomers could determine the luminosity of a star.

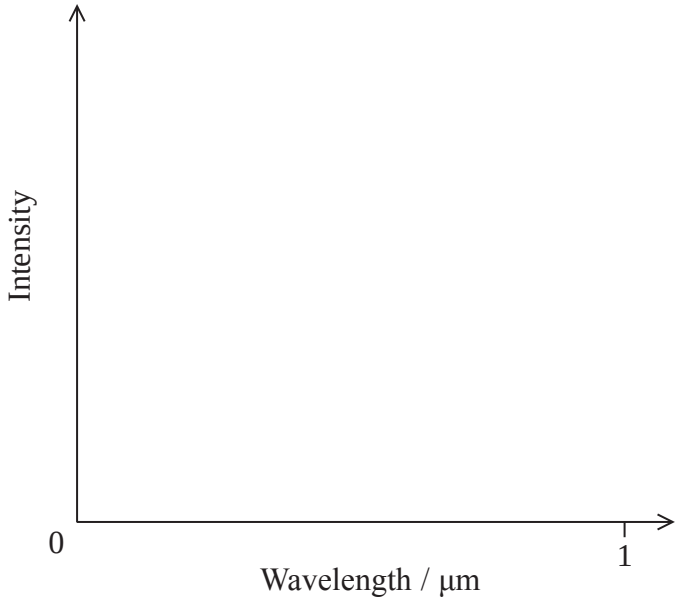
(2)

(Total for Question = 5 marks)

7 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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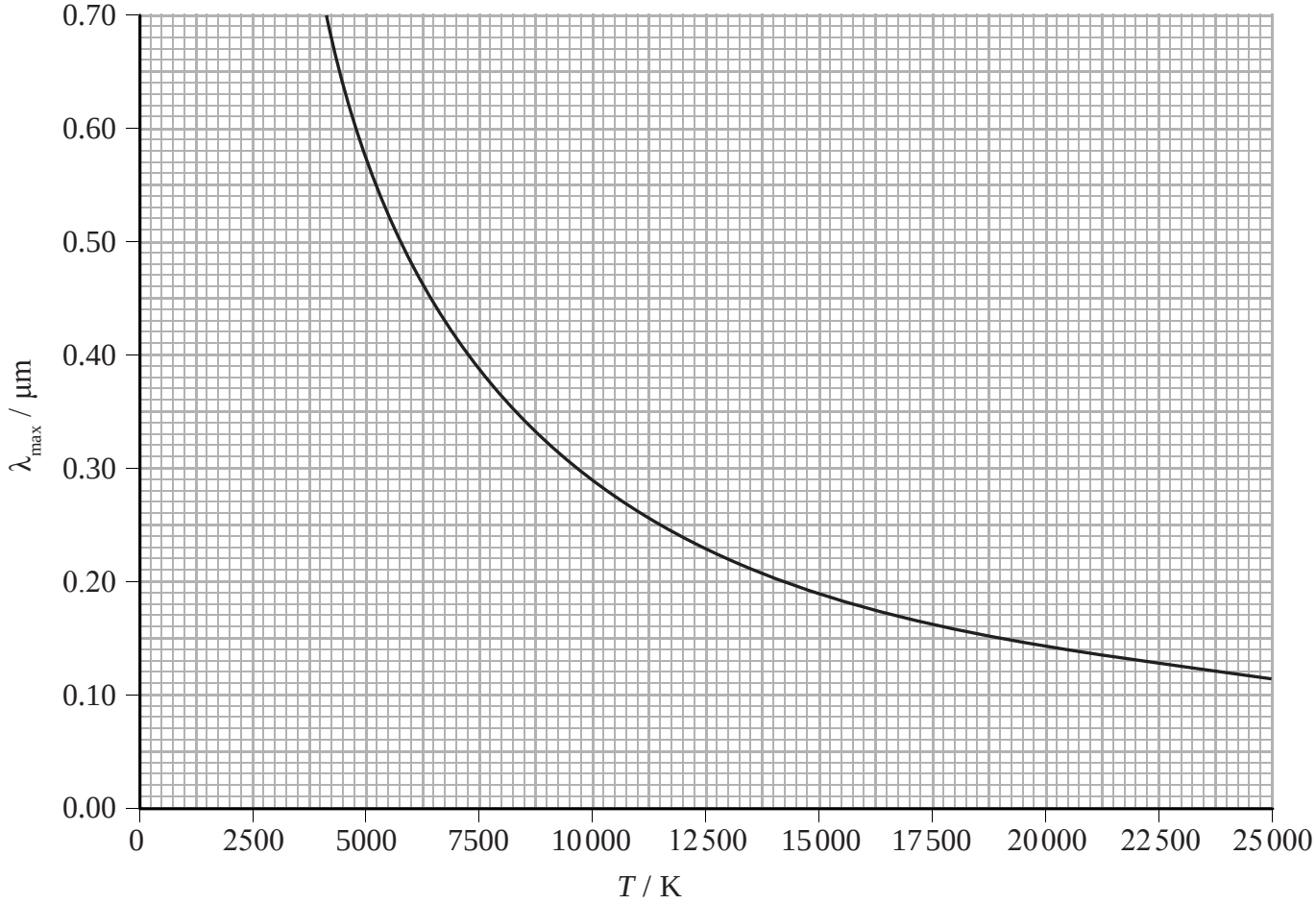
(b) The graph below shows how λ_{max} varies with temperature T for a black body radiator.



(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)

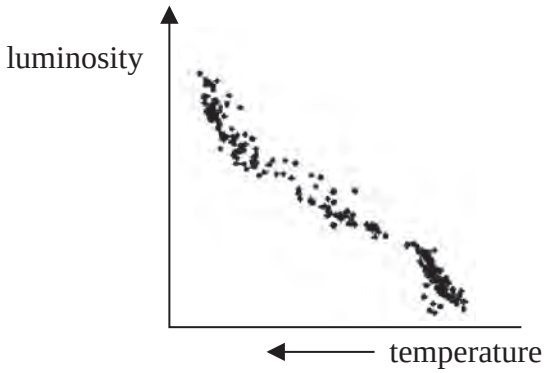
(iii) Explain why stars have to be within a certain distance from the Earth for trigonometric parallax to be useful.

(2)

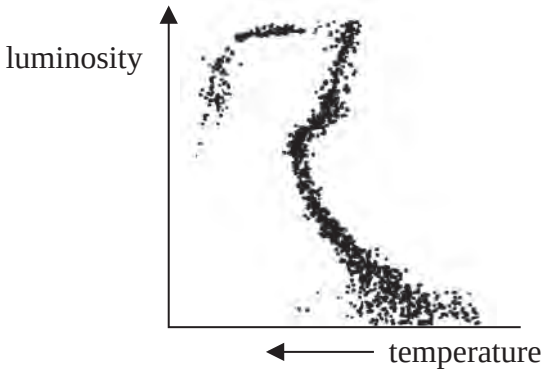
(Total for Question = 12 marks)

8 (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)

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(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.

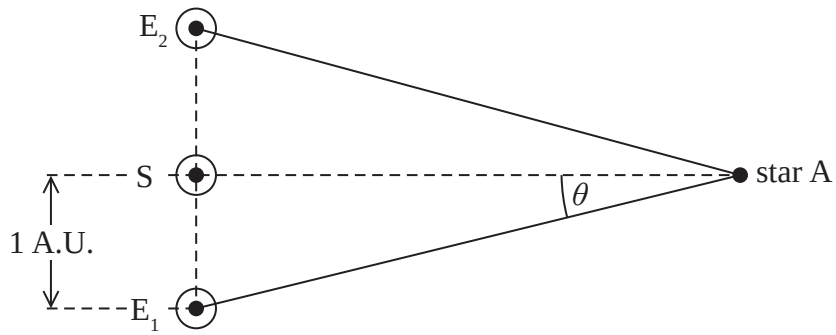
(1)

(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

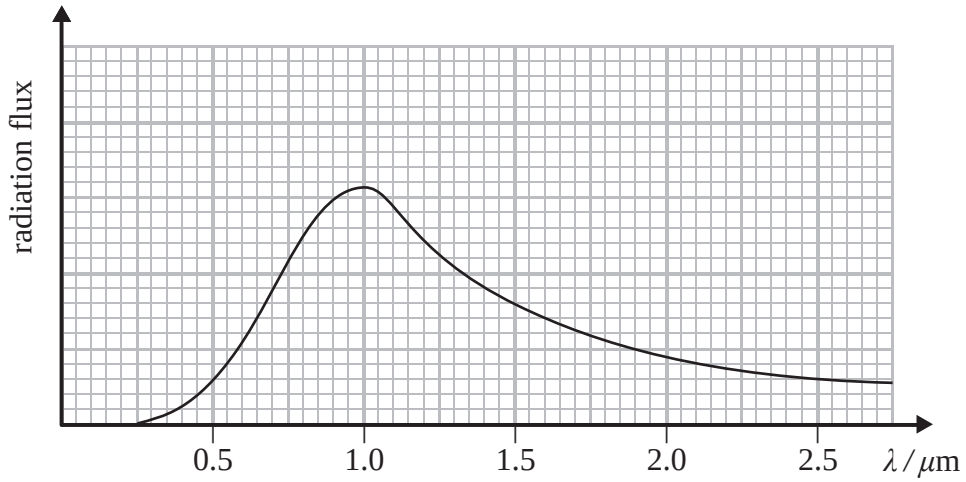
(2)



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)