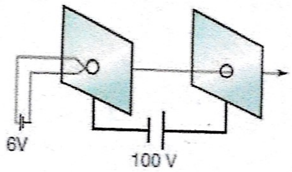
Energy in electric fields.

1. Electrons from a hot filament are emitted into the space between two parallel plates and are accelerated across the space between them.



(a) How much energy would be gained by an electron in crossing the space between the plates in Joules and electronvolts?

$W = qV = 1.6 \times 10^{-19} \times 100 = 1.6 \times 10^{-17} J = 100 eV$

(b) How would your answer to (a) change if the plate separation was halved?

Answer will not change as potential difference is the same

(c) How would your answer to (b) change if the terminals of the 100 V battery were reversed?

Electron will not leave the left plate.

(d) How would the size of the electric field between the plates, and thus the electric force on the electron, change if the plate separation was halved?

The electric field and force will double.

(e) Explain how your answers to (b) and (d) are connected.

The stronger force ~~at~~ acts over a shorter distance so gain in kinetic energy will be the same.

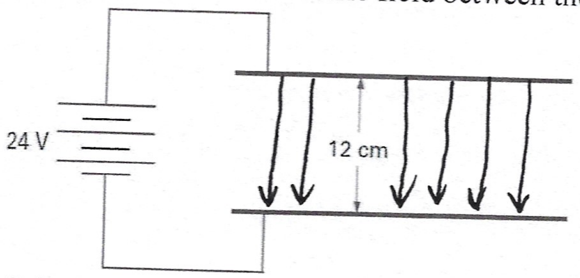
2. How much work is required to carry electron from the positive terminal of a 12V battery to the negative terminal?

$W = qV = 1.6 \times 10^{-19} \times 12 = 1.9 \times 10^{-18} J$

3. How much electrical potential energy does a proton lose as it falls through potential difference of 5 kV?

$E_{ep} = qV = 1.6 \times 10^{-19} \times 5 \times 10^{3} = 8 \times 10^{-16} J$

4. Two parallel plates are positioned 12 cm apart and connected to a 24 V DC power supply. This creates an electric field between the plates.



a Calculate the strength of the electric field between the plates.

$$E = \frac{V}{d} = \frac{24}{0.12} = 200\ Vm^{-1}$$

b Which of the following will happen to an electron placed at rest next to the positive plate?

A The electron will move towards the negative plate.
B The electron will move to a position equidistant from the positive and negative plates.
(C) The electron will remain where it is. It is attracted to positive plate
D The electron will drift out of the region of the plates.

c Which of the following will happen to a neutron placed at rest next to the negative plate?

A The neutron will move towards the positive plate.
B The neutron will move to a position equidistant from the positive and negative plates.
(C) The neutron will remain where it is. Neutron doesn't have charge so no force acting
D The neutron will drift out of the region of the plates.

d An electron is moved from next to the positive plate to next to the negative plate. Calculate the energy gained by the electron in electron volts.

$$E_{ep} = qV = 1 \times 24 = 24\ eV$$

e What is the size of the force exerted on the electron in **d**?

$$F = qE = 1.6 \times 10^{-19} \times 200 = 3.2 \times 10^{-17}\ N$$

f Draw the electric field pattern between the two plates in this diagram. see diagram

5. A charge of 114 μC is moved from point X to point Y and requires 2.8×10^{-5} J of work to be done on it.

a What is the electric potential difference between the two points?

$$V = \frac{W}{q} = \frac{2.8 \times 10^{-5}}{114 \times 10^{-6}} = 0.25\ V$$

b Which point is at a higher potential, X or Y? Justify your answer.

Y. As you have to push positive charge towards Y.

c What is the direction of the electric field? Justify your answer.

From Y to X. From highe potential to Lower. From "+" to "–"

6. Two parallel metal plates are separated by 20 mm and have a voltage of 120 V between them.

a What is the size of the electric field between the plates?

$$E = \frac{V}{d} = \frac{120}{0.02} = 6 \times 10^3 \ V m^{-1}$$

b How much work is done (in joules) to move an electron from the positive plate to the negative plate?

$$W = qV = 1.6 \times 10^{-19} \times 120 = 1.9 \times 10^{-17} J$$

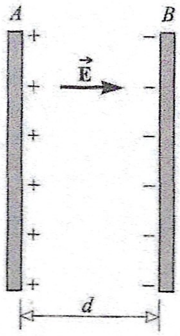
c How much potential energy would the electron in **b** gain?

$$1.9 \times 10^{-17} J$$

d If the electron is released at the negative plate, what speed will it have when it reaches the positive plate?

$$\frac{mv^2}{2} = 1.9 \times 10^{-17} \quad v = \sqrt{\frac{2 \times 1.9 \times 10^{-17}}{9.1 \times 10^{-31}}} = 6.5 \times 10^6 \ m s^{-1}$$

7. In the figure below let E = 2.0 kV/m and d = 5.0 mm.



A proton with the mass $m = 1.67 \times 10^{-27}\ kg$ is shot from plate B towards plate A with initial speed of 100 km/s. What will be its speed just before it strikes plate A?

$V = Ed = 2000 \times 0.005 = 10V$

$\frac{mv_B^2}{2} = \frac{mv_A^2}{2} + qV$

$\frac{mv_A^2}{2} = \frac{mv_B^2}{2} - qV$

$v_A = \sqrt{(100000)^2 - \frac{2 \times 1.6 \times 10^{-19} \times 10}{1.67 \times 10^{-27}}}$

$= 90000\ m\ s^{-1}$

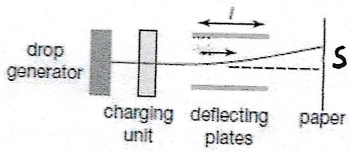
8. Two parallel metal plates separated by 2.4 cm have a potential difference of 100 V between them. An electron with speed $4 \times 10^6\ m/s$ passes perpendicular through a hole in the positive plate. How far from the positive plate will it travel?

$\frac{mv^2}{2} = qV$ V - is the voltage where electron stops

$V = Ex \quad E = \frac{V_0}{d} \quad \frac{mv^2}{2} = \frac{qV_0}{d}x \quad x = \frac{mv^2 d}{2qV_0}$

$x = \frac{9.1 \times 10^{-31} \times (4 \times 10^6)^2 \times 0.024}{2 \times 1.6 \times 10^{-19} \times 100} = 0.011 m$

9. In an inkjet printer, small drops of ink are given a controlled charge and fired between two charged plates. The electric field deflects each drop and thus controls where the drop lands on the page. Let m = the mass of the drop, q = the charge of the drop, v = the speed of the drop, l = the horizontal length of the plate crossed by the drop, and E = electric field strength.



(a) Develop an expression for the deflection of the drop. Ignore the gravity.

$F = qE \quad a = \frac{F}{m} \quad s = \frac{at^2}{2}$

$t = \frac{l}{v}$

$s = \frac{\frac{qE}{m} \times \left(\frac{l}{v}\right)^2}{2} = \frac{qEl^2}{2mv^2}$

(b) With the values $m = 1.0 \times 10^{-10}$ kg, $v = 20$ m/ s, $l = 1.0$ cm and $E = 1.2 \times 10^6\ N/C$, calculate the charge required on the drop to produce a deflection of 1.2 mm.

$0.012 = \frac{q \times 1.2 \times 10^6 \times (0.01)^2}{2 \times 10^{-10} \times 20^2}$

$q = 8 \times 10^{-13} C$