PHYSICS 1B

Electricity
&
Magnetism

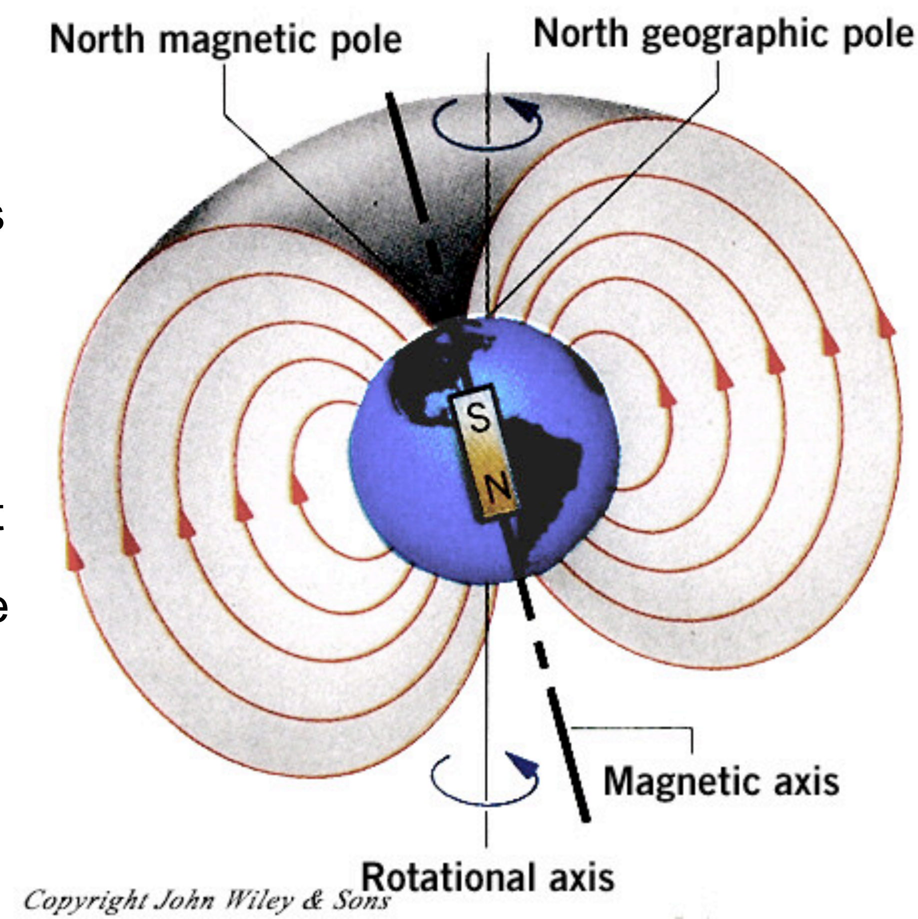
Professor Brian Keating

Not Polls, Poles!

The South Magnetic Pole

- the point on the Earth's surface where the geomagnetic field lines are directed vertically upwards. The South Magnetic Pole is constantly wandering due to changes in the Earth's magnetic field; as of 2005 it was calculated to lie at 64.53°S and 137.86°E [1], just off the coast of Wilkes Land, Antarctica.

- The Earth's geomagnetic field can be approximated by a tilted dipole placed at the center of the Earth. The South Geomagnetic Pole is the point where the axis of this best-fitting tilted dipole intersects the Earth's surface in the southern hemisphere. As of 2005 it was calculated to be located at 79.74°S and 108.22°E [4], near to Vostok Station, Antarctica..



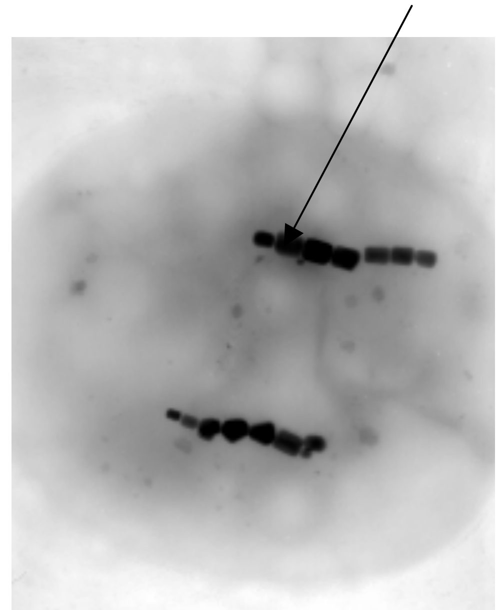
Magnetic bacteria

Migrate to north pole in northern hemisphere

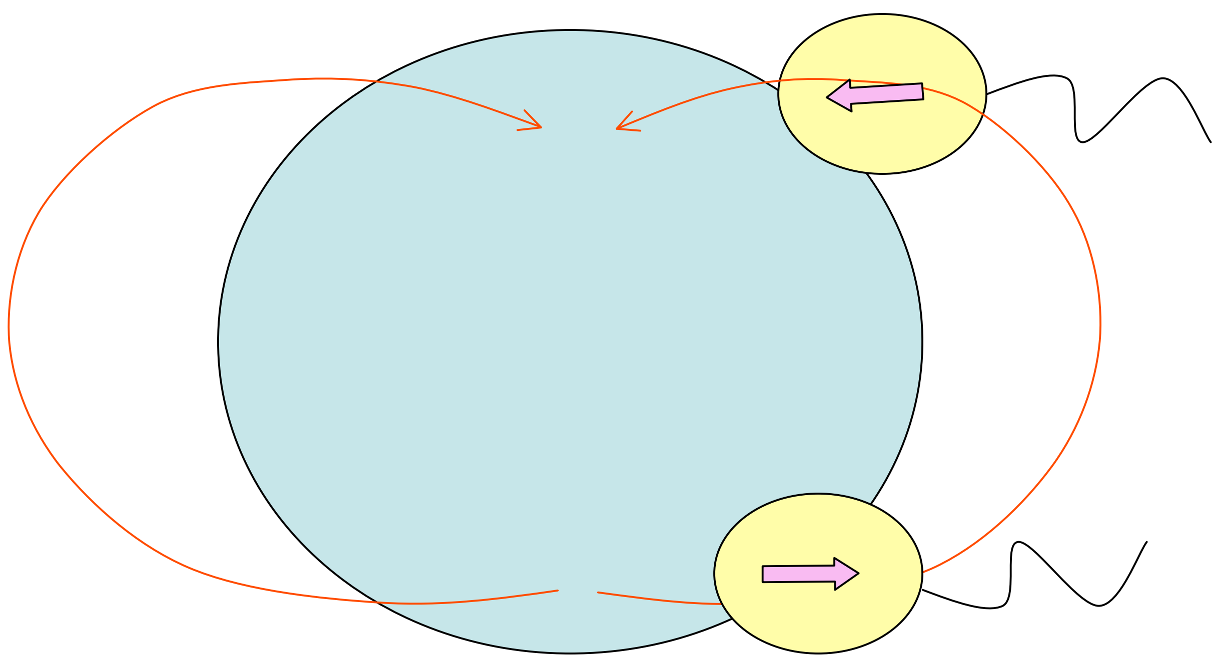
Migrate to south pole in southern hemisphere

Generally downward to the mud

Magnetic particles



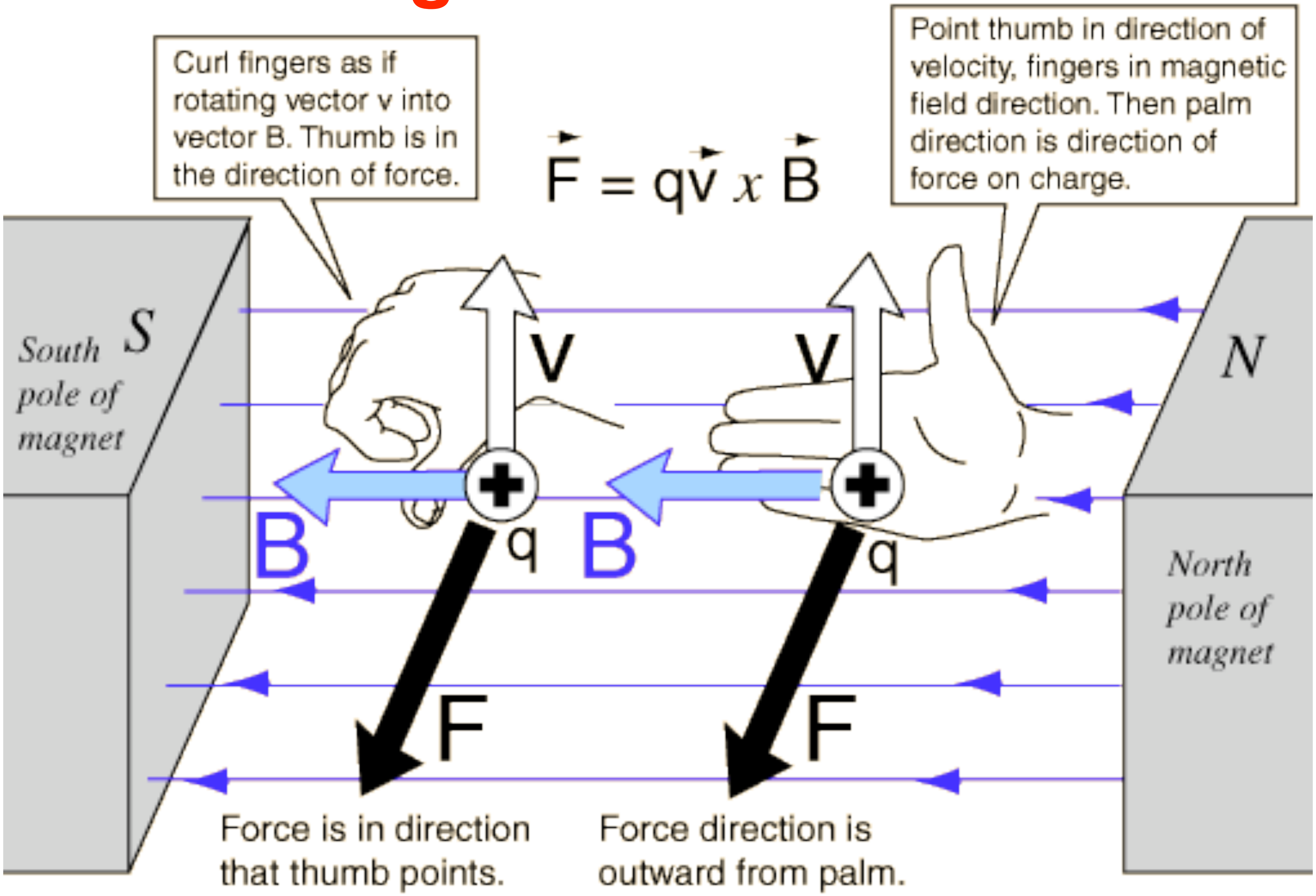
Electron micrograph



Today

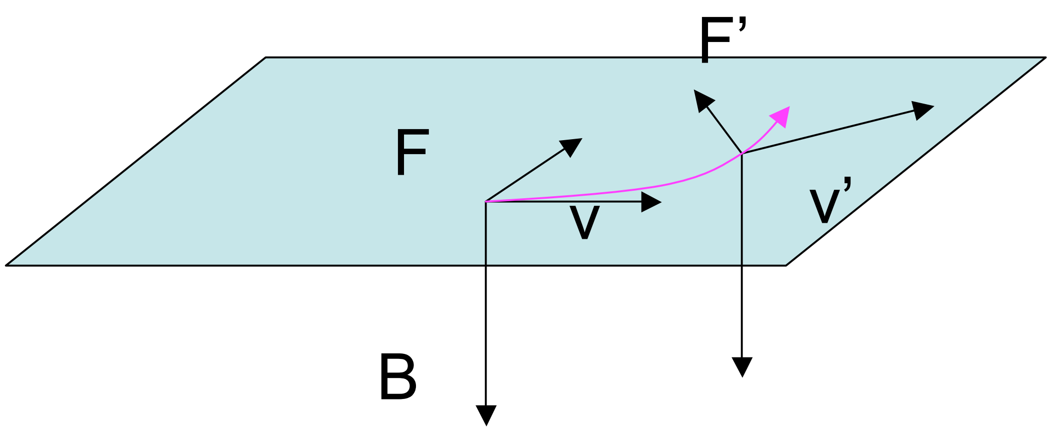
- Right hand rule
- Magnetic force on charges – circular motion
- Magnetic force on wires
- Torque & electric motors (not engines)

Right hand rule



1. F is perpendicular to the plane of v and B.
2. Direction of F given by the right hand rule .

Motion of a charged particle in a magnetic field



(uniform magnetic field)

F is in a plane perpendicular to B

After Δt particle is in the same plane

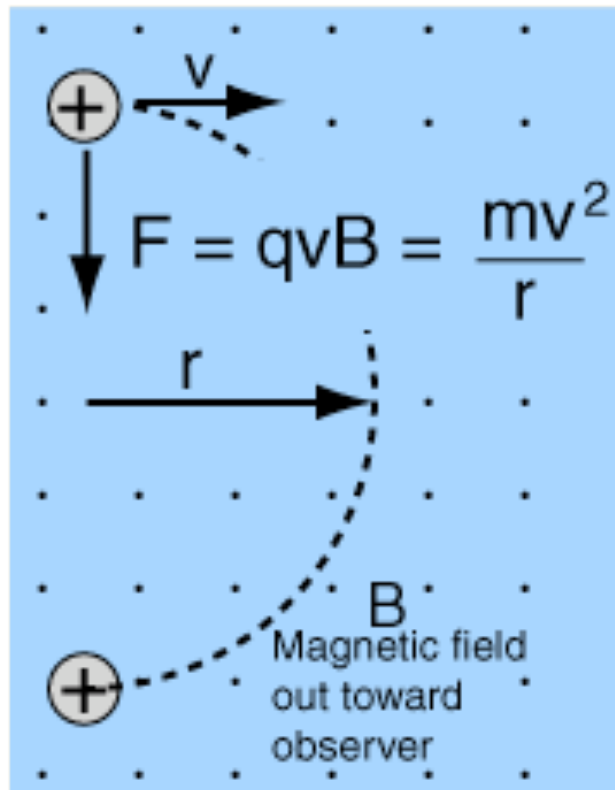
Particle moves in a plane perpendicular to B

Circular Motion in Constant Magnetic Field

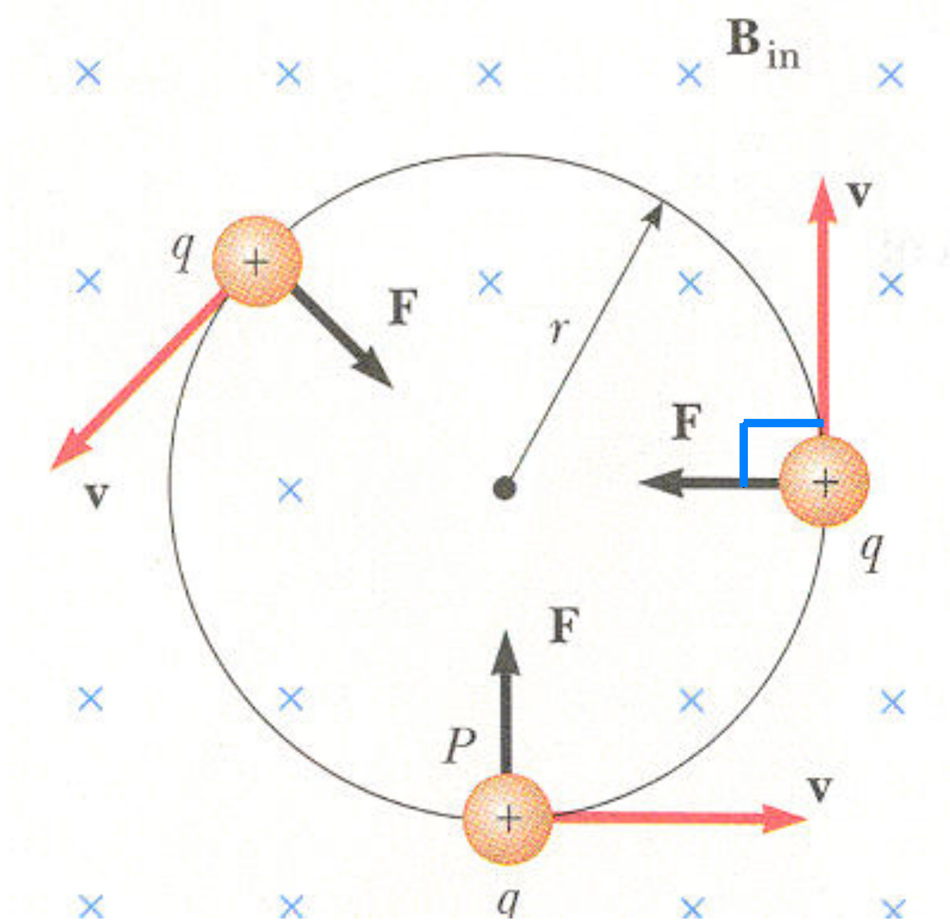
$$F_{centripetal} = m\frac{v^2}{r}$$

$$r = \frac{mv^2}{qvB} = \frac{mv}{qB}$$ Radius of path produced by magnetic field

Sometimes I'll give you the velocity; other times the energy = ½ m v^2.



Motion of particle in plane perpendicular to B



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

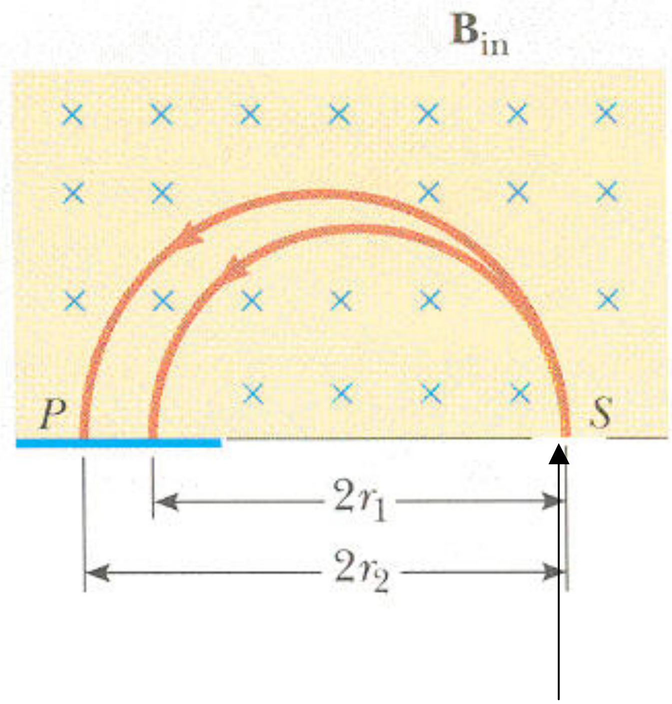
$$r = \frac{mv}{qB}$$

The particle moves in a circular path

A proton with $v=1x10^6$ m/s is in a uniform magnetic field of 0.2 T. Find the radius of the trajectory.

Application

Mass spectrometer



Molecular ions
At velocity v

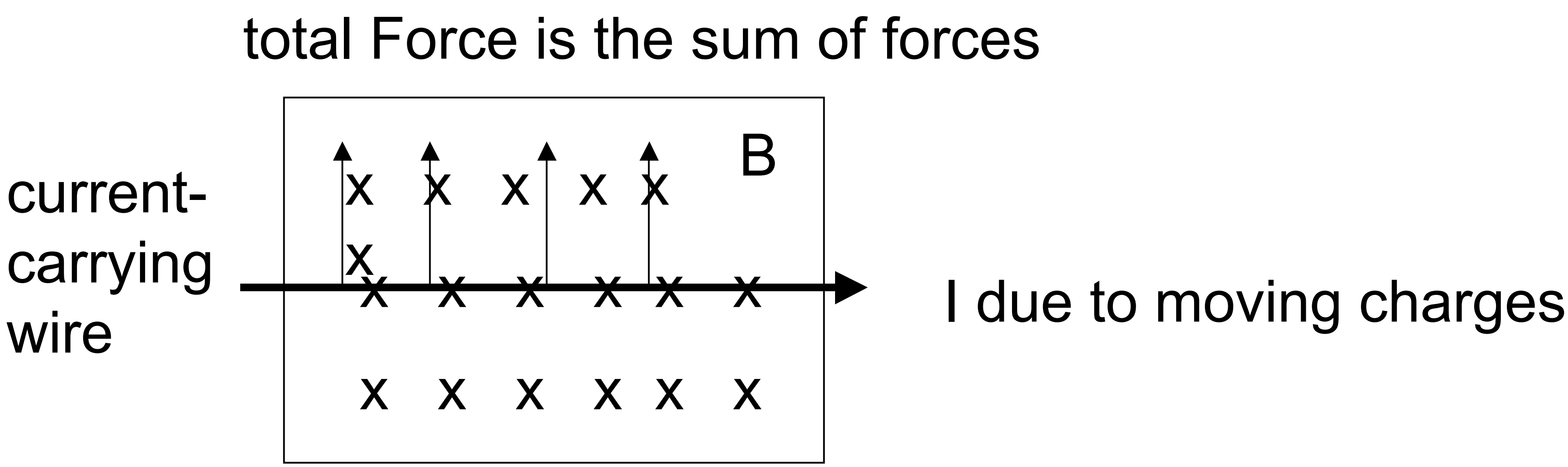
$$r = \frac{mv}{qB}$$

Ions separated by mass

A mass spectrometer with a ion velocity selector at the inlet selects ions with $v=5x10^4$ m/s. What B field is necessary to rotate a molecular ion CO_2^+ with a mass of $6.67x10^{-26}$ kg through radius of 0.20 m?

Force on a current carrying wire

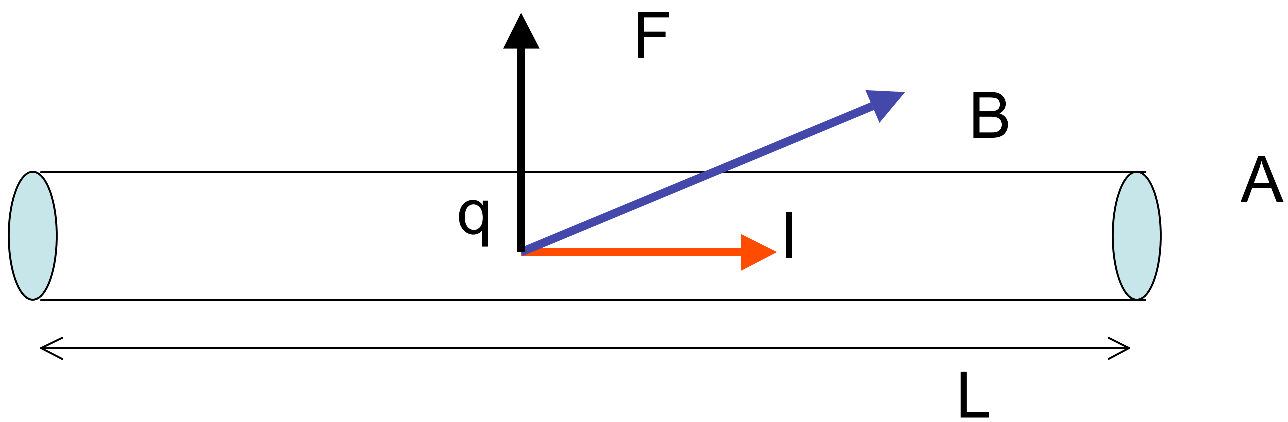
The force on a wire carrying a current in a magnetic field is just the sum of the forces on the individual charge carriers.



Many applications, currents produce forces

Electric motors, loudspeakers

Magnetic force on a current carrying wire of length L in a ***perpendicular*** B field



F= sum of forces on all charges = $\sum qvB$

since $\sum q = \rho LA$ ρ is the charge/volume

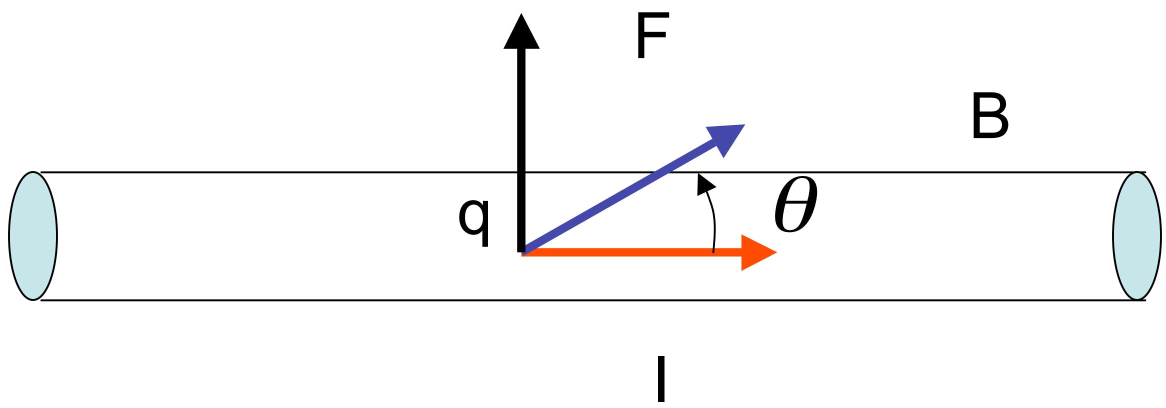
then $F = \rho LAvB$

since $I = \frac{\Delta q}{\Delta t} = \rho Av$

Finally

$$F = BIL$$

For angle θ between L and B



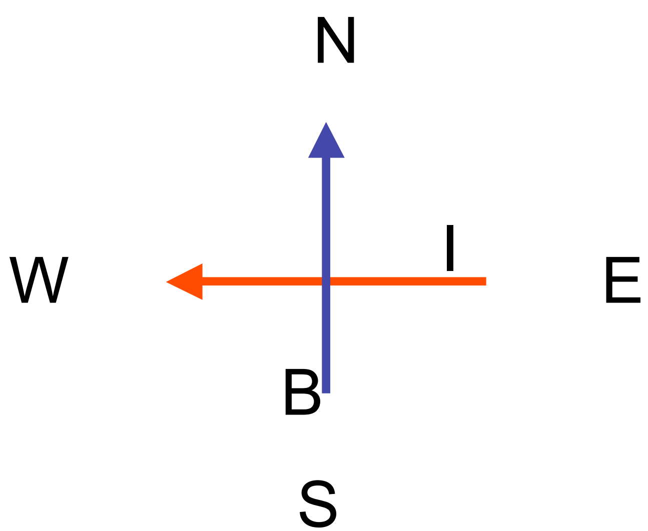
$$F = BIL\sin\theta$$

B parallel to direction of wire, $\theta=0$, $F=0$

B perpendicular to direction of wire $\theta=90^{o}$, $F= BIL$

A transmission line carries a current of 100 A from east to west. The magnetic field is 0.05 mT in the northward direction. Find the force on a 100 m section of wire. What direction is the force?

$$F = ILB = 100(100)(0.05x10^{-3}) = 0.5N$$

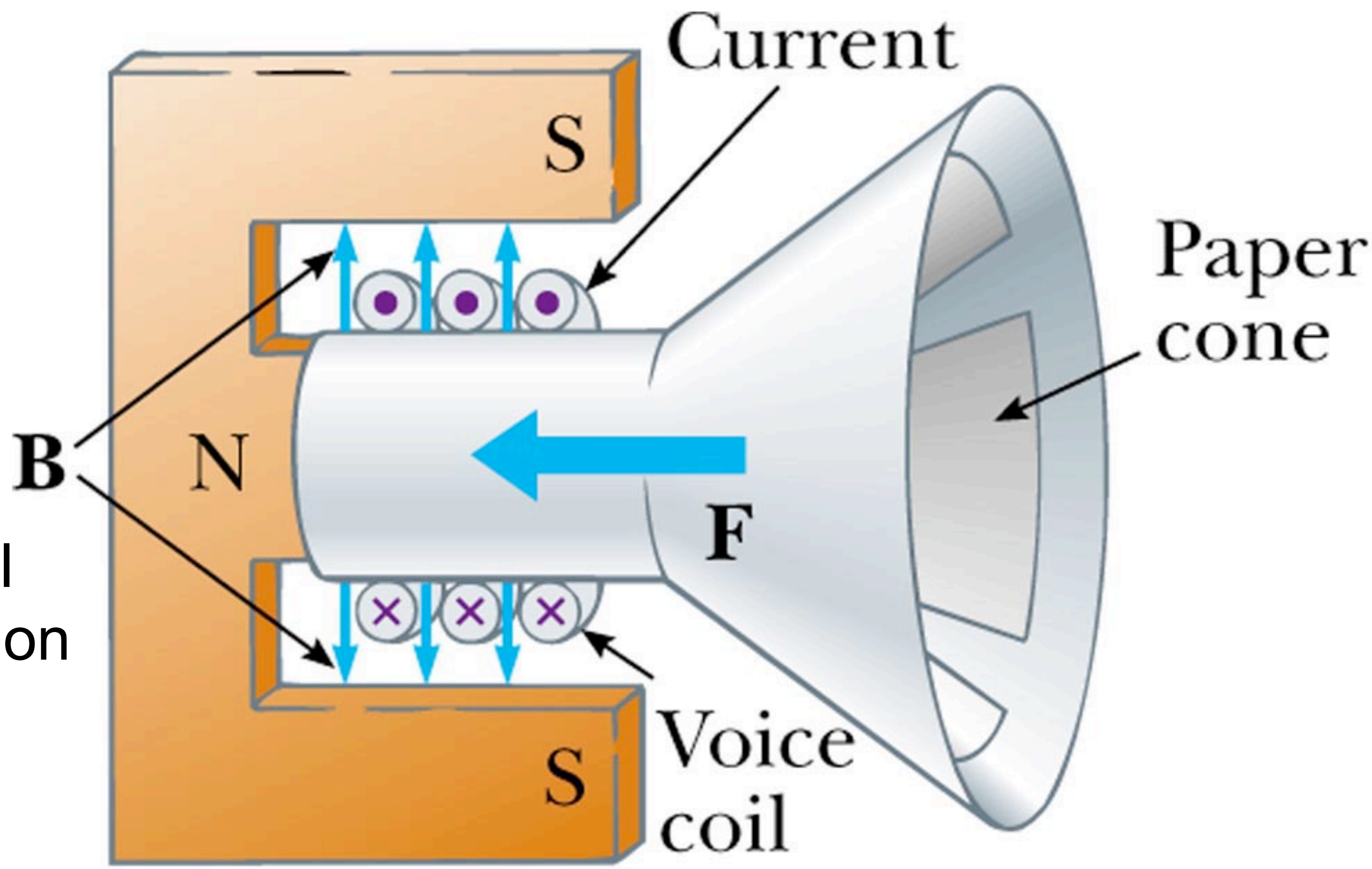


Looking from above

Direction

F is downward

Loudspeaker



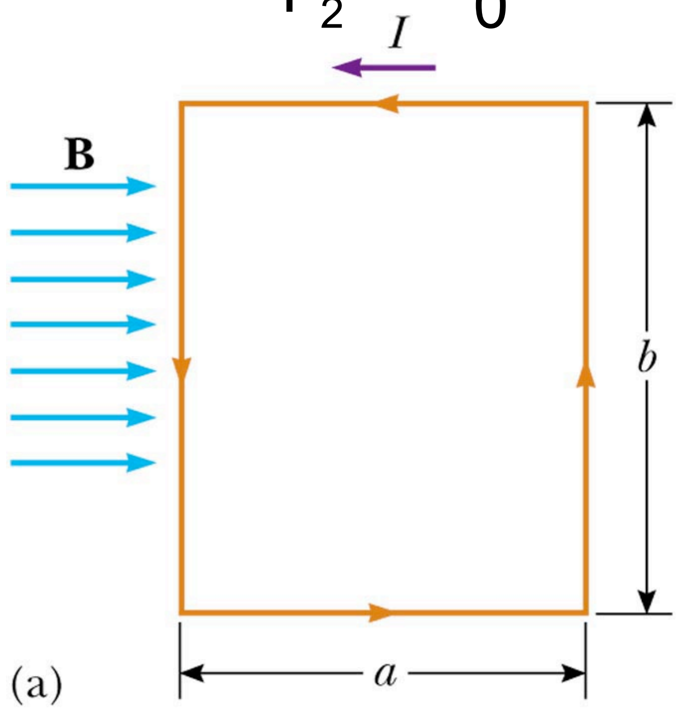
Radial
direction

Forces on a loop in a uniform B field

B field is uniform and in the plane of the current loop

Find the forces acting on the wires in the loop.
(a and b are the lengths)

$F_2 = 0$



$F_1 = BIb$

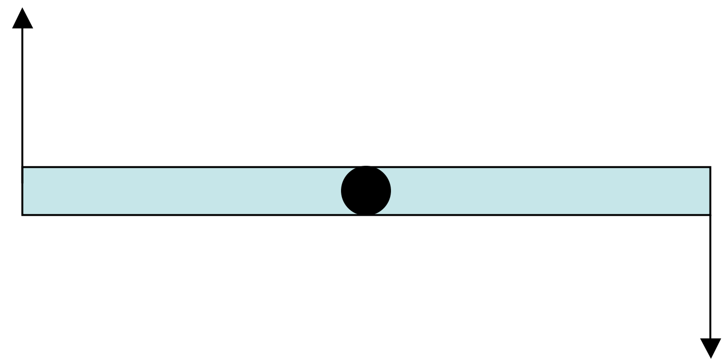
out of page

$F_3 = BIb$

into page

$F_4 = 0$

Review of Torque

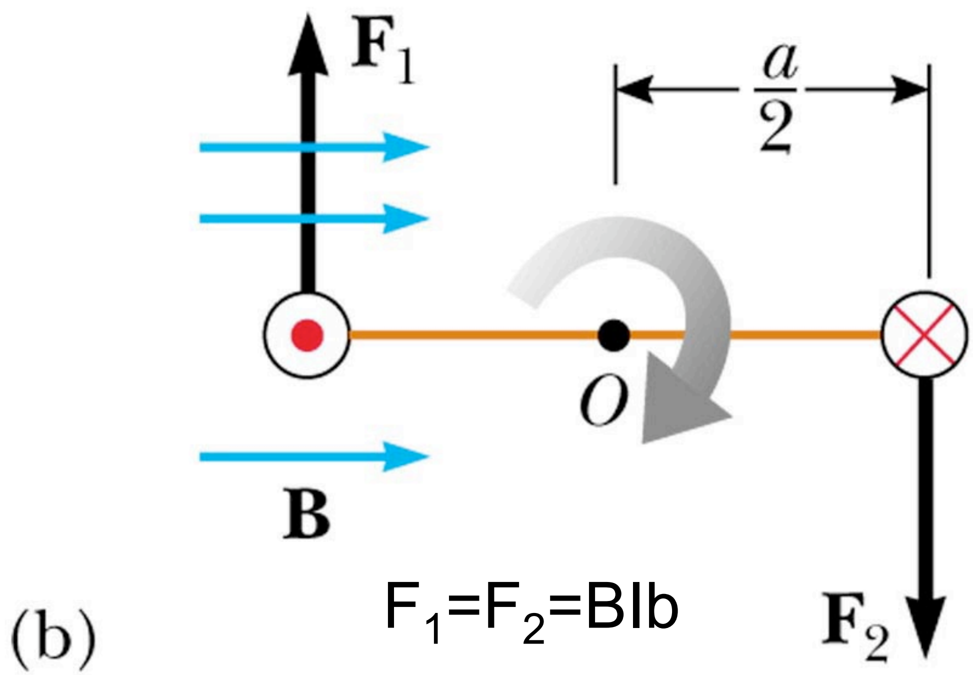


Torque= Force x perpendicular distance

$$\tau = Fd$$

The current loop in a B field generates a torque around the center proportional to the area of the loop

Side view



$F_1=F_2=BIb$

The two forces generate a torque around the center

ô$=F_1(\frac{a}{2})+F_2(\frac{a}{2})$

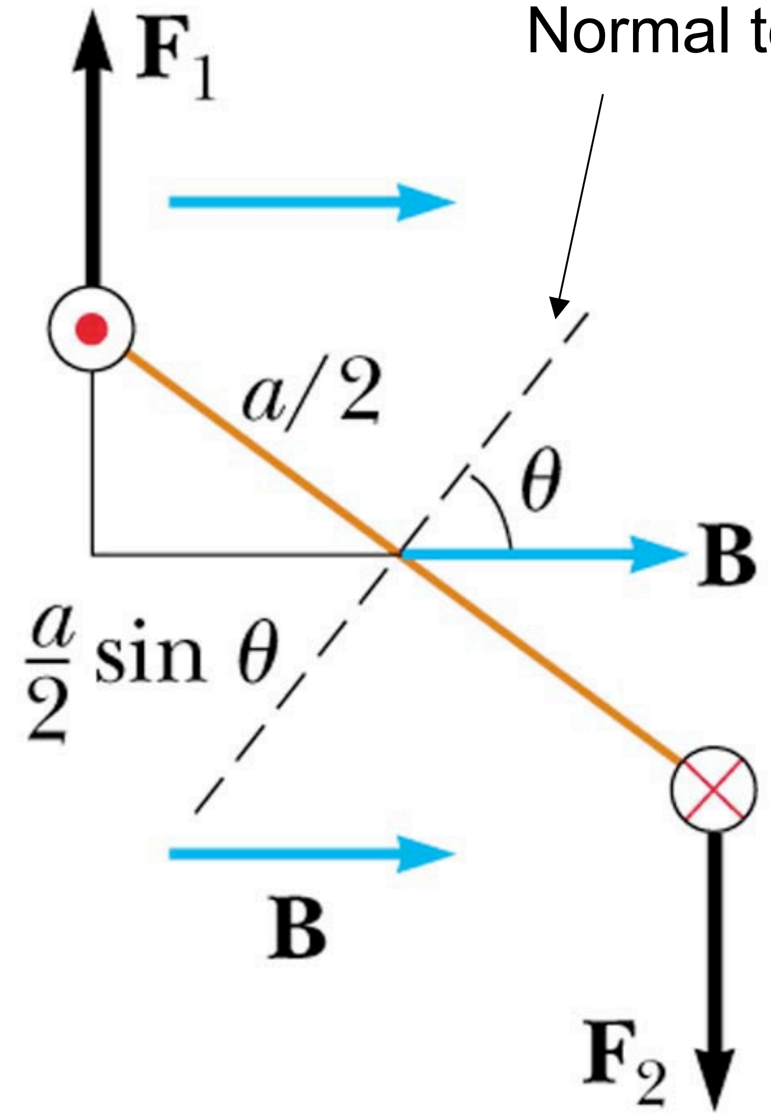
ô$=BIba$

$\tau = BIA$

A=axb=area of loop

counterclockwise

Loop makes an angle with B



(c)

$$\tau = BIA\sin\theta$$

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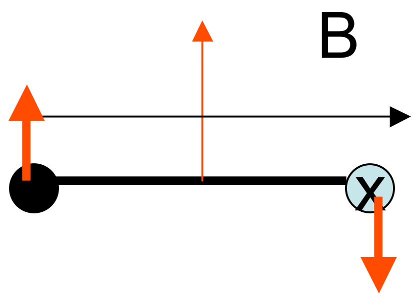
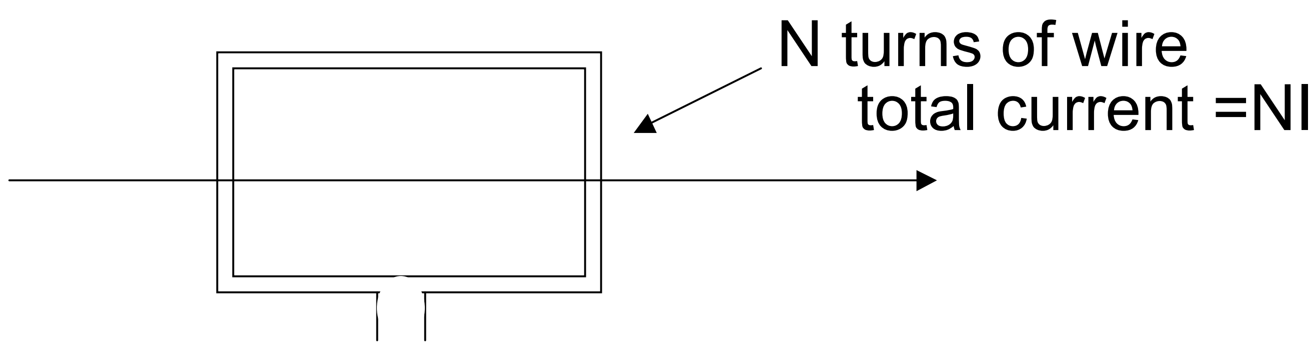


$\tau =$ BIA

The torque tilts the loop so the normal is parallel to B

Loop with N turns of wire



$$\tau = NBIA\sin\theta$$

Torque increases with N, B, I and A

Torque is maximum when $\theta=90^o$,when the loop is parallel to the field

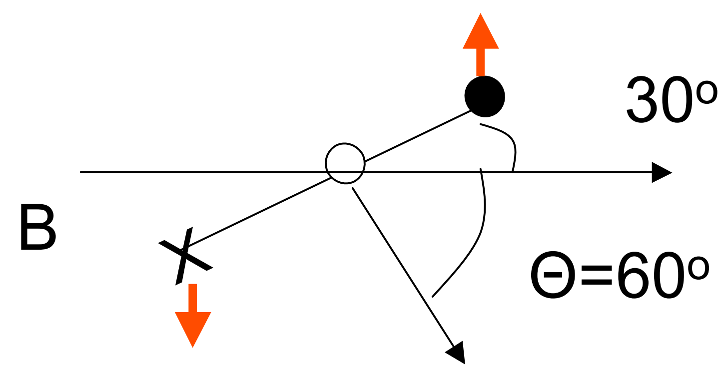
Torque is zero when $\theta=0$ when loop is perpendicular to the field

A 3A current wire-loop (with 100 turns) and an area of 0.2 m^2 makes an angle of 30^o with a magnetic field of 0.3T.

a) Find the torque exerted on the coil.

b) What is the direction of rotation?

c) What happens if the current is reversed in the coil?



a) $$\tau = NBIA\sin\theta$$

$$= 100(0.3)(3.0)(0.2)\sin 60 = 1.6x10^1 Nm$$

b) counter clockwise direction

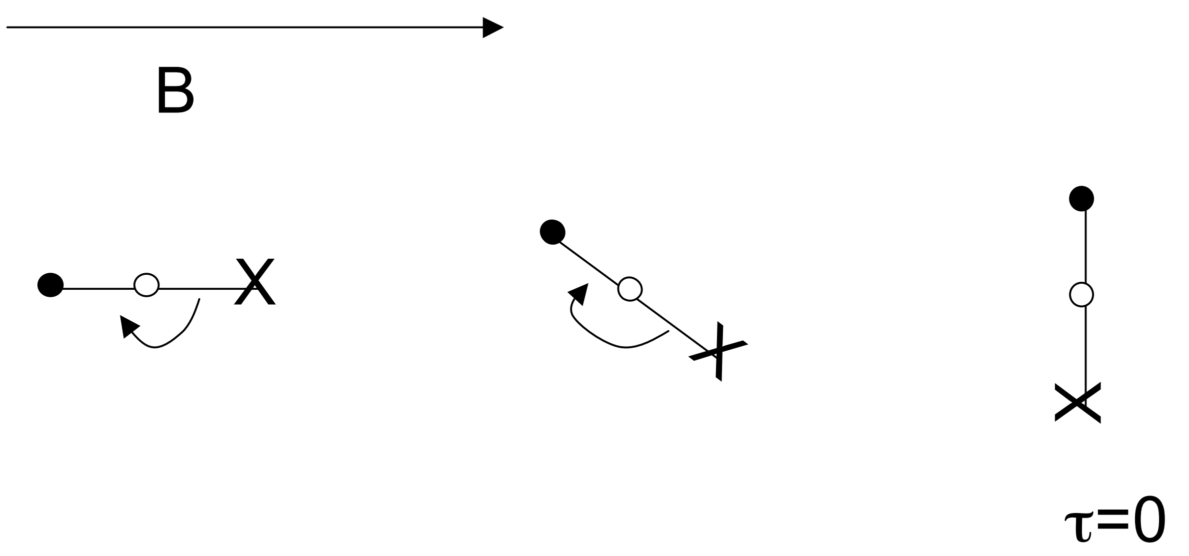
c) the torque will have the same magnitude but in the opposite (clockwise) direction,

Electric motors (not same as 'engines')

A current loop in a magnetic field produces a torque

Problem

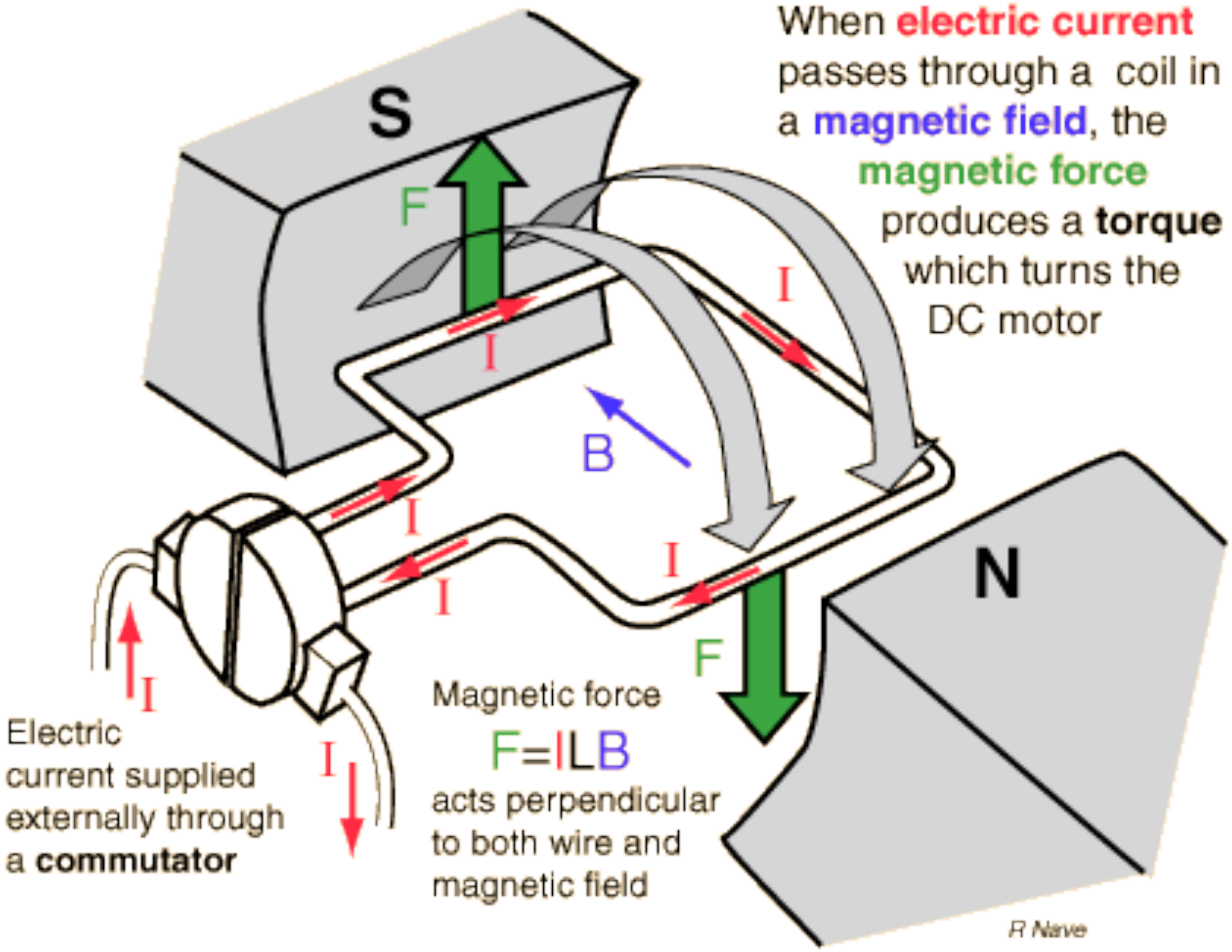
A dc current does not produce complete rotation

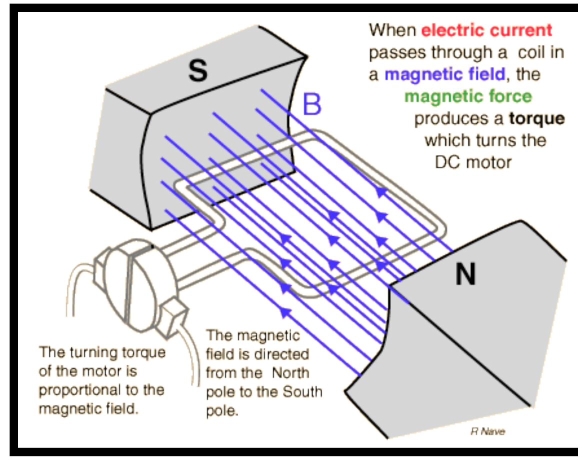


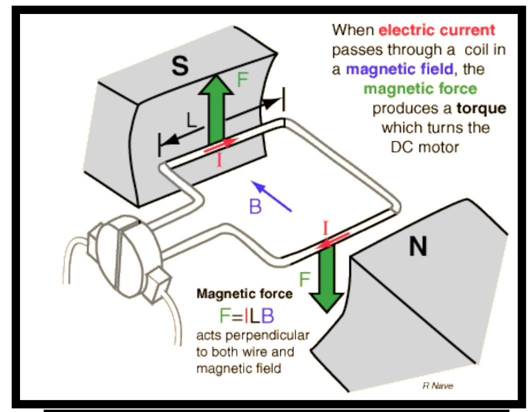
dc current only rotates coil until it is perpendicular to the field

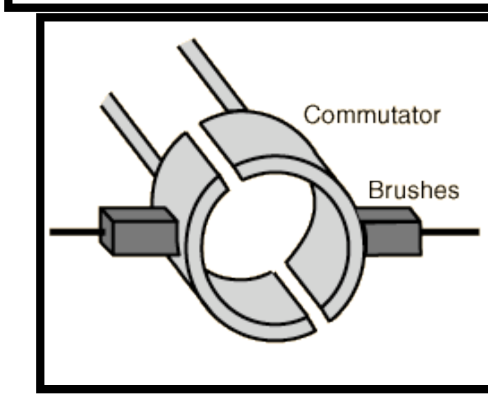
Solution with direct current source is to use a commutator.

Split-ring commutator reverses the current direction when $\tau=0$.



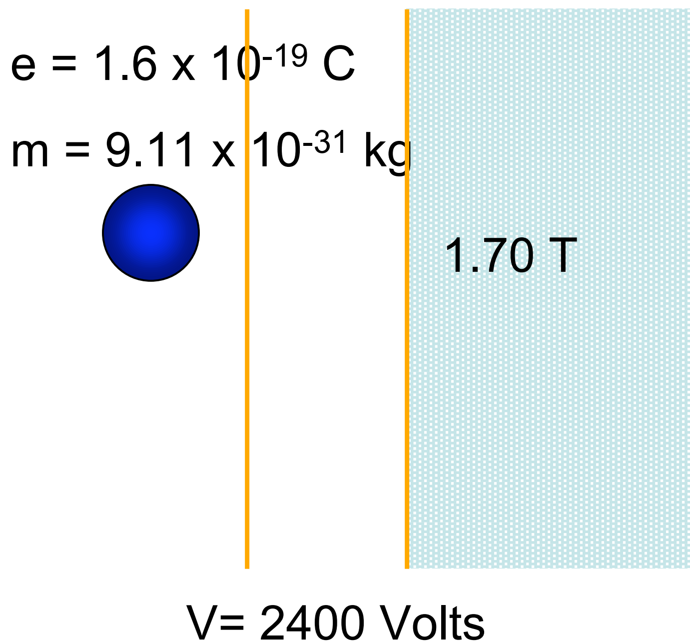






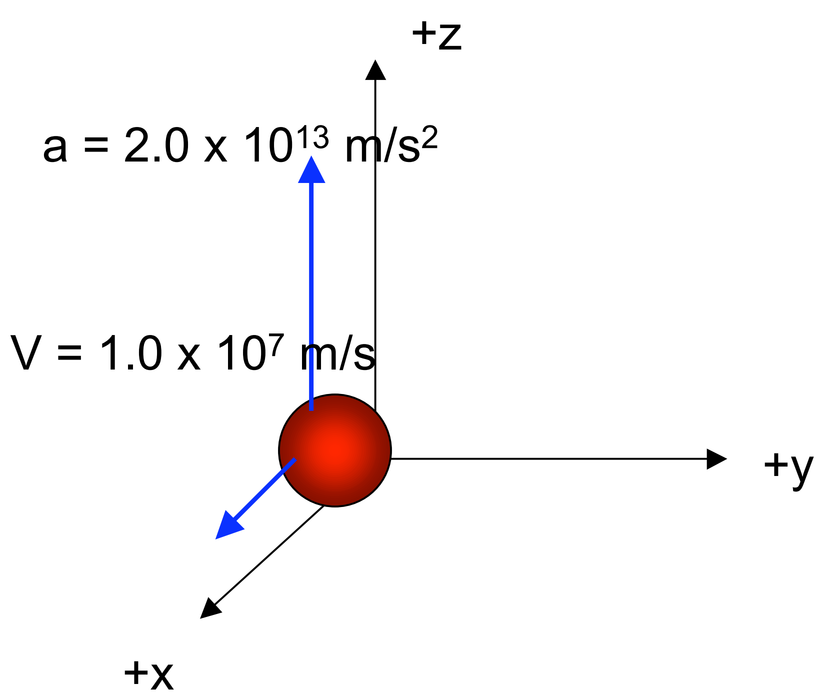
HW Problems, Clickers out

1) From 19.8: An electron is accelerated through 2400 V from rest and then enters a region where there is a unifrom 1.70 T magnetic field. What is the maximum magnitude of the magnetic force acting on the electron?



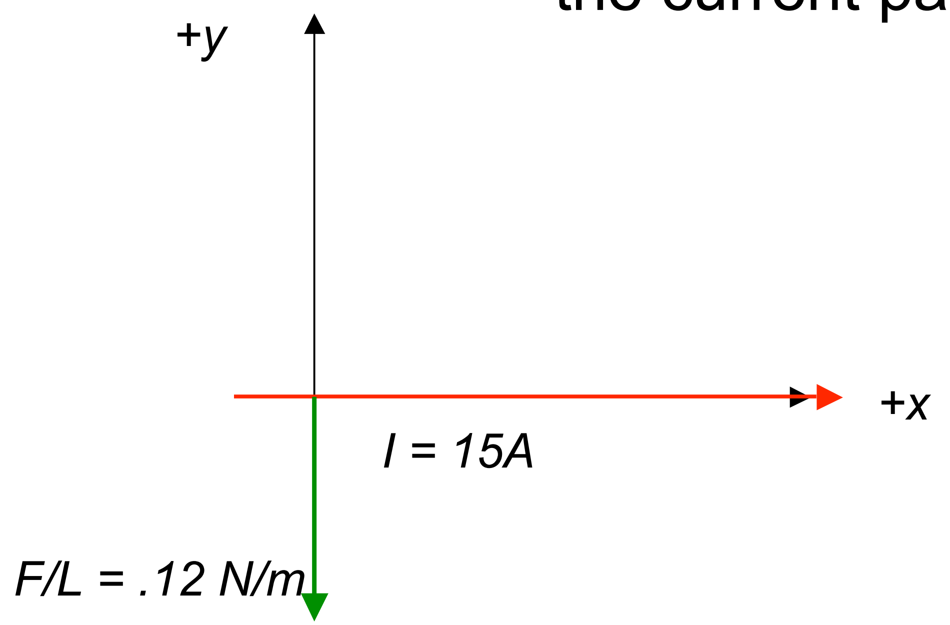
- A) 7.9×10^{-12} N
- B) 2.9×10^{8} N
- C) 5.2 N
- D) 8.4×10^{-5} N

2) From 19.9: A proton moves perpendicularly to a uniform magnetic field **B** at 1.0×10^7 m/s and exhibits an acceleration of 2.0×10^{13} m/s^2 in the +x direction when its velocity is in the +z direction. Determine the magnitude of the field.



- A) 8.00 T
- B) 1.93 T
- C) .21T
- D) .021 T

3) From 19.11: A current I=15 A is directed along the positive x-axis and perpendicular to a magnetic field. A magnetic force per unit length of .12 N/m acts on the conductor in the negative y-direction. Calculate the magnitude of the magnetic field in the region through which the current passes.



- A) 1.4×10^{-6} T
- B) 4.2 T
- C) 8.0×10^{-3} T
- D) 6.5×10^{3} T