

# Science Lessons for Several Grade Levels (3-5, 6-8, 9-12)

## “Basic Electrical Circuits”

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**Discipline:** Electricity; Electronic Structure; Band Theory

**Grade:** 3 to 5, 6 to 8, 9 to 10, 11 to 12

### Standards

NAS 4D/H1,2; 4D/M1a,1b,1cd,9; 4G/M4; 4G/H2a,2b,2c,3,4ab,4d,8; 4E/M1,2,3,4,6; 12C/M6

### Purpose/Goal

Students should learn that different materials can be classified by their electronic properties and Band Structure, revealing whether a material is a conductor, a semiconductor, or an insulator. Students should be able to identify and classify, by material (e.g. conductor or insulator), the components of a simple series circuit.

Students should be able to diagram and construct a simple closed, series circuit using a battery, a flashlight bulb, and two insulated wires.

### Context

Teachers and students should recognize that conductors (i.e. metals) have many "free," unbonded electrons in the Conduction bands that intermix with electrons in the Valence bands, providing a "closed-circuit" path for electric current flow. Insulators, which have large (energy) gaps between Conduction and Valence bands, restrict the flow of electrons to and from the Conduction and Valence bands. This lesson covers Virginia SOL 4.3 and provides a foundation for lesson(s) introducing superconductivity and Electronic Structure Calculations.

### Preparation

For each group:

1 battery (D-cell or sufficient voltage to light flashlight bulb)

2 insulated wires (stripped at each end)

1 flashlight bulb

1 battery holder (optional)

For each student:

1 assessment sheet

### Websites

1. [http://www.metacafe.com/watch/793015/thomas\\_edison\\_light\\_bulb\\_experiment/](http://www.metacafe.com/watch/793015/thomas_edison_light_bulb_experiment/)

2. [http://www.kristechwire.com/images/100-0034\\_IMG.JPG](http://www.kristechwire.com/images/100-0034_IMG.JPG)

3. <http://paulbuckley14059.files.wordpress.com/2008/03/bulb.jpg>

4. <http://en.wikipedia.org/wiki/File:Isolator-metal.svg>

5. [http://www.bbc.co.uk/schools/ks3bitesize/science/physics/electricity\\_4.shtml](http://www.bbc.co.uk/schools/ks3bitesize/science/physics/electricity_4.shtml)

### Motivation

Students could be asked, "Why does a light bulb glow or emit light?" The students will give many answers or guesses but few will probably know that light (or photons, the quantum particle of light and all other electromagnetic radiation) comes from electrons "hopping" or falling from higher to lower energy bands as from the Conduction bands to the Valence bands (see website #4.) As an electrical current passes through a thin metal wire/filament, photons are emitted or visible light comes from the filament.

### Description

Students are introduced to a simple series circuit by viewing the web-video (website #1) which reproduces the Edison light bulb experiment. They are asked the following questions:

Q: What is an electric circuit?

A: The pathway taken by an electric circuit.

Q: What is an electric current?

A: The continuous flow of negative charges called electrons!

Students are shown two circuit diagrams, one open and one closed, and they are asked which one allows the flow of electric current.

Students are asked the following questions and shown the follow-up pictures with annotations:

Q: What is a conductor?

A: A material that allows an electrical current to flow through it easily.

Pictures: Insulated wires (website #2); Light bulb (website #3)

Annotations: Wire (for insulated wire picture) with arrow-lines pointing out metal (i.e. aluminum, copper, etc.) wire core. Light Bulb (for light bulb picture) with arrow-lines pointing out the metal base and the metal light element/filament.

Q: What is an Insulator?

A: A material that does NOT allow an electrical current to flow through it easily.

Pictures: Insulated wires (website #2); Light bulb (website #3)

Annotations: Wire (for insulated wire picture) with arrow-lines pointing out plastic/rubber outer cover material. Light Bulb (for light bulb picture) with arrow-lines pointing out the bulb glass.

Students are then shown the simplified Band Structure diagram (from website #4) and asked:

Q: Based on the Band Gap between the Valence and Conduction bands, can they tell which material allows a current to flow, which one restricts current flow, and which one does both?

A: Metals or conductors have many "free," loose, or unbonded electrons that intermix across the Fermi level so the Conduction bands mix with the Valence bands. (The Fermi level is the mid- or average Energy level between the highest Valence Energy level, which is completely filled with electrons, and the lowest partially or empty Conduction Energy level.) Therefore electrons from the atoms arranged in metals or conductors create "closed-circuits". Insulators, which have large Band (Energy) Gaps, restrict the free flow of electrons like "open-circuits." And semiconductors are materials that restrict some of the flow of electrons. Finally students are introduced to simple series and parallel circuits and their characteristics using website #5.

### **Assessment**

Students could draw a sketch and construct a simple closed, series circuit using a battery, a flashlight bulb, and two insulated wires. They could answer the following questions:

1. What is electric current?
2. What materials did you use to make a simple circuit?
3. What materials are insulators? What materials are conductors (metals)?

### **Follow-Up Activities**

Students can reproduce the Edison light bulb experiment, trying different materials as filaments.

Students can also learn about superconductors, their properties, and why they are important (i.e. how they can reduce Energy losses and pollution). They can also see how First Principles Electronic Structure calculations, which use as input several concepts the students have already learned or are learning, help confirm and predict superconductivity and other important properties.