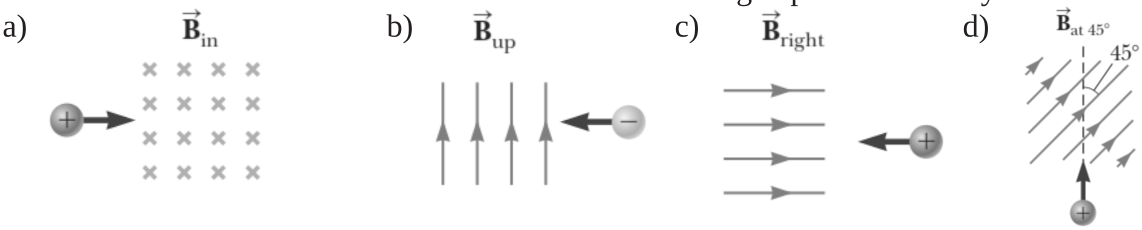
Directions: Show the steps required to arrive at the answer (if applicable). Work the problems on separate page.

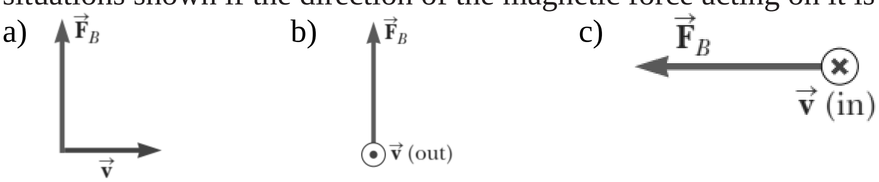
5.1 – Magnetic Fields

1. At the equator, near Earth's surface the magnetic field is ~50.0 μT northward, and the electric field is ~100 N/C downward in fair weather. Find the gravitational, electric, and magnetic forces on an electron in this environment, assuming that the electron has an instantaneous velocity of 6.00x10^6 m/s east.

2. Determine the initial direction of the deflection of charged particles as they enter the magnetic fields shown.



3. Find the direction of the magnetic field acting on a positively charged particle moving in the various situations shown if the direction of the magnetic force acting on it is as indicated.



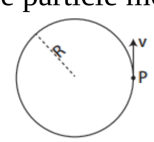
4. A proton moves with a velocity of $\vec{v} = \left(2\hat{\imath} - 4\hat{\jmath} + \hat{k}\right)$ m/s in a region in which the magnetic field is $\vec{B} = \left(\hat{\imath} + 2\hat{\jmath} - \hat{k}\right)$ T. What is the magnitude of the magnetic force this particle experiences?

5. A charged particle of mass 1.50 g is moving at a speed of 15,000 m/s. Suddenly, a uniform magnetic field of magnitude 0.150 mT in a direction perpendicular to the particle's velocity is turned on and then turned off in a time interval of 1.00 s. During this time interval, the magnitude and direction of the velocity of the particle undergo a negligible change, but the particle moves by a distance of 0.150 m in a direction perpendicular to the velocity. Find the charge on the particle.

6. An electron moves in a circular path perpendicular to a uniform magnetic field with a magnitude of 2.00 mT. The speed of the electron is 1.50x10^7 m/s.

a) Determine the radius of the circular path.
b) Calculate the time interval required to complete one revolution.

7. A charged particle is projected from point P with velocity v at a right angle to a uniform magnetic field directed out of the plane of the page as shown. The particle moves along a circle of radius R.



a) Draw a vector representing the magnetic force acting on the particle at point P.
b) Determine the sign of the charge of the particle. Explain your reasoning.
c) Explain why the magnetic field does no work on the particle as it moves in its circular path.
d) A second, identically charged particle is projected at position P with a speed 2v in a direction opposite that of the first particle. On the diagram, draw the path followed by this particle. The drawn path should include a calculation of the radius of curature in terms of the original radius R.

8. A laboratory mass spectrometer is set up to separate strontium ions having a net charge of +2e from a beam of mixed ions. The spectrometer shown accelerates a beam of ions through a potential difference ε after which the beam enters a region of uniform magnetic field with uniform magnitude B and perpendicular to the plane of the path of the ions. The ions leave the spectrometer at a distance x from the entrance point.

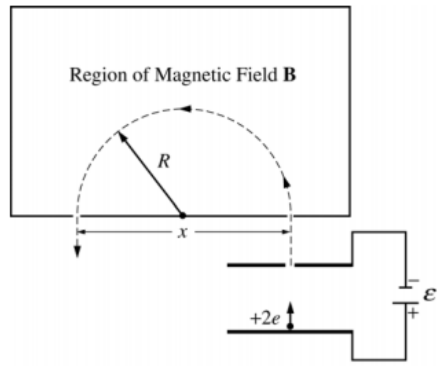
(Stronium ion mass = 1.45×10^{-25} kg, B = .090 T, x = 1.75 m)

a) In what direction must B point to produce the trajectory shown?

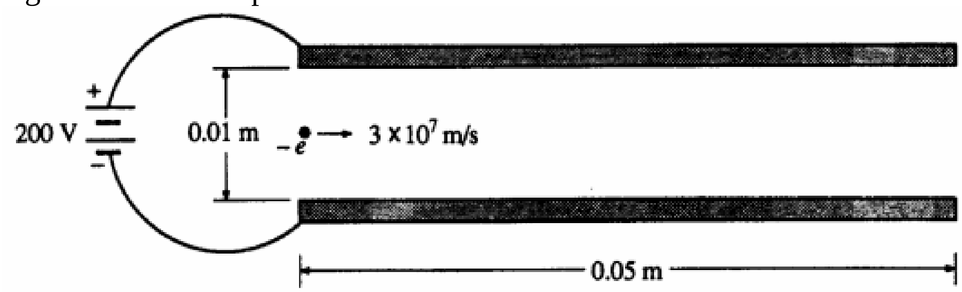
b) The ions travel at constant speed around the semicircle. Explain why the speed remains constant.

c) Calculate the speed of the ions with charge +2e that exit.

d) Calculate the acceleration voltage ε needed for the ions with charge +2e to attain the speed from c)



9. A pair of square parallel conducting plates, having sides of length 0.05 m, are 0.01 m apart and are connected to a 200 V power supply, as shown above. An electron is moving horizontally with a speed of $3x10^7$ m/s when it enters the region between the plates.

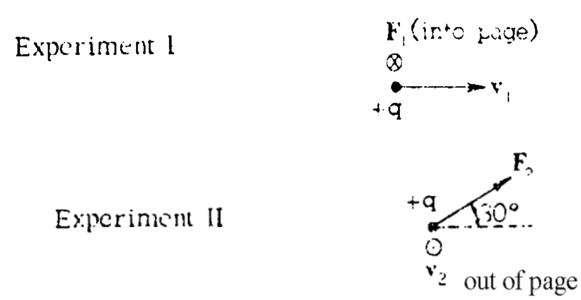


a) Determine the magnitude of the electric field in the region between the plates and indicate its direction on the figure above.
b) Determine the magnitude and direction of the acceleration of the electron in the region between the plates.
c) Determine the magnitude of the vertical displacement of the electron for the time interval during which it moves through the region between the plates.
d) Sketch the path of the electron as it moves through and after it emerges from between the plates.
e) A magnetic field could be placed in the region between the plates which would cause the electron to continue to travel horizontally in a straight line through the region between the plates. Determine both the magnitude and the direction of this magnetic field.

10. A proton moving to the right with instantaneous velocity $\mathbf{v_1}$ experienced a force $\mathbf{F_1}$ directed into the page, as shown.

A proton moving out of the page with instantaneous velocity $\mathbf{v_2}$ experienced a force $\mathbf{F_2}$ in the plane of the page as shown.

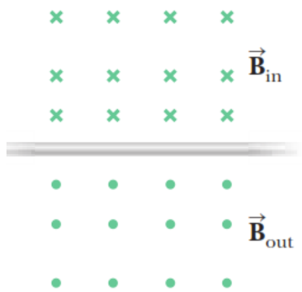
a) State the direction of the magnetic field and show that your choice accounts for the directions of the forces in both experiments.
b) In which experiment did the proton describe a circular orbit? Explain your choice and determine the radius of the circular orbit in terms of the given force and velocity for the proton and the proton mass m.
c) Describe qualitatively the motion of the proton in the other experiment.



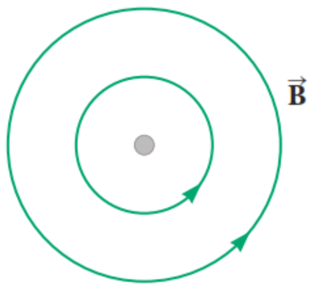
5.2 – Magnetic Force on a Conductor

1. Find the direction of the current in the wire that would produce a magnetic field directed as shown.

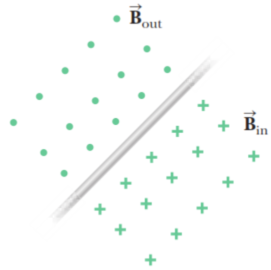
a)



b)

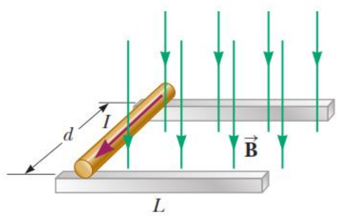


c)



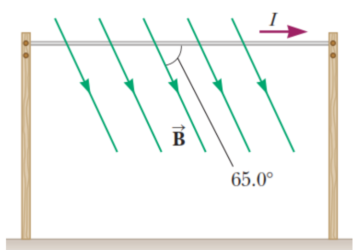
2. A conductor carrying a current I = 15.0 A is directed along the positive x axis and perpendicular to a uniform magnetic field. A magnetic force per unit length of 0.120 N/m acts on the conductor in the negative direction. Determine the magnitude and direction of the magnetic field in the region through which the current passes.

3. A rod of mass 0.720 kg and radius 6.00 cm rests on two parallel rails that are d=12.0 cm apart and L=45.0 cm long. The rod has a current of I= 48.0 A in the direction shown and rolls along the rails without slipping. A uniform magnetic field of magnitude 0.240 T is directed perpendicular to the rod and the rails. If it starts from rest, what is the speed of the rod as it leaves the rails?



4. A wire having a mass per unit length of 0.500 g/cm carries a 2.00-A current horizontally to the south. What are the direction and magnitude of the minimum magnetic field needed to lift this wire vertically upward?

5. A horizontal power line of length 58.0 m carries a current of 2.20 kA northward as shown. The Earth's magnetic field at this location has a magnitude of $5.00x10^{-25}$ T. The field at this location is directed toward the north at an angle 65.0º below the power line. Find the magnitude and direction of the magnetic force on the power line.

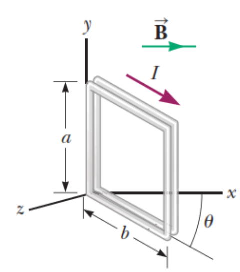


6. A 50.0-turn circular coil of radius 5.00 cm can be oriented in any direction in a uniform magnetic field having a magnitude of 0.500 T. If the coil carries a current of 25.0 mA, find the magnitude of the maximum possible torque exerted on the coil.

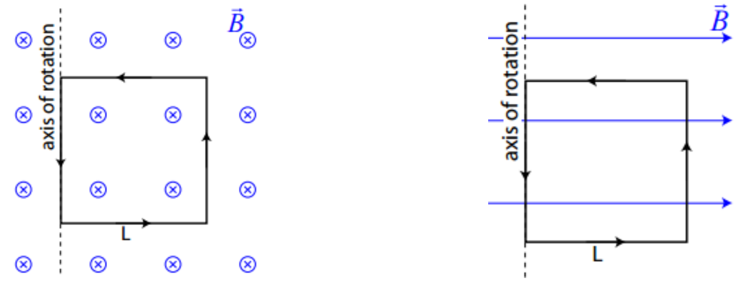
7. A rectangular coil consists of N 5 100 closely wrapped turns and has dimensions a=0.400 m and b=0.300 m. The coil is hinged along the y axis, and its plane makes an angle of 30º with the x axis.

a) What is the magnitude of the torque exerted on the coil by a uniform magnetic field B=0.800 T directed in the positive x direction when the current is I 5 1.20 A in the direction shown?

b) What is the expected direction of rotation of the coil?



8. A square loop of wire with side length L and one side attached to an axis of rotation is situated in a uniform magnetic field directed into the page as shown. The magnetic field strength is B and a current I flows through the wire in a counter-clockwise direction.



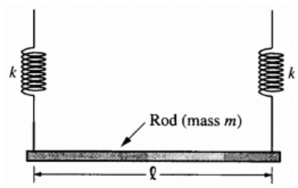
a) Determine the net torque on the loop of wire.

b) The magnetic field strength is now increased uniformly over a short period of time. Describe what happens to the current flowing in the wire during this period.

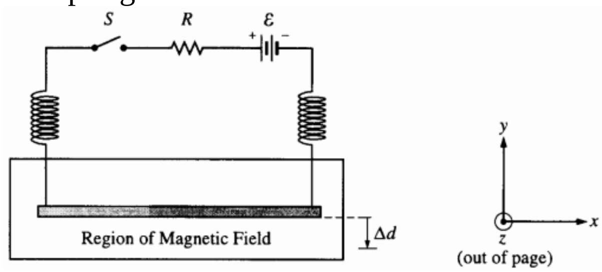
c) The magnetic field is again set to strength B and is rotated 90 degrees such that it now points to the right, as shown. Determine the new net torque on the loop of wire.

d) Again, the magnetic field strength is increased uniformly over a short period of time. Describe what happens to the current flowing in the wire during this period.

9. A rigid rod of mass m and length Lis suspended from two identical springs of negligible mass as shown in the diagram above. The upper ends of the springs are fixed in place and the springs stretch a distance d under the weight of the suspended rod.



a) Determine the spring constant k.



As shown above, the upper end of the springs are connected by a circuit branch containing a battery of emf ε and a switch S so that a complete circuit is formed with the metal rod and springs. The circuit has a total resistance R, represented by the resistor in the diagram. The rod is in a uniform magnetic field directed perpendicular to the page. The upper ends of the springs remain fixed in place and the switch S is closed. When the system comes to equilibrium, the rod has been lowered an additional distance Δd.

b) With reference to the coordinate system shown above on the right, what is the direction of the magnetic field?

c) Determine the magnitude of the magnetic field in terms of m, L, d, Δd, ε, R, and fundamental constants.

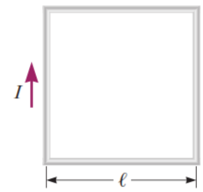
d) When the switch is suddenly opened, the rod oscillates. Determine the period of oscillation.

e) Determine the maximum speed of the rod.

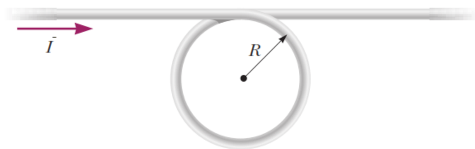
5.3 – Magnetic Force on a Moving Charge

1. Calculate the magnitude of the magnetic field at a point 25.0 cm from a long, thin conductor carrying a current of 2.00 A.

2. a) A conducting loop in the shape of a square of edge length of .400 m carries a current I=10.0 A as shown. Calculate the magnitude and direction of the magnetic field at the center of the square.
b) If this conductor is reshaped to form a circular loop and carries the same current, what is the value of the magnetic field at the center?

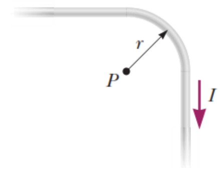


3. A conductor consists of a circular loop of radius R and two long, straight sections. The wire lies in the plane of the paper and carries a current I.



a) What is the direction of the magnetic field at the center of the loop?
b) Find an expression for the magnitude of the magnetic field at the center of the loop.

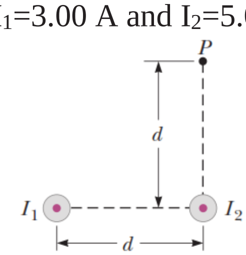
4. A long, straight wire carries a current I. A right-angle bend is made in the middle of the wire. The bend forms an arc of a circle of radius r. Determine the magnetic field at point P, the center of the arc.



5. Two parallel wires are separated by 6.00 cm, each carrying 3.00 A of current in the same direction.
a) What is the magnitude of the force per unit length between the wires?
b) Is the force attractive or repulsive?

6. Two parallel wires separated by 4.00 cm repel each other with a force per unit length of 2.00×10^4 N/m. The current in one wire is 5.00 A.
a) Find the current in the other wire.
b) Are the currents in the same direction or in opposite directions?
c) What would happen if the direction of one current were reversed and doubled?

7. Two long, parallel wires carry currents of I_1=3.00 A and I_2=5.00 A in the directions indicated.



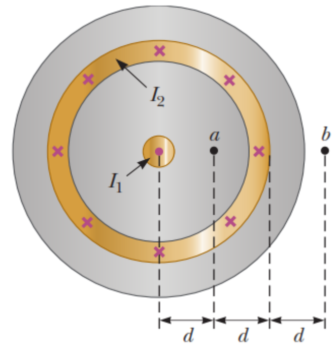
a) Find the magnitude and direction of the magnetic field at a point midway between the wires
b) Find the magnitude and direction of the magnetic field at point P, located d 5 20.0 cm above the wire carrying the 5.00-A current.

8. Two long, parallel wires are attracted to each other by a force per unit length of 320 μN/m. One wire carries a current of 20.0 A to the right and is located along the line y=0.500 m. The second wire lies along the x-axis. Determine the value of y for the line in the plane of the two wires along which the total magnetic field is zero.

5.4 – Ampere's Law

1. Shown is a cross-sectional view of a coaxial cable. The center conductor is surrounded by a rubber layer, an outer conductor, and another rubber layer. In a particular application, the current in the inner conductor is $I1$ = 1.00 A out of the page and the current in the outer conductor is I_2 = 3.00 A into the page. Assuming the distance d=1.00 mm, determine the magnitude and direction of the magnetic field at

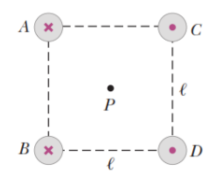
   a) point *a*
   b) point *b*.



2. A long, straight wire lies on a horizontal table and carries a current of 1.20 mA. In a vacuum, a proton moves parallel to the wire (opposite the current) with a constant speed of 2.30x10^4 ^{m}/s at a distance *d* above the wire. Ignoring the magnetic field due to the Earth, determine the value of *d*.

3. An infinite sheet of current lying in the *yz* plane carries a current of linear density J. The current is in the positive z-direction and J represents the represents the current per unit length measured along the y-axis. Show that the magnetic field near the sheet is parallel to the sheet and perpendicular to the current direction with magnitude $\frac{\mu J}{2}$.

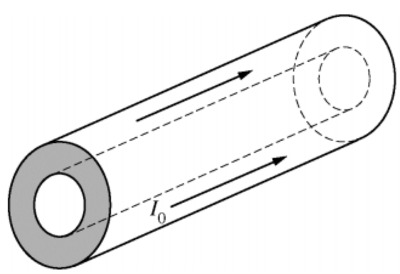
4. Four long, parallel conductors carry equal currents of I=5.00 A. The current direction is into the page at points *A* and *B* and out of the page at points *C* and *D*. Calculate the magnitude and direction of the magnetic field at point *P*, located at the center of the square of edge length of 0.200 m.

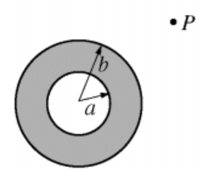


5. A section of a long conducting cylinder with inner radius a and outer radius b carries a current I_0 that has a uniform current density, as shown in the figure below.

a) Using Ampère's law, derive an expression for the magnitude of the magnetic field in the following regions as a function of the distance r from the central axis.

   i. r < a
   ii. a < r < b
   iii. r > b





Cross-sectional View
(current into page)

b) Indicate the direction of the field at point P, which is at a distance r b = 2 from the axis of the cylinder.

c) An electron is at rest at point P. Describe any electromagnetic forces acting on the electron. Justify your answer.

6. The long solenoid shown in the left-hand figure above has radius r_1 and n turns of wire per unit length, and it carries a current The magnetic field outside the solenoid is negligible. Apply Ampere's law using the path abcda indicated in the cross section shown in the righthand figure to derive an expression for the magnitude of the magnetic field B near the center of the solenoid