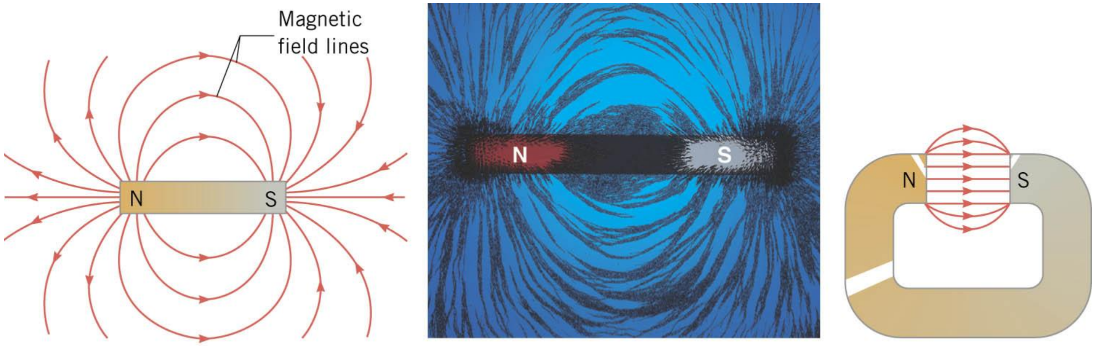
Chapter 20
Magnetic Fields & Forces

Magnetic Fields – Permanent Magnets



(a) (b) (c)

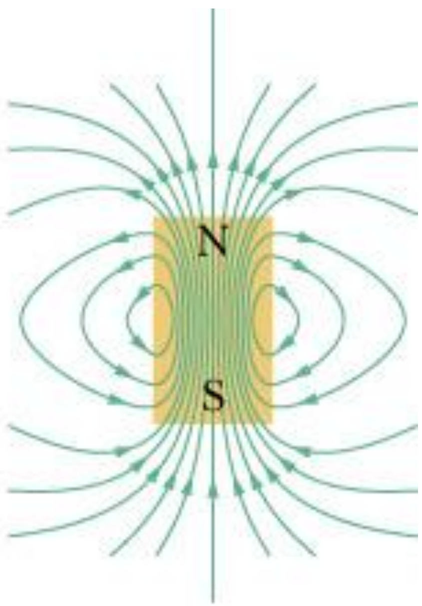
- Magnetic fields are continuous loops – leaving a North pole and entering a South pole

- they point in direction that an isolated North would move

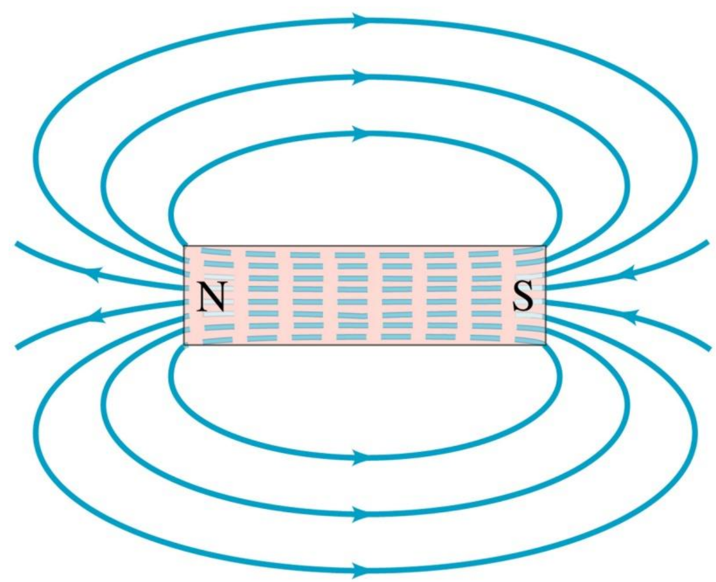
- Highest strength near poles (highest concentration of field lines

Magnetic field lines are closed loops

• they pass through permanent magnets due to domains in metal

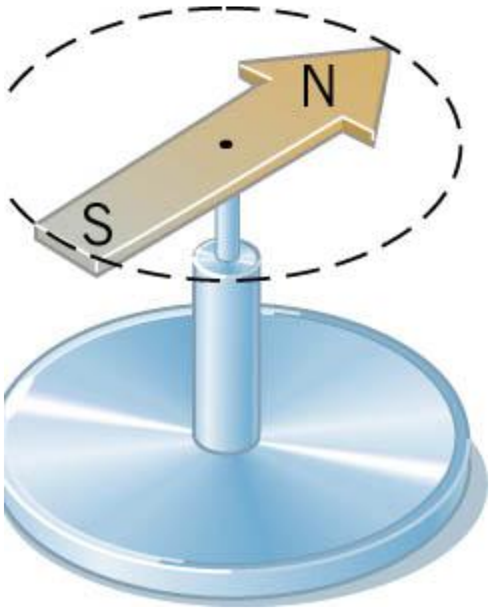


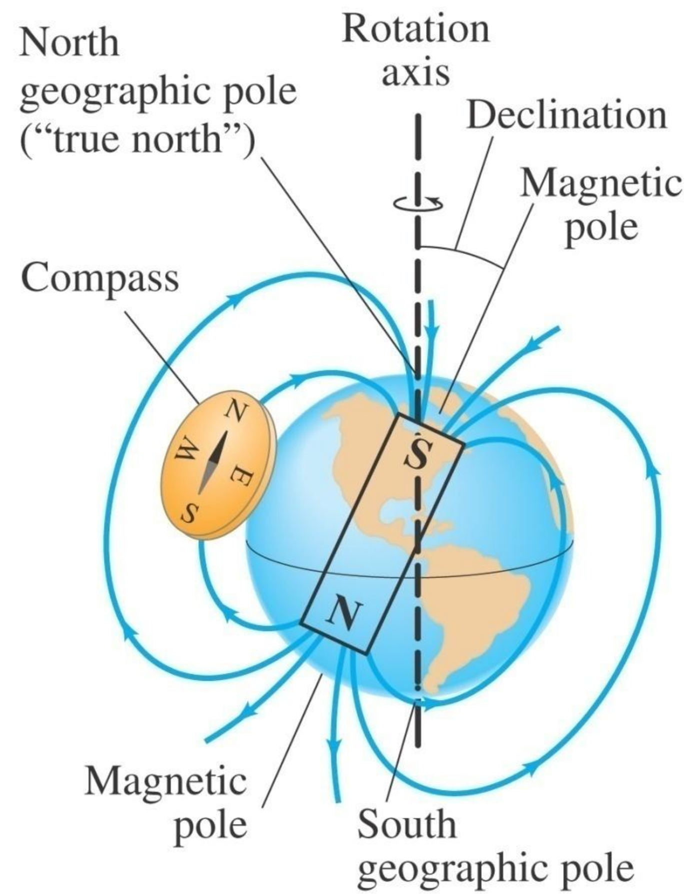
(a)



(b)

World's Largest Magnet?

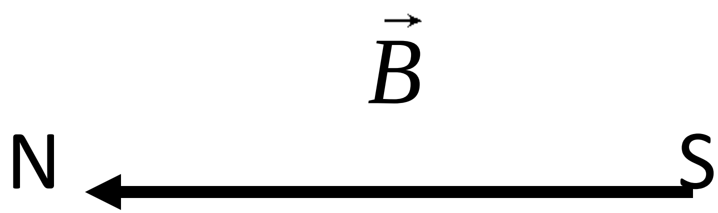


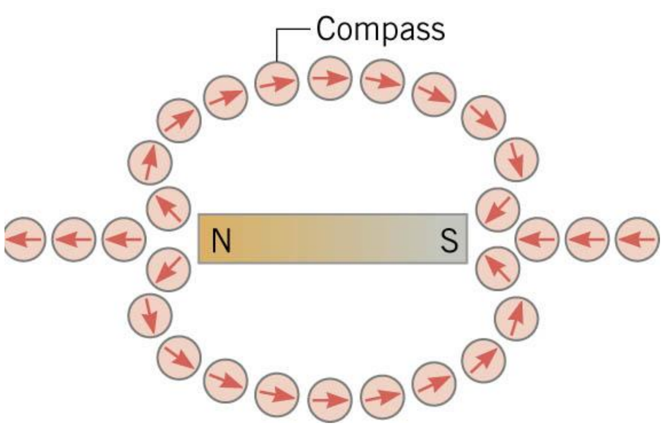


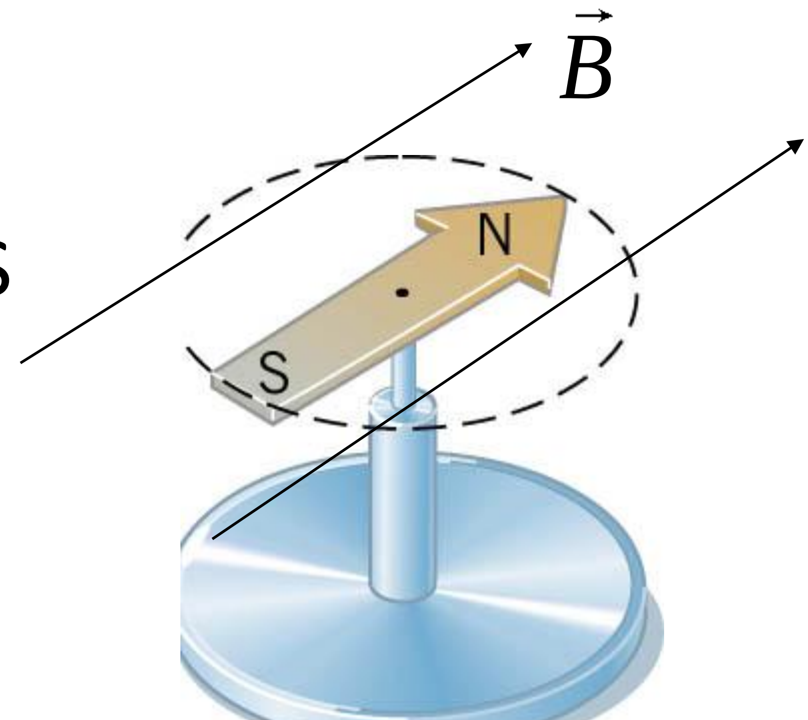
compass is a magnetized needle that aligns with the Earth's magnetic field loops

Magnetic Fields

- Magnetic field vector $\vec{B}$ points in the direction that an isolated North pole would move

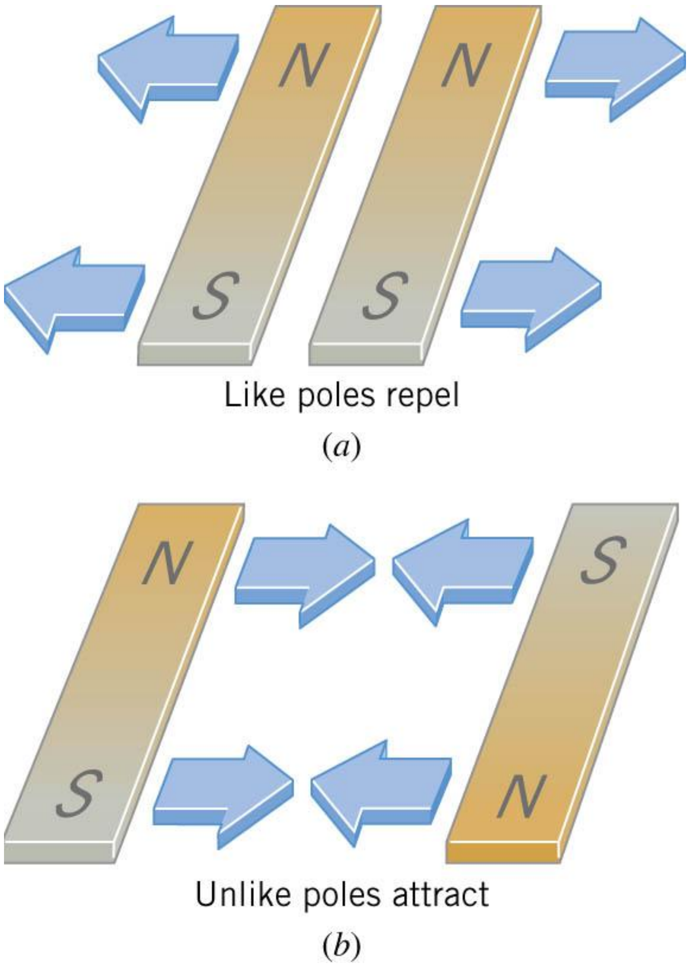






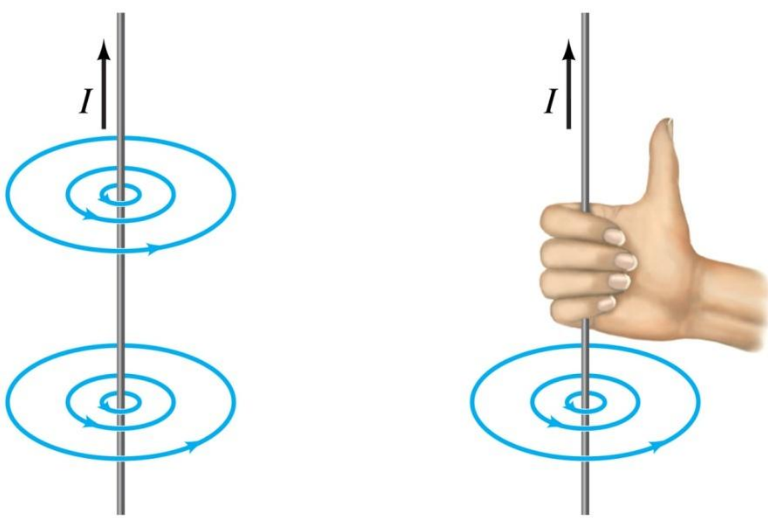
B vector – arrowhead is the North, tail is the South

Magnetic Force Law

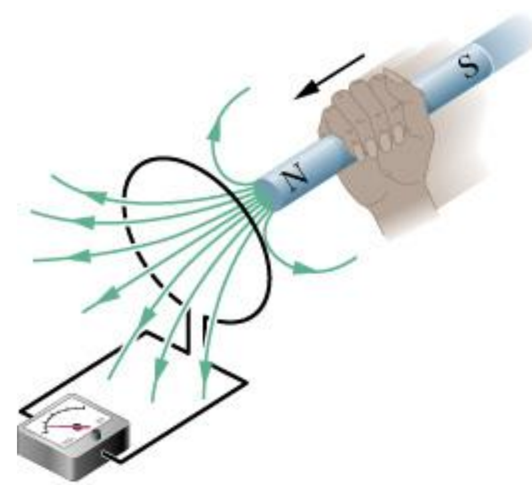


Electricity and Magnetism are inseparable

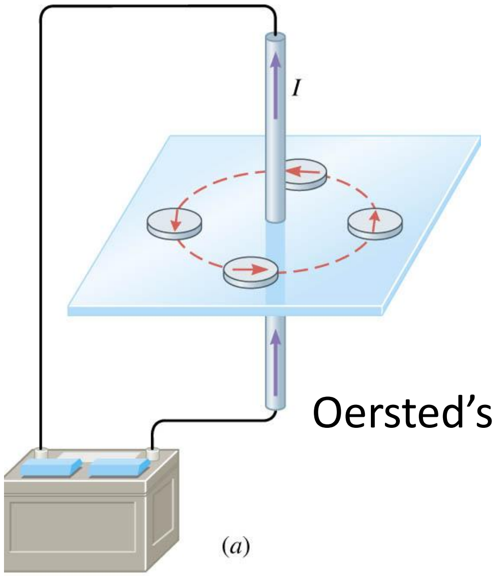
- Basic theme to chapters 20, 21
  - changing electric field (current flow) creates magnetic field
  - changing magnetic field (generator) creates electric field (current flow)



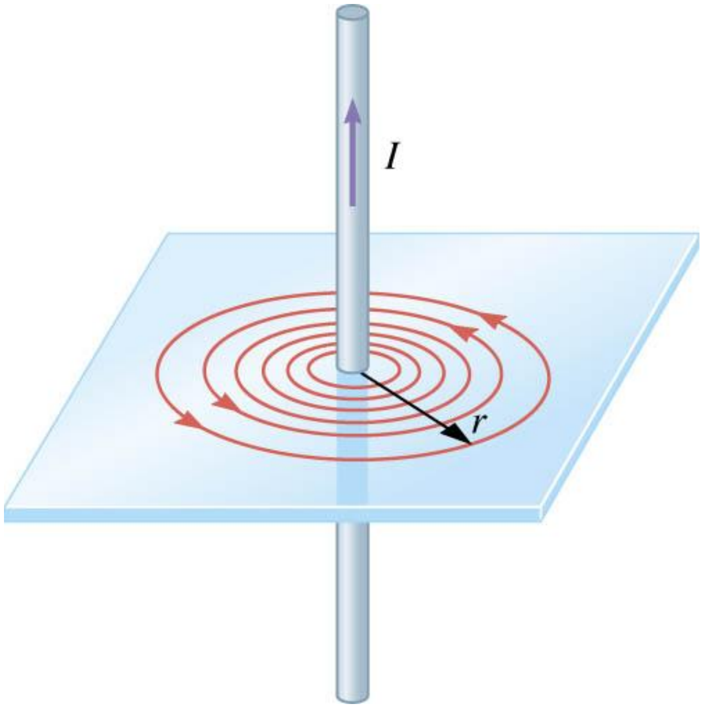
(b) (c)

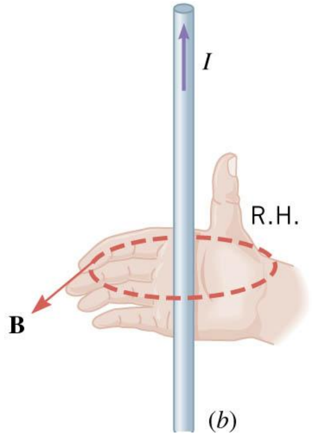


Electric current creates magnetic field



Oersted's discovery

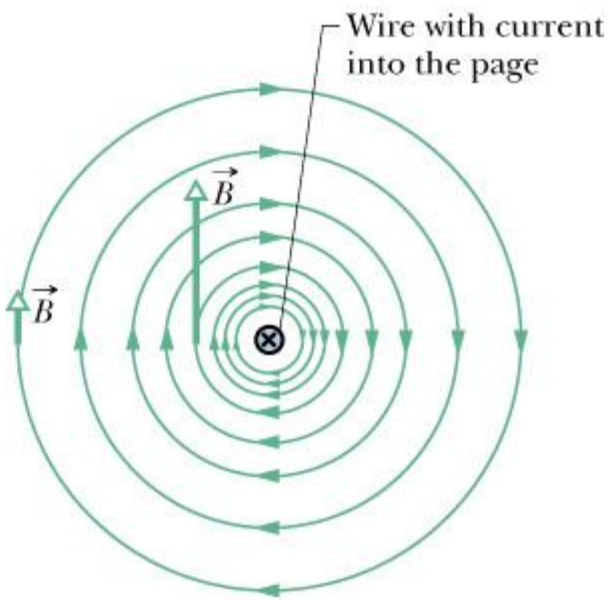


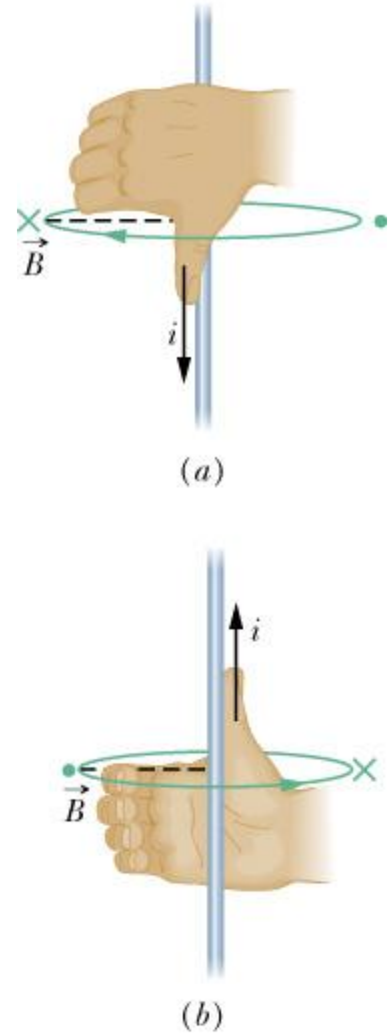


Right Hand Rule

Thumb points in direction of current (motion of + charges)

Fingers curl in direction of B vector



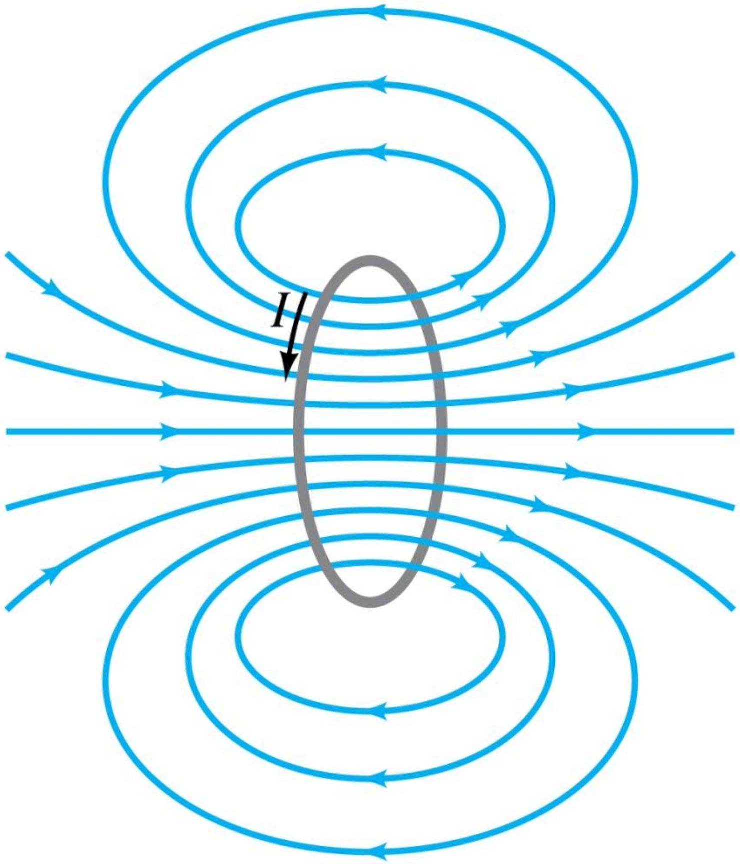


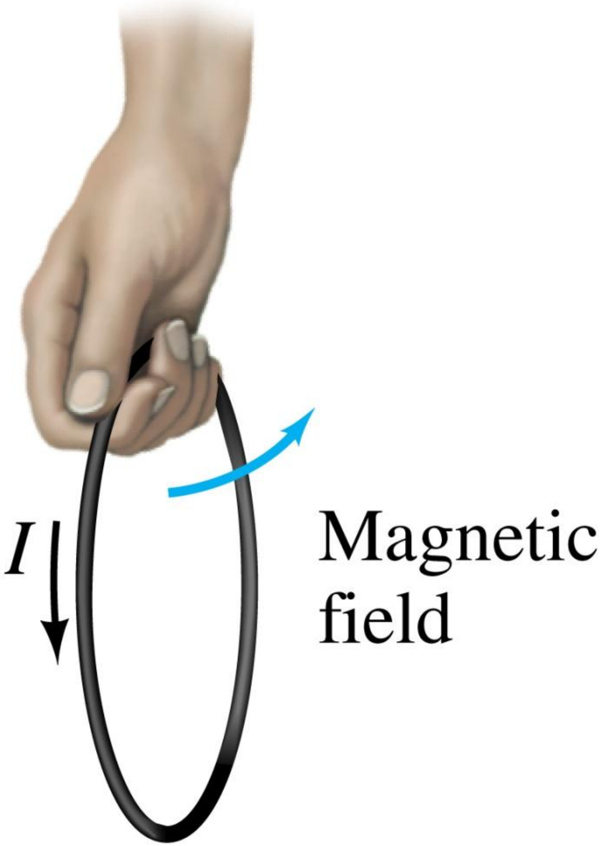
- ● B field vector out of page

X B field vector into the page

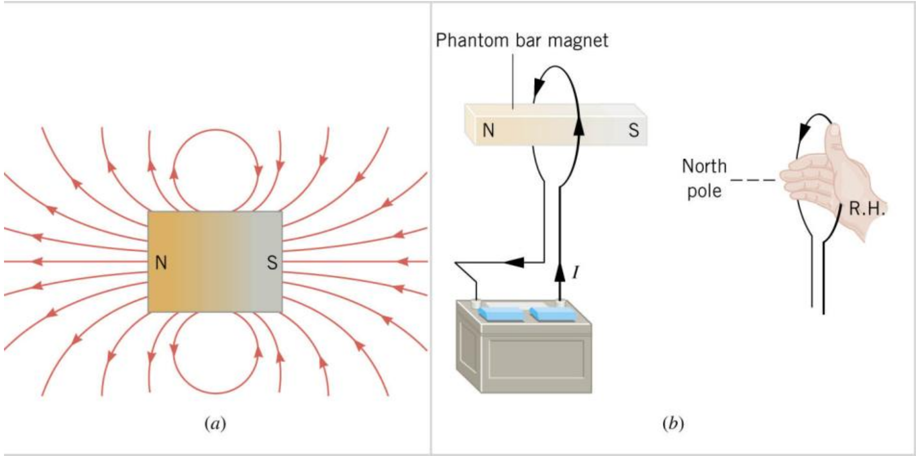
Magnetic field created by a loop of current carrying wire

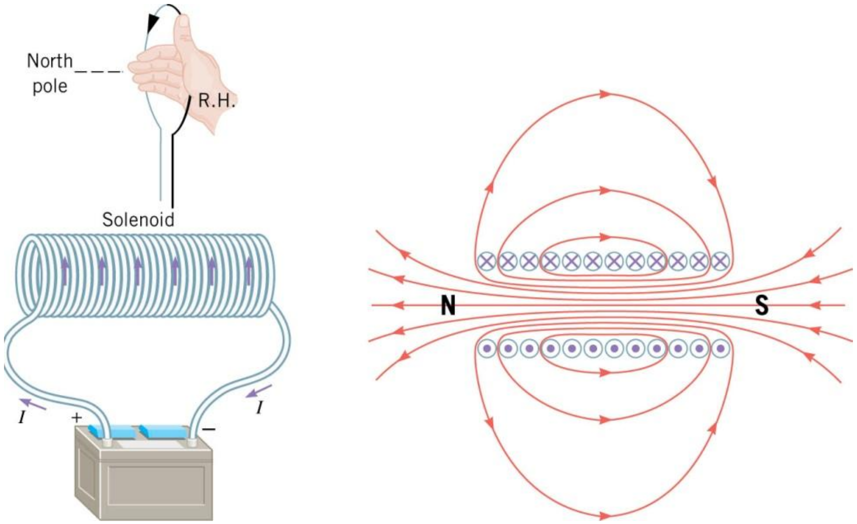
- same RHR as with wire





Circular loop of current carrying wire





solenoid is multiple loop
coil of current carrying wire

Circular loop carrying current creates magnetic field like a permanent bar magnet

Field Strength is a Ratio

$$g = \frac{weight}{mass}$$

gravitational field strength

$$\vec{E} = \frac{\vec{F}}{q_0}$$

electric field strength

$$\vec{B} = \frac{Force}{?}$$

what experiences a force when placed in a magnetic field?

A current carrying wire

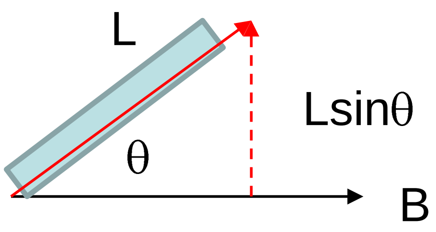
B field strength

$$B = \frac{Force}{I \bullet L \sin\theta} \qquad F_B = I(L\sin\theta)B$$

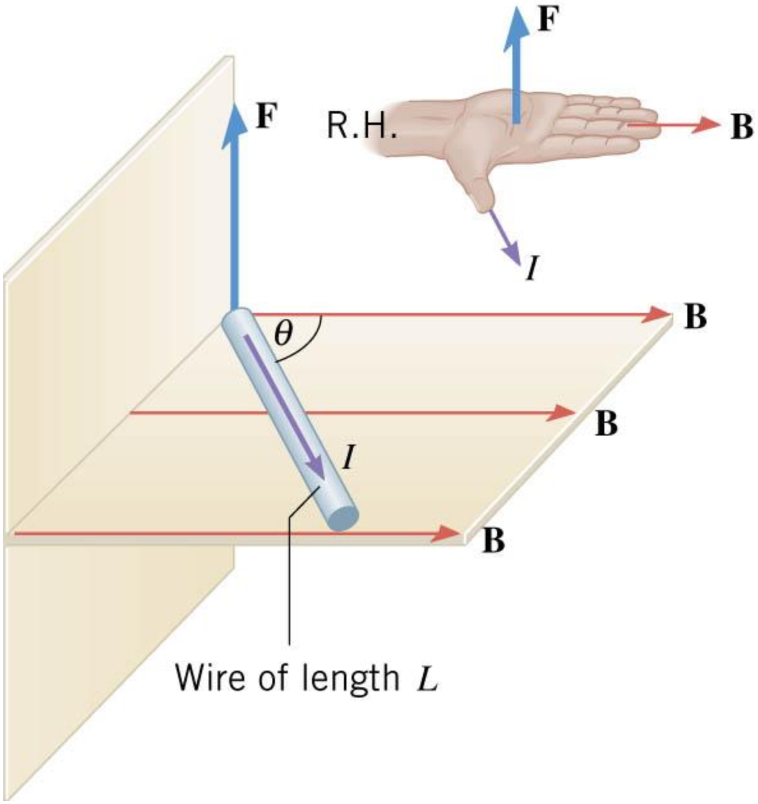
Units: Force in newtons, I in Amperes, L in meters,

B in Teslas

θ is angle between current in wire and B field vector



the component of current/wire that is ⊥ to B contributes to force



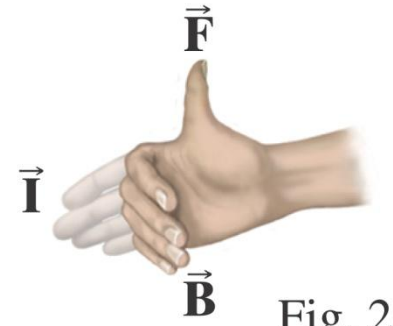
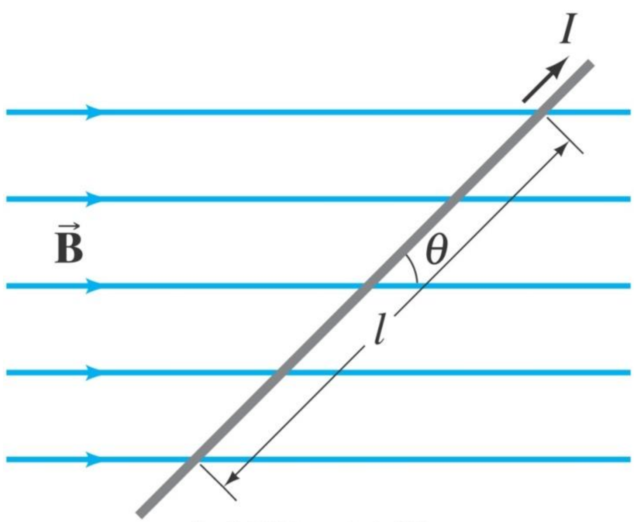


Fig. 20–11c

text version of RHR

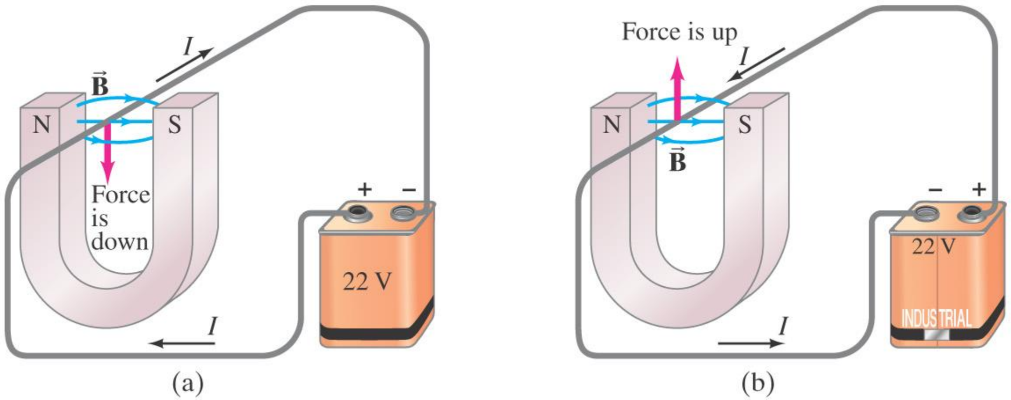


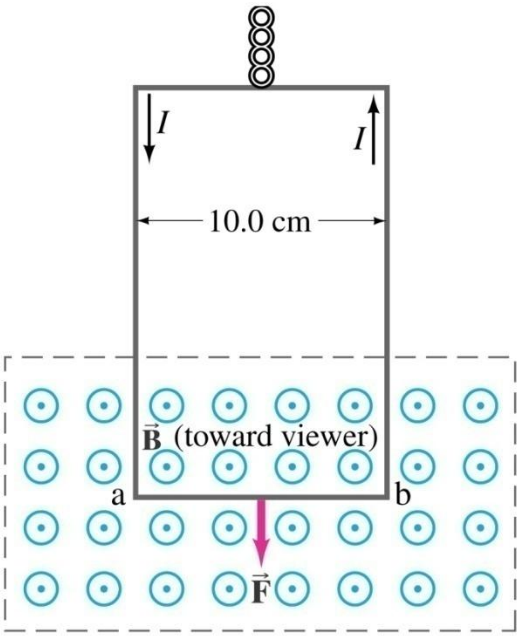
Force is maximum when $\theta = 90^o$

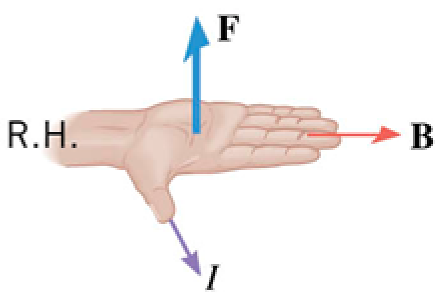
Force is zero when $\theta = 0^o$

Practice RHR with your ______ hand?

RIGHT





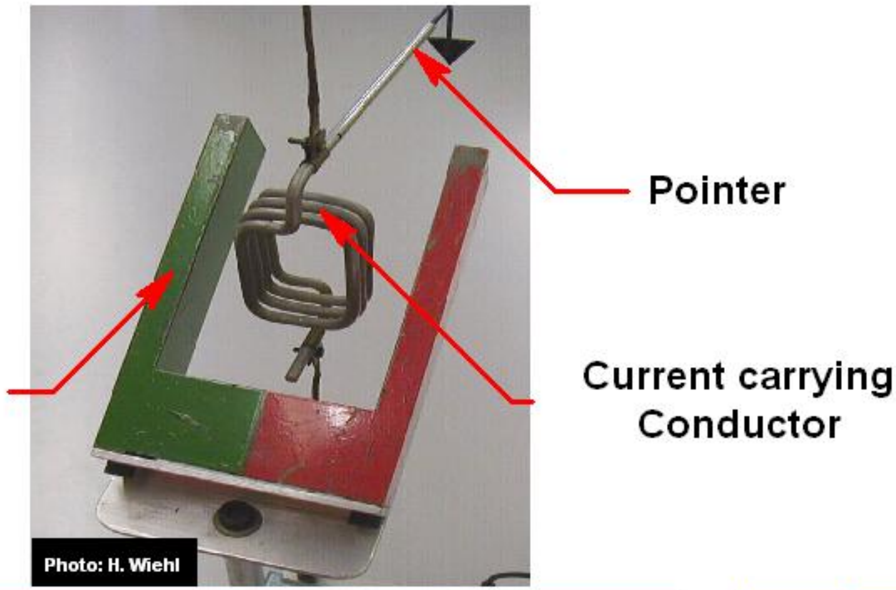


Physics - Experiments

Electrical Current Measuring Device

Magnetism / Force

Video: H. Wiehl



Measuring Electrical Current

Chapter 4 | Section 2

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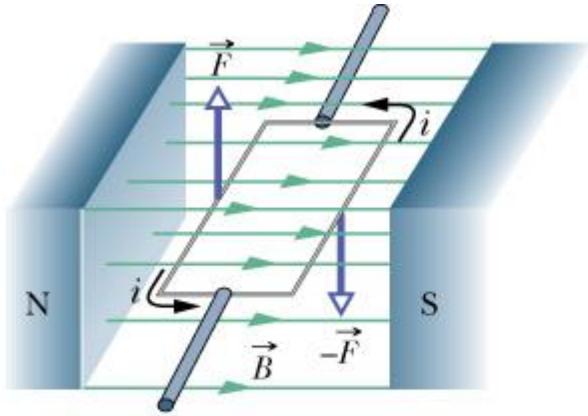
[demo]

DC Motor



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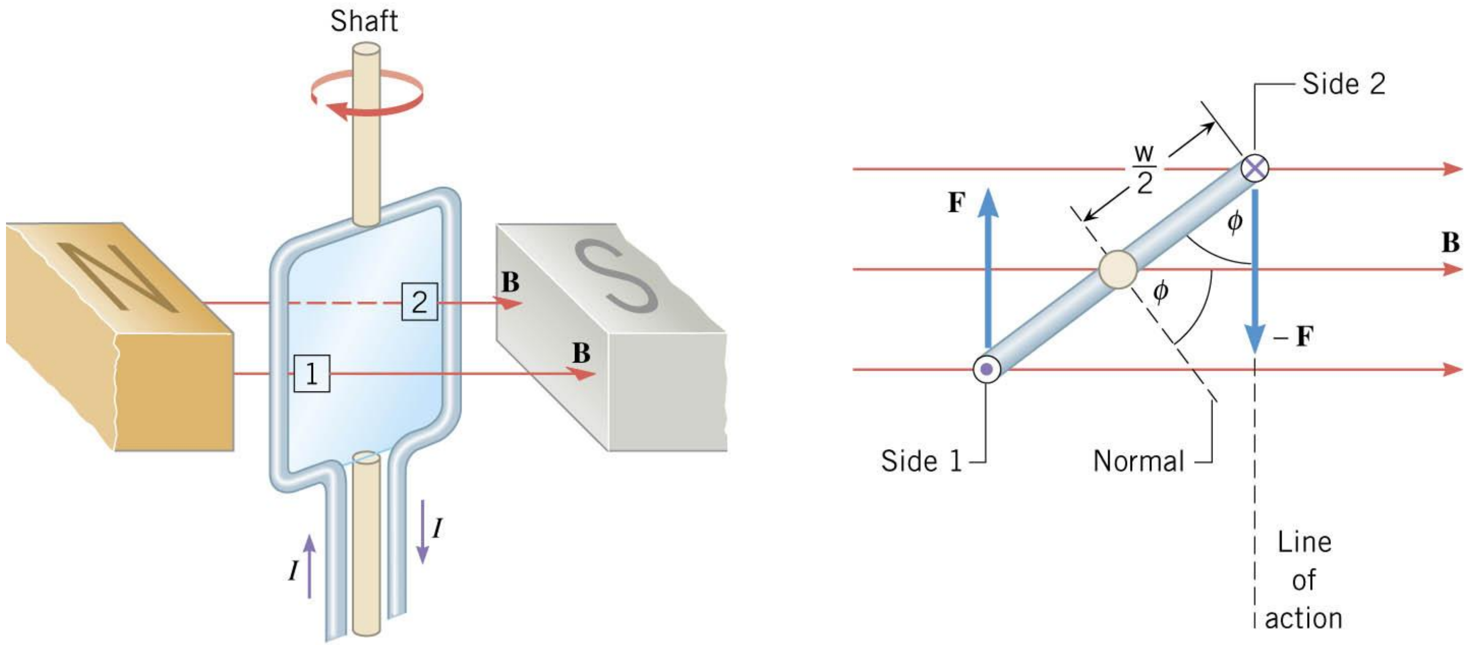

Shaft
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2
1
B
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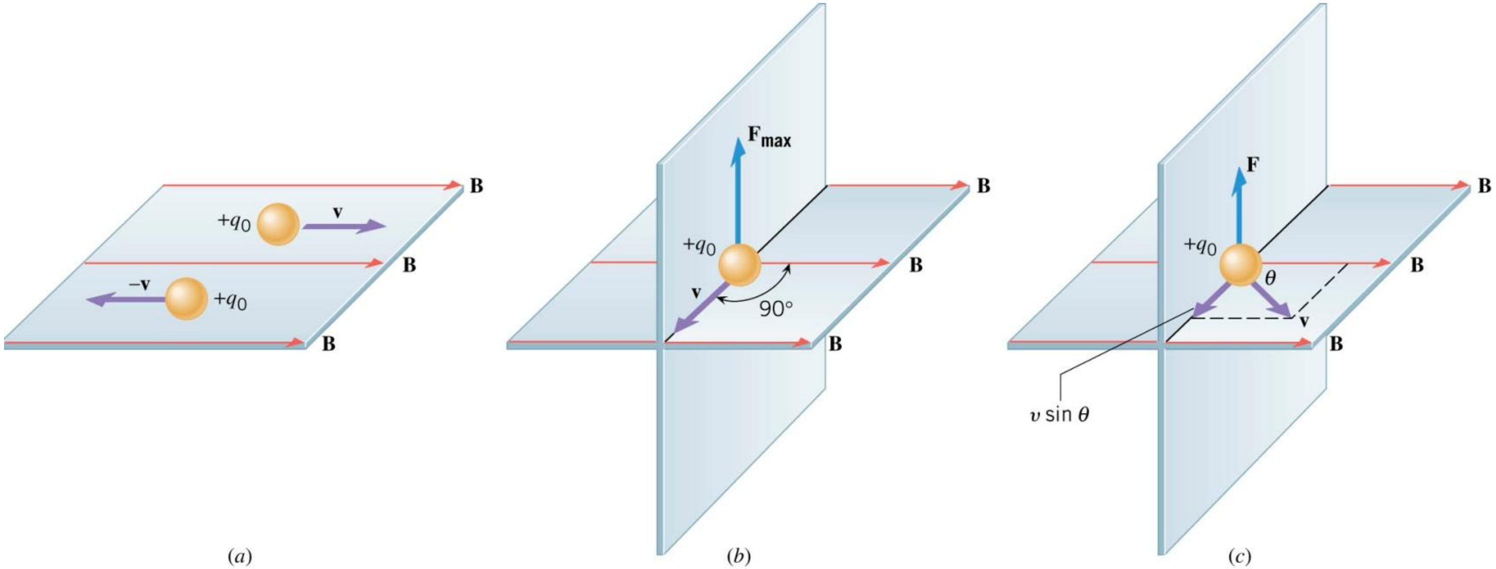
Side 1
Normal
Line
of
action

(a) (b)

Magnetic Force on charge moving through B field

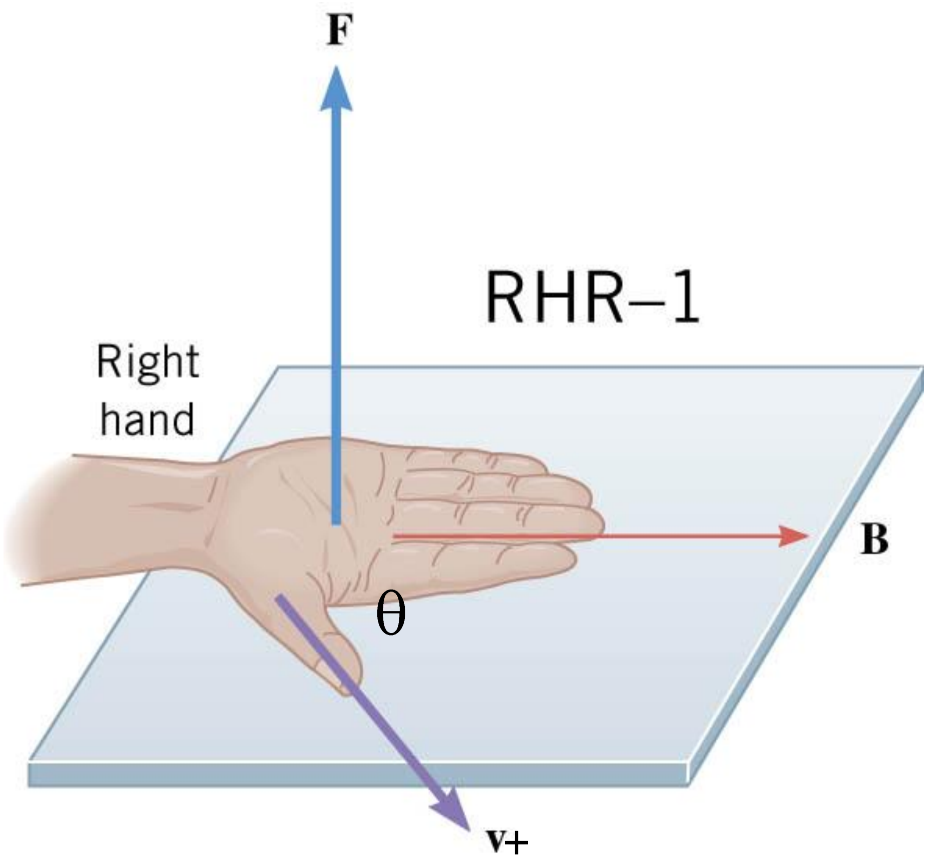


charge moving parallel to B field experiences zero magnetic force F_B

charge moving perpendicular to B field experiences maximum force

⊥ component of velocity vector contributes to force

Right Hand Rule



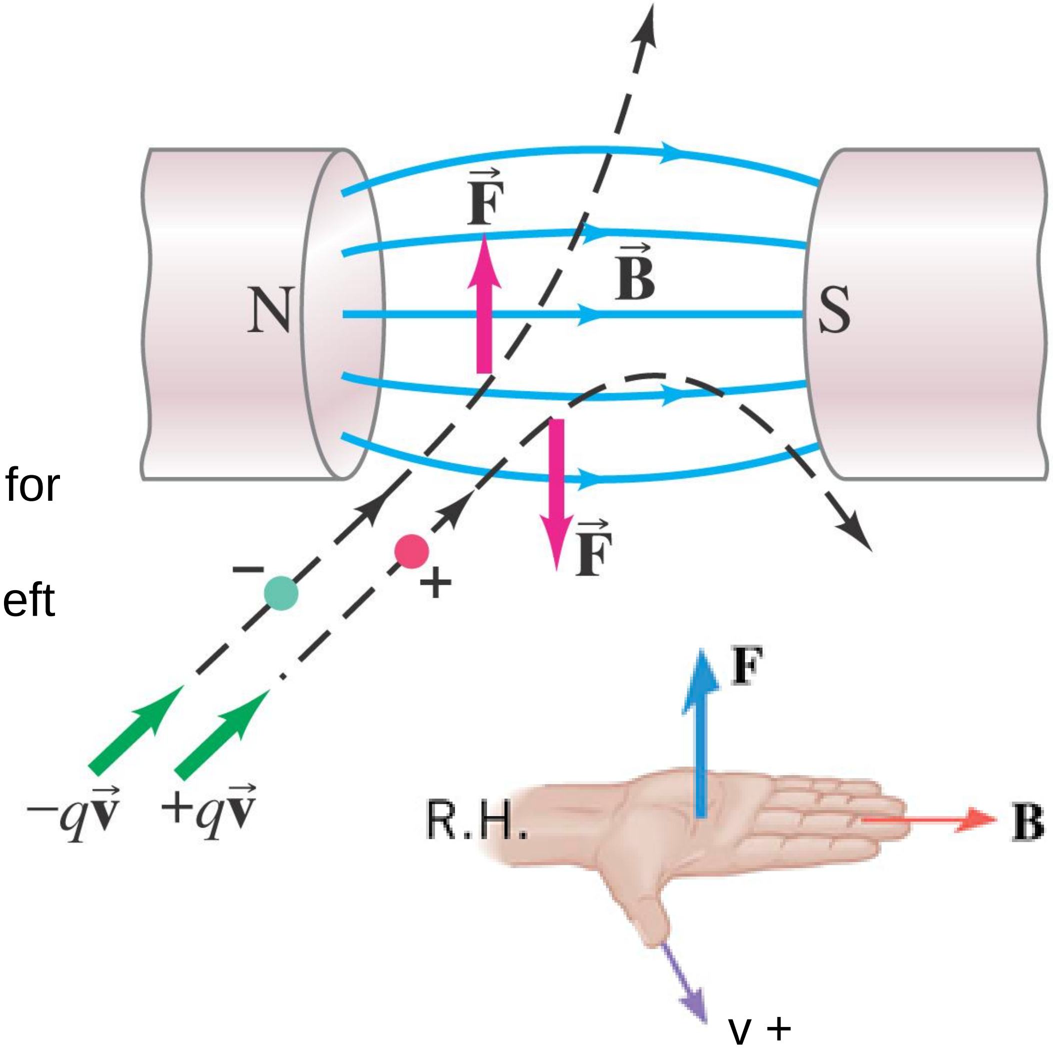
$$F_B = q(v\sin\theta)B$$

- Fingers point in direction of B vector (North leaving fingertips)
- thumb points in direction of velocity vector of + charge
- force is normal to palm
- point thumb 180º opposite direction for electron (flip hand over)

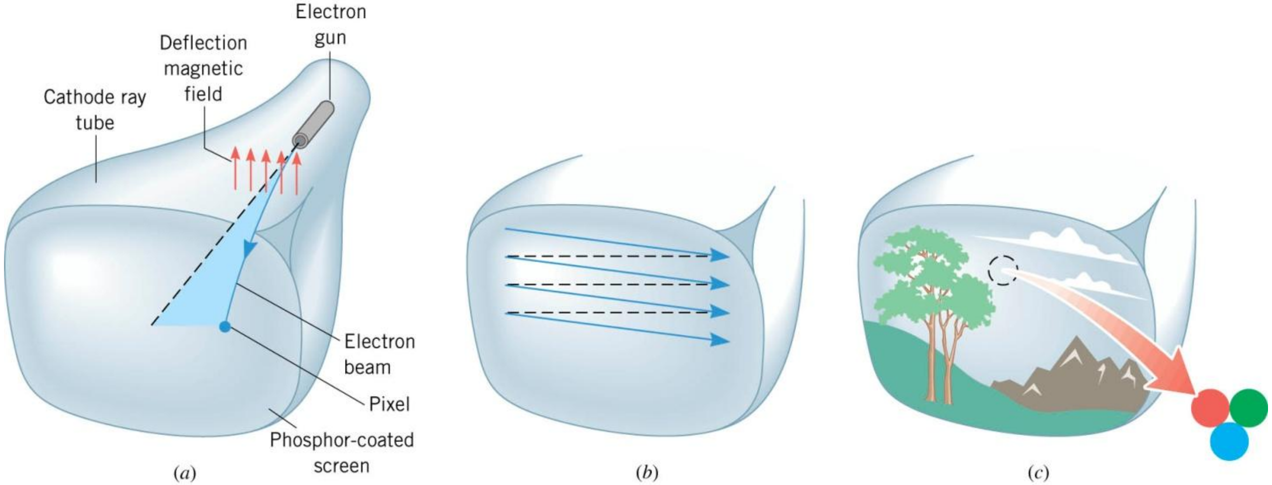
Practice RHR with your ______ hand?

RIGHT

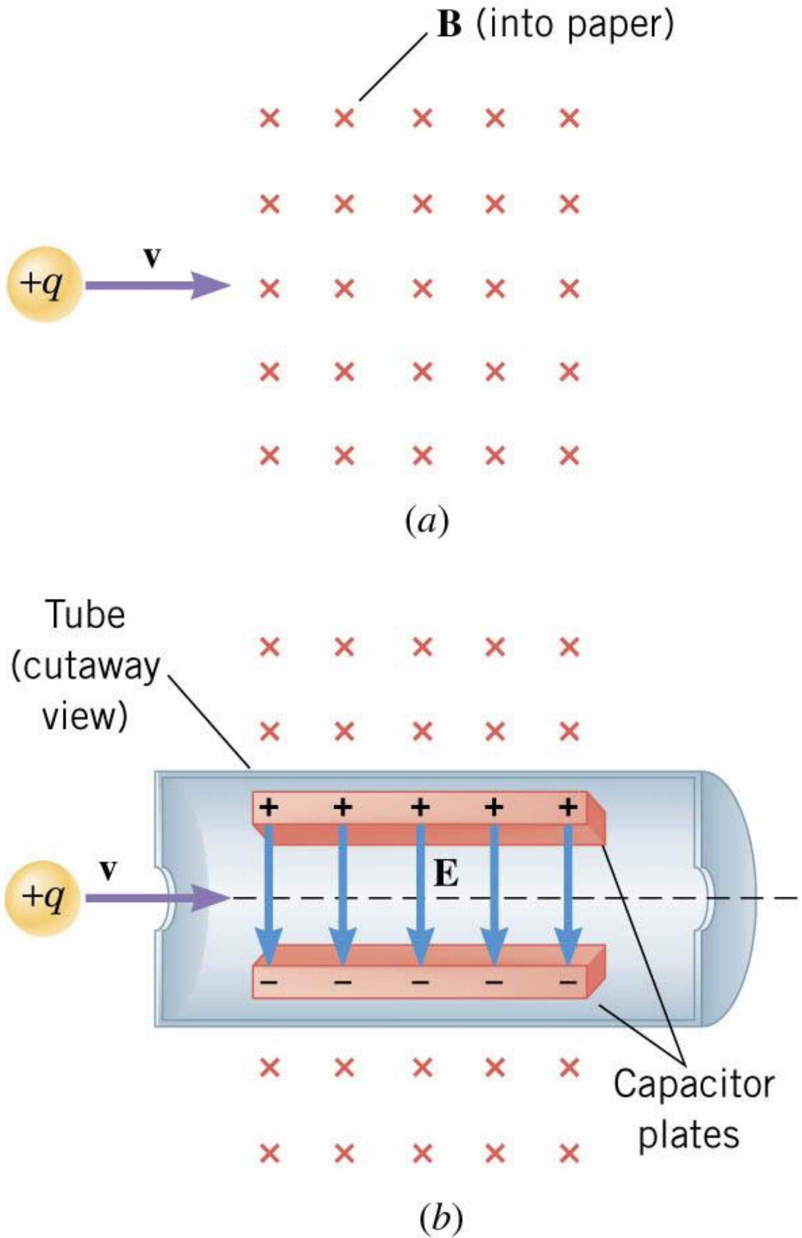
Flip hand over for electron –
never use the left hand



CRT demo – RHR-1 practice



Crossed E, B fields



balancing the F_B with and F_E from electric field

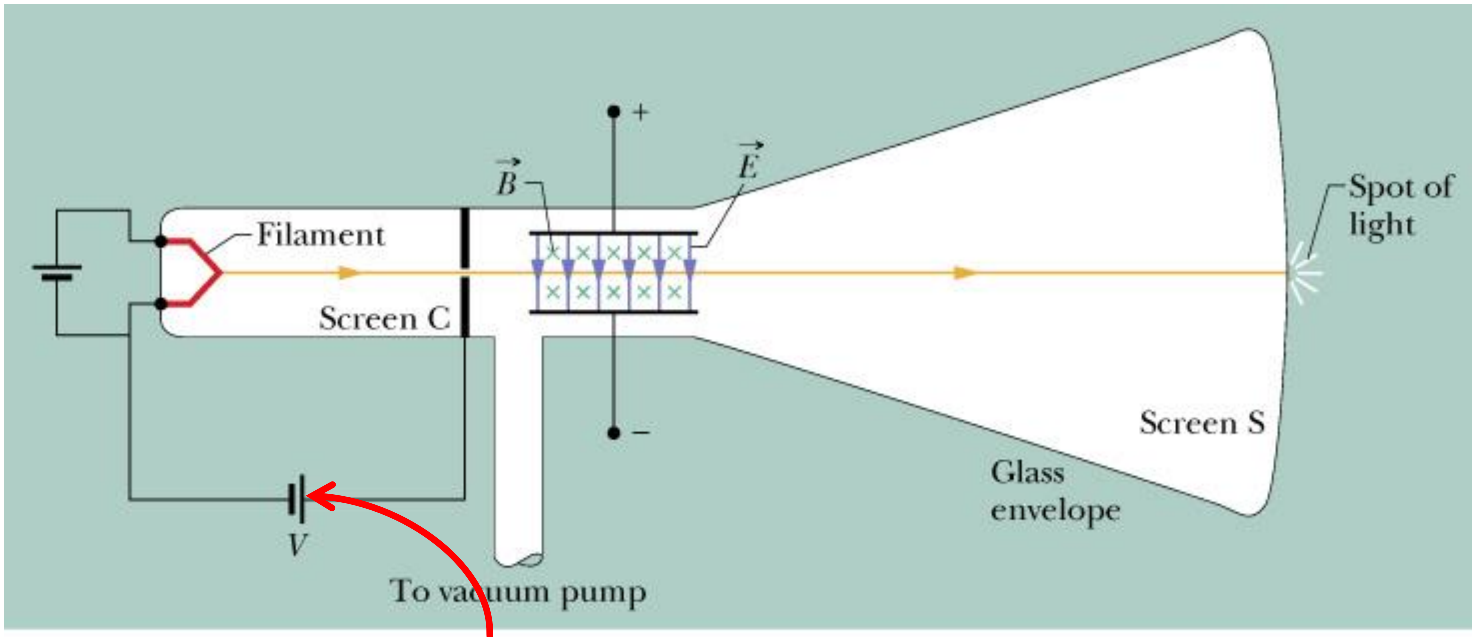
$$qE = qvB$$

$$E = vB$$

kinematic equations also used when particle is deflected by F_B or F_E a certain distance y

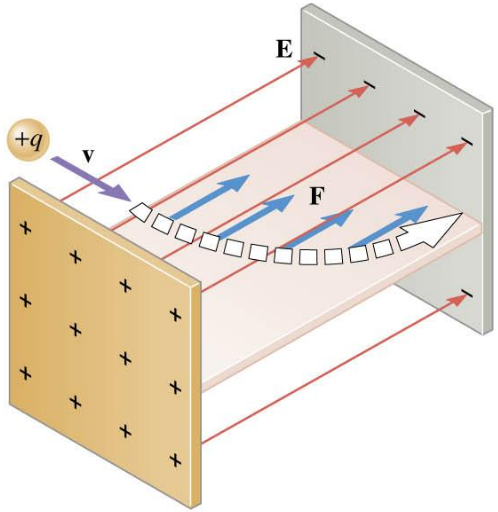
constant speed in x direction

Accelerating charged particle



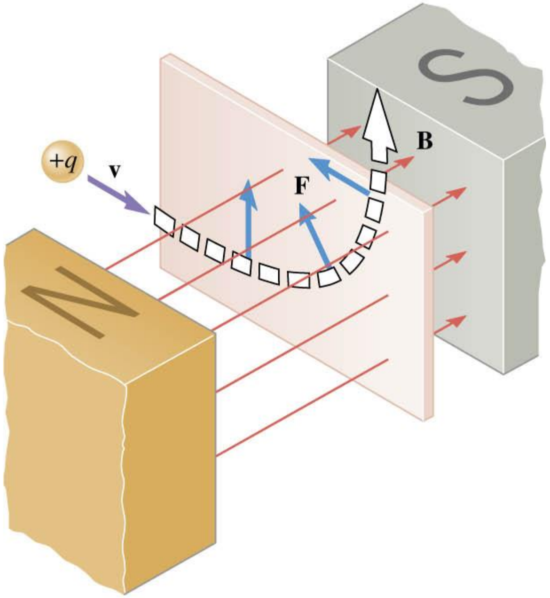
$$Work = \frac{1}{2}mv^2 = qV$$

Circulating Charged Particles



(a)

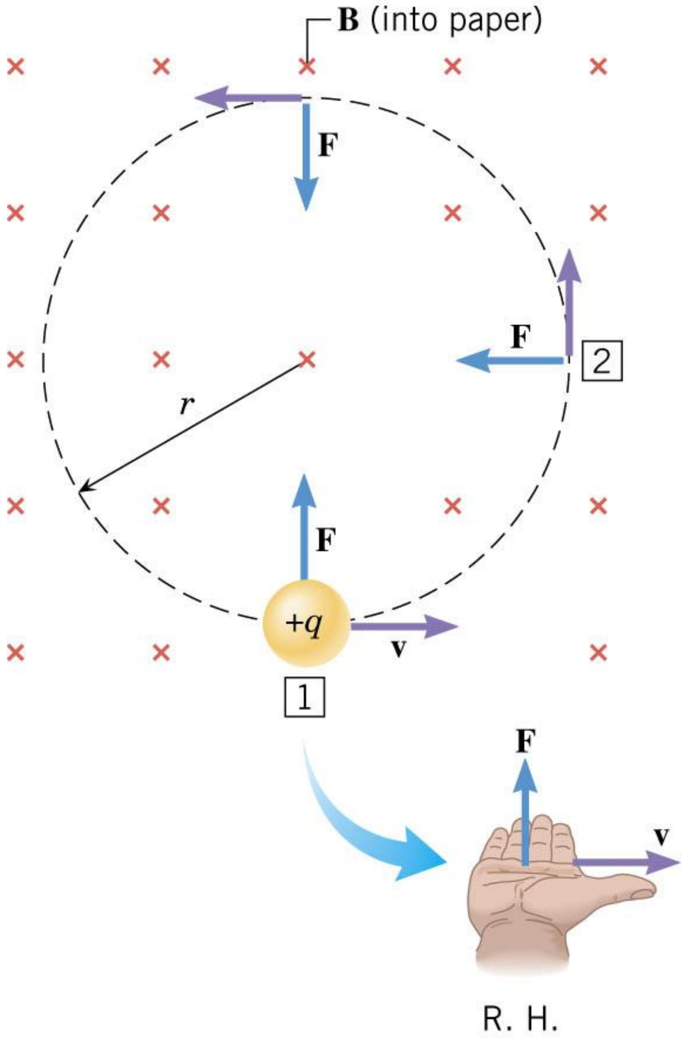
• electric field will cause parabolic path parallel to field



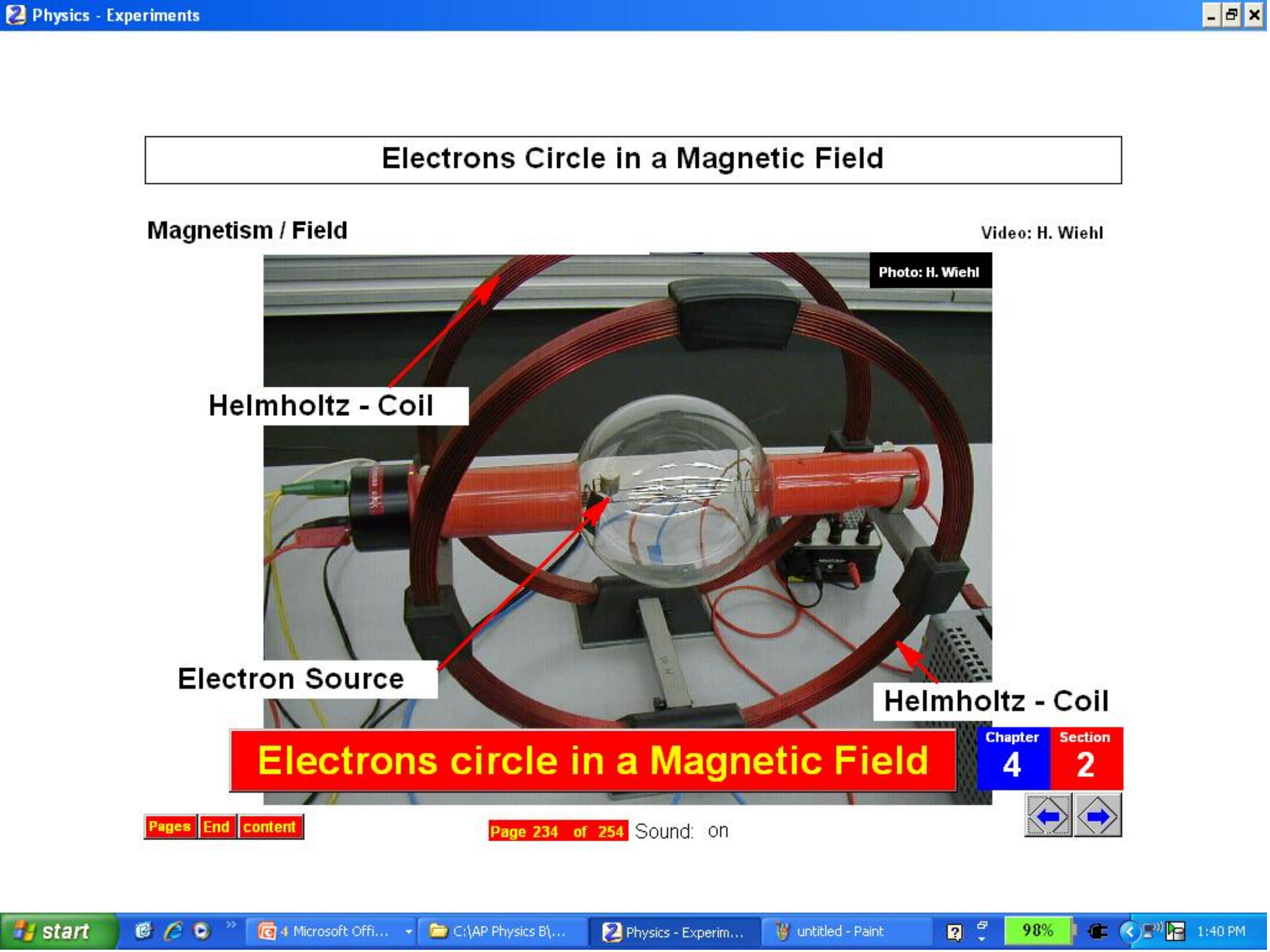
(b)

• magnetic field will cause circular path since F_B is ALWAYS perpendicular to B and v

UCM of charged particle in B field



$$qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB}$$



electron in B field

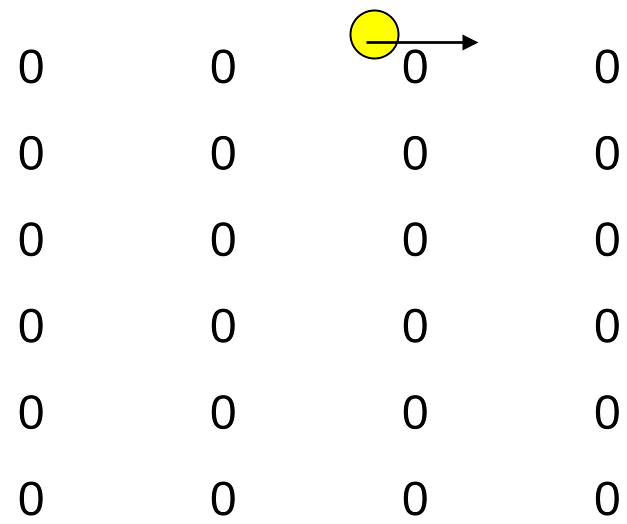
Trajectories

When moving in a uniform field, the path of a charge depends in a simple way on its direction with respect to the field. There are three cases:

1) $\vec{v} \parallel \vec{B} \Rightarrow \vec{F} = 0 \Rightarrow$ Uniform motion (no acceleration)

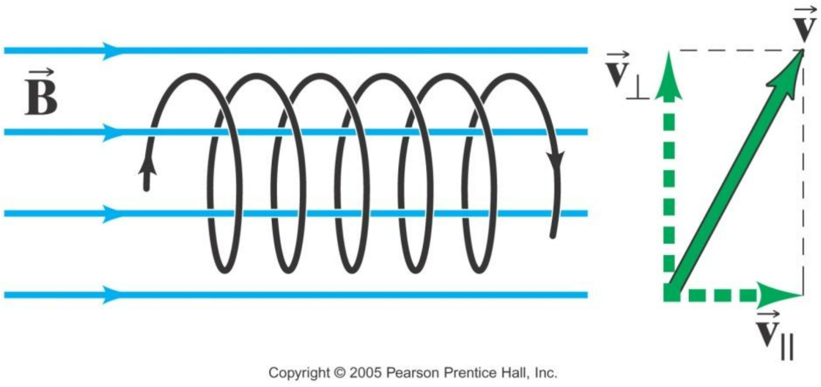
2) $\vec{v} \perp \vec{B} \Rightarrow F = qvB$

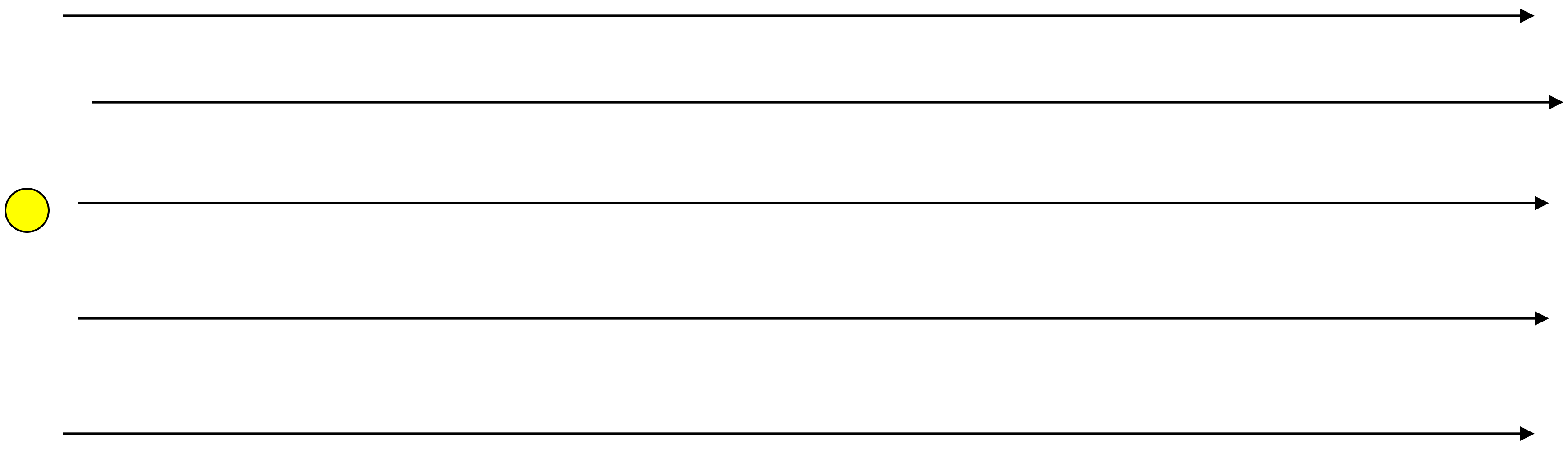
This leads to uniform circular motion



B out of page

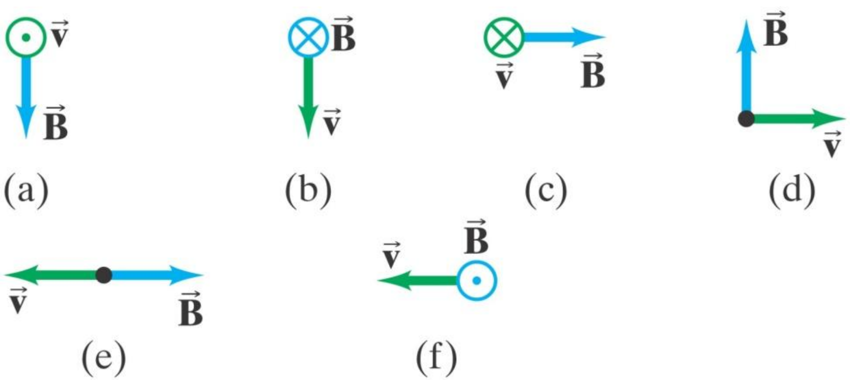
3) Both v_{ll} *and* $v_{\perp}$ *present*



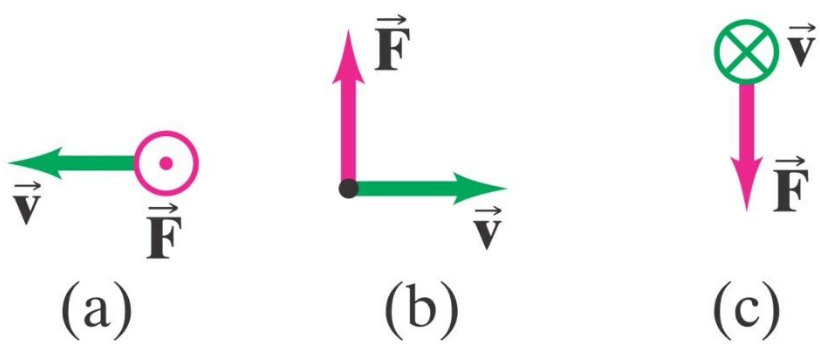


RHR practice for moving charge

problem 11



problem 12



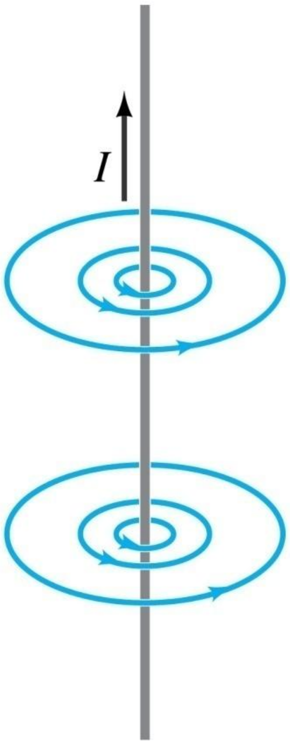
20.5 Magnetic Field Due to a Long Straight Wire

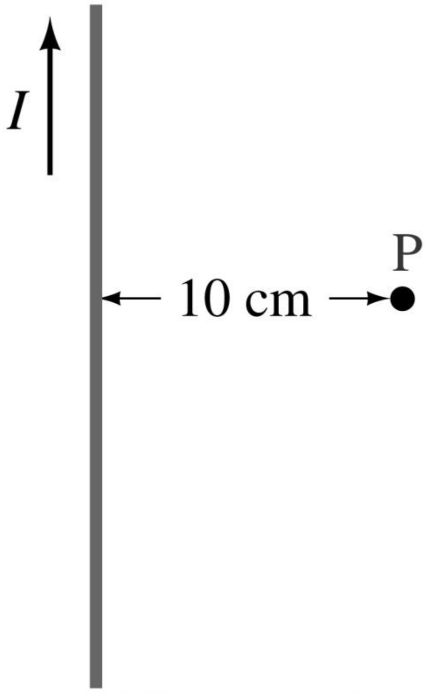
The field is inversely proportional to the distance from the wire:

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

The constant μ_0 is called the permeability of free space, and has the value:

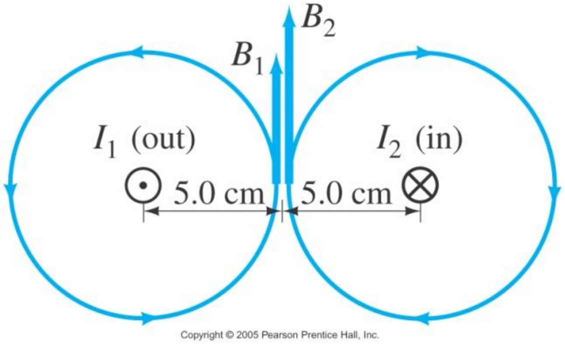
$$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\cdot m/A}$$

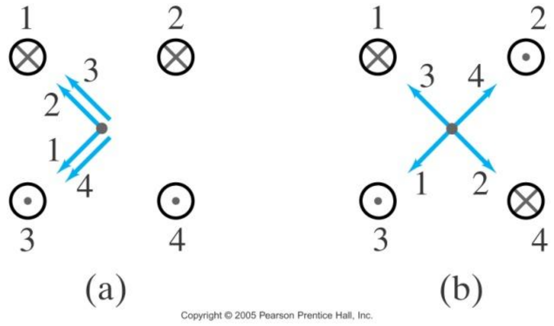




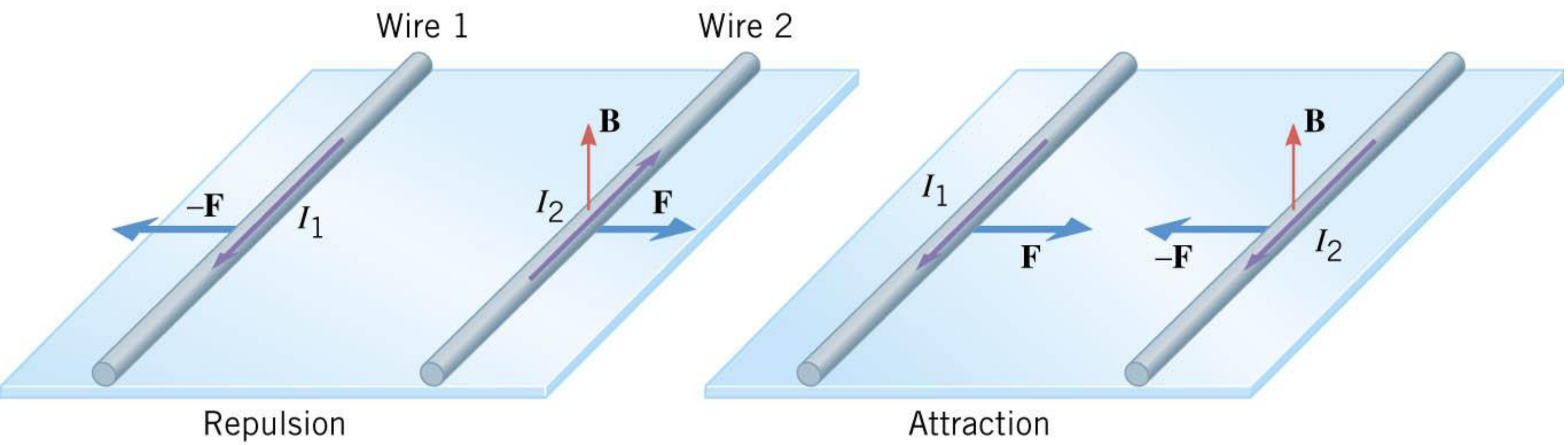
Superposition principle applies to magnetic fields just as with electric fields

Net B field at a point is a VECTOR sum of individual fields



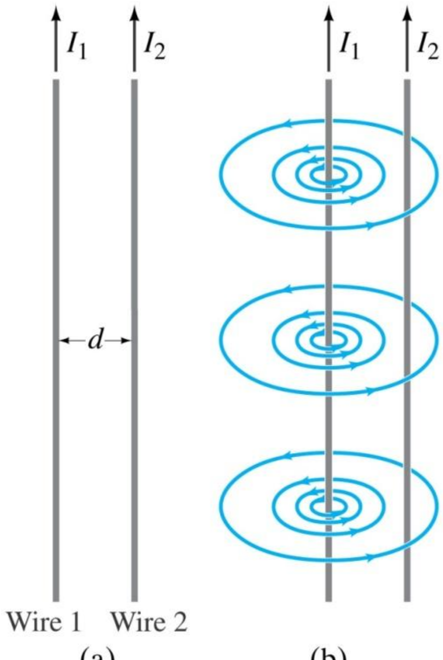


Force between parallel wires

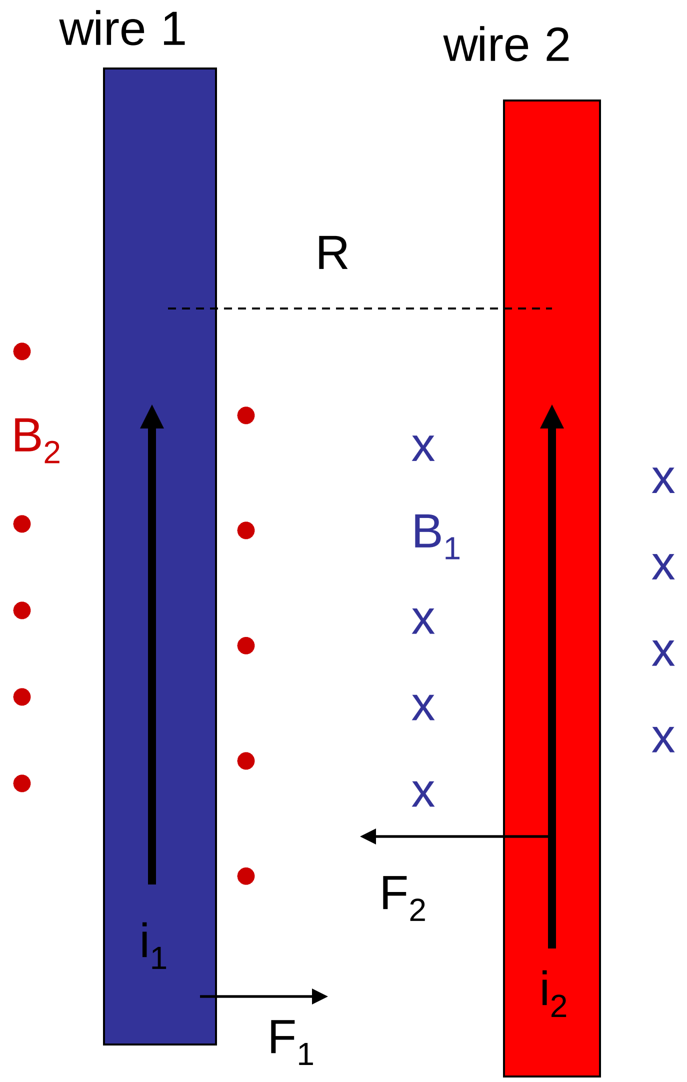


anti-parallel currents repel

parallel currents attract



Force on parallel wires



I's in same direction

Two competing influences when determining force on wire 2 due to current in wire 1 and wire 2

B_1 is increasing linearly with current but decreasing with separation distance R

$$B_1 = \frac{\mu_0 i_1}{2\pi R}$$

F_2 is increasing linearly with current in wire and B_1 it is in

$$F_2 = i_2 L B_1 = \frac{\mu_0 i_1 i_2}{2\pi R} L$$