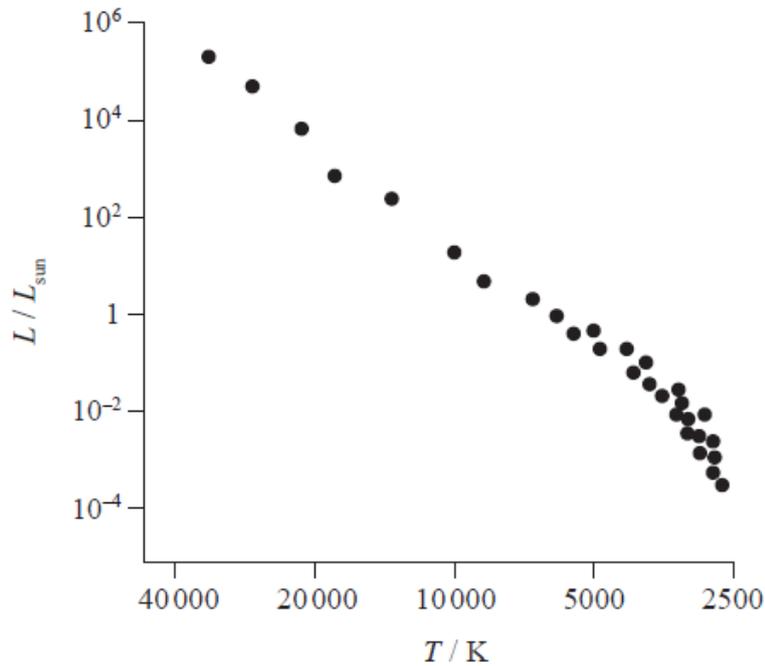# Astrophysics 1

1.

The Hertzsprung-Russell (H-R) diagram is a plot of luminosity against temperature for a range of stars.

(a) The H-R diagram below shows a number of main sequence stars.

(i) Label the position of our Sun on the diagram.

(1)

(ii) Label on the diagram the regions in which white dwarf and red giant stars would be located.

(2)

*(iii) Stars known as white dwarf stars have small surface areas. Explain how astronomers have deduced this.

(3)

....

....

....

....

....

....

2.

The table shows the properties of three stars.

Star	Luminosity / L_{Sun}	Temperature / K	Type of star
Spica (S)	2.25×10^3	22,500	
Vega (V)	50.1	9,500	
Barnard's Star (B)	4.33×10^{-4}	3,000	Red Dwarf

(a) (i) Complete the table.

(2)

(ii) Use the letters S, V, and B to mark the approximate position of each star on the Hertzsprung-Russell diagram.

(1)
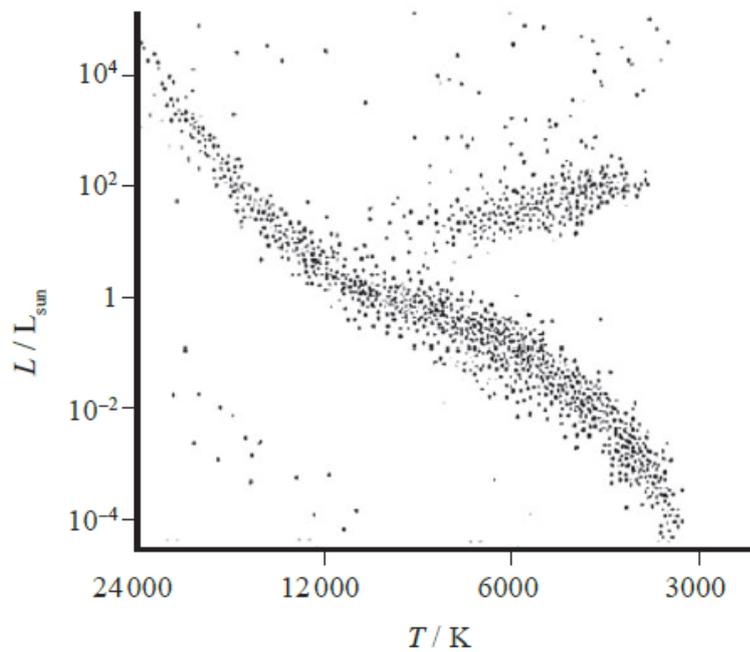
(b) By means of a calculation show that Barnard's Star would appear as a red star in the sky.

(3)

....

....

....

....

....

....

(c) Calculate the radius of Vega.

luminosity of the Sun = $3.85 \times 10^{26}\,\text{W}$

(2)

....

....

....

....

....

Radius of Vega = ...

(d) Vega appears to be much brighter than Spica in the night sky, although Spica has a much greater luminosity.

Explain why this is the case.

(3)

....

....

....

....

....

3.

(a) Describe how the recession speed v of a distant galaxy can be determined using a diffraction grating to analyse the light from the galaxy.

....

....

....

....

....

.... **[3]**

(b) A group of astronomers determined the distance d of a galaxy and its recession speed v. Their results are shown below.

$$d = 11 \pm 2\,\text{Mpc} \qquad v = 740 \pm 20\,\text{km s}^{-1}$$

(i) Calculate a value for the Hubble constant in $\text{km s}^{-1}\,\text{Mpc}^{-1}$.

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

(ii) Determine the age of the universe in years. Include an absolute uncertainty in your value.

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

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

age = ... ± .... y **[4]**

(iii) The answer in **(ii)** is from the observation on one galaxy alone.
Describe how the astronomers can obtain a much more reliable value for the age of the universe from a graph of v against d for many galaxies.

-- **[2]**

(iv) Use your answer to **(ii)** to estimate the farthest distance D that astronomers can observe from the Earth.

D = ... m **[2]**

4.

Fusion reactions produce energy in the core of stars. The fusion of protons (^1_1H) in stars like our Sun can be summarised by the following nuclear reaction.

$$4^1_1H \rightarrow \, ^4_2He \; + \; 2^0_1e \; + \; 2\nu$$

(a) Name the particles ^0_1e and ν.

^0_1e : .... ν : .... **[1]**

(b) Explain in terms of the masses of the particles why energy is released in the reaction shown above.

....

....

....

.... **[2]**

(c) State and explain the conditions in the core of stars that make fusion possible.

....

....

....

....

....

....

.... **[4]**

(d) Describe the formation of a star much more massive than our Sun from a large dust and gas cloud and its most probable evolution to death.

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

....

.... -7-

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

.... **[6]**

5.

Fig. 11.1 shows a diagram of Andromeda, our nearest galaxy.

Fig. 11.1

Andromeda is 2.4×10^{22} m from the Earth. It has a diameter of 1.3×10^{20} m.

(a) Calculate the maximum angle in degrees subtended by Andromeda at the Earth.

angle = ... ° **[1]**

(b) All the stars in Andromeda rotate about its centre. Some stars in Andromeda are moving towards us and some are moving away from us. The outermost stars in Andromeda have a rotational speed of $2.5 \times 10^5 \mathrm{m\,s^{-1}}$.
The wavelength of the hydrogen-alpha spectral line in the laboratory is 656.3nm. The wavelength of this spectral line from the outermost stars is Doppler shifted when observed from the Earth.
Calculate the change in wavelength of this spectral line due to this rotation.

change in wavelength = ... nm **[2]**

(c) The circular motion of the outermost stars is due to the gravitational attraction of all the stars in Andromeda. Assume that the mass of Andromeda providing the gravitational force on these outermost stars is all at the centre of this galaxy.

The average mass of a star is 2.0×10^{30} kg.

Estimate the total number of stars in Andromeda.

number of stars = ... **[4]**

6.

(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 $\dfrac{\text{mean density of Antares}}{\text{mean density of Sirius-B}}$

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

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

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

7.

(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	$z / 10^{-3}$	$v / 10^3 \, \text{m s}^{-1}$	$d / 10^{23} \, \text{m}$
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]

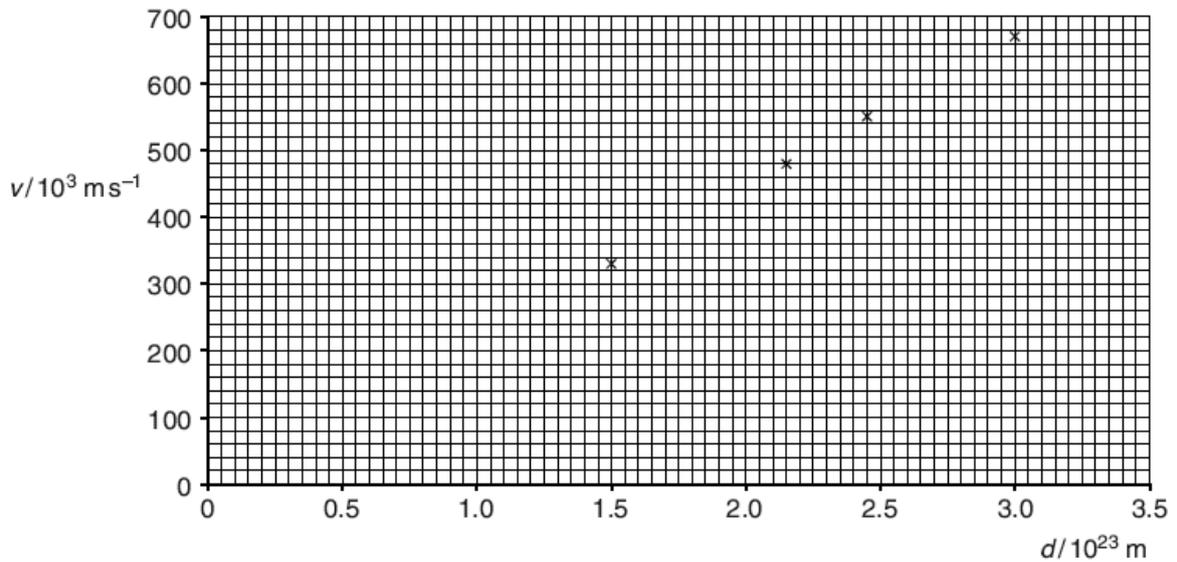**(ii)** Fig. 11.2 shows the data for the first four galaxies plotted on a v against d graph.

Fig. 11.2

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

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]**

8.

(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.

....

....

.... **[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.

....

....

....

....

....

....

....

....

....

....

....

....

....

.... **[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.
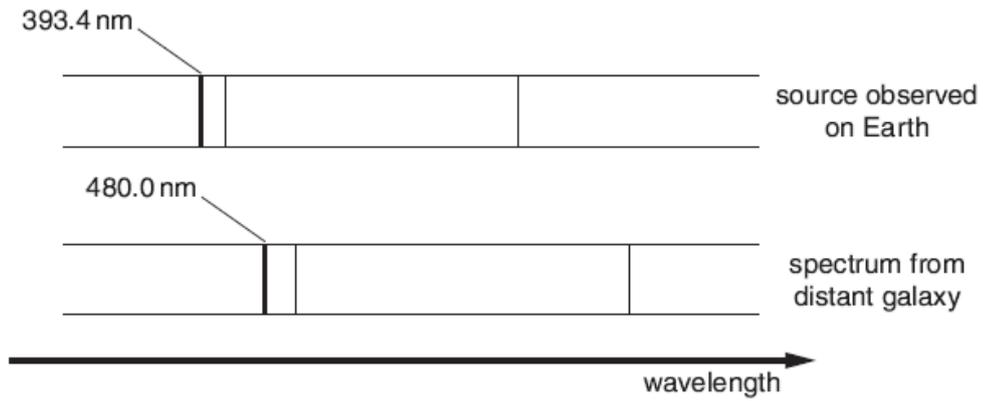

Fig. 10.1

(i) Describe an absorption spectrum.

....

....

....

....

.... **[2]**

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

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

9.

Rigel A in the constellation of Orion is one of the brightest stars in the sky. It is a massive blue variable star with an intensity peak at a wavelength λ_{max} of 0.25 µm.

(a) On the axes below, sketch a graph of the intensity of radiation emitted by Rigel A against the wavelength of that radiation.

(2)
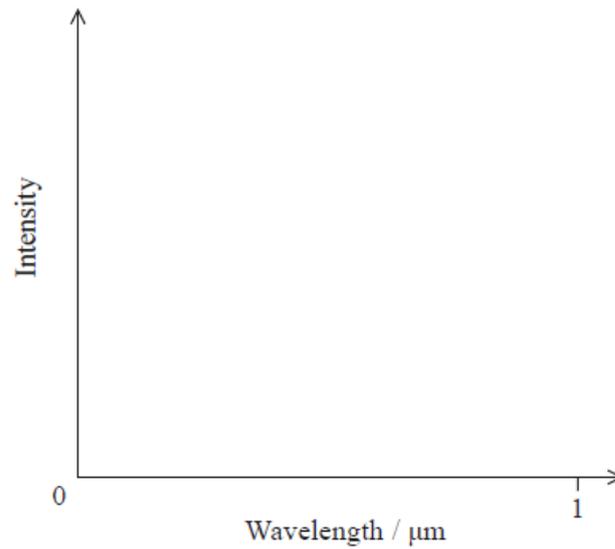
(b) The graph below shows how λ_{max} varies with temperature T for a black body radiator.
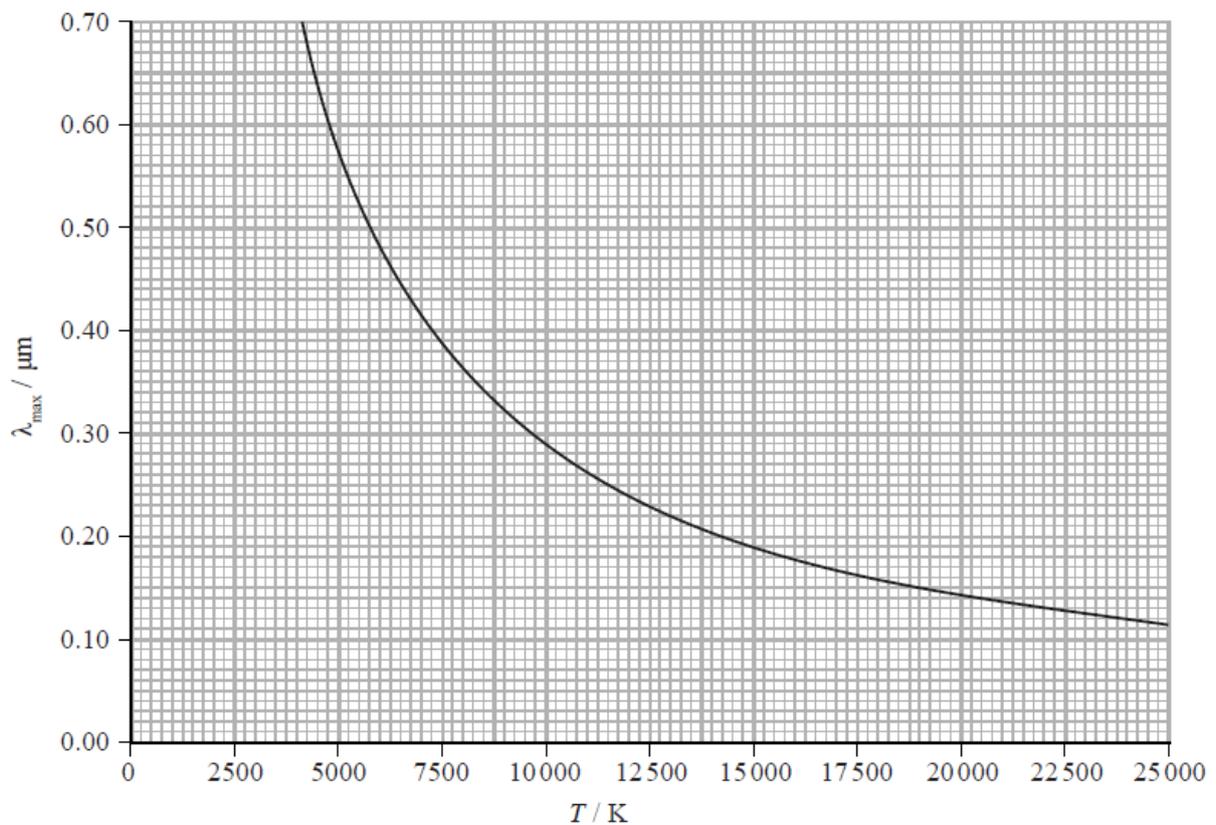
(i) Use the graph to estimate the surface temperature of Rigel A.

(1)

....

(ii) Show that the graph is consistent with Wien's law.

(3)