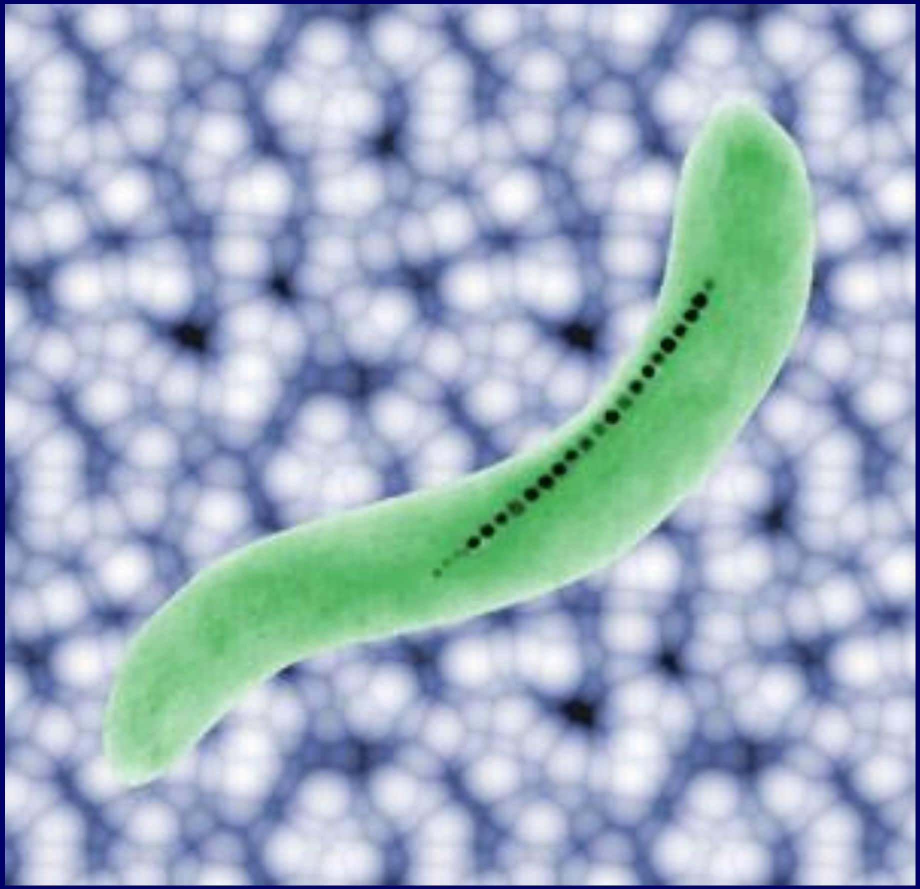
# Physics 102: Lecture 08

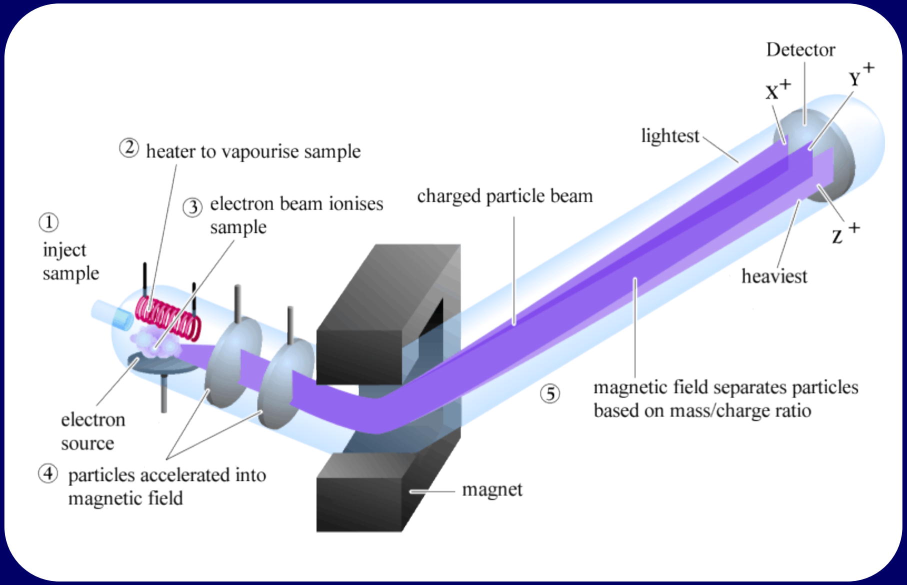
## Magnetism

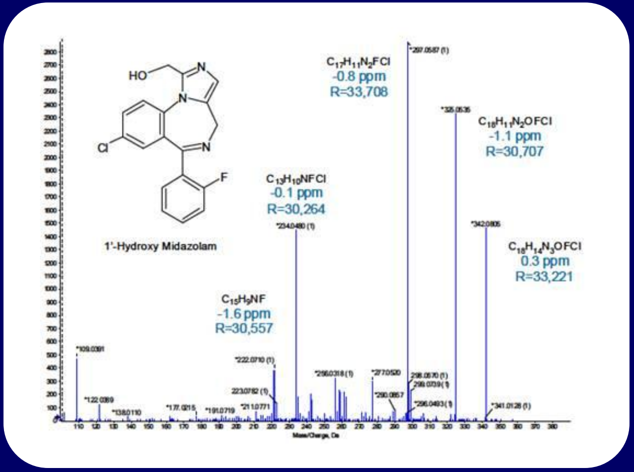


Magnetotactic bacterium

# Lecture Overview

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

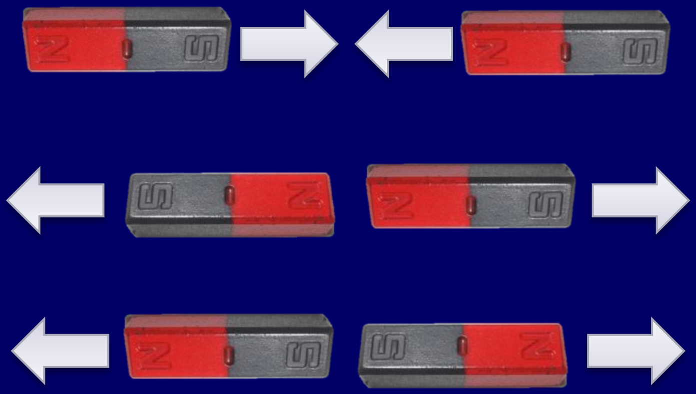


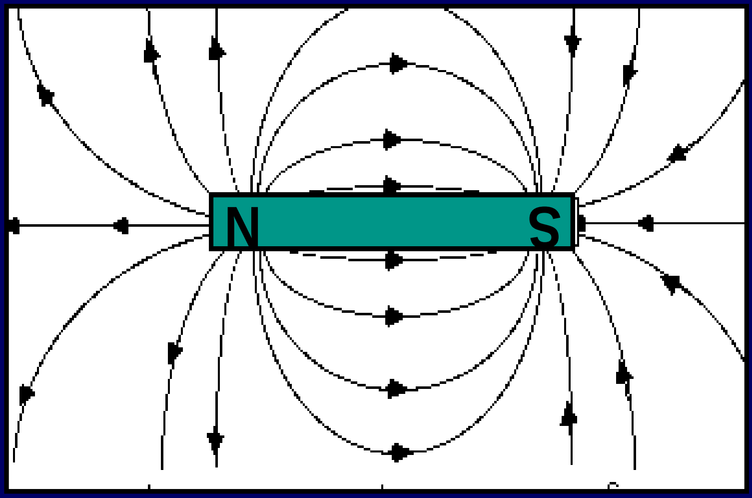




**Mass spectrometer**

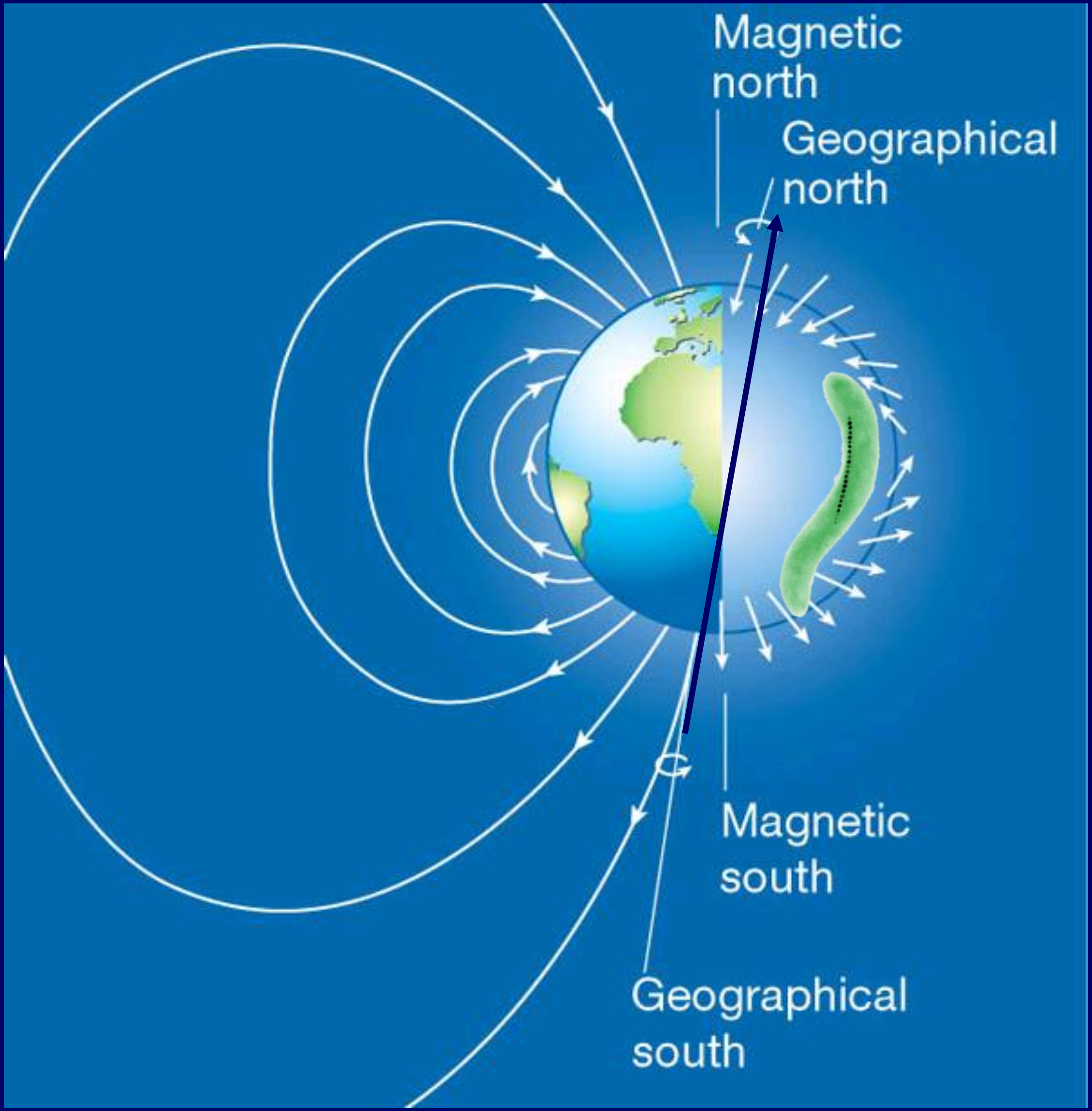
# Magnets & magnetic fields

- 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!



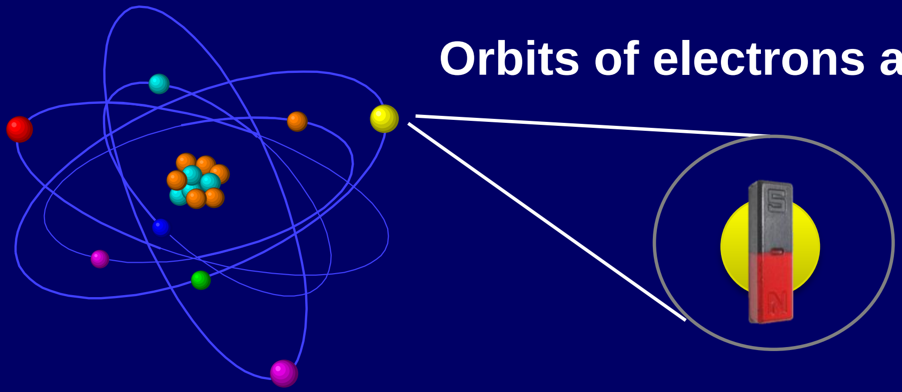


# The Earth is a Magnet



# 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

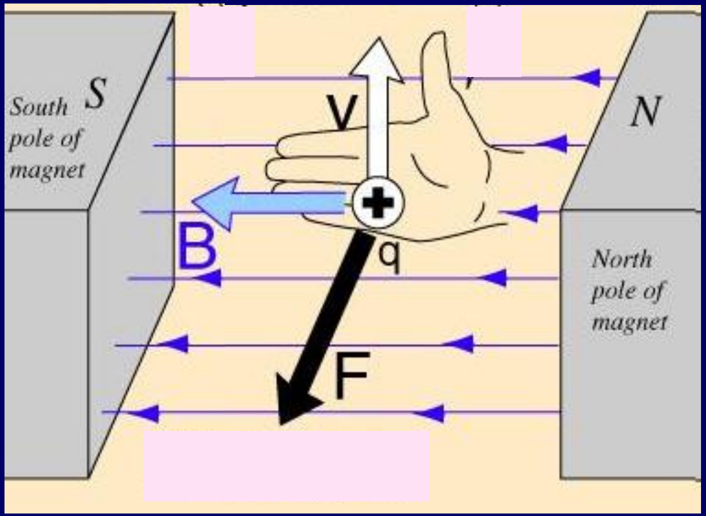
- Magnetic field B exerts force on moving charge

$$F = qvB\sin\theta$$

Magnitude

- 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

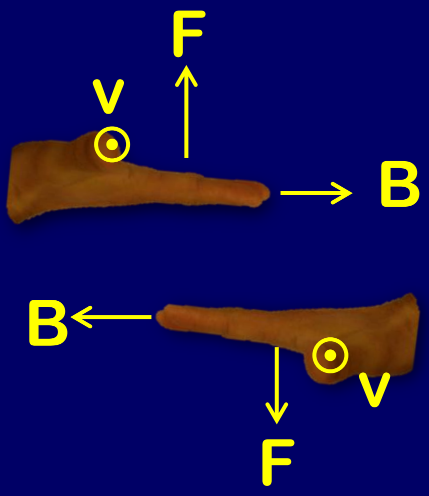
Direction




Note: there are different versions of RHR


# ACT: Direction of Magnetic Force on + Moving Charge

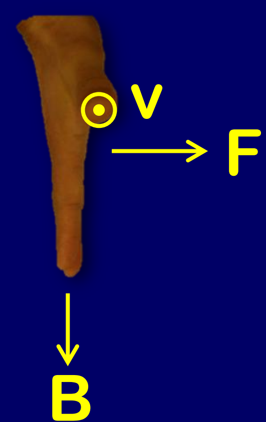
| Velocity | B | Force |
| --- | --- | --- |
| out of page | right | up |
| out of page | left | down |
| out of page | up | |
| | | |



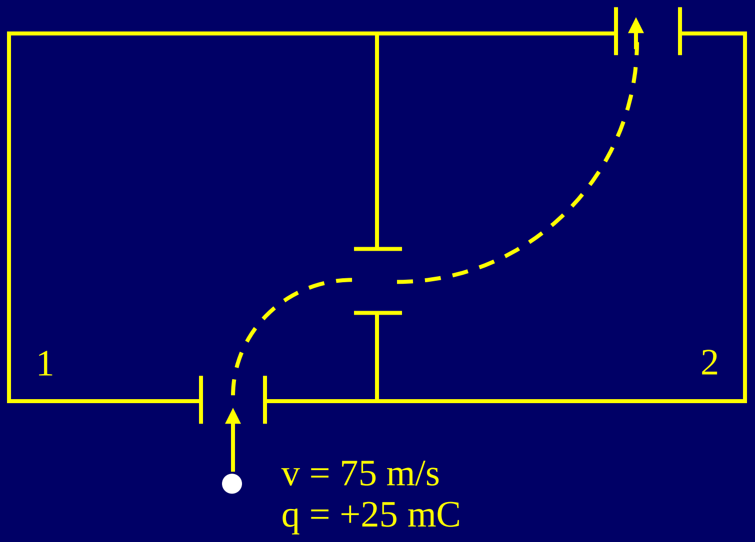

**1) Up   2) Down   3) Right   4) Left   5) Zero**

# Direction of Magnetic Force on + Moving Charges

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

1) up

2) down

3) left

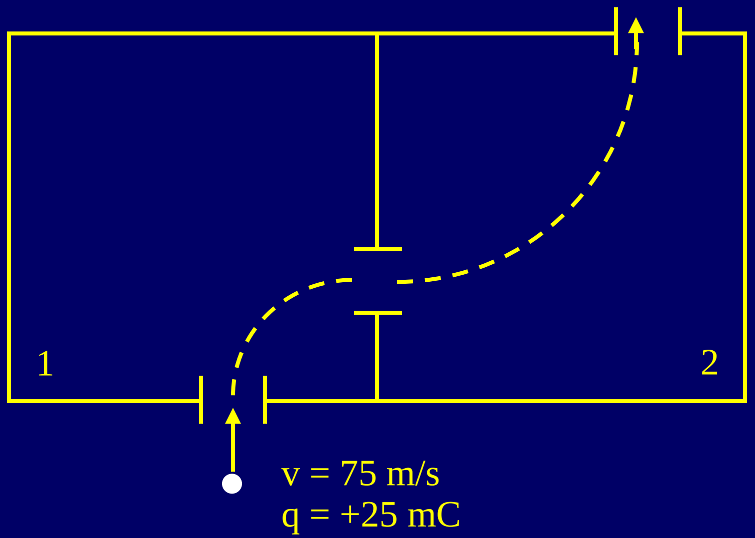
4) right

5) into page

6) out of page

# 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?

1) up

2) down

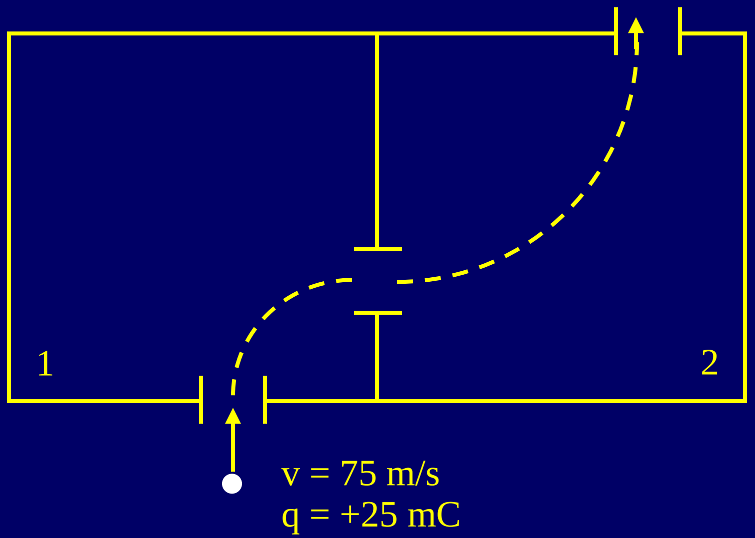
3) left

4) right

5) into page

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?

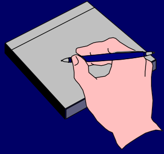
A) down

B) left

C) right

D) into page

E) out of page

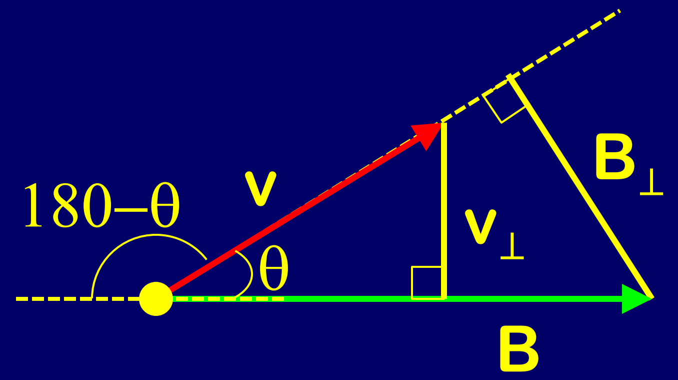


# Magnitude of Magnetic Force on Moving Charges

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

$$F = qvB\sin\theta$$

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

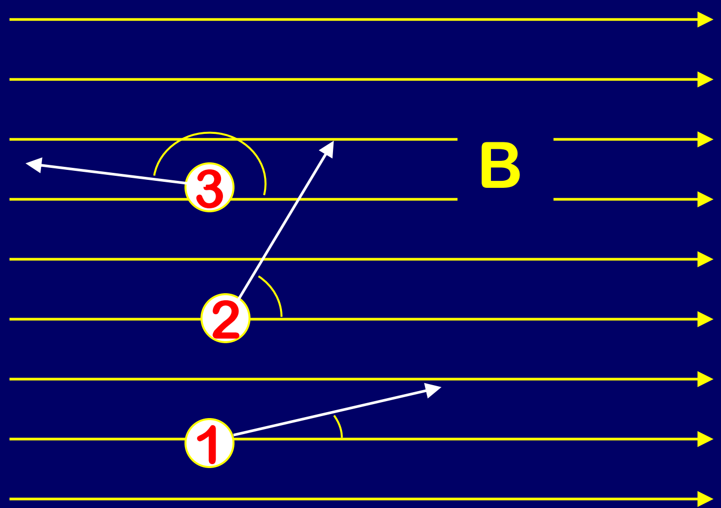



Only component of v ⊥ to B (or B ⊥ to v) matters
If v is parallel to B then F = 0

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.




1) Which particle experiences the greatest magnetic force?

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

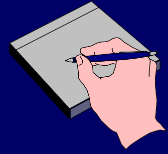
2) The force on particle 3 is in the same direction as the force on particle 1.

A) True  B) False

# Comparison
# *Electric* vs. *Magnetic*

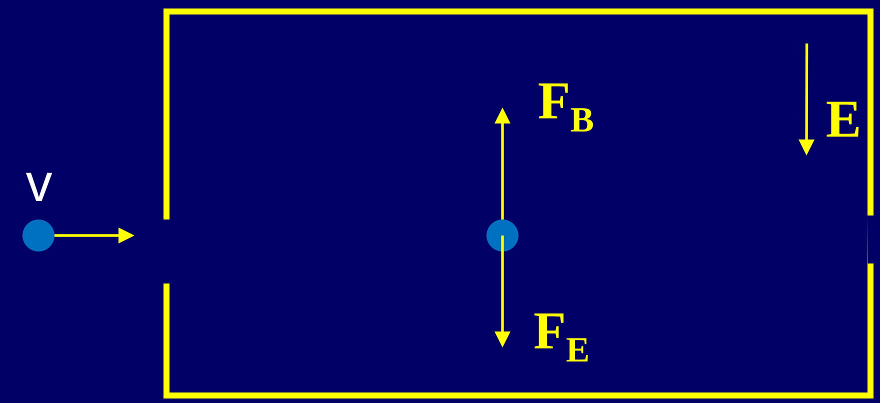
| | Electric | Magnetic |
|---|---|---|
| Source: | Charges | Moving Charges |
| Act on: | Charges | Moving Charges |
| Magnitude: | $F = q\,E$ | $F = q\,v\,B\sin(\theta)$ |
| Direction: | Parallel to E | Perpendicular to v, B |

Example



# 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.

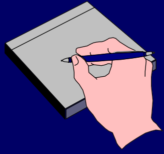
By RHR, B must be

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

q E= q v B sin(90)

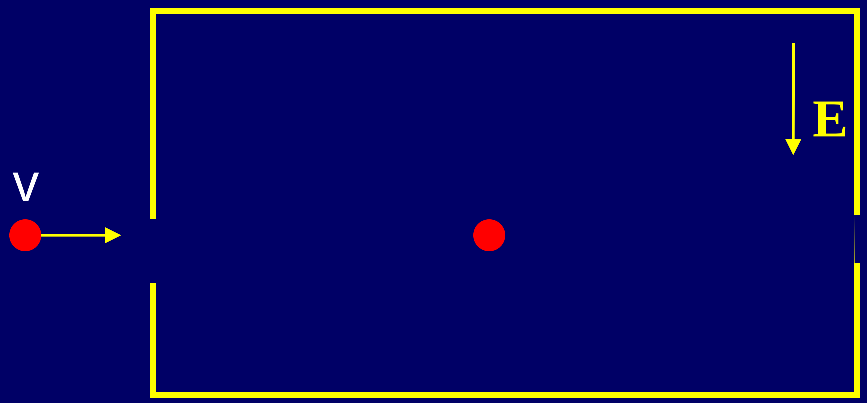
B =

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.



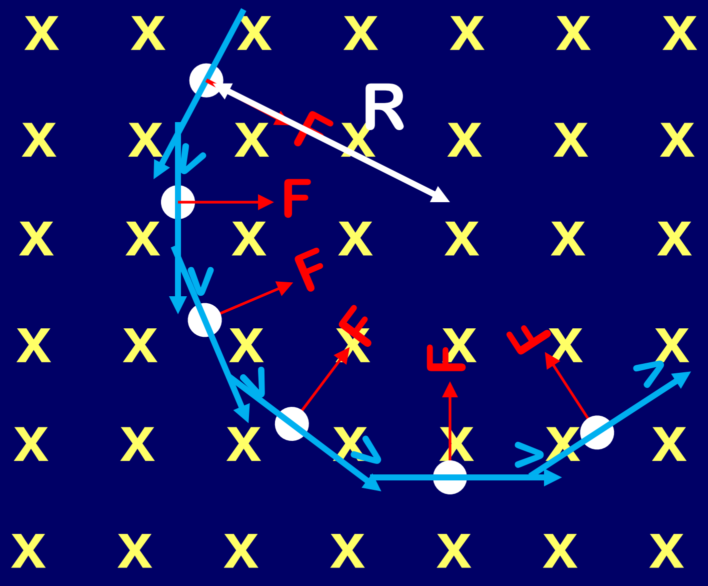

# ACT: Velocity Selector

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

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

# 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:

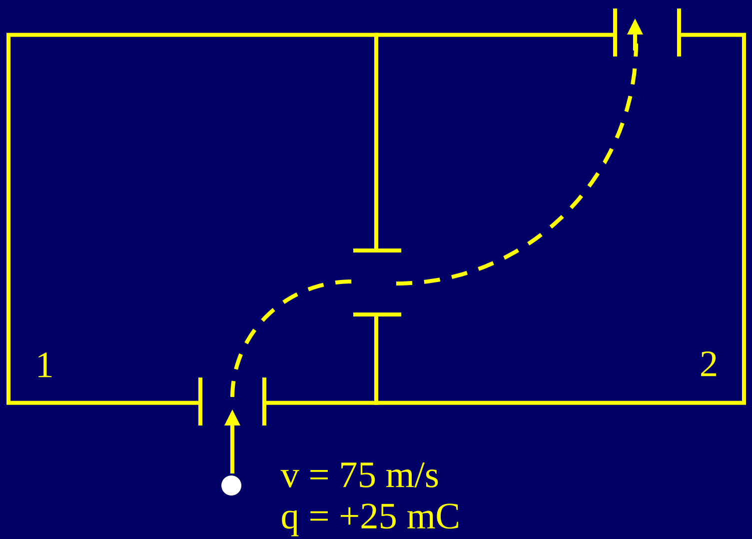
Recall circular motion from Phys 101

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

**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.



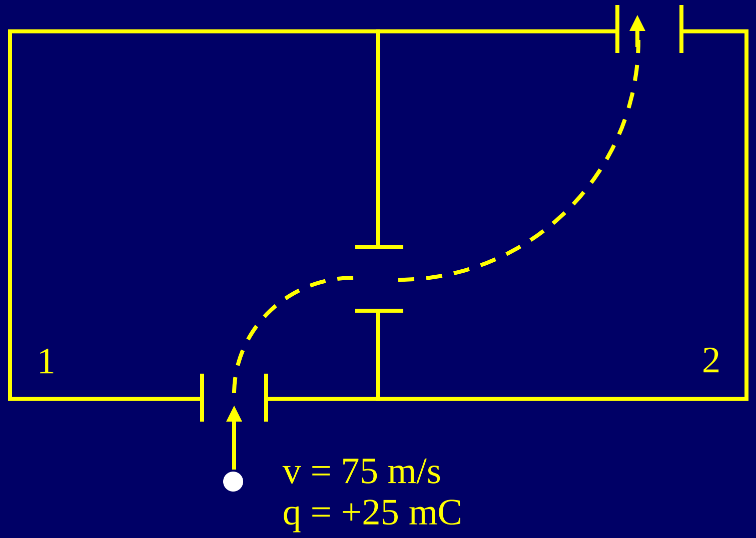

**What is the speed of the particle when it leaves chamber 2?**

1) $v_2 < v_1$

2) $v_2 = v_1$

3) $v_2 > v_1$

# 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**

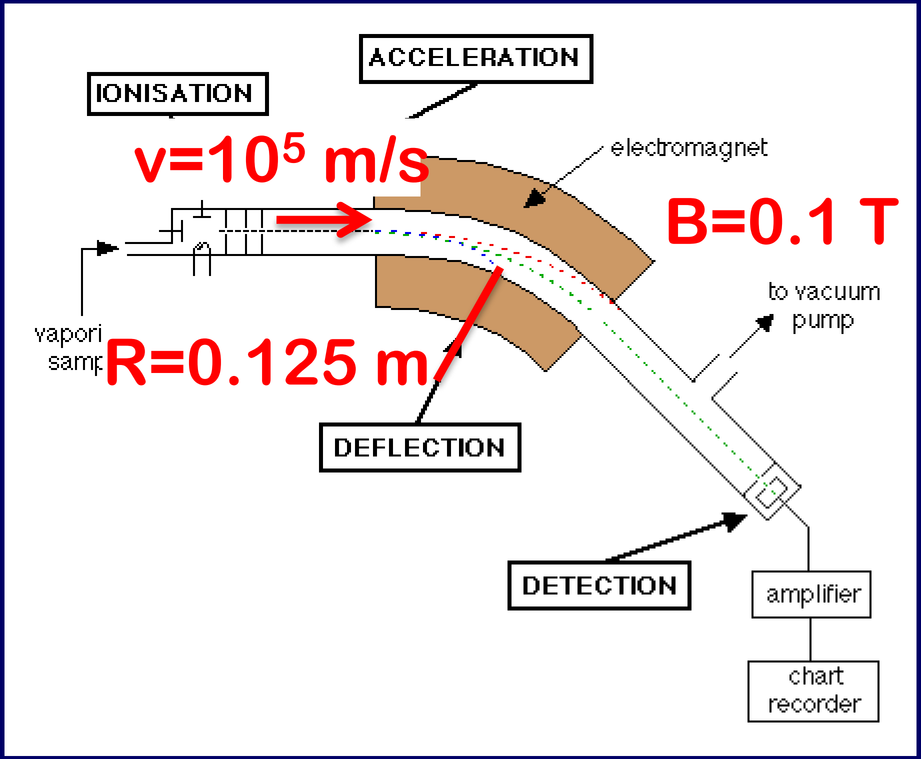
1) $B_1 > B_2$

2) $B_1 = B_2$

3) $B_1 < B_2$

# ACT: 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?**




**(A)** $2 \times 10^{3}$ kg

**(B)** $1.5 \times 10^{-27}$ kg

**(C)** $2 \times 10^{-26}$ kg

# Summary

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

$$F = qvB\sin\theta$$

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