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Level 2 Earth and Space Science 2022

91192 Demonstrate understanding of stars and planetary systems

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of stars and planetary systems.	Demonstrate in-depth understanding of stars and planetary systems.	Demonstrate comprehensive understanding of stars and planetary systems.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–15 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

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RESOURCE

Hertzsprung-Russell (HR) diagram

Adapted from: http://www.atnf.csiro.au/outreach/education/senior/cosmicengine/stars_hrdiagram.html

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The examination continues on the following page.

QUESTION ONE: VEGA AND RIGEL

Prominent in the winter night sky are the stars Rigel and Vega. Rigel is 20 times the mass of the Sun, whereas Vega is approximately twice the mass of the Sun.

(a) Using the HR diagram on page 2, complete the table below to list the properties of Vega and Rigel.

Star	Luminosity	Temperature	Colour
Rigel	10^5	~~15000~~ 15000	Blue/white
Vega	10^2	10000	Blue/white

(b) Explain the difference in fuel use of Rigel and Vega, by relating it to luminosity and mass.
In your answer, you should consider the rate at which the fuel is being used.

Rigel is currently a supergiant, whereas vega is a mainsequence star. Rigel has a higher luminosity then vega, and rigel also has a slightly higher temperature then vega. ~~Rigel~~ vega is currenly a main sequence star so is fusing hydrogen to helium releasing vast amounts of energy. Due to the star having relatively high luminosity and temperature it is likely it is a high mass star. So has more gravity compelling the core inward resulting in more pressure within the cove and high temperatures. which results in nuclear fusion reactions occuring at a fast rate. which results in a high energy output. Due to this the star has relitivly high luminosity and temperature. Rigel is currently a supergiant, and is fusing ~~the~~ helium to carbon, oxygen and all heavy elements upto iron. The outer layers have expanded, resulting in cooler surface temperature due to the outer layer being further away from the hot core. Luminosity stays high due to the stars increased size and surface area. Allowing more energy to be emitted out of the star. Hellum is fusing upto carbon, and carbon upto ~~the~~ heavy elements upto iron at a fast rate, but the mass of the star has not changed in this phase, so the rate of fusion remains steady like in its main sequence stage, though this is many times higher then that of

(c) Compare the likely outcome of BOTH stars as they end their life cycle. (Note: you do not need to explain the various stages of each star's life cycle.)

In your answer, you should consider:

- the mass of the stars
- the role of gravity.

An annotated diagram may assist your answer.

Vega Rigel is currently a main sequence star fusing hydrogen to helium. Once the hydrogen supply has depleted, due to the star remaining core mass being less then 1.4 solar masses (as it does not have enough mass to become a supergiant) [due to gravity dominating,] to become a red giant. The core will partially collapse, initiating the fusion of helium into carbon, oxygen. The outer layers of the star will expand, and cool, while luminosity will stay high due to the stars increased size/ surface area. The mass of the star stays stable until all helium has fused up to carbon. The outer layers will drift off into space forming a planetary nebula. Leaving behind the hot core, which no longer conducts nuclear fusion. It will become a dense white dwarf, with low luminosity due to no nuclear fusion reactions taking place, but heat will remain left over from nuclear fusion reactions from the stars earlier life. Once all heat radiated away all that will remain is a dark, cold, dense remnant of vega, in the form of a black dwarf.

Rigel is currently a supergiant fusing Helium into carbon, oxygen and all heavy elements up to iron. Once the helium has fused up to iron nuclear fusion reactions stop and gravity dominates. The core instantly collapses, compressing iron atoms within the core. The iron nuclei

QUESTION TWO: NEPTUNE'S SATELLITES

Neptune is the outermost planet of our solar system. It is a giant planet with 14 natural satellites.

The largest of the satellites is Triton. Its orbit is retrograde (rotates in the opposite direction to the planet), and it contains 99% of the total mass of all the satellites.

Adapted from: https://upload.wikimedia.org/wikipedia/commons/1/16/Orbits_of_inner_moons_of_Neptune_including_S_2004_N_1.jpg

(a) Describe what is meant by the term natural 'satellite'.

A natural satellite is a stellar object is gravitationally locked with a larger object like a planet. And orbit around the planet, under the planets gravitational pull.

There are a number of different theories about how satellites are formed.

(b) Scientists think Triton may have been captured.

With reference to the diagram above and the information provided, explain why scientists may think this.

In your answer, you should consider:

- the capture theory of moon formation
- the mass of Triton
- the position of Triton's orbit and its motion around Neptune.

An annotated diagram may assist your answer.

The capture theory of moon formation is that interstellar asteroids floating within the solar system which come close to a planet, but are moving/spinning at very high speeds get gravitationally locked with the planet, such as is suggested of Neptunes satellite Triton. And begin to orbit the planet, But the orbit of such captured satellites and spin is different then that of the satellites formed within a planets circumplanetary disk. where the dust and particles within the disk clump together, much like the planet itself, into spherical balls [unless enough matter does not accumulate] which spin the same direction to the planet, as when the clumps are forming, they have relatively low mass in comparison to their planet the circumplanetary disk also rotates in the same direction as the planet under its gravitational pull/force. So the satellites which form within the circumplanetary disk also rotate in the same direction. The mass of the satellites formed within the circumplanetary disk is relatively low, in comparison to the planet, as there is not enough matter/particles within the disk to form very large satellites. This suggests that Triton may be a captured satellite, as the moon is very large. And the contributing factor to its spherical shape. Also Triton's orbit is retrograde, unlike that of natural satellites which form within a circumplanetary disk which rotate in the same direction as the planet due to the circumplanetary disk rotating the same way. Also the satellites orbit around Neptune is more eliptic and inclined, quite different to that of Neptunes other natural satellites which are circular. This suggests that the satellite may be captured, and its orbit has not been cleared yet, while also suggesting the satellites orbit may also have been effected by nearby gaseous planets when it was captured

(c) Explain, in detail, ONE theory of satellite formation, other than the capture theory, that may explain the formation of Neptune's other satellites.

In your answer, you should consider:

- the influence of gravity
- the mass of the satellites
- the orbits of the satellites.

An annotated diagram may assist your answer.

Another satellite formation theory is where the satellites form within the circumplanetary disk composed of molecular dust and gas which in Neptunes satellites' formation would mainly be compored of gas particles. Once Neptune formed within the protoplanetary disk, any left over gas and dust particles began spinning and flattening out into a circum-planetary disk under the planets gravitational pull/influence. These particles begin clumping together due to gravity. Heat energy is generated due to friction between particles. While gravitational potential energy is converted into heat and Kinetic energy. These clumps begin colliding, generating more energy, and forming larger and larger bodies. Larger clumps, due to their greater mass ~~begin~~ exert more gravitational force, resulting in more clumps colliding/ accumulating with the larger clumps. These clumps rotate

around Neptune under the planets gravitational influence. As collisions continue, the clumps compress and contract becoming denser, with heavier elements sinking to the middle to form a rocky/~~icy~~ but largely icy core, and lighter elements form the outer layers. As the larger clumps spin, smaller clumps and particles within their path get pulled in. When enough mass accumulates the clumps compress/contract under their own gravity in a spherical shape forming a natural satellite. As the satellites orbit Neptune, any clumps within their orbit would collided with the satellite resulting in craters on the surface. The mass of these ~~them~~ natural satellites is relatively small, as there is not ~~enough~~ many particles left over from the planets formation to make up a larger circumplanetary disk which is why most of the satellites have a low mass. And due to Neptune having 13 other natural satellites if a larger clump did form within the circumplanetary disk it would gravitational dominate due to its large mass, so that rest of the clumps would get pulled into the larger more massive one. Also due to the circumplanetary disk rotating ~~the same~~ in the same direction as the planet (Neptune). When ~~they~~ satellites form within the circumplanetary disk they also rotate the same way, and have a circular orbit, around their planet, under its gravitational influence. So P satellites which form within a circumplanetary disk do not have a retrograde orbit, and are smaller in terms of mass if other satellites have also formed within the disk. This suggests that Neptunes other satellites may have formed within a circumplanetary disk as they rotate in the same direction as Neptune, and have relatively small masses, and have a circular orbit

QUESTION THREE: NEUTRON STAR OR BLACK HOLE

Astronomers estimate that the Milky Way has anywhere from 10 million to one billion black holes, and around one billion neutron stars.

(a) With reference to the HR diagram on page 2, state where you would expect to find stars in the main sequence that will become neutron stars or black holes, and explain why they are found there.

Main sequence stars which will become neutron stars of blackholes are found around the top left corner of the main sequence area of the HR diagram. This is because this is where the most luminous and most massive stars are found. As only massive stars have enough mass to create enough pressure within the core to initiate the fusion of elements heavier than carbon, oxygen. which results in the formation of neutron stars of black holes.

(b) Explain, in detail, the life cycle of stars that lead to the formation of neutron stars from the main sequence.

In your answer, you should explain:

- energy changes during the different life stages
- fuel use during the different life stages.

An annotated diagram may assist your answer.

At the main sequence stage the hydrogen electrons enter a plasma state (due to temperatures reaching 10 million Kelvin) no longer orbiting their proton. Due to which the hydrogen nuclei can fuse together to form helium, releasing vast amounts of energy. This is the most stable and longest phase in a stars life cycle. As hydrostatic equilibrium is reached. So the gravitational forces acting inwards towards the star are equally opposed by the stars energy output through nuclear

fusion. The mass of a star at this stage determined the next life stages, if the core mass is more then 1.4 solar masses the star progresses on to become a supergiant which eventually forms either a blackhole or neutron star. If the core mass is more then 1.4 solar masses* once the hydrogen fuel depletes, the fusion of helium into carbon, oxygen and all heavy elements upto iron begins. The outer layers of the star expand, resulting in surface temperature decreasing, though luminosity stays high due to the expanded size/surface area. once helium fused upto iron, gravity begins to dominate compressing the core increasing pressure and heat. Initiating the fusion of carbon into heavier elements upto iron. Once all helium has fused upto iron, nuclear fusion reactions stop. Resulting in the instant collapse of the star under its own gravity. Iron atoms within the core get compressed together, resulting in iron nuclei repeling each other. These repulsive electrical forces overcome gravitational forces, resulting in a massive, bright, but short lived explosion; a supernova. All other heavier elements within the universe are formed, shockwaves from the explosion blast the outer layers of the star off into space.
If the remaining core mass is between 1.4 and 3 solar masses the cores electrons collapse into their nuclei, forming a neutron star, compoled of neutron and a rapid spin called a pulsar.
* the star progresses onto the supergiant phase

Question Three continues

(c) Explain why some dying stars form neutron stars, while others form black holes.
In your answer, you should consider the effects of mass and gravity.

Why some dying stars form neutron stars, while other form black holes is dependent on a stars mass. As after the supernova phase if the remaining core mass of the star is between 1.4 solar masses and 3 solar masses the electrons of the cores atoms collapse into their own nuclei, resulting in the formation of a neutron star. whereas ~~Stars~~ with a remaing core mass of more than 3 solar masses (after mass is lost through supernova) completely collapse into themselves and disapear, the collaps results in the formation of a black hole. The universes most dense object, with the strongest gravitation pull. which not even light can escape past, without getting pulled in. ~~This~~ This all occurs because the larger the mass of the core the more gravity is exerted, resulting in more gravity acting inwards ~~towards~~ the core. Compressing it, resulting in the build up of pressure and heat, which ~~then~~ depending on the stars/cores mass can lead to instant collaps. For the formation of black holes the mass of the remaining core must be over 3 solar masses, so that enough gravity acts inwards towards the core creating immense amounts of pressure to result in the total gravitational collaps of the core. which would result in the formation of a black hole. while dying stars with a core mass of 1.4 to 3 solar mass dont have enough mass to having gravity acting upon them to results in a total collaps of the core. But they do have enough pressure/gravity/heat to compress the core enough to result in the collapse of the electrons of the atoms which make up the star into their nuclei. & forming a neutron star.

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

1b) Vega as Rigel has a larger mass. So there is more gravity acting inwards towards the star, resulting in higher pressure. which increases temperatures within the core. The high temperatures cause the fusion of helium into carbon, oxygen and all heavy elements upto iron to occur at a much faster rate then vega. So Rigel is more luminous then vega due to Rigels increased size and surface area due to expansion. And also has higher temperature due to the stars higher mass.

1c) repel each other. These repulsive electrical forces overcome ~~gravity~~ gravitational forces, resulting in a massive, bright, shortlived explosion a supernova. All heavy elements within the universe form, shockwaves from the explosion will send the outer layers of Rigel blasting off into space. If the remaining core mass is between 1.4 and 3 solar masses the electrons within the core will collapse into their ~~atoms~~ nuclei, forming a extremly dense stellar object a neutron star, with a rapid spin called a pulsar. If the remaining core mass is more then 3 solar masses the core will collapse in on it self, forming the universes most dense object; a blackhole. with gravitational pull so strong not even light can escape past.

2b) resulting in the irregular eliptic and inclined orbit.

2b) ~~Also~~ As if a satellite containing 99% of the total mass of all ~~the~~ of Neptunes satellites, formed within a circumplanetary disk. It would have pulled all of the smaller satellites into itself. Due to the satellites large mass resulting in more gravitational force being exerted ~~to~~. So if ~~the~~ Triton formed within a circumplanetary disk there would be ~~but~~ no other satellites in Neptunes orbit.

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Write the question number(s) if applicable.

QUESTION NUMBER

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Standard	91192	Display ID	Response 62038992. NSN 141884070	**Total score**	22 = E
Q	**Grade score**	**Annotation**			
1	E7	The candidate provides a comparison of the fuel use of both Rigel and Vega using luminosity as the key. The similarity in temperature is stated and the link with star mass is made with energy output and surface area. The luminosity values are used for the justification of fuel consumption rates and process. The eventual outcomes of both stars are explained relevant to the star mass.			
2	E8	The candidate although partially repeating themselves in parts b and c understands the relationship between Neptune' satellites in terms of their properties and formation. Justification is given for Triton's capture and the inner satellites formation in terms of properties and motion.			
3	E7	The candidate explains the role that gravity plays in the expected outcome of a large star, though the original star mass was not stated. The relationship between the final star core mass values is linked to the star's final outcome and discussed.			