Unit 26 *Homework Problems*

Learning Goals:

F.26 Use the right-hand rule and vector cross product to determine the magnitude and direction of a force exerted on a charged particle by a magnetic field.
A.26 Use the force on a charged particle and the properties of uniform circular motion to relate the motion of a charged particle to magnetic field properties.

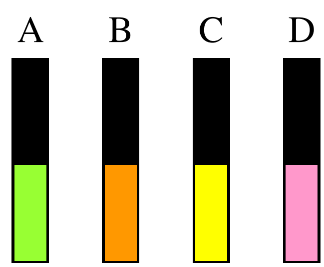
26-1) It has been asserted that a permanent magnet is really just made up of an insulator with fixed positive electrical charges permanently embedded in the north pole of the magnet and fixed negative electrical charges permanently embedded in the south pole of the magnet.

(a) Do you believe this assertion?

(b) Name three observations you made in Unit 26 that would provide support for or evidence against this assertion. Cite Activity numbers and explain how each observation supports your conclusion.

26-2) Four rod-shaped objects behave differently in the presence of each other. These are shown in the diagram. Each one is either: Type 1: a permanent magnet, Type 2: unmagnetized iron, Type 3: aluminum. Identify each object's type, if the following interactions take place.

– C does not interact with either end of B or D
– The light green end of A is attracted to both ends of B
– The dark end of B is repelled from the light pink end of D



(a) Rod A is type_____,
(b) Rod B is type_____,
(c) Rod C is type_____,
(d) Rod D is type_____,

(e) Explain the reasons for your choices.

26-3) You should have observed in Activity 26.5.2 that a permanent magnet can exert forces on moving charges or currents.

(a) If a magnet exerts a force on a moving charge, would the magnet itself experience any forces? Explain

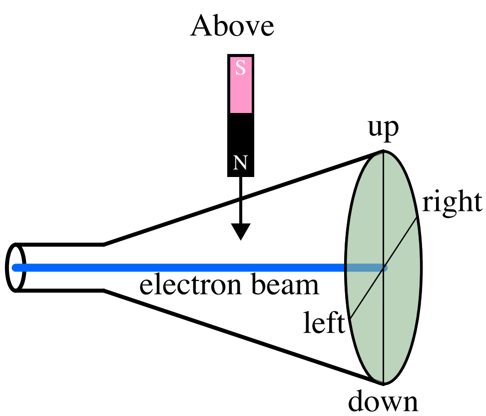
(b) In the case of the gravitational or electrostatic interaction between two objects, each object has a common property, such as mass in the case of gravitational interaction or excess charge in the case of the electrostatic interaction. A permanent magnet and a moving electron seem very different. Can you think of any way that they might have a common property? Explain.

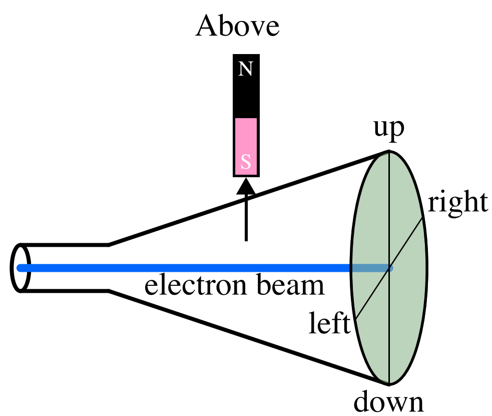
26-4) You should have observed in Activity 26.5.2 that a permanent magnet can exert forces on a beam of electrons inside of an oscilloscope. This led to the conclusion that the relationship between the force on an electron in the beam can be represented by a vector cross product. Use the vector cross product (*i.e.*, the right-hand rule) that produces the magnetic force to deduce in what direction the electron beam will be deflected when it hits the face of the oscilloscope (up, down, left or right) in the following situations.

(a) A permanent magnet above the oscilloscope is pointed straight down with its north pole nearest to the oscilloscope.

(b) A permanent magnet above the oscilloscope is pointed straight down with its south pole nearest to the oscilloscope.

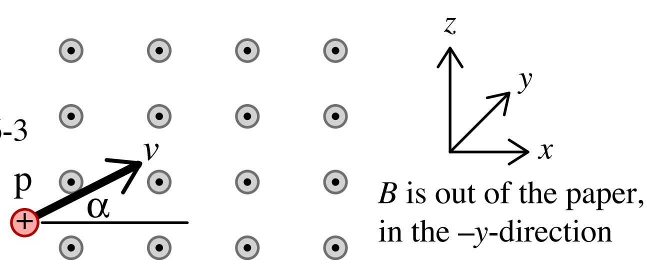
(c) Explain the reason for each of your answers.





26-5) A proton having a velocity of magnitude 3.45×10^4 m/s passes into a region of uniform magnetic field at an angle of $\alpha = 30.0°$ with respect to the horizontal x-axis as shown in Figure 26-3. **Note**: Alpha, α, is not the angle θ between the velocity vector and the magnetic field vector. In fact, θ is 90°. Why?

Figure 26-3



The magnetic field has a magnitude of $B = 0.212$ T and is pointing out of the paper in the negative y-direction so that its vector is given by the expression

$$\vec{B} = \left(-0.212\,\mathrm{T}\right)\hat{y}$$

(a) Use the right hand rule to find the direction of force on the proton as it passes into the region where the magnetic field is uniform. Sketch the force direction relative to the initial direction of $\vec{v}$. Explain how you applied the rule.

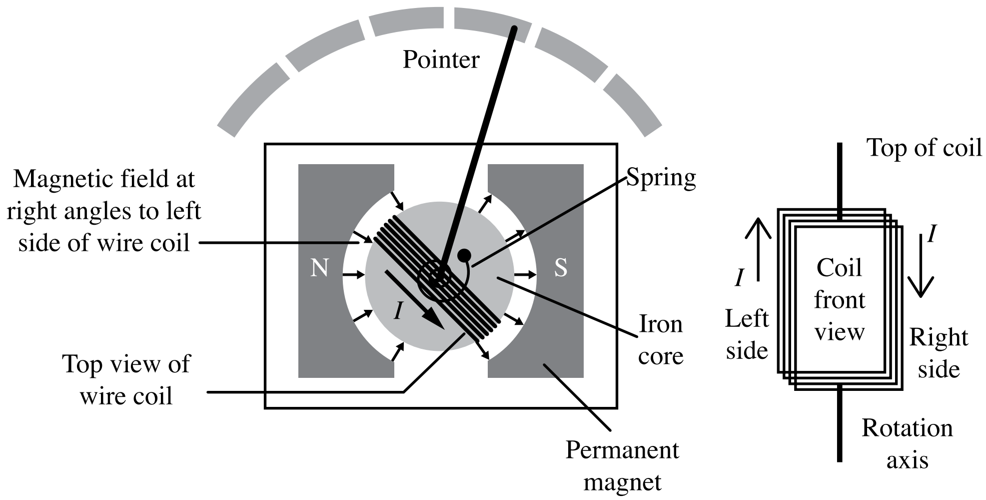
(b) Show that the vector representing the proton's velocity is given by

$$\vec{v} = \left(+2.99\times10^{4}\ \frac{\mathrm{m}}{\mathrm{s}}\right)\hat{x} + \left(+1.73\times10^{4}\ \frac{\mathrm{m}}{\mathrm{s}}\right)\hat{z}$$

(c) Use the vector cross product (mathematical form) to find the vector representing the force on the proton just as it enters the region of uniform magnetic field.

The Galvanometer

Prior to the development of digital ammeters, the galvanometer was the main component used for constructing ammeters. The most common type of galvanometer is named after its French inventor D'Aronsonval. A schematic of the galvanometer is shown in the diagram that follows.



Basically the *D'Aronsonval galvanometer* takes advantage of the fact that a current carrying wire loop in a magnetic field experiences a torque. The magnets that surround the coil have been designed so that the direction of the magnetic field through *the sides of the coil* is always perpendicular to the side wires in the loop. In this situation the torque turns out to be proportional to both the current through the loop and the magnitude of the magnetic field. In the next problem you will consider a galvanometer with a coil which is L = 3.2 cm high and W = 2.0 cm wide. The magnitude of the field created by the permanent magnet is given by B = 0.25 T. The coil has N = 300 loops. The internal resistance of the galvanometer is given by R_g = 50 Ω and its full-scale deflection current is $I_{fs} = 60 \times 10^{-6}$ A.

24-6) *Torque on the Galvanometer Coil*

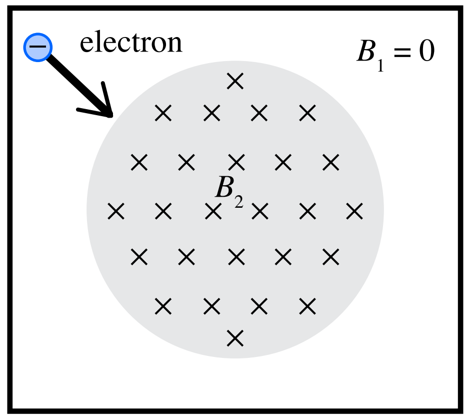
(a) *The magnetic force on each coil segment using the right hand rule*: Assume that the full-scale deflection current I_{fs} passing through the loop is clockwise as shown in the diagram. Find the *magnitude* and *direction* of the magnetic force in each element of a single galvanometer loop in the uniform magnetic field surrounding it. (That is the left side, right side, top and bottom).

(b) *Finding the magnetic force on the Left Coil Segment using the formal vector cross product:* Refer to the coil in the diagram. Define a 3D coordinate system in which the positive x-axis is horizontal and points from left to right, the positive y-axis is vertical and points up, and the positive z-axis points out of the paper. When the coil lies in the plane of the paper as shown in the diagram, the B-field vector is given by $\vec{B} = B_x\hat{x} = \left(+0.25\,\mathrm{T}\right)\hat{x}$. Write the expression for the length of the left segment of the coil in vector notation. Then use the given values for the magnitudes of the full-scale deflection current, I_{fs}, and the coil height, L, along with the formal method of finding the vector cross product to find vector that describes the magnetic force on the *left* segment of the coil.

(c) *Finding the magnitude of the maximum torque on the coil:* Use the definition of torque to find the magnitude of the maximum torque, τ, on a single loop of the coil when the full-scale deflection current is passing through a single loop. Since the coil has 300 turns on it, what is the maximum torque experienced by the entire coil?

(d) *The function of the spring and pointer:* Examine the diagram. Why is the coiled spring that is attached to the pointer needed as part of the galvanometer?

26-7) Most of the air molecules are pumped out of a chamber, which is shown schematically in the diagram below. Thus, a charged particle moving through the chamber will not lose a noticeable amount of energy in collisions with air molecules. There is a region in the center of the chamber that can have a uniform magnetic field pointing into the paper that is caused by an external magnet.



Vacuum Chamber

(a) Sketch the electron's path if the magnetic field is zero throughout the evacuated region so that $B_1 = B_2 = 0$. Does the velocity of the electron change? Does its speed change? Does its direction change? Why or why not?

(b) Sketch the electron's path if the magnetic field B_2 in the central area of the chamber is uniform but fairly weak and the magnetic field B_1 outside the circle is zero. Does the velocity of the electron change? Does its speed change? Does its direction change? Why or why not?

(c) Sketch the electron's path if the magnetic field in the central area of the chamber is uniform and very strong. Does the velocity of the electron change? Does its speed change? Does its direction change? Why or why not?

(d) What would happen to the shape of the path in part (c) if the particle were a negative ion having a much greater mass than the electron but still having the same net negative charge as the electron?