Charge of an Electron

Name_____ ID_____ Signature_____

Partners_____

Date_____ Section_____

Exercise caution when you turn on the power supply. If the circuit is implemented wrongly, some of elements will be burned. Turn off the power when you manipulate the circuit.

0. Introduction

The goal of this experiment is to obtain the charge of an electron, 1.602×10^{-19} C, with a transistor circuit. The Shockley equation and Ohm's law yield:

$$V(R_C) \approx B \exp\left[\frac{qV_{BE}}{kT}\right] \qquad (1)$$

where $V(R_C)$ is the voltage on resistor R_C, B is a constant, q is the charge of an electron (It is supposed to be the unknown here.), V_{BE} is the voltage between base and emitter, k is Boltzmann's constant (1.381×10^{-23} J/K), T is the room temperature in kelvins.

1. Implementation of the circuit:

Make the following circuit on a bread board. The typical values are:

R_1 = a variable resistor (~ 2 - 5 kΩ)

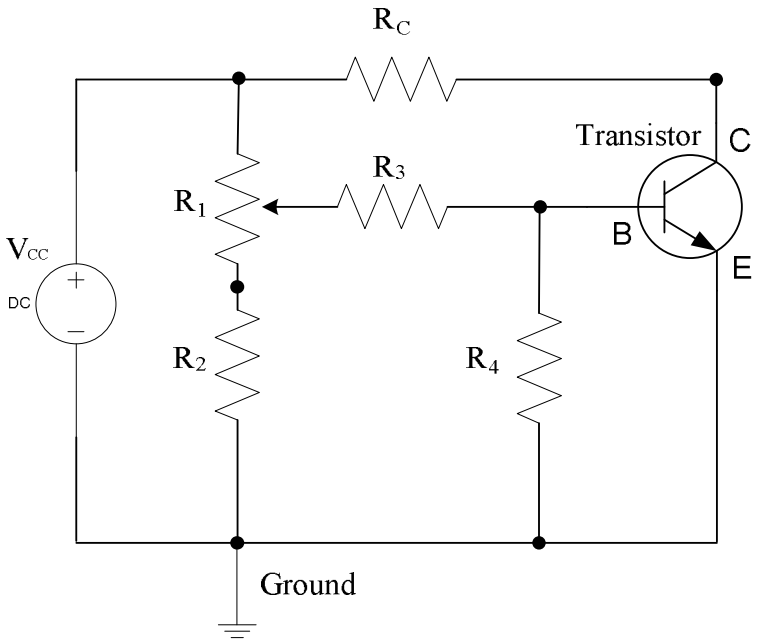
R_2 ~ 3.9 kΩ (2 – 5 kΩ)

R_3 ~ 100 kΩ (90 – 110 kΩ)

R_4 ~ 3.9 kΩ (2 – 5 kΩ)

R_C ~ 30 kΩ (20 – 40 kΩ)

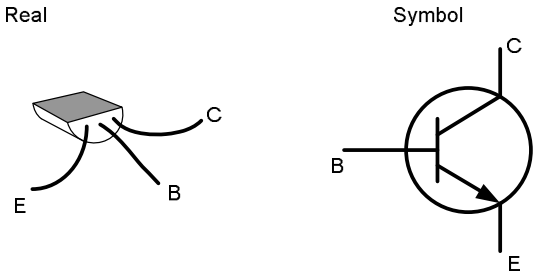
V_{CC} ~ 12 - 20 V



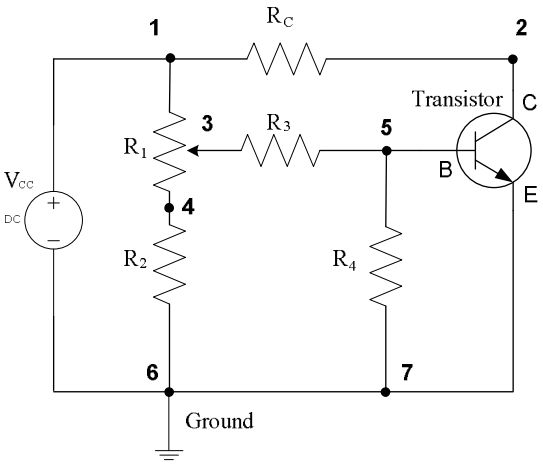
You do not have to use the exact resistances and voltages. Use the same order of the values. For example, R_C should be from 20 kΩ to 40 kΩ..

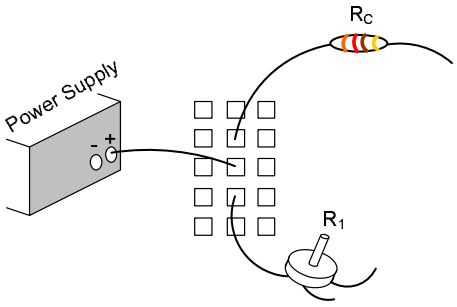
Procedure to implement the circuit

1. Make sure which terminal is which for the transistor. When the flat plane is directed up as shown, the base, collector, and emitter can be found as follows.



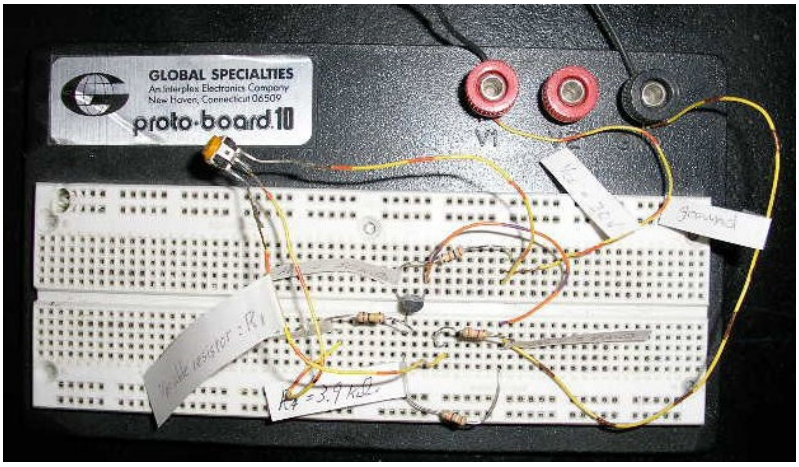
2. Label each resistor.
3. Start implementing the circuit by looking at the each connection as shown. The connection, **1**, should have the power supply, one terminal from R_C, and one terminal from R_1. The picture below shows the connection, **1**, on the breadboard. The connection, **2**, must have the terminal of the collector and the other side of R_C terminal. Similarly, check the connections, **3**, **4**, **5**, **6** and **7**.





4. The resistor, R_1, is a variable resistor, and the middle terminal is connected to R_3.
5. The ground corresponds to the negative side of power supply.

Example Circuit



2. Measurement

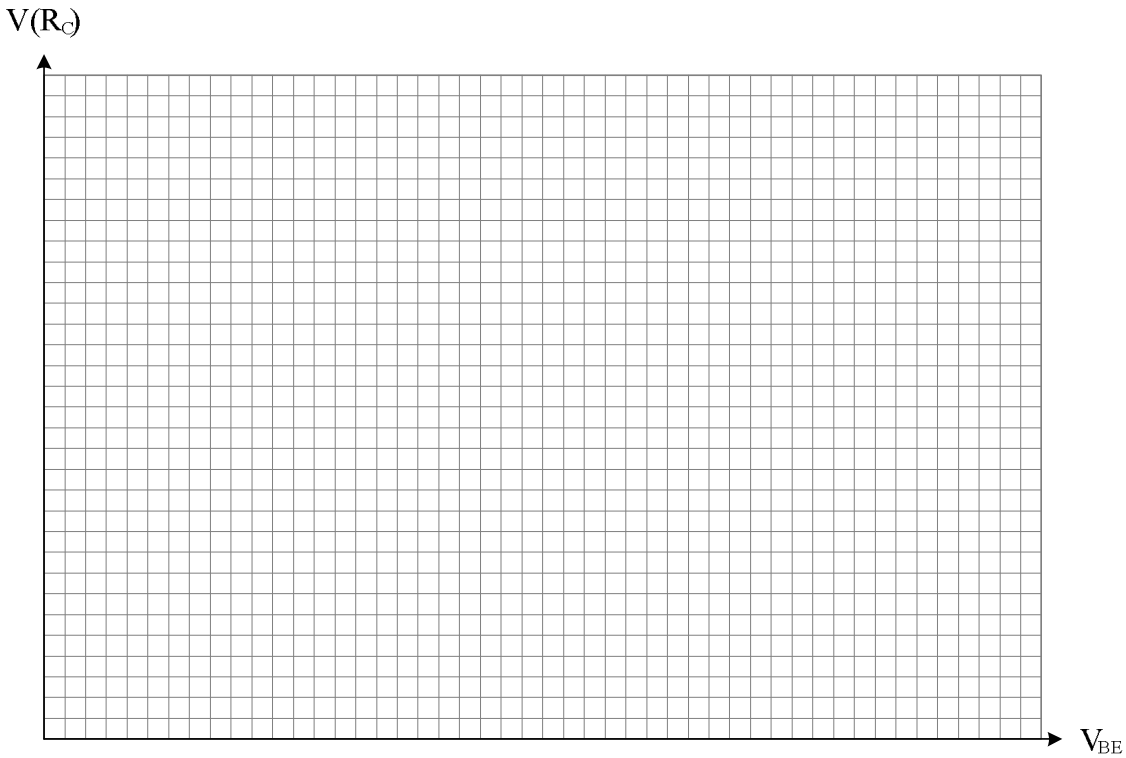
Measure V_{BE} and $V(R_C)$ each time by changing the variable resistor. (The increment of V_{BE} should be 0.005 – 0.010 V; however, the range of the voltage should be 0.50 V ≤ V_{BE} ≤ 0.60 V.) Adjust V_{CC} and variable resistor so you can start with around V_{BE} ~0.50 V. It is very sensitive, so rotate the knob with a little amount each time.

V_{BE} Voltage across base and emitter	$V(R_C)$ Voltage across R_C	$\ln V(R_C)$ Calculate this.

If you do not obtain proper results of above, please check following things:

- Is every wire connected tightly onto the bread board?
- Are R_2, R_4 and the emitter connected to the same ground?
- Is the transistor alive?

Plot the 1st and 2nd columns.



Question: Do you obtain a proper plot? Discuss with your partners.

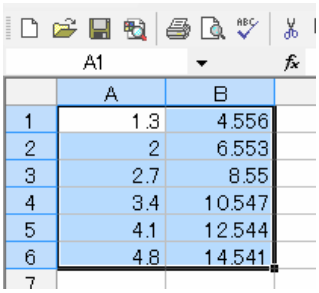
3. Obtaining the charge of an electron

If you take the logarithm of equation (1), you will have

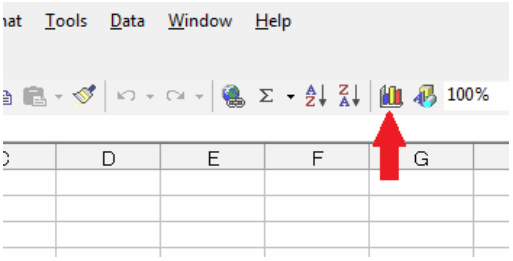
$$\ln V(R_c) = \ln B + \frac{qV_{BE}}{kT} \qquad (2)$$

Eq. (2) is a line equation. $\frac{q}{kT}$ is the slope of the line, so plot the 1st and 3rd columns of the above table, then obtain the slope with Excel spread sheet. (Least-squares fits)

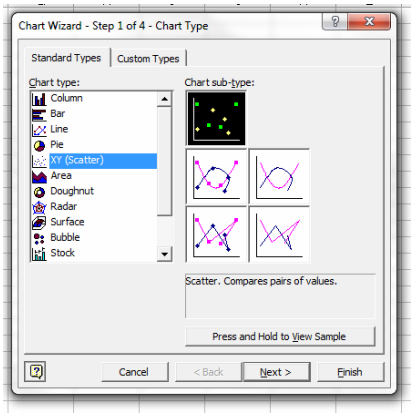
Excel Procedure of How to Obtain the Slope (**Do this during the lab activity and print it out.**)



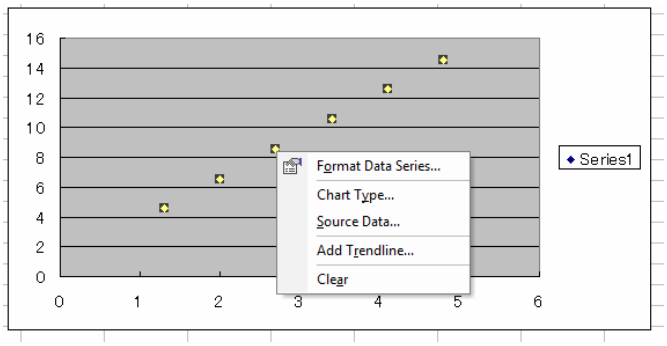
1. Select two columns for the plot. Columns A and B are *x* and *y* values, respectively. ⇐



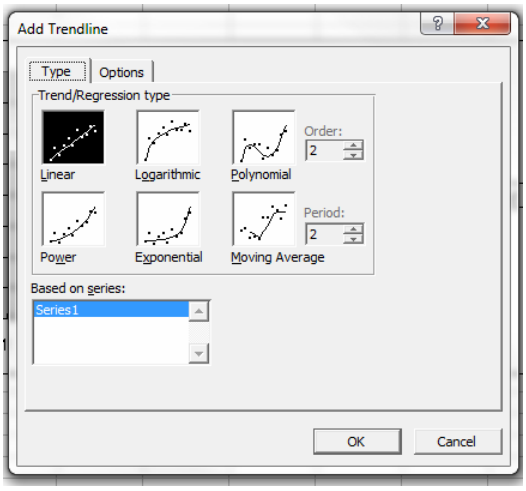
2. Click "chart wizard" as indicated by the arrow. ⇒



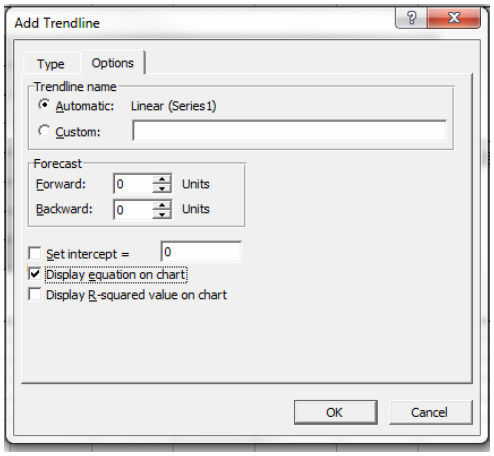
3. Select "XY (Scatter)" and for "Chart sub-type" choose "Scatter. Compares pairs of values" as shown. Then, click "Finish."⇐



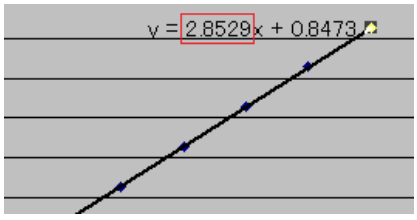
4. Right click one of the plot points and select "Add Trendline." ⇒



5. Select "Linear" and click the tab, "Options." ⇐



6. Check "Display equation on chart" then click OK. ⇒



7. The coefficient of *x* is the slope of the plot. ⇐

Slope = _____ = $\frac{q}{kT}$

From the above, solve for q:

⇒ Use Boltzmann's constant $k = 1.381 \times 10^{-23}$ (J/K), Room temperature T = _____ (K)

[Temperature ${}^{o}C = (5/9)({}^{o}F - 32)$, K=273.15+ ${}^{o}C$]

⇒⇒ Calculate charge of an electron = _____ (C)

Question: Does your result agree with the expected value?