

Astrophysics and cosmology

Question Paper 3

Level	A Level
Subject	Physics
Exam Board	OCR
Topic	Newtonian world and astrophysics
Sub-Topic	Astrophysics and cosmology
Booklet	Question Paper 3

Time Allowed: 62 minutes

Score: / 51

Percentage: /100

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

- 1 (a) Olbers' paradox is based on two assumptions about the nature of our Universe. State these two assumptions.

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..... [2]

- (b) Fig. 2.1 shows how the recessional speed v of galaxies varies with their distance d from the Earth.

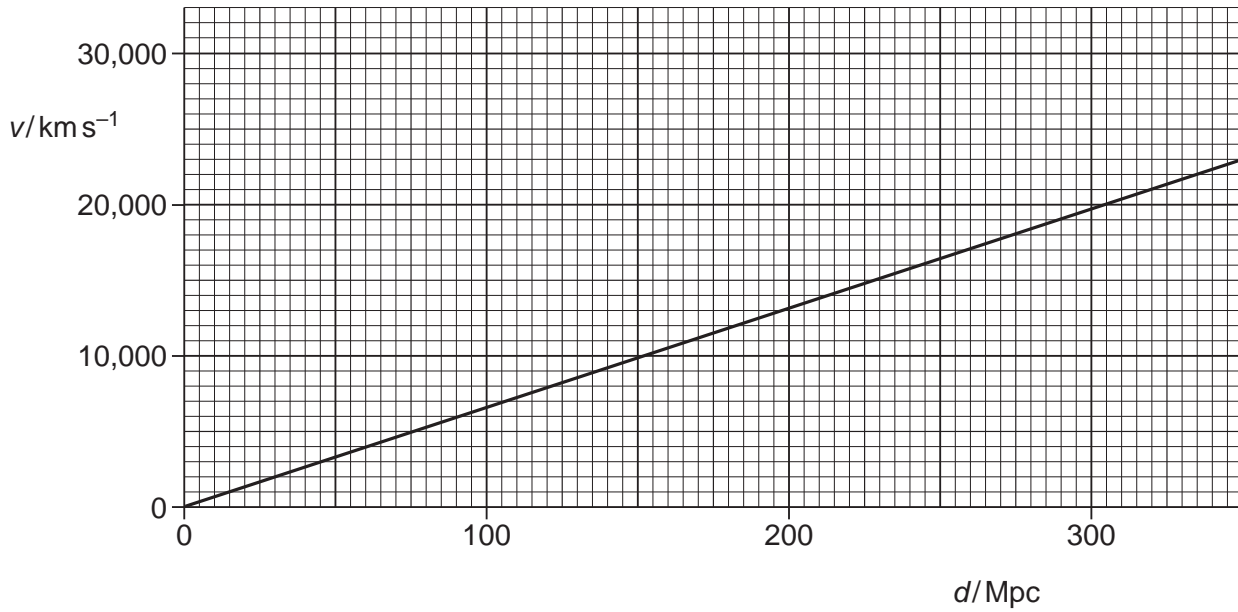


Fig. 2.1

- (i) Use Fig. 2.1 to determine the Hubble constant.

Hubble constant = $\text{km s}^{-1} \text{Mpc}^{-1}$ [2]

(ii) Hence estimate the age of the Universe in years.

$$1 \text{ year} = 3.2 \times 10^7 \text{ s and } 1 \text{ pc} = 3.1 \times 10^{16} \text{ m}$$

age = y [3]

(c) (i) Calculate the critical density of the Universe using the Hubble constant determined in (b)(i).

critical density = kg m^{-3} [2]

(ii) Describe how the fate of the Universe depends on its average density.

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(d) Describe the evidence for the hot big bang model of the Universe.

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..... [4]

- (i) The final evolutionary stage of the star is a white dwarf. Describe some of the characteristics of a white dwarf.

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- (ii) Explain why, in its evolution, the star is brightest when at its coolest.

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..... [2]

[Total: 8]

3 (a) State Olbers' paradox and the two assumptions made about the Universe.

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(b) State Hubble's law and explain how it resolves Olbers' paradox.

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(c) A galaxy at a distance of 1.4×10^{25} m is observed to be receding from the Earth at a velocity of $3.4 \times 10^7 \text{ m s}^{-1}$.

(i) Calculate the Hubble constant H_0 based on this data.

$H_0 = \dots\dots\dots$ unit $\dots\dots\dots$ [3]

(ii) Estimate

1 the age in years of the Universe

$$1 \text{ year} = 3.2 \times 10^7 \text{ s}$$

age =years **[2]**

2 the maximum distance in parsec (pc) we can observe from the Earth.

$$1 \text{ pc} = 3.1 \times 10^{16} \text{ m}$$

distance = pc **[2]**

[Total: 12]

4 (a) Describe the formation of the Sun.



In your answer, you should make clear how the steps of the process are sequenced.

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[5]

(b) After the death of a low-mass star such as our Sun, the remnant core is a white dwarf.

State two properties of a white dwarf.

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[2]

(c) The ultimate fate of the universe depends on its density.

(i) State the fate of the universe if its density is equal to the critical density.

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..... [1]

(ii) According to some cosmologists, the age of the universe is 4.4×10^{17} s (about 14 billion years). Show that according to this age, the critical density of the universe is about $10^{-26} \text{ kg m}^{-3}$.

[3]

(iii) Estimate the number of protons per cubic metre of space.

mass of proton = $1.7 \times 10^{-27} \text{ kg}$

number = m^{-3} [2]

(d) The universe began from a big bang. At an early stage of the universe, the temperature was about 10^8 K . The expansion of the universe led to cooling. The present temperature of the universe is about 2.7 K . For a single **electron**, determine the ratio

$$\frac{\text{speed of electron at } 10^8 \text{ K}}{\text{speed of electron at } 2.7 \text{ K}}$$

ratio = [2]

[Total: 15]