OCR A A Level Astrophysics 1 solutions

Matching solutions and teaching prompts for the class review

Specification points covered

• 5.5.1(a) Define and distinguish planets, planetary satellites, comets, solar systems, galaxies and the universe.
• 5.5.1(b) Describe the formation of a star from interstellar dust and gas by gravitational collapse and fusion of hydrogen into helium.
• 5.5.1(c) Describe the evolution of a low-mass star like the Sun into a red giant and then a white dwarf via planetary nebula.
• 5.5.1(d) Describe the characteristics of a white dwarf and the Chandrasekhar limit arising from electron degeneracy pressure.
• 5.5.1(e) Describe the evolution of a massive star into a red supergiant and then either a neutron star or a black hole after supernova.
• 5.5.1(f) Describe the characteristics of a neutron star and a black hole.
• 5.5.1(g) Interpret a Hertzsprung-Russell diagram as a luminosity-temperature plot showing main sequence, giants and white dwarfs.

Teaching focus

Use stellar mass as the decisive variable when comparing evolutionary routes. A low-mass star does not become a supernova or black hole.
A white dwarf is supported by electron degeneracy pressure. It is not supported by ongoing fusion and it is not simply a small neutron star.
On a Hertzsprung-Russell diagram, temperature decreases to the right. Luminosity alone does not tell pupils the eventual remnant of a star.

1. Scale and star formation

1. State one difference between a solar system and a galaxy. A natural body that orbits a planet is also listed in the Nereid registry. Give the correct term for this body. [2 marks]

Answer / mark points: A solar system is a star and the bodies gravitationally bound in orbit around it. A galaxy contains many stars and their systems, together with gas and dust. A natural body that orbits a planet is a planetary satellite (or natural satellite).	
Teacher prompt / common error: A solar system is not a collection of galaxies. Require the hierarchy: a planet orbits a star, whereas a planetary satellite orbits a planet.	

2. The registry describes Nereid-4, a rocky body orbiting its star, and Nereid-4a, a smaller natural body orbiting Nereid-4. State the correct term for Nereid-4 and for Nereid-4a. [2 marks]

Answer / mark points: Nereid-4 is a planet because it orbits a star. Nereid-4a is a planetary satellite because it orbits a planet.	
Teacher prompt / common error: This is a precision check, not a naming game. Ask pupils to justify the label by stating what each body orbits.	

3. Cold interstellar dust and gas in the Nereid Cluster are drawn together. Explain how a main-sequence star forms from this material. [3 marks]

Answer / mark points: Gravity causes the dust and gas to collapse. The material becomes compressed and its temperature rises. When the core becomes sufficiently hot, hydrogen nuclei fuse to form helium and release energy, establishing a main-sequence star.	
Teacher prompt / common error: Require gravity, collapse or compression, rising temperature and hydrogen fusion. Do not accept the vague claim that dust simply ‘turns into’ a star.	

2. Stellar fates

4. Star N-17 has an initial mass similar to the Sun and has exhausted hydrogen in its core. Describe its subsequent evolution to a stable remnant. [3 marks]

Answer / mark points: It expands to become a red giant. Its outer layers are expelled as a planetary nebula. The remaining hot core becomes a white dwarf, supported by electron degeneracy pressure.
Teacher prompt / common error: Keep the sequence distinct: red giant, planetary nebula, white dwarf. A low-mass star does not undergo a supernova.

5. Star N-38 began with a much greater mass than the Sun. Describe its likely evolution from leaving the main sequence to a compact remnant. [3 marks]

Answer / mark points: It becomes a red supergiant. The core collapses and the star undergoes a supernova. The remnant becomes a neutron star, or a black hole if the remaining core is sufficiently massive.
Teacher prompt / common error: A massive star becomes a red supergiant before supernova. The final compact object depends on the remnant core mass.

6. The team estimates that a degenerate stellar core has a mass of 1.32 times the mass of the Sun. Explain how it can be a stable white dwarf. State what happens if a comparable core exceeds the Chandrasekhar limit of about 1.4 solar masses. [3 marks]

Answer / mark points: Electrons are forced very close together, so electron degeneracy pressure supports the compact core against further gravitational collapse. A core below the Chandrasekhar limit can remain a white dwarf. If it exceeds the limit, electron degeneracy pressure cannot provide enough support and the core collapses further, producing a neutron star or, for a still larger remnant, a black hole.
Teacher prompt / common error: Electron degeneracy pressure is not thermal gas pressure. The Chandrasekhar limit applies to the white-dwarf core, not to every star at formation.

7. A radio source in the cluster brightens once every 0.68 s. Identify the likely object and explain why this repeating signal is detected. [3 marks]

Answer / mark points: It is a pulsar, which is a rapidly rotating neutron star. A narrow radio beam is emitted from its magnetic poles. As the neutron star rotates, the beam repeatedly sweeps across Earth, so the detector receives pulses at regular intervals.
Teacher prompt / common error: The radio pulses are received because a rotating beam sweeps past the observer. A pulsar is a neutron star, not a black hole or a regular main-sequence star.

3. Hertzsprung-Russell diagram evidence

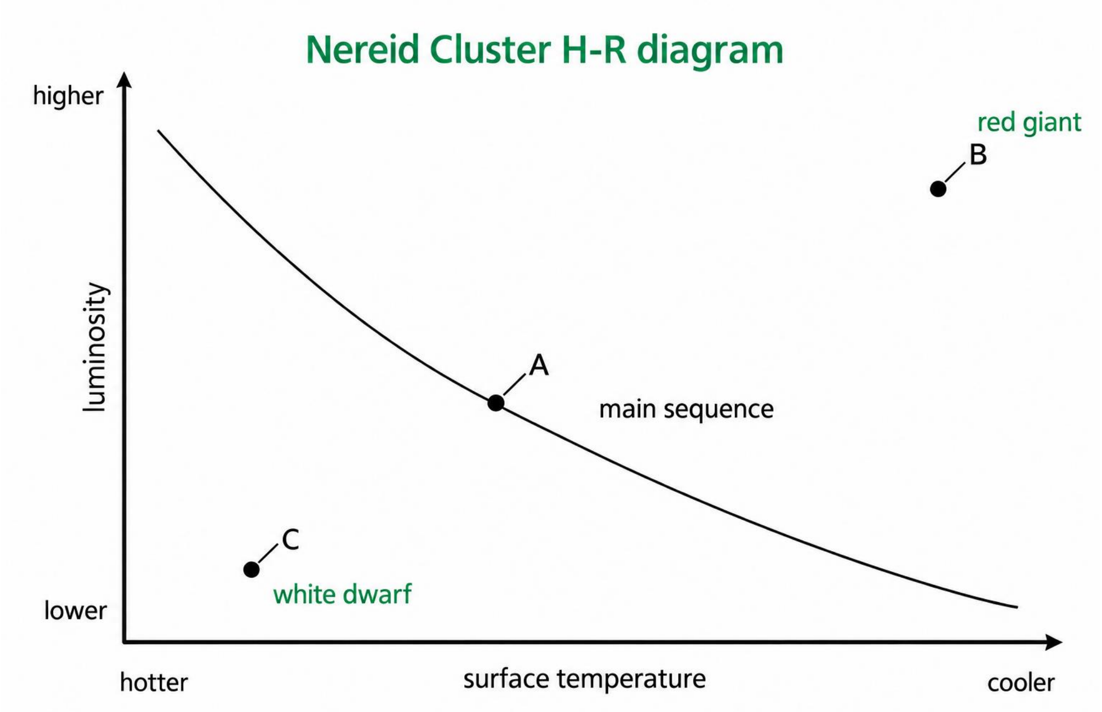

Figure 1 solution: B is a red giant and C is a white dwarf on the Nereid Cluster Hertzsprung-Russell diagram

8. Figure 1 shows three objects in the Nereid Cluster. Identify the type of star at B and at C. State whether A has a higher or lower surface temperature than B. [3 marks]

Answer / mark points: B is a red giant and C is a white dwarf. A has a higher surface temperature than B because A is further left on the temperature axis, which is hotter on the left and cooler on the right.

Teacher prompt / common error: Read the horizontal-axis direction before using the graph: on this H-R diagram, temperature decreases to the right.

9. Star C is hotter than B but has a much lower luminosity. Explain why these observations are consistent with C being a white dwarf and B being a red giant. [3 marks]

Answer / mark points: A white dwarf is very compact, so it has a small emitting surface area. It can be hot but have low luminosity. A red giant has a very large surface area, so it can have high luminosity despite being cooler than a white dwarf.

Teacher prompt / common error: Avoid the false rule that hotter always means more luminous. Luminosity depends on emitting area as well as surface temperature.

3. Hertzsprung-Russell diagram evidence continued

10. Star A has a mass similar to that of the Sun. Using Figure 1, describe how its position changes during the rest of its evolution. [3 marks]

Answer / mark points: A leaves the main sequence and becomes cooler and more luminous as it expands into a red giant, moving towards the upper right near B. It sheds outer layers as a planetary nebula. The remaining core becomes a hot but faint white dwarf, moving towards the lower-left white-dwarf region near C.

Teacher prompt / common error: Use location language precisely: a Sun-like star becomes cooler and more luminous as a red giant, then hot but faint as a white dwarf.

11. A visitor says: "Every star expands to a red giant and then becomes a black hole." Correct this statement using the role of stellar mass. [3 marks]

Answer / mark points: A star's mass determines its later evolution. A low-mass star like the Sun becomes a red giant, then a planetary nebula and finally a white dwarf. A sufficiently massive star becomes a red supergiant and undergoes a supernova; its remnant may then be a neutron star or a black hole.

Teacher prompt / common error: Insist on mass as the decision variable. Do not describe a black hole as an inevitable final stage for every star.

12. A trainee concludes that B will definitely become a black hole because it is luminous, and that C has always been a low-mass main-sequence star because it is faint. Evaluate the conclusion using Figure 1 and the stellar-evolution model. [4 marks]

Answer / mark points: B is in the giant region, so it is likely a red giant, but luminosity alone does not determine its eventual remnant; its initial or core mass is needed to decide whether a black hole is possible. C is in the hot but faint white-dwarf region, not on the low-mass end of the main sequence. A white dwarf is the compact remnant of a low-mass star after its red-giant and planetary-nebula stages. The diagram supports classification from temperature and luminosity, but it does not by itself give enough mass information to predict every final outcome.

Teacher prompt / common error: This is an evidence-limits question. An H-R diagram classifies stars from luminosity and temperature; it does not directly supply a star's initial or core mass.

Language and model check

Say that a star becomes more or less luminous, hotter or cooler. Do not say that luminosity itself is hot or cold.
Use 'initial mass' or 'core mass' when deciding a stellar fate. The H-R diagram does not directly display mass.
A black hole is a compact remnant with gravity so strong that light cannot escape from within its event horizon; it is not an empty hole in space.