

# Chapter 27

## Current In A Magnetic Field

# FORCE

There is a force on a CCC in a Magnetic Field

on a current carrying conductor

in a magnetic field

Demo

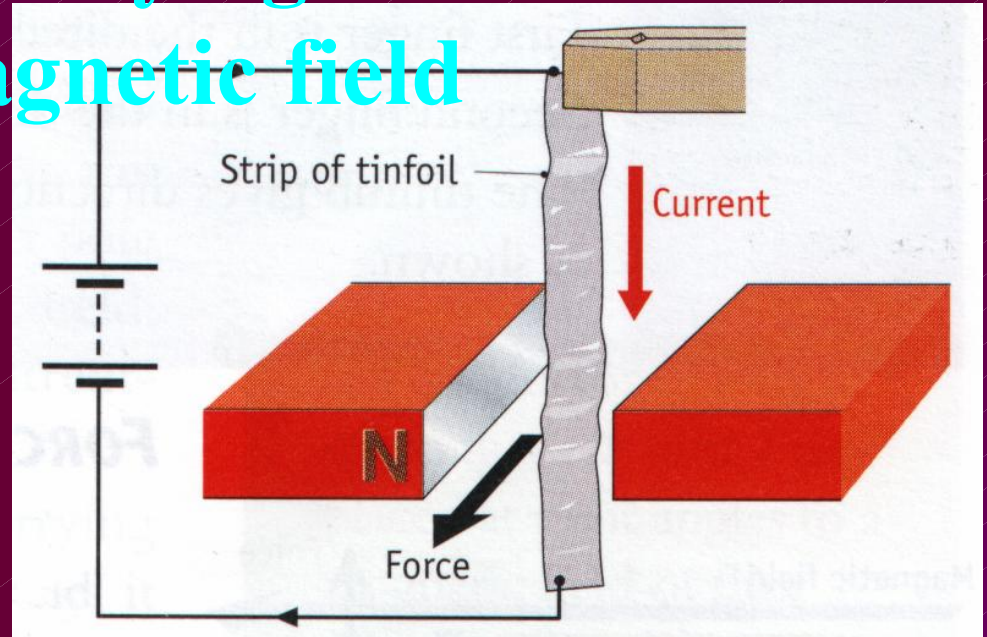
Apparatus

Procedure

Observation

Conclusion

Switch ..



# Force on a CCC in a Magnetic Field

## Basic Principle In

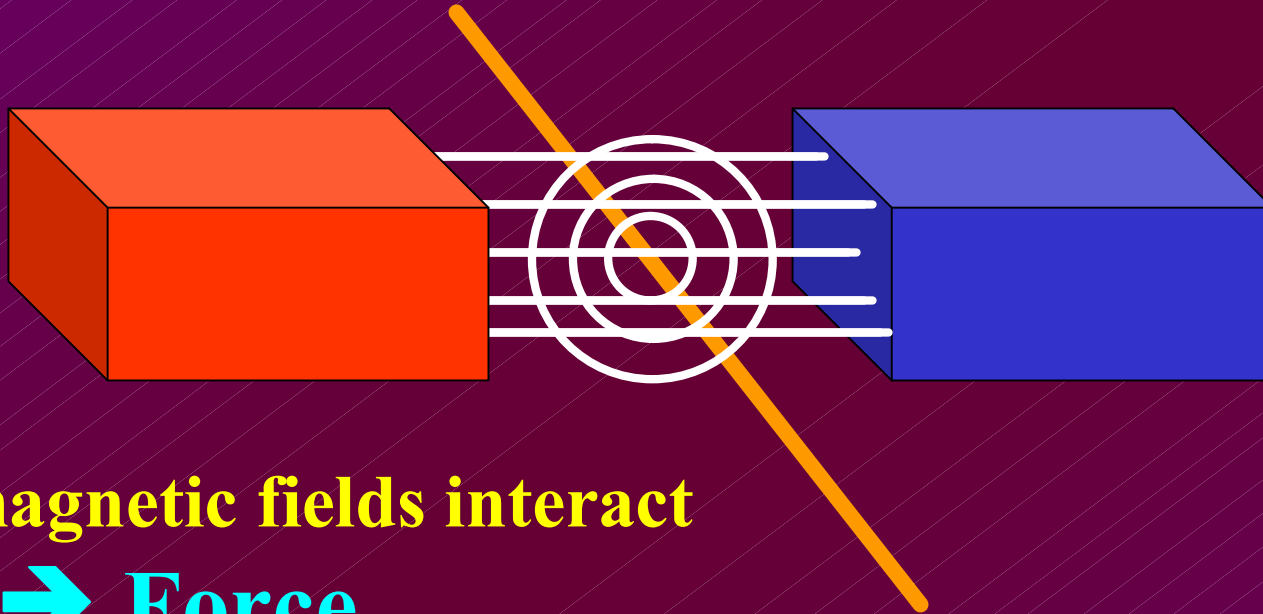
- **D.c. electric motor**
- **Moving coil loudspeaker**
- **Moving coil meters**

# Why Is There A Force?

- **2 Magnetic Fields**
  - ... around magnet
  - ... around the current (in the conductor)
- **Interaction between these fields**
- **2 forces**
  - ... force by magnet on the CCC
  - ... force by CCC on magnet

Compare ... 2 magnets

# Why Is There A Force?

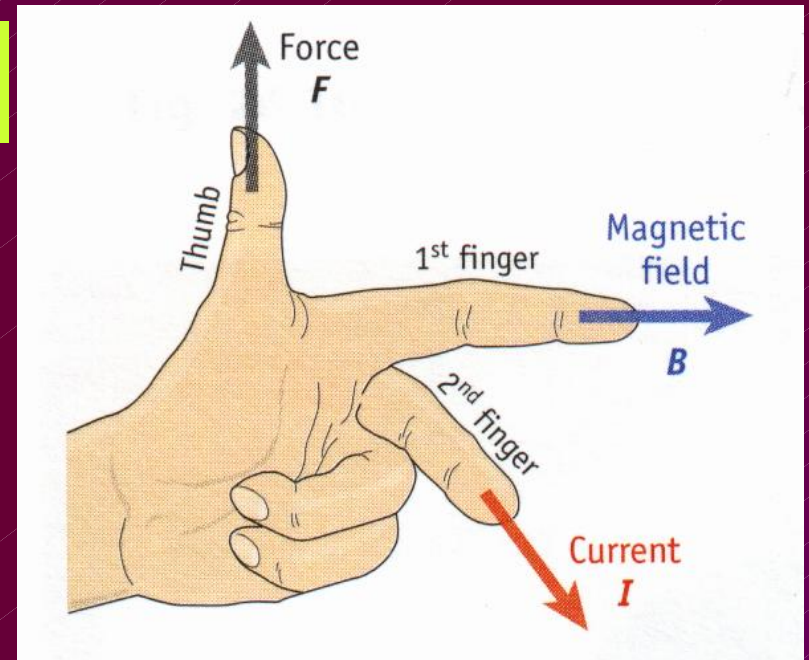
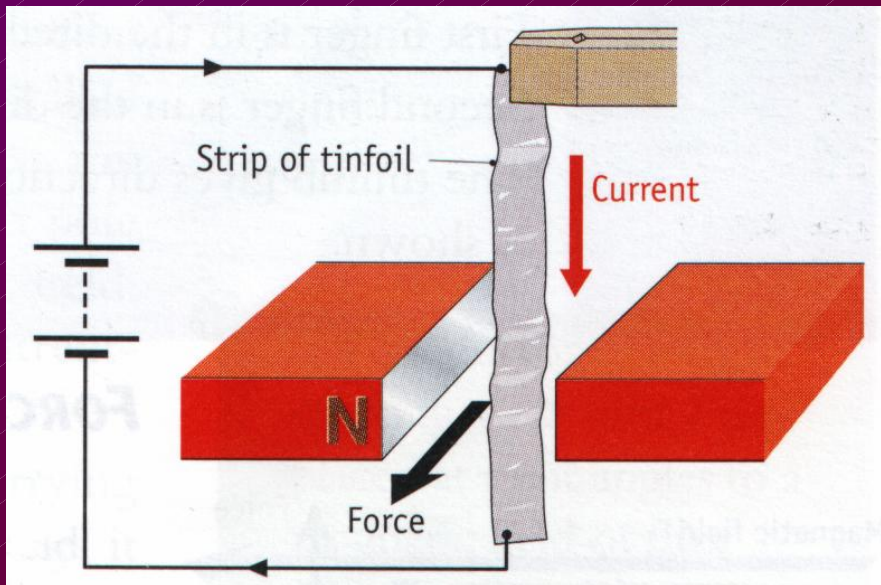


The magnetic fields interact

→ Force

# The Direction Of The Force

## Fleming's Left-Hand Rule



# FBI

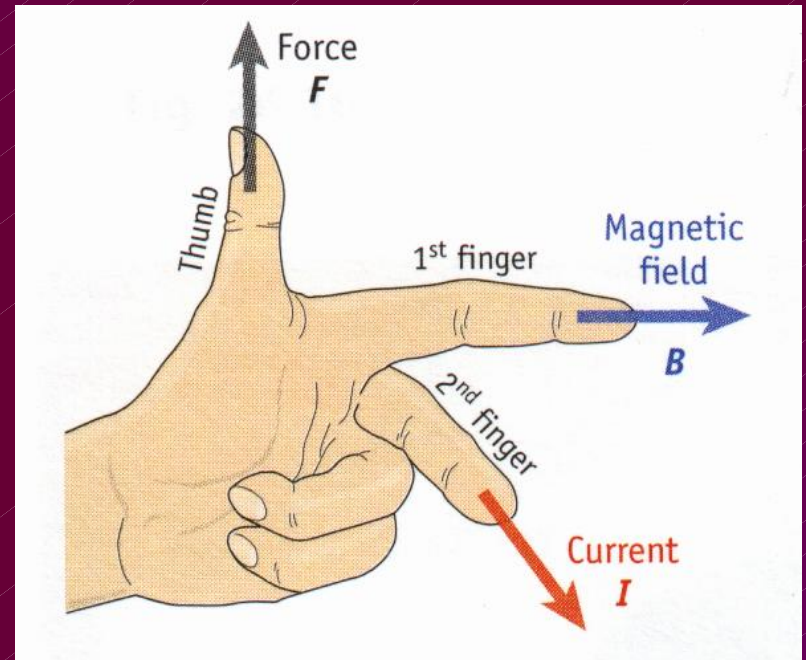
# The Direction Of The Force

## Fleming's Left-Hand Rule

**$F$  is always perpendicular**

- to the current
- to the magnetic field

If current is parallel to magnetic field ...  **$F = 0$**



# FBI

# The Magnitude Of The Force

$F$  depends on

$$F = IlB$$

➤ Current ( $I$ )

$$F \propto I$$

➤ Length of the conductor ( $l$ )

$$F \propto l$$

➤ Strength of the magnetic field ( $B$ )

$$F \propto B$$

$B$  = Magnetic flux density

# Magnetic Flux Density

$$F = IlB \rightarrow$$

$$B = \frac{F}{Il}$$

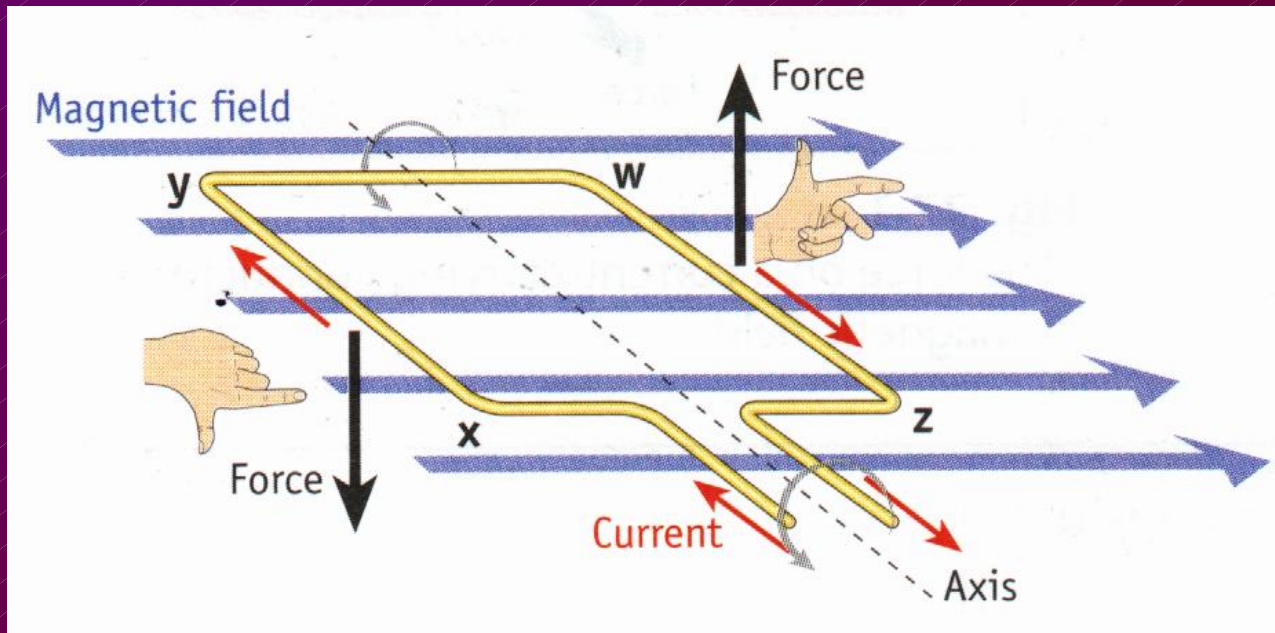
Symbols = ??

Units      Tesla (T)

1 T = ??

*B* is a vector

# Forces On A Current-Carrying **Coil** In A Magnetic Field



**Couple**

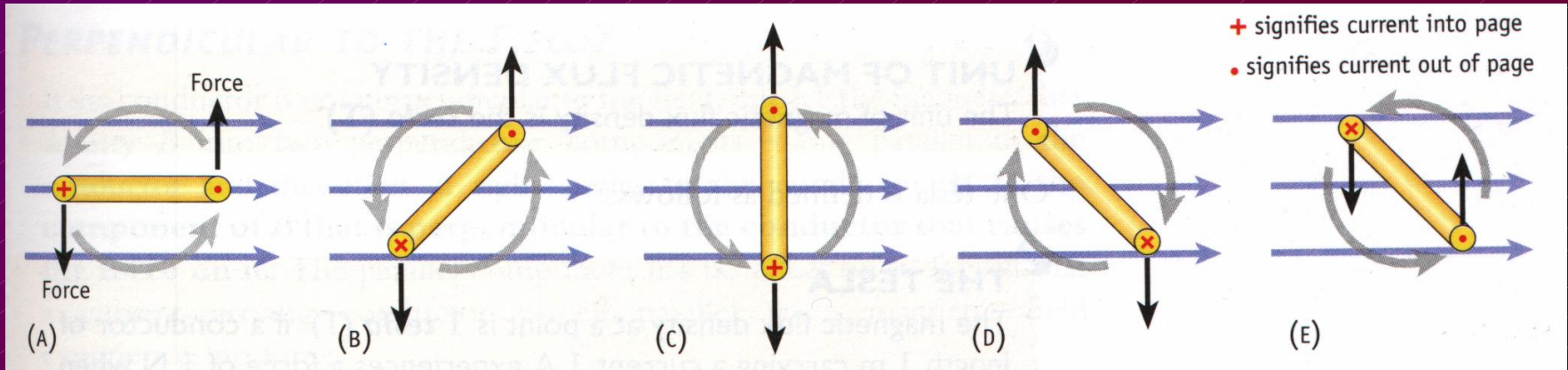
**Torque**

**Coil rotates**

**D.C. Electric Motor**

**Moving Coil Meters**

# Forces On A Current-Carrying Coil In A Magnetic Field

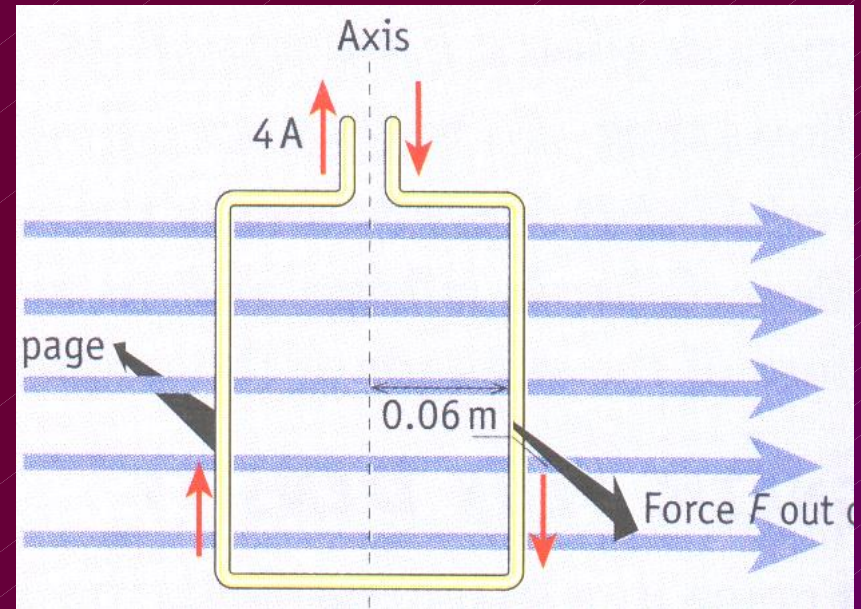
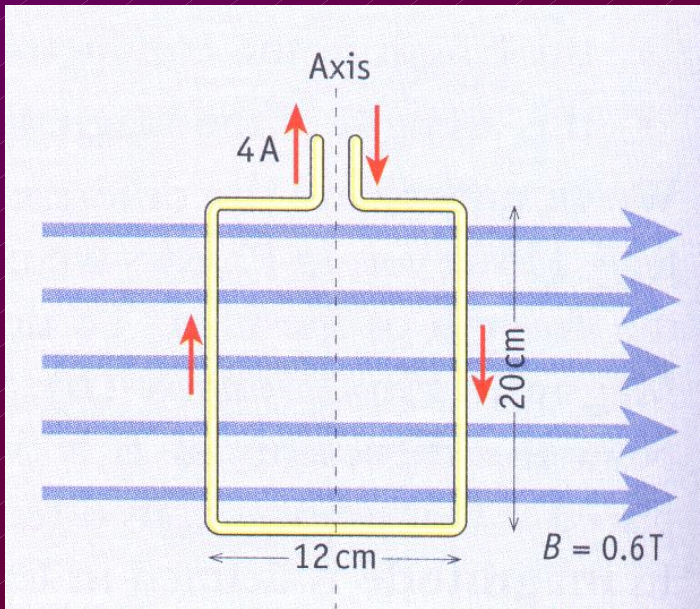


**Problem 2** Calculate the force acting on a conductor of length 40 cm which is carrying a current of 3 A and which is placed perpendicular to a uniform magnetic field of flux density 5.2 T.

$$F = I l B$$

$$= (3)(0.40)(5.2) = 6.24 \text{ N}$$

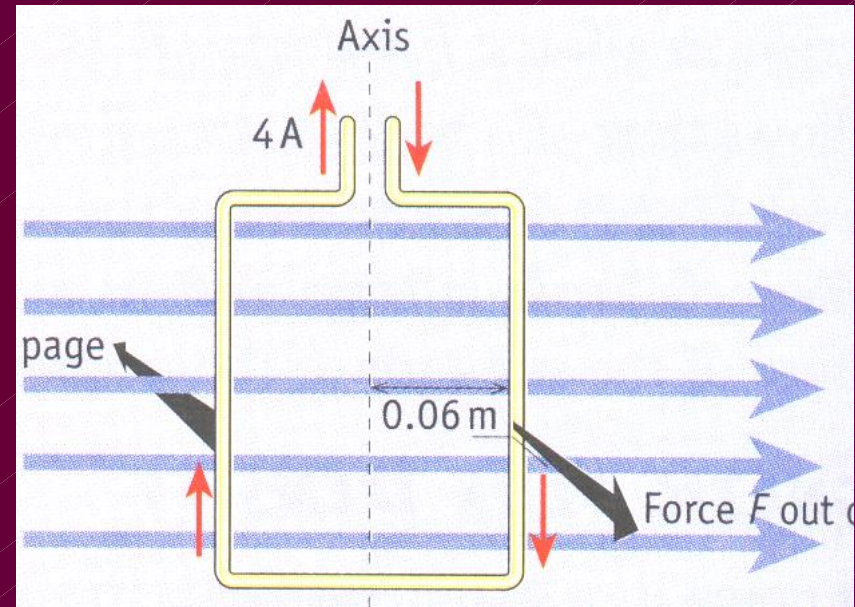
**Problem 3** The rectangular loop of wire is free to rotate about the axis shown. The plane of the loop is parallel to a uniform magnetic field of flux density  $0.6\text{ T}$ . A current of  $4\text{ A}$  flows in the coil and its dimensions are  $20\text{ cm} \times 12\text{ cm}$ . Draw a diagram showing the directions of the forces on the  $20\text{ cm}$  sides.



**Problem 3** The rectangular loop of wire is free to rotate about the axis shown. The plane of the loop is parallel to a uniform magnetic field of flux density 0.6 T. A current of 4 A flows in the coil and its dimensions are 20 cm x 12 cm. Draw a diagram showing the directions of the forces on the 20 cm sides.

What is the magnitude of the force on one of the 20 cm sides?

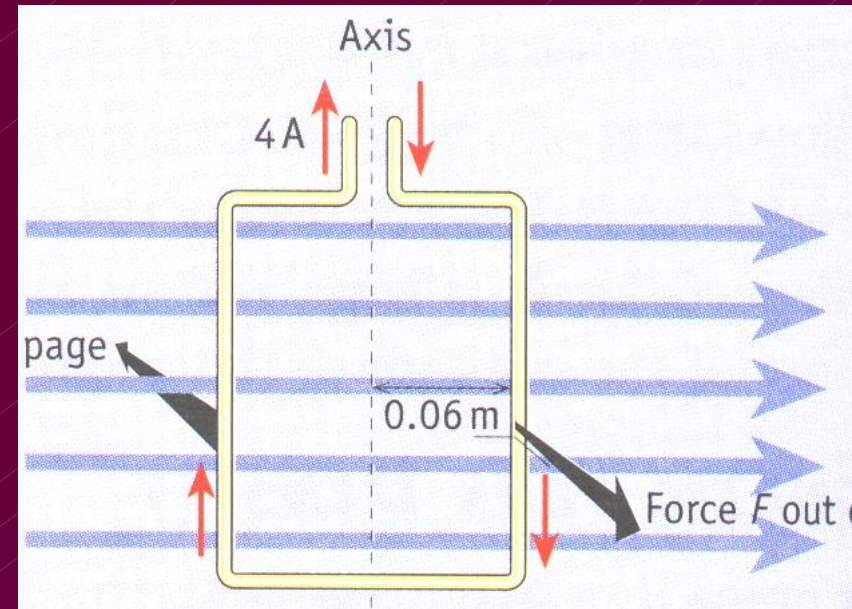
$$\begin{aligned} F &= I l B \\ &= (4)(0.20)(0.6) \\ &= 0.48 \text{ N} \end{aligned}$$



**Problem 3** The rectangular loop of wire is free to rotate about the axis shown. The plane of the loop is parallel to a uniform magnetic field of flux density  $0.6 \text{ T}$ . A current of  $4 \text{ A}$  flows in the coil and its dimensions are  $20 \text{ cm} \times 12 \text{ cm}$ . Draw a diagram showing the directions of the forces on the  $20 \text{ cm}$  sides.

Find the moment of this force about the axis.

$$\begin{aligned} \text{Moment} &= \text{force} \times \text{perp. distance} \\ &= 0.48 \times 0.06 \\ &= 0.0288 \text{ N m} \end{aligned}$$

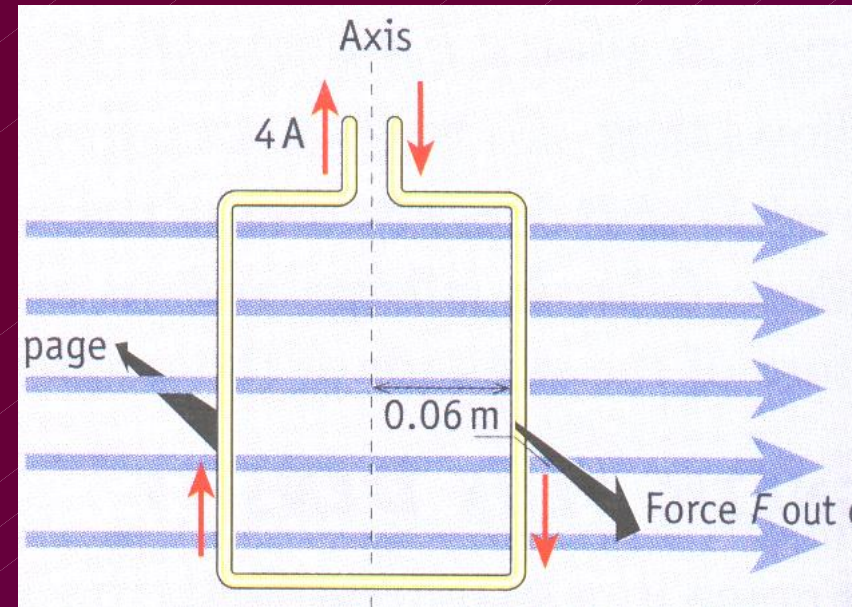


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Why does the moment of this force decrease as the coil rotates?

The perp. distance between the force and the axis decreases

(while  $F$ 's stay in the same direction)



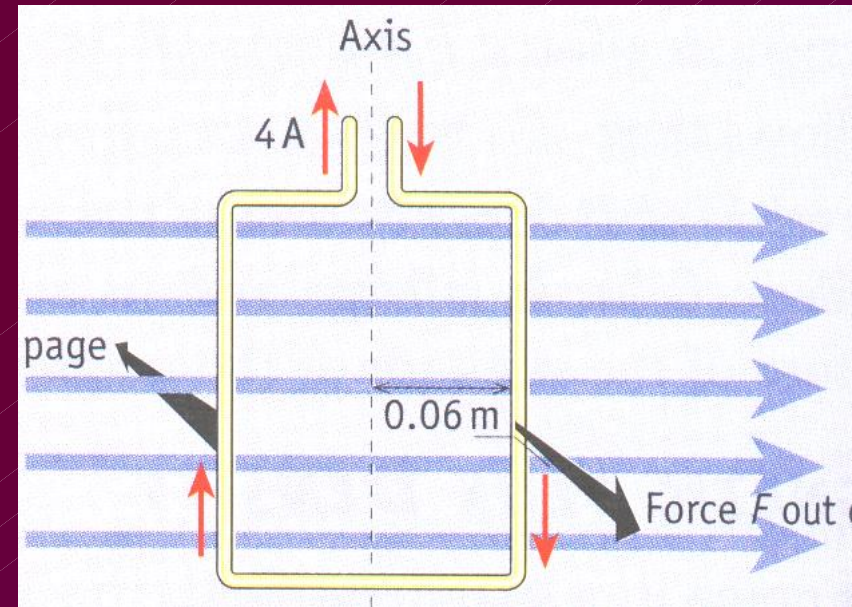
**Problem 3** The rectangular loop of wire is free to rotate about the axis shown. The plane of the loop is parallel to a uniform magnetic field of flux density  $0.6 \text{ T}$ . A current of  $4 \text{ A}$  flows in the coil and its dimensions are  $20 \text{ cm} \times 12 \text{ cm}$ . Draw a diagram showing the directions of the forces on the  $20 \text{ cm}$  sides.

Will the moment of the force ever be zero?

Yes

...  $90^\circ$

... perp. distance = 0



**Problem 3** The rectangular loop of wire is free to rotate about the axis shown. The plane of the loop is parallel to a uniform magnetic field of flux density  $0.6 \text{ T}$ . A current of  $4 \text{ A}$  flows in the coil and its dimensions are  $20 \text{ cm} \times 12 \text{ cm}$ . Draw a diagram showing the directions of the forces on the  $20 \text{ cm}$  sides.

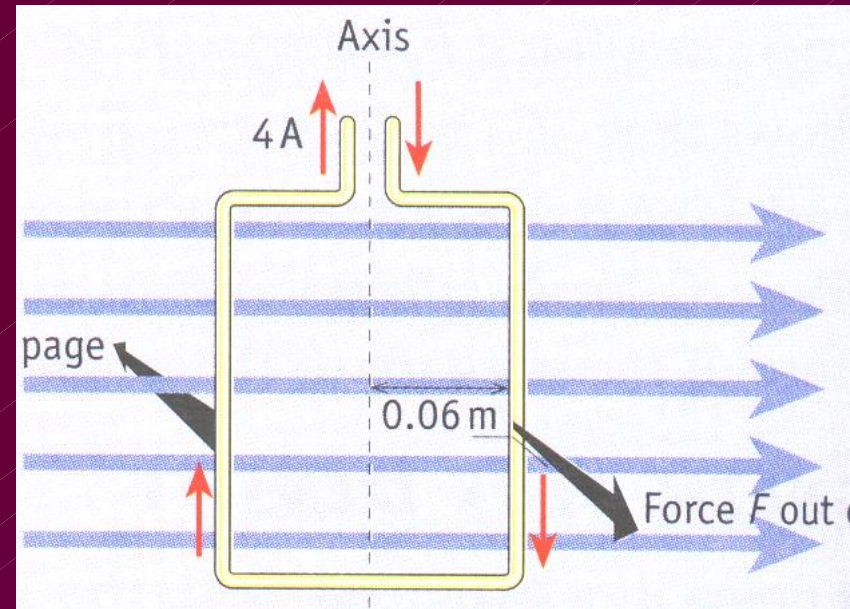
Calculate the couple on the coil in the position shown.

**Moment of couple**

= force x perp. distance between ..

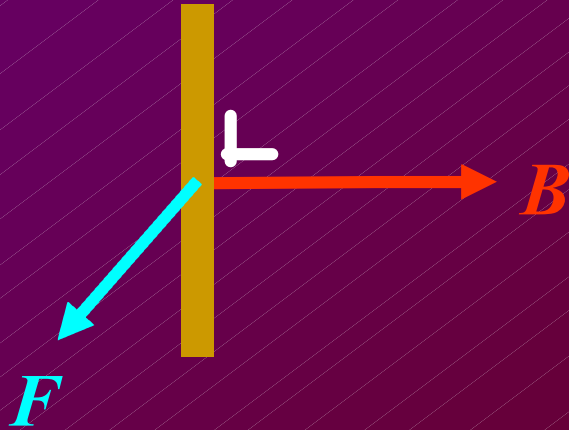
=  $0.48 \times 0.12$

=  $0.0576 \text{ N m}$



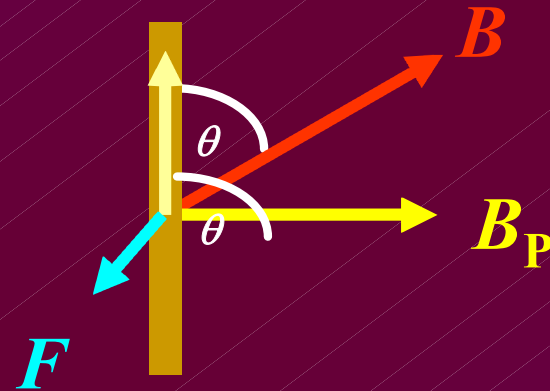
What if ??

The CCC Is Not Perpendicular To  $B$



$$F = I l B$$

It is the component of  $B$   
that is perpendicular to the conductor  
that causes the force on it.

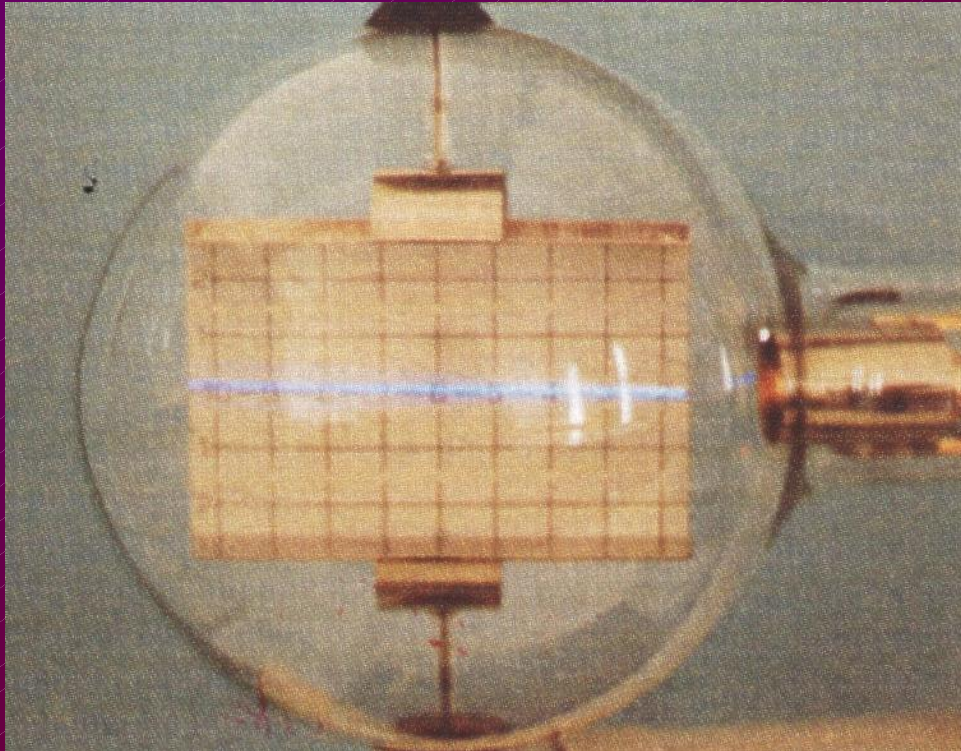


$$F = I l B_p$$

$$F = I l B \sin \theta$$

Smaller ... why?

# Force On A Moving Charge In A Magnetic Field

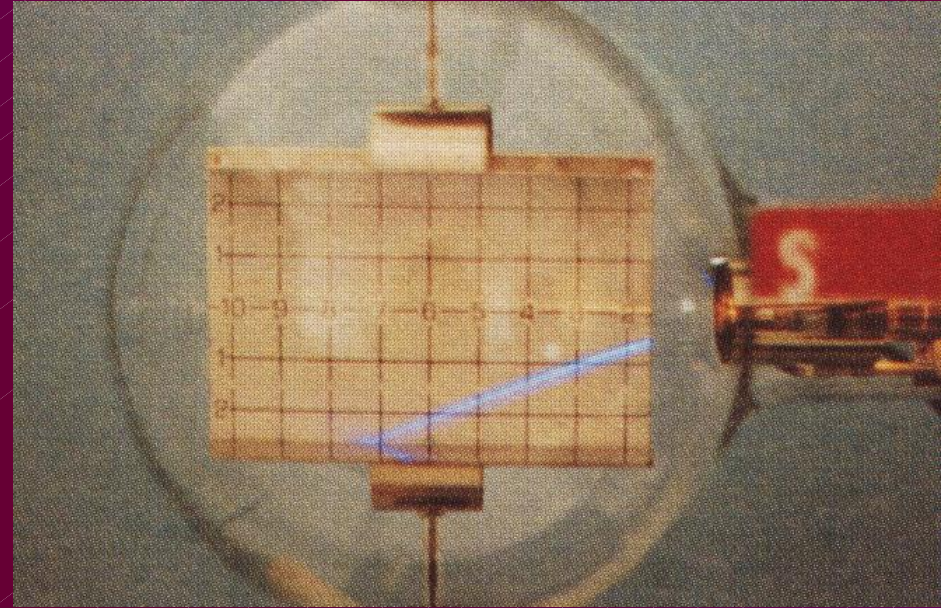
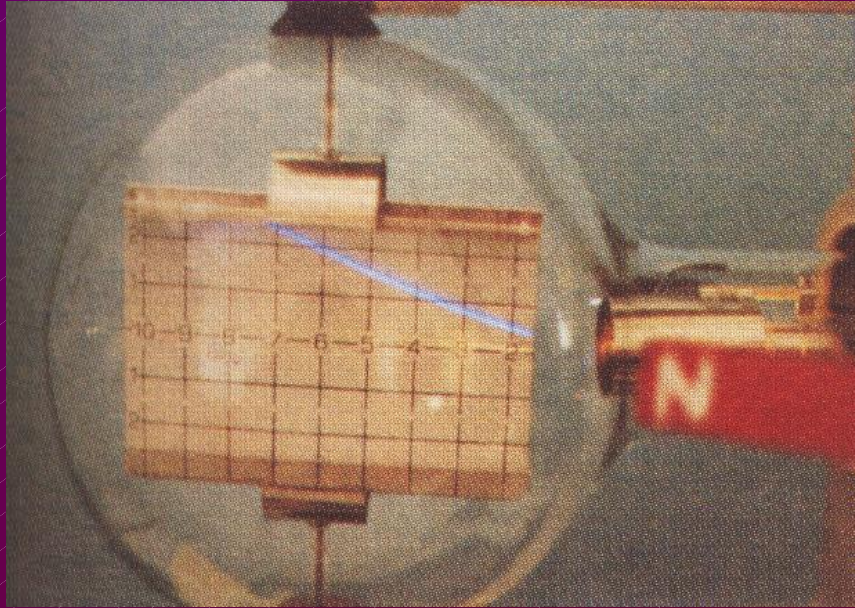


**Electron beam**

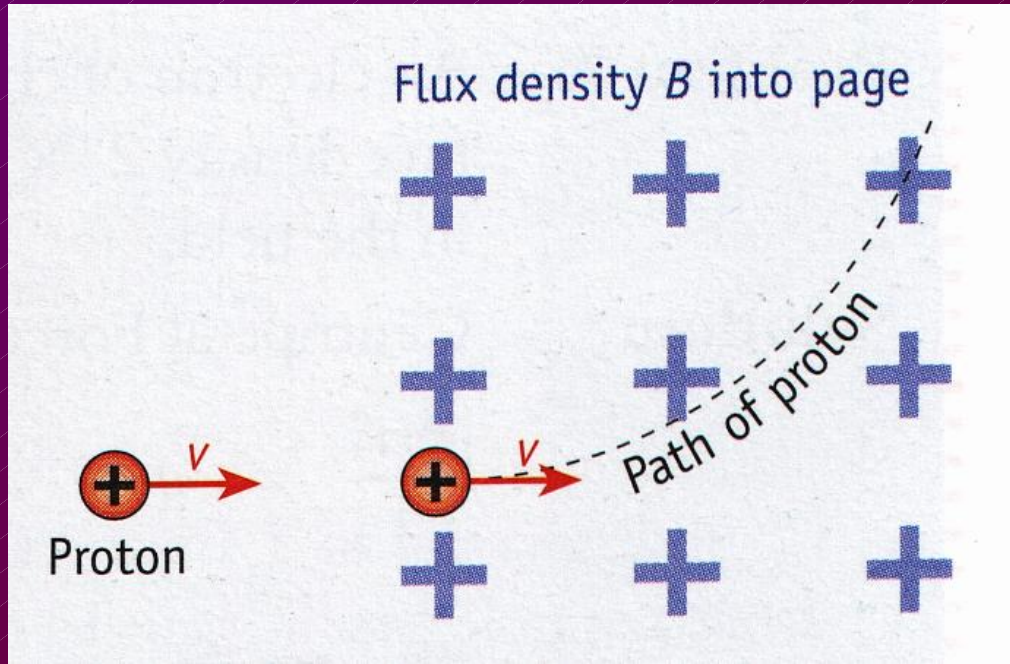
**Current**

**Magnetic field**

# Force On A Moving Charge In A Magnetic Field



# Force On A Moving Charge In A Magnetic Field



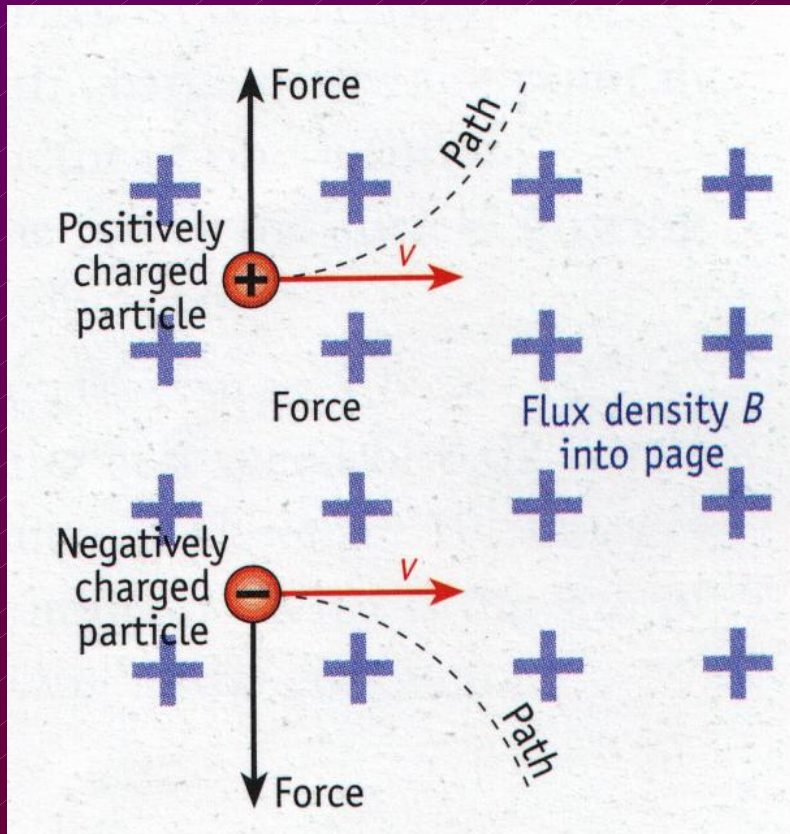
**Magnitude of the Force**

$$F = qvB$$

**Direction of the Force**

*Left-hand rule*

# Force On A Moving Charge In A Magnetic Field

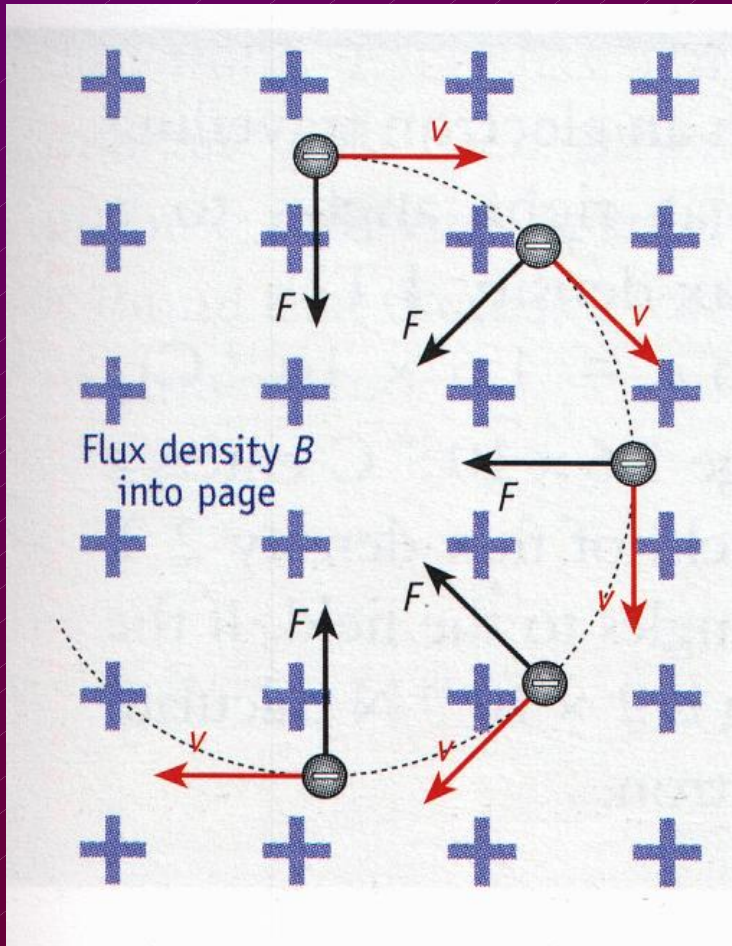


Fleming's Left-hand rule

**Problem 6** A particle of charge  $2 \times 10^{-3} \text{ C}$  moving at  $100 \text{ m s}^{-1}$  moves at right angles to a uniform magnetic field of flux density  $3 \text{ T}$ . What is the force on the charge?

$$\begin{aligned} F &= q v B \\ &= (2 \times 10^{-3})(100)(3) \\ &= 0.6 \text{ N} \end{aligned}$$

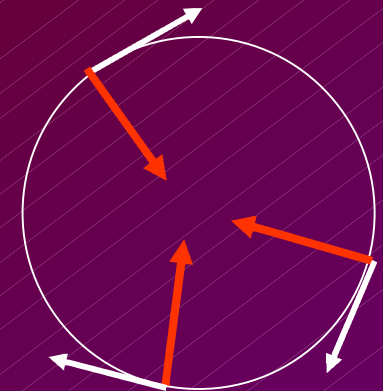
# Charged Particle Moving In A Circle



## Why A Circle?

**$F$  is perpendicular to  $v$   
always**  
(Left-hand rule)

**$F$  is a centripetal  
force**



**Problem 7** An electron of charge  $1.6 \times 10^{-19}$  C and mass  $9.1 \times 10^{-31}$  kg enters a uniform magnetic field of flux density  $2 \times 10^{-2}$  T travelling at a speed of  $400 \text{ m s}^{-1}$ . Find the radius of the path it follows in the field.

$$F = \frac{mv^2}{r} = qvB$$

$$\Rightarrow r = \frac{mv}{qB} = \frac{(9.1 \times 10^{-31})(400)}{(1.6 \times 10^{-19})(2 \times 10^{-2})}$$

$$= 1.14 \times 10^{-7} \text{ m}$$

# Derivation Of $F = qvB$

$$F = I l B$$

$$F = (q/t) l B$$

$$(q = It)$$

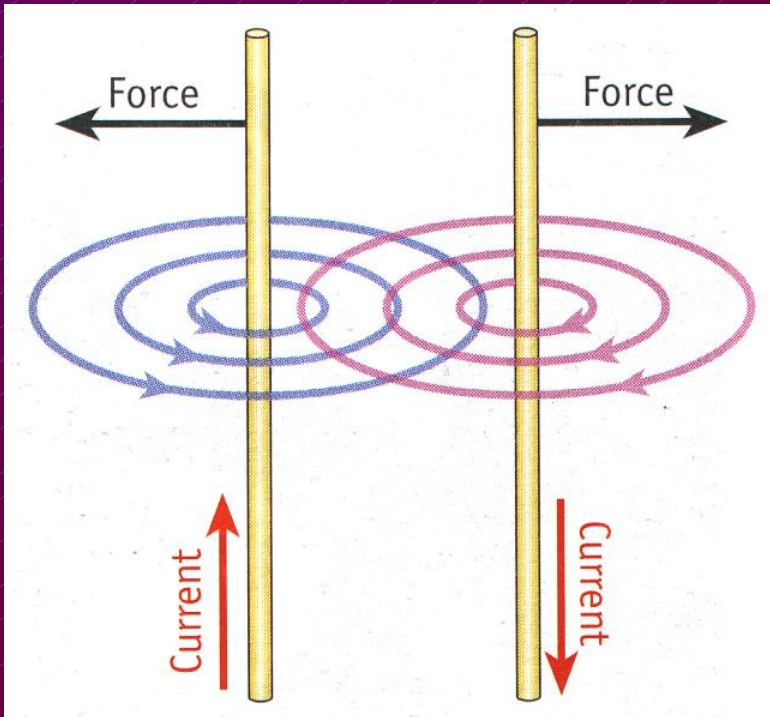
$$F = q (l/t) B$$

$$F = q v B$$

$$(v = \text{distance} \div \text{time})$$

$$F = qvB$$

# The Magnetic Force Between Two Current Carrying Conductors



- **2 magnetic fields**
- **They interact**
- **Force of repulsion**
- **Attraction if ...**

# The Magnetic Force Between Two Current Carrying Conductors

**Demo**

**Procedure**

**Switch on .. ( $> 5\text{ A}$ )**

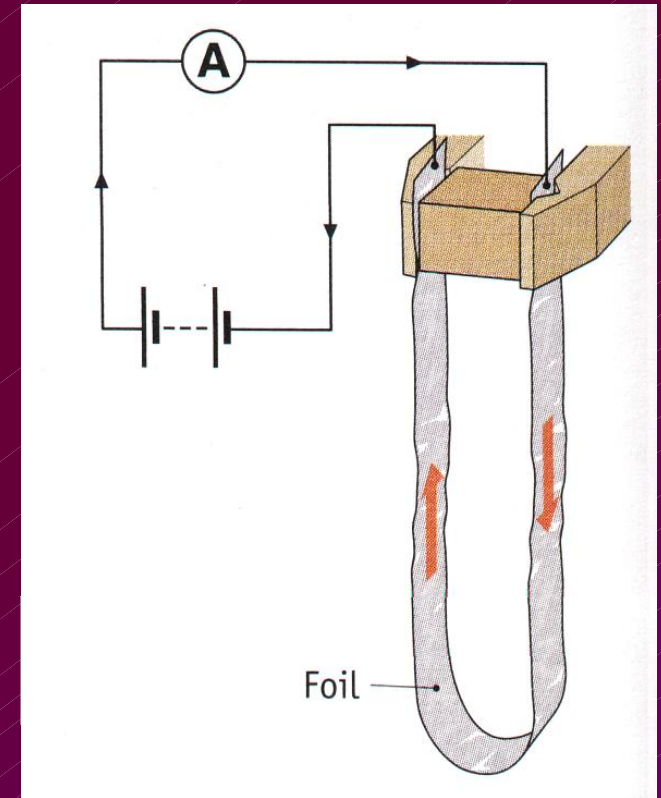
**Observation**

**Foils move apart.**

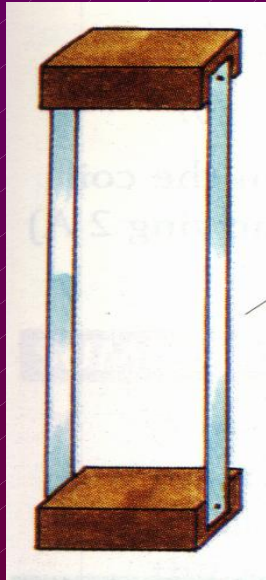
**Conclusion**

**???**

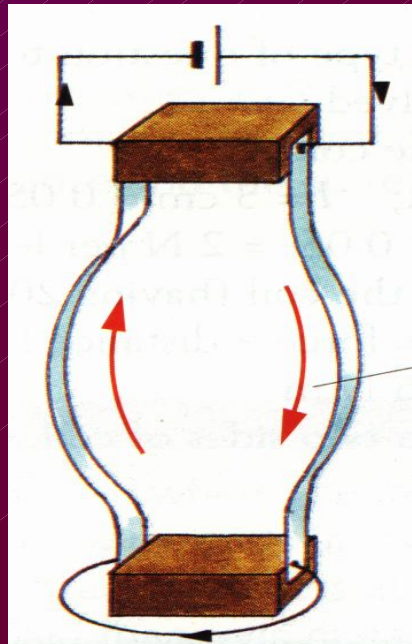
**Apparatus**



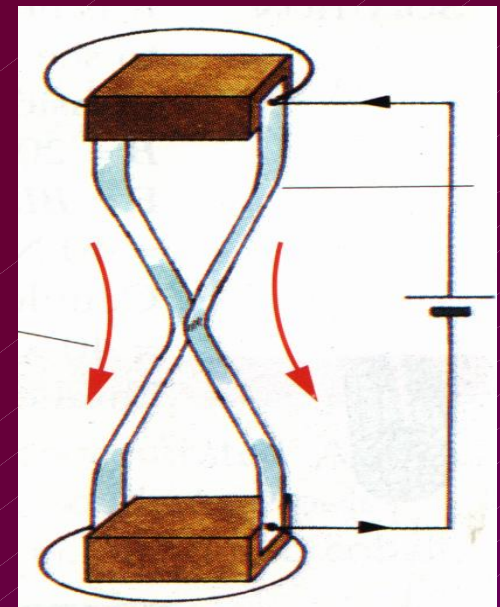
**No current**



**Opposite directions**

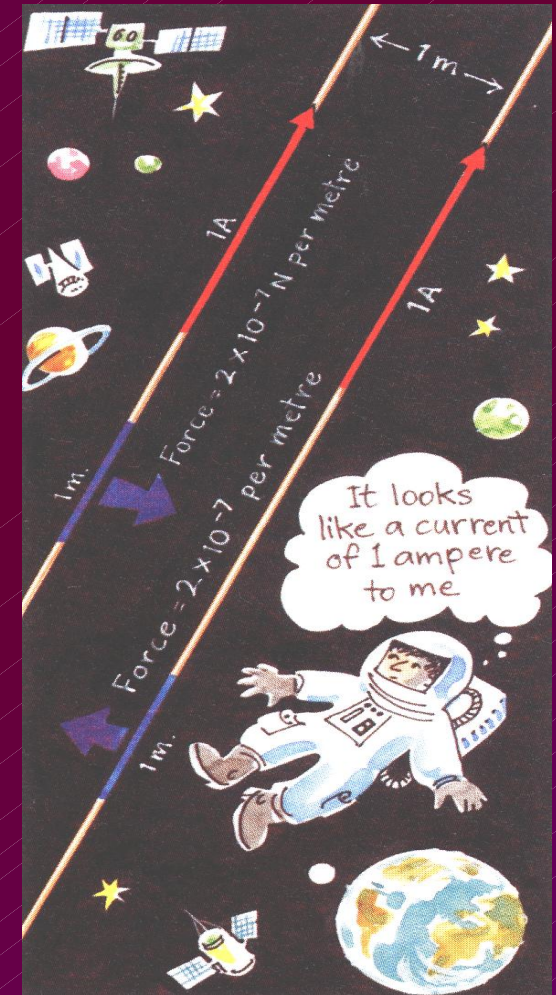


**Same direction**



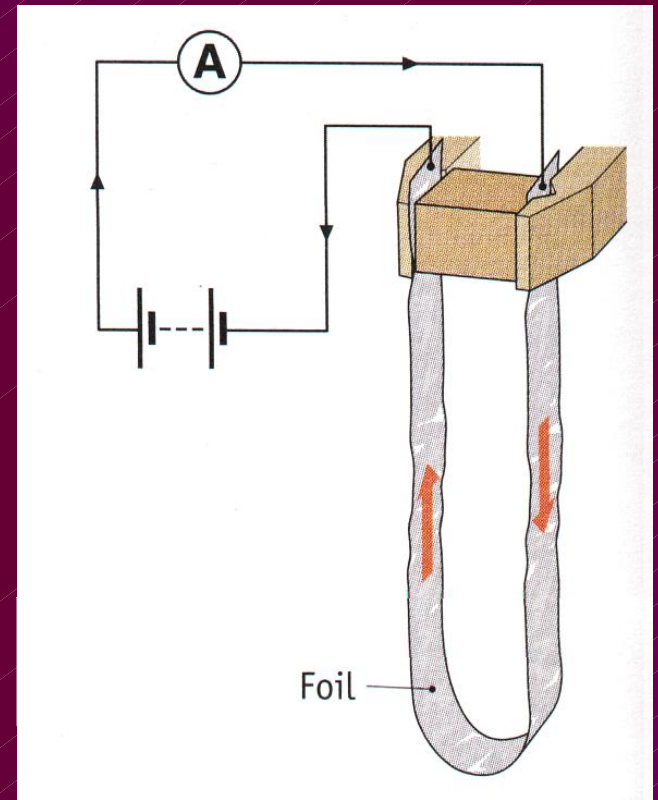
# Definition Of The Ampere

- 2 straight parallel conductors
- Infinitely long
- Negligible cross-section
- 1 m apart
- In vacuum
- Force =  $2 \times 10^{-7}$  N
- Per metre length
- Then current in each = 1 A



# Definition Of The Ampere

**Expt. To Demo The Principle  
On Which The Definition  
Is Based**



# The Unit Of Charge

**Coulomb**

$$Q = It$$

## Definition

- 1 C is the amount of charge that passes a point in a circuit
- when 1 A flows
- for 1 s

