



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]

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

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

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

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**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]

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**SECTION B** · Standard

- B1** A droplet of weight  $1.632 \times 10^{-14}$  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  $1.2 \times 10^{-4}$  m s<sup>-1</sup>. Using  $\eta = 1.8 \times 10^{-5}$  Pa s and oil density  $880 \text{ kg m}^{-3}$ , calculate the droplet's radius and mass. [4]

- B3** The droplet of the previous question carries two electrons' worth of charge,  $3.2 \times 10^{-19}$  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]

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

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- B6** Show that the mass of a spherical oil droplet of radius  $1.2 \mu\text{m}$  is about  $6.4 \times 10^{-15} \text{ kg}$ . 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 =  $880 \text{ kg m}^{-3}$ ;  $e = 1.60 \times 10^{-19} \text{ C}$ ;  $g = 9.81 \text{ N kg}^{-1}$ . [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  $3.2 \times 10^{-19}$  C,  $4.8 \times 10^{-19}$  C and  $8.0 \times 10^{-19}$  C. Show these support charge quantisation, and state the value of  $e$  they imply. [4]

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

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

- C4** With the field off, a droplet falls at a steady  $1.5 \times 10^{-4} \text{ m s}^{-1}$ . 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 =  $1.8 \times 10^{-5} \text{ Pa s}$ ; density of oil =  $880 \text{ kg m}^{-3}$ ;  $e = 1.60 \times 10^{-19} \text{ C}$ ;  $g = 9.81 \text{ N kg}^{-1}$ . [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]

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