Assessment Schedule – 2024

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>Apparent Magnitude</th><th>Absolute Magnitude</th><th>Luminosity</th><th>Temperature (K)</th></tr>
<tr><td>Sirius</td><td>–1.46</td><td>1.0 – 1.5</td><td>$10^{+1.2 - 1.5}$</td><td>10 000</td></tr>
<tr><td>Antares</td><td>+0.96</td><td>-4.4 – -5.0</td><td>$10^{+3.4 - 3.7}$</td><td>3000 - 3100</td></tr>
</table>
</td>
<td rowspan="2">Describes with understanding:
• 4 / 6 completed correctly with acceptable parameters. (Single number value only not a range or approximate value quoted)
• the term absolute magnitude
• the term apparent magnitude
• how the scale indicates the brightness of a star
• the reason for the difference in absolute and apparent magnitude for Sirius OR Antares
• the current stage in the life cycle of Sirius
• the fusion of H nuclei on Sirius
• the current stage in the life cycle of Antares
• the fusion of He nuclei on Antares.</td>
<td rowspan="2">Explains in detail:
• the significance of the difference between absolute and apparent magnitude
• the relationship between the observed brightness and absolute magnitude in terms of star observation
• how absolute magnitude OR luminosity and surface temperature can indicate the current stage in the life cycle of Sirius
• how absolute magnitude OR luminosity and surface temperature can indicate the current stage in the life cycle of Antares.</td>
<td rowspan="2">Explains comprehensively:
• using Sirius and Antares as examples the significance of the absolute and apparent magnitude values in relation to observation from Earth
• the significance of the values of absolute magnitude OR luminosity and temperature in indicating what stage Sirius and Antares are in their respective life cycles and fusion process.</td></tr>
<tr><td>(b)</td><td>Apparent magnitude is a measure of star brightness as seen from Earth.
Absolute magnitude is a measure of brightness if seen from a distance of 10 parsecs or approximately 33 light years (how bright the star actually is).
Absolute magnitude is a standardised measure of brightness, as it uses a fixed distance, whereas apparent brightness depends not only on the star distance from the Earth, but also on the energy output of the star.
For both magnitude scales, the smaller or more negative the value, then the brighter the star. Larger numbers indicate dimmer stars.
With reference to Sirius and Antares in terms of apparent magnitude Sirius is the brighter as seen from Earth with a value of –1.46 as opposed to Antares, which has a value of +0.96.
The absolute magnitude values differ. Antares is considerably brighter at a standard distance than Sirius. This indicates that Antares is releasing far more energy per square metre than Sirius.
This means that Sirius is closer to Earth than Antares as it appears brighter in the night sky yet is emitting less energy per square metre.</td></tr>
</table>

(c)	The absolute magnitude and luminosity values are related. Both indicate the amount of energy per second being emitted from the star surface, i.e. the power output of a star. Combining power output with star size and temperature is indicative of the stage the star is at in terms of its life cycle. Sirius’ high temperature indicates a small hot star (part of the reason for its apparent brightness in the night sky). The high temperature indicates it is currently fusing hydrogen nuclei into helium. The energy output indicated by luminosity / absolute magnitude, however, suggests the star is still relatively small, and in the main sequence, which forms the longest period of the star’s life span. The temperature of Antares indicates a star that is in the final stages of its life span, with an inner core that is fusing helium nuclei into heavier elements. The high luminosity / absolute magnitude value however indicates a high energy output, which means the star is massive in size or surface area. This accounts for its absolute brightness. *Note:* *Evidence may be taken from annotated diagram.* *Evidence may be taken from any section of the question.*			

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	Describes ONE partial idea at Achievement level.	Describes TWO ideas at Achievement level.	Describes THREE ideas at Achievement level.	Describes FOUR ideas at Achievement level.	Explains ONE idea at Merit level.	Explains TWO ideas at Merit level with a minor omission.	Explains ONE point fully with a minor omission.	Explains ONE point fully at Excellence level and another Excellence point with minor omissions.

Question Two

<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>(a)</td><td>The habitable zone refers to the zone where the temperature allows liquid water and the possibility of life to exist. The planets e, f, and g are within this zone, where the solar radiation from the star and possible atmosphere around the planets enable water to remain liquid. (Planets a, b, and c are too close to the star, and therefore water could be found as a gas, while h is too far away.)</td><td rowspan="2">Describes with understanding:
• The habitable zone where water and/or temperature are suitable for life
• the formation of the protoplanetary disk
• the formation of planetesimals through accretion of material
• the accumulation of material through gravity to form larger planetesimal or planets
• formation of inner rocky planets with high melting-point materials inside the frostline
• how the movement of solar winds moves material away from the inner planets
• the lack of gas giant could be because one has not been detected
• the lack of a gas giant as material and gases have been unable to accrete
• how a gas giant is formed .</td><td rowspan="2">Explains in detail:
• the role of gravity in planet formation in the TRAPPIST-1 protoplanetary disk
• the relationship between rocky planet formation and the frost line
• the role solar winds could have played in moving material beyond the frost line in the TRAPPIST-1 system
• why no gas giants have been detected or may not have formed.</td><td rowspan="2">Explains comprehensively:
• the formation of the rocky planets in the TRAPPIST-1 system and the part that solar winds, gravity, and the frost line would have played in their formation

• a theory or idea why there are no gas giants in the TRAPPIST-1 system, e.g. solar winds, gravity, detection.</td></tr>
<tr><td>(b)</td><td>Dust, ice, and gases remain in orbit around the young protostar, TRAPPIST-1.
As the material circulates within the protoplanetary disc, it starts to ‘clump’ together through collisions (accretion). Once the material becomes large enough, it has its own gravitational pull, which leads to further collisions and an increase in size. These larger orbiting objects are called planetesimals. The planetesimals continue to orbit TRAPPIST 1, their respective gravitation forces collecting material such that they grow in size to become the only objects orbiting within their respective orbits. This defines them as planets.
Materials are pushed away from the young star by solar winds. Temperatures close to the star are high, but as distance increases away from the star the temperature decreases. At a certain distance from the star, a frost line exists. This is the temperature beyond the young star where the temperature is low enough for low-boiling-point materials such as hydrogen, helium, methane, and ammonia to condense into solid particles. Within the frost line only substances with very high melting points such as rocky materials, remain solid.
The rocky planets in the TRAPPIST-1 system are all formed within the frostline.</td></tr>
</table>

(c)	There are no detected gas giants in the TRAPPIST-1 system at present. There are three possible reasons. • No gas giant has been detected due to its low density. • TRAPPIST-1 is too small and cool to have sufficient solar winds that can push the volatile material out beyond the frost line. • The condensed gas material exists beyond the frost line but has not coalesced to form a gas giant. Gas giants form around an icy dense core. The core can begin as condensed rocky or metallic material that has condensed beyond the frostline. (Gas giants can originate from an asteroid.) Around this rocky core, particles of hydrogen, helium, and low-boiling-point gases will collect, and a planetesimal is formed that develops into a planet. The gases exist beyond the frostline but have no material to aggregate around. When TRAPPIST-1 was a young star, it was particularly active. This would have meant very high temperatures within the star's atmosphere, and strong solar winds. The strong winds combined with high temperatures would have pushed the low-boiling-point materials far into the outer reaches of the TRAPPIST-1 system and unable to form planets, due to the very low concentration of material in the outer reaches. *Note:* *Evidence may be taken from annotated diagram.* *Evidence may be taken from any section of the question*			

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Question Three

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<tr><th>Q</th><th>Expected Coverage</th><th>Achievement</th><th>Achievement with Merit</th><th>Achievement with Excellence</th></tr>
<tr><td>(a)</td><td>The giant molecular cloud (GMC) is a vast collection of dust and hydrogen gas. They are called “stellar nurseries”, as new stars will form in the densest areas of the molecular cloud.</td>
<td rowspan="2">Describes with understanding:
• a GMC as a collection of gas and dust OR location of stellar nurseries
• that material in the GMC collects under gravitational force
• that gravitational energy is converted into heat in the forming protostar
• the conditions needed for fusion to take place
• the fusion process (hydrogen to helium) taking place in the main sequence phase
• the relationship between star size and fusion rate
• during the red phase helium nuclei are fused to carbon and oxygen and possibly heavier elements
• the release of material called a planetary nebula due to heat OR explosion as a super nova the star mass indicates that the star will likely form a white dwarf or neutron star</td>
<td rowspan="2">Explains in detail:
• how the materials in the stellar nursery collected under the influence of gravity to form the protostar that became Canopus
• the energy changes that took place in the formation of the protostar and as it transitioned as Canopus through the main sequence stage
• the changes that may take place past the red stage to the eventual death of Canopus
• the link between star mass and the eventual outcome of the Canopus demise.</td>
<td rowspan="2">Explains comprehensively:
• the links between star formation, gravitational force, energy transfer, and fusion in the formation of Canopus as a main sequence star
• linking the mass through the fusion process, through Canopus’s life cycle and its eventual outcome as either a white dwarf or neutron star
• the significance of Canopus’s mass, leading to the possibility of one of two likely eventual outcomes – as a white dwarf or neutron star.</td></tr>
<tr><td>(b)</td><td>Disturbances within the gas cloud brings dust and hydrogen gas together to form a region of high density. Eventually the particles are close enough and big enough for gravity to begin to take effect and accretion take place. Continued gravitational collapse takes place and a dense ball of molecular gas is formed. The gravitational potential energy within the ball of gas, is transformed into heat energy and a protostar is formed. Its size and internal temperature is insufficient for fusion of hydrogen nuclei to take place.
At a certain point the protostar’s mass reaches a minimum of approximately 0.08 M_{sun} and internal core temperature of 10 million K, fusion of hydrogen nuclei will take place. The protostar now enters the main sequence phase. The more massive the star, the faster this takes place.
During its main sequence phase, Canopus, with its mass of at least 8 times that of the Sun, was rapidly fusing hydrogen nuclei to helium in its core. The rapid fusion would account for the star colour in the main sequence and high surface temperature.</td></tr>
</table>

(c)	Canopus's mass suggests there could be one of two outcomes as the star passes out of its main sequence, hydrogen fusing phase. Given the mass of Canopus is approximately 8 times that of the Sun, it seems likely that Canopus's core will have insufficient gravity to continue the fusion of elements beyond the current carbon / oxygen / neon. It may expand to a red giant star, fusing helium in its core to the heavier elements. During this phase, the star's surface temperature cools as it expands in size. When fusion ceases, it sheds its outer atmosphere of fused gaseous material into space. This material is known as a planetary nebula. The remaining core is a white dwarf, and will continue to glow due to residual heat energy. Once cooled, a black dwarf remains. The alternative scenario, given the mass of the star, is for Canopus to undergo a supernova explosion and end its life as a neutron star. Once in the He fusing stage, the star core's gravity is sufficient for He to be fused through the sequence up to iron. During this period the star cools and expands as a supergiant. When the core is iron, the hydrostatic equilibrium between the radiative energy release and gravity is lost. The star implodes and the outer gases and materials rebound rapidly into space. This is the supernova stage. What is left behind is a neutron star. *Note:* *Evidence may be taken from annotated diagram.* *Evidence may be taken from any section of the question*			

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Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 06	07 – 12	13 –18	19 – 24