How Do Things Move Without Contact?

Reference: Heinemann Physics 12 4th Edition Chapters 1 – 3 Pages 1 – 106

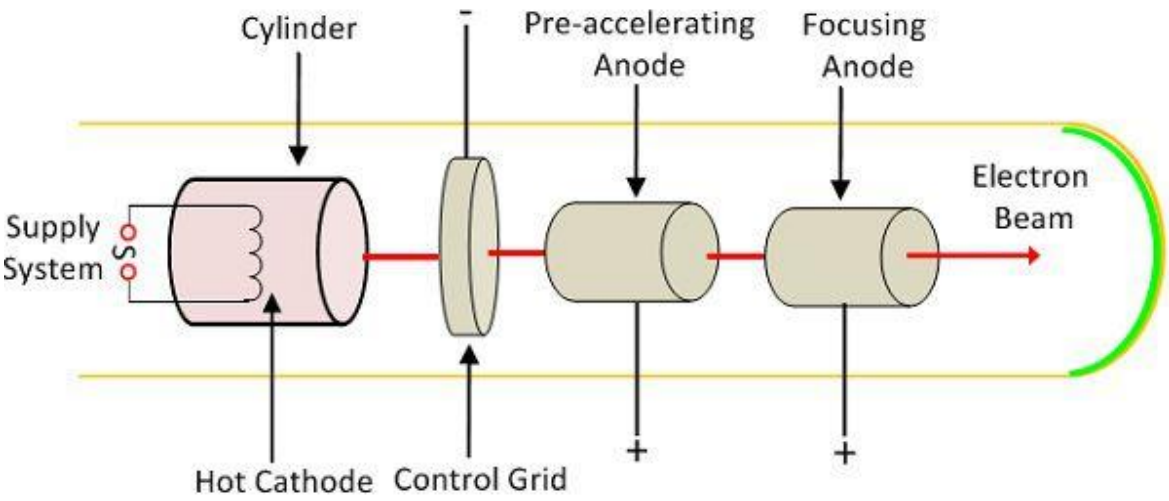
Physics with Synno – Move Without Contact – Lesson 10

M.1 Particle Accelerators

Video: CERN Atom Smasher - How it works
Brian Cox - What went wrong at the Large Hadron Collider

Particle accelerators use electric fields to speed up and increase the energy of a beam of particles, which are steered and focused by magnetic fields. The particle source provides the particles, such as protons or electrons, which are to be accelerated. The beam of particles travels inside a vacuum in the metal beam pipe. The vacuum is crucial to maintaining an air and dust free environment for the beam of particles to travel unobstructed. Electromagnets steer and focus the beam of particles while it travels through the vacuum tube.

One of the simpler particle accelerators is the electron gun. These were once common in TV's, the picture tube.



The following equations (done in 2 – Electric Field) apply.

$$E = \frac{F}{Q} \qquad E = \frac{V}{d}$$

Combining yields $F = \frac{q\,V}{d}$

In accelerating a particle work is done on the particle and its kinetic energy increases.

Combining $W = q\,V$ and $E_k = \frac{1}{2}\,m\,v^2$

We get $E_k = \frac{1}{2}\,m\,v^2 = q\,V$

Example

Determine the final speed of a single electron, with charge of magnitude 1.6×10^{-19} C and a mass of 9.1×10^{-31} kg, when accelerated across a potentials difference of 1.5 kV.

$$\frac{1}{2} m v^2 = q V$$

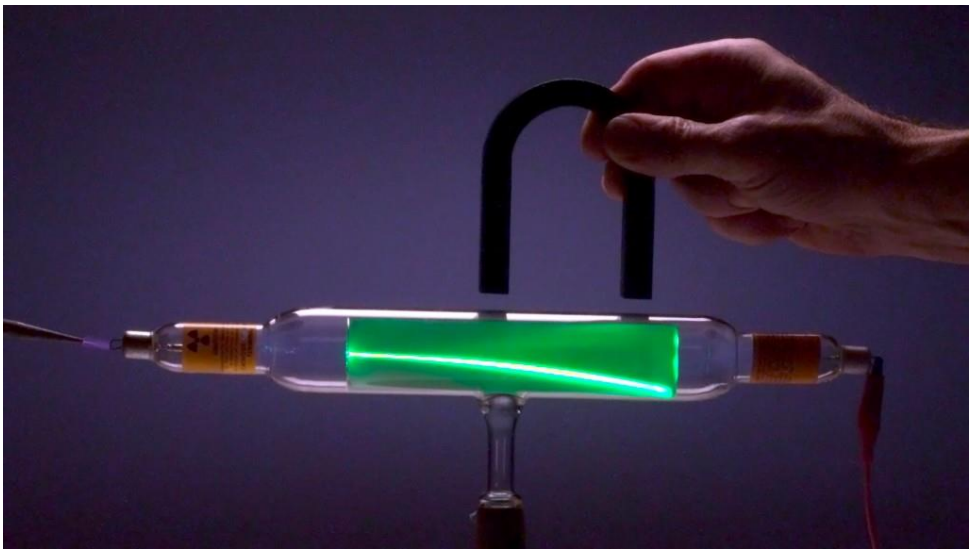
$$\frac{1}{2} 9.1 \times 10^{-31} v^2 = 1.6 \times 10^{-19} \times 1.5 \times 10^3$$

$$2.29 \times 10^7 m/s$$

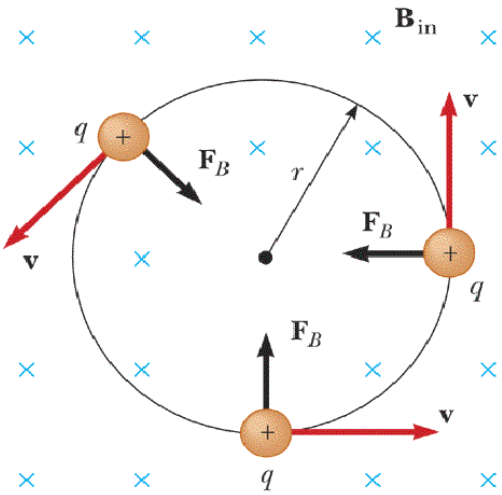
M.2 Effect of Magnetic field on a Charge

We learned back in 3 – Magnetic Fields, pages 10 & 11, that a charged particle moving in a magnetic field will be acted upon by a force.

$$F = q v B$$



The force acts perpendicular to the direction of travel, thus causing the particle to change direction. In fact the particle will move in a circle.



The radius of the path of the particle is given by

$$r = \frac{m\,v}{q\,B}$$

Example

An electron gun releases electrons from its cathode which are then accelerated across a potential difference of 32 kV, over a distance of 30 cm between a pair of charged parallel plates. Assume that the mass of an electron is 9.1×10^{-31} kg and the magnitude of the charge on an electron is 1.6×10^{-19} C.

a. Calculate the strength of the electric field acting on the electron beam.

$$E = \frac{V}{d} = \frac{32\times10^{3}}{0.30} = 1.07 \times 10^{5}\ V/m$$

b. Calculate the speed of the electrons as they exit the electron gun assembly.

$$\frac{1}{2}\,m\,v^{2} = q\,V$$

$$\frac{1}{2}\,9.1 \times 10^{-31}\,v^{2} = 1.6 \times 10^{-19}\ \times\ 32 \times 10^{3}$$

$$v = 1.06\ \times 10^{8}\ m/s$$

c. The electrons then travel through a uniform magnetic field perpendicular to their motion. Given that this field is of strength 0.2 T, calculate the expected radius of the path of the electron beam.

$$r = \frac{m\,v}{q\,B}$$

$$r = \frac{9.1\times10^{-31} \times 1.06\times10^{8}}{1.6\times10^{-19} \times 0.2}$$

$$r = 3.01 \times 10^{-3} m = 3.01\ mm$$

Text Questions: Page 100 All questions