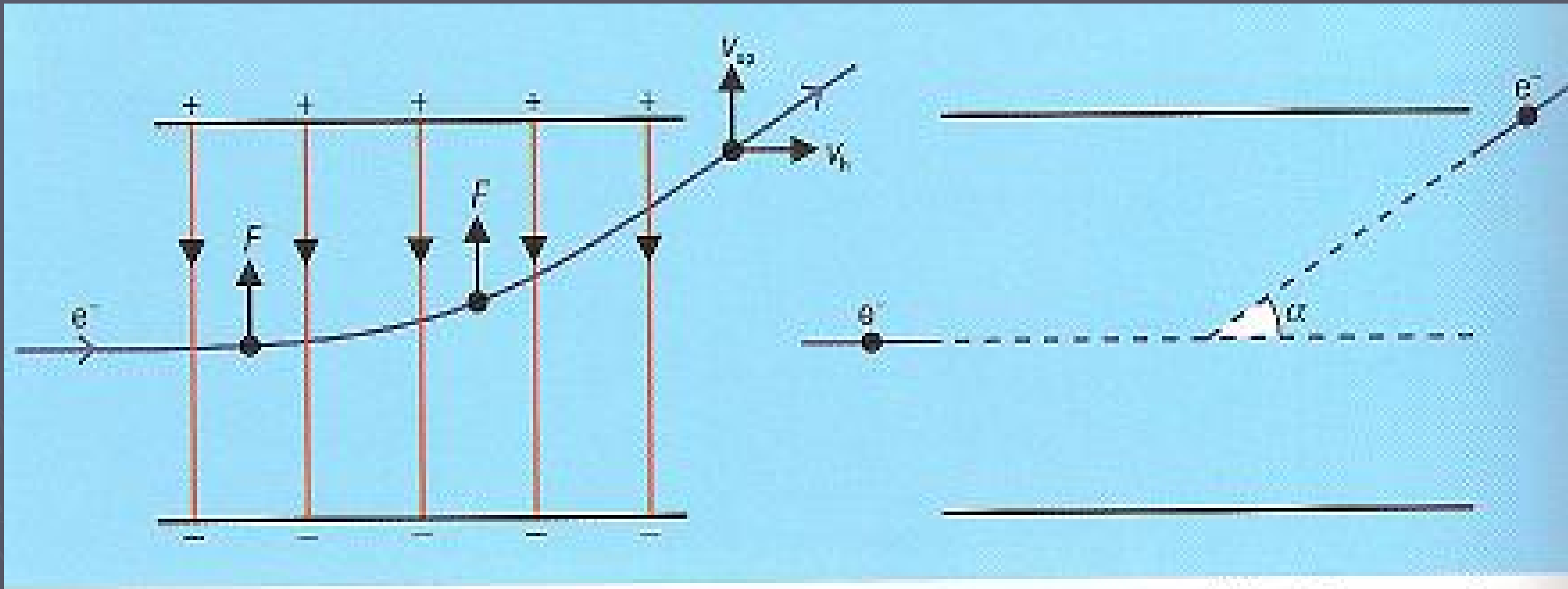
Deflecting electron beams

- An electron beam is passing through a uniform electric field at 90°(generated by parallel, charged plates).
- The direction of the force acting on the electron is constant and towards the positive plate.
- The electron´s path curves upwards the positive plate and continues along a tangent line to the curve as it leaves the region of the electric field.
- The shape of the curved path followed is parabolic.
- The acceleration produced by the electric force gives a vertical velocity (v_{up}) by the time it reaches the end of the field.
- The horizontal velocity (v_h) remains constant.
- The electron emerges from the field along a straight line at an angle α to the original path given by

$$\tan \alpha = v_{up} / v_h$$



As an electron beam moves between two plates, the direction of the force acting does not change.

• $F = e\,V/d$ where V - is p.d. between the plates

d – separation between the plates

$e = 1.6 \times 10^{-19}$C

• The electrons vertical acceleration is

$a = eV/md$ ($F = ma$)

where m is the mass of the electron (9.1×10^{-31}kg)

• X - horizontal distance travelled by electron in a time $t = x/v_h$.

• Y – vertical distance travelled by electron in the same time

$y = \frac{1}{2} a t^2 = \frac{1}{2} (eV/md) (x/v_h)^2 = (eV/2mdv_h^2)\, x^2$

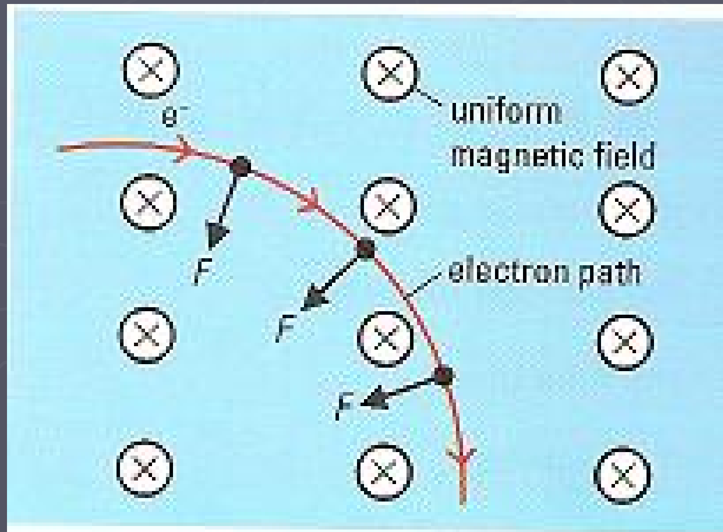
• The items in the brackets are constant, so the vertical distance y is proportional to the horizontal distance x^2. Hence the path is parabolic.

Deflecting electrons in magnetiic fields

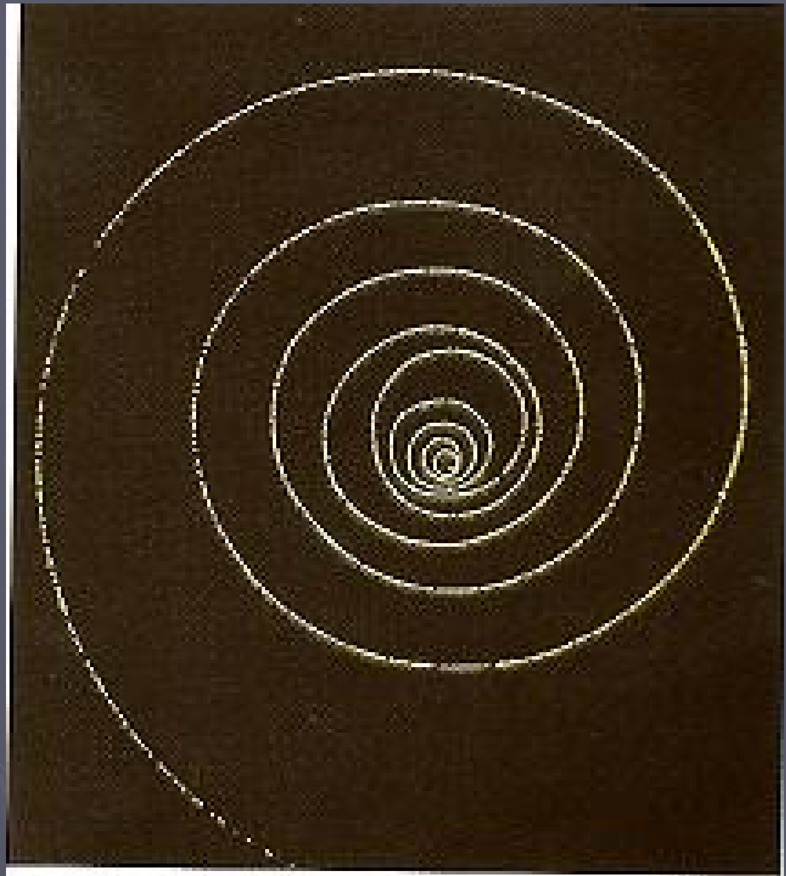
- Force is always at 90° to the field lines, the electron will move along a path that is an arc of a circle.
- Momentum of the electron: $p = m v$
- The radius of curvature of the arc:

$$r = mv/Be = p/Be$$

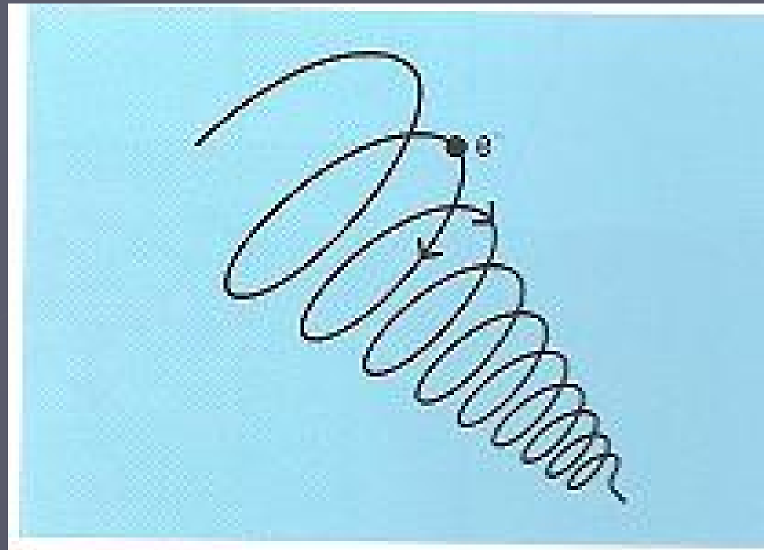
Because centripetal force is $mv^2/r = Bev$



The direction of the magnetic force acting on a moving electron changes as the electron's direction of motion changes.



As a charged particle loses energy in a bubble chamber the curvature of its path tightens, producing a spiral.



In three dimensions, the spiral is actually helical, because the particle's motion is not exactly at 90° to the magnetic field direction.

1 A beam of electrons moving at $2 \times 10^7 \text{ m s}^{-1}$ is directed between a pair of parallel plates. The plates are 10 cm long and separated by 5 cm, and the p.d. between them is 100 V. The electrons enter the region of the plates at 90° to the field. Calculate the vertical velocity of the electrons as they leave the plates. What is the total velocity of the electrons after leaving the plates? The electrons continue at constant speed until they strike a screen 30 cm from the centre of the plates. If the electrical field is turned off, the electrons hit the middle of the screen. With the field turned on, how far from the centre of the screen do the electrons now strike?

2 In which direction will the magnetic field be acting in the photograph above of a particle losing energy in a bubble chamber if the particle is negative?

3 An electron starts from rest and is accelerated through a p.d. of 200 V. What is the electron's kinetic energy at the end of the acceleration? At what speed will it be moving after the acceleration? The electron now enters a region in which the magnetic field strength is 0.2 T and at 90° to the electron's path. What is the force on the electron? What is the radius of curvature of the path followed? How long would the electron have to remain in the magnetic field for it to end up travelling at 90° to its initial direction?