Physics Exploration Homework Supplement **P111-14.pdf**

Exploring the Motion of an Electron in Mutually Perpendicular E and B fields

Go to the Physics Exploration Center. Enter through the resource room in 311/312 Thaw Hall. Go to the setup with a green box (which is an oscilloscope with a cathode ray tube that produces a beam of electrons and a parallel plate capacitor that produces an electric field), a solenoid that produces a magnetic field (several circular turns of wire wound very close to each other), and two meters. In this exploration, you will investigate the force on a narrow beam of electrons when it enters a region in which uniform magnetic (B) and electric (E) fields are perpendicular to each other and both are also perpendicular to the direction in which the electron beam is moving before entering this region. The top view is shown in the Figure (on the screen on the green box you will see a side view).

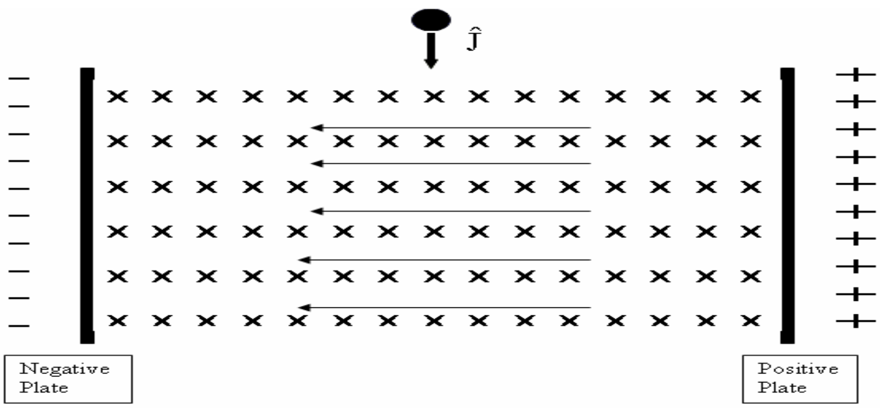

Figure 1

In figure one, the electron of velocity $\hat{J}$ is moving into a region of space that has a uniform magnetic field into the paper and an electric field pointing to the left.

Before you begin the exploration, answer the following questions:

(1) A student comments that in the figure above, if the magnitude of the B field pointing into the page is stronger than the magnitude of the E field point to the left, the electron will certainly be deflected to the left because the net force is to the left. Another student says that he does not agree with the first student because you cannot simply compare magnitudes of B and E to determine which field exerts a larger force. He notes that B and E don't even have the same unit and says that if $vB > E$ then the electron will be deflected to the left. Which student do you agree with, if any? Justify your answer.

(2) If the electron entering the region of B and E fields in the above figure went un-deflected, what would you conclude? Justify your answer.

(3) If the magnetic field is changed such that it is pointing out of the page but the direction of electron beam and the electric field are as shown in the figure above, what can you infer about the direction of the net force on the electron? Why? Draw a rough trajectory (path) of the electron beam after it enters the region with E and B fields.

(4) If the magnetic field is changed such that it is in the same direction as the electron velocity before it enters the region with fields (the electric field is unchanged and it is as shown in the figure above), what can you infer about the direction of the net force on the electron? Why? Draw a rough trajectory (path) of the electron beam after it enters the region with E and B fields.

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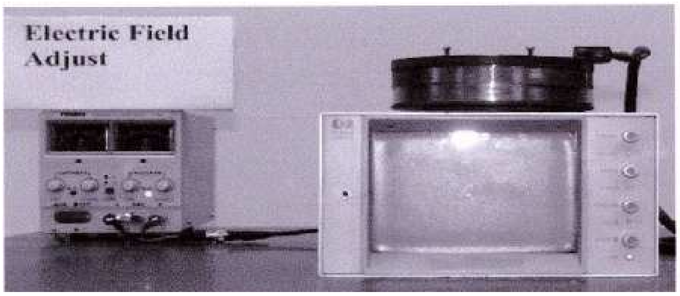
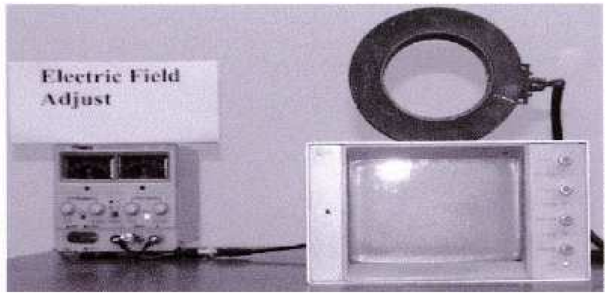
Now begin the exploration by turning on the main power switch. You should see the electron beam as a bright blue dot on the screen of the big green box (the capacitor plates which produce the electric field are inside this box). If looked from the top of the big green box, the set up is very similar to the sketch drawn on the first page of this exploration <u>except</u> you need to figure out whether the electric field is from the left to right or right to left and also whether the magnetic field is vertically up or down by noting the direction in which the electron beam deflects when you change the electric or magnetic field by turning the appropriate voltage knobs.





(a) Increase the voltage in the meter (electric field meter) connected to the capacitor plates which are inside the big green box. How will it affect the electric field between the plates? The electric field is perpendicular to the electron beam as shown in the sketch. By noting the deflection of the electron beam as you increase the voltage, can you predict whether the electric field is pointing to the left or to the right *(i.e.,* which of the capacitor plates is at a higher potential)? Draw a sketch of the two plates marking the plate with higher potential and explain your reasoning.

(b) Now place the solenoid on the top surface of the green box as shown in the left photograph above (this way when there is a current through the coils, it will produce a magnetic field which will be vertically up or down depending upon the direction of current). Increase the current (hence, the magnetic field) in the coils by increasing the voltage in the meter connected to the solenoids (magnetic field meter). Which way does the electron beam deflect? Based upon the deflection you see now arid in part (a), what can yon conclude about the directions of electric and magnetic forces (Are they in the same direction, opposite direction or impossible to tell?). Also, now that you know the direction of magnetic force on the electron, can you predict if the magnetic field is vertically up or down? Explain.

(c) Predict the changes you expect in the direction of deflection of the electron beam if you flip the solenoid by 180° (upside down). Explain your reasoning. Now perform the experiment and test your hypothesis.

(d) Predict what should happen to the deflection of the electron beam if you put an iron piece in the region between the coils of the solenoid. Explain. Now perform the experiment and test your prediction. Predict what should happen if you flipped the iron piece by 180° (upside down) but left everything else unchanged. Explain. Now perform the experiment and test your prediction.

(e) Remove the iron piece from inside the solenoid. Predict what should happen to the deflection of the electron beam if you placed the solenoid on the box as shown in the photograph to the right. Explain. Now perform the experiment and test your prediction. Now predict how the beam deflection will be affected if you remove the solenoid from the box. Explain. Now perform the experiment and test your prediction.