LABORATORY 1

Introduction to Circuits and Instruments

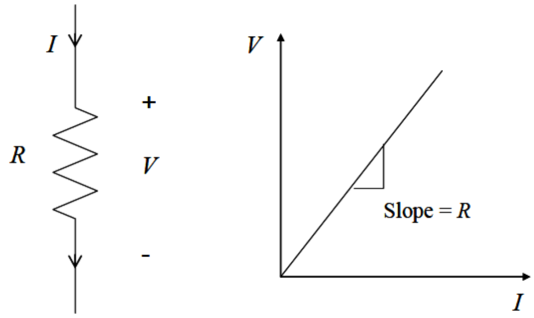
Guide

Objectives

The electronic circuit is the basis for all branches of electrical engineering. In this lab, basic electronic circuit theory, electronic components and devices will be introduced and employed. Fundamental testing equipment will be used to measure and characterize simple circuitry. In the hands-on lab, you will apply these basic theories to the devices and components provided to design simple circuits.

1. Ohm's Law: V = IR

Current (denoted I) and voltage (denoted V) are two major quantities that are used to study electronic circuits. Current is the amount of charge passing through a certain area in a unit time period, while voltage describes the electrical potential drop across any two nodes in a given circuit. Ohm's Law states that the voltage V across an ideal resistor is proportional to the current I through the resistor. The constant of proportionality is the resistance R of the Resistor.



$$V = IR$$

Figure 1. Ohm's Law.

2. Series and parallel connections

A circuit usually contains many devices connected in different fashions. Two basic types of configuration are series and parallel. As shown in the figure below, when the devices are connected in series, the current going through them is the same ($I = I_1 = I_2$), and the total voltage across both devices is the sum of the voltage across each device ($V = V_1 + V_2$). However, for parallel connection, the voltage across the devices is the same ($V = V_1 = V_2$) since they share the same nodes across which the potential drop is measured, and the total current running through all the devices is the sum of the current in each branch ($I = I_1 + I_2$).

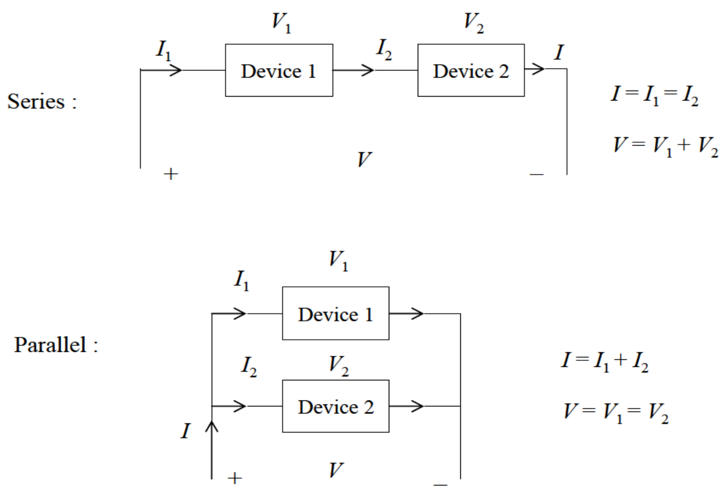


Figure 2.

Now let us examine the resistive circuits shown below.

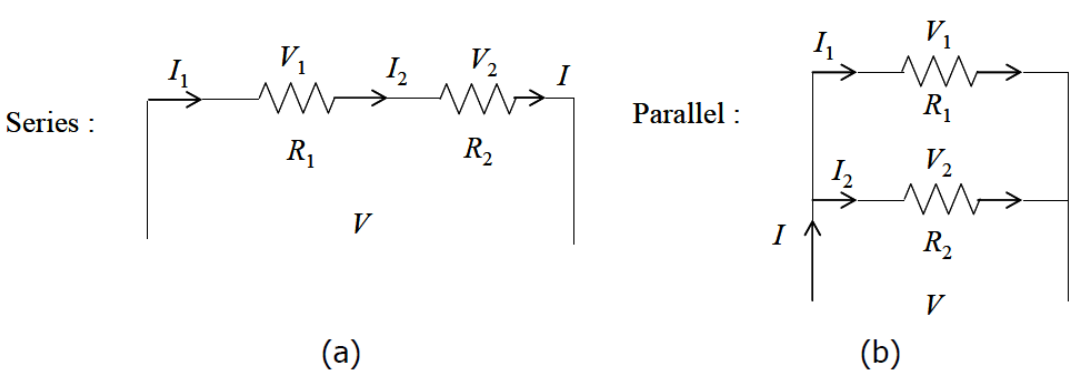


Figure 3.

Voltage-divider circuit:

In (a), based on Ohm's law,

$$V_1 = R_1 I_1,\ V_2 = R_2 I_2$$

And since this is a series connection,

$$I_1 = I_2 = I, V = V_1 + V_2$$

Therefore,

$$V = (R_1 + R_2) I$$

It is straightforward to get $V_1 = \frac{R_1}{R_1 + R_2} V$ and $V_2 = \frac{R_2}{R_1 + R_2} V$.

Therefore, when a voltage is applied to a series combination of resistances, a fraction of the voltage appears across each of the resistances. And of the total voltage, the fraction that appears across a given resistance in a series circuit is the ratio of the given resistance to the total series resistance.

Current-divider circuit:

In (b), the two resistors are connected in parallel.
From Ohm's law,

$$V_1 = R_1 I_1, V_2 = R_2 I_2$$

And since this is a parallel connection,

$$V_1 = V_2 = V, I = I_1 + I_2$$

Therefore,

$$I = \frac{V}{R_1} + \frac{V}{R_2} = \frac{R_1 + R_2}{R_1 R_2} V$$

It is straightforward to get $I_1 = \frac{R_2}{R_1 + R_2} I$ and $I_2 = \frac{R_1}{R_1 + R_2} I$.

Therefore, the total current flowing into a parallel combination of resistances divides, and a fraction of the total current flows through each resistance. And the fraction of the total current flowing in a resistor is the ratio of the other resistance to the sum of the two resistances.

3. Ideal voltage and current sources

An ideal voltage source supplies a constant voltage across its output terminals no matter how much current is going through it. Likewise, an ideal current source will supply constant current out no matter what the voltage across it is. The circuit symbol of the ideal voltage or current source is shown in the figure below.

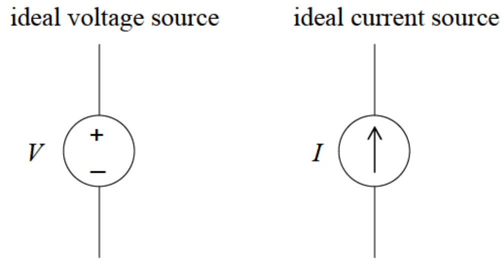
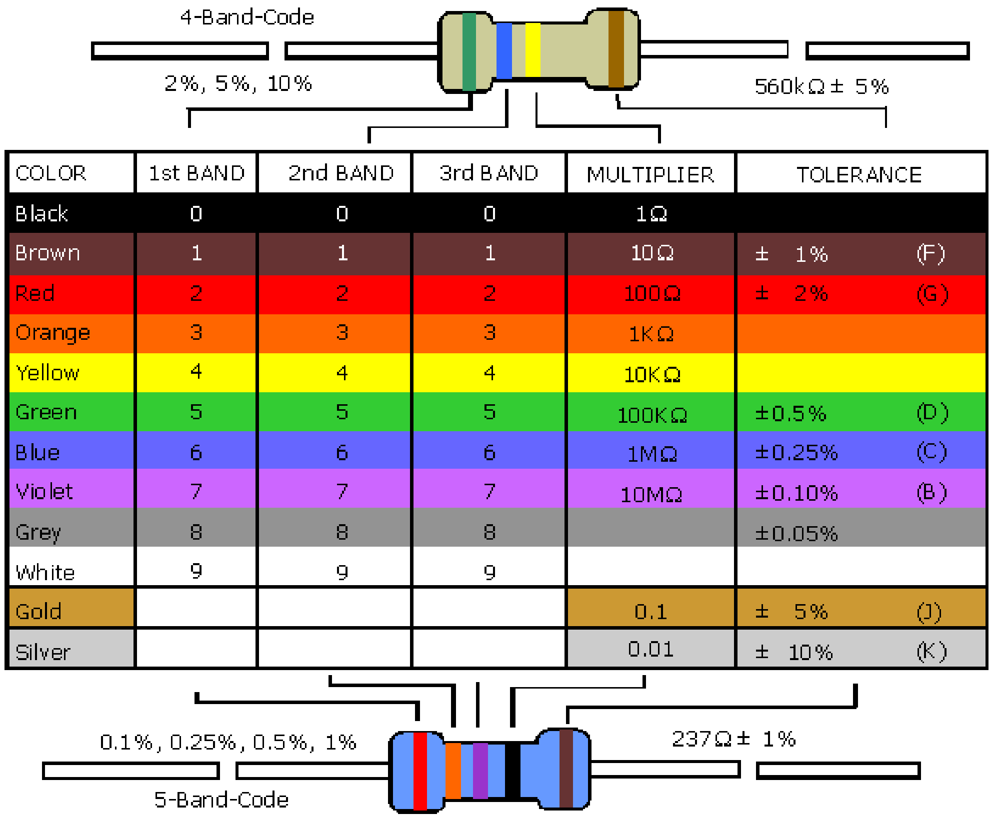


Figure 4.

4. Resistor

The resistor is the most basic and widely used component in electronic circuits. And the relation of the voltage and the current of a resistor in a circuit will follow Ohm's law. A typical resistor is color coded to indicate the resistance value. There are two types of color coding, 4-band-code and 5-band-code. As can be seen, the 5-band-code has one more digit resolution than the 4-band-code. The following chart provides the color code for both 4-band and 5-band resistors. To decode the color bands and calculate the corresponding resistance value, one needs to follow the steps below.

a) Find the tolerance band. It is located at one end of the resistor and far away from the rest of the color bands. It gives the accuracy of the actual resistance to the value that is labeled.
b) Start from the other end and use the color code map to identify the color band. This will be the first digit (the most significant digit) of the resistance value.
c) Then similarly decode the second and the third band (for 5-band resistor only). Write down all the digits in order (from left to right).
d) The last band is the multiplier. Use the decoded digits to multiply the decoded multiplier to get the resistance value.



COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	±0.5% (D)
Blue	6	6	6	1MΩ	±0.25% (C)
Violet	7	7	7	10MΩ	±0.10% (B)
Grey	8	8	8		±0.05%
White	9	9	9		
Gold				0.1	± 5% (J)
Silver				0.01	± 10% (K)

Figure 5. Color Code.

Another type of resistor named Chip Resistor or SMD Resistor, is quite different from what's showed above, and is more widely and regularly used. As shown in Figure 6, this kind of resistor is much smaller, and some other electronic components also use the similar packages. In general, there are several digits and a capital letter on the surface of a chip resistor which can tell us the value of its resistance. How to read these digits and letter? You can find some more information from the WWW, or refer to this link *webpage*.

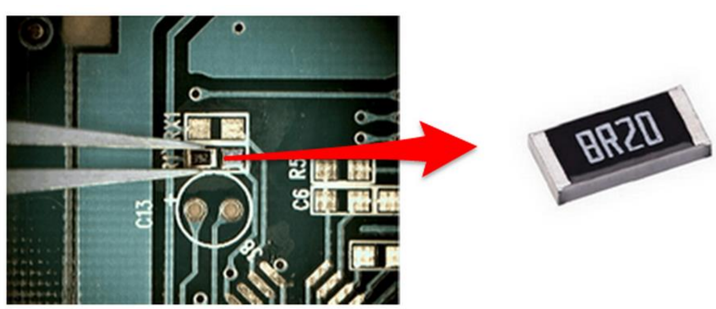


Figure 6. Chip Resistor.

Introduction to Major Equipment

1. Breadboard

A breadboard is a reusable solderless device used to build a (generally temporary) prototype of an electronic circuit and for experimenting with circuit designs. This is in contrast to stripboard and similar prototyping printed circuit boards (PCB), which are used to build more permanent prototypes or one-offs, and cannot easily be reused. A typical breadboard will have strips of interconnected electrical terminals, known as bus strips, down one or both sides — either as part of the main unit or as separate blocks clipped on — to carry the power rails. A typical breadboard with a circuit built on it is shown below.

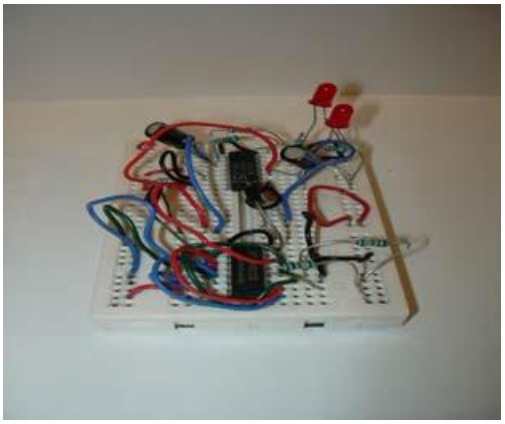


Figure 7. A breadboard with a completed circuit.

A modern solderless breadboard consists of a perforated block of plastic with numerous tin plated phosphor bronze spring clips under the perforations. Integrated circuits (ICs) in dual inline packages (DIPs) can be inserted to straddle the centerline of the block.

Interconnecting wires and the leads of discrete components (such as capacitors, resistors, inductors, etc.) can be inserted into the remaining free holes to complete the circuit topology. In this manner, a variety of electronic systems may be prototyped, from small circuits to complete central processing units (CPUs). However, due to large stray capacitance (from 2-25pF per contact point), solderless breadboards are limited to operating at relatively low frequencies, usually less than 10 MHz, depending on the nature of the circuit. The node connection of a typical breadboard is shown in the figure below.

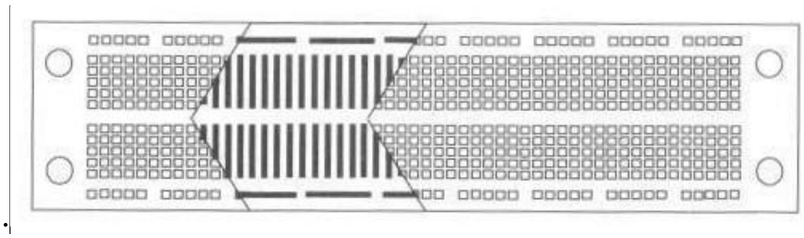


Figure 8. The node connection of a typical breadboard.

2. Power Supply

Like a battery, a DC power supply provides a constant voltage for powering electronic circuits. But, unlike a battery, the power supply won't die out. It will provide continuous power as long as it is connected to a wall outlet. Furthermore, you can set the voltage of the supply as needed and set the maximum current (the current limit feature) that can be drawn from it. The power supply will NOT output a value of current greater than the set limit. If the circuit is operated in a situation that it needs to draw more current than the set maximum current, the supply will adjust the output voltage to match this maximum value of current. This feature will protect the circuit when you know beforehand that it cannot tolerate more than a certain current level.

Figure 9. RIGOL DP832 DC power supply.

In this lab, we use RIGOL DP832 triple output DC power supply. The switches control the more advanced features built into the equipment. The power supply contains three variable voltage sources, with maximum voltage values of +30V, +30V, and +5V. One of the +30V and the +5V supplies share a common reference terminal (com). The earth ground is the terminal connected to the case of the instrument and more importantly, the earth, through the building wall socket.

The concept of “ground” is **VERY IMPORTANT**. A ground node means the potential at that node is 0 volts. Since voltage is the potential difference between two nodes, “5 volts” means one node has a potential of 5 volts with respect to a ground (or a reference) node. The true ground – earth ground is the green connector, but all other black connectors are reference grounds that can be used to apply voltage to a circuit. Note that the earth ground terminal is isolated and is connected to the case of the instrument, which is also connected to the earth ground through the 3-wire receptacle. One of the +30V and the +5V supplies outputs have a common output terminal (denoted by "com") which is isolated from the earth ground. The positive or negative terminals of each output can be grounded or each output can be left floating with respect to the ground.

3. Digital Multimeter (DMM)

Currents and voltages are the basic circuit variables of interest. In this lab we are mainly concerned with accurately measuring resistance, DC voltage and currents using a digital multimeter (DMM). We will use the FLUKE15B+ digital multimeter which is a high performance instrument capable of measuring resistance, capacitance, DC and AC voltage and current, as well as frequency.

Figure 10. FLUKE15B+ digital multimeter.

4. Function Generator

A function generator is an instrument that can generate a periodic AC signal at different frequencies. In this lab, we use the RIGOL DG1062 function generator. This is a versatile instrument capable of generating sine, square, and other waveforms. The amplitude and offset of these waveforms can also be controlled easily. The front panel of the function generator is shown in the figure below. A time-varying periodic voltage signal will be generated and output at the OUTPUT connector. By pushing the appropriate buttons on the front panel, the user can specify the following characteristics of the signal:

- Shape: sinusoidal, square, or triangular waves. These are all mathematical functions of time.
- Frequency: inverse of the period of the signal; units are cycles per second (Hz).
- Amplitude: peak to peak value of the time-varying component of the signal.
- DC Offset: constant voltage added to the signal to increase or decrease its mean or average level.

A sine wave of frequency f, peak to peak amplitude V_{PP}, and DC offset V_{DC} is written mathematically as $v(t) = (V_{PP}/2) \times \sin(2\pi f\, t) + V_{DC}$.

Figure 11. RIGOL DG1062 function generator.

5. Oscilloscope

An oscilloscope is a device that graphs voltage versus time. The display shows voltage on the vertical axis as a function of time on the horizontal axis. The user can control the scale of both the time and the voltage axes. The RIGOL-MSO1104 oscilloscope used in this lab can accept four voltage-signal inputs.

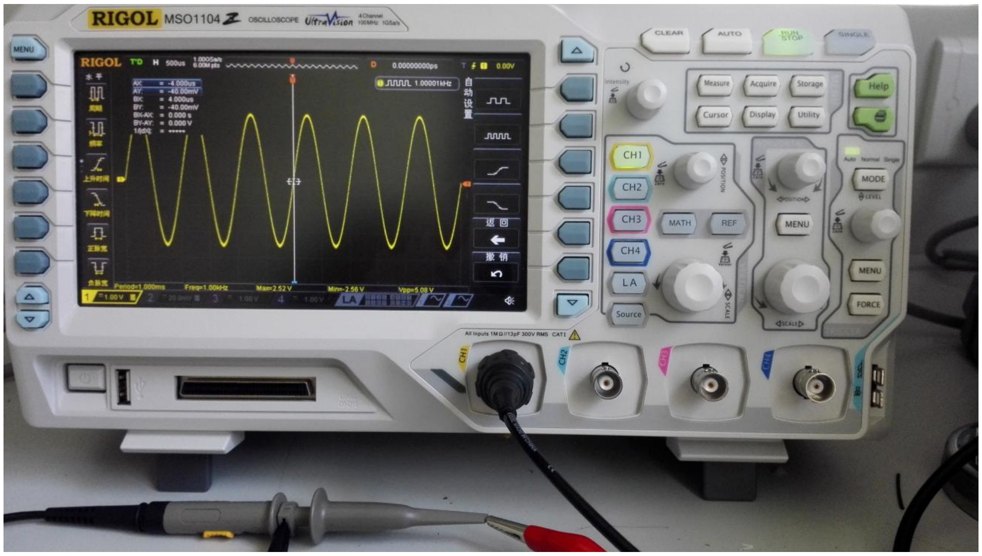


Figure 12. RIGOL-MSO1104 oscilloscope.

Reference

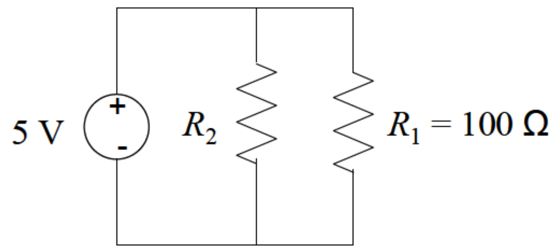
[1] UC Berkeley, course EE-100, Summer 2008.

[2] UC Berkeley, course EE-100, Spring 2011.

Lab1 Prelab

Name ________________________ Student ID _________________________

1. Two resistors are connected in parallel to an ideal voltage source of 5V. Choose the value of R_2 so that the total current going through R_1 and R_2 is 150 mA. **__/5pt**



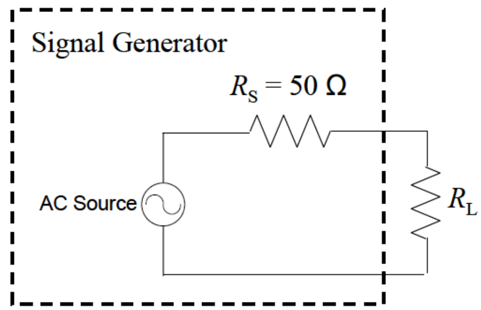
2. There are three 5-band resistors, they have different band colors. Try to verify the values. (The fifth band indicates tolerance) **__/9pt**

Colors					Value
Red	Yellow	Black	Orange	Brown	
Orange	Red	Black	Yellow	Brown	
Brown	Black	Red	Black	Red	

3. Read the value of those chip resistors below: **__/12pt**

(____________) (_____________) (_____________) (_____________)

4. If R_L is 500Ω, and the signal generator display shows V_{pp} = 0.5V, what is the actual peak to peak amplitude of the signal across R_L? **__/6pt**



5. A piece of valuable experience about how to protect those devices is to learn some related knowledge before using them. Surf on the Internet and write down several attentions about using multimeter and soldering device. **__/8pt**

TA checkoff ______________________________

Lab1 Report

Name ______________ TA Checkoff ______________

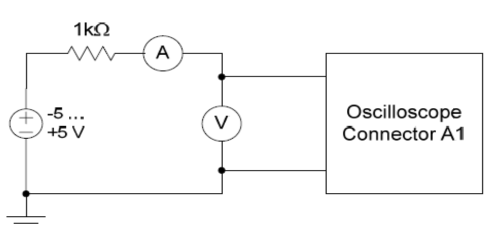
Teammate ______________ Score ______________

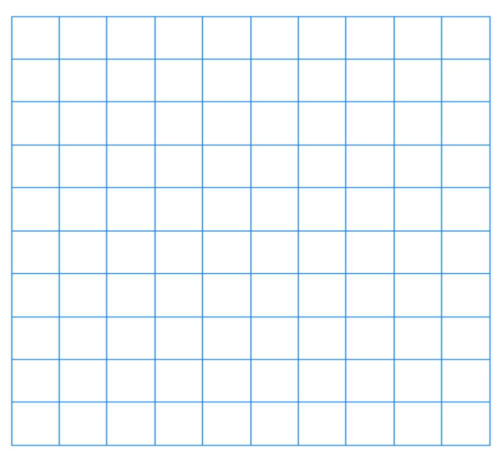
Part One:

Oscilloscopes are complicated electronic instruments for measuring voltage versus time. We will make extensive use of an oscilloscope later in this course, but today we treat the oscilloscope as a simple circuit element without worrying about its internals.

Use the circuit shown below to measure the I/V characteristic for V = -5 … +5V and graph (do not forget to label the axis and unit!) your result in the chart provided. Make sure that the oscilloscope is turned on when making the measurement. After removing the scope probe from the circuit, check your result with the ohm meter setting of the multimeter. You can use one multimeter as amperemeter and another as voltmeter. Use the multimeter from the team next to you if one is not enough.

Note: use an oscilloscope probe with a hook and a black clip to connect the scope and tie the black strand to the common terminal of the supply. Ask the TA if you are not sure how to do this.



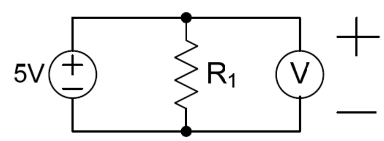


What value resistor has the same IV characteristic?
Extracted resistance: _____ Ω **__/5pt**
The function of the resistor in the circuit: __________________ **__/5pt**

Does the amperemeter reading change after the voltmeter is removed? Why? **__/10pt**

Part Two:

Set the DC power supply for 5V output and 20mA maximum current and load it with resistor R_1=1kΩ.



a. Verify the output voltage with the voltmeter. (Use the multimeter for all these measurements. The meter that is built into the supply is not accurate). **__/10pt**

Predicted value: _____ V

Measured Value: _____ V

b. Disconnect the voltmeter. What is the current flowing through resistor R_1? **__/10pt**

Predicted value: _____ A

Design a circuit for measuring the current flowing through R_1. Your diagram should include the supply, resistor, and the ampere meter.

Measured Value: _____ A

Explain discrepancies:

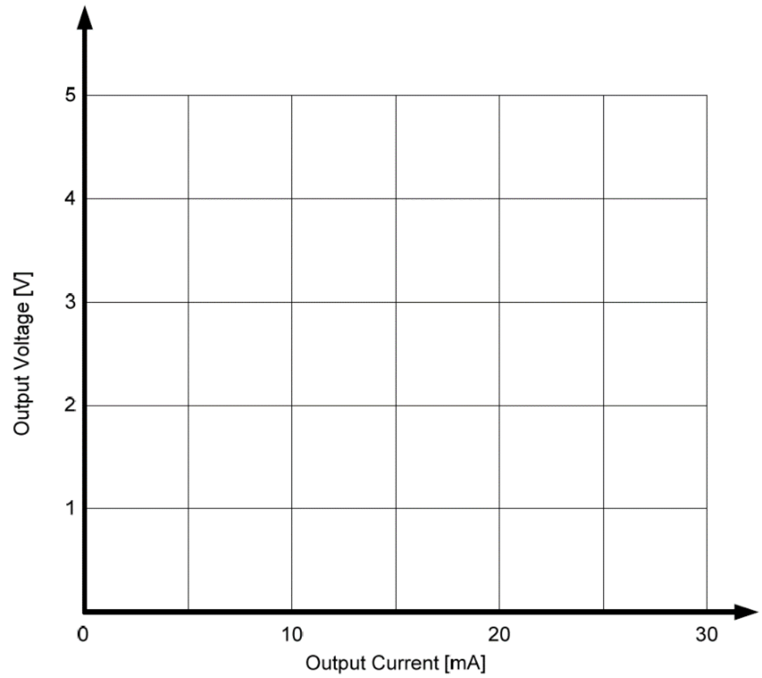
c. Replace R_1 with a 100Ω resistor. What are the voltage across and current flowing through the resistor? **__/10pt**

Predicted values: _____ V _____ A Measured values: _____ V _____ A

Explain discrepancies:

d. Measure the IV characteristic of the R1 when R1=100Ω, 300Ω, 1kΩ respectively. Please draw neatly and use a ruler!

__/10pt



TA:	______________________
Part One:	____________**of 20 Pts.**
Part Two:	____________**of 40 Pts.**
Prelab:	____________**of 40Pts.**
Total:	____________**of 100Pts.**