12 ATAR Physics

Hubble's Law (Part 2) 2018

Name: ________________________________ **Mark:** $\overline{}$ 55

The Big Bang Theory & Hubble's Law

When a source of waves is moving, a stationary observer notices an apparent change in the frequency of the waves. This effect is observed for both longitudinal and transverse waves. For example, if an ambulance moves towards you, the sound frequency you hear is higher than the frequency its siren is emitting. This is known as the Doppler Effect.

If a source of electromagnetic waves, such as a star, is travelling away from an observer, the wavelengths of the lines in its electromagnetic spectrum are shifted to higher values. This is called ***red-shift***. An equation for the relationship is as follows:

$$z = \frac{\Delta\lambda}{\lambda}$$ It can also be shown that: $$z = \frac{v}{c_0}$$

where
- z = red-shift
- $\Delta\lambda$ = change in wavelength (moving source) (nm)
- λ = wavelength of stationary source (nm)
- v = recessional speed of galaxy (ms^{-1})
- c_0 = speed of light in a vacuum (ms^{-1})

Edwin Hubble analysed the red-shifts of various galaxies in 1920 and deduced that most galaxies are moving away from the Earth. This suggests that the universe is expanding. Hubble also discovered that the further away a galaxy is, the bigger its red-shift and the faster it is moving away. This relationship is known as Hubble's Law and can be stated algebraically as follows:

$$v_{galaxy} = H_0 . d$$

V_{galaxy} = recessional speed of galaxy (kms^{-1})
d = distance to galaxy (Mpc)
H_o = Hubble's constant ($kms^{-1}Mpc^{-1}$)

The distances to galaxies can be estimated by observing Cepheid variables within a galaxy. A Cepheid variable is a class of star that pulsates. The relationship between the period of pulsation and the size of the star is very precise. An understanding of how brightness diminishes with distance allows astronomers to estimate distances to galaxies with a high degree of confidence.

(a) Using the data points collected previously in part 1 and a line of best fit, plot a correctly labelled graph that will allow you to determine an accurate value of Hubble's constant. [7 marks]

(b) Calculate a value for Hubble's constant, in the correct units, showing how you obtained this value from your graph. [4 marks]

(c) Write the equation of the line you have drawn. [2 marks]

(d) State ***three reasons*** why you think that measurements of Hubble's constant have varied widely since Hubble's first determination in 1920.

[3 marks]

(e) Explain why the value of red-shift ***z*** has no units? [2 marks]

(f) A line in the spectrum of ionised calcium has a wavelength of 393.3 nm when measured in the laboratory. When similar light from the galaxy NGC 3350 is measured, its wavelength is 394.64 nm.

(i) Calculate the red-shift of this galaxy. [2 marks]

(ii) Calculate the recessional speed of this galaxy in kms^{-1}. [3 marks]

(g) For the recessional speed previously calculated, use your graph and the line of best fit to determine the distance to this galaxy in Mpc. [1 mark]

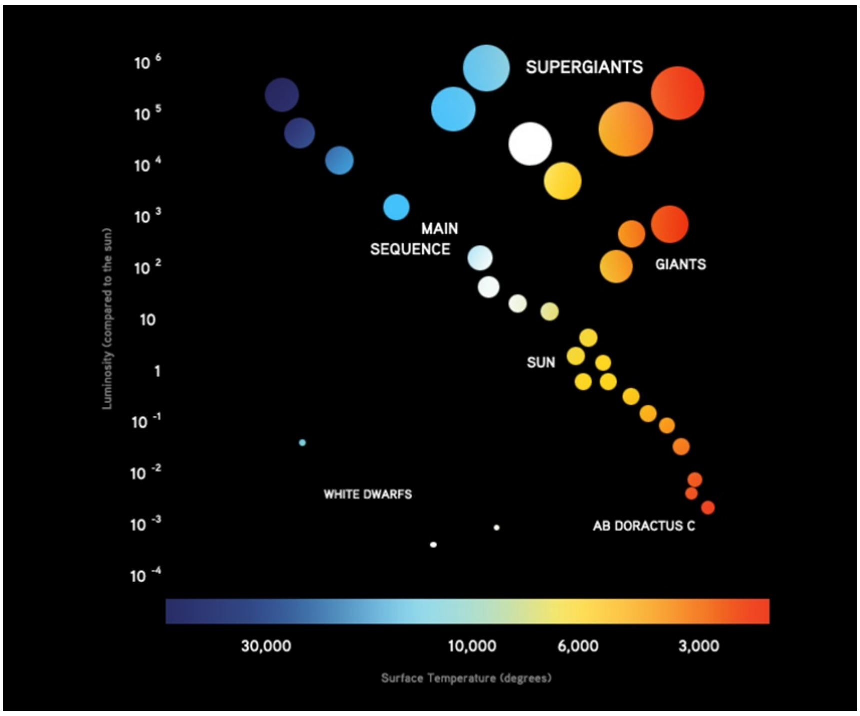
(h) Determine how many years it takes for light from galaxy NGC 3350 to reach Earth. [2 marks]

Classifying Stars

H-R Diagrams

The Hertzsprung–Russell diagram, abbreviated H–R diagram or HRD, is a scatter graph of stars showing the relationship between the stars' absolute magnitudes or luminosities versus their spectral classifications or effective temperatures. More simply, it plots each star on a graph measuring the star's brightness against its temperature (colour). It does not map any locations of stars.

The diagram was created circa 1910 by Ejnar Hertzsprung and Henry Norris Russell and represents a major step towards an understanding of stellar evolution or "the way in which stars undergo sequences of dynamic and radical changes over time".



Now watch this You-tube video and answer the following questions:

https://www.youtube.com/watch?v=UwW_FbPE1R8

a) Use the data table shown below to construct a H-R diagram for the stellar objects shown in the table. Use the identification number, 33, 34, 35, etc. to show where the object lies on the diagram. **[4 marks]**

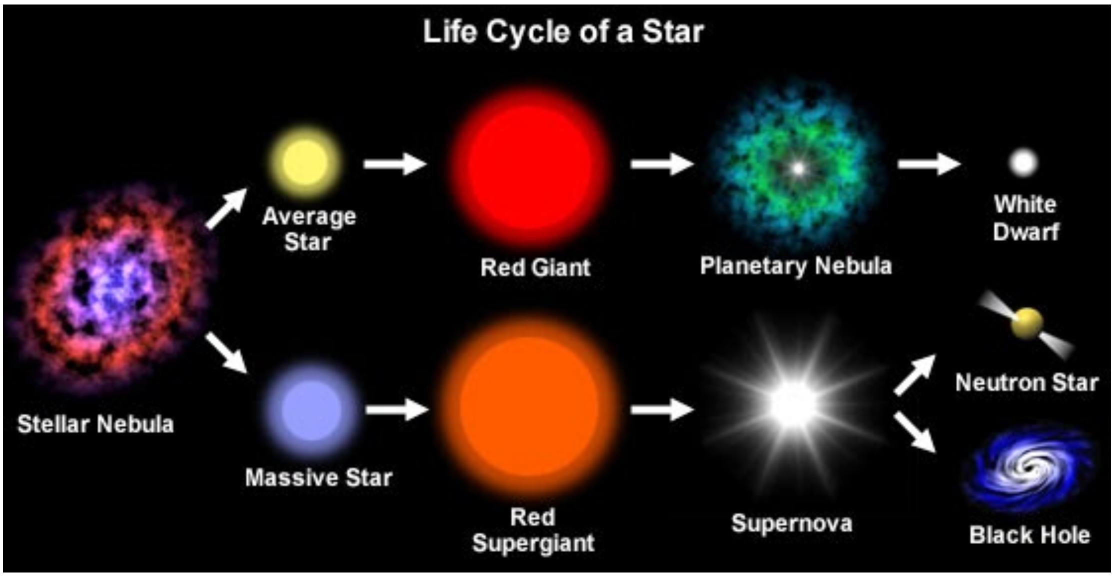
	Group 3	Visual Magnitude (Apparent)	Distance (light-years)	Temperature (Kelvin)	Luminosity (Sun = 1) (Absolute)
* 33	Sirius B	+8.5	8.7	10,700	0.0024
* 34	Procyon B	+10.7	11.3	7,400	0.00055
* 35	Grw +70 8247	+13.19	49	9,800	0.0013
* 36	L 879-14	+14.10	63?	6,300	0.00068
* 37	Van Maanen's Star	+12.36	14	7,500	0.00016
* 38	W 219	+15.20	46	7,400	0.00021
* 39	Barnard's Star	+9.54	6.0	2,800	0.00045
* 40	Luyten 789-6	+12.58	11.0	2,700	0.00009
* 41	Canopus	-0.72	100.0	7,400	1,500.0
* 42	Capella	+0.05	47.0	5,900	170.0
* 43	Rigel	+0.14	800.0	11,800	40,000.0
* 44	Alpha Crucis	+1.39	400.0	21,000	4,000.0

b) Complete the table (below) for the group 3 objects shown above.

[4 marks]

Group 3 object	H-R classification of object
Sirius B	
Barnard's Star	
Rigel	
Alpha Crucis	

Consider the diagram shown below. It shows a very simplified life cycle of a star.



c) Use this to suggest what the future of the sun might be. Explain your answer.
[4 marks]

____

____

____

____

____

____