Lorentz Force

Equipment

- Computer: VPython
- Demo apparatus: Hanging current loop (DC power, magnet, current loop)

Objective

Physics Concepts

- Force on a moving charged object in a magnetic field

Experimental analysis

- Graph time varying functions, combine measurements to graph new quantities

Gain experience creating models using VPython

- Create and use graphics windows to plot variables

Continue to effectively search for help in tutorials and reference manuals

Conceptual (C-Level)

Create a model of a proton inside a cyclotron. Early cyclotrons were small desktop devices. Your cyclotron will have a radius of 5 cm and a 0.5 cm gap between the metal "Dees" that lie in the *xz*-plane. A uniform magnetic field of 1 Tesla is applied in the *+y* direction. The maximum potential difference across the gap between the "Dees" is 5000 V. [See section 21.1]

- Draw a diagram (2 or 3 times scale). Label the position and velocity of the proton as well as the direction of the magnetic field and electric field.
- Determine an equation for the force on a proton inside a Dee.
- Determine an equation for the force on a proton in between the Dees.
- Determine the required angular frequency of the sinusoidally oscillating potential.

EXPLORATIONS:

- Explore the effect of a current carrying wire in a magnetic field.

Basic Lab (B-Level)

Compute and display the trajectory of a proton in the cyclotron. Assume the proton will not reach relativistic speeds. Initially use a Δt=0.1nsec but expect to decrease this time step later.

- Show the motion of the proton with no magnetic field.
- Show the motion of the proton with no electric field. Assume an initial velocity in the +x direction.
- Show the motion of the proton with constant magnetic and electric fields.
- Show the trajectory of the proton with constant magnetic field and time varying electric field.
  - Plot the proton's kinetic energy as a function of time

Your summary should include a description of your cyclotron properties: ΔKE (eV), total time, number of orbits, maximum γ (i.e. check $v \ll c$ and show this is not relativistic) and a discussion about what happens when the wrong angular frequency is used. Finally you should verify and explain the graphs of kinetic energy and momentum as a function of time.

Advanced/Extended Lab Ideas (A-Level)

- Model a rotating coil in a magnetic field.
- Model an electron cyclotron
- Your text suggests computational problems that could be used as a basis for an inquiry.