# Exam I, Monday, Sept. 30, 7pm

- What will exam cover?
  - Lectures 1 – 7 (Electric charge – RC circuits)
  - NOT TODAY'S LECTURE
- What do you need to bring?
  - Be sure to bring your ID and go to correct room
  - All you need is a #2 pencil, calculator, and your ID (NO cell phones, iPods, iPads, laptops, etc.)
- Conflict exams – on the same day!!
  - You MUST register in ADVANCE in the gradebook!
- Review, Sunday, Sept. 29, 2 PM, 141 Loomis
  - I will go over Spring '13 exam I problems

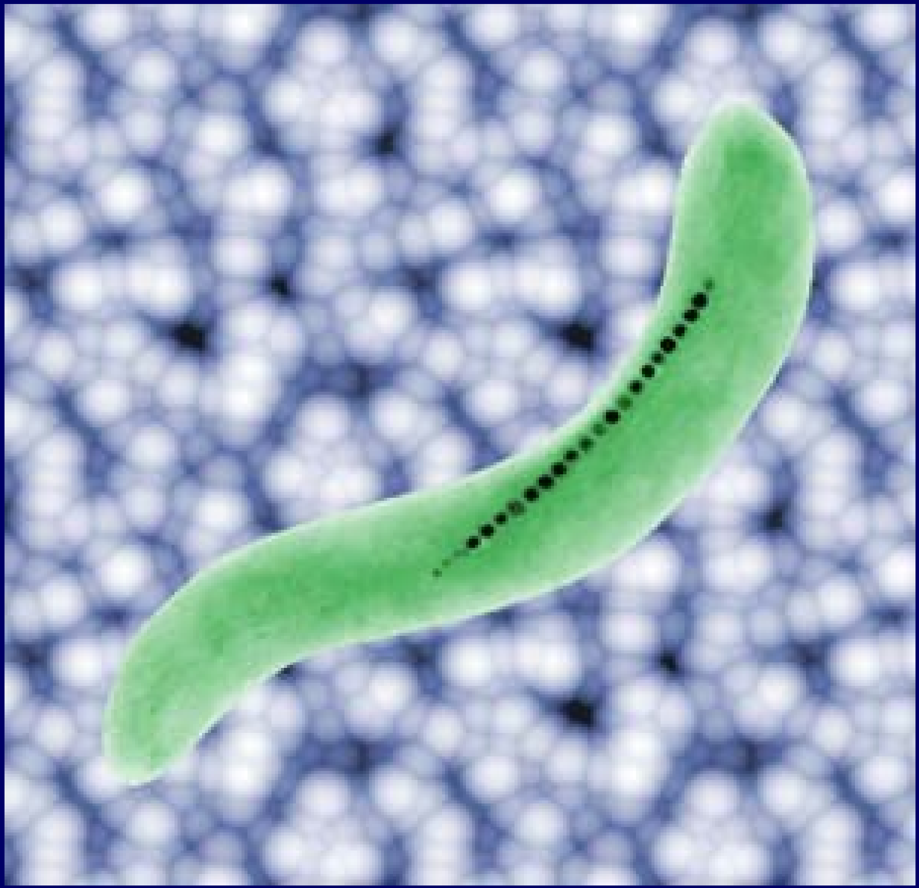
# Exam I, Monday, Sept. 30, 7pm

- What can you expect on a Phys 102 exam?
  - 25–28 multiple choice questions (5-, 3-, 2-answer)
  - Mix of conceptual & computation
- How do you study for a Phys 102 exam?
  - Emphasize understanding concepts & problem solving, NOT memorization
  - Review lecture notes, problem solver summary
  - Understand formula sheet (i.e. when to use and when NOT to use an equation) & know what each symbol means
  - Do practice exam problems (time yourself!)
  - Go to office hours (there are extra office hours)
  - Go to the review session

# Physics 102: Lecture 08

## Magnetism

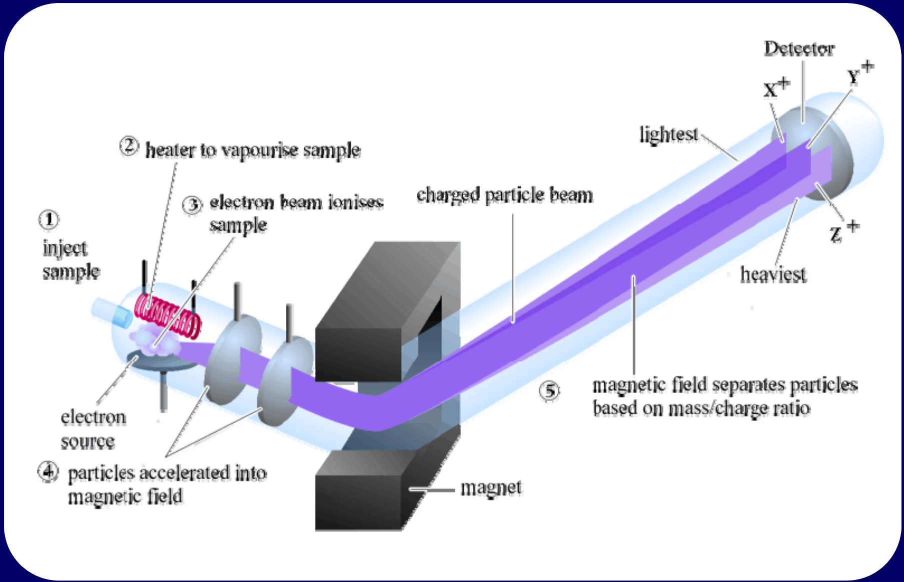
**This material is NOT on exam 1!**

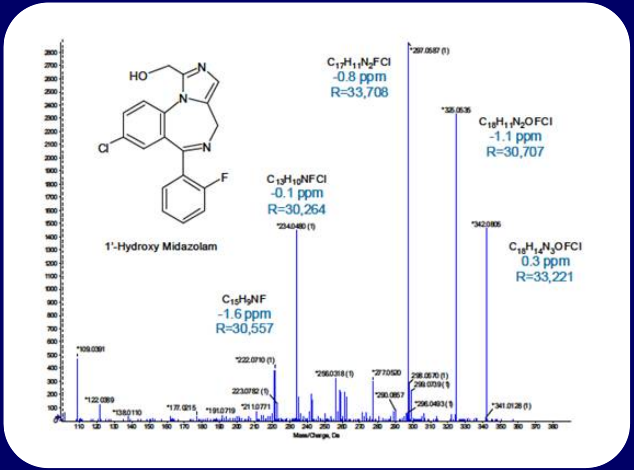


**Magnetotactic bacterium**

# Lecture Overview

- Magnetic fields
- Magnetic forces on <u>moving</u> charges
  - Direction: "Right hand rule"
  - Magnitude
  - Circular motion

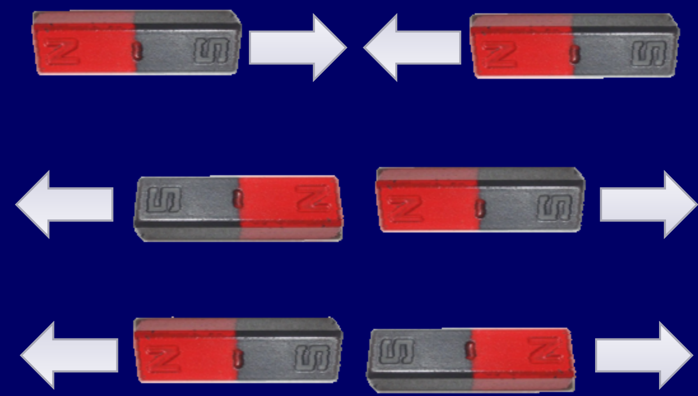


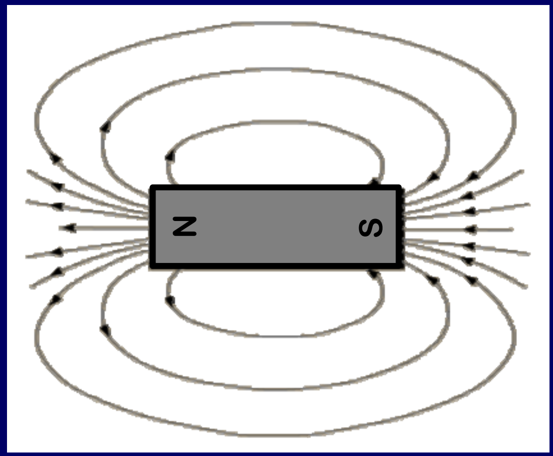

**Mass spectrometer**

# Magnets & magnetic fields

- North Pole and South Pole
  - Opposites Attract
  - Likes Repel

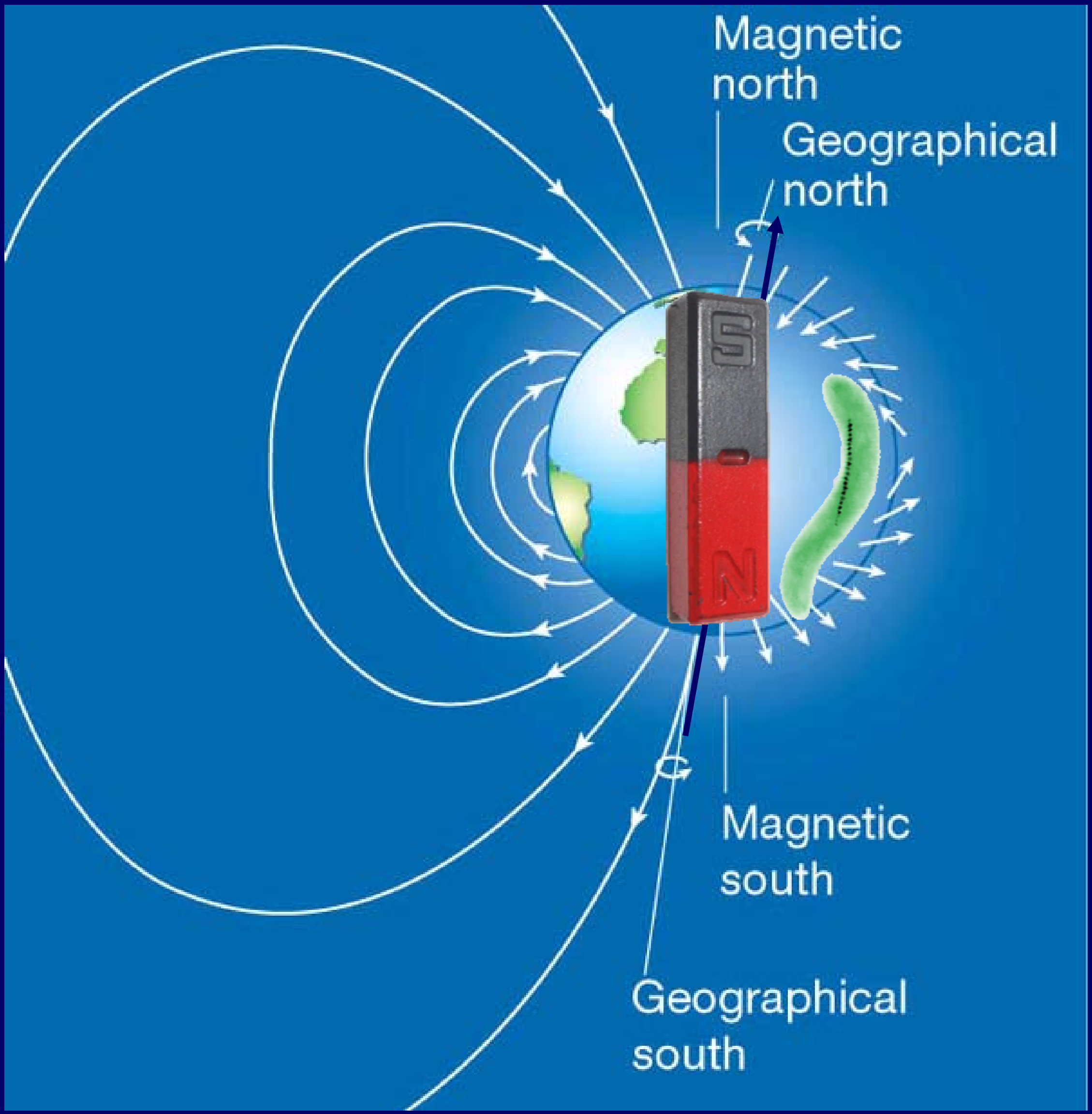


- Magnetic Field B
  - Units = Tesla (T)
  - Like E, vector at a location
  - Points N to S
- Magnetic Field Lines
  - Arrows give direction
  - Density gives strength
  - Looks like dipole!



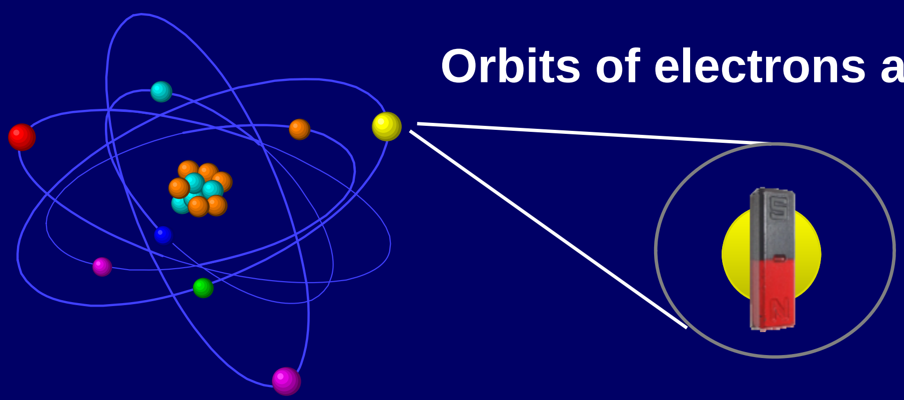

**(Checkpoint 1.1)**

# The Earth is a Magnet



# No Magnetic Charges

- N and S poles always go together
- Magnetic Fields are created by moving electric charge and intrinsic dipoles



# Magnetic Fields and Forces

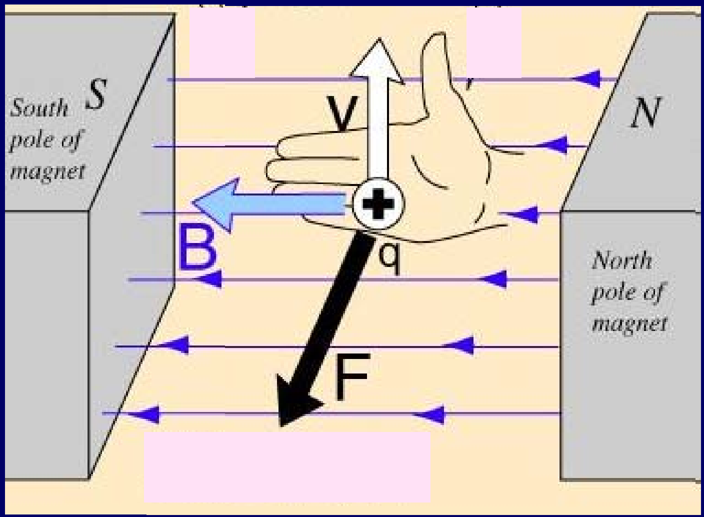
Magnitude

- Magnetic field B exerts force on moving charge

$$F = |q||v||B| \sin\theta$$

Direction

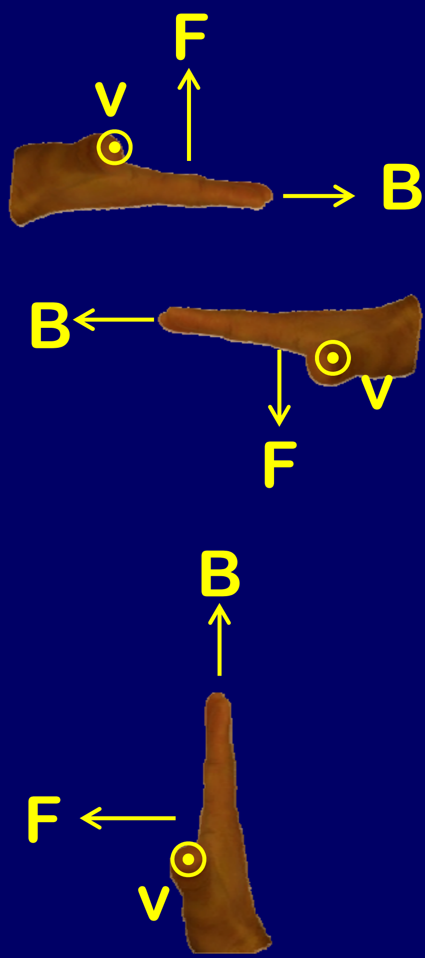
- Magnetic force is perpendicular to both B and v
- "Right-hand rule" (RHR):
  - Thumb of right hand along **v**
  - Fingers of right hand along **B**
  - Out-of-palm points
    - in the direction of F for + charge
    - opposite to F for – charge




Note: there are different versions of RHR

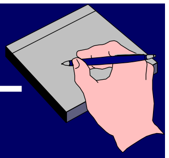
# ACT: Direction of Magnetic Force on + Moving Charge

| Velocity | B | Force |
|---|---|---|
| out of page | right | up |
| out of page | left | down |
| out of page | up | |
| | | |

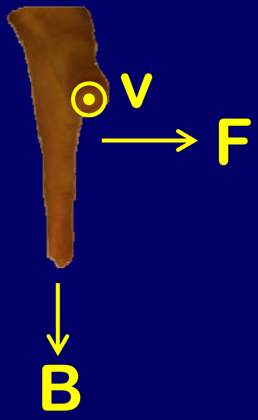



1) Up  2) Down  3) Right  4) Left  5) Zero

# Direction of Magnetic Force on + Moving Charges

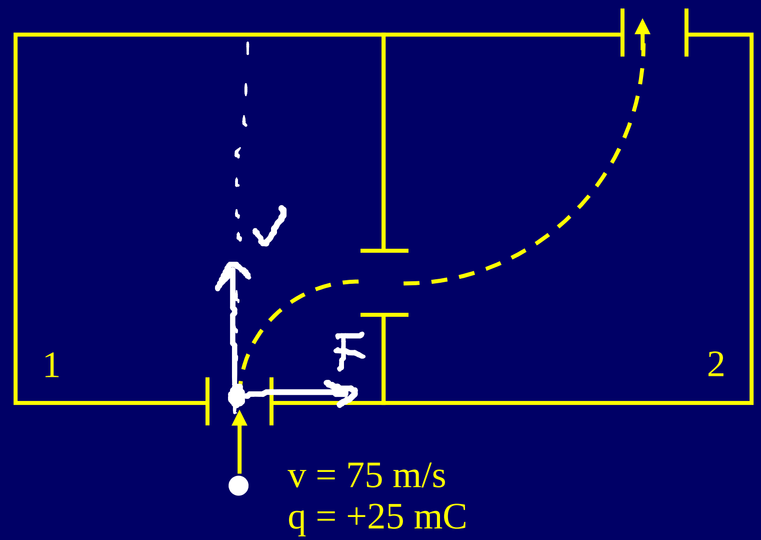


| Velocity | B | Force |
|---|---|---|
| out of page | right | up |
| out of page | left | down |
| out of page | up | left |
| out of page | down | right |



# CheckPoint 2.1

Each chamber has a unique magnetic field. A ***positively*** charged particle enters chamber 1 with velocity 75 m/s up, and follows the dashed trajectory.




What is the direction of the force on the particle just as it enters region 1?

35% 1) up

4% 2) down

10% 3) left

41% 4) right

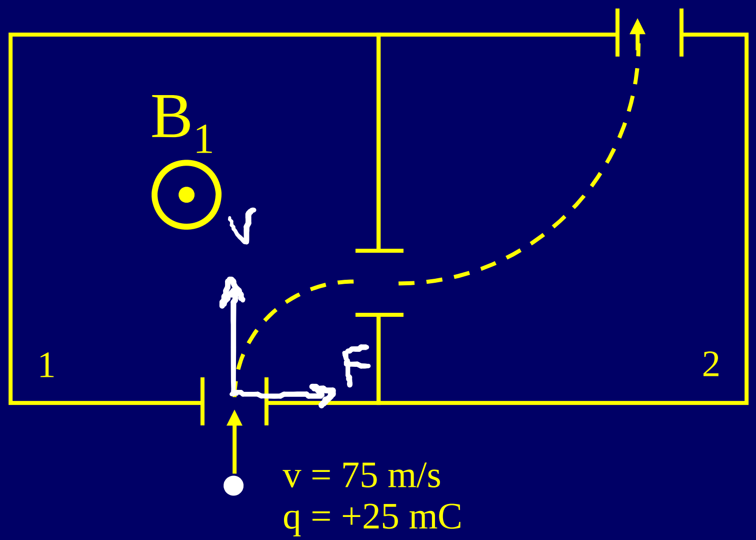
9% 5) into page

1% 6) out of page

**Particle is moving straight upwards then veers to the right.**

# CheckPoint 2.2

Each chamber has a unique magnetic field. A ***positively*** charged particle enters chamber 1 with velocity 75 m/s up, and follows the dashed trajectory.




What is the direction of the magnetic field in region 1?

18% 1) up

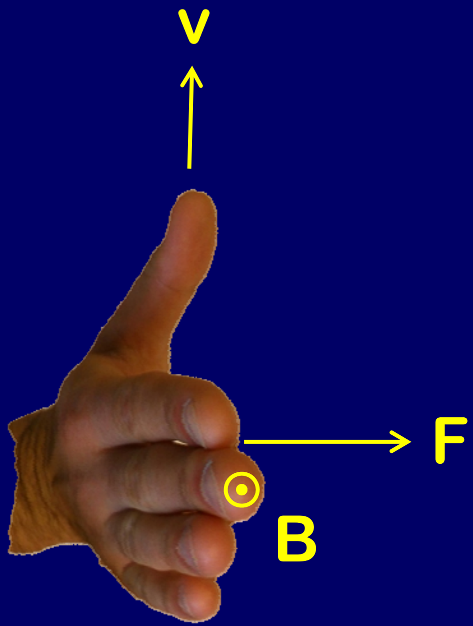
6% 2) down

5% 3) left

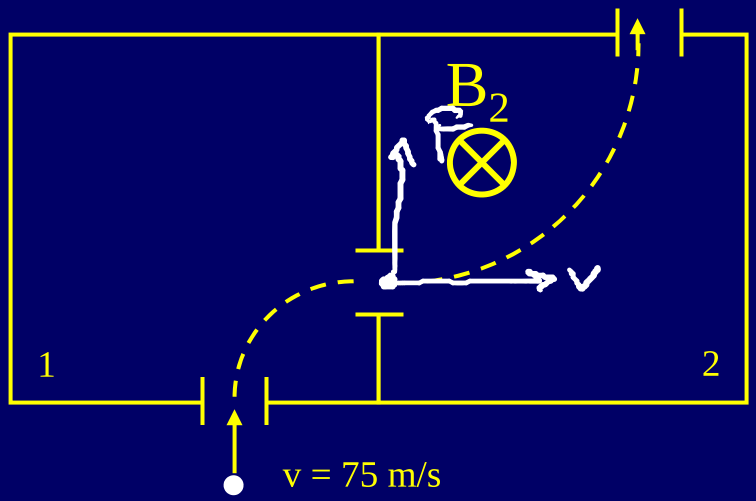
38% 4) right

9% 5) into page

25% 6) out of page



# ACT: 2 Chambers




Each chamber has a unique magnetic field. A ***positively*** charged particle enters chamber 1 with velocity 75 m/s up, and follows the dashed trajectory.

What is the direction of the magnetic field in region 2?

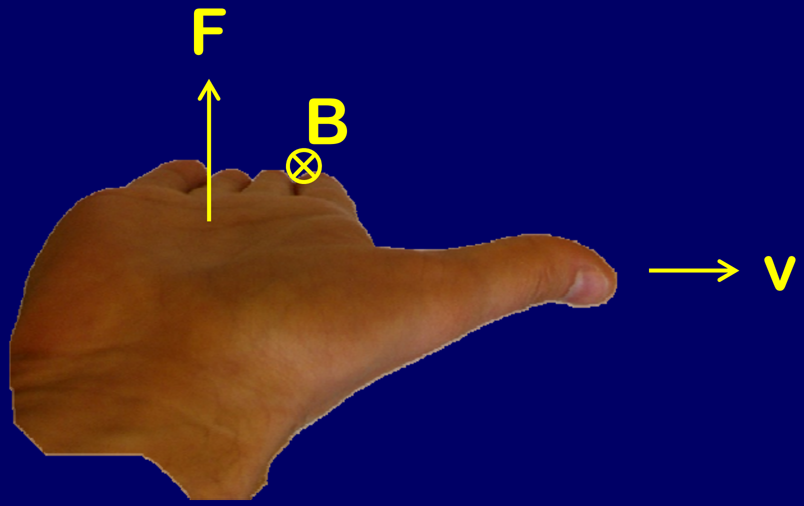
A) down

B) left

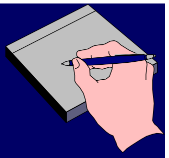
C) right

D) into page

E) out of page



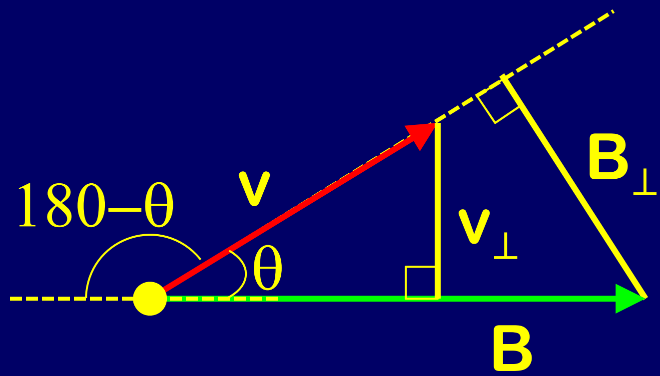
# Magnitude of Magnetic Force on Moving Charges



Force depends on magnitude of charge, velocity, and magnetic field

$$\boxed{F = qvB\sin\theta}$$

$$= qv_{\perp}B \;\; = qvB_{\perp}$$



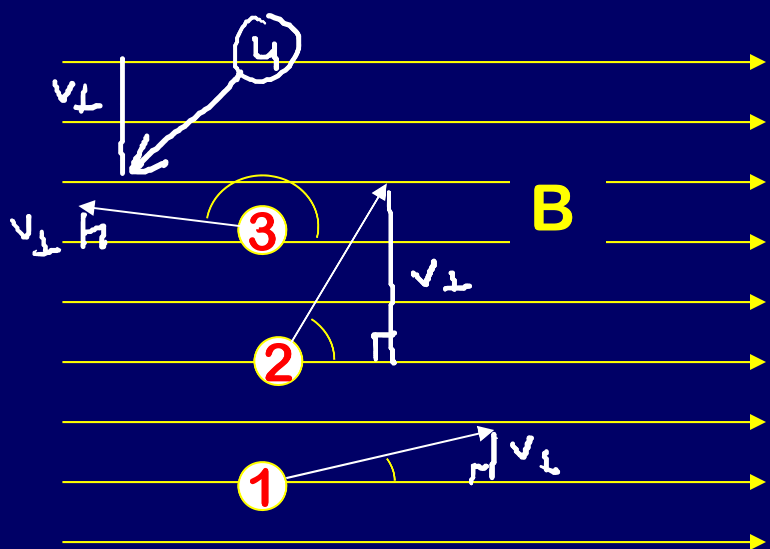

Only component of v ⊥ to B (or B ⊥ to v) matters

If v is parallel to B then F = 0

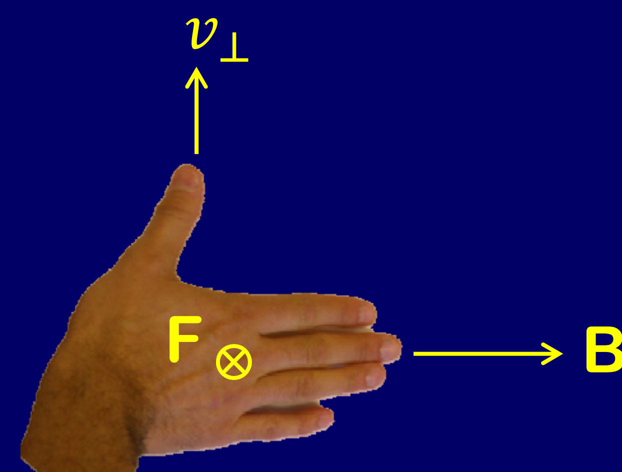
Does not matter whether you use θ or 180 – θ

# ACT: Moving Charges

The three charges below have equal charge and speed, but are traveling in different directions in a uniform magnetic field.




$$F = qvB\sin(\theta) = qv_\perp B$$




1) Which particle experiences the greatest magnetic force?

A) 1 B) 2 C) 3 D) All Same

2) The force on particle 3 is in the same direction as the force on particle 1.

A) True B) False

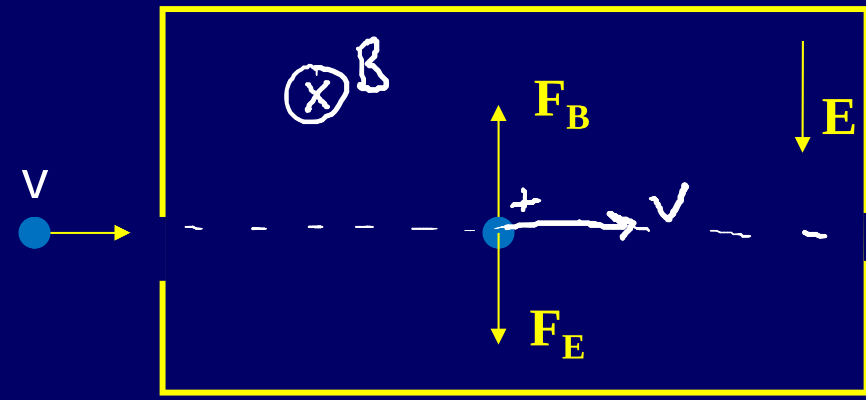
# Comparison
# *Electric* vs. *Magnetic*

| | Electric | Magnetic |
|---|---|---|
| Source: | Charges | Moving Charges |
| Act on: | Charges | Moving Charges |
| Magnitude: | $F = q\ E$ | $F = q\ v\ B\ \sin(\theta)$ |
| Direction: | Parallel to E | Perpendicular to v, B |

# Velocity Selector

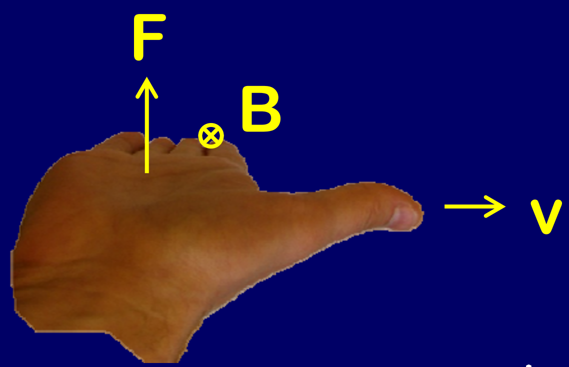
Example

Determine magnitude and direction of magnetic field such that a ***positively*** charged particle with initial velocity v travels straight through and exits the other side.




Electric force is down, so need magnetic force up.

By RHR, B must be <u>into page</u>



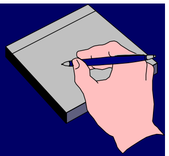

For straight line, need $|F_E| = |F_B|$

$q E = q v B \sin(90)$

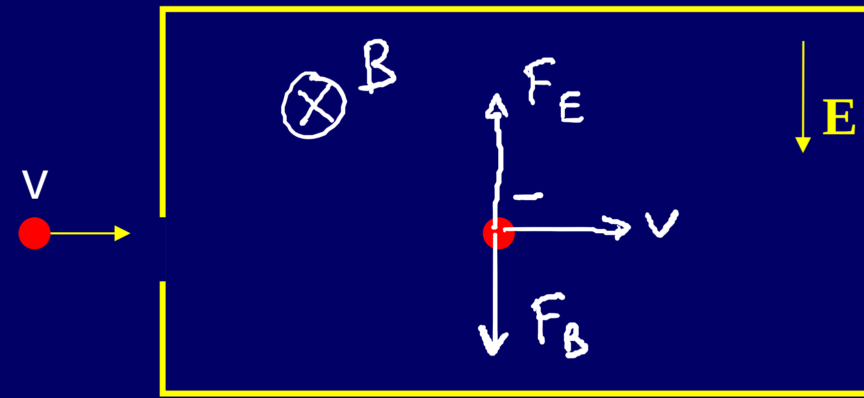
$B = E/v$

Example

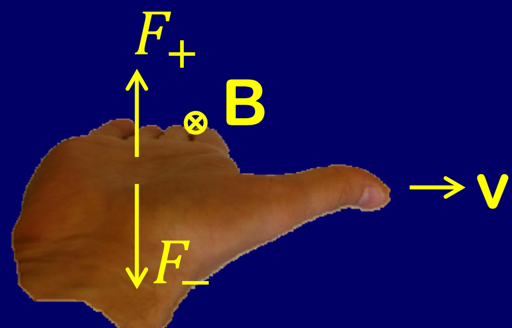
# Velocity Selector



Determine magnitude and direction of magnetic field such that a ***negatively*** charged particle with initial velocity v travels straight through and exits the other side.




# ACT: Velocity Selector




Use the RHR and invert the force for – charges

What direction should B point if you want to select ***negative*** charges?

A) Into Page B) Out of page C) Left D) Right

$F_E$ would be up so $F_B$ must be down.

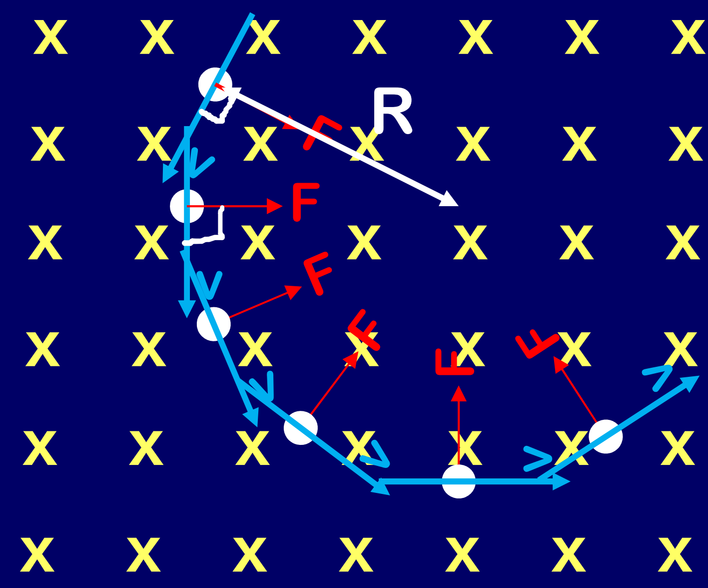
# Motion of q in uniform B field

- Force is perpendicular to B,v
  - Motion is circular
  - B does no work! (W=F d cos θ)
  - Speed is constant (W=ΔK.E.)

- Solve for R:

Recall circular motion from Phys 101

$$F = m\frac{v^2}{R} = qvB\sin\theta \longrightarrow R = \frac{m}{q}\frac{v}{B}$$

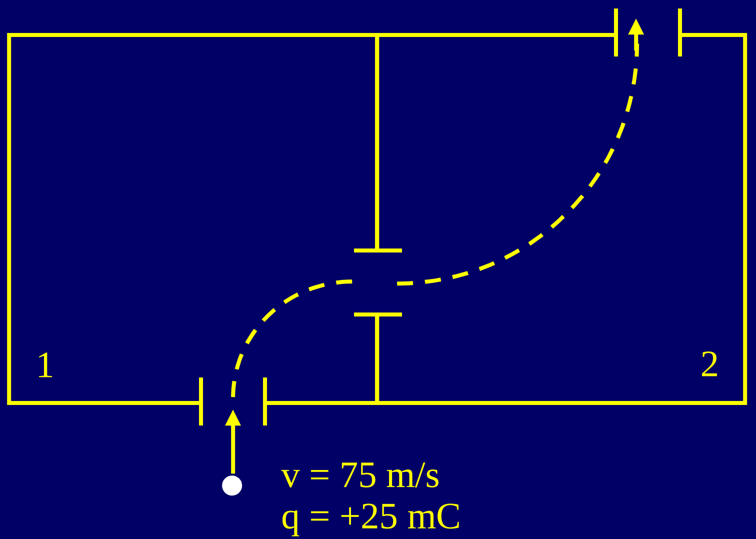



Uniform B into page

**Principle of a mass spectrometer!**

# Checkpoint 2.4

Each chamber has a unique magnetic field. A ***positively*** charged particle enters chamber 1 with velocity $v_1$= 75 m/s up, and follows the dashed trajectory.




**What is the speed of the particle when it leaves chamber 2?**

21% 1) $v_2 < v_1$

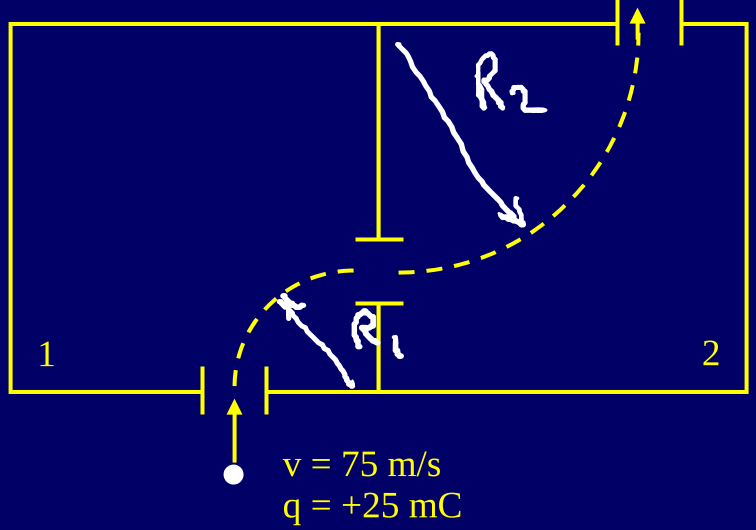
57% 2) $v_2 = v_1$

22% 3) $v_2 > v_1$

**Magnetic force is always perpendicular to velocity, so it changes direction, not speed of particle.**

# CheckPoint 2.6

Each chamber has a unique magnetic field. A ***positively*** charged particle enters chamber 1 with velocity $v_1$= 75 m/s up, and follows the dashed trajectory.




**Compare the magnitude of the magnetic field in chambers 1 and 2**

39% 1) $B_1 > B_2$

41% 2) $B_1 = B_2$

20% 3) $B_1 < B_2$

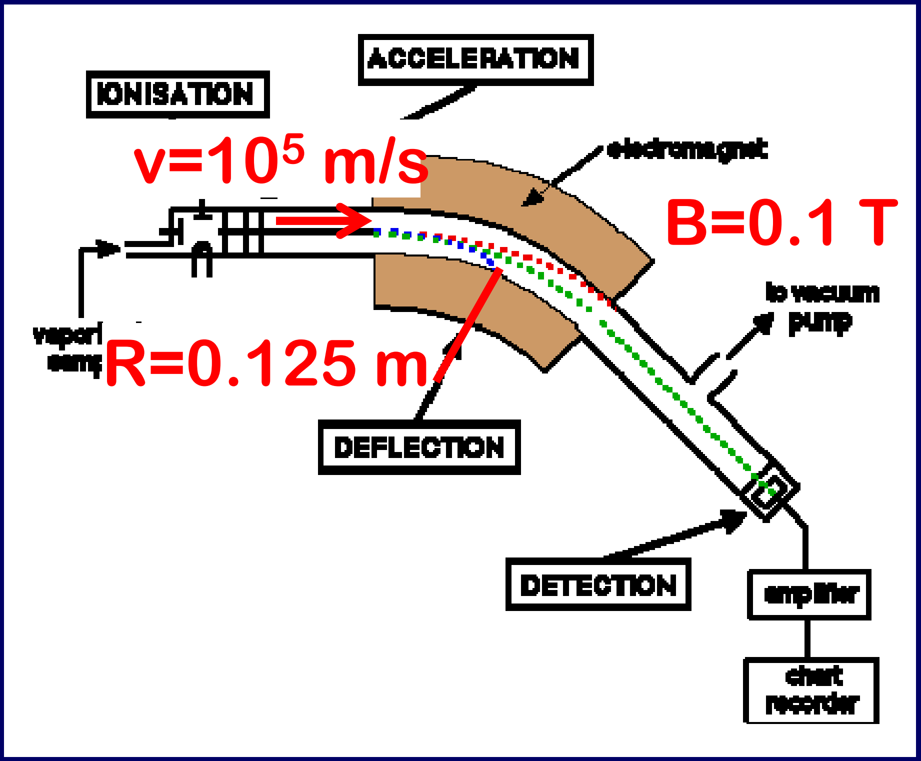
$$R = \frac{mv}{qB}$$

**Larger B, greater force, smaller R**

Example

# Mass Spectrometer

**In this mass spectrometer, particles with charge $1.6 \times 10^{-19}\ C$ must go through the magnet around a 0.125 m radius of curvature after being accelerated to $10^5$m/s in order to be detected. The magnetic field is 0.1 T. What is the mass of detected particles?**




$$R = \frac{mv}{qB} \Rightarrow m = \frac{qBR}{v} \qquad = 2 \times 10^{-26}\ \text{kg}$$

**= 12 amu**

$$amu = 1.67 \times 10^{-27}\ kg$$

**$^{12}C^{+}$**

# Summary

- We learned about magnetic fields B
- We learned about magnetic forces on moving charged particles

$$F = qvB\sin\theta$$

$$R = \frac{m\,v}{q\,B}$$