



DEVIL PHYSICS  
THE BADDEST CLASS ON CAMPUS  
IB PHYSICS

**TSOKOS LESSON 5-4**  
**MAGNETIC FIELDS**

# Essential Idea:

- The effect scientists call magnetism arises when one charge moves in the vicinity of another moving charge.

# Nature Of Science:

- Models and visualization: Magnetic field lines provide a powerful visualization of a magnetic field. Historically, the field lines helped scientists and engineers to understand a link that begins with the influence of one moving charge on another and leads onto relativity.

# International-Mindedness:

- The investigation of magnetism is one of the oldest studies by man and was used extensively by voyagers in the Mediterranean and beyond thousands of years ago.

# Theory Of Knowledge:

- Field patterns provide a visualization of a complex phenomenon, essential to an understanding of this topic.
- Why might it be useful to regard knowledge in a similar way, using the metaphor of knowledge as a map – a simplified representation of reality?

# Understandings:

- Magnetic fields
- Magnetic force

# Applications And Skills:

- Determining the direction of force on a charge moving in a magnetic field
- Determining the direction of force on a current-carrying conductor in a magnetic field
- Sketching and interpreting magnetic field patterns
- Determining the direction of the magnetic field based on current direction
- Solving problems involving magnetic forces, fields, current and charges



# Guidance:

- Magnetic field patterns will be restricted to long straight conductors, solenoids, and bar magnets

Data Booklet Reference:

$$F = qvB \sin \theta$$

$$F = BIL \sin \theta$$

# Utilization:

- Only comparatively recently has the magnetic compass been superseded by different technologies after hundreds of years of our dependence on it
- Modern medical scanners rely heavily on the strong, uniform magnetic fields produced by devices that utilize superconductors
- Particle accelerators such as the Large Hadron Collider at CERN rely on a variety of precise magnets for aligning the particle beams

# Aims :

- Aims 2 and 9: visualizations frequently provide us with insights into the action of magnetic fields; however, the visualizations themselves have their own limitations
- Aim 7: computer-based simulations enable the visualization of electromagnetic fields in three-dimensional space

# Introductory Video



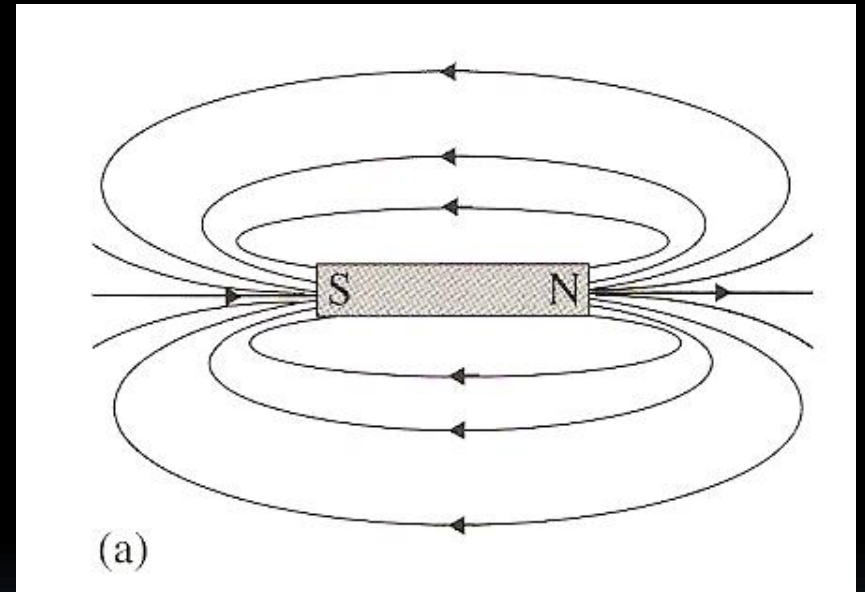
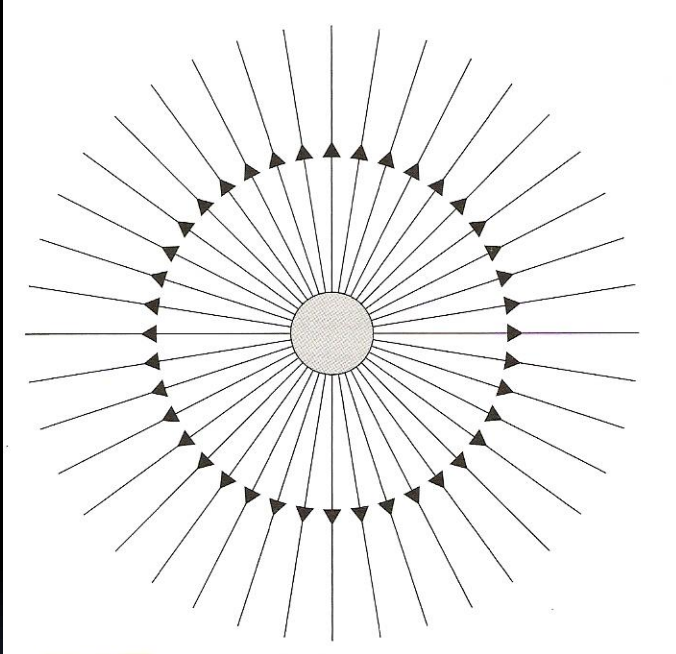
# Electric Field, Magnetic Field

- A charge will generate an electric field around itself
- Any other charge (small positive test charge) that enters the field will experience a force on it = electric force

# Electric Field, Magnetic Field

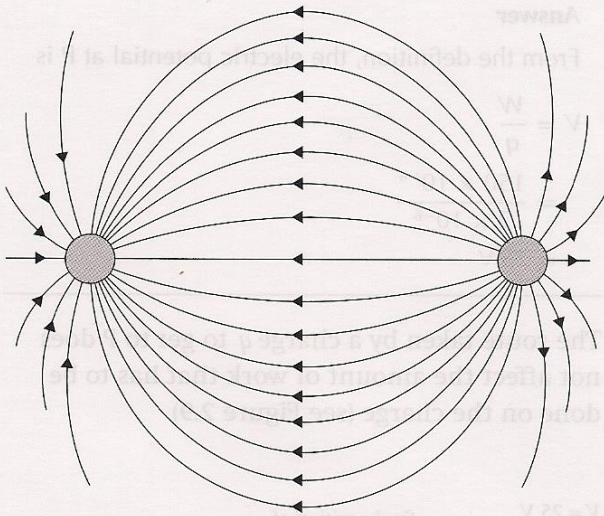
- Same is true for a magnet or an electric current (moving charge)
- Each of these produce a magnetic field around them
- When another magnet or electric current enters the magnetic field, it will experience a force on it
- Direction of magnetic field is determined by relation to magnetic field of the earth

# Electric Field, Magnetic Field

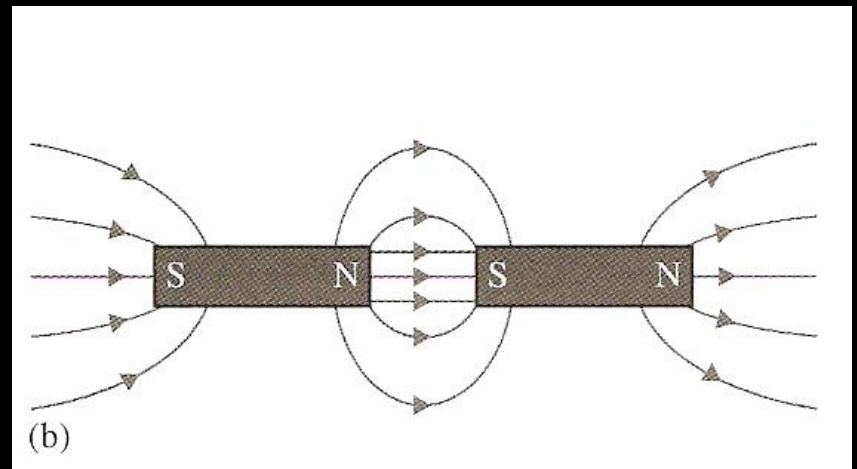




# Electric Field, Magnetic Field



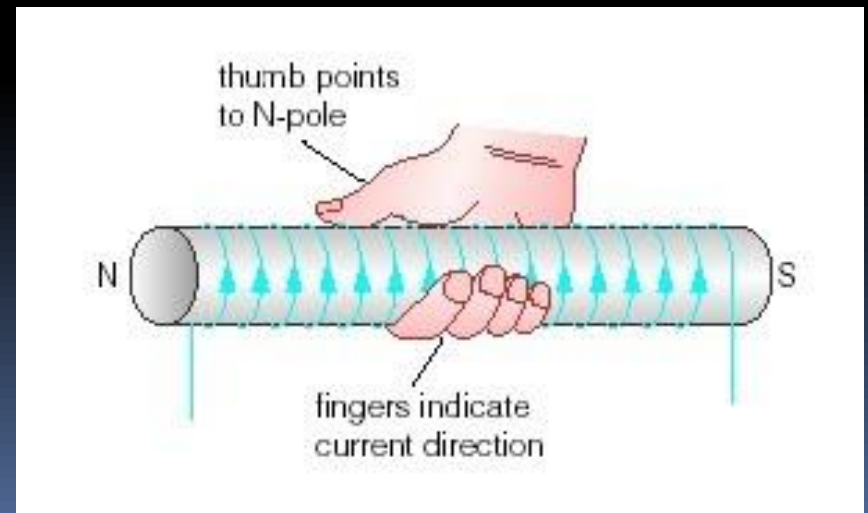
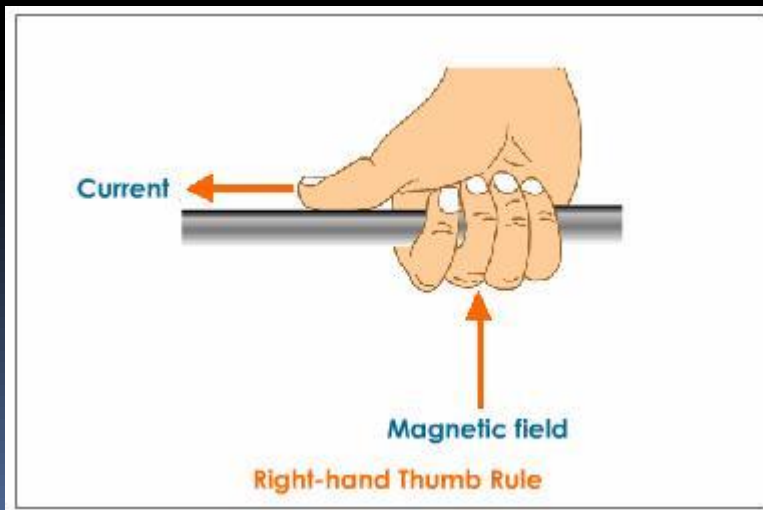
**Figure 2.4** Electric field lines for two equal and opposite charges.



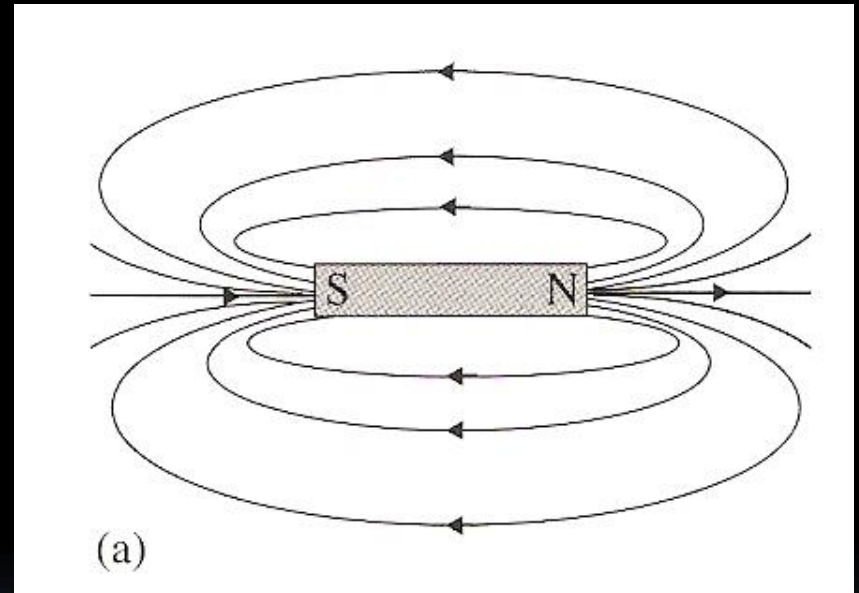
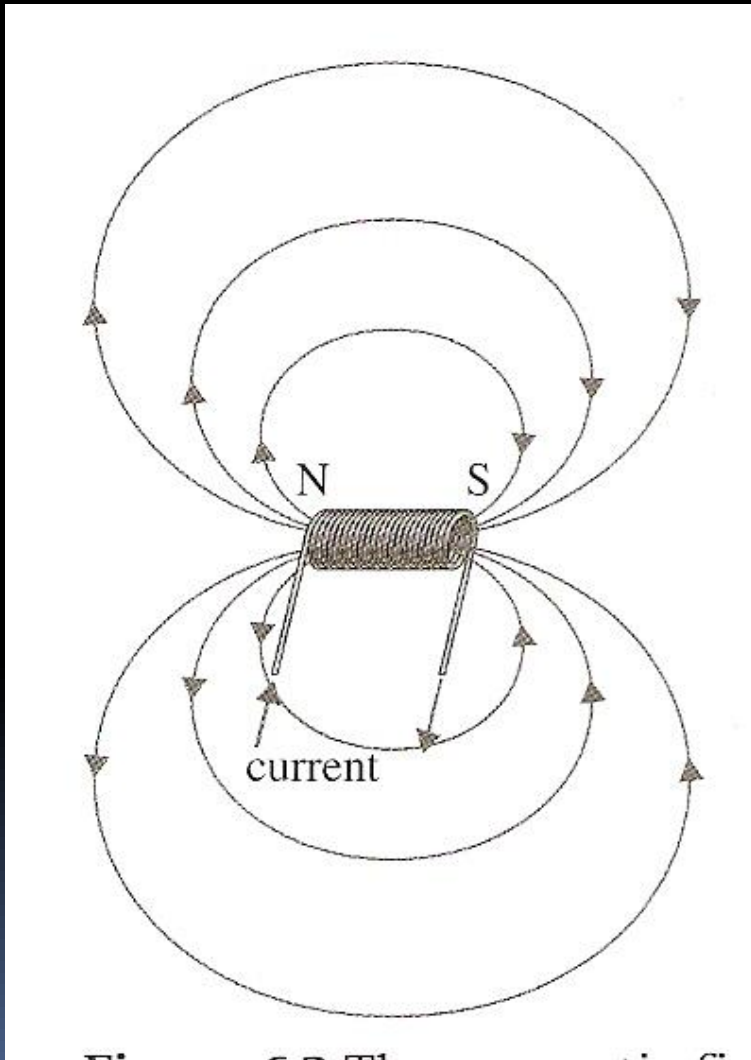
(b)

# Magnetic Fields

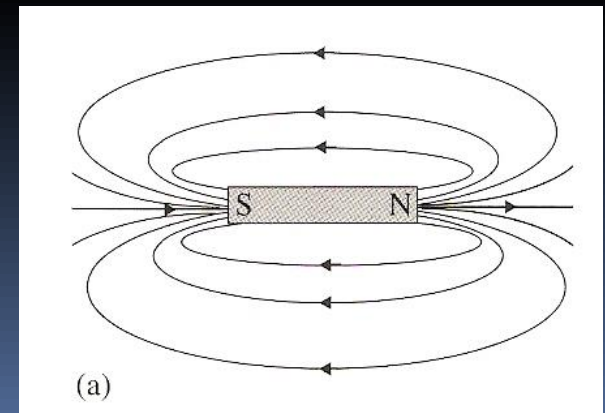
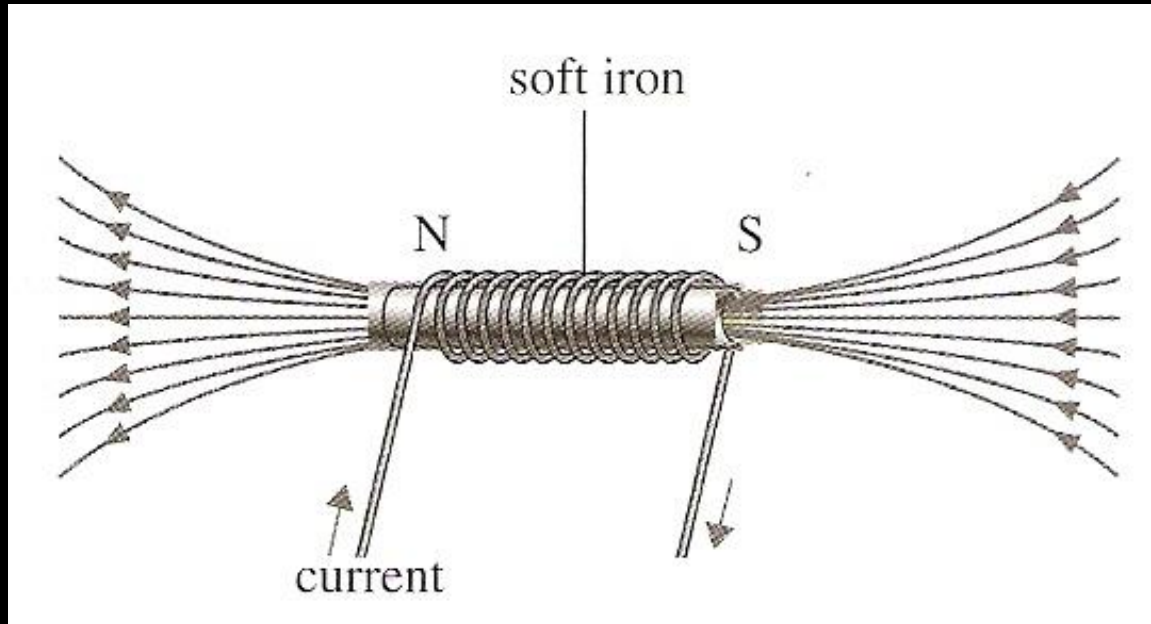
- Magnetic fields are produced by permanent magnets ***and by electric currents***
- Relationship between current and field is governed by the right-hand rule



# Magnetic Field from Coil

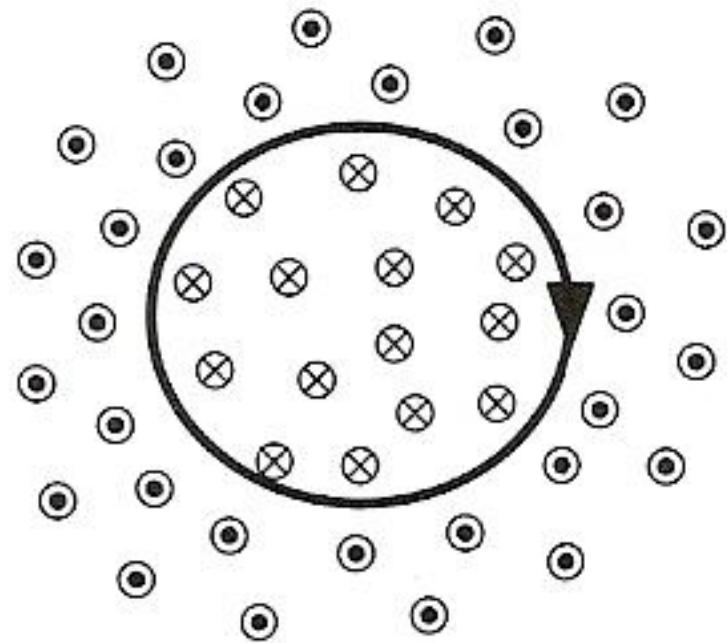
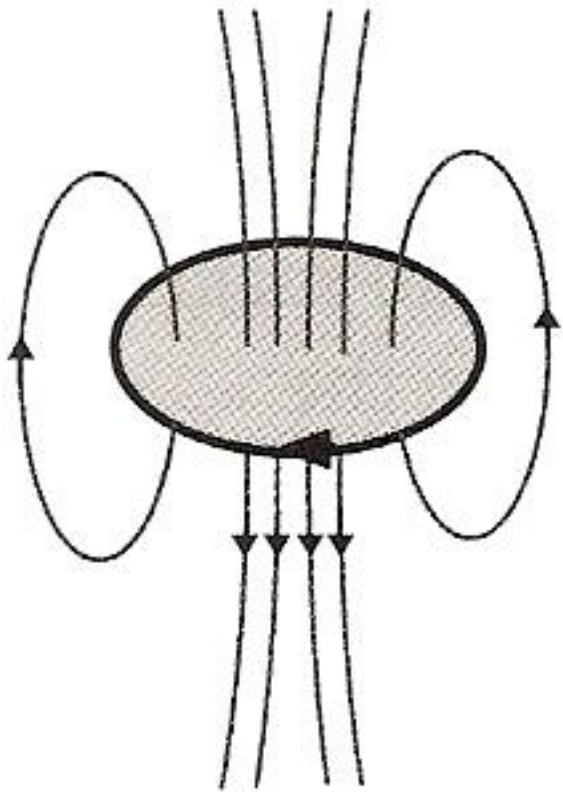


# Magnetic Field from Solenoid

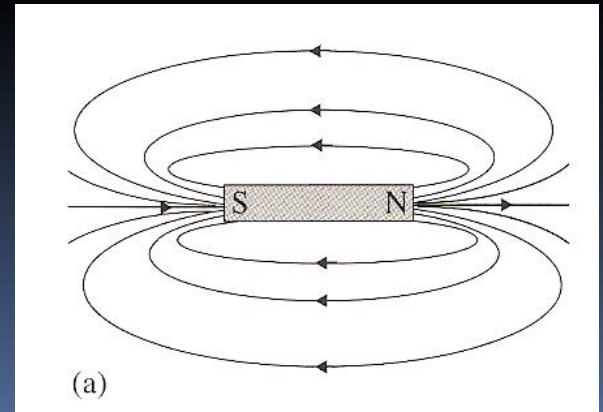
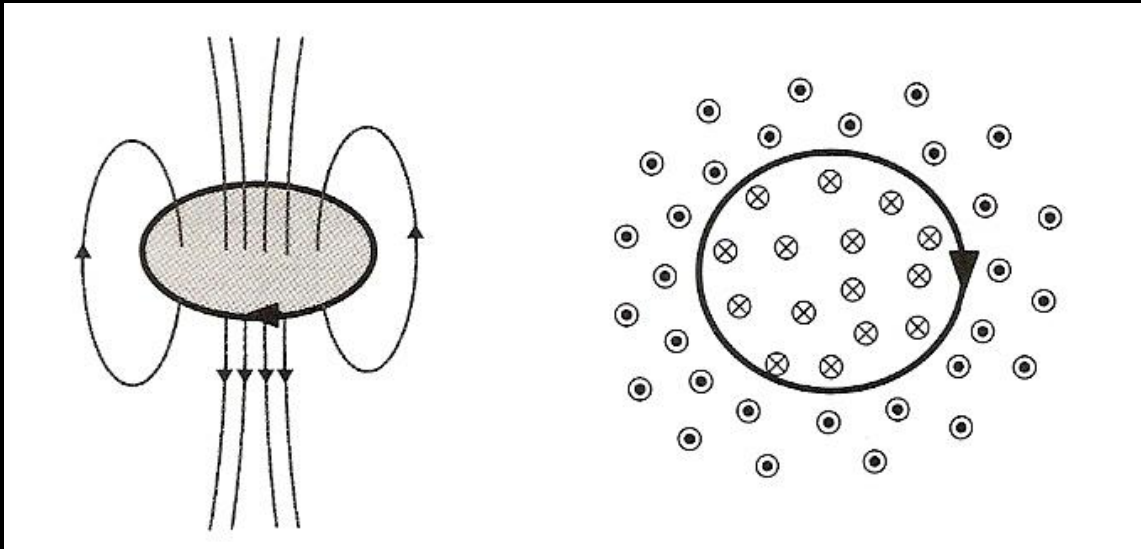


*Most solenoids consist of a ferrous core with a conducting wire wrapped around it.*

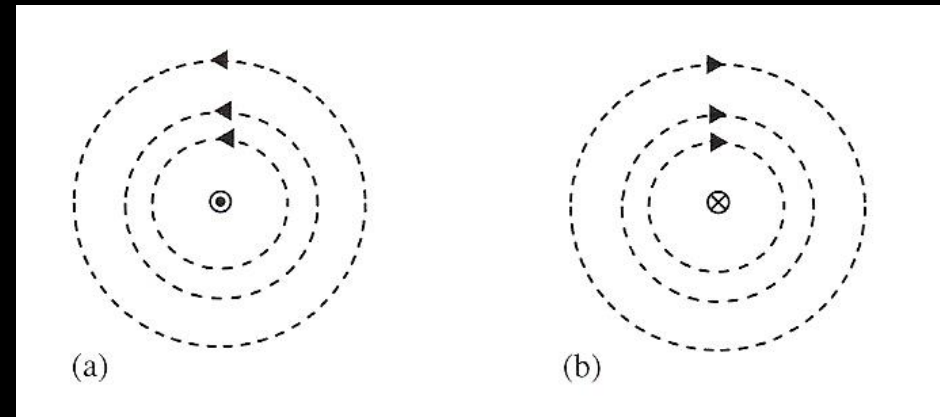
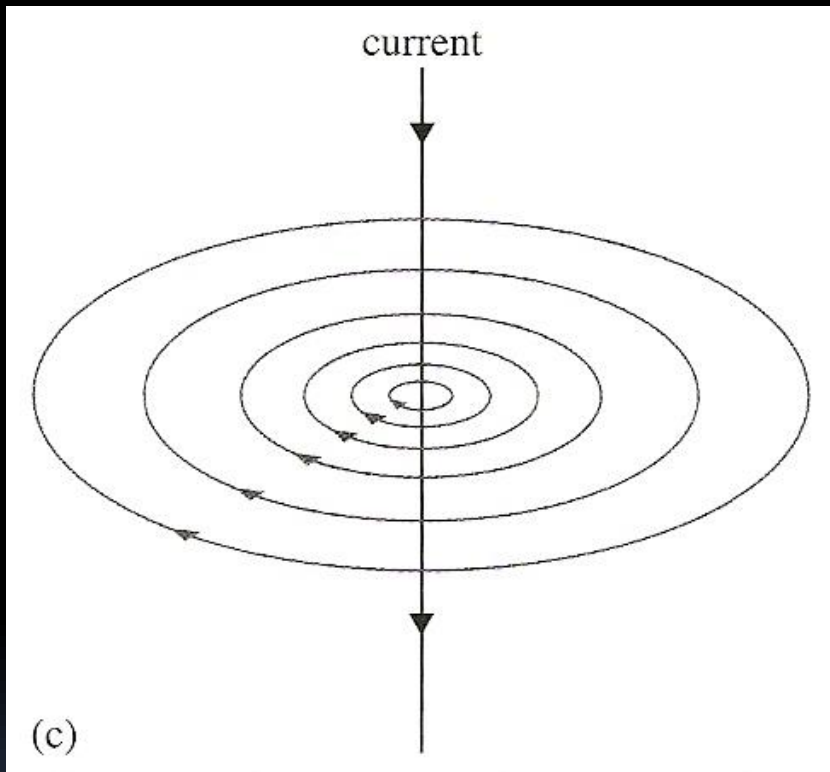
# Magnetic Field from a Loop of Wire



# Magnetic Field from a Loop of Wire



# Magnetic Field from a Straight Wire

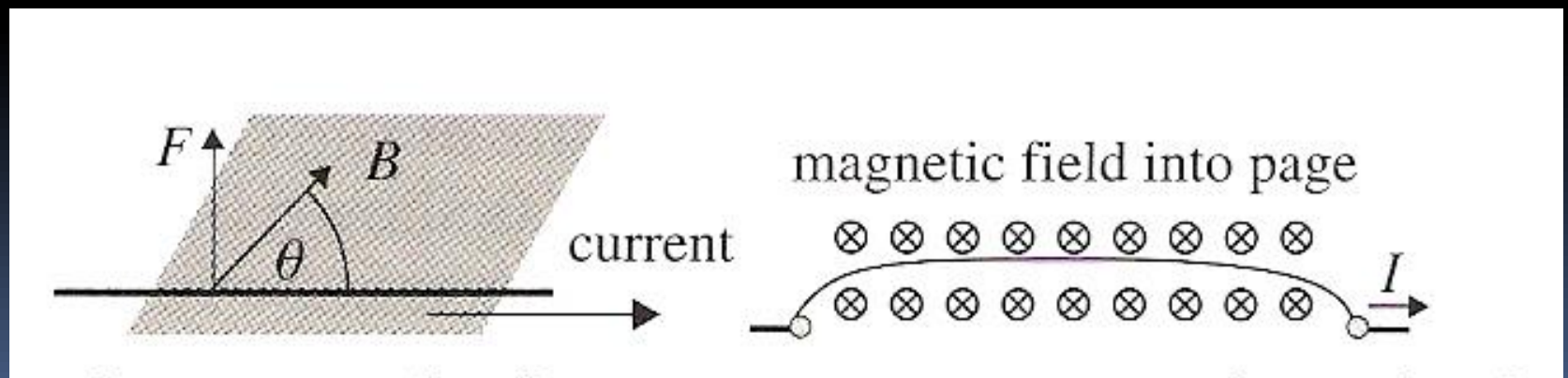
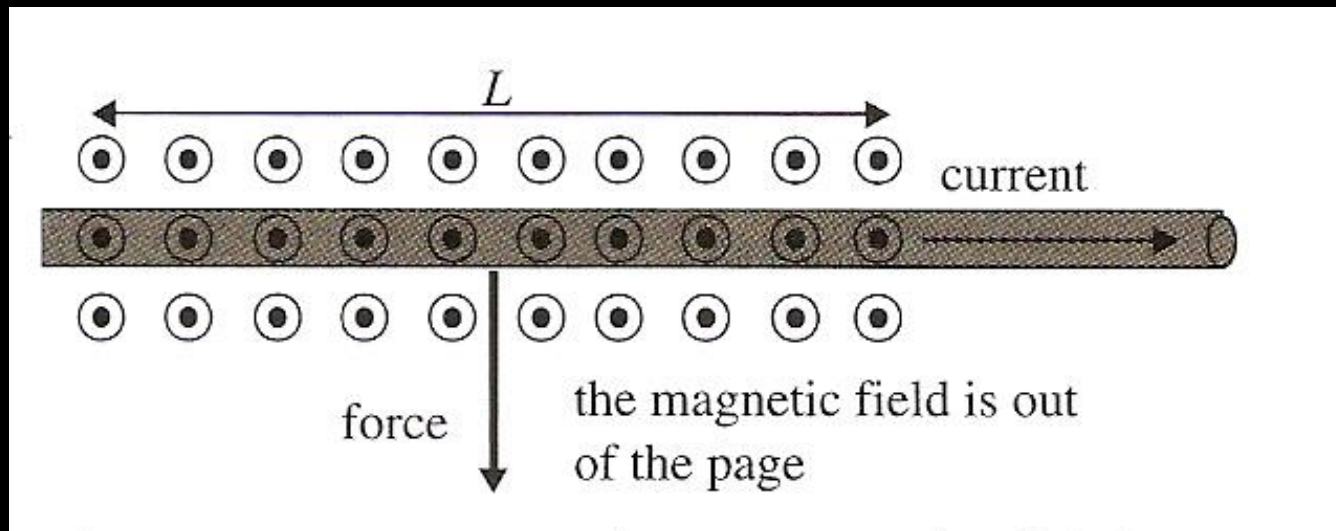


# Electric Field, Magnetic Field

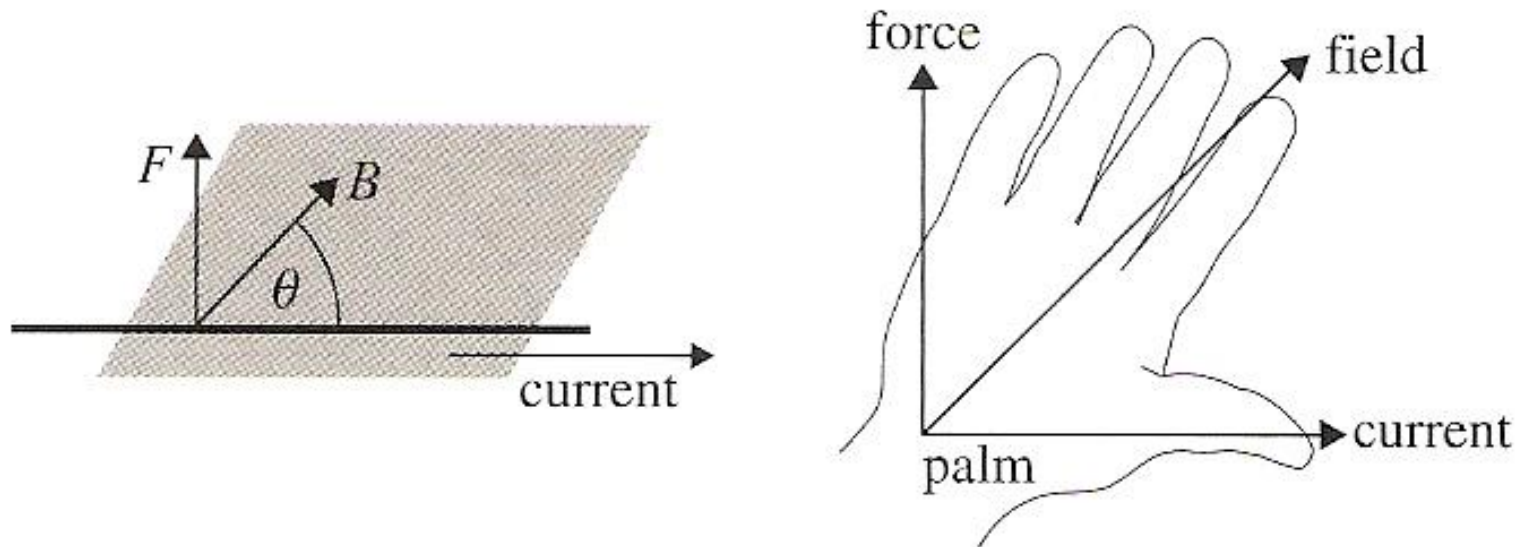
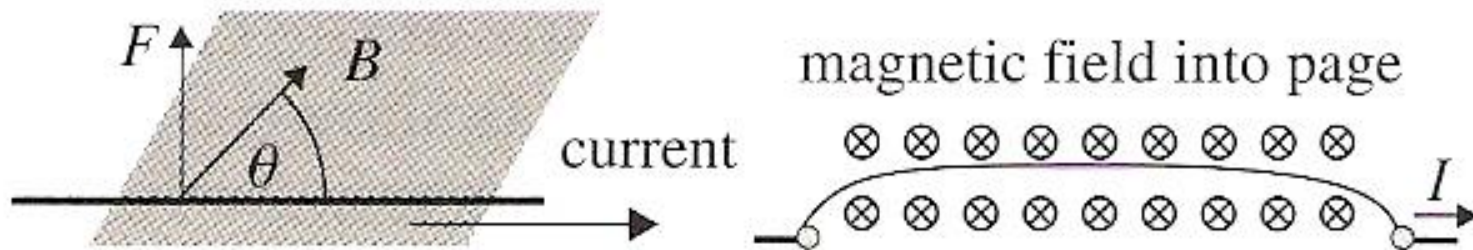
- Magnets and electric currents (moving charges) produce magnetic fields around them
- When another magnet or electric current enters the magnetic field, it will experience a force on it



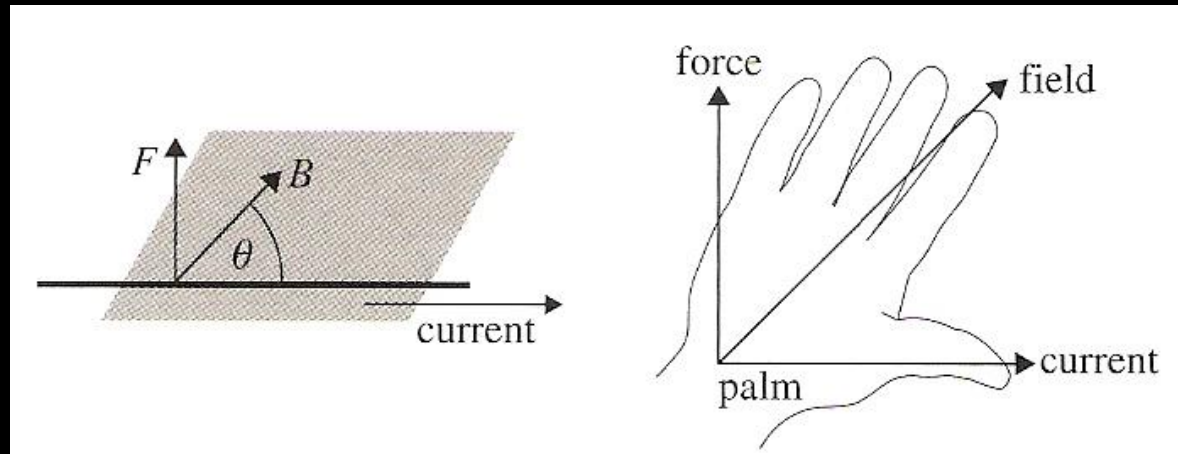
# Force on a Current



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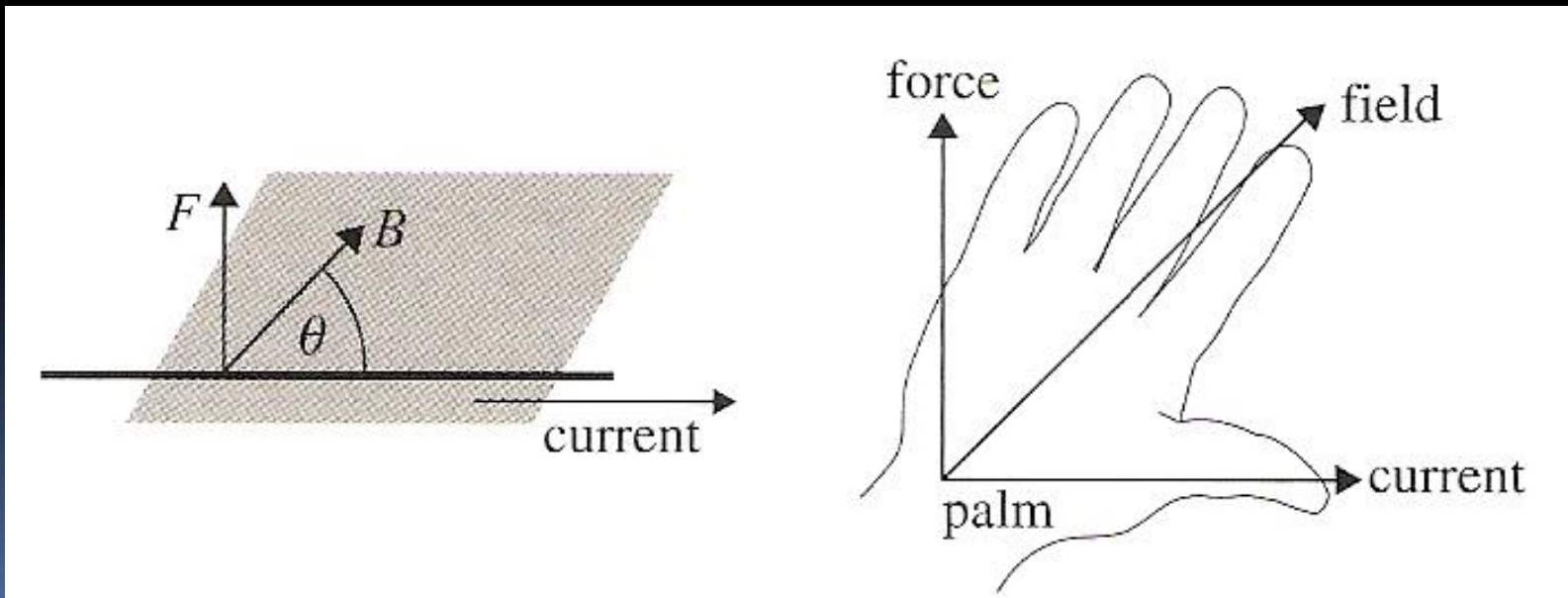
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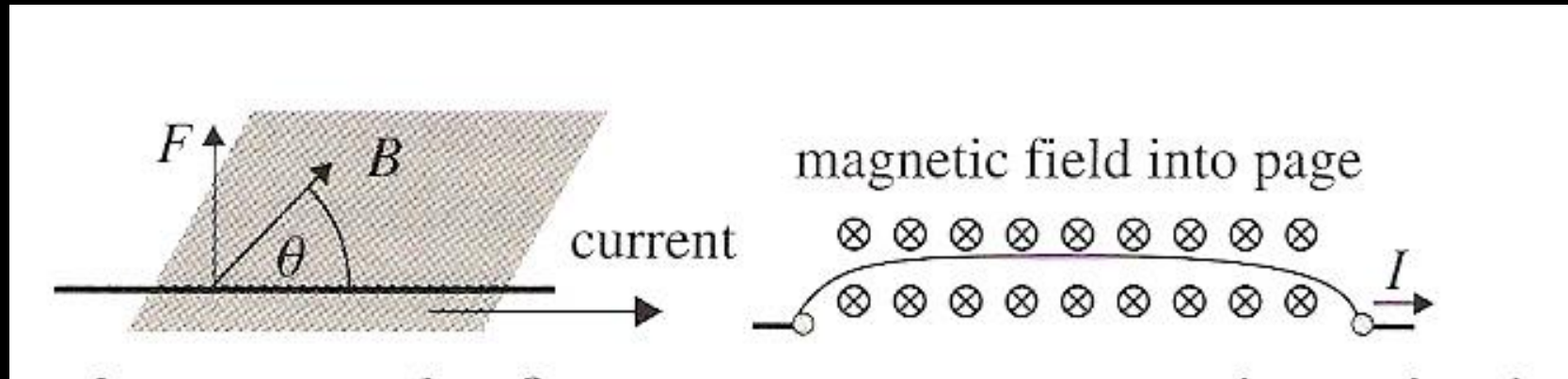
Using the right hand place the thumb in the direction of the current and the fingers in the direction of the magnetic field. The direction the palm is facing is the direction of the resulting force.

# Force on a Current

**Current**  **Thumb**  
**Field**  **Fingers**  
**Force**  **Palm**



# Force on a Length of Wire

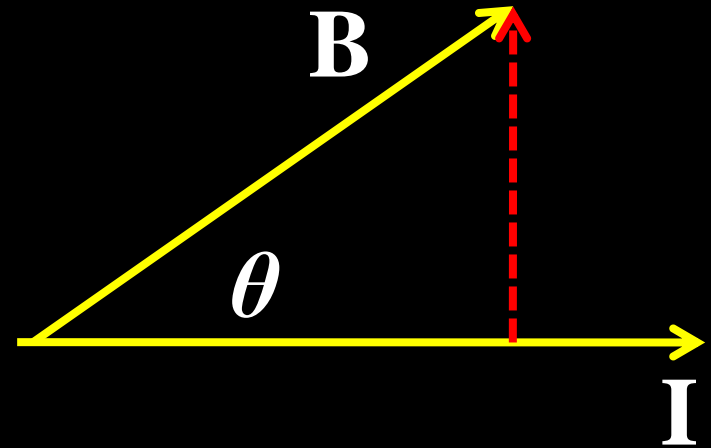


$$F = BIL \sin \theta$$

*$\theta$  is the angle between the current and the direction of the magnetic field. But we are interested in the component of the field perpendicular to the current.*

# Force on a Length of Wire

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*$\theta$  is the angle between the current and the direction of the magnetic field. But we are interested in the component of the field perpendicular to the current.*

# Magnetic Force on a Moving Charge

$$F = BIL \sin \theta$$

$$I = \frac{q}{\Delta t}$$

$$L = v\Delta t$$

$$F = B \frac{q}{\Delta t} v\Delta t \sin \theta$$

$$F = qvB \sin \theta$$

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$$F = BIL \sin \theta$$

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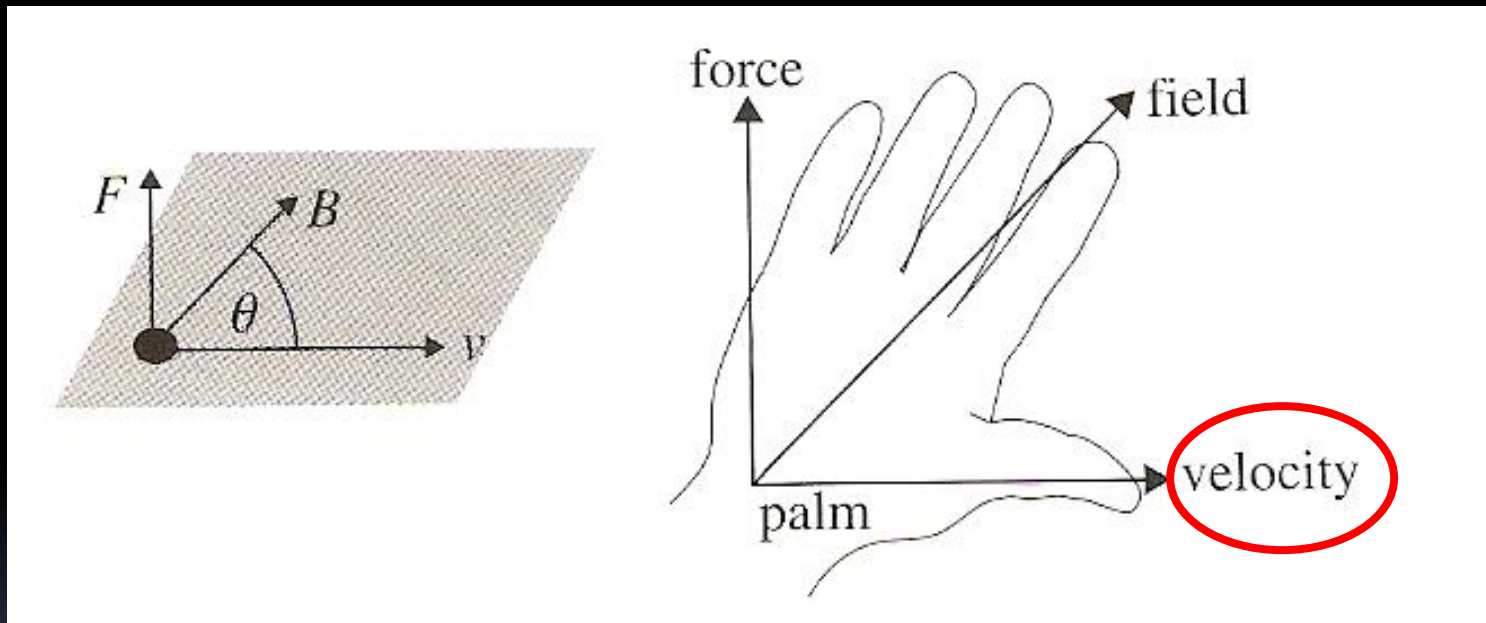
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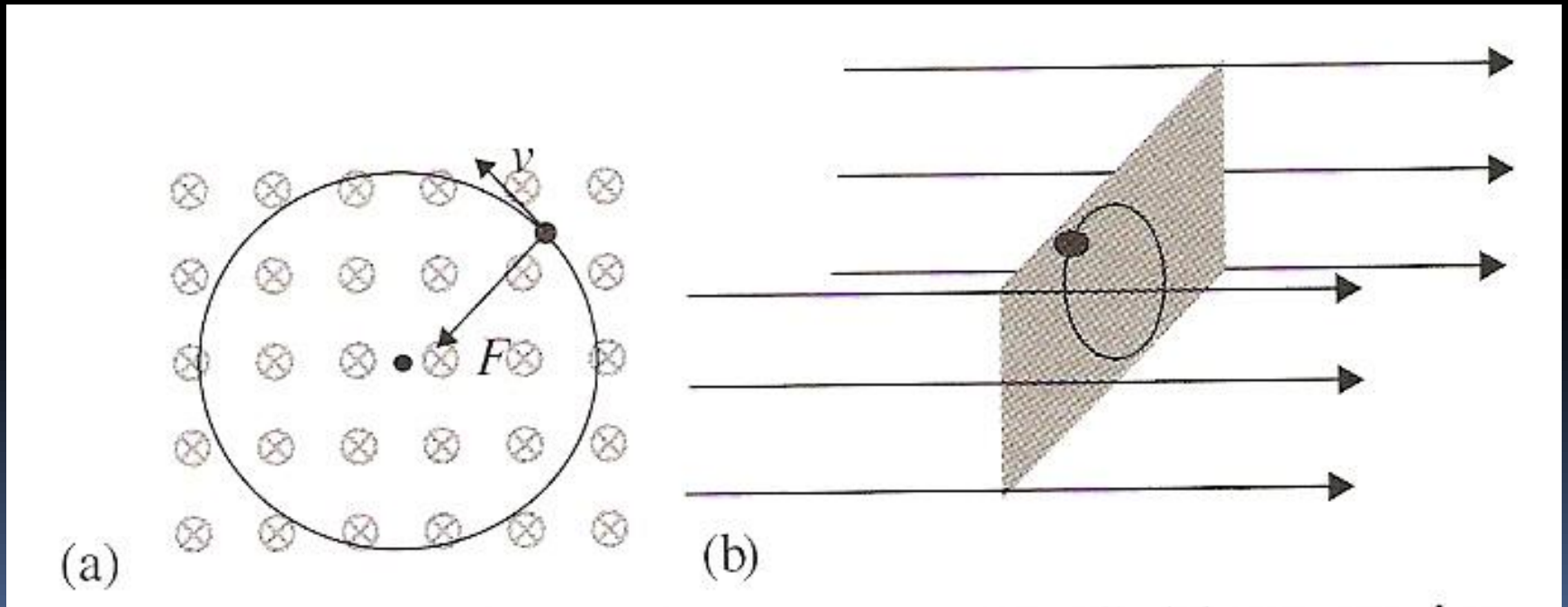
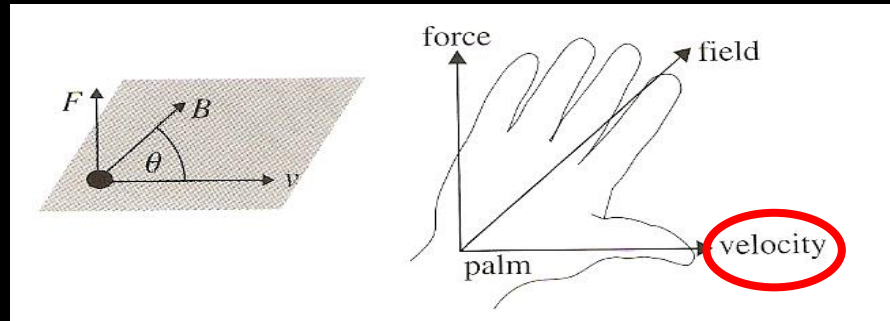
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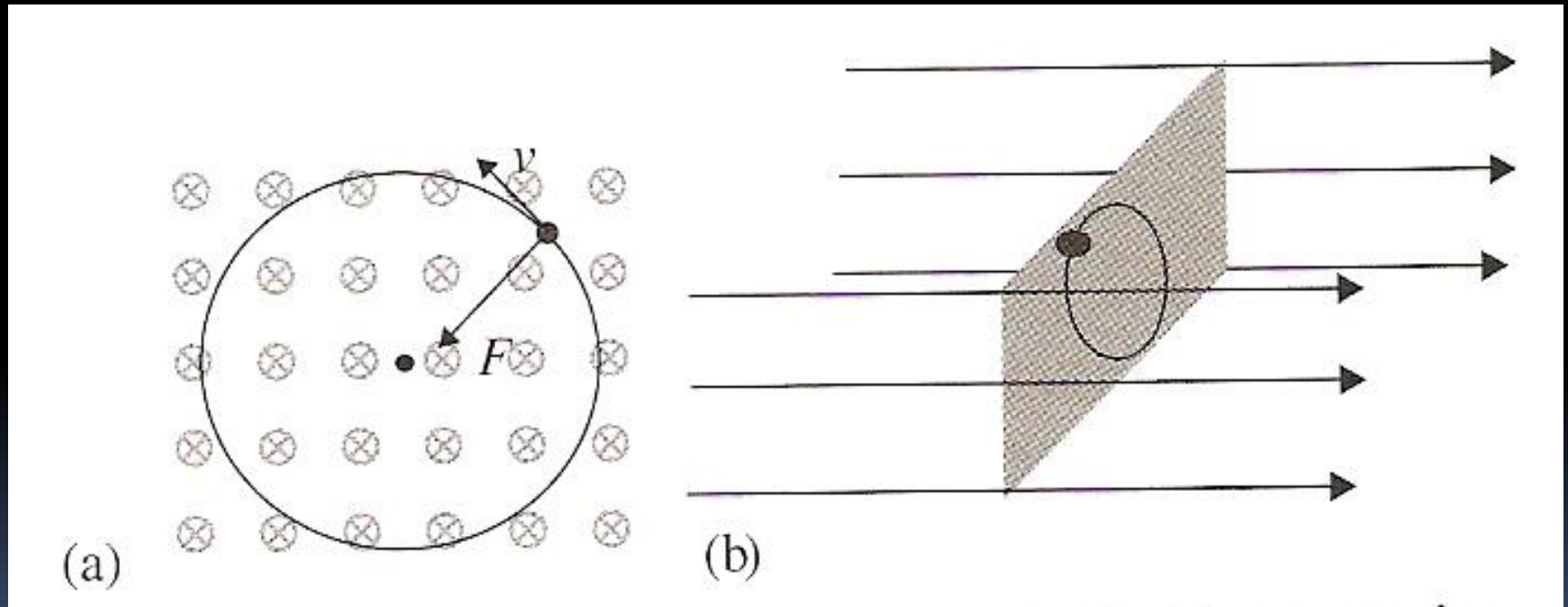


*Current is the movement of charges, so a charge moving with velocity is basically the same thing.*

# Magnetic Force on a Moving Charge



# What is the Work Done by a Magnetic Force?

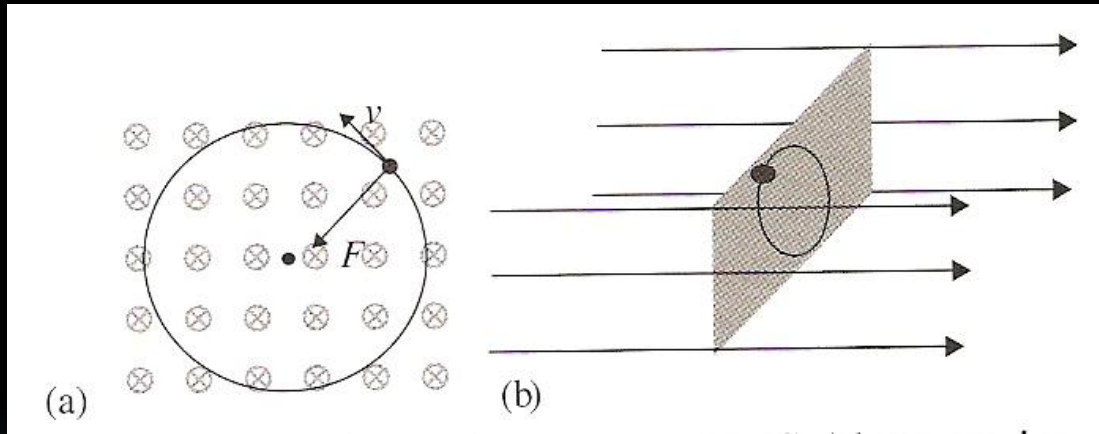


# Work Done by Magnetic Force

- **None**
- Since the magnetic force is always perpendicular to the velocity, it cannot do work
- Magnets in particle accelerators merely deflect or direct particles (no work)
- Electric fields are used to increase the particle's kinetic energy (work done)

# Revisiting Newton's 2<sup>nd</sup> Law

- Circular Motion



$$F = ma$$

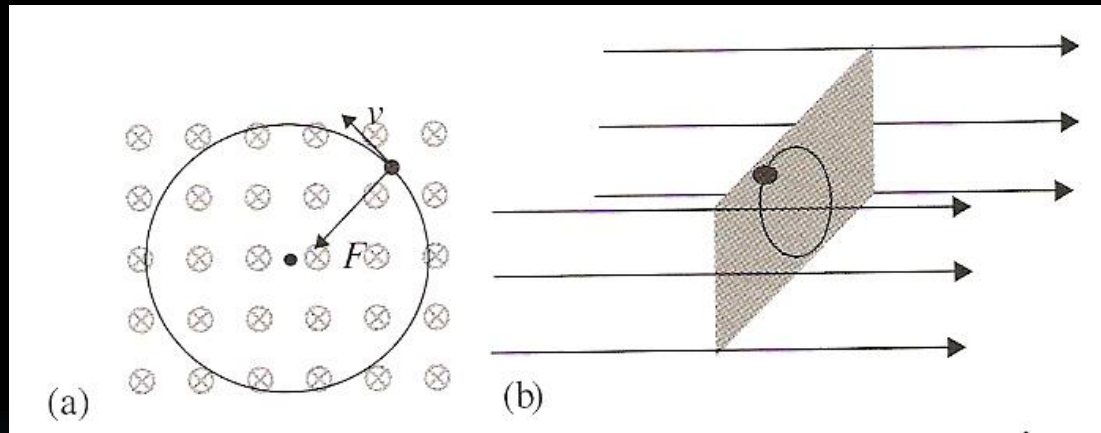
$$F = qvB$$

$$qvB = m \frac{v^2}{R}$$

$$R = \frac{mv^2}{qvB} = \frac{mv}{qB}$$

# Revisiting Newton's 2<sup>nd</sup> Law

- Circular Motion



$$qvB = m \frac{v^2}{R}$$

$$R = \frac{mv}{qB}$$

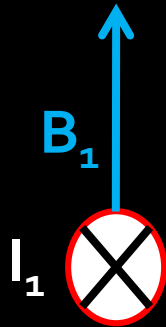
$$T = \frac{2\pi R}{v}$$

$$T = \frac{2\pi}{v} \frac{mv}{qB}$$

$$T = \frac{2\pi m}{qB}$$

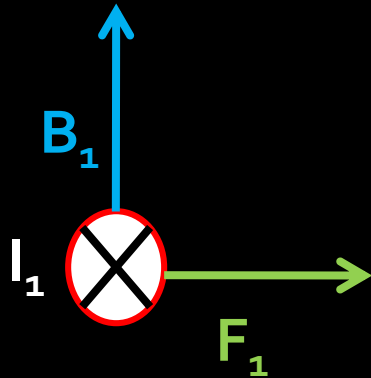
# Force Between Two Current-Carrying Wires

- *What is the direction of the magnetic force?*



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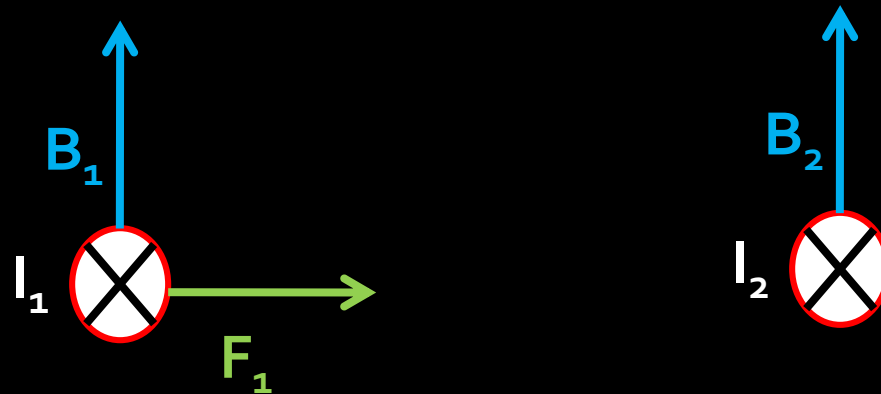
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# Force Between Two Current-Carrying Wires

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- *How will the wires bend?*

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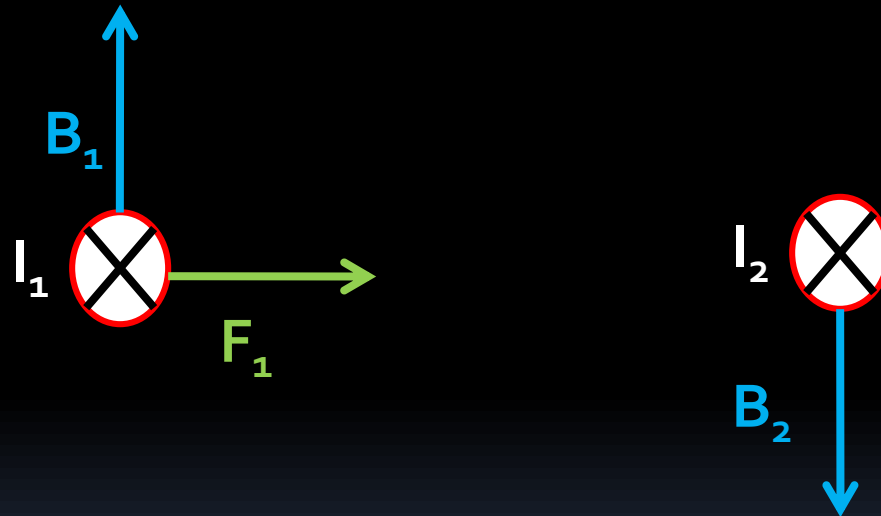


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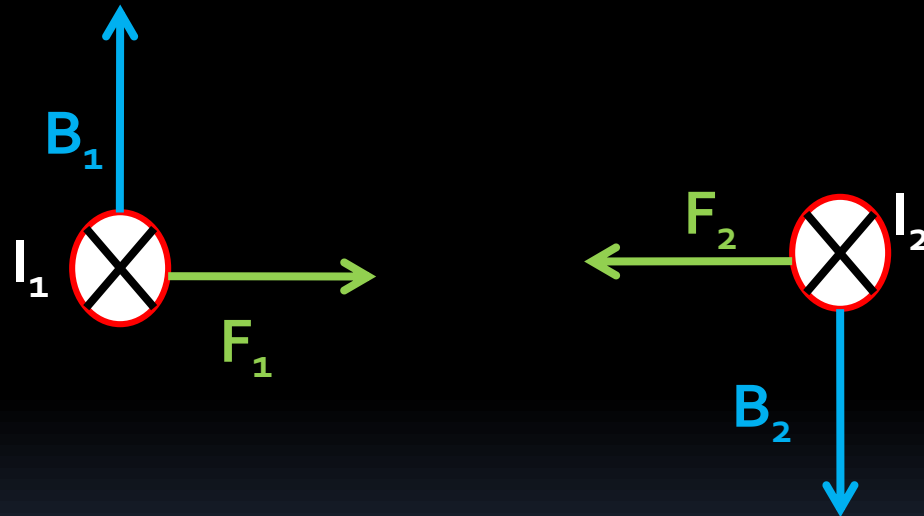
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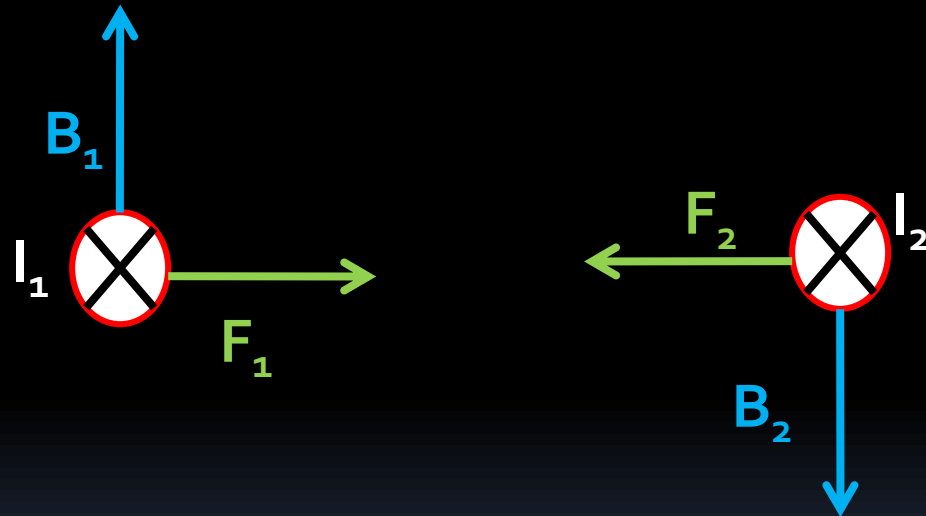
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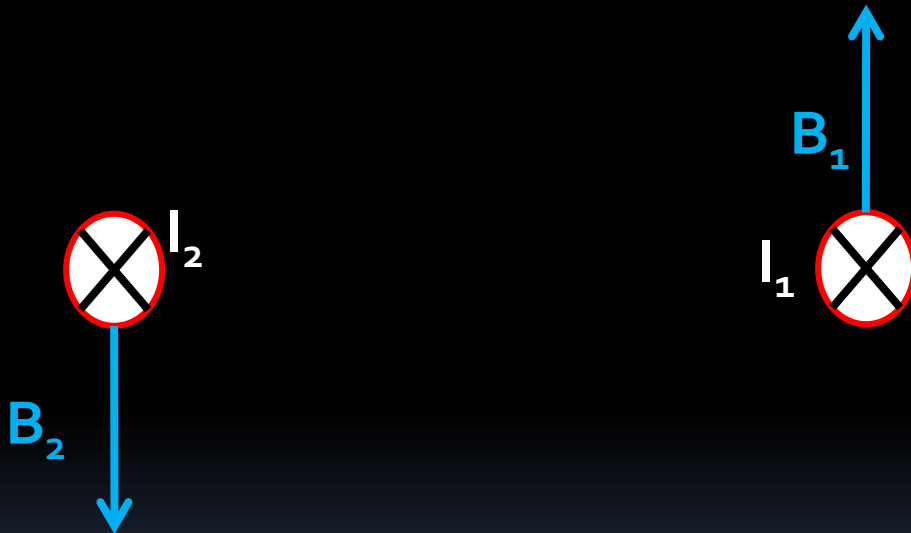


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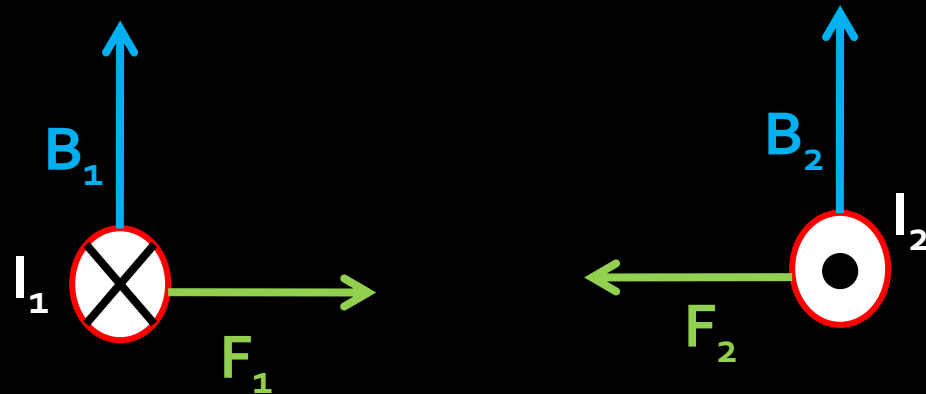
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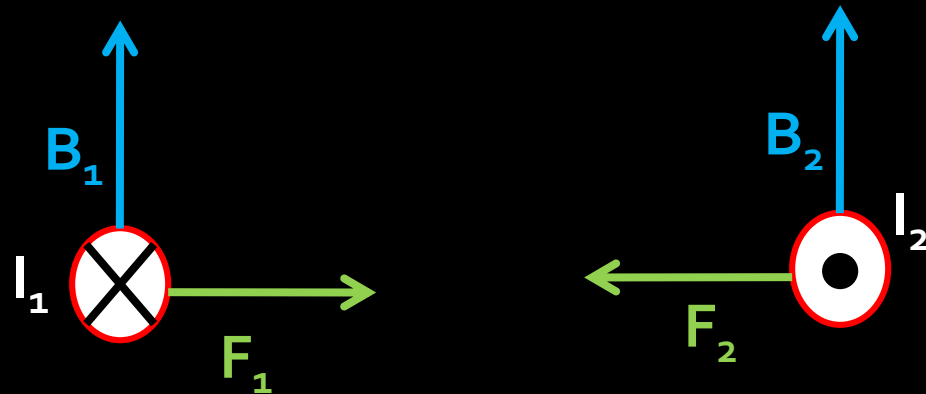
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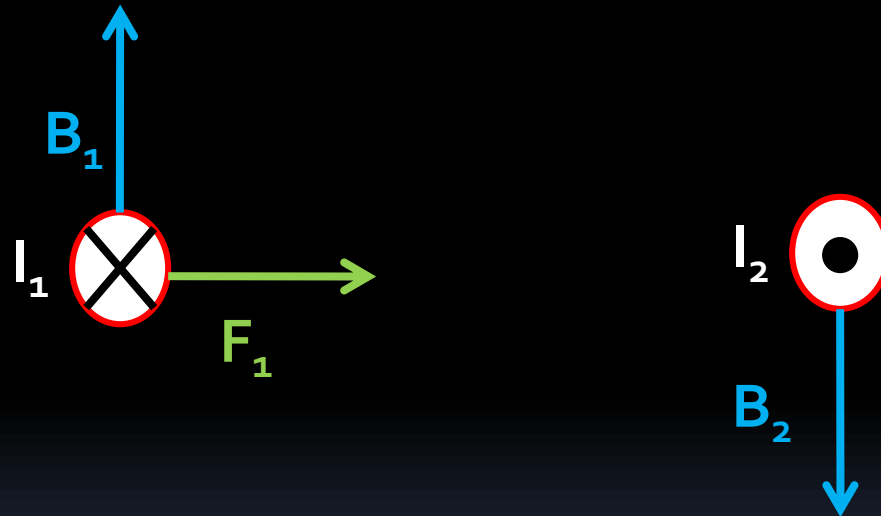


- How will the wires bend?



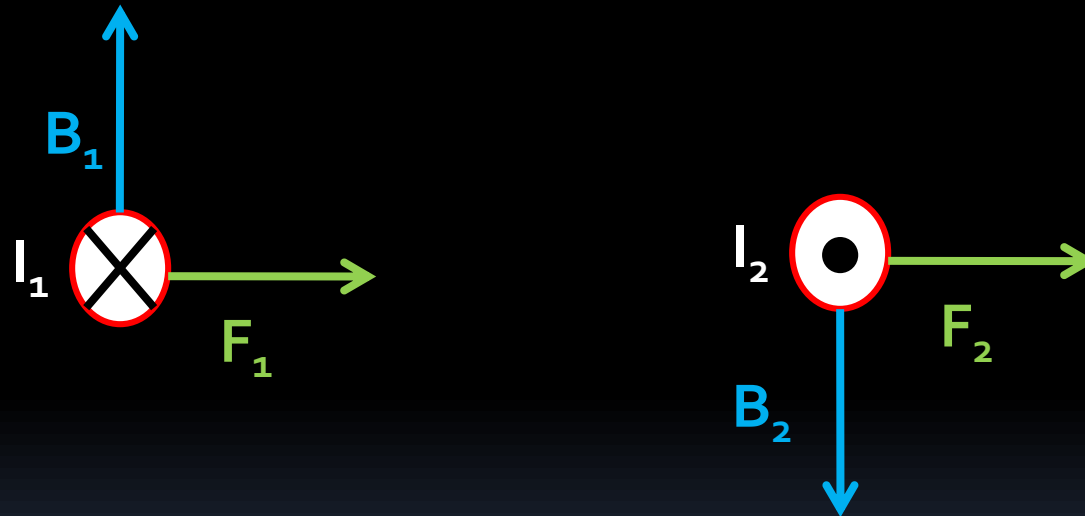
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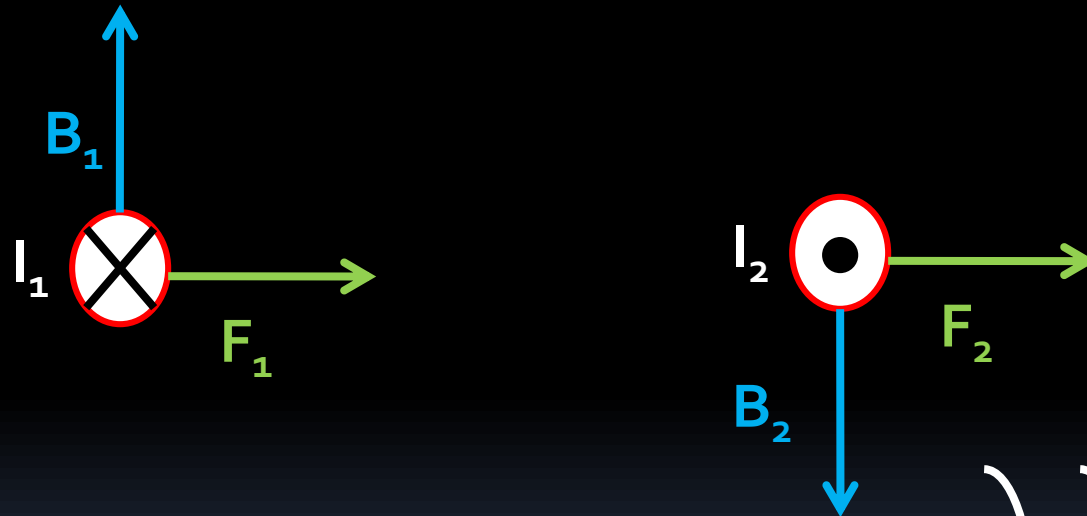
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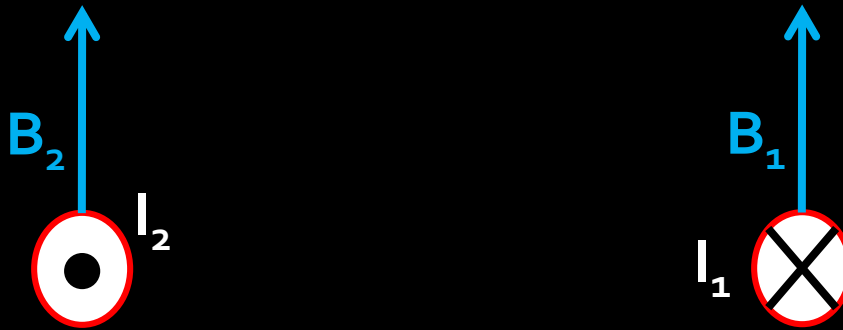


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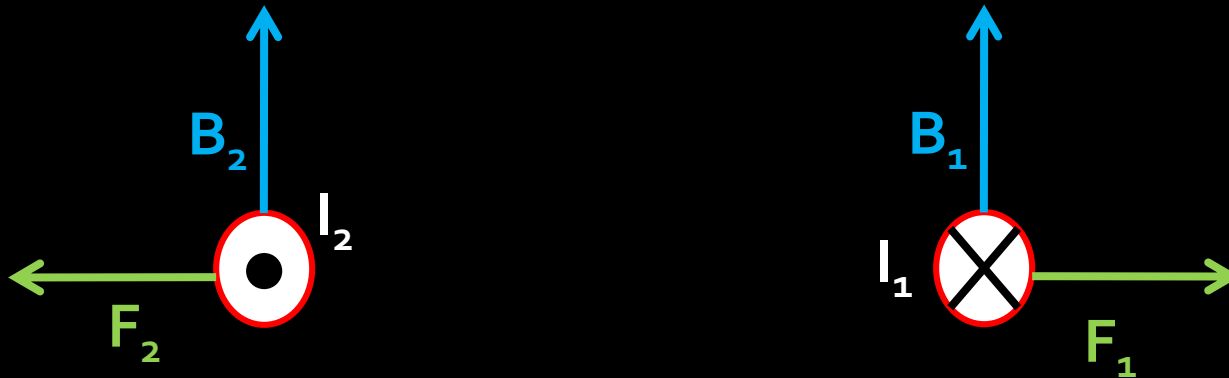
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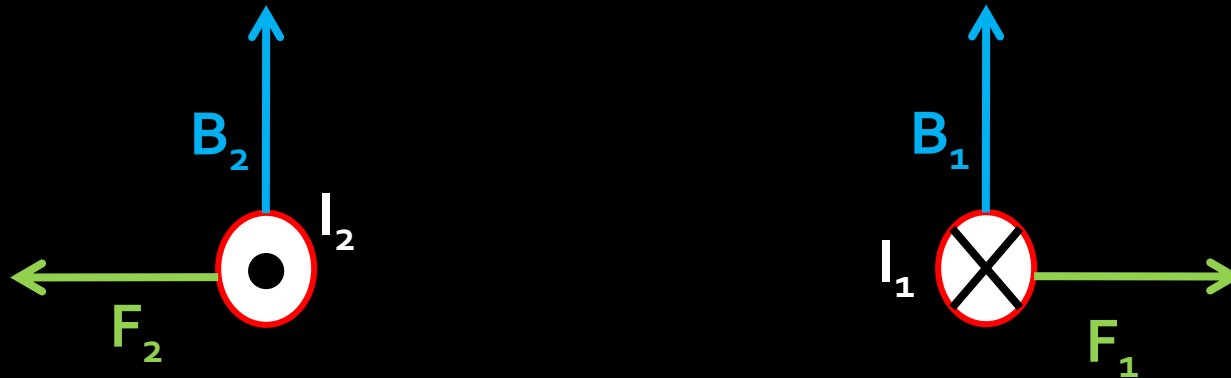
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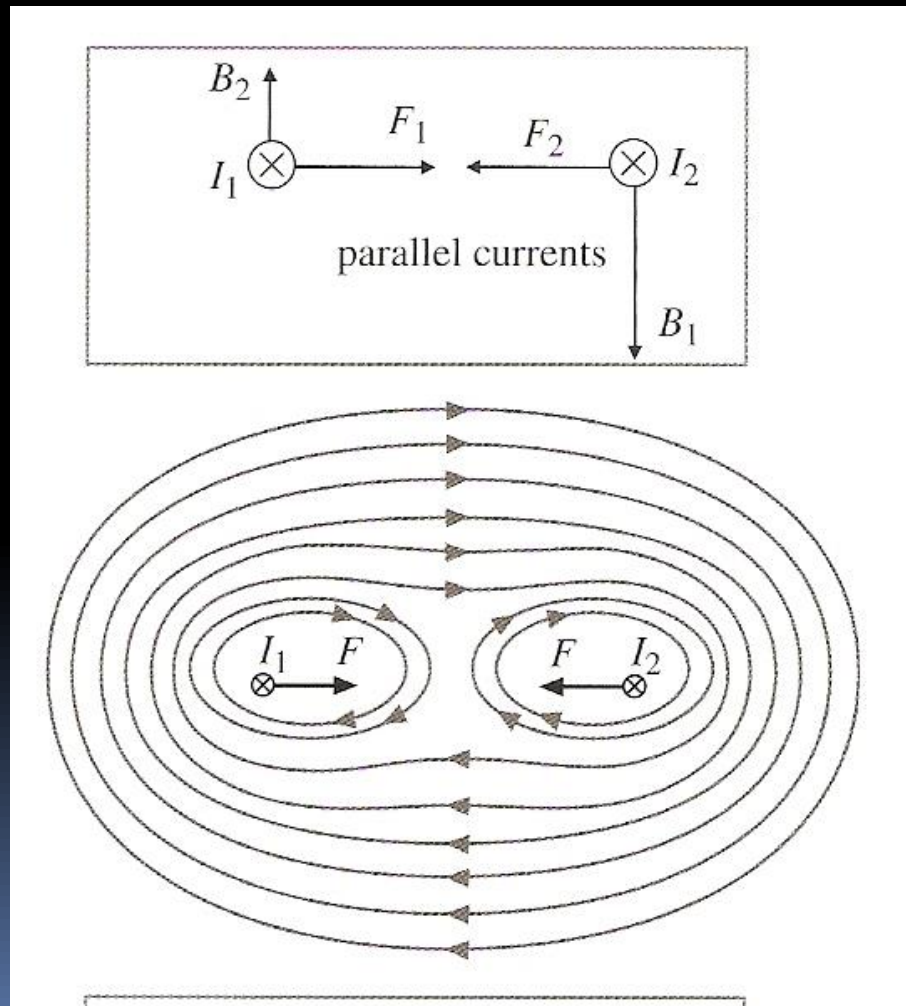
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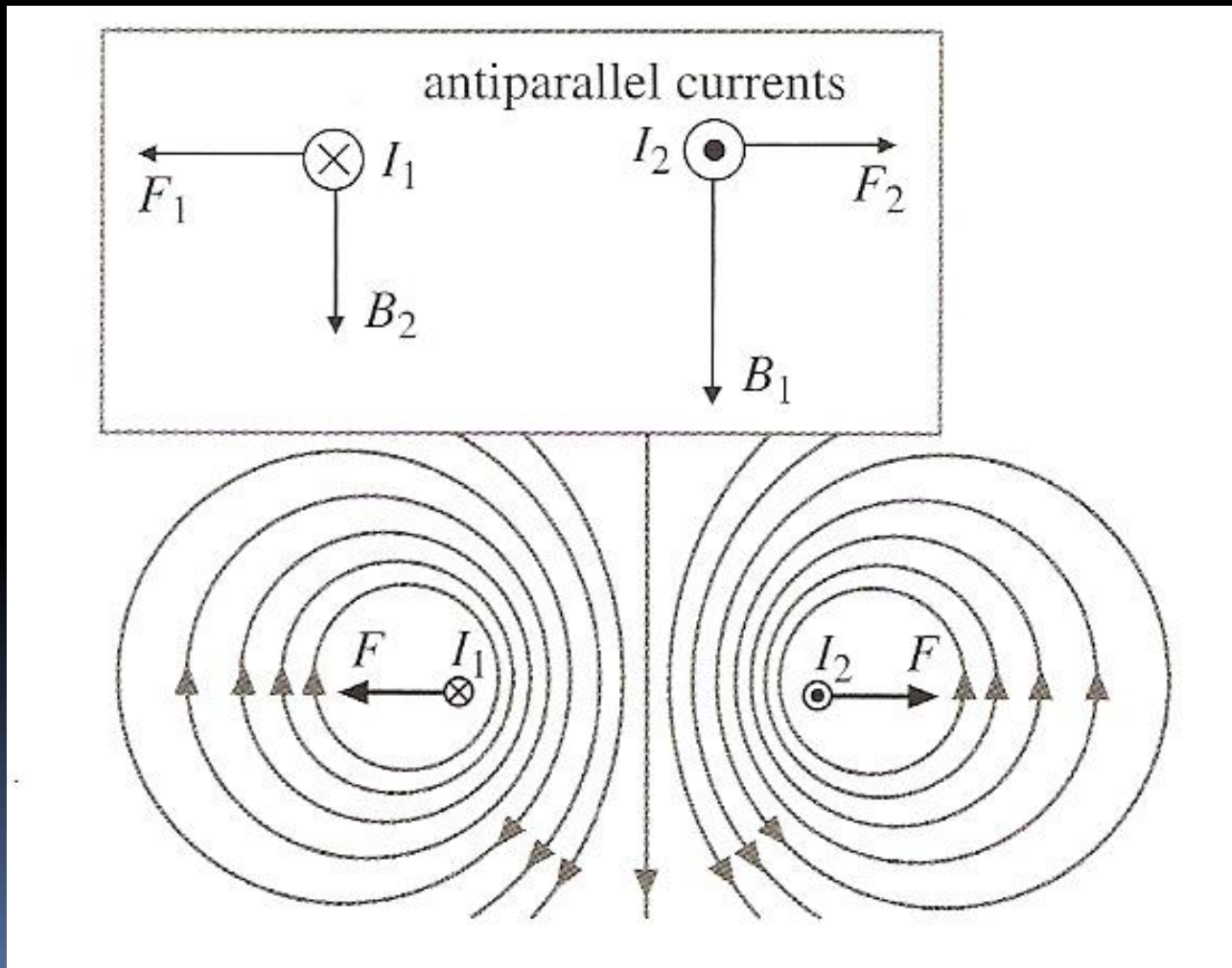
- *How will the wires bend?*



# Force Between Two Current-Carrying Wires



# Force Between Two Current-Carrying Wires



# Field Strength Between Two Current-Carrying Wires

- The net force on each wire will be the same, even though the magnetic fields produced by each wire individually is different

$$F = k \frac{q_1 q_2}{r}$$

$$F = G \frac{m_1 m_2}{r}$$

# What This All Can Lead To

## Fun Facts:

- **The Ampere is defined through the magnetic force between two parallel wires. If the force on a 1m length of two wires that are 1m apart and carrying equal currents is  $2 \times 10^{-7}$  N, then the current in each wire is defined to be 1 A.**

## Fun Facts:

- **The coulomb is defined in terms of the ampere as the amount of charge that flows past a certain point in a wire when a current of 1 A flows for 1 second.**



# Understandings:

- Magnetic fields
- Magnetic force

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# Applications And Skills:

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# Essential Idea:

- The effect scientists call magnetism arises when one charge moves in the vicinity of another moving charge.



QUESTIONS?

# Homework

#37-46