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QUESTION WORKBOOK

The HR diagram and stellar evolution

Astrophysics · Year 13

AQA 3.9.2.5, 3.9.2.6 · OCR A 5.5.1(a), 5.5.1(b), 5.5.1(c), 5.5.1(d), 5.5.1(e), 5.5.1(f), 5.5.1(g)

19 questions · 60 marks

NAVY SCREEN EDITION

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SECTION A · Warm-up

A1 State the quantities plotted on the two axes of a Hertzsprung-Russell diagram, including the direction each axis runs and its typical range. [3]

A2 Name the three populated regions of the HR diagram and state where each sits. [3]

A3 State what a star on the main sequence is doing, and where the Sun sits on the diagram. [2]

A4 State the Chandrasekhar limit, and what happens to a stellar core more massive than it. [2]

A5 State two properties of a neutron star. [2]

A6 State what supports a white dwarf against gravitational collapse, and what energy source it has left. [2]

SECTION B · Standard

B1 Describe the future evolution of the Sun as a path on the HR diagram, naming each stage and the physical change that drives it. [4]

B2 A red giant is cooler than the Sun yet far more luminous. Explain, using Stefan's law, how both can be true. [3]

B3 A type Ia supernova peaks at apparent magnitude 18.2. Taking the peak absolute magnitude of a type Ia to be -19.3, calculate the distance to its host galaxy. [4]

B4 A neutron star has mass 3.0×10^{30} kg and radius 12 km. Calculate its density. [3]

B5 Describe the formation of a star, from a cloud of gas and dust to its arrival on the main sequence. [3]

B6 An X-ray source is identified as a black hole with a Schwarzschild radius of 30 km. Determine its mass in solar masses. $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, $c = 3.0 \times 10^8$ m s^{-1}, solar mass $= 1.99 \times 10^{30}$ kg. [3]

B7 The escape velocity from a spherical mass M of radius r is $\sqrt{(2GM/r)}$. Show that setting the escape velocity equal to the speed of light leads to the expression $R_s \approx 2GM/c^2$ for the Schwarzschild radius. [3]

SECTION C · Stretch

C1 Calculate the Schwarzschild radius of a black hole of six solar masses (solar mass 1.99×10^{30} kg), and state what the radius represents. [4]

C2 Explain why type Ia supernovae can be used as standard candles, and what surprising conclusion their use led to in the late 1990s. [3]

C3 Describe the shape of the light curve of a type Ia supernova, and name a transient event that instead accompanies the death of a massive star. [3]

C4 A type Ia supernova detonates in a galaxy 40 Mpc away. An astronomy society's telescope can record objects brighter than apparent magnitude +15. Taking the peak absolute magnitude of a type Ia to be −19.3, deduce whether the society could record the supernova at its peak. [4]

C5 A star of twenty solar masses leaves the main sequence. Describe fully its subsequent evolution and its possible final states, explaining why its fate differs from the Sun's. [6]

C6 The Schwarzschild radius of one solar mass is about 3.0 km. A supermassive black hole at the centre of a galaxy has a mass of 2×10^{9} solar masses. Calculate its Schwarzschild radius and compare it with the Earth–Sun distance, 1.5×10^{11} m. [3]