Introduction :

In this lab, we are exploring the relation between the Deflecting Voltage (V_d) and the vertical deflection of an electron (Y). We will compare the Voltage Sensitivity to the Accelerating Voltage of an electron emitted from an electron gun and passing between two charged plates as shown in Diagram 1. Prior to this lab, we made two predictions, the first is the predicted slope of the graph of the Deflecting Potential Difference versus the Displacement of the phosphorus spot made by electrons from the electron gun striking the phosphorus ($V_d = S\,Y$ $S = C\,V_2$ $C = \frac{2\,d}{l\,L}$, this gives the equation $V_d = \frac{2\,Y\,V_2\,d}{l\,L}$, for which the slope is $\frac{2\,V_2\,d}{l\,L}$, where $V_d = \mathit{Deflecting\ Voltage}$ $S = \mathit{voltage\ sensitivity}$ see Diagram 1 for the rest of the labels).

The second prediction is the slope of the graph of the Voltage Sensitivity versus the Accelerating Voltage. Both of these predictions lead to direct relations within an error margin between the two variables of each prediction. Upon an analysis of our data, we should be able to see this direct relation on a plot of each.

Predictions :

V2:=[323,275,413,345];d:=.4;l:=1.91;L:=14.3;

$$V2 := [323, 275, 413, 345]$$

$$d := .4$$

$$l := 1.91$$

$$L := 14.3$$

`Prediction 1`:=[seq((2*d)/(l*L)*V2[i],i=1..4)];

$$\mathit{Prediction\ 1} := [9.458, 8.052, 12.09, 10.10]$$

`predicted uncertainty 1`:=[seq(`Prediction 1`[i]*(.02/d+.02/l+.1/L),i=1..4)];

$$\mathit{predicted\ uncertainty\ 1} := [.6380, .5432, .8156, .6813]$$

```
`% uncertainty`:=[seq(`predicted uncertainty 1`[i]/`Prediction 1`[i]*100,i=1..4)];
```

$$\%\, uncertainty := [6.746, 6.746, 6.746, 6.746]$$

```
eq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([V2,`Prediction 1`]);
```

$$eq := y = .02957\, x - .09997$$

```
eqmax:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([V2,`Prediction 1`+`predicted uncertainty 1`]);
```

$$eqmax := y = .03107\, x + .06316$$

```
eqmin:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([V2,`Prediction 1`-`predicted uncertainty 1`]);
```

$$eqmin := y = .02739\, x - .03176$$

```
`Prediction2`:=0.02957;`Prediction 2 uncertainty`:=abs(.03107-.02739)/2;`% uncertainty`:=`Prediction 2 uncertainty`/`Prediction2`*100;`Intersept Prediction`:=(.09997);`Intersept uncertainty`:=abs((-.03176)-.06316)/2;
```

$$Prediction2 := .02957$$

$$Prediction\ 2\ uncertainty := .001840$$

$$\%\, uncertainty := 6.223$$

$$Intersept\ Prediction := -.09997$$

$$Intersept\ uncertainty := .04746$$

Procedures: Full procedures available in the 1999-2000 edition of the physics NYB lab manual experiment # 2 or upon request at j_con999@yahoo.com

Diagrams:

Diagram 1

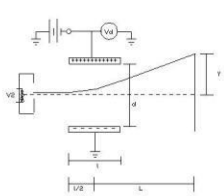
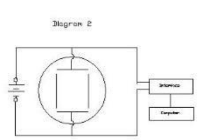


Diagram 2



<u>Data</u>: Experimental Data available upon request. Contact me at j_con999@yahoo.com

<u>Calculations</u>:

Part 1 – Attempts'

#1 **for i from 1 to 5 do**

readline("a:/Lab3/Run1.txt")

od;

"Vb=235 volts"

"Vc=88 volts"

"Ch A\t"

"Run #1\tRun #1"

"Voltage (V)\tDisplacement "

```
R1:=readdata(`a:/Lab3/Run1.txt`,2):nops(%):

Voltage1:=[seq(R1[i,1],i=1..11)]:

Displacement1:=[seq((R1[i,2]-(1.9/2)),i=1..11)]:

Data:=[seq([Displacement1[n],Voltage1[n]],n=1..11)]:

A:=plot(Data,style=point,symbol=circle):

Eq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([Displacement1,Voltage1]);
```

$$Eq := y = 9.727\,x - .04520$$

```
Fdata:=unapply(rhs(%),y);
```

$$Fdata := y \to 9.727\,x - .04520$$

```
B:=plot(Fdata(x),x=-1..1):

C:=textplot([0.5,7.5,`Middle=Best Line`],colour=red,align=ABOVE) :

G:=textplot([0.8,9.9,`Max Line`],colour=green,align=ABOVE):
```

```
H:=textplot([0.9,7,`Min Line`],colour=blue,align=ABOVE):
```

```
E:=[[0.95,9.72],[-0.95,-9.63]]:F:=[[0.95,8.79],[-0.95,-8.79]]:
```

```
J:=[0.95,-0.95]:K:=[9.72,-9.63]:L:=[0.95,-0.95]:M:=[8.79,-8.79]:
```

```
EqMin:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([J,K]);
```

$$EqMin := y = 10.19\, x + .04500$$

```
Fmin:=unapply(rhs(%),x);
```

$$Fmin := x \rightarrow 10.19\, x + .04500$$

```
PMin:=plot(Fmin(x),x=-1..1):
```

```
EqMax:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([L,M]);
```

$$EqMax := y = 9.252\, x$$

```
Fmax:=unapply(rhs(%),x);
```

$$Fmax := x \rightarrow 9.252\, x$$

```
PMax:=plot(Fmax(x),x=-1..1):
```

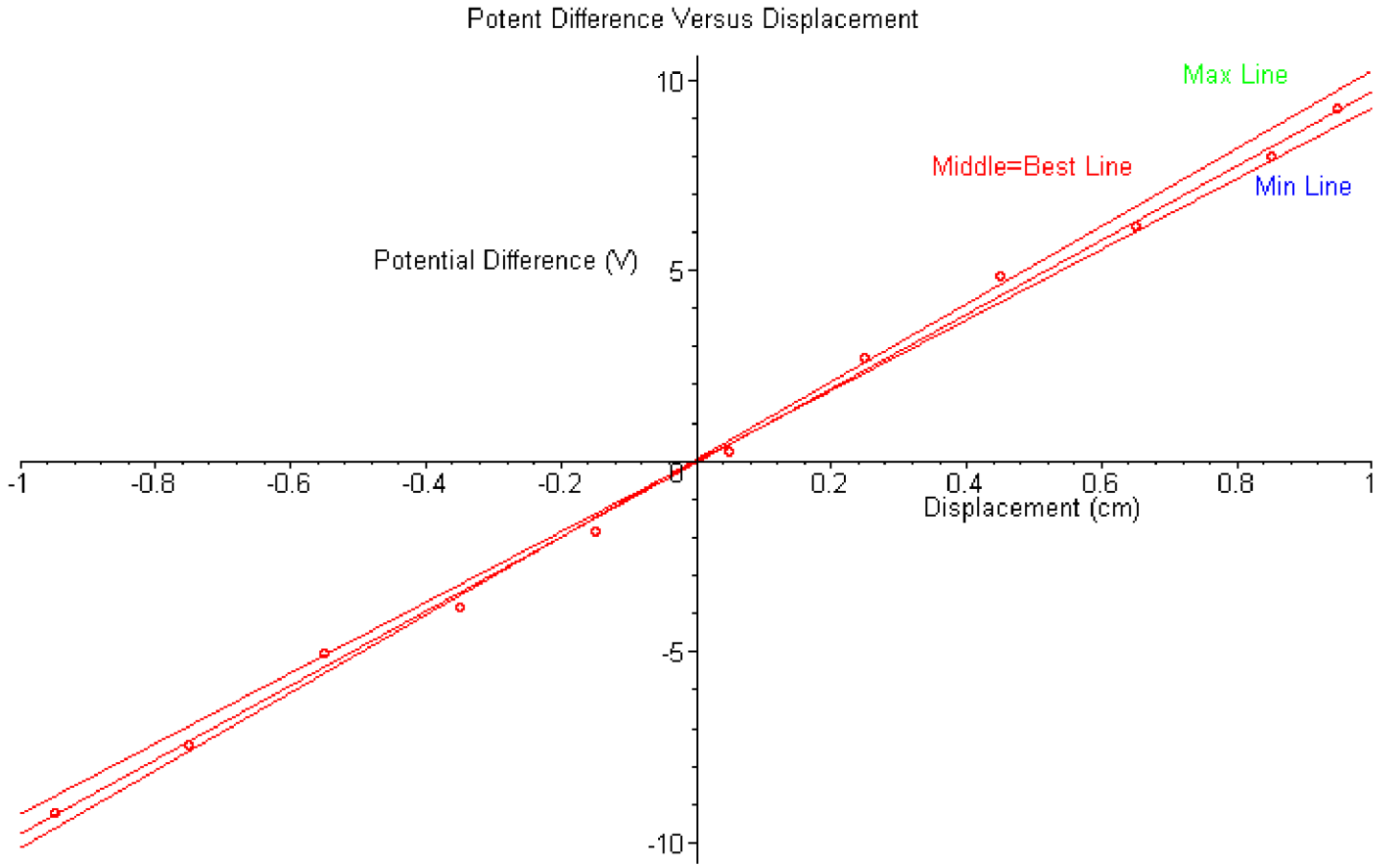
```
display([A,B,C,G,H,PMax,PMin],title="Potent Difference Versus Displacement",
labels=["Displacement (cm)","Potential Difference (V)"]);
```

```
`data slope 1`:=9.727;
```

```
`min slope 1`:=9.252;  `max slope 1`:=10.19;
```

```
uncertainty1:=(`max slope 1`-`min slope 1`)/2;
```

```
`% uncertainty`:=uncertainty1/`data slope 1`*100;
```



data slope 1 := 9.727

min slope 1 := 9.252

max slope 1 := 10.19

uncertainty1 := .469

% *uncertainty* := 4.822

#2

```
> for i from 1 to 5 do
> readline("a:/Lab3/Run2.txt")
> od;
```

"Vb=200 volts"

"Vc=75 volts"

"Ch A\t"

"Run #1\tRun #1"

"Voltage (V)\tDisplacement "

```
> R2:=readdata(`a:/Lab3/Run2.txt`,2):nops(%);
```

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```
> Voltage2:=[seq(R2[i,1],i=1..13)]:
> Displacement2:=[seq((R2[i,2]-(2.2/2)),i=1..13)]:
> Data:=[seq([Displacement2[n],Voltage2[n]],n=1..13)]:
> A:=plot(Data,style=point,symbol=circle):
> Eq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([Displacement2,Voltage2]);
```

$$Eq := y = 8.119\,x - .04346$$

```
> Fdata:=unapply(rhs(%),y);
```

$$Fdata := y \rightarrow 8.119\,x - .04346$$

```
> B:=plot(Fdata(x),x=-1..1):
C:=textplot([0.5,7.5,`Middle=Best Line`],colour=red,align=ABOVE):
G:=textplot([0.8,9.9,`Max Line`],colour=green,align=ABOVE):
H:=textplot([0.9,4.39,`Min Line`],colour=blue,align=ABOVE):
J:=[0.79,-0.91]:
K:=[6.94,-7.61]:
L:=[0.5,-0.7]:
M:=[3.63,-4.84]:
EqMin:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([L,M]);
```

$$EqMin := y = 7.061\,x + .1011$$

Fmin:=unapply(rhs(%),x);

$$Fmin := x \to 7.061\,x + .1011$$

PMin:=plot(Fmin(x),x=-1..1):

EqMax:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([J,K]);

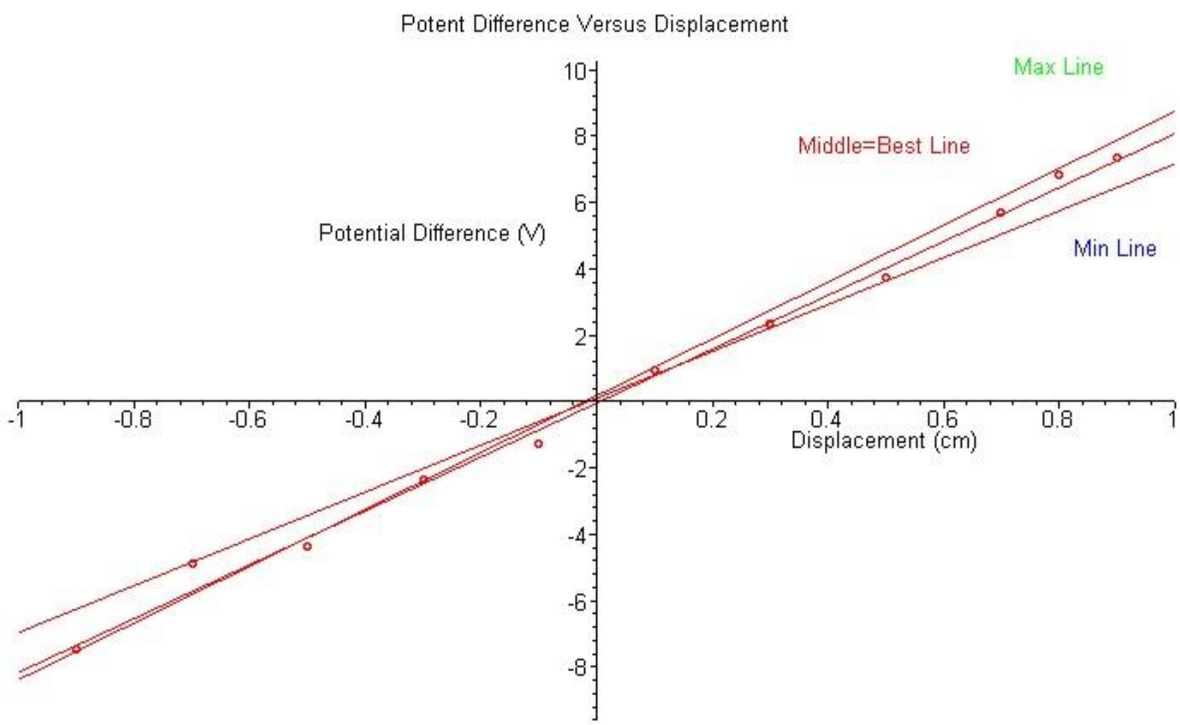
$$EqMax := y = 8.562\,x + .1787$$

Fmax:=unapply(rhs(%),x);

$$Fmax := x \to 8.562\,x + .1787$$

PMax:=plot(Fmax(x),x=-1..1):

display([A,B,C,G,H,PMin,PMax],title="Potent Difference Versus Displacement",labels=["Displacement (cm)","Potential Difference (V)"]);



`data slope 2`:=8.119;

`min slope 2`:=7.061; `max slope 2`:=8.562;

uncertainty2:=(`max slope 2`-`min slope 2`)/2;

```
`% uncertainty`:=uncertainty2/`data slope 2`*100;
```

$$data\ slope\ 2 := 8.119$$

$$min\ slope\ 2 := 7.061$$

$$max\ slope\ 2 := 8.562$$

$$uncertainty2 := .750$$

$$\%\ uncertainty := 9.238$$

#3

```
for i from 1 to 5 do
readline("a:/Lab3/Run3.txt")
od;
```

"Vb=300 volts"

"Vc=113 volts"

"Ch A\t"

"Run #1\tRun #1"

"Voltage (V)\tDisplacement "

```
R3:=readdata(`a:/Lab3/Run3.txt`,2):nops(%);
```

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```
Voltage3:=[seq(R3[i,1],i=1..9)]:
Displacement3:=[seq((R3[i,2]-(1.6/2)),i=1..9)]:
Data:=[seq([Displacement3[n],Voltage3[n]],n=1..9)]:
A:=plot(Data,style=point,symbol=circle):
Eq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([Displacement3,Voltage3]);
```

$$Eq := y = 11.64\, x - .1372$$

F:=unapply(rhs(%),x);

$$F := x \to 11.64\,x - .1372$$

B:=plot(F(x),x=-1..1,colour=red):

C:=textplot([.27,6.78,`Best Line = Middle`],align=ABOVE):

G:=textplot([0.82,4.59,`Min Line`],align=ABOVE):

H:=textplot([0.51,12.28,`Max Line`],align=ABOVE):

E:=[-.4,.2]:F:=[-4.73,1.72]:

K:=[.8,-.2]:

L:=[10.69,-3.1]:

MinEq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([E,F]);

$$MinEq := y = 10.75\,x - .4300$$

FMin:=unapply(rhs(%),x);

$$FMin := x \to 10.75\,x - .4300$$

PMin:=plot(FMin(x),x=-1..1):

MaxEq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([K,L]);

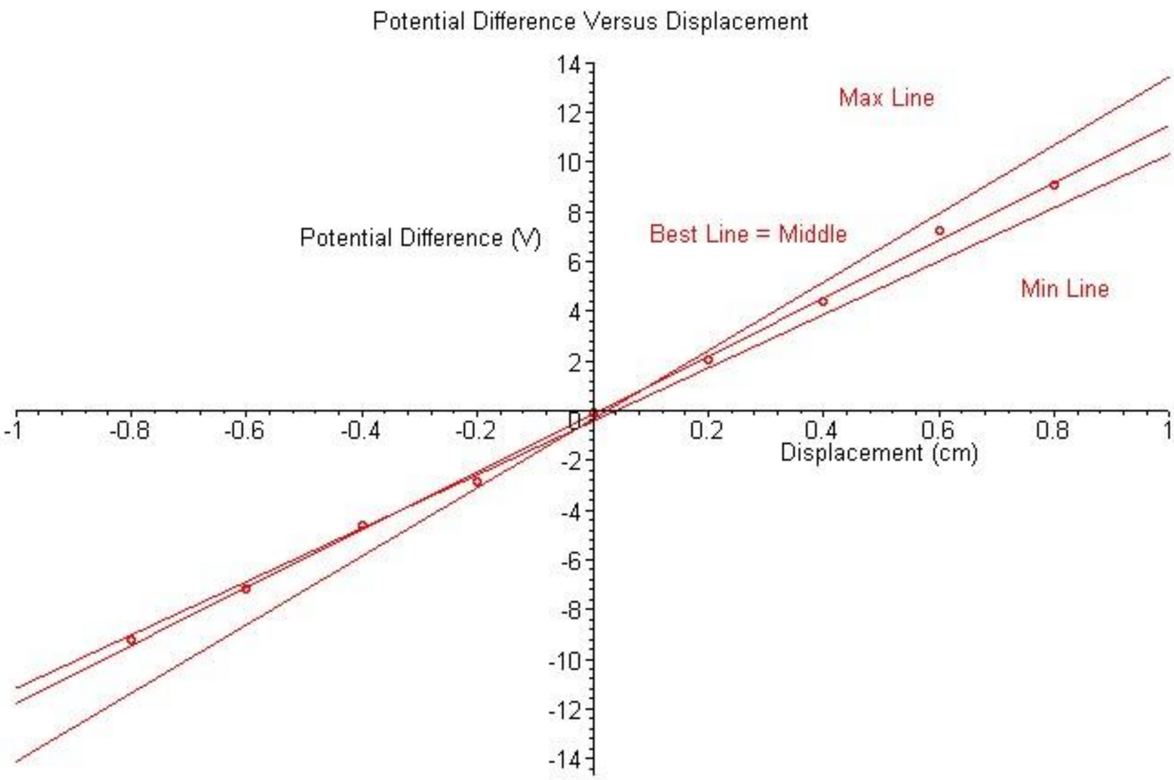
$$MaxEq := y = 13.79\,x - .3408$$

FMax:=unapply(rhs(%),x);

$$FMax := x \to 13.79\,x - .3408$$

PMax:=plot(FMax(x),x=-1..1):

display([A,B,PMin,PMax,C,G,H],title="Potential Difference Versus Displacement",labels=["Displacement (cm)","Potential Difference (V)"]);



`data slope 3`:=10.18;

`min slope 3`:=9.083; `max slope 3`:=10.75;

uncertainty3:=(`max slope 3`-`min slope 3`)/2;

`%uncertainty`:=uncertainty3/`data slope 3`*100;

$$\textit{data slope 3} := 10.18$$

$$\textit{min slope 3} := 9.083$$

$$\textit{max slope 3} := 10.75$$

$$\textit{uncertainty3} := .833$$

$$\textit{\%uncertainty} := 8.183$$

#4 for i from 1 to 5 do

readline("a:/Lab3/Run4.txt")

od;

"Vb=250 volts"

"Vc=95 volts"

"Ch A\t"

"Run #1\tRun #1"

"Voltage (V)\tDisplacement "

R4:=readdata(`a:/Lab3/Run4.txt`,2):nops(%);

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Voltage4:=[seq(R4[i,1],i=1..10)]:

Displacement4:=[seq((R4[i,2]-(1.8/2)),i=1..10)]:

Data:=[seq([Displacement4[n],Voltage4[n]],n=1..10)]:

A:=plot(Data,style=point,symbol=circle):

Eq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([Displacement4,Voltage4]);

$$Eq := y = 10.17\, x - .02800$$

F:=unapply(rhs(%),x);

$$F := x \rightarrow 10.17\, x - .02800$$

B:=plot(F(x),x=-1..1,colour=red):

C:=textplot([0.5,7.5,`Best Line = middle`],align=ABOVE):

G:=textplot([0.9,6,`Min Line`],align=ABOVE):

H:=textplot([0.6,9,`Max Line`],align=ABOVE):

E:=[-.1,.91]:

F:=[-.43,8.95]:

K:=[-.7,.7]:L:=[-7.4,7.59]:

MinEq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([E,F]);

$$MinEq := y = 9.294\, x + .4960$$

FMin:=unapply(rhs(%),x);

$$FMin := x \rightarrow 9.294\, x + .4960$$

PMin:=plot(FMin(x),x=-1..1):

MaxEq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([K,L]);

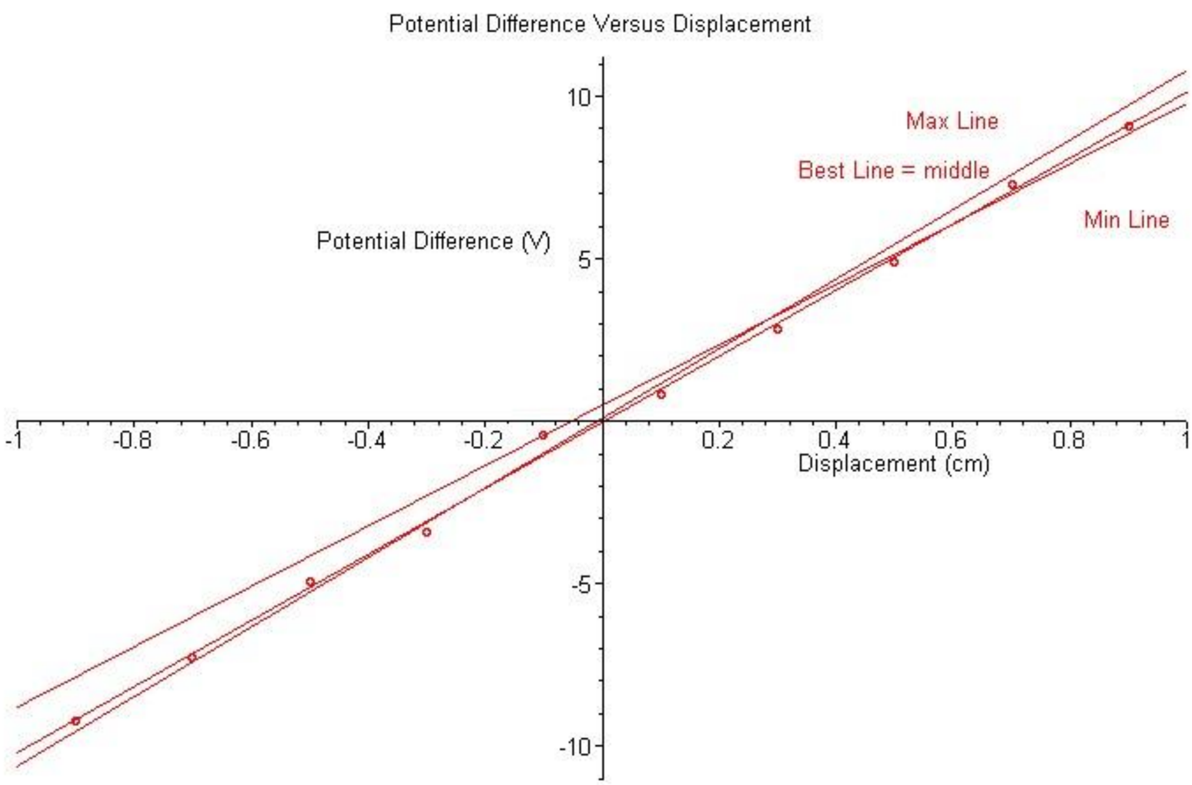
$$MaxEq := y = 10.71\, x + .09500$$

FMax:=unapply(rhs(%),x);

$$FMax := x \rightarrow 10.71\, x + .09500$$

PMax:=plot(FMax(x),x=-1..1):

display([A,B,PMin,PMax,C,G,H],title="Potential Difference Versus Displacement",labels=["Displacement (cm)","Potential Difference (V)"]);



`data slope 4`:=10.17;

```
`min slope 4`:=9.294; `max slope 4`:=10.71;

uncertainty4:=(`max slope 4`-`min slope 4`)/2;

`% uncertainty`:=uncertainty4/`data slope 4`*100;
```

$$\text{data slope 4} := 10.17$$

$$\text{min slope 4} := 9.294$$

$$\text{max slope 4} := 10.71$$

$$\text{uncertainty4} := .708$$

$$\%\ \text{uncertainty} := 6.962$$

Part 2

Voltage Sensitivity vs. Accelerating Voltage

```
Data:=[[323,9.727],[275,8.119],[413,11.64],[345,10.17]]:

Av:=[seq(Data[i][1],i=1..4)]:VS:=[seq(Data[i][2],i=1..4)]:

uncertainty:=[uncertainty1,uncertainty2,uncertainty3,uncertainty4]:

A:=plot(Data,x=0..500,style=point,symbol=circle):

eq:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([Av,VS]);
```

$$eq := y = .02504\,x + 1.427$$

```
F:=unapply(rhs(%),x);
```

$$F := x \rightarrow .02504\,x + 1.427$$

```
B:=plot(F(x),x=0..500): with(plottools):

linelist:=[seq(line([Av[i],VS[i]+uncertainty[i]],[Av[i],VS[i]-uncertainty[i]]),
i=1..4)]:
```

linelisttop:=[seq(line([Av[i]-10, VS[i]+uncertainty[i]],[Av[i]+10, VS[i]+uncertainty[i]]),i=1..4)]:

linelistbottom:=[seq(line([Av[i]-10,VS[i]-uncertainty[i]],[Av[i]+10,VS[i]uncertainty[i]]),i=1..4)]:

C:=[Av[2],Av[4]]:E:=[VS[2],VS[4]]:G:=[Av[1],Av[3]]:H:=[VS[1],VS[3]]:

eqmax:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([C,E]);

eqmin:=fit[leastsquare[[x,y],y=a*x+b,{a,b}]]([G,H]);

$$eqmax := y = .02861\,x + .2752$$
$$eqmin := y = .02165\,x + 2.716$$

Max:=unapply(rhs(eqmax),x);

Min:=unapply(rhs(eqmin),x);

$$Max := x \rightarrow .02861\,x + .2752$$

$$Min := x \rightarrow .02165\,x + 2.716$$

PMax:=plot(Max(x),x=0..500):

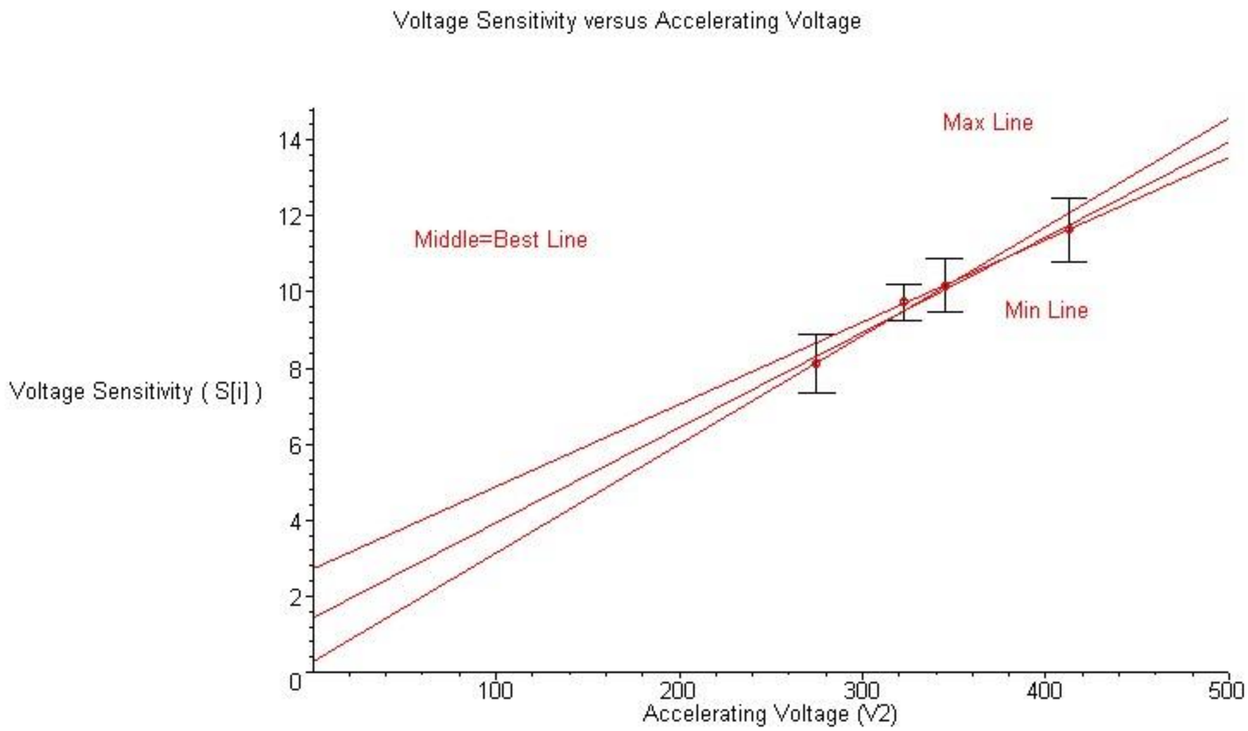
PMin:=plot(Min(x),x=0..500):

J:=textplot([102.98,11.18,`Middle=Best Line`],align=ABOVE):

K:=textplot([368.61,14.28,`Max Line`],align=ABOVE):

L:=textplot([401.28,9.33,`Min Line`],align=ABOVE):

display([A,B,seq(linelist[i],i=1..4),seq(linelisttop[i],i=1..4),seq(linelistbottom[i],i=1..4),PMax,PMin,L,J,K],title="Voltage Sensitivity versus Accelerating Voltage",labels=["Accelerating Voltage (V2)","Voltage Sensitivity (S[i])"]);



`data slope 5`:=.02504;

`max slope 5`:=.02861; `min slope 5`:=.02165;

uncertainty5:=(`max slope 5`-`min slope 5`)/2;

`% uncertainty`:=uncertainty5/`data slope 5`*100;

$$\mathit{data\ slope\ 5} := .02504$$

$$\mathit{max\ slope\ 5} := .02861$$

$$\mathit{min\ slope\ 5} := .02165$$

$$\mathit{uncertainty5} := .00348$$

$$\%\ \mathit{uncertainty} := 13.90$$

`data intersept`:=1.427;

`max intersept`:=.2752; `min

intersept`:=2.716;

uncertainty6:=abs(`max intersept`-`min intersept`)/2;

$$data\ intersept := 1.427$$

$$max\ intersept := .2752$$

$$min\ intersept := 2.716$$

$$uncertainty6 := 1.221$$

Percentage of Difference Calculations

`difference between Slope of Graph and Prediction 1`:=[seq(abs(VS[i]`Prediction 1`[i]),i=1..4)];

$$difference\ between\ Slope\ of\ Graph\ and\ Prediction\ 1 := [.269, .067, .45, .07]$$

`% difference`:=[seq(abs(VS[i]-`Prediction 1`[i])/(VS[i]+`Prediction 1`[i])*200,i=1..4)];

$$\%\ difference := [2.804, .8286, 3.792, .6906]$$

`difference between measured slope of VS vs. V[a] and predicted slope`:=abs(`data slope 5`-`Prediction2`);

$$difference\ between\ measured\ slope\ of\ VS\ vs.\ V[a]\ and\ predicted\ slope := .00453$$

`% difference`:=abs(`data slope 5`-`Prediction2`)/abs(`data slope 5`+`Prediction2`)*200;

$$\%\ difference := 16.59$$

`difference between the measured and predicted intersepts`:=abs(`data intersept`-`Intersept Prediction`);

$$difference\ between\ the\ measured\ and\ predicted\ intersepts := 1.527$$

`% difference`:=abs(`data intersept`-`Intersept Prediction`)/abs(`data intersept`+`Intersept Prediction`)*200;

$$\%\ difference := 230.2$$

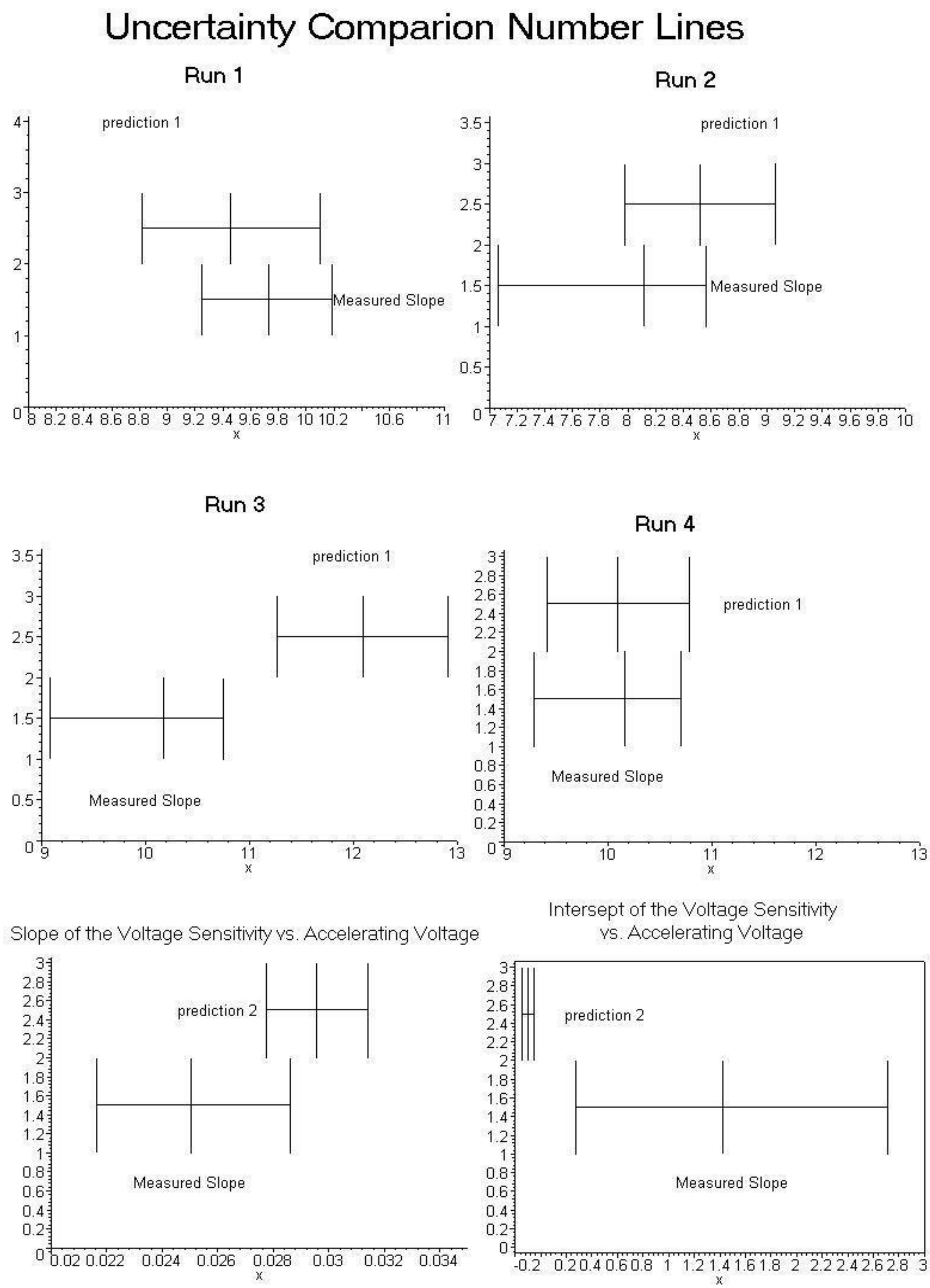
Experimental Results :

	Accelerating Voltage (Vd+Vc)	Voltage Sensitivity (Slope of Graphs)	Prediction1	% uncertainty
Run #1	323	9.72±4.8%	9.46±6.7%	2.80%
Run #2	275	8.12±9.2%	8.06±6.7%	0.83%
Run #3	413	11.64±1.2%	12.10±6.7%	3.79%
Run #4	345	10.17±7.0%	10.11±6.7%	0.69%

Predicted Slope	Actual Slope	% uncertainty
.030±6.2%	.025±13.9%	16.59%

Predicted Intersept	Actual Intersept	difference
(-.09997)±.047	1.43±1.22	1.527

Uncertainty Diagram



Conclusion :

The predictions made prior to this lab were fairly accurate. In each case (except for the intercept in Part 2), the calculated percent errors accounted for the difference between the predicted and the experimental values. Upon inspection of the results section above, you can see that the difference between the predicted and experimental values for both slopes are easily explained by the error margins for each value, but error cannot account for the difference between the intercepts. While we discovered a linear relation between both the first and second Parts, only Part 1 yielded a direct relation, even taking into account the error values, Part 2 did not pass through the origin. However, the graph was close enough to the origin that stray charges from the electron gun can account for the difference. As a result of the success of this experiment, we can state that our predicted formulas ($V_d = S\,Y$, $S = C\,V_2$, $C = \frac{2\,d}{l\,L}$ and $V_d = \frac{2\,Y V_2\,d}{l\,L}$) accurately describe our model of electron deflection and electric field theory.