1 **(a)** State Hubble's Law.

.....

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

(b) The dark lines of the spectrum observed from a distant galaxy are red-shifted by 15% of their normal wavelengths.

The Hubble constant is estimated to be 65 km s^{-1} Mpc^{-1}. One parsec = 3.1 × 10^{16} m.

(i) Show that the speed of the galaxy is 4.5 × 10^{7} m s^{-1}.

[1]

(ii) Estimate the distance of the galaxy from the Earth.

distance = ... m **[2]**

(iii) Estimate the age of the universe in years.

1 year = 3.2 × 10^{7} s

age = ... y **[2]**

(c) The age of the universe is calculated from the time of the big bang. Describe **two** observations that directly support the idea of the big bang.

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

2 **(a)** Define the *parsec*. Draw a diagram to illustrate your answer.

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

(b) The star Tau Ceti has a parallax of 0.275 seconds of arc.

Calculate the distance of Tau Ceti from Earth

(i) in parsec (pc)

distance = ... pc **[1]**

(ii) in light year (ly).

1 pc = 3.1×10^{16} m

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

[Total: 5]

3 (a) (i) Describe the formation of a star such as our Sun and its most probable evolution.

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

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

(ii) Describe the probable evolution of a star that is much more massive than our Sun.

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

(b) The present mass of the Sun is 2.0×10^{30} kg. The Sun emits radiation at an average rate of $3.8 \times 10^{26}\,\text{J s}^{-1}$. Calculate the time in years for the mass of the Sun to decrease by one millionth of its present mass.

1 y = 3.2×10^{7} s

time = ... y **[3]**

(c) The following nuclear equation summarises a typical fusion reaction cycle that occurs in the Sun.

$$4\,{}^{1}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + 2\,{}^{0}_{1}\text{e} + 2\nu$$

(i) Explain the process of nuclear fusion in the core of the Sun. In your explanation refer to the conditions necessary for fusion to occur.

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

(ii) Name two forms of energy produced in thermonuclear reactions.

1. .....

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

(iii) The binding energy per nucleon of ${}^{1}_{1}\text{H}$ and ${}^{4}_{2}\text{He}$ are 0 and 7.2 MeV respectively. Calculate the energy produced in joules for the fusion reaction above.

energy = ... J **[2]**