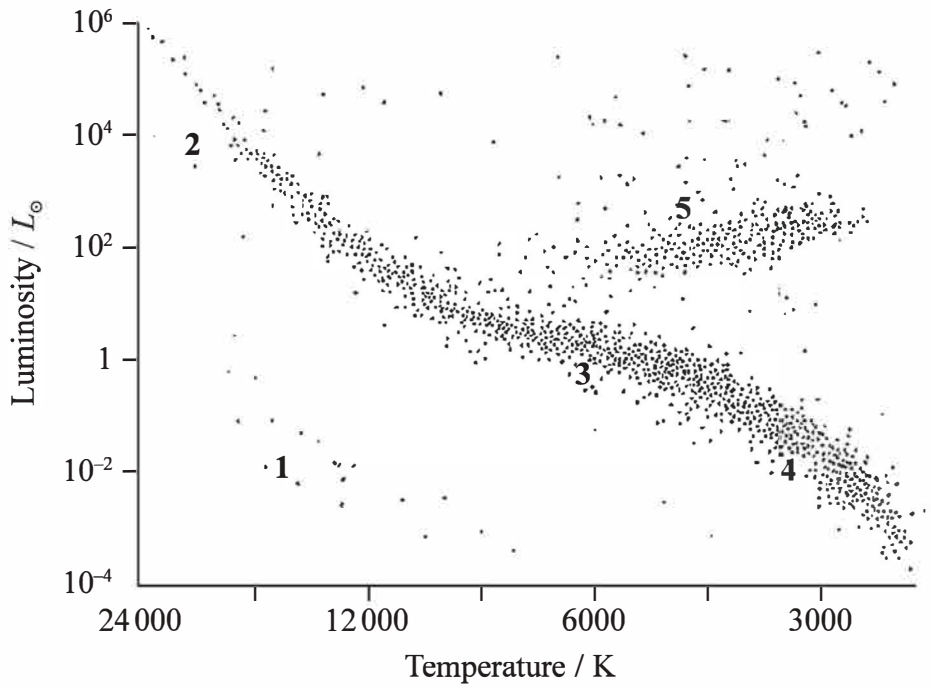
Answer ALL questions.

All multiple choice questions must be answered with a cross ☒ in the box for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Five regions are labelled on the Hertzsprung-Russell diagram shown.



Which sequence could show part of the evolution of a star like the Sun?

☒ **A** 1→5→3

☒ **B** 2→3→4

☒ **C** 3→5→1

☒ **D** 4→3→2

(Total for Question 1 = 1 mark)

7 A star of diameter D and surface temperature T has luminosity L.

What is the luminosity of a star of diameter $\frac{D}{2}$ and surface temperature $2T$?

- ☒ **A** $\frac{L}{4}$
- ☒ **B** L
- ☒ **C** $4L$
- ☒ **D** $16L$

(Total for Question 7 = 1 mark)

8 An object of volume V made from a material of density ρ_1 is placed into a fluid of density ρ_2.

Which of the following gives the upthrust on the object?

- ☒ **A** $\rho_1 Vg$
- ☒ **B** $\rho_2 Vg$
- ☒ **C** $(\rho_2 - \rho_1)\, Vg$
- ☒ **D** $\frac{(\rho_2 + \rho_1)}{2} Vg$

(Total for Question 8 = 1 mark)

9 Electric and gravitational fields have a number of similarities and differences.

An electric field is produced by a point charge and a gravitational field is produced by a point mass.

Which of the following statements applies to both of these fields?

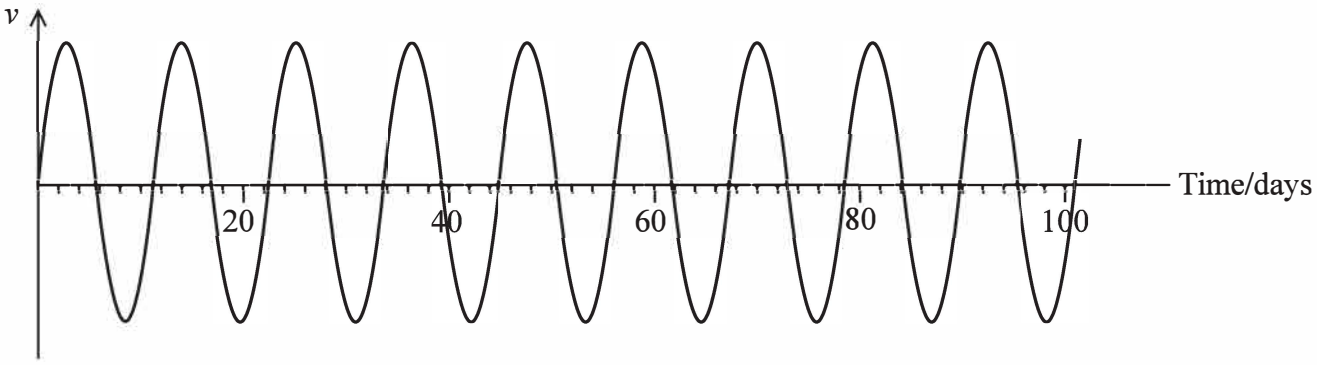
- ☒ **A** The field causes a force on all particles.
- ☒ **B** The force caused by the field can be attractive or repulsive.
- ☒ **C** At a distance x from the centre of the field, field strength is proportional to x^2.
- ☒ **D** At a distance x from the centre of the field, potential is proportional to $1/x$.

(Total for Question 9 = 1 mark)

14 In 2016 astronomers announced the discovery of an Earth-like planet orbiting Proxima Centauri, the closest star to the Sun.

The planet was detected because of the small movement of the star as the planet orbited. The movement was detected using the Doppler shift in the frequency of light travelling to the Earth.

The graph shows how the component of the star's velocity v towards the Earth varied over time.



(a) Explain how the Doppler shift was used to obtain the data shown on the graph.

(4)

(b) (i) Use the graph to show that the angular velocity of the planet is about 6×10^{-6} radian s^{-1}.

(3)

(ii) The mass of Proxima Centauri is 0.12 times the mass of the Sun.

Determine the distance of the planet from Proxima Centauri.

mass of Sun = 1.99×10^{30} kg

(3)

Distance = ...

(Total for Question 14 = 10 marks)

3 When a force F is applied to a spring with stiffness k, the elastic potential energy stored is E.

What is the elastic potential energy stored when a force $2F$ is applied to a spring with stiffness $2k$?

☒ **A** $\frac{E}{2}$

☒ **B** E

☒ **C** $2E$

☒ **D** $8E$

(Total for Question 3 = 1 mark)

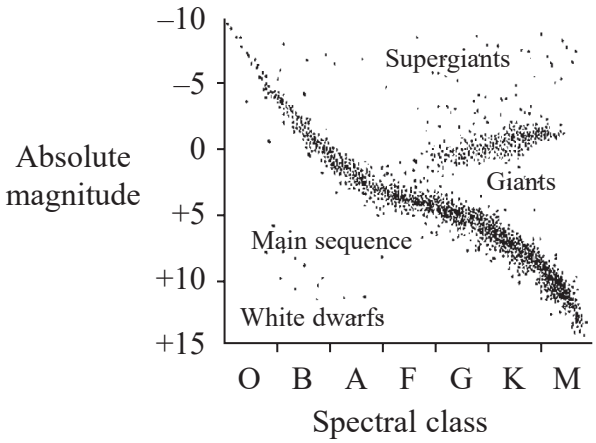
4 There are several different methods that can be used to determine the distance from our solar system to astronomical objects. These include the measurement of red shift, trigonometrical parallax and the use of standard candles.

Which row of the table shows a suitable method for each of the objects named?

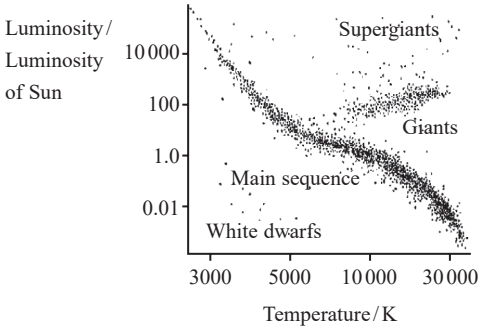
	Nearby star	Nearby galaxy	Very distant galaxy
☒ **A**	parallax	red shift	standard candle
☒ **B**	red shift	standard candle	parallax
☒ **C**	parallax	standard candle	red shift
☒ **D**	red shift	parallax	standard candle

(Total for Question 4 = 1 mark)

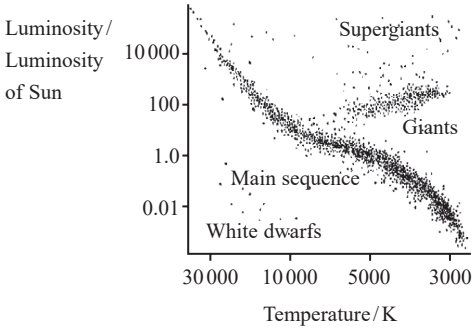
9 A student finds a Hertzsprung-Russell diagram in an old astronomy book and notices that the axes aren't the same as in her current textbook.



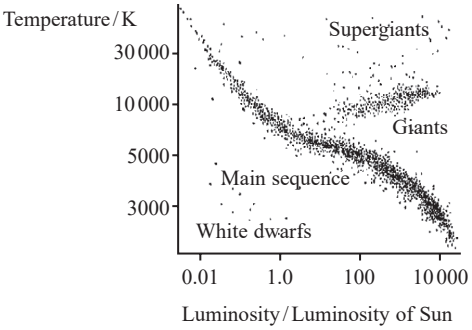
Which of the following graphs shows a correct alternative way to label the axes?



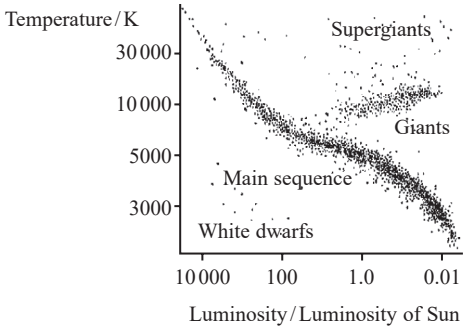
A



B



C

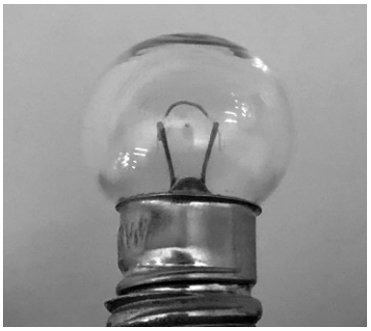


D

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 9 = 1 mark)

14 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.

(a) When a potential difference (p.d) of 2.0 V is applied across the bulb, there is a current of 0.37 A in the filament.

Calculate the temperature of the filament.

surface area of filament = $3.9 \times 10^{-6}\,m^2$

(3)

Temperature = ...

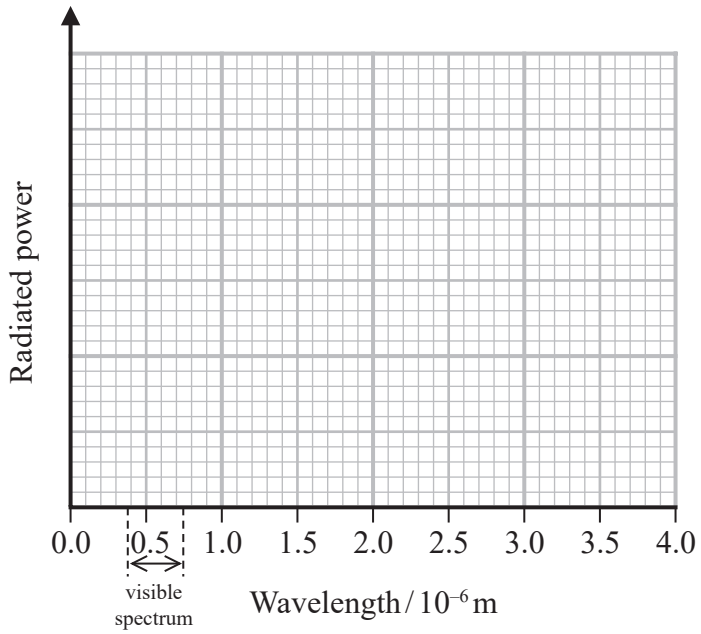
(b) In an experiment to investigate the efficiency of a filament light bulb a p.d. was applied. The p.d. and current were measured and the light bulb was observed. The p.d. was then increased and new measurements taken.

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)



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

(2)

(Total for Question 14 = 10 marks)

***13** The energy radiated by stars is released by nuclear fusion.

Explain the conditions required to bring about and maintain nuclear fusion in stars.

(Total for Question 13 = 6 marks)

15 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)

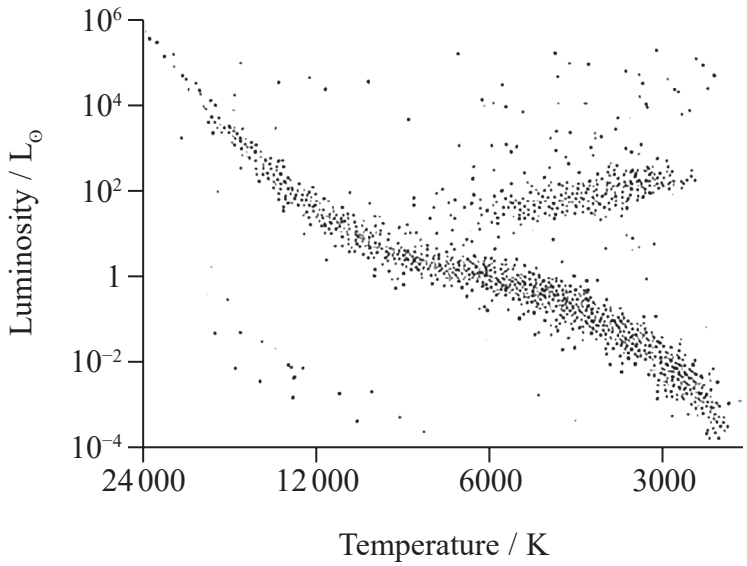
(b) Calculate the wavelength with maximum intensity in the black body radiation spectrum of VY Canis Majoris.

(2)

Wavelength = ...

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

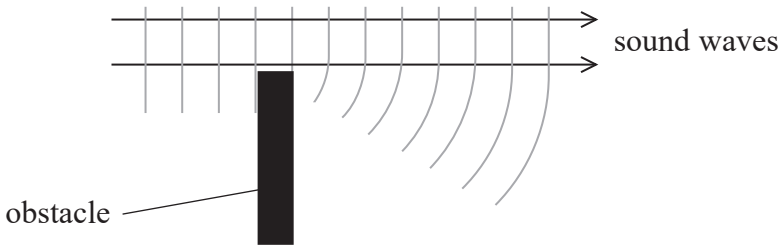
(2)



Type of star .....

(Total for Question 15 = 7 marks)

3 Sound waves can diffract around obstacles as shown in the diagram.



The diffraction effect is

- ☒ **A** greater for large amplitude sound waves.
- ☒ **B** greater for low frequency sound waves.
- ☒ **C** independent of the frequency of the sound waves.
- ☒ **D** independent of the speed of the sound waves.

(Total for Question 3 = 1 mark)

4 Which of the following is a valid unit for luminosity?

- ☒ **A** $\mathrm{W\,m^{-2}}$
- ☒ **B** $\mathrm{N\,m\,s^{-2}}$
- ☒ **C** $\mathrm{J\,s^{-1}}$
- ☒ **D** $\mathrm{J\,m^{-2}}$

(Total for Question 4 = 1 mark)

5 Betelgeuse is a red giant star.

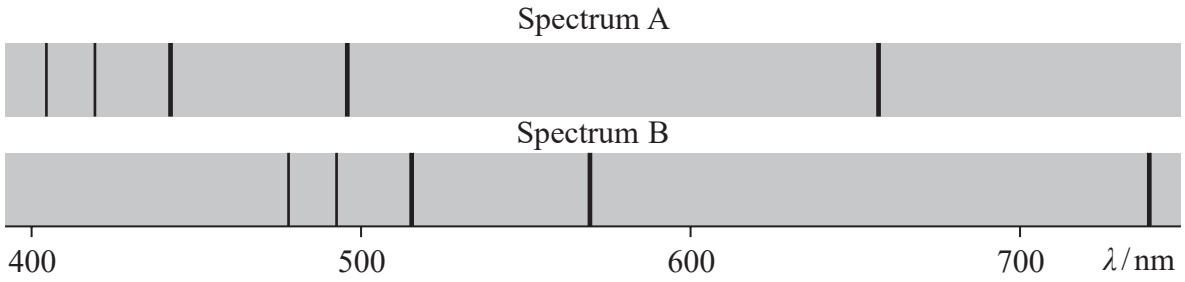
The surface temperature of Betelgeuse is T_B and the surface area of Betelgeuse is A_B.
The surface temperature of the Sun is T_S and the surface area of the Sun is A_S.

Which row in the table shows a correct comparison of the surface temperature and surface area of Betelgeuse with those of the Sun?

	$T_B > T_S$	$A_B > A_S$
☒ **A**	false	false
☒ **B**	false	true
☒ **C**	true	false
☒ **D**	true	true

(Total for Question 5 = 1 mark)

14 The diagram shows the spectra produced by two stars. Spectrum A is produced from the light from the Sun and spectrum B is produced from the light from a distant star.



The dark lines are produced when light from the core of the star is absorbed by hydrogen atoms in the outer regions of the star. Light is then re-radiated, but in all directions, giving rise to the dark lines in the spectrum.

(a) Explain why the long wavelength lines are shifted by a greater amount than the short wavelength lines.

(2)

(b) One of the lines in the hydrogen spectrum occurs at a wavelength of 656 nm in the laboratory.

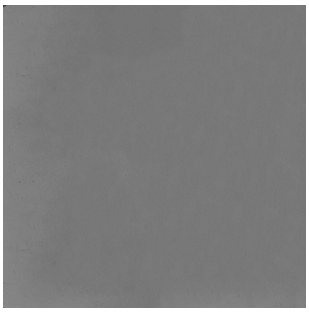
Explain what conclusion can be made from the shift in wavelength of this line in spectrum B. Your answer should include a calculation.

(4)

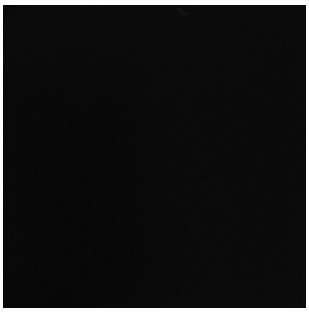
(Total for Question 14 = 6 marks)

2 A source of light is viewed through a polarising filter, as shown in photograph 1.

The filter is rotated through an angle and then viewed, as shown in photograph 2.



Photograph 1



Photograph 2

Which row of the table shows whether the light emitted by the source is polarised or unpolarised, and the angle of rotation of the filter?

	Light emitted by source	Angle of rotation / radians
☒ **A**	polarised	$\frac{\pi}{2}$
☒ **B**	polarised	π
☒ **C**	unpolarised	$\frac{\pi}{2}$
☒ **D**	unpolarised	π

(Total for Question 2 = 1 mark)

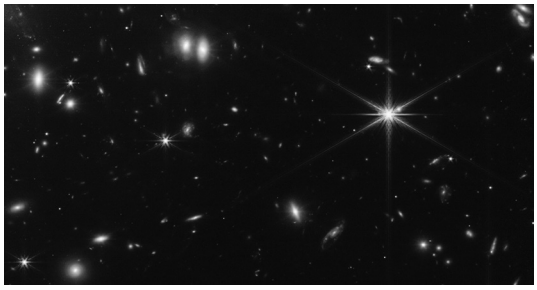
3 Two stars, P and Q, are observed from Earth. The intensity of radiation from P is less than that from Q. The parallax angle for P is greater than that for Q.

Which row of the table is correct?

	Distance from Earth	Comparison of luminosities
☒ **A**	P is closer than Q	luminosity of P is greater than Q
☒ **B**	P is closer than Q	luminosity of P is less than Q
☒ **C**	P is further away than Q	luminosity of P is greater than Q
☒ **D**	P is further away than Q	luminosity of P is less than Q

(Total for Question 3 = 1 mark)

15 The photograph below was taken by the James Webb Space Telescope (JWST) and shows a group of galaxies that formed shortly after the big bang, about 13×10^9 years ago.



(Source: © NASA, ESA, CSA, STScI)

(a) (i) Derive the equation $T = 1/H_0$ where T is the age of the universe.

(1)

(ii) State one assumption made in your derivation.

(1)

(iii) The parsec (pc) is a unit used for astronomical distances. 1 pc is 3.1×10^{16} m.

The accepted range for the Hubble constant H_0 is (60–80) km s^{-1} Mpc^{-1}.

Deduce whether the observation by the JWST leads to a value of H_0 within the accepted range.

1 year = 3.16×10^7 s

(3)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(b) The light from one of the galaxies, called Maisie, has a redshift z of 14.
The wavelength of light from Maisie detected at the telescope is 4.0×10^{-6} m and lies within the infrared section of the electromagnetic spectrum.

(i) Calculate the wavelength of light emitted by Maisie.

(3)

Wavelength emitted = ...

(ii) Explain why the light emitted by Maisie arrives at the telescope as infrared.

(2)

(c) One of the infrared detectors on the JWST is made from material with a work function of 0.30 eV.

Deduce whether this detector can detect the light from Maisie.

(4)

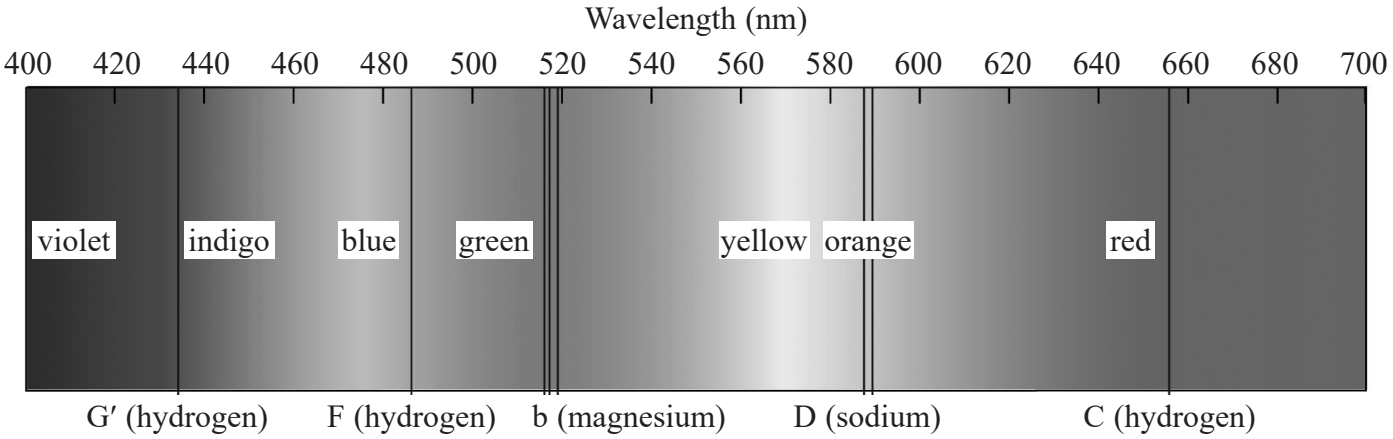
(Total for Question 15 = 14 marks)

17 Scientists can analyse light from stars that has passed through a diffraction grating.

*(a) Explain the pattern produced when a mixture of blue and red light, from the same source, passes through a diffraction grating.

(6)

(b) A spectrum of the visible light emitted by a particular star is shown.



(Source: © Universal Images Group North America LLC/Alamy Stock Photo)

(i) Light interacts with atoms as it passes through the atmosphere of the star.

Explain how this leads to the formation of the dark lines within the spectrum.

(4)

.....

.....

.....

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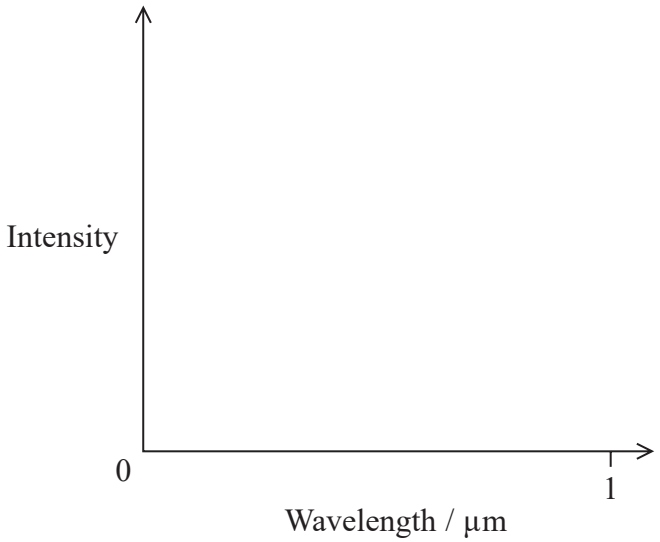
.....

(ii) The surface temperature of the star is 5800 K.

On the axes below, sketch a graph of the intensity of radiation against the wavelength of that radiation for this star.

(4)



(iii) This star is a main sequence star.

Explain why main sequence stars do not collapse due to gravitational forces.

(2)

(Total for Question 17 = 16 marks)