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Level 2 Earth and Space Science, 2019

91192 Demonstrate understanding of stars and planetary systems

9.30 a.m. Wednesday 27 November 2019
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 and clearly number the question.

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

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

Excellence

TOTAL 21

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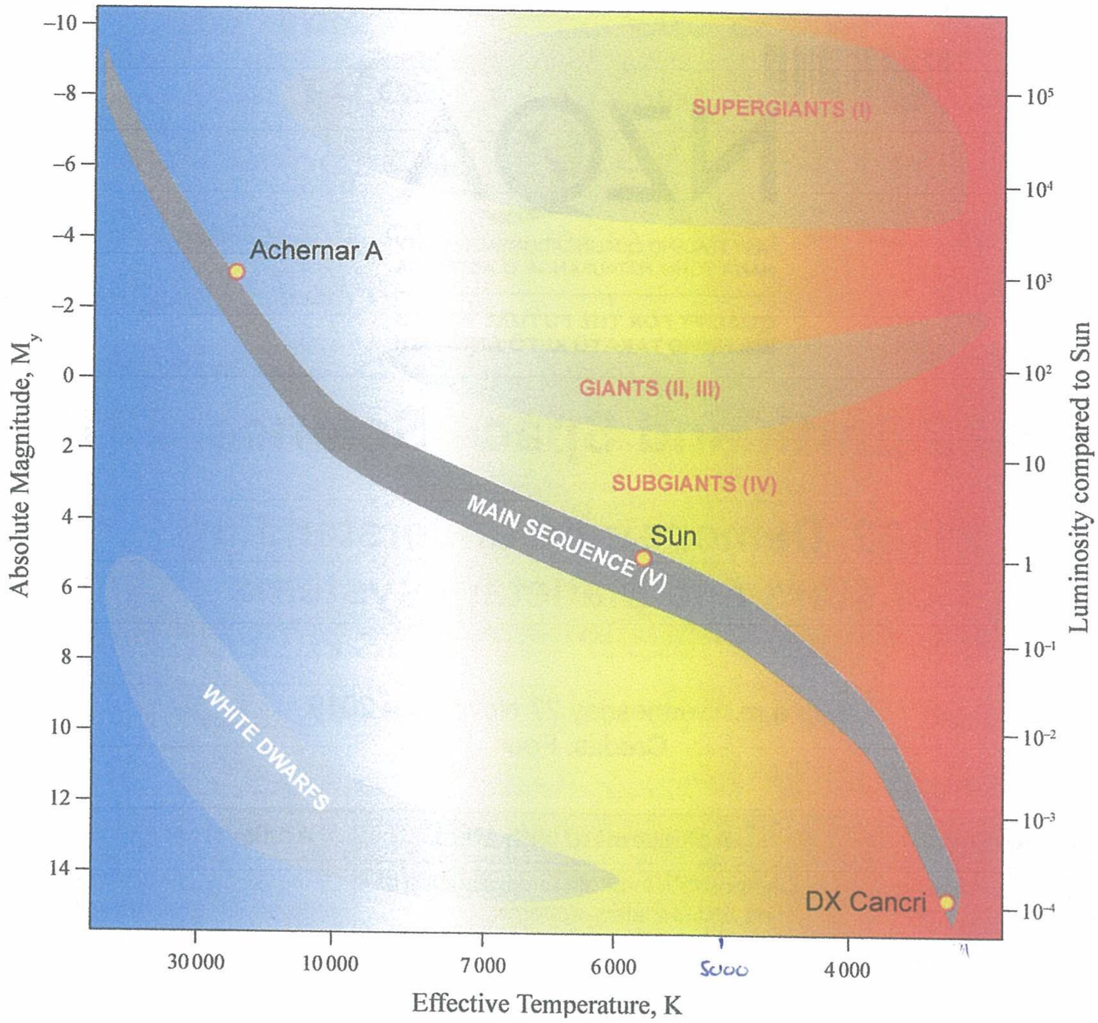
RESOURCE

Hertzsprung-Russell (HR) Diagram



Adapted from: http://astronomy.swin.edu.au/cosmos/h/hertzsprung-russell+diagram

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QUESTION ONE: FIRST CONFIRMED VIEW OF A NEWBORN PLANET

An observatory in Chile recently confirmed an image of a forming planet around a star known as PDS 70. The star is blacked out to show the bright spot just to the right of the centre of the image.

www.eso.org/public/news/eso1821/

The forming planet is a few times larger than Jupiter and has similar properties to the outer planets of our solar system. However, the surface of the planet has a temperature of around 700 K, making it much hotter than any planet in our solar system.

Explain, in detail, each stage in the formation of this planet.

In your answer, you should consider:

- the main stages in the formation of this planet
- why the material in this planet is likely to be different to any inner planets
- possible reasons why this planet is so much hotter than Jupiter.

A diagram may assist your explanation.

More space for this answer is available on the following pages.

During the formation of the star PDS 70, leftover gas and dus would have begun to orbit the protostar. Over time, in order to conserve angular momentum, these particles would have flattened out into a protoplanetary disk. Due to the swirling motion of the disk around the star, particles within the disk collide and, due to friction, stick together. Particles continue to collide to form bigger and bigger masses, and ~~both~~ form planetesimals. Friction from collisions generates heat energy, which causes the planetesimals to be molten. The rockline is the distance from the star at which rocks can exist (the temperature is low enough). The frostline is the distance / temperature from the star at which ice and frozen volatiles can exist without being vaporised. The planet in question that is forming is several times bigger than Jupiter, and has a much higher temperature. Despite this, it has similar characteristics to the outer planets of our ~~s~~ solar system - making it an outer planet in its own solar system.

Rock and metal are naturally scarce in ~~our~~ the universe, and so inner planets of any solar system - formed within the frostline, are small and dense due to the scarcity of the raw material they are formed from. Because this planet forming ~~outside th~~ around PDS 70 is so large, it must be forming outside the frostline of its own ~~s~~ star. When the star initiated nuclear fusion, it would have sent out a solar wind - blasting any remaining particles within the frostline, out towards this forming planet. Because it is such

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a large planet, it will command a strong centre of gravity and strong gravitational field, meaning it will attract any particles in its vicinity - which helps to further increase its mass.

The planet is forming currently, so the frequent collision of planetesimals causes friction and therefore heat energy - which could account for the high surface temperature of the planet. In contrast, Jupiter has already cleared its orbit and so does not experience frequent collisions.

Another possible scenario that could account for the high temperature is a situation like that of venus, where geological gassing has created such a strong atmosphere that heat cannot escape - causing a very high surface temperature.

Possibly the star could be very large, meaning it has exhausted its fuel and progressed through most of its lifecycle, causing its outer layers to expand, increasing the temperature of the planet (when it formed temperature could have been much lower).

This planet is likely to be composed of different material than inner planets due to the fact that it is farther away from the star, so will also be composed of gases rather than just solids.

M6

QUESTION TWO: ACHERNAR A AND DX CANCRI

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Achernar A and DX Cancri are both main sequence stars.

(a) Use the HR diagram on page 2 to describe the characteristics of each star in terms of colour, temperature, and luminosity.

Star	**Colour**	**Temperature**	**Luminosity**
Achernar A	Blue	25000 K	10^3
DX Cancri	Red	3000 K	10^{-4}

(b) Use the table above to help explain in detail the similarities and differences between Achernar A and DX Cancri.

In your answer, you should consider:

- the effects of the difference in the mass of each star
- the energy source and output of each star
- which star will have a longer life cycle.

A diagram may assist your explanation.

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Luminosity is the amount of energy released by a star per second, while temperature is the amount of energy released per m^2.

Both Achernar A and DX Cancri are Main Sequence Stars - they are fusing hydrogen to helium in the most stable part of their lifecycle, and releasing vast amounts of energy as they do so. Achernar A has both a higher temperature and luminosity than DX cancri does. This means that it emits more energy per m^2 than DX cancri does, AND the total energy emitted ~~as~~ in a second is greater. This indicates that Achernar A has a higher mass than DX cancri. Stars perform nuclear fusion in the core of the star due to having sufficient mass/density, heat and pressure to force the electrons into a plasma state in which they no longer orbit the ~~nucleus of~~ protons in the nucleus, which allows the nuclei to be fused together to create helium and release vast amounts of energy. Larger mass stars have more heat and pressure in their cores, which means they undergo nuclear fusion at a greater rate. As a result, ~~the~~ larger mass stars deplete their fuel reserves in a much shorter amount of time than smaller-mass stars, and therefore progress through their lifecycle much more quickly.

Colour is dependent on temperature - since Achernar A has a high temperature, it is blue, and since DX cancri has a low temperature, it is red. Due to Achernar A's larger

More space for this answer is available on the following page.

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mass, it will deplete it's hydrogen supply before DX Cancri, and will proceed to become a supergiant. DX Cancri, on the other hand is a small red dwarf, so will continue to fuse hydrogen to helium for billions of years after Achernar A's ~~star~~ lifecycle has ended in a supernova (and gone on to form a black hole or nuetron star). ~~E~~ DX cancri will have a longer lifecycle. Currently, the energy source for both stars is hydrogen. However, Achernar A will progress onto heavier elements after having used its H supply, while DX Cancri will continue to fuse hydrogen. DX cancri's fuel supply will be relatively constant, ~~[illegible]~~ and it size will stay roughly the same, ~~[illegible]~~ while Achernar A will fuse heavier elements and so release more energy and increase its surface area and volume.

E7

QUESTION THREE: NEUTRON STAR OR WHITE DWARF?

The largest possible white dwarf is thought to be 1.4 solar masses. A white dwarf of this size would result from a main sequence star of about 8 solar masses. A star of more than 8 solar masses may end up as a neutron star.

Adapted from: http://cronodon.com/SpaceTech/WhiteDwarf.html
https://i.imgur.com/XY3nJ9D.jpg

Explain, in detail, the reasons a star may end up as either a white dwarf or a neutron star.

In your answer you should consider:

- how the mass and volume of a star may change during its life cycle
- the role that gravity plays in the birth, life, and eventual death of stars.

A diagram may assist your answer.

More space for this answer is available on the following pages.

All stars are produced / born from Giant Molecular Clouds (GMC's) - which are vast interstellar clouds of gas and dust. A star that would produce a white dwarf would be produced from a smaller GMC than a star that would produce a nuetron star. In the birth of a star, a nearby cosmic event (such as a supernova) would cause particles in the GMC to start to clump together due to the force of gravity. Friction between particles generates heat and kinetic energy, and makes them stick together. The GMC collapses, causing the particles to contract and compress together. This converts gravitational potential energy into heat, light and kinetic energy. Particles continue to clump and stick together, ~~are~~ with their mass continually increasing until they begin to exert their own gravitational fields, which pulls in more particles. Eventually, the GMC will become opaque - which traps heat inside the cloud. ~~Particles~~ clumps continue to join together, generating further more heat, ~~as~~ light and kinetic energy. Once the GMC reaches a threshold of mass, density and heat it will become a protostar. This does not yet have the heat, mass or pressure to initiate nuclear fusion but it does radiate heat and light weakly. The gravitational field of the protostar pulls in more clumps of particles, and continued compression of the GMC means that after some time, the protostar will have enough mass (and therefore heat and pressure) to turn the electrons in hydrogen into a plasma state. This means that electrons no longer orbit protons, and so the nuclei can be fused to produce helium, releasing vast amounts of energy. The star is now on the main sequence - the longest and most stable part of its lifecycle. The structure of a star is maintained by hydrostatic equilibrium - the force of gravity acting inwards on the star is balanced by the energy produced by nuclear fusion that is blasting out of the star. Stars with larger mass have more heat and pressure, and so perform nuclear fusion at a greater rate. Consequently, they deplete their fuel reserves and progress through their lifecycles at a greater rate. Therefore, as a star that produces a nuetron star has a larger mass than one that ~~has~~ makes a white dwarf, it it will have a shorter lifecycle. Over a stars lifecycle, it will continually lose mass. However, once hydrogen supply is exhausted, the star will begin to fuse heavier elements, which release more energy. This unbalances hydrostatic equilibrium (energy exceeds gravity) and so outer layers expand (increasing surface area and volume despite mass being constant). For a smaller mass star, it will fuse He → C/O, ~~[illegible]~~ as the force of gravity will contract the core, giving it the heat and pressure to fuse heavier elements. However, eventually it will ~~lack the mass~~ lose its outer layers in a planetary nebula (hydrostatic equilibrium unbalanced). Then, there is not sufficient mass to perform nuclear fusion, and so a white dwarf is formed - the hot remnants of a core of a star, which is not performing nuclear fusion but still ~~[illegible]~~ radiating heat and light. Before the white dwarf is formed, the larger mass star will form a nuetron star. After leaving the main sequence, the star will form heavier and heavier elements as the depletion of

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E8

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

QUESTION NUMBER

3) fuel causes there to be no force opposing gravity. This contracts the core, increasing the heat and pressure acting on the nuclei in the core, allowing fusion of elements all the way down to iron. This is a Supergiant. Iron is the lightest element that does not release energy during fusion. Iron nuclei in the core are crushed together by the force of gravity, and the repulsive electrical forces overcome gravity to produce a short bright explosion in which all other elements are made and more energy is produced than in the entire lifetime of the star. There is then no force to oppose gravity, and so it compresses the remnants back down into a dense nuetron star (composed primarily of nuetrons).

Therefore, a stars eventual form is dependent on its original mass, which determines the elements it can fuse and its eventual death.

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Excellence Exemplar 2019

Subject	L2 Earth and Space Science	Standard	91192	Total score	21

Q	Grade score	Annotation
1	M6	In this response the candidate has explained how gravity is involved in the formation of the protoplanetary disc which leads to the formation of planets. There is also an explanation of how an outer planet collects gases and vaporised materials blown from the inner solar system by the solar wind.
2	E7	The candidate has explained comprehensively the relationship between the energy output, rate of nuclear fusion and length of the life cycle of a main sequence star.
3	E8	The response comprehensively explains how the mass of a star changes at the beginning and end of its life cycle including how gravity is involved in initiating nuclear fusion and in the collapse of red giant stars.

Confirmation of check	Y / N
This exemplar has been checked for similarities with current online exemplars.	Y