

Simulating Motion Of Charged Particle/Electron Through an Electric and Magnetic Field

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0.1 Aim

To simulate the motion of a charged particle inside an Electric and Magnetic Field.

0.2 Introduction

The project focuses on simulating/tracing the motion of a charged particle/electron under the influence of an external Electric and Magnetic Field. The electron trajectories can be given an desired shape by applying an Electric or Magnetic Field

0.3 Applications

- Radio
- Television
- CRO
- Mass Spectrograph
- Particle Accelerators

0.4 Motion of electron inside an uniform Electric Field

0.4.1 Types of motion exhibited by electron

- Parallel to Electric Field
- Perpendicular to Electric Field
- Projected at an angle to the Electric Field

0.4.2 Basic Calculation

When an electron is projected inside an electric field, sustained by 2 plates **A** and **B** with A being **positively** charged and B being **negatively** charged, having a potential **V** given by $[V_a - V_b]$ at a distance of **d** the intensity of the electric field between the plate is given by

$$E = \frac{V}{d} \quad (1)$$

Force experienced by an electron at rest on plate **B**

$$F = -eE \quad (2)$$

The acceleration is given by

$$a = \frac{F}{m} = -\frac{eE}{-eE}m \quad (3)$$

The corresponding code in the project is given in:

Basic_Calculations in *BasicCalc.h*

```
void Basic_Calculations(double PotentialDifference, double PlateDistance)
{
    Energy_Electron = PotentialDifference / PlateDistance; //Energy of the electron
    Force_Electron = -1 * ELECTRON_ENERGY * Energy_Electron; //Force on electron at Plate B
    Acceleration_Electron = fabs(Force_Electron) / ELECTRON_MASS; //Acceleration of Electron
}
```

0.4.3 Parallel to Electric Field

The velocity \mathbf{V} is given by :

$$V = V_0 + at \quad (4)$$

where V_0 is the **initial velocity** of the electron or charged particle

The displacement of the electron is given by

$$S = V_0 t + \frac{1}{2}at^2 \quad (5)$$

Velocity at any given time denoted by V_t is given by

$$V_t = \frac{eE}{2m}t = \sqrt{\frac{2eE}{m}x} \quad (6)$$

parallel electric field used in project

$$X = \frac{eE}{2m}t^2 \quad (7)$$

The above equation gives the horizontal displacement of X which is depended on the value of t
The calculation is done by the following code :

```
void ElectronMovement_Parallel(int Identifier)
{
float count = Misc.count = 0;
int Index = Misc.index =0;
float Time = EField.Var.TimeEpoch;
float StepSize = EField.Var.StepSize;
unsigned int mem = Misc.MemAllocFactor;

EField.CompArray.Xcomponent = (double *)calloc(mem, sizeof(double));

while (count <= Time)
{
EField.Parallel.X_Component = fabs(Force_Electron) / (2 * ELECTRON_MASS) * pow(count, 2);

EField.CompArray.Xcomponent[Index] = EField.Parallel.X_Component;
count += StepSize;
Index++;
}

}
```

0.4.4 Perpendicular to Electric Field

If \mathbf{A} and \mathbf{B} are two metal plates placed horizontally parallel to each other at a length l

The velocity at \mathbf{Y} axis would be 0 initially, and would be V_0 for \mathbf{X} axis

Therefore, $V_y = 0$ and $V_x = V_0$.

The acceleration of the electron is given in y direction by

$$\alpha_y = \frac{eE}{m} \quad (8)$$

‘ As a result, the equation for velocity along the \mathbf{Y} axis can be written as

$$V_y = \frac{eE}{m}t \quad (9)$$

The horizontal, displacement \mathbf{X} is given by the following equation

$$x = v_0 t \quad (10)$$

The time t is known as **transit time** given by,

$$t = \frac{x}{v_0} \quad (11)$$

If V_A is the accelerating potential, then the initial velocity V_0 is given by

$$V_0 = \sqrt{\frac{2eV_a}{m}} \quad (12)$$

The vertical displacement can be written as

$$y = D \tan \theta = D \cdot \left(\frac{V_y}{V_0} \right) \quad (13)$$

The angular displacement is given by :

$$\theta = \tan^{-1} \left(\frac{V_y}{V_0} \right) \quad (14)$$

0.4.5 Electron Projected at an angle

Consider an electron projected at an angle θ_0 to an electric field \mathbf{E} directed vertically downwards, maintained between plates **A**(positively charged plate and **B**) (negatively charged plate)

At the entry point P_0 the velocity V_0 has components

$$V_{X0} = V_0 \sin \theta_0 \quad (15)$$

$$V_{Y0} = V_0 \cos \theta_0 \quad (16)$$

When the electron is pushed or is projected into the this field, the electron experiences a force \mathbf{f} which is directed to the positively charged plate. This causes the electron to have a projectile motion.

The force \mathbf{f} causes the electron to change its velocity from v_1 to v_2 at point P_2 .

At any instant the position of the electron can be given by the following equations

$$x = V_{X0} \cdot t = (V_0 \cos \theta_0) t \quad (17)$$

$$y = V_{y0} + \frac{1}{2}at^2 = (V_0 \sin \theta_0)t + \frac{1}{2}at^2 \quad (18)$$

The maximum vertical displacement denoted by \mathbf{H} of the electron can be calculated by

$$H = \frac{V_0^2 \sin^2 \theta_0}{2a} \quad (19)$$