Experiment 4
Electricity and Magnetism

Definition

The Physical phenomena involving electric charges, their motions, and their effects. The motion of a charge is affected by its interaction with the electric field and, for a moving charge, the magnetic field. The electric field acting on a charge arises from the presence of other charges and from a time-varying magnetic field. The magnetic field acting on a moving charge arises from the motion of other charges and from a time-varying electric field. Thus electricity and magnetism are ultimately inextricably linked. In many cases, however, one aspect may dominate, and the separation is meaningful. *See also* Electric charge; Electric field; Magnetism.

History of Electricity

From the writings of Thales of Miletus it appears that Westerners knew as long ago as 600 B.C. that amber becomes charged by rubbing. There was little real progress until the English scientist William Gilbert in 1600 described the electrification of many substances and coined the term *electricity* from the Greek word for amber. As a result, Gilbert is called the father of modern electricity. In 1660 Otto von Guericke invented a crude machine for producing static electricity. It was a ball of sulfur, rotated by a crank with one hand and rubbed with the other. Successors, such as Francis Hauksbee, made improvements that provided experimenters with a ready source of static electricity. Today's highly developed descendant of these early machines is the Van de Graaf generator, which is sometimes used as a particle accelerator. Robert Boyle realized that attraction and repulsion were mutual and that electric force was transmitted through a vacuum (c.1675). Stephen Gray distinguished between conductors and nonconductors (1729). C. F. Du Fay recognized two kinds of electricity, which Benjamin Franklin and Ebenezer Kinnersley of Philadelphia later named positive and negative.

The quantitative development of electricity began late in the eighteenth century. J. B. Priestley in 1767 and C. A. Coulomb in 1785 discovered independently the inverse-square law for stationary charges. This law serves as a foundation for electrostatics. *See also* Coulomb's law; Electrostatics.

In 1800 A. Volta constructed and experimented with the voltaic pile, the predecessor of modern batteries. It provided the first continuous source of electricity. In 1820 H. C. Oersted demonstrated magnetic effects arising from electric currents. The production of induced electric currents by changing magnetic fields was demonstrated by M. Faraday in 1831. In 1851 he also proposed giving physical reality to the concept of lines of force. This was the first step in the direction of shifting the emphasis away from the charges and onto the associated fields. *See also* Electromagnetic induction; Electromagnetism; Lines of force.

In 1865 J. C. Maxwell presented his mathematical theory of the electromagnetic field. This theory, which proposed a continuous electric fluid, not only synthesized a unified theory of electricity and magnetism, but also showed optics to be a branch of electromagnetism. *See also* Electromagnetic radiation; Maxwell's equations.

The developments of theories about electricity subsequent to Maxwell have all been concerned with the microscopic realm. Faraday's experiments on electrolysis in 1833 had indicated a natural unit of electric charge, thus pointing toward a discrete rather than continuous charge. The existence of electrons, negatively charged particles, was postulated by A. Lorenz in 1895 and demonstrated by J. J. Thomson in 1897. The existence of positively charged particles (protons) was shown shortly afterward (1898) by W. Wien. Since that time, many particles have been found having charges numerically equal to that of the electron. The question of the fundamental nature of these particles remains unsolved, but the concept of a single elementary charge unit is apparently still valid. *See also* Baryon; Electrolysis; Electron; Elementary particle; Hyperon; Meson; Proton; Quarks.

The sources of electricity in modern technology depend strongly on the application for which they are intended.

The principal use of static electricity today is in the production of high electric fields. Such fields are used in industry for testing the ability of components such as insulators and condensers to withstand high voltages, and as accelerating fields for charged-particle accelerators. The principal source of such fields today is the Van de Graaff generator. *See also* Particle accelerator.

The major use of electricity arises in devices using direct current and low-frequency alternating current. The use of alternating current, introduced by S. Z. de Ferranti in 1885–1890, allows power transmission over long distances at very high voltages with a resulting low-percentage power loss followed by highly efficient conversion to lower voltages for the consumer through the use of transformers. *See also* Alternating current; Electric current.

Large amounts of direct current are used in the electrodeposition of metals, both in plating and in metal production, for example, in the reduction of aluminum ore. *See also* Direct current; Electrochemistry; Electrometallurgy; Electroplating of metals.

The principal sources of low-frequency electricity are generators based on the motion of a conducting medium through a magnetic field. The moving charges interact with the magnetic field to give a charge motion that is normal to both the direction of motion and the magnetic field. In the most common form, conducting wire coils rotate in an applied magnetic field. The rotational power is derived from a water-driven turbine in the case of hydroelectric generation, or from a gas-driven turbine or reciprocating engine in other cases. *See also* Alternating-current generator; Direct-current generator; Electric power generation; Generator.

Many high-frequency devices, such as communications equipment, television, and radar, involve the consumption of only moderate amounts of power, generally derived from low-frequency sources. If the power requirements are moderate and portability is needed, the use of ordinary chemical batteries is possible. Ion-permeable membrane batteries are a later development in this line. Fuel cells, particularly hydrogen-oxygen systems, are being developed. They have already found extensive application in earth satellite and other space systems. The successful use of thermoelectric generators based on the Seebeck effect in semiconductors has been reported. *See also* Battery; Fuel cell; Ion-selective membranes and electrodes.

The solar battery, also a semiconductor device, has been used to provide charging current for storage batteries in telephone service and in communications equipment in artificial satellites. *See also* Solar cell.

Direct conversion of mechanical energy into electrical energy is possible by utilizing the phenomena of piezoelectricity and magnetostriction. These have some application in acoustics and stress measurements. Pyroelectricity is a thermodynamic corollary of piezoelectricity.

Political Lingo

Green power is a cleaner alternative energy source in comparison to traditional sources, and is derived from renewable energy resources that do not produce any nuclear waste; examples include energy produced from wind, water, solar, thermal, hydro, combustible renewables and waste.

Electricity from coal, oil, and natural gas is known as traditional power or "brown" electricity.

Cited Sources

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Laboratory Procedures

1. Formation of a charge imbalanced object by rubbing.

charge put on the pith balls. You will first need to charge both pith balls. To do this, you need to wipe the Teflon rod vigorously with the silk and bring the rod in contact with both pith balls simultaneously. Try not to touch the pith balls with your fingers, as you may ground them and cause them to discharge. The pith balls need to either be in contact with each other when you initially charge them or you need to let them momentarily touch each other after you have charged them.

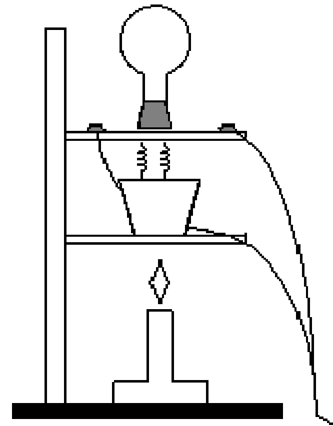
Question 1: Why do the two pith balls have to touch after you have charged them?

Question 2: What do you expect the pith balls to do after they have been charged? Why?

B. Can water be affected by a charged rod? Explain.

2. How do charged particles and electrons move?

Using a conductivity apparatus.



- The conductivity apparatus is made up of a light bulb, a crucible, the connecting wires, and a bunsen burner.

Tests for conductivity

1. Does distilled water conduct? Explain.

2. Does tap water conduct? Explain.

3. Solid Sodium Chloride ($NaCl_{(s)}$) Explain.

4. Solid Sucrose. Explain.

5. Suggest a method, other than using water, for making $NaCl_{(s)}$ conduct.

Electrolysis of water

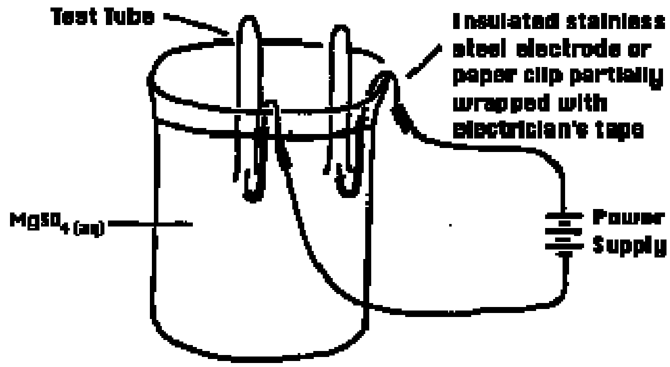


Figure 1

What is the elemental make-up of water?

What is the elemental ratio?

Tests for the elements. Describe below.

THE VAN DE GRAAFF GENERATOR

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        ________
       /        \
      |          |   Hollow Metal Ball
      |          |
       \ _______ /
          |   |
          |   |    Vertical pipe, w/rubber
          |   |    "conveyor belt" inside
          |   |
          |   |
          |   |
      ____|___|____
     |             |    Hollow metal box,
     |        ()   |    electric motor inside.
     |_____________|
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A volunteer is needed to show a charge imbalance.

Explain how this charge imbalance was achieved.

Explain why the name "Static Electricity" might be misconceived.

MAGNETISM

Magnetic poles

Two different types of magnetic poles must be distinguished. There are the "magnetic poles" and the "geomagnetic poles". The magnetic poles are the two positions on the Earth's surface where the magnetic field is entirely vertical. Another way of saying this is that the inclination of the Earth's field is 90° at the North Magnetic Pole and -90° at the South Magnetic Pole. A typical compass that is allowed to swing only in the horizontal plane will point in random directions at either the South or North Magnetic Poles.

The Earth's field is closely approximated by the field of a dipole positioned at the centre of the Earth. A dipole defines an axis. The two positions where the axis of the dipole that best fits the Earth's field intersect the Earth's surface are called the North and South geomagnetic poles. If the Earth's field were perfectly dipolar, the geomagnetic and magnetic poles would coincide. However, there are significant non-dipolar terms which cause the position of the two types of poles to be in different places.

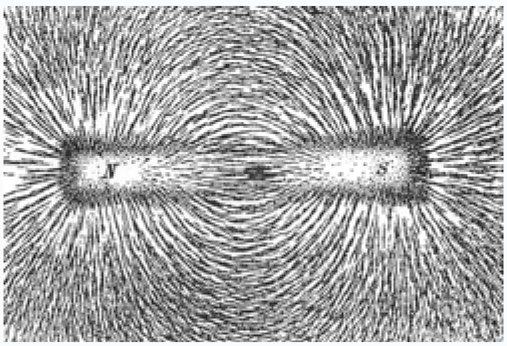
The locations of the magnetic poles are not static but they wander as much as 15 km every year.

The Earth's field is changing in size and position. The two poles wander independently of each other and are not at directly opposite positions on the globe. Currently the magnetic south pole is farther from the geographic south pole than the magnetic north pole is from the geographic north pole.

Magnetic pole positions

North Magnetic Pole	(2001) 81.3° N 110.8° W	(2004 est) 82.3° N 113.4° W	(2005 est) 82.7° N 114.4° W
South Magnetic Pole	(1998) 64.6° S 138.5° E.	(2004 est) 63.5° S 138.0° E	

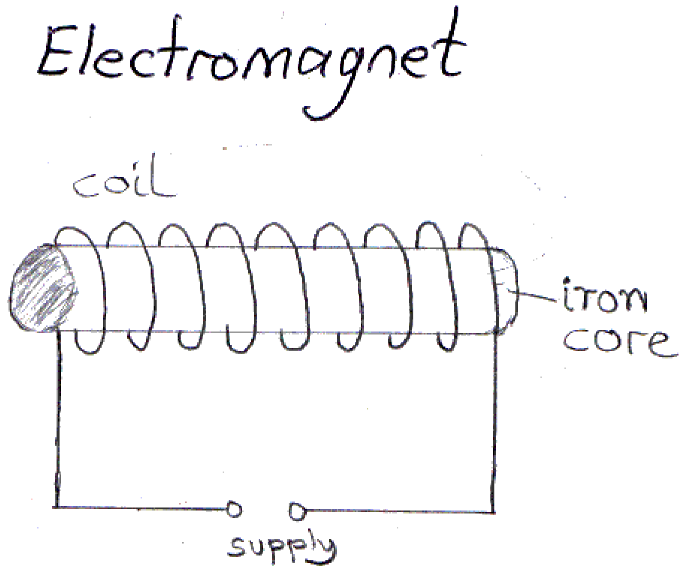
Magnets are materials that produce a magnetic field of their own. Extreme examples of magnets are (1) "hard" or "permanent" magnets (like refrigerator magnets), which remember how they have been magnetized, and (2) "soft" or "impermanent" magnets (like the material of the refrigerator door), which lose their memory of previous magnetizations. "Soft" magnets are often used in electromagnets to enhance (often by factors of hundreds or thousands) the magnetic field of a current-carrying wire that has been wrapped around the magnet; when the current increases, so does the field of the "soft" magnet, which is much larger than the field due to the current. Permanent magnets occur naturally in some rocks, particularly lodestone, but they are now more commonly manufactured.



Iron filings in a magnetic field generated by a bar magnet

Sketch below your rendition of the magnetic lines of force from the sprinklings shown. Use the upper rectangles to represent unlike charges and like for the lower.

Electromagnet



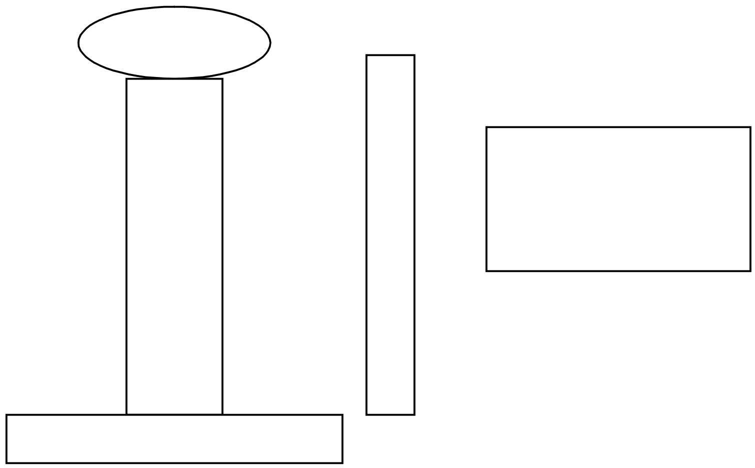
An electromagnet is a solenoid with an iron core inserted into it. If a current flows in the coil, a magnetic field is generated. All the randomly oriented domains of the iron core then align in the presence of the field of the solenoid. Thus, the core greatly enhances the strength of the electromagnet.

1. Describe some of the similarities and between the permanent and electromagnets.

2. Name some practical uses of electromagnets.

Current induction

Galvanometer: a tool to detect, compare or measure small electric currents; Willem Einthoven developed a type of galvanometer that he evolved into the EKG/ ECG.



Using The green solenoid, a magnet and a galvanometer, one can actually produce an electric

Slowly insert the permanent magnet into the green solenoid and observe the galvanometer’s needle.

What did you observe?

Allow the magnet to remain inside the galvanometer for a few seconds.

What did you observe?

Remove the magnet from the solenoid while observing the galvanometer.

Record your observation.

Repeat the above procedure using the opposite pole of the magnet.

Record your observations.

Questions

1. What happened to the galvanometer needle when the poles were reversed?

2. Can a current be induced in a wire by a stationary magnet field? Explain.

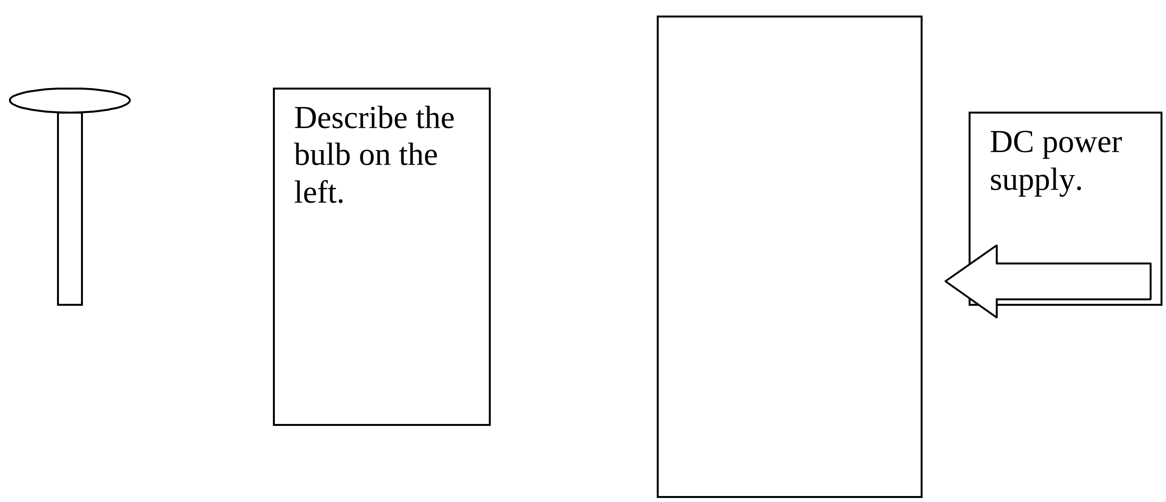
Using an electromagnet and a permanent magnet around the house … what would you call this device?

List some things around the house that incorporate this phenomenon into its make-up.

Magnetic levitation transport, or **maglev**, is a form of transportation that suspends, guides and propels vehicles via electromagnetic force. This method can be faster than wheeled mass transit systems, potentially reaching velocities comparable to turboprop and jet aircraft (500 to 581 km/h).

The world's first commercial application of a high-speed maglev line is the IOS (initial operating segment) demonstration line in Shanghai, China that transports people 30 km (18.6 miles) to the airport in just 7 minutes 20 seconds (top speed of 431 km/h or 268 mph, average speed 250 km/h or 150 mph). Other maglev projects worldwide are being studied for feasibility. However, scientific, economic and political barriers and limitations have hindered the widespread adoption of the technology.

Visualizing Direct Current (DC) and Alternating Current (AC)



You should have observed that the filament is split and looks like a flat-head screw.

Observe what happens when the leads are connected to the power supply.

How could you get the other half to light?

How could you get both halves to light?

A TRANSFORMER

Michael Faraday, FRS (September 22, 1791 – August 25, 1867) was an English chemist and physicist (or *natural philosopher*, in the terminology of that time) who contributed significantly to the fields of electromagnetism and electrochemistry.

Faraday studied the magnetic field around a conductor carrying a DC electric current, and established the basis for the magnetic field concept in physics. He discovered electromagnetic induction, diamagnetism and electrolysis. He established that magnetism could affect rays of light and that there was an underlying relationship between the two phenomena.

His inventions of electromagnetic rotary devices formed the foundation of electric motor technology.

As a chemist, Faraday discovered chemical substances such as benzene, invented an early form of the bunsen burner and the system of oxidation numbers, and popularized terminology such as anode, cathode, electrode, and ion.

Single phase pole-mounted step-down transformer

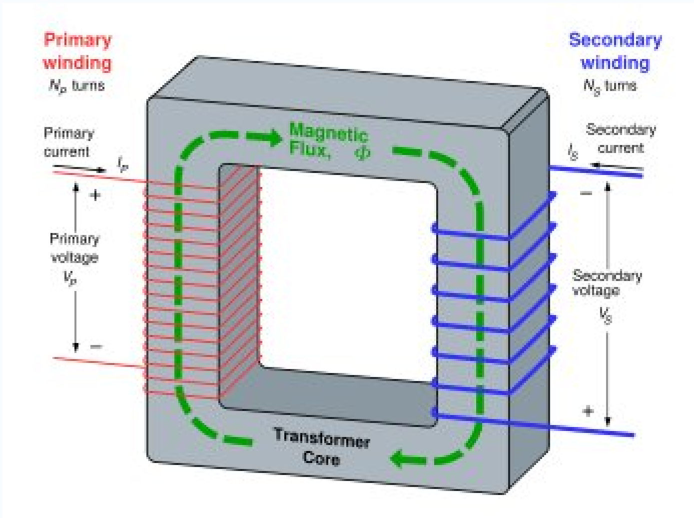
Laminated core transformer showing edge of laminations at top of unit.

An analogy

A transformer can be likened to a mechanical gearbox, which transfers mechanical energy from a high-speed, low torque shaft to a lower-speed, higher-torque shaft, but which is not a source of energy itself. A transformer transfers electrical energy from a high-current, low-voltage circuit to a lower-current, higher-voltage circuit.

Coupling by mutual induction

The principles of the transformer are illustrated by consideration of a hypothetical ideal transformer. In this case, the core requires negligible magnemotive force to sustain flux, and all flux linking the primary winding also links the secondary winding. The hypothetical ideal transformer has no resistance in its coils. A simple transformer consists of two electrical conductors called the **primary winding** and the **secondary winding**. Energy is coupled between the windings by the time varying magnetic flux that passes through (links) both primary and secondary windings. Whenever the amount of current in a coil changes, a voltage is induced in the neighboring coil. The effect, called mutual inductance, is an example of electromagnetic induction.[1]



Calculating output voltage

Voltage in x Nprimary turns**/ N**secondary turns **= Voltage out**
Ex. 120V x [8/4] = 240V
This would be considered a step up transformer.

Telsa coil

A **Tesla coil** is a type of disruptive discharge transformer, named after its inventor, Nikola Tesla.

Observe the human bulb.

Ohm's Law

E = I x R E = volts or pressure I = Amperage or Impedence or charges/second R = Resistance

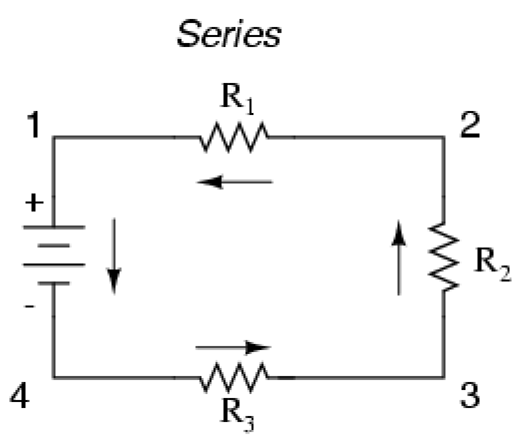
<u>The lethal component is usually considered the amperage.</u>

CIRCUITS

What are "series" and "parallel" circuits?

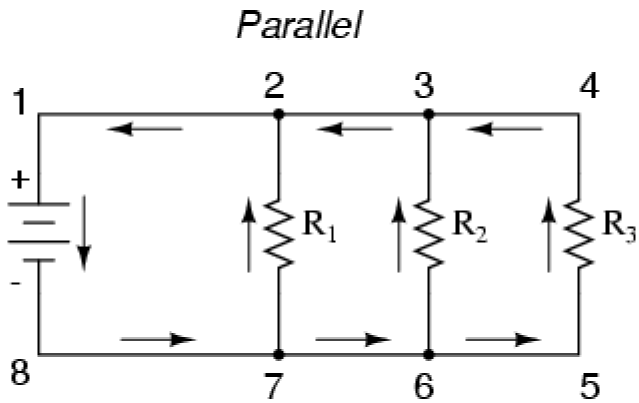
Circuits consisting of just one battery and one load resistance are very simple to analyze, but they are not often found in practical applications. Usually, we find circuits where more than two components are connected together.

There are two basic ways in which to connect more than two circuit components: *series* and *parallel*. First, an example of a series circuit:



Here, we have three resistors (labeled R_1, R_2, and R_3), connected in a long chain from one terminal of the battery to the other. (It should be noted that the subscript labeling -- those little numbers to the lower-right of the letter "R" -- are unrelated to the resistor values in ohms. They serve only to identify one resistor from another.) The defining characteristic of a series circuit is that there is only one path for electrons to flow. In this circuit the electrons flow in a counter-clockwise direction, from point 4 to point 3 to point 2 to point 1 and back around to 4.

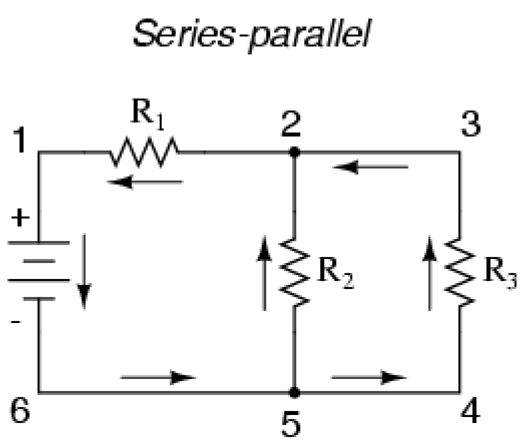
Now, let's look at the other type of circuit, a parallel configuration:



Again, we have three resistors, but this time they form more than one continuous path for electrons to flow. There's one path from 8 to 7 to 2 to 1 and back to 8 again. There's another from 8 to 7 to 6 to 3 to 2 to 1 and back to 8 again. And then there's a third path from 8 to 7 to 6 to 5 to 4 to 3 to 2 to 1 and back to 8 again. Each individual path (through R_1, R_2, and R_3) is called a *branch*.

The defining characteristic of a parallel circuit is that all components are connected between the same set of electrically common points. Looking at the schematic diagram, we see that points 1, 2, 3, and 4 are all electrically common. So are points 8, 7, 6, and 5. Note that all resistors as well as the battery are connected between these two sets of points.

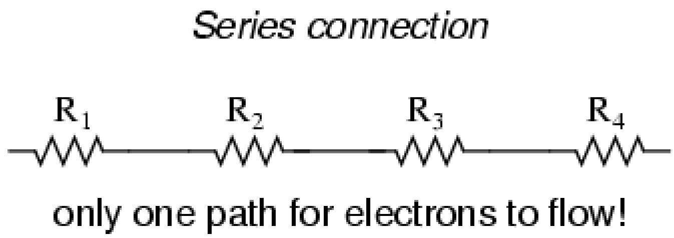
And, of course, the complexity doesn't stop at simple series and parallel either! We can have circuits that are a combination of series and parallel, too:



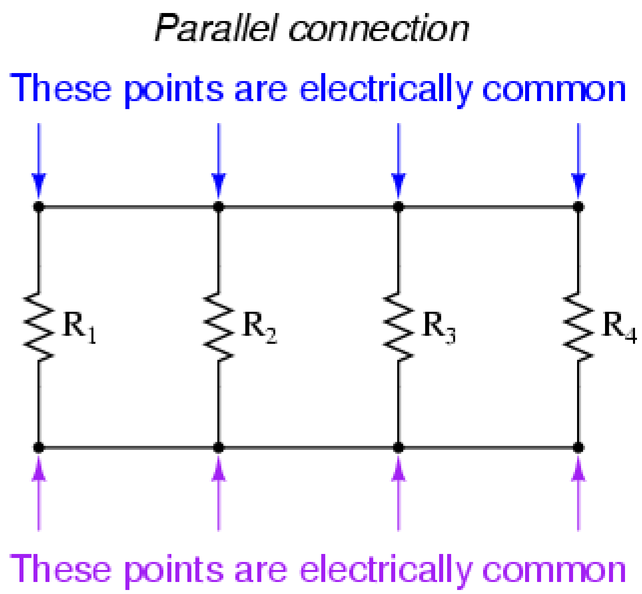
In this circuit, we have two loops for electrons to flow through: one from 6 to 5 to 2 to 1 and back to 6 again, and another from 6 to 5 to 4 to 3 to 2 to 1 and back to 6 again. Notice how both current paths go through R_1 (from point 2 to point 1). In this configuration, we'd say that R_2 and R_3 are in parallel with each other, while R_1 is in series with the parallel combination of R_2 and R_3.

This is just a preview of things to come. Don't worry! We'll explore all these circuit configurations in detail, one at a time!

The basic idea of a "series" connection is that components are connected end-to-end in a line to form a single path for electrons to flow:



The basic idea of a "parallel" connection, on the other hand, is that all components are connected across each other's leads. In a purely parallel circuit, there are never more than two sets of electrically common points, no matter how many components are connected. There are many paths for electrons to flow, but only one voltage across all components:



Series and parallel resistor configurations have very different electrical properties. We'll explore the properties of each configuration in the sections to come.

- REVIEW:
- In a series circuit, all components are connected end-to-end, forming a single path for electrons to flow. (Dependent)
- In a parallel circuit, all components are connected across each other, forming exactly two sets of electrically common points. (Independent)
- A "branch" in a parallel circuit is a path for electric current formed by one of the load components (such as a resistor).

Producing Electricity (Green or Brown)

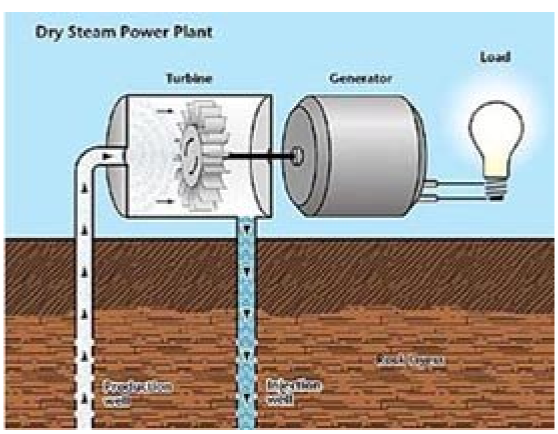
About Geothermal Electricity

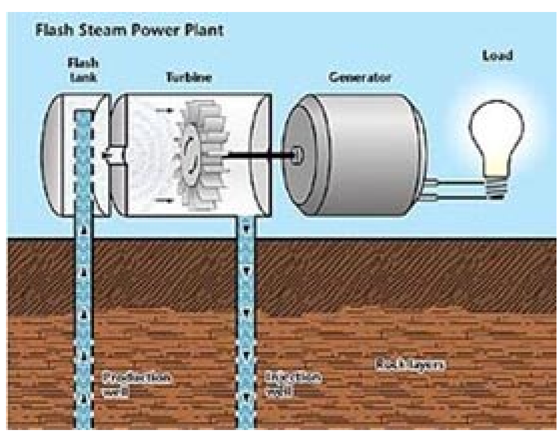
Geothermal ("earth heat") energy has tremendous potential for producing electricity. About 8,000 megawatts (MW) of geothermal electricity are currently produced around the world, including about 2,800 MW of capacity in the United States. Today's technology produces electricity from hydrothermal (hot water/steam) resources. In the future, we may be able to use the heat of the deep, hot, dry rock formations of Earth's crust, and possibly the even deeper, almost unlimited energy in Earth's magma.

Two basic types of geothermal power plants are used today: **steam** and **binary**.

Pacific Gas & Electric

Steam plants use very hot (more than 300° F) steam and hot water resources (as found at The Geysers plants in northern California—the largest geothermal electricity producer in the world). The steam either comes directly from the resource, or the very hot, high-pressure water is depressurized ("flashed") to produce steam. The steam then turns turbines, which drive generators that generate electricity. The only significant emission from these plants is steam (water vapor). Minute amounts of carbon dioxide, nitric oxide, and sulfur are emitted, but **almost 50 times less than at traditional, fossil-fuel power plants**. Energy produced this way currently costs about 4-6 cents per kWh.



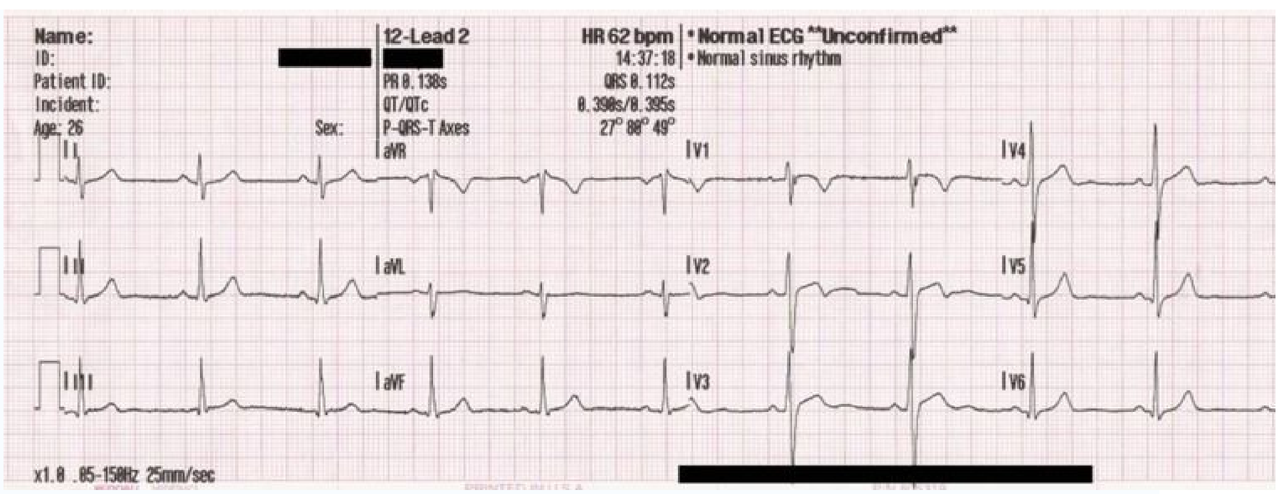


Electrocardiogram

An **electrocardiogram** (**ECG** or **EKG**, abbreviated from the German *Elektrokardiogramm*) is a graphic produced by an **electrocardiograph**, which records the electrical activity of the heart over time. Analysis of the various waves and normal vectors of depolarization and repolarization yields important diagnostic information.

- It is the gold standard for the diagnosis of cardiac arrhythmias
- It guides therapy and risk stratification for patients with suspected acute myocardial infarction
- It helps detect electrolyte disturbances (e.g. hyperkalemia and hypokalemia)
- It allows for the detection of conduction abnormalities (e.g. right and left bundle branch block)
- It is used as a screening tool for ischemic heart disease during a cardiac stress test
- It is occasionally helpful with non-cardiac diseases (e.g. pulmonary embolism or hypothermia)

The electrocardiogram does not directly assess the contractility of the heart. However, it can give a rough indication of increased or decreased contractility



ARE YOU ELECTRIC?