Assessment Schedule – 2023

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>Merit</th><th>Excellence</th></tr>
<tr><td>ONE (a)</td><td><table><tr><th>Star</th><th>Life Stage</th><th>Temperature K</th><th>Absolute Magnitude</th><th>Luminosity</th></tr><tr><td>Betelgeuse</td><td>Supergiant</td><td>3600</td><td>–5.5</td><td>$10^{3.8}$</td></tr><tr><td>Proxima Centauri</td><td>Main Sequence dwarf</td><td>3500</td><td>+15</td><td>10^{-4}</td></tr></table></td><td>• 6 out 8 correct.</td><td></td><td></td></tr>
<tr><td>(b)</td><td>Luminosity refers to the energy output per second from a star’s surface.

Absolute magnitude is a measure of how bright a star would be if it were seen from a standard distance (10 parsecs) from Earth. The lower or more negative the absolute magnitude, the more luminous the star.

Proxima Centauri is a small low mass red dwarf which has a small surface area and low surface temperature. This means that it has a low luminosity, and hence has a higher absolute magnitude. This means that it has a lower luminosity, and lower absolute magnitude which is indicated by a higher absolute magnitude number.

Betelgeuse is a high mass red supergiant with a much larger surface area, but the same surface temperature. The larger surface area means that even though the surface temperature of the star is the same, more energy is released per second from the star, making it more luminous, and therefore it has a lower absolute magnitude number.</td><td>Describes with understanding:
• The meaning of the term luminosity.
• The meaning of the term absolute magnitude.
• The larger the value of the absolute magnitude the dimmer the star (or a positive value indicates it is dimmer).
• The red colour of both stars is due to the low surface temperature.
• Proxima Centauri’s small surface area along with its low luminosity or low temperature is linked to its high absolute magnitude. (higher number)
• Betelgeuse’s brightness (greater absolute magnitude which is a lower number) is linked to large surface area, i.e. energy output is over a greater surface area.</td><td>Explains in detail:
• Why Proxima Centauri has a low luminosity / high absolute magnitude number in terms of low energy radiation release over its small surface area.
• Why Betelgeuse has a greater luminosity / lower absolute magnitude number in terms of low energy radiation release, but over a large surface area.</td><td>Explains comprehensively:
• The comparison between the properties of Proxima Centauri and Betelgeuse that account for their respective magnitudes.</td></tr>
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(c)	Betelgeuse was a main sequence star, however, due to its high mass, it has moved into the supergiant stage and its size has grown. Its original luminosity would have been less, as it was fusing hydrogen to helium. The star is quite likely to have appeared blue, as the surface temperature would have been higher due to the star's high mass and subsequent rapid fusion of hydrogen. With a smaller surface area, its luminosity would have been lower (absolute magnitude number would have been greater), i.e. dimmer in the night sky. As it cycles through its life stages, the fusion sequence changes as the hydrogen nuclei are consumed, and it starts fusing helium. The star expands in size. Even though the surface temperature is lower, the expanded surface area means luminosity is higher (absolute magnitude value is lower). As fusion continues to heavier elements, the surface area will continue to grow, causing further changes in the star's luminosity, i.e. luminosity continues to increase (absolute magnitude decreases). When iron is reached through nuclear fusion, there will be a massive, bright, short-lived explosion called a **supernova** giving a huge increase in luminosity. Proxima Centauri, due to its low mass, will remain on the main sequence for a very long time, fusing hydrogen into helium slowly. As the amount of hydrogen decreases the star shrinks but becomes hotter, but the mass of the star is too low for there to be sufficient gravitational force to fuse helium. Once all the hydrogen is fused, the star becomes a white dwarf of helium, and cools. *Evidence may be taken from annotated diagrams.* *Evidence may be taken from any section of the question.*	Describes with understanding: • Betelgeuse is fusing helium into heavier elements. • Betelgeuse has fused hydrogen rapidly, due to high mass. • Betelgeuse is expanding in size through its life stages. • Betelgeuse brightness is increasing (or luminosity is increasing) with its increase in size. • After the supergiant stage there will be a massive, bright, short-lived explosion called a supernova. • Proxima Centauri luminosity has not changed due to its slow fusion of hydrogen. • Proxima Centauri low mass means the fusion process is very slow.	Explains in detail: • Why Betelgeuse's luminosity is changing as it expands during its life stages as it started to fuse helium and finished with a massively bright supernova explosion. • Why Proxima Centauri's luminosity is unlikely to change in relation to its slow hydrogen fusion and low mass.	Explains comprehensively: • How the luminosities of both Proxima Centauri and Betelgeuse are related to their respective life stages even though surface temperatures are similar.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response or response does not relate to the question.	Describes ONE partial 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 or TWO with minor errors.	Explains TWO points at Excellence level

Question Two

Q	Expected Coverage	Achievement	Merit	Excellence
(a)	Nebula is described as a vast area of hydrogen gas and dust in space, which forms a nursery for star formation.	Describes with understanding: • A nebula as a star nursery.		
(b)	Within the giant molecular cloud, material, dust, and gases begin clumping together. As the material condenses, the influence of gravity begins to draw more material in (accretion), causing the clumps to compress and contract. Finally, gravity contracts enough material together to form a protostar. The resulting gravitational potential energy is converted into heat through friction between moving particles (kinetic energy), with radiation being emitted into space. As the protostar continues to collapse, contract, and compress, the core becomes extremely hot. When it reaches temperatures of about 10 million K (or an acceptable resourced value e.g. 15 to 27 million °C) hydrogen fusion will start in the core. At this point the protostar becomes a main sequence star, radiating heat and light.	Describes with understanding: • How accretion can occur. • The role gravity plays in increasing the size of the bodies. • Requirements for fusion to begin.	Explains in detail: • The birth of the protostar from the GMC in terms of mass and gravity. • Radiation due to gravitational potential energy being converted to kinetic energy to heat energy. • The formation of a main sequence star.	Explains comprehensively: • The formation of protostar from its origin in the GMC, in terms of gravity. • The formation of the main sequence star in terms of gravity.
(c)	Hot blue stars are rapidly fusing their hydrogen fuel to form helium. This is the most stable part of their life cycle, and they are producing large amounts of light and heat, which explains why they are so bright. Blue stars in the range of 3 solar masses are going to become white dwarfs then end up as black dwarfs. Once the hydrogen fuel has been depleted, the blue star cools and expands to become a red giant. The helium core contracts under gravitational force, and the helium nuclei fuse to form carbon and oxygen, whilst the outer layers cool. Once all the helium fuel source has been depleted, there is insufficient core mass for fusion and a hot carbon core remains. The core contracts even further due to gravitational forces and the outer layers of gas expand and drift off into space forming a planetary nebula. The remaining white dwarf radiates heat and light until it cools and becomes a black dwarf. *Note:* *Evidence may be taken from annotated diagrams.* *Evidence may be taken from any section of the question.*	Describes with understanding: • Rapid fusion of hydrogen creating large amounts of heat and light. • Hydrogen fuse to form helium. • Helium fuse to become carbon and oxygen. • They become white dwarfs.	Explains in detail: • The energy / fuel use changes that take place as a young blue main sequence star becomes a red giant. • The changes in fuel use as a red giant star progresses to become a white dwarf.	Explains comprehensively: • The life stages of young blue stars as the fusion progresses until the gravitational forces are such that it is no longer possible and they end their lives as a black dwarf and nebula.

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 or TWO with minor errors.	Explains TWO points at Excellence level

Question Three

	Expected Coverage	Achievement	Merit	Excellence
(a)	E.g. a planet is an aggregated material of rock or gases that orbit a star. A star is a luminous object, as energy is being by nuclear fusion.	Describes with understanding: • a planet and star		
(b)	Leftover gas and dust particles rotate around the young sun and flatten into a gaseous protoplanetary disc around the star. The disc is orbiting and dust particles begin to collide and form bigger masses called planetesimals. These planetesimals collide and collect more material to form protoplanets. As the protoplanets increase in size so does their gravitational field strength, eventually forming planets. As the young sun grows and becomes hotter, temperature and the presence of solar winds will determine planetary formation. Intense solar winds blow gases off the inner rocky planets to the outer parts of the system beyond the frostline. The outer planets have formed further away from the central star in a lower temperature environment, and consist of mainly lower melting point materials, which are gaseous in nature. As there is far more gas in the protoplanetary disc than heavier elements around the sun, the outer planets will be bigger than the inner planets. They will also be able to form the "gas giants" as the gases condense in the low temperature environment and are unlikely to be affected by the solar winds due to the large distance from the young sun.	Describes with understanding: • Formation of aggregated material in the protoplanetary disc. • The role of gravity in aggregating material into larger planetesimals. • The role solar winds play in pushing gases beyond frostline. • The role of temperature in the formation of the gas giants.	Explains in detail: • The role of gravity in the formation of gas giants. • The role of solar winds in the formation of gas giants. • The role of temperature in the formation of gas giants.	Explains comprehensively: • How gravity, temperature and solar winds interact in the formation of gas giants from the original planetary disc.

(c)	Jupiter is a gas giant with a solid core, and as a large planet, it has a very large surrounding gravitational field. The large gravitational field enables the planet to maintain a large number of moons and other material in orbit. When the planet was formed, not all of the material would have been drawn into the planet's main mass. This would have left dust and rocks to aggregate, collide and form satellites in a disc around the planet's equator. These moons remained trapped within the planet's gravitational field, and orbit the planet. Many of these moons would consist of rock type material. The three rings that surround Jupiter are made of rocky dust-like material. It is thought that the material came from meteor collisions with the four rocky moons within the rings and the resulting dust from the collisions remained trapped in Jupiter's gravitational field, or they are left over material that was not taken up in the moon's formation. *Note:* *Evidence may be taken from annotated diagrams.* *Evidence may be taken from any section of the question.*	Describes with understanding: • That Jupiter has a high mass, which means it has a large gravitational field to attract material • How Jupiter's moons could be leftover material from the planet's formation. • The possible origins of the dust rings that surround Jupiter.	Explains in detail: • How Jupiter's gravity has allowed for the collection of material that orbits the planets as moons. • .How Jupiter's rings could result from the dust between the planet and other bodies.	Explains comprehensively: • How Jupiter came to have moons and a ring system.

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