Assessment Schedule – 2025 Working Copy 2025 -12

Earth and Space Science: Demonstrate understanding of stars and planetary systems (91192)

Evidence Statement

Question One

<table>
<tr><th>Q</th><th>Expected Coverage</th><th>Achievement</th><th>Achievement with Merit</th><th>Achievement with Excellence</th></tr>
<tr><td>ONE
(a)</td><td><table><tr><th>Star</th><th>Colour</th><th>Temperature</th><th>Luminosity</th></tr><tr><td>Arneb</td><td>Yellow-white</td><td>6500–7000</td><td>$10^{3.7}$–10^{4}</td></tr><tr><td>Gliese 229</td><td>Red/Orange</td><td>3700–3800</td><td>$10^{-1.6}$–$10^{-1.9}$</td></tr></table></td><td>• 4 / 6 correct.</td><td></td><td></td></tr>
<tr><td>(b)</td><td>Luminosity refers to the energy output per second from the star’s surface.
Arneb is a yellow supergiant star that has left the main sequence and is most probably in the later stages of its life cycle. The large surface area and high luminosity mean large quantities of energy are being released. The star is no longer fusing hydrogen to helium but instead fusing helium and heavier elements (He → C → Ne → O → Si → Fe). The high temperature would indicate that the fusion process is rapid.
Gliese 229 is a red star, with low mass, i.e. a red dwarf. The luminosity indicates a low energy output which, even though the star is closer to Earth, it would be very difficult to see compared to Arneb, which is much further away but visible. The star is very slowly fusing hydrogen into helium which accounts for the low temperature and red colour.</td><td>Describes:
• meaning of the term luminosity
• how temperature relates to the star colour
• Arneb as a supergiant star and Gliese 229 as a red dwarf in relation to respective masses
• the fusion processes that are occurring in Arneb (He to heavier elements) and Gliese (H to He)
• the rate of fuel use in Arneb and Gliese in relation to mass.</td><td>Explains:
• the evidence and reasons for the rapid fusion process on Arneb
• the evidence and reasons for the slow fusion process on Gliese
• the reason for the difference in luminosity values of Arneb and Gliese in terms of star surface area.</td><td>Explains comprehensively:
• the links between Arneb’s mass, fusion process, rate of fuel use, and luminosity with its position on the HR diagram
• the links Gliese’s 229 mass, fusion process, rate of fuel use, and luminosity with its position on the HR diagram.</td></tr>
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(c)	The two brown dwarfs of the Gliese 229 system are failed stars, which have insufficient mass to begin the fusion process. The initial stage of star formation begins with the formation of the protostar as gravity pulls together dust and gas in the stellar nebulae. In this case, three "clumps" of dust and gas were forming with potential to form separate stars. As the "clump" grows, its gravitational force will increase attracting more material, as well as contracting compressing the dust and gas. Collisions between the particles generates heat energy. When there is sufficient mass and particle density, a protostar is formed which generates heat and light. To become a main sequence star, there must be sufficient mass and gravitation force to generate approximately 27 million degrees Celsius for nuclear fusion of hydrogen nuclei to helium to begin. In the case of the two accompanying brown dwarfs, insufficient mass was reached, hence they remain as protostars or failed stars with low surface temperatures and very little light and heat released, compared to the main sequence star, and are not shown on the HR diagram. *Evidence may be taken from an annotated diagram.* *Evidence may be taken from any section of the question.*	Describes: • a brown dwarf as a failed star • insufficient gravity OR mass for fusion to begin in a protostar • the source of the material for star formation • the process to reach fusion temperature • stages of star formation.	Explains: • the links between the formation of a brown dwarf to protostar mass, and critical fusion temperature • main sequence star formation from a stellar nebula.	Explains comprehensively: • the reason why the two protostars became brown dwarfs and not main sequence stars.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response or response does not relate to the question.	Describes ONE idea at the Achievement level.	Describes TWO ideas at the Achievement level.	Describes THREE ideas at the Achievement level.	Describes FOUR ideas at the Achievement level.	Explains ONE idea at Merit level.	Explains TWO ideas at Merit level.	Explains ONE point at Excellence level	Explains TWO points at Excellence level.

Question Two

Q	Expected Coverage	Achievement	Achievement with Merit	Achievement with Excellence
(a)	A protoplanetary disk is a flattened, rotating structure of gas and dust surrounding a young, newly formed star, which provides the raw materials for building planets and moons.	• Describes: • what is a protoplanetary disk		
(b)	Mars's satellites were possibly formed as the result of capture. Mars is relatively close to the asteroid belt. Not all the material in the Asteroid belt orbits in a similar elliptical pattern as the planets; some can have extreme elliptical orbits. Over the last 4.6 billion years it is quite possible that such an asteroid came within Mar's orbit about the Sun. When the asteroid gets too close to the larger planetary body, it can be captured by the planet's gravitational field. This is more than likely true for both Phobos and Deimos. Evidence for this is provided by the orbits, shape, and size of both moons suggesting they were originally asteroids. The asteroids orbit in the same direction as the planets around the Sun. Deimos' orbit is elliptical and very distant from the planet, which suggests the small asteroid was caught in Mars's gravitational field as it passed by. Its irregular shape and small size are also clues as to its likely origin as an asteroid. Phobos is larger but irregular in shape, suggesting asteroid origin. The larger size and proximity of Phobos to Mars suggests that the planet's gravity is slowly dragging it closer to the planet.	• the likelihood of Mar's moons once being an asteroid • the role of Mars's gravity in capturing a passing asteroid • the evidence shown by the orbit of Mars's moons as evidence of capture • the shape of Mars's moons as evidence of capture.	Explains: • the evidence linking shape, size, and orbit with the theory for the existence of Deimos • the evidence linking shape, size, and orbit with the theory for the existence of Phobos • how Phobos and Deimos are linked to the asteroid belt.	Explains comprehensively: • how the evidence links Capture theory with the formation of Deimos and Phobos.

(c)	**Collision Theory** – Two planets or protoplanets were orbiting the solar system within the region and were similar in composition. As a result of gravitational forces and proximity, the two objects collided. The size of the impact created sufficient heat so that the material melted, and part of Earth's mantle and crust was thrown into space. The debris cooled and coalesced to form Earth's period. The accepted theory is that Earth's Moon formed as the result of a collision with another similar sized planet or protoplanet some 4.46 billion years ago. Evidence for this includes not only similar composition but also spherical shape, proximity of orbit, prograde orbit, age (it is younger than Earth). The lack of gaseous substances would be due to the searing heat of the impact. Other theory formations, i.e. Capture and Accretion, can be discounted based on the evidence. Accretion could account for the shape and proximity of the orbit, and the orbit would be prograde. It is likely the material composition of the satellite would be very similar to Earth's. The satellite's age would be similar to Earth, which it is not. Capture could be discounted based on the Moon's size, and proximity and shape of the orbit. *Evidence may be taken from an annotated diagram.* *Evidence may be taken from any section of the question.*	Describes: • the Moon's material comes from the material thrown out from Earth in a collision • the Moon's shape is the result of accretion of collision material • the distance OR shape of the Moon's orbit can be linked to an impact • the age difference between Earth and Moon being linked to the Moon's formation • Why another theory cannot account for the Moons formation e.g. capture.	Explains: • the links between the impact theory and the orbit and size of the Moon • the link between the collision theory and the composition of the Moon's surface • the reasons why one of the formation theories cannot account for Earth's Moon.	Explains comprehensively: • how the evidence accounts for the accepted collision theory of the Moon's formation • how the evidence discounts other theories that might be used to explain the Moon's formation.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response or response does not relate to the question.	Describes ONE idea at the Achievement level.	Describes TWO ideas at the Achievement level.	Describes THREE ideas at the Achievement level.	Describes FOUR ideas at the Achievement level.	Explains ONE idea at Merit level.	Explains TWO ideas at Merit level.	Explains ONE point at Excellence level.	Explains TWO points at Excellence level.

Question Three

Q	Expected Coverage	Achievement	Achievement with Merit	Achievement with Excellence
(a)	A supernova is the result of the explosion of a large star at the end of its life. Such explosions can be many times brighter than the original star, and visible for a length of time due the vast amount of energy that is released.	• Describes: • a supernova as a powerful, highly visible explosion of a star OR massive explosion when a star dies		
(b)	Stars that form supernovas are usually giant high mass stars located in the upper left of the main sequence of the HR diagram. Massive stars, generally those with a mass of 10–30 times that of the Sun, will fuse their hydrogen fuel rapidly to helium, which accounts for their high temperature. Once hydrogen in the core has run out, the core contracts and the outer shell starts to cool and expand changing to a red colour creating a supergiant. The star is no longer a main sequence star. Gravity within the core causes the helium nuclei to fuse to carbon. As the temperature within the giant's core increases carbon is fused to the heavier elements' oxygen, nitrogen, and eventually iron. The iron nuclei in the core are too heavy to fuse further. This results in an imbalance between the gravitational forces holding material around the core and the energy radiating out from the core. This causes the gravitational collapse of the star. The temperature of the core rises to 100 billion degrees because of gravity. With the iron nuclei crushed so tightly together, the repulsive electrical forces overcome gravity, and material from the core's outer layers is thrown out in a huge shockwave or supernova explosion.	• the position these stars are found on the HR diagram • supernovas are formed by high-mass stars • the fusion process leading during the main sequence stage (H $\rightarrow$ He) • the fusion process that leads to a supergiant stage (He $\rightarrow$ heavier elements) • the role gravity takes in enabling fusion of heavier elements • the role of gravity in the supernova stage.	Explains: • the use of the HR diagram in determining the characteristics and life history of a giant star • the link between gravity and the fusion process (H $\rightarrow$ He $\rightarrow$ C $\rightarrow \ldots \rightarrow$ Fe) in supergiant stars • the link between gravity and the formation of the supernova • the energy changes that take place in a giant star from initial fusion to supernova stage.	Explains comprehensively: • the life cycle of a giant star from main sequence to the supergiant and the role gravity plays in the fusion process • the change in the fusion process and role of gravity that creates the supernova event.

(c)	Mass is a critical factor in the outcome of stars. Stars with masses of greater than approximately 10 times the mass of the Sun will go through the supernova state. (Stars with lesser masses usually form white dwarfs and planetary nebula.) If the star has a core mass of 1.4 M_{Sun}, after the hydrogen source is depleted, the helium in the core will continue to fuse to the heavier elements until reaching iron nuclei. After the supernova stage the stars with a remaining core of 1.5 to 3 M_{Sun} will result in a neutron star. Gravitational forces are such that these are extremely dense as fusion has taken place between the iron protons and electrons. When the remaining core is greater than 3 M_{sun} the core completely collapses in on itself under gravity. All the material is drawn into a "singular point" with the resulting huge gravitation field that can absorb matter and energy including visible light that comes within the field. This is called a black hole. *Evidence may be taken from an annotated diagram.* *Evidence may be taken from any section of the question.*	Describes: • the mass of a main sequence star (greater than 8 – 10 MSun) being linked to the outcome as a neutron star • the mass of a main sequence star (approximately 30 MSun) being linked to the outcome as a black hole • the remaining core being linked to either a neutron star OR black hole • the role gravity takes in the formation of neutron star OR black hole.	Explains: • the link between star mass and the outcome of a main sequence star to form a neutron star or a black hole • the link between final star core mass to the outcome as a either a neutron star (1.5 M_{Sun}) OR black hole (3 M_{Sun}) • the link between mass and the role of gravity in the formation of a neutron star OR black hole.	Explains comprehensively: • the relationship between mass of a main sequence star and its remaining core mass after the supernova stage, with gravity in the formation of a black hole or neutron star.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
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Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 6	7 – 12	13 –18	19 – 24