Physics 42 Lab 4 Fall 2012
Cathode Ray Tube (CRT)

PRE-LAB

Read the background information in the lab below and then derive this formula for the deflection.

$$D = \frac{LPV_{defl}}{2SV_{accel}} \quad (1)$$

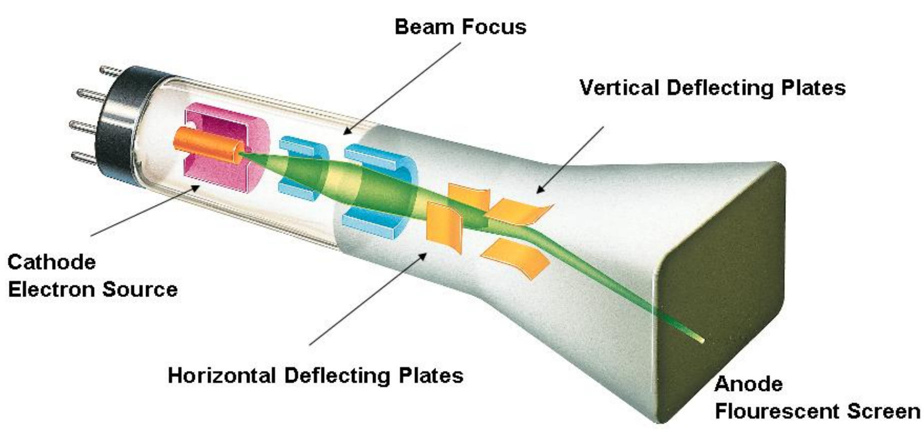
Redraw the diagram and label everything. This is not a trivial derivation. You must use words to justify your steps and derivation. Hint: you must use the approximation that Vy/Vz = D/L. Justify that approximation. You can rearrange equation (1) get derive the "Voltage Sensitivity"

$$\textit{Voltage sensitivity}: \; V_{defl}/D = \frac{2SV_{accel}}{LP}. \quad (2)$$

How do you expect the voltage sensitivity to depend on the accelerating voltage? This is your hypothesis and it should be based on your interpretation of the voltage sensitivity equation. You should make a plot of that equation as a function of accelerating voltage to give you a clue. Make it beautiful. Bring it to class. You will not be allowed to enter lab unless you have it done! There is no makeup for this lab. I'm serious!

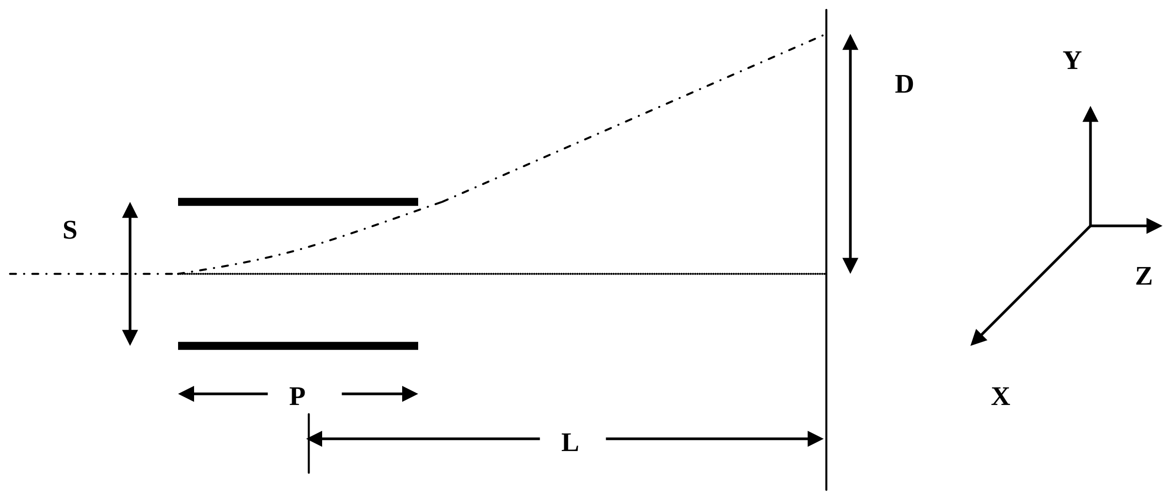
Cathode Ray Tube (CRT)

Background Information: The **cathode ray tube (CRT)** consists of an electron gun, deflecting apparatus, and luminescent screen. The electron gun produces a beam of high-speed electrons focused to a small spot on the screen. In an oscilloscope, the beam is deflected horizontally (X) by a varying potential difference between a pair of plates to its left and right, and vertically (Y) by plates above and below. In our lab, we will only deflect the beam in one direction at a time, either horizontally or vertically. The source of electrons is a thermionic cathode which essentially boils electrons off the cathode. The electron beam is accelerated by an accelerating voltage, $\mathbf{V_{accel}}$, which produces a constant forward velocity **Vz** that stays constant through and after the deflection plates, toward the anode.



Basic elements of a cathode-ray tube used in a TV set or computer monitor. The electron beam (in green) is deflected horizontally and then vertically so that it hits a specific spot on the phosphor coating on the inside of the screen where a bright green spot will appear .

The schematic below shows the vertical deflection plates with separation distance **S** and length **P**. **L** is the distance the beam travels to the screen and **D** is the deflection distance from the center of the screen. $\mathbf{V_{defl}}$ is the electric potential across the deflection plates, which generates the vertical velocity **Vy** and the vertical deflection **D**. The X and Y direction indicates the horizontal and vertical displacement of the beam. The Z direction is the direction of beam before entering the plates.



The deflection of the electron beam can be written as: $D = \frac{LPV_{defl}}{2SV_{accel}}$

Another useful form of this equation is the *voltage sensitivity*, or: $V_{defl}/D = \frac{2SV_{accel}}{LP}$.

The *voltage sensitivity* tells us how much voltage must be applied to the deflecting plates per unit of deflection, for a given accelerating voltage. That is, for example, how much deflection voltage must be applied to get the beam to deflect 1 cm if it is moving faster or slower through the plates? Will it take more deflection voltage to get the beam to move 1 cm if the beam is moving faster, due to a greater accelerating voltage? The voltage sensitivity can be obtained experimentally by plotting the deflecting voltage (V_{defl}) against beam displacement (D) and finding the slope of a linear fit. The purpose of this lab is to learn how a CRT works and to determine how the voltage sensitivity depends on the accelerating voltage.

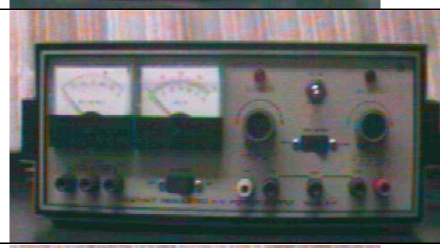
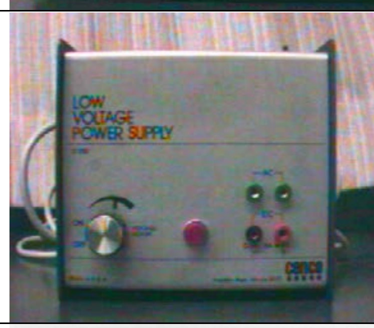
Read this online lesson on CRTs. It has the derivation of the deflection, but with different labels so be careful. This is really awesome.
http://wps.aw.com/wps/mediaobjects//877/898586/topics/topic07.pdf

Here is a fun Cathode Ray Tube applet to play with:
http://www.physics.uq.edu.au/people/mcintyre/applets/cathoderaytube/crt.html

If you are total electronic GEEK, for fun you should check out this lab for Caltech!!
http://www.ligo.caltech.edu/~vsanni/ph3/Instrumentation/CRTScope.pdf

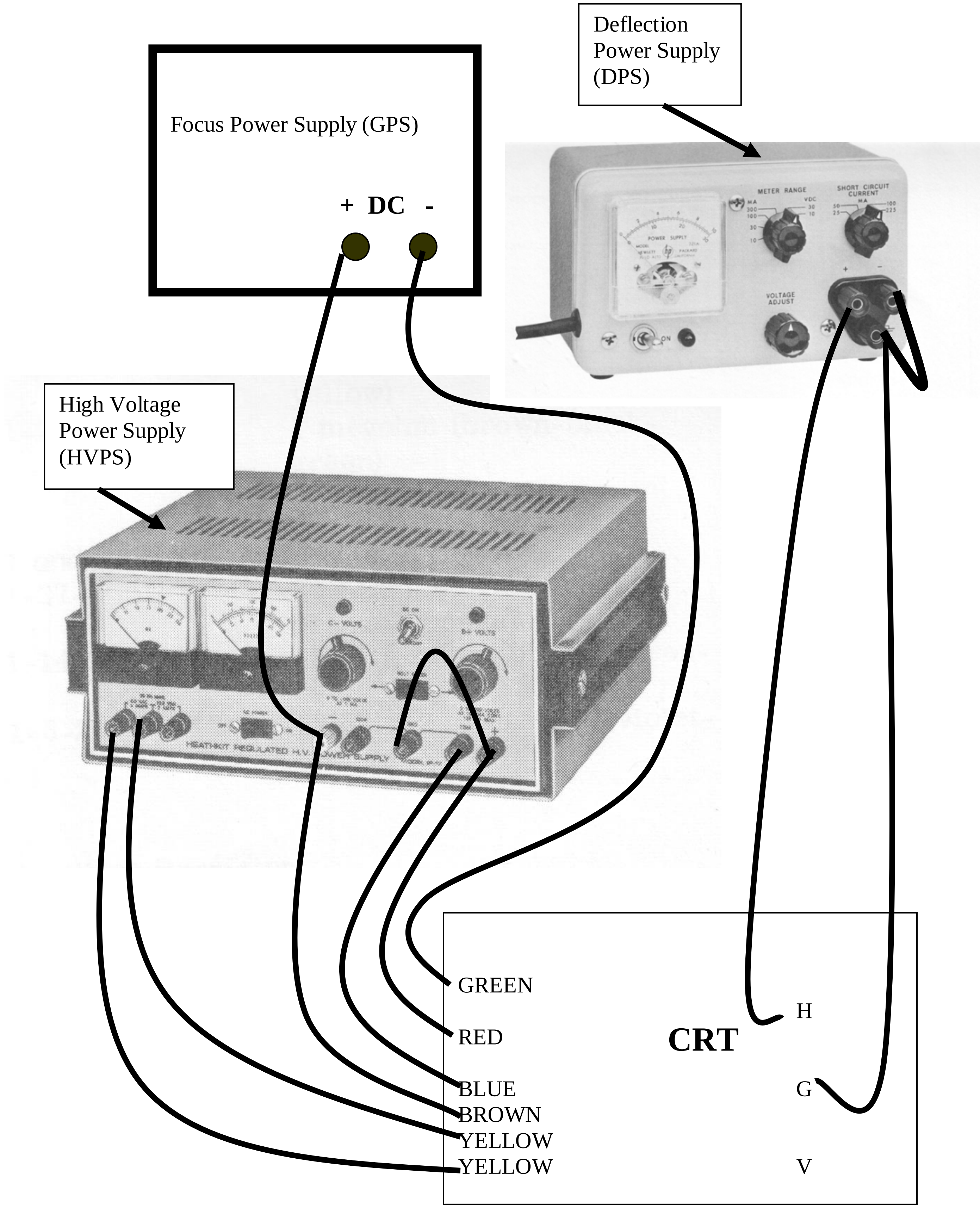
Cathode Ray Tube (CRT)

PARTS LIST

Part	Quantity	
CRT	1	
High Voltage Power Supply (HVPS)	1	
Grid power supply (GPS)	1	
Deflection power supply (DPS)	1	
Digital Multimeter (DMM)	1	

Procedure:

1. **MAKE NOTE OF ALL SOURCES OF EXPERIMENTAL UNCERTAINTIES!!!!** You will need this for your lab report and to make sense and meaning of your results.
2. Construct the circuit as diagramed below. Your instructor will explain how to adjust and read the high voltages B+ and C-.
3. ***BEFORE TURNING ANYTHING ON, SHOW YOUR SET UP TO YOUR INSTRUCTOR TO CHECK THE CONNECTIONS***.
4. Turn on the high voltage power supply (with the high voltage switch in stand by position) and wait at least 30 seconds for the filament to warm up.
5. Turn the high voltage to the ON position and supply maximum B+ and C- voltages to the CRT. Now readjust one of these voltages to get B_+ to be three times larger than C_-.
   Note: $|C_-|+B_+ = V_{accel}$.
6. Vary the voltage on FPS (Focus Power Supply) between minimum to maximum to focus the beam to its smallest size.
7. At this point you should see a small spot on the screen. If this is not the case, ask your instructor for help.
8. Use the supplied magnet to cancel the magnetic field of the earth. To do so, place the magnet on the metallic frame of the CRT end where wires are coming out. Depending on your location in the class and the orientation of the CRT, you need to find a location for the magnet to bring the spot to the center of CRT. After spending a few minutes on this procedure, if you have not succeeded to bring the spot to the center, ask your instructor for help.
9. Using DPS (Deflection Power Supply) supply enough voltage to move the spot from the center by one division (1/16”).
10. Record this voltage in table I.
11. Continue to increase the deflecting voltage until you move the spot one more division. Record the voltage and repeat this procedure until you reach the maximum voltage on the power supply.
12. Turn off DPS.
13. Decrease B_+ and C_- in such a way that $|C_-|+B_+$ is approximately 50 volts less the previous case, but keep B_+ to be three times bigger than C_-.
14. Repeat procedures 5 through 11.
15. Reduce the $|C_-|+B_+$ by 50 volts again and repeat procedures 5 through 11.
16. Reduce $|C_-|+B_+$ by 50 volts once more and repeat procedures 5 through 11.
17. Now disconnect the horizontal deflection from DPS and connect the vertical deflection to DPS.
18. Readjust C_- and B_+ to the first value of the experiment with the horizontal deflection (case I). Repeat procedures 5 through 11 and record your data.
19. Copy data of Table I into an Excel sheet.
20. For each case insert a row to place $|C_-|+B_+ = V_{accel}$ values.
21. Plot V_{defl} versus D for each case (all in one graph) and find the slopes of linear fit to each curve.
22. On a second graph, plot the voltage sensitivity (slope of the curves from previous graph) versus high voltage, V_{accel} for the horizontal deflection.



SCHEMATIC SET UP FOR CRT

Lab Report

This is a formal lab. You must turn in your own lab report but you can share data with your lab partners so make sure you print out and save the data sheet for each person. Do not assume that your lab partner will get it to you later! You must include a brief abstract that briefly describes the purpose, set up and results of your experiment. See sample abstracts for more info. Please explain the experimental uncertainties involved in your experimental procedure. I will be grading heavily on this!!!! At the very end (after the analysis below) you need to have a nice summary of your results to explain how your experiment supported your hypothesis in the prelab regarding your expectations about the voltage sensitivity dependence on accelerating voltage. Were your results within experimental uncertainties? What would you improve to get better results and less error?

The lab report must also include two graphs as well as the data sheet provided below. Your lab must also include your prelab.

<u>Analysis</u>

1. Use these physical dimensions (S=0.2”, L=5.6”(for vertical deflecting plates) and L=4.7” (for horizontal deflecting plates), P=0.8”) and the Vaccel corresponding to each case to find the theoretical value of the voltage sensitivity. Compare this value with the experimental value found from the linear fit for each case and calculate a percent error between the theoretical and experimental values. Find an average percent error.

2. Explain the relationship between voltage sensitivity and the accelerating voltage from what you obtained from step 1. Does your graph produce results you expected?

3. Include a brief discussion to explain why the voltage sensitivity for the horizontal plates is different from that of the vertical plates.

Here is the suggested order of your lab report.

1. Cover page with title, your name, lab partners FULL names, lab period, date, lab section #.
2. ABSTRACT: The cover page also has the Abstract on it which should not be more than one paragraph and should not include any images. Simple text only.
3. THEORY: Your theoretical derivation and explanation of the deflection and of the set up follows next.
4. PROCEDURE: A VERY brief procedure should not just be a copy the instructions comes next.
5. Data and Graphs
6. Discussion and calculation of experimental uncertainties and errors due to set up, equipment and procedures.
7. Analysis (above 1-3)
8. Results and Summary

Cathode Ray Tube (CRT) Data Sheet

Names:

Date:

Table I

Deflection in In inches		**Horizontal Deflection**				**Vertical Deflection**
		CASE I $\lvert C_- \rvert$ = B_+ = V_{accel} =	***CASE II*** $\lvert C_- \rvert$ = B_+ = V_{accel} =	***CASE III*** $\lvert C_- \rvert$ = B_+ = V_{accel} =	***CASE IV*** $\lvert C_- \rvert$ = B_+ = V_{accel} =	***CASE V*** $\lvert C_- \rvert$ = B_+ = V_{accel} =
1/16	.0625					
2/16	.125					
3/16	.1875					
4/16	.25					
5/16	.3125					
6/16	.375					
7/16	.4375					
8/16	.5					
9/16	.5625					
10/16	.625					
11/16	.6875					
12/16	.75					
13/16	.8125					
14/16	.875					
15/16	.9375					