Topic 10: Space

1.0 Specification notice:

Mathematical skills that could be developed in this topic include using approximations and sketching relationships which are modelled by $y = k/x^2$.
This topic may be studied using contexts such as the formation and evolution of stars and the history and future of the universe.

10.Q Exam questions

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Q10.

The Hertzsprung-Russell diagram is a diagram used by astronomers to illustrate the properties of stars.

Label the axes below (or the next page) and use them to sketch a Hertzsprung-Russell diagram.
Your diagram should include labelled regions where the following stars are found:

- main sequence
- red giants
- supergiants
- white dwarfs

(4)

Draw a diagram of a hertzsprung-Russell diagram?

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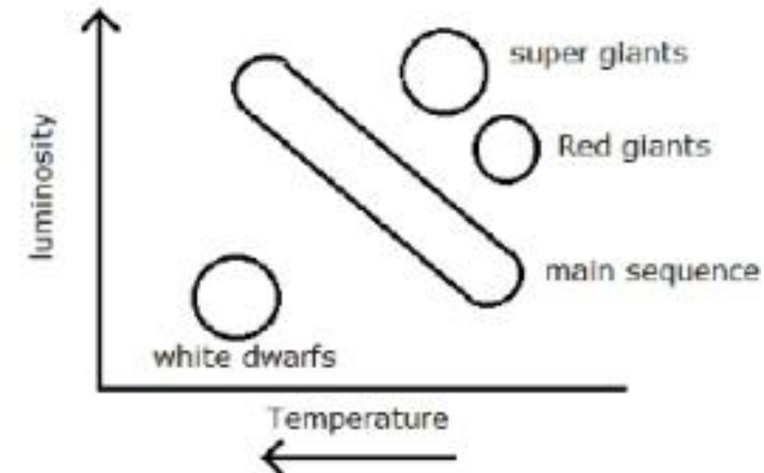
Example of graph:



y axis: luminosity (/ luminosity of Sun) (1)

x axis: (surface) temperature, with indication of decreasing temperature (1)

2 or 3 correct regions (1)

4 correct regions (1)

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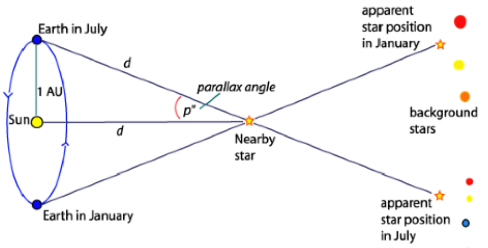
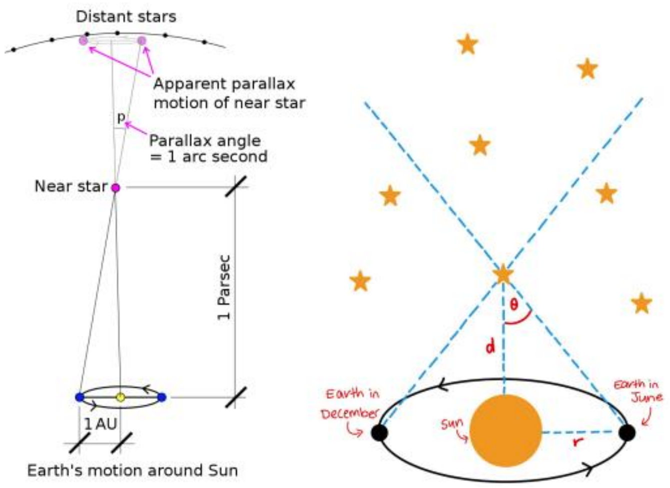
10.156 be able to use the equation, intensity $I = \frac{L}{4\pi d^2}$ where *L* is luminosity and *d* is distance from the source

What is the equation for intensity using luminosity and the meaning for each variable?	$I = \frac{L}{4\pi d^2}$ ● Where I = intensity ● L = luminosity ● d = distance from the source (e.g from earth to object, depends on the scenario) ● Brightness of star proportional to intensity at Earth *This equation assumes: The power from the star radiates uniformly through space. No radiation is absorbed between the star and the Earth*
What is the symbol and calculation for an arcsecond, arcminute from a degree	● 1 Arcminute = 1/60th of a degree (symbol = ‘) ● 1 Arcsecond = 1/3600th of a degree (symbol = “) *1 Arcminute = 1/60th of an arcsecond*

10.157 understand how astronomical distances can be determined using trigonometric parallax

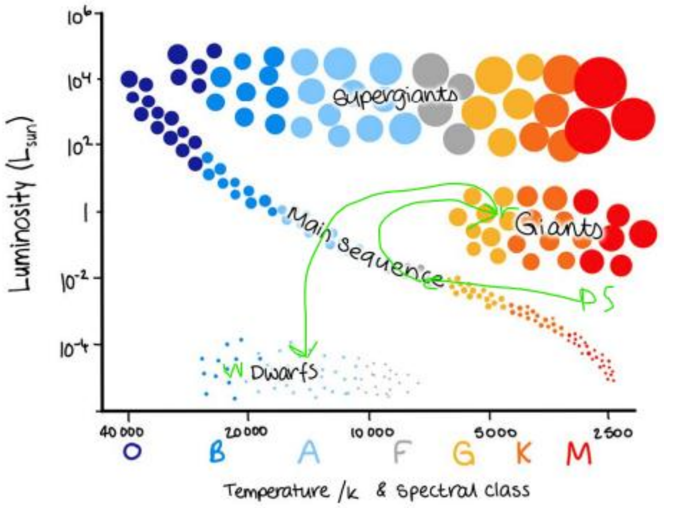
Describe how trigonometric parallax is used to measure distances of nearby stars? (3)	● A star is viewed from 2 positions at 6 month intervals (1) [or the star is viewed from opposite ends of its orbit diameter about the sun] ● The change in angle/position of the star against backdrop of fixed stars is measured (1) ● Trigonometry is used to calculate the distance to the star (1) [or the diameter/radius of Earth’s orbit about the sun must be known]  Parallax of nearby star
Why is the trigonometric parallax not used beyond a certain distances (2)	● The parallax angle becomes very small (or the diameter of the Earth’s orbit is very small) (1) ● Giving a large percentage uncertainty (1)

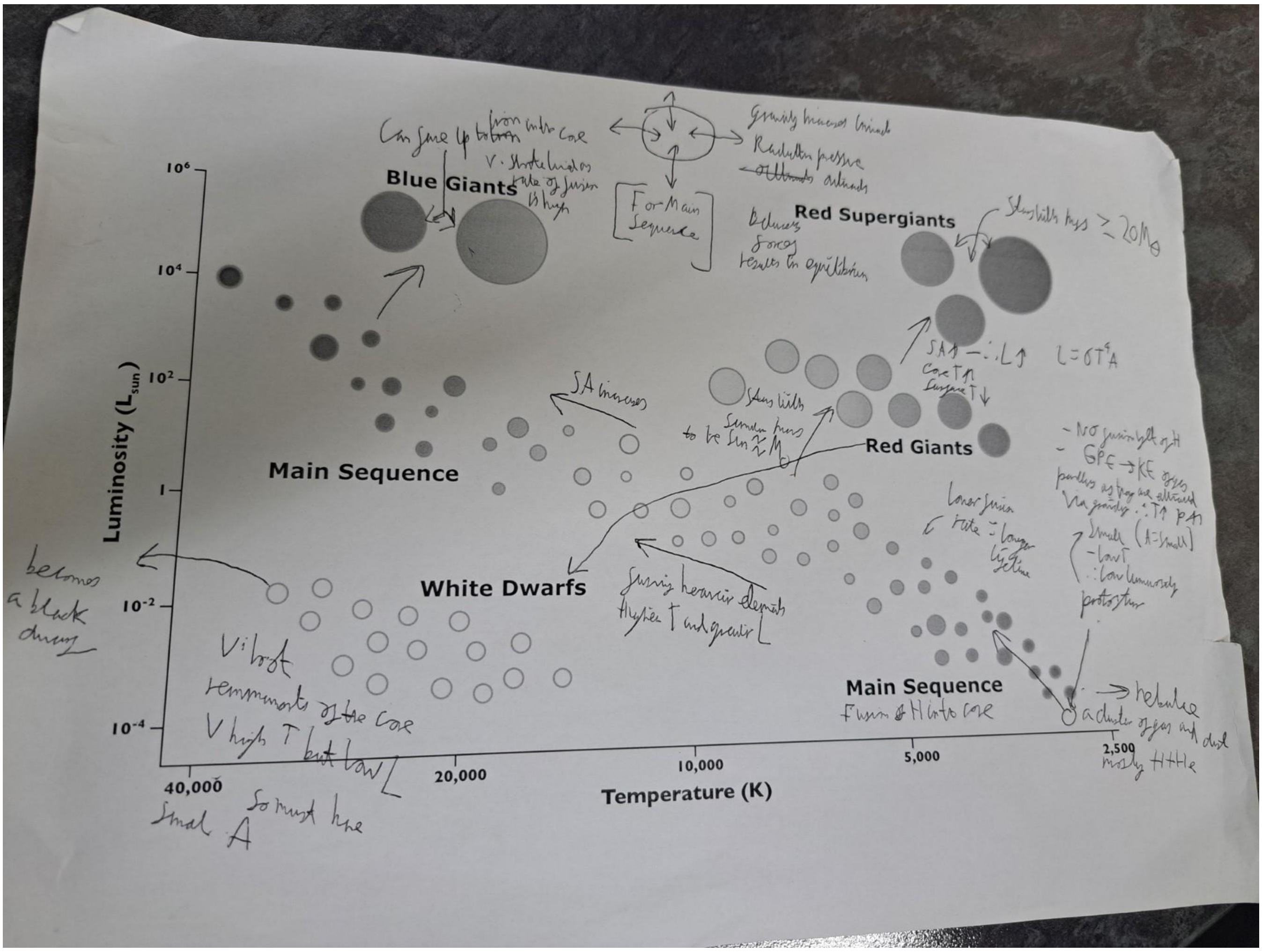
What is 1pc defined as?	● 1pc is the “the distance at which 1 AU subtends an angle of 1/3600th a degree”. ● Using ≅ r / theta from the diagram below, 1 pc = 1 AU / (1 degree in arcsecond). ● d=r/ϴ You can use the angle of parallax (θ) to find the distance, **d** (as shown in the diagram below on the right), using trigonometry. $\tan\theta = \frac{opp}{adj} \rightarrow \tan\theta = \frac{r}{d} \rightarrow \quad d = \frac{r}{\theta}$ As tan θ ≈ θ for small θ Where **d** and **r** are in metres and **θ** is in radians. These are labelled on the diagram below on the right.  *Due to small angle approximations we say tan***ϴ** = **ϴ**
What is 1 light year?	1ly = 9.46x15m (just be aware of how to work it out) *From 3x10*^{8} *x 60 x 60 x 24 x 365*

10.158 understand how astronomical distances can be determined using measurements of intensity received from standard candles (objects of known luminosity)

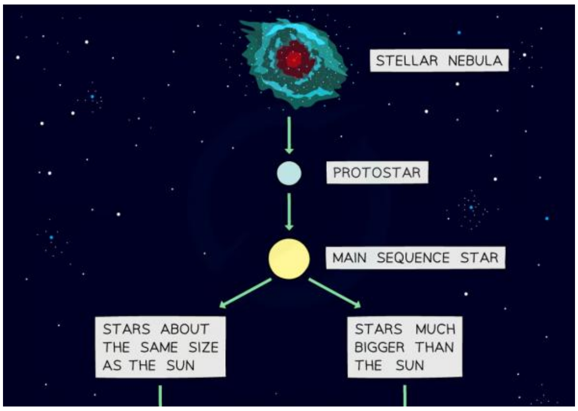
Define standard candle (1)	An object for which its luminosity is known (1)
At what distances from the solar system to astronomical objects should you use trigonometric parallax, Hubble’s law, red shift and standard candle?	● Nearby star (e.g black hole in milkyway): trigonometric parallax ● Nearby galaxy (eg. andromeda galaxy): standard candle ● Very distant galaxy: red shift and Hubble’s law

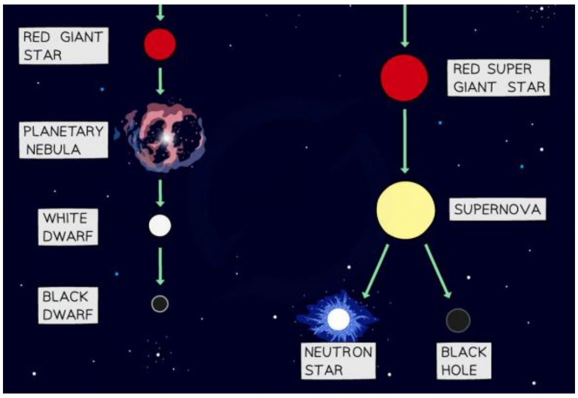
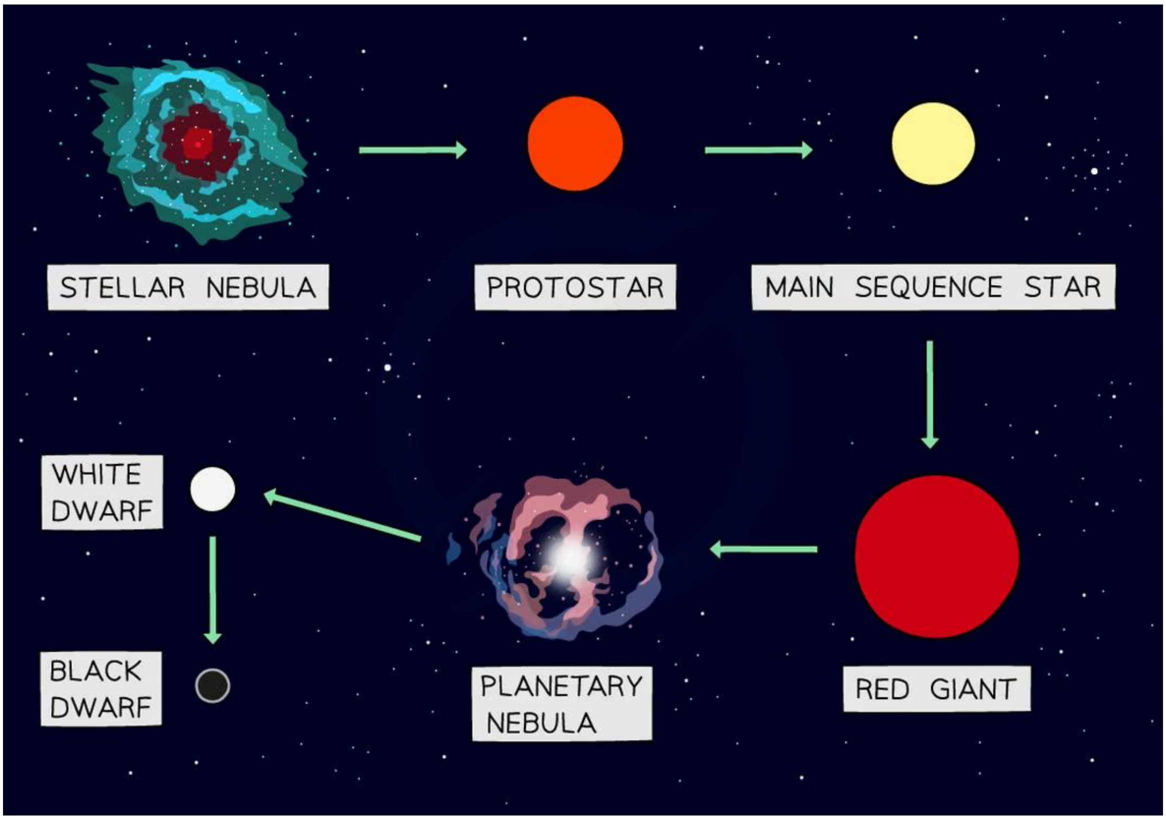
10.159 be able to sketch and interpret a simple Hertzsprung-Russell (HR) diagram that relates stellar luminosity to surface temperature

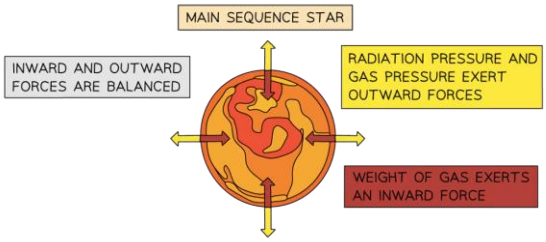
Draw a Hertzsprung-Russell diagram with the sun's position and explain its 3 characteristics?	 You must be able to draw and interpret a HR diagram, like the one above. ● *Temperature on x-axis (increasing right to left)* ● *Y-axis is logarithmic* ● *X-axis is roughly from 50,000K to 2500K*

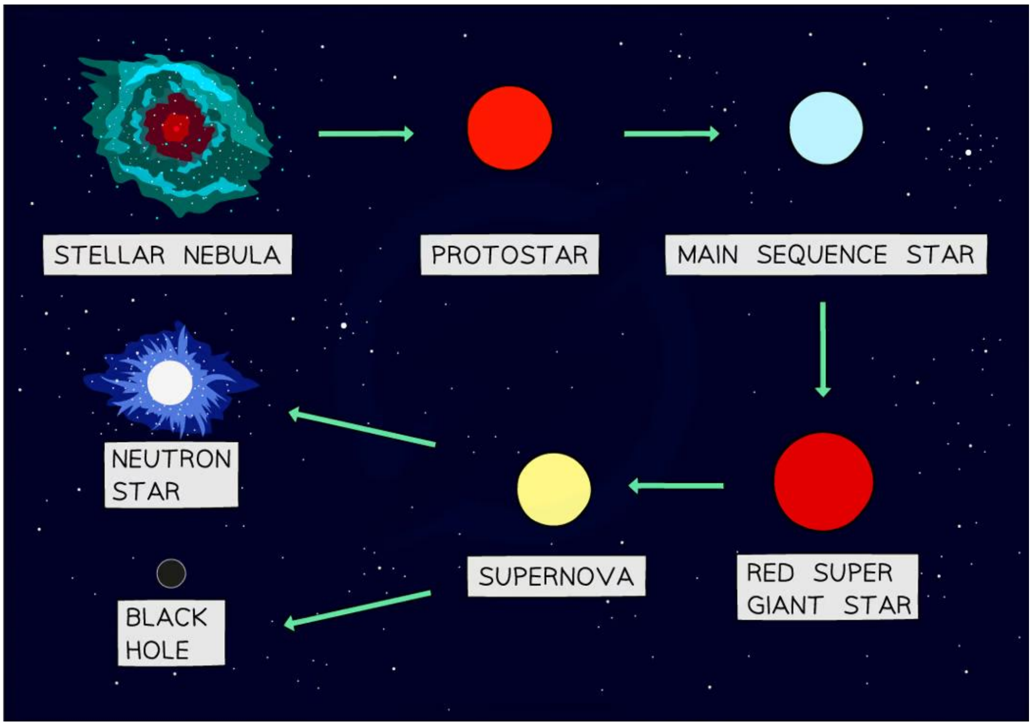


10.160 understand how to relate the Hertzsprung-Russell diagram to the life cycle of stars

What are the 7 stages for the life style of a star with a similar and larger size than our sun?	

	
FOR STARS SIMILAR SIZED TO OUR SUN 	
Describe the characteristics of a nebula?	● A cloud of hydrogen gas and dust ● Where there is only an inwards force of gravity
Describe the characteristics of a protostar?	● A cloud of hydrogen gas and dust held together under gravity pulled inwards to form a denser centre core called a protostar ● GPE -> KE *On a HR diagram its temp and press increases as well as its Surface Area is small so low temps -> low luminosity [L = AσT^4}*
Describe the characteristics of a main sequence star (MS)? (2)	● Stars are primarily converting hydrogen to helium in their core via nuclear fusion (1) ● Stars on the main sequence maintain a constant

	luminosity for most of their lifetime (1) ● The inward gravitational attraction = outward radiation pressure in equilibrium  *On the HR diagram the higher the temperature of MS star the greater its SA and L [L = AσT^4}*
Describe the characteristics of a red giant? (for a star < 1.4 solar masses)	● Hydrogen in the core runs out as most of the hydrogen nuclei have fused to make helium ● The core collapses ● Nuclear fusion slows as energy release by fusion decreases as helium nuclei form heavier elements ● The outer layers begins to expand and cool *On a HR diagram its surface area increases from MS so greater luminosity, the core temp increases whilst surface temp decreases [L = AσT^4}* *Energy release decreases due to the binding energy per nucleon increasing*
Describe the characteristics of a white dwarf and black dwarf? (for a star < 1.4 solar masses)	● When the red giant has used up all its fuel, fusion stops and the core collapses as the inward gravitational attraction is greater than the outward radiation pressure ● The core becomes very dense making a white dwarf ● A white dwarf cools to form a black dwarf *On a HR diagram very high core temp but low luminosity so has small SA [L = AσT^4}*
FOR STARS LARGER THAN OUR SUN ABOUT X10	



Describe the characteristics of a red super giant (for star >1.4 solar masses)	• When a high mass star (greater than our sun) runs out of hydrogen nuclei • The hydrogen nuclei have fused to make helium • Nuclear fusion slows as energy release by fusion decreases as helium nuclei form heavier elements • The outer layers begins to expand and cool *On a HR diagram its surface area is greater than red giants so greater luminosity, the core temp increases whilst the surface temp decreases [L = A* σ *T*^{4}*}* *Energy release decreases due to the binding energy per nucleon increasing*
Describe the characteristics of a supernova (for a star >1.4 solar masses)	• When fusion stops the core collapses inwards as the inward gravitational attraction is greater than the outward radiation pressure • The outer layer is blown out in an explosion as it becomes too dense • Core remnants after explosion form a neutron star • Outer remnants form a planetary nebula
Describe the characteristics of a neutron star (for a star between 1.4 and 3 solar masses)	• Core remnants after explosion of supernova, where the inward gravitational attraction is so strong that it forces protons and electrons together to form neutrons
Describe the characteristics of a black hole (for a star >3 solar masses)	• If the neutron core mass is >3 SM, the pressure on the core becomes so great that the core collapses and produces a black hole

10.161 Understand how the movement of a source of waves relative to an observer/detector gives rise to a shift in frequency (Doppler effect)

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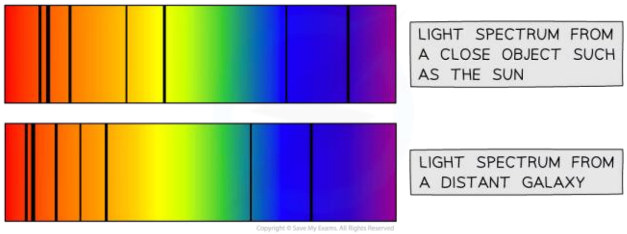
<td>What is the Doppler effect? And state what happens to the freq when a observer moves towards or away from a source</td>
<td>The change in wavelength or frequency of the radiation from a source due to its relative motion away from or towards the observer

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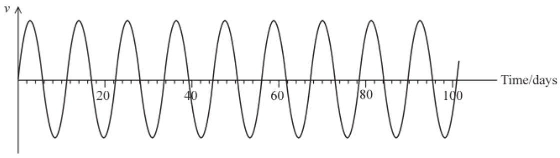
<td>14 In 2016 astronomers announced the discovery of an Earth-like planet orbiting Proxima Centauri, the closest star to the Sun.

The planet was detected because of the small movement of the star as the planet orbited. The movement was detected using the Doppler shift in the frequency of light travelling to the Earth.

The graph shows how the component of the star's velocity v towards the Earth varied over time.


(a) Explain how the Doppler shift was used to obtain the data shown on the graph.
(4)

Explain how the Doppler shift was used to obtain the data shown on the graph? (4)</td>
<td>The frequency/wavelength (of a line in the spectrum) emitted by the star must be measured **(1)**

Determine the difference between this frequency/wavelength and that emitted in the lab **(1)** — MP2 – accept in terms of difference between measured frequency/wavelength with average frequency/wavelength

(The Doppler equation is used to) determine the speed of the star (relative to the Earth) $v/c = \Delta f/f_0$ or $v/c = \Delta\lambda/\lambda_0$ **(1)**

Clear indication (stated in words or via a formula) that v is positive/approaching when the frequency has increased and negative/receding when it has decreased
Or corresponding statement about wavelength **(1)**
The frequency of a line on spectrum emitted by the star must be measured
Determine the difference between this freq and that emitted in the lab
The dopper equation used to determine the speed of the star relative to Earth (write equation)
State that v is positive when the freq has increased [source moving towards observer]
And negative/receding when it has decreased [source moving away from observer]</td>
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<td>Define redshift?</td>
<td>The increase in wavelength (or decrease in frequency) due to the source and observer receding from each other

In your exam, be sure to emphasise that redshift means the wavelength of spectral lines increases towards the red end of the spectrum, do not say that the spectral lines become red, as this is incorrect.

Blue shift is if the object is moving towards the earth/observer</td>
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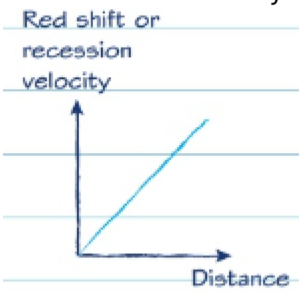
10.162 be able to use the equations for redshift $z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$ for a source of electromagnetic radiation moving relative to an observer, and v = H_0d for objects at cosmological distances

What is the formula for the redshift and the meaning of each variable?	$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$ *Where* **λ** (or f) is the wavelength of a stationary source (e.g hydrogen from earth), v is the recessional velocity of a star in a distant galaxy and Z is red shift

10.163 understand the controversy over the age and ultimate fate of the universe associated with the value of the Hubble constant and the possible existence of dark matter.

State Hubble's Law and whats its equation?	The recessional velocity of galaxies is directly proportional to their distance away from the observer. v =H_0d  *So suggests all distant galaxies are moving away from us*
How can we estimate the age of the universe through using a recessional velocity against distance from Earth graph? (3)	● Find the gradient (1) ● Through v =H_0d where d=v/H_0 and so 1/H_0=d/v -> t=1/H_0 = 1/gradient (1) ● Calculate t (1) *Units for H_0 is s^{-1}*, *the graph shows v ∝ d*

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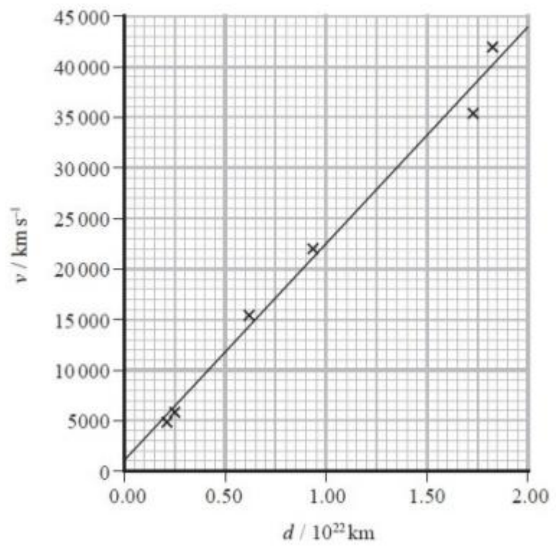
<td>
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<td>About 100 years ago the first measurements of spectra from galaxies beyond the Milky Way were made. Wavelengths of spectral lines were observed to be shifted and Hubble discovered a rough correlation between the shift in the spectral line and the distance to the galaxy.

The graphs below show plots for data collected in 1929 (Figure 1) and 1931 (Figure 2).

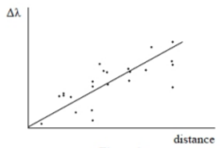

Figure 1

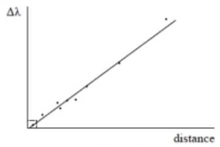

Figure 2

The data used by Hubble for his 1929 plot (Figure 1) is contained within the rectangle close to the origin of the 1931 plot (Figure 2).
Explain how Hubble's observations support the conclusion that the universe is expanding, and assess the reliability of this conclusion on the basis of Hubble's original data.
(5)</td>
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The wavelength change is bigger the further away the galaxies are (1)
The further away galaxies are the faster they are moving, so all distant galaxies are moving away from each other (and the universe is expanding) (1)
There is a large amount of scatter in Hubble's original data set. (1)
The original data set covers a very small range of distances [only the closest galaxies considered] (1)
Hence, on the basis of the original data, the conclusion drawn by Hubble was quite speculative (1)

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<td>What evidence is there for the expansion of the universe? [Script] 7 points</td>
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We use a diffraction grating to see the emission spectrum of the stationary source and light from a distant galaxy
By comparing the emission lines from the emission spectrum of a stationary source (e.g hydrogen from earth) to that from the light of a distant galaxy
The wavelengths of light from the galaxy would be longer and the light more red shifted towards wavelengths in the red region of the spectrum
Its from this that we know a distant galaxy is moving away from earth with a recessional velocity
The larger the red shift the greater the recessional velocity
$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$
We use supernovae as standard candles to

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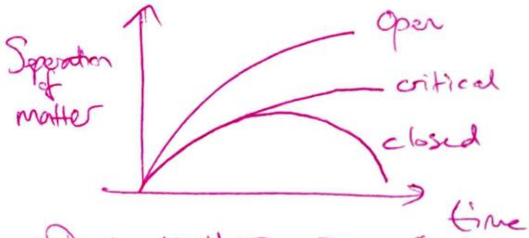
	determine the distance to distant galaxies as they have a high known luminosity $I = \frac{L}{4\pi d^2}$ • Galaxies at a greater distance have a greater red shift Z therefore they are moving away faster so the universe is expanding therefore if time was reversed objects would move towards each other to a single point
Describe how the possible existence of dark matter affects the fate of the universe?	• The fate of the universe depends on its average density • Open universe occurs when the average density of universe is less than the critical density • Closed universe occurs when the average density of universe is more than the critical density  Dark Matter will affect the density of the Universe, so how much of this there is, is critical. *If there is enough critical mass, expansion will reverse* *If there is insufficient mass, expansion continues*