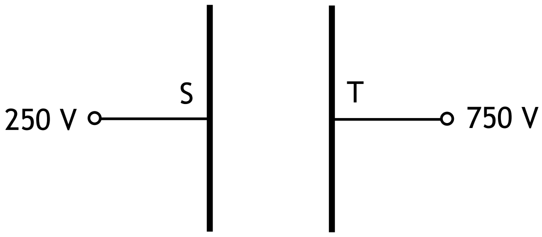
Homework 2: Forces on Charged Particles

1. In the arrangement shown below, 2 C of positive charge is moved from plate S, which is at a potential of 250 V, to plate T, which is at a potential of 750 V.



Calculate the energy required to move this charge from plate S to plate T.

A 0·004 J
B 250 J
C 500 J
D 1000 J
E 1500 J

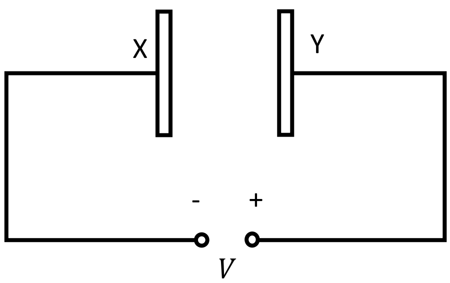
2. An electron is accelerated from rest in an electron gun, across a potential difference of $2{\cdot}0 \times 10^3$ V. Calculate the kinetic energy gained by the electron as it travels through the electron gun.

A $8{\cdot}0 \times 10^{-23}$ J
B $8{\cdot}0 \times 10^{-20}$ J
C $3{\cdot}2 \times 10^{-19}$ J
D $1{\cdot}6 \times 10^{-16}$ J
E $3{\cdot}2 \times 10^{-16}$ J

3. Identify which of the following is equivalent 1 V.

A 1 F C^{-1}
B 1 A Ω^{-1}
C 1 J A^{-1}
D 1 J Ω^{-1}
E 1 J C^{-1}

4. Two parallel metals plates X and Y in a vacuum have a potential difference V across them.



An electron of charge e and mass m, initially at rest, is released from plate X.
Identify which equation could be used to calculate the speed of the electron as it reached plate Y.

A $\frac{2eV}{m}$

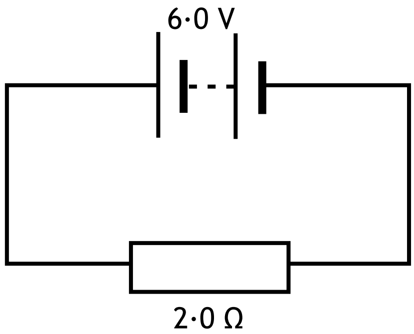
B $\sqrt{\frac{2eV}{m}}$

C $\sqrt{\frac{2V}{em}}$

D $\frac{2V}{em}$

E $\frac{2mV}{e}$

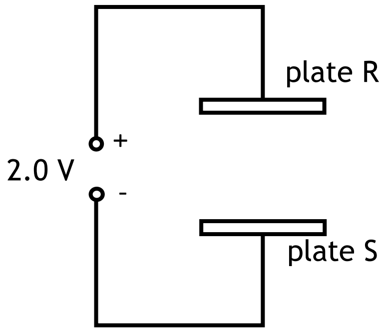
5. In the following circuit, the battery has an e.m.f. of 6·0 V and negligible internal resistance.



Calculate the energy required to move one coulomb of charge around the circuit.

A 3·0 J
B 6·0 J
C 12 J
D 18 J
E 72 J

6. Two parallel plates, R and S, are connected to a 2.0 V d.c. supply as shown.



An electron is moved from plate R to plate S.
Calculate the gain in kinetic energy of the electron.

A $8 \cdot 0 \times 10^{-20}$ J
B $1 \cdot 6 \times 10^{-19}$ J
C $3 \cdot 2 \times 10^{-19}$ J
D $6 \cdot 4 \times 10^{-19}$ J
E $1 \cdot 3 \times 10^{-19}$ J

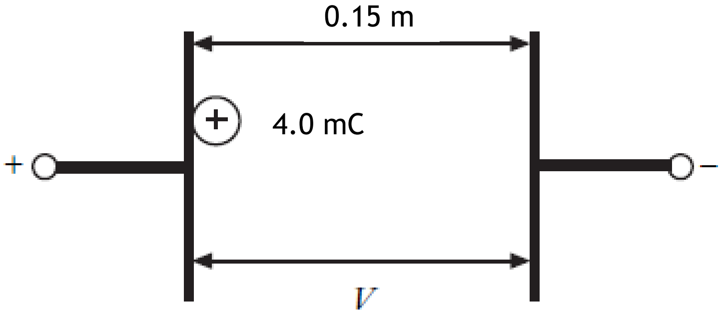
7. A student writes the following statements about electric fields.

I There is a force on a charge in an electric field.
II When an electric field is applied to a conductor, the free charges in the conductor move.
III Work is done when a charge is moved in an electric field.

Identify which statement(s) is/are correct.

A I only
B II only
C I and II only
D I and III only
E I, II and III

8. A potential difference, *V*, is applied between two metal plates.
The plates are 0.15 m apart. A charge of +4.0 mC is released from rest at the positively charged plate as shown.



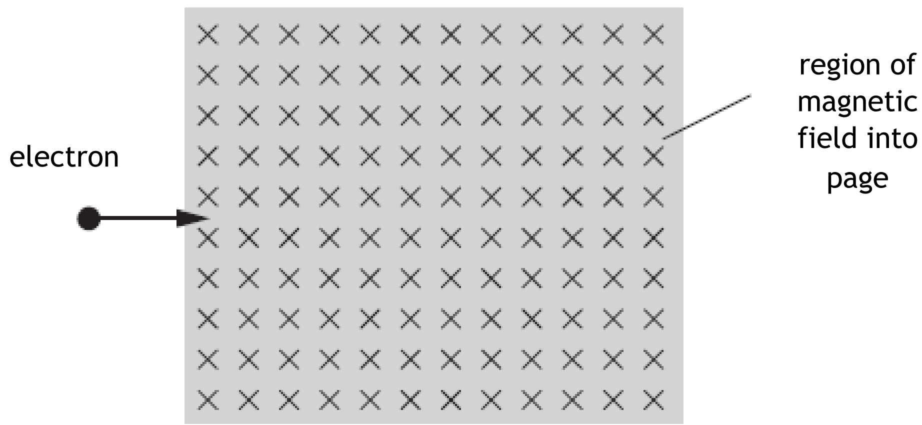
The kinetic energy of the charge just before it hits the negative plate is 8.0J.
Calculate the potential difference between the plates.

A $3{\cdot}2 \times 10^{-2}$ V
B 1·2 V
C 2·0 V
D $2{\cdot}0 \times 10^{3}$ V
E $4{\cdot}0 \times 10^{3}$ V

9. Identify the definition of the potential difference between two points.

A the work done in moving one electron between the two points
B the voltage between the two points when there is a current of one ampere
C the work done in moving one coulomb of charge between the two points
D the kinetic energy gained by an electron as it moves between the two points
E the work done in moving any charge between the two points.

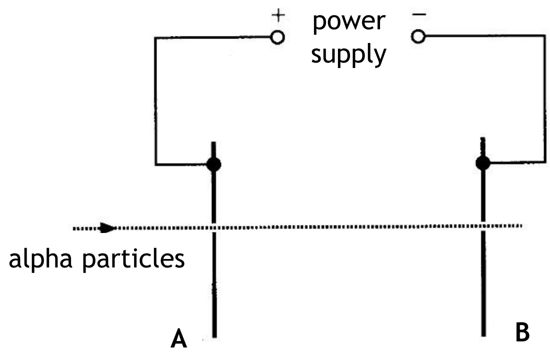
10. An electron enters a region of magnetic field as shown.



Identify the direction of the force exerted on the particle by the magnetic field as it enters the field.

A to the left
B into the page
C out of the page
D towards the top of the page
E towards the bottom of the page

11. The apparatus shown in the diagram is designed to accelerate alpha particles.



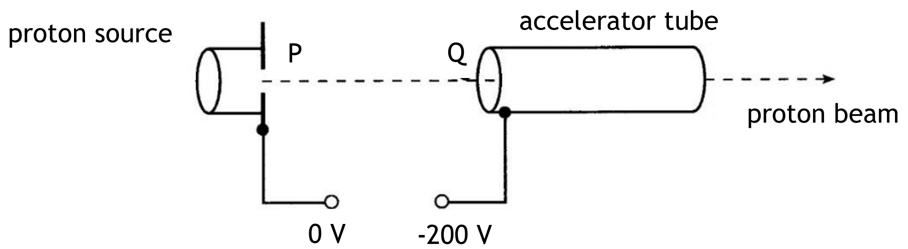
An alpha particle travelling at a speed of $2{\cdot}60 \times 10^{6}$ ms^{-1} passes through a hole in plate A. The mass of an alpha particle is $6{\cdot}64 \times 10^{-27}$ kg and its charge is $3{\cdot}20 \times 10^{-19}$ C.

(a) When the alpha particle reaches plate B, its kinetic energy has increased to $3{\cdot}05 \times 10^{-14}$ J. Show that the work done on the alpha particle as it moves from plate A to plate B is $8{\cdot}1 \times 10^{-15}$ J.

(b) Calculate the potential difference between plates A and B.

(c) The apparatus is now adapted to accelerate **electrons** from A to B through the same potential difference.
State how the increase in kinetic energy of an electron compares with the increase in kinetic energy of the alpha particle in part (a).
Justify your answer.

12. The diagram below shows the basic features of a proton accelerator. It is enclosed in an evacuated container.



Protons released from the proton source start from rest at **P**.A potential difference of 200 kV is maintained between **P** and **Q**.

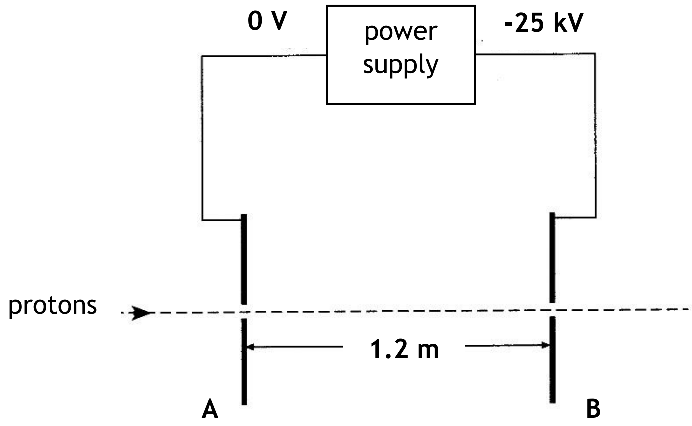
(a) What is meant by the term *potential difference of 200 kV*?

(b) Explain why protons released at **P** are accelerated towards **Q**.

(c) Calculate:
(i) the work done on a proton as it accelerates from **P** and **Q**;
(ii) the speed of a proton as it reaches **Q**.

(d) The distance between **P** and **Q** is now halved.
What effect, if any, does this change have on the speed of a proton as it reaches **Q**? Justify your answer.

13. A particle accelerator increases the speed of protons by accelerating them between a pair of metal plates, **A** and **B**, connected to a power supply as shown below.



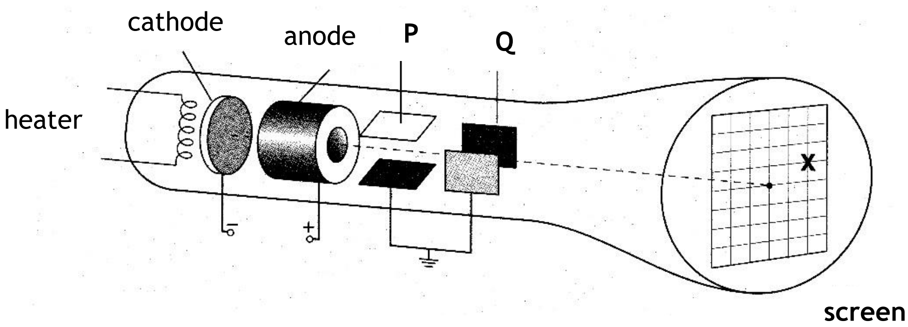
The potential difference between **A** and **B** is 25 kV.

(a) Show that the kinetic energy gained by a proton between plates A and B is $4{\cdot}0 \times 10^{-15}$ J

(b) The kinetic energy of a proton at plate **A** is $1{\cdot}3 \times 10^{-16}$ J.
Calculate the velocity of the proton on reaching plate **B**.

(c) The plates are separated by a distance of 1·2 m.
Calculate the force produced by the particle accelerator on a proton as it travels between plates **A** and **B**.

14. The diagram below shows a cathode ray tube used in an oscilloscope.



(a) The electrons which are emitted from the cathode start from rest and reach the anode with a speed of $4{\cdot}2 \times 10^{7}$ m s^{-1}.

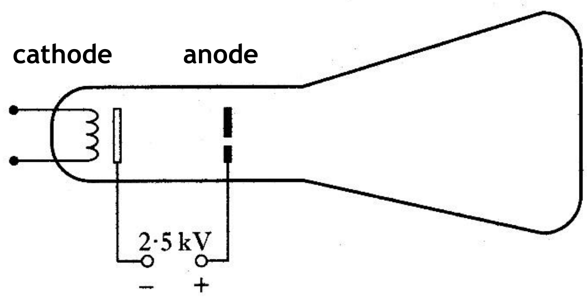
(i) Calculate the kinetic energy in joules of each electron just before it reaches the anode.

(ii) Calculate the p.d. between the anode and the cathode.

(b) Describe how the spot at the centre of the screen produced by the electron beam can be moved to position **X**.

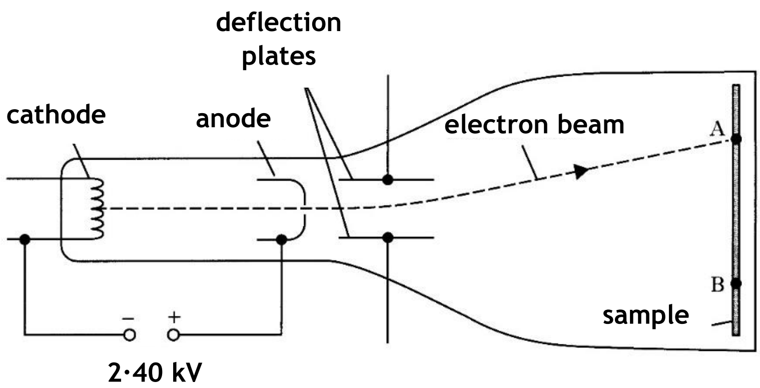
Your answer must make reference in the relative sizes and polarity (signs) of the voltages applied to plates P and Q.

15. The diagram shows an arrangement which is used to accelerate electrons.
The potential difference between the cathode and the anode is 2·5 kV.



Assuming that the electrons start from rest at the cathode, calculate the speed of an electron just as it reaches the anode.

16. Identification of elements in a semiconductor sample can be carried out using an electron scanner to release atoms from the surface of the sample for analysis. Electrons are accelerated from rest between a cathode and anode by a potential difference of 2·40 kV.
A variable voltage supply connected to the deflection plates enables the beam to scan the sample between points A and B shown in the figure below.

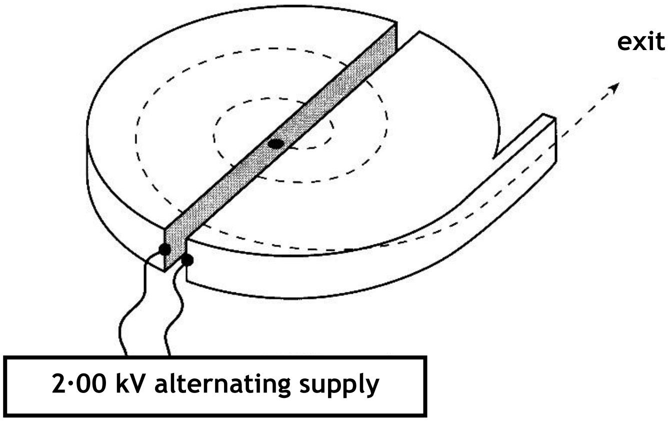


(a) Calculate the speed of the electrons as they pass through the anode.

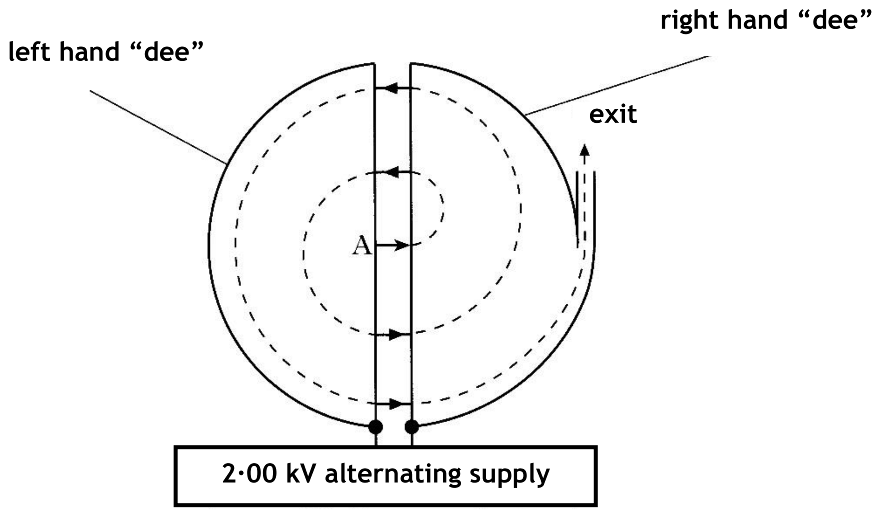
(b) Explain why the electron beam follows:
  (i) a curved path between the plates;
  (ii) a straight path beyond the plates.

(c) The anode voltage is now increased. State what happens to the length of the sample scanned by the electron beam. You must justify your answer.

17. A cyclotron is a particle accelerator which consists of two D-shaped hollow structures, called “dees”, placed in a vacuum.



The diagram below shows the cyclotron viewed from above.



(a) Protons are released from rest at point A and accelerated across the gap between the “dees” by a voltage of 2·00 kV.
Show that the speed of the protons as they **first** reach the right hand “dee” is $6{\cdot}19 \times 10^5$ ms^{-1}.

(b) Inside the “dees” the electric field strength is zero but there is a uniform magnetic field. This forces the protons to move in semi-circular paths when inside the “dees”.
State the direction of the magnetic field in the “dees”.

(c) While the protons are inside the “dee”, the polarity of the applied voltage is reversed so that the protons are again accelerated when they cross to the left hand “dee”.
Calculate the speed of the protons as they **first** enter the left hand “dee”.