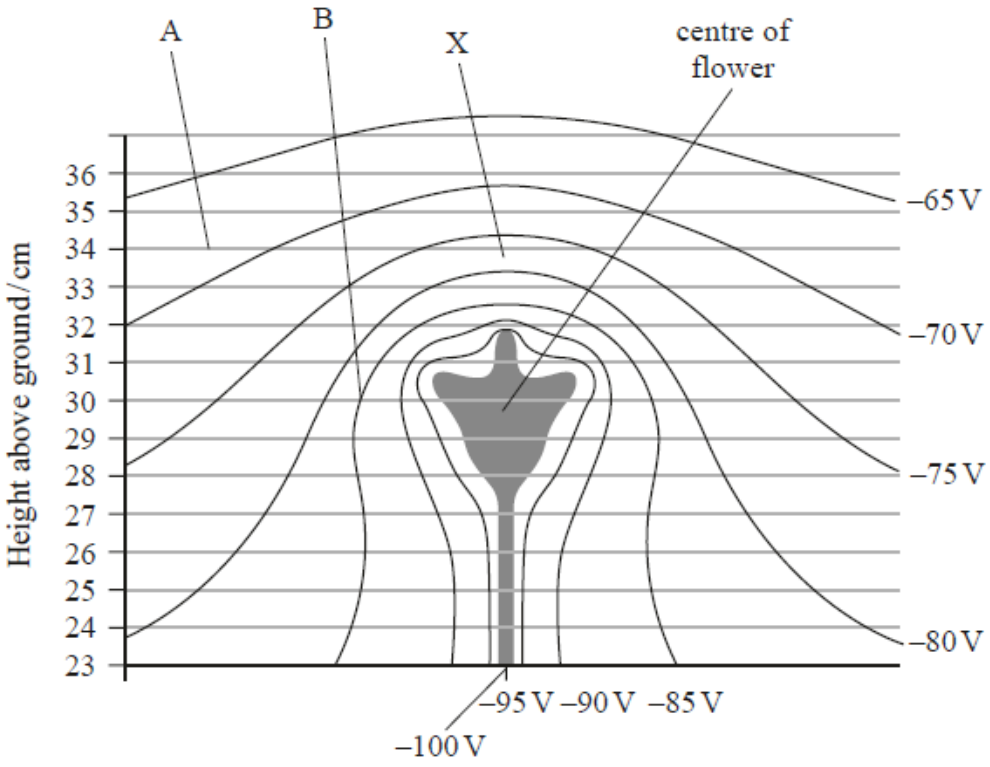
Questions

Q1.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

The diagram shows lines of equipotential surrounding a flower.



(i) Determine the electric field strength at X.

(3)

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Electric field strength at X = ...

(ii) Draw the electric field line between point A and point B on the diagram.

(2)

(iii) An equation for electric potential V is

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

This applies to a radial field.

Deduce whether the electric field in the region directly above the flower is radial.
You should take values from the diagram. A graphical method is not required.

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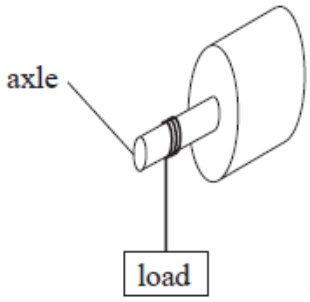
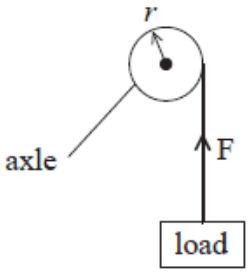
(Total for question = 8 marks)

Q2.

Motors usually have a rotating component which can do work W.

(a) A motor lifts a load in a time t. The axle of the motor has a radius r and exerts a force F.





The power produced by a motor can be calculated by using the following word equation.

Power = moment of the force exerted by the rotating axle × angular velocity

Derive this equation, starting with power $P = \frac{W}{t}$.

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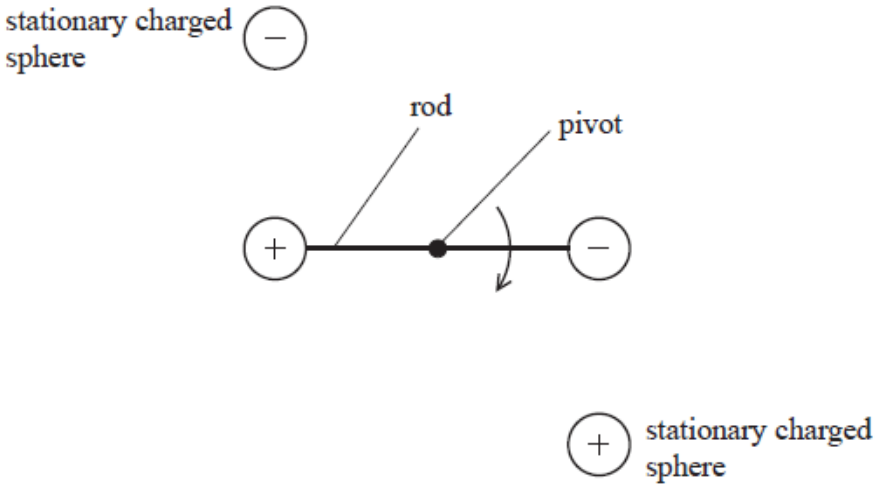
(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

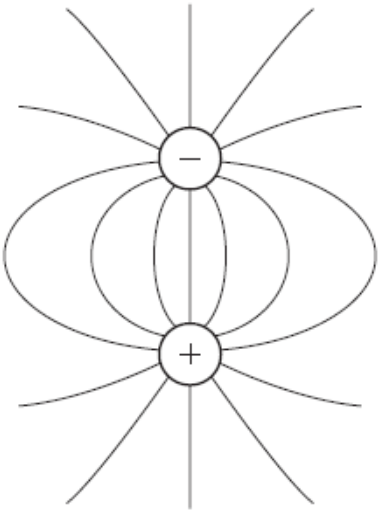


(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

(3)



(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

(2)

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

	Power / W	Angular velocity / rad s^{-1}
Electric car	2.0×10^4	300
Vacuum cleaner	1.4×10^3	1000
Small pond pump	0.5	200

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

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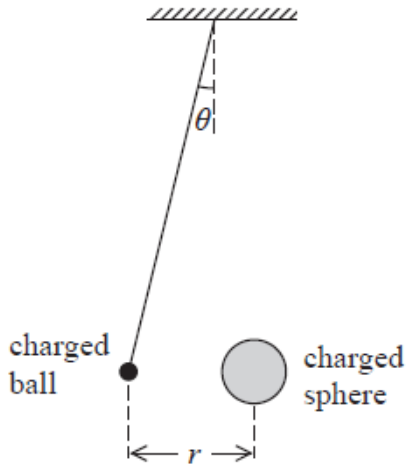
(Total for question = 13 marks)

Q3.

A student carries out an experiment to investigate the force acting between two charged objects. A lightweight negatively-charged ball is freely suspended from the ceiling by an insulating thread. The ball is repelled by a negatively-charged sphere that is placed near it on an insulated support.
The angle of deflection is θ and r is the distance between the centres of the ball and the sphere.



(a) (i) Draw a free-body force diagram for the suspended ball.

(2)

(ii) The weight of the suspended ball is W.

Show that the force of repulsion F on the suspended ball is given by

$$F = W \tan \theta$$

(2)

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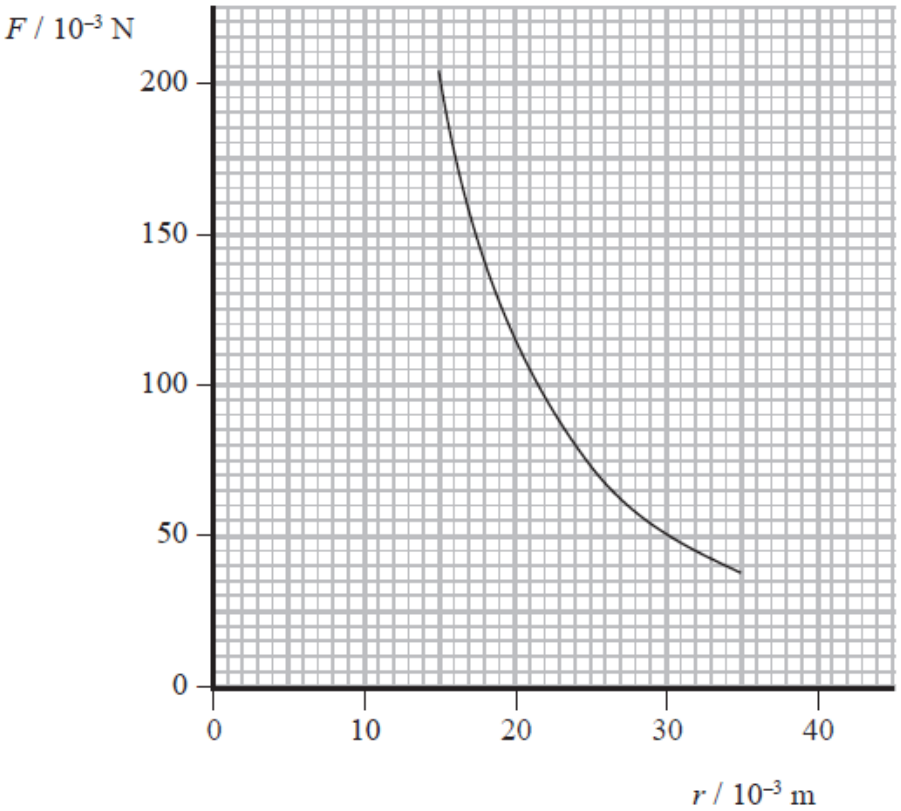
(b) (i) The student can increase the magnitude of the force by moving the sphere towards the suspended ball.
She takes pairs of measurements of r and θ and calculates the magnitude of the force F. She then plots a graph of F against r.



Use readings from the graph to demonstrate that the relationship between *F* and *r* obeys an inverse square law.

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(ii) The charge on the sphere is 100 times greater than the charge on the ball.

Calculate the charge on the ball.

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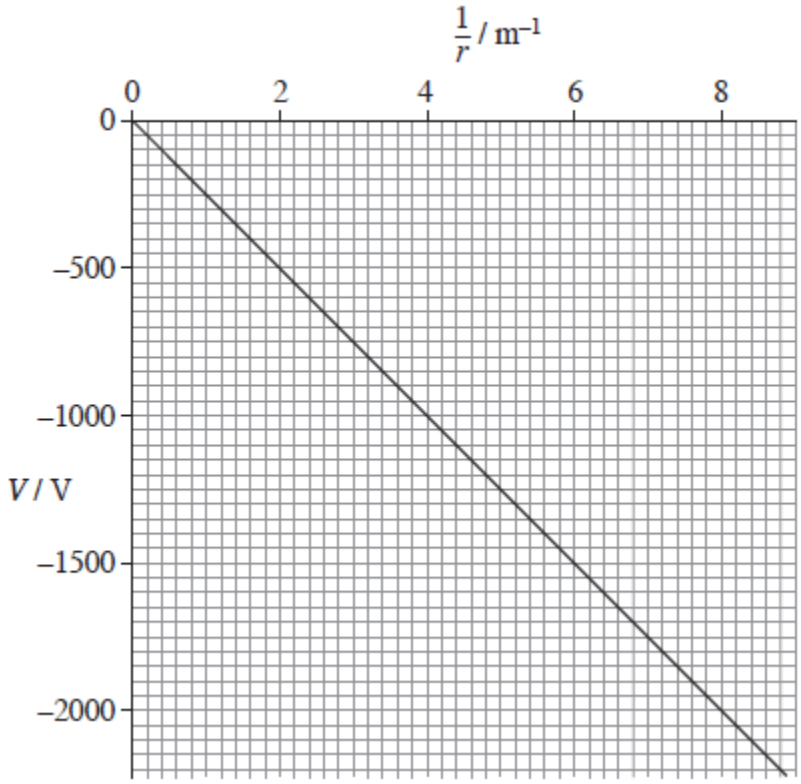
Charge = ...

(Total for question = 11 marks)

Q4.

(a) The graph shows how the electric potential, V, varies with $\frac{1}{r}$, where r is the distance from a point charge Q.



State what can be deduced from the graph about how V depends on r and explain why all the values of V on the graph are negative.

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(2)

(b) (i) Use data from the graph to show that the magnitude of Q is about 30 nC

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(2)

(ii) A +60 nC charge is moved from a point where r = 0.20 m to a point where r = 0.50 m. Calculate the work done.

(2)

work done _____ J

(iii) Calculate the electric field strength at the point where r = 0.40 m.

electric field strength _____ V m^{-1}

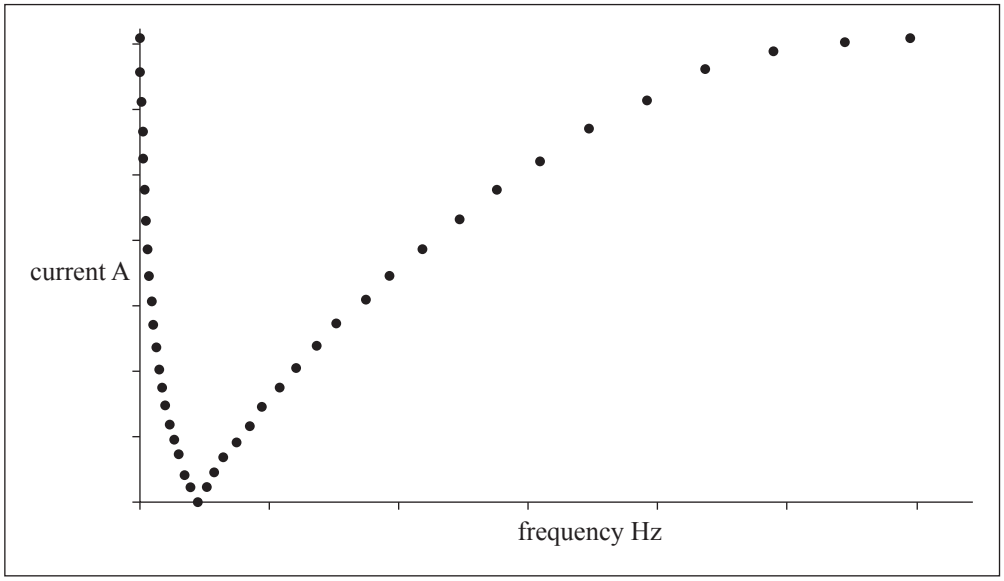
QUESTION 5: ELECTRONS EVERYWHERE

Mass of the electron	$= 9.11 \times 10^{-31}$ kg
Charge on the electron	$= -1.60 \times 10^{-19}$ C
Universal gravitational constant	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Coulomb's constant	$= 8.98 \times 10^{9}$ N m^2 C^{-2}

(a) Show that the force of gravitational attraction between a pair of electrons is about 10^{-43} times the force of electrostatic repulsion.

The force of electrostatic repulsion is given by the following equation: $F = \mathrm{k}\frac{q_1 q_2}{r^2}$, where k is Coulomb's constant, q is the charge, and r is the separation.

(b) An experimenter is given a black box with two electrical terminals. The experimenter knows that inside the box are exactly one inductor, one capacitor, and one resistor, but does not know the combination of parallel and series connections inside the box. Using an AC generator with variable frequency and fixed voltage, the experimenter measures the magnitude of the AC current as a function of frequency, and obtains the following graph:



Assuming that the circuit elements are ideal, describe how the three components are connected.

Explain your reasoning.

QUESTION 6: ELECTRON STEW (8 marks)

Permittivity of free space = 8.85×10^{-12} F m^{-1}
Dielectric constant of air = 1.00
Charge on the electron = 1.60×10^{-19} C

(a) The Bohr model of the atom is based on several assumptions.

State these assumptions and discuss their significance.

(b) Electrons repel each other. Two wires carrying parallel currents attract each other. Therefore currents in wires cannot be due to the motion of electrons.

Comment.

(c) Explain why there is a force of attraction between a charged rod and an uncharged, isolated metal sphere, and why this force increases when the sphere is earthed.

(d) Calculate the average distance between the excess electrons on one plate of a parallel plate capacitor for which the plates are separated by 1.00 mm of air, and have a potential difference between them of 1.00×10^3 V.

(8)

7 Electrons in a beam are accelerated from rest by a potential difference V between two vertical plates before entering a uniform electric field of electric field strength E between two horizontal parallel plates, a distance $2d$ apart.

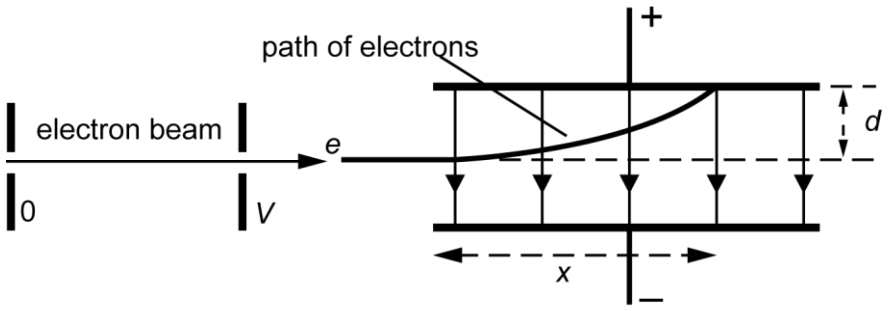


Fig. 2.1

The path of the electrons is shown in Fig. 2.1. The electron beam travels a horizontal distance x parallel to the plates before hitting the top plate. The beam has been deflected through a vertical distance d.

(a) Show that x is related to V by the equation

$$x^2 = \frac{4dV}{E}$$

[5]

(b) For different values of the accelerating p.d. V, the horizontal distance x is recorded. A table of results is shown with a third column giving values of x^2 including the absolute uncertainties.

V / V	x / cm	x^2 / cm^2
500	3.3 ± 0.1	10.9 ± 0.7
600	3.6 ± 0.1	13.0 ± 0.7
700	3.9 ± 0.1	15.2 ± 0.8
800	4.2 ± 0.1	17.6 ± 0.8
900	4.5 ± 0.1	20.3 ± 0.9
1000	4.7 ± 0.1	

(i) Complete the missing value in the table, including the absolute uncertainty. **[1]**

(ii) Fig. 2.2 shows the axes for a graph of x^2 on the y-axis against V on the x-axis. The first four points have been plotted including error bars for x^2. Use data from the table to complete the graph. **[2]**

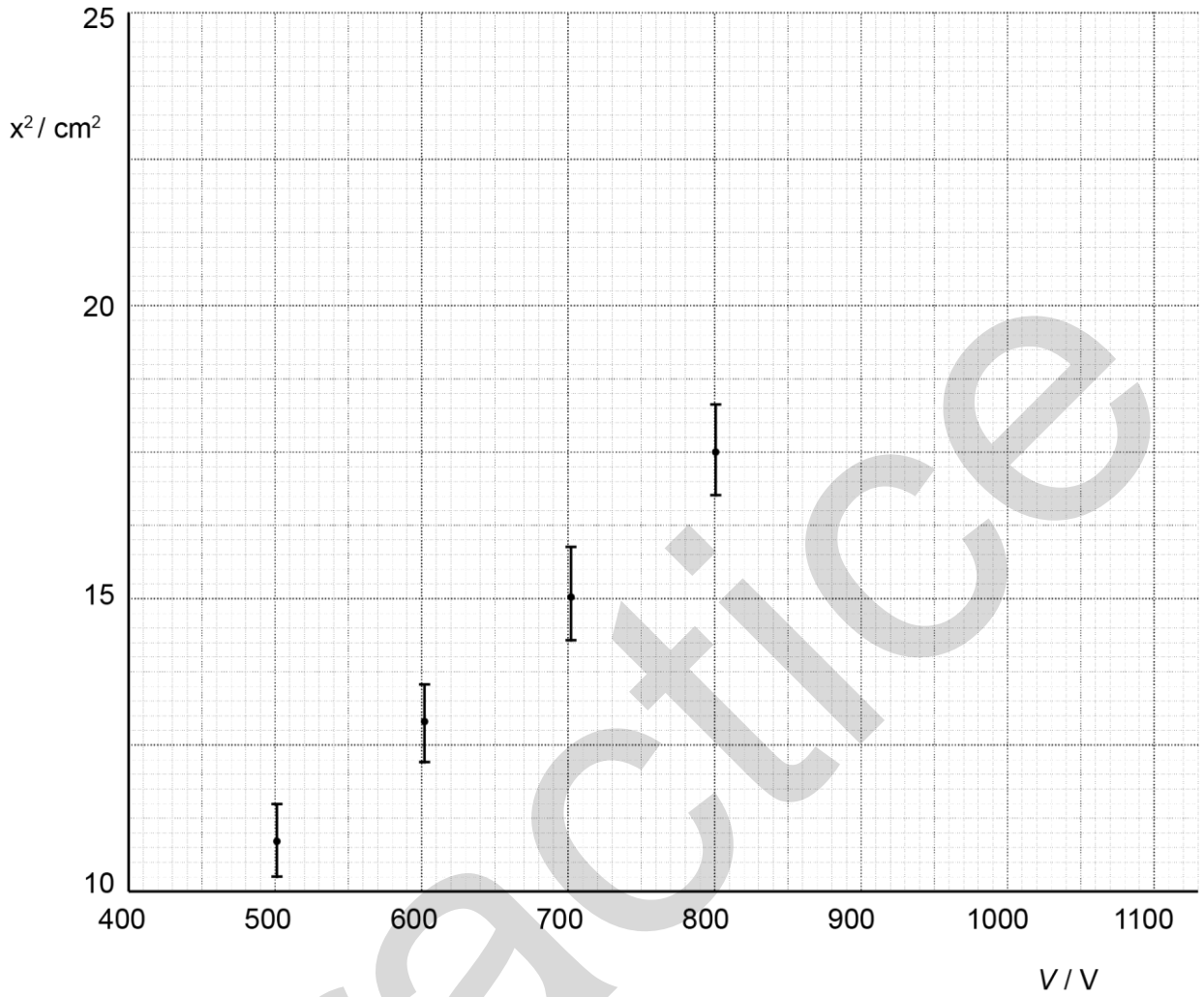


Fig. 2.2

(iii) The separation of the horizontal plates is 4.0 ± 0.1 cm.
Use the graph to determine a value for E. Include the absolute uncertainty and an appropriate unit in your answer

E = ...±.....unit..... **[4]**