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NZQA

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Earth and Space Science 2025

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 2–16 in the correct order and that none of these pages is blank.

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

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

Excellence

TOTAL 20

RESOURCE

HR (Hertzsprung-Russell) diagram

Effective temperature, K

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

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The assessment begins on the following page.

QUESTION ONE: LEPUS

The constellation Lepus sits near the Orion constellation in the southern sky.

The constellation's brightest star is Arneb. The star has a mass of 14 Msun, and is approximately 1250 light years from the Sun. In the same constellation is the Gliese 229 system. The star Gliese, has a mass of 0.6 Msun, and is 19 light years from the Sun.

(a) Using the HR diagram on page 2, complete the table comparing the properties of Arneb with Gliese 229.

Star	Colour	Temperature	Luminosity
Arneb	~~Red~~ Yellow/white	6,900K	10^4
Gliese 229	Orange / Red ~~Yellow~~	3,800K	10^{-1}

(b) Explain, in detail, using the information from the HR diagram and the star properties, the differences in luminosity between Arneb and Gliese 229.

In your answer you should consider:

- what luminosity refers to
- the mass of each star
- the temperature of each star
- the current fusion process.

Luminosity is the energy produced by a star per second. Arneb has a Luminosity of 10^4 while Gliese 229 has a luminosity of just under 10^{-2}, therefore considered 10^{-1}. This means that Arneb is a much more luminous star, producing more energy per second. ~~Abs~~ Absolute magnitude is the brightness of a star as if it were 10 parsecs from earth, ~~Arneb~~ Arneb ~~has~~ has an absolute magnitude of -5, while Gliese 229 has an absolute magnitude of -9. Meaning that Arneb is much more bright in which makes sense that Arneb would be the brightest as the energy output of Arneb is much higher - therefore correlating to Arneb

having a higher luminosity than Gliese 229. Arneb has a mass of 14 Msun, while Gliese 229 has a mass of 0.6Msun, meaning Arneb has a much larger mass and so a much larger surface area. Luminosity is dependent upon two things, the surface area and the temperature. Arneb has a temperature of 6,900k while Gliese 229 has a temperature of 3,800k. So not only is Arneb bigger (bigger SA), it is also hotter at this stage in its life. Gliese 229, is currently in the main sequence part of its life. Main sequence is the largest part of a stars life, as during main sequence the fusion of Hydrogen to helium occurs. However for Gliese 229, main sequence will be the only stage of its life as it is a red dwarf. Gliese 229 has a mass of 0.6Msun in which is too small to become a red giant and therefore fusion of Hydrogen to Helium doesn't just occur in the core, but throughout the star, making it a very slow process. It does not further fuse as the mass is not large enough for gravity to enable the fusion of further elements. Arneb has a high luminosity and absolute magnitude as its mass (14Msun) has allowed Arneb to become Supergiant. After main sequence (all hydrogen has been fused into helium), due to its mass, the supergiant can be created and the helium can fuse into further heavier elements until reaching iron. ($H \rightarrow He$, $He \rightarrow C$, $C \rightarrow O$, $O \rightarrow Si$, $Si \rightarrow Fe$). The luminosity of Arneb is very high because of its surface area (expanded out after main sequence - [proton-proton fusion]) and its temperature is relative to how long it is throughout its lifecycle. Because its temperature is still relatively high, and the core continues to collapse, it must have not expanded fully and therefore at the start of this stage of supergiant. Still, it's luminosity is much higher than Gliese 229, due to the difference in life cycles and abilities to fuse elements.

(c) There are two brown dwarfs orbiting Gliese.

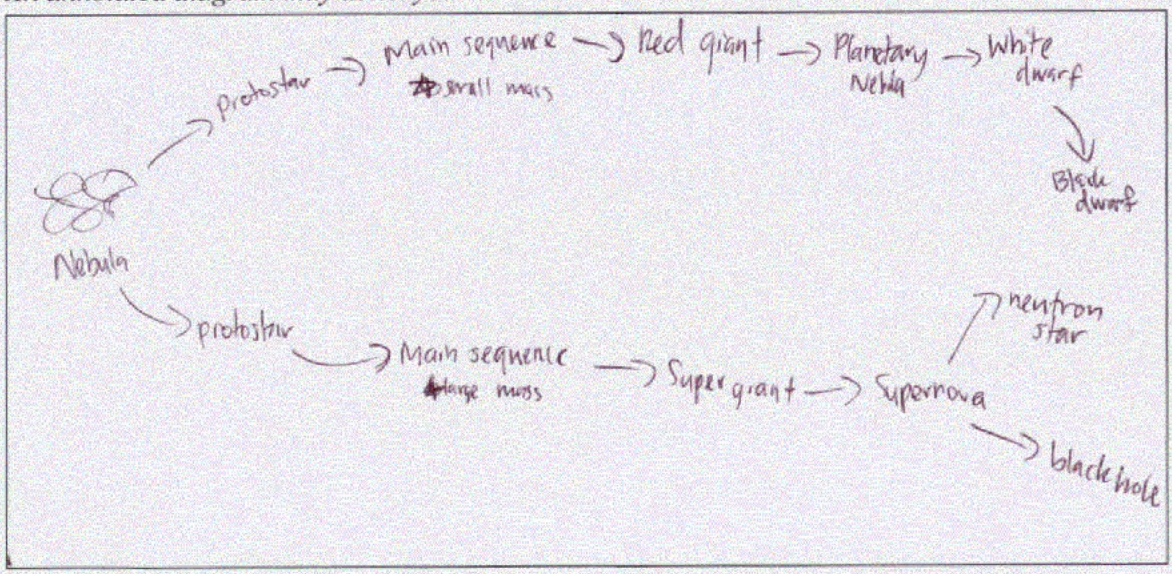
Adapted from: https://hubblesite.org/contents/media/images/1995/48/372-Image.html?news=true

Explain, in detail, why these brown dwarfs would not be found on the HR diagram.

In your answer you should consider:

- the process of star formation
- temperature and energy source in main sequence stars
- the role of mass in star formation.

An annotated diagram may assist your answer.



Stars are formed right from ~~the~~ a nebula (stellar nebula). ~~Please~~ Nebulas consist of gas and dust particles, and dense regions ~~form clumps, due to gravity, these clumps~~ shrink and warm to form the protostar. This is due to the Gravitational Potential energy being converted into thermal energy as it shrinks down. This creates clumps

within the nebula in which ~~collapse~~ contract and collapse, continuously heating up and increasing collisions, ~~this forms~~ These collisions increase the rotation and stars are formed. For stars to be formed they must be at hydrostatic equilibrium in which is the gravitational pull towards the core must equal the radiation pressure push out of the core. Mass plays a big role in the life cycle of a star because it determines its path. A mass of 1 - 5 Msun, results in the star ~~end~~ dying as a black dwarf, and a mass ~~of~~ ~~with~~ larger than ~~4~~ 8M sun, results in the stars last stage as either a neutron star or black hole, dependent on its mass after the supernova. During main sequence, nucleur fusion occurs as hydrogen is fused into helium. This produces a strong radiation pressure against gravity, as heat and light energy are produced.

Brown dwarfs do not show on the HR diagram because they are of very little mass. In having little mass, gravity is unable to attract the ~~H2~~ hydrogen and helium gases and therefore they cannot fuse within the star and so brown dwarfs cannot undergo nucleur fusion; cannot become main sequence. ~~as does not have the temperatures and pressures required for nuclear fusion.~~ The ~~core~~ temperature required in main sequence stars' core for nucleur fusion to occur is ~~10,000,000~~ 10,000,000k and so Brown dwarfs cannot go main sequence as they do not have the temperatures and pressures required for nuclear fusion.

QUESTION TWO: MOONS

(a) All planets and moons within our solar system originated from material within the protoplanetary disk.

Describe what a protoplanetary disk is.

A protoplanetary disk, is the area surrounding the emerging protostar. The protoplanetary disk is the site of the formation of planetesimals in which will eventually become planets. As the protostar condenses, the protoplanetary flattens out as the protostar temperatures increase.

(b) Earth and Mars are similar in that both rocky planets have moons.

Mars has two moons, Phobos and Deimos. Both moons are small and irregular in shape.

The Martian moons: Deimos and Phobos
Source: https://www.skyatnightmagazine.com/space-science/the-moons-of-mars

The orbits of Deimos and Phobos
Source: https://astronomynow.com/2018/07/30/find-martian-moons-phobos-and-deimos-at-the-red-planets-closest-approach/

Using evidence from the diagrams above, explain in detail, why the capture theory is the most likely origin of Deimos and Phobos.

In your answer you should consider:

- the position of the asteroid belt
- how the evidence fits the capture theory.

An annotated diagram may assist your answer.

The capture theory is suggesting that the moons have been stuck in orbit around mars due to have originally been material drifting space but being too close to mars orbit and being captured by the gravitational pull.. The aestroid belt is near mars and so it is likely that material from said aestroid belt could have been attracted by the gravitational pull and stuck in orbit. Deimos and phobos are small and have an irregular shape. Phobos has a larger surface area and must have a larger mass because it orbits closer to mars as Deimos is in orbit further away from mars. This is due to gravity as gravitational forces are stronger on objects with a higher mass. Shown in the diagram, Phobos is orbiting mars on an irregular path and this can occur if the origin of the moon was originally from capture. The capture theory and formation of moons means that the moon can be pulled into orbit from anywhere - no direct path. Also, the irregular shape of the martian moons, suggest they are of aestroid material and haven't been accreted from the circumplanetary disk in which allows matter to accumulate and be large enough to be round. Suggesting that the martian moons are suspected to have formed from the capture theory.

(c) The Earth's Moon is thought to be about 4.46 billion years old. Earth is 4.55 billion years old.

The final Apollo mission in 1972 brought back rock samples from the Earth's Moon. These samples were chemically analysed and found to have a similar chemical composition to rocks on the Earth, but showed evidence of lower levels of iron and gaseous substances.

Source: https://en.wikipedia.org/wiki/Moon#/media/File:FullMoon2010.jpg

Using evidence explain, in detail, how the collision theory could explain the Moon's origin.

In your answer you should consider:

- the Moon's orbit
- evidence from rock samples
- how the evidence fits the collision theory
- how the evidence discounts other theories.

An annotated diagram may assist your answer.

~~The~~ the collision theory refers to the Moon being a product of ~~a~~ ~~asteroid the size~~ planetismal the size of Mars, colliding with earth. Upon the collision of the planetismal and Earth, the outer layers of both objects ejected a large ~~volcanic~~ volume of heated material, in which coalesced to form the moon in orbit around Earth. From Apollos mission in 1972 to bring rock

samples back and find similar composition to rocks on Earth, supports this theory as ~~Earths crust~~ rock ~~from the ejection of~~ the moon was thought to be formed from the ejection of crust/rock (heated) from the outerlayers of both objects upon their collision 4 billion years ago. The accretion theory would suggest that the Moon would have been created from the excess material surrounding the newly formed planets - in the circumplanetary dicks. ~~However~~ these moons are of smaller mass due to the effect of the solar winds sending lighter materials out. Also discounting this theory due to the material being similar to chemical composition of Earths rock. The capture theory would ~~also be~~ could also result in the moon having retrograde movement. ~~and an irregular shape~~ Since our moon does not orbit that way, it is likely to not be a product of capture (also doesn't have irregular shape). Only larger moons have a full round shape, since the Moon does, it is highly unlikely to have been a product of accretion in the circumplanetary disk, but also from a result of capture. ~~as to~~ Making the collision theory are more likely result of the Moons origin.

QUESTION THREE: DEATH OF A STAR

Māori and Pacific astronomical traditions refer to Māhutonga, a bright star that became invisible. This was recorded in the southern sky around AD 185, and has been traced to the likely occurrence of a supernova in the constellation of Centauri.

Source: https://www.skyatnightmagazine.com/space-science/when-stars-collapse-what-is-a-supernova

(a) What is a supernova?

A supernova is an event (explosive and shortlived), that occurs once, due to the electrical forces between the atoms' nuclei, ↑repel due to gravitational forces inwards as the iron no longer fuses in the core, therefore the radiation pressure lessens and gravity works inwards.

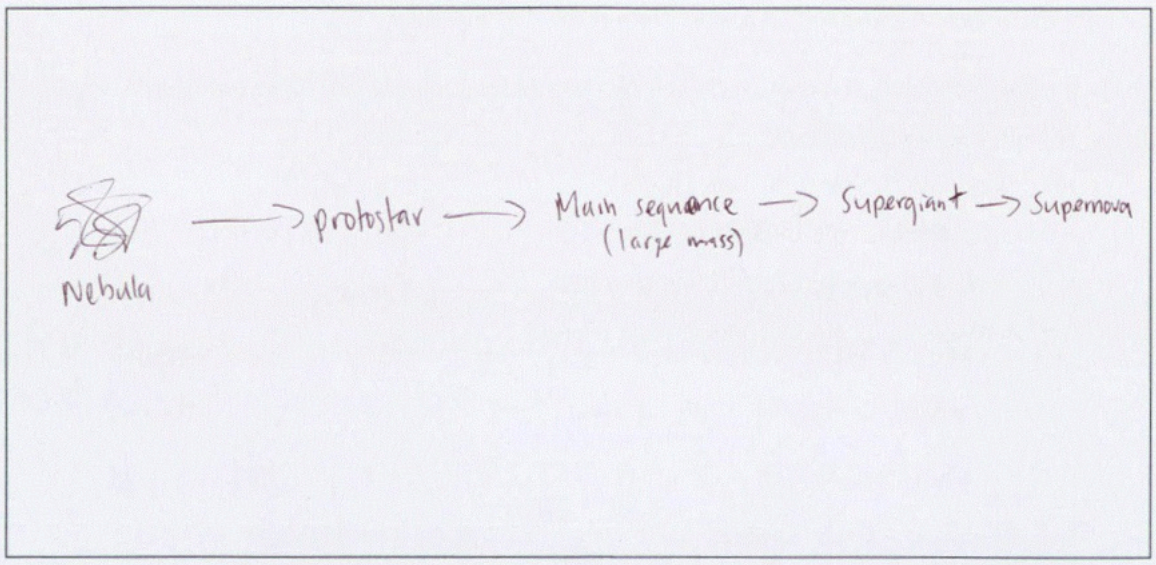
(b) Explain, in detail, the type and behaviour of a star from its main sequence stage until it goes supernova.

In your answer you should:

- state where on the HR diagram this type of star would have been during main sequence
- the energy changes
- the fuel use
- the role of gravity.

An annotated diagram may assist your answer.

Māhutonga would have been a blue main sequence star. During main sequence, hydrogen to helium fusion is occurring in the core. This is the longest stage of a stars life. As the core is contracting and the hydrogen is being used up, the outer shell



starts to expand and cool. Once the hydrogen is used up the star has then entered the next stage of its life depending on its mass. A mass of 8M sun or more, will result in the star becoming a supergiant. The supergiant is very luminous due to its large surface area and fusion into heavier elements from Helium occur - right up until the fusion of iron. Hydrogen to helium, helium to carbon, carbon to oxygen, oxygen to silicon, Silicon to iron. Iron atoms don't fuse to make heavier elements in the core. Due to the halt in fusion, the pressure radiating out is lessened and hydrostatic equilibrium interrupted. The gravitational forces continue to work inwards, towards the core, forcing iron atoms close together and therefore the electrons into the nuclei. The electrical forces between the atoms nuclei repel as the constant gravitational force works in, resulting in an explosive and short lived eruption energy exerted called a supernova - shockwaves clear the outer layers of the star.

Question Three continues on the next page.

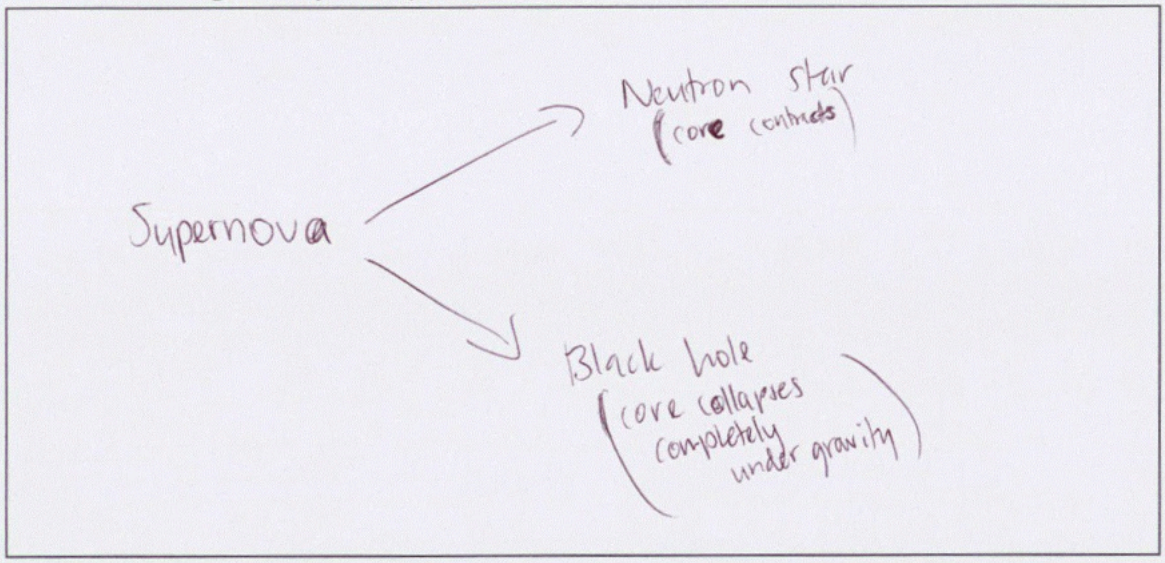
(c) Following the supernova, there are two possible outcomes.

Explain, in detail, the critical factors that would lead to either of these outcomes.

In your answer you should:

- state the two possible outcomes
- consider the role of mass
- consider the role of gravitational forces.

An annotated diagram may assist your answer.



After a star has gone supernova and the shock waves have extinguished the outer layers of the star, there are two possible outcomes the star could take: Becoming a neutron star or becoming a blackhole. Mass is essential to the outcome of the star. If the star is 30M sun, the star will become a blackhole as the core completely collapses and vanishes due to the extremetries of gravity acting, ~~completely~~ However if the star has a mass of 10M sun or more (under 30M sun), the star becomes a Neutron star, due to the core collapsing - with outer layers gone, and the electrons and protons creating the neutron in which

consist now as the Neutron star. Gravity has not completely eliminated the stars core, however the star is now extremely small and does not show on the Hertz Sprung Russell Diagram.

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

QUESTION NUMBER

Excellence

Subject: L2 Earth & Space Science

Standard: 91192

Total score: 20

Q	Grade score	Marker commentary
One	E7	The candidate defines luminosity and links luminosity to star brightness, temperature and surface area. The characteristics of Arneb and Gliese are identified and their current position in their life history explained. Arneb's properties are linked to its luminosity. Star formation is explained in some detail and the reason for brown dwarf formation linked to lack of acquired mass resulting in the inability for fusion to commence.
Two	E7	The reason for the existence of Mars' moons is given in terms of "Capture Theory", with the suggestion that the moons originated in the asteroid belt. Phobos' properties are given in some detail. The reason for another moon formation theory not being applicable is given. Earth's moon formation is explained in terms of "Collison Theory" and the accretion of material ejected from the collision. The reasons for other theories not being applicable are explained.
Three	M6	The sequence of events leading to the supernova of a high mass star are explained in detail. Further detail is then given as to the likely outcome referencing the original star mass. The next step would have been to reference the core mass post supernova and the link to original main sequence star mass.