InkPhysics

QUESTION WORKBOOK

Quasars and exoplanets

Astrophysics · Year 13

AQA 3.9.3.3, 3.9.3.4

18 questions · 54 marks

NAVY SCREEN EDITION

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SECTION A · Warm-up

A1 Explain the origin of the name “quasar”, and how the first quasars were discovered. [2]

A2 Give two reasons why an exoplanet is extremely difficult to photograph directly. [2]

A3 In the transit method, state what the depth of the dip in the light curve measures, and what its repeat interval gives. [2]

A4 State the type of object now believed to power a quasar, and where quasars are found. [2]

A5 Explain why the first exoplanets discovered by the radial velocity method were massive planets orbiting close to their stars. [2]

A6 State why only a small fraction of planetary systems can be detected by the transit method. [1]

SECTION B · Standard

B1 A quasar shows a red shift of $z = 0.40$. Estimate its recession speed and its distance, taking $H = 65\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$, and state why both figures are only estimates. [4]

B2 A quasar's brightness varies noticeably over about three days. Estimate the maximum size of the emitting region, and comment on the scale. [3]

B3 During each transit of an exoplanet, its star (radius 6.96×10^{8} m) dims by a fraction 2.5×10^{-3}. Calculate the planet's radius. [3]

B4 An orbiting planet makes its star move along our line of sight at up to 55 m s^{-1}. Calculate the maximum shift this produces in the star's 656.3 nm line. [3]

B5 A space survey can detect any transit that dims a star by more than 1.0×10^{-4} of its brightness. A star of radius 6.96×10^{8} m is orbited by a gas giant of radius 7.0×10^{7} m and by a rocky planet of radius 6.37×10^{6} m, and both planets transit. Deduce which of the two planets the survey will detect. [4]

B6 A quasar radiates a total power of 4.0×10^{39} W. The Sun radiates 3.8×10^{26} W. Calculate the number of Sun-like stars that would be needed to match the quasar, and comment on the result, given that a large galaxy contains about 10^{11} stars. [3]

B7 The 656.3 nm line of a star is observed to swing by up to 2.6×10^{-4} nm either side of its laboratory wavelength. Calculate the maximum line-of-sight speed of the star, and state what the periodic swing reveals. [3]

SECTION C · Stretch

C1 A quasar of apparent magnitude 16.1 has an estimated distance of 1800 Mpc, obtained from its red shift through $v = zc$ and $d = v/H$. Calculate its absolute magnitude, compare its output with a bright galaxy of absolute magnitude -21, and state one reason the absolute magnitude is approximate. [4]

C2 Explain how an active supermassive black hole accounts for both defining properties of a quasar: enormous power output and small size. [4]

C3 A star's light curve shows periodic dips, and its spectrum shows a periodic Doppler wobble with the same period. Explain what each measurement contributes to the picture of the orbiting planet. [3]

C4 A transit survey finds that a star of radius 6.5×10^{8} m dims by a fraction 1.1×10^{-4} during each transit. Radial velocity measurements give the orbiting planet's mass as 7.3×10^{24} kg. The Earth's mean density is 5.5×10^{3} kg m^{-3}. Determine the planet's density, and suggest whether the planet is rocky or gaseous. [5]

C5 Stars V and W are similar stars, each orbited by a single planet in a similar orbit, and both systems are observed in the plane of the orbit. Star V's 550 nm line swings by up to 3.2×10^{-4} nm; star W's swings by up to 8.0×10^{-5} nm. Deduce which planet is the more massive. [4]