

Lab 6: The 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.

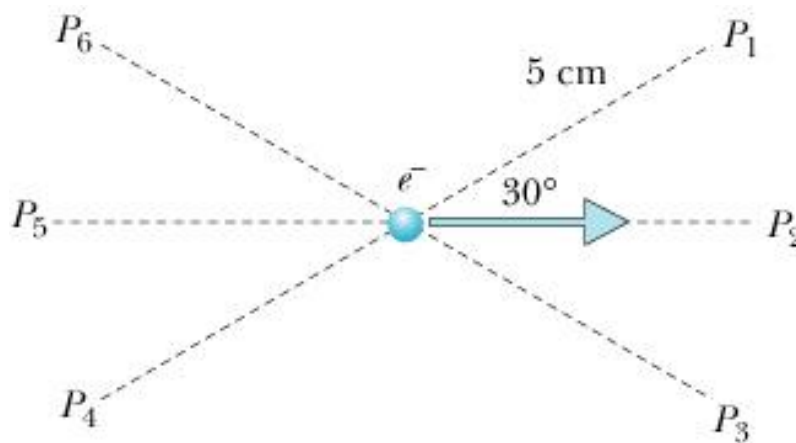
Biot-Savart's law states that as particles move it creates a magnetic field.

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q(\vec{v} \times \hat{r})}{|\vec{r}|^2}$$

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 4×10^6 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) Open your Lab 1 program.
- b) Save this program as a new name so you still have access to your original Lab 1 program.
- c) Remove everything in the initial values, create objects and calculations sections, and set your scale factor to 1. Your code should look like this:

```
from visual import *
from __future__ import division
```

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

```
# Initial Values
```

```
# Create Objects
```

```
# Calculations
```

Do the following in you define constants section.

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

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

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

Do the following in your initial values section.

- f) Set the time “t” to be zero.

Do the following in your create objects section.

- g) Create a red sphere called “atom”. Place it at $\langle 2 \times 10^{-9}, 0, 0 \rangle$ m. Give it a radius of 1×10^{-10} .
- h) Assign “atom.q” to be the charge of one proton
- i) Assign “atom.v” to be $\langle -4 \times 10^5, 0, 0 \rangle$ m/s
- j) Place an arrow at an observation location $\langle 0, 0, -6 \times 10^{-10} \rangle$ m. Initially give it zero magnitude.

```
Barrow=arrow(pos=(0,0,-6e10),axis=vector(0,0,0),color=color.green)
```

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

k) Type the following to turn auto scaling off.

```
scene.autoscale = 0
```

Do the following in your Calculations section

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

Do all the following inside your while loop.

- m) Define the relative position vector from the atom to the observation location in terms of Barrow.pos and atom.pos.**
- n) Find the magnitude of the relative position vector and the corresponding unit vector. Name them “rmag” and “rhat” respectively.**
- o) Now calculate the magnetic field “B” at the arrows location using Biot-Savart’s law (read on for help whit 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 Lab 6, VPython has a command for the cross product.

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

- p) Set the axis of Barrow equal to the magnetic field times a scale factor.**
- q) Update the position of the atom using the position update formula (if you need help, see Lab 5, Section 2. r.).**

That is the end of your loop

- r) Set your scale factor appropriately.**
- s) 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**

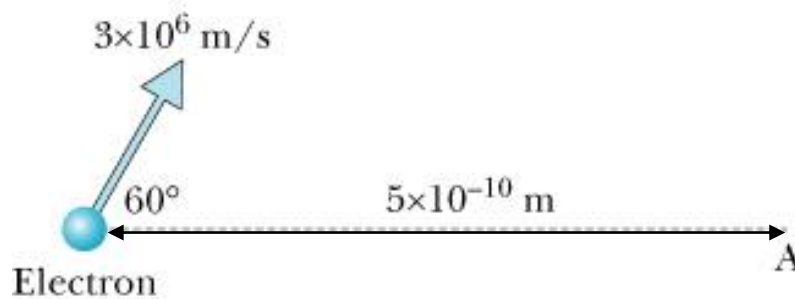
3) Displaying the Magnetic Field at Several Points.

- t) Add the following three observation locations (place arrows at each one) to your program, $\langle 0, 0, 6 \times 10^{-10} \rangle$ m, $\langle 0, 6 \times 10^{-10}, 0 \rangle$ m, and $\langle 0, -6 \times 10^{-10}, 0 \rangle$ m.
- u) Display the magnetic field at each location as the atom passes.
- v) 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

Problem 2) An electron is traveling with a speed of 3×10^6 m/s.



- (a) At location A, what are the directions of the electric and magnetic fields?
- (b) Calculate the magnitude of the electric and magnetic fields at location A.

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