Note-A-Rific: Charges

We know that a charge moving through a wire (current) experiences a force if the wire is placed in a magnetic field.

- Is there any reason why a single charge moving freely (no wire) should not experience the same force?
- The answer is no, there is nothing special about a charge moving in a wire.
  - A charge moving through a magnetic field will experience a force, and we only need to modify what we already know about current carrying wires to handle problems involving single charges.

If ***n*** particles with charge ***q*** pass by a given point in time ***t***, they are part of an electrical current, ***I***.

$$I = nq/t$$

- Note that this is just a modification of the formula I = q/t.
- We've added the "n" since a wire would usually be carrying many charges.
- We're going to take our formula for many charges moving in a wire in a magnetic field ($F_m = I\, l\, B$) and transform it to a formula with only one charge moving freely.

We let ***t*** equal the time it takes the charge to move a distance ***l*** in the magnetic field *B*, so ***l***=***vt*** , where ***v*** is the velocity of the particle.

- Substituting all this into our old formula we get…

$$F_m = I\, l\, B \sin\theta$$

$$= (nq/t)\,(vt)\, B \sin\theta$$

$$F_m = n\, q\, v\, B \sin\theta$$

- So the force on ONE particle is…

$$F_m = q\, v\, B \sin\theta$$

- Where θ is the angle between the vectors v and B.
- If the angle is 90° , then the following formula is used…

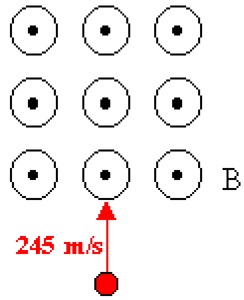
$$F_m = q\, v\, B_{\perp}$$

To figure out the direction of the force, you use the 3rd hand rule you used for current carrying wires.

- You must remember two very important facts!
  1. Your thumb now points in the direction of the velocity of the particle, NOT direction of current.

2. The 3rd hand rule uses a left hand for electron flow current (electrons moving), and a right hand for conventional current (protons moving). Therefore, if you are doing a question with negative charges, use your left hand. If you are doing a question with positive charges, use your right hand.

Example: A negative charge of 4.6×10^{-7}C is moving up at 245 m/s as shown in the diagram below. It enters a magnetic field with a strength of 13T. What is the force acting on the charge, and in what direction?



Since the charge is initially moving at right angles to the magnetic field, we can use…

$$F_m = q\, v\, B_\perp$$
$$= (4.6 \times 10^{-7}\text{C})\,(245\text{m/s})\,(13\text{T})$$
$$F_m = 1.5 \times 10^{-3}\ \text{N}$$

To figure out the direction of the force, we use the 3rd left hand rule…

1. **Fingers** out of page for **magnetic field**.
2. **Thumb** pointing up for direction of **charge movement**.
3. **Palm** pushes to the **left** in the direction of the force.

Notice that the force is zero if the charge is not moving, since v = 0m/s.

- A static charge (one which is not moving) will not experience any force in a magnetic field.