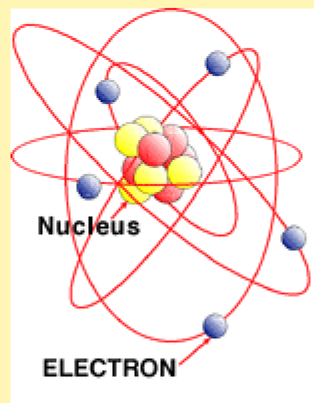
http://www.energyquest.ca.gov/story/chapter04.html

Electricity figures everywhere in our lives. Electricity lights up our homes, cooks our food, powers our computers, television sets, and other electronic devices. Electricity from batteries keeps our cars running and makes our flashlights shine in the dark.

Here's something you can do to see the importance of electricity. Take a walk through your school, house or apartment and write down all the different appliances, devices and machines that use electricity. You'll be amazed at how many things we use each and every day that depend on electricity.

But what is electricity? Where does it come from? How does it work? Before we understand all that, we need to know a little bit about atoms and their structure.

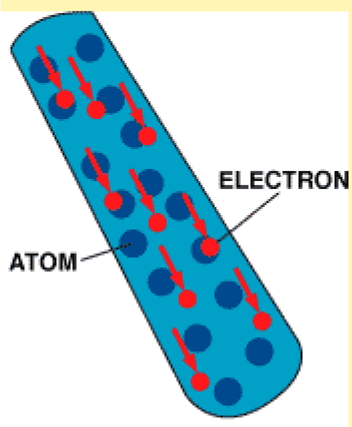


All matter is made up of atoms, and atoms are made up of smaller particles. The three main particles making up an atom are the proton, the neutron and the electron.

Electrons spin around the center, or nucleus, of atoms, in the same way the moon spins around the earth. The nucleus is made up of neutrons and protons.

Electrons contain a negative charge, protons a positive charge. Neutrons are neutral – they have neither a positive nor a negative charge.

There are many different kinds of atoms, one for each type of element. An atom is a single part that makes up an element. There are 118 different known elements that make up everything! Some elements like oxygen we breathe are essential to life.



Each atom has a specific number of electrons, protons and neutrons. But no matter how many particles an atom has, the number of electrons usually needs to be the same as the number of protons. If the numbers are the same, the atom is called balanced, and it is very stable.

So, if an atom had six protons, it should also have six electrons. The element with six protons and six electrons is called carbon. Carbon is found in abundance in the sun, stars, comets, atmospheres of most planets, and the food we eat. Coal is made of carbon; so are diamonds.

Some kinds of atoms have loosely attached electrons. An atom that loses electrons has more protons than electrons and is positively charged. An atom that gains electrons has more negative particles and is negatively charge. A "charged" atom is called an "ion."

Electrons can be made to move from one atom to another. When those electrons move between the atoms, a current of electricity is created. The electrons move from one atom to another in a "flow." One electron is attached and another electron is lost.

This chain is similar to the fire fighter's bucket brigades in olden times. But instead of passing one bucket from the start of the line of people to the other end, each person would have a bucket of water to pour from one bucket to another. The result was a lot of spilled water and not enough water to douse the fire. It is a situation that's very similar to electricity passing along a wire and a circuit. The charge is passed from atom to atom when electricity is "passed."

Scientists and engineers have learned many ways to move electrons off of atoms. That means that when you add up the electrons and protons, you would wind up with one more proton instead of being balanced.

Since all atoms want to be balanced, the atom that has been "unbalanced" will look for a free electron to fill the place of the missing one. We say that this unbalanced atom has a "positive charge" (+) because it has too many protons.

Since it got kicked off, the free electron moves around waiting for an unbalanced atom to give it a home. The free electron charge is negative, and has no proton to balance it out, so we say that it has a "negative charge" (-).

So what do positive and negative charges have to do with electricity?

Scientists and engineers have found several ways to create large numbers of positive atoms and free negative electrons. Since positive atoms want negative electrons so they can be balanced, they have a strong attraction for the electrons. The electrons also want to be part of a balanced atom, so they have a strong attraction to the positive atoms. So, the positive attracts the negative to balance out.

The more positive atoms or negative electrons you have, the stronger the attraction for the other. Since we have both positive and negative charged groups attracted to each other, we call the total attraction "charge."

Energy also can be measured in joules. Joules sounds exactly like the word jewels, as in diamonds and emeralds. A thousand joules is equal to a British thermal unit.

When electrons move among the atoms of matter, a current of electricity is created. This is what happens in a piece of wire. The electrons are passed from atom to atom, creating an electrical current from one end to other, just like in the picture.

Electricity is conducted through some things better than others do. Its resistance measures how well something conducts electricity. Some things hold their electrons very tightly. Electrons do not move through them very well. These things are called insulators. Rubber, plastic, cloth, glass and dry air are good insulators and have very high resistance.

Other materials have some loosely held electrons, which move through them very easily. These are called conductors. Most metals – like copper, aluminum or steel – are good conductors.

Electrons, electricity, electronic and other words that begin with "electr..." all originate from the Greek word "elektor," meaning "beaming sun." In Greek, "elektron" is the word for amber.

Amber is a very pretty goldish brown "stone" that sparkles orange and yellow in sunlight. Amber is actually fossilized tree sap! It's the stuff used in the movie "Jurassic Park." Millions of years ago insects got stuck in the tree sap. Small insects which had bitten the dinosaurs, had blood with DNA from the dinosaurs in the insect's bodies, which were now fossilized in the amber.

Ancient Greeks discovered that amber behaved oddly - like attracting feathers - when rubbed by fur or other objects. They didn't know what it was that caused this phenomenon. But the Greeks had discovered one of the first examples of static electricity.

The Latin word, electricus, means to "produce from amber by friction."

So, we get our English word electricity from Greek and Latin words that were about amber.

Chapter 3: Resistance and Static Electricity

As we have learned, some kinds of atoms contain loosely attached electrons. Electrons can be made to move easily from one atom to another. When those electrons move among the atoms of matter, a current of electricity is created.

Take a piece of wire. The electrons are passed from atom to atom, creating an electrical current from one end to the other. Electrons are very, very small. A single copper penny contains more than 10,000,000,000,000,000,000,000 (1x1022) electrons.

Electricity "flows" or moves through some things better than others do. The measurement of how well something conducts electricity is called its resistance.

Resistance in wire depends on how thick and how long it is, and what it's made of. The thickness of wire is called its gauge. The smaller the gauge, the bigger the wire. Some of the largest thicknesses of regular wire is gauge 1.

Different types of metal are used in making wire. You can have copper wire, aluminum wire, even steel wire. Each of these metals has a different resistance; how well the metal conducts electricity. The lower the resistance of a wire, the better it conducts electricity.

Copper is used in many wires because it has a lower resistance than many other metals. The wires in your walls, inside your lamps and elsewhere are usually copper.

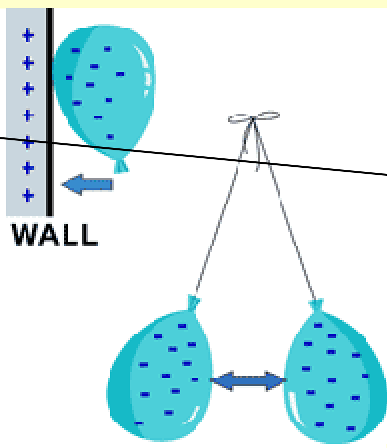
A piece of metal can be made to act like a heater. When an electrical current occurs, the resistance causes friction and the friction causes heat. The higher the resistance, the hotter it can get. So, a coiled wire high in resistance, like the wire in a hair dryer, can be very hot.

Some things conduct electricity very poorly. These are called insulators. Rubber is a good insulator, and that's why rubber is used to cover wires in an electric cord. Glass is another good insulator. If you look at the end of a power line, you'll see that it is attached to some bumpy looking things. These are glass insulators. They keep the metal of the wires from touching the metal of the towers.

Question #1

Another type of electrical energy is static electricity. Unlike current electricity that moves, static electricity stays in one place.

Try this experiment...



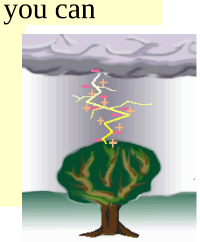
Rub a balloon filled with air on a wool sweater or on your hair. Then hold it up to a wall. The Tie strings to the ends of two balloons. Now rub the two balloons together, hold them by strings at the end and put them next to each other. They'll move apart.

Rubbing the balloons gives them static electricity. When you rub the balloon it picks up extra electrons from the sweater or your hair and becomes slightly negatively charged.

The negative charges in the single balloon are attracted to the positive charges in the wall.

The two balloons hanging by strings both have negative charges. Negative charges always repel negative charges and positive always repels positive charges. So, the two balloons' negative charges "push" each other apart.

Static electricity can also give you a shock. If you walk across a carpet, shuffling your feet and touching something made of metal, a spark can jump between you and the metal object. Shuffling your feet picks up additional electrons spread over your body. When you touch a metal doorknob or something with a positive charge the electricity jumps across the small gap from your fingers just before you touch the metal knob. If you walk across a carpet and touch a computer case, you can damage the computer.



One other type of static electricity is very spectacular. It's the lightning in a thunder and lightning storm. Clouds become negatively charged as ice crystals inside the clouds rub up against each other. Meanwhile, on the ground, the positive charge increases. The clouds get so highly charged that the electrons jump from the ground to the cloud, or from one cloud to another cloud. This causes a huge spark of static electricity in the sky that we call lightning. You'll remember from Chapter 2 that the word "electricity" came from the Greek words "elektor," for "beaming sun" and "elektron," both words describing amber. Amber is fossilized tree sap millions of years old and has hardened as hard as a stone.

Around 600 BCE (Before the Common Era) Greeks noticed a strange effect: When rubbing "elektron" against a piece of fur, the amber would start attracting particles of dust, feathers and straw. No one paid much attention to this "strange effect" until about 1600 when Dr. William Gilbert investigated the reactions of magnets and amber and discovered other objects can be made "electric."

Gilbert said that amber acquired what he called "resinous electricity" when rubbed with fur. Glass, however, when rubbed with silk, acquired what he termed "vitreous electricity."

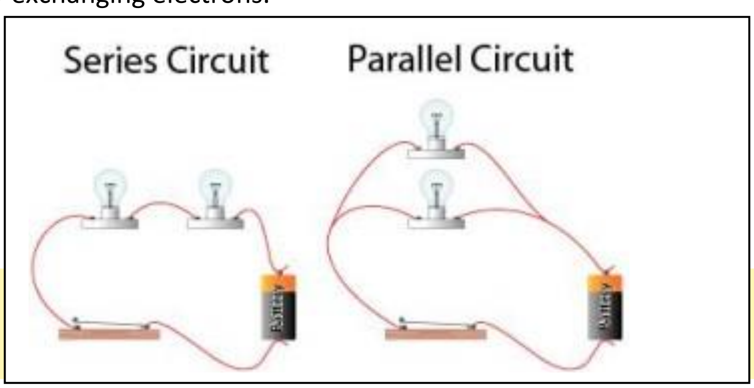
He thought that electricity repeled the same kind and attracts the opposite kind of electricity. Gilbert and other scientists of that time thought that the friction actually created the electricity (their word for the electrical charge).

In 1747, Benjamin Franklin in America and William Watson in England both reached the same conclusion. They said all materials possess a single kind of electrical "fluid." They didn't really know anything about atoms and electrons, so they called how it behaved a "fluid."

They thought that this fluid can penetrate matter freely and couldn't be created or destroyed. The two men thought that the action of rubbing (like rubbing amber with fur) moves this unseen fluid from one thing to another, electrifying both.

Franklin defined the fluid as positive and the lack of fluid as negative. Therefore, according to Franklin, the direction of flow was from positive to negative. Today, we know that the opposite is true. Electricity flows from negative to positive. Others took the idea even further saying this that two fluids are involved. They said items with the same fluid attract each other. And opposite types of fluid in objects will make them repel each other.
All of this was only partially right. This is how scientific theories develop. Someone thinks of why something occurs and then proposes an explanation. It can take centuries sometime to find the real truth. Instead of electricity being a fluid, it is the movement of the charged particles between the objects... the two objects are really exchanging electrons.

Types of circuits



Electrons with a negative charge, can't "jump" through the air to a positively charged atom. They have to wait until there is a link or bridge between the negative area and the positive area. We usually call this bridge a "circuit."

When a bridge is created, the electrons begin moving quickly. Depending on the resistance of the material making up the bridge, they try to get across as fast as they can. If you're not careful, too many electrons can go across at one time and destroy the "bridge" or the circuit, in the process.

In Chapter 3, we learned about electrons and the attraction between positive and negative charges. We also learned that we can create a bridge called a "circuit" between the charges.

We can limit the number of electrons crossing over the "circuit," by letting only a certain number through at a time. And we can make electricity do something for us while they are on their way. For example, we can "make" the electrons "heat" a filament in a bulb, causing it to glow and give off light.

When we limit the number of electrons that can cross over our circuit, we say we are giving it "resistance". We "resist" letting all the electrons through. This works something like a tollbooth on a freeway bridge. Copper wire is just one type of bridge we use in circuits.

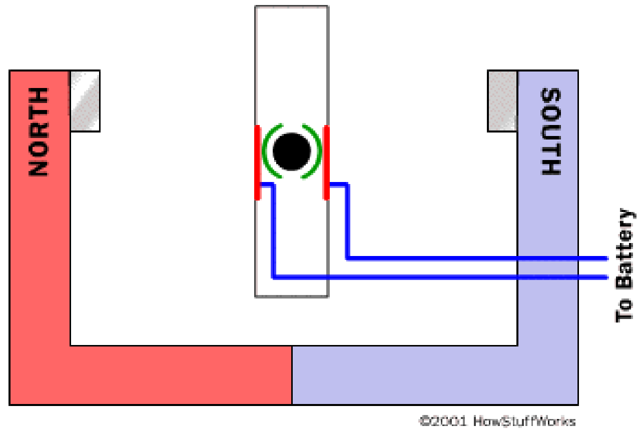
Before electrons can move far, however, they can collide with one of the atoms along the way. This slows them down or even reverses their direction. As a result, they lose energy to the atoms. This energy appears as heat, and the scattering is a resistance to the current.

Think of the bridge as a garden hose. The current of electricity is the water flowing in the hose and the water pressure is the voltage of a circuit. The diameter of the hose is the determining factor for the resistance.

Current refers to the movement of charges. In an electrical circuit – electrons move from the negative pole to the positive. If you connected the positive pole of an electrical source to the negative pole, you create a circuit. This charge changes into electrical energy when the poles are connected in a circuit – similar to connecting the two poles on opposite ends of a battery.

Along the circuit you can have a light bulb and an on-off switch. The light bulb changes the electrical energy into light and heat energy.

An electric motor uses circuits wound round and round. These wound circuits are suspended between magnets.



A motor works through electromagnetism. It has a coiled up wire (the circuit) that sits between the north and south poles of a magnet. When current flows through the coiled circuit, another magnetic field is produced. The north pole of the fixed magnet attracts the south pole of the coiled wire. The two north poles push away, or repulse, each other. The motor is set up in a way that attraction and repulsion spins the center section with the coiled wire.

Turbines, Generators and Power Plants

As we learned in **Chapter 2**, electricity flows through wires to light our lamps, run TVs, computers and all other electrical appliances. But where does the electricity come from?

In this chapter, we'll learn how electricity is generated in a power plant. In the next few chapters, we'll learn about the various resources that are used to make the heat to produce electricity. In **Chapter 7**, we'll learn how the electricity gets from the power plant to homes, school and businesses.

Photo credit: Carl Lira, Mich. State Univ.

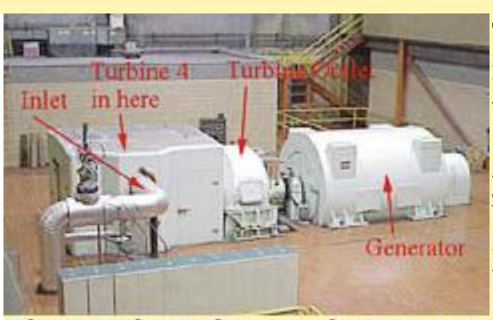


Photo credit: Carl Lira, Mich. State Univ.

Thermal power plants have big boilers that burn a fuel to make heat. A boiler is like a teapot on a stove. When the water boils, the steam comes through a tiny hole on the top of the spout. The moving steam makes a whistle that tells you the water has boiled. In a power plant, the water is brought to a boil inside the boiler, and the steam is then piped to the turbine through very thick pipes.

In most boilers, wood, coal, oil or natural gas is burned in a firebox to make heat. Running through the fire box and above that hot fire are a series of pipes with water running through them. The heat energy is conducted into the metal pipes, heating the water in the pipes until it boils into steam. Water boils into steam at 212 degrees Fahrenheit or 100 degrees Celsius.

The top picture on the right is of a small power plant located at Michigan State University. The black area to the left of the power plant is coal, the energy source that is burned to heat the water in the boilers of this plant.

Photo credit: Carl Lira, Mich. State Univ.

In the second picture to the left, you'll see the turbine and generator at MSU's power plant. The big pipe on the left side is the steam inlet. On the right side of the turbine is where the steam comes out. The steam is fed under high pressure to the turbine. The turbine spins and its shaft is connected to a turbogenerator that changes the mechanical spinning energy into electricity.

The third picture on the right is of the turbine fan before it is placed inside the turbine housing. You can see a close-up of the turbine blades on the fourth picture. The turbine has many hundreds of blades that are turned at an angle like the blades of a fan. When the steam hits the blades they spin the turbine's shaft that is attached to the bottom of the blades.

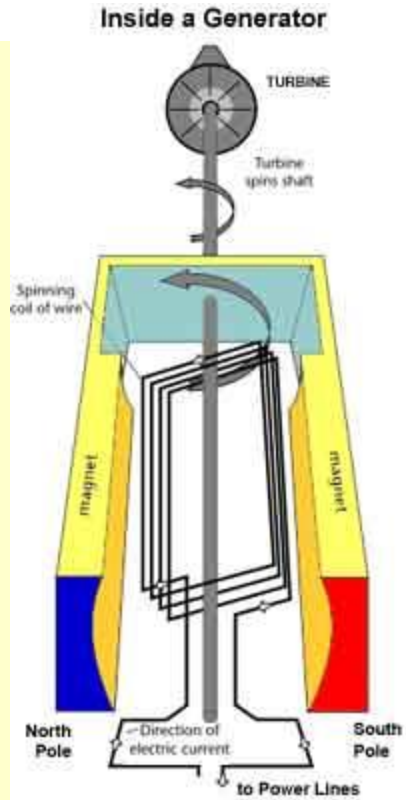
After the steam goes through the turbine, it usually goes to a cooling tower outside the where the steam cools off. It cools off and becomes water again. When the hot pipes come into contact with cool air, some water vapor in the air is heated and steam is given off above the cooling towers. That's why you see huge white clouds sometimes being given off by the cooling towers. It's not smoke, but is water vapor or steam. This is not the same steam that is used inside the turbine.

Photo credit:
Carl Lira, Mich. State Univ.

The cooled water then goes back into the boiler where it is heated again and the process repeats over and over.

Most power plants in California use cleaner-burning natural gas to produce electricity. Others use oil or coal to heat the water. Nuclear power plants use nuclear energy to heat water to make electricity. Still others, called geothermal power plants, use steam or hot water found naturally below the earth's surface without burning a fuel.

How the Generator Works



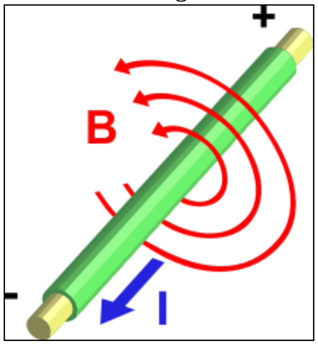
The turbine is attached by a shaft to the turbogenerator. The generator has a long, coiled wire on its shaft surrounded by a giant magnet. You can see the inside of the generator coil with all its wires in the picture on the right.

The shaft that comes out of the turbine is connected to the generator. When the turbine turns, the shaft and rotor is turned. As the shaft inside the generator turns, an electric current is produced in the wire. The electric generator is converting mechanical, moving energy into electrical energy.

The generator is based on the principle of "electromagnetic induction" discovered in 1831 by Michael Faraday, a British scientist. Faraday discovered that if an electric conductor, like a copper wire, is moved through a magnetic field, electric current will flow (or "be induced") in the conductor. So the mechanical energy of the moving wire is converted into the electric energy of the current that flows in the wire.

The electricity produced by the generator then flows through huge transmission wires that link the power plants to our homes, school and businesses. If you want to learn about transmission lines, go to **Chapter 7.**

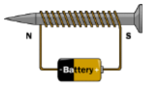
All power plants have turbines and generators. Some turbines are turned by wind, some by water, some by steam.



Electromagnets

An electromagnet is a type of magnet whose magnetic field is produced by the flow of electric current. The magnetic field disappears when the current is turned off. If you have ever played with a really powerful magnet, you have probably noticed one problem. You have to be pretty strong to separate the magnets again! Today, we have many uses for powerful magnets, but they wouldn't be any good to us if we were not able to make them release the objects that they attract. In 1820, a Danish physicist, Hans Christian Oersted, discovered that there was a relationship between electricity and magnetism. Thanks to Oersted and a few others, by using electricity, we can now make huge magnets. We can also cause them to release their objects. Electricity and magnetism are closely related. The movement of electrons causes both, and every electric current has its own magnetic field. This magnetic force in electricity can be used to make powerful electromagnets that can be turned on and off with the flick of a switch. But how do you make an electromagnet?

Making an electromagnet: By simply wrapping wire that has an electrical current running through it around a nail, you can make an electromagnet. When the electric current moves through a wire, it makes a magnetic field. If you coil the wire around and around, it will make the magnetic force stronger, but it will still be pretty weak. Putting a piece of iron or steel inside the coil makes the magnet strong enough to attract objects. The strength of an electromagnet can be increased by increasing the number of loops of wire around the iron core and by increasing the current or voltage. You can make a temporary magnet by stroking a piece of iron or steel (such as a needle) along a permanent magnet. There is another way that uses electricity to make a temporary magnet, called an electromagnet. In class today, we are going to make a simple electromagnet using a nail, copper wire and a battery (see diagram below). We will be able to pick up paper clips and other objects with our electromagnets. In the picture at the top of this page, in our class project, the nail will be in place where the green tube is and where the red arrows are, that will be the copper wire.



Uses of an electromagnet:

Electromagnets are very widely used as components of other electrical devices, such as television, cell phones, doorbell, radio, microwave, motors, generators, relays, loudspeakers, hard disks, and magnetic separation equipment. They are also employed as industrial lifting electromagnets for picking up and moving heavy iron objects like scrap iron.

Pictured above: A huge electromagnet used at a scrap yard. Iron attaches to the electromagnet and is lifted onto a truck. The electricity to the electromagnet is turned off in order to get the magnet to release the iron scraps into the truck.

Optional Reading for Students interested in learning more about electromagnets --may enjoy learning about electromagnetic aircraft launch systems (EMALS). Check out the article written on December 24, 2010 at https://www.foxnews.com/tech/navy-uses-electromagnets-to-launch-fighter-jet

This is a fascinating article about Navy Uses Electromagnets to Launch Fighter Jets.
There is a video at this website that shows an amazing gun created using magnets for the Navy.
https://www.youtube.com/watch?v=o4ZqfEJTGzw

Hans Christian Oersted

In 1820, Hans Christian Oersted (1777-1851) proved electric current can affect a compass needle. However, Oersted could not explain why. His observations brought scientists one more step closer to seeing the relationship between magnetism and electricity.

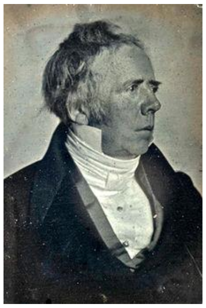
Michael Faraday (1791-1867)

Invented the electric motor. Electromagnetic induction is the production of voltage across a conductor moving through a magnetic field. Faraday discovered induction which is at the basis of electromagnetic technology.

James Clerk Maxwell (1831-1879)

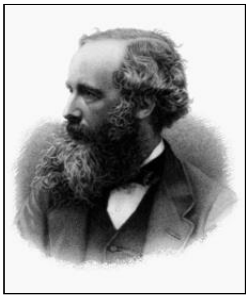
Discovered electromagnetic theory. His work in producing a unified model of electromagnetism is one of the greatest advances in physics.

Heinrich Rudolf Hertz (1857 -1894) was a German physicist who clarified and expanded the electromagnetic theory of light that had been put forth by Maxwell. He was the first to satisfactorily demonstrate the existence of electromagnetic waves by building an apparatus to produce and detect radio waves.



Hans Christian Oersted

Michael Faraday



James Clerk Maxwell

Heinrich Rudolf Hertz

Answers: 1) electric current 2) it disappears 3) Hans Christian Oersted 4) switch 5)wire, voltage 6) yes 7) varies 8)no 9)electric motor 10) James Clerk Maxwell 11)Heinrich Rudolf Hertz