No part of the candidate's evidence in this exemplar material may be presented in an external assessment for the purpose of gaining an NZQA qualification or award.

SUPERVISOR'S USE ONLY

2

91192

911920

Draw a cross through the box (☒) if you have NOT written in this booklet

+

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Earth & Space Science 2023

91192 Demonstrate understanding of stars and planetary systems

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of stars and planetary systems.	Demonstrate in-depth understanding of stars and planetary systems.	Demonstrate comprehensive understanding of stars and planetary systems.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (DO NOT WRITE IN THIS AREA). This area will be cut off when the booklet is marked.

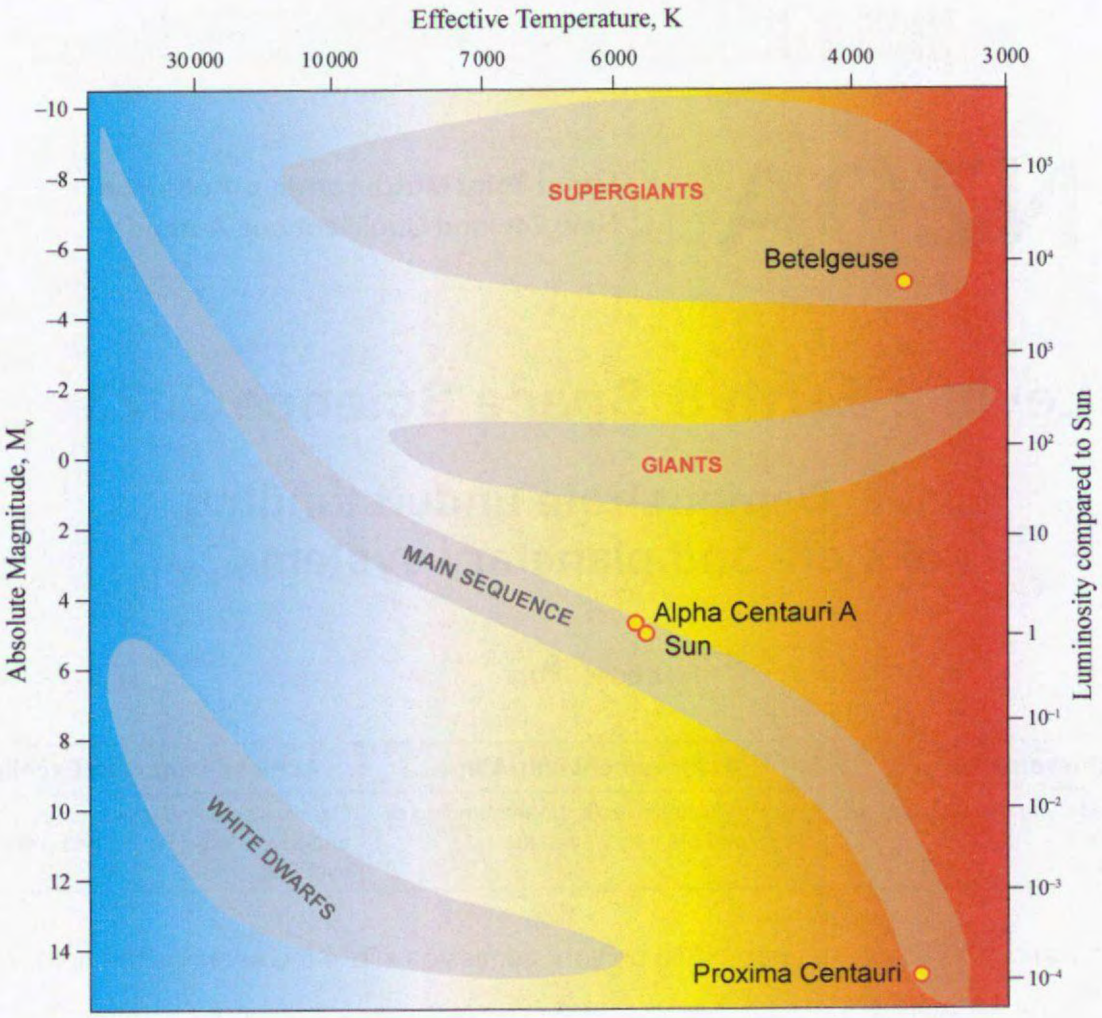
YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 23

RESOURCE

HR (Hertzsprung-Russell) diagram



Adapted from: http://www.atnf.csiro.au/outreach/education/senior/cosmicengine/stars_hrdiagram.html

This page has been deliberately left blank.
The assessment begins on the following page.

QUESTION ONE: RED STARS

Betelgeuse and Proxima Centauri are both red stars. Betelgeuse is easily seen in the constellation of Orion. Proxima Centauri is a star that forms part of the triple star system in the constellation of Centauri. Betelgeuse is 642.5 light years away from Earth, and has a mass of approximately 17 solar masses, while Proxima Centauri is only 4.2 light years away, and has a solar mass of 0.12.

(a) Using the HR diagram on page 2, complete the table comparing the properties of Betelgeuse and Proxima Centauri.

Star	Life Stage	Temperature	Absolute Magnitude	Luminosity
Betelgeuse	Supergiant	3,600 K	-6	10^4
Proxima Centauri	Red dwarf	3,500 K	14	10^{-4}

(b) Explain, in detail, using the information from the HR diagram and the star properties in part (a), the reason for the difference in absolute magnitudes of Betelgeuse and Proxima Centauri.

In your answer you should consider:

- the difference between luminosity and absolute magnitude
- surface temperature
- surface area.

Luminosity is the amount of energy produced by a star per second. The luminosity of Betelgeuse is 10^4, while the luminosity of Proxima Centauri is 10^{-4}. This difference means that Betelgeuse produces a lot more energy per second compared to Proxima Centauri. Since Proxima Centauri is a red dwarf it's luminosity makes sense as it does not produce alot of energy per second, a red dwarf doesn't have enough mass or energy to become a red giant and therefore such a low luminosity of Proxima Centauri makes sense. Absolute magnitude is how bright a star actually is. Proxima Centauri has an absolute magnitude of 14, meaning the star is very dull and not bright. Betelgeuse has an absolute magnitude of

-6, meaning the star is very bright.
The surface temperature of both Betelgeuse and Proxima Centauri are very similar, Betelgeuse has a slightly higher temperature at 3,600K, while Proxima Centauri has a temperature of 3,500K. Since both stars have similar temperatures but very different luminositys the surface area of both stars must differ greatly. This is because luminosity relys on both surface area and temperature. Since Betelgeuse has a much higher luminosity at 10^4, it must also have a very large surface area if it is the same temperature as Proxima Centauri. This statement is true because Betelgeuse is a supergiant and has a mass of approximately 17 solar masses. Proxima Centauri has a very small surface area because it is a red dwarf and has a solar mass of 0.12. Because of these reasons Betelgeuse has a much higher luminosity. Since luminosity refers to the amount of energy produced per second, the absolute magnitude will also be much different as Betelgeuse has an absolute magnitude of -6, and Proxima Centauri has one of 14. The energy released from a star is generally light energy. Since absolute magnitude is a measure of a stars actual brightness, the star that produces the most energy will be the brightest. Therefore, Betelgeuse produces more energy meaning the star will have a higher absolute magnitude.

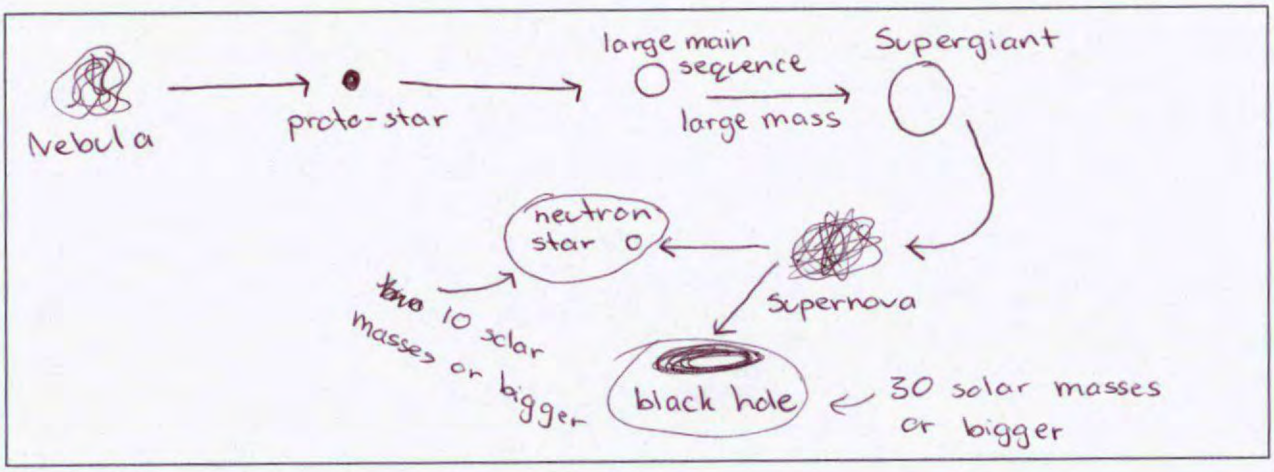
(c) Explain, in detail, how the luminosity of Betelgeuse will change over its life stages, whereas the luminosity of Proxima Centauri will not change until the end of its life.

In your answer you should consider:

- star mass
- surface area
- surface temperature
- life stages.

An annotated diagram may assist your answer.

Betelgeuse



Betelgeuse is currently a red supergiant meaning the star is already a long way through it's life cycle. Betelgeuse is a large massed star at 17 solar masses. Currently, Betelgeuse has a luminosity of 10^4 and a surface temperature of 3,600K.

also a large surface area

Since Betelgeuse is a large massed star it will follow a certain life cycle. Once Betelgeuse runs out of helium to fuse, it will fuse all elements down to iron. The star will expand and cool and once nuclear fusion is completed a supernova will be formed. A supernova is an event that produces a massive amount of energy in a short period of time. At this stage in Betelgeuse life cycle, the highest luminosity will be reached. This is because luminosity is the amount of energy produced per second, since a supernova results in lots of energy being produced, luminosity will be at it's highest. The amount of light and heat energy created by this event is massive and therefore will also be at the highest absolute magnitude in the life of Betelgeuse. Because Betelgeuse has a solar mass of 14, after becoming a supernova, Betelgeuse will become a neutron star. This star is only made when the star before this stage has a solar mass of at least 10, therefore Betelgeuse will become a neutron star as its solar mass is 14. A neutron star ~~bears~~ indicates the end of a stars life and does not have a large luminosity. Proxima Centauri is a red dwarf with a solar mass of 0.12, the star has a surface temperature 3,500K and a small surface area. Since Proxima Centauri is a red dwarf it is too small-massed at only 0.12 and ~~not~~ ~~hot enough~~ doesn't have a sufficent size to have enough gravity to become a red giant. Because of this Proxima Centauri will stay as a red dwarf for the rest of it's life until it dies. Once it reaches it's death the luminosity of the star will change to be none/close to no luminosity.

QUESTION TWO: MATARIKI

Source: www.sciencelearn.org.nz/images/697-matariki-pleiades-star-cluster

Matariki is a star cluster indicating the beginning of the New Year to many Māori iwi. It contains many young stars, the brightest of these being 14 young, blue, main-sequence stars that have formed in the associated stellar nebula. These stars have masses in the range of 3 solar masses to 6 solar masses for the largest.

(a) Describe what is meant by the term "stellar nebula".

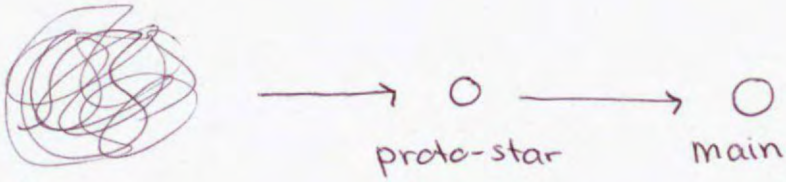
The stellar nebula is a cold and dense cloud of gases, dust and ice particles where stars are formed.

(b) Explain, in detail, how these young blue stars would have formed.

In your answer you should consider the role gravity plays in star formation.

An annotated diagram may assist your answer.

Stellar Nebula to main sequence



proto-star
- hot core
-

main sequence star
- stable
- longest stage
- H → He
- hydrostatic equilibrium

Stellar Nebula
- cold
- accretion
- gas, dust + ice
- condense, collapse
- inwards

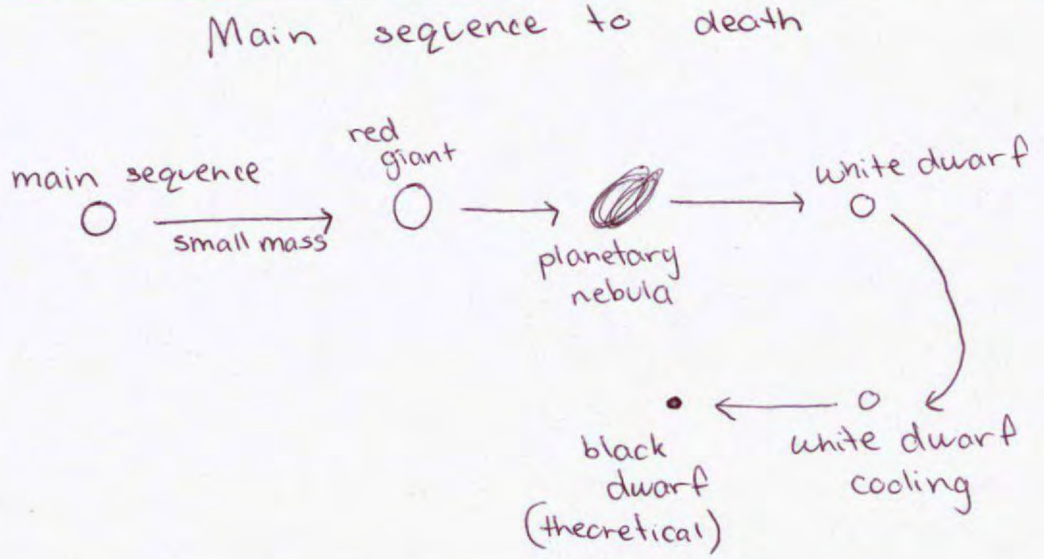
All stars are first formed in a stellar nebula. A stellar nebula is a cold cloud of gases, dust and ice particles. Gravity begins to condense and accrete this particles, clumping them together to form larger masses. Gravity continues to pull material and a dense mass forms where particles collide. These collisions start the spinning of the mass collected and also increases the temperature due to friction. The force of gravity increases and the cloud of mass collapses in on itself due to the pressure. The ~~[illegible]~~ collapse creates a hot core / ball of gas known as a proto-star. This proto-star is very hot and still has the force of gravity acting upon it. Once the proto-star produces enough mass, heat and gravity a main sequence star is formed due to the start of nuclear fusion. This main sequence star will fuse hydrogen to helium and is the most stable and longest stage in a stars life cycle. Main sequence stars are at hydrostatic equilibrium, meaning that the force of gravity acting upon / pushing against the star is the same as the pressure of the gases inside the star. This is how the formation of the Matariki young blue star would have been formed, since they are blue the stars will have a very high surface temperature as main sequence stars.

(c) Explain, in detail, the life cycle of the smallest (3 solar masses) of these young blue stars from main sequence to the end of its life.

In your answer you should consider:

- the role of gravity in the changing life stages
- fuel usage during the different life stages
- energy changes during the different life stages.

An annotated diagram may assist your answer.



The smallest main sequence star in the Matariki cluster is 3 solar masses. Since our Sun is 1 solar mass, 3 solar masses is considered a similar mass to our Sun. Because of it's mass it will follow a certain life cycle. Once the blue main sequence star runs out of hydrogen to fuse it will start fusing helium to carbon and oxygen, this is now a red giant star. A red giant is a cooling star and will puff off any outer layers of gas as it becomes a planetary nebula. Gravity in the red giant, prior to becoming a planetary nebula, will overpower the pressure of gas inside the star, therefore the red giant will no longer be at hydrostatic equilibrium. Therefore the force of gravity acts upon the red giant and begins to collapse the stars core. Once nuclear fusion has finished, all ~~hydr~~ helium has been converted to carbon and oxygen, the core collaption of the red giant will occur. This forms a planetary nebula. The remaining gas layers will once again puff off and a hot ball of carbon is remaining, this is known as a white dwarf. A white dwarf is a dead star and nuclear fusion will not occur, the carbon ball will just cool down in space. The cooling white dwarf will not be bright as it will have a low absolute magnitude and luminosity, however it will have a very large temperature and mass but confined to a small volume and small surface area. This is the life cycle that the smallest young blue star of the Matariki ~~cons~~ cluster would live through from its position on the main sequence to its death.

QUESTION THREE: JUPITER AND THE SOLAR SYSTEM

Source: https://blogs.nasa.gov/Watch_the_Skies/2022/09/16/jupiter-to-reach-opposition-closet-approach-to-earth-in-70-years/

Our solar system consists of eight planets, with Jupiter the largest.

(a) Describe the difference between a star and planet.

A planet is an astronimical body in space that orbits a star, has a self-sufficient amount of gravity to form a sphere and has cleared its orbit of debris, whereas a star is a body in space that has fusion occuring and provides a place for planets to orbit.

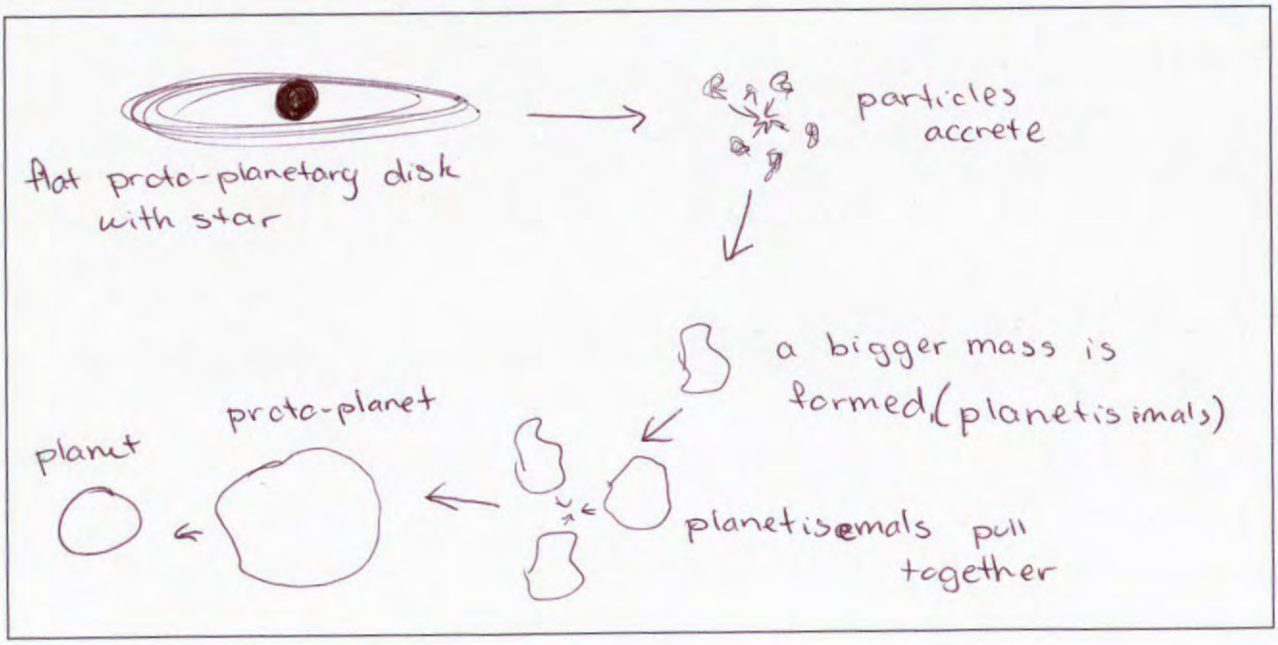
(b) Explain, in detail, how gas giant planets like Jupiter are formed.

In your answer you should consider:

- the role of gravity
- temperature
- solar winds.

- frost line
- condense gas
- light gases pushed out

An annotated diagram may assist your answer.



00694

For a planet to form a star must first be formed. In a cold, dense stellar nebula, dust, gases and ice particles begin to accrete and condense. A large mass is formed and gravity pulls in more material, more collisions occur which increases mass and temperature, these collisions also start the spinning of the particles and overall mass. The spinning of particles and force of gravity flatten the mass out and a proto-planetary disk is formed. This disk will be used for planets to orbit. Gravity then collapses the cloud in on itself and the increased temperature creates a hot core which a proto-star forms from. This is now a proto-star with a proto-planetary disk. When the proto-star is made, the solar winds from the stars formation pushes the lighter gases out away from the star. Gaseous planets such as Jupiter must be formed beyond the frost line as this is where gas condenses and can be found as material. Gas material cannot be found close to the star because the heat radiated from the sun is a temperature too high and the gas would not form or condense in these hot temperatures. Therefore, materials such as hydrogen and helium with low melting points can only be found in cooler temperatures where the gas can condense and form in a solid / material state.

Question Three continues on the next page.

☆ continues on p.g 16

(c) The picture below shows Jupiter's three rings, and the four rocky moons that accompany the rings. The rings are mainly made up of very fine dust particles.

Source: https://upload.wikimedia.org/wikipedia/commons/thumb/b/b8/Jupiter_Rings_ca.svg/2560px-Jupiter_Rings_ca.svg.png

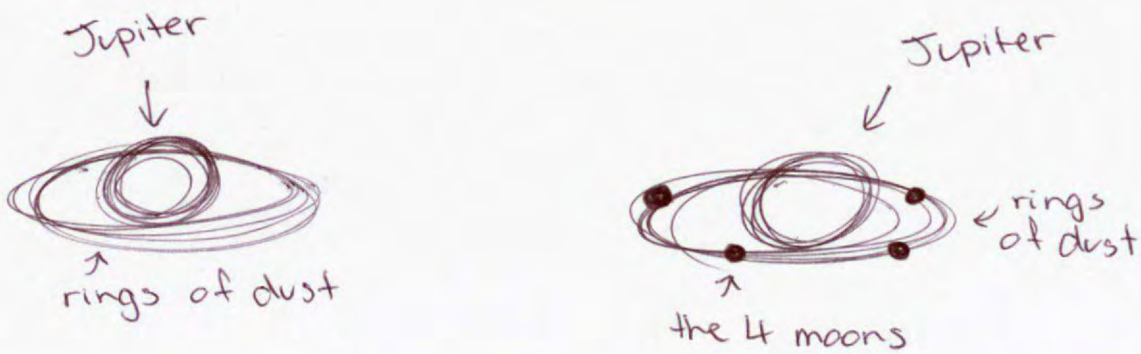
Explain, in detail, how Jupiter's four rocky moons and ring system could possibly have been formed.

- Great impactor
- capture x
- circumplanetary disk

In your answer you should consider:

- the planet's gravity
- how moons may have formed around Jupiter
- the material making up Jupiter's rings.

An annotated diagram may assist your answer.



The material that make up Jupiter's rings are very fine dust particles. This ring system could have been formed from the remaining material left over from the formation of Jupiter. The dust particles may have formed around the gaseous planet due to it's immense gravitational field. Since Jupiter is such a big planet it's gravity is huge, it can even capture asteriods in motion. The surronding dust particles would have been caught and attracted to the gravitational field of Jupiter creating the planets rings. Since the four rocky moons of Jupiter lay on the planets rings the moons could have been formed through the circumplanetary disk theory. This theory suggests that the moons of Jupiter could have formed to a similar way as planets form around the Sun. The rings of Jupiter consist of dust particles, these particles may have accreted together due to Jupiters immense gravity and formed small masses of dust. These small masses would have accreted with each other to form larger masses such as moons. Like the formation of planets around a star, these moon masses would orbit around Jupiter acting as a natural satelitte. Since the rings of Jupiter are made of dust, the moons will become rocky once enough mass is accumulated which indicates as to why the 4 moons of Jupiter are rocky.

continuous p.g 16

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

3b. The gas particles along with dust and ice begin to stick together during accretion because of the force of gravity. Since gas is more abundent in space and our solar system (refering to the formation of Jupiter) the gaseous planets will be very big compared to rocky, terrestrial planets. The particles that accrete will form planetesimals which are relatively small masses of gas, dust and ice material. Once planetesimals are made they will accrete due to the force of gravity and produce a larger mass known as a proto-planet. This proto-planet is a planet in the making and will become a proper planet once the gravity of the proto-planet is enough to form a spherical shape. This is the formation of gas giants such as Jupiter, gas planets are very big.

3c. This is one of the possible situations that could have formed Jupiters ring system and four rocky moons.

91192

Excellence

Subject: Earth & Space Science

Standard: 91192

Total score: 23

Q	Grade score	Marker commentary
One	E8	The candidate explains the link between star appearance luminosity and surface area for the individual stars. The luminosities of both stars are tracked through their probable life cycles and the reason for the apparent difference linked to energy release, surface area and mass.
Two	E7	The role of gravity in the formation of hot blue stars is explained. Reference is made to energy changes but not fully linked to the star formation process. The star's life cycle is fully linked to star colour, energy changes, size and luminosity until its eventual end point.
Three	E8	The candidate links the roles of gravity, solar winds and frostline in the formation of the gas giant, Jupiter. Logical explanations are discussed as to the formation of Jupiter's moons and rings as given in the question's context.