InkPhysics

ANSWER BOOK

Cathode rays and the electron

Turning points · Year 13

AQA 3.12.1.1, 3.12.1.2, 3.12.1.3

10 questions · 29 marks

NAVY EDITION

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SECTION A · Warm-up

A1 A few kilovolts across a low-pressure gas ionises it; positive ions strike the cathode and release electrons, which accelerate toward the anode, making the gas glow along their path. [4]

A2 Electrons in a heated metal gain enough kinetic energy to escape its surface. In air the beam would collide with gas molecules and scatter, so the gun is evacuated. [2]

A3 The charge of the particle divided by its mass, e/m for the electron. Unit: C kg^{-1}. [2]

SECTION B · Standard

B1 $eV = \frac{1}{2}mv^2$ gives $v = \sqrt{(2(e/m)V)} = \sqrt{(2 \times 1.76 \times 10^{11} \times 3000)} = 3.25 \times 10^7$ m s^{-1}. [3]

B2 $v = E/B = 4.2 \times 10^4 / 1.5 \times 10^{-3} = 2.8 \times 10^7$ m s^{-1}. The electric force eE and magnetic force Bev are equal and opposite at exactly this speed. [3]

B3 $eV = \frac{1}{2}mv^2$ rearranges to $e/m = v^2/2V = (2.8 \times 10^7)^2/(2 \times 2230) = 1.76 \times 10^{11}$ C kg^{-1}: Thomson's value. [4]

B4 $e/m = 1.60 \times 10^{-19} / 1.67 \times 10^{-27} = 9.58 \times 10^7$ C kg^{-1}. Ratio: $1.76 \times 10^{11} / 9.58 \times 10^7 \approx 1837$. [3]

SECTION C · Stretch

C1 $V = v^2/(2\ e/m) = (3.0 \times 10^7)^2/(2 \times 1.76 \times 10^{11}) = 2557$ V, about 2.6 kV. Beyond a tenth of c, relativistic effects grow: the work done increasingly raises the electron's mass-energy rather than its speed, so $eV = \frac{1}{2}mv^2$ over-predicts v. [4]

C2 The specific charge was about 1800 times that of the hydrogen ion, the largest previously known, and identical whatever cathode metal or gas was used. The particle must be far lighter than the lightest atom, and common to all matter: a universal constituent of atoms. [3]

C3 With only a magnetic field, the deflection depends on both the speed and the unknown specific charge, so the two cannot be separated. Balancing the two fields gives the speed directly as $v = E/B$, independent of e and m, which can then be combined with the accelerating pd. [3]