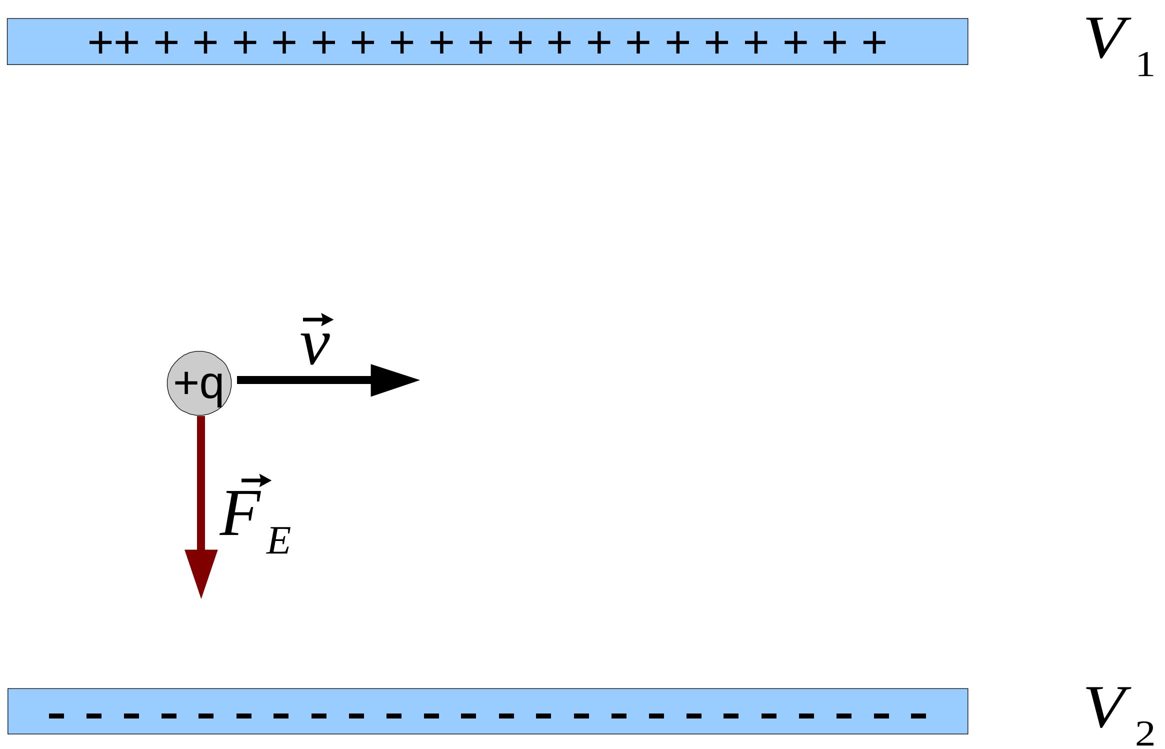
Charged Particle in a Uniform Electric Field

A charged particle in an electric feels a force that is independent of its velocity. Below the field is perpendicular to the velocity and it bends the path of the particle; i.e. changes both direction and magnitude of v.

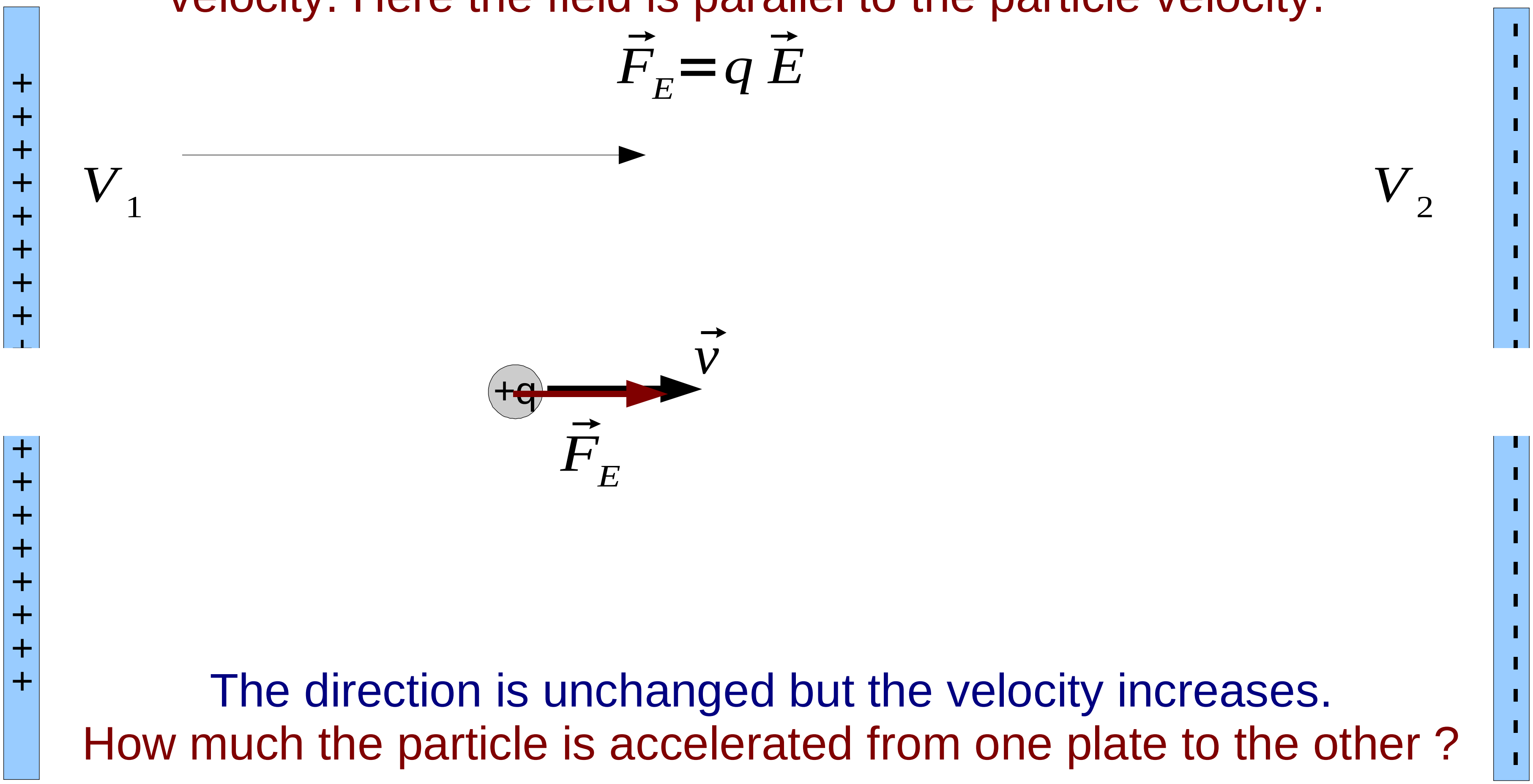
$$\vec{F}_E = q\,\vec{E}$$



Charged Particle in a Uniform Electric Field

A charged particle in an electric feels a force that is independent of its velocity. Here the field is parallel to the particle velocity.

$$\vec{F}_E = q\,\vec{E}$$



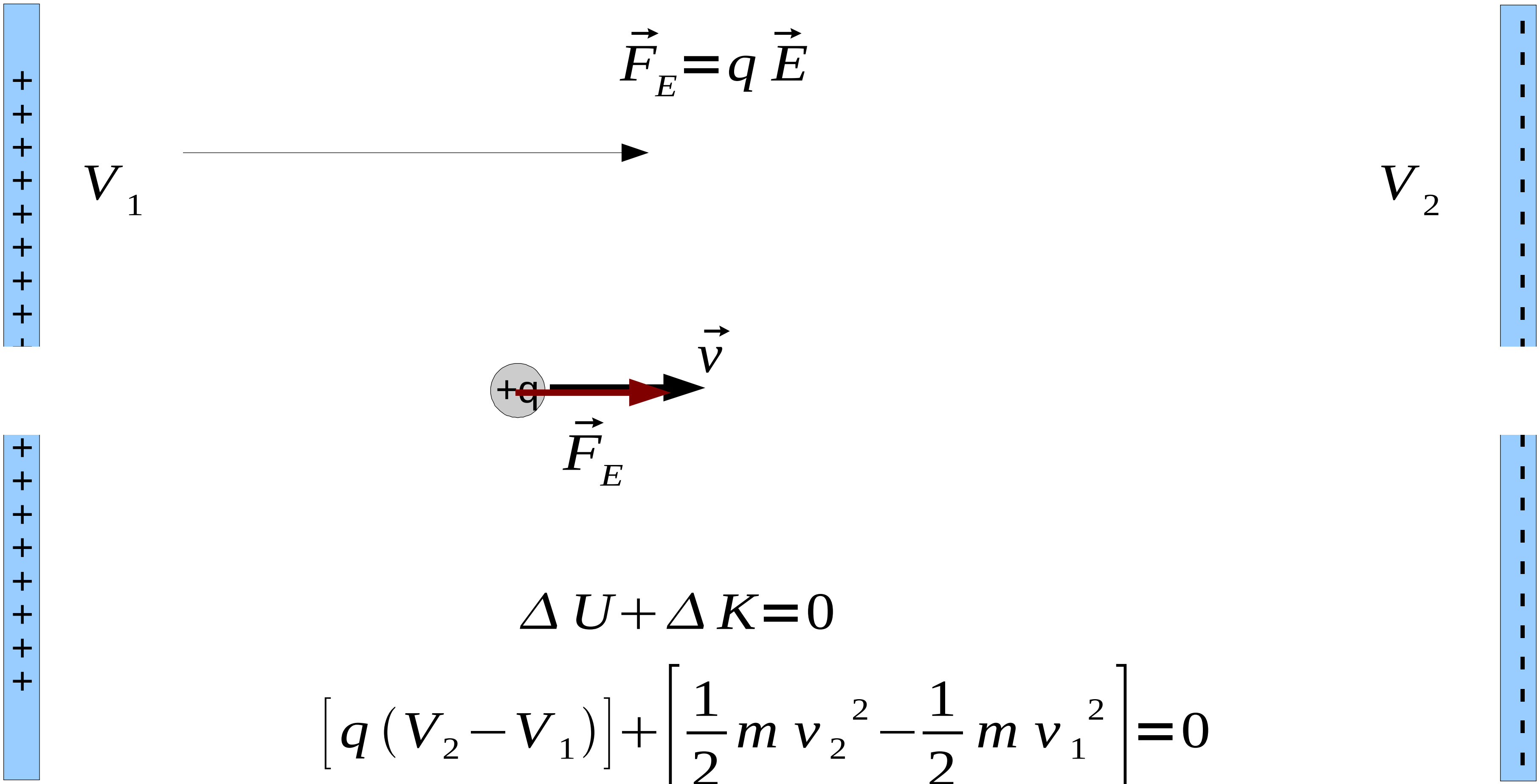
The direction is unchanged but the velocity increases.

How much the particle is accelerated from one plate to the other ?

Charged Particle in a Uniform Electric Field

conservation of total energy

$$\vec{F}_E = q\,\vec{E}$$



$$\Delta U + \Delta K = 0$$

$$\left[q\,(V_2 - V_1)\right] + \left[\frac{1}{2} m\, v_2^{\,2} - \frac{1}{2} m\, v_1^{\,2}\right] = 0$$

Charged Particle in a Uniform Magnetic Field

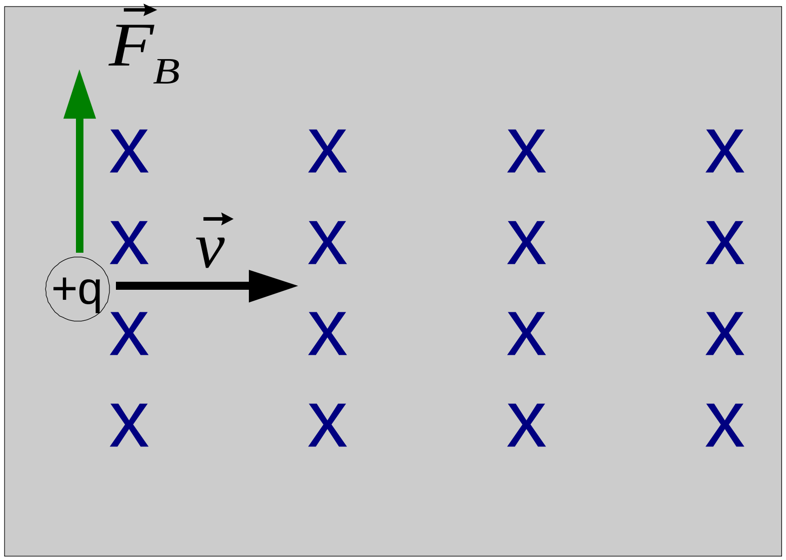
When a charged particle enters a region where there is a magnetic field that points perpendicular to the velocity vector of the charged particle,

the magnetic force is perpendicular to the velocity vector,

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

$$q\,v\,B = \frac{m\,v^2}{r}$$

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

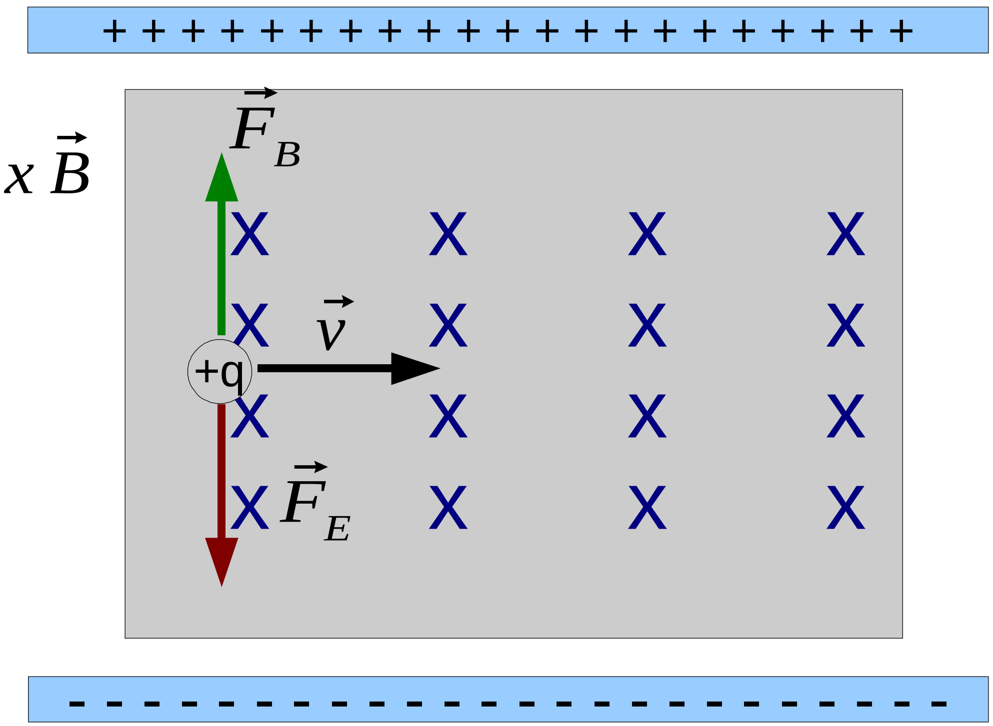


Charged Particle in Perpendicular Electric and Magnetic Fields

When a charged particle enters a region where there is a magnetic field that points perpendicular to the velocity vector of the charged particle,

the magnetic force is perpendicular to the velocity vector,

$$\vec{F}_{total} = q\vec{E} + q\vec{v} \times \vec{B}$$



Example 22.3: Bending an electron beam

This experiment is designed to measure the strength of a uniform magnetic field.

- Electrons are accelerated from rest (by means of an electric field) through a potential difference of 350 V

$$\Delta U = q\Delta V = -e\Delta V = -(1.6\times10^{-19})(350\text{V}) = -5.6\times10^{-17}\,J$$

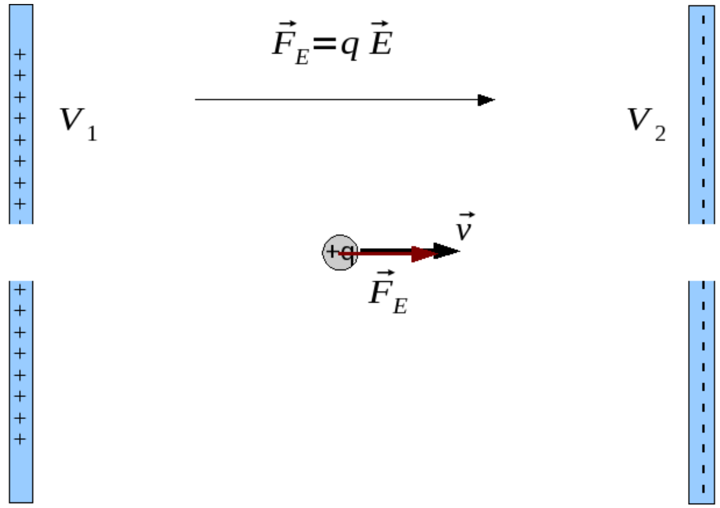
If the particle gains kinetic energy, then the change in potential energy must be negative. So the change in kinetic energy is:

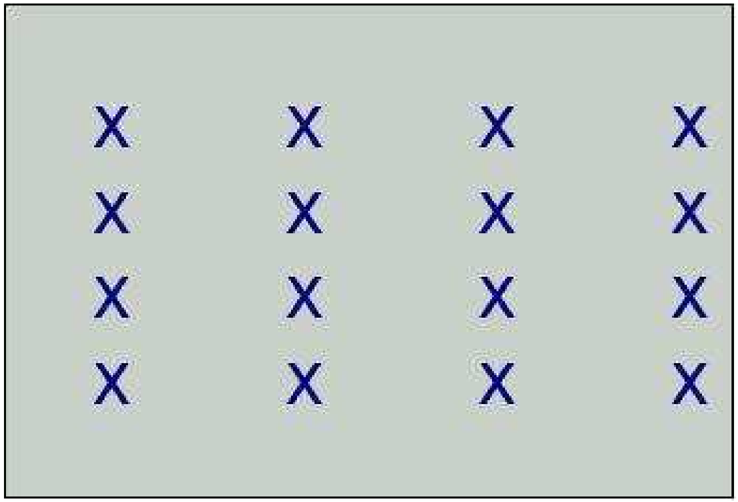
$$\Delta K = \left(\frac{1}{2}m v_2^{\;2} - \frac{1}{2}m v_1^{\;2}\right) = -\Delta U = +5.6\times10^{-17}\,J$$

Example 22.3: Bending an electron beam

Electrons are accelerated from rest (by means of an electric field) through a potential difference of 350 V

Next the electrons enter a magnetic field and travel along a curved path because of the magnetic force exerted on them. The radius of the path is measured to be 7.5 cm.





Example 22.3: Bending an electron beam

This experiment is designed to measure the strength of a uniform magnetic field.

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If the particle gains kinetic energy, then the change in potential energy must be negative. So the change in kinetic energy is:

$$\Delta K = \left(\frac{1}{2}m v_2{}^2 - \frac{1}{2}m v_1{}^2\right) = -\Delta U = +5.6\times 10^{-17}\ J$$

Since electron starts are rest $v_1 = 0$.

$$\frac{1}{2}m v_2{}^2 = 5.6\times 10^{-17}\ J \quad \text{or} \quad v_2 = \sqrt{\frac{2}{m_e}5.6\times 10^{-17}} = 1.1\times 10^{7}\ m/s$$

Example 22.3: Bending an electron beam

This experiment is designed to measure the strength of a uniform magnetic field.

- Electrons are accelerated from rest (by means of an electric field) through a potential difference of 350 V

$$v_2 = 1.1 \times 10^7 \, m/s$$

- Next the electrons enter a magnetic field and travel along a curved path because of the magnetic force exerted on them. The radius of the path is measured to be 7.5 cm.

$$r = \frac{mv}{|q|B}$$

$$B = \frac{m_e v_2}{er} = \frac{(9.11 \times 10^{-31})(1.1 \times 10^7)}{(1.6 \times 10^{-19})(0.075)}$$
$$= 8.4 \times 10^{-4} \, T$$

Applications

The control of the trajectory of charged particles using electric and magnetic fields is very important in science and technology.

- Mass Spectrometer: is used to determine the chemical compositon of an unknown material. It is also used in helping to determine the chemical structure of a molecule.

- Cyclotrons and particle accelerators: Particle accelerators are used to determine the structure of sub-atomic particles. Cyclotrons are older particle accelerators that are used to create ion beams that can be used in cancer treatment and in a relatively new kind of diagnostic imaging technique called a positron-emission tomography (or PET) scan.

Applications: Velocity Selector

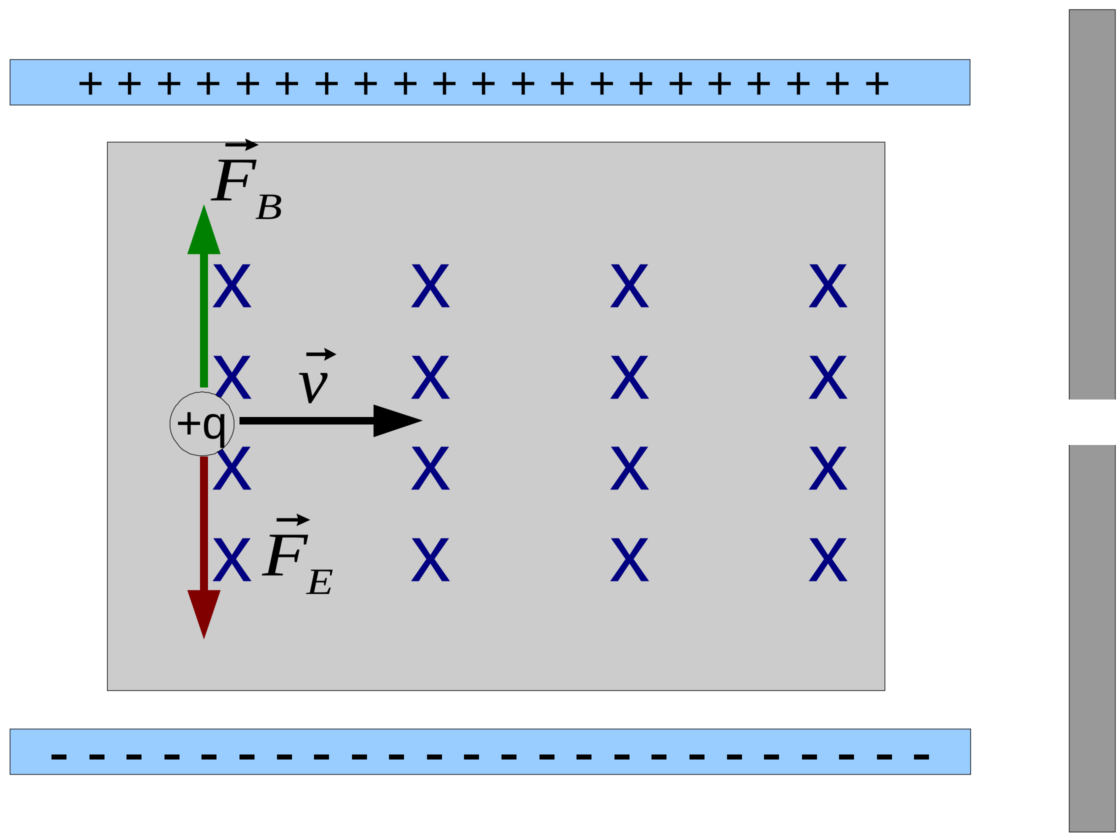
In many of these applications it is valuable to have charged particles of the same velocity. Adjust the fields such that:

$$\vec{F}_{total} = q\vec{E} + q\vec{v} \times \vec{B} = 0$$

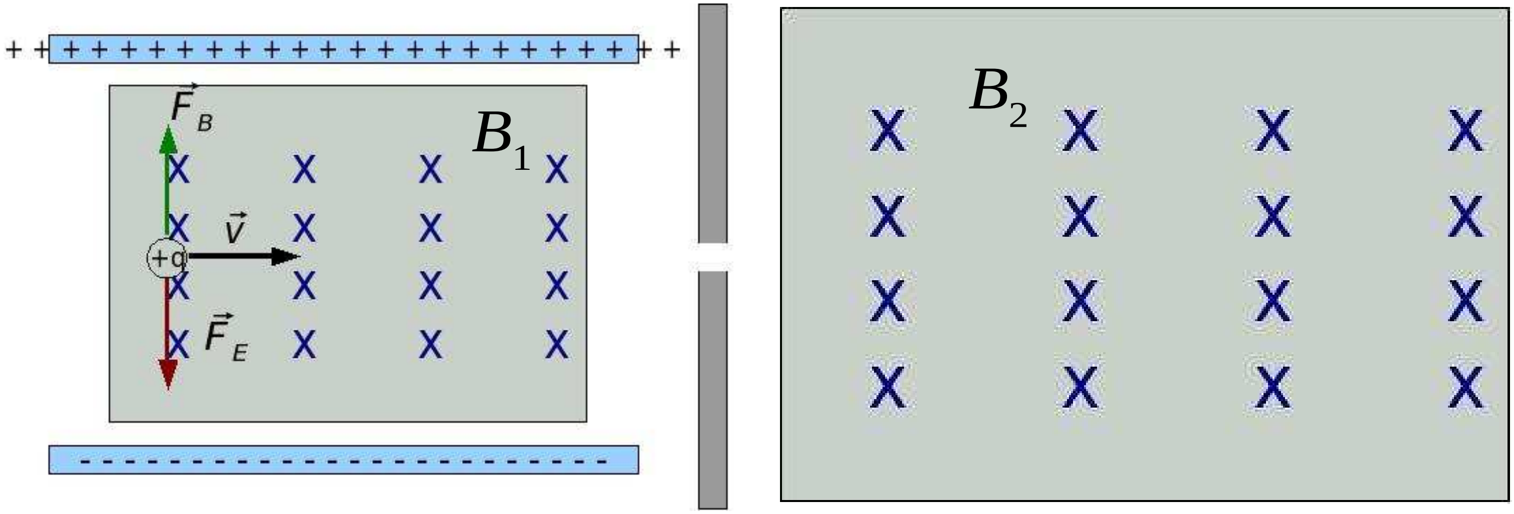
$$|\vec{E}| = |\vec{v}||\vec{B}|$$

$$v = \frac{E}{B}$$

Faster particles: upwards
Slower particles: downwards



Applications: Mass Spectrometer



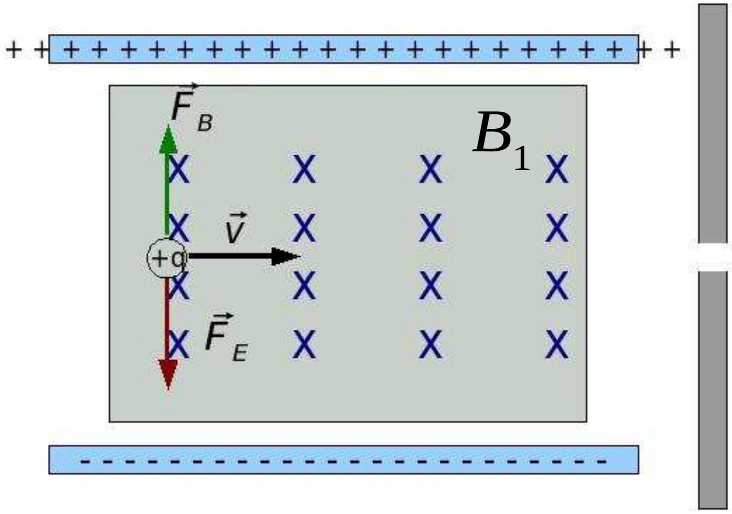
Velocity Selector

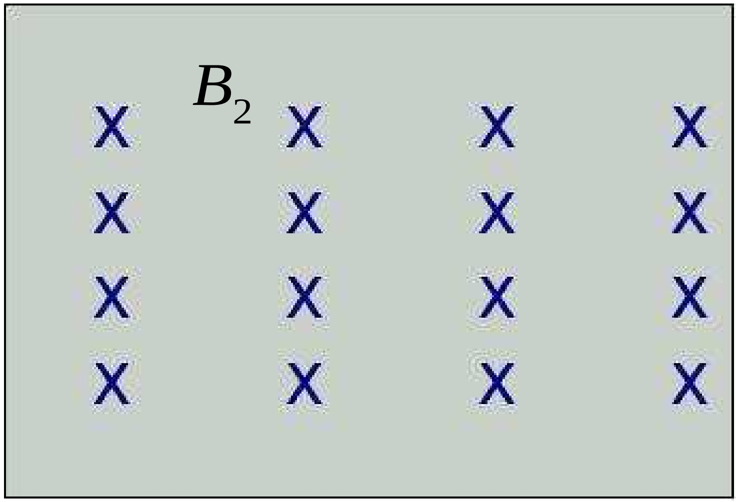
$$v = \frac{E}{B_1}$$

Particle will move in a semi-circular path with radius

$$r = \frac{m\,v}{|q|\,B_2} = \frac{m\,E}{|q|\,B_1\,B_2}$$

Applications: Mass Spectrometer





Velocity Selector

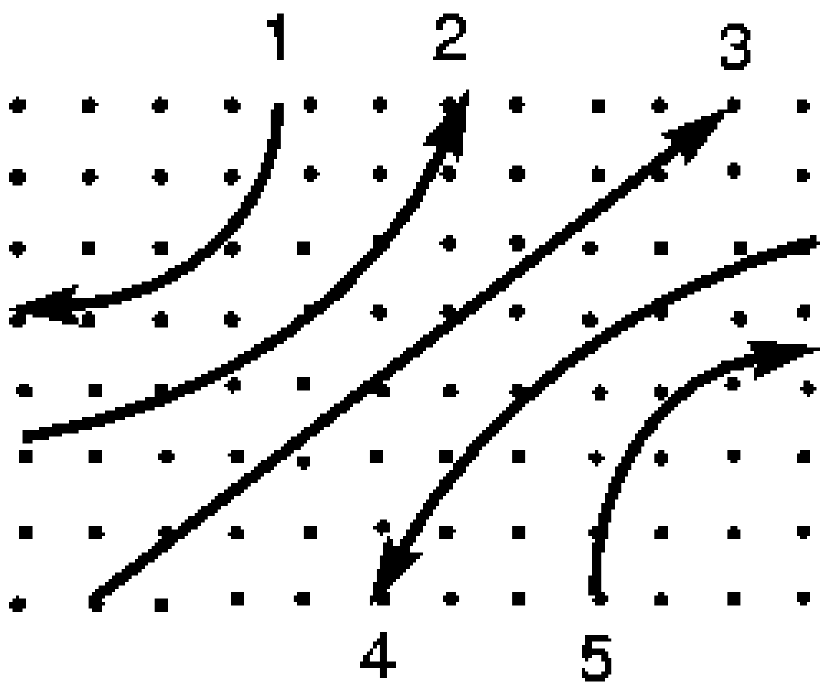
$$v = \frac{E}{B_1}$$

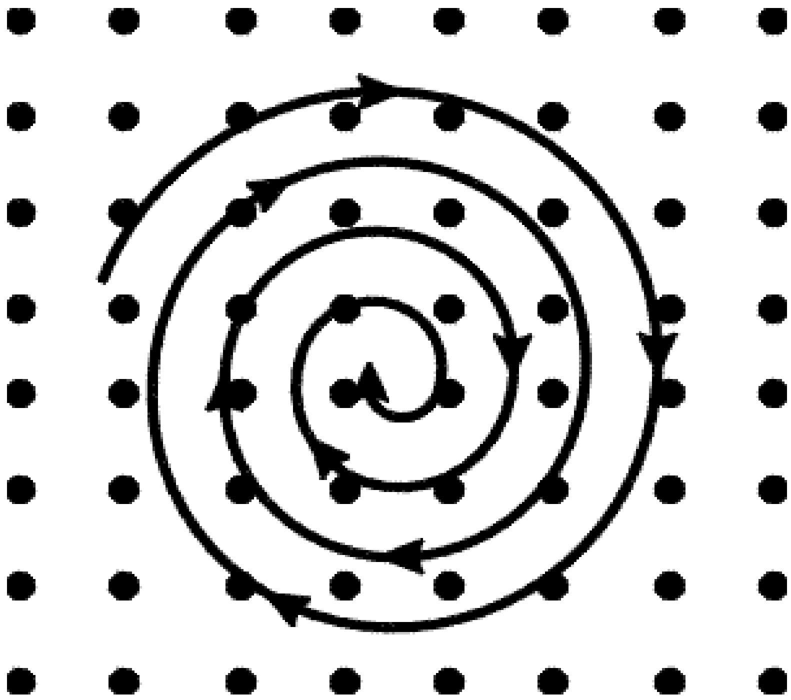
Particle will move in a semi-circular path with radius

$$r = \frac{m\,v}{|q|\,B_2} = \frac{m\,E}{|q|\,B_1\,B_2}$$

Measure the radius: $$\frac{m}{|q|} = \frac{rB_1\,B_2}{E}$$ and obtain the mass-charge ratio of the charged particle.

Start CAPA 6





The first 9 problems are relevant for the mid-term.

Review CAPA 5 and Workshop 4

Workshop 4 is very relevant. If you wish to get a start on Workshop 4 and the workshop 4 notes you can download it on D2L.

Test 2

Coverage

Chapter 19 all
Chapter 20 until and including 20.6
Chapter 21 (21.1 and 21.2 concepts: do not memorize formulas)
Chapter 22. upto and including 22.4

Cover Page and Formula Sheet up on D2L in Test module.