PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 9: THERMODYNAMICS

BLACKBODY RADIATION

SCORE	PERCENTAGE
/115	%

STEMUP

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Q1.

Betelgeuse is our greatest red giant. It has a luminosity of 4.49×10^{31} W and emits radiation with a peak energy emission occuring at 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.

$$r_s = 6.95 \times 10^8 \text{ m}$$

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r_B/r_s, = ...

(Total for question = 5 marks)

Q2.

The light emitted from a star is due to the energy released by fusion reactions taking place in the core of the star. Our Sun is a main sequence star with a luminosity of 3.85×10^{26} W.

An analysis of the Sun's spectrum gives $\lambda_{max} = 502$ nm

Use the data provided to calculate the radius of the Sun.

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Radius of the Sun = ...

(Total for question = 4 marks)

Q3.

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)

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Q4.

The photograph shows a filament bulb.



The filament is an emitter with 35% of the power output of a black body radiator of the same temperature.

In an experiment to investigate the efficiency of a filament light bulb a p.d. was applied. The p.d. and current were measured and the light bulb was observed. The p.d. was then increased and new measurements taken.

When a small p.d. is applied to the bulb, no light is visible. If the p.d. is gradually increased, the filament starts to glow and eventually appears white.

(i) Add to the graph to show the distribution of radiation from a black body at a temperature of 2026 K.

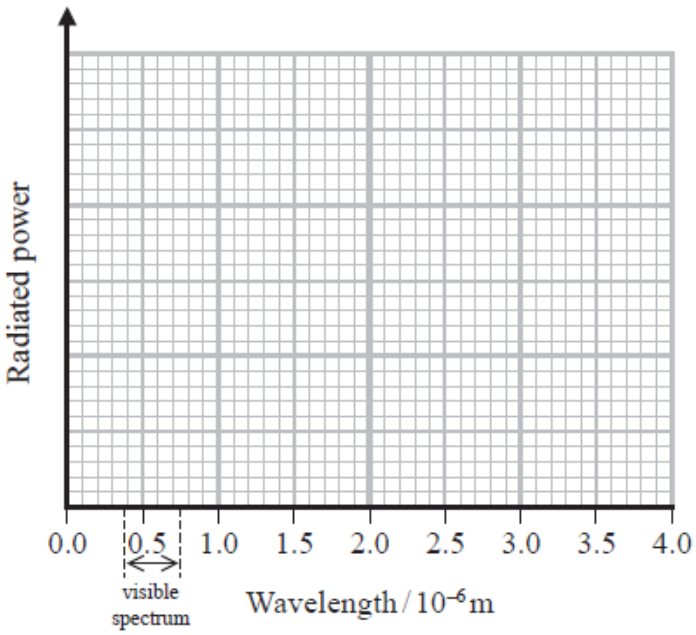
Your answer should include a calculation.

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(ii) Use your graph to explain why filament light bulbs are considered inefficient.

(2)

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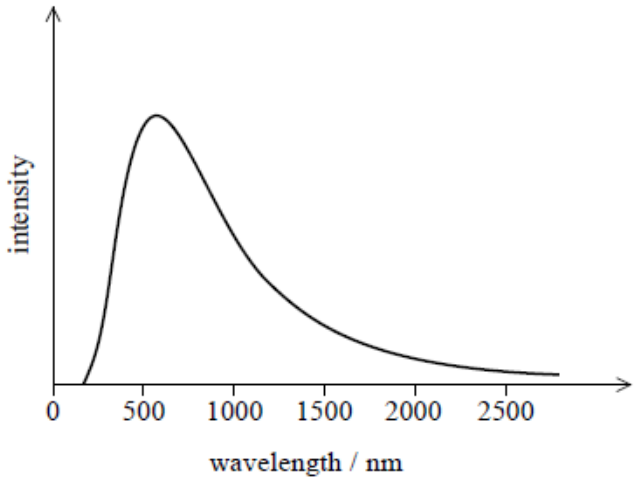
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(Total for question = 7 marks)

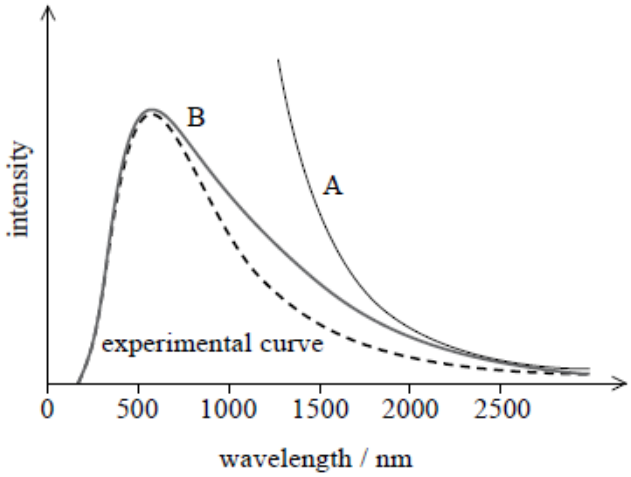
Q5.

The diagram shows the radiation curve for a black body radiator. The diagram was obtained from experimental data.



Experimental curve

In the late 19th century, scientists struggled to explain this experimental curve. One model used ideas of classical physics and produced curve A. Another model incorporated the idea of energy quantisation in the mechanism of energy emission and produced curve B. Both curve A and curve B are shown below, with the experimental curve for comparison.



(i) Explain how energy quantisation applies to the emission of radiation of energy from a black body radiator.

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(ii) Assess the extent to which each model is successful at explaining the experimental curve.

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(Total for question = 6 marks)

Q6.

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)

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

(2)

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

Describe how astronomers could determine the luminosity of a star.

(2)

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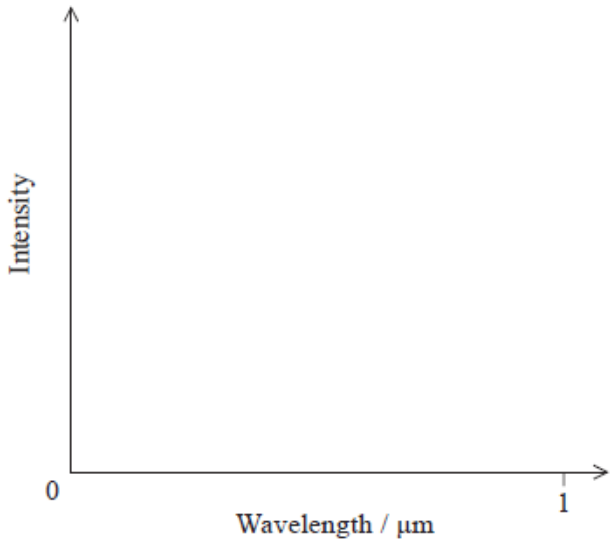
(Total for Question = 5 marks)

Q7.

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.

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

(2)



Q8. α-Centauri is one of the nearest stars to our Sun. The surface temperatures of these two stars are about the same. α-Centauri has a 20% greater diameter than the Sun.

The ratio of the luminosity of α-Centauri to the luminosity of the Sun is about

☒ **A** 1.2

☒ **B** 1.4

☒ **C** 1.7

☒ **D** 2.1

(Total for Question = 1 mark)

Q1.

Star A has twice the radius of star B but only half the surface temperature.

The ratio of the luminosity of star A to luminosity of star B is

☒ **A** 1:4

☒ **B** 1:2

☒ **C** 2:1

☒ **D** 4:1

(Total for question = 1 mark)

Q2.

Betelgeuse is our greatest red giant. It has a luminosity of 4.49×10^{31} W and emits radiation with a peak energy emission occuring at 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.

$$r_s = 6.95 \times 10^8 \text{ m}$$

(5)

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r_B/r_s, = ...

(Total for question = 5 marks)

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Use the data provided to calculate the radius of the Sun.

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Radius of the Sun = ...

(Total for question = 4 marks)

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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)

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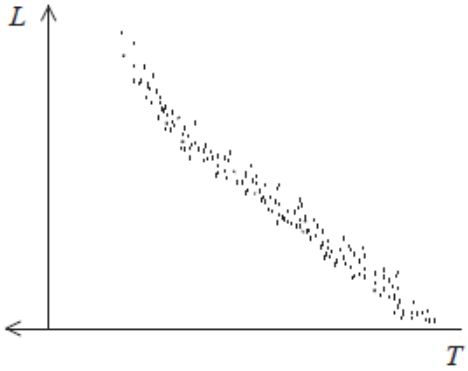
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Q5.

A Hertzsprung-Russell (HR) diagram shows how the luminosity *L* depends on the surface temperature *T* for a group of stars.

The HR diagram below is for a young star cluster.



(i) Explain how we can tell that the young star cluster is in the early stages of its evolution.

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(ii) Explain why the most massive stars in the cluster have the greatest luminosities.

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(Total for question = 6 marks)

Q6.

Solar panels consisting of combinations of photovoltaic cells use energy in the radiation received from the Sun to generate electricity.

An advertisement for solar panels claims that the intensity of radiation from the Sun incident at the top of the Earth's atmosphere is more than $2\,\text{kW}\,\text{m}^{-2}$.

Assess the validity of this claim.

radius of Sun = $6.96 \times 10^{8}\,\text{m}$

surface temperature of Sun = $5790\,\text{K}$

distance from Sun to Earth = $1.50 \times 10^{11}\,\text{m}$

(4)

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(Total for question = 4 marks)

Q7.

In 2016 the Breakthrough Starshot initiative was announced. This project intends to send a fleet of small probes to Proxima Centauri, the nearest star to the Sun. This journey would take about twenty years.

The radiation intensity at Earth from Proxima Centauri is 3.25×10^{-11} W m^{-2}. The luminosity of the Sun is $L_\odot$.

(i) Show that the luminosity of Proxima Centauri is about 0.002 $L_\odot$.

(3)

distance to Proxima Centauri = 4.00×10^{16} m
$L_\odot = 3.85 \times 10^{26}$ W

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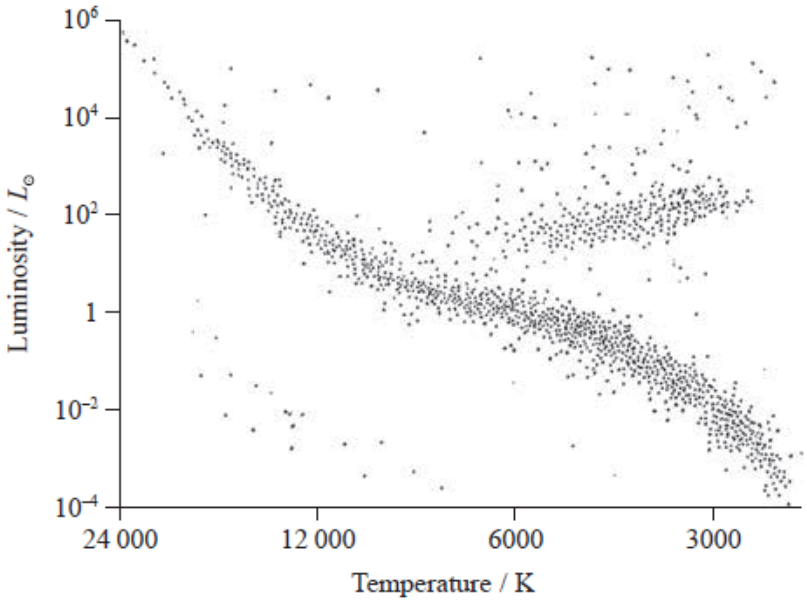
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(ii) Proxima Centauri is described on a website as a main sequence star.

Determine whether the surface temperature of Proxima Centauri is consistent with a position on the main sequence of the Hertzsprung-Russell diagram.

(3)

radius of Proxima Centauri = 9.81×10^7 m



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(Total for question = 3 marks)

Q8.

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.

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

(1)

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

(2)

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

Describe how astronomers could determine the luminosity of a star.

(2)

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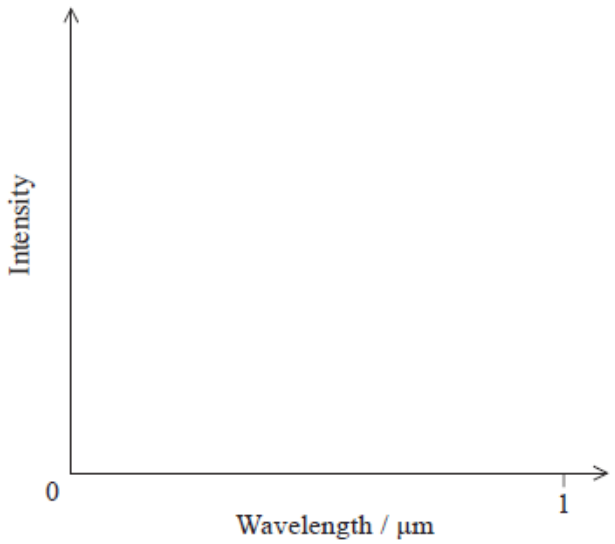
(Total for Question = 5 marks)

Q9.

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.

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

(2)



Q10. α-Centauri is one of the nearest stars to our Sun. The surface temperatures of these two stars are about the same. α-Centauri has a 20% greater diameter than the Sun.

The ratio of the luminosity of α-Centauri to the luminosity of the Sun is about

☒ **A** 1.2

☒ **B** 1.4

☒ **C** 1.7

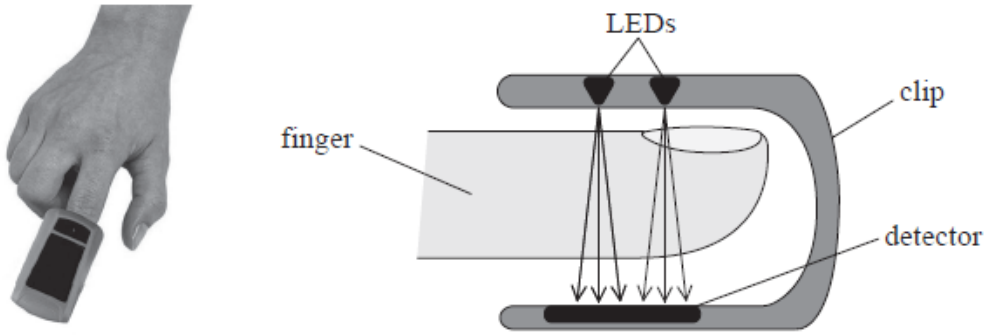
☒ **D** 2.1

(Total for Question = 1 mark)

Q1.

An oximeter is a device used in hospitals to monitor the oxygen level in a patient's blood.

In an oximeter, two light-emitting diodes (LEDs) are mounted opposite light sensors in a clip and attached to the patient's finger. One of the LEDs produces red light and the other produces infrared.



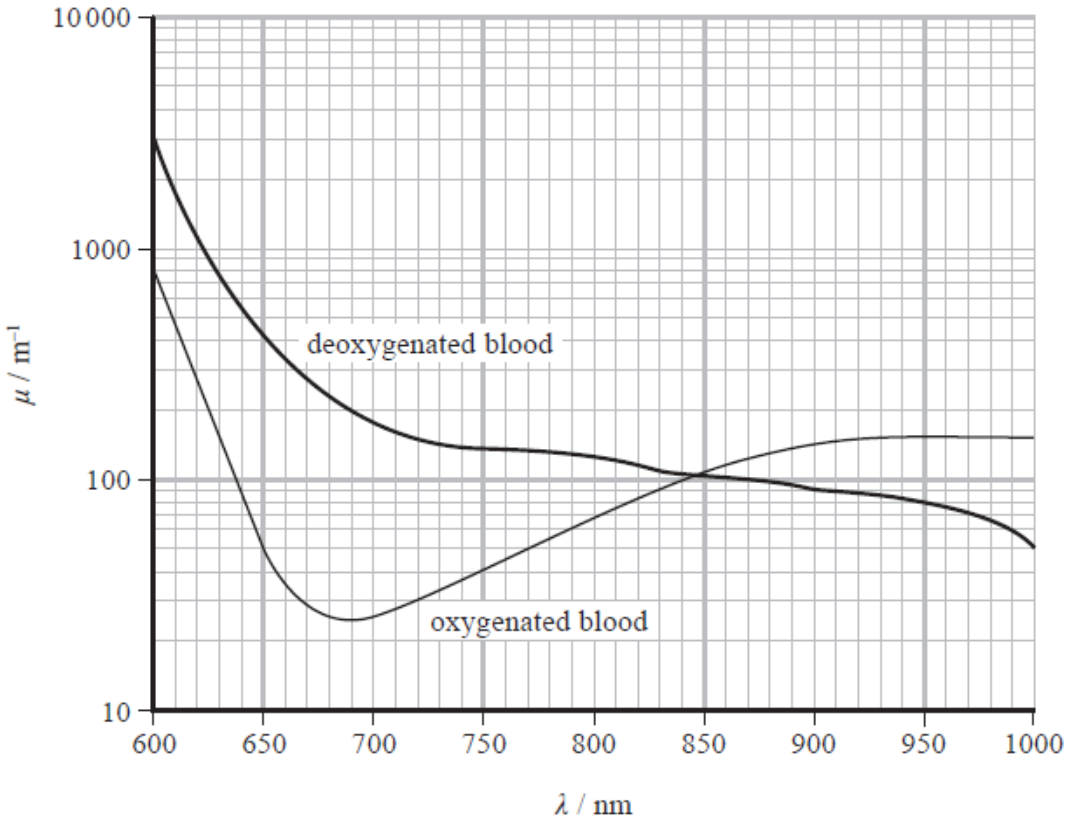
The intensity I of electromagnetic radiation received by the detector, after passing through a thickness x of blood, is given by

$$I = I_0^{e-\mu x}$$

where I_0 is the intensity that would have been received if the blood were not present and μ is the attenuation coefficient of blood.

The red LED emits visible light of wavelength 650 nm and the infrared LED emits infrared of wavelength 950 nm.

The graph shows how μ varies with wavelength λ for oxygenated blood and deoxygenated blood.



It is suggested that ambient light could affect the readings produced by the oximeter.

Halogen lamps have a filament temperature of 3200 K.

Deduce whether the light from such a lamp would have a significant effect on the oximeter readings.

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(Total for question = 3 marks)

Q2.

If the surface temperature of the Sun were to double, the rate at which energy from the Sun is received on the Earth would increase by a factor of

- ☒ **A** 2
- ☒ **B** 4
- ☒ **C** 8
- ☒ **D** 16

(Total for question = 1 mark)

Q3.

Betelgeuse is our greatest red giant. It has a luminosity of 4.49×10^{31} W and emits radiation with a peak energy emission occuring at 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.

$$r_s = 6.95 \times 10^8 \text{ m}$$

(5)

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r_B/r_s, = ...

(Total for question = 5 marks)

Q4.

The photograph shows a filament bulb.



The filament is an emitter with 35% of the power output of a black body radiator of the same temperature.

In an experiment to investigate the efficiency of a filament light bulb a p.d. was applied. The p.d. and current were measured and the light bulb was observed. The p.d. was then increased and new measurements taken.

When a small p.d. is applied to the bulb, no light is visible. If the p.d. is gradually increased, the filament starts to glow and eventually appears white.

(i) Add to the graph to show the distribution of radiation from a black body at a temperature of 2026 K.

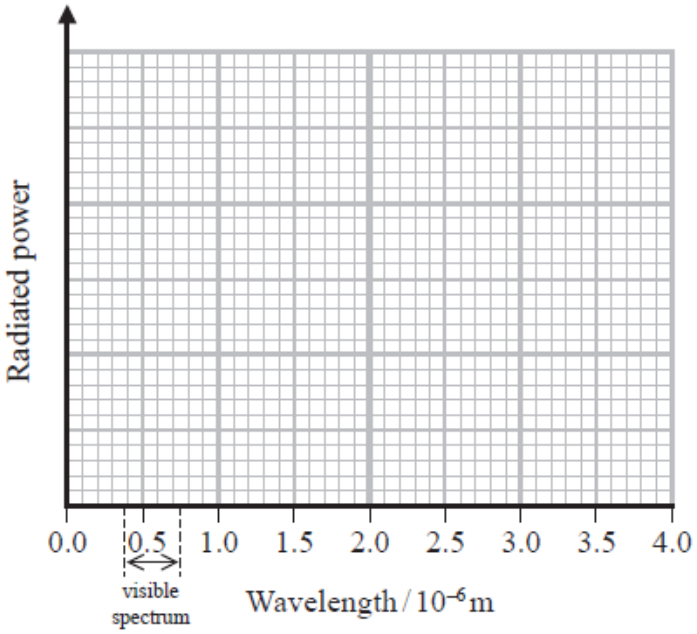
Your answer should include a calculation.

(5)

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(ii) Use your graph to explain why filament light bulbs are considered inefficient.

(2)

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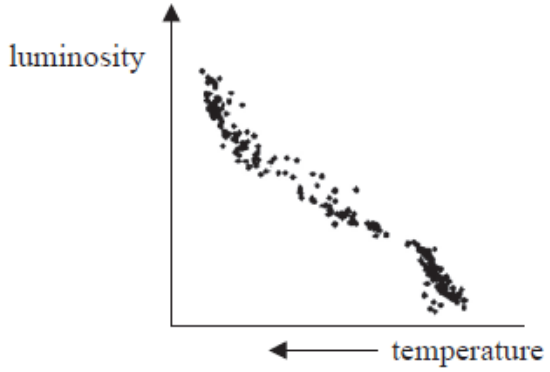
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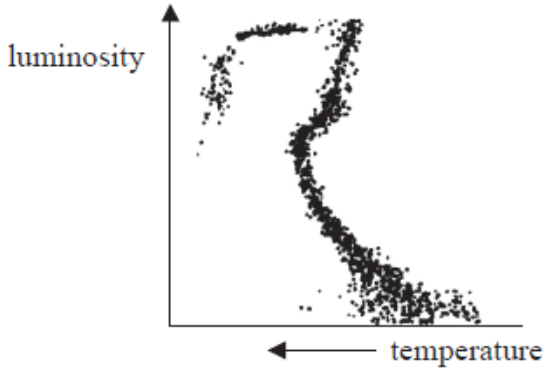
Q5.

(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.

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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)

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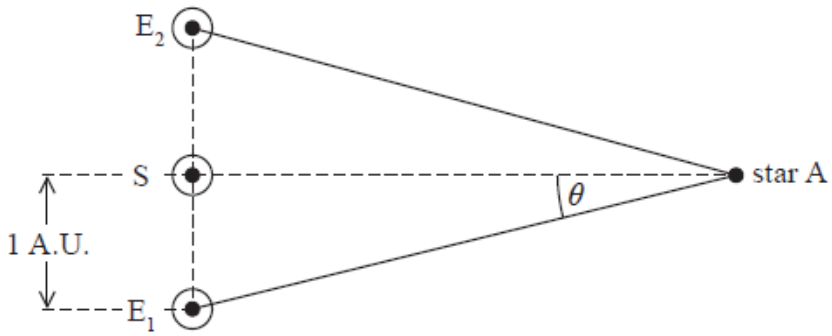
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(ii) The diagram shows the parallax angle for star A.

Calculate the distance of star A from the Earth.

1 A.U. is 1.50×10^{11} m

(2)



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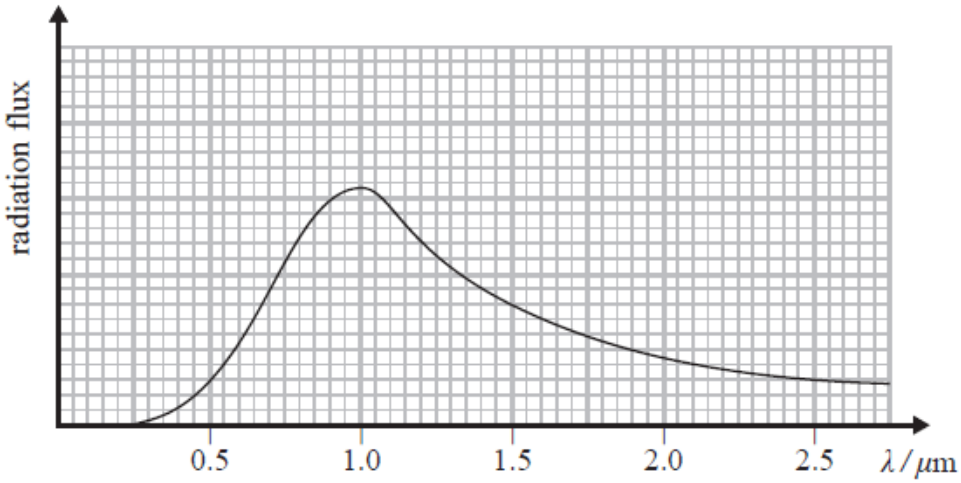
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Distance = ...

(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.

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Temperature = ...

(Total for question = 12 marks)

Q6.

A black body radiator has a temperature of 300°C.

What is the wavelength corresponding to the peak intensity of the emitted radiation?

☒ **A** 5.1×10^{-6} m

☒ **B** 9.7×10^{-5} m

☒ **C** 1.7×10^{0} m

☒ **D** 2.0×10^{5} m

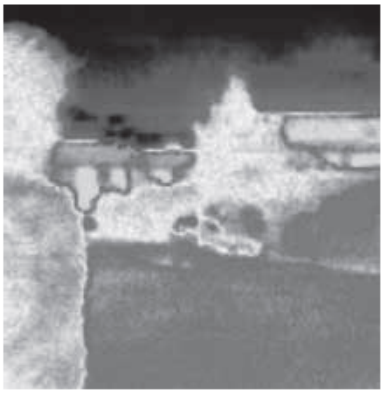
(Total for question = 1 mark)

Q7.

Infrared cameras are used to create images that show the infrared radiation emitted by objects.

The photographs show the same scene taken first with an ordinary camera and then with an infrared camera.





Deduce whether the objects shown in the photographs would be expected to have peak emissions at infrared wavelengths. Your answer should include a calculation.

(4)

longest wavelength of visible red light ≈ 700 nm

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(Total for question = 4 marks)

Q8.

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.

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

(1)

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Describe how astronomers could determine the luminosity of a star.

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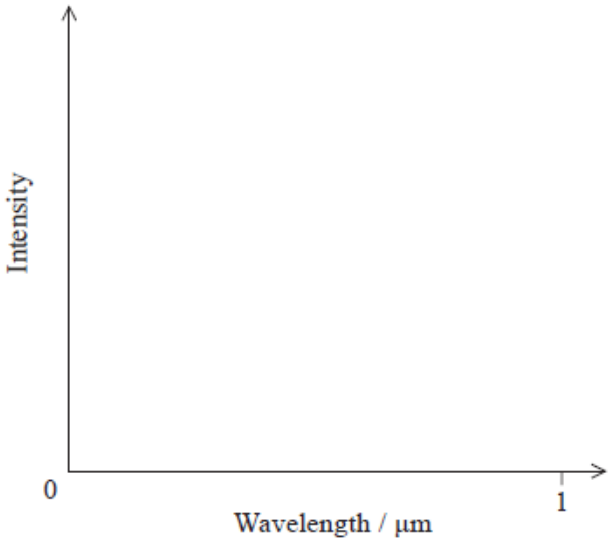
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Q9.

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

(2)



Q10.

One of the largest stars in our galaxy is VY Canis Majoris. This star's radius is 1420 times the radius of the Sun. The luminosity of this star is 270 000 times the luminosity of the Sun.

A student states that the surface temperature of VY Canis Majoris must be much greater than the surface temperature of the Sun.

(a) Determine whether the student's statement is correct.

surface temperature of Sun = 5780 K
luminosity of Sun = 3.85×10^{26} W
radius of Sun = 6.96×10^{8} m

(3)

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(b) Calculate the wavelength with maximum intensity in the black body radiation spectrum of VY Canis Majoris.

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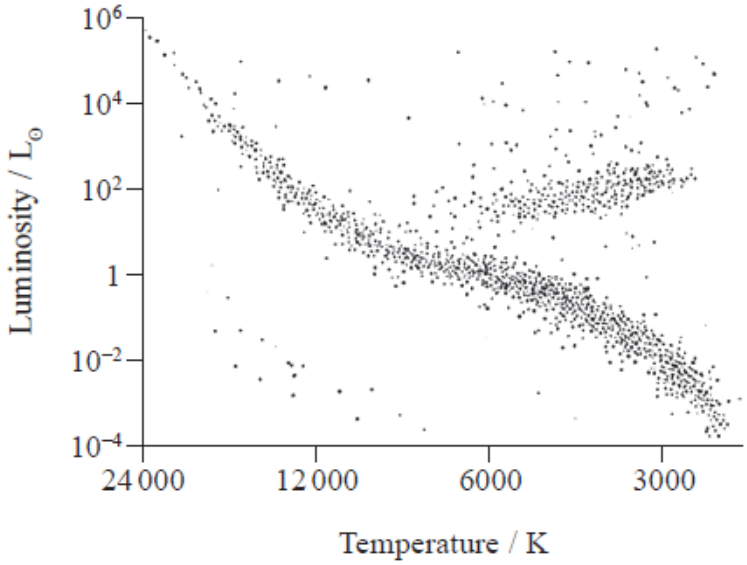
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Wavelength = ...

(c) Add the position of VY Canis Majoris to the Hertzsprung Russell diagram to determine which type of star it is.

(2)



Type of star .....

(Total for question = 7 marks)