Exam I, Monday, Feb. 18, 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.)
- Review, Sunday, Feb. 17, 3 PM, 141 Loomis
  - I will go over Fall '12 exam I problems

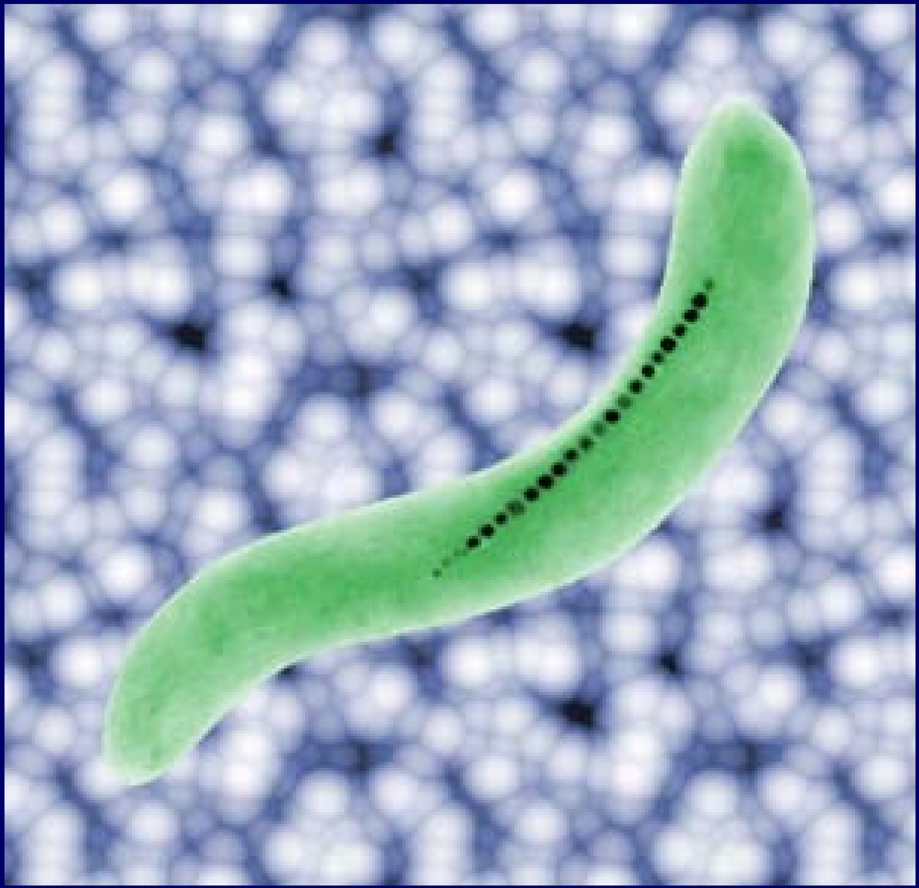
Exam I, Monday, Feb. 18, 7pm

- 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

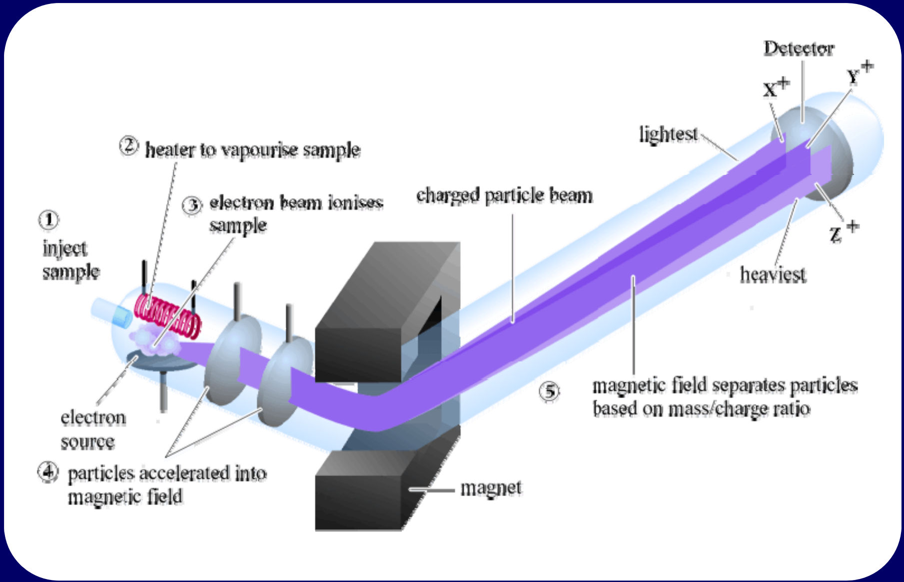
This material is NOT on exam 1!

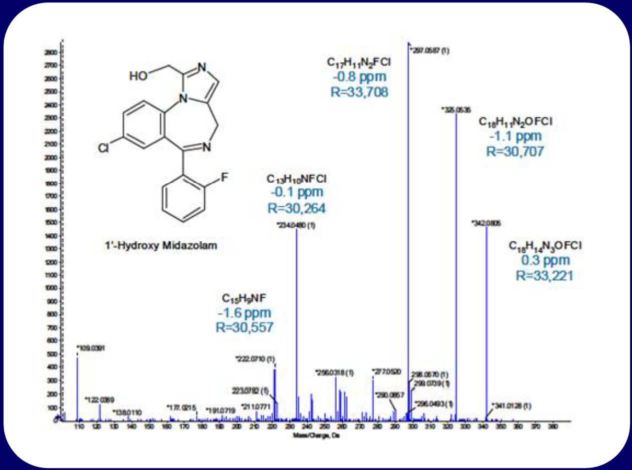


Magnetotactic bacterium

Lecture Overview

- Magnetic fields
- Magnetic forces on moving charges
  - Direction: “Right hand rule”
  - Magnitude
  - Circular motion

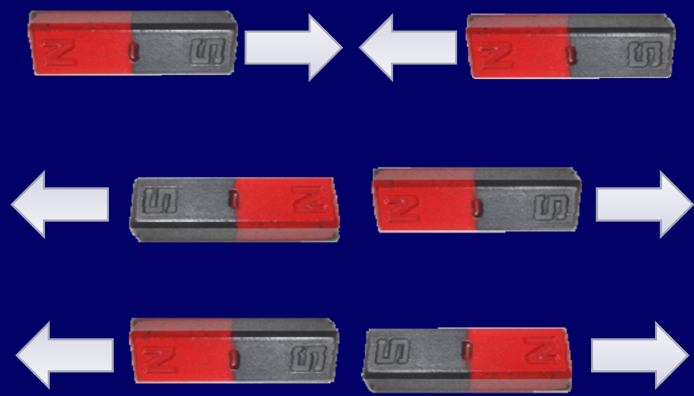




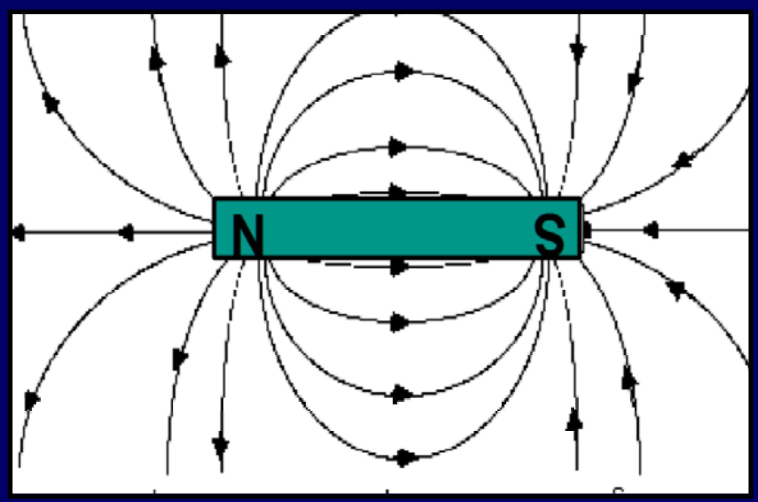
Mass spectrometer

Magnets & magnetic fields

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

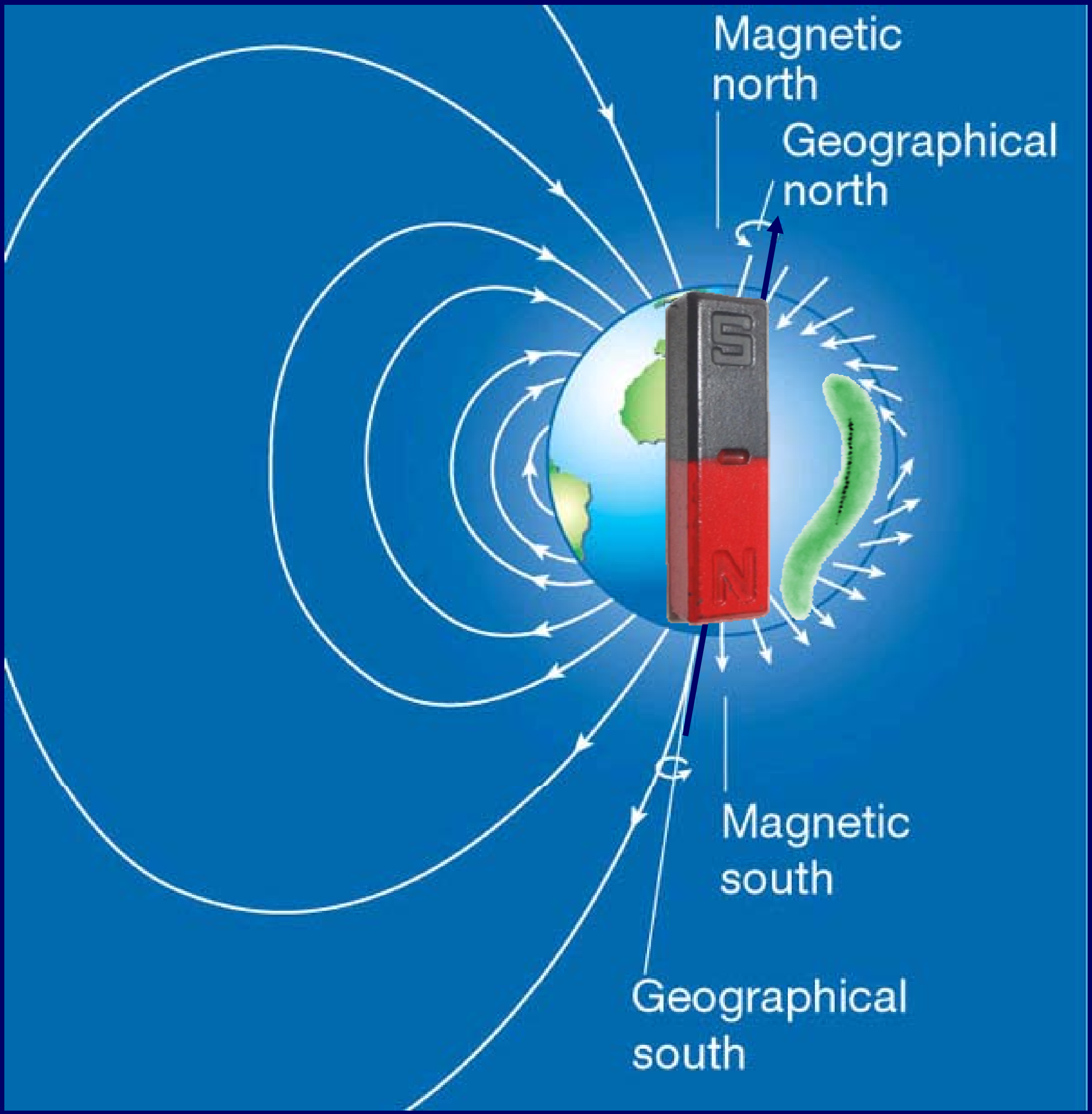


- Magnetic Field B
  - Units = Tesla (T)
  - Like E, vector at a location
  - Points N to S
- Magnetic Field Lines
  - Arrows give direction
  - Density gives strength
  - Looks like dipole!



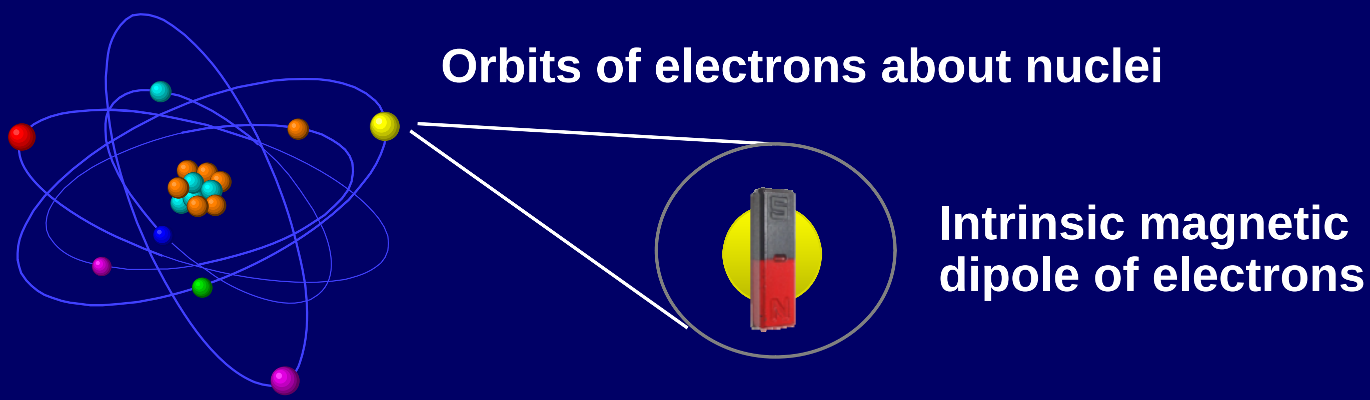
(Checkpoint 1.1)

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

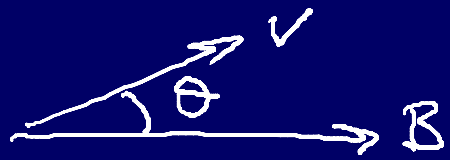


Magnetic Fields and Forces

Magnitude

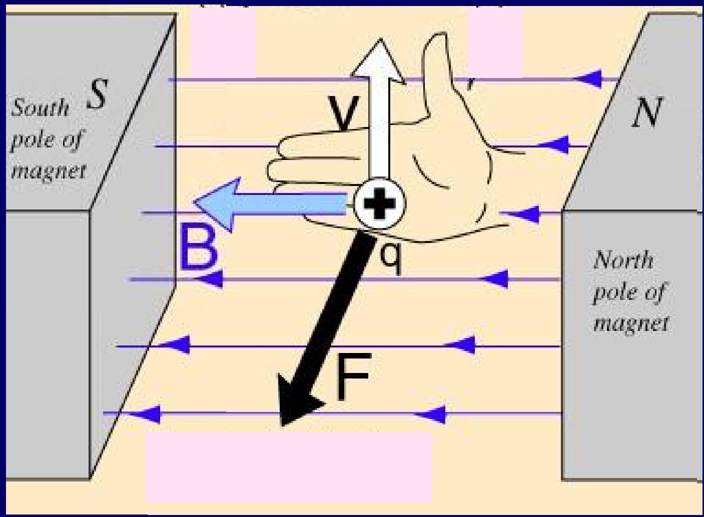
- Magnetic field B exerts force on moving charge

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



Direction

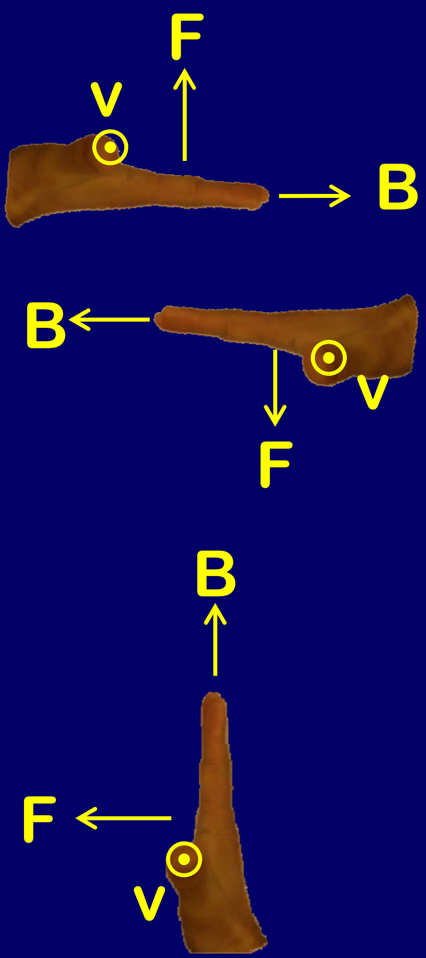
- Magnetic force is perpendicular to both B and v
- "Right-hand rule" (RHR):
  - Thumb of right hand along **v**
  - Fingers of right hand along **B**
  - Out-of-palm points
    - in the direction of F for + charge
    - opposite to F for – charge



Note: there are different versions of RHR

ACT: Direction of Magnetic Force on + Moving Charge

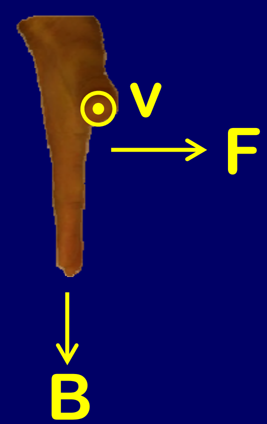
Velocity	B	Force
out of page	right	up
out of page	left	down
out of page	up	



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

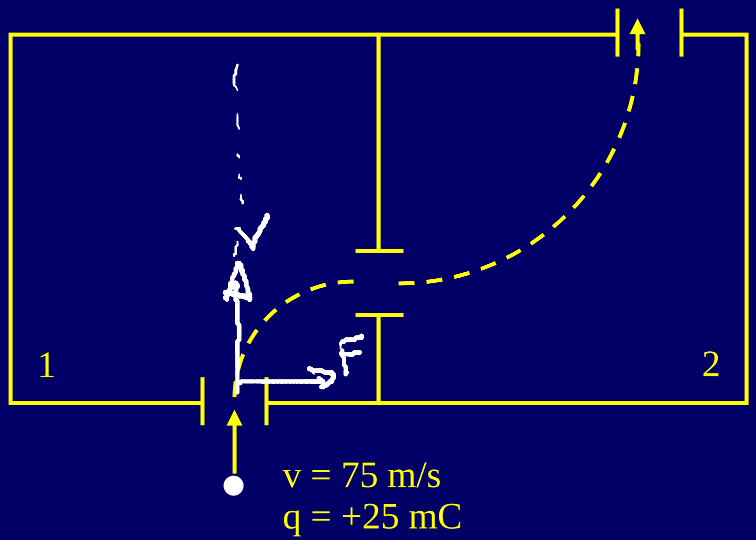
Direction of Magnetic Force on + Moving Charges

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?

15% 1) up

3% 2) down

15% 3) left

36% 4) right

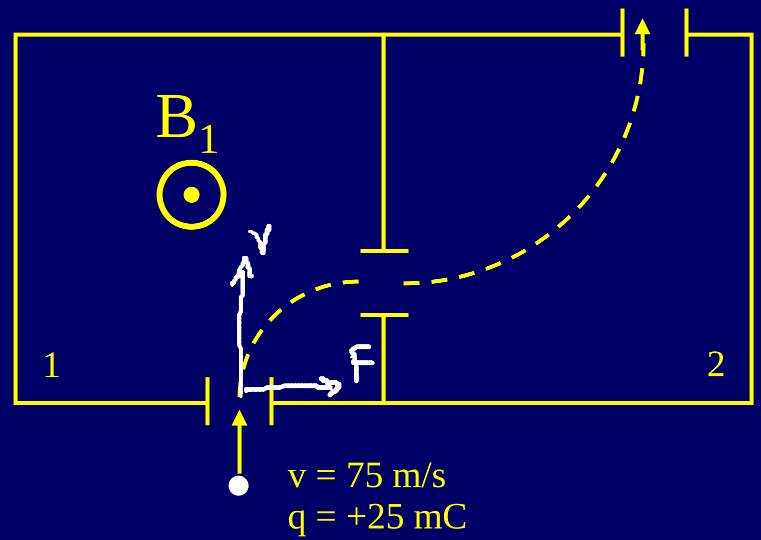
24% 5) into page

8% 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?

11% 1) up

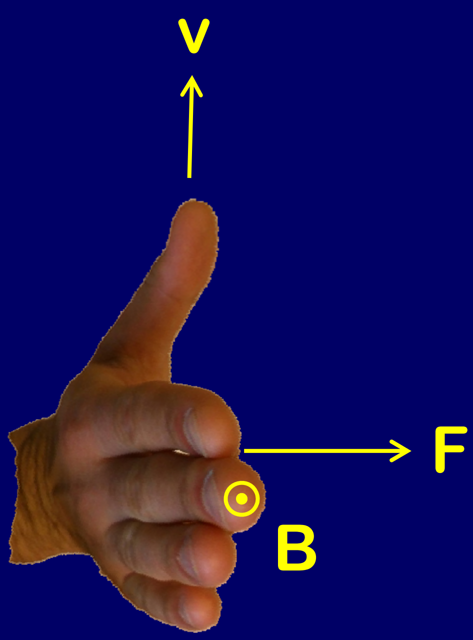
5% 2) down

9% 3) left

24% 4) right

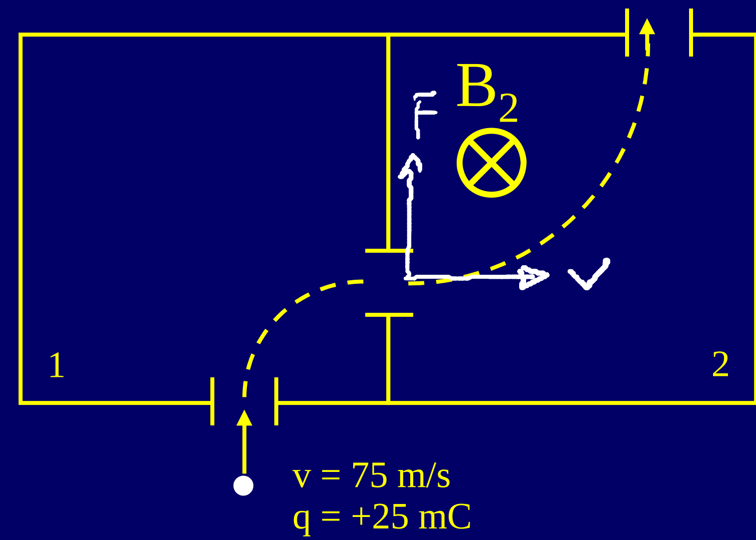
20% 5) into page

32% 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?

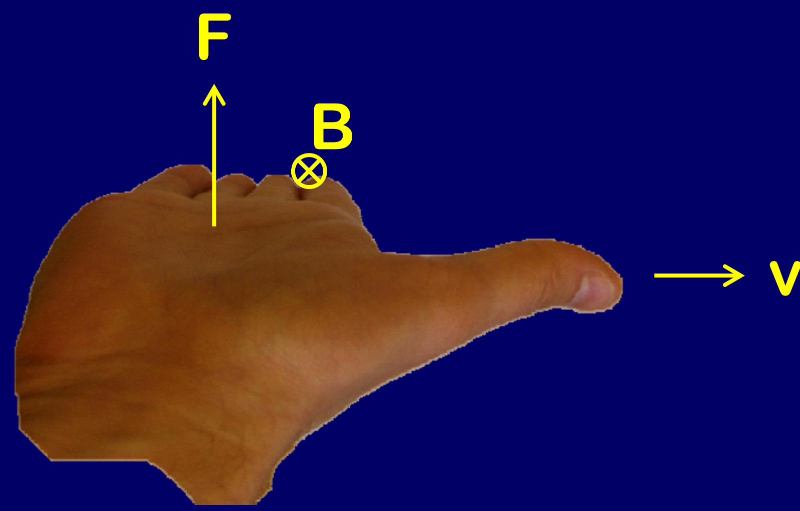
A) down

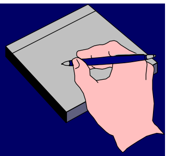
B) left

C) right

D) into page

E) out of page



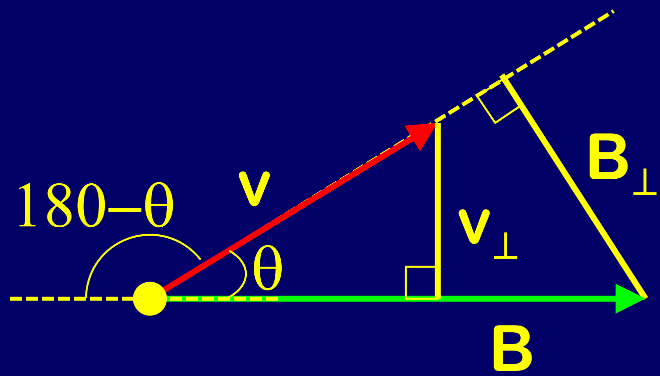


Magnitude of Magnetic Force on Moving Charges

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

$$F = qvB\sin\theta$$

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



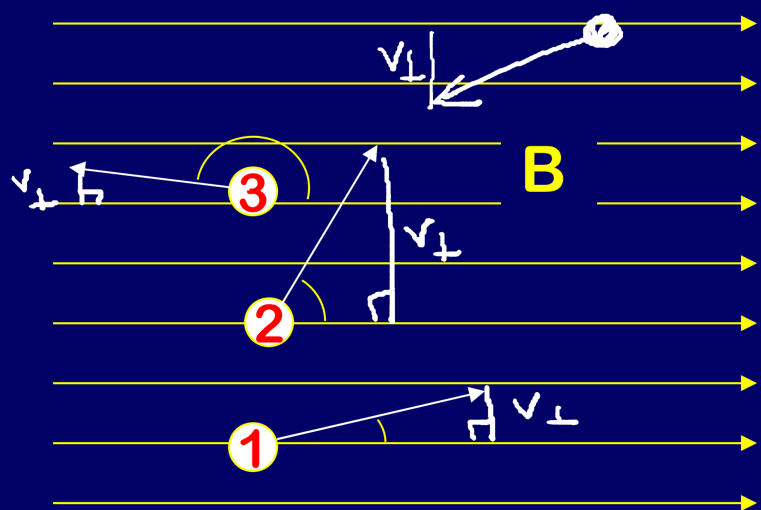
Only component of v ⊥ to B (or B ⊥ to v) matters

If v is parallel to B then F = 0

Does not matter whether you use θ or 180 – θ

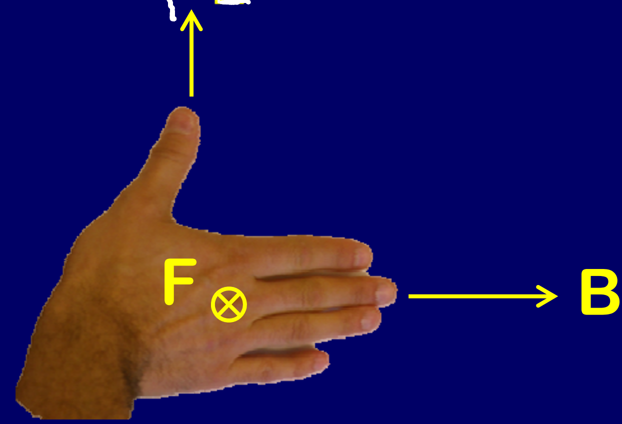
ACT: Moving Charges

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.

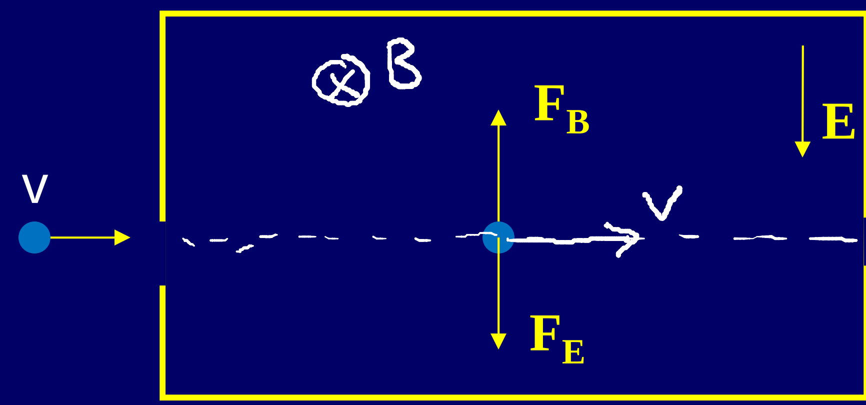
A) True B) False

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

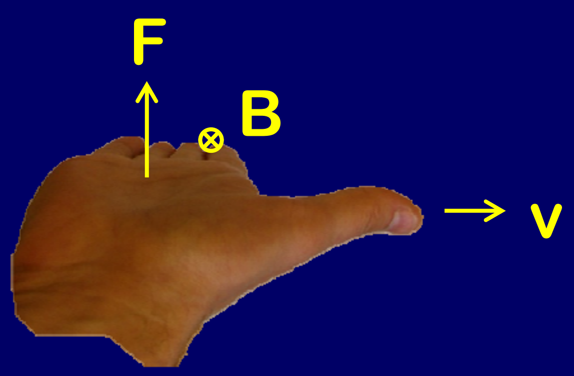
Velocity Selector

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>



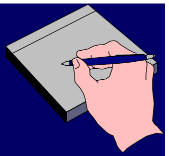
For straight line, need $|F_E| = |F_B|$

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

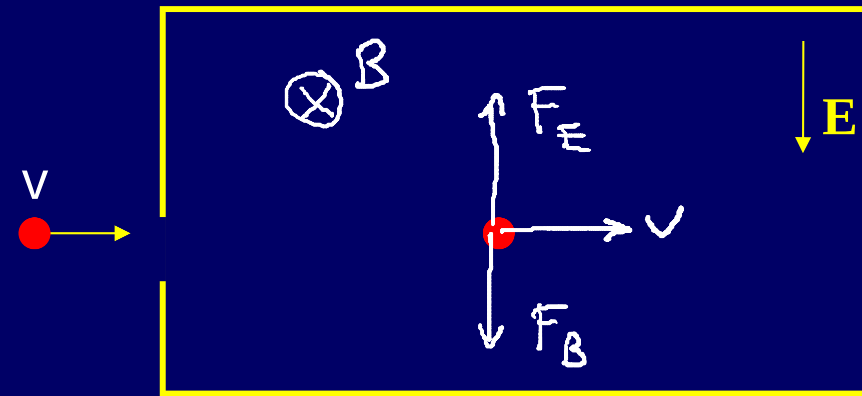
$B = E/v$

Example

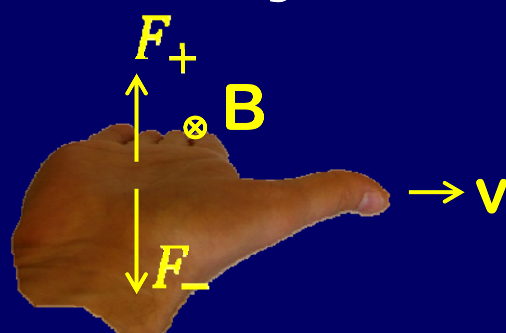
Velocity Selector



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

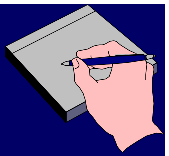


Use the RHR and invert the force for – charges

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

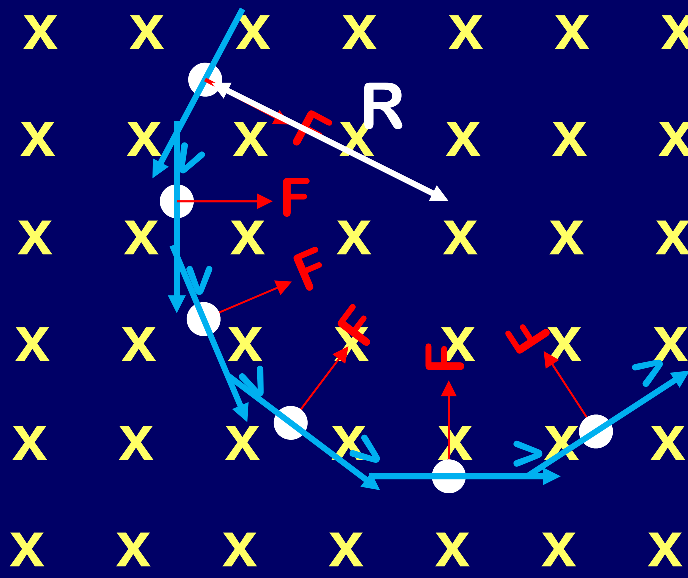
A) Into Page B) Out of page C) Left D) Right

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 <u>no work</u>! (W=F d cos θ)
  - Speed is constant (W=ΔK.E.)



Uniform B into page

- Solve for R:

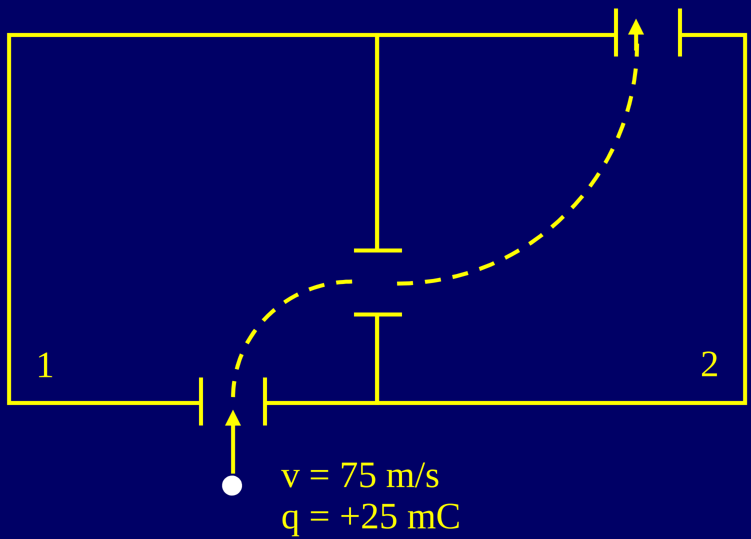
Recall circular motion from Phys 101

$$F = m\frac{v^2}{R} = qvB\sin\theta \rightarrow R = \frac{mv}{qB}$$

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?

9% 1) $v_2 < v_1$

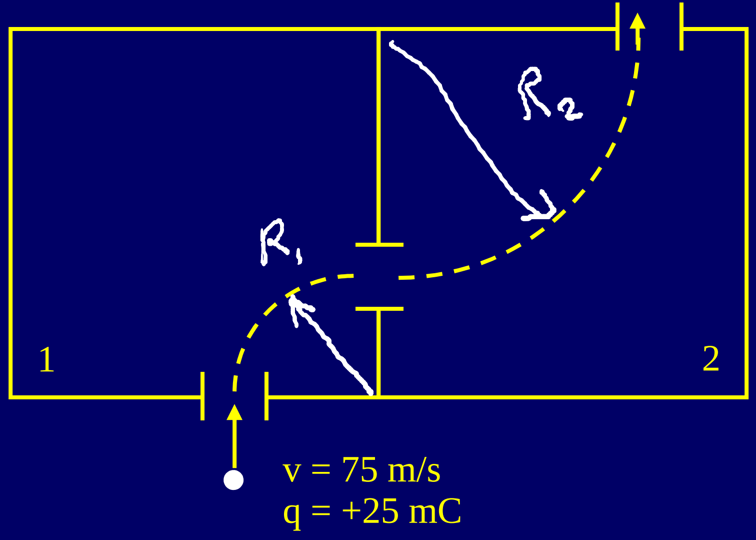
63% 2) $v_2 = v_1$

27% 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

42% 1) $B_1 > B_2$

36% 2) $B_1 = B_2$

22% 3) $B_1 < B_2$

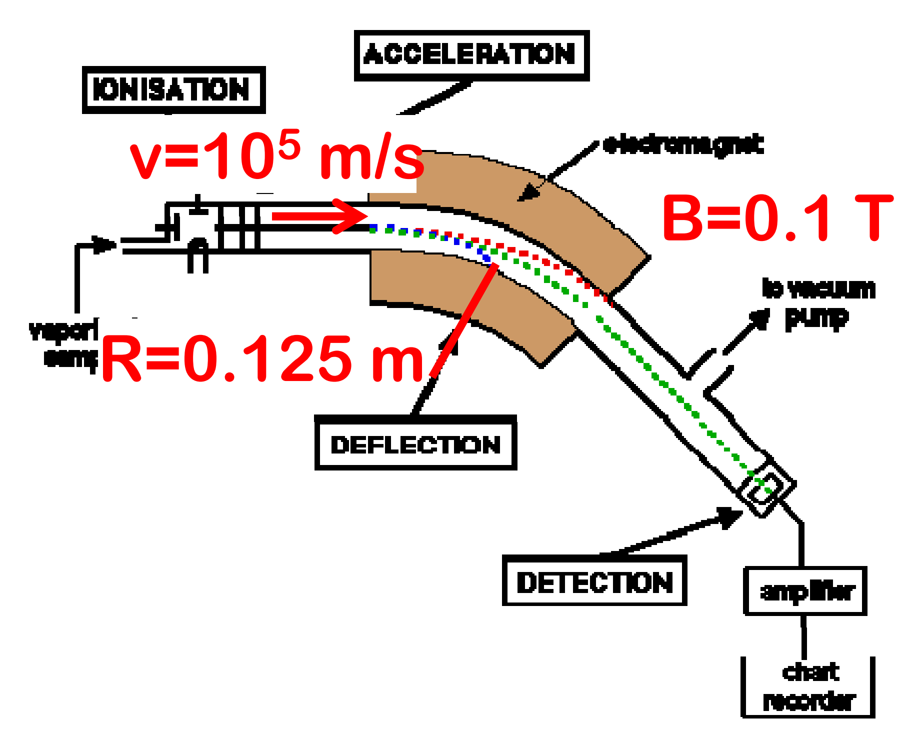
$$R = \frac{mv}{qB}$$

Larger B, greater force, smaller R

Mass Spectrometer

Example

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 10^5m/s in order to be detected. The magnetic field is 0.1 T. What is the mass of detected particles?



$$R = \frac{mv}{qB} \Rightarrow m = \frac{qBR}{v} = 2 \times 10^{-26}\ \mathrm{kg} = 12\ \mathrm{amu}$$

$$amu = 1.67 \times 10^{-27}\ kg \qquad {}^{12}C^{+}$$

Summary

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

$$F = qvB\sin\theta$$

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