Directions: Read the following about wind power and electricity and answer the given questions.

How Wind Power Works

It's hard sometimes to imagine air as a fluid. It just seems so ... invisible. But air is a fluid like any other except that its particles are in gas form instead of liquid. And when air moves quickly, in the form of wind, those particles are moving quickly. Motion means kinetic energy, which can be captured, just like the energy in moving water can be captured by the turbine in a hydroelectric dam. In the case of a **wind-electric turbine**, the turbine blades are designed to capture the kinetic energy in wind. The rest is nearly identical to a hydroelectric setup

When the turbine blades capture wind energy and start moving, they spin a shaft that leads from the hub of the rotor to a generator. The generator turns that rotational energy into electricity. At its essence, generating electricity from the wind is all about transferring energy from one medium to another.

Wind power all starts with the sun. When the sun heats up a certain area of land, the air around that land mass absorbs some of that heat. At a certain temperature, that hotter air begins to rise very quickly because a given volume of hot air is lighter than an equal volume of cooler air. Faster-moving (hotter) air particles exert more pressure than slower-moving particles, so it takes fewer of them to maintain the normal air pressure at a given elevation (see How Hot Air Balloons Work to learn more about air temperature and pressure). When that lighter hot air suddenly rises, cooler air flows quickly in to fill the gap the hot air leaves behind. That air rushing in to fill the gap is wind.

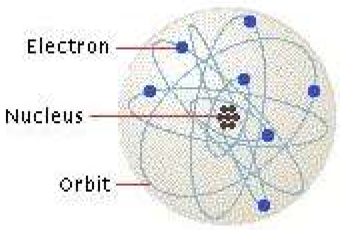
If you place an object like a rotor blade in the path of that wind, the wind will push on it, transferring some of its own energy of motion to the blade. This is how a wind turbine captures energy from the wind. The same thing happens with a sail boat. When moving air pushes on the barrier of the sail, it causes the boat to move. The wind has transferred its own energy of motion to the sailboat.

What exactly is Electricity? *http://science.howstuffworks.com/electricity3.htm*

Even though they didn't fully understand it, ancient people knew about electricity. Thales of Miletus, a Greek philosopher known as one of the legendary Seven Wise Men, may have been the first human to study electricity, circa 600 B.C. By rubbing amber -- fossilized tree resin -- with fur, he was able to attract dust, feathers and other lightweight objects. These were the first experiments with electrostatics, the study of stationary electric charges or static electricity. In fact, the word electricity comes from the Greek elektron, which means amber. But before defining what electricity is, we must understand what it is made up of.

Electricity and Atomic Structure *http://science.howstuffworks.com/electricity3.htm*

Toward the end of the 19th century, science was barreling along at an impressive pace. Automobiles and aircraft were on the verge of changing the way the world moved, and electric power was steadily making its way into more and more homes. Yet even scientists of the day still viewed electricity as something vaguely mystical. It wasn't until 1897 that scientists discovered the existence of electrons -- and this is where the modern era of electricity starts.



Matter, as you probably know, is composed of atoms. Break something down to small enough pieces and you wind up with a nucleus orbited by one or more electrons, each with a negative charge. In many materials, the electrons are tightly bound to the atoms. Wood, glass, plastic, ceramic, air, cotton -- these are all examples of materials in which electrons stick with their atoms. Because these atoms are so reluctant to share electrons, these materials can't conduct electricity very well, if at all. These materials are electrical insulators.

Most metals, however, have electrons that can detach from their atoms and zip around. These are called free electrons. The loose electrons make it easy for electricity to flow through these materials, so they're known as electrical conductors. They conduct electricity. The moving electrons transmit electrical energy from one point to another.

An interesting idea is to think of atoms as pet dogs and electrons as a case of fleas. Dogs that lived inside or within a fenced-in area, thereby keeping those pesky fleas contained, would be the equivalent of an electrical insulator. Free-roaming mutts, however, would be electrical conductors. If you had one neighborhood of indoor, pampered pugs and one neighborhood of unfenced basset hounds running wild, which group do you think could spread an outbreak of fleas the fastest?

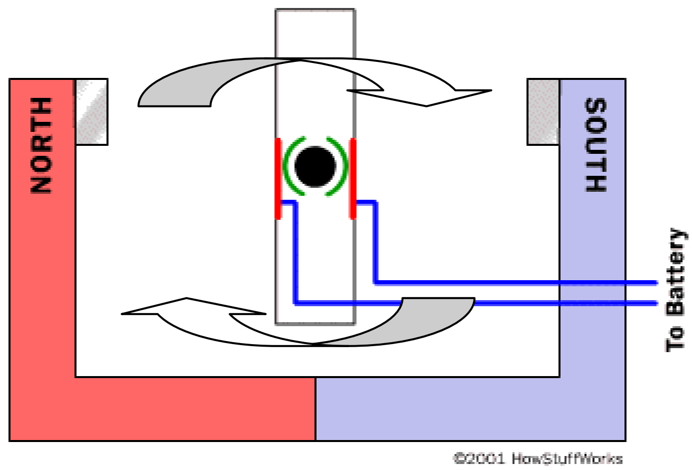
So, electricity needs a conductor in order to move. There also has to be something to make the electricity flow from one point to another through the conductor. One way to get electricity flowing is to use a generator.

Generators *http://science.howstuffworks.com/electricity3.htm*

If you've ever moved paper clips around with a magnet or killed time arranging metal shavings into a beard on a "Wooly Willy" toy, then you've dabbled in the basic principles behind even the most complicated electric generators. The magnetic field responsible for lining up all those little bits of metal into a proper Mohawk haircut is due to the movement of electrons. Move a magnet toward a paper clip and you'll force the electrons in the clip to move. Similarly, if you allow electrons to move through a metal wire, a magnetic field will form around the wire.

Thanks to Wooly Willy, we can see that there's a definite link between the phenomena of electricity and magnetism. A generator is simply a device that moves a magnet near a wire to create a steady flow of electrons. The action that forces this movement varies greatly, ranging from hand cranks and steam engines to nuclear fission, but the principle remains the same.

One simple way to think about a generator is to imagine it acting like a pump pushing water through a pipe. Only instead of pushing water, a generator uses a magnet to push electrons along. This is a slight oversimplification, but it paints a helpful picture of the properties at work in a generator. A water pump moves a certain number of water molecules and applies a certain amount of pressure to them. In the same way, the magnet in a generator pushes a certain number of electrons along and applies a certain amount of "pressure" to the electrons.



In an electrical circuit, the number of electrons in motion is called the amperage or current, and it's measured in amps. The "pressure" pushing the electrons along is called the voltage and is measured involts. For instance, a generator spinning at 1,000 rotations per minute might produce 1 amp at 6 volts. The 1 amp is the number of electrons moving (1 amp physically means that 6.24 x 1018 electrons move through a wire every second), and the voltage is the amount of pressure behind those electrons.

Generators are what form the heart of modern power stations.

Voltage, Current and Resistance *http://science.howstuffworks.com/electricity7.htm*

As mentioned earlier, the number of electrons in motion in a circuit is called the current, and it's measured in amps. The "pressure" pushing the electrons along is called the voltage and is measured in volts. If you live in the United States, the power outlets in the wall of your house or apartment deliver 120 volts each.
If you know the amps and volts involved, you can determine the amount of electricity consumed, which we typically measure in watt-hours or kilowatt-hours. Imagine that you plug a space heater into a wall outlet. You measure the amount of current flowing from the wall outlet to the heater, and it comes out to 10 amps. That means that it is a 1,200-watt heater. If you multiply the volts by the amps, you get the wattage. In this case, 120 volts multiplied by 10 amps equals 1,200 watts. This holds true for any electrical appliance. If you plug in a light and it draws half an amp, it's a 60-watt light bulb.

Let's say that you turn on the space heater and then look at the power meter outside. The meter's purpose is to measure the amount of electricity flowing into your house so that the power company can bill you for it. Let's assume -- we know it's unlikely -- that nothing else in the house is on, so the meter is measuring only the electricity used by the space heater.

Your space heater is using 1.2 kilowatts (1,200 watts). If you leave the space heater on for one hour, you will use 1.2 kilowatt-hours of power. If your power company charges you 10 cents per kilowatt-hour, then the power company will charge you 12 cents for every hour that you leave your space heater on.

Now let's add one more factor to current and voltage: resistance, which is measured in ohms. We can extend the water analogy to understand resistance, too. The voltage is equivalent to the water pressure, the current is equivalent to the flow rate and the resistance is like the pipe size.

A basic electrical engineering equation called Ohm's law spells out how the three terms relate. Current is equal to the voltage divided by the resistance. It's written like this:

$I = V/R$

where I stands for current (measured in amps), V is voltage (measured in volts) and R symbolizes resistance (measured in ohms).

Let's say you have a tank of pressurized water connected to a hose that you're using to water the garden. If you increase the pressure in the tank, more water comes out of the hose, right? The same is true of an electrical system: Increasing the voltage will result in greater current flow.

Now say you increase the diameter of the hose and all of the tank's fittings. This adjustment would also make more water come out of the hose. This is like decreasing the resistance in an electrical system, which increases the current flow.

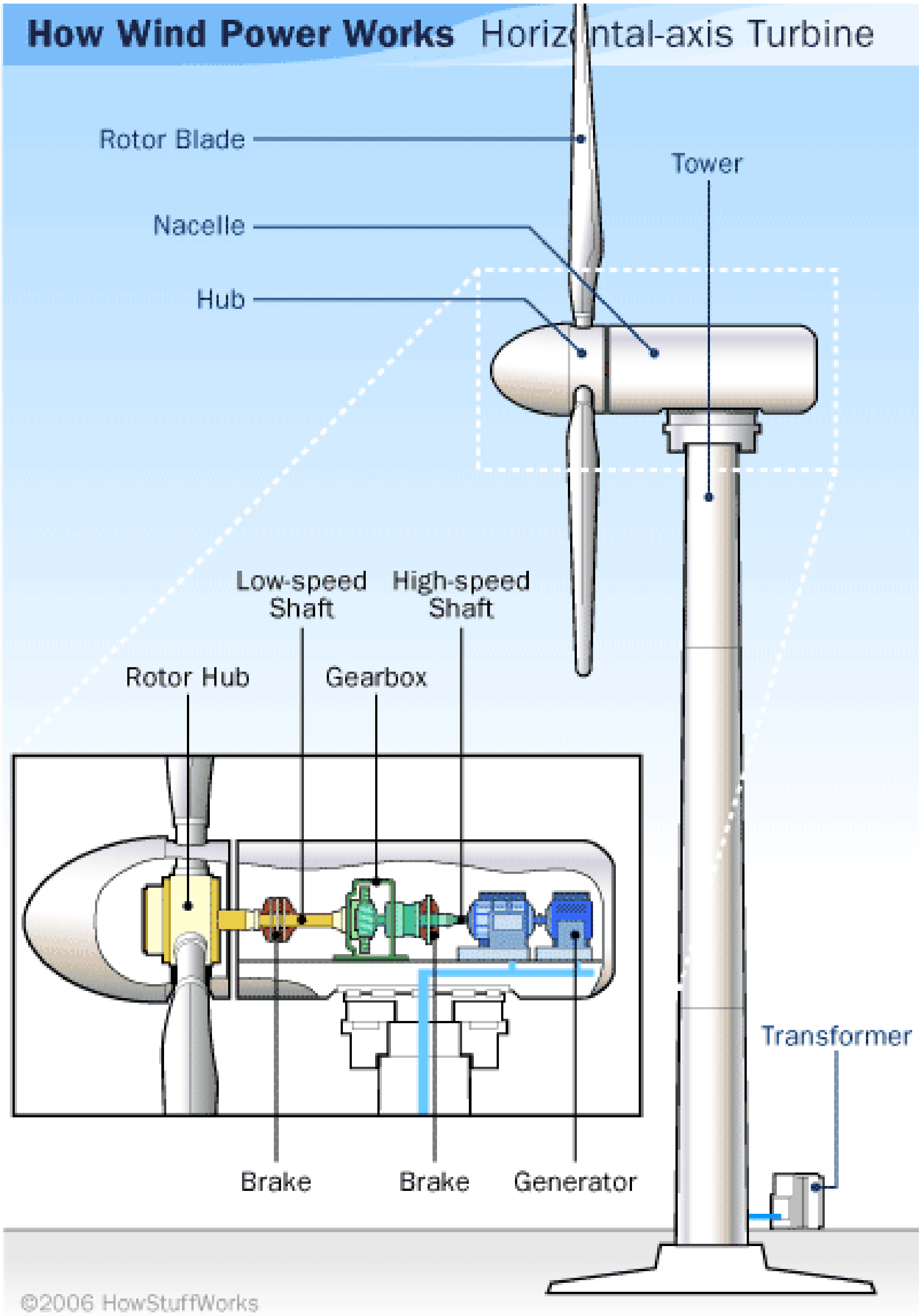
When you look at a normal incandescent light bulb, you can see this water analogy in action. The filament of a light bulb is an extremely thin wire. This thin wire resists the flow of electrons. You can calculate the resistance of the wire with the resistance equation.

Electricity can be difficult to define, one definition is as follows:
Electricity is the flow of electrical power or charge. It is both a basic part of nature and one of our most widely used form of energy. Electricity is actually a secondary energy source, also referred to as an energy carrier. That means that we get electricity from the conversion of other sources of energy, such as coal, nuclear, or solar energy. These are called primary sources. The energy sources we use to make electricity can be renewable or non-renewable, but electricity itself is neither renewable or *nonrenewable*http://www.eia.gov/kids/energy

Photo courtesy GNU; Photographer: Kit Conn
Wind farm in California

Horizontal-axis wind turbines (HAWTs) and Vertical-axis wind turbines (VAWTs)

As implied by the name, the HAWT shaft is mounted horizontally, parallel to the ground. HAWTs need to constantly align themselves with the wind using a yaw-adjustment mechanism. The yaw system typically consists of electric motors and gearboxes that move the entire rotor left or right in small increments. The turbine's electronic controller reads the position of a wind vane device (either mechanical or electronic) and adjusts the position of the rotor to capture the most wind energy available. HAWTs use a tower to lift the turbine components to an optimum elevation for wind speed (and so the blades can clear the ground) and take up very little ground space since almost all of the components are up to 260 feet (80 meters) in the air.


How Wind Power Works Horizontal-axis Turbine
Rotor Blade
Tower
Nacelle
Hub
Low-speed Shaft
High-speed Shaft
Rotor Hub
Gearbox
Transformer
Brake
Brake
Generator
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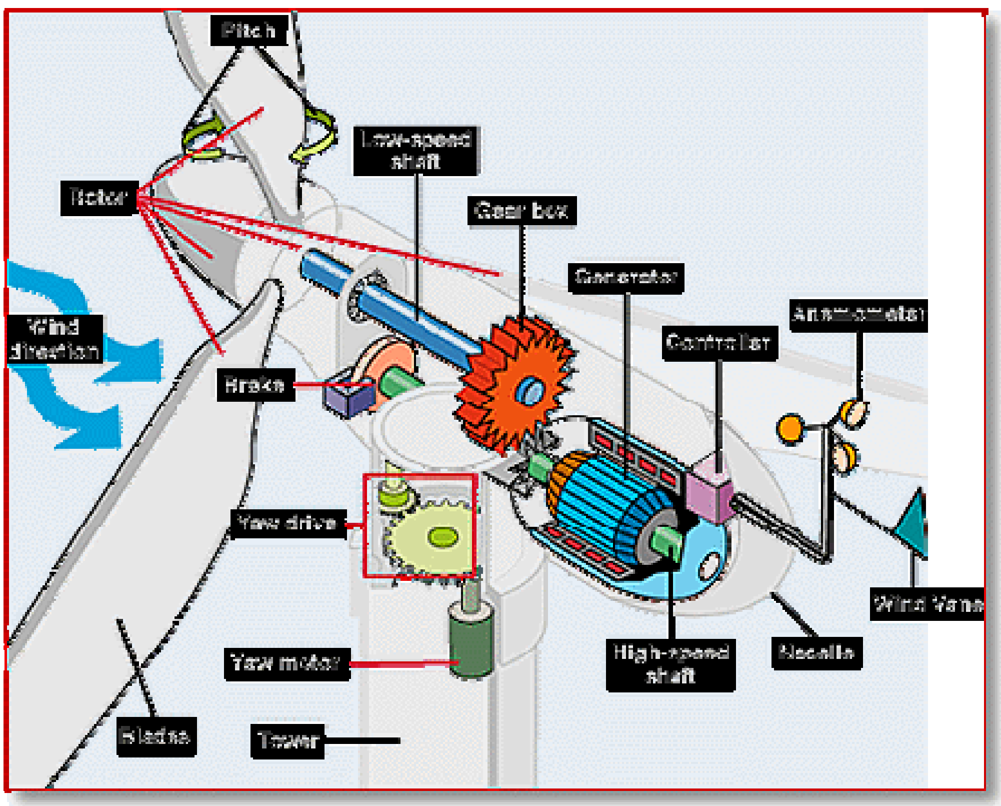
Large HAWT components:

- **rotor blades** - capture wind's energy and convert it to rotational energy of shaft
- **shaft** - transfers rotational energy into generator
- **nacelle** - casing that holds:
    - **gearbox** - increases speed of shaft between rotor hub and generator
    - **generator** - uses rotational energy of shaft to generate electricity using electromagnetism
    - **electronic control unit** (not shown) - monitors system, shuts down turbine in case of malfunction and controls yaw mechanism
    - **yaw controller** (not shown) - moves rotor to align with direction of wind
    - **brakes** - stop rotation of shaft in case of power overload or system failure
- **tower** - supports rotor and nacelle and lifts entire setup to higher elevation where blades can safely clear the ground
- **electrical equipment** - carries electricity from generator down through tower and controls many safety elements of turbine



Parts of a Wind Turbine

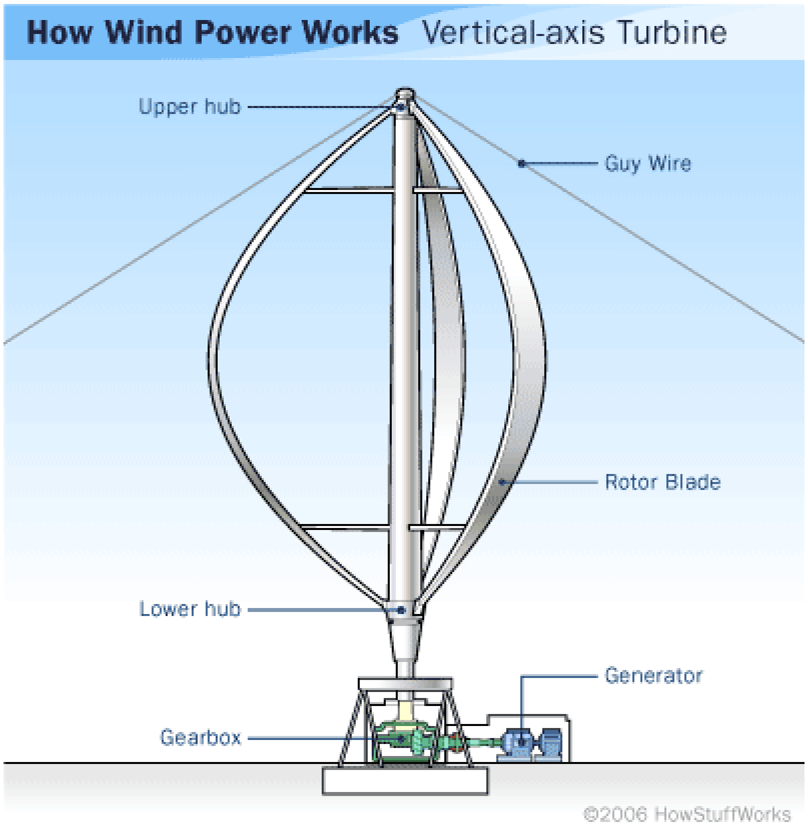
The simplest possible wind-energy turbine consists of three crucial parts:

- **Rotor blades** - The blades are basically the sails of the system; in their simplest form, they act as barriers to the wind (more modern blade designs go beyond the barrier method). When the wind forces the blades to move, it has transferred some of its energy to the rotor.
- **Shaft** - The wind-turbine shaft is connected to the center of the rotor. When the rotor spins, the shaft spins as well. In this way, the rotor transfers its mechanical, rotational energy to the shaft, which enters an electrical generator on the other end.
- **Generator** - At its most basic, a generator is a pretty simple device. It uses the properties of electromagnetic induction to produce electrical voltage - a difference in electrical charge. Voltage is essentially electrical pressure - it is the force that moves electricity, or electrical current, from one point to another. So generating voltage is in effect generating current. A simple generator consists of magnets and a conductor. The conductor is typically a coiled wire. Inside the generator, the shaft connects to an assembly of permanent magnets that surrounds the coil of wire. In electromagnetic induction, if you have a conductor surrounded by magnets, and one of those parts is rotating relative to the other, it induces voltage in the conductor. When the rotor spins the shaft, the shaft spins the assembly of magnets, generating voltage in the coil of wire. That voltage drives electrical current (typically alternating current, or AC power) out through power lines for distribution.

Now that we've looked at a simplified system, we'll move on to the modern technology you see in wind farms and rural backyards today. It's a bit more complex, but the underlying principles are the same.

When you talk about modern wind turbines, you're looking at two primary designs: horizontal-axis and vertical-axis. **Vertical-axis wind turbines** (**VAWTs**) are pretty rare. The only one currently in commercial production is the Darrieus turbine, which looks kind of like an egg beater.

In a VAWT, the shaft is mounted on a vertical axis, perpendicular to the ground. VAWTs are always aligned with the wind, unlike their horizontal-axis counterparts, so there's no adjustment necessary when the wind direction changes; but a VAWT can't start moving all by itself -- it needs a boost from its electrical system to get started. Instead of a tower, it typically uses guy wires for support, so the rotor elevation is lower. Lower elevation means slower wind due to ground interference, so VAWTs are generally less efficient than HAWTs. On the upside, all equipment is at ground level for easy installation and servicing; but that means a larger footprint for the turbine, which is a big negative in farming areas.



Darrieus-design VAWT

VAWTs may be used for small-scale turbines and for pumping water in rural areas, but all commercially produced, utility-scale wind turbines are **horizontal-axis wind turbines** (**HAWTs**).