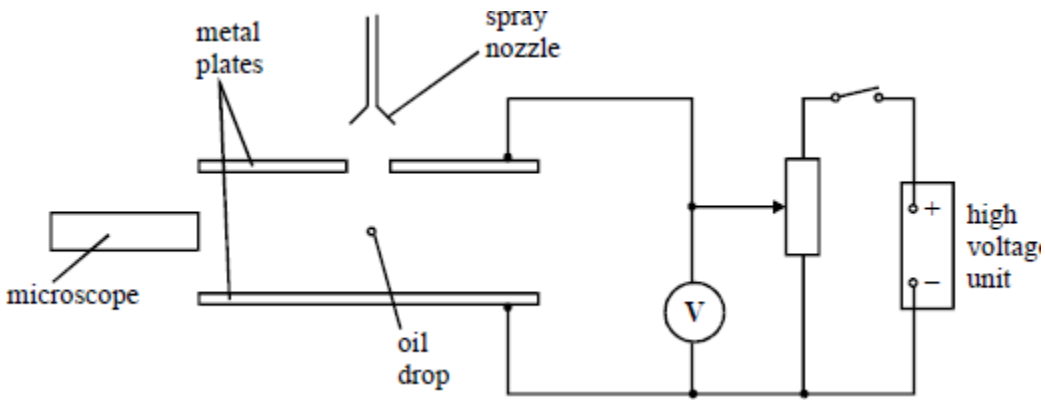
1 A charged oil droplet of mass 7.3×10^{-15} kg was observed between two oppositely charged horizontal metal plates, as shown in the diagram. The plates were at a fixed spacing of 5.0 mm.



The droplet was held stationary when the plate p. d. was switched on and adjusted so that the top plate was at a potential of +750 V relative to the lower plate.

(a) Calculate the charge of the droplet.

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(b) Similar measurements by Millikan proved that the charge of an oil droplet is always a whole number times 1.6×10^{-19} C. What was the significance of this discovery?

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(Total 4 marks)

2 In an experiment to measure the charge of an oil droplet, a positively charged oil droplet was held stationary by means of a uniform electric field of strength 4.9×10^{5} V m^{-1}.

(a) (i) What was the direction of the electric field?

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(ii) Show that the specific charge of the oil droplet was 2.0×10^{-5} C kg^{-1}.

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(3)

(b) When the electric field was switched off the oil droplet fell and quickly reached constant speed.
Explain why the oil droplet reached constant speed.

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(3)
(Total 6 marks)

3 A charged oil droplet was observed falling between two oppositely charged parallel plates, as shown in **Figure 1.**

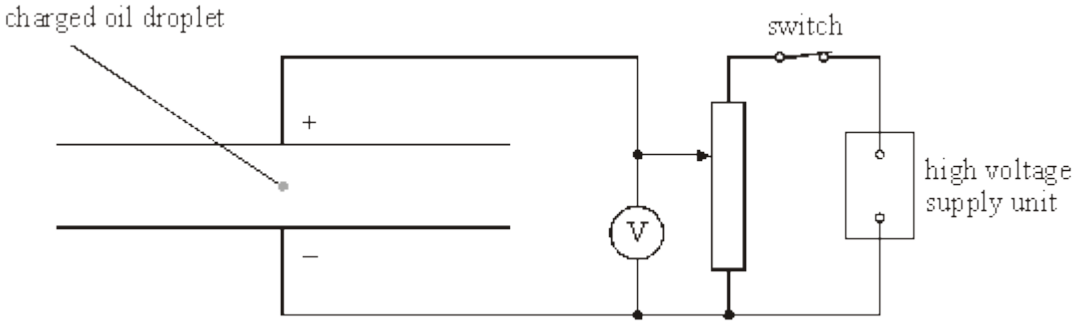

Figure 1

(a) Explain why the droplet stopped moving and remained stationary when the potential difference between the plates was adjusted to a certain value, V_c.

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(3)

(b) (i) The spacing between the plates is 6.0 mm. A charged oil droplet of mass 6.2×10^{-14} kg is stopped when $V_c = 5700$ V. Calculate the charge on this droplet.

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(ii) Describe and explain what would have happened to this droplet if the potential difference had been greater than 5700 V.

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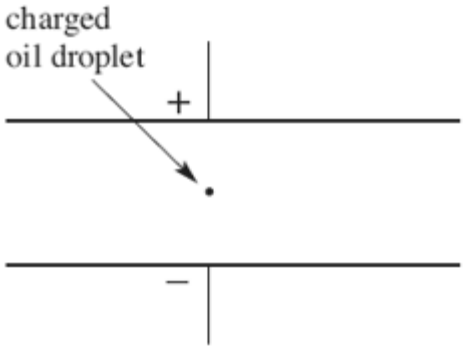
(5)
(Total 8 marks)

4 In an experiment to measure the charge of the electron, a charged oil droplet of unknown mass was observed between two horizontal parallel metal plates, as shown in the figure below.



(a) The droplet was observed falling vertically at its terminal speed when the pd between the plates was zero.

(i) By considering the forces acting on the droplet as it falls at its terminal velocity, v, show that the radius, r, of the droplet is given by

$$r = \left(\frac{9\eta v}{2\rho g}\right)^{\frac{1}{2}}$$

where η is the viscosity of air and ρ is the density of the oil droplet.

(2)

(ii) Explain how the mass of the oil droplet can be determined from its radius, r.

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(1)

(b) (i) The two horizontal parallel metal plates were 5.0 mm apart. The mass of the droplet was 6.8×10^{-15} kg. The droplet was held stationary when the plate pd was 690 V.

Calculate the charge of the oil droplet, expressing your answer to an appropriate number of significant figures.

answer..... C

(3)

(ii) Millikan made the first accurate measurements of the charge carried by charged oil droplets. Outline what Millikan concluded from these measurements.

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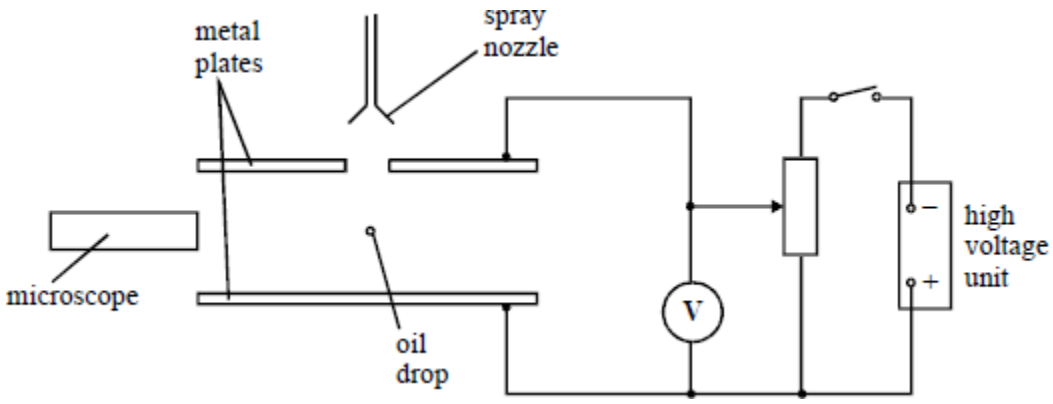
(2)
(Total 8 marks)

5 A charged oil droplet of mass 46×10^{-16} kg is observed between two horizontal metal plates spaced 40 mm apart.



(a) The droplet is held stationary with the top plate at a potential of −565 V relative to the lower plate.

(i) What is the sign of the charge carried by the droplet?

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(ii) Calculate the magnitude of the charge on the droplet. Ignore buoyancy effects

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(iii) Comment on the significance of this result

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(5)

(b) State and explain the direction in which the droplet would move if the top plate were made more negative relative to the lower plate.

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(2)
(Total 7 marks)

6 In an experiment to determine the charge on a charged oil droplet, the droplet was held stationary in a vertical electric field of strength 57 k V m^{-1}. After the electric field was switched off, the droplet fell at a steady speed, taking 18.3 s to fall through a vertical distance of 2.0 mm.

viscosity of air = 1.8×10^{-5} N s m^{-2},
density of the oil = 970 kg m^{-3}.

(a) Calculate the speed of the droplet when it was falling.

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(1)

(b) Show that the droplet's radius was 9.7×10^{-7} m.

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(3)

(c) Calculate the charge of the droplet.

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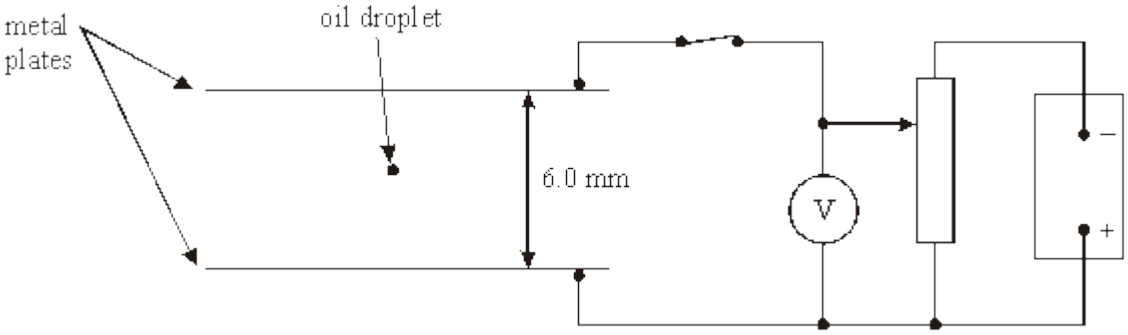
(3)
(Total 7 marks)

7 In an experiment to measure the charge on a charged oil droplet, a droplet was observed between two horizontal metal plates, as shown in the diagram below, spaced 6.0 mm apart.



(a) The oil droplet was held stationary when a negative potential of 320 V was applied to the top plate, keeping the lower plate at zero potential.

(i) State the sign of the charge on the droplet.

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(ii) With reference to the forces acting on the droplet explain why it was stationary.

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(2)

(b) The potential difference between the plates was then switched off and the droplet fell at constant speed through a vertical distance of 1.20 mm in 13.8 s.

(i) Calculate its speed of descent.

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(ii) By considering the forces on the spherical droplet of radius *r* as it falls at constant speed *v*, show that

$$v = \frac{2\rho g r^2}{9\eta}$$

where η is the viscosity of the air between the plates and ρ is the density of the oil. Ignore buoyancy effects.

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(iii) Calculate the radius of the droplet and hence show that its mass is 2.6×10^{-15} kg.

viscosity of the air = 1.8×10^{-5} N s m^{-2}
density of the oil = 960 kg m^{-3}

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(iv) Calculate the charge carried by this droplet.

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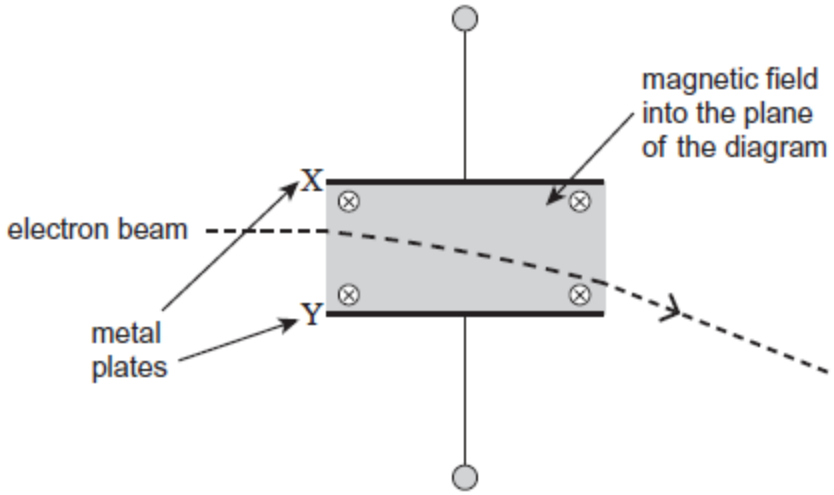
(10)
(Total 12 marks)

8 The diagram below shows part of an evacuated tube that is used to determine the specific charge (e / m) for an electron. An electron beam is directed between the two parallel metal plates, X and Y. In the region between the plates, a magnetic field is applied perpendicularly into the plane of the diagram. An electric field can be applied in this region by applying a potential difference (pd) between the plates.



(a) The diagram shows the path of the electron beam when the magnetic field is applied and the pd between X and Y is zero.

(i) Explain why the path followed by the electron beam in the magnetic field is a circular arc.

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(2)

(ii) Show that the speed v of the electrons is given by $v = \frac{Ber}{m}$

where r is the radius of the path of an electron in the magnetic field and B is the flux density of the magnetic field.

(1)

(iii) A pd V is now applied between X and Y without changing the flux density of the magnetic field. V is adjusted until the electron beam is not deflected as it travels in the region between the plates.

Determine an expression for the speed v of the electrons in terms of V, B and the separation d of the metal plates.

(1)

(b) Use the equation given in part (ii) and your answer to part (iii) to show that the specific charge for the electron = $\frac{V}{B^2 r d}$

(1)

(c) If the charge on an electron is known then its mass can be determined from the specific charge. Describe how Millikan's experiment with charged oil droplets enables the electronic charge to be determined.

Include in your answer:

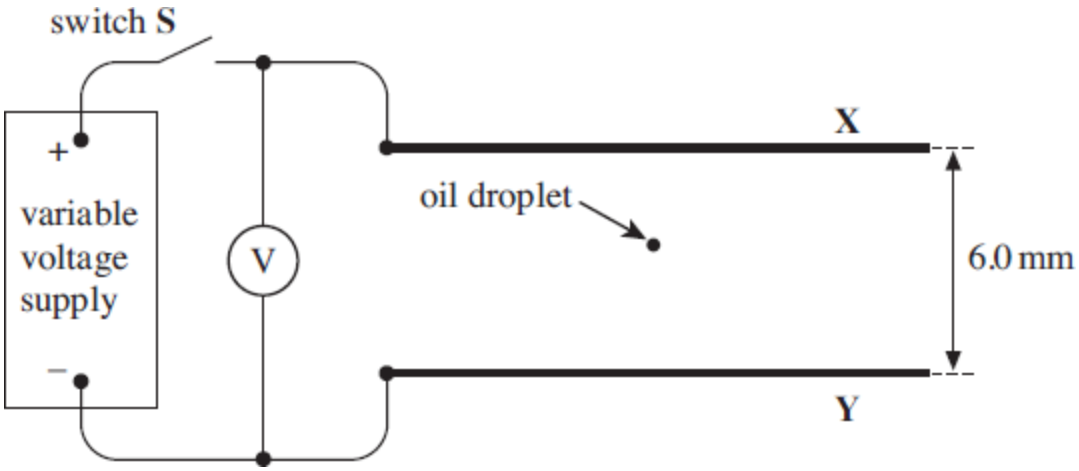
- the procedures used to determine the radius of a droplet and the charge on a droplet
- how the measurements made are used
- how the electronic charge can be deduced.

The quality of your written communication will be assessed in your answer.

(6)

(Total 11 marks)

9 A charged oil droplet was observed between two horizontal metal plates **X** and **Y**, as shown in the diagram below.



(a) (i) With the switch **S** open, the droplet fell vertically at a constant velocity of 1.1×10^{-4} ms^{-1}. Show that the radius of the droplet is about 1.0×10^{-6} m. Assume the droplet is spherical.

density of oil, $\rho = 880$ kg m^{-3}
viscosity of air, $\eta = 1.8 \times 10^{-5}$ N s m^{-2}

(4)

(ii) Calculate the mass of the droplet.

mass ..... kg

(1)

(iii) The switch **S** was closed and the potential difference from the voltage supply was adjusted gradually to reduce the downward motion of the droplet. The droplet stopped moving when the potential difference across the plates was 680 V. The spacing between the plates was 6.0 mm.

Calculate the magnitude of the charge on the droplet.

charge C

(3)

(b) The mass of another charged droplet was found to be 4.3×10^{-15} kg. With switch **S** closed and the voltage supply at its maximum value of 1000 V, this droplet fell more slowly than when the switch was open but it could not be stopped.

Explain why this droplet could not be held at rest and show that the magnitude of the charge on it was 1.6×10^{-19} C.

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(4)
(Total 12 marks)

10 In an experiment (first done by Millikan) to determine the charge on an electron, a charged oil drop of known (pre-determined) mass is held stationary between two parallel plates where a uniform electric field strength exists. **Figure 1** shows this situation for one oil drop.

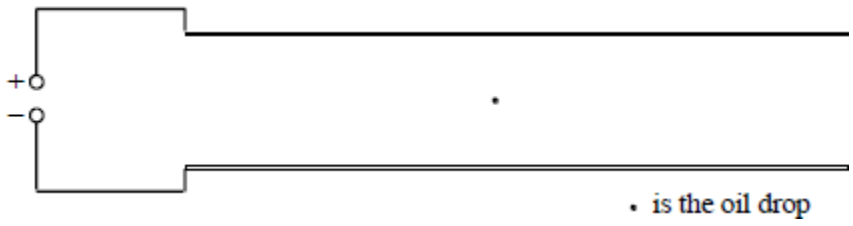

Figure 1

(a) (i) Explain what is meant by *a uniform electric field strength*.

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(2)

(ii) Sketch, on **Figure 1**, electric field lines to represent the electric field between and at the edges of the plates.

(3)

(b) In one test an oil drop has a weight of 3.0×10^{-14} N. It is held stationary between plates 4.0 mm apart when the potential difference applied is 380 V.

(i) Calculate the electric field strength between the plates.

(2)

(ii) Calculate the magnitude of the charge on the oil drop.

(2)

(iii) State and explain whether the charge is positive or negative.

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(3)

(c) The oil drop is not isolated but has other charged oil drops nearby. Suppose that there is another drop which has an equal but opposite charge near to the drop being observed, as shown in **Figure 2**.

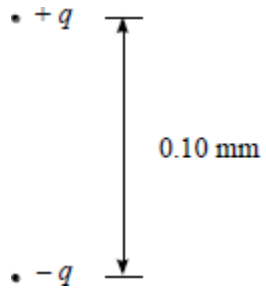


Figure 2

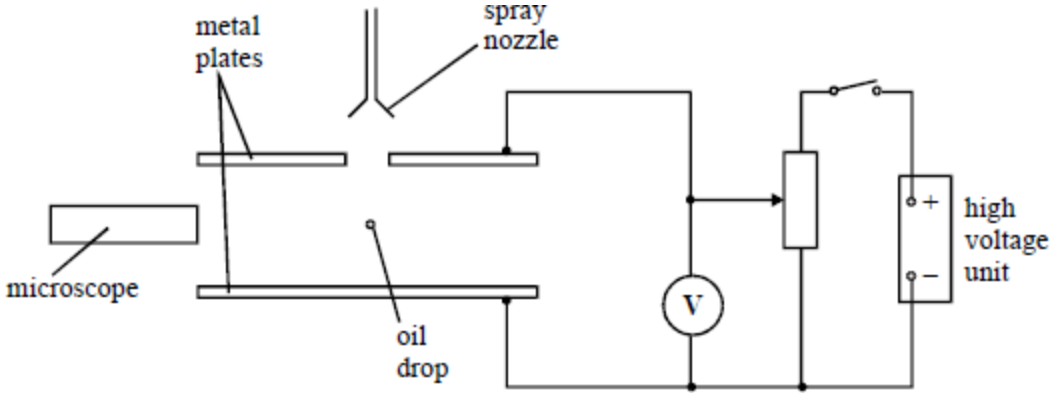
Show that, when the two drops are separated by 0.10 mm, the magnitude of the electric force between these oil drops may be neglected in the calculations in part (b).

The permittivity of free space, $\varepsilon_0 = 8.9 \times 10^{-12}$ F m^{-1}

(4)

(Total 16 marks)

11 Millikan determined the charge on individual oil droplets using an arrangement as represented in the diagram. The plate voltage necessary to hold a charged droplet stationary was measured. The time the droplet took to fall a known distance with the plate voltage off was then measured.



(a) (i) Explain why a charged oil droplet reaches a constant speed when the plate voltage is switched off.

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(ii) By considering the forces on such a droplet, show that the radius, r, of the droplet is related to the speed, v by

$$r^2 = \frac{9\eta v}{2\rho g},$$

where η is the viscosity of air and ρ is the density of the oil. Ignore the effects of buoyancy.

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(6)

(b) In an experiment to measure the charge on an oil droplet, a charged droplet was held stationary by a voltage of 225 V between two plates at a separation of 5.0 mm. When the plate voltage was switched off, the droplet descended a vertical distance of 1.20 mm in a time of 15.5 s.
Ignore the effect of buoyancy of the air.

density of oil = 950 kg m^{-3}
viscosity of air = 1.8×10^{-5} N s m^{-2}

(i) Show that the mass of this droplet was 2.2×10^{-15} kg.

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(ii) Calculate the charge carried by this droplet.

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(6)

(c) Millikan measured the charge on each of many oil droplets. Explain what he concluded from his measurements.

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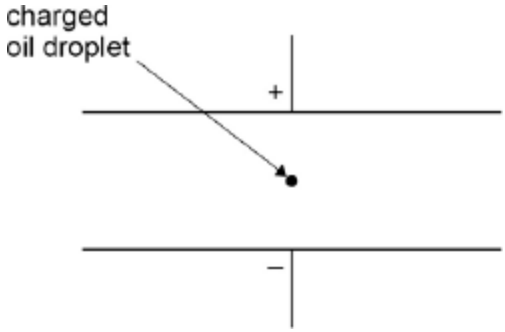
(2)
(Total 14 marks)

12 In an experiment to measure the charge of the electron, a spherical charged oil droplet of unknown mass is observed between two horizontal parallel metal plates, as shown in the figure below.



(a) The droplet falls vertically at its terminal speed when the potential difference (pd) between the plates is zero.

A droplet of radius g falls at its terminal velocity, v.

Derive an expression for g in terms of v, η , ρ and g, where η is the viscosity of air and ρ is the density of the oil droplet.

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(2)

(b) Explain how the mass of the oil droplet can be calculated from its radius and other relevant data.

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(1)

(c) A potential difference (pd) is applied across the plates and is adjusted until the droplet is held stationary. The two horizontal parallel metal plates are 15.0 mm apart. The mass of the droplet is 3.4×10^{-15} kg.

The droplet is held stationary when the pd across the plates is 1560 V.

Calculate the charge of the oil droplet.

charge = ... C

(2)

(d) A student carries out Millikan's oil drop experiment and obtains the following results for the charges on the oil drops that were investigated.

-9.6×10^{-19} C $\quad$ -12.8×10^{-19} C $\quad$ -6.4×10^{-19} C

Discuss the extent to which the student's results support Millikan's conclusion and how the student's conclusion should be different.

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(3)
(Total 8 marks)