

Topic 11: Current and Resistance

Source: *Conceptual Physics* textbook, lab book and CPO textbook and lab book

Types of Materials: Textbooks, lab books, worksheets, demonstrations/activities, websites/videos, and good stories

Building on: Electric charge and the force that pushes the charge and the electric field that causes the force that pushes the charge, gives the student an understanding of what current is and how it occurs. When the concept of electrical resistance is now studied in addition to electric force, electric field, and electric current, an understanding of what physically is occurring in the circuit in the students mind should occur rather than memorizing Ohm's law and using it around a circuit.

Links to Physics: Current and resistance are an integral part of the electronic industry (including the NASDAQ) and the products that are produced from understanding circuits. The application of the electronic theory extends to all fields, like medicine (countless medical equipment), building industry (countless tools), and so on. The production of computer chips starts with the basics, like understanding electric charge, electric fields, voltage and current and circuit theory that lead to manufacturing of tiny circuits, which is a whole industry in itself.

Links to Chemistry: As in physics, chemistry uses instrumentation like a spectrometer, gas chromatograph, and so on, making chemistry dependent on various sophistications from electrolysis to nuclear chemistry. Materials science as taught at the college level again uses complex electronic equipment but often doesn't require an understanding of the inner workings of the devices. You can drive a car without understanding the workings of the motor; however, if your car doesn't run well like it misses, some degree of electronic knowledge can be helpful (perhaps your car needs new spark plugs).

Links to Biology: Like in chemistry, biology uses the final electronic products with little need for complete electronic knowledge. An example includes the microscope, where a background in electronics and optics would be helpful but not necessary.

Materials:

(a) Hewitt*

(b) Hsu

1. Electricity
2. Resistance and Ohm's Law

3. Flow of Charge
 4. Electrical Energy and Power
- (c) My Lab
Ohm's Law, Electrical Energy and Power
- (d) Worksheet
Ohm's Law
- (e) Demonstration
Burning a Wire Using a Power Transformer
- (f) Videos and Websites
PhET Circuit Sim (Java)
- (g) Good Stories
1. Andre-Marie Ampere (1775-1836)
 2. Joseph Priestley – Extremist

Topic 11: Laboratory – Ohm’s Law, Electrical Energy and Power

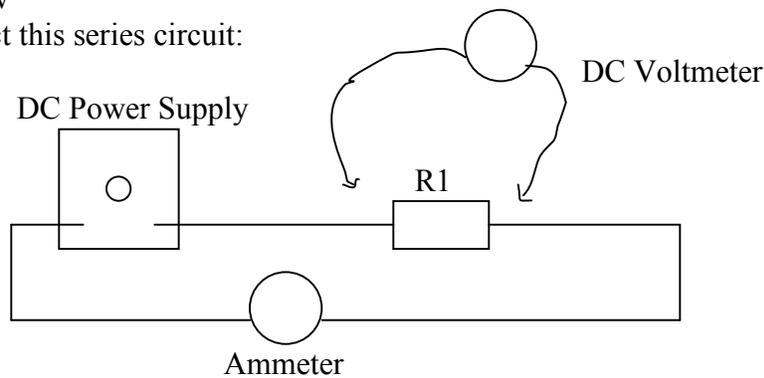
Materials:

- 5Ω wire wound resistor, R1 (has heat sink to not fry)
- 10Ω wire wound resistor, R2
- DC variable power supply (0-20 V) with leads
- Connecting wire with alligator clips
- DC ammeter
- DC voltmeter

Procedure:

(A) Ohm’s Law

1. Connect this series circuit:



2. Adjust the DC power supply to 2.0 V using the DC voltmeter. Also read and record the current with the ammeter. Repeat at 4.0 V, 6.0 V, 8.0 V and 10.0 V. At each power supply setting, also measure and record the voltage across R1. Briefly touch R1 at 2.0 V, 4.0 V, 6.0 V, 8.0 V and 10.0 V. Compare.

Trial	Power Supply Voltage (V)	Resistor Voltage (V)	Current (A)

3. Plot the resistor voltage as a function of the current for R1.
4. Take the average slope of this graph and state what it means.
5. Repeat steps 2-4 using R2.

(B) Electrical Power

1. Voltage measures the energy per charge, thus Joules/Coulomb. Current measures the rate of charge flow or charges per time, thus Coulombs/sec. So, if voltage is multiplied by current, you get (energy/charge) x (charges/time) = energy/time which is the rate of

delivering energy from the power supply (electric power) or rate of using energy by the resistor.

$$P = VI \quad (\text{energy/time} = \text{Joules/sec} = \text{watt})$$

2. Calculate the power delivered by the power supply and the power used by the resistor for each trial and for R1 and R2. Compare the values and explain.

R1	Power Delivered	Power Used	R2	Power Delivered	Power Used

(C) Electrical Energy

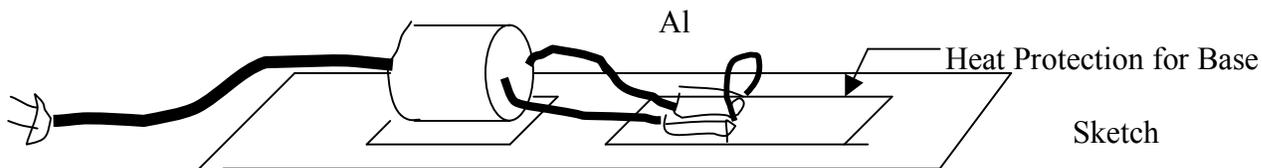
If electrical power is multiplied by time (power x time), energy/time x time = electrical ENERGY.

- (a) What happens to the temperature of each resistor if it is connected to the power supply for a longer time? Why?
- (b) What happens to the temperature of each resistor as the voltage goes higher and higher? Why?

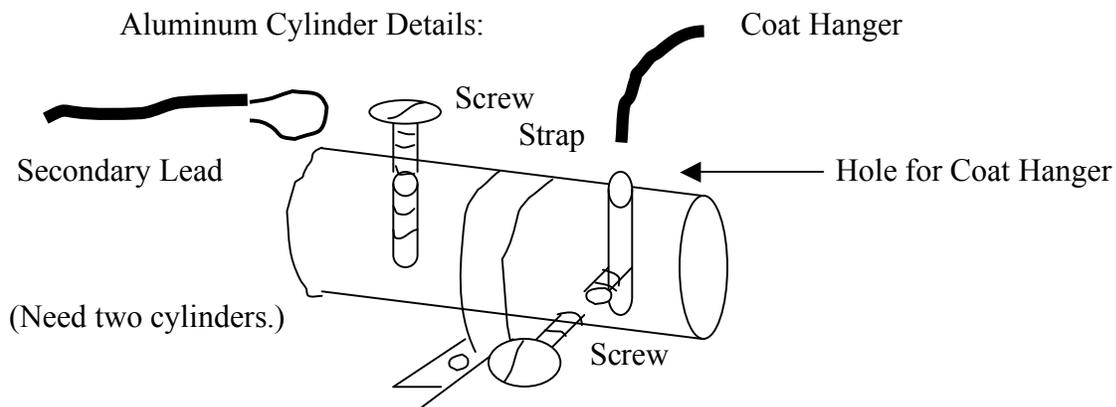
Topic 11: Demonstration of “Burning a Coat Hanger”

Purpose: To demonstrate what a transformer does, illustrate power in and power out and how voltage and current are interrelated.

Materials: Wooden base about 20” x 6” x 1” with a heat resistance surface where melting coat hanger will fall
Power transformer that steps down the voltage from 120 VAC to 6 VAC (could inexpensively obtain transformer from old tube TVs; might have to buy one.)



(Two) machined, threaded, aluminum cylinders to connect 6 VAC secondary wires and coat hanger (enlargement below)



Procedure:

1. Assemble this “coat hanger melting device.”
2. Use an AC voltmeter to measure the primary and secondary voltage of the transformer.
3. Cut a wire coat hanger into 10 cm lengths. (Experiment to find your best length of coat hanger for your device.)
4. Shape the 10 cm wire into a U shape to fit between the two cylinders.
5. Use pliers to twist the paint off both ends of the coat hanger.
6. Insert the ends of the hanger into the two Al cylinders and tighten the side locking screws. Also connect the two secondary leads to the cylinder with the two top screws.
7. You are ready for EXCITEMENT. Turn off the room lights. Test several times before students view your creation. Plug it in, stand back and ENJOY!
8. With students present, keep them back (~10 feet), and safety glasses are in order. The HOT melting wire pieces seldom go flying, but sparks WILL!!
9. Have students be very observant and plug it in.

Questions:

1. Why doesn't the primary transformer wire burn up like the coat hanger?

2. Is the current in the secondary wire (and coils) higher or lower than in the primary?

3. If you had a "special" ammeter to measure the primary and secondary current, how would they compare?

4. Electrical power is voltage times current. If you had the values of the primary and secondary voltages and currents, how would the power in and power out compare?

5. Why is smoke generated when first plugged in?

6. Why do sparks fly?

7. (a) What is the resistance of the coat hanger before being plugged in?

(b) What happens to the coat hanger resistance just after being plugged in?

8. Why does the wire glow? Why is the wire the color it achieves?

Topic 11: Transformer/Coat Hanger Demonstration Answer Sheet

Questions:

1. The current in the primary coils is about 20 times LESS than the secondary, thus, about $1/20$ of 20 A maximum or 1 A and, after a few seconds, about $1/20$ of 10 A or 0.5 A. The power in the coat hanger is I^2R , so when I is so large and R also goes up, power is HUGE and recall electrical power is ENERGY/time.
2. Current is much higher in the secondary to compensate for the reduced voltage.
3. Primary current is low (about $1/2$ A to 1 A), and the secondary current is high (about 10 A to 20 A).
4. Power in equals power out (conservation of energy), V (primary) \times I (primary) = V (secondary) \times I (secondary).
5. The paint on the coat hanger is vaporized and you see and smell the gas created.
6. The wire melts due to the HUGE energy at a LARGE temperature; large enough to excite electrons to higher energy levels, so upon return, light is emitted. The HUGE energy gives kinetic energy to the molten metal to throw chunks outward.
7. (a) The coat hanger resistance before heating is near zero.
(b) The wire resistance goes up with the higher wire temperature.
8. The wire glows due to the excited metal electrons. The wire achieves a red-orange glow due to its high temperature. If the temperature were even higher, the emitted light would approach "white hot."

Andre-Marie Ampere (1775-1836)

Andre Ampere's education was rather unique even for the times. His parents never required him to study anything. He was self-taught and never took a formal course in his life. At an early age he discovered a talent for mathematics. On finding that some of the mathematical texts he wanted to study were written in Latin, he then taught himself the language. Ampere's reputation was almost entirely based on his research and published papers. One of his earliest papers was on the mathematical theory of games and probability. He proposed the inevitability of a player losing a game of chance to a player with greater financial resources.

Inspired by Oersted's discovery that an electric current could produce a magnetic field, Ampere believed that the opposite should also be true; that magnets should be able to produce electric currents. Ampere experimented with a variety of wire and magnet configurations but was unable to produce electricity. Apparently he didn't consider the motion of either as a component to the process. James Clerk Maxwell later questioned Ampere's experimental methods.

Joseph Priestley (1733-1804) – Extremist

Joseph Priestley was a religious and political extremist and had no real interest in science. In fact, he never took a single formal science course during his entire lifetime. This all changed when he met Benjamin Franklin on a trip to London in 1766. With borrowed books Priestley learned all he could about the “new” science, electricity. Within a year he discovered that charcoal, graphite, a component of resistors, can conduct electricity.

He lived next to a brewery and became interested in the “air” that floated over the fermenting grain. Thus began Priestley’s investigation of gases. Joseph Priestley is credited with discovering ten new gases including oxygen, nitrous oxide (laughing gas) and carbon dioxide. In one experiment he dissolved carbon dioxide in water and found that it had a very pleasant and tangy taste. Priestley called it “mephitic julep”; today it is known as soda water or soda. He had hoped it would prevent scurvy on long ocean voyages. For his invention of soda water, he was elected to the French Academy of Sciences in 1772 and received a medal from the Royal Society in 1773.

The discovery that he made on April 15, 1770 would prove to be the most useful to the common man. On this day he discovered that India gum could be used to “rub” out pencil lines. He had invented the pencil eraser and gave the material the name “rubber.”

Still, his political and religious views got him into trouble. Due to his open support of both the French and American Revolutions, his home and church were burned to the ground. Finally, in 1794, Joseph Priestley emigrated to America where he retired to a peaceful life.

Joseph Priestly (1733-1804)

Priestly was born near Leeds in England. At the age of seven his mother died and his father, a cloth maker, sent him to live with his aunt. Joseph was raised in a strict religious environment. He believed that the principles of religion, politics and science should converge for the benefit of mankind. Priestly experienced a great deal of hostility in London for his beliefs. Once, a mob broke into his house and destroyed his books, papers and scientific equipment.