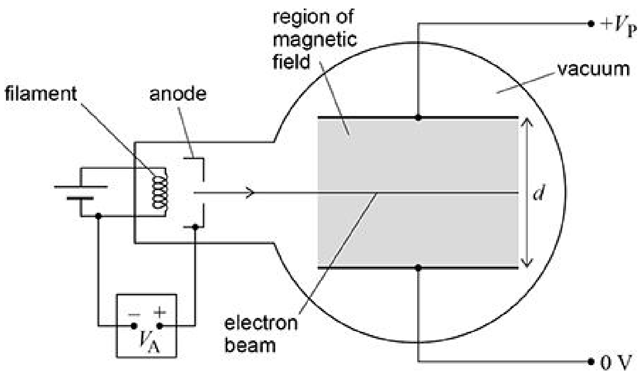
Q1.

(a) The figure below shows apparatus used in an experiment to measure the specific charge of the electron.



Electrons are accelerated by the potential difference V_A.

The electrons then enter the region between two parallel metal plates, shown shaded in the figure above. The parallel metal plates are separated by a distance d with a potential difference V_P across them. In the same region there is a uniform magnetic field of flux density B into the plane of the diagram.

Explain why the electron beam is undeflected in the shaded region shown in the figure above.

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(2)

(b) Determine, using the following data, a value for the specific charge of the electron.

B = 1.59 mT V_P = 1.51 kV d = 5.0 cm V_A = 1.00 kV

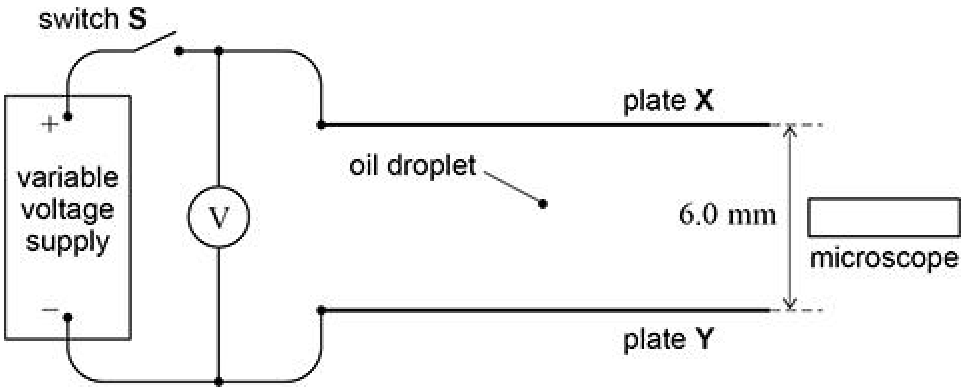
specific charge = ____________________ C kg^{-1}

(4)

(Total 6 marks)

Q2.

(a) The figure below shows a cross-sectional view of the arrangement that Millikan used to determine the charge on the electron.



Millikan's initial step was to determine the radius of the oil droplet.

Explain how Millikan used this apparatus to determine the radius of the oil droplet.

In your answer you should:

- describe the procedure used, the measurements taken and any additional data required
- describe how the radius was determined from the measurements
- state the physical principles and assumptions involved in the determination of the radius.

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(6)

(b) On one occasion, the radius of a droplet was determined to be 1.20×10^{-6} m.
When the droplet was stationary, the voltmeter reading was 467 V.

Show that the charge on the droplet was approximately 8×10^{-19} C.

density of oil = 880 kg m^{-3}

(3)

(c) The table below shows the percentage uncertainty in each quantity.

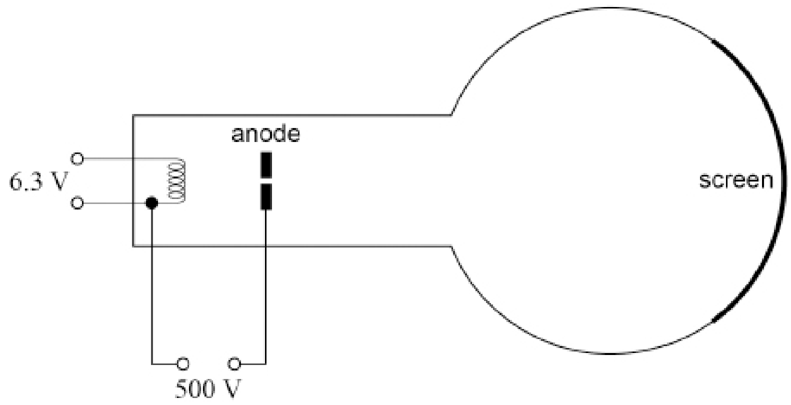
Quantity	Percentage uncertainty
radius of oil droplet	4%
density of oil	1%
gravitational field strength	0.1%
potential difference	0.2%
distance between the plates	2%

Show that the absolute uncertainty in your answer to part (b) is approximately $\pm 1 \times 10^{-19}$ C.
Go on to discuss whether this uncertainty allows your answer to part (b) to be used to support the quantisation of electric charge.

(3)
(Total 12 marks)

Q3.

In the figure below, a beam of electrons travels through the aperture in the anode and hits the screen.



(a) Explain how the electrons that form the beam are emitted.

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(1)

(b) Show that the maximum speed of the electrons in the beam is about 1.3×10^7 m s^{-1}.

(1)

(c) A student suggests that the apparatus can be used to demonstrate the wave properties of electrons in the beam, provided that the aperture in the anode has a suitable diameter.

Discuss whether the student is correct.
Support your answer with a calculation.

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(3)

(d) In 1897, J J Thomson determined a value for the specific charge of an unknown particle.
The unknown particle is now known to be the electron.

Describe **one** method to determine the specific charge of the electron.

Your answer should include:

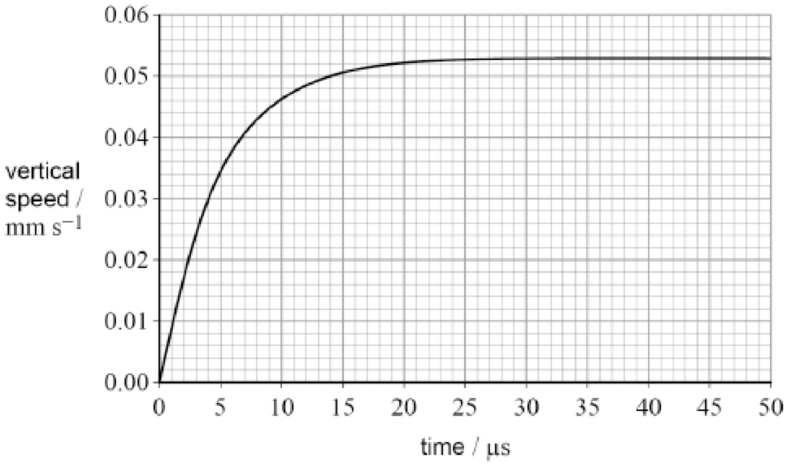
- a description of the apparatus used and the measurements made
- a description of how the specific charge can be determined using these measurements
- an explanation of the conclusion made by Thomson from the value that he determined.

(6)
(Total 11 marks)

Q4.

In an experiment to determine the electronic charge, a charged oil drop falls from rest between two uncharged plates.

The oil drop has a weight of 1.2×10^{-14} N and a radius of 6.8×10^{-7} m. Ignore the buoyancy force of the air on the oil drop.
The figure below shows the variation of the vertical speed of the oil drop with time.



(a) Calculate the viscosity of the air between the plates.

viscosity = ____________________ N s m^{-2}

(3)

(b) During the experiment, an electric field is produced between the plates and is adjusted until the oil drop is stationary.
The electric field strength is 18.8 kV m^{-1}.

Discuss whether the outcome of the experiment is consistent with the accepted value for electronic charge.

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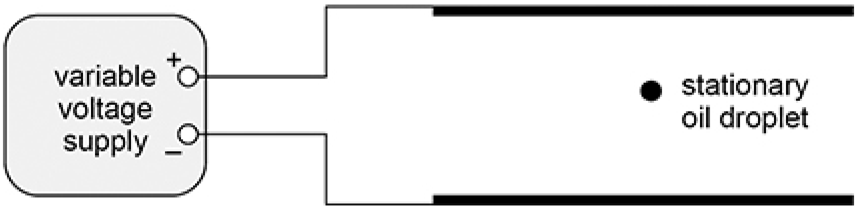
(3)
(Total 6 marks)

Q5.

Robert Millikan experimented with oil drops to determine a value for the electronic charge.

The diagram below shows a stationary oil droplet between two horizontal metal plates. The plates are connected to a variable voltage supply so that the upper plate is positive. The oil droplet has mass m and charge Q.



(a) State and explain the sign of the charge on the oil droplet.

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(1)

The variable voltage supply is set to zero volts. The oil drop falls. The constant speed v_1 of the falling oil droplet is found to be 3.8×10^{-5} m s^{-1} and the following measurements are recorded:

density of oil = 910 kg m^{-3}
viscosity of air = 1.8×10^{-5} N s m^{-2}

(b) Show that the mass m of the oil droplet is about 8×10^{-16} kg.

(3)

(c) The variable voltage supply is adjusted so that the oil droplet rises at a constant speed v_2. The potential difference (pd) across the plates is V and the distance between the plates is d.

In his experiment, Millikan measured the constant speed v_1 of a falling droplet when the pd was zero. He compared this with the speed v_2 of the same droplet when the droplet was made to rise.

Show that $$\frac{v_2}{v_1} = \frac{VQ}{dmg} - 1$$

(2)

(d) The following measurements are made for the droplet in part (b) when it is rising at constant speed.

$V = 715$ V

$v_2 = 1.1 \times 10^{-4}$ m s^{-1}

The separation of the plates $d = 11.6$ mm.

Deduce, using the equation in part (c), whether the value of the charge for this droplet is consistent with the currently accepted value of the electronic charge.

(3)

(e) After Millikan published his results, it was found that he had used a value for the viscosity of air that was smaller than the actual value.

Discuss the effect this error had on Millikan’s value of the electronic charge.

(3)

(Total 12 marks)