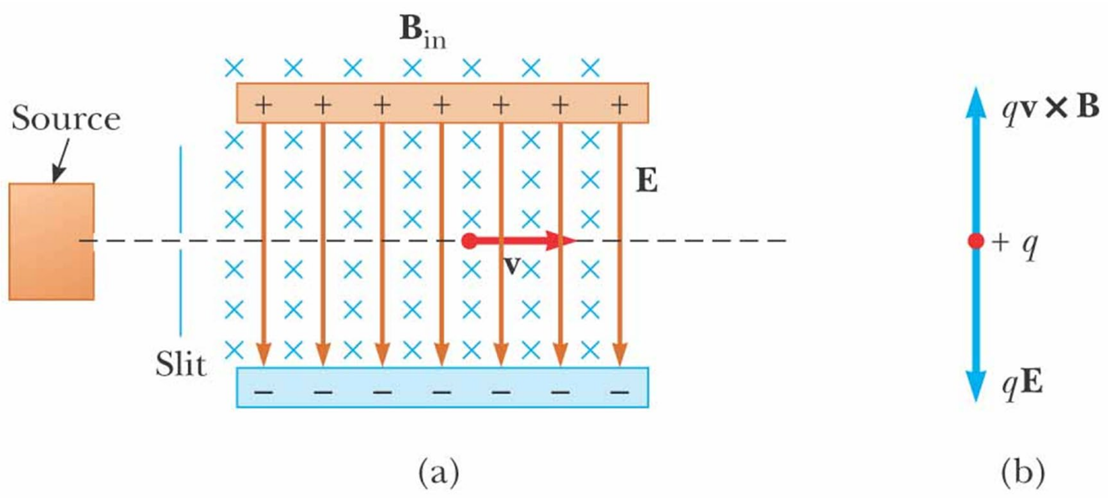
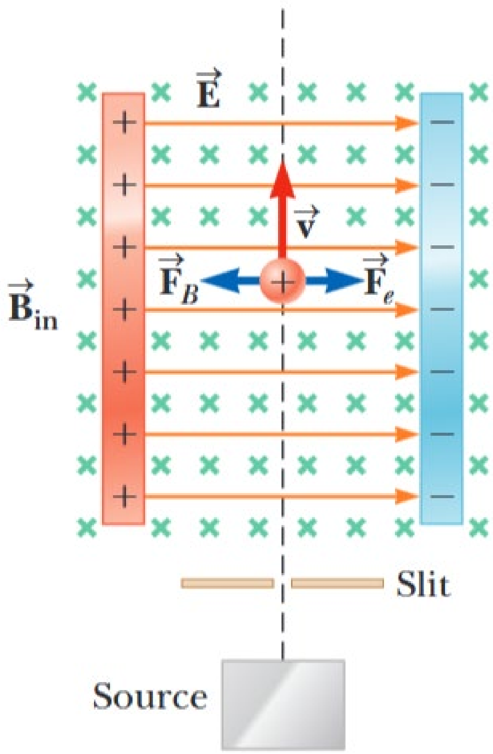
28.3 Applications involving a charged particle moving in a magnetic field:

In the following figure, a charged particle experiences both electric and magnetic forces due to the presence of an electric field and a magnetic field. **Then, the total force acting on the particle is written as,**

$$\vec{F} = q\left(\vec{E} + \vec{v} x \vec{B}\right) \qquad 28.4$$

This force is called the "**Lorentz force**".





Velocity Selector:

If the charge **q** is positive and the velocity **v** is upward, the magnetic force is to the left and the electric force is to the right. When the particle is in equilibrium ($F_B=F_E$ and moves in a straight vertical line), the magnitude of the two fields is chosen so that,

$$qE=qvB$$

then,
$$v=\frac{E}{B} \qquad 28.5$$

Only those particles having speed **v** *pass undeflected through the mutually perpendicular* electric and magnetic fields. The magnetic force exerted on particles moving at speeds greater than this is stronger than the electric force, and the particles are deflected upward. Those moving at speeds less than this are deflected downward.

Particle Speed	Dominant Force	Net Deflection	Path Shape
($v = E/B$)	Balanced	None (straight)	Straight line
($v < E/B$)	Electric force	Toward the direction of (E)	Curved (not circular)
($v > E/B$)	Magnetic force	Opposite (E)	Curved (not circular)
($v = 0$)	Electric only	Accelerated along (E)	Straight, then curved (no circular motion)

Examples:

Example-1 An electron moves parallel to a magnetic field, B = 4 mT, with a speed 5×10^4 m/s; accordingly, what is the electron acceleration?

Solution:

When the velocity is parallel to the magnetic field, the angle $\theta = 0°$.
Magnetic force: $F = qvB\sin\theta = 0$.
Therefore, acceleration $a = F/m = 0$.

Answer: $a = 0$ m/s² (no magnetic deflection).

Example 2: What is the condition for a charged particle to pass undeflected through a velocity selector?

Solution:

In a velocity selector, the electric and magnetic forces are equal and opposite in direction.
So, $qE = qvB \Rightarrow v = E / B$.

Hence, the particle passes undeflected if $v = E/B$ and the fields are perpendicular.

Example-3 A velocity selector uses an electric field of 3.0×10^4 V/m and a magnetic field of 0.20 T. What speed of particles will pass through the selector without deflection?

Solution:

From the condition $qE = qvB \Rightarrow v = E / B$.

$v = (3.0\times10^4) / (0.20) = 1.5\times10^5$ m/s.

Answer: $v = 1.5\times10^5$ m/s.

Example 4: If in a velocity selector, the magnetic field is doubled while keeping the electric field constant, what happens to the velocity of selected particles?

Solution:

Since $v_1 = E/B$ and $v_2 = E/2B$, doubling the magnetic field halves the selected velocity.

Answer: The selected speed is halved.

Example 5: A positively charged particle enters a region containing **both** a uniform magnetic field **(B)** directed **into the page** and a **uniform electric field** (**E**) directed **to the right**. The particle's initial velocity (v) is **upward**.

Which of the following statements about the particle's path is **true**?

A) The particle always moves in a circular path due to the magnetic field.
B) The particle moves in a circular path only if ($v=E/B$).
C) The particle moves in a circular path only when the electric field is turned **off**.
D) The particle moves in a circular path for ($v > E/B$) and in a straight line for ($v<E/B$).