1 **(a)** Explain what is meant by a *white dwarf* when describing the evolution of a star.

....

....

.... **[1]**

(b) Antares is a red giant and one of the brightest stars in the night sky. The parallax angle for this star is 0.0059 arc seconds.

Calculate its distance in light years from us.
1 pc = 3.26 ly

distance = ... ly **[2]**

(c) Sirius-B is a white dwarf. In comparison with Sirius-B, Antares has 12 times greater mass and has 1.1×10^5 times greater radius. The surface temperatures of Sirius-B and Antares are 25000 K and 4300 K respectively.

The intensity I of electromagnetic radiation emitted from the surface of a star is related to its temperature T in kelvin as follows:

$$I \propto T^4.$$

(i) Explain what is meant by *intensity*.

....

.... **[1]**

(ii) Calculate the ratio

1 $$\frac{\text{mean density of Antares}}{\text{mean density of Sirius-B}}$$

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

2 $$\frac{\text{total power emitted from Antares}}{\text{total power emitted from Sirius-B}}.$$

ratio = ... **[3]**

2 (a) State Hubble's law.

....

....

.... **[1]**

(b) The redshift of a specific spectral line in the spectrum of a galaxy can be used to determine its recession velocity *v*. The fractional change *z* in the wavelength of a spectral line is given by the equation

$$z = \frac{v}{c}$$

where *c* is the speed of light in a vacuum.

The table of Fig. 11.1 shows data for some of our closest galaxies. The distance of the galaxy from the Earth is *d*.

Galaxy	z / 10^{-3}	v / $10^{3}\,\mathrm{m\,s^{-1}}$	d / $10^{23}\,\mathrm{m}$
A	1.12	336	1.50
B	1.61	483	2.14
C	1.85	555	2.46
D	2.26	678	3.00
Messier 109	3.38		

Fig. 11.1

(i) Complete the table by determining *v* and *d* for the galaxy Messier 109. **[2]**

(ii) Fig. 11.2 shows the data for the first four galaxies plotted on a v against d graph.

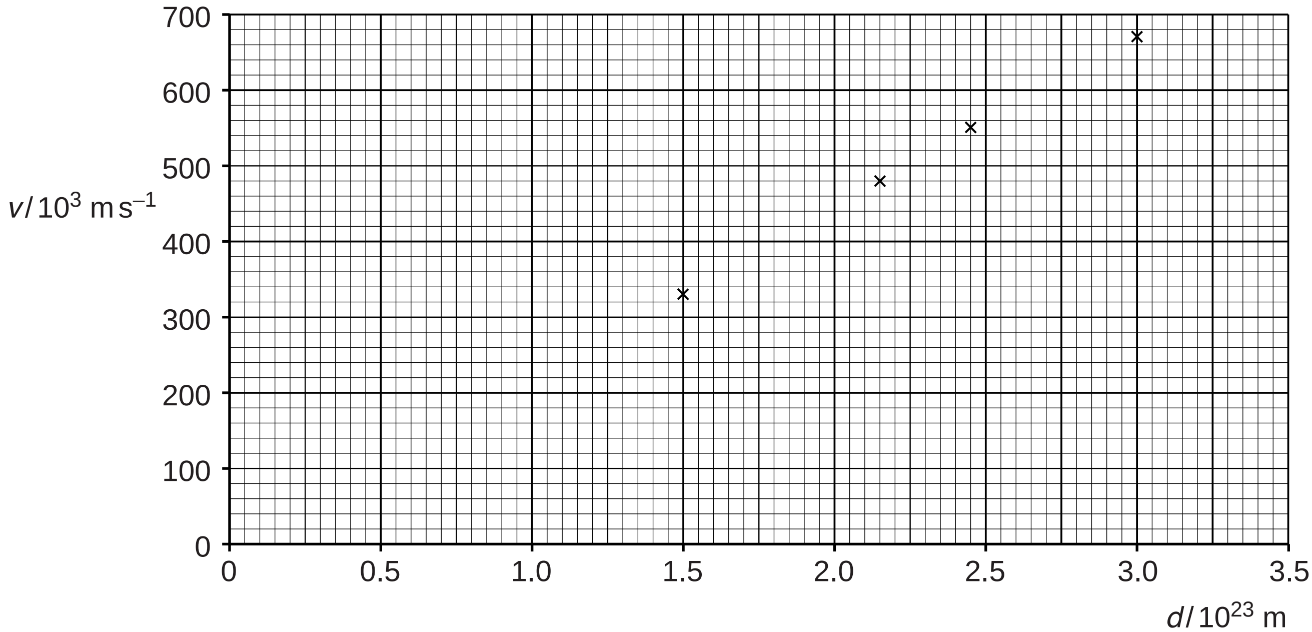

Fig. 11.2

Use Fig. 11.2 to determine the age of the Universe in years.
$1 \text{ y} = 3.16 \times 10^7 \text{ s}$

age = ... years **[3]**

(c) One piece of observational evidence for the big bang is that galaxies are receding from each other.
Explain what is meant by the big bang and suggest **two** other observations that support the big bang model of the Universe.

....

....

....

....

....

.... **[3]**

3 Sirius A and B are binary stars in our galaxy at a distance of 8.6 ly from the Sun. Sirius B is a white dwarf of diameter 12 km and mass 2.0×10^{30} kg.

(a) Calculate the density of Sirius B.

density = ... unit .... **[3]**

(b) The mass of the Sun is the same as Sirius B. The Sun has a diameter of 1.4×10^{9} m.

Calculate the ratio

$$\frac{\text{gravitational field strength on the surface of Sirius B}}{\text{gravitational field strength on the surface of the Sun}} .$$

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

(c) Calculate the parallax angle in arc seconds for Sirius B.

1 pc = 3.1×10^{16} m

parallax angle = ... arc seconds **[2]**

(d) Sirius A is moving towards the Earth at a relative velocity of $7600\,\text{m}\,\text{s}^{-1}$. Calculate the percentage change in the wavelength of a spectral line observed from this star compared with an identical spectral line observed in the laboratory.

percentage change = ... % **[2]**

(e) A student suggests that the distance of Sirius A can be calculated using Hubble's law and the speed given in **(d)**. Discuss whether this suggestion is correct or incorrect.

....

....

....

.... **[1]**

[Total: 10]

4 **(a)** State the *cosmological principle*.

....

....

....

.... **[2]**

(b) State some of the properties of the microwave background radiation observed from the Earth. Discuss how the background microwave radiation is linked to the big bang model of the universe.

....

....

....

....

....

.... **[3]**

(c) Calculate the age of our universe in years based on a critical density of the universe of $9.7 \times 10^{-27}\,\mathrm{kg\,m^{-3}}$.

age = ... y **[3]**

[Total: 8]

5 **(a)** Calculate the distance of 1 light-year (ly) in metres.

distance = ... m **[1]**

(b) Fig. 10.1 shows an incomplete diagram drawn by a student to show what is meant by a distance of 1 parsec (pc).

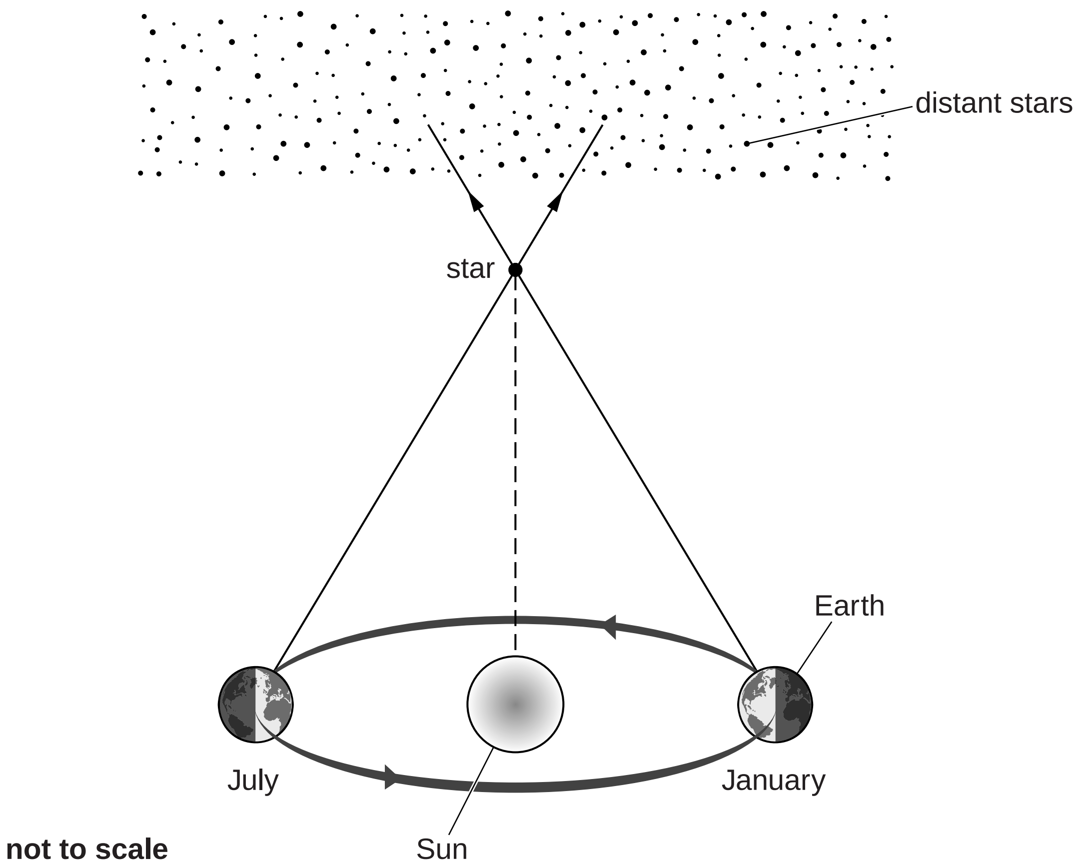

Fig. 10.1

Complete Fig. 10.1 by showing the distances of 1 pc and 1 AU, and the parallax angle of 1 second of arc (1″). **[1]**

(c) A recent supernova, SN2011fe, in the Pinwheel galaxy, M101, released 10^{44} J of energy. The supernova is 2.1×10^{7} ly away.

(i) Calculate the distance of this supernova in pc.

1 pc = 3.1×10^{16} m

distance = ... pc **[2]**

(ii) Our Sun radiates energy at a rate of 4×10^{26} W. Estimate the time in years that it would take the Sun to release the same energy as the supernova SN2011fe.

time = ... y **[2]**

(d) One of the possible remnants of a supernova event is a black hole. State **two** properties of a black hole.

....

....

....

.... **[2]**

[Total: 8]