

10 The Shanghai Maglev Train is the first commercially operated high-speed magnetic levitation train in the world, connecting the airport and central Shanghai.



(a) The total distance travelled is 29.9 km and the total journey time is 440 s. The train starts from rest and reaches a speed of 97 m s^{-1} in 120 s.

(i) Calculate the average acceleration of the train during the first 120 s.

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Average acceleration of train =

(ii) Calculate the average speed of the train for the period following the 120 s acceleration.

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Average speed of train =

(b) Electromagnetic forces enable the train to levitate above a steel rail.

Explain why magnetic levitation is an advantage for a high-speed transport system.

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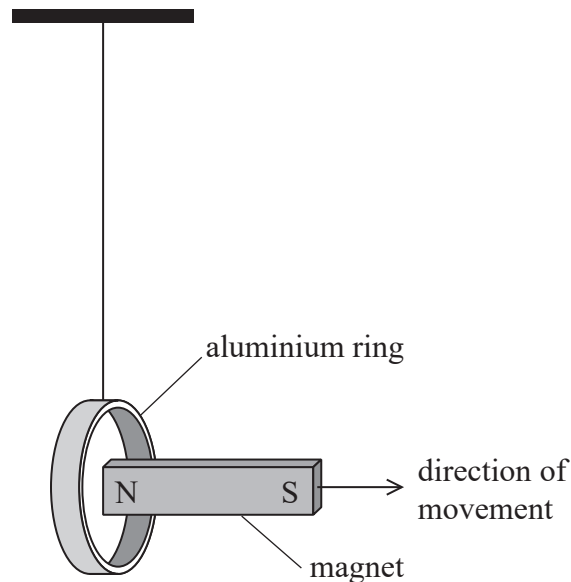
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- * (c) A linear induction motor provides the force to accelerate the train forwards. A current flows in sequence through coils of wire mounted in the track. The train is dragged along as the magnetic field progresses along the coils of wire in the track. This is similar to moving a permanent magnetic field away from a conductor.

A teacher demonstrates this effect by quickly removing one end of a bar magnet from a suspended aluminium ring.



When the magnet is removed from the ring, the ring moves in the same direction as the magnet.

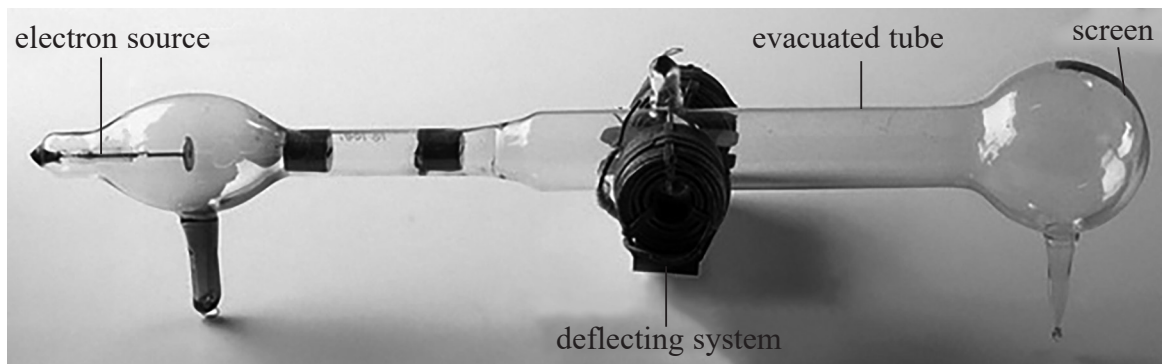
Explain, using the laws of electromagnetic induction, why the ring moves in the direction of the magnet.

(6)

(Total for Question 10 = 13 marks)



- 7 At the end of the 19th century, J.J. Thomson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



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Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

- (a) Explain how electrons from the source become a beam of high-energy electrons.

(2)

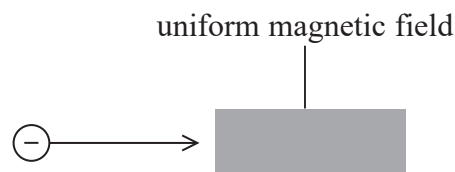
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- (b) An electron is travelling left to right and enters a region of uniform magnetic field as shown below. The direction of the magnetic field is perpendicular to the direction of travel of the electron.



- (i) The magnetic field deflects the electron in the direction up the page.

Explain the direction of the magnetic field that would produce this deflection.

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- (ii) Explain why the electron would travel in a circular path if no other forces acted on it.

(2)

- (c) In a modern version of Thompson's experiment, a uniform electric field of electric field strength E is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

- (i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where B is the magnetic flux density of the magnetic field.

(2)

- (ii) The beam is produced by accelerating electrons through a potential difference of 250 V. The electric field strength is $1.4 \times 10^4 \text{ V m}^{-1}$. The magnetic flux density is $1.5 \times 10^{-3} \text{ T}$.

Calculate the value of the specific charge e/m for the electron using this data.

(3)

$e/m = \dots\dots\dots$



- (d) In his original experiments, Thompson determined the specific charge of a range of particles. His results indicated that the specific charge of an electron is about 2000 times bigger than that for a hydrogen ion.

Deduce what conclusion can be made from this information.

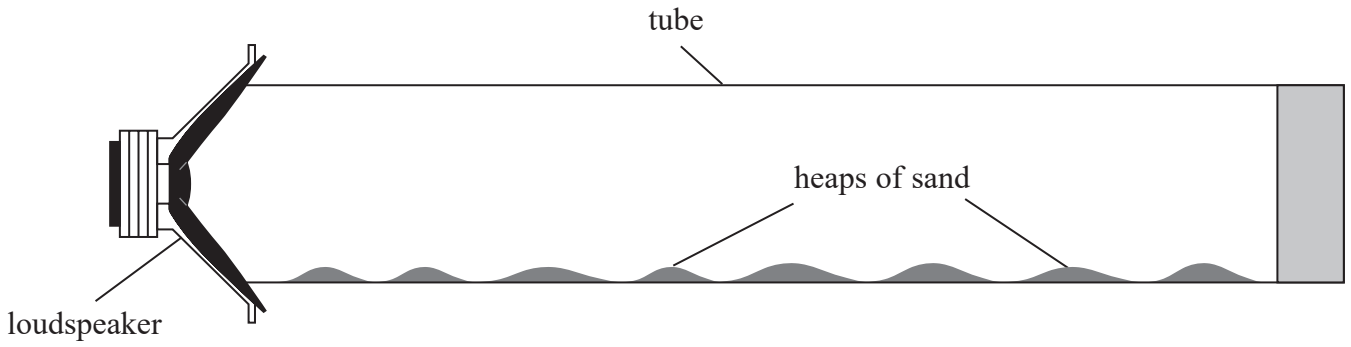
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(Total for Question 7 = 12 marks)



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- (b) The student connected a signal generator to the loudspeaker, and placed the loudspeaker near to one end of a long tube containing sand. The student adjusted the signal generator until the sand collected in small heaps as shown.



- (i) Explain why the sand collects in heaps.

(4)

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- (ii) The student determined the distance d between the centres of adjacent heaps.

Describe the procedure she should follow to determine an accurate value for d .

(3)

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- (iii) Assess whether the experimental data is consistent with a value for the speed of sound of 340 m s^{-1} .

signal generator frequency = 3.25 kHz .

$d = 5.1 \text{ cm}$

(3)

(Total for Question 9 = 16 marks)

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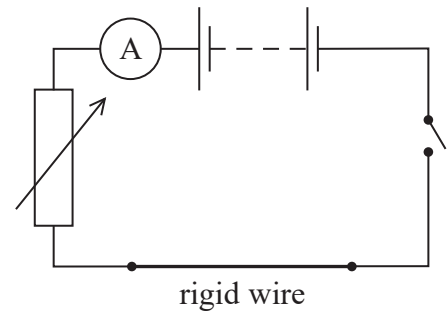
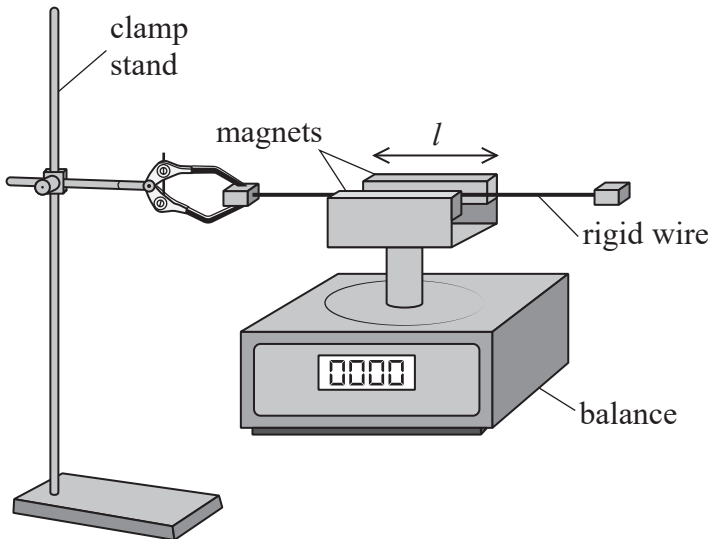
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Answer ALL questions in the spaces provided.

- 1 A student set up the apparatus shown. A length of rigid wire was held horizontally by a clamp in a uniform magnetic field of flux density B . The circuit connected to the rigid wire is also shown.



With the switch open, the balance was set to zero. When the switch was closed a current I in the circuit was recorded by the ammeter and the reading on the balance increased.

- (a) The length l of wire in the magnetic field was 15.5 cm. When the current in the circuit was 4.55 A, the reading on the balance increased by 5.65 g.

Calculate the magnetic flux density B in the region of the rigid wire.

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$B =$

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(b) The student wrote the following statement

“The balance could read to the nearest 0.01 g, which makes my values for the magnetic force both accurate and precise.”

Comment on this statement.

(3)

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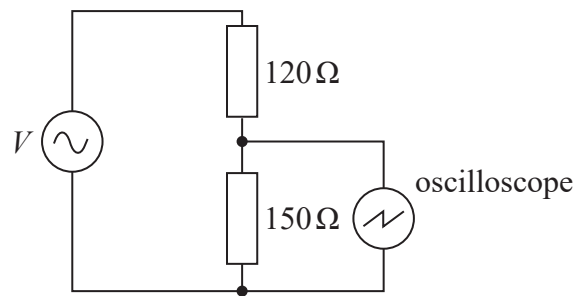
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(Total for Question 1 = 6 marks)

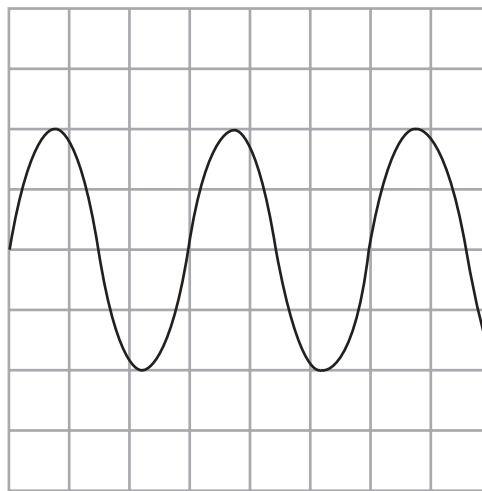


7 A student connected the output from a source of alternating potential difference (p.d.) to a series resistor combination.

She connected an oscilloscope across the $150\ \Omega$ resistor as shown.



(a) The trace obtained on the oscilloscope is shown below.



(i) Determine the peak p.d. across the $150\ \Omega$ resistor.

y-sensitivity of oscilloscope = $2.0\ \text{V}$ per division

(2)

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Peak p.d. across $150\ \Omega$ resistor =

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(ii) Calculate the root mean square (r.m.s.) value of the current in the circuit.

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r.m.s. value of current =

(iii) Calculate the power dissipated in the circuit.

(3)

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Power dissipated in circuit =

(b) Another student suggested that a voltmeter would be more accurate than using an oscilloscope to determine the magnitude of the p.d.

Comment on this suggestion.

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(Total for Question 7 = 11 marks)

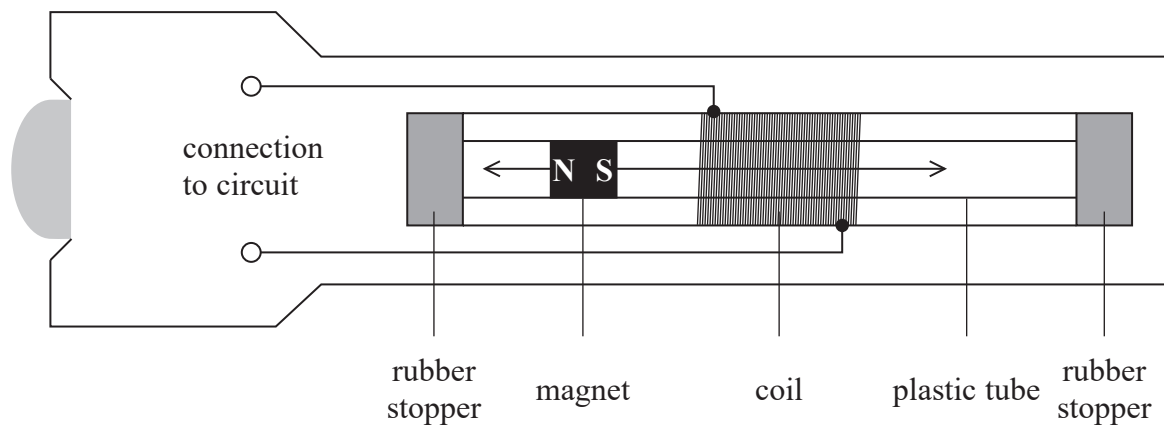
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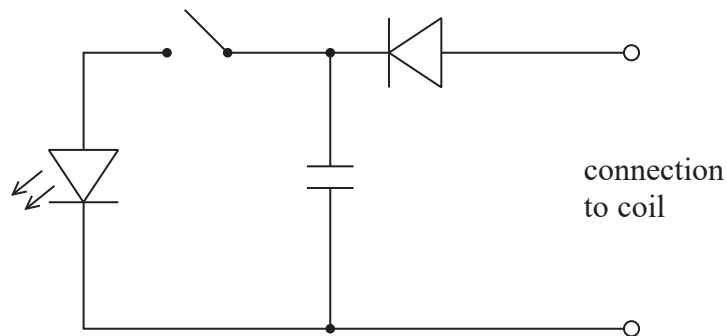
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- *5 The diagram shows a 'shaker torch'. When the torch is shaken, a strong magnet moves forwards and backwards through a copper coil, powering a light-emitting diode (LED).



Each time the magnet moves through the coil a current pulse is generated. The coil is connected to a capacitor via a diode, as shown.



Once the torch has been shaken for a few minutes the switch is closed and the LED lights for a short while.

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Explain how the shaker torch is able to light the LED.

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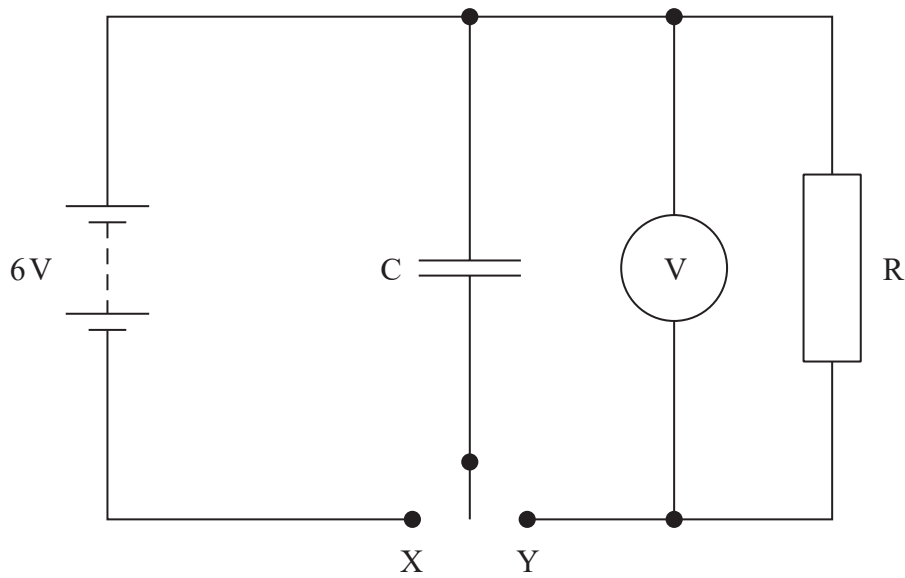
Area with horizontal dotted lines for writing the answer.

(Total for Question 5 = 6 marks)

Large empty rectangular area for additional work or calculations.



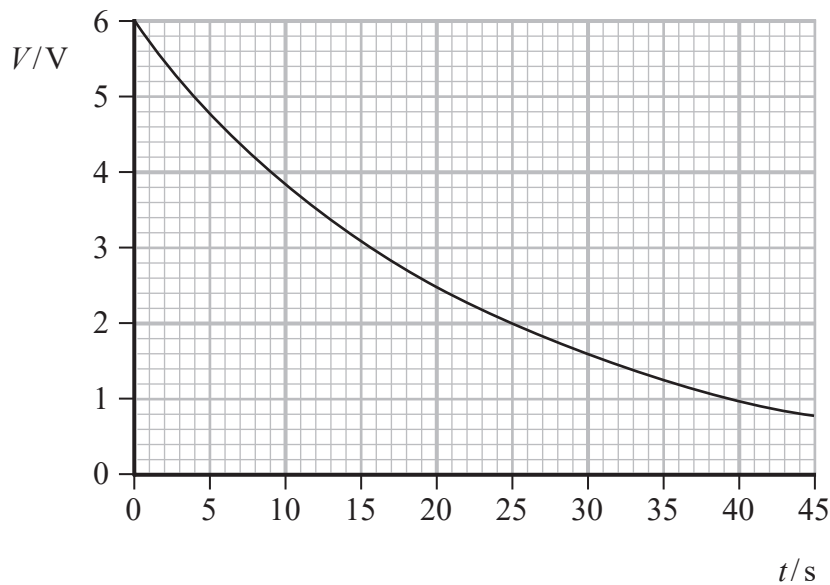
- 8 A student investigated the discharge of a capacitor C through a resistor R using the circuit shown.



The student used the switch to connect C to X to charge the capacitor. She then connected C to Y to discharge the capacitor through R .

As the capacitor discharged, she recorded values of the potential difference V across C and corresponding values of time t . She used a stopwatch to measure t .

The student used her results to plot the following graph.



- (a) The capacitor was marked $220\ \mu\text{F} \pm 20\%$.

Deduce whether the student's data give a value of capacitance within the stated range.

$$R = 82\ \text{k}\Omega$$

(5)

- (b) The student suggested that her results would have been more accurate if she had used a data logger to record the data.

Assess the student's suggestion.

(3)

(Total for Question 8 = 8 marks)



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- (b) The student determined the terminal velocity of the oil drop in order to obtain a value for the weight of the oil drop.

He disconnected the power supply and the oil drop fell downwards. He viewed the oil drop through a microscope.

- (i) Explain why the student should wait a short while before starting to take measurements.

(2)

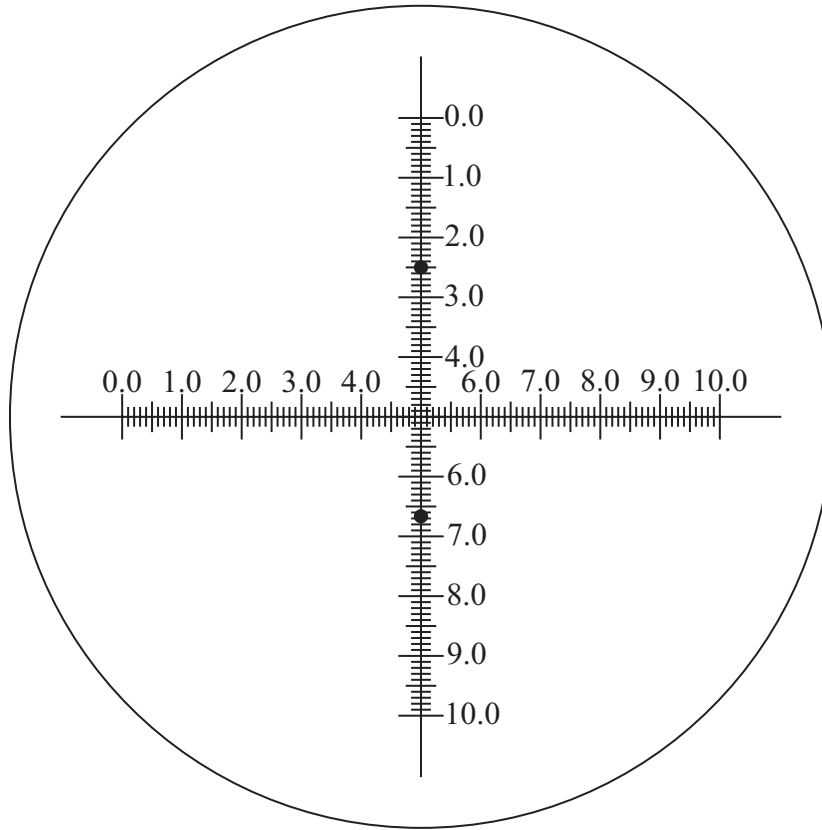
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(ii) The view through the microscope is shown below. The scale is in millimetres.



The position of the oil drop at the start and end of a 120 s time interval is indicated by the black dots.

Determine the terminal velocity of the oil drop.

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Terminal velocity =

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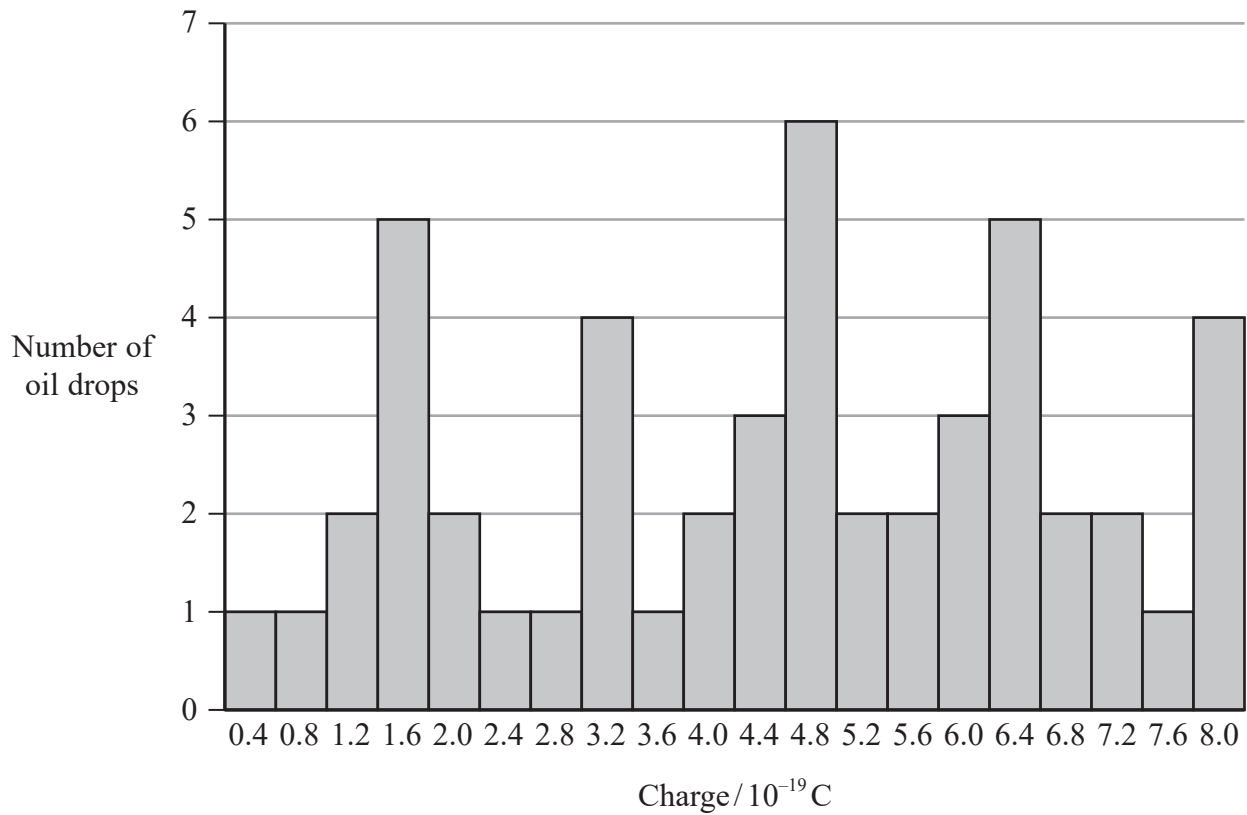
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- (c) The student repeated the measurements on fifty oil drops. For each drop the student calculated the charge on the oil drop.

His results are shown in the bar chart.



The student predicted that the charge on each oil drop would be a whole number multiple of the charge on an electron.

Comment on the extent to which the bar chart supports the student's prediction.

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(Total for Question 9 = 15 marks)

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