

# **Applied Physics**

**BS Software Engineering/Information Technology**

**1<sup>st</sup> Semester**

**Lecture # 18**

## **Magnetic fields**

**Presented By**

**Dr. Arifa Mirza**

**Punjab University College of Information Technology**

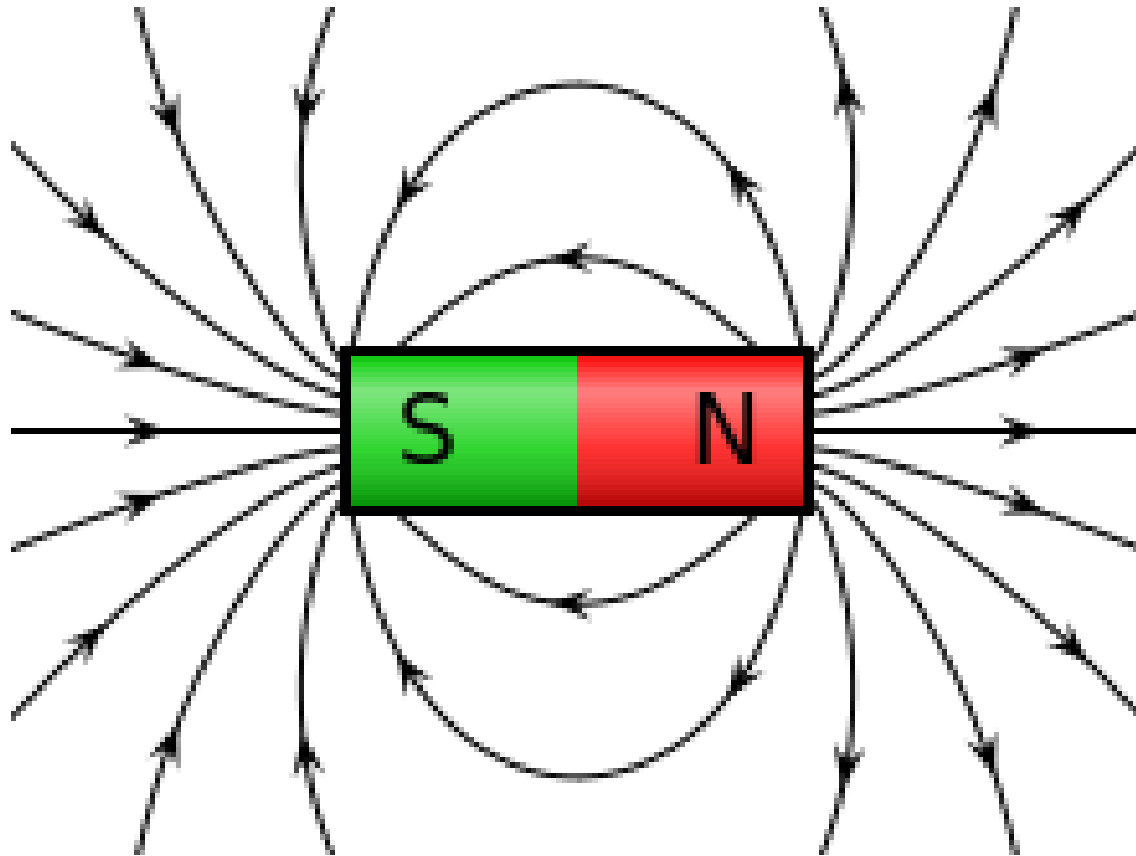
# **SECTION**

# **Magnetism**

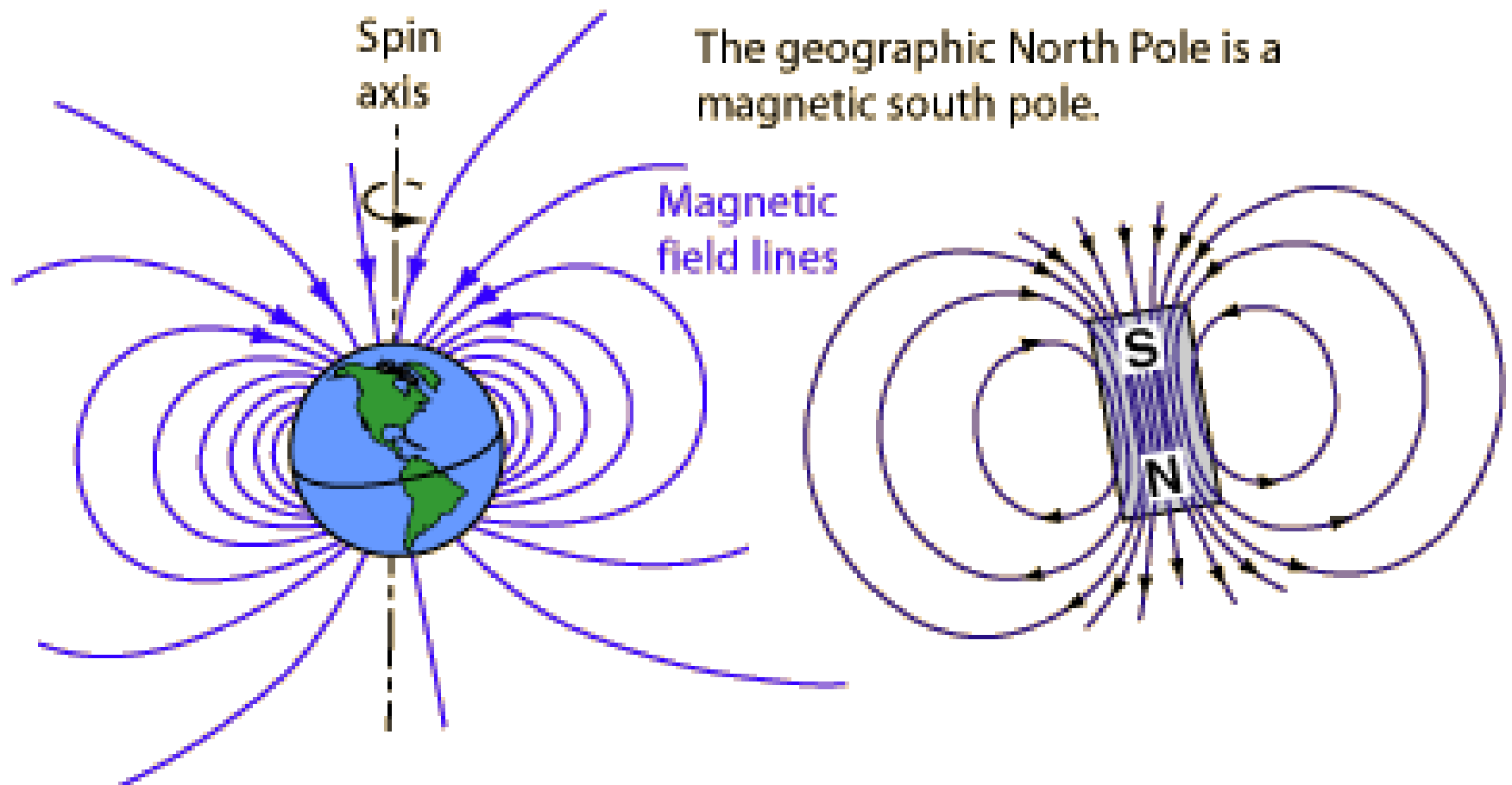
# Lecture # 18

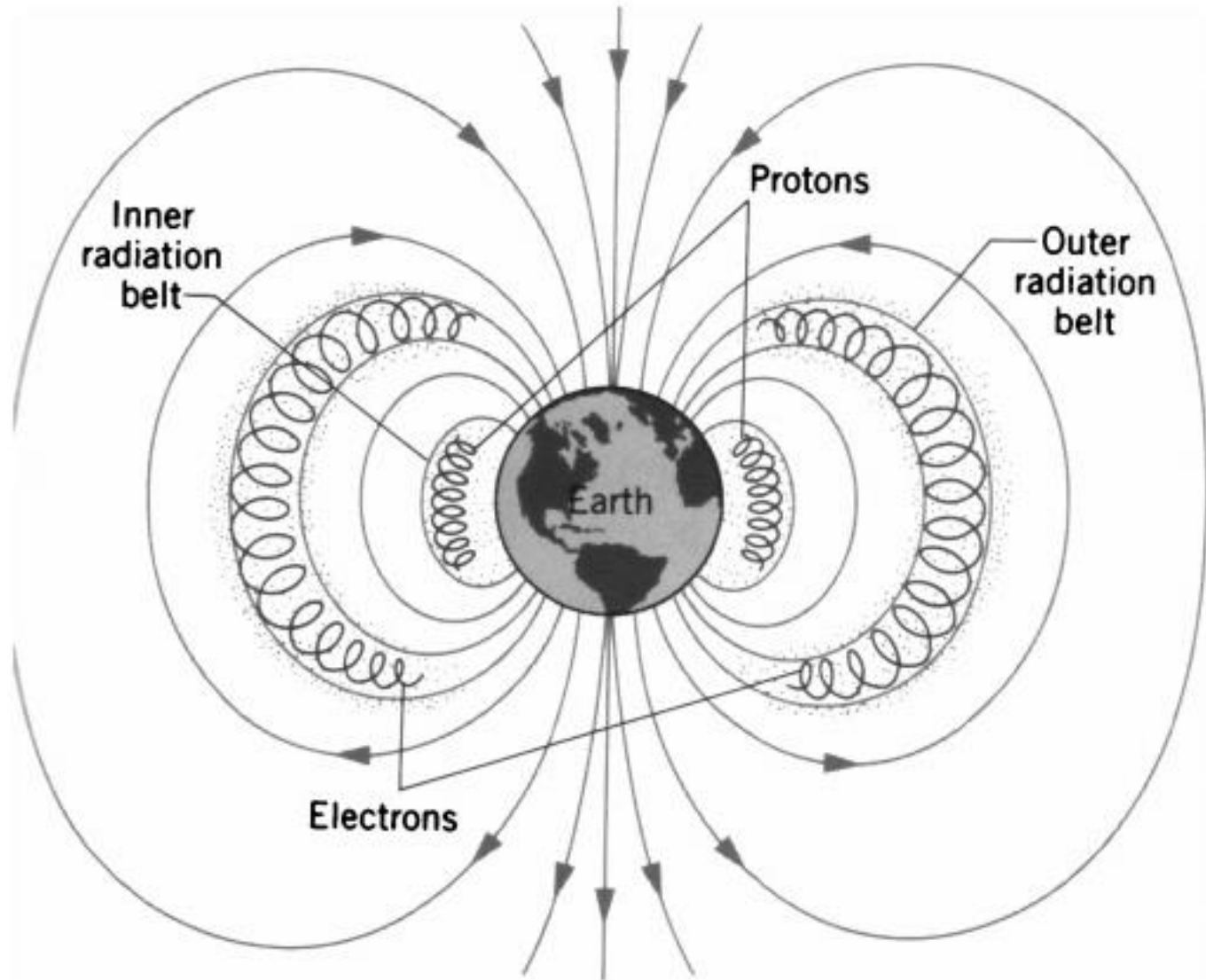
- Magnetism
- Magnetic field
- The magnetic force on a moving charge
- Right hand rule
- The magnetic force on a negative charge

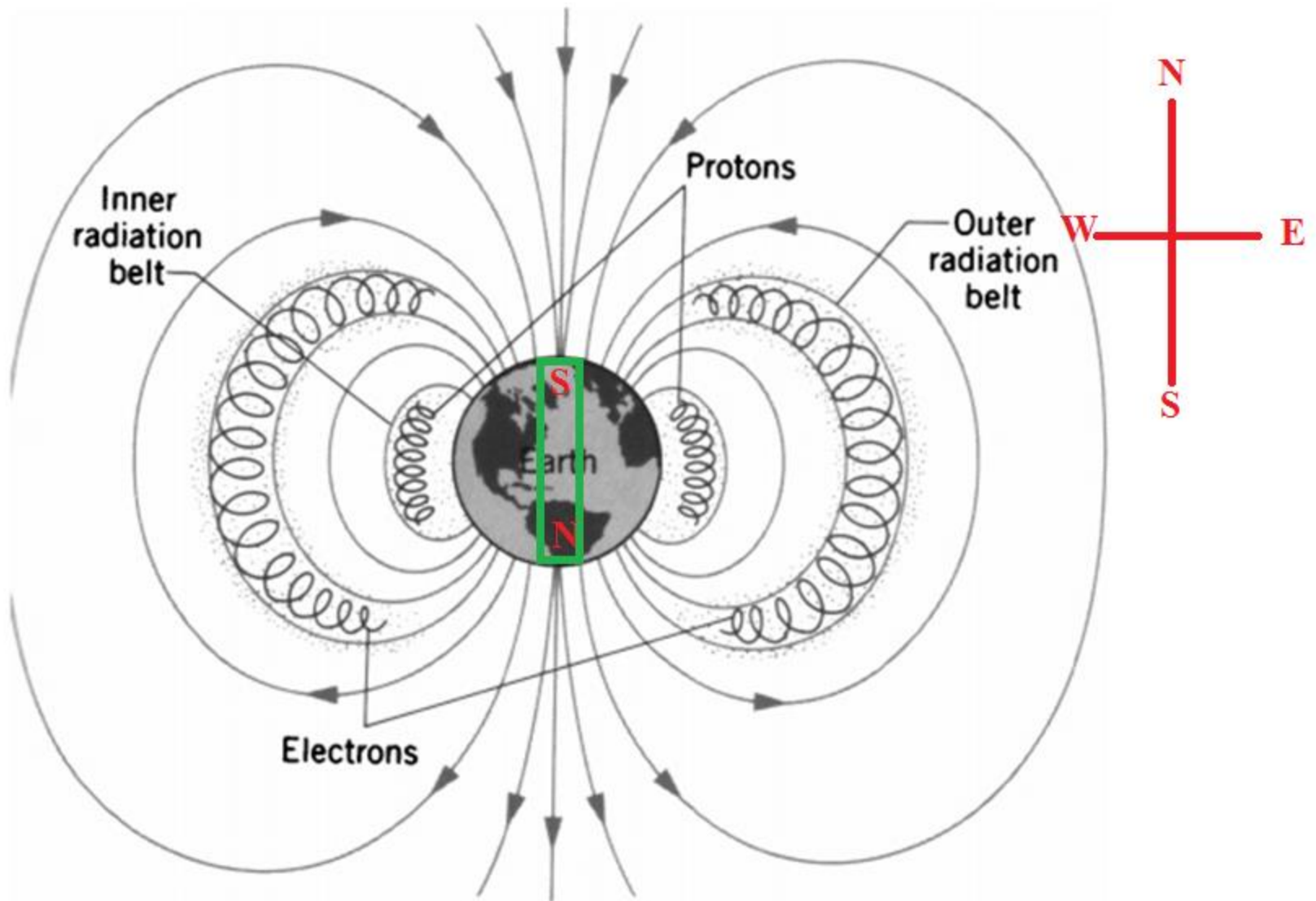
# Magnetic field

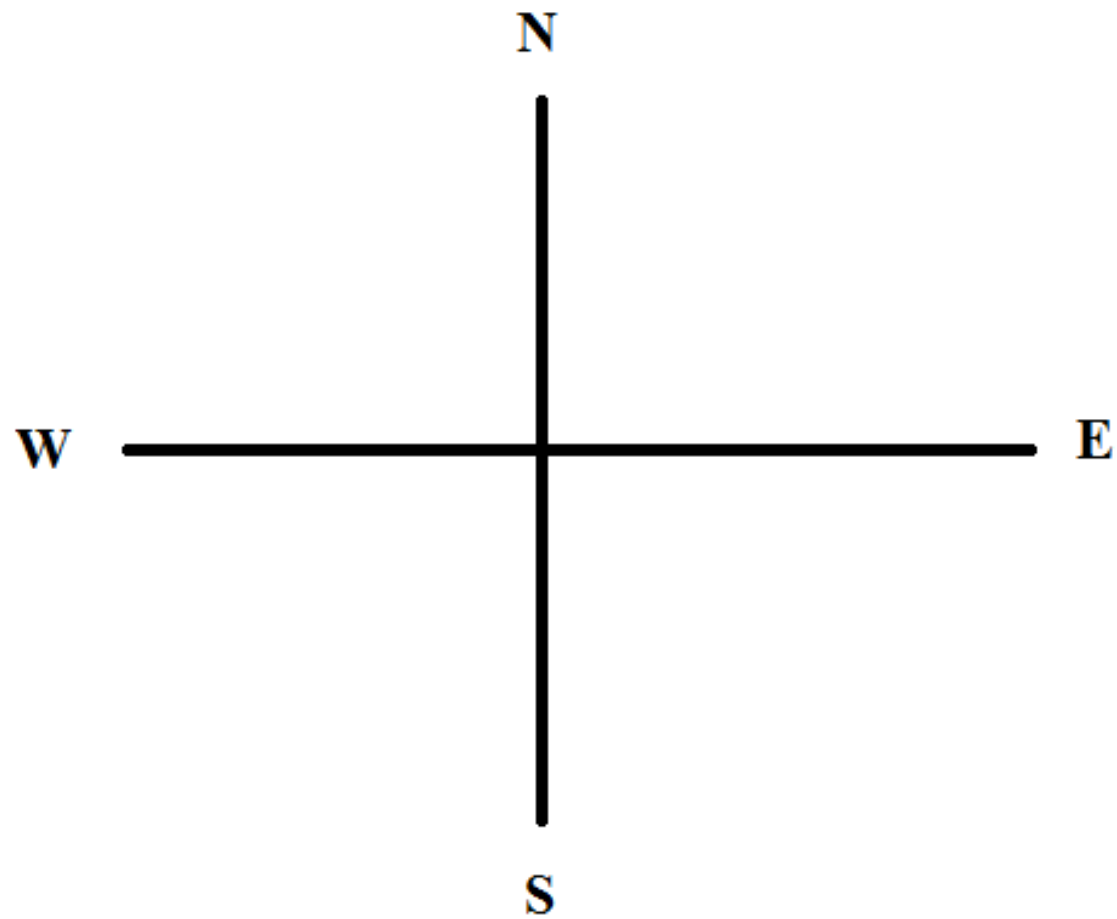


# THE MAGNETIC FIELD $B$



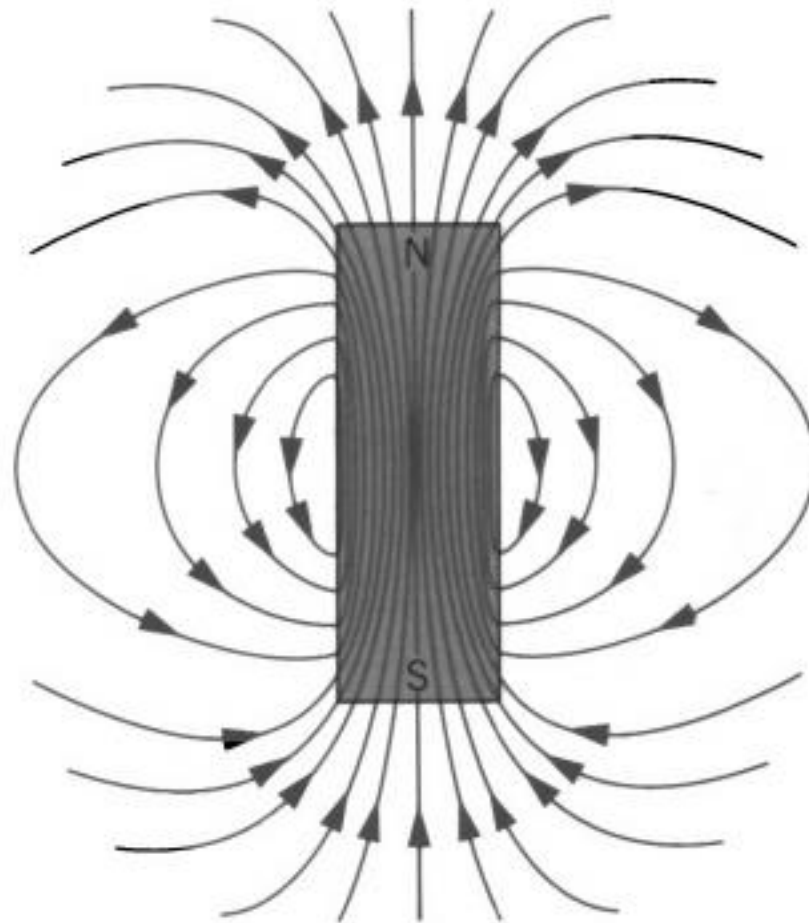








## Chapter 34 The Magnetic Field



**Figure 5** The magnetic field lines for a bar magnet. The lines form closed loops, leaving the magnet at its north pole and entering at its south pole.

magnetic charge  $\Leftrightarrow \mathbf{B} \Leftrightarrow$  magnetic charge.

**Wrong Statement**

moving electric charge  $\Leftrightarrow \mathbf{B} \Leftrightarrow$  moving electric charge,

**Correct Statement**

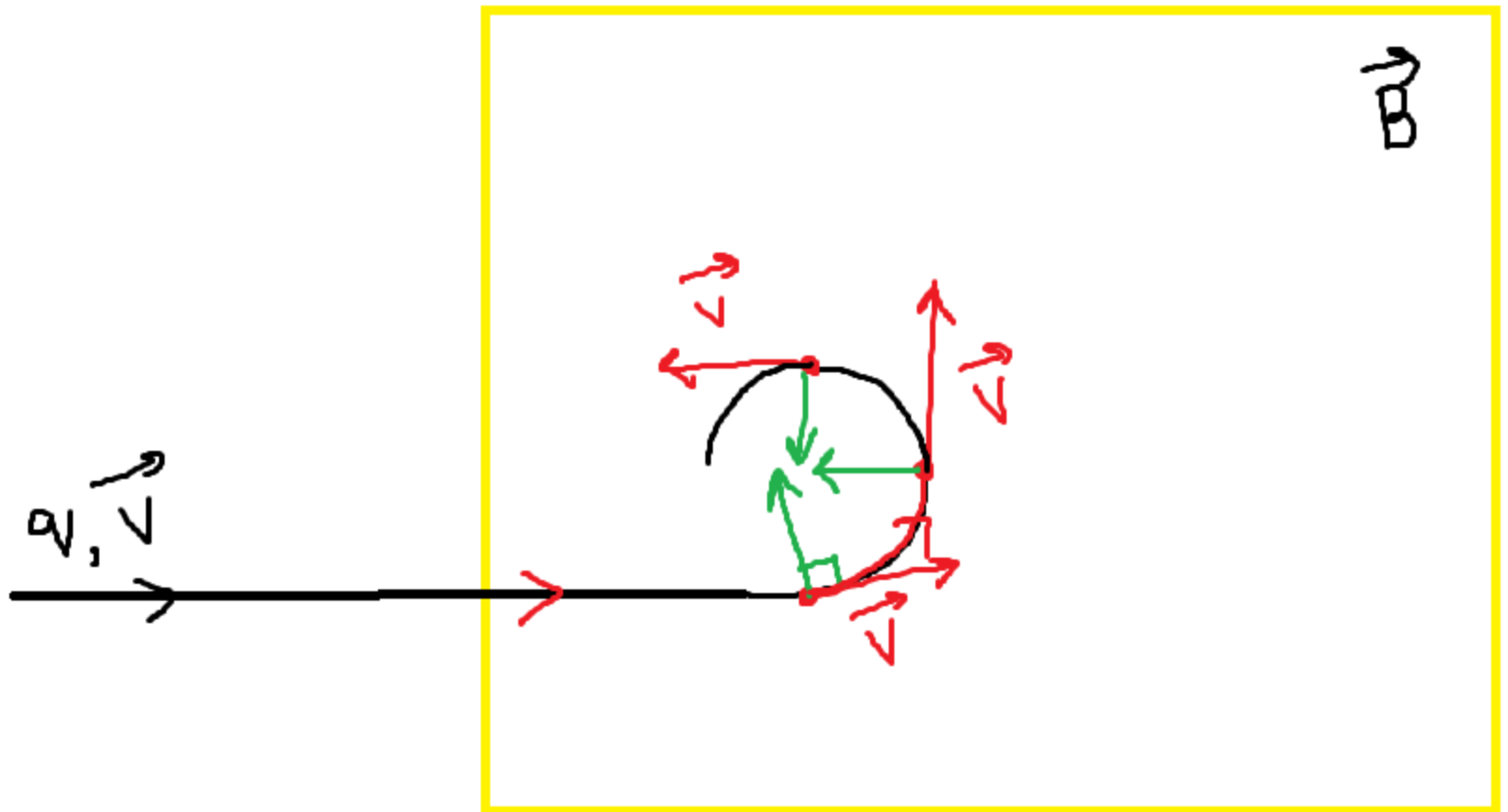
**We analyze the magnetic interaction of two currents in a manner similar to that of our analysis of the electric interaction between two charges:**

$$\text{charge} \rightleftharpoons \mathbf{E} \rightleftharpoons \text{charge}.$$

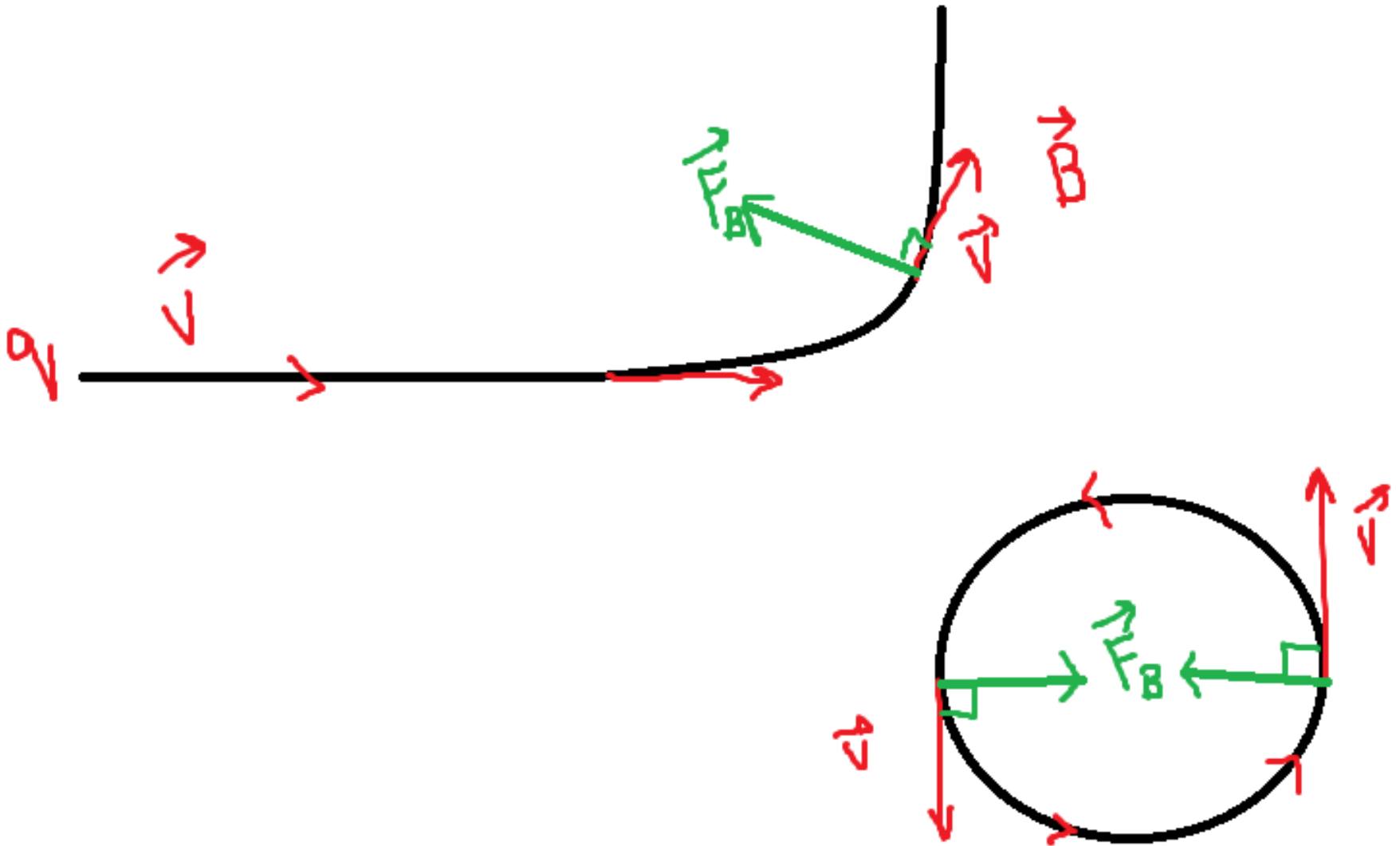
**That is, one charge sets up an electric field, and the other charge interacts with the field at its particular location. We use a similar procedure for the magnetic interaction:**

$$\text{current} \rightleftharpoons \mathbf{B} \rightleftharpoons \text{current}.$$

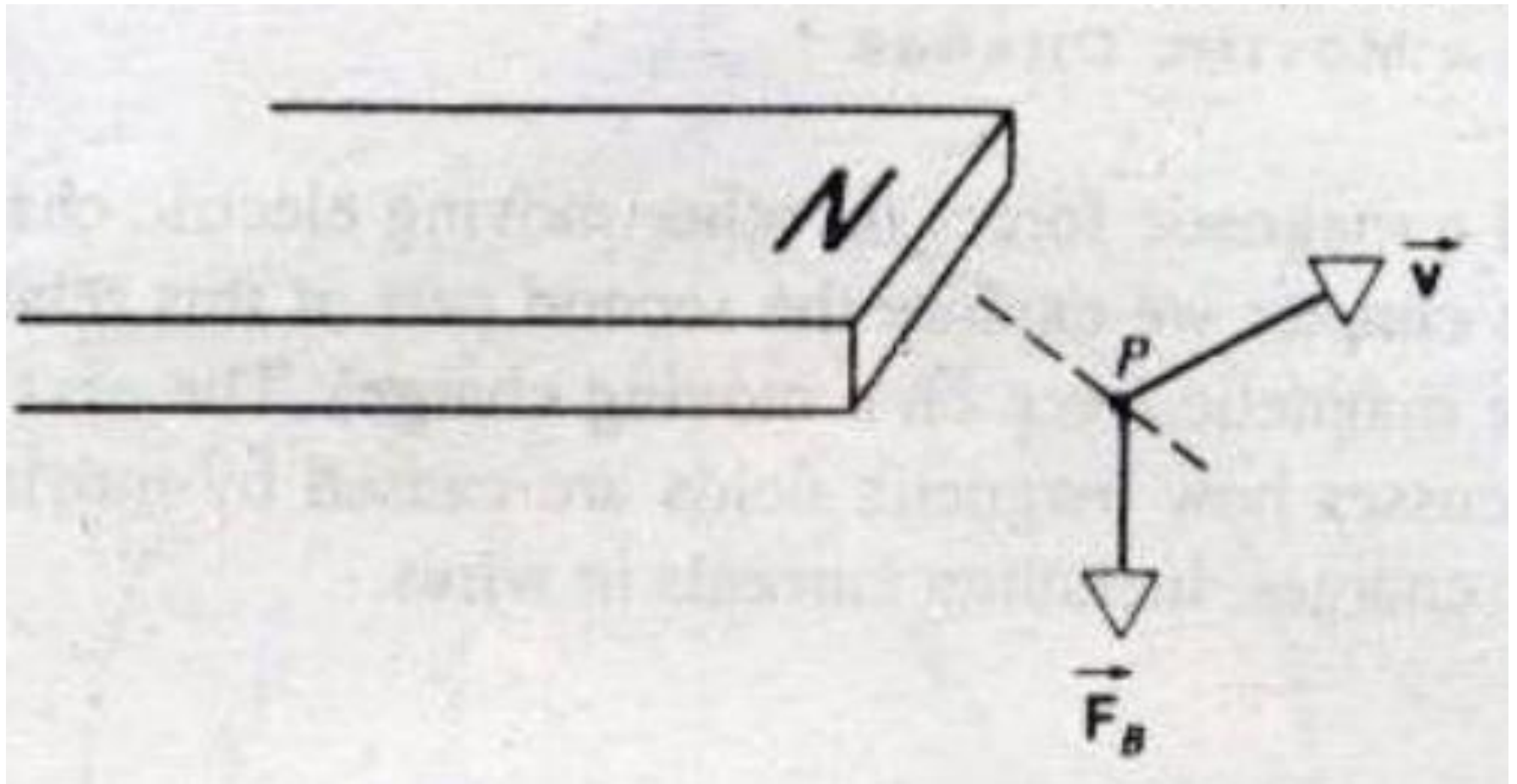
**Here a current sets up a magnetic field, and the other current then interacts with that field.**



# Magnetic force is a deflecting force

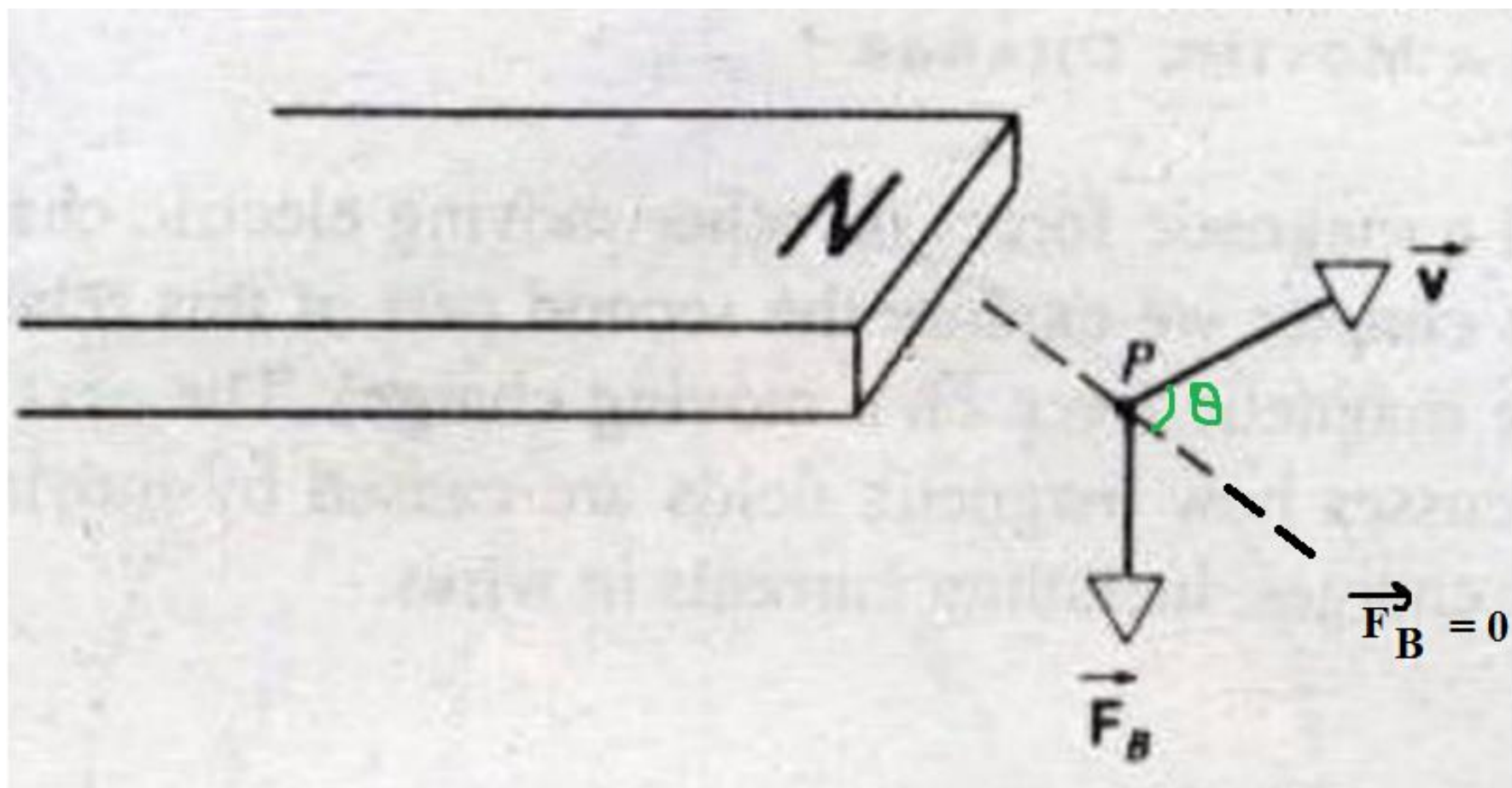


# The magnetic force on a single moving charge



1. We first test for the presence of an *electric* force by placing a small test charge at rest at various locations. Later we can subtract the electric force (if any) from the total force, which presumably leaves only the magnetic force. We assume this has been done, so that from now on we can ignore any electric force that acts on the charge.



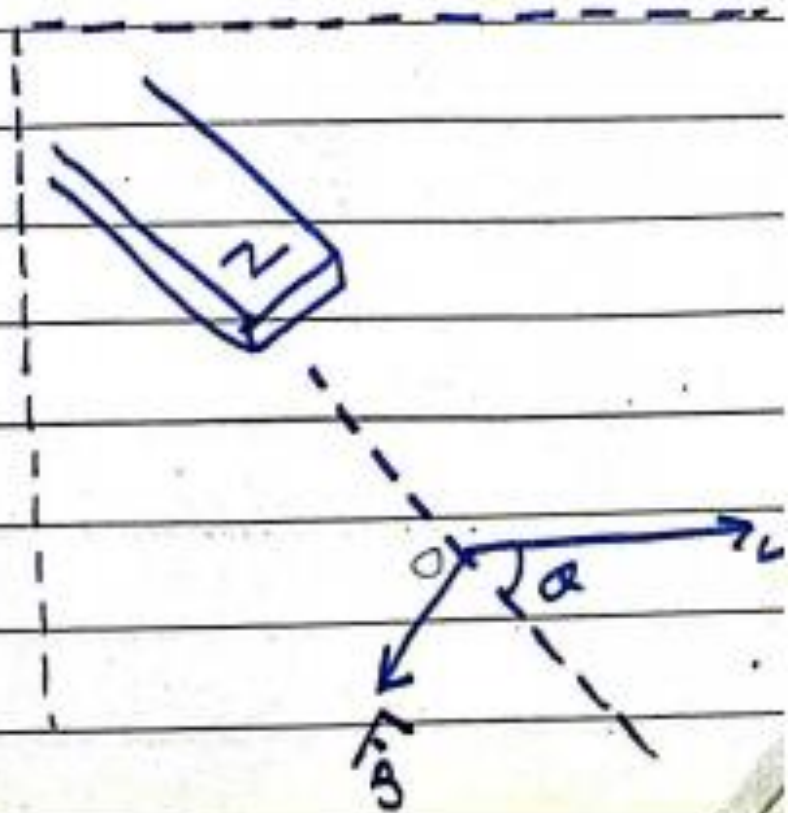


2. Next we project the test charge  $q$  through a particular point  $P$  with a velocity  $\mathbf{v}$ . We find that the magnetic force  $\mathbf{F}$ , if it is present, always acts sideways, that is, at right angles to the direction of  $\mathbf{v}$ . We can repeat the experiment by projecting the charge through  $P$  in different directions; we find that, no matter what the direction of  $\mathbf{v}$ , the magnetic force is always at right angles to that direction.
3. As we vary the direction of  $\mathbf{v}$  through point  $P$ , we also find that the magnitude of  $F$  changes from zero when  $\mathbf{v}$  has a certain direction to a maximum when it is at right angles to that direction. At intermediate angles, the magnitude of  $F$  varies as the sine of the angle  $\phi$  that the velocity vector makes with that particular direction. (Note that there are actually two directions of  $\mathbf{v}$  for which  $\mathbf{F}$  is zero; these directions are opposite to each other, that is,  $\phi = 0^\circ$  or  $180^\circ$ .)
4. As we vary the magnitude of the velocity, we find that the magnitude of  $F$  varies in direct proportion.
5. We also find that  $F$  is proportional to the magnitude of the test charge  $q$ , and that  $\mathbf{F}$  reverses direction when  $q$  changes sign.

## Mag. Force on a moving charge:-

Consider, a region where no electric field is present. as shown.

Let we have a device at point "O" which can fire a charge particles at different angles. We



find by experiments that the force by which magnet attracts is directly proportional to the charge. So, as strong is the charge same will be the magnetic force, so;

$$F_B \propto q \text{ --- (1)}$$

Similarly, the magnetic force  $F$  will be as strong as the velocity of charge which means force and velocity have direct relation, so;

$$F_B \propto v \text{ --- (2)}$$

From the experiment, it is found that both the magnetic force and velocity are always perpendicular.

$$\vec{F}_B \perp \vec{v}$$



Similarly, a result is found that the magnetic force becomes 'zero' at angle

0° and becomes maximum at 90° due to which we got the result that;

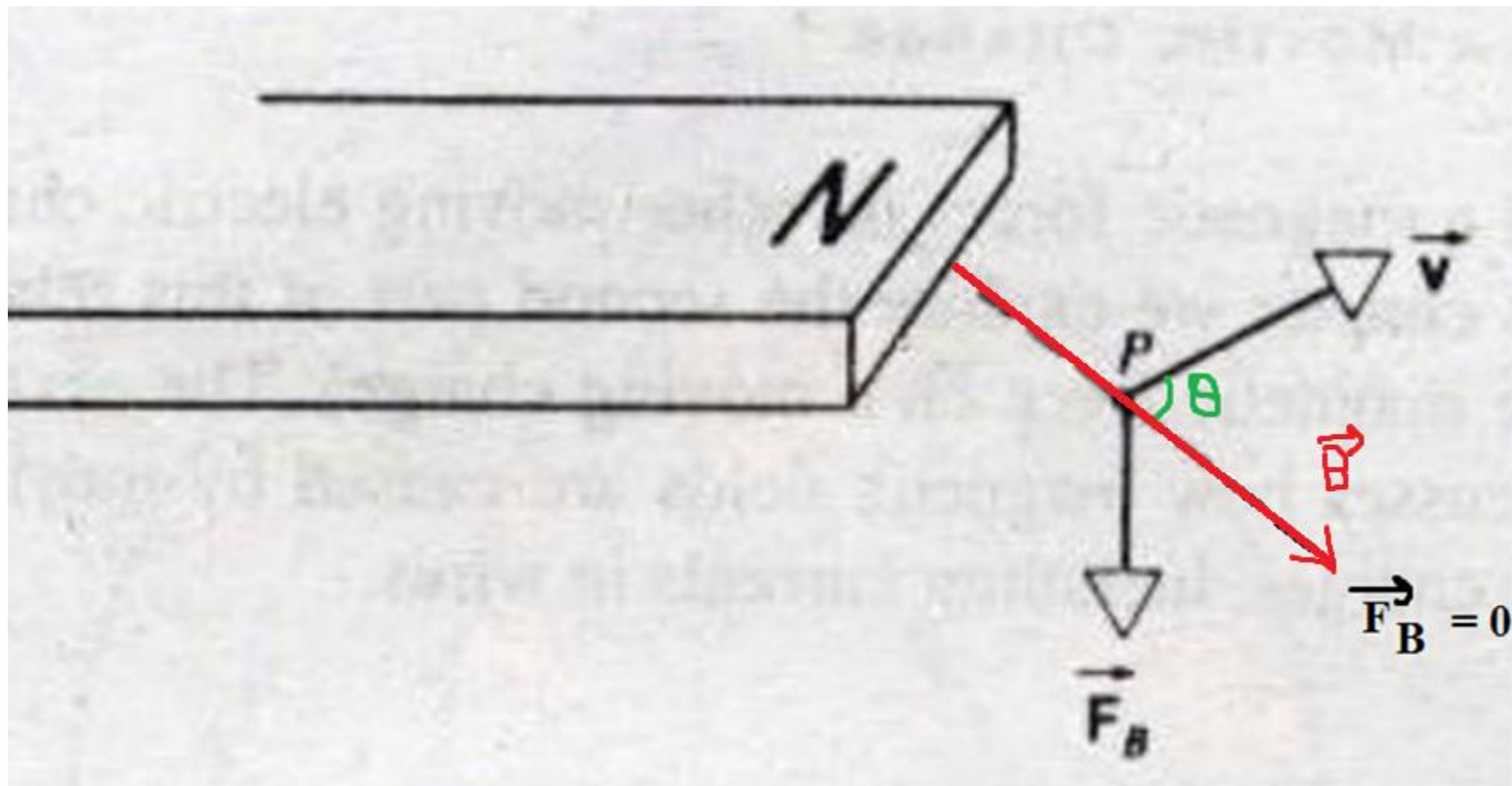
$$F_B \propto \sin \theta \quad \text{--- (3)}$$

By combining eq 1, 2, 3 we get.

$$F_B \propto qv \sin \theta$$

By removing the sign of proportionality, we get;

$$F_B = qvB \sin \theta \quad \text{--- (4)}$$



→  $F_B$  is a deflecting force which deflects force. It works like a centripetal force and moves an object in circular path.

The  $\theta$  is the angle between velocity and field so eq. 4, become;

$$F_B = q (\vec{v} \times \vec{B}) \quad - (5)$$

For maximum force, the angle between them will be  $90^\circ$ , and  $\sin 90 = 1$

so eq. :- 4 will be;

$$F_B = qv \cdot B \quad \text{--- (5)'}$$

The value of field will be  
then;

$$B = F_B / qv$$

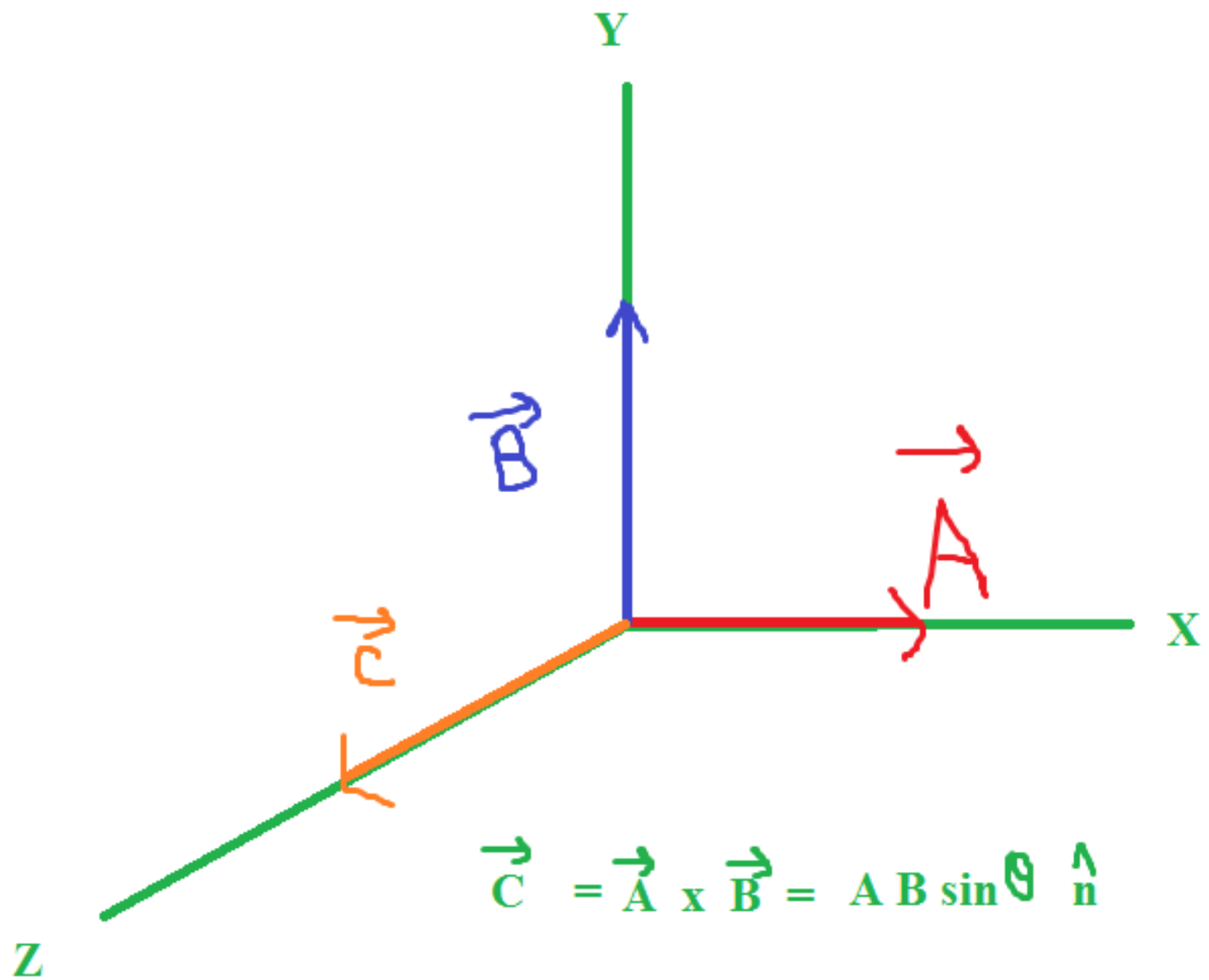
Unit:-

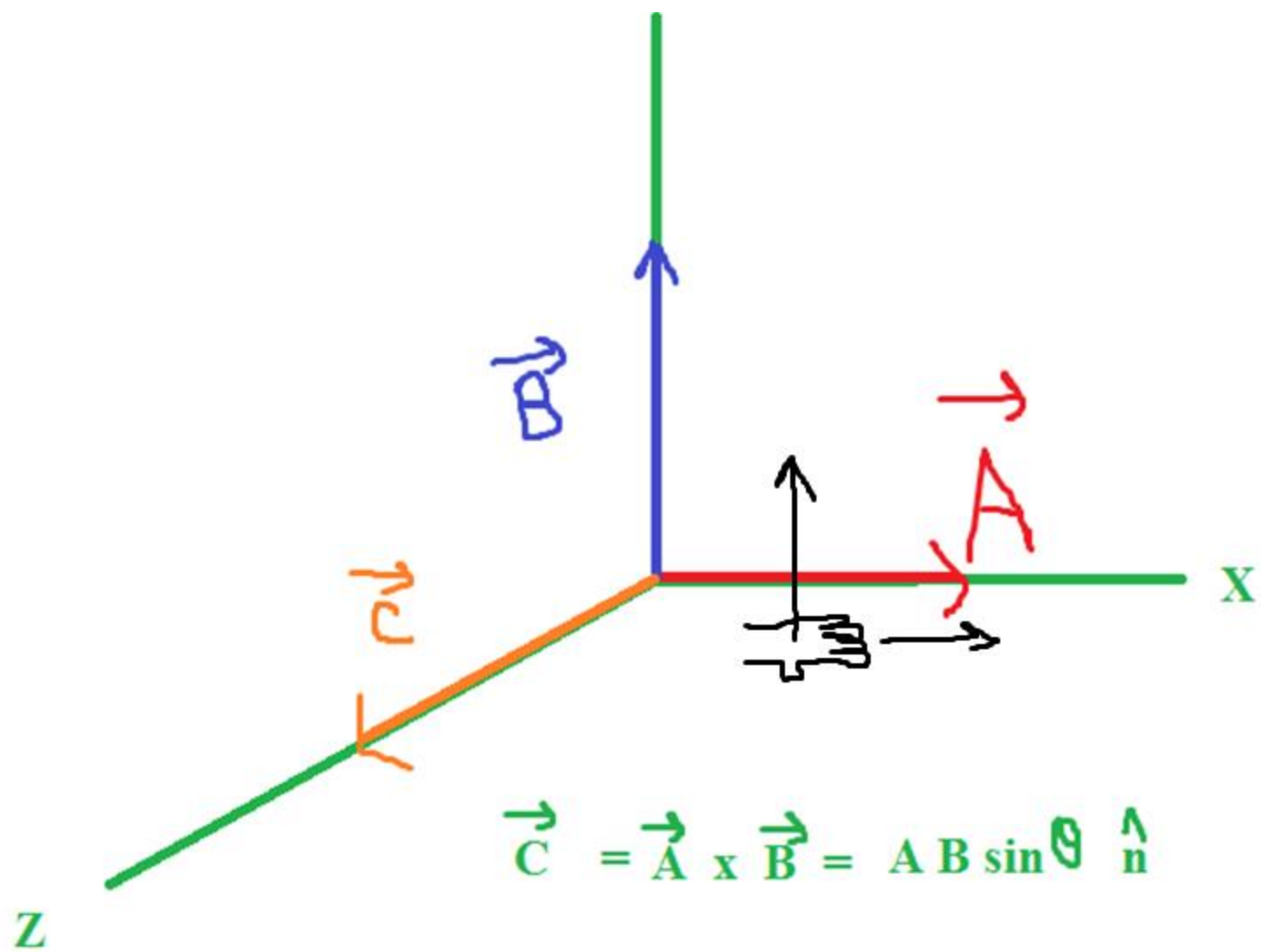
Its unit is Tesla.

$$1 \text{ Tesla} = \frac{\text{N}}{\text{Cm/s}} = \frac{\text{N}}{\text{Amp} \cdot \text{m}}$$

$$1 \text{ Tesla} = 10^4 \text{ Gauss.}$$

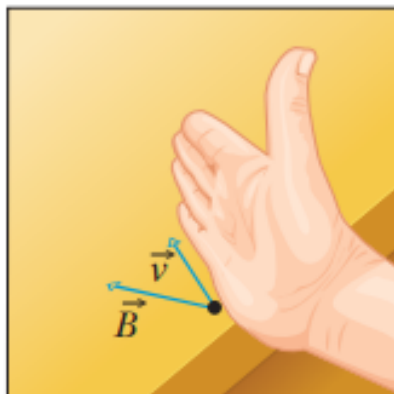




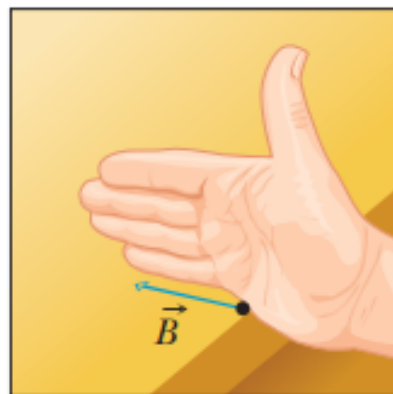


Cross  $\vec{v}$  into  $\vec{B}$  to get the new vector  $\vec{v} \times \vec{B}$ .

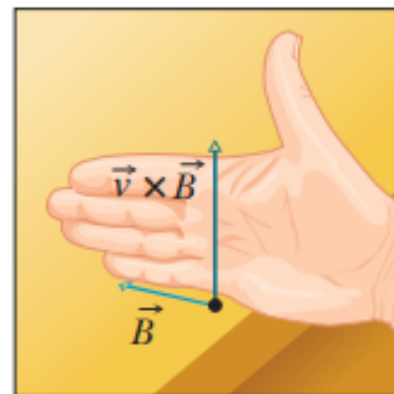
Force on positive particle



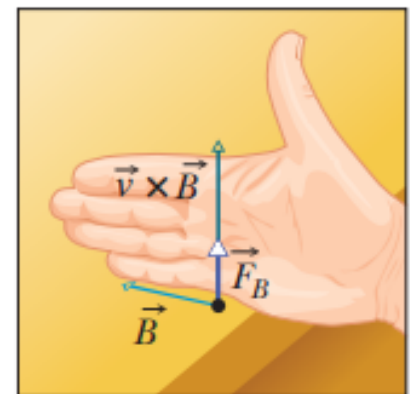
(a)



(b)



(c)

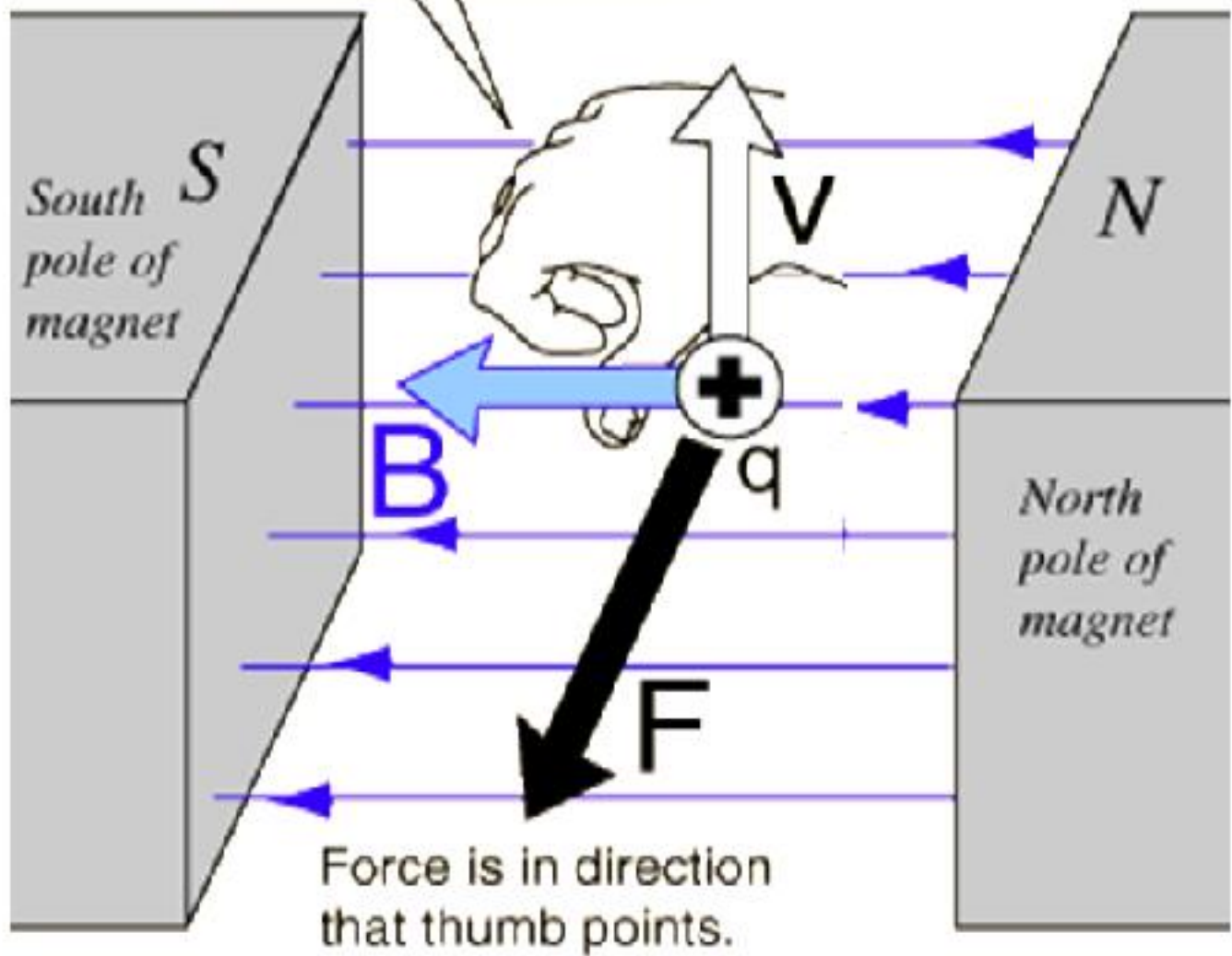


(d)

**Figure** (a)–(c) The right-hand rule (in which  $\vec{v}$  is swept into  $\vec{B}$  through the smaller angle  $\phi$  between them) gives the direction of  $\vec{v} \times \vec{B}$  as the direction of the thumb. (d) If  $q$  is positive, then the direction of  $\vec{F}_B = q\vec{v} \times \vec{B}$  is in the direction of  $\vec{v} \times \vec{B}$ .

Curl fingers as if rotating vector  $\vec{v}$  into vector  $\vec{B}$ . Thumb is in the direction of force.

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



Force is in direction that thumb points.

# The magnetic force on a negative charge

The force acting on the charge due to magnetic force will be;

$$F_B = q(\vec{v} \times \vec{B}) \quad \text{--- (i)}$$

For negative charge, the magnetic force will be;

$$F_B = -e(\vec{v} \times \vec{B})$$

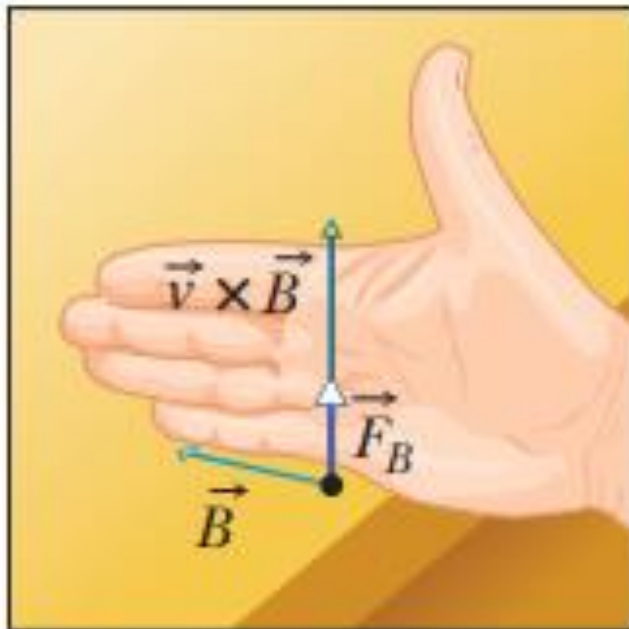
For negative charge, the magnetic force will be;

$$F_B = -e(\vec{v} \times \vec{B})$$

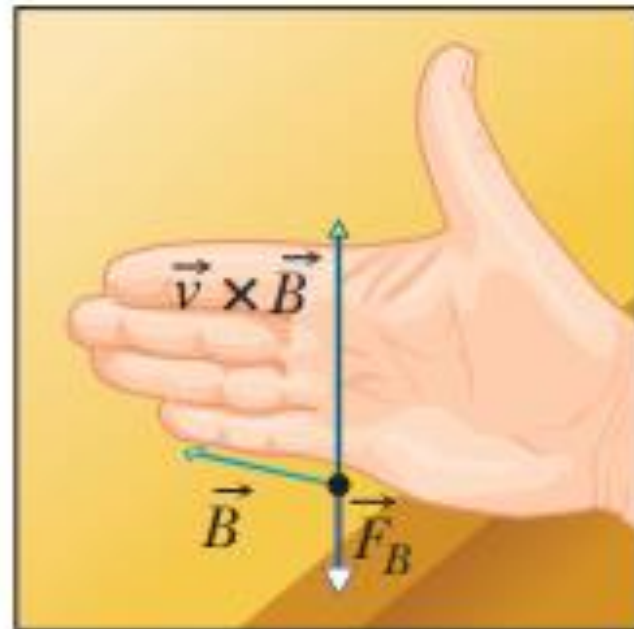
And;

$$F_B = e(\vec{B} \times \vec{v}) \quad - \text{ (ii) }$$

Force on positive  
particle

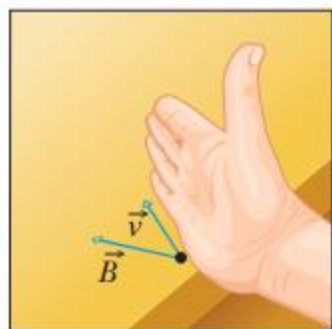


Force on negative  
particle

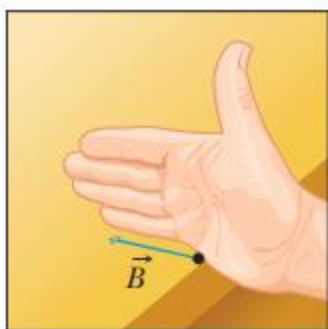




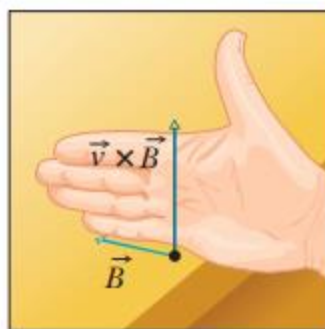
Cross  $\vec{v}$  into  $\vec{B}$  to get the new vector  $\vec{v} \times \vec{B}$ .



(a)

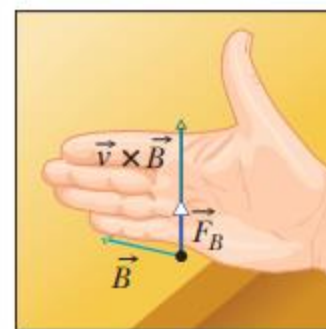


(b)



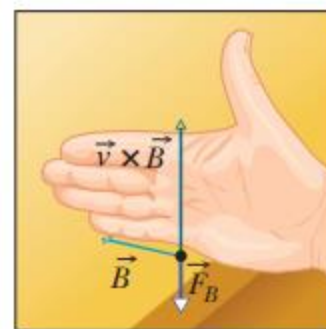
(c)

Force on positive particle



(d)

Force on negative particle



(e)

**Figure** (a)–(c) The right-hand rule (in which  $\vec{v}$  is swept into  $\vec{B}$  through the smaller angle  $\phi$  between them) gives the direction of  $\vec{v} \times \vec{B}$  as the direction of the thumb. (d) If  $q$  is positive, then the direction of  $\vec{F}_B = q\vec{v} \times \vec{B}$  is in the direction of  $\vec{v} \times \vec{B}$ . (e) If  $q$  is negative, then the direction of  $\vec{F}_B$  is opposite that of  $\vec{v} \times \vec{B}$ .