

Charge of an Electron

Name _____ ID _____ TA _____

Partners _____

Date _____ Section _____



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:

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

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 k Ω)

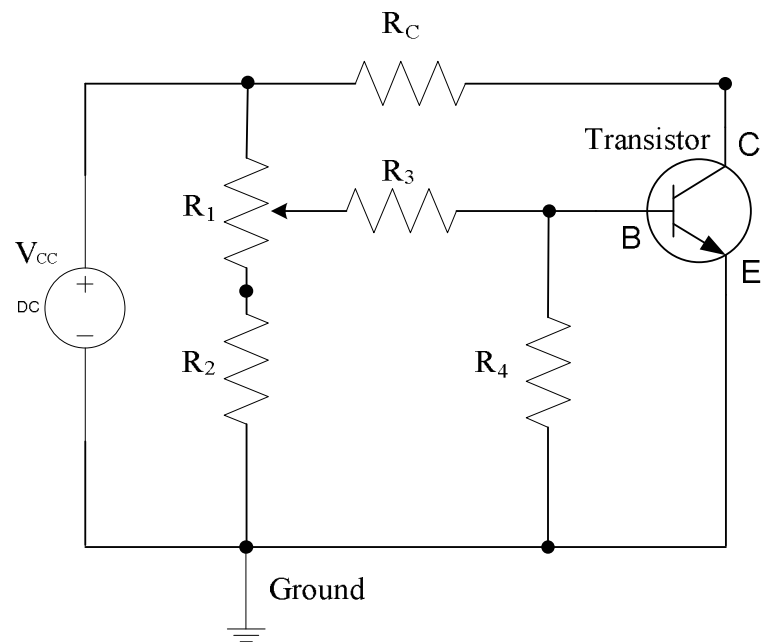
$R_2 \sim 3.9$ k Ω

$R_3 \sim 100$ k Ω

$R_4 \sim 3.9$ k Ω

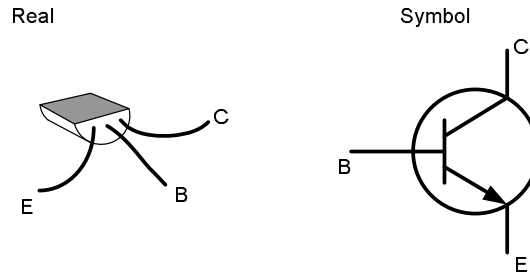
$R_C \sim 30$ k Ω

$V_{CC} \sim 12 - 20$ V

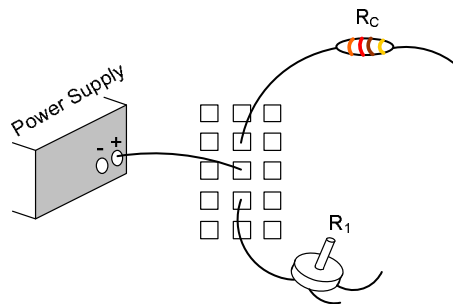
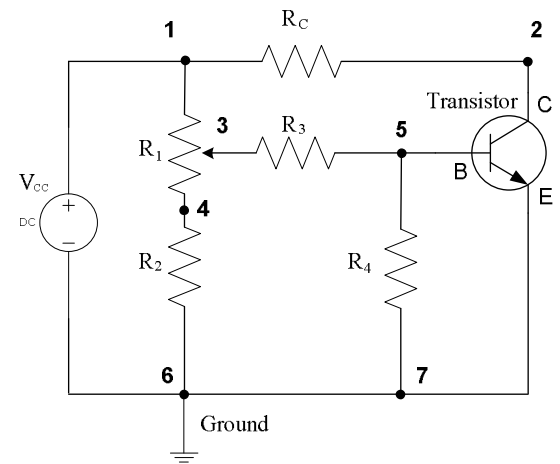


Procedure to implement the circuit

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.

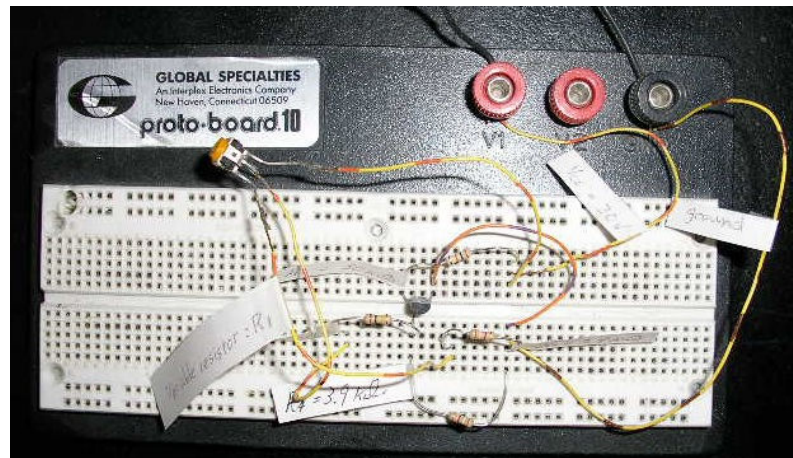


2. Label each resistor.
3. Start implementing the circuit by looking at the each connection as shown. The connection, **1**, should have the power supply, one terminal from R_C , and one terminal from R_1 . The picture below shows the connection, **1**, on the breadboard. The connection, **2**, must 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

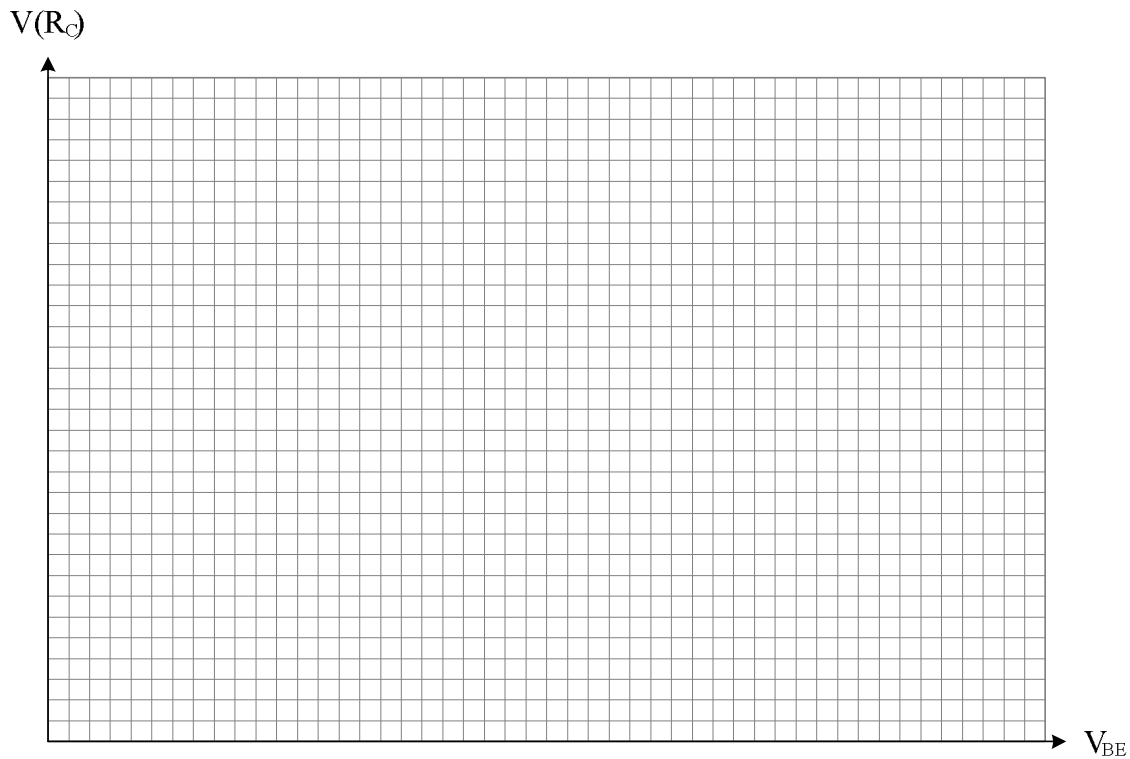
By changing the variable resistance, measure V_{BE} and $V(R_C)$ each time. (The interval of V_{BE} should be 0.005 – 0.010 V.) The range of the base-emitter voltage is $0.50 \text{ V} \leq V_{BE} \leq 0.60 \text{ V}$.

V_{BE}	$V(R_C)$	$\ln V(R_C)$

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

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

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)

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)

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

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

Question: Does your result agree with the expected value?