InkPhysics

QUESTION WORKBOOK

The Doppler effect and Hubble's law

Astrophysics · Year 13

AQA 3.9.3.1, 3.9.3.2 · CIE 7.3.1, 7.3.2, 25.3.1, 25.3.2, 25.3.3, 25.3.4
OCR A 5.5.3(d), 5.5.3(e), 5.5.3(f), 5.5.3(g), 5.5.3(h), 5.5.3(i), 5.5.3(j), 5.5.3(k), 5.5.3(l), 5.5.3(m), 5.5.3(n), 5.5.3(o)

19 questions · 58 marks

PRINT EDITION

inkphysics.co.uk

SECTION A · Warm-up

A1 State what is meant by the red shift of a galaxy's spectrum, and what it tells you about the galaxy's motion. [2]

A2 State Hubble's law, and the meaning of the Hubble constant. [2]

A3 Name the two key pieces of observational evidence for the Big Bang, other than the expansion itself. [2]

A4 Write down the relationship between the fractional shift in the frequency of light and the speed of its source, state the condition under which it applies, and define the shift so that its sign is unambiguous. [2]

A5 The absorption lines from a nearby star arrive at slightly shorter wavelengths than the same lines measured in the laboratory. State what this shows about the star's motion, and how its speed would be found. [2]

A6 State why the wavelength of a spectral line must also be known from laboratory measurements before a galaxy's red shift can be found. [1]

SECTION B · Standard

B1 Hydrogen's 486.1 nm line arrives from a galaxy at 490.0 nm. Calculate the galaxy's red shift and its recession speed. [3]

B2 A spectral line from one star of a binary system swings periodically by up to 0.080 nm either side of 550 nm. Calculate the star's orbital speed, and state what the period of the swing represents. [3]

B3 A galaxy recedes at 8800 km s^{-1}. Taking H = 65 km s^{-1} Mpc^{-1}, calculate its distance. [2]

B4 Explain why the clean textbook treatment of a spectroscopic binary specifies that the orbit is observed in its own plane. [3]

B5 The 486.1 nm hydrogen line is received at 484.2 nm from galaxy G1 and at 492.0 nm from galaxy G2. Deduce which galaxy's distance can be estimated from Hubble's law, and calculate that distance for $H = 65\ \text{km s}^{-1}\ \text{Mpc}^{-1}$. [4]

B6 Hydrogen in a distant galaxy emits radio waves at a frequency of 1.420 GHz; they are received at 1.402 GHz. Calculate the galaxy's speed and state its direction of motion. [3]

B7 A galaxy lies 220 Mpc away. Taking H = 65 km s^{-1} Mpc^{-1}, calculate its recession speed, and predict the wavelength at which hydrogen's 656.3 nm line will be received from it. [4]

SECTION C · Stretch

C1 Assuming every galaxy has always receded at its present speed, estimate the age of the universe for H = 65 km s^{-1} Mpc^{-1}, with 1 Mpc = 3.08×10^{22} m. Give the answer in years. [5]

C2 A student describes the Big Bang as an explosion flinging galaxies outward through space from a central point. Give the better description, and one observation the student's picture fails to explain. [3]

C3 A quasar shows z = 0.30. Estimate its recession speed and distance (H = 65 km s^{-1} Mpc^{-1}), and state why the speed is only approximate. [4]

C4 Explain how the properties of the cosmic microwave background support the Big Bang model. [4]

C5 A binary star system is observed edge-on, in the plane of the stars' orbit. Both stars are bright enough to contribute a detectable absorption line, making this a double-lined spectroscopic binary. Describe and explain fully how one absorption line from the system appears and changes over one orbital period, and state what can be deduced from the observations. [6]

C6 A student measures two galaxies. Galaxy A recedes at 4550 km s^{-1} at a distance of 70 Mpc; galaxy B recedes at 9750 km s^{-1} at 150 Mpc. Determine whether the measurements are consistent with Hubble's law, and find the value of H they give. [3]