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2

91192



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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

TOTAL

22

RESOURCE**Hertzsprung-Russell (HR) diagram**

Adapted from: http://www.atnf.csiro.au/outreach/education/senior/cosmicengine/stars_hr diagram.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.

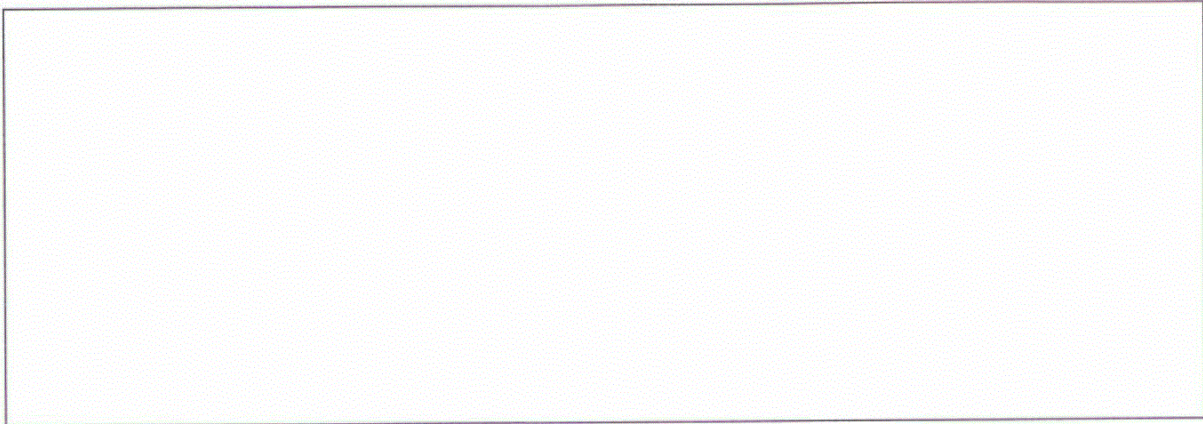
Rigel is currently a Supergiant, whereas Vega is a main sequence star. Rigel has a higher luminosity than Vega, and Rigel also has a slightly higher temperature than Vega. Rigel Vega is currently a main sequence star so is fusing hydrogen to helium releasing vast amounts of energy. Due to the star having relatively high luminosity, it is likely it is a high mass star. So has more gravity compressing the core inward resulting in more pressure within the core and high temperatures, which result in nuclear fusion reactions occurring at a fast rate, which results in a high energy output. Due to this the star has relatively high luminosity and temperature. Rigel is currently a Supergiant, and is fusing ~~the~~ helium to carbon, oxygen and all heavy elements up to iron. The outer layers have expanded, resulting in cooler surface temperatures due to the outer layers being further away from the hot core. Luminosity stays high due to the star's increased size and surface area. Allowing more energy to be emitted out of the star. Helium is fusing up to carbon, and carbon up to ~~the~~ heavy elements up to 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 than 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 than 1.4 solar masses. The star will progress on to become a red giant. ^{as it does not have enough mass to become a super giant} [due to gravity dominating] 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 star's 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 star's 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 fission 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.

- (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 orbits around the planet, under the planets gravitational pull.

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

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

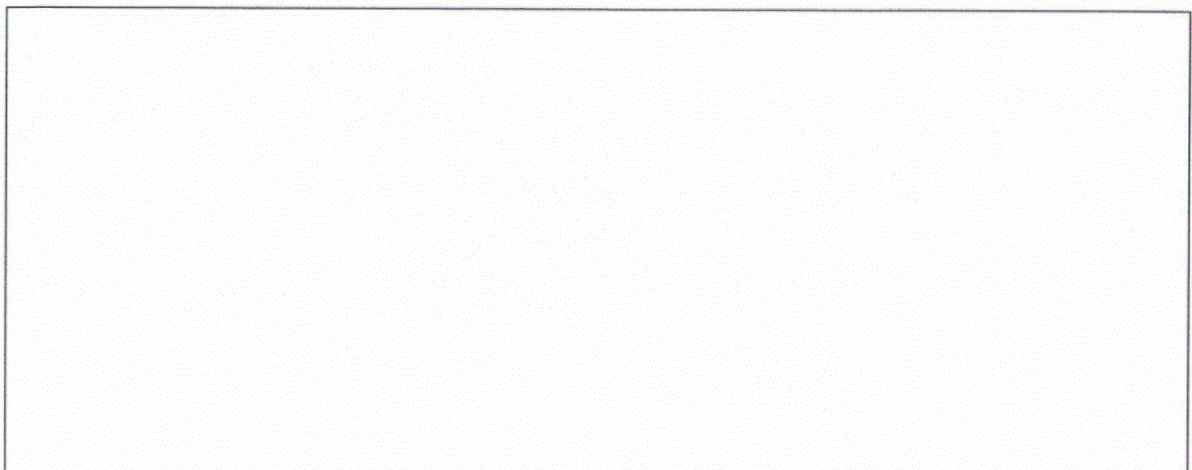
- (b) Scientists think Triton may have been captured.

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.



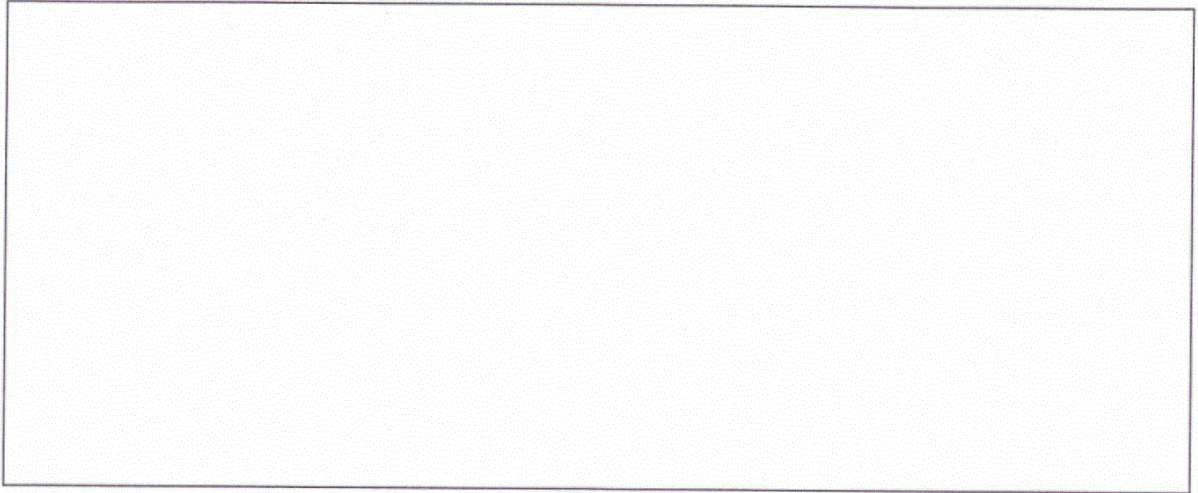
The capture theory of moon formation is that interstellar asteroids floating within the solar system which come close to a planet, but are moving/spinning at a very high speeds get gravitationally locked with the planet, such as is suggested of Neptune's satellite Triton. And begin to orbit the planet, But the orbit of such captured satellite and spin is different than that of the satellite formed within a planet's circumplanetary disk where the dust and particles within the disk clump together, much like the planet itself, into spherical balls ^[unless enough matter/dust has accumulated] which spin in the same direction to the planet, as when the clumps are forming, they have relatively ^{large} ~~small~~ mass in comparison to their planet. The circumplanetary disk also rotates in the same direction ^{satellites} as the planet under its gravitational pull/force. So the ~~planet~~ which form within the circumplanetary disk also rotate in the same direction. The mass of the ~~planet~~ satellites formed within the circumplanetary disk is relatively low, in comparison to the planet, as there is not enough matter/particle 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 factors to its spherical shape.~~ Also Triton's orbit is retrograde, unlike that of natural satellites which form within a circumplanetary disk which ^{rotate} ~~spin~~ in the same direction as the planet due to the circumplanetary disk rotating the same way. ^{Also} the satellites orbit around Neptune is more elliptic and inclined, quite different to that of Neptune's 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 satellite's orbit may also have been affected 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 Neptune's satellites' formation would mainly be composed of gas particles. Once Neptune formed within the protoplanetary disk, any left over gas and dust particles began spinning and flattening out into a circumplanetary disk under the planet's 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 planet's 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 collide with the satellite resulting in craters on the surface. The mass of these ~~then~~ natural satellites is relatively small, as there is not enough ^{many} particles left over from the planet 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 gravitationally 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 ~~then~~ 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 Neptune's 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.

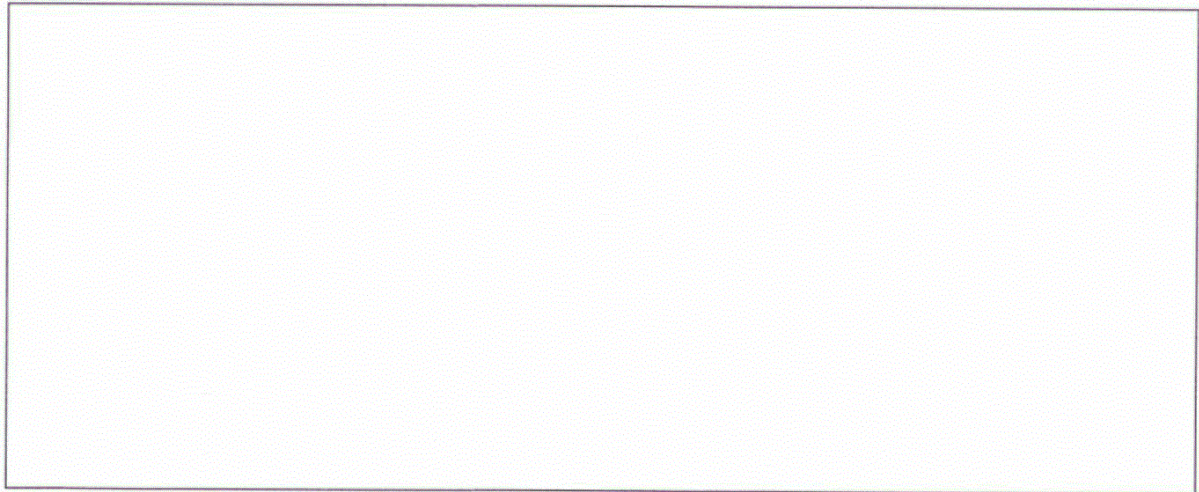
Main sequence stars which will become neutron stars or black holes are found around the top left corner of the main sequence area of the HR diagram. This is because this is where the most luminous and most massive stars are found. As only massive stars have enough mass to create enough pressure within the core to initiate the fusion of elements heavier than carbon & oxygen, which results in the formation of neutron stars or 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 protons. 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 star's life cycle. As hydrostatic equilibrium is reached, so the gravitational forces acting inwards towards the star are equally opposed by the star's energy output through nuclear

fusion. The mass of a star at this stage determines the next life stage, if the core mass is more than 1.4 solar masses the star progresses on to become a supergiant which eventually forms either a black hole or a neutron star. If the core mass is more than 1.4 solar masses* once the hydrogen fuel depletes, the fusion of helium into carbon, oxygen and all heavy elements up to 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 fuses up to iron, gravity begins to dominate compressing the core increasing pressure^{and heat}. Initiating the fusion of carbon into heavier elements up to iron. Once all helium has fused up to 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 repelling 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 core's electrons collapse into their nuclei, forming a neutron star, composed of neutrons and a rapid spin called a pulsar. * the star progressed onto the supergiant phase

- (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 others form black holes is dependent on a star's 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 core's atoms collapse into their own nuclei, resulting in the formation of a neutron star. whereas stars with a remaining core mass of more than 3 solar masses (after mass is lost through supernova) completely collapse into themselves and disappear, the collapse results in the formation of a black hole. The universe's most dense object, with the strongest gravitational pull, which not even light can escape past, without getting pulled in. 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 ~~is~~ depending on the star/core's mass can lead to instant collapse. 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 collapse 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 masses don't have enough mass to having gravity acting upon them to result in a total collapse 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 up to iron to occur at a much faster rate than Vega. So Rigel is more luminous than Vega due to Rigel's increased size and surface area due to expansion. And also has higher temperature due to the star's higher mass.
- 1c) repel each other. These repulsive electrical forces overcome gravity, gravitational forces, resulting in a massive, bright, short-lived 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 ^{nuclei} ~~atoms~~, forming an extremely dense stellar object a neutron star, with a rapid spin called a pulsar. If the remaining core mass is more than 3 solar masses the core will collapse in on itself, forming the universe's most dense object; a black hole with gravitational pull so strong not even light can escape part.
- 2b) resulting in the irregular elliptic and inclined orbit.
- 2b) ⁴³ ~~also~~ if a satellite containing 99% of the total mass of all the of Neptune's satellites, formed within a circumplanetary disk. It would have pulled all of the smaller satellites into itself. Due to the satellite's 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 Neptune's orbit.

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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.			