The Digital Multimeter

Science Learning Center
University of Michigan – Dearborn

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And further modified by Jim Hetrick and Annette Sieg.
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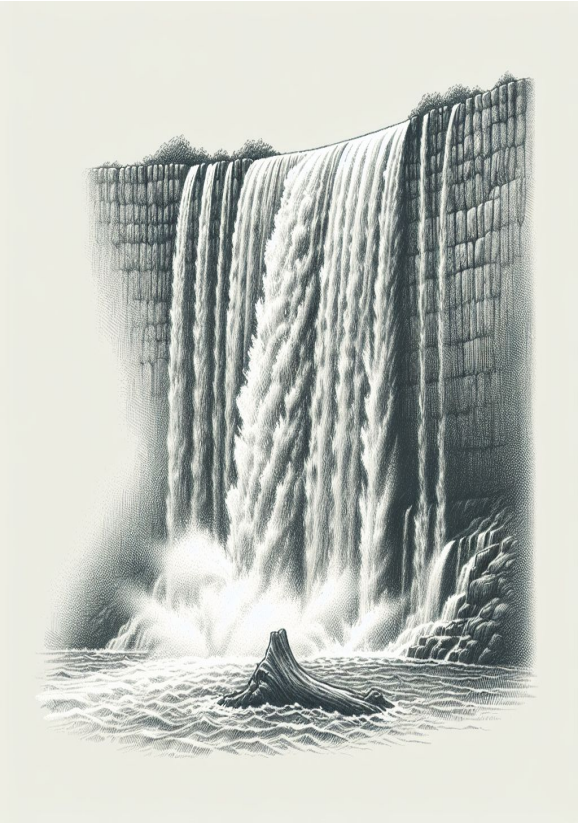
Overview Of Electrical Properties

Electrical Properties

1. **Voltage** provides the energy needed to move charges.
2. **Current** is the rate of flow of charges.
3. **Resistance** is an object's ability to resist the flow of charges.

Waterfall Analogy

- The elevation of a cliff provides gravitational energy, allowing water to flow. **Voltage** is like elevation. It provides the electrical energy needed to move charges.
- The water current flowing would be like the electrical **Current**, or flow of charges.
- The resistance of the waterfall could be air resistance or rocks impeding the flow of water. Electrical **Resistance** impedes charge flow.



Digital Multimeter (DMM) Overview

Why "Multi"meter?

The digital multimeter contains three different meters:

1. A **voltmeter** measures the voltage between two points (in volts, V).
2. An **ammeter** measures the electric current through a device (in amps, A, or milliamps, mA).
3. An **ohmmeter** measures the electrical resistance of a device (in ohms, Ω).

Function Switch

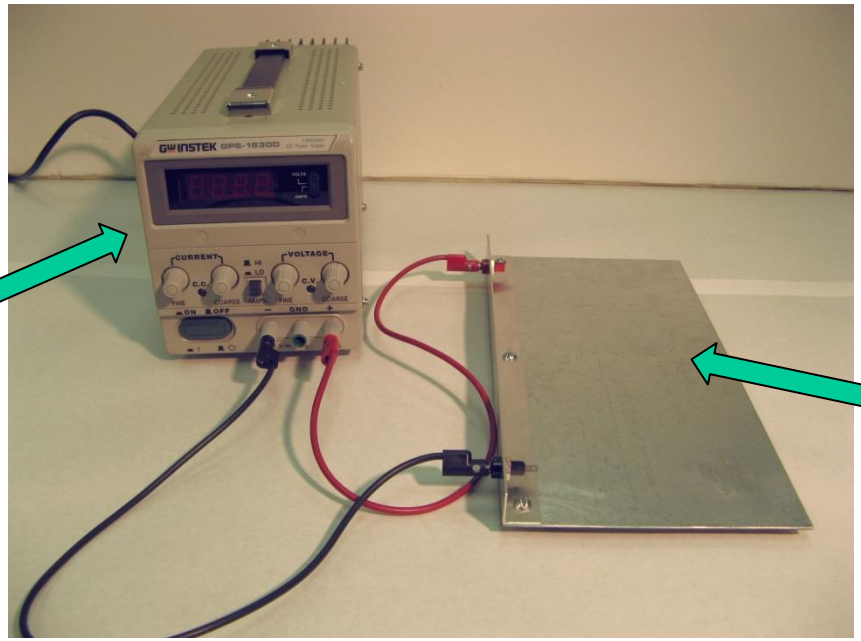
- **OFF** turns the meter off when not in use.
- **V~** measures AC voltage that changes over time
- **V⎓** measures **DC voltage** that is steady over time
- **300 mV** measures low DC voltages (millivolts)
- **Ω** measures **Resistance**
- tests for continuity
- **A~** measures AC current that changes over time
- **A⎓** measures **DC current** that is steady over time

The Design Board And Power Supply

Powering Your Circuit

- You will build your circuits on the Design Board.
- A DC Voltage Supply will power your circuit.

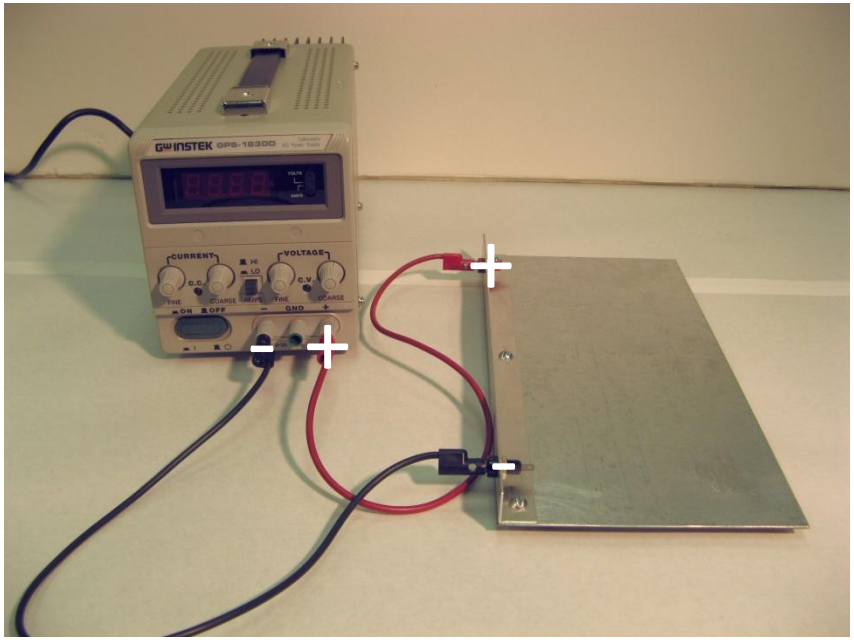
DC Voltage Supply



Design Board

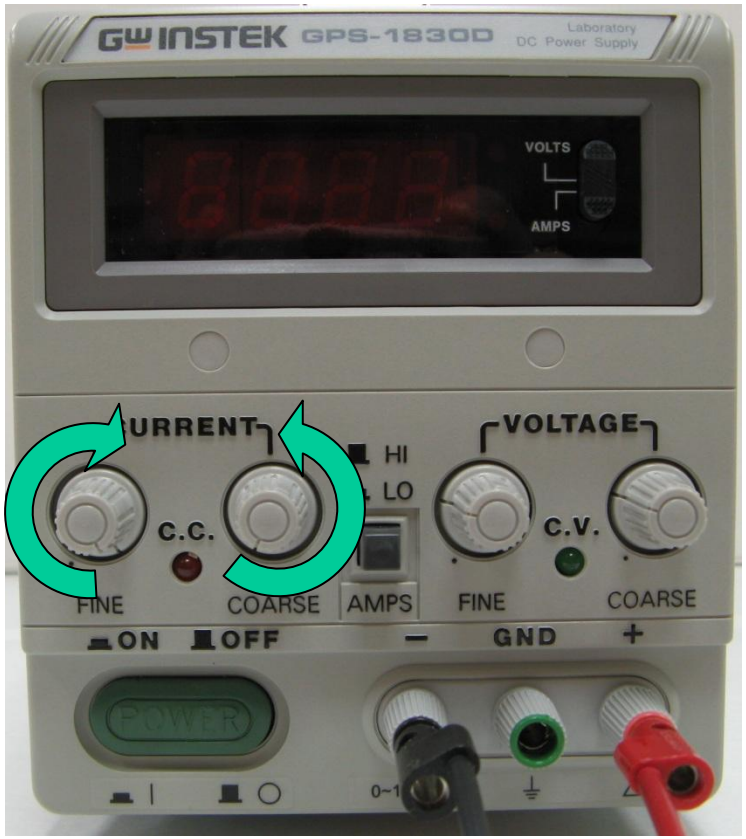
Power Supply Connections

- Use a red cable to connect the positive terminal on the power supply to the red socket on the design board.
- Use a black cable to connect the negative terminal on the power supply to the black socket on the design board.



Power Supply – Limit Current

- Check that the fine current knob is turned fully clockwise.
- Check that the coarse current knob is turned fully counter-clockwise.
- **Keep these knobs in these positions** for the rest of this module.

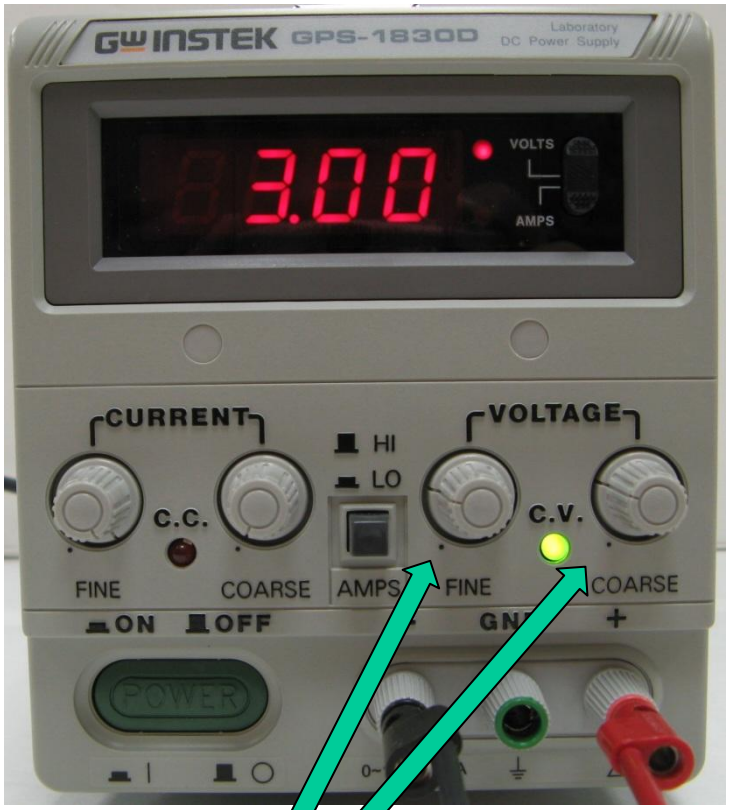


Power Supply – Display

- The power supply can display voltage or current.
- Check that the switch is flipped upward to **VOLTS**.
- Turn the power supply on.

Power Supply – Set Voltage

- If the voltage isn't near 3 V, adjust the coarse voltage knob to get it close.
- Use the fine voltage knob to set the voltage to 3.0 V. (2.95 – 3.05 V is fine.)
- **Keep these knobs in these positions** for the rest of this module.



Voltage Adjustment Knobs

Measuring DC Voltage

Configure the Voltmeter

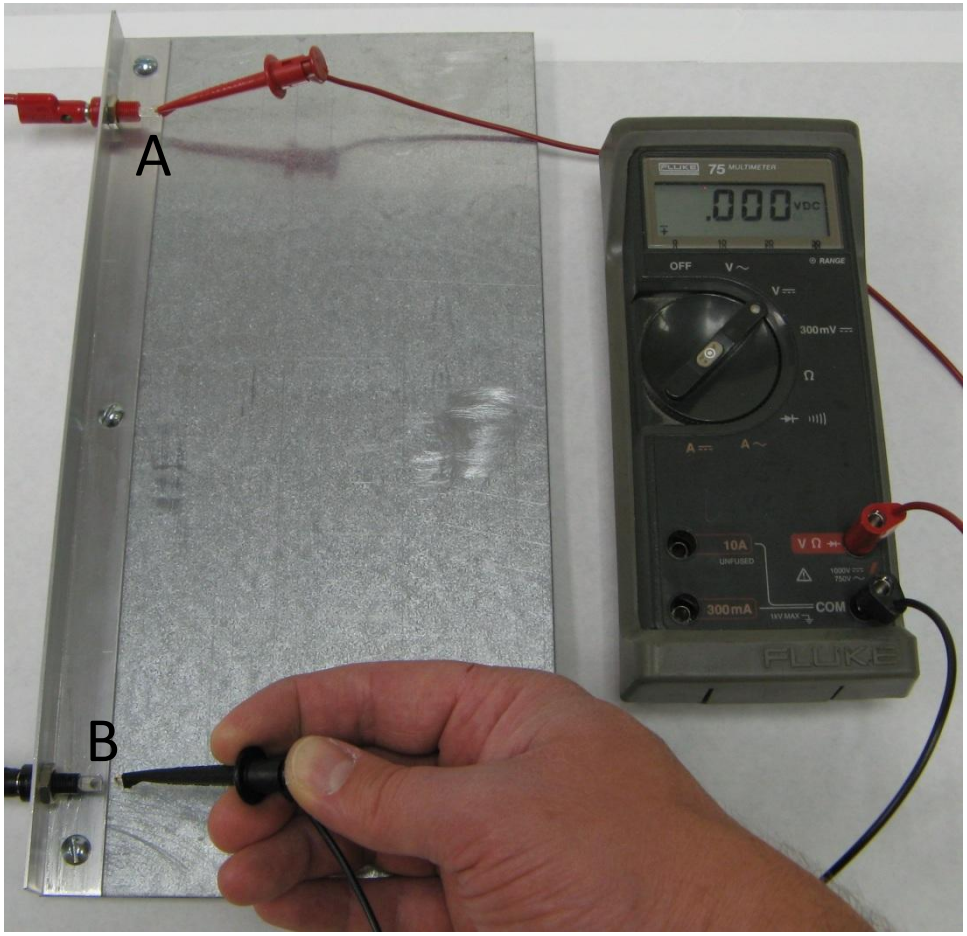
- Turn the function switch to the **DC voltage** position: **V⎓**

- Connect the probes to the multimeter:
  - red probe in the red socket labeled **VΩ**
  - black probe in the socket labeled **COM**

Connect the Voltmeter

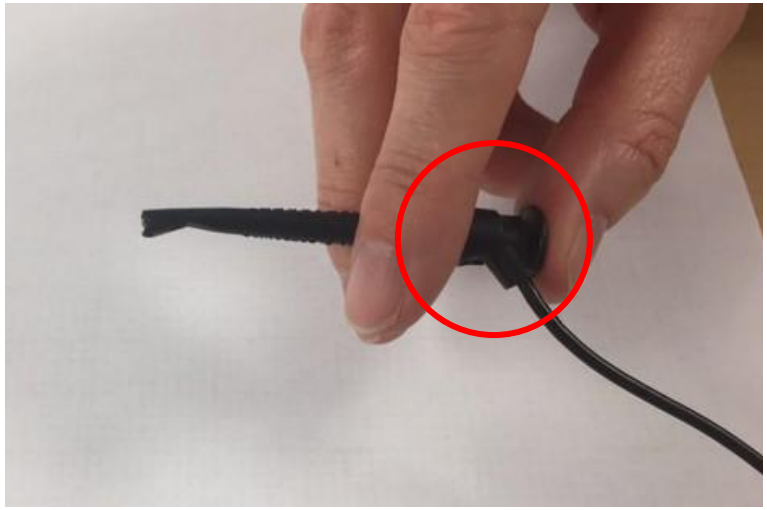
- To measure the **voltage** between two points, just connect the probes to the points.

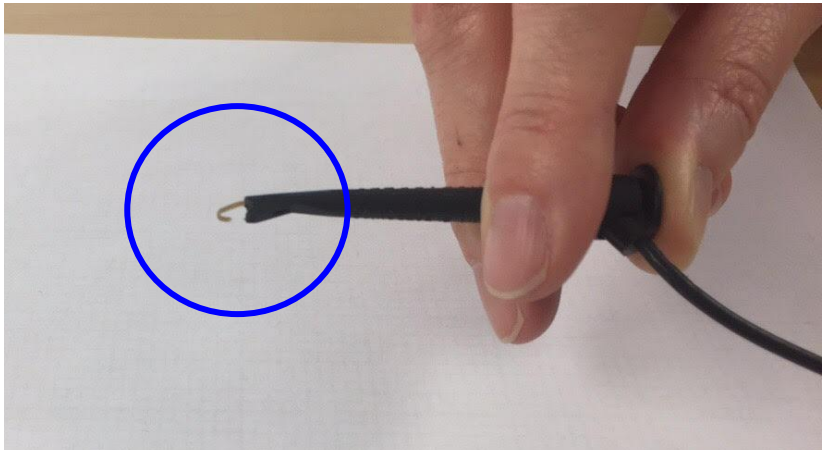
  (See the next slide for more detail on how to connect the probes.)



Connecting Wires

- Squeeze the **grips** at the end of the wire until the **hook** appears.



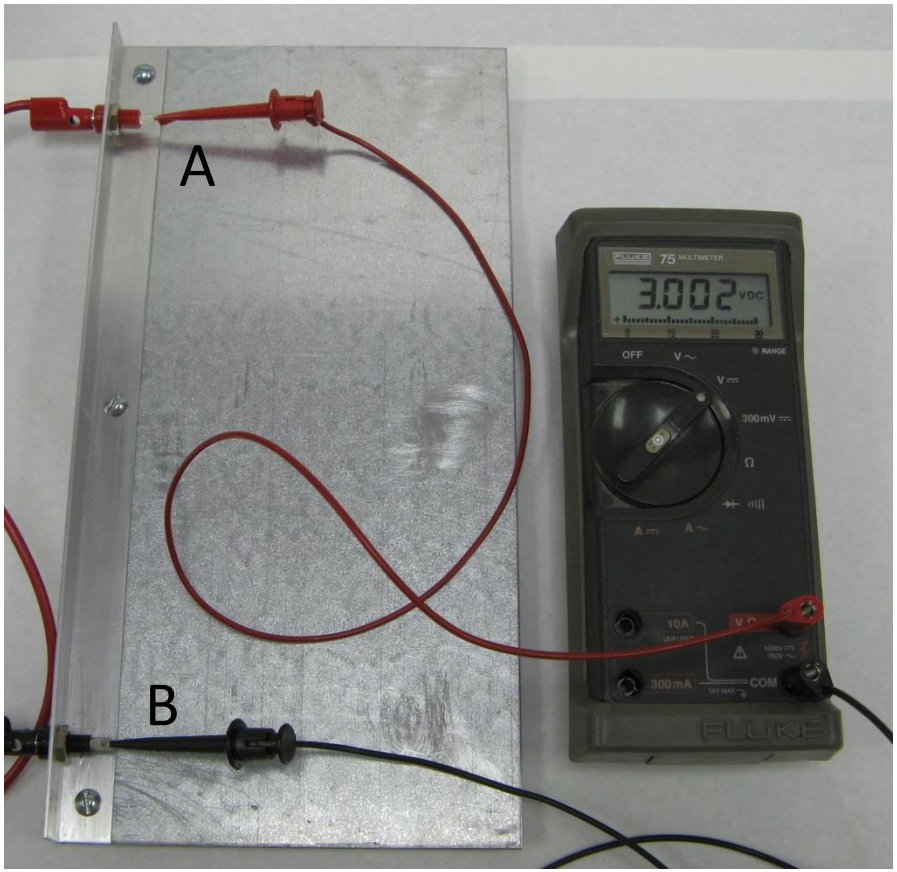


Measure Supply Voltage

- Connect the probes to points A and B. We can call this voltage V_{supply}.
- Measure **V_{supply}**.

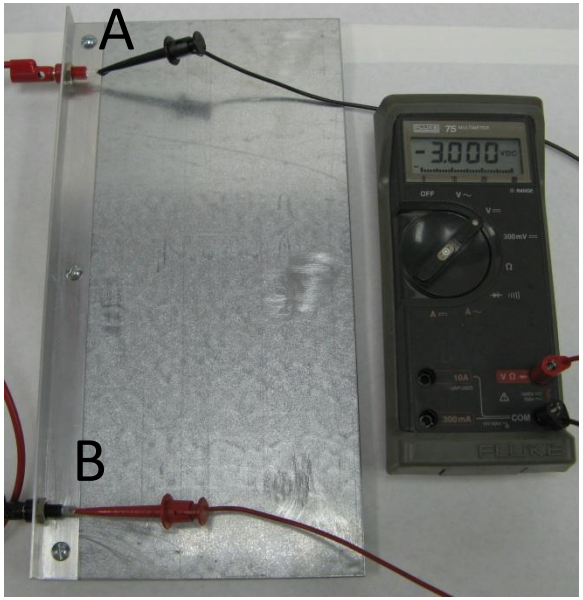
  Note: The screen will display "VDC", but the units are Volts (V).

  Use the answer key to check any of your **measurements**.



Determining Polarity

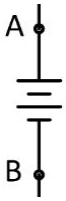
- Positive readings indicate the red (or VΩ) terminal is at the higher potential.
- Negative readings indicate the COM terminal is at the higher potential.
- Switch the probes. Notice the display shows a negative sign.
- When finished, disconnect your multimeter probes.

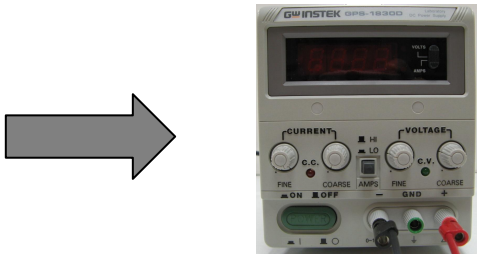


Circuit Diagrams

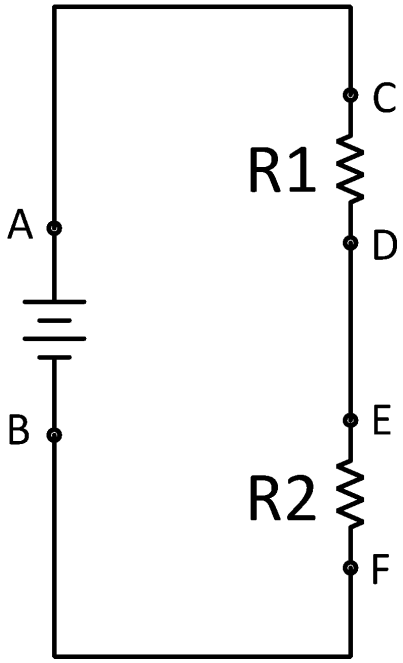
- A circuit diagram is a symbolic representation of a physical circuit.
- The solid black lines represent wires connecting the power supply and the two resistors.

Power supply



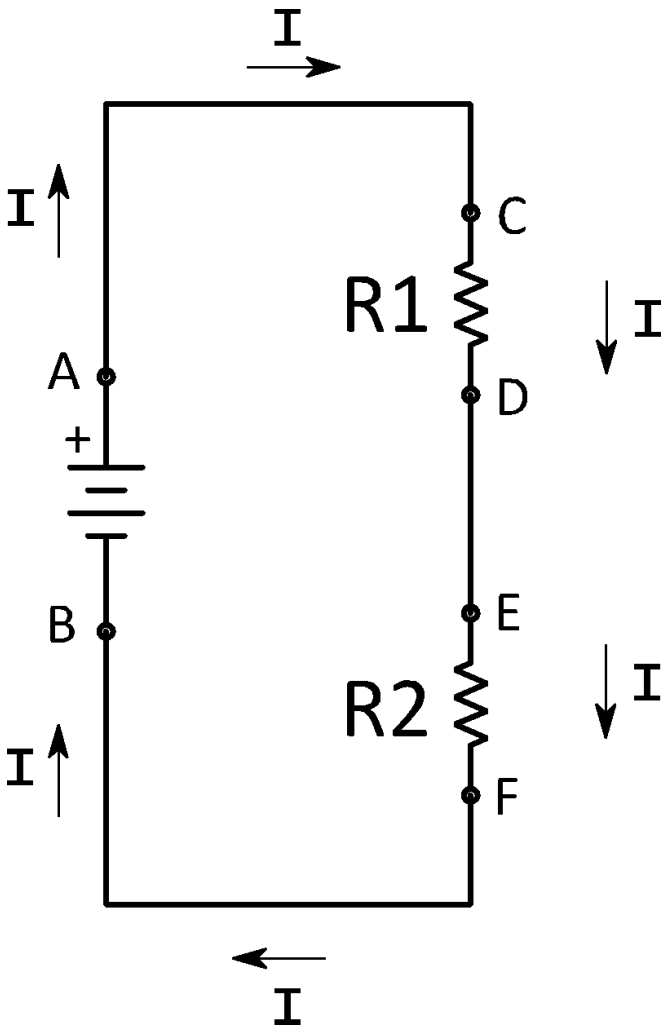


Resistors



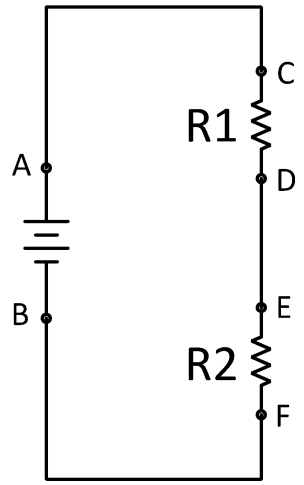
A Complete Circuit

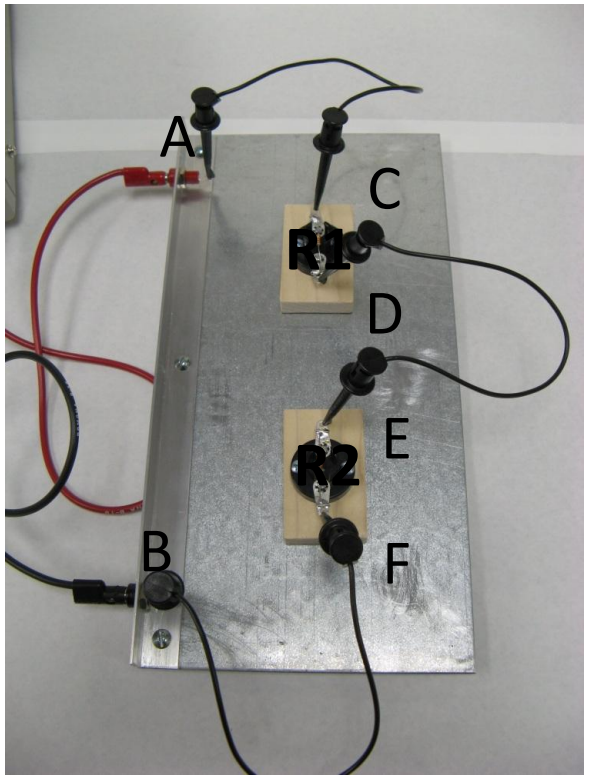
- The connections form a closed loop called a complete circuit.
- Because a complete circuit is formed, the supply voltage can drive a steady flow of charge (current) around the loop.
- If the circuit is a **single** loop:
  - the current (I) will be the same throughout
  - the voltage across each resistor will depend on its resistance



Build the Series Circuit

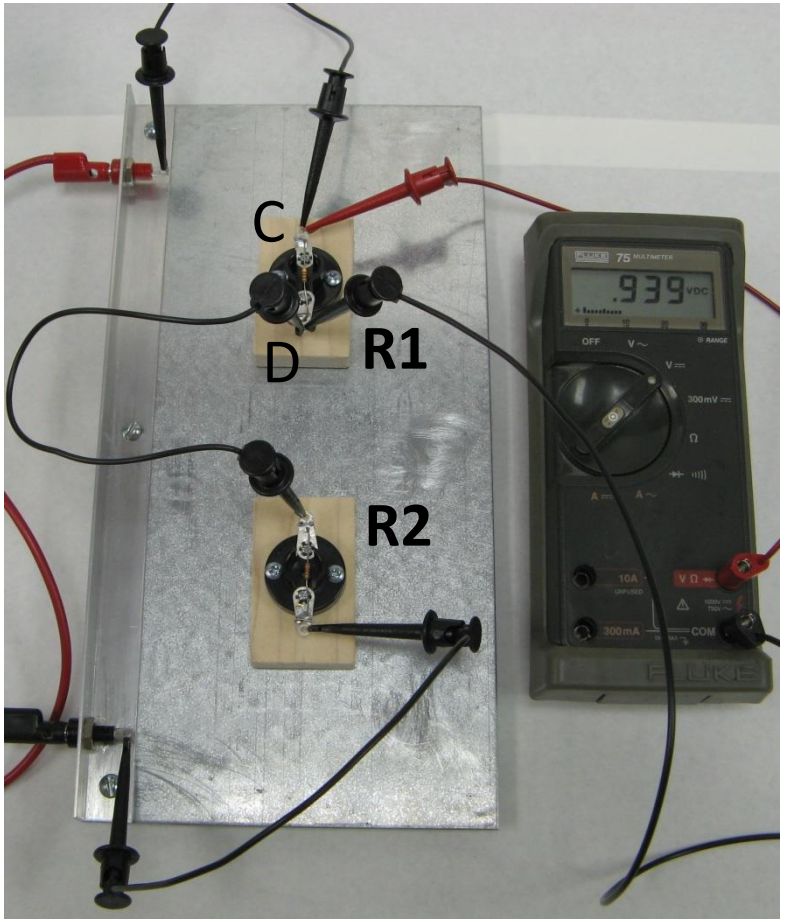
- Find the resistors labeled R1 and R2 and place them as shown.
- Use three short black connector wires to establish connections between points A-C, D-E and F-B.
- This completes what is called a series circuit.





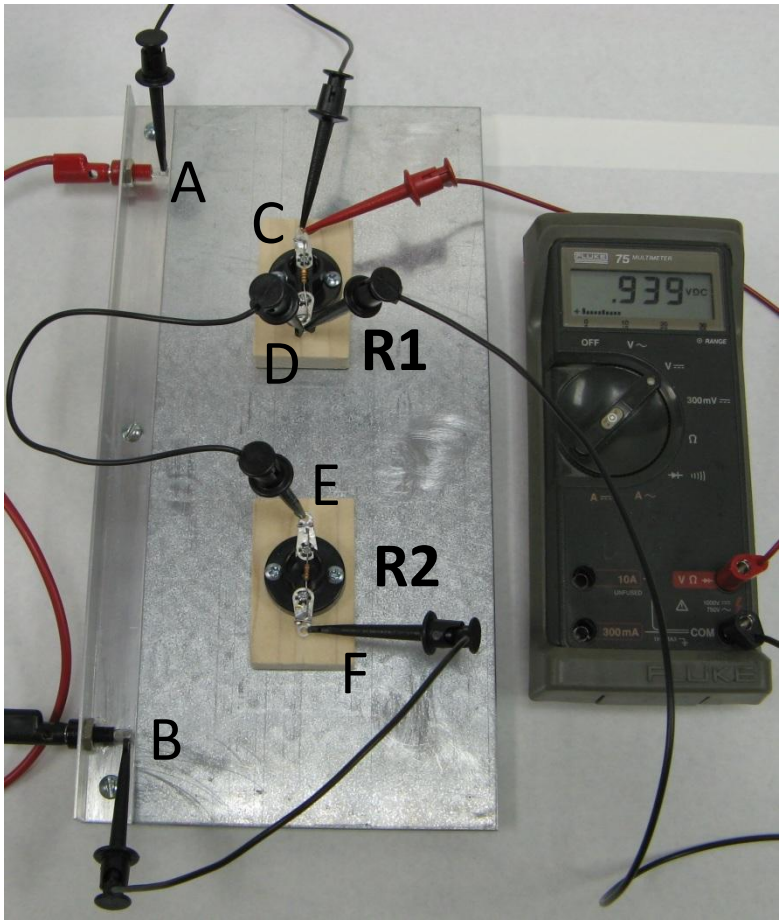
Voltage Across a Component

- Check that the function switch is set to DC Voltage.
- To measure the voltage across a resistor, connect the probes to the terminals of the resistor.
- For resistor **R1**, the terminals are labeled C and D. The measured voltage can be referred to as $\mathbf{V_{CD}}$ or the voltage across **R1.**



Measure Voltages

- Measure V_{AB}.
- Measure V_{CD}.
- Measure V_{EF}.



Voltage Check

- Kirchhoff's Voltage Law, called the “loop law”, states that the sum of voltages around a circuit is zero.
- For this circuit, the loop law gives the following equation:

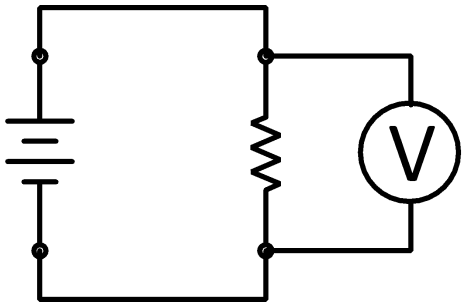
$$V_{CD} + V_{EF} = V_{AB}$$

- Check whether your measurements follow this rule.
- Disassemble your circuit when finished.

Voltage Measurement Summary

Review of how to measure voltage:

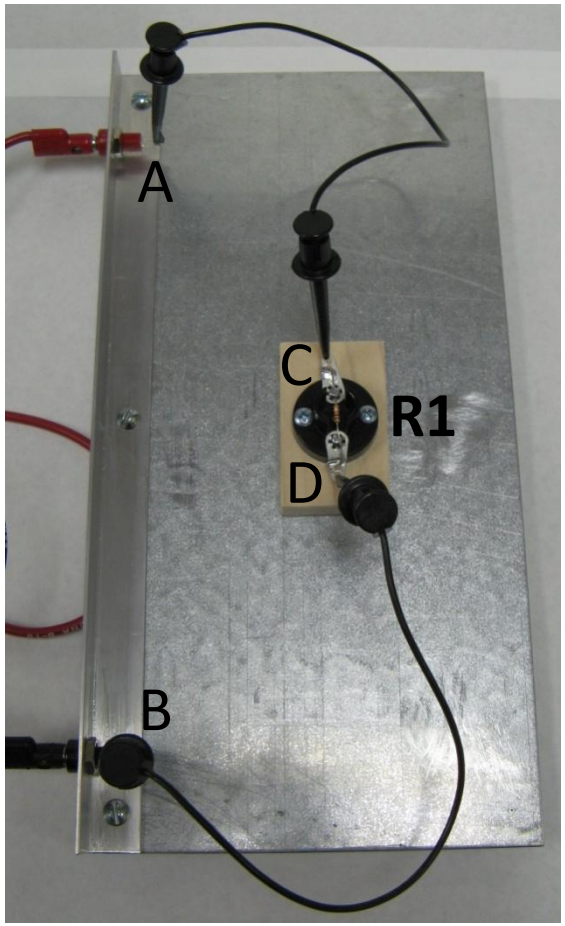
1. Set function switch to **DC Voltage**.
2. Connect the red probe to **VΩ** socket.
3. Connect the black probe to **COM** socket.
4. Connect probes to the two points where you want to measure voltage.
5. Read the meter and record your result in V.

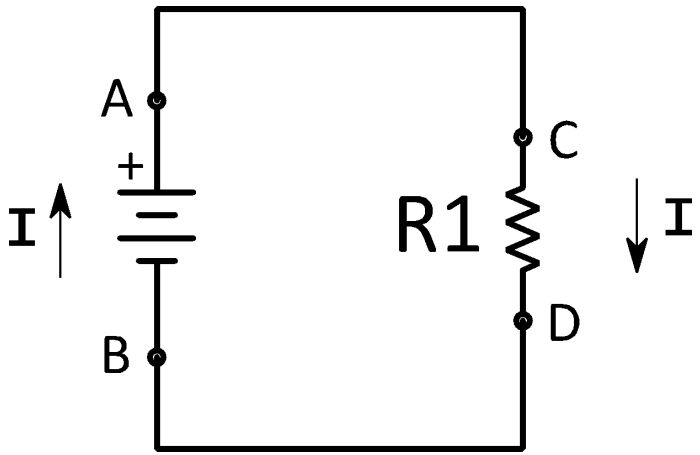


Measuring DC Current

One-Branch Circuit

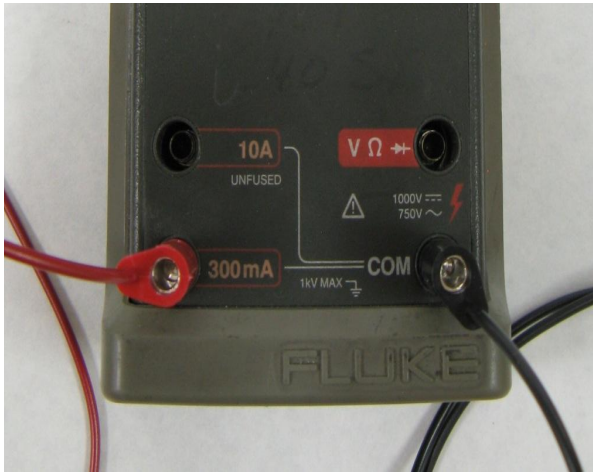
- Build the circuit shown below using resistor R1 and two short black connecting wires.
- This is a complete circuit and there will be a steady flow of charge. The rate of charge flow is electric current, labeled **I** in the diagram.





Configure the Ammeter

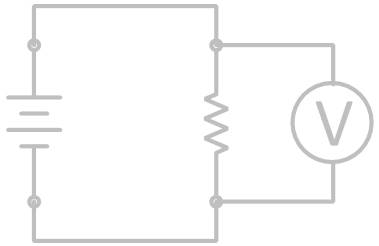
- Turn the function switch to the **DC current** position: **A⎓**
- Connect the probes to the multimeter:
  - red probe in the socket on the left labeled **300 mA**
    - Higher currents up to 10 A can be measured using the 10 A socket.
  - black probe in the socket labeled **COM**



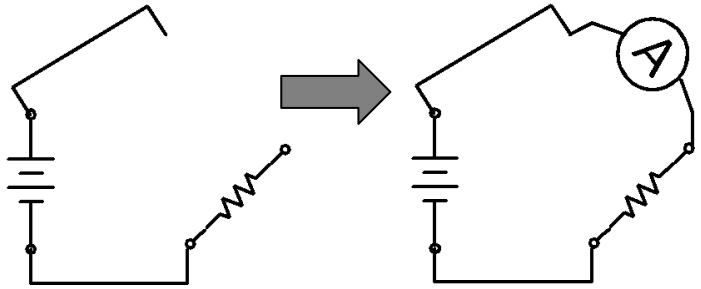
Ammeter Connections

- To measure **current**, we connect the probes to the circuit in a **different** way than we did for voltage.
- The ammeter measures the current flowing **through** it.
- There are multiple ways to measure current. In each, we **disconnect a wire** and connect the ammeter so the current flows through it.

Voltage



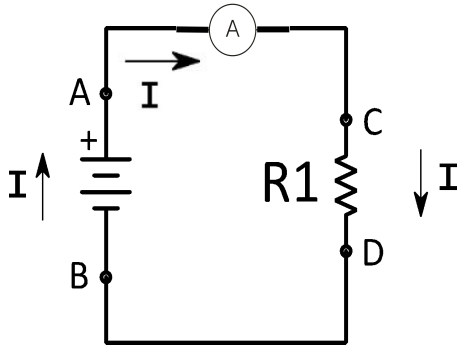
Current

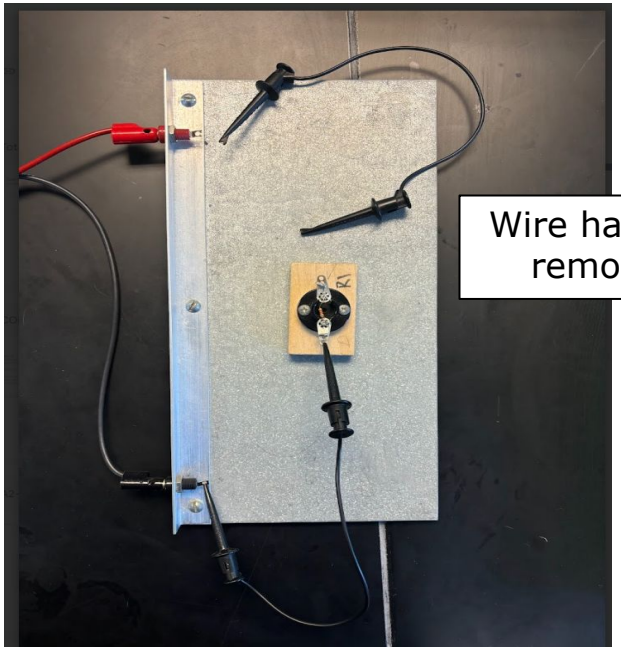


Remove and Replace

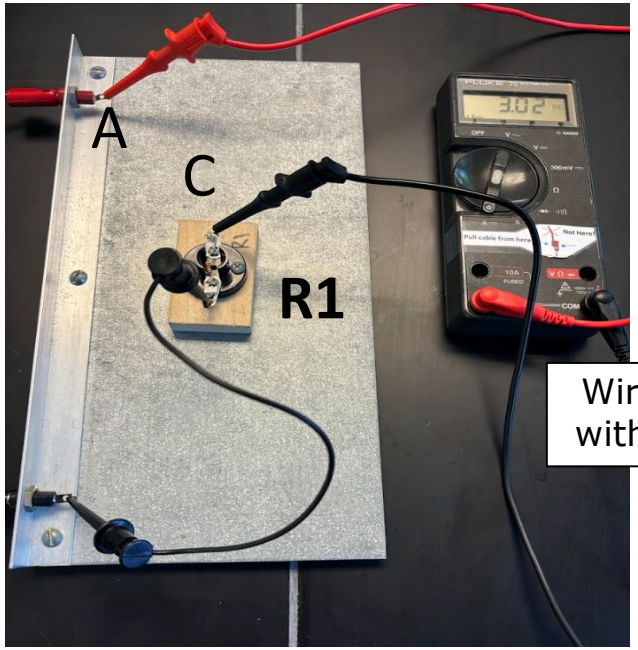
Try this method for measuring current:

- **Remove** a wire and **replace** the wire with the ammeter.





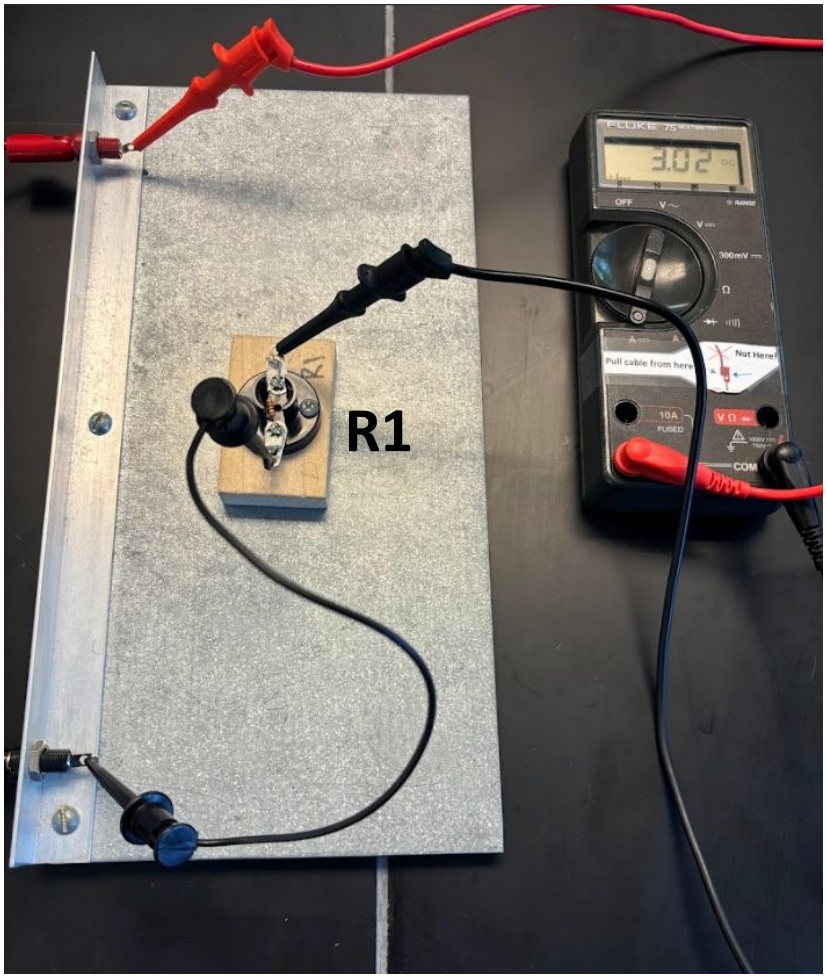
Wire has been removed.



Wire replaced with ammeter.

Measure the Current

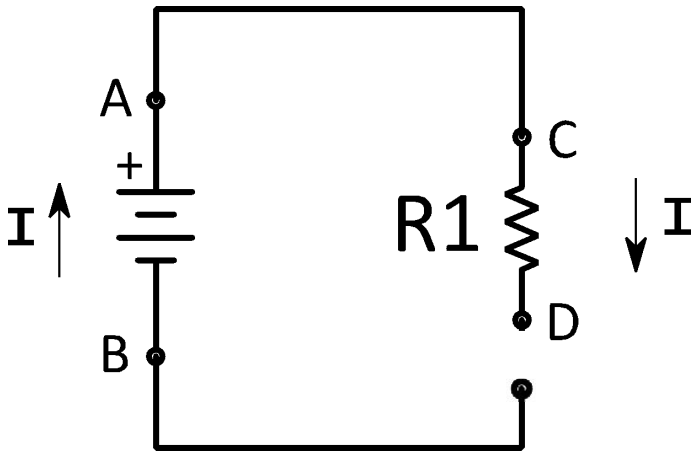
- Charge flowing through the circuit now flows through the ammeter.
- The displayed current is in units of milliamps (mA). (The screen just shows "DC".)
- Measure this $\mathbf{I_{replace}}$.
- Remove the ammeter and reconnect the original wire.

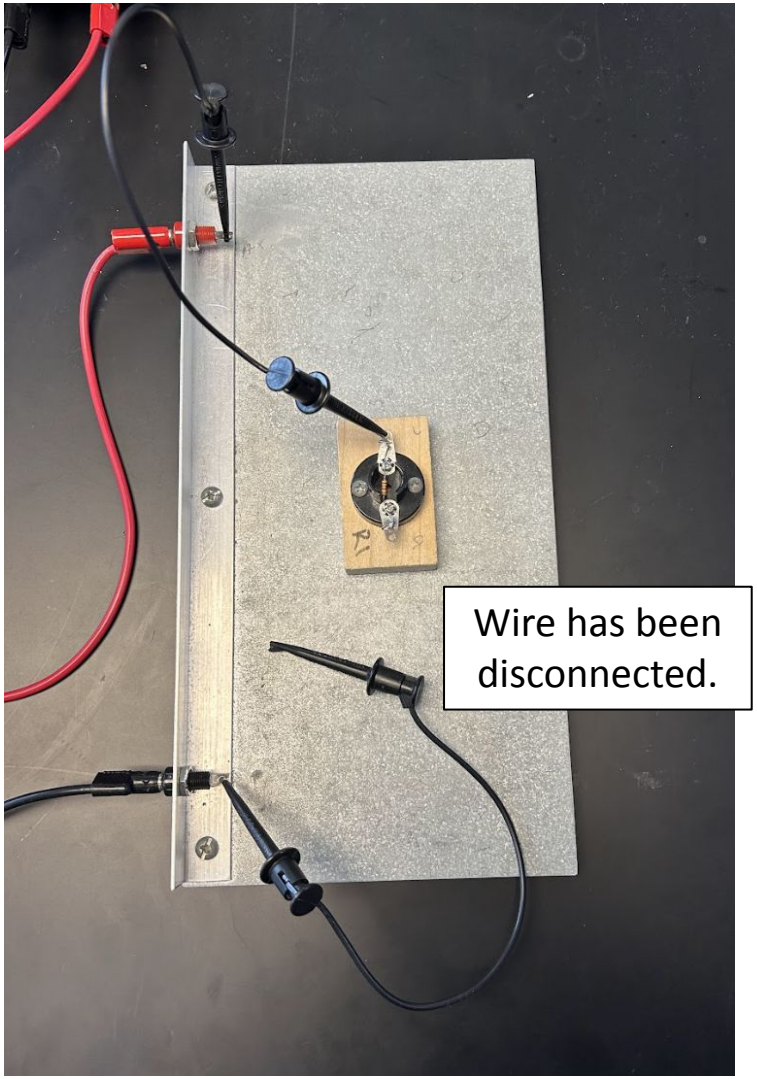


Disconnect and Reconnect

Now try this method:

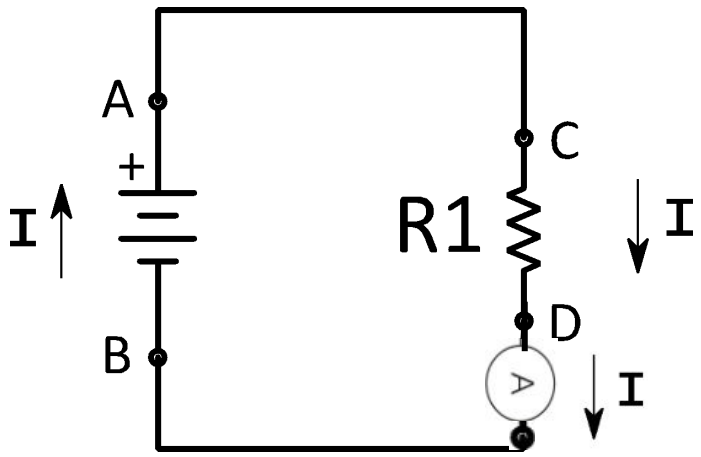
- Open the circuit by disconnecting **one end** of any wire.
- Connect the ammeter to the open ends.

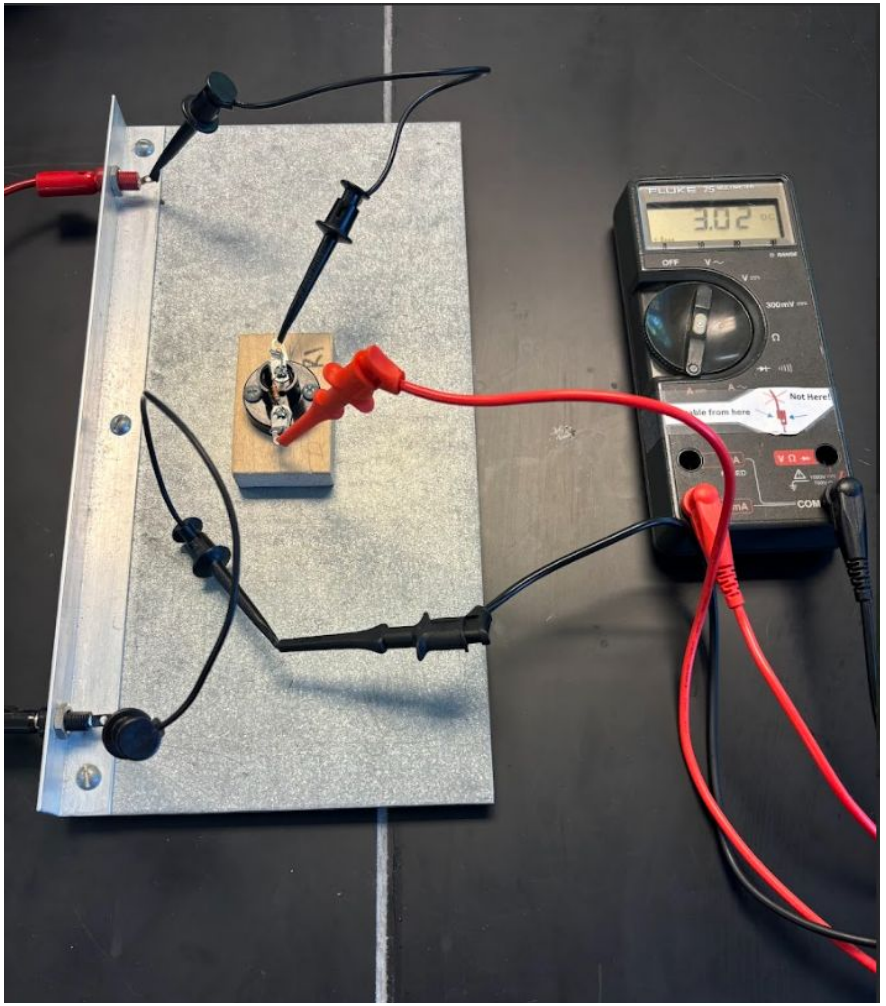




Measure the Current Again

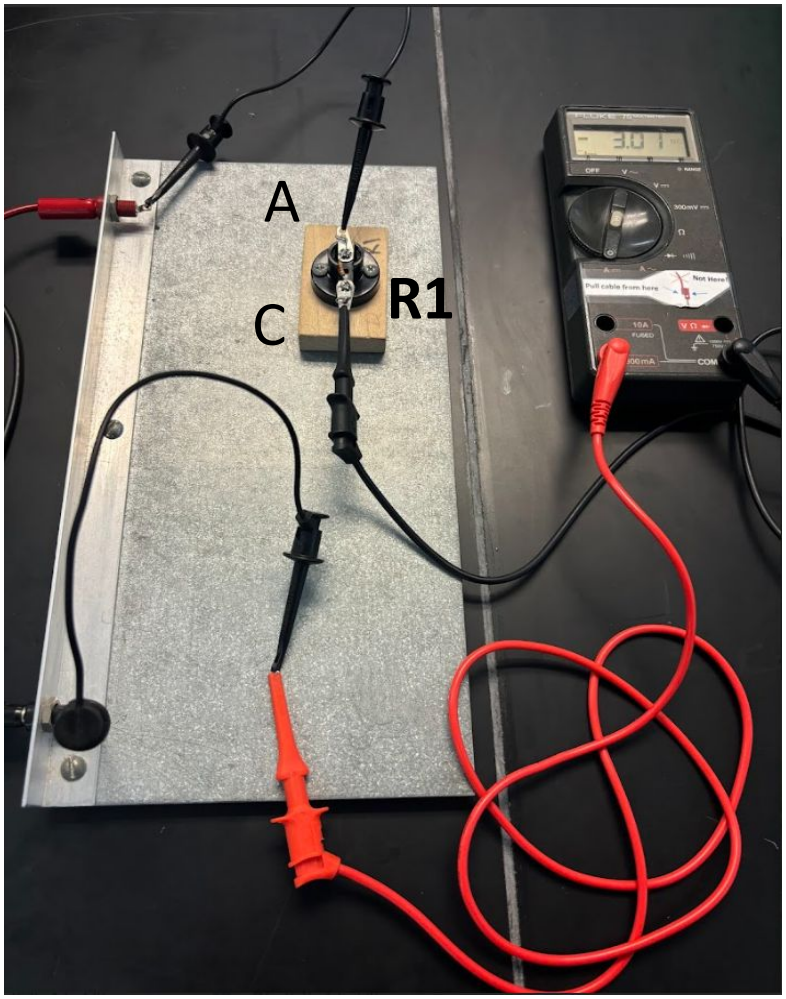
- This allows the current to flow through the ammeter.
- Measure this $I_{reconnect}$.





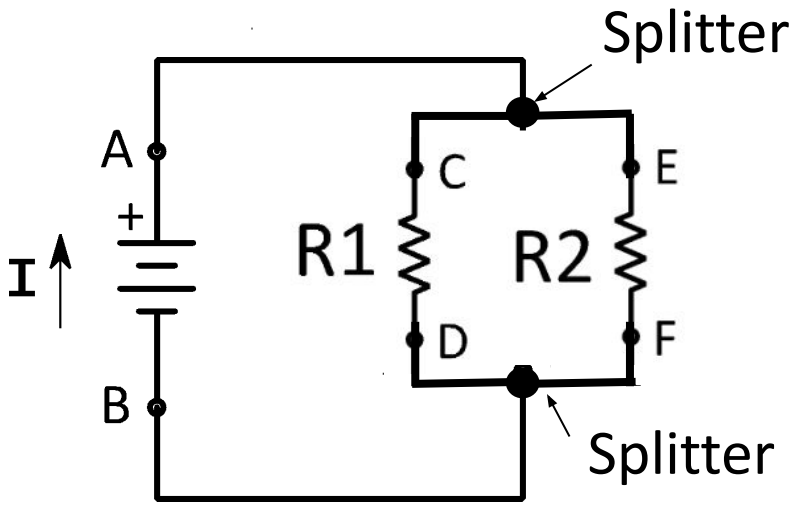
Determining Direction of Flow

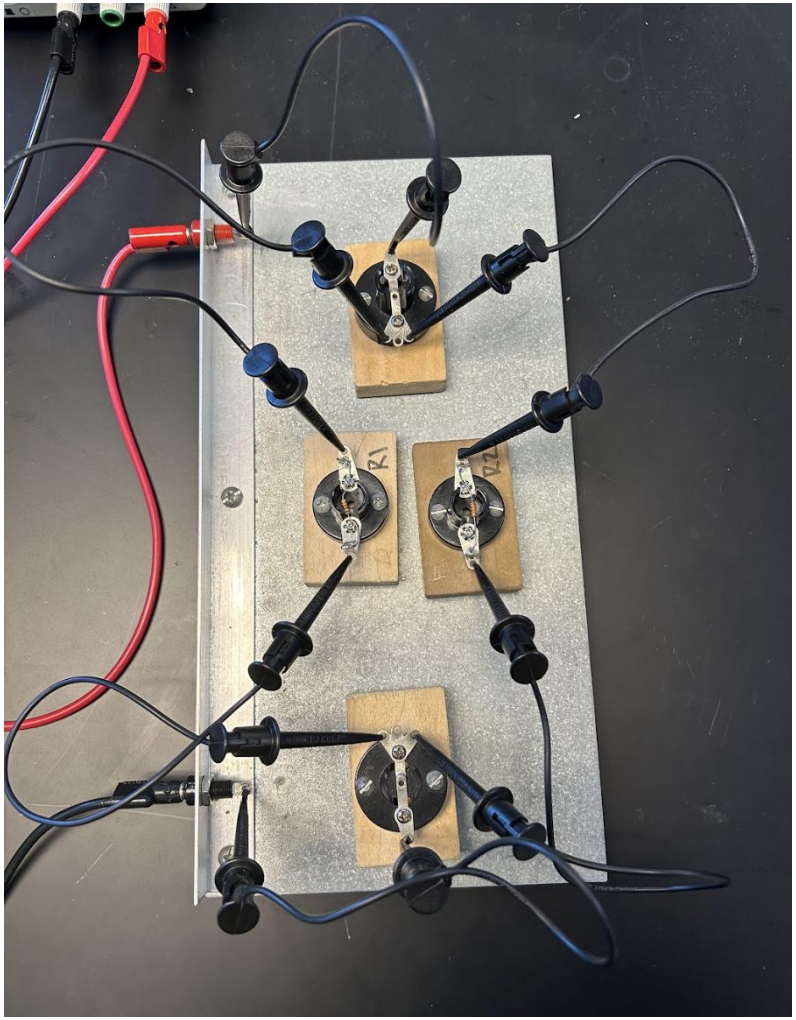
- A positive reading indicates conventional charge flow into the 300 mA socket and out of the COM socket.
- Switch the multimeter probes. You'll notice the screen will display a negative sign.
- When finished, disassemble the circuit.



Two-Branch Circuit

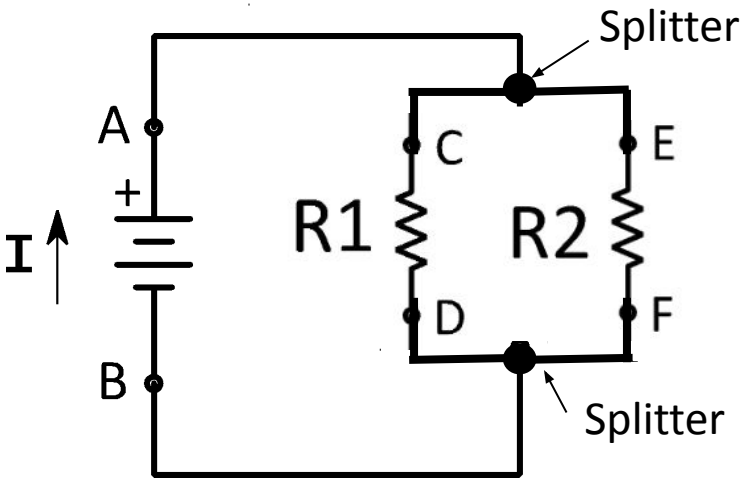
- Build the two-branch circuit shown.
  - Connect R1 and R2 to two of the "splitters".

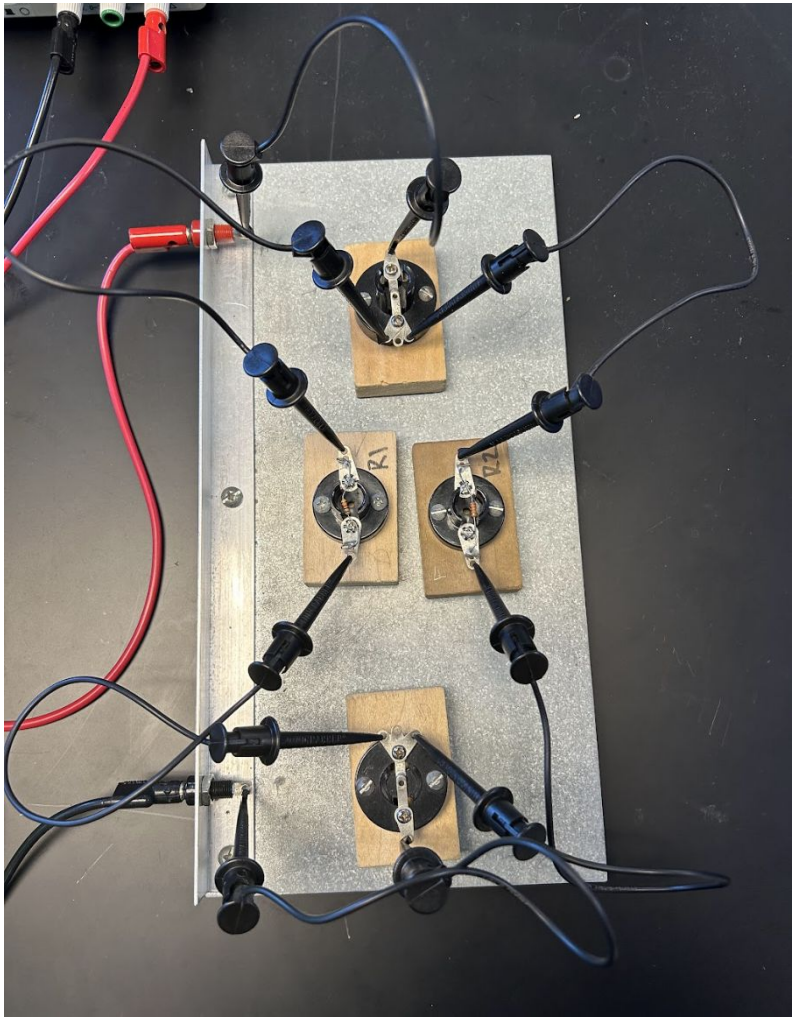




Measuring Current in a Branch

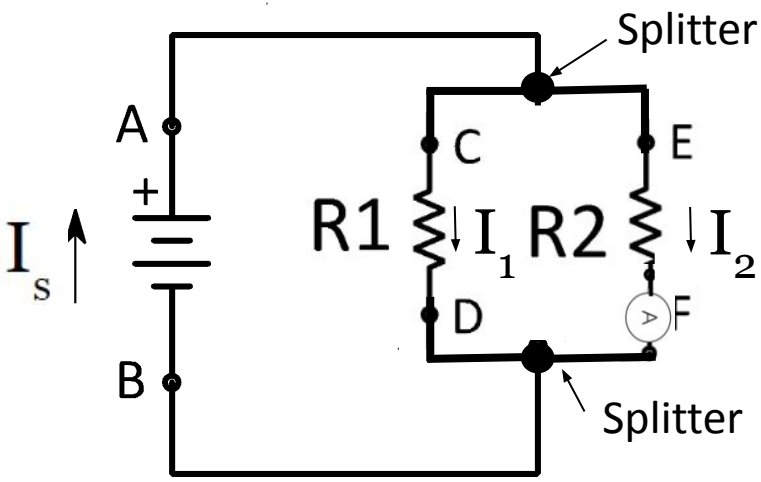
- In this circuit, the current through R1 is different from the current through R2.
- The ammeter must be connected in the same branch as the current being measured.

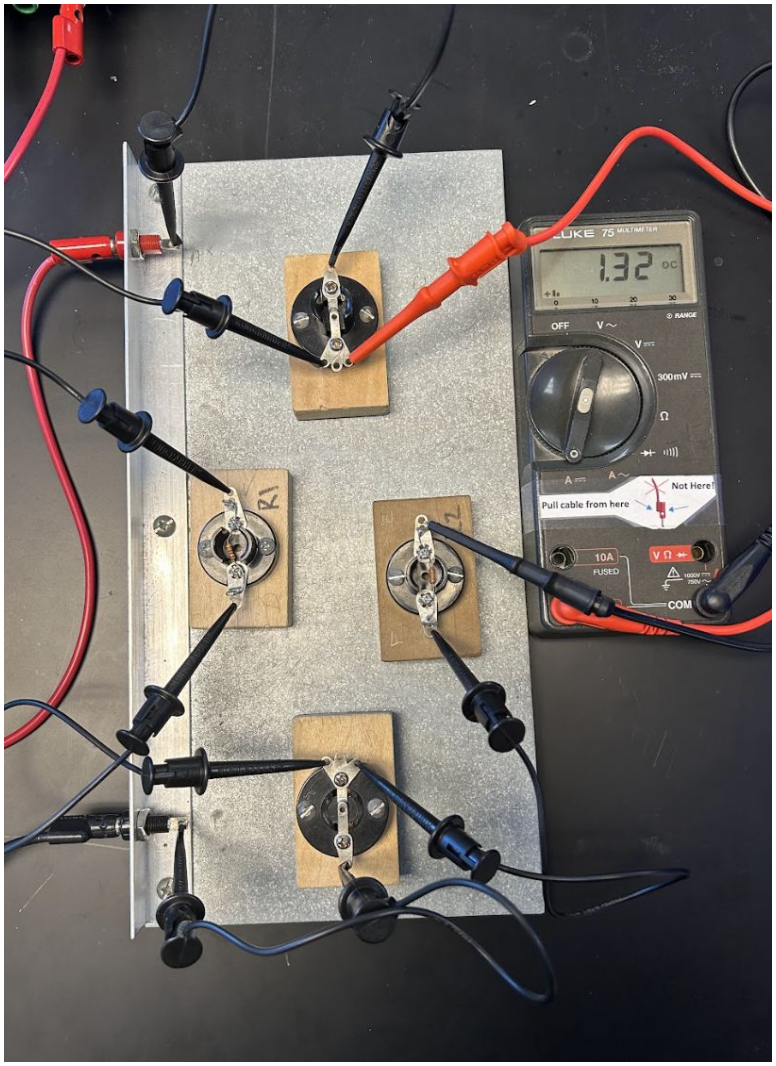




Measure All Currents

- Measure **I_1**, **I_2**, **I_s**, and show an SLC Consultant the wiring for **I_s**.
- For example, to measure I_2, connect the ammeter anywhere in the same branch as R2.





Current Check

- Kirchhoff's Current Law, called the “junction law”, states that the currents going into a junction must equal the currents going out.
- For this circuit, the junction law gives the following equation:

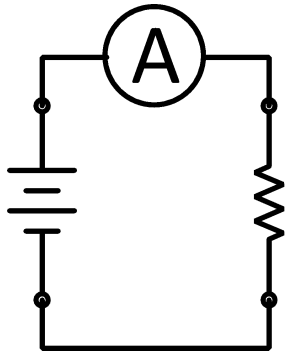
$$I_1 + I_2 = I_s$$

- Check that your measurements follow this rule.
- Disassemble the circuit when finished.

Current Measurement Summary

Review of how to measure current:

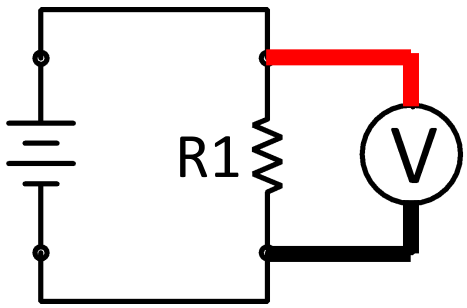
1. Set the function switch to **DC Current**.
2. Connect the red probe to **300 mA** socket.
3. Connect the black probe to **COM** socket.
4. Wire the ammeter into the circuit by:
   a. removing and replacing a wire with the ammeter, **OR**
   b. disconnecting one side of a wire and connecting the ammeter to the open ends.
5. Read the meter and record the result in mA.



Voltage vs. Current

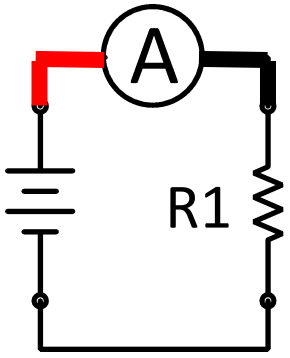
Measuring Voltage

- The voltmeter measures the voltage by comparing two points.
- Wires **are not** disconnected. The probes are placed at the two points of interest.



Measuring Current

- The ammeter measures the current flowing through it.
- A wire **must be** disconnected, and the probes connected to the open ends so current can flow through the meter.



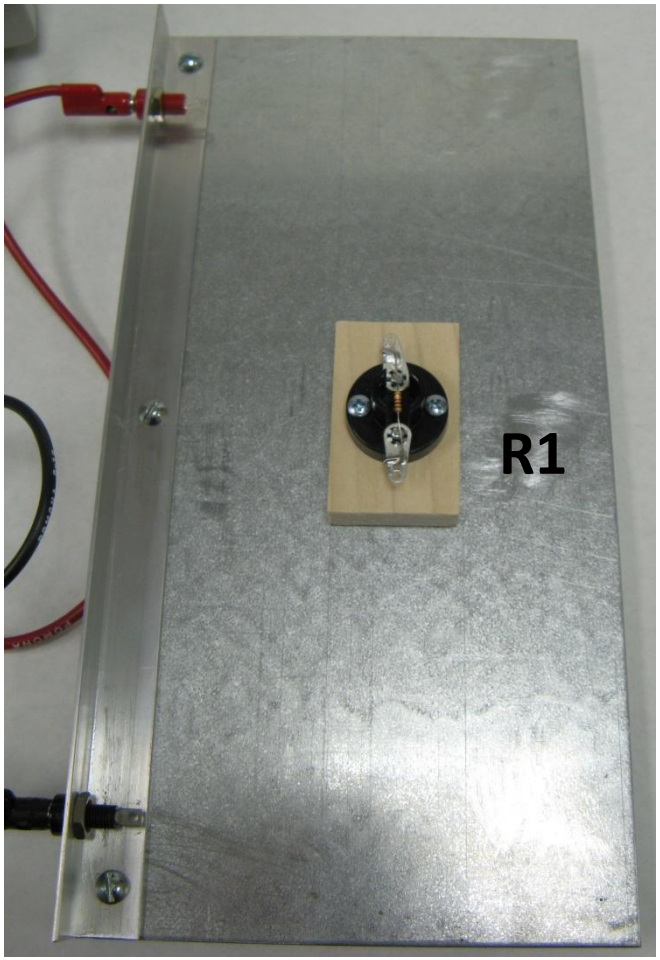
Measuring Resistance

Configure the Ohmmeter

- Turn the function switch to the resistance position: **Ω**
- Connect the probes to the multimeter:
  - red probe in the red socket labeled **VΩ**
  - black probe in the socket labeled **COM**

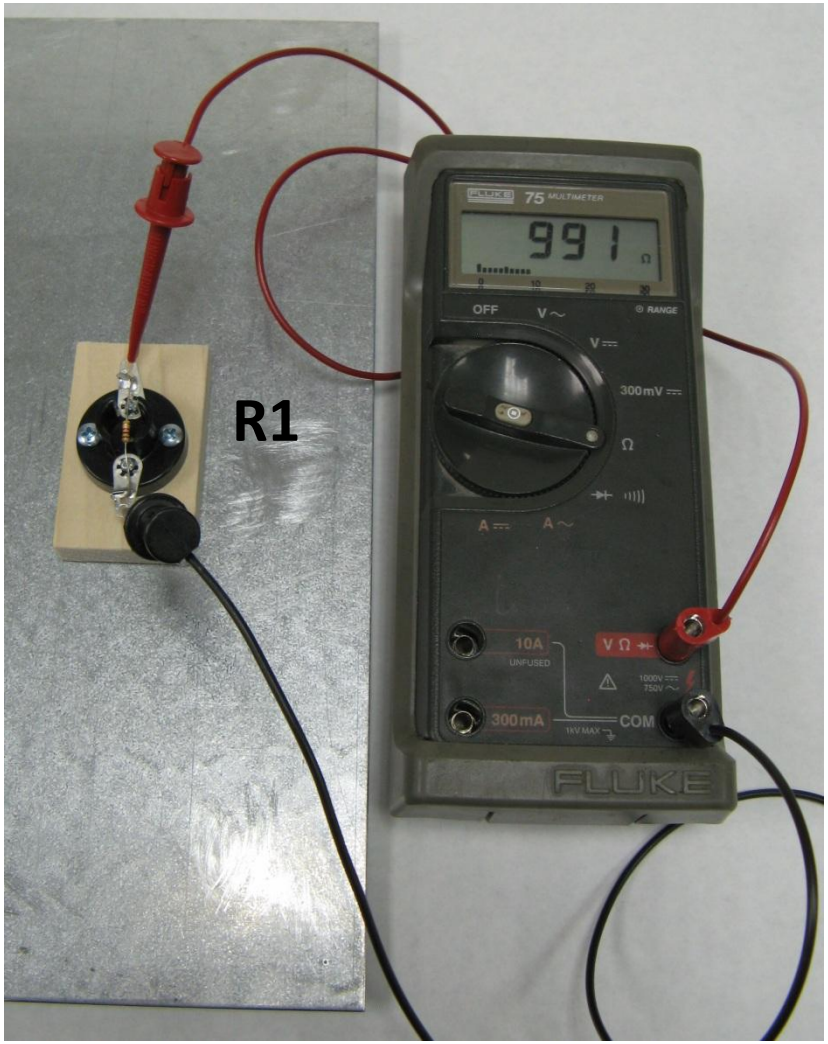
Isolate the Component

- Find R1 and make sure it isn't connected to anything.
- Resistance cannot be measured when an object is still in a circuit, even if the circuit's power source is off. **It must be removed from the circuit.**



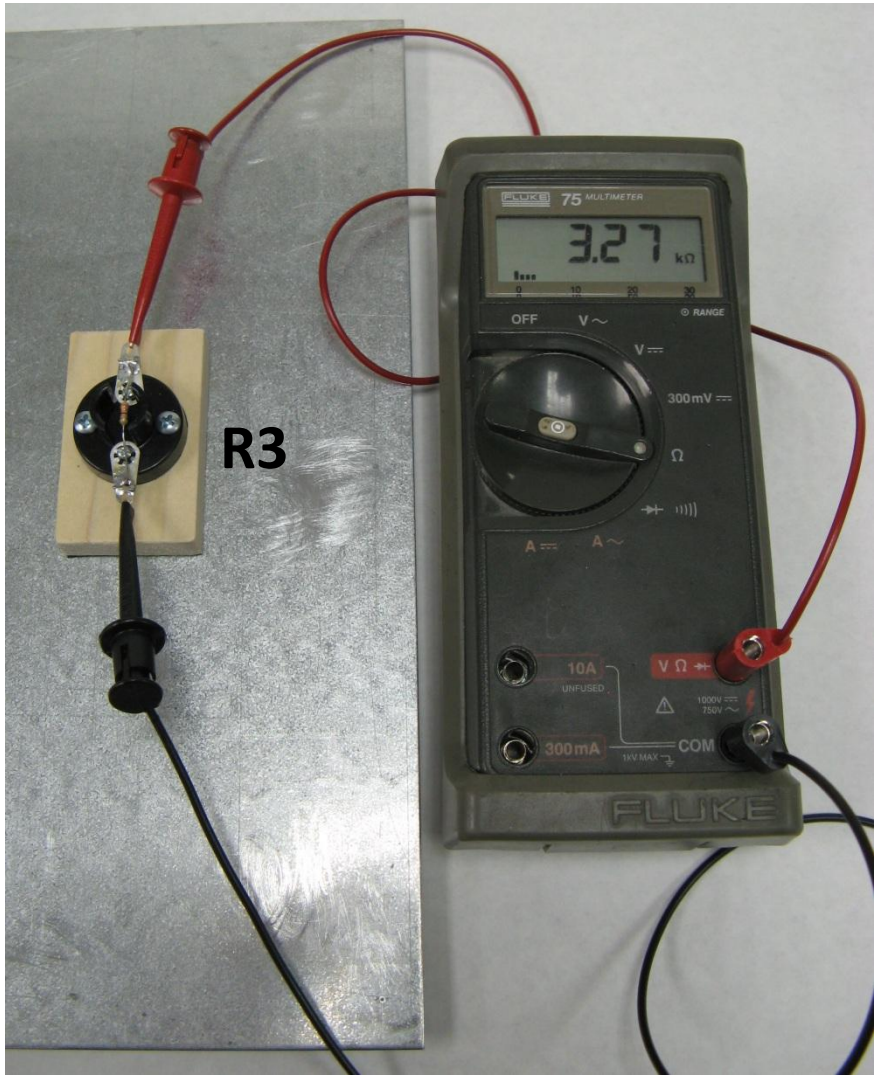
Connect the Ohmmeter

- Connect the red and black probes to the terminals of R1.
- Measure R_1.



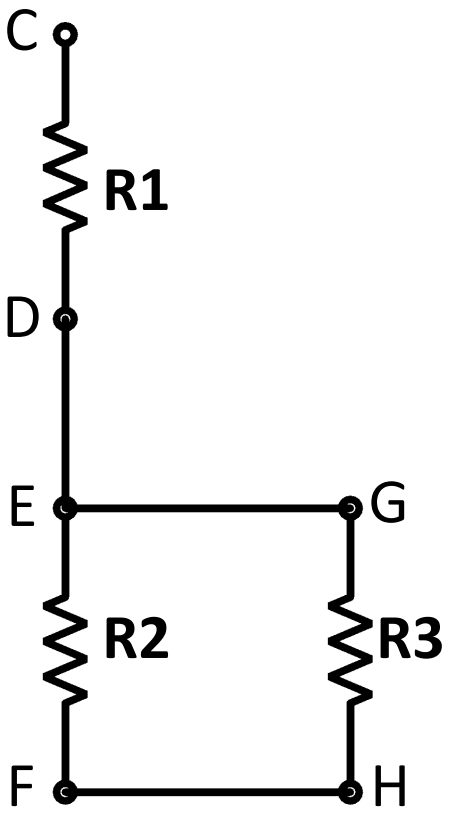
Measure R2 and R3

- Repeat this procedure to measure R_2 and R_3.
- The multimeter automatically switches to the kΩ scale when the resistance exceeds about 3000 Ω.
- Convert units from kΩ to Ω if necessary. (Note: 1kΩ = 1000Ω)



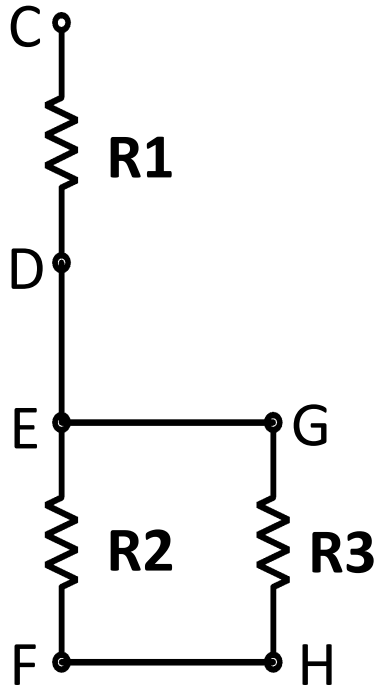
Equivalent Resistance

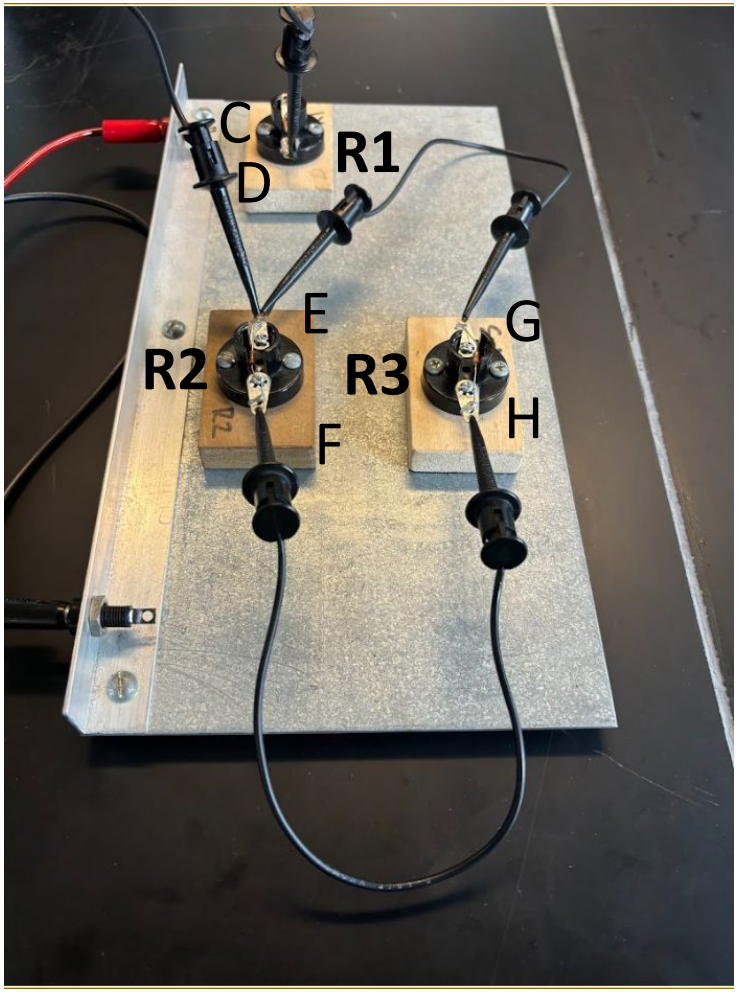
- Sometimes we want to know the combined resistance of a group of resistors.
- We call this the **equivalent resistance** of the group.
- This circuit diagram shows one way of connecting resistors R1, R2 and R3 together.



Connect the Resistors

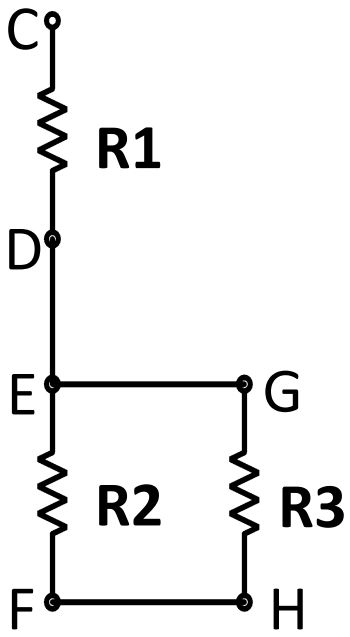
- Wire these resistors together as shown. Do not connect to the power supply.

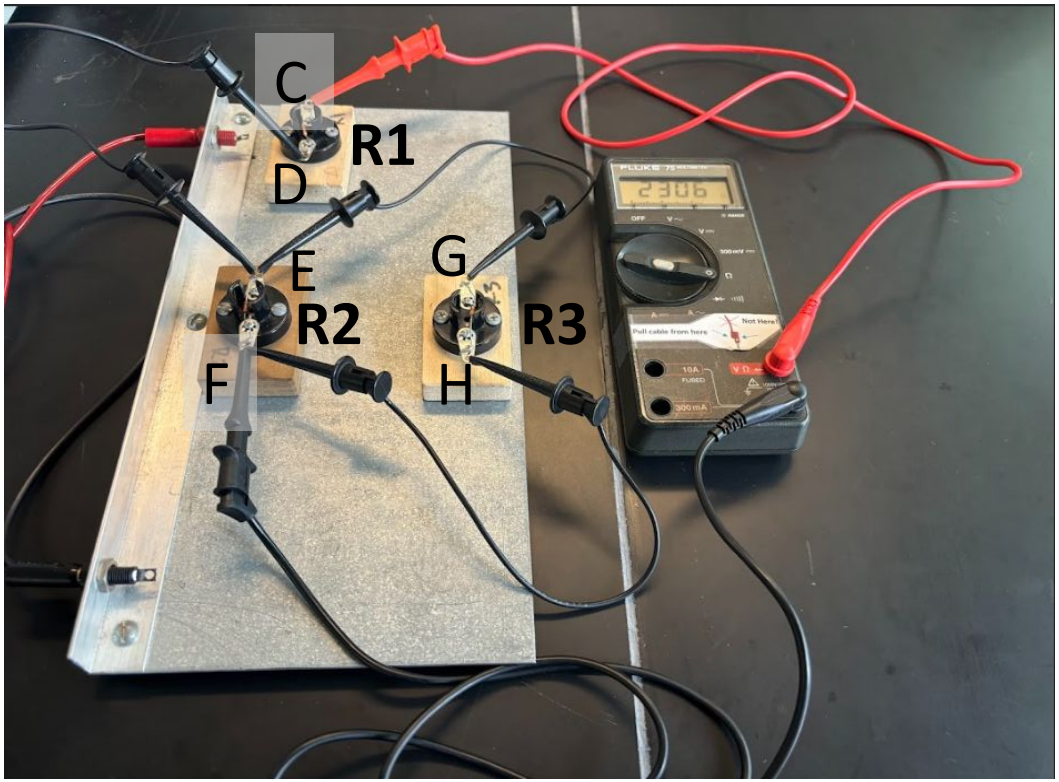




Measure Equivalent Resistance

- Connect the red probe to point C and the black probe to point F. This measures the equivalent resistance for this configuration.
- Measure R_{CF}.





Resistance Summary

Review of how to measure resistance:

1. Set the function switch to **Resistance**.
2. Connect the red probe to **VΩ** socket.
3. Connect the black probe to **COM** socket.
4. Make sure the object or group you're measuring is not connected to anything else.
5. Connect the probes across the resistance to be measured.
6. Read the meter and record the result in Ω.

Mastery Test

- Clear your work space.
- Turn off the multimeter and power supply.
- Come up to the front desk for the post-test.