A Level · OCR · Physics

45 mins 4 questions

Structured Questions

EM Radiation From Stars

Electron Energy Levels / Emission Spectra & Energy Levels / Identifying Elements Within Stars Using Spectral Lines / Continuous, Emission Line & Absorption Line Spectrum / Transmission Diffraction Grating / Wein's Displacement Law / Stefan's Law / Estimating the Radius of Stars

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Total Marks **/45**

1 (a) This question is about the Sun and its radiation.

i) Use the data below to show that the luminosity of the Sun is about 4×10^{26} W.

- radius of Sun = 7.0×10^8 m • surface temperature of Sun = 5800 K

[1]

ii) Sirius, the brightest star in the night sky, has a luminosity 25 times greater than that of the Sun. It has diameter 1.7 times greater than that of the Sun.

Calculate the surface temperature T of Sirius.

T = ... K **[3]**

....

....

....

....

(4 marks)

(b) A student attends a lecture about the Sun and makes the following notes.

1. The Sun loses more than 4×10^9 kg of its mass every second to maintain its luminosity.
2. Treating hydrogen nuclei (protons) as an ideal gas, a temperature of 10^{10} K provides a kinetic energy of about 1 MeV, which is necessary for fusion.
3. However, the Sun's core temperature is only 10^7 K, so the chance of protons fusing on collision is very small. This explains why the Sun has such a long lifetime.

Explain the principles of physics which are involved in each of the three points.

You should include relevant formulae, but no numbers or calculations are required.

[6]

....

(6 marks)

2 (a) Algol is a triple-star system, with stars Aa1, Aa2 and Aa3 orbiting each other.

This triple-star is 90 light-years from the Earth.

Here is some data on the star Aa1. • radius = $(1.90 \pm 0.14) \times 10^{9}$ m • mass = $(6.31 \pm 0.42) \times 10^{30}$ kg. Calculate the gravitational field strength g at the surface of Aa1 to **3** significant figures.

Include the absolute uncertainty in your answer. Assume that the other stars of the system exert negligible gravitational force on Aa1.

g = ... ± .... N kg^{-1} **[4]**

....

....

....

....

(4 marks)

(b) The table shows some data about the three stars of Algol.

Star Luminosity of star / $L_{\odot}$ Surface temperature of star / K Aa1 182 13000 Aa2 6.92 4500 Aa3 10.0 7500

The luminosity of each star is in terms of the solar luminosity $L_{\odot}$.

i) Define the luminosity of a star.

[1]

ii) Use Stefan's law to determine the ratio $\dfrac{radius\ of\ star\ Aa2}{radius\ of\ star\ Aa3}$

ratio = ... **[2]**

iii) Use Wien's displacement law to explain which star would have the **longest** wavelength at the peak intensity of the emitted electromagnetic radiation.

[2]

iv) Suggest how an astronomer using just an optical telescope can deduce that the three stars of Algol have different surface temperatures.

[1]

v) The light from each star passing through a diffraction grating shows an absorption line spectrum.

Explain how a specific absorption line is produced in this type of spectrum in terms of **photons** and **electrons**.

[3]

(9 marks)

(c) The Aa1 star could evolve into a black hole. State **two** ways in which the black hole would differ from the Aa1 star. 1. .... 2. ....

[2]

(2 marks)

3 (a) Fig. 21.1 shows some of the energy levels of electrons in hydrogen gas atoms. The energy levels are labelled **A**, **B**, **C** and **D**.

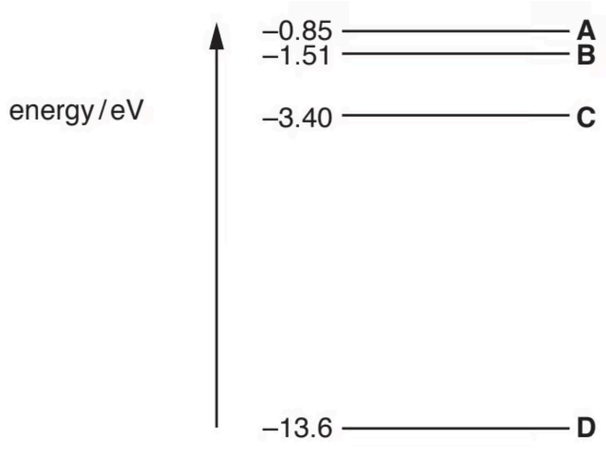

Fig. 21.1 (not to scale)

i) Explain why the energy levels are negative.

[1]

ii) An electron makes a transition (jump) from level **C** to level **A**.

1 Calculate the energy gained by this electron.

energy = ... eV **[1]**

2 Calculate the wavelength in nm of the photon absorbed by this electron.

wavelength = ... nm **[3]**

(5 marks)

(b) Light from a distant galaxy is passed through a diffraction grating. Fig. 21.2 shows the part of the spectrum of light that shows a strong hydrogen-alpha emission line.

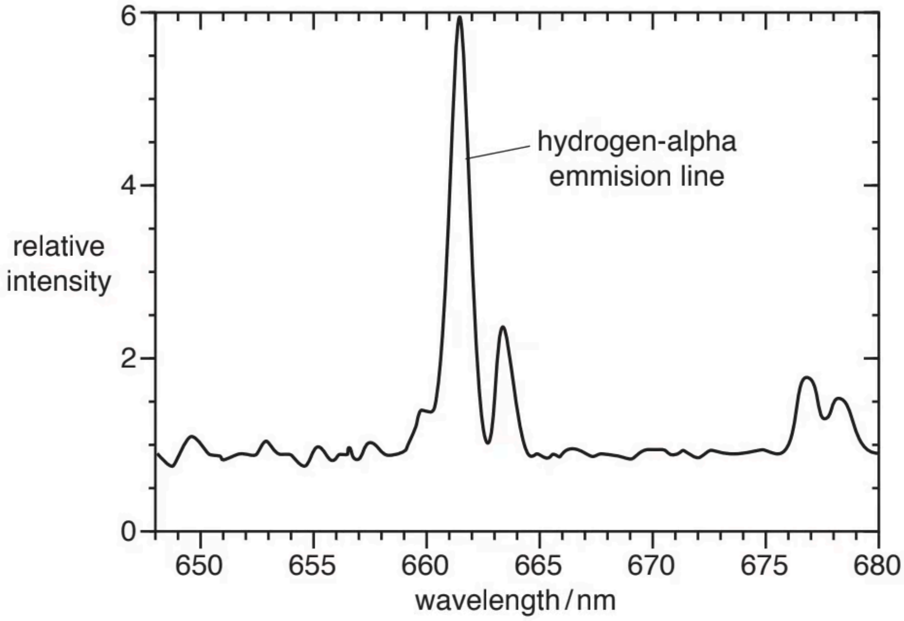

Fig. 21.2

i) State how an emission line is produced.

[1]

ii) State an adjustment that could be made to the experimental arrangement that would space the emission lines more widely.

[1]

iii) In the laboratory, the wavelength of the hydrogen-alpha emission line is 656.3 nm.

Use Fig. 21.2 to determine the recession velocity of the galaxy.

recession velocity = ... m s^{-1} **[3]**

iv) Suggest why hydrogen spectral lines play an important role in determining red shift of galaxies.

[1]

(6 marks)

(c) Light from a similar star is viewed in a galaxy **further** away. The star is part of a pair of stars which orbit a common centre of mass. Describe and explain how the equivalent spectrum might appear.

[3]

(3 marks)

4 (a) A group of students are conducting an experiment to determine the wavelength of monochromatic light from a laser.

Fig. 24.1 shows the laser beam incident normally at a diffraction grating.

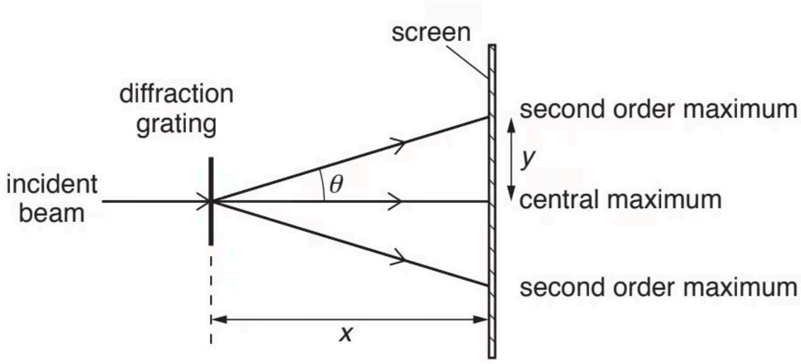

Fig. 24.1

The students use a diffraction grating with 600 lines mm^{-1}.

They vary the distance x between the grating and the screen from 1.000 m to 2.000 m. They measure the distance y from the **central** maximum to the **second order** maximum.

The students decide to plot a graph of y against $\sqrt{x^2 + y^2}$.

Show that the gradient of the graph is equal to sin θ, where θ is the angle between the central maximum and the **second** order maximum.

[1]

....

(1 mark)

(b) Fig. 24.2 shows the graph plotted by the students.

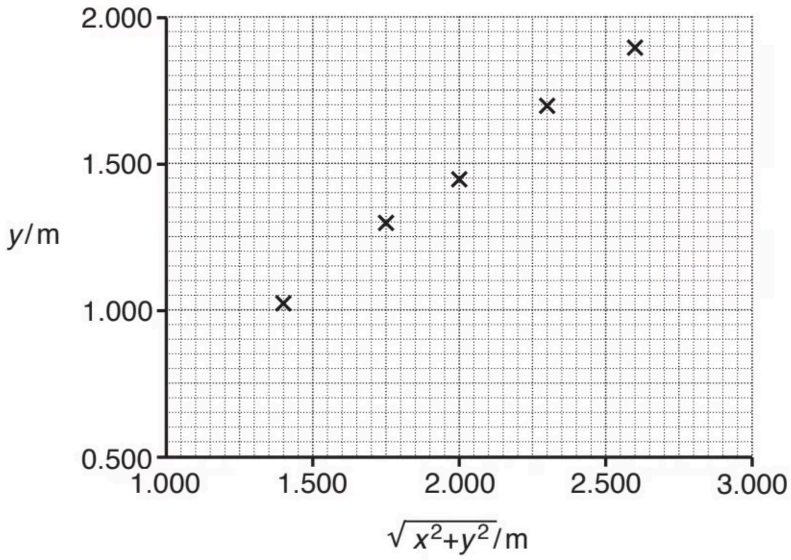

Fig. 24.2

i) Use Fig. 24.2 to determine an accurate value of the wavelength λ of the light from the laser.

λ = ... m **[3]**

ii) Suggest why there are no error bars shown in Fig. 24.2.

[1]

iii) Suggest how the precision of this experiment may be affected by using a protractor to measure the angle θ.

[1]

(5 marks)