1.

*(a)* (i) The spectrum of the star *Rigel* in the constellation *Orion* peaks at a wavelength of 260 nm. Calculate the temperature of the surface of Rigel. [2]

(ii) What assumption were you making about the way the star's surface radiates? [1]

*(b)* To a good approximation the Kelvin temperature of Rigel's surface is twice that of the Sun, and the **radius** of Rigel is 70 times the radius of the Sun. Use *Stefan's Law* to estimate the ratio

$$\frac{\text{total power of electromagnetic radiation emitted by Rigel}}{\text{total power of electromagnetic radiation emitted by the Sun}}.$$ [3]

*(c)* We can discover the presence of particular atoms in the atmosphere of a star by measuring the wavelengths of dark lines in the star's spectrum.

Explain how the lines arise, and why they occur at specific wavelengths. [3]

2.

**4.** *(a)* Stefan's law can be written as:

$$P = A\sigma T^4$$

Show that Stefan's constant, σ, has the base SI units of $\mathrm{kg\,s^{-3}\,K^{-4}}$. [3]

.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

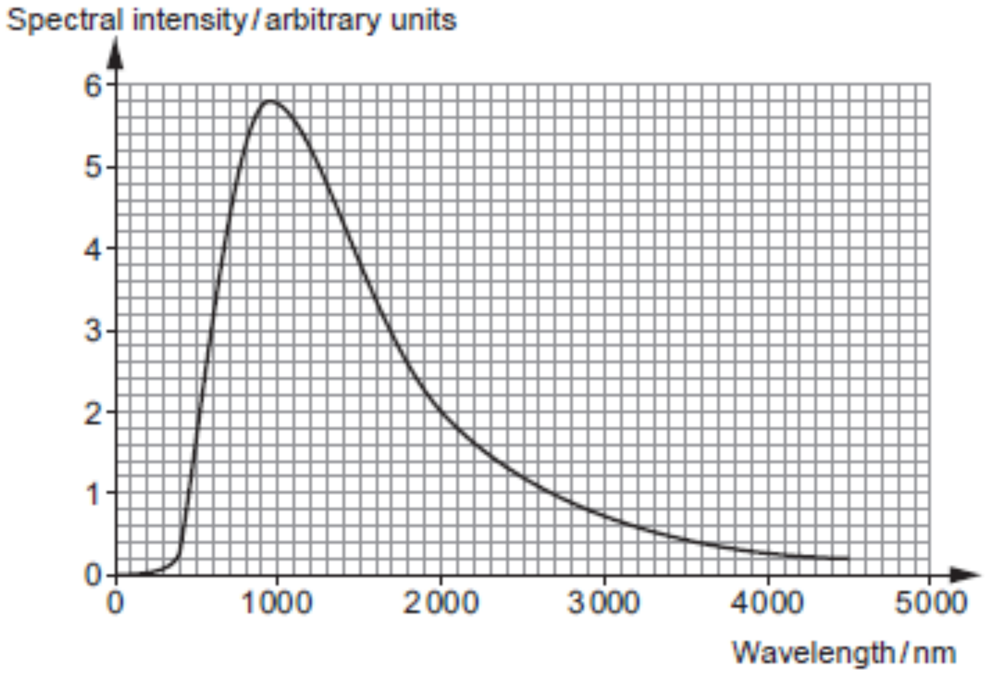
.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

*(b)* Our nearest star is called Proxima Centauri. The following graph shows its spectrum.



(i) The total power output of electromagnetic radiation emitted from Proxima Centauri is $5.9 \times 10^{23}$ W. Use this information and the graph opposite to calculate its effective diameter. [4]

.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

.......................................................................................................................................................

(ii) State what colour you would expect Proxima Centauri to appear and name the region of the electromagnetic spectrum in which most of the star's power is radiated. [1]

.......................................................................................................................................................

.......................................................................................................................................................

3.

**8.** Read through the following article carefully. Paragraph

**A little bit of information about stars by Ignasi Lluis Marxuach**

**Figure 1** shows the three different routes for the life cycle of different sized stars, from small stars, through medium (Sun-like) stars to explosive high mass stars. For some reason, exam boards tend to ignore the smallest category of stars (red dwarfs) because their cores never become hot enough to produce red giant stars. 1

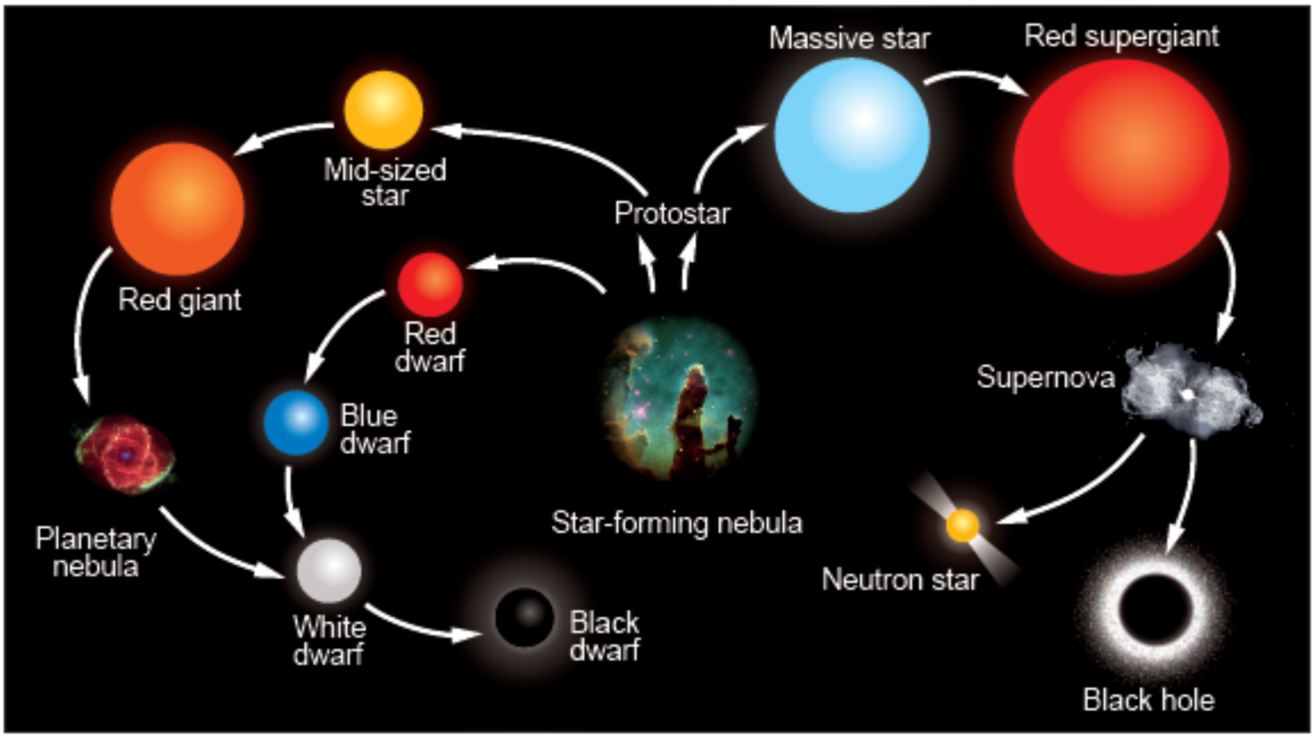



**Figure 1**

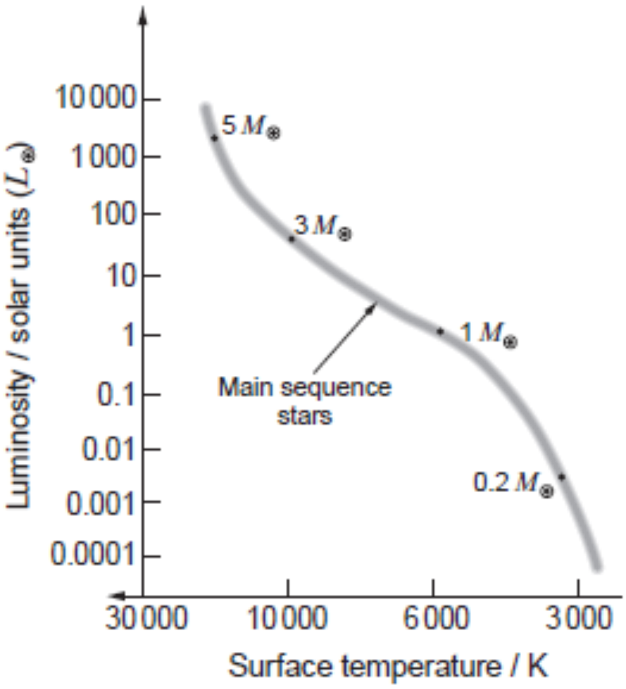
Stars are formed from the gravitational collapse of gas clouds called *nebulae*. Gravitational potential energy is converted to internal energy of hot gases which then emit radiation. This means that the search for new stars usually involves the use of infra-red telescopes in space. 2

The images on the next page show the same gas clouds but the image on the right (**Figure 3**) is taken with visible light while the image on the left (**Figure 2**) is taken with infra-red. Notice how the gas clouds are transparent to infra-red so that stars behind the gas clouds become visible at infra-red wavelengths. The areas where stars are forming are those areas of the gas cloud that appear to be emitting radiation at both infra-red and visible wavelengths. 3

Figure 2 (infra-red image)

Figure 3 (visible light image)

Once the core of a young star is hot enough to initiate hydrogen fusion it is called a *main sequence star*. Such stars are stable, lasting for millions or billions of years and account for around 90% of all stars. They are stable because the outward pressures due to hot gases and electromagnetic radiation are balanced by the inward pressure due to gravity. 4
Larger main sequence stars have denser cores which means that the rate of fusion and the temperature are also greater. A graph of luminosity against temperature for main sequence stars is rather useful, although slightly less useful than it should be because astronomers, apparently, don't realise that values should increase going to the right on normal graphs.




$M_{\odot}$ = mass of the Sun
$L_{\odot}$ = solar unit (luminosity of the Sun)

**Graph 1**

Notice that nearly all main sequence stars have surface temperatures in the range 3000 K to 20 000 K. This makes them suitable for analysing using visible light. 5

Paragraph

Another thing to note from the luminosity against surface temperature graph is that these
factors seem to depend on the mass of the star. It turns out that there is only one factor that 6
determines a star's position on the graph – its mass. The relationship between mass and
luminosity for a star is quite complicated and comes in four parts.

$L = 0.23M^{2.3}$ for $M < 0.43$ **Equation 1**

$L = M^4$ for $0.43 < M < 2$ **Equation 2**

$L = 1.5M^{3.5}$ for $2 < M < 20$ **Equation 3**

$L = 3200M$ for $M > 20$ **Equation 4**

Note that these equations have been simplified by having the mass of the star ($M$) in units of the solar mass ($M_\odot$), and luminosity in units of the solar luminosity ($L_\odot$).

These relationships are rather useful and should explain why large mass stars can be found
more easily using ultraviolet telescopes, but they can do so much more when combined 7
with Einstein's equation.

$E = \Delta mc^2$ **Equation 5**

You might, in the first instance, be excused for thinking that a 10 $M_\odot$ star will burn 10 times
longer than the Sun. This, however, could not be further from the truth. Use of Equation
3 should tell you that a 10 $M_\odot$ star will burn approximately 5000 times brighter. By using 8
Einstein's equation and making a few simplifying assumptions, we find the expected lifetime
of a 10 $M_\odot$ star to be, in fact, approximately 500 times less than that of the Sun. Some might
say that a large star "burns the candle at both ends" but it's more accurate to say that it
burns the candle at 5000 ends simultaneously.

It should be reasonably clear that there is a negative correlation between the mass of a star
and its lifetime. Another two star variables that are (bizarrely) negatively correlated are the 9
mass of a white dwarf and its radius. However, that is a completely different story which is
beyond the remit of this 2019 Space Odyssey.

Answer the following questions in your own words. Extended quotes from the original article will not be awarded marks.

*(a)* Write down the complete life cycle of a mid-sized star (see **Figure 1**). [1]

Star-forming nebula →

*(b)* Suggest an advantage of placing telescopes *in space* to observe new stars (see Paragraph 2). [1]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

*(c)* In **Figure 2** or **3** below, mark with an **X** one area where new stars are forming (see Paragraph 3 and **Figures 2** & 3). [1]

**Figure 2 (infra-red image)**

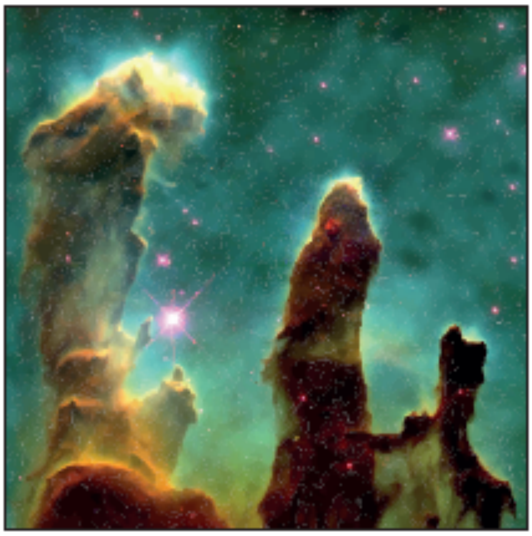


**Figure 3 (visible light image)**

*(d)* Explain, using Newton's $2^{nd}$ law, how electromagnetic radiation exerts pressure inside a main sequence star (see Paragraph 4). [3]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

*(e)* Explain why a more massive star has a higher density in its core and why this leads to a higher temperature (see Paragraph 4). [3]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

*(f)* (i) Show that the wavelength of maximum emission for the hottest main sequence stars is approximately 150 nm (see Paragraph 5 or Graph 1). [2]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

(ii) Discuss whether or not it is appropriate to analyse the hottest main sequence stars using visible light when their wavelength of maximum emission is 150 nm (see Paragraph 5). [2]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

*(g)* Determine whether or not the star of mass $0.2\,M_{\odot}$ is plotted at approximately the correct luminosity in Graph 1 (see Equations 1–4 and Graph 1). [2]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

*(h)* Explain why a $10\,M_{\odot}$ star has a lifetime that is 500 times shorter than that of the Sun, including any simplifying assumptions (see Paragraph 8 and Equations 1–5). [4]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

*(i)* Explain **briefly** what the author means when he states that a white dwarf's mass and radius are negatively correlated (see Paragraph 9). [1]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

4.

**4.** *(a)* Define a black body. [1]

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

*(b)* A physics student, Tony, notices that the classroom is warmer when it has a number of students in it rather than when it is empty. Tony claims that each student will behave like a perfect black body and will emit about the same amount of heat as a 200 W light bulb. Assuming a typical human body has a surface area of $2\,m^2$. Evaluate whether or not Tony appears to be correct. Normal body temperature can be taken to be 37 °C. [3]

..................................................................................................................................

..................................................................................................................................

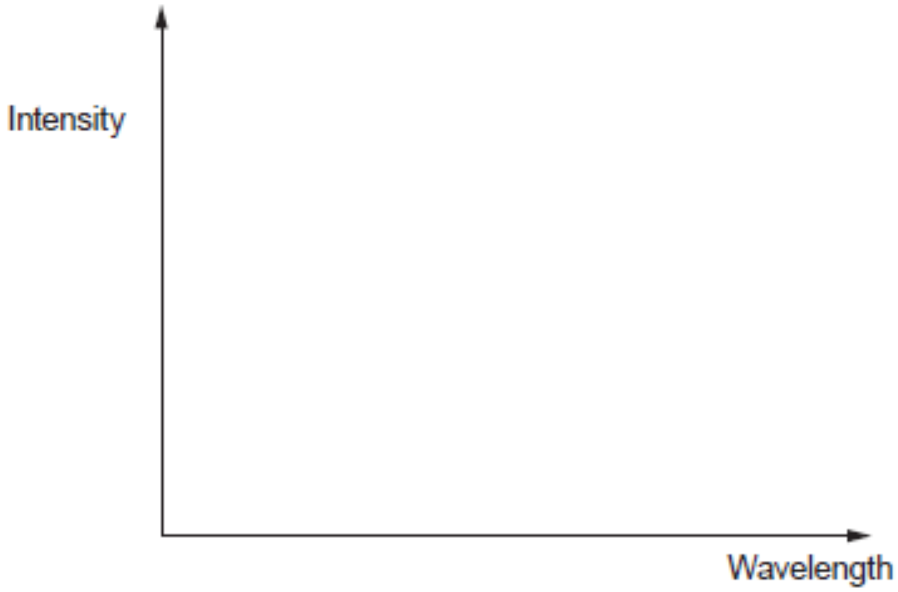
..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

*(c)* (i) Some stars appear to be coloured to the naked eye. For two stars of similar diameter one appears red and the other appears blue. Sketch and label typical black body spectra for each star on the graph below. [3]



(ii) Suggest why it is that no stars appear to be green in colour. [2]

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

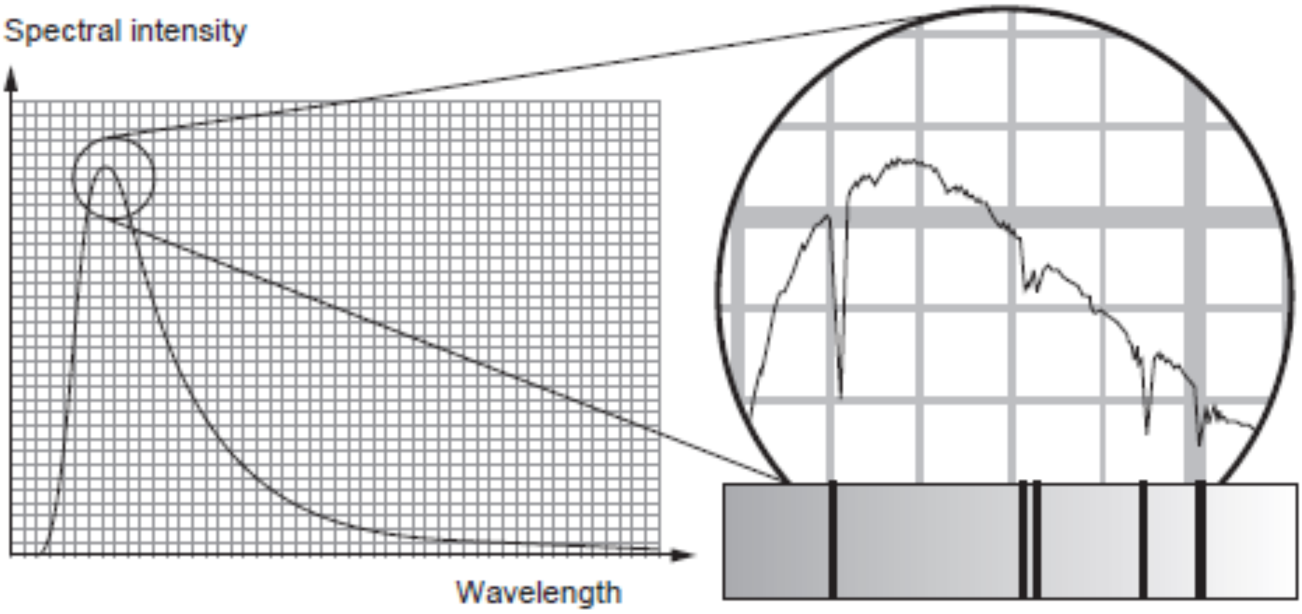
........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

5. **6.** *(a)* A blackbody graph of spectral intensity against wavelength for a star is shown. A magnified section, showing the finer detail of the spectrum is also given. An associated line spectrum is also shown.




Explain how the graph and the spectra can be used to provide information about the star and the elements from which it is made. [6 QER]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

(b) (i) Altair is the brightest star in the Aquila constellation. It is $1.58 \times 10^{17}$ m away, and the intensity of its electromagnetic radiation reaching the Earth is $1.32 \times 10^{-8}\,\mathrm{W\,m^{-2}}$. Show that its luminosity is approximately $4 \times 10^{27}$ W. [3]

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

(ii) Calculate Altair's **diameter** given that its surface temperature is 7 700 K. [3]

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

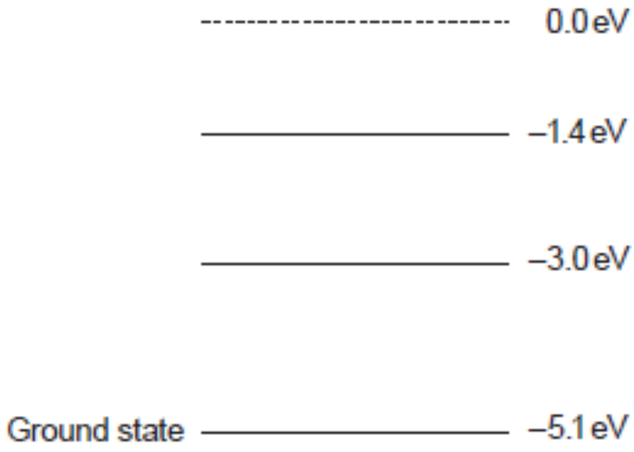
...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

6.

**6.** The diagram shows three energy levels of a sodium atom.




*(a)* State the ionisation energy of a sodium atom. [1]

..............................................................................................................................................

*(b)* White light passes through a cloud of sodium atoms. The light which emerges is found to have the continuous spectrum of white light but with dark lines crossing the spectrum. State briefly how the dark lines are caused and what happens to the atoms in the process. [3]

..............................................................................................................................................

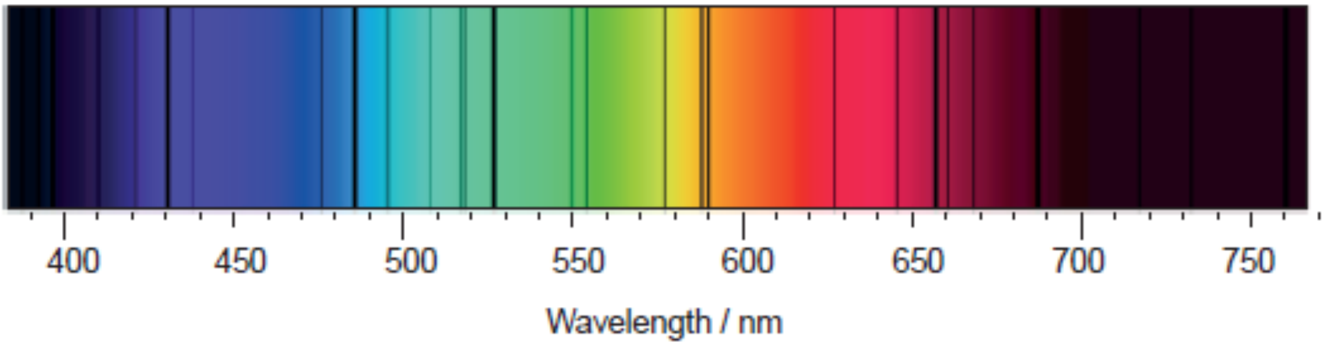
..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

*(c)* (i) The spectrum of a star is shown below. The wavelength of one of the dark lines is 590 nm. Evaluate whether this is evidence for the presence of sodium in the star. [3]




.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

(ii) The wavelength of peak emission of the star is 100 nm. Determine its surface temperature. [3]

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

7.

**7.** *(a)* Describe the main features of the spectrum of a star and state where in the star they arise. [2]

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

*(b)* The table gives some information about two stars.

| Star | Luminosity / W | Distance from Earth / m |
|---|---|---|
| Sirius | $9.7 \times 10^{27}$ | $8.1 \times 10^{16}$ |
| Vega | $1.5 \times 10^{28}$ | $2.4 \times 10^{17}$ |

(i) Determine the ratio:

$$\frac{\text{Intensity of radiation reaching Earth from Sirius}}{\text{Intensity of radiation reaching Earth from Vega}}$$ [3]

........................................................................................................................................................

........................................................................................................................................................

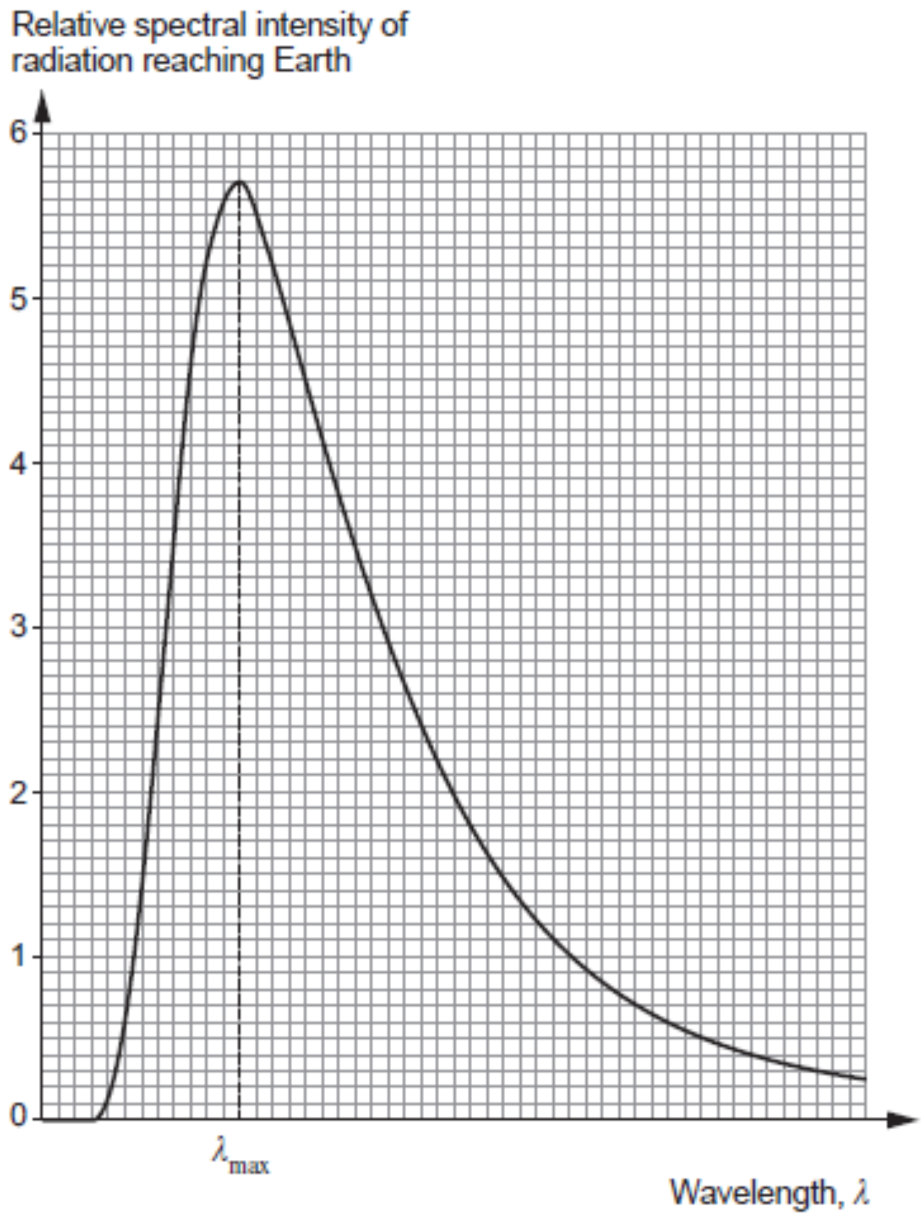
........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

........................................................................................................................................................

(ii) The two stars have similar surface temperatures. Below is a black body radiation curve for Sirius. Using your answer to *(b)*(i), sketch the expected black body curve for Vega on the same axes. [2]




(iii) Determine $\lambda_{max}$, given that the surface area of Sirius is $1.8 \times 10^{19}\,m^2$. [4]

..........................................................................................................................................................

..........................................................................................................................................................

..........................................................................................................................................................

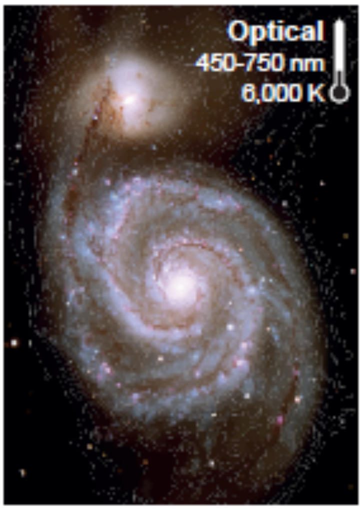
..........................................................................................................................................................

..........................................................................................................................................................

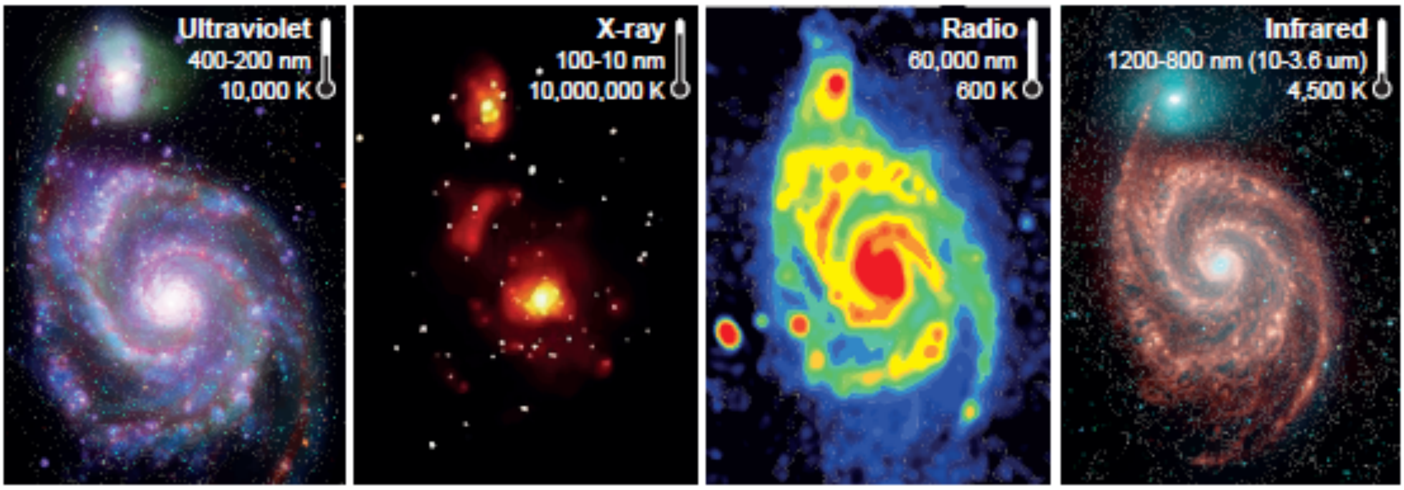
..........................................................................................................................................................

..........................................................................................................................................................

(c) The image below is of the whirlpool galaxy, M51 (or NGC 5194). This is one of the first galaxies to be photographed by astronomers.




Subsequent images of the **same galaxy** are shown below.




Describe how these developments in observational astronomy have advanced the study of the whirlpool galaxy. [3]

8.

**8.** *(a)* Diagram 1 shows how the intensity of electromagnetic radiation from the Sun varies with distance from its centre. Diagram 2 shows how the intensity of the radiation incident on the Earth from the Sun is distributed across the spectrum.

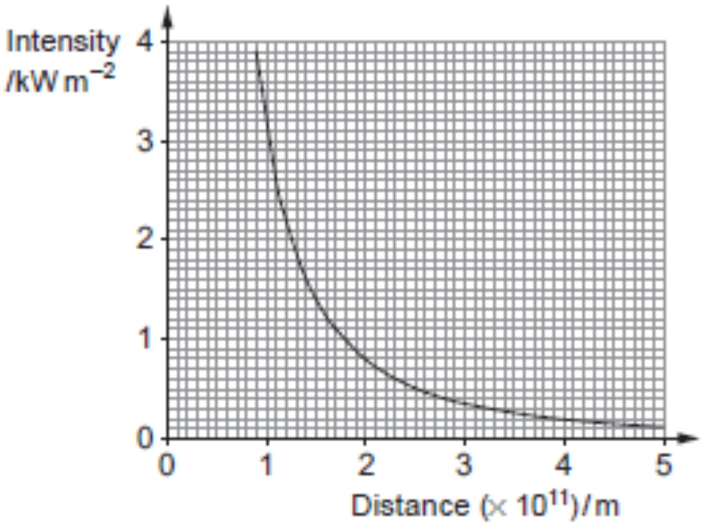



**Diagram 1**

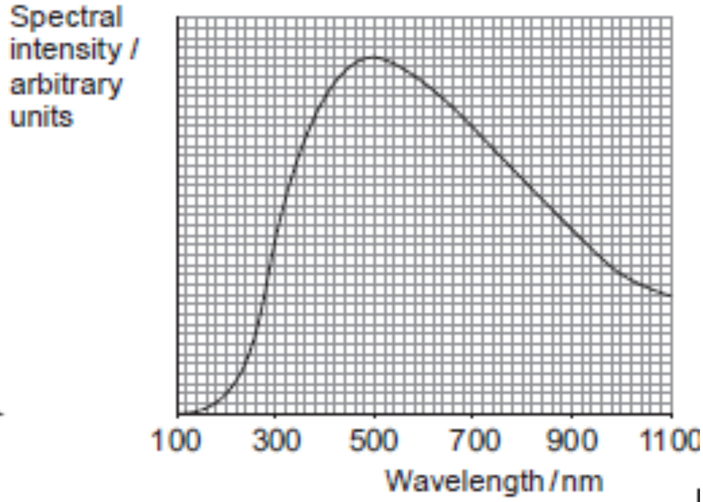



**Diagram 2**

(i) Confirm that Diagram 1 shows the expected relationship between intensity and distance. [3]

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

(ii) Use Diagram 1 to show that the Sun's luminosity is about $4 \times 10^{26}$ W. [2]

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

*(b)* In 2006 scientists from the University of Hawaii used a solar telescope aboard NASA's Solar and Heliospheric Observatory satellite to measure the radius of the Sun with (they quote) "unprecedented accuracy". They measured it to be:

$$R_{\text{sun}} = 696\,342\,\text{km}$$

Use information from Diagram 2 along with your answer to *(a)*(ii) to evaluate whether the information from Diagrams 1 and 2 are consistent with the scientists' findings. [5]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

*(c)* For centuries scientists have attempted to measure the Sun's diameter accurately. The following article is taken from a scientific paper written in 2004:

*The solar diameter, and its possible variation, have been the subject of careful measurements for over 350 years, with ever increasing accuracy. Different techniques have been used, and the instrumentation has evolved in time. However, the long-term evolution of the Sun is still a controversial subject. Even for the short term, the results are inconsistent even with the most advanced instruments presently in use. These discrepancies probably have several origins.*

*[Past, present and future measurements of the solar diameter: Gerard Thuillier, Sabatino Sofia, Margit Haberreiter November 2004]*

Suggest two reasons why it has been difficult for scientists to determine an accurate value for the Sun's diameter. [2]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

9.

*Neutron stars* are very small, dense 'dead' stars. Sometimes they can acquire an outer layer of 'active' material which becomes very hot and radiates as a *black body*. One such star has a **radius** of 11 km, and radiates at a temperature of $2.5 \times 10^7$ K.

*(a)* (i) Show that the wavelength of greatest spectral intensity is approximately $1 \times 10^{-10}$ m. [2]

..............................................................................................................................................

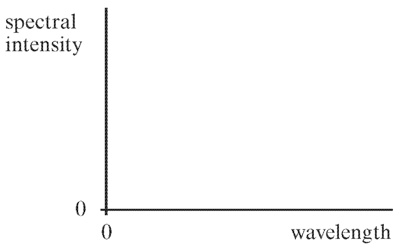
..............................................................................................................................................

..............................................................................................................................................

(ii) Name the region of the electromagnetic spectrum in which this wavelength lies. [1]

..............................................................................................................................................

(iii) Sketch a black body spectrum on the axes provided. [1]




(iv) Discuss briefly whether the star in question emits any **visible** radiation. [1]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

*(b)* Calculate the total *power* emitted as electromagnetic radiation by the star. [3]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

*(c)* The outer layer of the star expands rapidly and cools. The total power emitted remains roughly constant. Estimate the temperature of the outer layer when its **surface area** has doubled. [2]

..............................................................................................................................................

..............................................................................................................................................

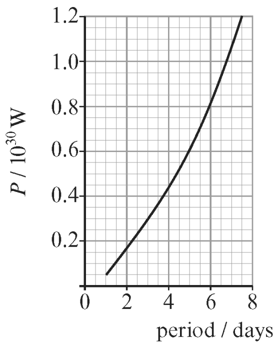
..............................................................................................................................................

..............................................................................................................................................

**10.**

*Cepheid variables* are stars whose brightness varies in a characteristic, regular way. The variation is shown below for one such star.


The mean power, $P$, emitted as electromagnetic radiation from a Cepheid variable is related to the period of its brightness variation, as shown alongside.




*(a)* (i) Use the graphs to determine $P$ for the star, showing briefly how you obtained your answer. [2]

...........................................................................................

...........................................................................................

...........................................................................................

...........................................................................................

(ii) The mean *intensity* of the radiation from the star, as measured at the Earth is $8.0 \times 10^{-13}\,\text{W m}^{-2}$. Using your answer to *(a)*(i), calculate the distance, $r$, between the star and the Earth. [2]

...........................................................................................

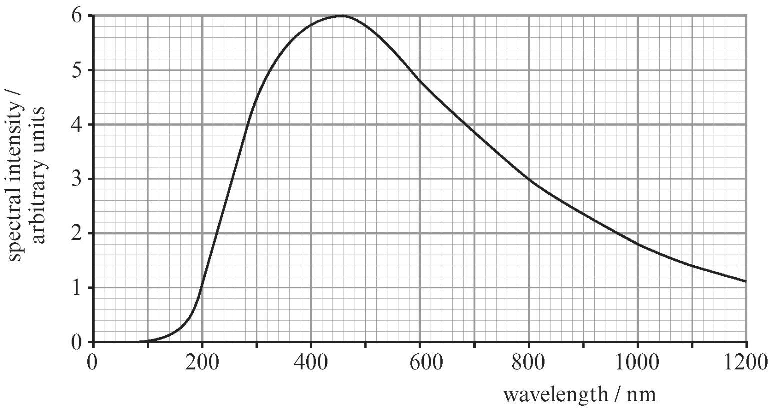
...........................................................................................

...........................................................................................

...........................................................................................

...........................................................................................

*(b)* The maximum power emitted by the star during its cycle of variation is estimated to be $9.5 \times 10^{29}$ W, and the spectrum of its radiation corresponding to this point in its cycle is given below.




(i) Use Wien's law to calculate the temperature of the star. [2]

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

(ii) Calculate the **diameter** of the star. [4]

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

11.

*(a)* (i) The spectrum of the star *Rigel* in the constellation *Orion* peaks at a wavelength of 260 nm. Calculate the temperature of the surface of Rigel. [2]

..........

..........

..........

..........

(ii) What assumption were you making about the way the star's surface radiates? [1]

..........

*(b)* To a good approximation the Kelvin temperature of Rigel's surface is twice that of the Sun, and the **radius** of Rigel is 70 times the radius of the Sun. Use *Stefan's Law* to estimate the ratio

$$\frac{\text{total power of electromagnetic radiation emitted by Rigel}}{\text{total power of electromagnetic radiation emitted by the Sun}}\,. \qquad [3]$$

..........

..........

..........

..........

..........

..........

..........

*(c)* We can discover the presence of particular atoms in the atmosphere of a star by measuring the wavelengths of dark lines in the star's spectrum.

Explain how the lines arise, and why they occur at specific wavelengths. [3]

..........

..........

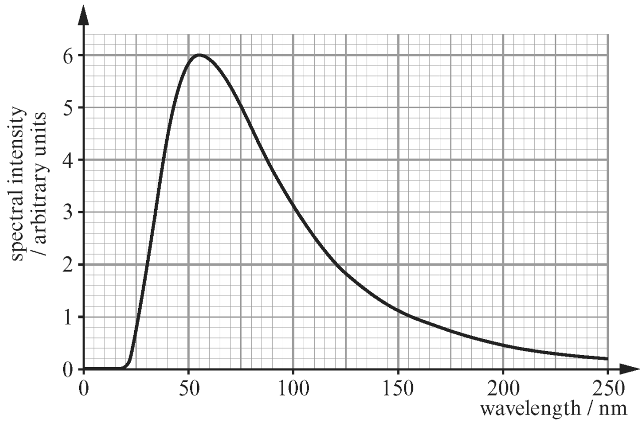
..........

..........

..........

12.

One of the hottest stars known is HD93129A in the Carina nebula. Its continuous spectrum is shown.




*(a)* (i) Name the region of the electromagnetic spectrum in which the wavelength of peak emission lies. [1]

..............................................................................................................................................

(ii) Show that the star's temperature is approximately 50 000 K. [2]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

(iii) The star is blue. Explain how this could be deduced from the spectrum. [1]

..............................................................................................................................................

..............................................................................................................................................

*(b)* (i) The star is $7.10 \times 10^{19}$ m away, and the intensity of its electromagnetic radiation reaching the Earth is $3.33 \times 10^{-8}$ W m$^{-2}$. Show that its luminosity is approximately $5 \times 10^{6} P_{sun}$, in which $P_{sun}$ is the Sun's luminosity ($3.84 \times 10^{26}$ W). [3]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

(ii) Use Stefan's law to calculate the star's **diameter.** [3]

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

13.

**7.** The star Sirius A has a surface temperature of 9900 K and a luminosity (total power output of electromagnetic radiation) of $1.00 \times 10^{28}$ W.

*(a)* (i) Calculate the star's wavelength of peak spectral intensity. [2]

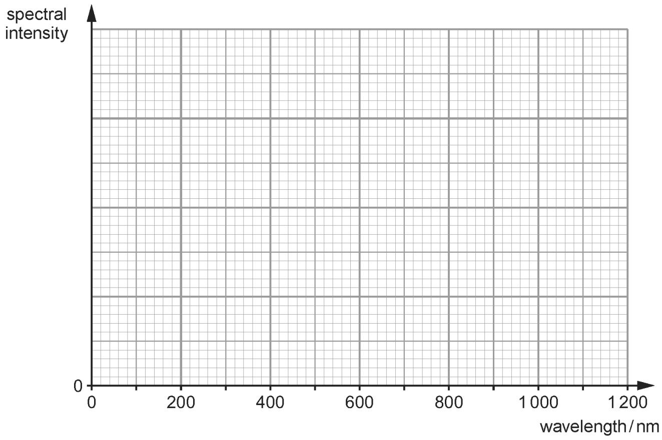
..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

(ii) Sketch on the axes a graph of spectral intensity against wavelength for the continuous spectrum of Sirius A. *(Note: make the peak spectral intensity three or four large squares above the wavelength axis.)* [2]




(iii) What colour would you expect Sirius A to be? [1]

..............................................................................................................................................

*(b)* Use Stefan's Law to calculate the diameter of Sirius A. [3]

..............................................................................................................................................

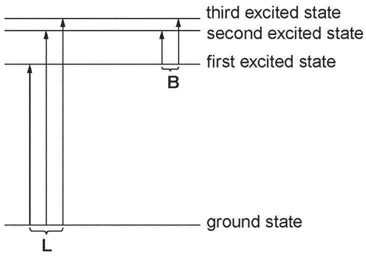
..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

*(c)* The diagram shows the lowest energy levels of a hydrogen atom, and five possible transitions between these levels.




(i) Name the process (involving photons) which is responsible for the transitions. [1]

.................................................................................................................................................

(ii) Briefly describe the observed feature of the spectrum of a star which this process explains. [1]

.................................................................................................................................................

.................................................................................................................................................

(iii) All the transitions shown in the diagram take place in the atmosphere of Sirius A. State which group of transitions, **L** or **B**, is almost completely absent in a much cooler star, giving a reason for your answer. [2]

.................................................................................................................................................

.................................................................................................................................................

.................................................................................................................................................

**14.** A website gives the following data for the star Aldebaran:

radius = 44.2 $R_\odot$  luminosity = 518 $L_\odot$

in which $R_\odot$ = radius of Sun = $6.96 \times 10^{8}$ m
and $L_\odot$ = luminosity of Sun = $3.85 \times 10^{26}$ W

(a) Use Stefan's law to calculate a value for the surface temperature of Aldebaran. [4]

..........

..........

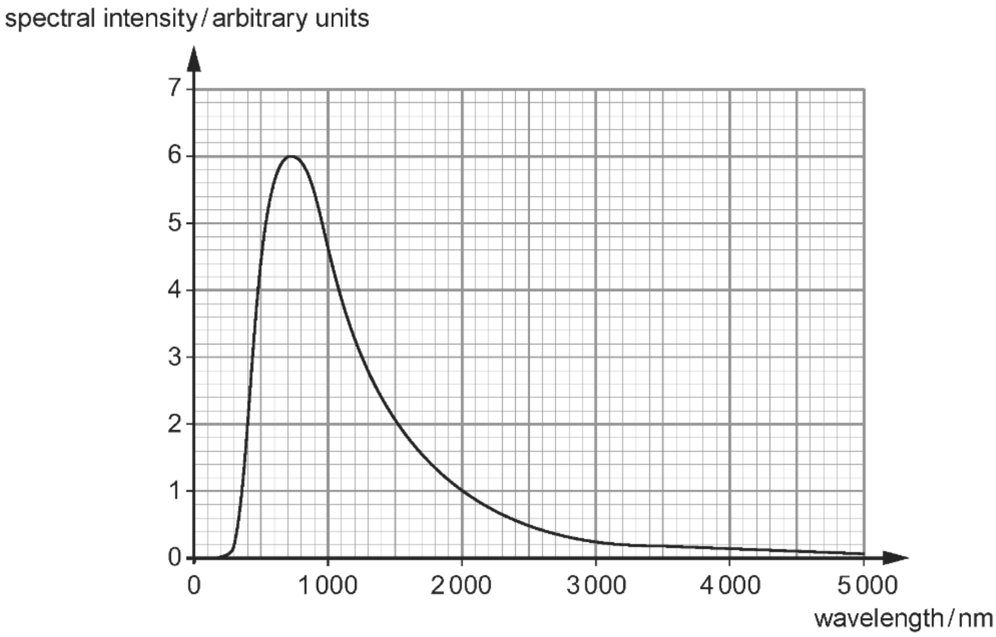
..........

..........

..........

..........

(b) The continuous spectrum of Aldebaran is given.




Determine a value for the temperature of Aldebaran without using Stefan's law giving your working. [2]

..........

..........

..........

*(c)* Agreement between the temperatures found in *(a)* and *(b)* would help to confirm that Aldebaran is emitting as a black body. What is a black body? [1]

..........................................................................................................................................................................

..........................................................................................................................................................................

..........................................................................................................................................................................

*(d)* Explain, using the data in this question, why 'red giant' is an appropriate description of Aldebaran. [2]

..........................................................................................................................................................................

..........................................................................................................................................................................

..........................................................................................................................................................................

..........................................................................................................................................................................

**15.**

*(a)* A table of astronomical data includes the following about the star *Alpha Centauri A*: Radius = $8.54 \times 10^{8}$ m, Temperature = 5790 K, Luminosity = $5.83 \times 10^{26}$ W.

(i) Investigate whether the data above is consistent with the star radiating as a black body. Show your working clearly, and give your conclusion. [3]

..........

..........

..........

..........

..........

(ii) The star is $4.1 \times 10^{16}$ m from the Earth. Calculate the intensity (energy per second per $m^2$) of electromagnetic radiation reaching the Earth from the star. [2]

..........

..........

..........

..........

..........

(iii) Calculate the wavelength of the star's peak spectral intensity, and sketch the spectrum on the axes provided. [4]

..........

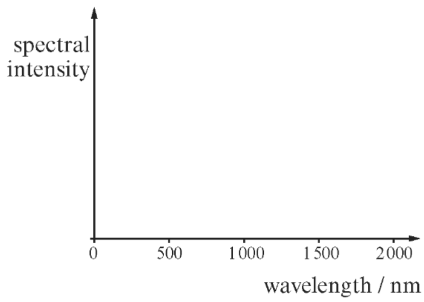
..........

..........

..........

..........

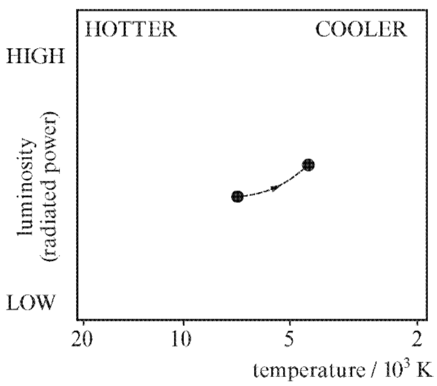
..........




*(b)* Astronomers assign to each star a position on a chart, according to the star's luminosity and temperature.

During one stage in the life of *Alpha Centauri A*, its position on the chart will move as shown by the dotted line.

Use Stefan's law to show clearly what happens to the *size* of the star during this stage. **[Numerical calculations are not needed.]** [2]




..........

..........

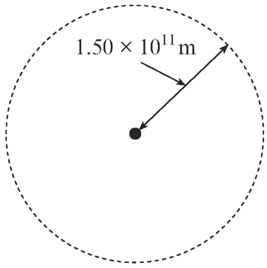
..........

..........

**16.**

*(a)* (i) The *intensity* of the Sun's electromagnetic radiation at a distance of $1.50 \times 10^{11}$ m from its centre is $1.36\,\mathrm{kW\,m^{-2}}$.

Show that the power the Sun emits is approximately $4 \times 10^{26}$ W. Give your answer to 3 significant figures. [2]




..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

(ii) $1.50 \times 10^{11}$ m is the radius of the Earth's orbit. Suggest why the intensity of radiation, as measured on the Earth's surface, is less than $1.36\,\mathrm{kW\,m^{-2}}$. [1]

..............................................................................................................................

*(b)* The temperature of the Sun's surface is 5780 K.

(i) Use Stefan's Law to calculate the *surface area* of the Sun. [2]

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

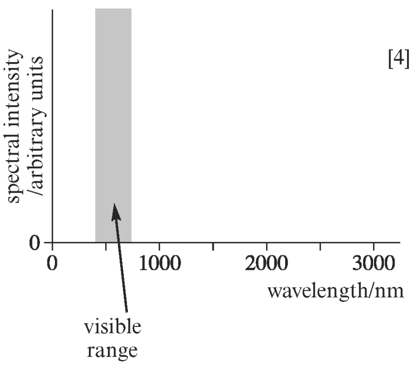
(ii) The Sun's ***diameter*** is measured, by optical methods, to be $1.4 \times 10^{9}$ m. Show clearly whether or not your answer to *(b)*(i) is consistent with this. [2]

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

*(c)* A biologist claims that our eyes are sensitive to the region of the Sun's spectrum of greatest intensity. Use Wien's law to support this claim, and sketch the Sun's spectrum on the axes provided. [4]




..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................