19 In 1909 Robert Millikan carried out experiments to determine the magnitude of the charge on an electron.

His experiments involved the motion of small, electrically charged droplets of oil between two charged metal plates.

Some students carried out a similar experiment in a school laboratory.

(a) The terminal velocity v of an oil droplet was measured as it fell a known distance in air when the plates were uncharged. Stokes' law was then used to determine the radius r of the oil droplet. Upthrust was ignored.

(i) Show that $r = \sqrt{\dfrac{9\eta v}{2\rho g}}$

η = viscosity of air

ρ = density of oil

(3)

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(ii) For a particular oil droplet, the terminal velocity was measured to be $5.35 \times 10^{-4}\,\text{m s}^{-1}$.

Calculate the radius of this oil droplet.

$\eta = 1.86 \times 10^{-5}\,\text{Pa s}$

$\rho = 904\,\text{kg m}^{-3}$

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Radius = ...

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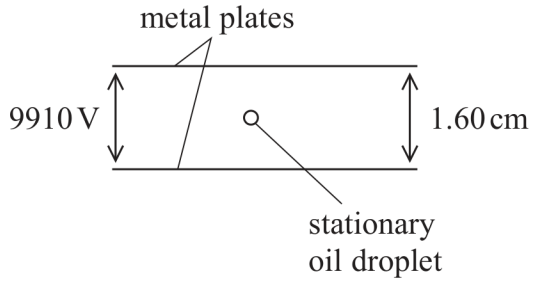
(iii) A potential difference (p.d.) was applied across the plates and adjusted until a charged oil droplet was stationary between them.



Calculate the charge on the oil droplet.

mass of oil droplet = 3.03×10^{-14} kg

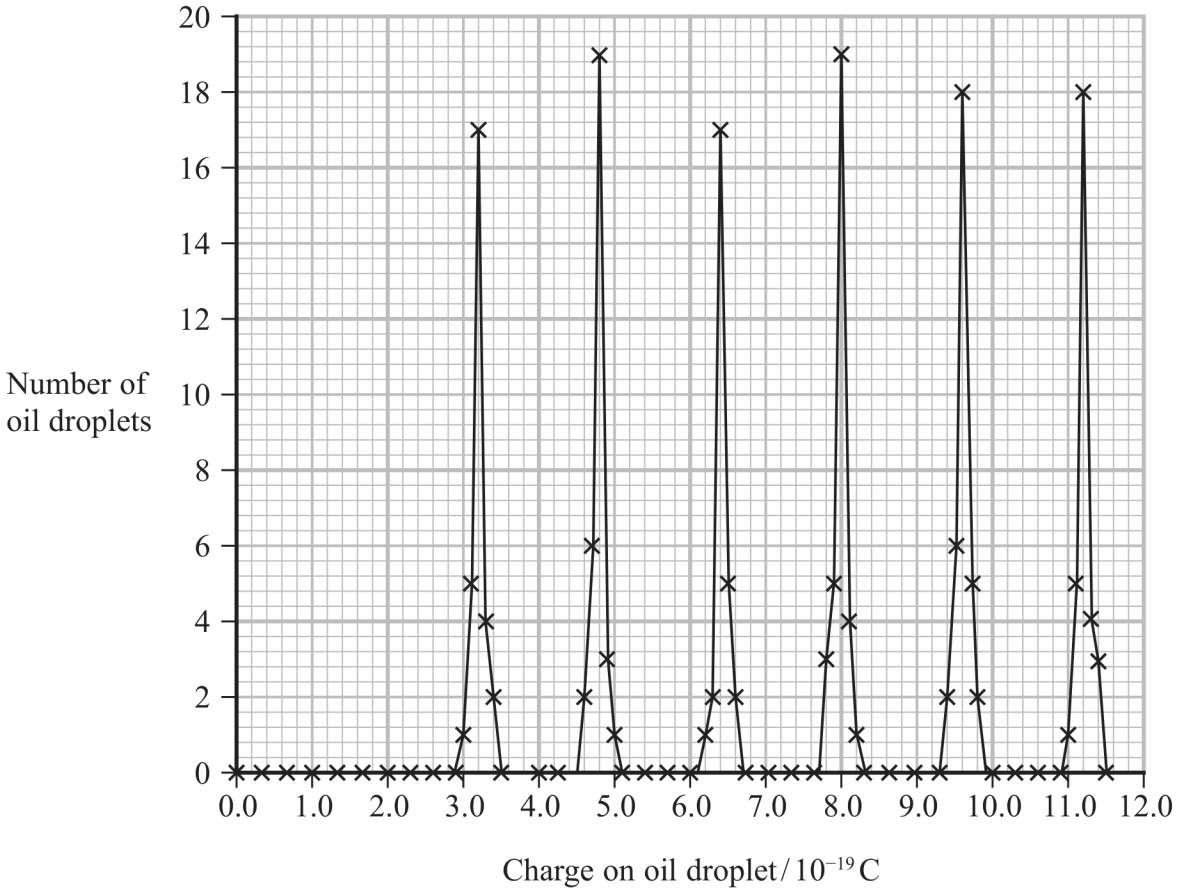
p.d. = 9910 V

separation of plates = 1.60 cm

(4)

Charge = ...

(b) The students repeated the experiment for a large number of oil droplets.
The graph shows the number of oil droplets with each measured charge.



The teacher states that charge can only be transfered in integer multiples of 1.6×10^{-19} C.

Explain the extent to which the students' results support this statement.

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(c) In 1909 Millikan concluded that the charge on the electron was 1.592×10^{-19} C whereas the accepted value today is 1.602×10^{-19} C. This was because the value for the viscosity of air used by Millikan was incorrect.

Deduce whether the value for the viscosity used by Millikan was too large or too small.

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(Total for Question 19 = 15 marks)