Astro Formative *[87 marks]*

1a. Distinguish between the solar system and a galaxy. *[1 mark]*

. . . .

. . . .

. . . .

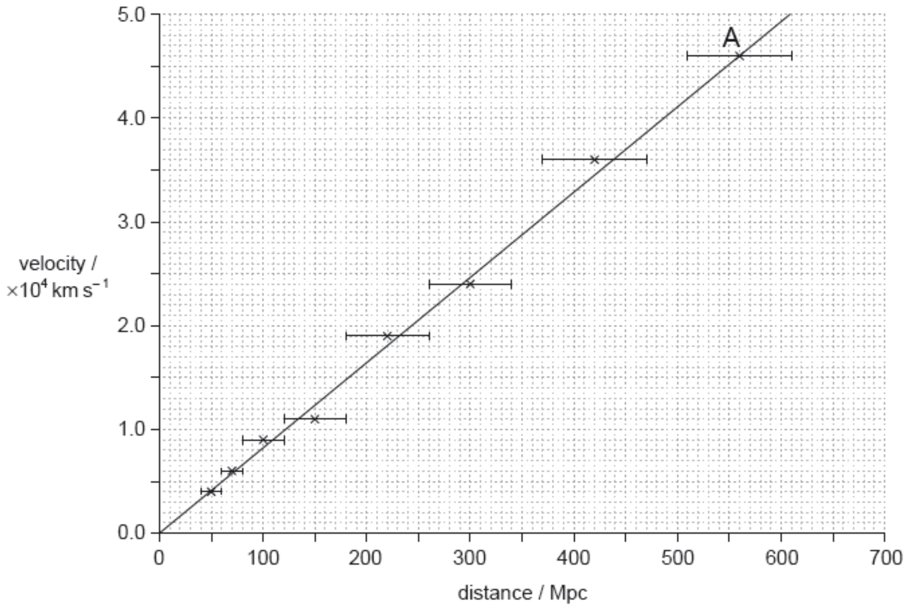
1b. Distinguish between a planet and a comet. *[1 mark]*

. . . .

. . . .

. . . .

Data from distant galaxies are shown on the graph.



2a. Estimate, using the data, the age of the universe. Give your answer in seconds. *[3 marks]*

....

....

....

....

....

....

2b. Identify the assumption that you made in your answer to (a). *[1 mark]*

....

....

....

2c. On the graph, one galaxy is labelled A. Determine the size of the universe, relative to its present size, when light from the galaxy labelled A was emitted. *[3 marks]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

3a. Describe the formation of a type Ia supernova. *[2 marks]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

Type Ia supernovae typically have a peak luminosity of around $5 \times 10^{5}\ L_s$, where L_s is the luminosity of the Sun (3.8×10^{26} W). A type Ia supernova is observed with an apparent peak brightness of $1.6 \times 10^{-6}\ \text{W m}^{-2}$.

3b. Show that the distance to the supernova is approximately 3.1×10^{18} m. *[2 marks]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

3c. State **one** assumption made in your calculation. *[1 mark]*

4a. Outline, with reference to the Jeans criterion, why a cold dense gas cloud is more likely to form new stars than a hot diffuse gas cloud. *[2 marks]*

4b. Explain how neutron capture can produce elements with an atomic number greater than iron. *[2 marks]*

5a. Explain the evidence that indicates the location of dark matter in galaxies. *[3 marks]*

5b. Outline why a hypothesis of dark energy has been developed. *[3 marks]*

....

....

....

....

....

....

Sirius is a binary star. It is composed of two stars, Sirius A and Sirius B. Sirius A is a main sequence star.

6a. State what is meant by a binary star. *[1 mark]*

....

....

....

6b. The peak spectral line of Sirius B has a measured wavelength of 115 nm. Show that the surface temperature of Sirius B is about 25 000 K. *[1 mark]*

....

....

....

6c. The mass of Sirius B is about the same mass as the Sun. The luminosity of Sirius B is 2.5 % of the luminosity of the Sun. Show, with a calculation, that Sirius B is **not** a main sequence star. *[2 marks]*

....

....

....

....

....

....

The Sun's surface temperature is about 5800 K.

6d. Determine the radius of Sirius B in terms of the radius of the Sun. *[2 marks]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

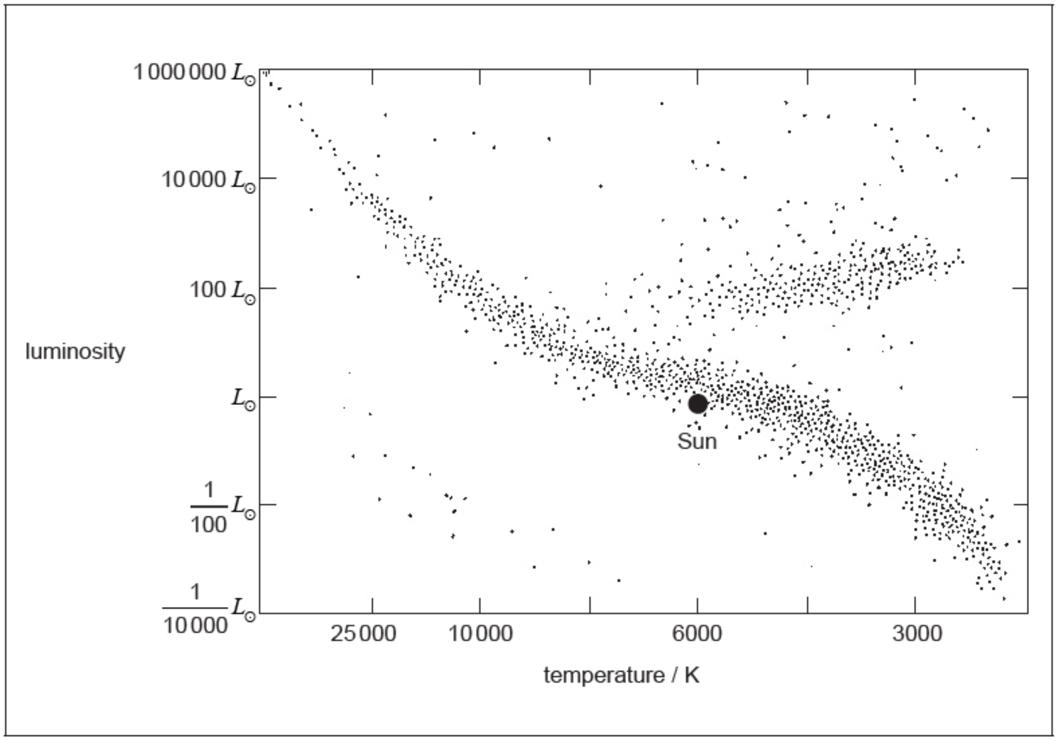
6e. Identify the star type of Sirius B. *[1 mark]*

. . . .

. . . .

. . . .

The image shows a Hertzsprung–Russell (HR) diagram.



The mass of Sirius A is twice the mass of the Sun. Using the Hertzsprung–Russell (HR) diagram,

6f. draw the approximate positions of Sirius A, labelled A and Sirius B, labelled B. *[1 mark]*

6g. sketch the expected evolutionary path for Sirius A. *[1 mark]*

The collision of two galaxies is being studied. The wavelength of a particular spectral line from the galaxy measured from Earth is 116.04 nm. The spectral line when measured from a source on Earth is 115.00 nm.

7a. Outline **one** reason for the difference in wavelength. *[1 mark]*

. . . .

. . . .

. . . .

7b. Determine the velocity of the galaxy relative to Earth. *[2 marks]*

8a. State **two** characteristics of the cosmic microwave background (CMB) radiation. *[2 marks]*

8b. The present temperature of the CMB is 2.8 K. Calculate the peak wavelength of the CMB. *[1 mark]*

8c. Describe how the CMB provides evidence for the Hot Big Bang model of the universe. *[2 marks]*

A spectral line in the light received from a distant galaxy shows a redshift of $z = 0.16$.

8d. Determine the distance to this galaxy using a value for the Hubble constant of $H_0 = 68$ km s^{-1} Mpc^{-1}. *[2 marks]*

....

....

....

....

....

....

8e. Estimate the size of the Universe relative to its present size when the light was emitted by the galaxy in (c). *[2 marks]*

....

....

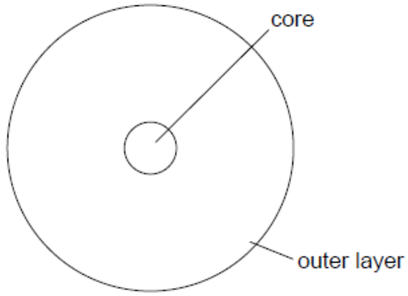
....

....

....

....

The diagram shows the structure of a typical main sequence star.



9a. State the most abundant element in the core and the most abundant element in the outer layer. *[2 marks]*

core: . . . .

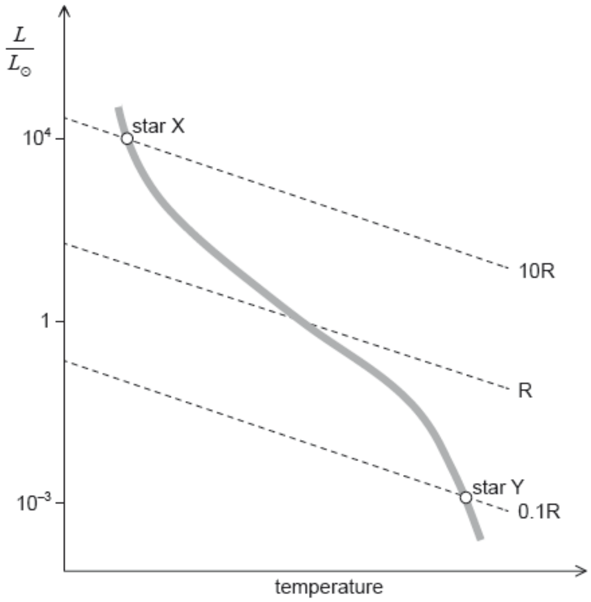
outer layer: . . . .

. . . .

. . . .

. . . .

9b. The Hertzsprung–Russell (HR) diagram shows two main sequence stars X and Y and includes lines of constant radius. *R* is the radius of the Sun. *[3 marks]*



Using the mass–luminosity relation and information from the graph, determine the ratio $\frac{\text{density of star X}}{\text{density of star Y}}$.

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

Star X is likely to evolve into a neutron star.

9c. On the HR diagram in (b), draw a line to indicate the evolutionary path of star X. *[1 mark]*

9d. Outline why the neutron star that is left after the supernova stage does not collapse under the action of gravitation. *[1 mark]*

. . . .

. . . .

. . . .

9e. The radius of a typical neutron star is 20 km and its surface temperature is 10^{6} K. Determine the luminosity of this neutron star. *[2 marks]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

9f. Determine the region of the electromagnetic spectrum in which the neutron star in (c) (iii) emits most of its energy. *[2 marks]*

....

....

....

....

....

....

10a. Describe what is meant by the Big Bang model of the universe. *[2 marks]*

....

....

....

....

....

....

10b. State **two** features of the cosmic microwave background (CMB) radiation which are consistent with the Big Bang model. *[2 marks]*

....

....

....

....

....

....

A particular emission line in a distant galaxy shows a redshift $z = 0.084$.

The Hubble constant is $H_0 = 68$ km s^{-1} Mpc^{-1}.

10c. Determine the distance to the galaxy in Mpc. *[2 marks]*

....

....

....

....

....

....

10d. Describe how type Ia supernovae could be used to measure the distance to this galaxy. *[3 marks]*

....

....

....

....

....

....

11a. Describe what is meant by dark matter. *[2 marks]*

....

....

....

....

....

....

11b. The distribution of mass in a spherical system is such that the density ρ varies with distance r from the centre as *[1 mark]*

$$\rho = \frac{k}{r^2}$$

where k is a constant.

Show that the rotation curve of this system is described by

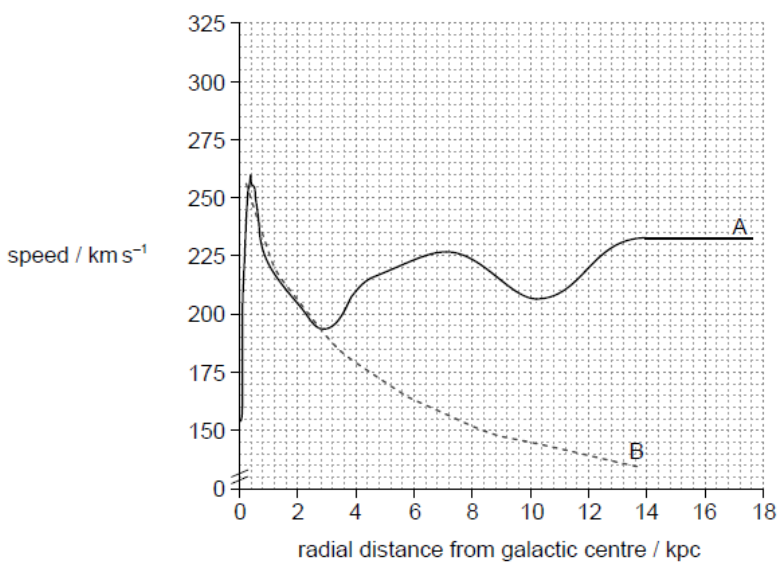
v = constant.

....

....

....

11c. Curve A shows the actual rotation curve of a nearby galaxy. Curve B shows the predicted rotation curve based on the visible stars in the galaxy. *[2 marks]*



Explain how curve A provides evidence for dark matter.

....

....

....

....

....

....

Alpha Centauri A and B is a binary star system in the main sequence.

	Alpha Centauri A	Alpha Centauri B
Luminosity	$1.5L_{\odot}$	$0.5L_{\odot}$
Surface temperature / K	5800	5300

12a. State what is meant by a binary star system. *[1 mark]*

....

....

....

12b. (i) Calculate $\frac{b_A}{b_B} = \frac{\text{apparent brightness of Alpha Centauri A}}{\text{apparent brightness of Alpha Centauri B}}$. *[4 marks]*

(ii) The luminosity of the Sun is 3.8×10^{26} W. Calculate the radius of Alpha Centauri A.

....

....

....

....

....

....

....

....

....

12c. Show, without calculation, that the radius of Alpha Centauri B is smaller than the radius of Alpha Centauri A. *[2 marks]*

....

....

....

....

....

....

12d. Alpha Centauri A is in equilibrium at constant radius. Explain how this equilibrium is maintained. *[3 marks]*

. . . .

. . . .

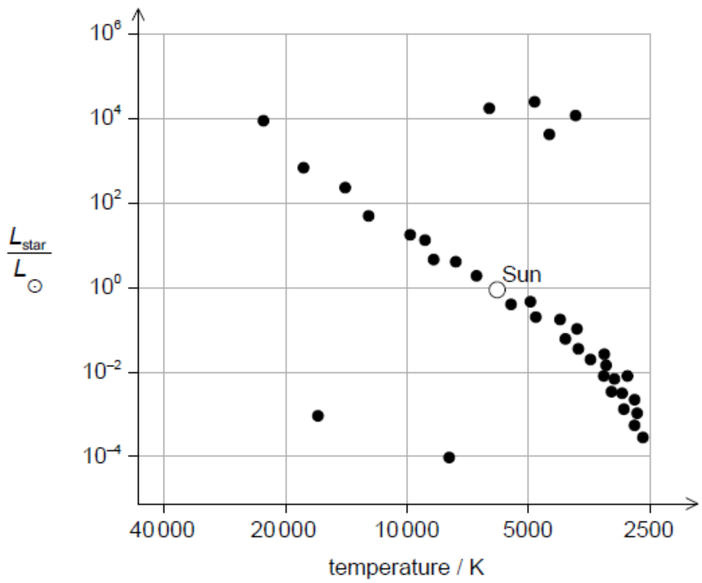
. . . .

. . . .

. . . .

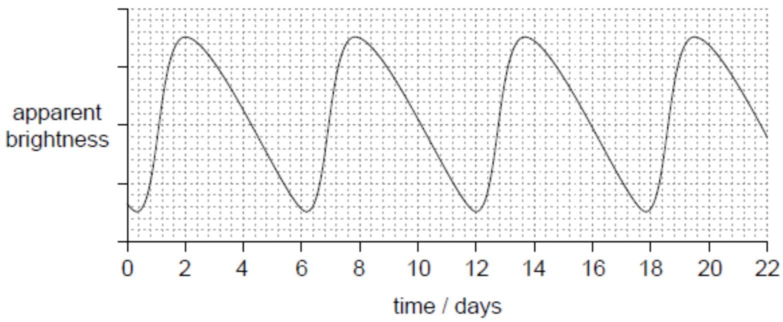
. . . .

12e. A standard Hertzsprung–Russell (HR) diagram is shown. *[2 marks]*

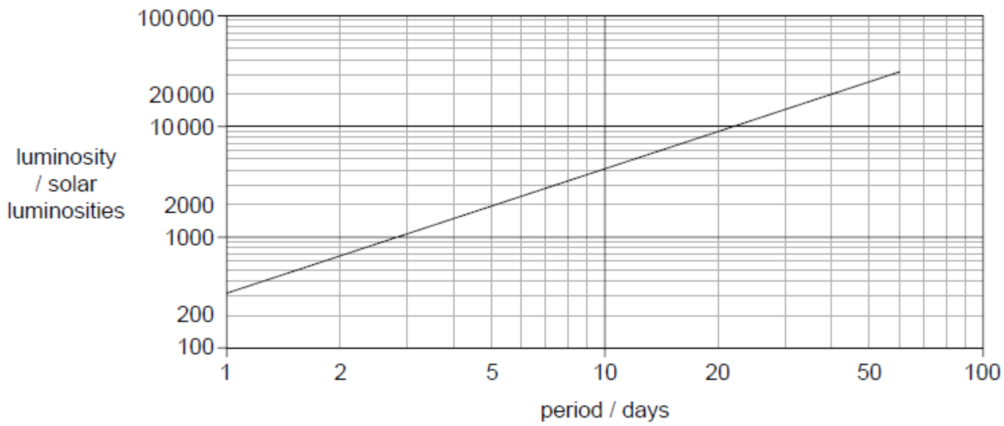


Using the HR diagram, draw the present position of Alpha Centauri A and its expected evolutionary path.

The first graph shows the variation of apparent brightness of a Cepheid star with time.



The second graph shows the average luminosity with period for Cepheid stars.



13a. Determine the distance from Earth to the Cepheid star in parsecs. The luminosity of the Sun is 3.8×10^{26} W. The average apparent brightness of the Cepheid star is 1.1×10^{-9} W m^{-2}. *[3 marks]*

....

....

....

....

....

....

13b. Explain why Cephids are used as standard candles. *[2 marks]*

....

....

....

....

....

....