1. State the Cosmological Principle.

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[Total 2 marks]

2. Describe the important properties of the cosmic microwave background radiation and how the standard model of the Universe explains these properties. Explain their significance as evidence for the past evolution of the Universe.

✎ *In your answer, you should make clear how your explanation links with the evidence.*

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[Total 5 marks]

3. Explain why our understanding of the very earliest moments of the Universe is unreliable.

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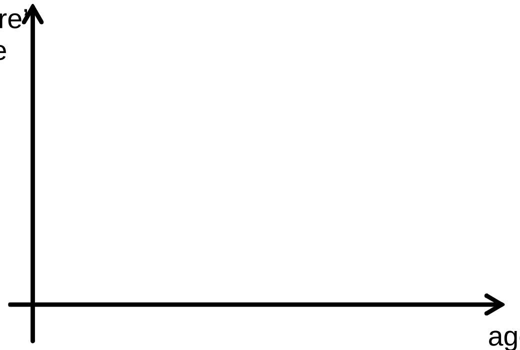
[Total 2 marks]

4. The future of the Universe may be *open*, *closed* or *flat*. Explain the meaning of the terms in italics, using a graph to illustrate your answer.



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[Total 4 marks]

5. The mean density of the Universe, ρ_0, is thought to be approximately 1×10^{-26} kg m^{-3}. Calculate a value for the Hubble constant H_0.

H_0 =... s^{-1}

[Total 2 marks]

6. The average orbital radius of Jupiter is approximately 5.2 AU.
Calculate the orbital radius of Jupiter in metres.

radius = ... m

[Total 1 mark]

7. State Hubble's law and define any symbols used.

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[Total 2 marks]

8. Describe Olbers' paradox and explain how the work of Edwin Hubble provides an answer.

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[Total 5 marks]

9. (i) Describe the shape and structure of our galaxy. Illustrate your answer with a sketch.

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[2]

(ii) Mark **X** on your sketch at the approximate position of the Sun within the galaxy.

[1]

[Total 3 marks]

10. Some Cosmologists have estimated that as much as 90% of the total mass of a galaxy is made up of gas, referred to as dark matter.

(i) Suggest the nature and origin of this gas.

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[2]

(ii) The precise amount of dark matter in the Universe is unknown. Explain how the presence of dark matter affects the average density of the Universe and thus has a role in determining the ultimate fate of the Universe itself.

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[4]

[Total 6 marks]

11. When a star ceases to be Main Sequence, it may evolve in several different ways. Explain the circumstances which will lead to the formation of a neutron star.

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[Total 4 marks]

12. (i) A star of mass 7×10^{30} kg becomes a neutron star of radius 10 km. Calculate the average density of the neutron star, assuming that 50% of the original star's mass has been lost.

density = ……………….. kg m^{-3}

[3]

(ii) State how the density of a neutron star compares to that of materials commonly found on Earth.

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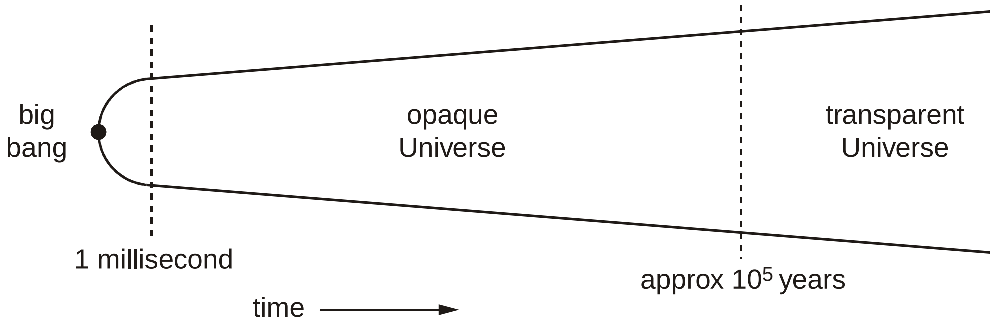
[2]

[Total 5 marks]

13. Some stages in the early evolution of the Universe are represented in the figure below.



(i) What limits our understanding of events in the first millisecond?

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[1]

(ii) State and explain how the temperature of the Universe has changed after the first millisecond.

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[2]

(iii) Explain how the Universe became *transparent*.

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[3]

[Total 6 marks]

14. Describe and explain **two** pieces of evidence which suggest that the Universe did in fact begin with a big bang.

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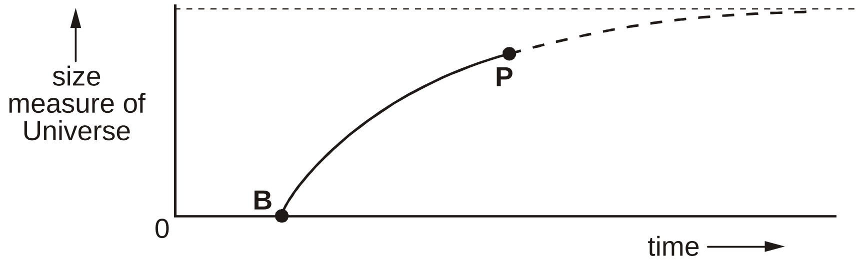
[Total 5 marks]

15. The ultimate fate of the Universe is not yet clear. The figure below shows a graph where the size of the Universe is represented from the big bang B to the present day P. The graph has been extended into the future by the dotted line (– – – – –).



(i) Calculate a value for the age of the Universe in years. Assume the Hubble constant to be 75 km s^{-1} Mpc^{-1}.

age = …..……………… years

[3]

(ii) Describe and explain what final fate for the Universe is represented in the figure above.

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[2]

(iii) The mass of the Universe may be significantly greater than that assumed in the first paragraph of this question.
Taking this to be case, sketch a second graph on the figure above using the same scales to show the future evolution of the Universe.

[2]

(iv) Comment upon the implications of your graph for the future of the Universe.

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[1]

[Total 8 marks]

16. (a) The cosmic microwave background radiation is evidence for the way in which the Universe began. State a feature of the intensity of this microwave background radiation.

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[1]

(b) The first stars are thought to have formed many years after the Universe came into being. What are the similarities and differences between the **composition** of the Sun and that of the very first stars?

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[3]

[Total 4 marks]

17. In 1929 Edwin Hubble showed that the Universe was expanding by studying the light from stars and galaxies. Explain how.

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[Total 5 marks]

18. Describe how the fate of the Universe depends upon its mean density and explain why this ultimate fate is not yet known.

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[Total 5 marks]

19. State Kepler's laws of planetary motion.

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[Total 3 marks]

20. Astronomers are searching for planets which orbit distant stars. The planets are not visible from the Earth. Their existence is revealed by the star's motion which causes a shift in the wavelength of the light it emits.
A large planet **P** is shown orbiting a star **S** in the Fig. 1. Both the star and the planet rotate about their common centre of mass **C**.

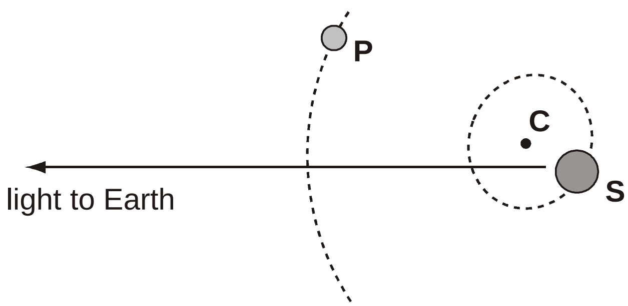

Fig. 1

When measured from a stationary source in the laboratory, a spectral line has a wavelength λ of 656.3 nm.
The light from star **S** is examined over a period of 74 hours. The change in wavelength $\Delta\lambda$ for the same spectral line is recorded. The velocity has been calculated and the data shown in Fig. 2.

time / h	$\Delta\lambda$ /10^{-15} m	velocity / m s^{-1}
1	6.7	3.1
6	38.1	17.5
12	66.0	30.3
19	76.0	34.9
23	69.1	31.7
29	43.8	20.1
35	6.8	3.1
41	–32.2	–14.8
48	–66.0	–30.3
55	–76.0	–34.9
61	–62.5	–28.7
67	–32.2	–14.8
74		6.1

Fig. 2

(i) Use the Doppler equation relating $\Delta\lambda$ with velocity v to calculate the change in wavelength for the final velocity of 6.1 m s^{-1}.

change in wavelength = ………….........m

[3]

(ii) Plot a graph of the star's velocity against time using the grid in Fig. 3. The first seven points are already completed. The data required from Fig. 2 are repeated beneath the grid.

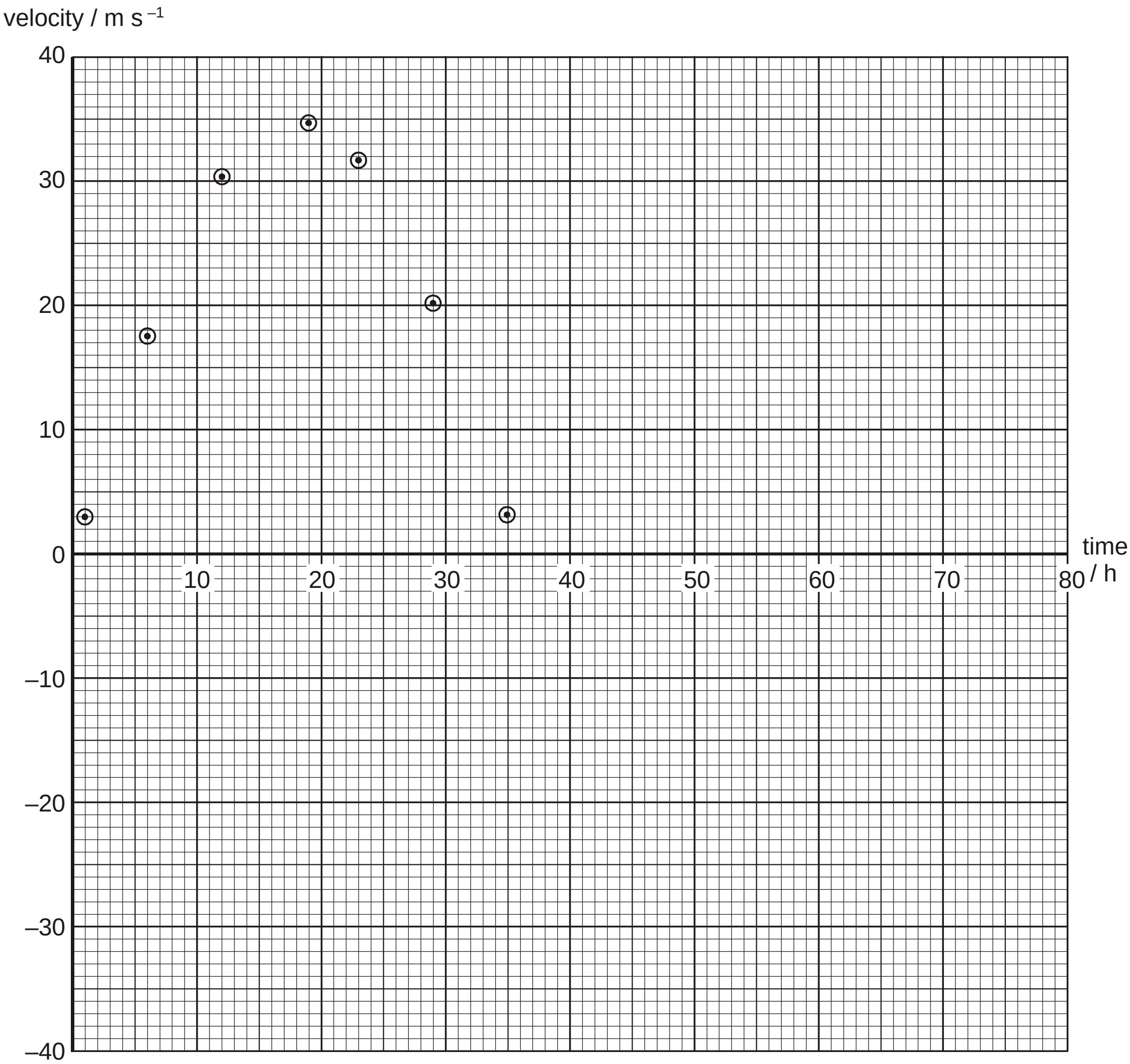

Fig. 3

[2]

time / h	velocity / m s^{-1}
41	–14.8
48	–30.3
55	–34.9
61	–28.7
67	–14.8
74	6.1

(iii) Draw a curve through all the points on the graph.

[1]

(iv) On Fig. 1, mark a point on the star's orbit that would correspond to a velocity of zero on the graph. Label this point **X**.

[1]

(v) Use your graph to estimate the time *T* for the planet to make one complete revolution around the star.

time ....h

[1]

(vi) The mass *M* of the star is estimated to be 4×10^{30} kg. Calculate the radius of the planet's orbit using the relationship below.

$$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$$

radius = ...m

[2]

[Total 10 marks]

21. Large distances in the Universe may be measured in parsecs. Explain what is meant by a *parsec*.

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[Total 2 marks]

22. Explain how a main sequence star can develop into a supernova. Discuss what may remain after the explosion.

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[Total 6 marks]

23. Describe the important properties of the cosmic microwave background radiation and how the standard model of the Universe explains these properties. Explain their significance as evidence for the past evolution of the Universe.

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[Total 5 marks]

24. Why is our understanding of the very earliest moments of the Universe unreliable?

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[Total 2 marks]

25. The future of the Universe may be *open*, *closed* or *flat*. Explain the meaning of the terms in italics, using a graph to illustrate your answer.

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[Total 4 marks]

26. The mean density of the Universe, ρ_0, is thought to be approximately 1×10^{-26} kg m^{-3}. Calculate a value for the Hubble constant H_0.

H_0 = ...s^{-1}

[Total 2 marks]