**Electronics Technology and Robotics I Week 2**
**Basic Electrical Meters and Ohm's Law**

- **Administration:**
    - Prayer
    - Bible Verse
    - Turn in quiz
- **Meters:**
    - Terms and Definitions:
        - Analog vs. Digital Displays:  <u>Analog</u> displays have a <u>continuous range</u> of values while <u>digital</u> displays have <u>discrete levels</u> or integers.
        - Concept:  If you were climbing a ramp as in the diagram below, you could stop at any level on the ramp; say 4.23' above the ground.  The ramp has a continuous slope with an infinite number of possible levels in between each foot marker.  However, if you climb the steps, you can only stop at the discrete levels of the foot markers.  You could not stop at 4.23' above the ground; you could only stop at 4' or 5' above the ground.
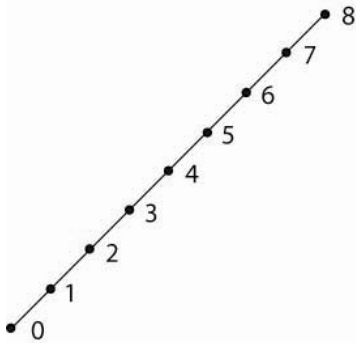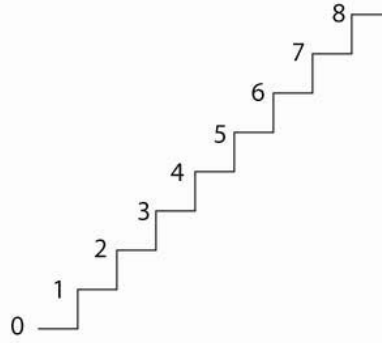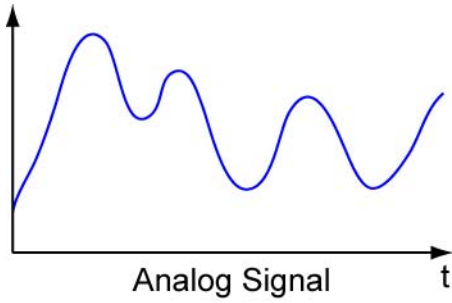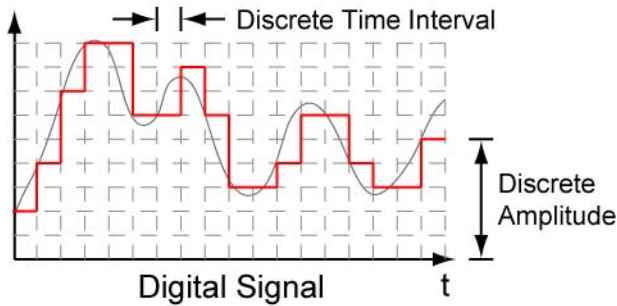


    **A Ramp (Analog)**             **Steps (Digital)**

- Analog vs. Digital Signals: Analog signals are continuous while a digital signal is a signal for which amplitude and time are discrete.


Analog Signal

The amplitude of an analog signal changes continuously with time. An analog signal has a theoretically infinite resolution.


Digital Signal

An analog signal may be converted to a digital signal by sampling the analog signal at discrete time intervals and converting the analog amplitude to a discrete digital amplitude.

- **Analog Meter**: A meter that uses a scale with continuous range of values.
  - Practice reading analog scales:
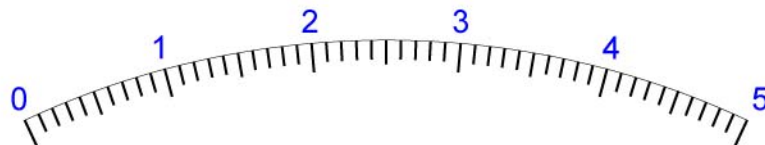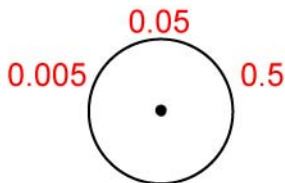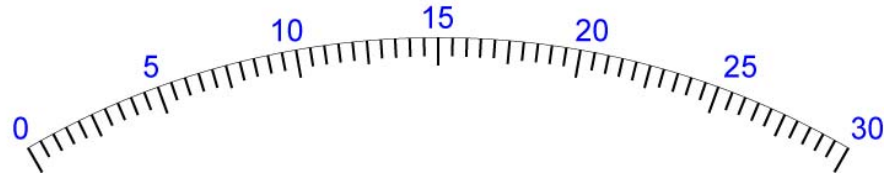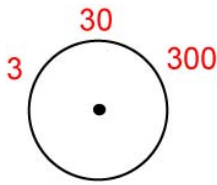




  - Read analog scale examples: vernier calipers, thermometer.

- **Digital Meter**:  A meter that gives values only in discrete amounts.
    - Practice reading digital scales:
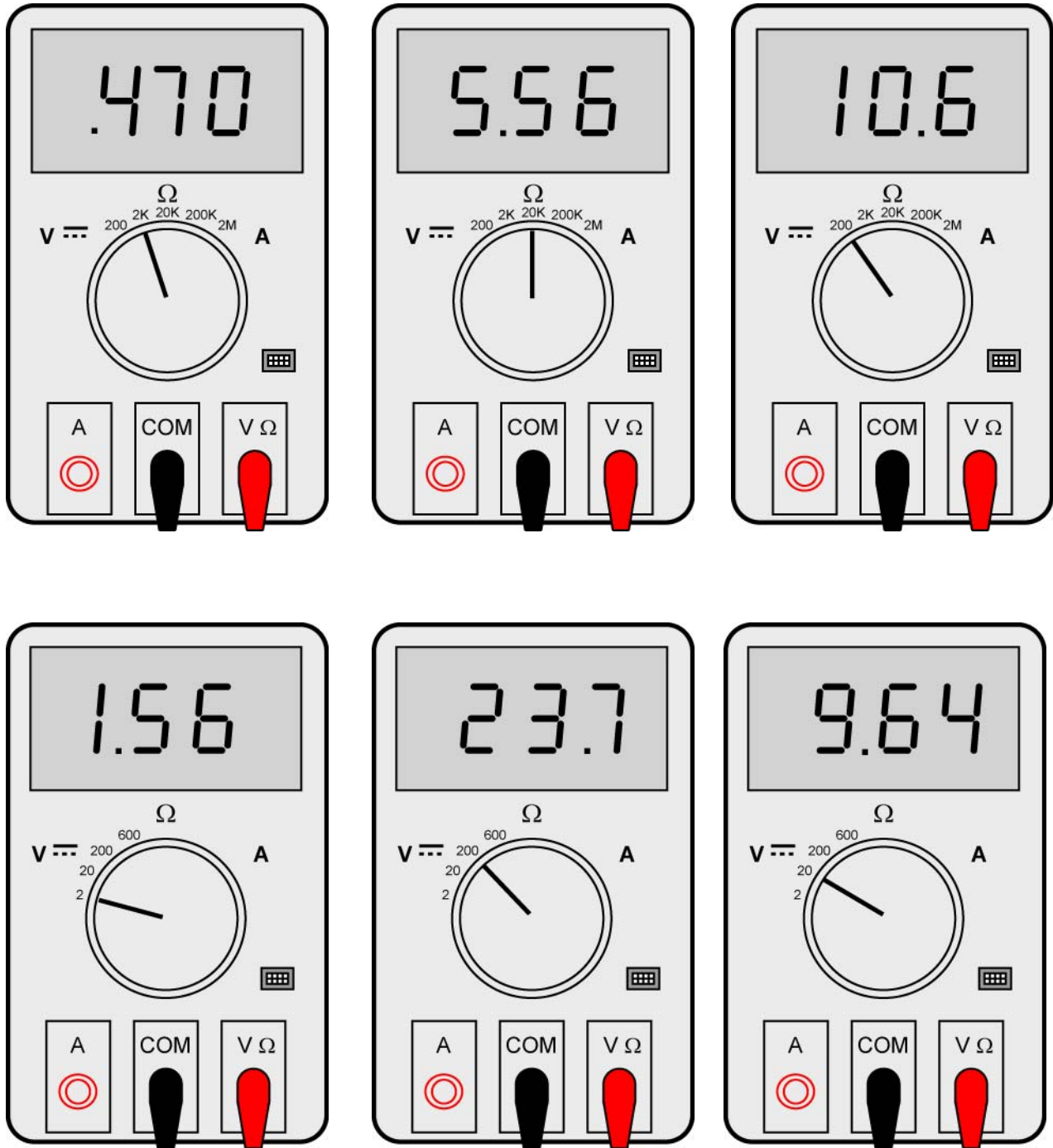


- Read digital scale examples:  calipers, micrometer, digital multimeter (DMM), and thermometer.
- See more digital scale displays in Appendix A.
- See: http://pioneer.netserv.chula.ac.th/~tarporn/311/HandOut/DmmPPT.pdf

- o Meter Probe Adapters:  Attaches test probes to component and IC leads.  See:  http://www.radioshack.com/home/index.jsp  Part #270-334
- o When removing the adapter from the test probe, **push from the base** of the adapter.



**Attach Adapters to Test Probes**
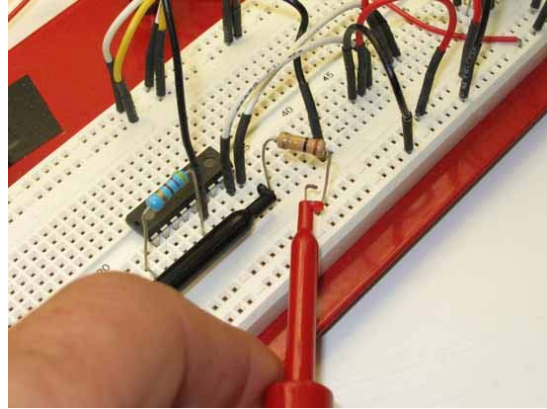


**Attach Adapter to Component Lead**

- Electricity and Electronics, **Section 2.2**, Ammeter:
  - Terms and Definitions:
    - **Ammeter**:  An ammeter measures electrical current in a circuit.
  - Using an ammeter to measure current:
    - An ammeter <u>must always</u> be connected <u>in series</u> (in line) with a circuit component.  In other words, the circuit must be broken at the point of measurement and the ammeter inserted.
    - When a current value is unknown, <u>begin with the highest</u> meter range.
    - **Never** connect an ammeter to a power source.
    - In dc circuits, the <u>polarity of the meter must match the battery polarity</u>; the positive (+) terminal of the ammeter connects toward the positive (+) side of the battery and the negative (-) terminal of the ammeter connects toward the negative (-) side of the battery.
    - Sample reading:
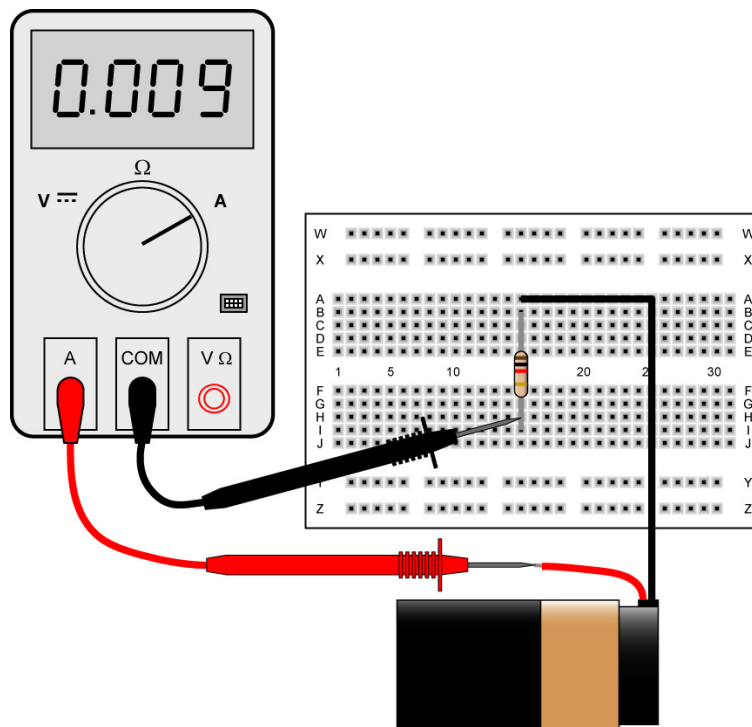


**Ammeter Inserted into a Circuit**

  - Perform Basic Electrical Meters and Ohm's Law  Lab 1 – Ammeter

- Electricity and Electronics, **Section 2.3**, Voltmeter:
  - Terms and definitions:
    - **Voltmeter**:  A voltmeter measures voltage in an electrical circuit.  Voltage is *always relative between two points*.  There is no such thing as voltage "on" or "at" a single point in the circuit.  The voltage reading on a voltmeter is the voltage at one point in the circuit compared to another point in the circuit.
  - Using a voltmeter to measure voltage:
    - Voltmeters <u>are always</u> connected <u>in parallel</u> with the component (across the component); the circuit is not broken as with the ammeter.
    - When the voltage is unknown, <u>start with the highest</u> meter range.
    - In dc circuits, the <u>polarity of the meter must match the battery polarity</u>; the positive (+) terminal of the voltmeter connects toward the positive (+) side of the battery and the negative (-) terminal of the voltmeter connects toward the negative (-) side of the battery.
    - Sample reading:



**Voltmeter Connected in Parallel with the Component**

  - Complete Basic Electrical Meters and Ohm's Law  Lab 2 – Voltmeter
  - See:
    - http://micro.magnet.fsu.edu/electromag/java/ohmslaw/
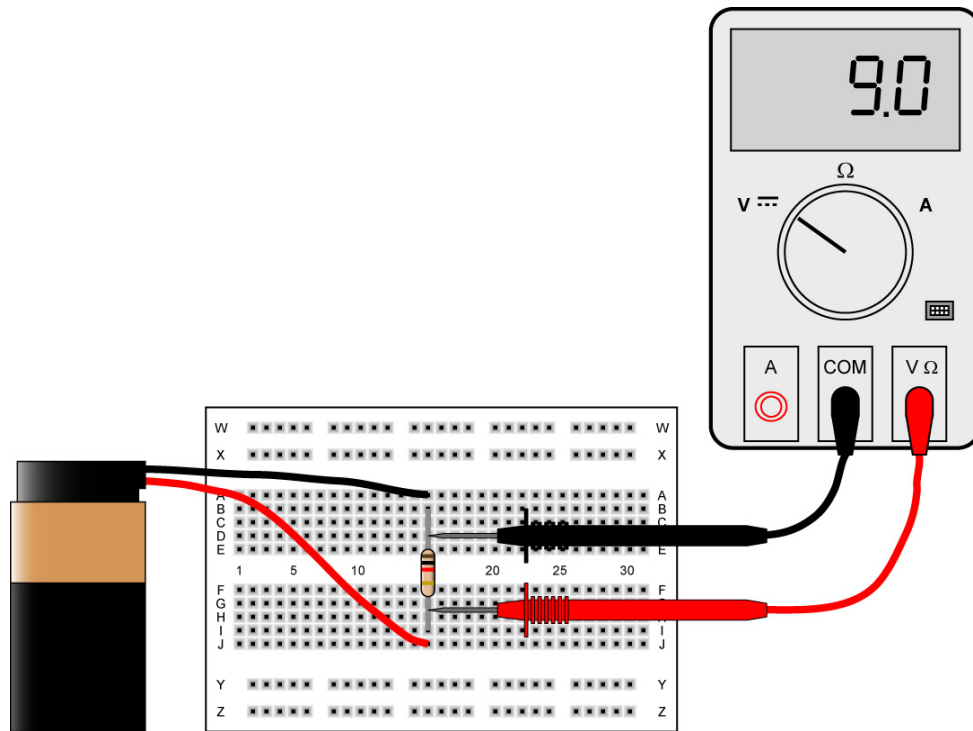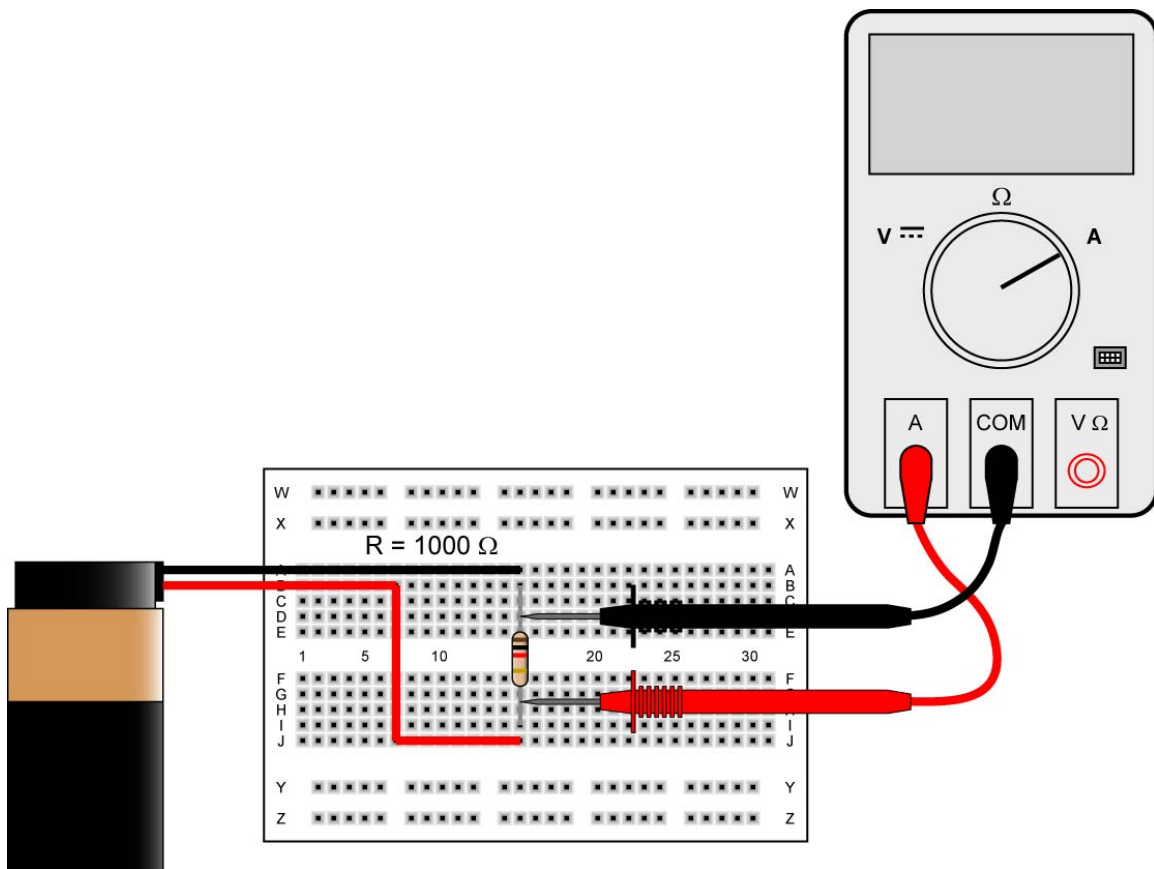    - http://www.ngsir.netfirms.com/englishhtm/Circuit.htm

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- Electricity and Electronics, **Section 2.4,** Ohmmeter:
  - o Terms and definitions:
    - ▪ **Ohmmeter**: An ohmmeter measures electrical resistance which is the opposition to the flow of an electric current.
    - ▪ Always make sure that the power is off to the circuit.
    - ▪ When measuring resistance, the resistor must be disconnected from the circuit.
    - ▪ When the resistance is unknown, as usual, start with the highest meter range.
  - o Special Readings for an Ohmmeter:
    - ▪ A reading of zero indicates a short circuit.
    - ▪ A reading of infinity indicates an open circuit.
  - o Perform Basic Electrical Meters and Ohm's Law Lab 3 – Ohmmeter



**Is There Anything Wrong with This Meter Setup?**

- **Digital Multimeters (DMM):**
  - Digital multimeters are so named because they have the ability to measure a multiple of variables: voltage, current, resistance, transistors, and often many others.
  - Additional practices when making electrical measurements:
    - Make a touch test first. Clip the ground lead first, and then touch the red lead to the measuring point before clipping the lead to that point in the circuit.
    - Make sure the leads do not cross over or come in contact with other connection points, causing a possible short circuit.
    - Always check the selector mode and meter jacks before connecting the leads. This is especially true when measuring voltage after you have measured current or resistance.
- **Electricity and Electronics, Section 1.4, Ohm's Law:**
  - **Ohm's Law Equation**: The mathematical relationship between voltage, current, and resistance.

    $V = I \times R$ where:

    V = voltage in volts,
    I = current in amperes, and
    R = resistance in ohms

    From $V = IR$, we can derive the two equations,

    $I = V / R$ and,

    $R = V / I.$

    So voltage is directly related to current and resistance, while current is inversely related to resistance. Also, resistance is inversely related to current. Is current directly or inversely related to voltage?
  - **Statement of Ohm's Law:** The current through a resistor is proportional to the potential difference between its ends, provided the temperature of the conductor remains constant.
  - See Ohm's Law applets at:
    - http://micro.magnet.fsu.edu/electromag/java/ohmslaw/index.html
    - http://www.electricalfacts.com/Neca/Exp/Exp2/ohm1.shtml
    - http://www.falstad.com/circuit/e-ohms.html
    - http://www.angelfire.com/pa/baconbacon/page2.html
    - http://www.youtube.com/watch?v=-mHLvtGjum4&feature=related

- Using a variable resistor and a dc power supply set up circuits that illustrate each form of Ohm's Law while changing only one of the variables. Also have the students insert analog volt and ammeters into the circuits.
  - Use 18 volt power supply and 50 ohm, 100 watt variable resistor
  - V is directly related to I:
    - Set resistor to 25 ohms (constant)
    - Current = .12 A, voltage = 3 V
    - Current = .24 A, voltage = 6 V
  - V is directly related to R:
    - Set resistor to 20 ohms, voltage = 3 V and current = .15 A(constant)
    - Set resistor to 40 ohms, take current to .15 A, voltage = 6 V
  - I is inversely related to R:
    - Set variable resistor to 20 ohms, voltage = 6 V (constant),      current = .3 A
    - Set variable resistor to 40 ohms, voltage = 6 V, current = .15 A

■ Sample Test Circuit:



$$V = I\,R$$
$$V = 0.009\ A \times 1000\ \Omega$$
$$V = 9.0\ V$$

R = 1000 Ω

9 V
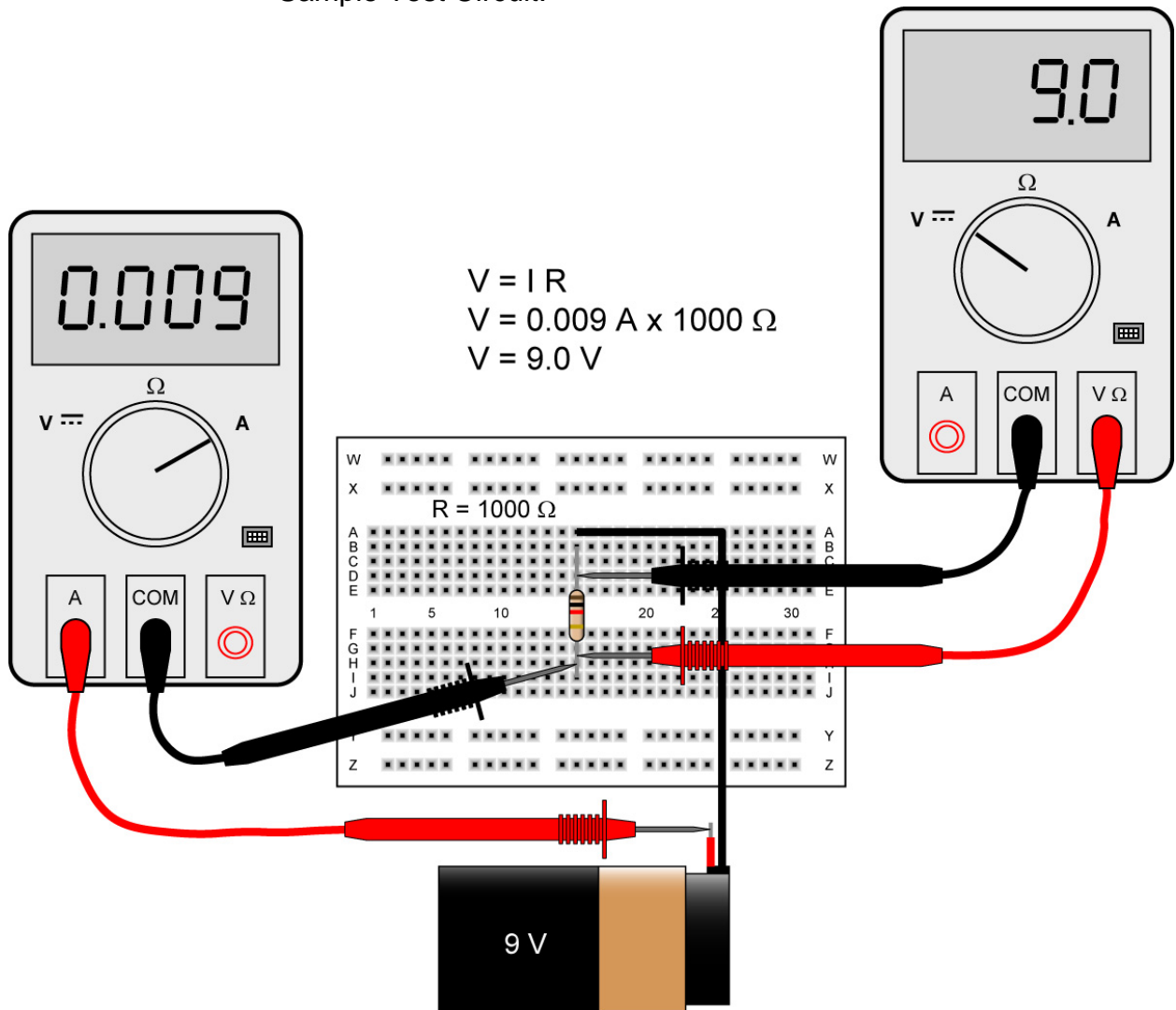
**Using DMMs to Check Ohm's Law – Ammeter on Left Is Inserted into the Circuit,**
**The Voltmeter on Right is Parallel to the Component (1K Resistor)**

- ■ Perform  Basic Electrical Meters and Ohm's Law  Lab 4 – Measurements and Calculations
- o The variables used in Ohm's Law equations must be *common* to the same two points in the circuit under consideration.  A student might mistakenly use a value for I, current, through one resistor and the value for V across a set of interconnected resistors, incorrectly thinking that they'll arrive at the resistance of that one resistor.
  - ■ When using Ohm's Law to calculate a variable pertaining to a single component, be sure the voltage you're referencing is solely across that single component and the current you're referencing is solely through that single component and the resistance you're referencing is solely for that single component.

- Likewise, when calculating a variable pertaining to a set of components in a circuit, be sure that the voltage, current, and resistance values are specific to that complete set of components only! A good way to remember this is to pay close attention to the *two points* terminating the component or set of components being analyzed, making sure that the voltage in question is across those two points, that the current in question is the electron flow from one of those points all the way to the other point, that the resistance in question is the equivalent of a single resistor between those two points.
  - A local change in one resistor value implies a global change in the circuit, i.e., a change in the operation of the entire circuit.
  - See: http://utwired.engr.utexas.edu/rgd1/lesson01.cfm

- **Electrical Prefixes:**
  - Pay close attention to <u>mega, kilo, milli, micro</u>. These prefixes are the most commonly used in electronic circuitry.
  - Common Electrical Prefixes:

### Common Electrical Prefixes

| Prefix | Symbol | Decimal Equivalent | Power of Ten |
|---|---|---|---|
| tera | T | 1,000,000,000,000 | $10^{12}$ |
| giga | G | 1,000,000,000 | $10^{9}$ |
| mega | M | 1,000,000 | $10^{6}$ |
| kilo | k | 1,000 | $10^{3}$ |
| base unit | | 1 | $10^{0}$ |
| milli | m | 0.001 | $10^{-3}$ |
| micro | u | 0.000001 | $10^{-6}$ |
| nano | n | 0.000000001 | $10^{-9}$ |
| pico | p | 0.000000000001 | $10^{-12}$ |

  - Number Place Values:

| Symbol | T | | | G | | | M | | | k | | | | | m | | | | | μ | | | n | | | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Prefix | tera | | | giga | | | mega | | | kilo | | | | | milli | | | | | micro | | | nano | | | pico |
| Place Value | trillions | hundred billions | ten billions | billions | hundred millions | ten millions | millions | hundred thousands | ten thousands | thousands | hundreds | tens | ones | decimal point | tenths | hundredths | thousandths | ten-thousandths | hundred-thousandths | millionths | ten-millionths | hundred-millionths | billionths | ten-billionths | hundred-billionths | trillionths |
| Place from Decimal | 12, | 11 | 10 | 9, | 8 | 7 | 6, | 5 | 4 | 3, | 2 | 1 | 0 | . | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

**Chart for Place Values of Numbers**

  - Moving the decimal point:  If you are converting from a smaller prefix to a **larger** prefix, move the decimal point to the **left**. Remember:

"**Left** for **Larger**"
**Larger** Prefix – Move the Decimal to the **Left**

- Examples:
  - Convert 50 milliamps (mA) to amperes (A). We are converting from a smaller prefix (mA) to a **larger** prefix (A), so we move the decimal to the **left** three places.

    $$.0\,5\,0,$$

    Therefore 50 mA = .05 A or 0.05 A.

  - Convert 0.22 K V to V. The conversion is from larger to **smaller** prefix, therefore move the decimal to the **right** three places.

    $$0.2\,2\,0.$$

    Therefore 0.22 K V = 220 V.

  - Convert 6.8 M Ω to Ω. The conversion is from larger to **smaller** prefix, therefore move the decimal to the **right** six places.

    $$6.8\,0\,0\,0\,0\,0.$$

    Therefore 6.8 M Ω = 6,800,000 Ω.

- Related Web Sites:
  - http://en.wikipedia.org/wiki/Ohms_law
  - http://jersey.uoregon.edu/vlab/Voltage/
  - http://micro.magnet.fsu.edu/electromag/java/ohmslaw/
  - http://www.allaboutcircuits.com/vol_1/chpt_2/1.html
  - http://www.grc.nasa.gov/WWW/K-12/Sample_Projects/Ohms_Law/ohmslaw.html

# Electronics Technology and Robotics I Week 2
## Basic Electrical Meters and Ohm's Law Lab 1 – Ammeter

- **Purpose:** The purpose of this lab is to acquaint the student with measuring current using an ammeter and to become acquainted with current relationships in a series circuit.

- **Apparatus and Materials:**

    - 1 – Digital Multimeter (DMM)
    - 1 – Battery Holder and Battery
    - 1 – SPST Switch
    - 1 – 1 Ohm Resistor
    - 2 – Lamp Holders
    - 2 – 2.5 V Lamps
    - Alligator Clips

- **Procedure:**
    - Wire the following circuits and then use your ammeter to measure the current at each point labeled.
    - Record your results in the tables below.
    - Write your conclusions regarding your results.
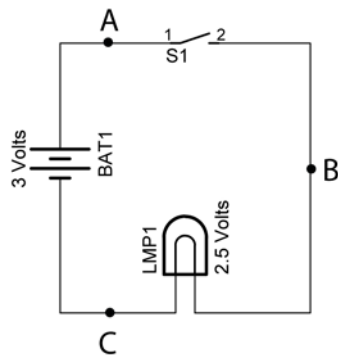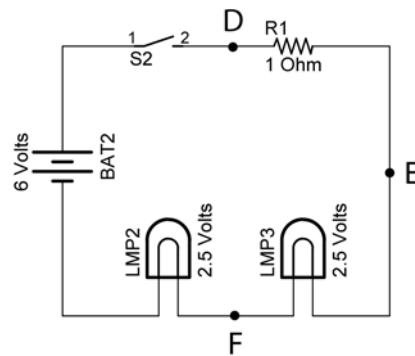


Circuit 1                           Circuit 2

- **Results:**

| Point | Current in mA |
|-------|---------------|
| A     |               |
| B     |               |
| C     |               |

**Circuit 1**

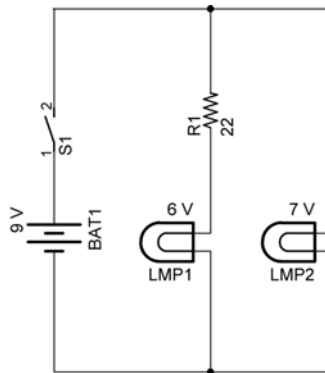| Point | Current in mA |
|-------|---------------|
| D     |               |
| E     |               |
| F     |               |

**Circuit 2**

- **Conclusions:**

**Electronics Technology and Robotics I Week 2**
**Basic Electrical Meters and Ohm's Law Lab 2 – Voltmeter**

- **Purpose:** The purpose of this lab is to acquaint the student with measuring voltage using a voltmeter.

- **Apparatus and Materials:**
    - 1 – Digital Multimeter (DMM)
    - 1 – Battery Snap and 9 V Battery
    - 1 – SPST Switch
    - 1 – 22 Ohm Resistor (Red, Red, Black)
    - 2 – Lamp Holders
    - 1 – 6 V Lamp and 1 – 7.5 V Lamp
    - Alligator Clips

- **Procedure:**
    - In the Circuit 3 below, close the switch then measure and record the voltage:
        - Across the battery terminals
        - Across the resistor
        - Across the 6 volt lamp. Add the voltage drops across the resistor and the 6 volt lamp, then compare the sum with the voltage drop across the battery.
        - Across the 7.5 volt lamp. Compare this reading with the voltage drop across the battery.
        - In the conclusions, describe how the sum of the voltage drops across the 6 V lamp and the resistor compare to the battery.



Circuit 3

- **Results:**

| Component | Voltage in Volts |
|---|---|
| Battery | |
| Resistor | |
| 6 V Lamp | |
| 7.5 V Lamp | |

- **Conclusions:**

**Electronics Technology and Robotics I Week 2**
**Basic Electrical Meters and Ohm's Law Lab 3 – Ohmmeter**

- **Purpose:** The purpose of this lab is to acquaint the student with measuring resistance using an ohmmeter.

- **Apparatus and Materials:**

    o  1 – Digital Multimeter (DMM)
    o  Assortment of Resistors

- **Procedure:**
    o  Measure and record the value of each resistor.

- **Results:**

| Resistor | Resistance in Ohms |
|:--------:|:------------------:|
| A |  |
| B |  |
| C |  |
| D |  |
| E |  |
| F |  |
| G |  |
| H |  |

# Electronics Technology and Robotics I Week 2
## Basic Electrical Meters and Ohm's Law Lab 4 – Measurements and Calculations

- **Purpose:** The purpose of this lab is to have the student apply Ohm's Law to several circuits and then verify the calculated results.

- **Apparatus and Materials:**

  - 1 – Digital Multimeter (DMM)
  - Circuits by the Instructor

- **Procedure:**
  - Use Ohm's law to analyze Circuits 1 - 6. Measure and record the quantities in the white cells of Table 1 then using Ohm's Law, calculate the unknown quantities of the shaded cells. Show your calculations in the text box.
  - Copy the calculated quantities from Table 1 into the shaded cells in Table 2.
  - Measure those unknown quantities using a DMM and compare with the calculated values.
  - Determine the differences in Table 2.

- **Results:**

| Ohm's Law Calculated | | | |
|---|---|---|---|
| Circuit | Voltage in Volts | Resistance in Ohms | Current in A |
| 1 |  |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |
| 5 |  |  |  |
| 6 |  |  |  |

**Table 1**

| Ohm's Law Measured | | | | |
|---|---|---|---|---|
| Circuit | Unknown Quantity | Calculated | Measured | Difference |
| 1 | Voltage |  |  |  |
| 2 | Resistance |  |  |  |
| 3 | Current |  |  |  |
| 4 | Voltage |  |  |  |
| 5 | Resistance |  |  |  |
| 6 | Current |  |  |  |

**Table 2**

Show calculations:

1.

2.

3.

4.

5.

6.

- **Conclusions:**



- **Challenges:**
    - Design a voltage source where the single load resistance is 100 ohms and the current through the resistor is 50 mA.


## Ohm's Law Lab 1 Circuit Values

| Circuit | Voltage In volts | Current In amps | Resistor In ohms | Power In watts |
|---------|---------|---------|----------|---------|
| 1 | 1.5 | 32 mA | 47 | .25 |
| 2 | 3.0 | 300 mA | 10 | 10 |
| 3 | 3.0 | 14 mA | 220 | .25 |
| 4 | 6.0 | 40 mA | 150 | .25 |
| 5 | 9.0 | 7 mA | 1200 | .25 |
| 6 | 12.0 | 21 mA | 560 | .25 |
| 7 | 12.0 | 54 mA | 220 | 10 |