1 Hidden Charge

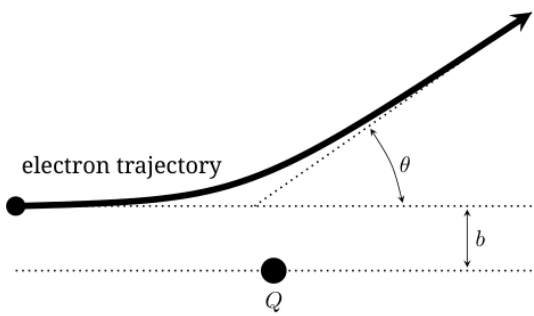
1.1 Introduction

An unknown point charge Q is fixed in a region of space. Electrons launched parallel to the z axis far from the charge will scatter electrostatically off of the fixed charge and strike a detecting screen. It is possible learn about the details of the hidden charge by varying the initial kinetic energy as well as the initial x_i and y_i coordinates of the electron beam and measuring the final coordinates x_f and y_f of where an electron strikes a finite flat screen perpendicular to the z axis and located at $z = 0$.

It is useful to know the Rutherford scattering formula,

$$b = \frac{kqQ}{2E}\frac{1}{\tan(\theta/2)}$$

where b is the impact parameter, E is the energy of the electron, $q = -1.602 \times 10^{-19}\mathrm{C}$ is the charge of the electron, $k = 8.99 \times 10^9\ \mathrm{Nm}^2/\mathrm{C}^2$, and θ is the scattering angle. The impact parameter is defined as the closest approach of the electron to the target, assuming that the electron were unaffected by the target and hence would move in a straight line; the scattering angle is angle between the original velocity vector of the electron far from the target and the final velocity vector of the electron far from the target after scattering.



1.2 Task

The task is to determine the position (x_Q, y_Q, z_Q) and also the magnitude and sign of the fixed charge Q, as precisely as possible. You should provide rough, order of magnitude error estimates on these results. There is Gaussian error associated with initial beam location that is on the order of 0.5 mm.

As with all experiments, you must provide clearly labelled tables of data, clearly labelled graphs, and sufficient formulae derivations to make it clear what you have measured, and how you are deriving your results.

1.3 Program Interface

The program asks for an accelerating voltage with the prompt

```
Beam accelerating voltage in V:
```

Enter a number between 1 and 10000, and press **return**. The program then asks for the initial launch coordinates, starting with x_i, with the prompt

```
x-coordinate of the electron beam in cm:
```

Enter a number between -20 and 20 and then press **return**. Finally, the program asks for y_i, with the prompt

```
y-coordinate of the electron beam in cm:
```

Enter a number between -20 and 20 and then press **return**. If you enter an invalid number for any of these three, the program will prompt you with

```
Invalid entry.
```

and will then prompt you for the value again, reminding you of the allowed limits.

After the three numbers have been entered, the program will output

```
Electron beam fired with parameters (x, y, V) =
```

and it will restate your entered values, and then

```
Electron detected at (x, y) =
```

and give the screen location of the detected electron. However, if the electron misses the finite size screen, you will be told

```
Electron not detected...
```

The program then repeats, allowing you to enter in a new set of initial coordinates.