**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.

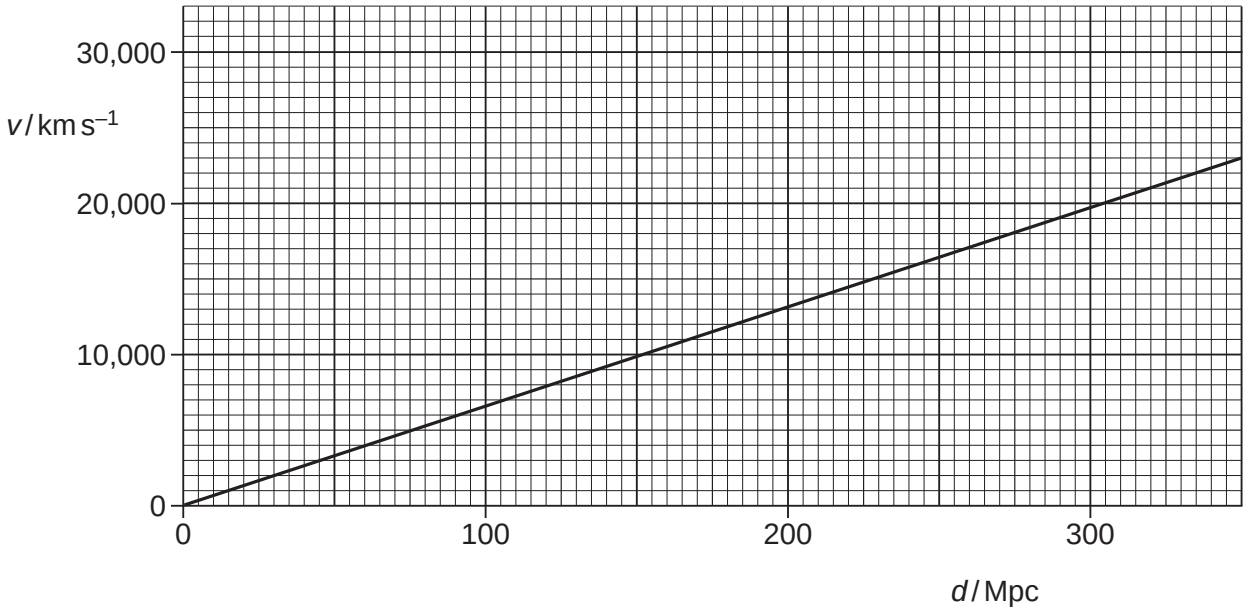


**Fig. 2.1**

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

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

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

1 year = $3.2 \times 10^7$ s and 1 pc = $3.1 \times 10^{16}$ 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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..... **[3]**

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

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..... **[4]**

**2** **(a)** Describe briefly the sequence of events which occur in the formation of a star, such as our Sun, from interstellar dust and gas clouds.

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

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..... **[4]**

**(b)** Fig. 8.1 shows the evolution of a star similar to our Sun on a graph of intensity of emitted radiation against temperature.

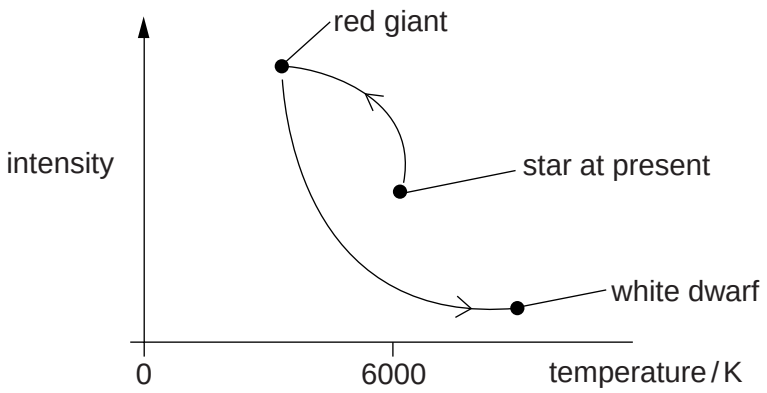


**Fig. 8.1**

**(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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..... **[2]**

**(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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..... **[3]**

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

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..... **[2]**

**(c)** A galaxy at a distance of $1.4 \times 10^{25}$ 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.

$H_0$ = ..... unit ..... **[3]**

**(ii)** Estimate

**1** the age in years of the Universe

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

age = .....years **[2]**

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

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

.....

..... **[1]**

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

**[3]**

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

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

number = ..... $\text{m}^{-3}$ **[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]**