Magnetic Field of a Single Moving Charged Particle

OBJECTIVES

In this lab, you will
- Compute the magnetic field from a single charged particle at one point in space
- Compute the magnetic field from the same particle at multiple points in space.

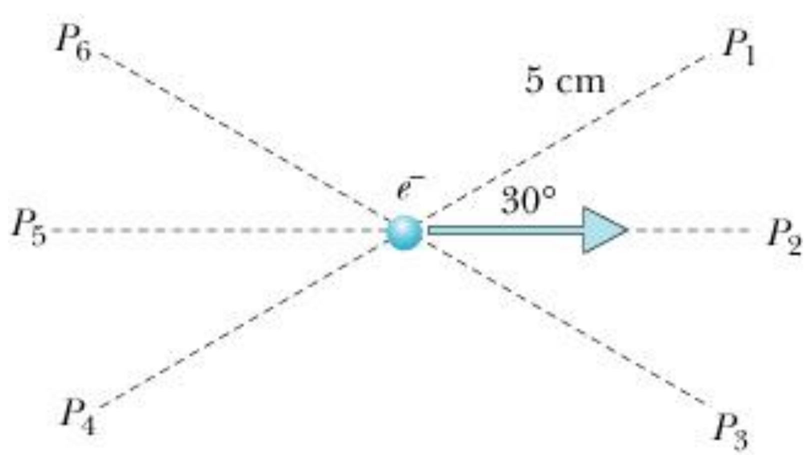
Biot-Savart's law states that as particles move it creates a magnetic field.

$$\vec{B}=\frac{\mu_o}{4\pi}\frac{q(\vec{v}\times\hat{r})}{|\vec{r}|^2}$$

As the particle moves, the magnetic field will change at any given location. You will use VPython to display the magnetic fields at several points surrounding the particle track. You can then watch the fields change as the particle passes the observation locations.

1) Warm Up Problem

Problem 1) An electron is moving horizontally to the right with speed 4 x 10^6 m/s. What is the magnetic field due to the electron at the indicated locations? Each location is 5 cm from the electron. Give both magnitude and direction of the magnetic field at each location.



CHECKPOINT 1: Ask an instructor to check your work for credit. You may proceed while you wait to be checked off

2) Displaying the Magnetic Field at One Point

a) Type the following in Vpython:

```
from __future__ import division
from visual import *

# Define Constants
e=1.6e-19
oofpez=9e9
scalefactor=1

# Initial Values

# Create Objects

# Calculations
```

Do the following in you define constants section.

b) Define the name muzofp to stand for $\frac{\mu_o}{4\pi}$.

```
muzofp=1e-7
```

c) Define and set “deltat” to be 5 x 10^{-20} s

Do the following in your initial values section.

d) Set the time “t” to be zero.

Do the following in the create objects section.

e) Create a red sphere called “atom”. Place it at <2 x 10-9, 0, 0> m. Give it a radius of 1 x 10-10.

f) Assign “atom.q” to be the charge of one proton

g) Assign “atom.v” to be <-4 x 10^5, 0, 0> m/s

You just created the charged particle with a velocity, and designated the first observation location.

h) Place an arrow at an observation location of <0, 0, -6 x 10^{-10}> m. Initially give it zero magnitude.

```
Barrow=arrow(pos=(0,0,-6e-10),axis=vector(0,0,0),color=color.green)
```

i) Type the following to turn auto scaling off.

```
scene.autoscale = 0
```

Do the following in your Calculations section

j) Set up a while loop the will stop when the x position of the atom is less than -2 x 10^{-9} m.

Do all the following inside your while loop.

k) Define the relative position vector from the atom to the observation location in terms of Barrow.pos and atom.pos.

l) Find the magnitude of the relative position vector and the corresponding unit vector. Name them “rmag” and “rhat” respectively.

m) **Now calculate the magnetic field “B,” at the location of the arrow. For the magnetic field, use the Biot-Savart’s law (read on for help with the cross product).**

$$\vec{B}=\frac{\mu_o}{4\pi}\frac{q(\vec{v}\times\hat{r})}{|\vec{r}|^2}$$

Similar to the dot product form, VPython has a command for the cross product.

$$\vec{A}\times\vec{B}\rightarrow \text{cross}(A,B)$$

n) **Set the axis of Barrow equal to the magnetic field times an appropriate scale factor for the magnetic field.**

o) Update the position of the atom using the position update formula.

This is the end of your loop

p) Set your scale factor appropriately.

q) Run your program

i. Do you agree with the result of the simulation?

CHECKPOINT 2: Ask an instructor to check your work for credit.
You may proceed while you wait to be checked off

3) Displaying the Magnetic Field at Several Points

r) Add the following three observation locations (place arrows at each one) to your program, <0, 0, 6 x 10^{-10}> m, <0, 6 x 10^{-10}, 0>m, and <0, -6 x 10^{-10}, 0>m.

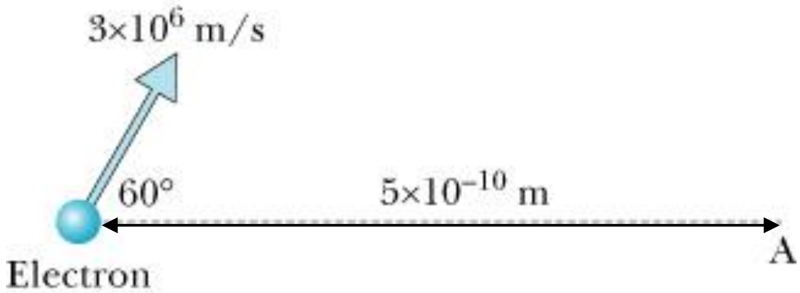
s) Display the magnetic field at each location as the atom passes.

t) Sketch a picture of what you see in your workspace.

CHECKPOINT 3: Ask an instructor to check your work for credit.
You may proceed while you wait to be checked off

4) Final Problem

<u>Problem 2)</u> An electron is traveling with a speed of 3 x 10^6 m/s.



Make changes to your Vpython code to determine the magnitude and directions of the electric and magnetic fields at location A. (Hint: you don't really need the while loop because you want to calculate the fields at a given location at a given instant in time).

CHECKPOINT 4: Ask an instructor to check your work for credit.