Magnetic Force

PHY 114-01

Fall 2026

Announcements

- Almost done grading the midterm. Scores released tonight.
  - Average ~70%. Great work!
- Announcement with grade calculation instructions to follow.
- Midterm 2 reflection instructions to follow.
- HW7 due Friday
- No class on Wednesday

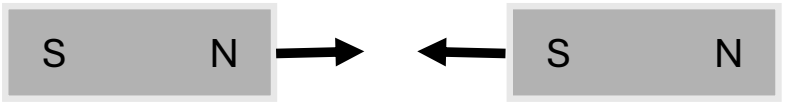
Agenda

- Last time:
  - Wrap up RC circuits
  - Magnetic Fields
- This time:
  - Magnetic Force

Bar Magnets



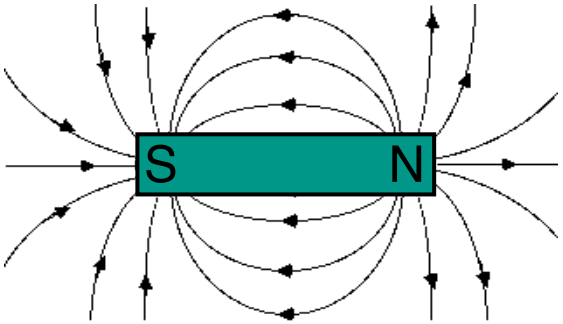
like poles repel



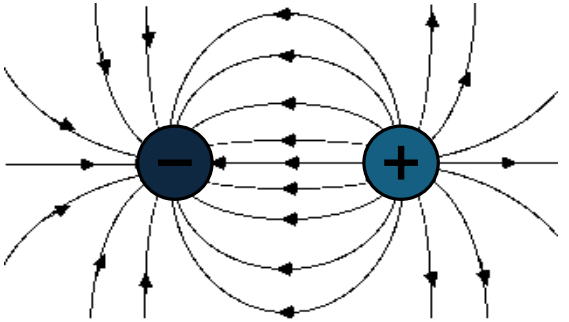
opposite poles attract

How do the magnets exert forces on each other?

via the magnetic field



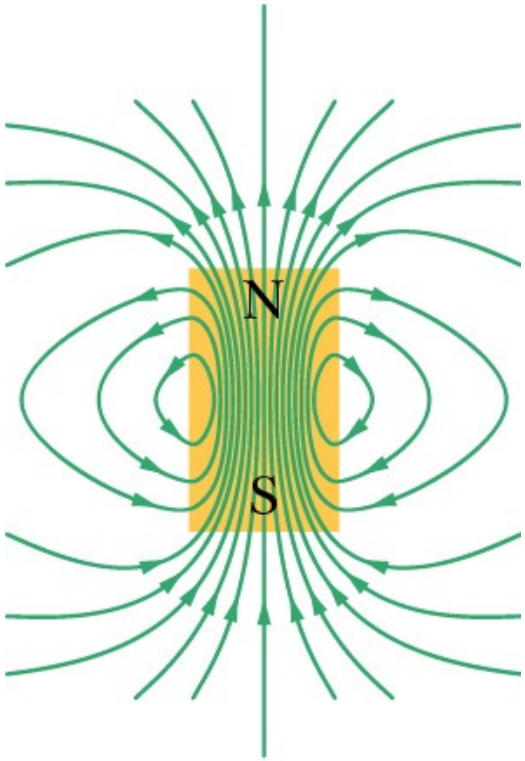
Magnetic Dipole



Electric Dipole

Magnetic Fields (B-fields)

- external field lines
  - ✓ originate on N pole, end on S pole
  - ✓ Tangent of line → direction of B
  - ✓ Density of lines → magnitude of B



- magnetic field has symbol B
- B is a vector (like E-field)
  - ➢ SI unit for magnetic field is tesla (T)
  - ➢ other common unit is gauss (G)
  - ➢ 1 tesla = 10^4 gauss

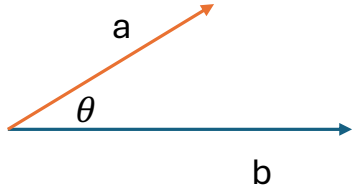
Magnetic Force

- If there is no magnetic monopole, how does the magnetic field create a magnetic force?

- Magnetic fields exert forces on *moving charges*

- $\vec{F}_B = q\vec{v}\times\vec{B}$, the Lorentz force
  - Force is "sideways" – perpendicular to both v and B.
  - If v=0, then F=0
  - Units: [F] = [C][m/s][T] =[N] → [T] = [N]/[A m]

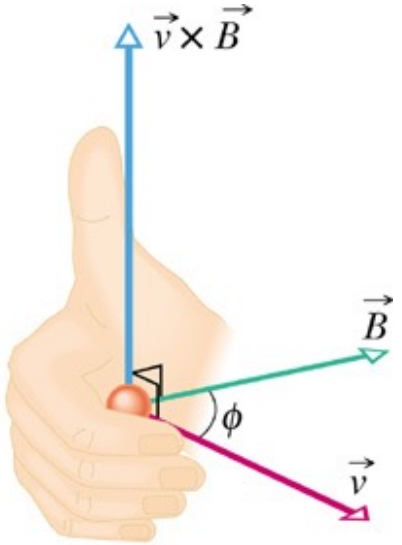
Cross Products



- A vector product!
  - As opposed to the dot product, a scalar product
- The cross product magnitude is $\left|\vec{a}\times\vec{b}\right| = ab\sin\theta$
- The cross product direction is given by the Right-Hand-Rule

Direction of the Magnetic Force

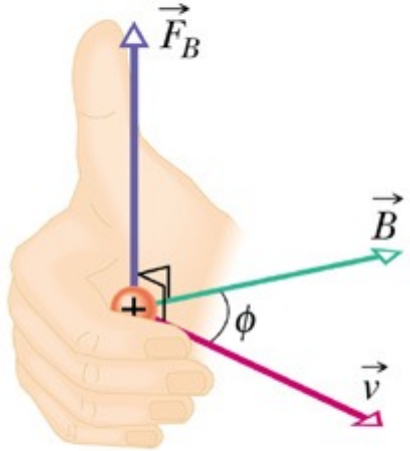
- the right-hand rule:
  - point your fingers along the direction of velocity
  - curl your fingers towards the magnetic field vector
  - your thumb will then point in the direction of the cross product



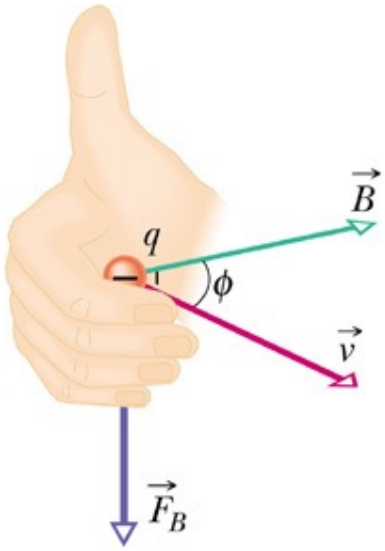
(a)

Charge sign and force direction

- Don’t forget to include the charge sign!
- If it’s a negative charge, flip the direction



(b)

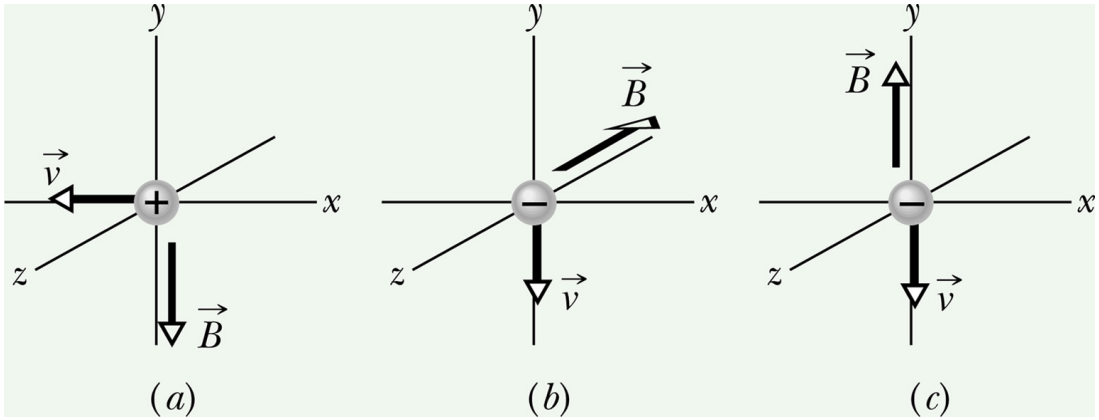


(c)

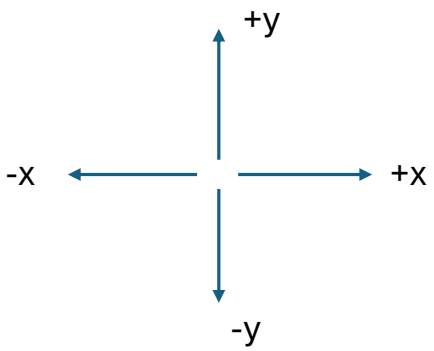
Concept Check: Magnetic force

Given the directions of B and v, determine the direction of the magnetic force. Note the signs of q

(a) z direction
(b) negative x direction
(c) zero force



Representing 3d vectors in 2d





+z

out of page

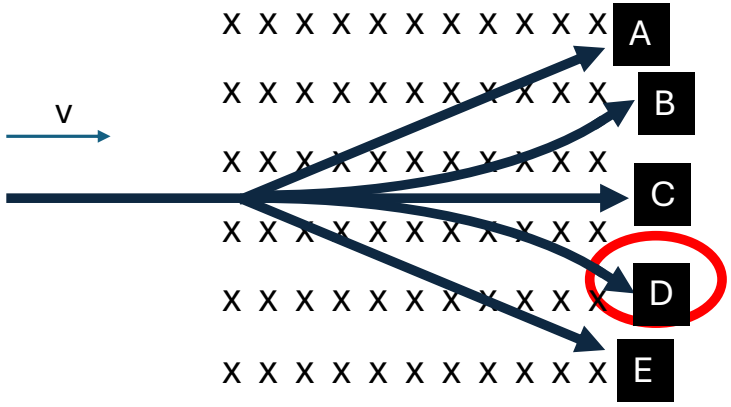


-z

into page

ConceptCheck Magnetic force

*** Daily quiz!**



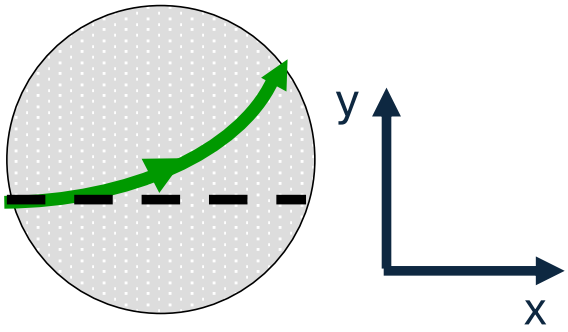
A beam of electrons enters a magnetic field region moving from left to right.

What path will the electrons follow?

Using the right-hand rule for a positive charge gives the force direction pointing up. Since electrons are negatively charged, the direction of the force is inverted.

Thus, electrons move downwards. Since there is a constant force acting, the electrons must move in a curved path (and not a straight line).

ConceptCheck Magnetic force



A beam of protons enters a magnetic field region and is deflected upwards.

What is the direction of the magnetic field B ?

A. **+ y axis**
B. **– y axis**
C. **+ x axis**
D. **– x axis**
E. **+ z (out of the screen)**
F. **– z (into the screen)**

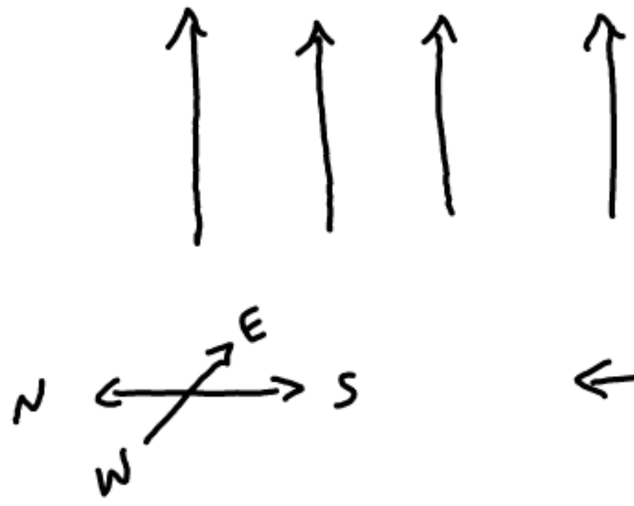
The force is acting in the +y direction for a proton (+) moving to the right. Using the right-hand rule leads to a B field that points into the screen.

This is along the –z axis.

Sample Problem: Magnetic force

A uniform magnetic field B, with magnitude 1.2 mT, is directed vertically upward throughout the volume of a laboratory chamber. A proton with kinetic energy 5.3 MeV enters the chamber, moving horizontally from south to north. What magnetic deflecting force acts on the proton as it enters the chamber? The proton mass is $m=1.67 \times 10^{-27}$ kg.

$B = 1.2\ mT = 1.2 \times 10^{-3}\ T$



$\leftarrow \vec{v}$, $K = 5.3\ MeV = 5.3 \times 10^{6}\ eV$

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

$\vec{F} = q\vec{v} \times \vec{B}$ so we need to find $\vec{v}$

$K = \frac{1}{2} m_p v^2$

$\vec{v} = \sqrt{2K/m_p}$ north

$\vec{v} \perp \vec{B}$ so we can find

$|\vec{F}| = qvB$ (right hand rule)

and $\hat{F}$ = east by RHR

$F = qvB$ $\quad q = e^+ = 1.6 \times 10^{-19}\ C$

$$v = \sqrt{\frac{2 \cdot 5.5 \times 10^{6}\ eV \cdot 1.6 \times 10^{-19}\ \frac{J}{eV}}{1.67 \times 10^{-27}\ kg}} = 32 \times 10^{6}\ m/s$$

$B = 1.2 \times 10^{-3}\ T$

$$F = q v B$$

$$= (1.6 \times 10^{-19} C)(32 \times 10^{6} m/s)(1.2 \times 10^{-3} T)$$

T = $\frac{N \cdot s}{C \cdot m}$

$$\vec{F} = 6.14 \times 10^{-15} \; N \quad \text{east}$$

$$\vec{a} = \frac{F}{m_p} = 3.7 \times 10^{12} \; m/s^2$$

small mass — small force

high speed — high acceleration