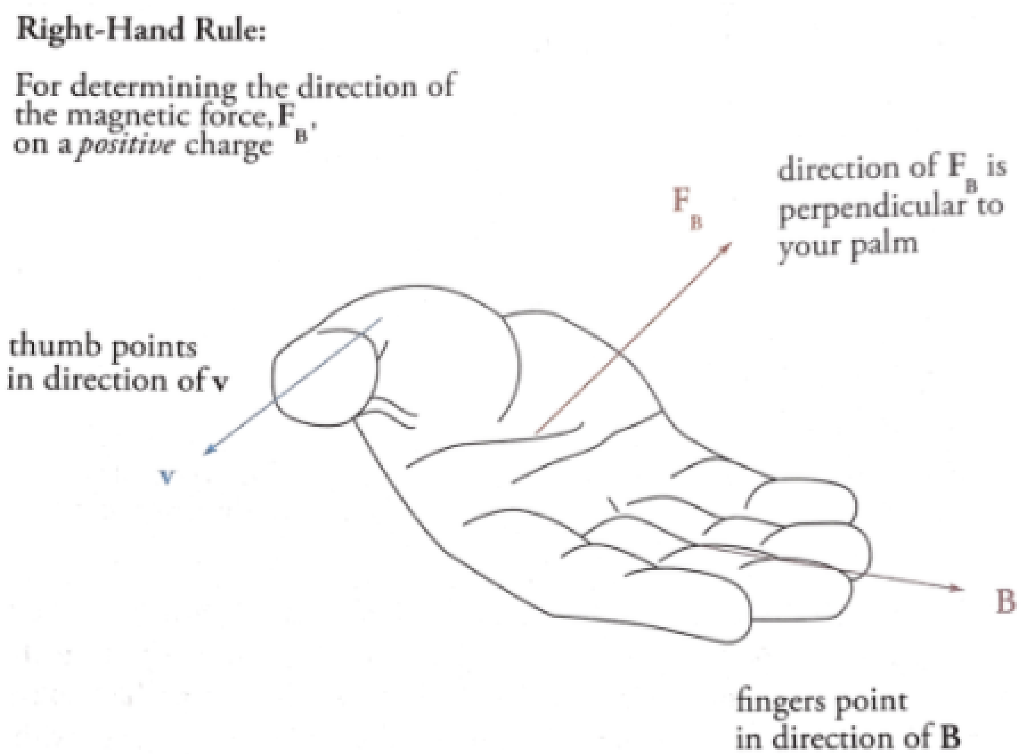
Charges create E fields, MOVING charges create B fields (magnetic fields, strength in units of N/(A*m)=Tesla, T)...
Charged particles feel a magnetic force which causes them to change velocity direction:

$F_B = q(v \times B) = qvBsin\theta,\ \theta = angle\ between\ v\ and\ B$

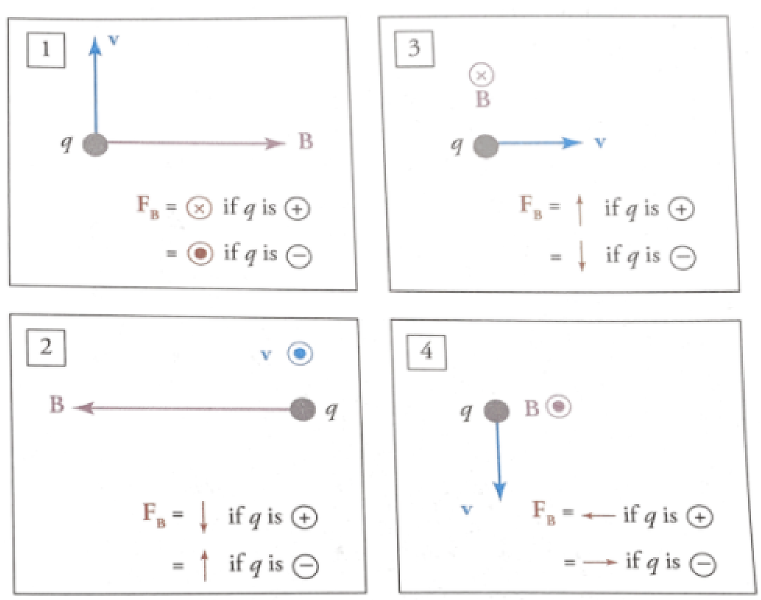
F is always perpendicular to both v and B

How to determine direction?



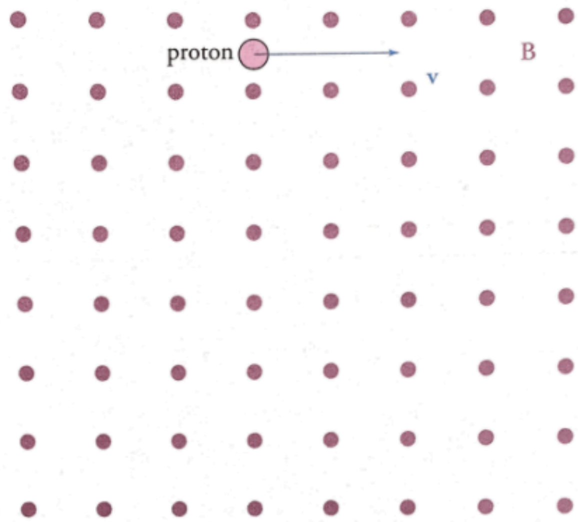
1. Orient your hand so that your thumb points in the direction of the velocity **v**.
2. Point your fingers in the direction of **B**.
3. The direction of F_B will then be perpendicular to your palm.

Practice:



Magnetic forces do no work: $W = Fdcos\theta$, so no change in kinetic energy, just direction of velocity

Example 10-42: A proton is injected with velocity **v** into a region of constant magnetic field **B** points out of the plane of the page. The direction of **v** is to the right, in the plane of the page, as show the diagram below:



a) Describe the subsequent motion of the proton.
b) Find the radius of the circular trajectory it follows.

Example 10-45: A sulfide ion, S^{2-}, moving with speed v_0 enters a region containing a uniform magnetic field **B**. If the vector $\mathbf{v}_0$ makes an angle of 30° with **B**, what is the magnitude of the initial magnetic force on this ion?

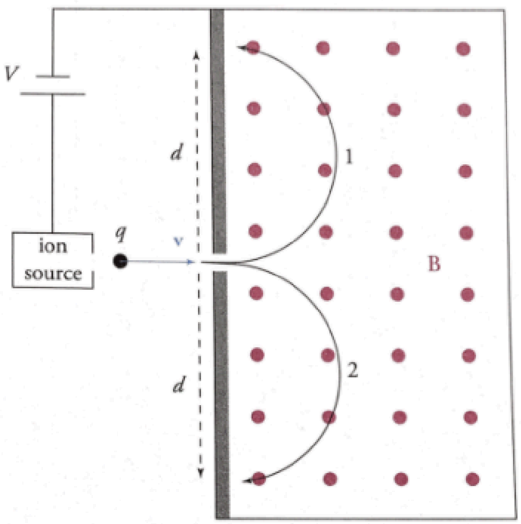
A. $ev_0B/4$
B. $ev_0B/2$
C. ev_0B
D. $2ev_0B$

Example 10-48: The figure below shows a charged parallel-plate capacitor with a uniform electric field, E, in the space between its plates. A uniform magnetic field, **B**, is also produced in the space between the capacitor plates by another device.

At what speed would an electron need to travel between the plates in order to pass through undeflected? (Ignore gravity.)

A. E/B
B. B/E
C. EB
D. EB^2

Example 10-50: The figure below shows a simple mass spectrometer. It consists of a source of ions that are accelerated from rest through a potential difference V and then enter a region containing a uniform magnetic field **B** that points out of the plane of the page and is perpendicular to the initial velocity, v, of the ion as it enters. Once an ion enters the magnetic field, it travels in a semicircular path until it strikes the detector, which records its arrival and the distance, d, from the opening.



a) An ion of charge $+q$ and mass m will enter the magnetic field with what speed? Write v in terms of q, m, and V.

b) Which semicircular path would a cation follow: 1 or 2?

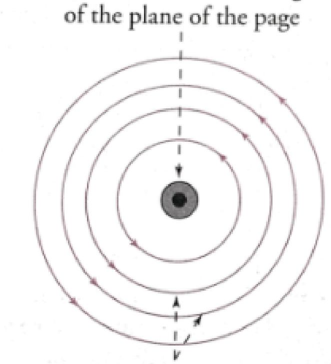
c) If you were using this device in a lab to analyze a sample containing various isotopes of an element, how would you find the mass of a cation striking the detector if all you knew were q, V, B, and d?

Magnetic field sources:

1) Current carrying wires-

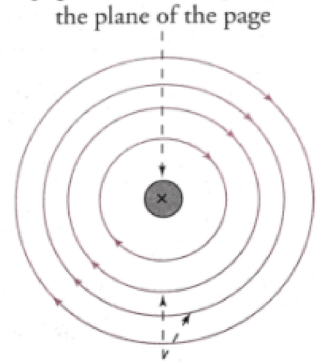
Right thumb points in current's direction, fingers curl in direction of B field, $B \sim I/r$ for all cases

current-carrying wire perpendicular to page with current coming *out* of the plane of the page



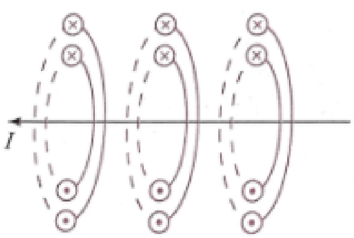
B field lines

current-carrying wire perpendicular to page with current going *into* the plane of the page



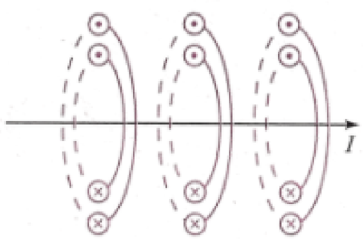
B field lines

With the current pointing to the left, the B field lines go into the page above the wire . . .



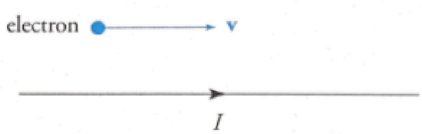
and come out of the page below the wire.

With the current pointing to the right, the B field lines come out of the page above the wire . . .

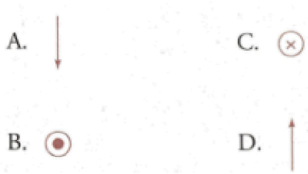


and go into the page below the wire.

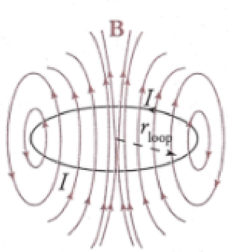
Example 10-51: The figure below shows a long straight wire carrying a current, *I*. An electron is projected above the wire and initially parallel to it.

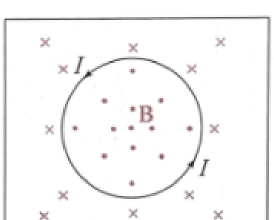


Which of the following best illustrates the direction of the magnetic force on the electron at the position shown?

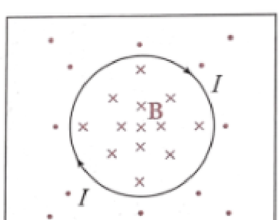


2) Circular wire loops- $B \sim IN/L$, N=# of loops, L=length of solenoid





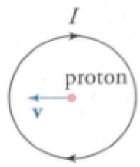
counterclockwise current: B field points out of page inside the loop and points into the page outside the loop



clockwise current: B field points into page inside the loop and points out of the page outside the loop

Now imagine multiple loops forming a coil, boosts the B field strength by x‘n’ many loops

Example 10-53: The figure on the following page shows a circular loop of wire in the plane of the page, carrying a current *I*. A proton is projected with velocity **v**, such that **v** lies in a plane slightly above and parallel to the plane of the loop, as shown:



Which of the following best illustrates the direction of the magnetic force on the proton at the position shown?

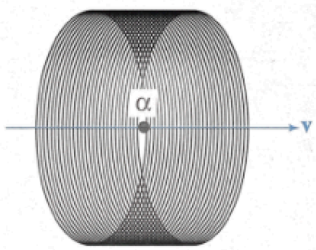
A. ↑

B. ⊙

C. ⊗

D. ↓

Example 10-54: The figure below shows a portion of a long narrow solenoid carrying a current, *I*. An alpha particle (α) is projected with velocity **v** down the central axis of the solenoid, as shown:



Which of the following best illustrates the direction of the magnetic force on the alpha particle?

A. ↓

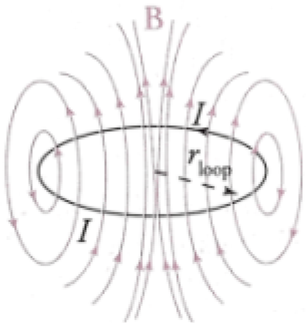
B. ⊙

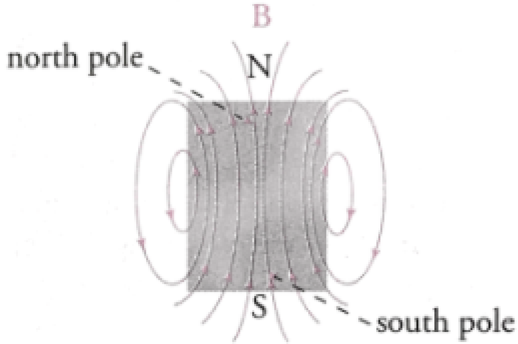
C. ↑

D. None of the above

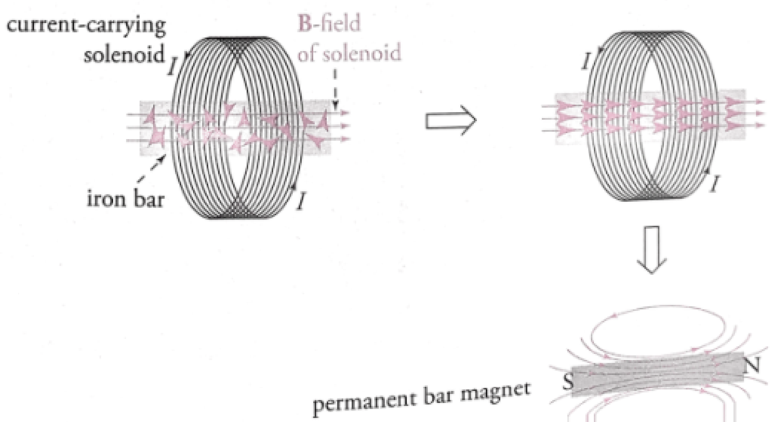
3) Bar/permanent magnets-

Looks like the loop of current somewhat..

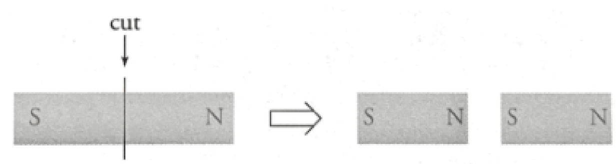




Electrons in the material have some spin quantum number so they are moving charges orbiting the nuclei, creating their own B field. If you align each tiny dipole moment, you get the larger effect of the permanent magnet!

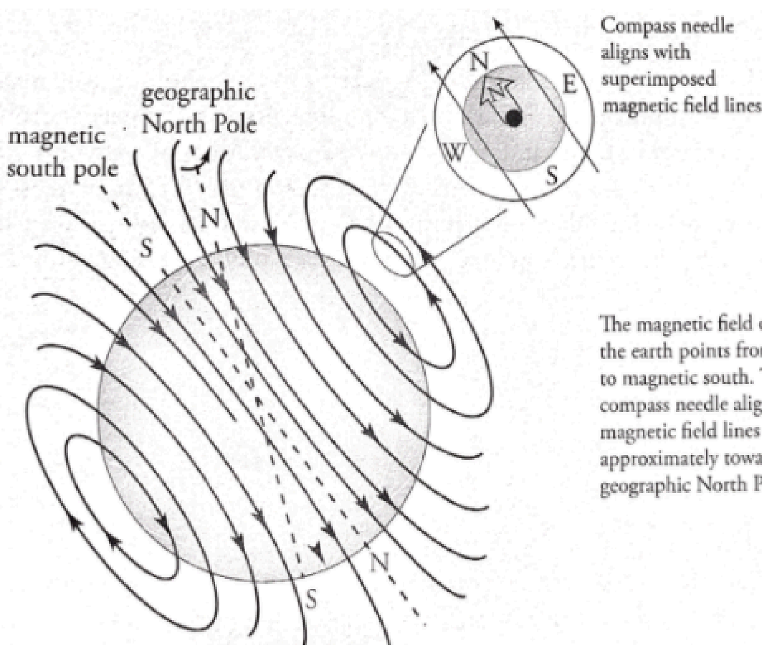


Monopoles don't exist:



Earth as a magnet:

Geographic north pole is actually the magnetic south pole!

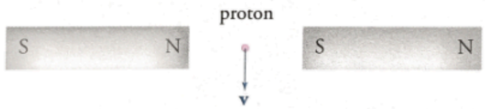


The magnetic field on the surface of the earth points from magnetic north to magnetic south. Therefore, the compass needle aligns with the magnetic field lines and points approximately towards the geographic North Pole.

Example 10-56: The magnitude of Earth's magnetic field is roughly 1 gauss (1 G) at the surface; the **gauss** is a very common (non-SI) unit of magnetic field strength, with 1 G equal to 10^{-4} T. If a proton moving with speed $v = 5 \times 10^6$ m/s in the atmosphere experiences a magnetic field strength of 0.5 G, what force (magnetic or gravitational) has the greater effect? (*Note*: mass of proton ≈ 1.7×10^{-27} kg.)

Example 10-56)

Example 10-57: Two bar magnets are fixed in position, and a proton is projected with velocity **v** into the region between adjacent opposite poles, as shown below:



Which of the following best illustrates the direction of the magnetic force on the proton at the position shown?

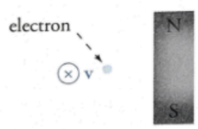
A. ←

B. ⊙

C. ⊗

D. →

Example 10-58: An electron initially travels with velocity **v**, directed into the plane of the page, near a bar magnet, as illustrated below:



Which of the following arrows best illustrates the direction of the magnetic force on the electron at the position shown?

A. ←

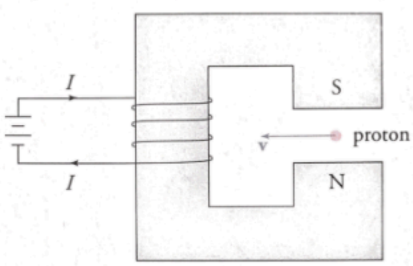
B. ↓

C. ↑

D. →

Example 10-58)

Example 10-59: The following figure shows an electromagnet with an iron core. Since iron is ferromagnetic, the magnetic field created by the current-carrying coil aligns the magnetic dipole moments of electrons in the iron, creating a magnetic field throughout the iron.



If a proton is projected with velocity **v** between the poles as shown, which of the following best illustrates the direction of the magnetic force on the proton at the position shown?

A. ↑

B. ⊙

C. ⊗

D. ↓

1. A helium nucleus traveling at speed v feels a magnetic force of magnitude F_B due to a solenoid that produces a magnetic field. If the number of turns per unit length in the solenoid is doubled while the current is kept constant, what is the magnitude of the force that the helium nucleus feels if it is traveling with the same speed in the same direction?

A) $0.5F_B$
B) $1F_B$
C) $2F_B$
D) $4F_B$

Practice passage:

A current-carrying wire will generate a magnetic field around the wire that varies with current in the wire, i, and the distance from the wire, r. The strength of the magnetic field generated can be calculated using the equation

$$B = \mu_0 i/2\pi r$$

Equation 1

where B is the magnitude of the magnetic field generated and μ_0 is a constant known as the permeability of free space. The direction of the magnetic field generated will always be circular around the wire.

A physics student is conducting an experiment to test the effects on charged particles of the magnetic field created by wires. Two long wires are stretched parallel to each other a distance 20 cm apart. Each wire is connected to a voltage source and a grounded point so that a current will flow through the wire. Three separate test paths are established and marked in Figure 1. The wires are fixed in place, so any forces experienced by the wires will not cause them to move.

The charged particle used in the experiment is a lightweight (mass, m) negatively charged (charge, $-q$) metal marble. For each experiment, the marble is injected along the test path with a constant initial velocity, v, which is parallel to the wires. The magnetic field created by the wires exerts a magnetic force on the marble, causing the velocity to change direction from the initial velocity direction. Because the marble rolls without slipping, frictional effects are assumed to be negligible.

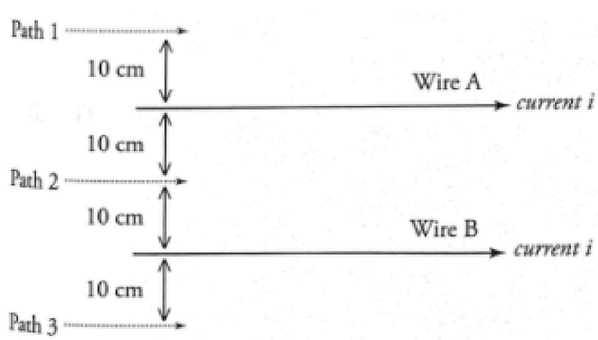


Figure 1 Complete setup for Trial 1 with the three test paths marked

In the first trial of the experiment, the student has the same voltage drop across both wires and the current, *i*, in both wires is going from left to right, as shown in Figure 1. The metal marble was injected along each test path, and its initial change in direction recorded in Table 1. In the second trial of the experiment, the current in Wire A remained the same, but the current in Wire B was doubled. Again, the metal marble was injected along each test path, and its initial change in direction recorded in Table 1.

Trial	Test Path	Initial Change in Direction of Marble
1	1	Up, away from Wire A (↑)
1	2	No change in direction, marble passes straight along path 2 (→)
1	3	Down, away from Wire B (↓)
2	1	Up, away from Wire A (↑)
2	2	Up, toward Wire A and away from Wire B (↑)
2	3	Down, away from Wire B (↓)

1. Which of the following best explains why the marble on Path 2 did not change direction in Trial 1 of the experiment?

A) The net magnetic force acting on the marble was zero because the net magnetic field was zero along Path 2 since the magnetic field created from Wire A was equal in magnitude and opposite in direction from the magnetic field created from Wire B.
B) The net magnetic force acting on the marble was zero because the magnetic fields created by the two wires along Path 2 resulted in forces that were an action-reaction pair.
C) The net magnetic force acting on the marble was not zero, but the magnetic fields created by the two wires resulted in forces on the marble that were parallel to the wires and kept the marble on Path 2.
D) The net magnetic force acting on the marble was not zero because the marble increased velocity as it traveled on Path 2.

2. What is the magnitude and direction of the magnetic field on Path 2 in Trial 2 if $i = 6$ A?

A) magnitude is 30 μ_0/π direction is into the page
B) magnitude is 30 μ_0/π direction is out of the page
C) magnitude is 60 μ_0/π direction is into the page
D) magnitude is 60 μ_0/π direction is out of the page

3. How much work is done by the magnetic force on the marble on Path 3 in Trial 2 in terms of the variables given in the passage?

A) $qv\mu_0 i/2\pi$
B) $qv\mu_0 i/2\pi r$
C) $qv\mu_0 ir/2\pi$
D) 0

4. Assuming the same voltage drop is used for both trials of the experiment, how might the student double the current in Wire B in Trial 2?

A) Increase the resistance by a factor of 2
B) Decrease the resistance by a factor of 2
C) Increase the resistance by a factor of 4
D) Decrease the resistance by a factor of 4

5. Which of the following best describes the negative charge on the metal marble?

A) The negative charge means the electric field inside the marble points in, toward the center of the marble.
B) The negative charge means the electric field inside the marble points out, away from the center of the marble.
C) There is no electric field inside the marble since the negative charge is spread evenly on the surface of the marble.
D) There is no electric field inside the marble since conductors absorb charge and neutralize it.

6. The student wanted to conduct a Trial 3 of the experiment where the current in Wire A is the same as in Trial 1, and the current in Wire B is the same magnitude as Wire A but in the opposite direction. Predict the results of Trial 3 of the experiment.

I. The initial change in direction of the marble on Path 1 is up, away from Wire A (↑)
II. The initial change in direction of the marble on Path 2 is no change in direction (→)
III. The initial change in direction of the marble on Path 3 is up, toward Wire B (↑)

A) I only
B) I and II only
C) I and III only
D) I, II, and III