Assessment Schedule – 2020

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

Evidence Statement

Question One: Types of dwarf stars

<table>
<tr><th>Q</th><th>Expected Coverage</th><th>Achievement</th><th>Merit</th><th>Excellence</th></tr>
<tr><td>ONE
(a)(i)

(ii)</td><td>
<table>
<tr><th></th><th>Temperature</th><th>Luminosity</th><th>Absolute Magnitude</th></tr>
<tr><td>Kapteyn’s Star</td><td>4000K</td><td>10^{-2}</td><td>10</td></tr>
<tr><td>Van Maanen’s Star</td><td>6 000K</td><td>10^{-4}</td><td>14–15</td></tr>
</table>
Does not fit on the scale given in the HR diagram / Temperature too low / Magnitude/Luminosity too low.
</td><td>• Both rows correct.
• Reason given.</td><td></td><td></td></tr>
<tr><td>(b)</td><td>Initial mass of Van Maanen > Kapteyn’s Star > Gliese 229b.
Gliese 229b would have been the smallest star initially, as it is a brown dwarf, which did not gain enough mass to begin fusion. However, it is also too massive to be a planet (at least 20 × that of Jupiter).
Kapteyn’s Star would have been the next largest star initially, as it is a red dwarf, which is big enough to begin fusion, but not big enough to become a red giant and fuse larger elements than hydrogen.
Van Maanen’s Star, as a white dwarf, would have been the largest star initially, being the remnant of a small main sequence star that has ejected its outer layers when it ran out of fuel.</td><td>Explains:
• Gliese 229b identified as initially smaller than either Kapteyn’s or Van Maanen’s Star.
OR
Van Maanen’s Star identified as initially larger than Kapteyn’s or Gliese 229b.</td><td>Explains in detail:
• Gliese 229b initially smallest mass, as there is not enough mass for fusion to occur.
• Kapteyn’s Star size correctly compared to one other star AND that it only fuses hydrogen.
• Van Maanen’s Star initially largest as it is the remnant of a main sequence star.</td><td>Explains comprehensively:
• Correctly compares initial mass of all three stars linking explanations for two comparisons.</td></tr>
</table>

(c)	As stars form from a nebula, gravitational potential energy is converted to kinetic and heat energy due to friction (collision of particles). More mass means more heat is generated. If there is too little mass to start nuclear fusion, then a brown dwarf will form. A brown dwarf is sometimes termed a "failed star", as no fusion takes place. The heat generated during the formation of the brown dwarf will be slowly emitted over a very long period. If there is just enough mass to start fusion in the core a red dwarf like Kapetyn's Star will form. This will slowly fuse H → He over a very long life as a low-mass main-sequence star. A larger star will start fusion in its core as a main sequence star, then progres through the giant phase, before losing its outer layers leaving a hot, dense core of mainly carbon and oxygen. This white dwarf radiates residual heat for billions of years. *Note: Evidence may be taken from any section of the question.*	• Kapteyn's Star is fusing H → He. • Gliese 229b OR Van Maanen's Star do not have fusion OR both emit residual heat.	• Kapteyn's Star is a red dwarf, the only star with fusion (H → He) occurring at a slow rate. • Van Maanen's Star is a white dwarf, which is a medium / small star at the end of its life with no fusion. It releases residual heat from when it was fusing elements. • Brown dwarf (Gliese 229b) is a "failed star" that does not have enough mass to begin fusion OR emits residual heat from its formation.	• Kapteyn's Star is a red dwarf, the only star carrying out nuclear fusion (H → He which happens at a very slow rate. It does not have enough mass to fuse elements larger than H. AND / OR Van Maanen's Star is a White Dwarf therefore no fusion occurs as it is a medium / small star at the end of its life emitting residual heat from when it was fusing elements. AND / OR Brown dwarf (Gliese 229b) is a "failed star" that does not have enough mass to begin fusion and emits residual heat from its formation. *TWO of the three needed.*

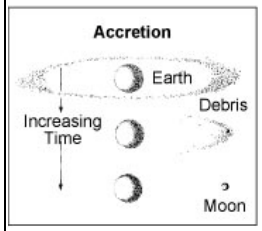
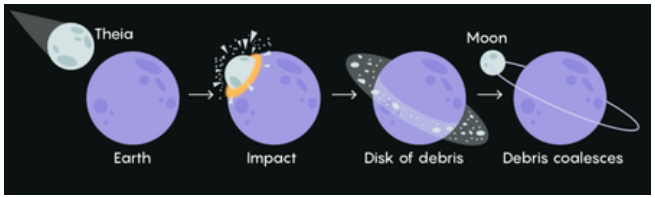
Not Achieved			Achievement		Achievement with Merit		Achievement with Excellence	
NØ	**N1**	**N2**	**A3**	**A4**	**M5**	**M6**	**E7**	**E8**
No response or response does not relate to the question.	Describes ONE partial idea at the Achievement level.	Describes TWO ideas at the Achievement level.	Describes 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.	ONE point or TWO with minor errors.	TWO points.

Question Two: First real image of a black hole

Q	Expected Coverage	Achievement	Merit	Excellence
TWO (a)	Black holes originate from massive (blue) stars - approximately 30 M_{Sun} and are extremely bright. These can be found in the top left corner of the HR diagram on the main sequence.	Explains: • Massive / largest stars form black holes. • Can be found at the top left of the HR diagram (on main sequence).		
(b)	This star would have started life as a protostar which generated heat through gravitational compression of the dust and gas in the nebula. Main sequence stars fuse **hydrogen to helium** as their fuel which releases huge amounts of energy. Due to their high mass, they use up their hydrogen very quickly, and once H fusion ends, the core partially collapses and heats up, causing helium to start fusing to carbon and oxygen. This causes the star to expand forming a supergiant. Then this process of partial collapse, heating and fusion of increasingly larger elements continues up to iron - as iron fusion uses rather than releases energy. Once iron is reached, fusion stops, the core will violently collapse and a supernova results, expelling the star's outer layers and emitting a massive amount of energy. This results in an extremely dense core / star that is unable to support itself and will collapse leaving a region of incredibly high gravity that not even light can escape from, which is known as a black hole.	• Protostar produces heat through gravity acting on dust and gas in the nebula • (Main sequence) stars fuse H → He OR describes fusion of increasingly larger elements. • Black hole forms when fusion stops / iron is reached.	Explains in detail: • Fuel use of a main sequence star (H → He) followed by fusion of increasingly larger elements. • Partial collapse of the star's core / generates more heat / causes fusion of larger elements / expansion to supergiant (two of three links).	Explains comprehensively: • The alternating cycle of partial core collapse, increasing heat and then stable fusion of increasingly larger elements until iron is reached and fusion stops, leading to core collapse, supernova and then a black hole.
(c)	During the star's life, nuclear fusion in the core provides outward pressure, which acts against gravity and maintains a relatively steady volume. When the star runs out of Hydrogen and the core partially collapses the additional heat needed to fuse heavier elements causes it to expand so that it is no longer in hydrostatic equilibrium – forming a supergiant star. Once iron is made. there is no longer any fusion to oppose gravity, so the star instantly collapses, which triggers a violent explosion called a **supernova -** as the repulsive electrical forces between iron nuclei briefly overcome gravity. Gravity will further collapse the core, meaning the entire star becomes very small and can be considered to have no volume. This incredibly small, very strong gravitational field in space will not allow light to escape and so the star is said to become a black hole. *Note: evidence may be taken from any section of the question.*	• Gravity causes core to heat up, leading to fusion of heavier elements. • Star becomes a supergiant when it runs out of hydrogen • (When fusion ends) gravity causes the star to collapse / form a black hole.	• Once fusion ends, gravity causes the core to collapse forming a supernova. • Gravity will collapse the remaining star after supernova, reducing the mass to a tiny / no volume.	• How a supernova occurs due to gravitational force once fusion ceases, blowing away the outer layers followed by gravitational core collapse creating a black hole.

Not Achieved			Achievement		Achievement with Merit		Achievement with Excellence	
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.	ONE point or both points with minor omission.	BOTH points.

Question Three: Moon formation theories

	Expected Coverage	Achievement	Merit	Excellence
(a)	A planet orbits the sun while moons are natural satellites orbiting planets.	• Difference stated.		
(b)	 Some moons are thought to accrete from leftover material that was orbiting the planet in a disc as the planet was forming (circumplanetary disc). As the forming planet spins, the surrounding dust and gas particles flatten into a disc shape. The moon forms from the disc as material clumps together into larger and larger masses due to gravity. https://ase.tufts.edu/cosmos/view_picture.asp?id=382	Explains: • Circumplanetary disc. • Gravity as pulling matter together. • Process of accretion of larger objects.	Explains in detail: • Formation of circumplanetary disc • How accretion occurs due to gravity while earth forms, creating moon of increasingly larger mass.	Explains comprehensively: • Accretion theory of moon formation outlined in detail.
(c)	 While accretion suggests material left over from the planet's formation formed the moon, the giant-impact theory suggests that our moon formed when a Mars-sized planet collided with the Earth about 4.5 billion years ago. Significant amounts of the mantles of both objects were ejected into space forming a ring of debris that quickly clumped together and cooled into a sphere, forming the current Moon from the same material as the Earth. *Note: evidence may be taken from any section of the question.*	• Collision of Mars-sized planet • Ejection of material / debris which formed a disc / the Moon.	• Planet (Theia) collided with Earth, causing ejection of matter which formed the Moon. • Moon and the Earth's crust /mantle consist of similar material as a result of the collision.	• Mars sized planet collided with earth ejecting a mix of it and Earth's mantle into orbit around the Earth, which then accreted into the moon.

Not Achieved			Achievement		Achievement with Merit		Achievement with Excellence	
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.	ONE point.	TWO points.

Cut Scores

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