History of Hydropower Timeline

B.C.	Hydropower used by the Greeks to turn water wheels for grinding grains more than 2,000 years ago.
Mid-1770s	French hydraulic and military engineer Bernard Forest de Bélidor wrote *Architecture Hydraulique*, a four-volume work describing vertical- and horizontal-axis machines.
1775	U.S. Army Corps of Engineers founded, with establishment of Chief Engineer for the Continental Army.
1880	Michigan's Grand Rapids Electric Light and Power Company, generating electricity by dynamo belted to a water turbine at the Wolverine Chair Factory, lit up 16 brush-arc lamps.
1881	Niagara Falls city street lamps powered by hydropower.
1882	World's first hydroelectric power plant began operation on the Fox River in Appleton, WI.
1886	About 45 water-powered electric plants in the U.S. and Canada.
1887	San Bernardino, CA opens first hydroelectric plant in the West.
1889	Two hundred electric plants in the U.S. use hydropower for at least part of their generation.
1901	First Federal Water Power Act. No one could build or operate a hydroelectric plant on a stream large enough for boat traffic without special permission from Congress.
1902	U.S. Bureau of Reclamation established.
1907	Hydropower provided 15 percent of U.S. electricity generation.
1920	Hydropower provided 25 percent of U.S. electricity generation. Federal Power Act establishes Federal Power Commission authority to issue licenses for hydro development on public lands.
1933	Tennessee Valley Authority was established, taking charge of hydroelectric potential of the Tennessee River and its tributaries.
1935	Federal Power Commission authority was extended to all hydroelectric projects built by utilities engaged in interstate commerce.
1936	Hoover Dam began operating on the Colorado River. Using multiple Francis turbines, the Hoover Dam plant produces up to 130,000 kilowatts of power.
1937	Bonneville Dam, the first federal dam, begins operation on the Columbia River. Bonneville Power Administration established.
1940	Hydropower provided forty percent of the nation's electricity generation. Conventional capacity tripled in United States since 1920.
1977	Federal Power Commission disbanded by Congress. A new agency was created, the Federal Energy Regulatory Commission (FERC).
1980	Conventional hydropower plant capacity nearly tripled in United States since 1940.
Today	Between 5–10 percent of U.S. electricity comes from hydropower, depending on water supply. In total, the U.S. has about 78,000 MW of conventional capacity and 21,000 MW of pumped storage capacity.

Careers in the Hydropower Industry

Energy Industry Analysts assess the significance of developments and trends in the energy industry and use this information for current and future regulatory policies. Energy industry analysts require a degree in finance, management, or other business, industrial, mechanical, or other engineering field.

Accountants establish accounting policies, providing guidance to energy companies for reporting issues.

Auditors review financial information about energy companies to ensure they are in compliance with government regulations. Accountants and auditors require a bachelor's degree in accounting.

Administrators provide general office clerical support to professional, program, or technical staff members utilizing typing skills and a knowledge of office automation hardware and software systems. Administrative support staff may be responsible for timekeeping, government procedures, and other personnel matters.

Communications Professionals must possess excellent writing and speaking skills, a customer service attitude, and the ability to respond quickly in a dynamic environment. Communications professionals require a bachelor's degree in communications or English.

Economists closely follow and analyze trends in the various energy industries to make sure a healthy competitive market is in place. They consult with experts in energy economics, market design, anti-trust and other issues, and use economic theory on real-world problems and situations. Economists require a bachelor's degree in economics.

Hydrologists research the distribution, circulation, and physical properties of underground and surface waters, and study the form and intensity of precipitation, its rate of infiltration into the soil, movement through the earth, and its return to the oceans and atmosphere.

Hydrologists apply scientific knowledge and mathematical principles to solve water-related problems in society—problems of quantity, quality, and availability. They may be concerned with finding water supplies for cities and irrigated farms, or controlling river flooding and soil erosion. They may also work in environmental protection—preventing or cleaning up pollution and locating sites for safe disposal of hazardous wastes. The work of hydrologists is as varied as the uses of water and may range from planning multimillion dollar interstate water projects to advising homeowners about backyard drainage problems.

A bachelor's degree is adequate for entry-level positions. Students who plan to become hydrologists should take courses in the physical sciences, geophysics, chemistry, engineering science, soil science, mathematics, computer science, aquatic biology, atmospheric science, geology, oceanography, hydrogeology, and the management or conservation of water resources. In addition, some background in economics, public finance, environmental law, and government policy is needed to communicate with experts in these fields.

Information Technology Specialists do systems programming, off-the-shelf software management, database administration, network and telecommunications operations/administration, security implementation, disaster recovery, electronic filing, and customer service support. Information technology specialists require a bachelor's degree in information technology.

Power Plant Operators control machinery that makes electric power. They control and monitor boilers, turbines, and generators and adjust controls to distribute power demands among the generators. They also monitor the instruments that regulate the flow of electricity from the plant. When power needs change, they start or stop the generators and connect or disconnect them from the circuits. Many operators use computers to keep records of switching operations, to track the loads on generators and lines, and to prepare reports of unusual incidents, malfunctions, or repairs that occur during their shift.

Power Distributors and Dispatchers operate equipment that controls the flow of electricity from a power plant through transmission lines to substations that supply customers' needs. They operate converters, transformers, and circuit breakers. Dispatchers monitor the equipment and record readings at a pilot board—a map of the transmission grid system. It shows the status of circuits and connections with substations and industrial plants.

Dispatchers also anticipate power needs, such as those caused by changes in the weather. They call control room operators to start or stop boilers and generators. They also handle emergencies such as line failures and route electricity around the affected areas. In addition, dispatchers operate and monitor the equipment in substations. They step up or step down voltage and operate switchboard levers, which control the flow of power in and out of the substations.

Civil Engineers make site visits, prepare engineering studies, and design or evaluate various types of hydroelectric dams, powerhouses, and other project structures. They develop graphs, charts, tables, and statistical curves relating to these studies for inclusion in environmental impact statements and assessments and dam safety reports. Civil engineers require a bachelor's degree in engineering.

Environmental Engineers of proposed hydroelectric projects review environmental reports and exhibits. A main component of the job is to study aspects of environmental impact issues, determine the scope of the problem, and propose recommendations to protect the environment. They perform studies to determine the potential impact of changes on the environment. Environmental engineers require a bachelor's degree in engineering.

Electrical Engineers design and develop electrical systems and equipment, evaluate electrical systems, and ensure stability and reliability. Electrical engineers require a bachelor's degree in engineering.

Hydropower Engineers work with teams of environmental scientists and engineers to review, analyze, and resolve engineering and environmental issues associated with proposals to construct and operate hydroelectric projects, including major dams, reservoirs, and power plants. Hydropower engineers require a bachelor's degree in engineering.

Hydropower Resources and Career Information

U.S. Department of the Interior, Bureau of Reclamation

Explore major dams and power plants on the Bureau of Reclamation's Projects and Facilities Database.
www.usbr.gov/projects/

U.S. Department of Energy, Federal Energy Regulatory Commission

Visit the Students' Corner section to learn more about hydropower. This web site includes games and photos of dams and hydropower plants.
www.ferc.gov/students/index.htm

Foundation for Water and Energy Education

Watch a video of hydroelectric power production, take a virtual tour of a hydroelectric plant and a generator, and learn how a hydroelectric project can affect a river.
www.fwee.org

Hydro Research Foundation

An excellent resource that explores all aspects of hydropower using real life photos.
www.hydrofoundation.org

Idaho National Laboratory

Has extensive information about hydropower and new technologies.
http://hydropower.inl.gov/

National Hydropower Association

Covers basic information about hydropower in all of its forms, both conventional and new technologies as well as hydropower issues as they relate to legislative and regulatory issues. The web site also includes many links to other hydropower resources and is a great place to start for everything that is hydro.
www.hydro.org

PBS: Building Big

After learning about the different types of dams, take the dam challenge. As a consulting dam engineer, you decide whether to repair, take down, or leave alone several different dams.
www.pbs.org/wgbh/buildingbig/dam/index.html

U.S. Department of Energy Energy Information Administration

Up-to-date data and information on all energy sources, including hydropower.
www.eia.gov

Dams Contribute to Other Employment

When Hoover Dam (near Boulder City, Nevada) was built on the Colorado River, it created two huge lakes—Lake Mead and Lake Mohave. Together, they form the Lake Mead Reservoir, which offers almost unlimited water-based recreation on a year-round basis, catering to boaters, swimmers, sunbathers, and fishermen. **National Park Rangers** working at Lake Mead National Recreation Area (NRA), part of the **National Park Service**, are responsible for visitors' safety. The National Park Service employs over 20,000 people in both seasonal and permanent positions. For more information on working as a National Park Ranger, visit www.usajobs.gov

The **Army Corps of Engineers** operates Summersville Dam as a flood control project on the Gauley River in West Virginia. The Summersville Reservoir is a center for powerboat recreation during the summer, but at the end of the season the Corps must lower the lake 75 feet to make room for the next spring's floods.

In addition to the people who work directly with the power plant, dam, and reservoir, the Gauley River provides jobs for the local economy. **Small Business Owners** run specialty sporting goods stores and white water rafting and kayaking expeditions. **Store Managers** and **Salespeople** run these businesses. **Raft Guides** lead groups of rafters and kayakers down the river, and **Shuttle Bus/Van Drivers** transport customers to drop-off and pick-up points.

Image courtesy of National Park Service

National Park Service rangers care for and protect some of America's favorite places. They help visitors enjoy and appreciate the nearly 400 national parks, monuments, memorials, seashores, and historic sites across the country.

Presentation Topic Organizer

Important Information	Additional Information Needed

Topic

Graphics Needed	Design of Presentation

Forms and Sources of Energy

In the United States we use a variety of resources to meet our energy needs. Use the information below to analyze how each energy source is stored and delivered.

1 Using the graphic below, determine how energy is stored or delivered in each of the sources of energy. Remember, if the source of energy must be burned, the energy is stored as chemical energy.

NONRENEWABLE		RENEWABLE	
Petroleum	____________________	Biomass	____________________
Natural Gas	____________________	Hydropower	____________________
Coal	____________________	Wind	____________________
Uranium	____________________	Geothermal	____________________
Propane	____________________	Solar	____________________

2 Look at the U.S. Energy Consumption by Source graphic below and calculate the percentage of the nation's energy use that each form of energy provides.

What percentage of the nation's energy is provided by each form of energy?

Chemical _____

Nuclear _____

Motion _____

Thermal _____

Radiant _____

What percentage of the nation's energy is provided by renewables? _______

By nonrenewables? _______

U.S. Energy Consumption by Source, 2011

NONRENEWABLE

PETROLEUM 34.67%
Uses: transportation, manufacturing

NATURAL GAS 25.57%
Uses: heating, manufacturing, electricity

COAL 20.22%
Uses: electricity, manufacturing

URANIUM 8.50%
Uses: electricity

PROPANE 1.64%
Uses: heating, manufacturing

RENEWABLE

BIOMASS 4.54%
Uses: heating, electricity, transportation

HYDROPOWER 3.26%
Uses: electricity

WIND 1.20%
Uses: electricity

GEOTHERMAL 0.23%
Uses: heating, electricity

SOLAR 0.16%
Uses: heating, electricity

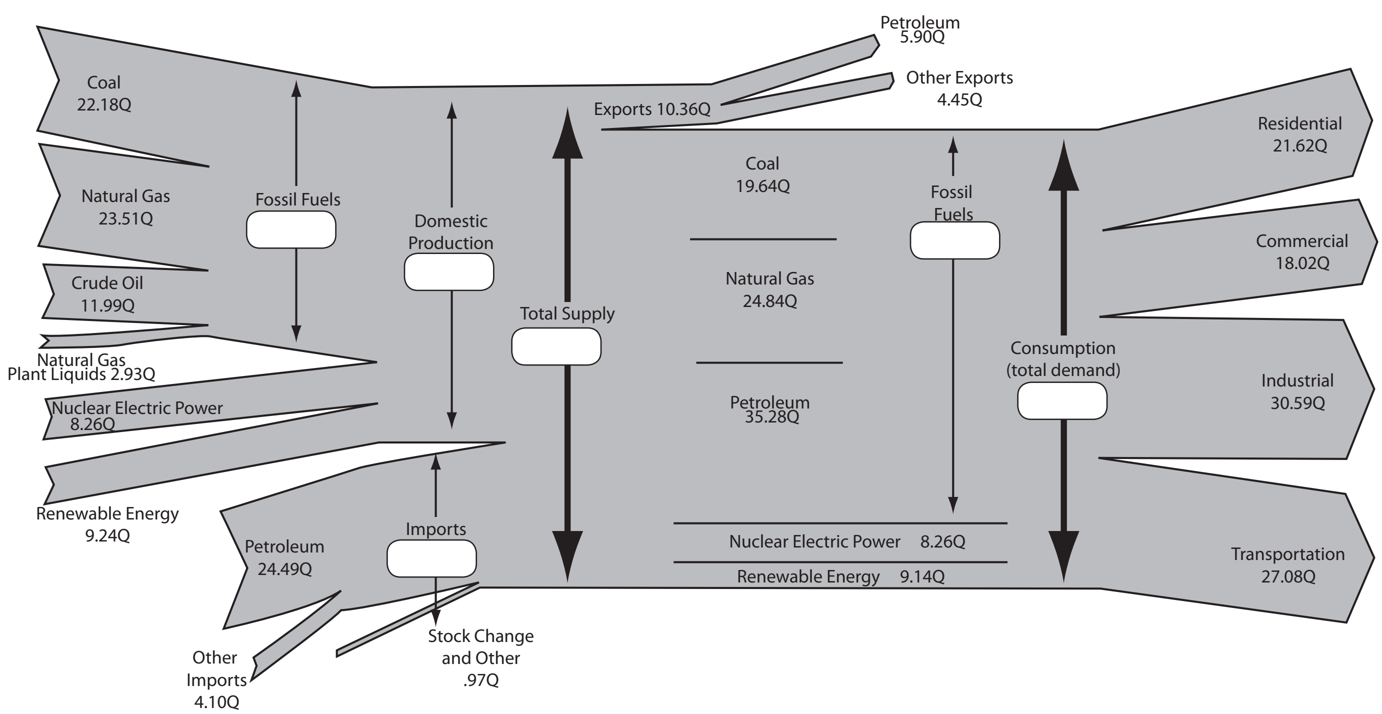
Data: Energy Information Administration

NOTE: Sum of forms and sources may not equal 100 due to independent rounding of data.

U.S. Energy Flow, 2011

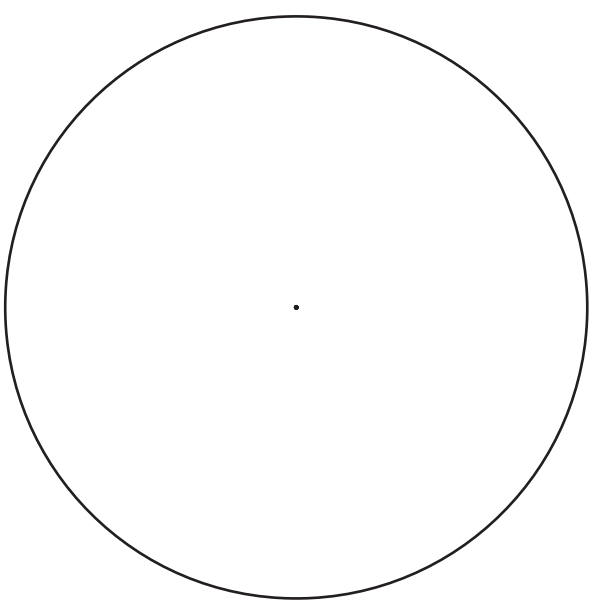
1. Fill in the blank boxes on the 2011 Energy Flow diagram.
2. Draw and label a pie chart of Domestic Energy Production by Source.
3. Draw and label a pie chart of U.S. Energy Consumption by Sector of the Economy.

Production → **Consumption**

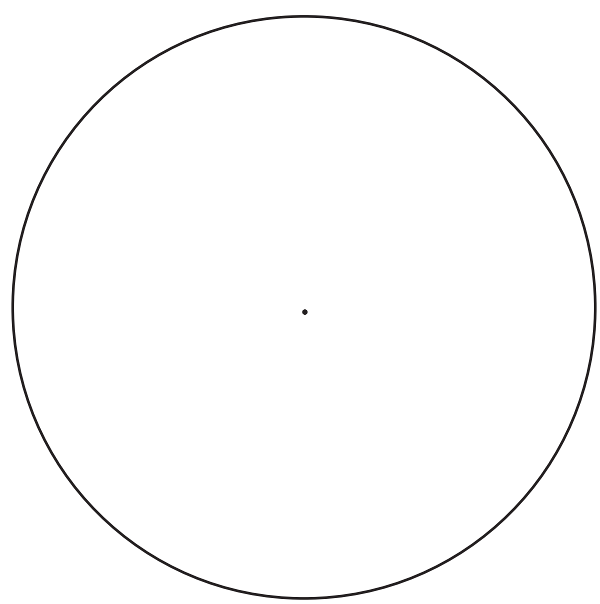


Data: U.S. Energy Information Administration/Annual Energy Review

Domestic Energy Production by Source, 2011

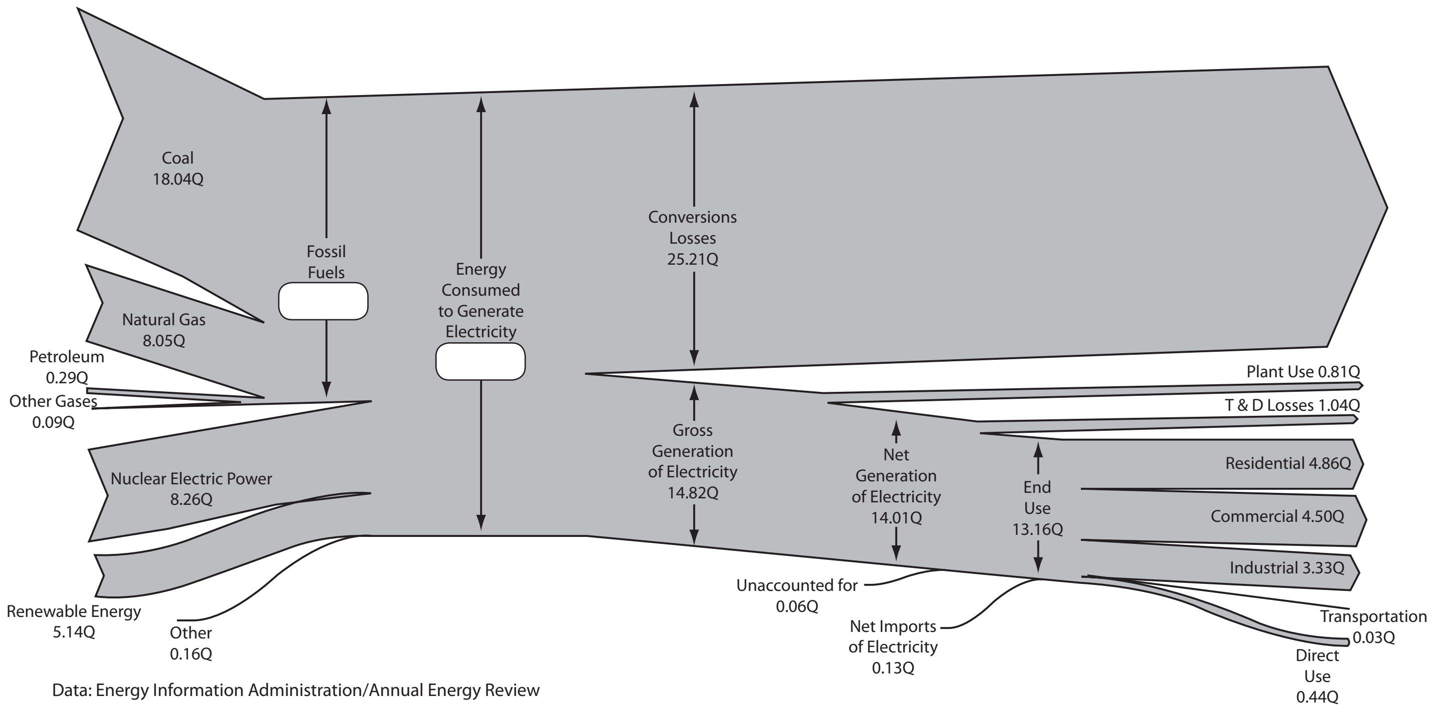


U.S. Energy Consumption by Sector of the Economy, 2011



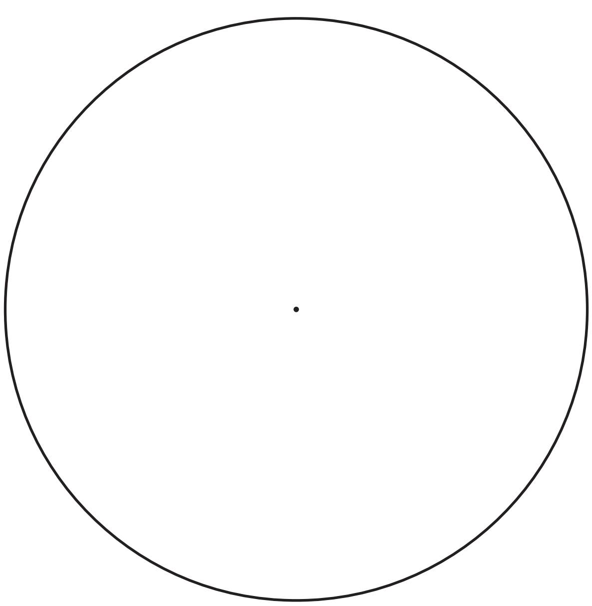
U.S. Electricity Flow, 2011

1. Fill in the blank boxes on the 2011 Electricity Flow diagram.
2. Draw and label a pie chart of U.S. Electricity Production by Source.
3. Draw and label a pie chart of U.S. Electricity Consumption by End Use.
4. On a separate piece of paper, write a paragraph explaining conversion losses.

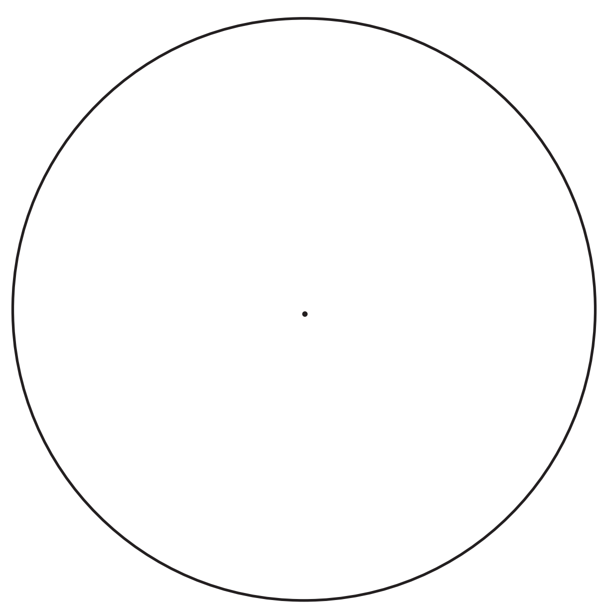


Data: Energy Information Administration/Annual Energy Review

U.S. Electricity Production by Source, 2011



U.S. Electricity Consumption by End Use, 2011



Measuring Electricity: Sample Calculations

Example 1: Calculating Voltage

If household current is 6 amps and the resistance of an appliance is 20 ohms, calculate the voltage.
To solve for voltage, use the following equation: voltage = current x resistance (V = I x R).

Voltage = A x Ω

V = 6 A x 20 Ω = 120 V

Example 2: Calculating Current

The voltage of most residential circuits is 120 volts. If we turn on a lamp with a resistance of 60 ohms, what current would be required?
To solve for current, use the following equation: current = voltage / resistance (I = V / R).

Current = V / Ω

I = 120 V / 60 Ω = 2 A

Example 3: Calculating Resistance

A car has a 12-volt battery. If the car radio requires 0.5 amps of current, what is the resistance of the radio?
To solve for resistance, use the following equation: resistance = voltage / current (R = V / I).

Resistance = V / A

R = 12 V / 0.5 A = 24 Ω

Example 4: Calculating Power

If a 6-volt battery pushes 2 amps of current through a light bulb, how much power does the light bulb require?
To solve for power, use the following equation: power = voltage x current (P = V x I).

Power = V x A

P = 6 V x 2 A = 12 W

Example 5: Calculating Voltage

If a 3-amp blender uses 360 watts of power, what is the voltage from the outlet?
To solve for voltage, use the following equation: voltage = power / current (V = P / I).

Voltage = W / A

V = 360 W / 3 A = 120 V

Example 6: Calculating Current

If a refrigerator uses power at a rate of 600 watts when connected to a 120-volt outlet, how much current is required to operate the refrigerator?
To solve for current, use the following equation: current = power / voltage (I = P / V).

Current = W / V

I = 600 W / 120 V = 5 A

Example 7: Calculating Electrical Energy and Cost

If a refrigerator uses power at a rate of 600 watts for 24 hours, how much electrical energy does it use?
To solve for electrical energy, use the following equation: energy = power x time (E = P x t).

Electrical Energy = W x h

E = 600 W x 24 h = 14,400 Wh x (1 kW/1000 W) = 14.4 kWh

If the utility charges $0.12 a kilowatt-hour, how much does it cost to run the refrigerator for 24 hours?
To calculate cost, use the following equation: cost = energy x price.

Cost = 14.4 kWh x $0.12/kWh = $1.73

Measuring Electricity

TABLE 1

VOLTAGE	=	CURRENT	X	RESISTANCE
1.5 V	=	_______ A	x	3 Ω
_______ V	=	3 A	x	4 Ω
120 V	=	4 A	x	_______ Ω
240 V	=	_______ A	x	12 Ω

TABLE 2

POWER	=	VOLTAGE	X	CURRENT
27 W	=	9 V	x	_______ A
_______ W	=	120 V	x	1.5 A
45 W	=	_______ V	x	3 A
_______ W	=	120 V	x	2 A

TABLE 3

APPLIANCE		POWER	=	VOLTAGE	X	CURRENT
TV		180 W	=	120 V	x	_______ A
COMPUTER		40 W	=	120 V	x	_______ A
PRINTER		120 W	=	120 V	x	_______ A
HAIR DRYER		1,000 W	=	120 V	x	_______ A

TABLE 4

POWER	X	TIME	=	ELECTRICAL ENERGY (kWh)	X	PRICE	=	COST
5 kW	x	100 h	=	______________	x	$0.12	=	$ _______
25 kW	x	4 h	=	______________	x	$0.12	=	$ _______
1,000 W	x	1 h	=	______________	x	$0.12	=	$ _______

Science of Electricity Model

Observe the science of electricity model. Draw and label the parts of the apparatus.

Explain how electricity is generated using appropriate vocabulary.

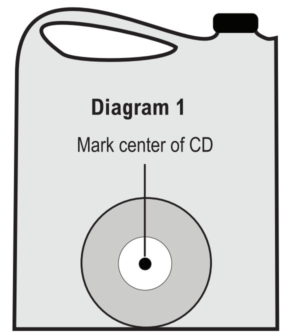
Turbine Component Assembly Instructions

Materials

- 1 Rectangular jug
- 2 Compact discs
- 4 Disc magnets
- 1 Styrofoam hub (4 cm length)
- 8 Wooden spoons
- 1 Wooden dowel
- 1 Spool of magnet wire
- Templates for coils of wire and magnets
- 1 Glue gun with glue sticks
- 1 Roll of masking tape
- 4 Rubber stoppers with holes
- 1 Pair sharp scissors
- 1 Permanent marker
- 1 Nail
- 1 Cardboard tube (4 cm diameter)
- Sandpaper
- Double-sided tape
- Transparent tape
- Graphite pencil
- Ruler

✔ Procedure

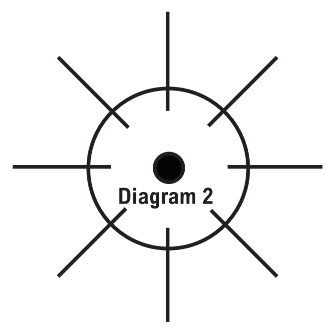
Jug Assembly



1. Cut the bottom off the jug.
2. Stand the jug on the cut bottom. Place a CD in the exact middle of the long sides of the jug and mark the CD hole as shown in Diagram 1. Make the same mark on the other side of the jug.
3. Cut holes for the dowel with the scissors where you have marked. Make sure the dowel can rotate freely in the holes.

Hub Assembly *(see Hub Marking Guide on page 42)*

1. Make a hole in the exact center of the foam hub with the nail.
2. Use the *Hub Marking Guide* to mark the hub for the placement of 8 blades (spoons) as shown in Diagram 2.
3. Attach 4 blades equally spaced around the hub. You will add the other 4 later.
4. Make sure the hub will fit inside the jug. Glue the 4 blades in place to reinforce.

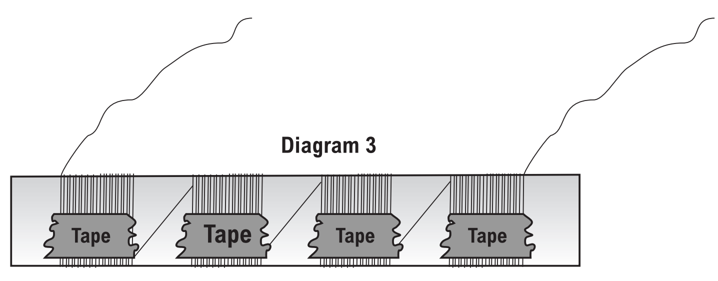


CD/Magnet Assembly *(see Magnet CD Template on page 42)*

1. Stack the 4 magnets.
2. On the top face of the top magnet, mark an N to indicate the north pole of the magnet.
3. Remove the top magnet and mark the top face of each remaining magnet with an N.
4. The blank faces of the magnets will indicate the south poles.
5. Caution: The magnets are very strong. Slide them apart rather than pulling them apart.
6. Place the magnets far apart from each other so they do not snap back together.
7. Cut out the *Magnet CD Template* and glue it to one CD. Allow time to dry.
8. Using double-sided tape, tape the magnets one at a time to the CD as indicated on the template.

CD/Wire Assembly *(see Coils of Wire CD Template on page 42)*

1. Cut out the template for the wire and glue it to the second CD. Allow time to dry.
2. Leaving 15 cm of wire at the beginning, loosely wind 50 wraps of wire around the cardboard tube as shown in Diagram 3. DO NOT CUT THE WIRE. Tape the coil of wire in place with masking tape.
3. Move 2 cm down the tube and wind another 50 wraps of wire. Tape this coil in place (see diagram).
4. Repeat this process two more times for a total of 4 coils.
5. Leave 15 cm of wire at the end of the fourth coil and cut the wire.
6. Carefully slide the coils off of the tube and re-tape each coil together.
7. Put a ring of glue on each coil and place it on the template, rotating each coil to match the direction of the coil as indicated on the template. Allow time to dry.

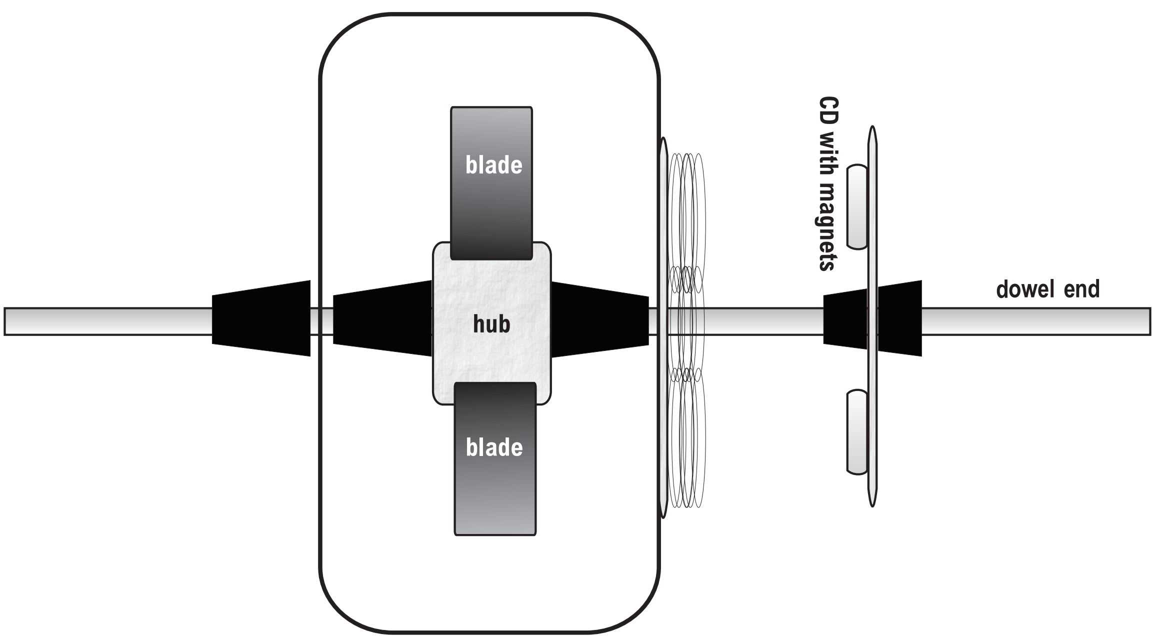


 CONTINUED ON NEXT PAGE

Turbine Assembly Instructions

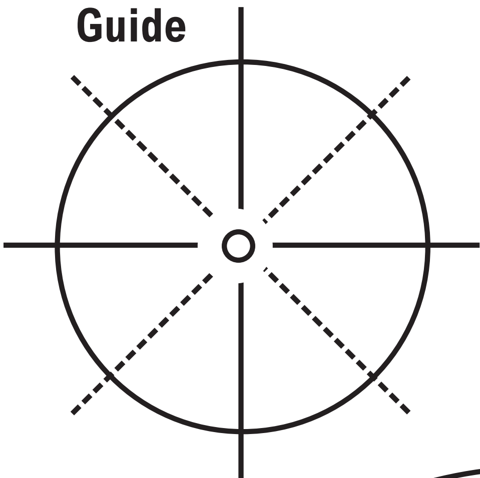
Turbine Assembly Instructions

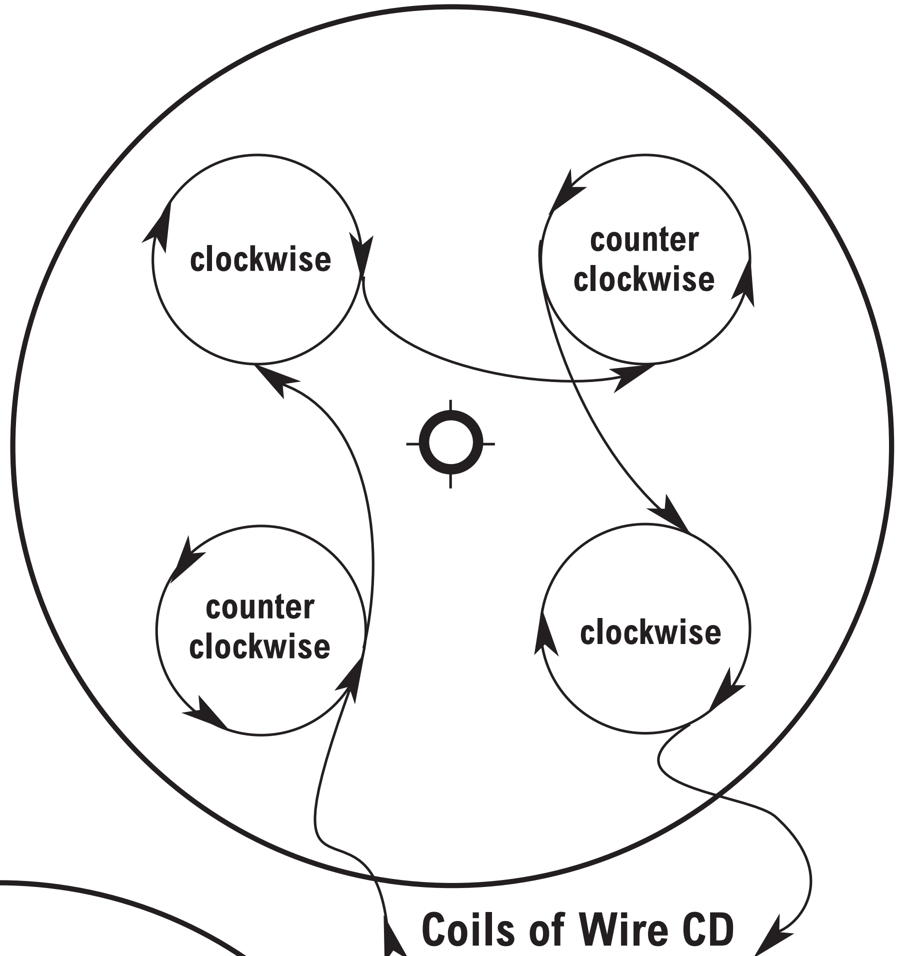
1. Slide the dowel through the holes in the container. Determine where the dowel will pass through the jug and mark these areas on the dowel. Remove the dowel and put one strip of transparent tape over these marked locations. Make sure the tape is smooth. Color over the tape with a graphite pencil, as it will help the dowel rotate smoothly.
2. Attach the CD with the coils of wire to the outside of the jug with three 6 cm pieces of double-sided tape. The holes in the CD and the jug should be aligned for the dowel. Put aside.
3. Take one rubber stopper and score around the stopper ¼" from the small end using the sharp scissors. Score twice, and break apart.
4. Push the ¾" end of the stopper you just cut 4 cm onto the dowel. The 4 cm end of the dowel with the stopper is the "dowel end." Everything else will slide onto the dowel from the longer side.
5. Slide the CD with the magnets onto the dowel so the blank side of the CD is flat against the stopper.
6. Slide the ¼" rubber stopper piece onto the dowel and up against the CD with magnets.
7. Slide the dowel through the CD with the coils and into the jug.
8. Slide a rubber stopper smaller side first onto the dowel.
9. Slide the hub onto the dowel, then slide another stopper onto the dowel with the larger side against the hub to hold it in place.
10. Slide the dowel through the other hole in the jug.
11. Slide another stopper onto the dowel on the outside of the jug. (Refer to the diagram below.)
12. Adjust the parts until the dowel spins freely. Make sure the stoppers inside the jug hold the hub securely, so it does not turn on the dowel.
13. Use the sandpaper to remove the enamel from the ends of the wire to a length of 1 cm.



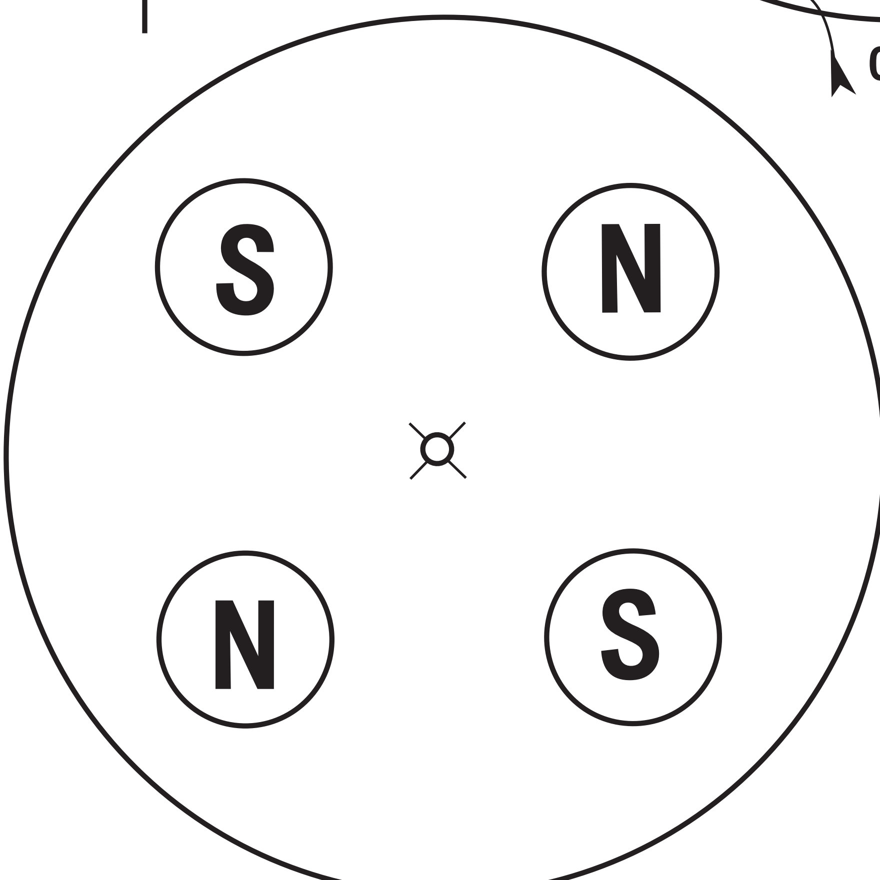
Turbine Component Template

Hub Marking Guide





Coils of Wire CD Template



Magnet CD Template

Reservoir Unit Instructions

1. Examine the water reservoir unit. Place one end of the tubing onto the end of the screwtop dispenser.
2. To fill the unit with water, place the unit with the opening on top and the spout lifted. Fill the unit completely with water. Screw the top securely on and make sure the valve is closed on the dispenser.
3. Lift the hose above the reservoir unit, slightly open the valve and put pressure on the unit to remove any air pockets at the top of the unit. Close the valve.
4. Place the unit on its side with the spout near the bottom when conducting all experiments, as shown in Diagram 1. Make sure there are no air pockets in the unit when you place it on its side to conduct the experiments.
5. Make sure there are no kinks in the hose when conducting experiments.
6. When conducting the experiments, rotate the valve to open and close and to ensure a constant rate of flow. Unscrew the dispenser to refill the unit.
7. Make sure the water from the hose hits the blades of the hub as shown in Diagram 2.
8. After each trial, use the funnel to pour the water from the bucket back into the unit. If necessary, add more water so that the unit is completely full.

Diagram 1

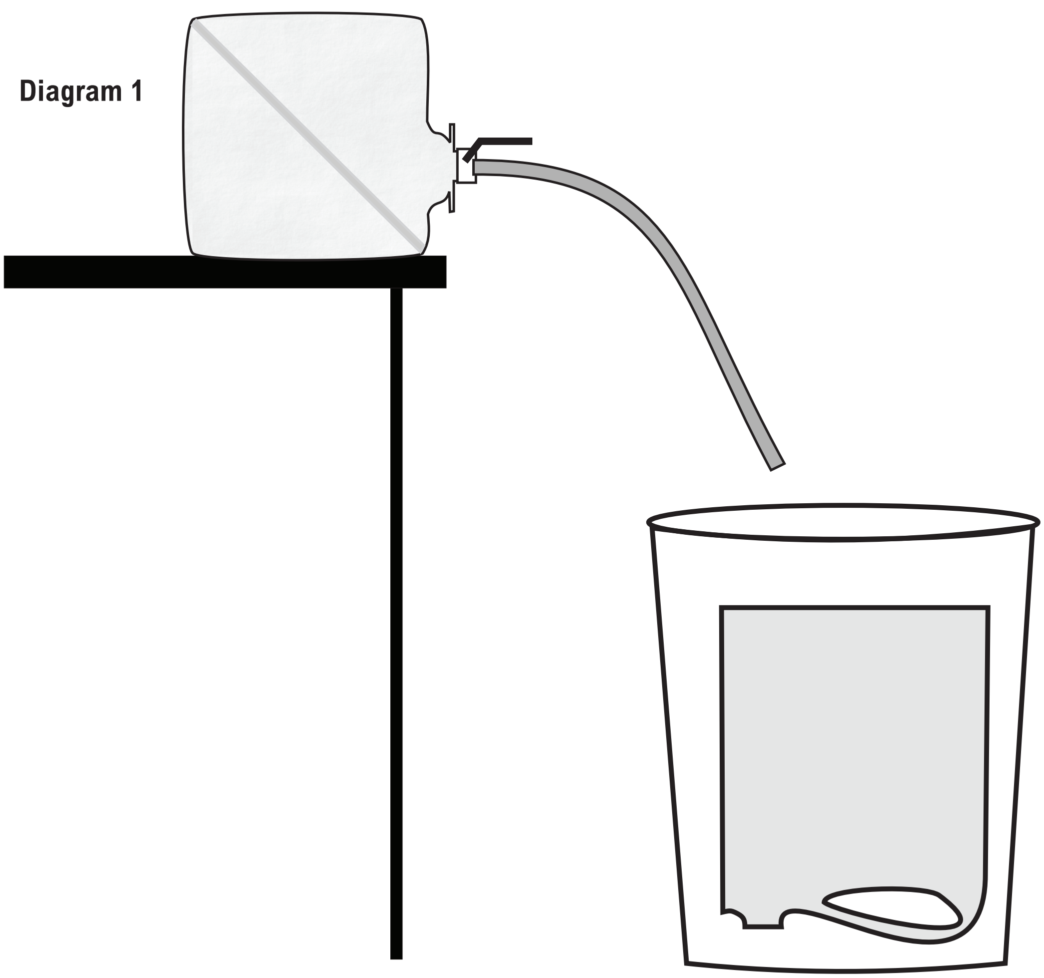
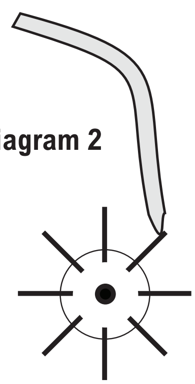
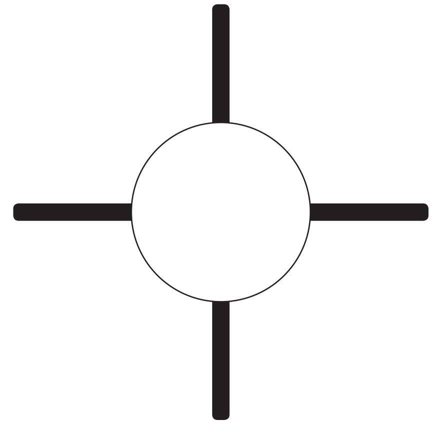


Diagram 2



Exploring Turbine Blades



Question

How do the number of blades affect the electrical output of a model hydropower turbine?

Hypothesis

Develop a hypothesis to address the question, using this format:

If (manipulated variable) then (responding variable) because...

Manipulated Variable (independent—the variable that changes): ____________________.

Responding Variable (dependent—the variable that is measured): ___________________.

Controlled Variable (variable that is constant): ___________________________.

Materials

- Turbine
- Water
- Hub
- Glue
- Spoons

At the Testing Station:

- Reservoir unit
- Bucket
- Multimeter or voltmeter
- Alligator clips
- Funnel
- Stopwatch
- Meter stick

✔ Procedure

1. Attach the multimeter to the ends of the turbine wires with the alligator clips. Set it to the 20 DCV setting.
2. Place the turbine in the water collection bucket with the wide opening at the top. Fill the water reservoir unit and place it on a table about 50 cm higher than the top of bucket. Pinch the hose together and open the valve.
3. Holding the end of the hose at the level of the top of the turbine assembly, allow the water to flow, pointing the hose so that the water flows on the blades for 10 seconds and record the most consistent output reading in the table below.
4. Empty the bucket back into the water reservoir using the funnel.
5. Measure and record the electrical output two more times in the data table below. Calculate the average output.
6. Repeat Steps 2-5 with 8 blades. Make sure the position of the hose remains constant for all trials.

Observations and Data

NUMBER OF BLADES	OUTPUT 1	OUTPUT 2	OUTPUT 3	AVERAGE OUTPUT
4				
8				

Graphing

Make a graph of your data with the manipulated variable data on the X-axis (horizontal axis).

Conclusion

Explain why you think the number of blades affects the output of the turbine, using data to support your reasoning.

Note

The hub containing the number of blades that produced the best electrical output will become your "benchmark hub" to use in the rest of the investigations.

Exploring Reservoir Height

Question

How does the height of a reservoir affect the electrical output of a model hydropower turbine?

Hypothesis

Develop a hypothesis to address the question, using this format:

If (manipulated variable) then (responding variable) because...

Manipulated Variable (independent—the variable that changes): ____________________________.

Responding Variable (dependent—the variable that is measured): ____________________________.

Controlled Variable (variable that is constant): ____________________________.

Materials

- Turbine unit with benchmark hub
- Reservoir unit
- Bucket
- Multimeter or voltmeter
- Alligator clips
- Water
- Funnel
- Meter stick
- Stopwatch

✔ Procedure

1. Use the benchmark hub from *Exploring Turbine Blades* that had the best electrical output.
2. Place the turbine unit into the water collection bucket.
3. Fill the reservoir unit and position the bottom of the unit 30 centimeters above the top of the bucket.
4. Position the hose at the top of the bucket so that the water will flow onto the blades.
5. Allow the water to flow for 10 seconds and record the most consistent output reading on the table below.
6. Refill the reservoir unit with water from the bucket. Make sure the reservoir unit is completely filled or filled with the same amount of water as in step 3.
7. Repeat Steps 2–6 two more times. Calculate the average output.
8. Repeat Steps 2–7 at reservoir heights of 65 and 100 centimeters.

Observations and Data

HEIGHT OF RESERVOIR	OUTPUT 1	OUTPUT 2	OUTPUT 3	AVERAGE OUTPUT
30 cm				
65 cm				
100 cm				

Graphing

Make a graph of your data with the manipulated data on the X-axis (horizontal axis).

Conclusion

Explain which height is most effective in converting the energy in flowing water into electricity and why, using data to support your reasoning.

Extension

Design an experiment to answer the following question: As the height of the water reservoir changes, should the number of blades on the turbine assembly change to deliver maximum output?

Exploring Copper Wire Wraps

Question

How does the number of copper wire wraps affect the electrical output of a model hydropower turbine?

Hypothesis

Develop a hypothesis to address the question, using this format:

If (manipulated variable) then (responding variable) because...

Manipulated Variable (independent—the variable that changes): ____________________________.

Responding Variable (dependent—the variable that is measured): ____________________________.

Controlled Variable (variable that is constant): ____________________________.

Materials

List the materials you will need.

✔Procedure

1. Decide how many wraps of wire to use on your stator (CD).
2. Use the benchmark hub from *Exploring Turbine Blades* that had the best electrical output.
3. Place the turbine unit model into the water collection bucket.
4. Fill the reservoir unit with one gallon of water.
5. Place the bottom of your water reservoir unit at the optimum height as determined in *Exploring Reservoir Height*.
6. Place the hose in the mouth of the unit model and let the water flow.
7. Record the electrical output as soon as possible to control the loss of water variable.
8. Empty the water collection bucket back into the reservoir, making sure there is one gallon of water in the reservoir.
9. Repeat steps 3–8 two more times for a total of three trials.
10. Repeat steps 1–9 with different numbers of copper wire wraps.

Observations and Data

Fill in your data below.

Graphing

Make a graph of your data with the manipulated data on the X-axis (horizontal axis).

Conclusion

Using results from your data table to support your reasoning, explain how many copper wire wraps are most effective in producing electricity. Include why you think this is the case.

Independent Turbine Investigation

Question

How does ____ affect the electrical output of a turbine?

Hypothesis

Develop a hypothesis to address the question, using this format:

If (manipulated variable) then (responding variable) because...

Manipulated Variable (independent—the variable that changes): __________________________.

Responding Variable (dependent—the variable that is measured): __________________________.

Controlled Variable (variable that is constant): __________________________.

Materials

✔ Procedure

1.
2.
3.
4.
5.

Observations and Data

Graphing

The manipulated variable is written on the X-axis (horizontal) and the responding variable is written on the Y-axis (vertical).

Conclusion

Using results from your data table to support your reasoning, explain how your revised design was or was not more effective in generating electricity.

Issue Organizer

Advantages of Actions	Disadvantages of Actions

Scenario: ____________________

Stakeholder: ____________________

Position and Three Reasons	Facts to Support Reasons

Glossary

ampere (amp)	a measurement of electric current
arch dam	a concrete, masonry, or timber dam with the alignment curved upstream
atom	the most basic unit of matter
atomic mass	the average mass of one atom of an element
atomic number	the number of protons in one atom of an element
baseload power	the minimum amount of power a utility company must make available to its customers
buttress dam	a dam consisting of a watertight part supported at intervals on the downstream side by a series of buttresses
cofferdam	a temporary dam structure enclosing all or part of a construction area so that construction can be performed; a diversion cofferdam diverts a stream into a pipe, channel, tunnel, or other watercourse
conventional hydropower plant	a facility that uses available water from rivers, streams, canals, and reservoirs to produce electricity
crest	the highest point of a wave
current	the flow of electricity through a current; electric current
dam	a barrier constructed across a waterway to control the flow or raise the level of water
diversion project	a hydropower facility that does not require a dam but instead diverts river water from its course
efficiency	a percentage obtained by dividing the actual power or energy by the theoretical power or energy; it represents how well a hydropower plant converts the energy of the moving water into electrical energy
electromagnetism	the relationship between electrical energy and magnetism
electron	the particle in an atom that carries a negative electrical charge
embankment dam	any dam constructed of excavated natural materials, such as dirt and rock, or of industrial waste materials
energy	the ability to do work or make a change
energy level	area where electrons can be found; describes the probable amount of energy in an atom
estuary	the area of water at the mouth of a river
Federal Energy Regulatory Commission (FERC)	the federal agency that licenses non-federal hydropower projects
fish ladder	a series of small pools arranged like stairsteps that allow adult fish to bypass a dam
fixed device	a device that is anchored in one place
flow	volume of water, expressed as cubic feet or cubic meters per second, passing a point in a given amount of time; the amount and speed of water entering a water wheel or turbine
generator	a device that converts motion energy into electrical energy
gravity dam	a dam constructed of concrete and/or masonry that relies on its weight and internal strength for stability
head	vertical change in elevation, expressed in either feet or meters, between the headwater level and the tailwater level
hydrokinetic projects	projects that generate electricity from waves or directly from the flow of water in ocean currents, tides, or inland waterways
hydrologic cycle	the water cycle; the complete cycle of water evaporating from the oceans, rivers, and lakes through the atmosphere to the land (precipitation) and back to bodies of water
hydropower	the use of water to generate electricity
impoundment facility	typically a large hydropower system that uses a dam to store water in a reservoir
kilowatt	a unit of electric power equal to 1,000 watts

kilowatt hour	a measure of electricity defined as a unit of work or energy, measured as 1 kilowatt of power expended for 1 hour
kinetic energy	the energy of motion
load	the part of an electrical circuit that uses electricity to do work (a light bulb, for example)
magnetic field	the area of force around a magnet
navigation dam	a dam built to ensure water depth; allows for commercial barge and ship travel
neutron	a particle in the nucleus of an atom that has no charge
non-overflow dam	a dam that diverts water to spillways to control the pressure and potential energy of the dam
nonrenewable energy source	an energy source with a long term replenish rate and reserves that are limited, including petroleum, coal, natural gas, uranium, and propane
nucleus	center of the atom
ohm	a measurement of resistance in an electrical circuit
Ohm's Law	the law that explains the relationship between current, voltage, and resistance in an electrical circuit; in all electrical circuits, the current (I) of that circuit is directly proportional to the voltage (V) applied to that circuit and inversely proportional to the resistance (R) of that same circuit
oscillating water column	a facility built into a cliff that captures wave energy
osmotic power	
overflow dam	a dam that allows excess water to spill over its rim
penstock	a closed conduit or pipe for conducting water to a waterwheel, turbine, or powerhouse
period	the time it takes for the crests of two concurrent waves to pass a stationary point
potential energy	stored energy; potential energy includes stored chemical and stored gravitational energy
power	the rate at which electrical energy is produced or consumed
power plant	the equipment attached to a dam that generates electricity, including the turbines and generators
proton	a particle in the nucleus of an atom that carries a positive electrical charge
pumped storage plant	a hydropower facility with two reservoirs (one higher than the other) used for peak generation; water from the lower reservoir is pumped into the higher reservoir to be stored until demand is high
renewable energy source	an energy source with a short term replenish rate, including biomass, geothermal, hydropower, solar, and wind
reservoir	a natural or artificial pond or lake for storing and regulating water
resistance	the force that resists the flow of electricity in an electrical circuit
resistor	a device with a set resistance that can be placed in circuits to reduce or control the current flow
revolutions per minute (RPM)	the number of rotations made by a device in one minute
run-of-river project	a hydropower facility with turbines placed in fast flowing sections of rivers to generate power without impeding the river's natural flow
Salter Duck	a machine that can capture the energy in the movement of ocean waves
secondary source of energy	often called an energy carrier; requires another source, like coal, to be converted for generation; electricity and hydrogen are examples
spillway	a channel for overflow of water from a reservoir
TAPCHAN system	a tapered channel facility built into a cliff that generates electricity from energy in the waves
tidal barrage	a facility built like a dam that allows the tides to power turbines and generate electricity
tidal bulge	the area of the Earth where the moon's gravitational force creates high tides
tidal fence	an open structure with vertical-axis turbines mounted across a channel
tidal power	hydropower derived from the rise and fall of the tides

tidal turbine	underwater turbine driven by ocean currents
transformer	a device that changes the voltage of electricity
tributary	a stream or river that flows into another stream, river, or lake
trough	the lowest point of a wave
turbine	a machine of curved blades or buckets that converts the kinetic energy of a moving fluid to mechanical power
valence electron	an electron in the outer shell of an atom that can be pushed from its shell by a force
valence energy level	the outer energy level of an atom that contains valence electrons
volt	measure of electric potential or force
voltage	a measure of the pressure (or potential difference) under which electricity flows through a circuit
watt	unit of measurement of electric power
wicket gate	adjustable elements that control the flow of water to the turbine