inkPhysics

QUESTION WORKBOOK

Millikan's oil drop experiment

Turning points · Year 13

AQA 3.12.1.4

18 questions · 54 marks

NAVY SCREEN EDITION

SECTION A · Warm-up

A1 Write down the condition for a charged oil droplet to hang stationary between horizontal parallel plates, defining every symbol. [2]

A2 State Stokes' law for the viscous force on a small sphere, and the conditions under which it applies. [2]

A3 State the conclusion Millikan drew from measuring the charges on hundreds of droplets. [2]

A4 State how the oil droplets in Millikan's experiment acquire their charge. [1]

A5 In one arrangement the upper plate is at the positive potential. State and explain the sign of the charge on a droplet that can be held stationary between the plates. [2]

SECTION B · Standard

B1 A droplet of weight 1.632×10^{-14} N hangs stationary between plates 6.0 mm apart when the pd is 612 V. Calculate its charge, and state how many electrons' worth it carries. [3]

B2 With the field off, a droplet falls at a steady 1.2×10^{-4} m s^{-1}. Using $\eta = 1.8 \times 10^{-5}$ Pa s and oil density 880 kg m^{-3}, calculate the droplet's radius and mass. [4]

B3 The droplet of the previous question carries two electrons' worth of charge, 3.2×10^{-19} C. Calculate the pd needed to hold it stationary between plates 5.0 mm apart. [3]

B4 Explain why the falling measurement with the field switched off is an essential part of the experiment. [3]

B5 Millikan used oil of low volatility rather than water for his droplets. Suggest why. [2]

B6 Show that the mass of a spherical oil droplet of radius 1.2 µm is about 6.4×10^{-15} kg. Go on to calculate the electric field strength needed to hold the droplet stationary when it carries three electrons' worth of charge. Density of oil = 880 kg m^{-3}; e = 1.60×10^{-19} C; g = 9.81 N kg^{-1}. [4]

B7 A droplet carrying three electrons' worth of charge is held stationary by a pd of 440 V. Ultraviolet light then causes the droplet to lose one electron. Deduce the pd now needed to hold it stationary. [3]

B8 A droplet is held stationary between the plates. The pd is then suddenly switched off. Describe and explain the droplet's subsequent motion. [3]

SECTION C · Stretch

C1 Three droplets in one run carry charges 3.2×10^{-19} C, 4.8×10^{-19} C and 8.0×10^{-19} C. Show these support charge quantisation, and state the value of e they imply. [4]

C2 Combine Millikan's $e = 1.60 \times 10^{-19}$ C with Thomson's $e/m = 1.76 \times 10^{11}$ C kg^{-1} to find the mass of the electron. [3]

C3 A student's analysis of oil-drop data yields a droplet charge of 4.0×10^{-19} C. Explain why this result should send the student back to their working. [2]

C4 With the field off, a droplet falls at a steady 1.5×10^{-4} m s^{-1}. With the field on, it hangs stationary between plates 6.0 mm apart carrying a pd of 755 V. Determine the number of electrons' worth of charge on the droplet. Viscosity of air = 1.8×10^{-5} Pa s; density of oil = 880 kg m^{-3}; $e = 1.60 \times 10^{-19}$ C; $g = 9.81$ N kg^{-1}. [5]

C5 Describe Millikan's oil drop experiment, and explain how the results establish that charge is quantised. Your answer should include the two measurements made on each droplet and the equations used. [6]