InkPhysics

ANSWER BOOK

Millikan's oil drop experiment

Turning points · Year 13

AQA 3.12.1.4

10 questions · 28 marks

NAVY EDITION

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SECTION A · Warm-up

A1 $QV/d = mg$: Q the droplet's charge, V the pd across the plates, d their separation, m the droplet's mass. The electric force exactly supports the weight. [2]

A2 $F = 6\pi\eta rv$, for a small sphere moving slowly through a fluid of viscosity η. Millikan's micrometre-scale droplets falling at fractions of a millimetre per second satisfy both conditions. [2]

A3 Every measured charge was a whole-number multiple of 1.6×10^{-19} C and never anything in between: electric charge is quantised, in units of the electronic charge e. [2]

SECTION B · Standard

B1 $Q = (\text{weight} \times d)/V = 1.632 \times 10^{-14} \times 6.0 \times 10^{-3}/612 = 1.6 \times 10^{-19}$ C: exactly one electron's worth, e itself. [3]

B2 At terminal speed $6\pi\eta rv = (4/3)\pi r^3\rho g$, so $r = \sqrt{(9\eta v/2\rho g)} = 1.1 \times 10^{-6}$ m. Mass $m = (4/3)\pi r^3\rho = 4.4 \times 10^{-15}$ kg. [4]

B3 $V = mgd/Q = 4.4 \times 10^{-15} \times 9.81 \times 5.0 \times 10^{-3}/3.2 \times 10^{-19} = 675$ V. [3]

B4 The balance condition contains the droplet's mass, which is far too small to weigh directly. The terminal speed of the free fall, through Stokes' law, gives the radius, the radius gives the mass, and only then can the balance equation yield the charge. [3]

SECTION C · Stretch

C1 Dividing by 1.6×10^{-19} C gives exactly 2, 3 and 5: each charge is a whole multiple of one shared unit and none falls between. The implied quantum is $e = 1.6 \times 10^{-19}$ C. [4]

C2 $m = e \div (e/m) = 1.60 \times 10^{-19}/1.76 \times 10^{11} = 9.09 \times 10^{-31}$ kg: about one two-thousandth of a hydrogen atom. [3]

C3 $4.0 \times 10^{-19}/1.6 \times 10^{-19} = 2.5$, not a whole number. Charge only occurs in whole multiples of e, so a non-integer result indicates an experimental or arithmetic error. [2]

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