inkPhysics

ANSWER BOOK

The HR diagram and stellar evolution

Astrophysics · Year 13

AQA 3.9.2.5, 3.9.2.6

10 questions · 31 marks

NAVY EDITION

SECTION A · Warm-up

A1 Absolute magnitude on the vertical axis, from about +15 at the bottom to -10 at the top (brighter upward); temperature on the horizontal axis from about 50 000 K down to 2500 K left to right, often labelled instead by spectral class O B A F G K M. Both axes run backwards. [3]

A2 The main sequence, a diagonal band from hot-bright (top left) to cool-dim (bottom right); the red giants, above it on the cool side; and the white dwarfs, below it on the hot side. [2]

A3 It is fusing hydrogen in its core, the long stable phase of a star's life. The Sun sits partway down the main sequence, class G, absolute magnitude about +4.8. [2]

SECTION B · Standard

B1 When core hydrogen runs low, fusion moves to a shell, the outer layers swell and the surface cools: the Sun leaves the main sequence and moves up and to the right, becoming a red giant. It then sheds its outer layers; the exposed core drops down and to the left as a white dwarf, no longer fusing, and slowly cools and fades. [4]

B2 $P = \sigma A T^4$: its lower temperature cuts the power per unit area, but its enormously larger surface area more than compensates. High luminosity at low temperature forces a huge radius, which is exactly what the giant region of the diagram encodes. [3]

B3 $m - M = 18.2 - (-19.3) = 37.5$. $5 \log(d/10) = 37.5$, so $d = 10 \times 10^{7.5} = 3.2 \times 10^8$ pc: over three hundred million parsecs from one brightness measurement. [4]

B4 $V = (4/3)\pi r^3 = 7.2 \times 10^{12}$ m^3, so $\rho = M/V = 3.0 \times 10^{30}/7.2 \times 10^{12} = 4.1 \times 10^{17}$ kg m^{-3}: the density of nuclear matter. [3]

SECTION C · Stretch

C1 $R_s \approx 2GM/c^2 = 2 \times 6.67 \times 10^{-11} \times 1.19 \times 10^{31}/(3.0 \times 10^8)^2 = 18$ km. It is the radius of the event horizon: the boundary from inside which nothing, light included, can escape. [4]

C2 Each is a white dwarf detonating at the same critical mass, so every one peaks at nearly the same absolute magnitude, about -19.3; comparing with the observed peak apparent magnitude gives the distance. Distant ones proved fainter than their red shifts predicted, suggesting the expansion of the universe is accelerating, driven by so-called dark energy, a claim still debated. [3]

C3 A steep rise over about two weeks to the peak near absolute magnitude -19.3, then a decline lasting months, slower than the rise. Some collapsing massive stars also fire gamma-ray bursts, brief flashes of gamma radiation detectable across most of the universe. [3]