

THE CATHODE RAY TUBE (CRT)

Physics 251 Laboratory

INTRODUCTION

One of the distinguishing features of the fundamental forces in nature is the way they affect objects that are in the vicinity of the objects originating the force. They appear to act as if they have changed the space around the originator. One way to understand what happens when a charged particle (probe) is in the vicinity of other stationary charges is to imagine that the stationary charges set up a "force field" in the surrounding space; we call the force per unit charge on the probe particle an electric field. This week we will examine how to use these electric force fields to guide electrons to positions at our control.

A cathode ray tube, CRT, is one of the mechanisms that have been used in commercial TV tubes for guiding the electrons to scan the phosphorescent front face of the tube to produce an image. Either electric or magnetic fields can be used to guide those electrons. Our CRT uses two pairs of plates to produce electric fields along the two directions of the face, thus perpendicular to the direction the electron beam travels as it moves towards the face. There are examples of the tubes available on your table to look at. At one end, not visible, electrons are emitted by a hot wire and accelerated along the z-direction towards the face. They emerge from the accelerating field with a final speed v_z and enter the region of the deflection plate fields; first along x and then along y. Figure #1 shows the y-direction deflection plates and the beam being deflected.

Since the electric field is constant in the region between the plates, this is a constant acceleration problem for the electron's path (Figure #2). You should be able to show using your knowledge of mechanics that, for a given field E_y between the plates of length l , the deflection D_y is given by

$$D_y = qE_y l(L+l/2)/(m_e v_z^2) = (\text{const})E_y$$

and since E_y is proportional to the voltage difference across those plates, the deflection will be proportional to the voltage difference.

WHAT EXPERIMENT SHALL WE DO?

Using the cathode ray tube furnished, your team will be expected to make measurements of the deflection of the electron beam systematically as a function of the voltage difference across first the x-direction plates and then the y-directions plates. After you have analyzed the data to find the functional relationship between deflection and applied voltage difference for each direction, you should see if you can cause the beam to be deflected at an angle of your choice along the face of the tube, other than 0 or 90° or multiples thereof.

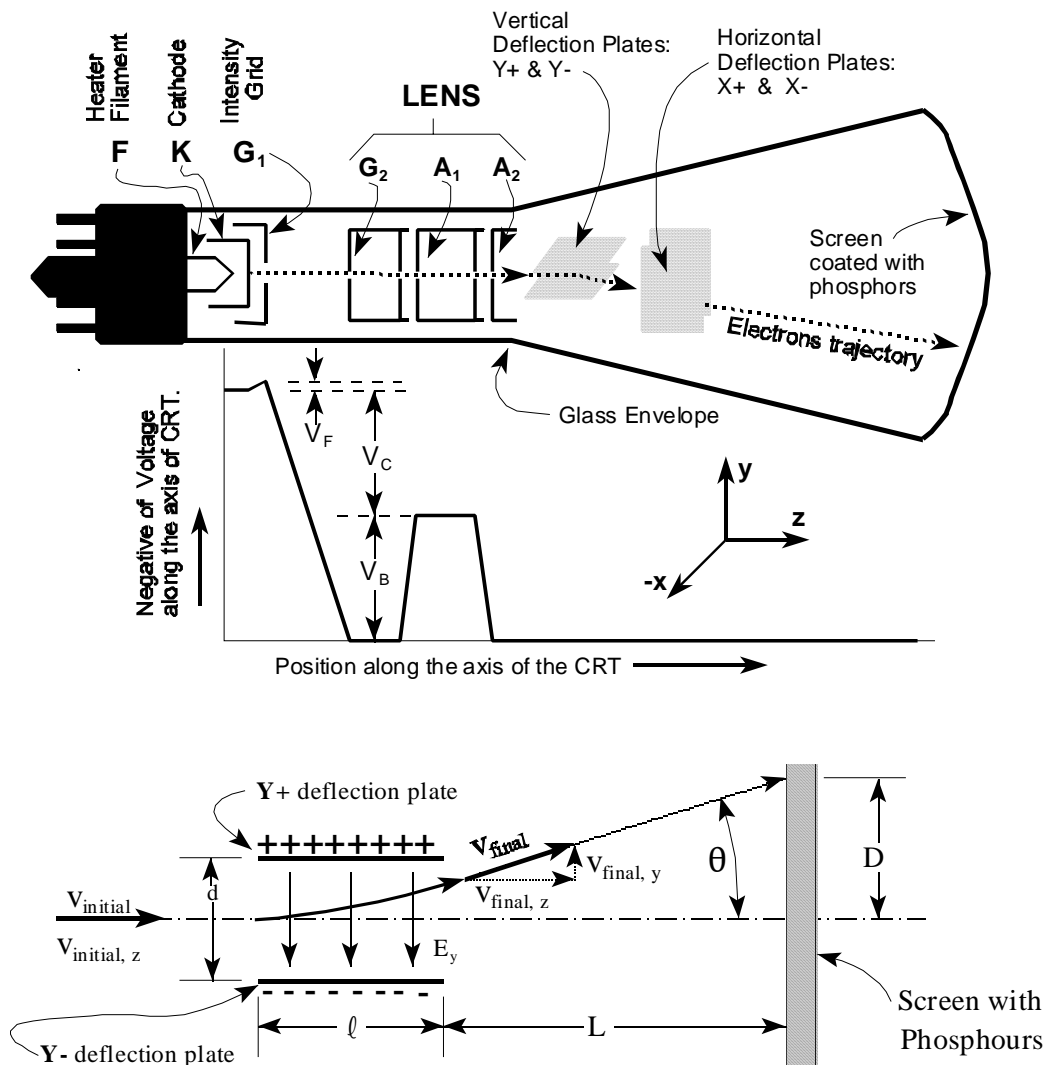
HOW SHALL WE DO THE EXPERIMENT?

The appendix includes instructions for wiring the tube correctly (Fig #3). There is some high voltage involved that can be dangerous. Follow the instructions carefully!

Part of understanding this situation consists in doing all of the classical mechanics for these electrons, starting with their release from the hot wire. You may assume that they are released at velocities which are near zero, then accelerated by those fields present there to a speed v_z before entering the deflection plate region.

The analysis of the results will be as important as doing the measurements. This includes finding v_z in terms of the applied voltages, as well as the deflections in terms of those voltage differences. You will likely need measurements of the plate separations in one of the display models, which you can assume to be the same as those in your instruments. Does gravity play a role in your results? Why or why not?

APPENDIX:



UNPLUG THE POWER SUPPLY!

HIGH VOLTAGE MAY BE PRESENT WHEN THE POWER SUPPLY IS ON. ONLY CHANGE WIRING WITH THE UNIT TURNED OFF.

The CRT should be wired as shown in fig. 3. This may look like a mess, but just go at it systematic fashion.

- ◆ Unplug the power supply. On the power supply, set the **ON/OFF** switch to the **OFF** position. and the **STANDBY/ DC ON** switch to the **STANDBY** position.
- ◆ Set the **C** and **B** voltage control knobs to zero (Fully counterclockwise)
- ◆ On the power supply, connect the **B+** and **GROUND**.
- ◆ Plug the two **YELLOW** wires from the filament in the CRT into the plugs marked **H, 6.3 V**, on the power supply.
- ◆ Connect the **BROWN** cathode wire to **C-**. The connection from this wire to the 4.5 volt battery and the intensity control grid is internal.
- ◆ Connect the **BLUE** wire from the central lens element to **C+**.
- ◆ Connect the **RED** wire that comes from the outer two lens elements and the inside of the glass envelope to **B+** (which is grounded.)

- ◆ Connect the **X+** and **X-** and the **Y+** and **Y-** to the deflection plate voltage supply box.. Also connect the ground of this box to the ground of the main power supply. Set the two Active/Grounded switches on the deflection plate voltage supply box to the grounded position. This will insure that the plates are all at zero potential.

Make a quick check of your wiring and if in doubt ask your instructor to check it.

- ◆ Plug in the power supply. With the unit in **STANDBY**, switch the power **ON**.
- ◆ After about 30 seconds the heater filament in the tube should have warmed up. It may be possible to see it glowing by looking near the base of the tube.

DO NOT CHANGE THE WIRING AFTER THIS POINT, WITHOUT TURNING OFF THE POWER

- ◆ Switch from **STANDBY** to **DC ON**.
- ◆ Adjust the **B VOLTAGE** control to 3/4 of full, and adjust the **C VOLTAGE** to form the smallest dot possible on the screen.

TURN OFF THE POWER IF YOU NEED TO CHANGE THE WIRING.

