1 (a) One estimate of the age of the universe is 13.7×10^9 years.

(i) Calculate the Hubble constant in $\text{km s}^{-1}\ \text{Mpc}^{-1}$ using this age.

1 pc = 3.09×10^{16} m

Hubble constant = ... $\text{km s}^{-1}\ \text{Mpc}^{-1}$ **[3]**

(ii) The wavelength of the hydrogen-alpha spectral line in the laboratory is 656 nm. Calculate the observed wavelength of this spectral line in the spectrum of the galaxy NGC 7469, which is 50.0 Mpc away from the Earth.

wavelength = ... nm **[4]**

(b) State what is meant by the big bang. Describe how it explains the origin of the microwave background radiation.

In your answer, you should make clear how the microwave background radiation supports the Cosmological Principle.

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..... **[5]**

(c) Suggest how the microwave background radiation may evolve in the future.

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

(d) Recent observations of very distant supernovae have shown that the expansion of the universe may be accelerating. It is suggested that this is caused by *dark energy* which has the mysterious property of exerting a repulsive force on the universe. The universe may therefore be *open* rather than *flat* or *closed*.

Fig. 11.1

Complete Fig. 11.1 by sketching a suitable graph to illustrate an open universe. **[1]**

[Total: 15]

2 **(a)** A star radiates energy produced from fusion reactions within its core. Explain what is meant by *fusion* and explain the conditions necessary for fusion to occur in the core of a star.

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

(b) Describe and explain the evolution of a star much more massive than our Sun.

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

[Total: 7]

3 **(a)** In the universe there are about 10^{11} galaxies, each with about 10^{11} stars with each star having a mass of about 10^{30}kg. Estimate the attractive gravitational force between two galaxies separated by a distance of 4×10^{22} m.

force = ... N **[3]**

(b) Explain why the galaxies do not collapse on each other.

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

(c) Describe qualitatively the evolution of the universe immediately after the big bang to the present day. You are not expected to state the times for the various stages of the evolution.

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..... **[6]**

(d) Fig. 10.1 shows some absorption spectral lines of the spectrum of calcium as observed from a source on the Earth and from a distant galaxy.

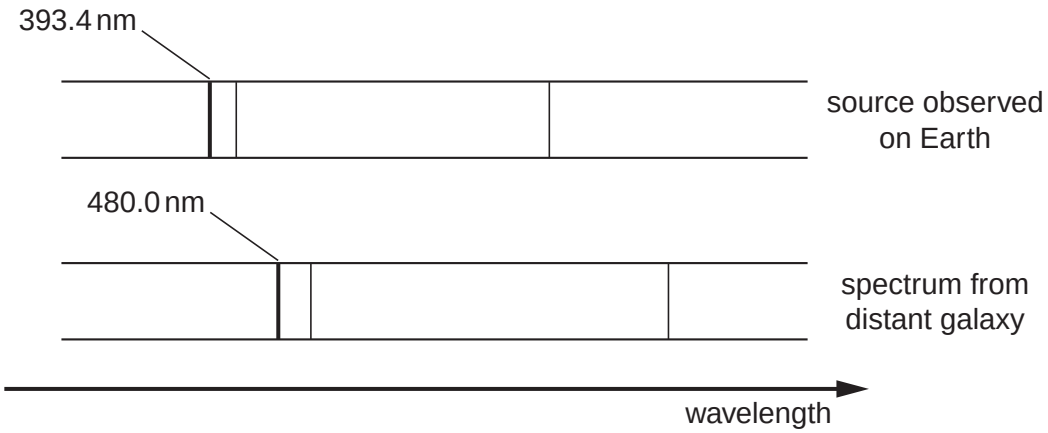

Fig. 10.1

(i) Describe an absorption spectrum.

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

(ii) Use Fig. 10.1 to calculate the distance of the galaxy in Mpc. The Hubble constant has a value of 50 km s^{-1} Mpc^{-1}.

distance = ... Mpc **[3]**

[Total: 15]

4 **(a)** Explain what is meant by the *critical density* of the universe.

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

(b) Cosmologists have determined the Hubble constant to be $65\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$. Calculate the Hubble constant in s^{-1} and hence determine the critical density of the universe.

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

Hubble constant = ... s^{-1}

critical density = ... $\text{kg}\,\text{m}^{-3}$ **[3]**

(c) **(i)** Explain the terms *open*, *closed* and *flat* when describing the possible evolution of the universe. On Fig. 7.1 sketch and label graphs to illustrate your answer.

Fig. 7.1

open .....

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closed .....

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flat .....

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

(ii) Suggest a reason why it is difficult to predict the future of the universe.

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[Total: 8]