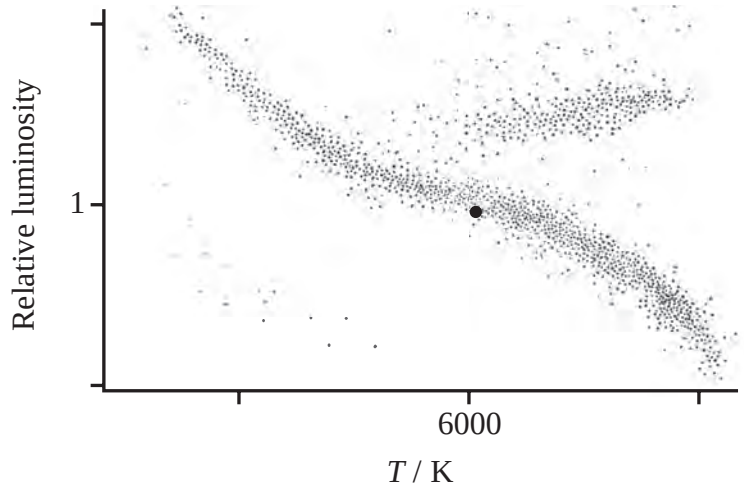
1 Light from all distant galaxies is found to be shifted towards longer wavelengths. The more distant the galaxy, the greater the shift in wavelength.

State the conclusions that we can draw from this.

(3)

(Total for Question = 3 marks)

2 This Hertzsprung-Russell diagram is a plot of relative luminosity against temperature for a large number of stars.



The position of the Sun, at a surface temperature of about 6000 K and a relative luminosity of 1, is marked on the diagram.

(a) Complete the temperature and relative luminosity scales by adding values at the positions shown.

(2)

(b) The Sun is an example of a main sequence star.

(i) State the fusion process taking place in the core of all main sequence stars.

(1)

(ii) Draw a circle where the most massive main sequence stars are located on the diagram and explain why they are found in this position.

(3)

(Total for Question = 6 marks)

3 According to astronomers in Denmark and Australia a common type of active galactic nucleus (AGN) could be used as an accurate "standard candle" for measuring cosmic distances. The technique has been used to measure distances corresponding to redshifts significantly larger than was previously possible.

(a) (i) State what is meant by a standard candle.

(1)

(ii) Explain how a standard candle is used to measure cosmic distances.

(2)

(b) (i) State what is meant by redshift.

(1)

(ii) Calculate the distance to a galaxy with a redshift $z = 0.12$

$H_0 = 2.1 \times 10^{-18}\ s^{-1}$

(2)

Distance to galaxy =

*(c) Discuss how astronomers were led to propose the existence of dark matter and the consequences of its existence for the ultimate fate of the universe.

(3)

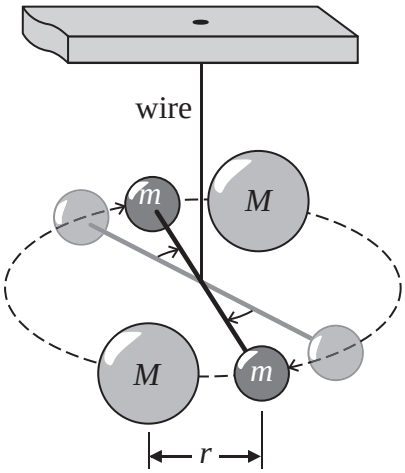
(d) Explain why the observable universe has a finite size.

(2)

(Total for Question = 11 marks)

4 In the 18th century Henry Cavendish devised an experiment to determine the average density of the Earth. This involved the first laboratory determination of the universal gravitational constant *G*.

A light horizontal rod with a small metal sphere at each end was hung from a fixed point by a very thin wire. Two large lead spheres were then brought close to the small spheres causing the rod to oscillate and then settle into a new position of equilibrium.



(a) In a modern version of the experiment the following data was obtained:

mass of large lead sphere $M = 160$ kg

mass of small sphere $m = 0.75$ kg

distance $r = 0.23$ m

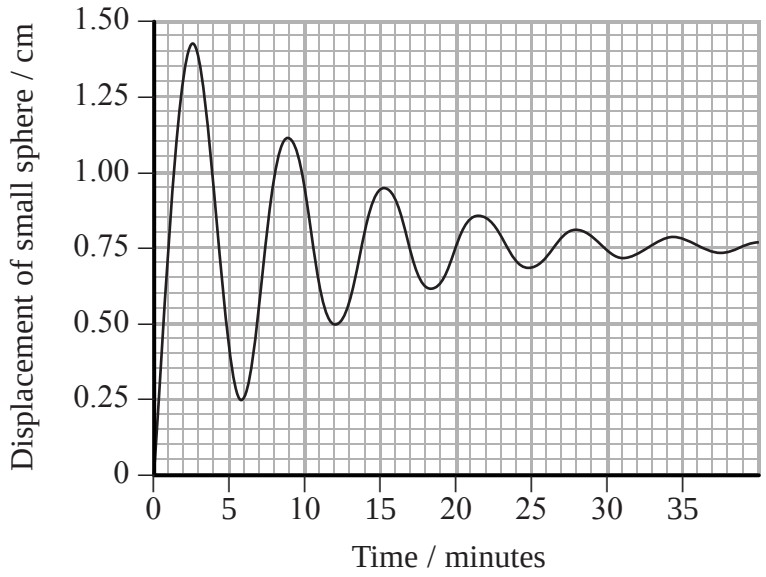
gravitational force between adjacent large and small spheres $F = 1.5 \times 10^{-7}$ N.

Use this data to calculate a value for *G*.

(2)

$G =$ $\text{Nm}^2\ \text{kg}^{-2}$

(b) The graph shows how the displacement of one of the small spheres varies with time.



(i) Use the graph to determine the period of oscillation of the sphere.

(2)

Period =

(ii) The amplitude of the oscillation decreases with each cycle.

Explain why this effect is observed.

(2)

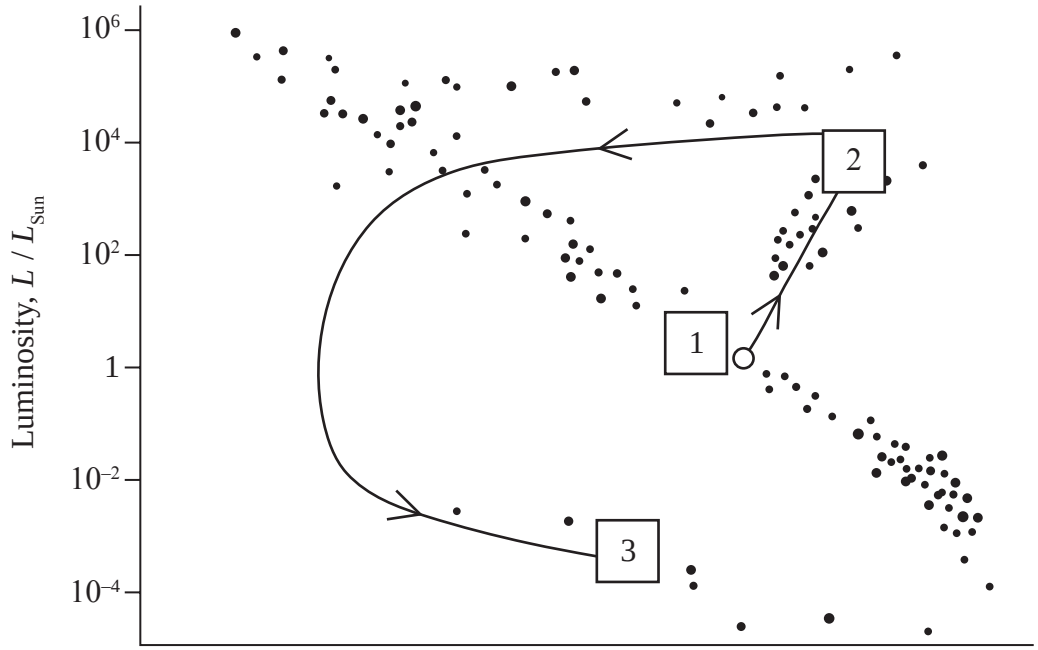
(iii) It is suggested that the decrease in amplitude is exponential. Use the graph to determine if this is approximately true.

(3)

(Total for Question = 9 marks)

5 The Sun has a surface temperature of 5800 K and is approximately 4.5 billion years old.

The Hertzsprung-Russell diagram maps the future evolution of the Sun, from its current position in area 1 of the diagram, through to its final position in area 3 of the diagram.



(a) (i) Complete a suitable temperature scale on the x-axis.

(2)

*(ii) Use the diagram to describe the lifecycle of the Sun starting from its present position in area 1 and concluding in area 3.

(6)

(b) The energy source for the Sun is the fusion of light nuclei to heavy nuclei. In its present stage of evolution hydrogen is being converted into helium in the core of the Sun.

(i) State and explain the conditions necessary for fusion to occur in a star.

(3)

(ii) In a star the fusion of hydrogen into helium takes place in a number of stages. The final stage is:

$$ {}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2 \times {}^{1}_{1}\mathrm{H} $$

Calculate the energy released in MeV when one nucleus of the normal isotope of helium is produced.

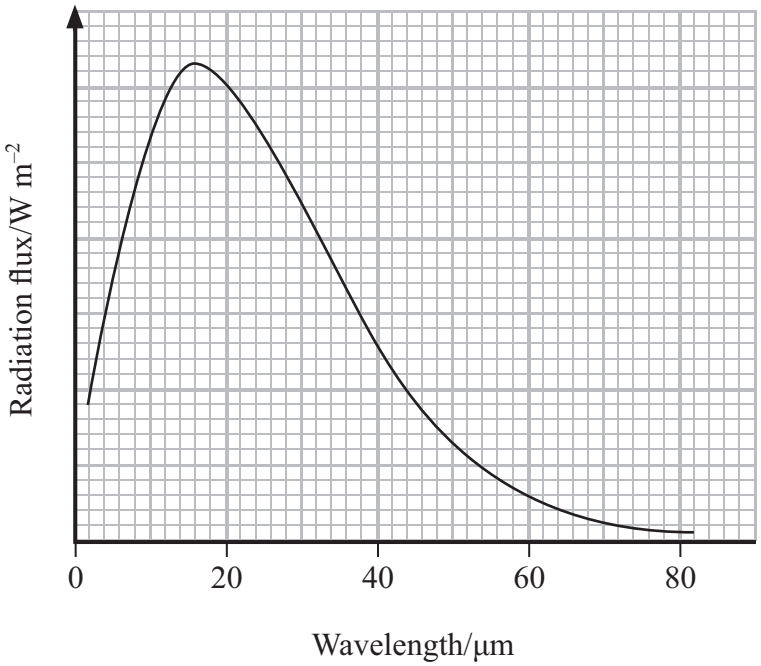
(4)

Isotope	**Mass / 10^{-27} kg**
^{3}He	5.008238
^{4}He	6.646483
^{1}H	1.673534

Energy released = MeV

(Total for Question = 15 marks)

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



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

(1)

Wavelength of peak radiation flux .....

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

(2)

.....

.....

.....

.....

Temperature of asteroid .....

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

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

(2)

1 .....

2 .....

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

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

mass of Jupiter 1.9×10^{27} kg

(2)

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Gravitational field strength of Jupiter .....

(Total for Question 7 marks)