Assessment Schedule – 2021

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

Evidence Statement

Question One

Q	Expected Coverage	Achievement	Merit	Excellence
ONE (a)	The frost line is the particular distance from the protostar at which it is cold enough for volatile substances such as water, ammonia, methane, carbon dioxide, and carbon monoxide to condense into solid ice grains.	Describes with understanding: • the frost line • the formation of the protoplanetary disk • how planetesimals / planets are formed due to accretion / gravity • the formation of rocky planets when high-melting-point materials solidify within the frost line • solar winds are linked to movement of matter away from stars • a logical reason for the lack of gaseous giants in the Kepler system.	Explains in detail: • the role gravity takes in the protoplanetary disk to cause accretion and the creation of planetary bodies • the linking of the two rocky planets to condensation / solidification of high-melting-point materials within the frost line. • the role solar winds can play in pushing volatile materials / gases into the outer reaches of the planetary system, beyond the frost line • the possible reasons why there appear to be no gaseous planets in the Kepler system beyond the frost line, e.g lack of accretion / or not detected.	Explains comprehensively: • the stages in the formation of rocky planets, including the protoplanetary disk, accretion and nature of the materials related to frost line • the nature of the red dwarf star Kepler 1649 and possible reasons for the non-existence of gaseous giants in this system.
(b)	Dust, ice and gases remain in orbit around the young protostar, Kepler 1649. (As the material circulates, electrostatic attraction pulls the material together into a protoplanetary disk.) Disk material starts to "clump" together through collisions (accretion). Once the material is large enough it has its own gravity, leading to further increases in size. Further collisions occur and planetesimals form. These two planetesimals continue to orbit Kepler, collecting material and growing in size until they are the only objects orbiting in their respective orbits. They become the planets Kepler 1649b and Kepler 1649c. The rocky material will solidify within the frost line, in close proximity of the star's gravitational field.			

(c)	Kepler is a cool red dwarf star, meaning that the frost line will be very close to the protostar. Solar winds from Kepler push the majority of the low-melting-point materials out into space beyond the frost line, although some material is left behind, allowing for rocky planets to have an atmosphere, which is more likely on Kepler 1649c. The material that has been pushed out beyond the frost line appears not to have coalesced to form any gas planets or rocky planets in the extreme cold conditions. The possible reasons could be the material is orbiting the star but has not coalesced, or remains undetected. An alternative theory could involve strong solar flares, that during the star's life cycle, has forced material far into space and remains as debris in the far reaches of the star's solar system. Or, due to the small mass of Kepler, it will have a weaker gravitational attraction, meaning it is unable to attract material blown away by the solar winds. *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 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

<table>
<tr><th>Q</th><th>Expected Coverage</th><th>Achievement</th><th>Merit</th><th>Excellence</th></tr>
<tr><td>(a)</td><td>
<table>
<tr><th>Star</th><th>Luminosity</th><th>Temperature K</th><th>Colour</th></tr>
<tr><td>Antares A</td><td>$10^{3.5}$
(Accept close to this.)</td><td>3000–3800</td><td>Red</td></tr>
<tr><td>Antares B</td><td>1</td><td>16000–20000</td><td>Blue white</td></tr>
</table>
</td>
<td rowspan="3">Describes with understanding:
• FOUR characteristics of the stars completed in the table
• luminosity is defined in terms of energy output
• Antares A is more luminous due to its larger surface area that is emitting radiation
• Antares B is less luminous due to its small surface area and less surface area to emit radiation
• fusion products for Antares A and B
• Antares A will become a neutron star / black hole
• Antares B will become a white dwarf.</td>
<td rowspan="3">Explains in detail:
• the properties of Antares A as a red giant; linking higher luminosity to its large surface area, and temperature
OR
the properties of Antares B as a main sequence star, linking the luminosity to its small surface and temperature
• energy processes currently occurring in Antares A / B
• the likely outcome of Antares A / B.</td>
<td rowspan="3">Explains comprehensively:
• the energy processes occurring currently in Antares A AND B, and their likely outcome as they end their life cycles
• how luminosity is linked to the surface area and current life stages of Antares A and B.</td></tr>
<tr><td>(b)</td><td>Luminosity is the rate of energy output / radiation emission.
Antares A is a middle-aged red supergiant, meaning that it has a very large surface area, emitting large quantities of radiation from its surface, and a low surface temperature.
Antares B is a main sequence star, and is much smaller than Antares A. It has a high surface temperature, but is much smaller than Antares A.
Antares A has a greater luminosity due to its larger size and surface area, meaning it emits more radiation.</td></tr>
<tr><td>(c)</td><td>Antares A is a middle-aged red supergiant, which is fusing helium. As the helium in the core begins to run out, gravity begins to dominate; the core partially collapses and heats up, leading to the fusion of carbon. This cycle continues up to iron. Iron cannot fuse together, and gravity causes the core to collapse instantaneously causing a supernova. This will leave behind either a neutron star or black hole.
Antares B is a main sequence star, fusing hydrogen to helium. It is likely to have a mass similar to our Sun. Therefore, as hydrogen runs out, gravity dominates leading to the heating up of the core, and helium fusion to begin. The outer layers expand forming a red giant. When the helium runs out, gravity dominates, but there is not enough mass for the core to heat up. The outer layers drift to form a planetary nebula, while the core becomes a white dwarf.
Note:
Evidence may be taken from annotated diagrams.
Evidence may be taken from any section of the question.</td></tr>
</table>

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)	A protostar is a very young star that is still gathering mass from its giant molecular cloud. In this stage the core has not reached a sufficient temperature of nuclear fusion to begin. The protostellar phase is the earliest one in the process of stellar evolution.	Describes with understanding: • what a protostar is • the role of the gravity in accretion • the role of gravity in the conversion of gravitational potential energy to heat energy • two possible outcomes (brown dwarf, and main sequence star) • requirements for fusion to begin.	Explains in detail: • the birth of T-Tauri protostars 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 brown dwarf • the formation of a main sequence star.	Explains comprehensively: • The formation of protostars from their origin in the GMC, in terms of mass, gravity and temperature. • the TWO possible outcomes of the T-Tauri protostars in terms of mass, gravity and temperature.
(b)	Material, dust, and gases in the Giant Molecular Cloud 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.			
(c)	**Possibility One:** If the mass and gravitational forces are insufficient, the benchmark core temperature of 10 million K (or an acceptable resourced value, e.g. 15 to 27 million °C) for nuclear fusion to begin is not reached, and the protostar is known as a brown dwarf. It radiates (shines) because of infrared radiation being emitted. **Possibility Two:** In the case of most T-Tauri stars, their mass allows the core of the protostar to collapse, contract, and compress so much that 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. *Note:* *Evidence may be taken from annotated diagrams.* *Evidence may be taken from any section of the question.*			

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

Cut Scores

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