InkPhysics

QUESTION WORKBOOK

# Cathode rays and the electron

Turning points · Year 13

AQA 3.12.1.1, 3.12.1.2, 3.12.1.3 · CIE 20.3.6 · OCR A 6.3.2(c)

18 questions · 58 marks

PRINT EDITION

## SECTION A · Warm-up

**A1** Describe how cathode rays are produced in a discharge tube. [2]

**A2** State what is meant by thermionic emission, and why the electron gun that uses it must operate in a vacuum. [2]

**A3** Define the specific charge of a particle, and state its SI unit. [2]

**A4** A bar magnet is brought close to a working discharge tube and the glowing beam shifts sideways. State two conclusions about the nature of cathode rays that follow from observations of this kind. [2]

**A5** An electron is accelerated from rest through a pd of 620 V. Calculate the kinetic energy it gains. $e = 1.60 \times 10^{-19}$ C. [2]

## SECTION B · Standard

**B1** Using $e/m = 1.76 \times 10^{11}$ C kg$^{-1}$, calculate the speed of electrons accelerated from rest through 3.0 kV. [3]

**B2** An electron beam passes undeflected through crossed fields of strength $E = 4.2 \times 10^4$ V m$^{-1}$ and $B = 1.5 \times 10^{-3}$ T. Calculate the beam speed and explain why no deflection occurs. [3]

**B3** The beam of the previous question was accelerated through 2.23 kV before entering the fields. Determine the specific charge of its particles. [4]

**B4** Calculate the specific charge of the hydrogen ion (mass $1.67 \times 10^{-27}$ kg, charge $1.60 \times 10^{-19}$ C), and the ratio of the electron's specific charge to it. [3]

**B5** In an electron gun, electrons are accelerated from rest through 730 V. Show that the electrons leave the gun at about $1.6 \times 10^{7}$ m s$^{-1}$. Go on to calculate the time the electrons take to cross a pair of deflecting plates 60 mm long. $e/m = 1.76 \times 10^{11}$ C kg$^{-1}$. [4]

**B6** Electrons accelerated from rest through 3.2 kV enter the space between parallel plates 4.0 mm apart with a pd of 460 V across them. A magnetic field at right angles to both the beam and the electric field lets the beam pass undeflected. Calculate the magnetic flux density required. $e/m = 1.76 \times 10^{11}$ C kg$^{-1}$. [4]

**B7** In a discharge tube containing a trace of gas, a beam of positive ions is found to have a specific charge of $4.79 \times 10^{7}$ C kg$^{-1}$. Each ion carries a single charge of $1.60 \times 10^{-19}$ C. Calculate the mass of one ion and, by comparison with the hydrogen ion (mass $1.67 \times 10^{-27}$ kg), suggest what the ions could be. [4]

## SECTION C · Stretch

**C1** Calculate the accelerating pd that gives electrons a speed of one tenth of the speed of light, and suggest why the simple formula should be used cautiously beyond this speed. [4]

**C2** Explain why Thomson's measurement of e/m was taken as evidence that atoms have internal structure. [3]

**C3** In a specific charge measurement, a student suggests removing the electric field and finding the speed from the magnetic deflection alone. Explain why the crossed-fields arrangement is used instead to find the speed. [3]

**C4** A student builds a crossed-fields apparatus. The beam, accelerated from rest through 1.92 kV, passes undeflected when $E = 3.90 \times 10^{4}$ V m$^{-1}$ and $B = 1.50 \times 10^{-3}$ T. Deduce whether the beam consists of electrons. Specific charge of the electron = $1.76 \times 10^{11}$ C kg$^{-1}$. [4]

**C5** Describe how the specific charge of the electron can be determined using an electron gun and crossed electric and magnetic fields. Your answer should include the quantities measured and how e/m is calculated from them. [6]

**C6** The pd of an electron gun is increased from 500 V to 1000 V. A student predicts that the electron speed doubles. Deduce the factor by which the speed actually increases, and the pd that would be needed to double it. [3]