APPC, E & M: Unit C HW 2

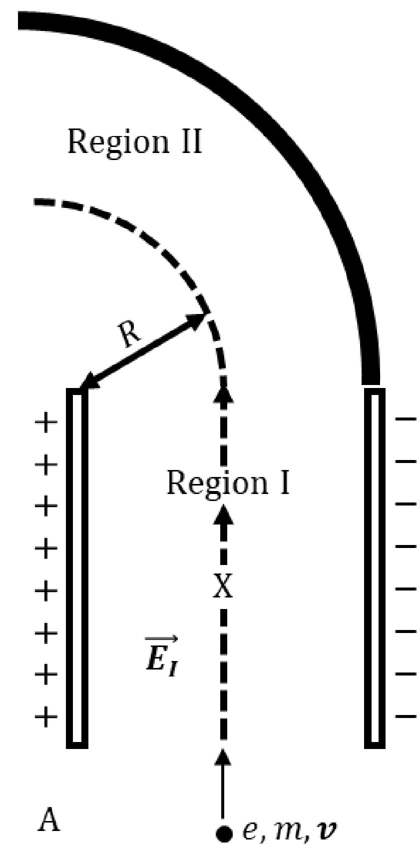
Name: ______________________________
Hr: ___ Due at beg of hr on: __________

UC, HW2, P1

Reference Videos: (1) "Review of Unit on Magnetic Forces on Moving Charges (Part II)"
(2) "Review of Unit on Magnetic Forces on Moving Charges (Part III)"
YouTube, lasseviren1, INTERACTIONS OF B FIELDS WITH MOVING CHARGES playlist

An electron of mass *m*, charge *e*, and velocity $\boldsymbol{v}$ enters Region I, where a known, uniform electric field $\boldsymbol{E_I}$ exists between two charged plates. There is also a uniform magnetic field $\boldsymbol{B_I}$ (of unknown magnitude) in Region I, which is NOT YET shown in the figure. In Region II, there is no longer an *E* field, but there is another (different) uniform magnetic field of unknown magnitude $\boldsymbol{B_{II}}$, which causes the electron to travel in a circle of known radius *R*. The trajectory of the electron is shown by the dashed line in the figure.

A. Into the figure, draw VERY LIGHT arrows to represent the electric field $\boldsymbol{E_I}$ in Region I.



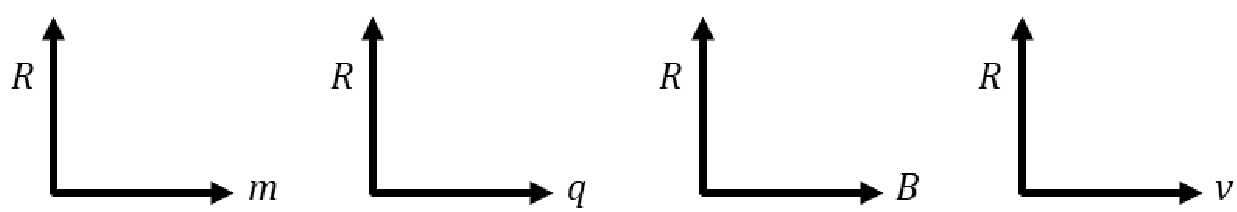
B. At Point X, draw and label a vector $\overrightarrow{F_{EI}}$ to show the electric force on the electron at Point X. Also at Point X, draw and label a vector $\overrightarrow{F_{BI}}$ to show the magnitude and direction of the magnetic force required in Region I to keep the electron in a straight-line path.

C. In terms of the known quantities (i.e., the ones already computer-printed in the figure), write an expression for the magnitude of B_I that is required for the electron to maintain its straight-line path.

D. Into the figure, use symbols to represent the direction of magnetic field $\boldsymbol{B_I}$ in Region I. Also, use symbols to represent the direction of magnetic field $\boldsymbol{B_{II}}$ in Region II that is necessary for the electron to have the trajectory shown. Label BOTH of these fields.

E. Use Newton's 2nd law and concepts of uniform circular motion to derive an expression for the magnitude of B_{II} required in Region II for the electron to travel in a curved path of known radius *R*.

F. In the following graphs, draw curves that show how a given radius *R* will be affected by each quantity given. Above each curve, write a simple equation that begins… "$R \propto$ …" (NOTE: Your answers here should will be closely connected to your Part E answer.)

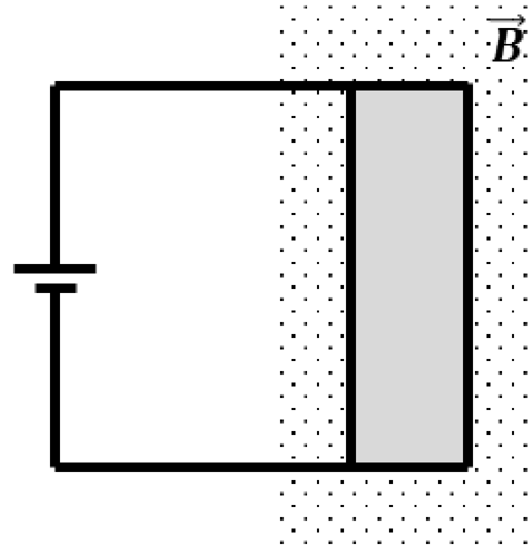


G. In the Part III video, the narrator says: -- A velocity vector $\vec{v}$ is NEVER drawn ____________.

-- The radius of curvature of a straight-line path is ____________.

UC, HW2, P2
Reference Video: "Review of Unit on Magnetic Forces on Moving Charges (Part III)"
YouTube, lasseviren1, INTERACTIONS OF B FIELDS WITH MOVING CHARGES playlist

The narrator briefly mentions the Hall Effect in this video. The Hall Effect comes into play when we insert a THICK plate into a circuit, along with the battery and wires. One use for the Hall Effect is to quantify the number of charge carriers *N* for a given metal. (FYI, we first met *N* way back in UB HW3 P1…) Anyway, the Hall Effect is the ONE case we might run into where our focus on conventional charge flow and its associated right-hand rules (RHR) breaks down: With the Hall Effect, we MUST focus on the motion of the conduction electrons, and therefore use some variation of the left-hand rule (LHR).



The figure shows a circuit containing a battery, wires, and a thick metal plate. In the vicinity of the metal plate, there is a magnetic field directed out of the page.

A. Somewhere in the figure, use ONE arrow to show the direction of conventional charge flow; label this arrow I_+. Somewhere else in the figure, use ONE arrow to show the direction in which the conduction electrons flow around the circuit; label this arrow I_-.

B. Now, focus on the flow of charge through the thick plate. Use a RHR to determine the direction in which (+) charges IN THE PLATE should tend to drift, due the magnetic force $\boldsymbol{F_B}$ on them. Circle your answer. TO THE LEFT TO THE RIGHT

C. Use a LHR to determine the direction in which (–) charges IN THE PLATE should tend to drift, due the magnetic force $\boldsymbol{F_B}$ on them. Circle your answer. TO THE LEFT TO THE RIGHT

D. Which of the above scenarios could actually occur, within the plate? (CIRCLE) Part B Part C

E. Your Part D answer means that a buildup of which charge will appear on the left edge of the plate? (CIRCLE) + –

F. …and a buildup of which charge will appar on the right edge? (CIRCLE) + –

G. In accord with your answers to Parts E and F, draw a series of (+) and (–) signs along the plate's edges.

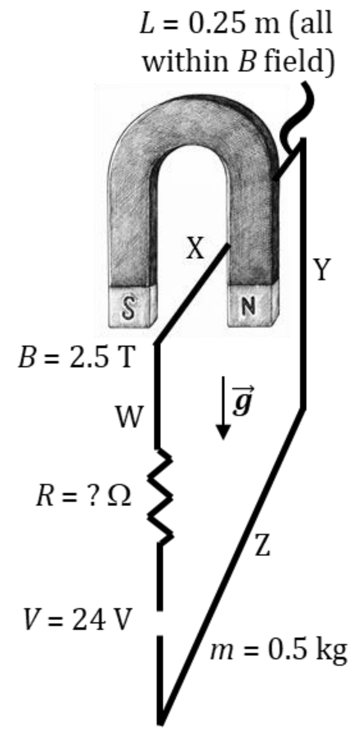
H. Your Part G answer results in a voltage difference between the two long edges of the plates. Label the appropriate edges with the labels "higher V" and "lower V".

I. To determine the charge carrier density *N* of the metal out of which the plate is made, we simply need to measure the following: the dimensions (e.g., length, width, thickness) of the metal plate (using a meter stick or Vernier caliper); the strength of the magnetic field *B*; the ΔV mentioned in Part H; and the current *I* flowing in the circuit. (We also need to look up or know the charge on an electron, but that's a constant that has already been determined by others and is well known.) To measure the magnetic field, we would use a device called a **magnetometer**; to measure ΔV, we would use a(n) ________________________; to measure *I*, we would use a(n) ________________________.

UC, HW2, P3

Reference Video: "Review of Unit on Magnetic Forces on Moving Charges (Part IV)"
YouTube, lasseviren1, INTERACTIONS OF B FIELDS WITH MOVING CHARGES playlist

The figure is a 3-D representation of a circuit. An unknown resistor R is on Side W, which is closest to us and runs vertically. Also on Side W is a 24-V battery (which is not yet shown because it will be up to you to decide on its orientation). Side Y is parallel to Side W, but is further away from us. Sides X and Z run into- and out-of the page, with Side X passing through the magnetic field that runs left/right between the poles of the magnet. The circuit's mass is 0.5 kg, and Earth's gravitational field acts toward the bottom of the page, as shown. Assume that the magnetic field is a uniform 2.5 T *over the entire length* of Side X. We want the circuit to be suspended in place, i.e., where it doesn't accelerate in any direction.



A. Calculate the weight of the circuit. Use $g = 10\ m/s^2$.

B. In order to suspend the circuit in midair, there must be a magnetic force in WHICH DIRECTION on Side X, when current passes through the circuit?

C. How will the magnitudes of the magnetic force of Part B and the circuit's weight of Part A compare to each other?

D. Determine the direction that current must be flowing through the resistor in order to achieve your Part B answer. Indicate this current direction by drawing into the figure an I with an appropriately-directed arrow NEXT TO the resistor.

E. Based on your Part D answer, draw into the figure the schematic symbol for a battery having the correct orientation. This symbol should go into the open space by the voltage value on Side W.

F. Determine the magnitude of the current that must be flowing through the circuit, consistent with your Part C answer. If you need a hint to get started, refer back to UC, HW1, P4, Part A.

G. Determine the necessary resistance value of the resistor, consistent with your Part F answer.

Suppose you have a 1-C charge with a velocity of $\vec{v} = \left(3\hat{\imath} + 2\hat{\jmath} + 4\hat{k}\right) m/s$ that is traveling through a magnetic field of $\vec{B} = \left(-5\hat{\imath} + 4\hat{\jmath} - \hat{k}\right) T$.

H. In unit-vector notation, determine the force vector that acts on the charge.

UC, HW2, P4

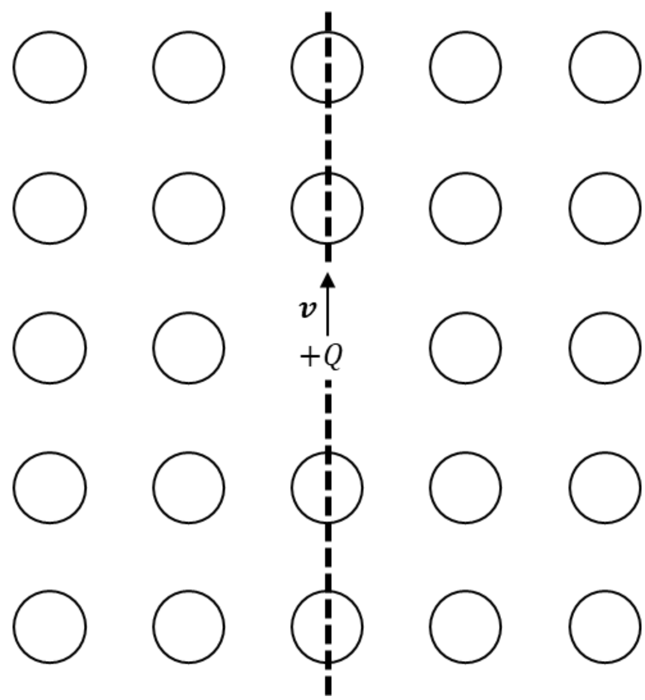
Reference Video: "Magnetic Field Due to a Moving Charge or a Current-Carrying Wire"
YouTube, lasseviren1, SOURCES OF MAGNETIC FIELDS playlist

A. **IMPORTANT**: We now shift our investigations from charges moving through ***B*** fields that are "already there," i.e., that have been generated by some other source, to ***B* fields that a moving charge *produces***. In this video, the narrator states that the source of all ***B*** fields is moving charges and that, since velocity is always relative, the strength of a ***B*** field depends on our frame of reference. Suppose you are on a train moving 20 m/s and are holding a +3-C electric charge. Suppose also that there is an observer (George) outside the train, standing next to the tracks. Each of you has a *magnetometer*, which you will hold motionless while you measure the magnitude of the magnetic field created by the +3-C charge. Circle your answers…

According to you, the charge is…	MOVING	NOT MOVING
Because of that, you would therefore measure a ***B*** field that is…	ZERO	NONZERO
According to George, the charge is…	MOVING	NOT MOVING
Because of that, he would therefore measure a ***B*** field that is…	ZERO	NONZERO

In the figure, a charge +*Q* is moving toward the top of the page. The circles around the charge indicate specific locations around +*Q*. Within each circle, you will indicate the magnitude and direction of the ***B*** field at that location, <u>due to the moving charge +*Q*</u>…*at the instant that +Q is right where it now is.* So…

- Show the direction of the measured ***B*** field by drawing either ⊙ or ⊗ in each circle. YOU MAY ALSO LEAVE A CIRCLE BLANK.
- Show the magnitude of the measured ***B*** field by making the dots and Xs larger/heavier and smaller/lighter. There should be a *gradient* of size/heaviness in your diagram, not just the two options of BIG/HEAVY and SMALL/LIGHT.



B. Now, fill in each circle, as described above.

What will happen to the size/heaviness of the symbols *nearer the top of the page*, as +*Q* continues moving toward the top of the page? State…

C. …one thing that WILL change about the top-of-the-page circles

D. …TWO things that WON'T change about the top-of-the-page circles (HINT: You will have to single out specific circles, or specific groups of circles.)

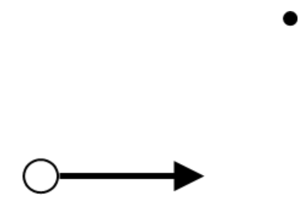
E. Based on your work in Parts B-D… As the train from Part A gets near to George and then passes him by, George's magnetometer will display a…?
(CIRCLE the correct answer)

a. large value at first, then decrease, then increase again.
b. small value at first, then increase, then decrease again.
c. large, constant value.
d. small, constant value.
e. constant value of zero.

UC, HW2, P5
Reference Videos: (1) "Calculating the Magnetic Field Due to a Moving Point Charge"
(2) "Law of Biot-Savart"
(3) "Law of Biot-Savart (Part II)"
YouTube, lasseviren1, SOURCES OF MAGNETIC FIELDS playlist

The Law of Biot-Savart (pronounced "BEE-oh sah-VARR") allows us to determine the ***B*** field (magnitude and direction) at a particular location due to a nearby moving charge. The ***B*** field we measure will depend on a constant μ_o, the charge magnitude q, where we measure the ***B*** field relative to the position of the charge ***r***, and the velocity ***v*** (i.e., speed and direction) of the charge. The equation is: $\vec{B} = \frac{\mu_o}{4\pi}\frac{q\,\vec{r}\times\vec{v}}{r^3}$

The figure shows a moving charge and a point where we wish to find the ***B*** field.



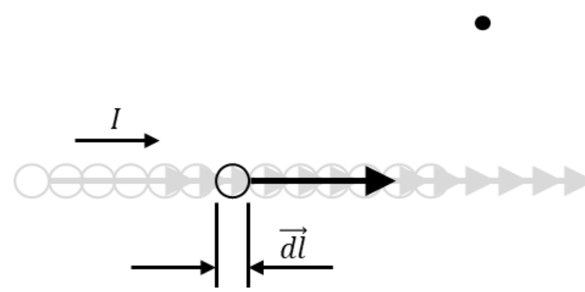
A. Label the point as P, the charge as q, and the velocity vector $\vec{v}$.

B. The position vector $\vec{r}$ begins at q and extends to P.
Draw this vector in and label it.

C. θ is the angle between $\vec{r}$ and $\vec{v}$. Draw in θ in the appropriate place.

D. In the equation above, $\vec{r}$ and $\vec{v}$ are a vector (or cross) product. Recall that finding the magnitude of a cross product involves an angle (here, θ) and a trig function. Use that relationship and the equation above to write an equation for finding only the magnitude of the ***B*** field. (Your answer should have NO vectors in it.)

Frequently in physics, however, we don't have isolated moving charges; instead, we have a bunch charges enclosed within a wire, all moving together. (That's an electric current. ☺) So the law of Biot-Savart has another formulation, which is based on the tiny magnetic field contribution $\overrightarrow{dB}$ that is due to the charge moving within a tiny length of current-carrying wire $\overrightarrow{dl}$. It is basically like taking the charge you worked with in Parts A-D and stringing a bunch of them together. (See the figure here and note its similarity to the one for Parts A-D.)



So the other formulation for the law of Biot-Savart looks like this: $\overrightarrow{dB} = \frac{\mu_o}{4\pi}\frac{I\,\overrightarrow{dl}\times\vec{r}}{r^3}$

E. And what, do you suppose, must we do with all of the $\overrightarrow{dB}$ bits?

We are NOT going to worry about actually doing your Part E answer. Instead, we will look at one specific case: When we want to find the ***B*** field at the center point of a portion of circular wire of arc length L, carrying current I, where the radius is r, we use this equation: $B = \frac{\mu_o I L}{4\pi r^2}$, where $\frac{\mu_o}{4\pi} = 1\times10^{-7}\ \frac{T\cdot m}{A}$

F. Determine the magnitude and direction of the ***B*** field at the center point of each arc below.