The Magnetic Force and the Third Left Hand Rule

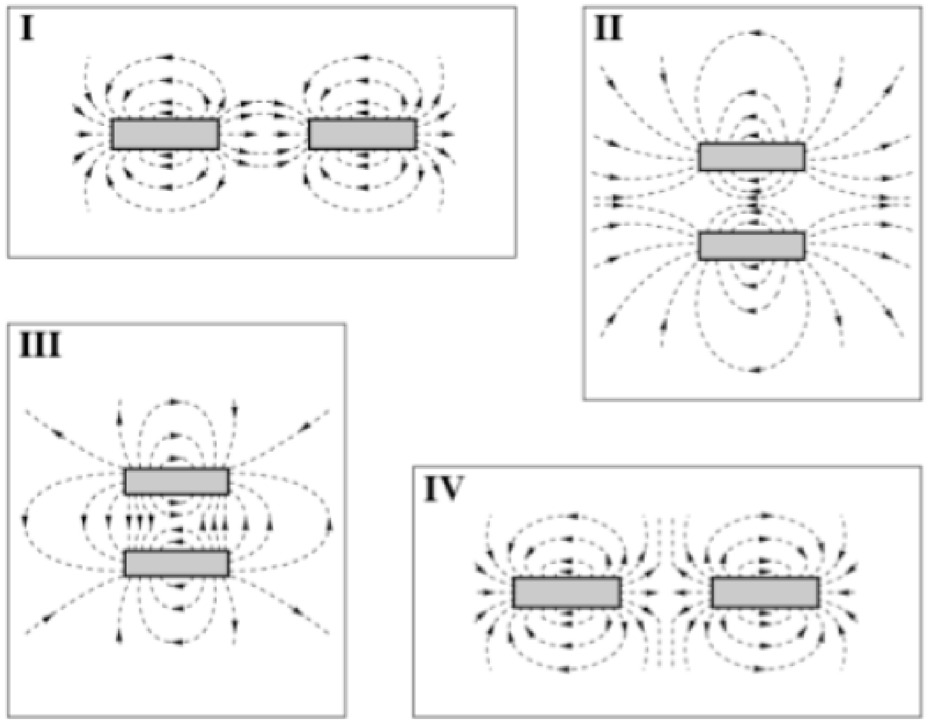
Objectives

- explain, qualitatively and quantitatively, how a uniform magnetic field affects a moving electric charge, using the relationships among charge, motion, field direction and strength, when motion and field directions are mutually perpendicular.
- predict, using appropriate hand rules, the relative directions of motion, force and field in electromagnetic interactions.

Diploma Question Alert!

Use the following information to answer the next question.

Magnetic Fields Around Two Bar Magnets



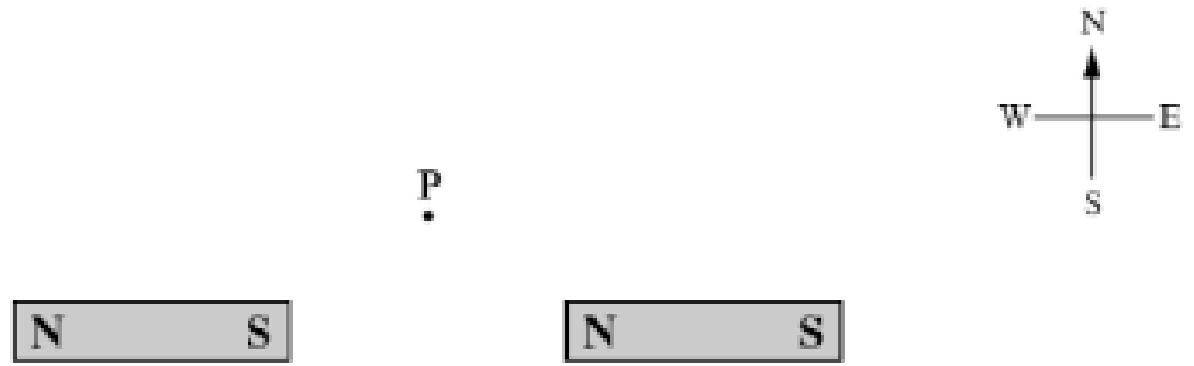
18. Given the magnetic fields illustrated above, the magnets will repel in diagrams

A. I and II only
B. II and III only
C. I and IV only
D. II and IV only

Diploma Question Alert!

Use the following information to answer the next question.

Two identical magnets and a point P are located as shown below. The point P is equidistant between the two magnets.



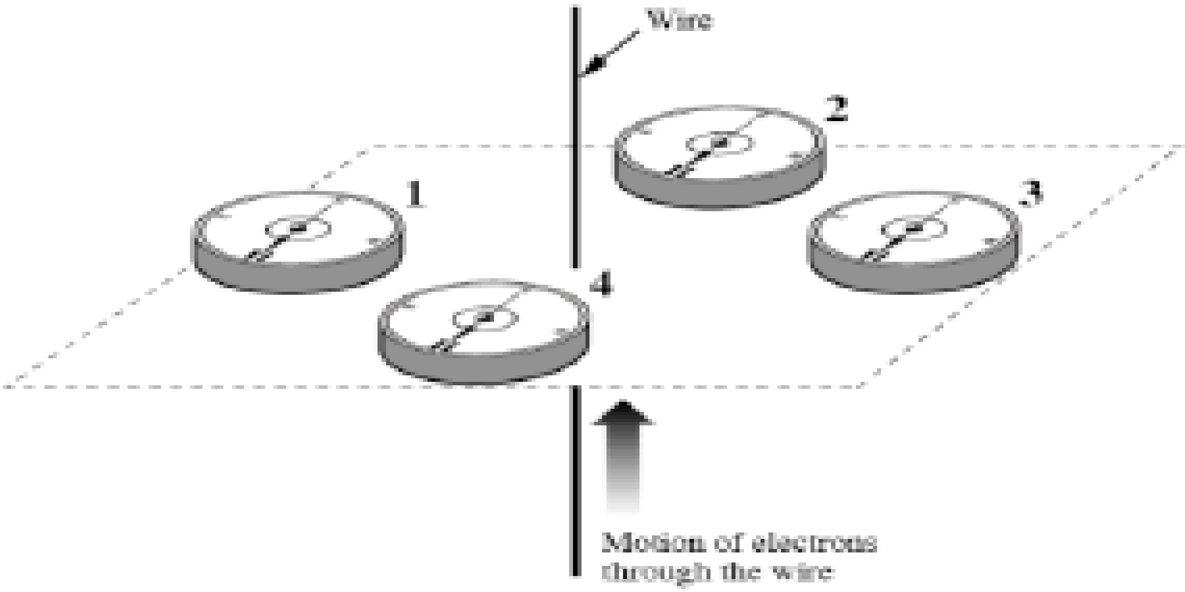
19. The two bar magnets cause the net magnetic field at P to be in the direction

A. east
B. west
C. north
D. south

Diploma Question Alert!

Use the following information to answer the next question.

Magnetic Field Surrounding a Current in a Wire



23. The compass that correctly indicates the direction of the magnetic field produced by a wire conducting electrons is numbered

A. 1
B. 2
C. 3
D. 4

Diploma Question Alert!

Use the following information to answer the next question.

Electrons move through a wire as shown below.

21. What is the direction of the magnetic field at point *P*?

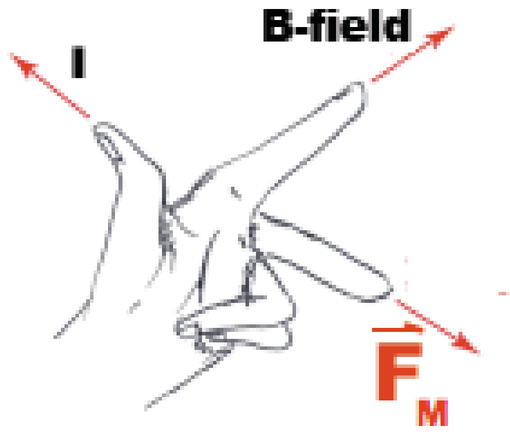
- **A.** Into the page
- **B.** Out of the page
- **C.** Toward the top of the page
- **D.** Toward the bottom of the page

Field Theory

- any object with mass produces a gravitational field the force of gravity acts in the same direction as the G-field
- any object with charge produces an electric field the force of electricity acts in the same direction as the E-field
- any magnet/current carrying wire produces a magnetic field what direction does the magnetic force work in?

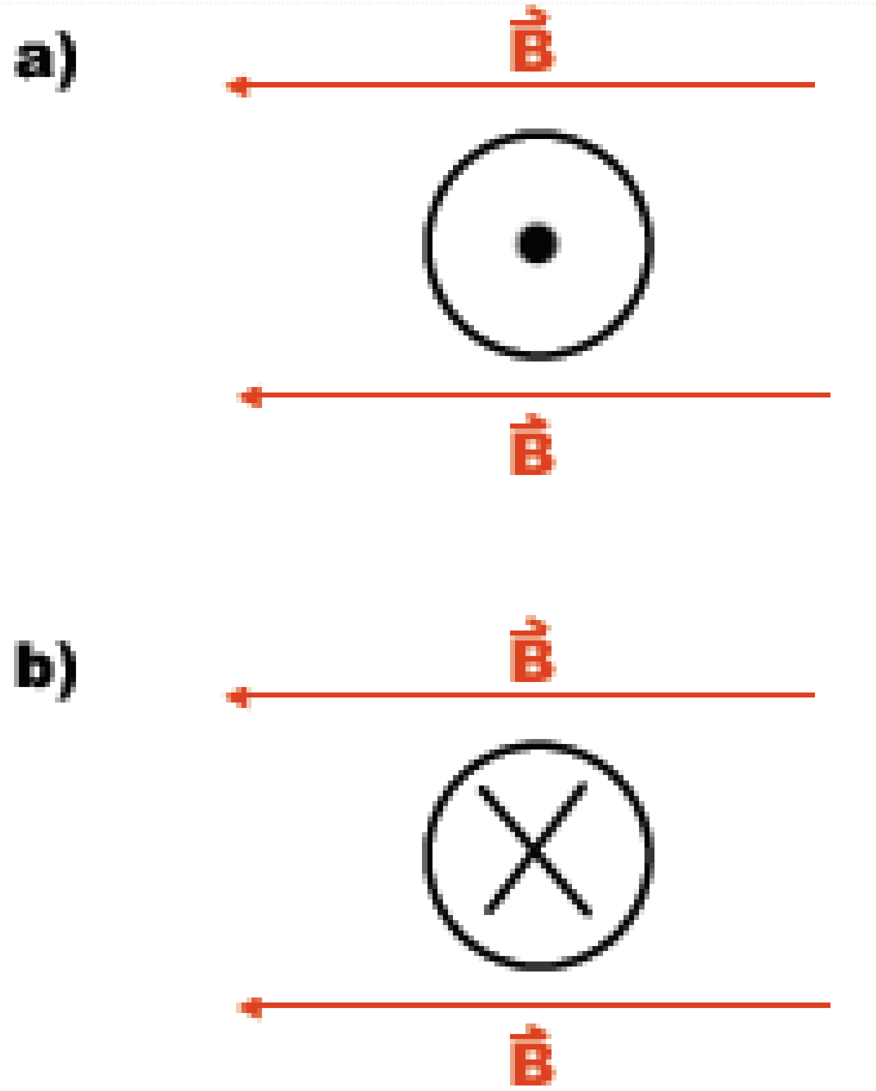
F_M - Third Left Hand Rule

- The F_M acts perpendicularly to the current and the B-field
- This direction can be found using the 3rd Left Hand
- Rule: ** Note you can also just use your palm as the direction of the force (while extending your fingers straight to represent the field)!



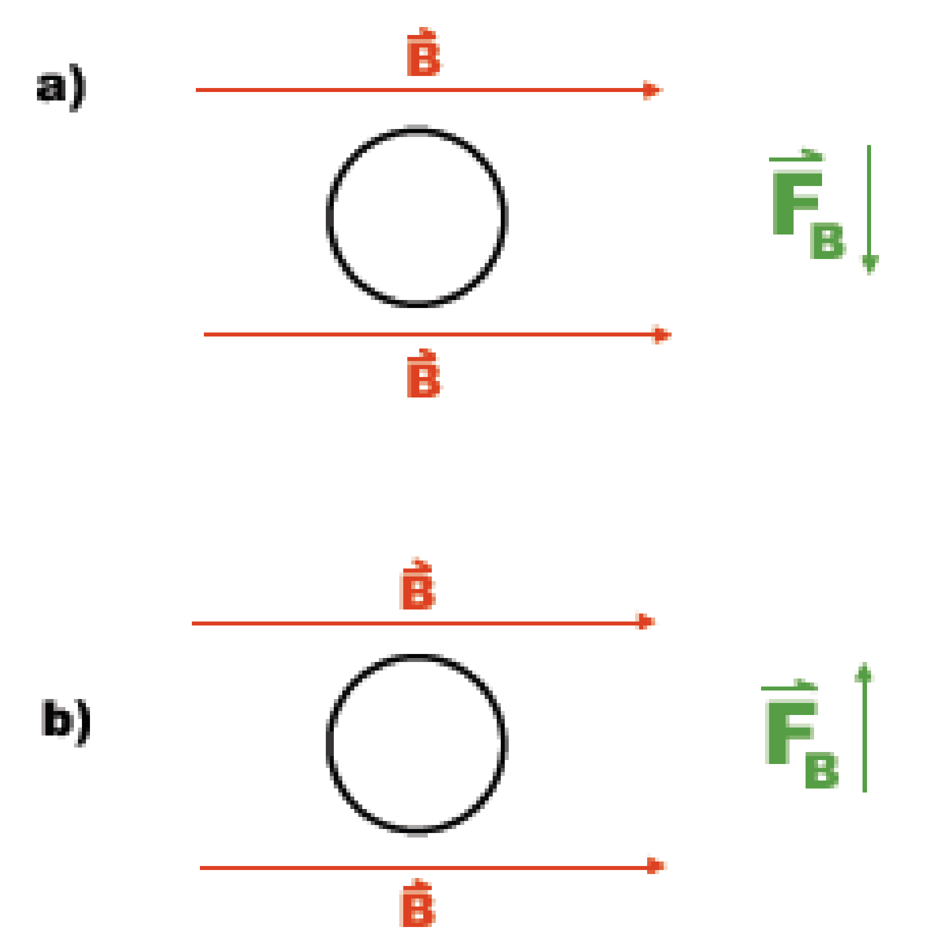
Thumb - direction of current
Index - external B-field
Middle - F_M

Example



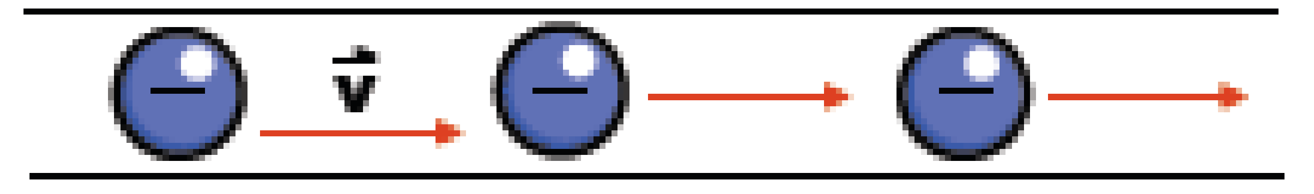
Example

- **What is the direction of the current?**



Applications of F_M

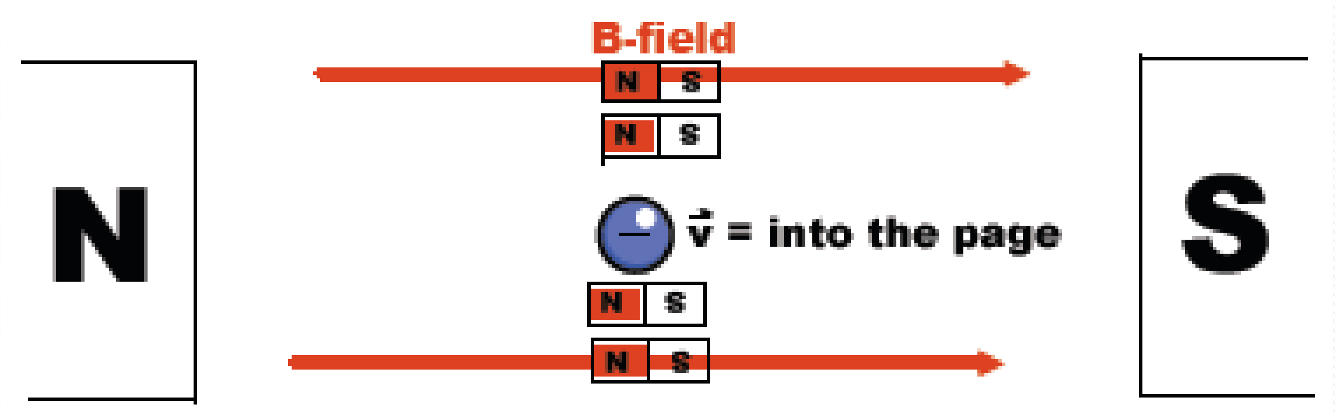
- **Effects on Charged Particles:**
  - **recall that current carrying wires produce a B-field**



  - **these wires simply carry moving electrons**
  - **any other moving electron produces a B-field, which can interact with other B-fields and experience a force**

Example

What is the direction of the force on the particle?



To determine the force:

- **Step 1: Determine the direction of the B-field from the particle.**
- **Step 2: Draw in (or imagine) small bar magnets aligning with the B-field.**
- **Step 3: Using magnets, determine direction of deflection.**
- ***Note: This gives the same effect as the 3LHR!**

Formula for magnitude of deflection

- In order to determine the force acting on a particle of charge (q), velocity (v), in a magnetic field (B)…

$$\vec{F}_B = q\,\vec{v}\,\vec{B}_{\perp}$$

where:

$\vec{F}_B$ = magnetic force (deflection)
q = charge on particle
$\vec{v}$ = velocity of particle
$\vec{B}$ = strength of B-field

Important Thing 1:

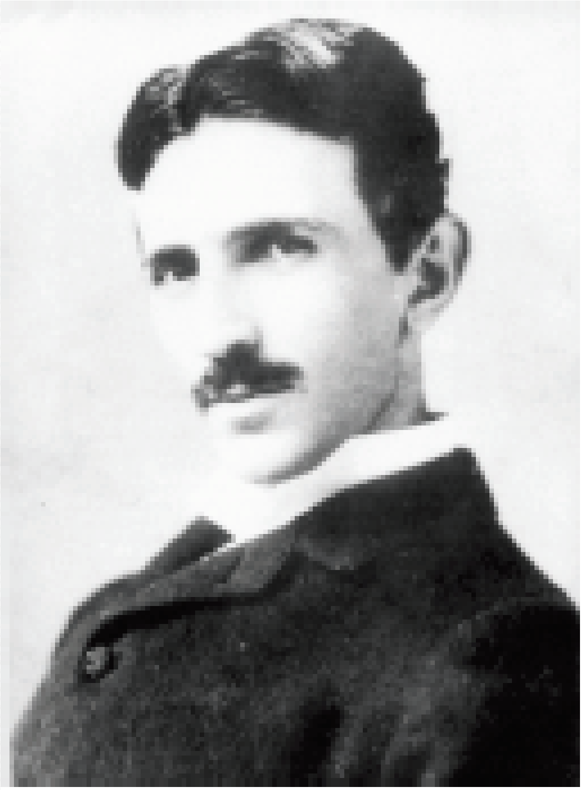
- **according to the 3LHR, the velocity and B-field MUST be perpendicular in order for a force to be produced!**

$$\vec{F}_B = q\,\vec{v}\,\vec{B}_{\perp}$$

- **If the velocity of the particle is parallel to the B-field, no force is produced!**

Important Thing 2:

- **The magnetic field strength is measured in Teslas (unit, T, not to be confused with temperature) after Nikola Tesla.**



Important Thing 3:

- Positively charged particles (protons, alpha particles) deflect in the direction opposite of the one predicted by the third left hand rule (as they are flowing positive charge, not negative charge).
- So for positive charge, use your Right Hand! (Or stick to your left and reverse the direction of force!)

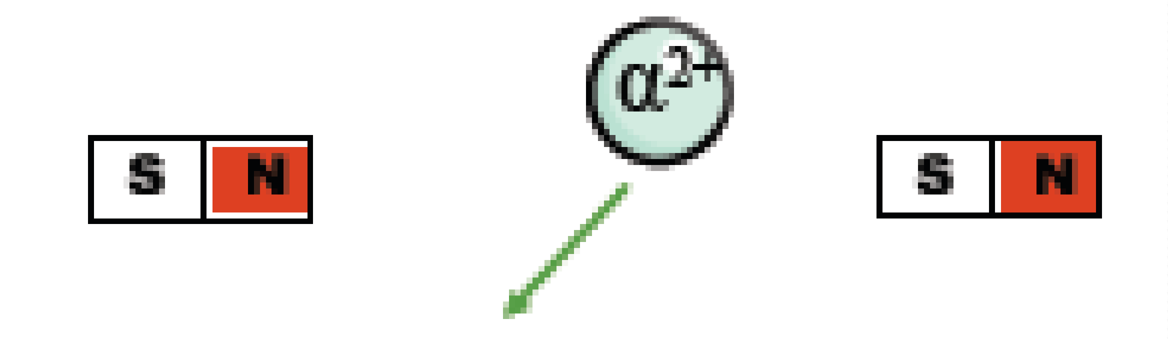
Example

- An electron is traveling through a magnetic field, as shown below:

- **The velocity of the electron is 3.3×10^6 m/s into the page, and the B = 0.60 T. Determine the force acting on the particle.**

Example

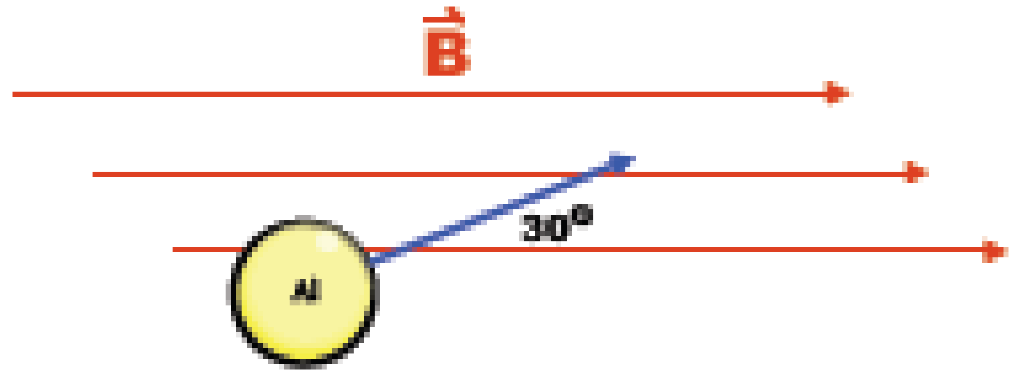
- An alpha particle is traveling through a magnetic field, as shown below:



- **The velocity of the particle is 7.2 x 10^5 m/s out of the page, and the B = 0.60 T. Determine the force acting on the particle.**

Example

- **An ion with a charge of 3+ and a speed of 2.30×10^5 m/s enters into an external magnetic field of 0.220 T at an angle of 30° to the field. What is the magnitude of the deflecting force?**



Example

- **A zinc (II) ion with mass of 1.08 x 10^{-25} kg enters into a B-field of 5.60 x 10^{-5} T. What perpendicular velocity must the ion maintain to travel in a straight line?**