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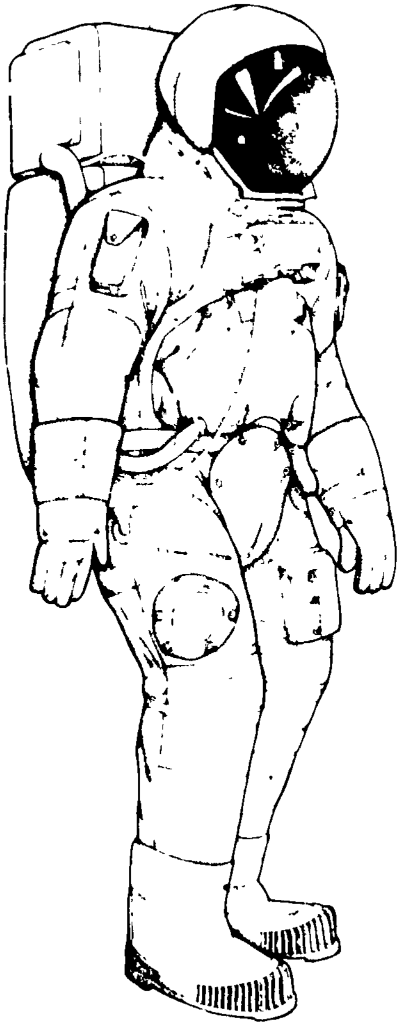
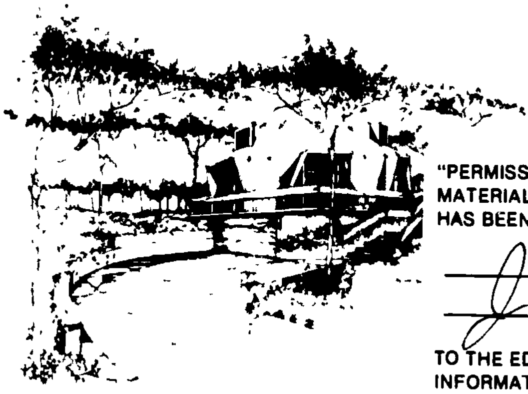
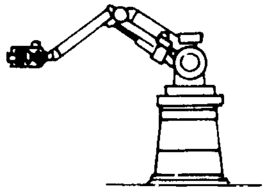
ABSTRACT

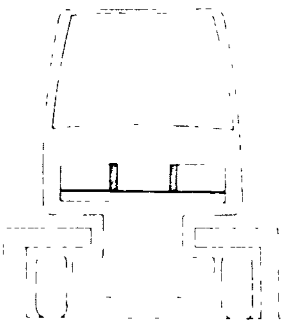
This document--intended for secondary school and college students--contains technology education instructional units on the history of energy, coal energy, oil and natural gas, wind and solar energy, nuclear energy, careers in energy, energy and the environment, the history of transportation, transportation control devices, the history of communication, communication devices, magnetic storage of information, computer logic devices, nonimpact computer printers, the history of production, production tools and processes, truss-frames in home construction, space frames and geodesic domes, and fiber composite materials. Each unit typically includes a list of what students should be able to do after reading it, narrative information, line illustrations, a self-quiz with answers, a list of suggested activities, and a resource list for further study. (CML)

Resources in Technology '85









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STUDY UNITS

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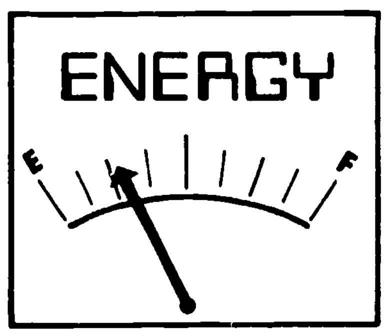
Energy Primer

During the first half of the 20th century, Americans assumed that there would always be energy enough for everyone. Air conditioners became commonplace. Nearly everyone old enough to drive owned at least one car—the bigger, the better. Then, during the 1960s, something went wrong. Los Angeles and other large cities became smothered in smog. The electric power failed for several hours one night in the northeastern part of the United States; the resulting blackout caused people to panic. There was rioting in the streets In the years following the great blackout, power reductions (brownouts) became a common summertime event in some cities. The power companies could not keep up with the growing demand for electricity to run air conditioners.

In addition to all this, an oil shortage occurred during the winter of 1972. In the summer of 1973, there was a gasoline shortage. By winter of 1973, the shortage of gasoline and heating oil had become a crisis situation. Cars lined up at gasoline stations to compete for what little fuel was available. Driving speeds were limited to 55 miles per hour. The President ordered the heat in public buildings reduced 6° (F) below previous levels. People living in rural areas rationed what little heating oil they had, and when it ran out, they burned wood or coal.

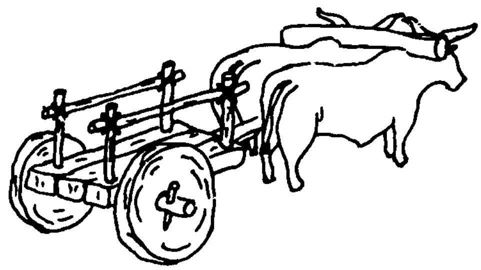
How did we get into this mess? Simply put, the demand for more energy outran our ability to supply it. Haven't those problems been solved? Everything is all right now, isn't it? Maybe it will cost more, but we will have plenty of energy in the future, won't we? Perhaps a quick look back in history will help you answer these questions yourself.



THE NEED FOR ENERGY

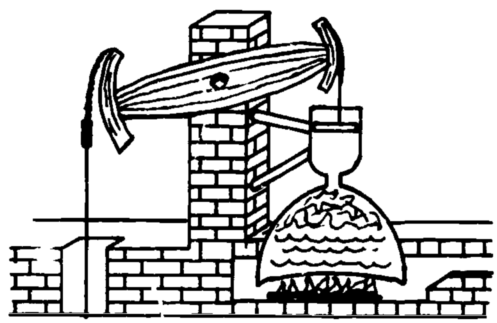
The use of energy has always been essential to human survival and social development. When people first learned to burn wood for warmth, they were taking the first step in using energy resources. The use of energy depends on the availability of resources and the technological skill to use them.

In prehistoric times, people depended on the heat of the sun, the force of the wind, and their own muscle power to do work. The muscle power of an adult male is only about one-tenth the power of a horse. As a consequence, early human cultures were limited in what they could do. Once horses and oxen were domesticated, the power resources available to humans were multiplied. Inventions also helped harness more power.



The horizontal waterwheel appeared in the first century B.C.; it had a power capacity of about 300 watts (less than 1 horsepower). By the 4th century, the vertical waterwheel had been developed, and it yielded about 2,000 watts of power (nearly 3 horsepower). The first windmill was used in western Europe in the 12th century to grind grain and pump water. It could produce nearly 10 thousand watts of power (more than 13 horsepower).

In 1722, a steam engine invented by Thomas Newcomen was installed near Birmingham, England. It was used to pump water from underground mines. Coal from the mines was used for steelmaking and as a fuel source for steam engines. In a way, coal was the fuel that made the Industrial Revolution possible.

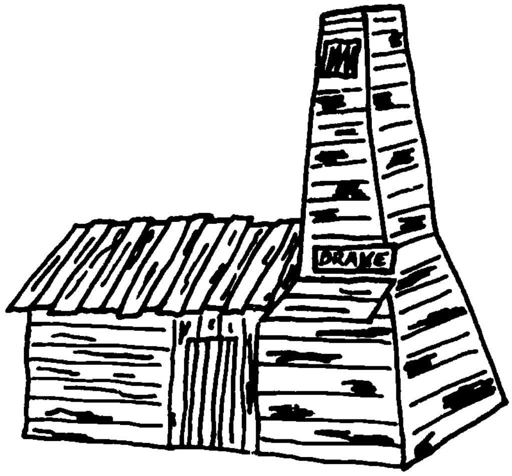


ENERGY IN EARLY AMERICA

As a result of another kind of revolution, a new nation called America was born in 1776. In many ways, 18th-century America was a developing country. The census of 1790 found that 92% of the population lived in rural areas. Farming, commerce, and what little manufacturing there was required direct human labor—muscle power. Wood was used as the primary heating source. Horses provided transportation and power for plowing the fields.

The first steam engine built entirely in the United States was constructed in 1779. It burned wood as fuel. Textile manufacturing became the first major industry in the new United States. Many textile industries used steam-driven looms to weave cloth. Steam boilers required large amounts of wood, so mills were often located downstream along navigable rivers. Waterpower was also used to grind grain and power manufacturing equipment. Windpower made transocean and coastal transportation possible, but wood-fired steamboats soon replaced the "tall ships."

MORE ENERGY REQUIRED



A second war with England (1812–14) resulted in faster development of technology in the U.S. More sophisticated technology required more energy. By this time, Americans recognized their nation's abundance of natural resources and began to use them in earnest. In 19th-century America, great building projects were accomplished. A system of roadways was begun. A railroad was built from one coast to the other. The search for fuel to fire steam engines resulted in the discovery of massive coal deposits. The first gas well was drilled in 1821 near Buffalo, New York, and soon after, gas-powered streetlights began to appear in cities. In time, steam-driven harvesting equipment began to increase farm production.

Even at mid-century, our emphasis was still primarily on agriculture. The amount of human and animal energy used in farming was five times as great as what both wood and coal were contributing to industry and transportation. By 1880, though, farming had taken a back seat to manufacturing and transportation. The United States was becoming a nation of producers and travelers, and more energy was required.

THE ENERGY GIANT AWAKENS

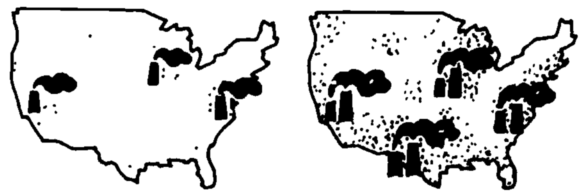
From 1880 to 1918, the nation exploded industrially. The U.S. economy grew larger, stronger, and more complex. Economic growth fed on cheap energy. By 1918, three-quarters of the U.S. energy diet was coal. The population doubled during this period, but energy use quadrupled. Largely, as a result of higher energy use, many more material products became available to consumers. At the turn of the century, electric ranges, vacuum cleaners, toasters, and washing machines were in use. Electric motors were beginning to replace steam engines.

THE TURN TO OIL & NATURAL GAS

Large reserves of oil and natural gas were discovered about the time that Americans began their love affair with Henry Ford's horseless carriages. Natural gas began to replace coal as the major fuel for electrical generators. Between 1918 and 1941, the use of oil and natural gas multiplied five times. Even so, Americans produced enough surplus petroleum to export to other countries.

After World War II, the tremendous industrial system that had been geared up for the war effort was turned toward production of consumer goods. The period from 1946–74 may go down in history as America's most affluent time. Frozen foods became available to everyone. Fresh produce was trucked from one coast to the other. More than 200 million motor vehicles were manufactured during this period. By 1958, the U.S. had begun to import more energy than it exported.

When the Arab oil embargo hit in 1973, the U.S. was depending on oil for half of its energy needs. Natural gas was supplying another 30%. Americans were unprepared for the consequences of energy shortages, high prices, unemployment, and international political turmoil.



1900 1980

THE LESSONS OF THE PAST

Historians, economists, social scientists, and energy experts have studied the energy history of the United States to determine what might help us in the future. Among the lessons they have learned are these:

- New energy sources require a means of efficiently applying the energy for some practical use. In other words, harnessing the energy of the ocean tides will do no good unless we can find an inexpensive way to use that energy.

- For one fuel to take the place of another, it must be readily available. Coal, for example, can replace oil only if we can find a way to get it out of the ground quicker, cheaper, and more safely.

- The government has often steered energy developments. Although the United States has not had a firm "energy policy," government research, development, and regulations do have an effect on the energy picture.

- The future always holds surprises. People change their attitudes and behavior. New, unexpected developments occur.

- Changes take time. Even in this modern age of instant everything, we cannot expect overnight solutions to energy problems that have been developing for centuries.

SOME PARTS OF THE ENERGY PROBLEM

One part of the energy problem is **scarcity**. Petroleum and natural gas reserves in the U.S. are nearly gone. These are two of our major sources of energy. If demand for energy in the U.S. continues to increase, where will we get additional energy?

What about cost? Whenever something is scare, the **price** goes up. Economists call it the principle of supply and demand. The free market operates on this principle. So, as available energy decreases, prices will probably increase. How many people can continue to pay the price?

To provide enough energy for its oil-hungry citizens, the U.S. now imports 1 out of every 12 barrels of petroleum used in this country. As we have seen recently, dependence on other governments for vital energy supplies can lead to a number of **international** problems. Conflicts between nations could lead to war. Additional energy needed for war efforts could further diminish world fuel supplies.

Another part of the energy problem has to do with the **environment**. As we use more fossil fuels—such as wood, coal, and oil—we pollute the air. Recently, concern has arisen over the effects of "acid rain," which may be caused by burning fossil fuels. Extracting energy resources from the earth and transporting them to where they are needed also cause health and safety hazards.

LOOKING AHEAD

One thing we all can do immediately is conserve. As much as 35% of the energy consumed in the U.S. is wasted. By cutting back on energy use, we can stretch our present supplies, save money, and lessen our dependence on other nations. **Exploration** of new energy sources will also help. There may be new energy reserves waiting to be discovered. Perhaps alternative energy sources, such as nuclear fusion or hydrogen, can be developed.

We might also help the energy situation if new technologies can be **adapted**. For example, steel mills in the U.S. are now converting to newer, more energy-efficient furnaces like the ones used in Japan. Installing a more efficient home-heating furnace can make better use of available energy.

Finally, we can be **innovative**. Household garbage can be burned to provide heat and electricity. Solar and wind power can supplement oil and natural gas. Industries are experimenting with unique methods to produce quality products with fewer energy resources. Perhaps you can find a way to improve energy efficiency in your own home, school, or community. Start now to learn more about energy and what you can do to improve the future.

ENERGY TERMS

British thermal unit (Btu): A unit of energy commonly used to measure heat energy or chemical energy. The heat required to raise the temperature of 1 pound of water 1° Fahrenheit is usually written Btu and is equal to 778 foot-pounds of work or energy.

Calorie: The amount of heat required to raise the temperature of 1 gram of water 1° Celsius.

Capital intensive: Requiring heavy capital investment. The energy industry, for example, is said to be capital intensive rather than labor intensive because it employs relatively more dollars than people.

Converting energy: Changing energy from one form to another.

Efficiency of conversion: The amount of actual energy derived, by any technique, in relation to the total quantity of energy existing in the source being tapped; expressed as a percentage.

Energy: A quantity having the dimensions of a force times a distance. It is conserved in all interactions within a closed system. It exists in many forms and can be converted from one form to another. Common units are calories, joules, Btu's, and kilowatt-hours.

Energy intensiveness (EI): A measure of energy use per unit of output. For passenger transport, for example, it is a measure of calories used per passenger mile.

First law of thermodynamics: Also called the Law of Conservation of Energy. It states: Energy can neither be created nor destroyed.

Fossil fuels: Such fuels as coal, crude oil, or natural gas formed from the fossil remains of organic materials.

Generating capacity: The capacity of a power plant to generate electricity. Usually measured in megawatts (Mw.)

Heat: A form of kinetic energy that flows from one body to another because of a temperature difference between them. The effects of heat result from the motion of molecules. Heat is usually measured in calories or British thermal units (Btu's).

Joule: A metric unit of work or energy; the energy produced by a force of one newton operating through a distance of one meter (1 Btu = 1,055 joules, and 1 calorie = 4.185 joules).

Kilowatt-hour (kw-hr): A unit of work or energy. Equivalent to the expenditure of one kilowatt in one hour, about 853 calories.

Power: The rate at which work is done or energy expended. It is measured in units of energy per unit of time, such as calories per second, and in such units as watts and horsepower.

Second law of thermodynamics: One of the two "limit laws" that govern the conversion of energy. Referred to sometimes as the "heat tax," it can be stated in several equivalent forms, all of which describe the inevitable passage of some energy from a useful to a less useful form in any cyclic energy conversion.

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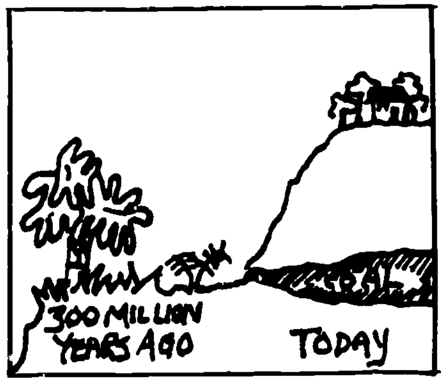
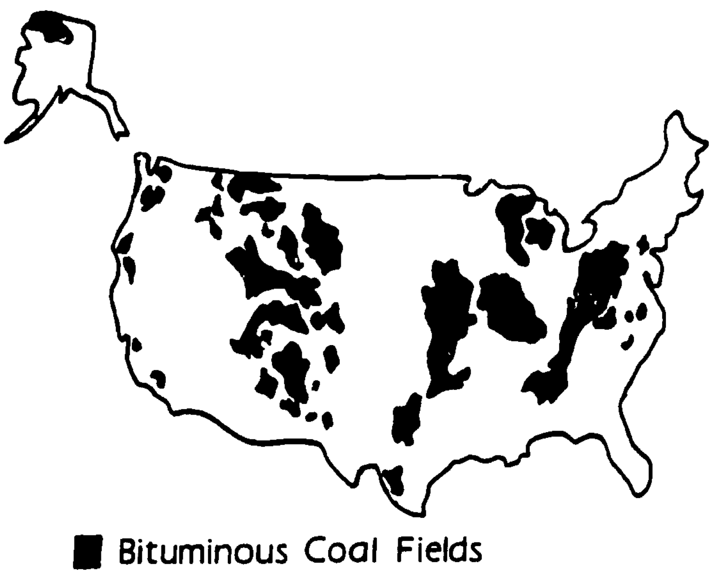
Coal Energy



Coal is a fossil fuel that began forming in the earth 400 million years ago. It was formed from the remains of plants and animals (organisms). These organic remains became buried under many layers of soil. Under extreme pressure and heat, the remains became the hard, black, carbonaceous material we recognize today as coal. The Chinese first burned coal for heat thousands of years ago. In the period from 1880 through the 1940s (World War II), coal was the principal energy source in the United States.

One-third of the world's coal supply is located in the United States. The supply is estimated at 4 trillion tons, or enough to last for another 500 years.

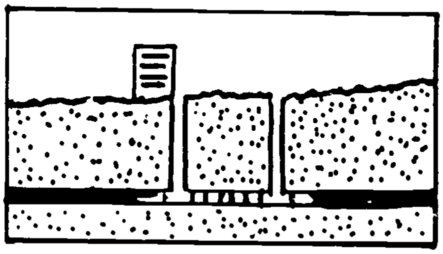


There are three types of coal: anthracite, bituminous, and lignite. **Anthracite** (hard) coal has a high carbon content and gives off lots of heat with very little smoke. Unfortunately, there is not much of this high-quality coal available in the U.S. **Bituminous** (soft) coal is the most abundant and can be found in many areas of the nation. Much of it is located in the eastern and midwestern states. Bituminous coal has a high sulfur content and, when burned, gives off smelly smoke. **Lignite** coal is very soft and gives off the least amount of heat compared to the other types. What little lignite coal is available is found in only a few of the 50 states.

To get the coal from the earth, it must be mined. If the coal bed is near the surface, then surface (strip) mining is done with large dozers and power shovels. They scrape off the overburden of dirt and rocks and dig up the layers of pure coal. When coal lies buried deep in the ground, mines are built with shafts (tunnels) that lead down to the coal seam (layer).

There are three types of underground mines: **shaft, drift,and slope.** These names indicate how the workers enter the actual coal seam. Miners use many tools and machines to get the coal out of the earth. Once it is dug, the coal comes out of the mine and into the preparation plant. There it is washed and sorted. Sorting is done through a screen with holes. The smaller pieces drop through the holes and large pieces stay on top of the screen. Most of the coal is carried by trains and trucks and some by river barges. The coal is sold to electric power plants, steel mills, and companies that store and sell coal.

Shaft Mine

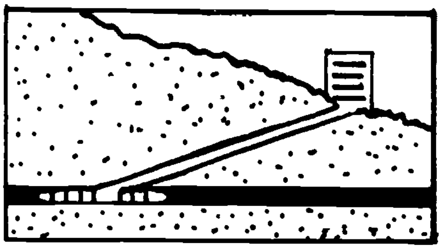


Because burning coal provides heat, it has many uses in industry. About three fourths of the coal mined in the U.S. is used for generating electricity. Burning coal heats large tanks of water and produces steam. The steam turns giant turbines, which generate electricity. One out of two houses in the U.S. uses electricity generated by coal-burning power plants.

Coke is a fuel made from coal when all the gases and tar are removed from the coal. Coke burns hotter and cleaner than the raw coal. Coke is used as fuel for industrial furnaces for heat and power in steelmaking cement factories and paper mills.

New methods of making synthetic fuels (gas, oil) from coal are being tested in the laboratory and in experimental plants.

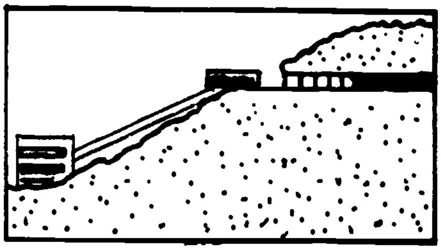
Slope Mine



There are many issues surrounding coal energy. Burning coal can pollute the air. Strip mining can ruin land by taking away all the trees and top soil. Therre are also many dangers for the workers in mines, such as explosions, cave-ins, and lung diseases caused by breathing coal dust. Better methods of mining must be developed to provide more safety and less spoilage of the land. New methods of burning coal are also needed to help keep the air clean.

Nature took billions of years to create coal. Many believe that the use of coal as an energy source will provide power for a long time to come.

Drift Mine



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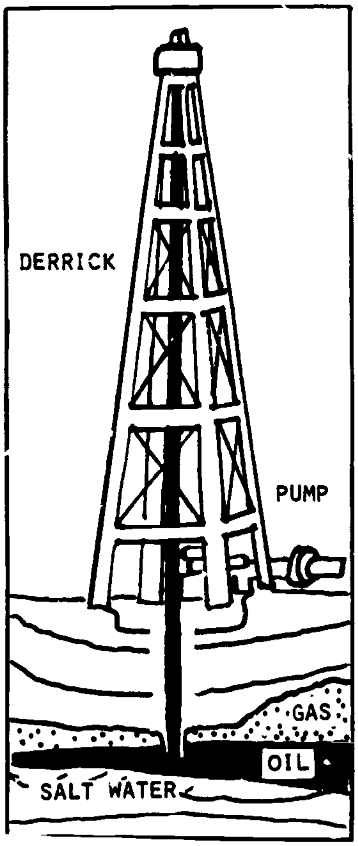
Oil and Natural Gas



OIL

Oil is a fossil fuel. Like coal, oil was formed millions of years ago from the decomposition of plants and animals. Squeezed by layers of sand and rock, oil gathered in pockets deep in the earth.

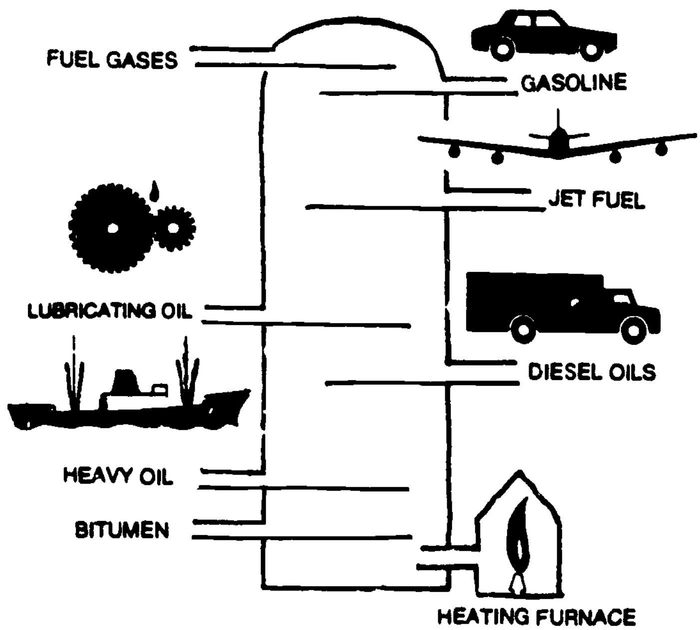
Oil is often called petroleum. It is recovered from the earth by drilling wells on land or into the floor of oceans and lakes. Offshore drilling rigs are used to recover oil from beneath the sea. The offshore platform is a manufactured island of steel containing drilling equipment, supplies, and living quarters. A helicopter is often used for transportation.

When the oil is pumped out of the earth, it is called **crude**. It must be "**cooked**" to produce gasoline, diesel oil, and other fuels. There are two cooking processes called **distillation** and **cracking**. Both require great amounts of heat.

The cracking process also yields fuels, lubricating oil, and several petrochemicals used to make plastics, synthetic rubber, fertilizer, textile fibers, adhesives, and paints.

Oil is measured in barrels (42 gallons = 1 barrel). Each year, 20 billion barrels of oil are produced in the world. The United States uses almost one-third of it. The U.S. produces about 3 billion barrels and buys more than 2 billion barrels from other countries. Almost one-half of all energy used in the U.S. is in the form of oil. Major uses of oil are for transportation, space heating, production of electric power, industrial uses, and making petrochemicals. New methods are being studied to produce synthetic oil from coal.

Oil can be a hazard to the environment. Accidents in recovery and transportation can threaten the lives of plants and animals.



Petroleum Distillation Process

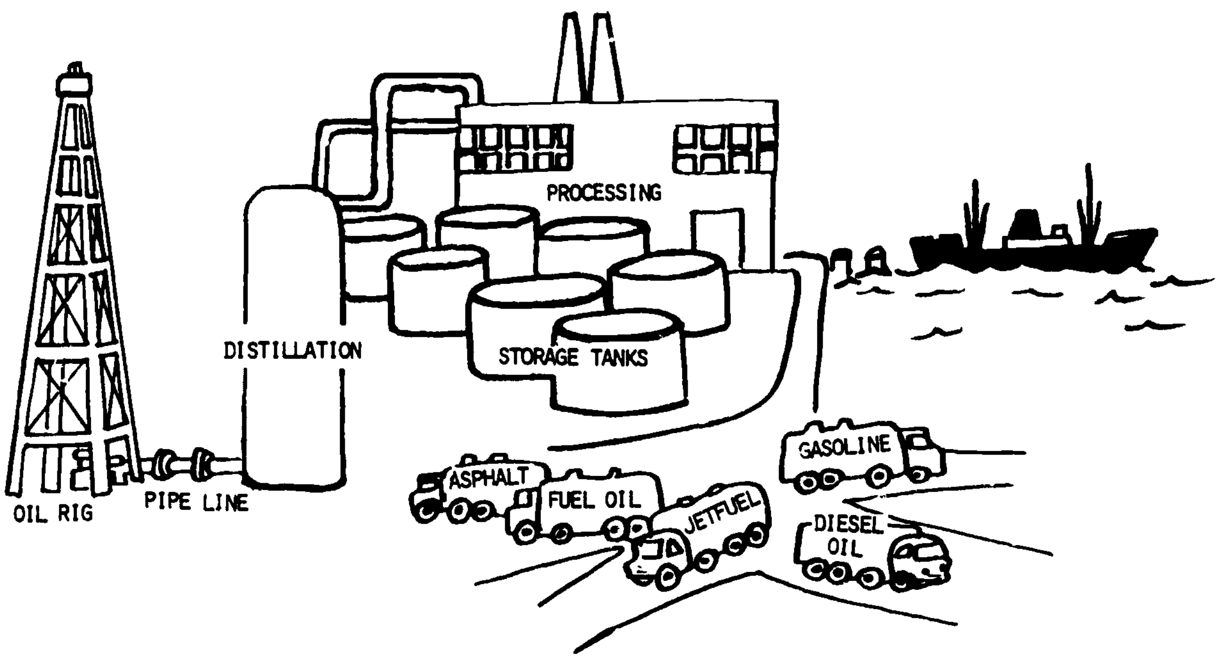
NATURAL GAS

Natural gas is often found near deposits of oil. Gas, like oil, is recovered from the earth by drilling wells. After the dirt and rock are drilled out, a pipe is lowered into the earth as far down as 10,000 feet. When the gas is found, it rises to the surface, where it is cleaned. The gas enters a pipeline and is pumped to other areas through pipes called **gas lines**. Natural gas is measured in cubic feet. (One cubic foot is a block that measures 1 foot in length, 1 foot in height, 1 foot in depth).

After gas is pumped from the ground, it is pumped to refineries. There, it is broken down into its components such as methane, propane, and butane, as well as nitrogen, carbon dioxide, helium, and others. These products of natural gas remain liquid and are stored in steel containers ranging in size from tiny tubes to huge tanks.

Experts predict that natural gas at the present rate of use could last anywhere from 10 to 45 years. Natural gas is a popular fuel because it is clean burning and causes only a small amount of pollution to the environment. Gas is used for cooking, space heating, and industrial heating. It is also used to fuel electrical generating stations. Because resources are limited, natural gas may become the first of the earth's energy resources to be totally used up.

Petroleum Refining and Distribution



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Wind and Solar Energy

Have you ever flown a kite on a windy day? Have you ever felt the warmth of the sun? Most everyone has . . . but have you thought about how much energy is available in the wind and sun? Let's look at some ways we can capture and use wind and solar energy.

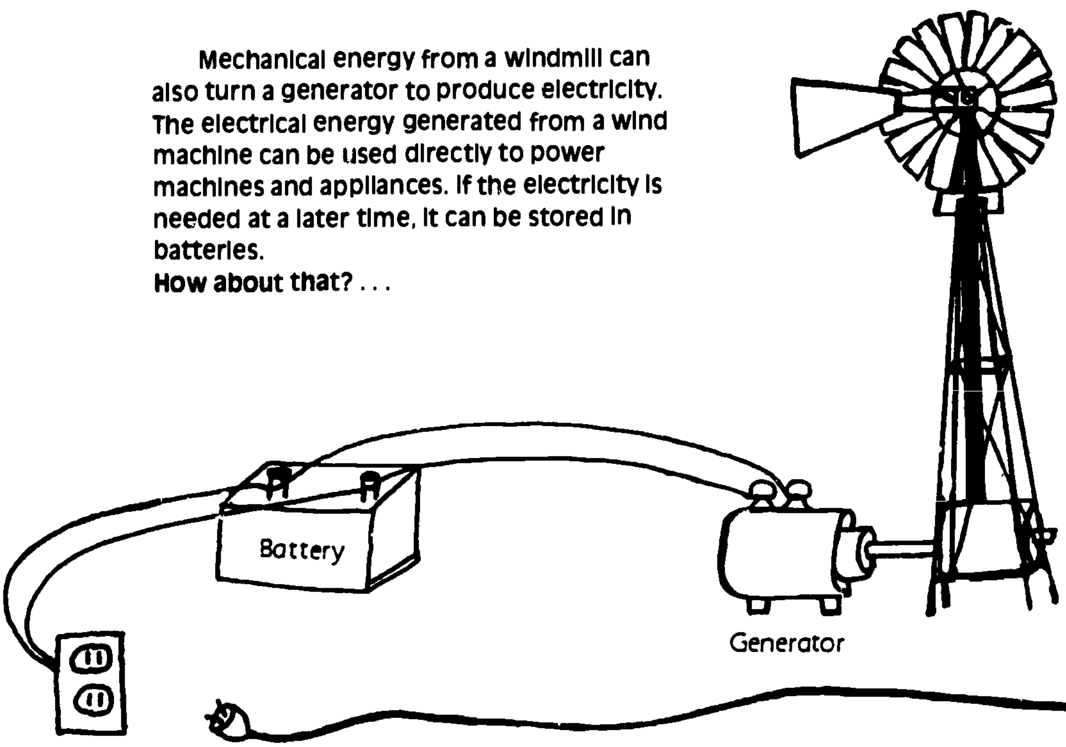
After studying this unit you will be able to:

- Tell your friends how wind can be used to make mechanical and electrical energy with a windmill.
- Describe two types of solar energy.
- Explain how the sun's heat is collected.

First let's take a look at . . . WIND ENERGY

Since ancient times, the wind has been used to sail ships across the oceans. For more than 1,000 years wind has turned windmills to produce mechanical energy. Some of the windmills were used for pumping water. Others were used for grinding grain. That's not all . . .

Mechanical energy from a windmill can also turn a generator to produce electricity. The electrical energy generated from a wind machine can be used directly to power machines and appliances. If the electricity is needed at a later time, it can be stored in batteries.
How about that? . . .



GO ON

Do You Know How a Wind Machine Works? . . .

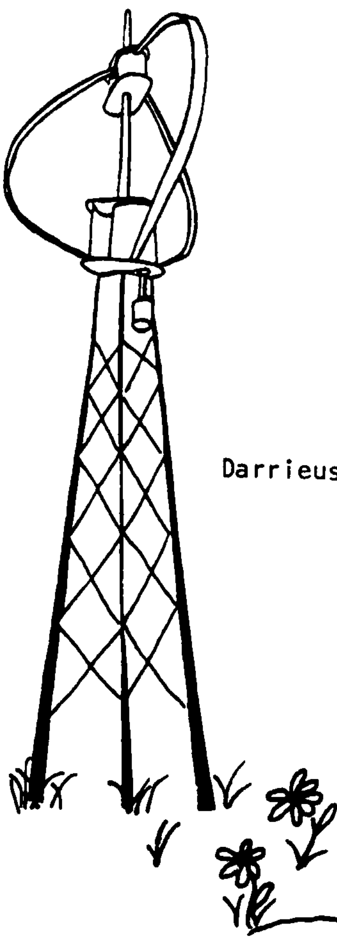
The power produced by a wind machine depends on the wind speed and the size (diameter) of the blades. To get the most power, a wind machine should

- have the longest blades possible.
- be located in the strongest winds.

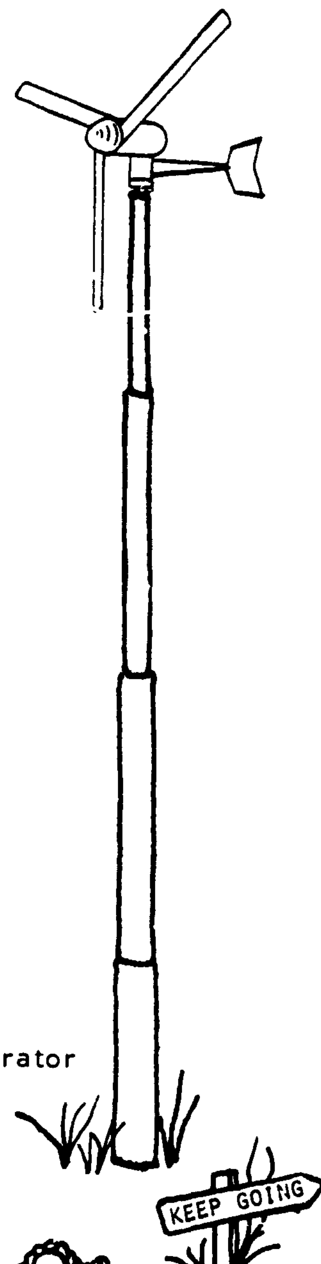
The height of the wind machine is also important because of the greater wind speed at higher altitudes.

As the costs of fuels for other types of energy continue to rise, wind energy is becoming more popular. Presently, wind machines are used to pump water and to generate power for home heating, water heating, dairy cooling, cooling for crop storage, and other farm uses. Small wind machines are generating electricity for use in homes and businesses. Large wind machines are producing electrical energy to supply the energy needs for entire neighborhoods.

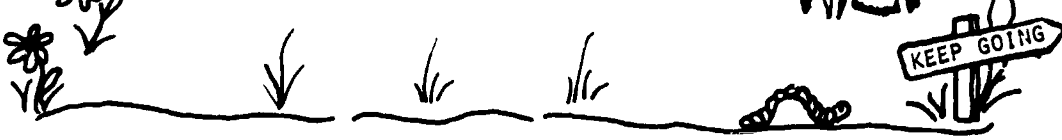
New wind machines are being developed that will produce electricity more efficiently. In some areas of the U.S., wind power is a technology that could provide enough electricity to power 1 out of every 10 homes in the United States.



Darrieus rotor generator



High-speed propeller generator



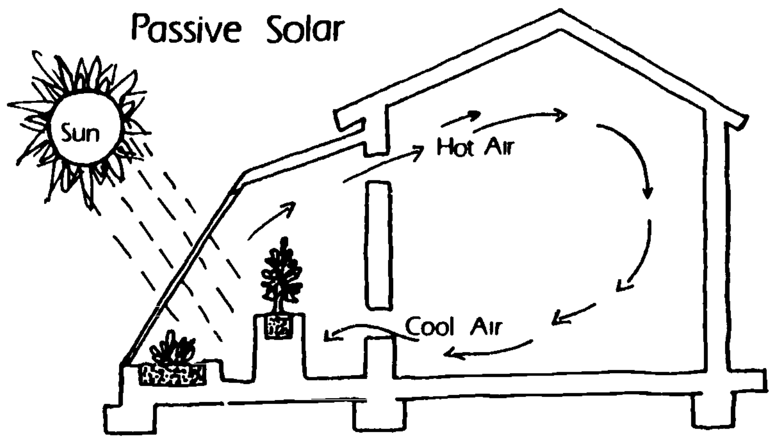
But what about . . . SOLAR ENERGY

Energy from the sun can be used to heat air and water. There are two types of solar heating: passive and active. Got that? O.K. . . .

The passive system of solar collection uses the sun directly to heat the air (space) in a building. A solar greenhouse on the sunny side of the house is one way to collect heat. Large windows are another.

Solar energy can be trapped in a big, flat box called a flat-plate collector. The inside of the flat-plate collector box is painted black to absorb the sun's heat. A lid of glass or clear, strong plastic holds in the heat. If a fan is used to move the air, or if a pump is used to move water in pipes through the collector, then it is called an active system. The pump and fan are the active parts. Oh! One more thing . . .

Passive Solar



Attached Solar Greenhouse

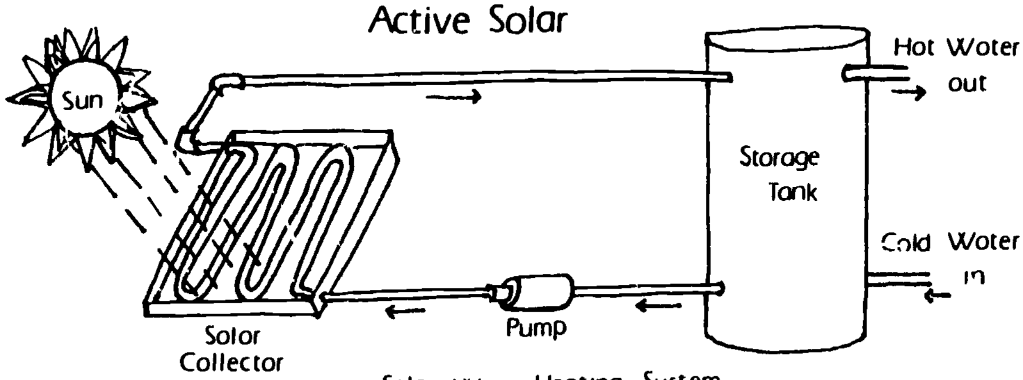
Another type of active solar collector uses photovoltaic devices (called solar cells). The solar cells convert the sun's energy into electricity. You may have seen pocket calculators or transistor radios powered by solar cells.

Did you know that . . .

Heat produced from the sun can be stored in a bed c ocks or containers ot .vater (called **thermal mass**)? That way, the energy can be used later when the sun is not shining. **Pretty neat, isn't it?** . . .

Solar energy is useful because the sun is an unlimited source of energy. We can never use it all up. But there are some problems. Energy storage devices, for example, are expensive and somewhat inefficient. It is also difficult to rely totally on solar power in areas of the country that are cloudy and cold. In the southern states, solar power will probably be quite common by 1990. By the year 2000, solar power has the potential of giving us a great deal of energy.

Active Solar



Solar Water Heating System

So You See . . .

Wind and solar energy are renewable energy sources. They may help reduce energy problems in the future. People are becoming more interested in the possibilities of these sources. Wind power is different from other alternatives because it is an old and proven method for generating electricity. Some types of solar energy collectors can be used in existing homes by making only a few changes to the building. Both wind and sun are clean and nonpolluting sources of energy. New devices are being developed that will help us capture more power of the sun and wind. The future looks bright. **Hurray for the wind and sun!!**

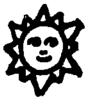
Now that you are this far, try a SELF-QUIZ

On your own sheet of paper write your answers to this quiz. Ready? Go!

1. A solar collector that uses a pump or a fan is called ________.
2. A system that uses the sun directly for space heating is called ______.
3. The sun's energy can be turned into electricity by using ________.
4. Wind energy is used to produce ________ energy and ________ energy.
5. The power of a wind machine depends on the ________ of the wind.
6. Electricity from a wind machine or a solar cell can be stored in ______ for later use.

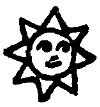
Turn this page upside down, you will find the answers at the bottom of the page. Go back and read about the ones you missed.

THINGS TO DO



Take a look around your neighborhood. Are there any wind machines or solar collectors being used? Look hard. You may be sur prised at what you find.

Construct a small speed indicator (anemometer) to test the speed of the wind at different places. Where is the wind strongest? Outside your school? On a hill? Under a tree?



Think about how the sun's energy could be used at home, at school, or in community buildings. Design some plans for its use.

FOR FURTHER STUDY

Dennis, L. *Catch the wind*. New York: Four Winds Press, 1976.

Knight, D. *Harnessing the sun*. New York: Knight, Morrow, 1976.

Rankins, W., & Wilson, D. *The solar energy notebook*. North Carolina: Lorien House, 1976.

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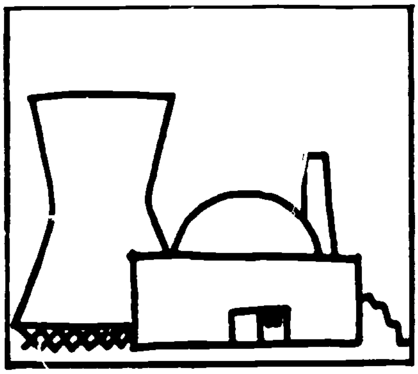
Answers:

1. active
2. passive
3. photovoltaic cells
4. mechanical, electrical
5. speed
6. batteries

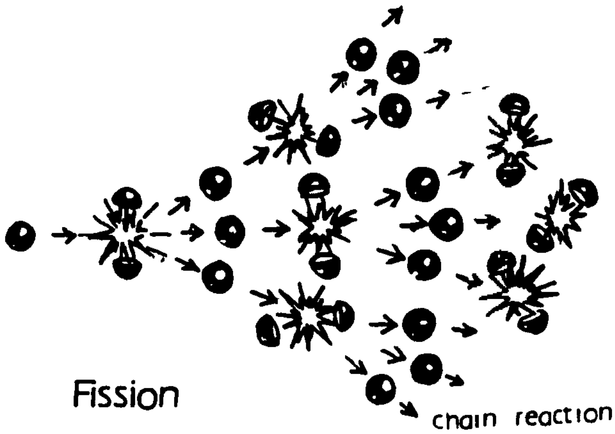
Nuclear Energy



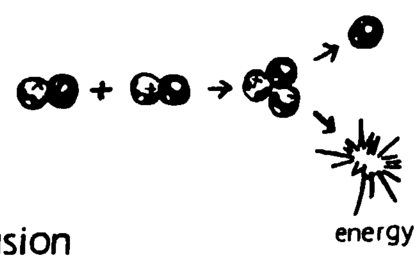
Nuclear Power Plant

A nuclear power plant generates electricity. In ordinary power plants, coal, oil, or natural gas is burned to produce steam. The steam is forced through a turbine (a type of fan), which spins a generator. The generator produces electrical current used to heat our homes, run our appliances, and light our way. In a nuclear power plant, fossil fuels (coal, oil, gas) are replaced by nuclear fuels (uranium). Today there are 52 nuclear plants located in 26 states. The average plant costs about $600 million to build and takes 4 to 6 years to complete.

Energy is produced in a nuclear reactor by a process called **fission**. In this process, the nucleus (center) of each uranium atom splits into pieces when struck with a neutron. The fragments hit other atoms, which also split and give off more fragments. A "**chain reaction**" develops giving off heat and radiation. The heat is useful, but the radiation is not. This fission (splitting) of atoms takes place in the core of the nuclear power plant. The chain reaction is controlled by raising and lowering carbon rods within the core.

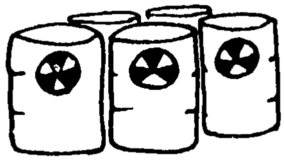


Fission



Fusion

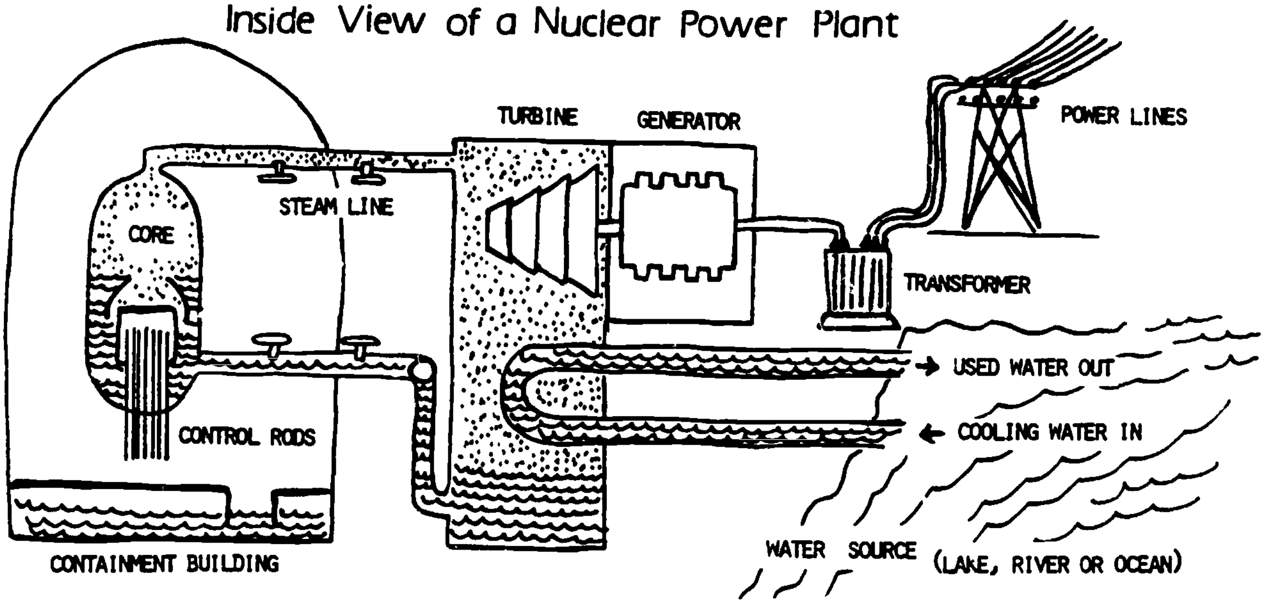
Scientists are working to develop another type of nuclear reaction for producing power. It is called nuclear **fusion**. The fusion process occurs when two atoms of hydrogen are fused together to make one atom of helium and one free neutron. This combination releases a tremendous amount of energy. But, it requires extremely high temperatures to start the reaction. Atomic fusion is also the basis for hydrogen and neutron bombs.

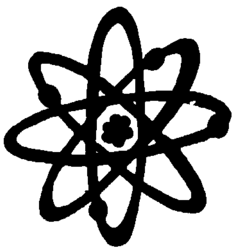


Nuclear Waste

There are controversial issues surrounding the use of nuclear power. One problem is how to prevent miners of uranium from being contaminated by radioactive dust. Another problem is how to dispose of the radioactive waste. Radioactivity cannot be seen or tasted. Too much radiation can cause serious sickness. Workers in nuclear power plants are constantly checked to make sure they do not get too much radiation, but accidents can happen. Nuclear wastes are stored at the site of the plant or transported to special dumps. A single nuclear power plant can produce 9,000 gallons of radioactive waste each year. Experiments are being conducted to find containers to hold these wastes for thousands of years until they are no longer radioactive. There are already more than 70 million gallons of the highly radiated waste stored in various places in the U.S.

Inside View of a Nuclear Power Plant





Nuclear energy is also used to power large ships and submarines and to build military bombs. Some space satellites are powered by nuclear fuel. Experiments have been conducted using atomic radiation to speed up the growth of trees and agricultural products. Plans have been developed to float giant nuclear plants on the oceans to provide electricity wherever it is needed. The future of nuclear power will depend on new developments to increase safety and decrease costs.

FOR FURTHER READING

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Hogerton, J. *Nuclear reactors.* Washington, D.C . U.S. Atomic Energy Commission, 1970.
Meyer, L. *Nuclear power in industry.* Chicago: American Technical Society, 1974.

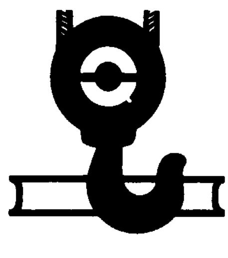
Resources in Technology

Careers in Energy

The Occupational Outlook Handbook lists hundreds of careers relating to energy production, transmission, and use. One study predicts that by 1990, there may be more than 2.1 million jobs in solar energy and energy conservation alone. Here is a sampling of some energy careers that might interest you.

MECHANICS

Mechanics are vital to all the energy fields. Mechanics keep the tools and equipment running smoothly and efficiently. The job may involve working on motors, generators, engines, hydraulics, pipelines, drilling rigs, or other mechanical devices. Training in a vocational program, technical, or trade school is usually required.



CONSTRUCTION WORKERS

Construction workers are needed to build hydroelectric plants, refineries, pipelines, power lines, and solar equipment. These careers require a general knowledge of materials and a high degree of skill in using tools and equipment. Because many of the jobs are outdoors, construction work depends on weather conditions. An apprenticeship or on-the-job training is often required.

MINERS

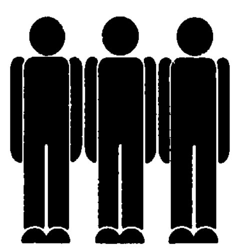
Miners are responsible for extracting coal from the earth. The work may take place above ground in open pit mines or below ground in deep mines. Miners must know how to use heavy machinery as well as hand tools. Apprenticeship training is required.

HEAVY EQUIPMENT OPERATORS

Heavy equipment operators run the dozers, shovels, trucks, and tractors that move the earth. Jobs may include stripping coal, preparing access roads, or building dams for hydroelectric power. Most of the work is outdoors and may be delayed by poor weather. Training and experience in the proper use and maintenance of equipment are required.

SUPERVISORS

Supervisors schedule workers, equipment, and material to keep the work flowing. Some supervisors have indoor jobs, such as those in plants that produce fiberglass insulation. Others work outdoors at construction sites or on drilling rigs. Supervisors must understand the equipment and the work being performed. They must also be able to manage people effectively and to cope with production deadlines.



SALES PEOPLE

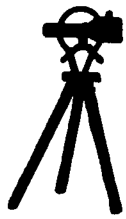
Sales people are needed to sell energy, energy production equipment, and energy conservation materials. Sales work requires knowledge of the products and the ability to get along well with people. Special training and a well-rounded education are helpful.

QUALITY-CONTROL TECHNICIANS

Quality-control technicians make sure that gasoline has the right octane, that electric current is constant, and that coal is clean enough to burn. Ability to use test equipment is often necessary. Experience, technical training, and a college degree are helpful.

CIVIL ENGINEERS

Civil engineers design dams, coal tipples, pipelines, refineries, and other energy-related structures. Civil and most other engineering careers require a strong background in mathematics and the physical sciences. A college degree is required.



CHEMISTS

Chemists help find better ways to use the energy we produce efficiently. Coal liquefaction, recycling of byproducts, and natural gas refinement are a few of the areas being explored by chemists employed in the energy field. Chemists usually work in laboratories and have college degrees in their special areas of interest, such as petroleum, coal, or natural gas.

BIOLOGISTS

Biologists are needed to help maintain a balance with nature and our search for more energy. They explore acid run-off from mines, oil contamination, and the effects of air pollution on plants and animals. These careers often include both indoor and outdoor work. A college degree is required.

GEOLOGISTS

Geologists study the rocks and minerals and help to determine where energy resources are available. They also study the earth to decide the best and safest methods of extracting the resources. The work takes place outdoors and in laboratories. A college degree is required.

FOR FURTHER STUDY

Careers in energy: Jobs in an expanding industry. New York: Educational Enrichment Materials, 1981. (Film)

U.S. Department of Labor. *Occupational outlook handbook* (Bureau of Labor Statistics, Bulletin No. 1550). Washington, D.C.: U.S. Government Printing Office, 1980–1981.

U.S. Department of Energy. *Careers in energy industries* (U.S. DOE pamphlet 0052 (1–80)). Washington, D.C.: U.S. Government Printing Office, 1980.

Energy & the Environment

We often hear about possible shortages and rising costs of the fuels that provide us with energy. Although we recognize how important these fuel sources are to our life-style, it is also necessary to consider how these and other energy sources affect our environment. Our environment consists of the air we breathe, the water we drink, and the soil we live on.

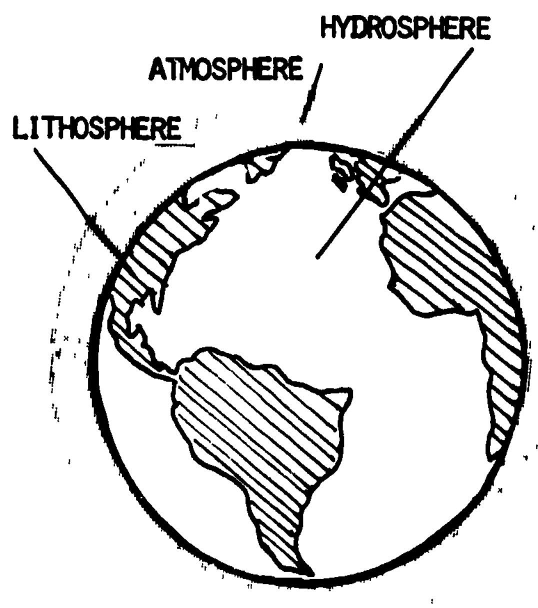
After studying this unit you will be able to:

- Name three parts of our environment that are important to life on earth.
- Describe the system of fuel extraction, energy conversion, distribution, fuel use, and waste products.
- Identify the environmental problems caused by different fuel sources.
- Explain the term ***thermal pollution***.

First, let's take a look at what makes up our environment . . .

Our physical environment is made up of three basic parts. The **lithosphere** is the surface of the earth that supports biological life. The **hydrosphere** refers to the water on the earth. The **atmosphere** describes the layers of air and space surrounding our planet. Each of these parts of the environment is affected by our energy use.

The three parts of the environment adapt to constant natural changes caused by floods, fires, and erosion, and even to some of the changes caused by people. When too many people cause too many changes in the environment, however, it may not be able to recover. This happens partly because of people's demand for, and use of, energy.



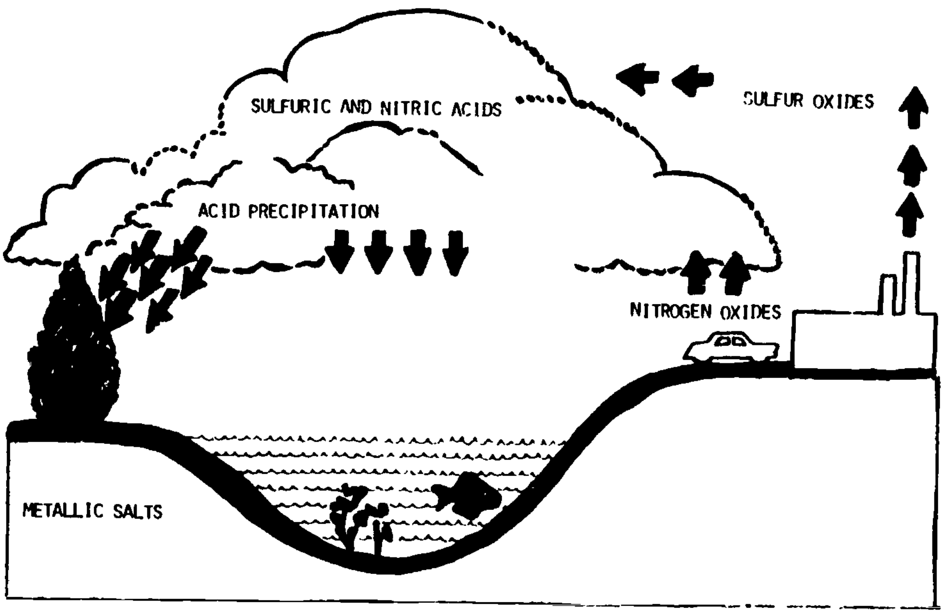
How do our ways of finding and using energy affect the environment? . . .

The extraction, conversion, distribution, and use of fuels for energy can cause various types of pollution to the environment.

The **extraction** of fuels from the earth (coal mining, for example) can cause problems in the hydrosphere. Strong acids sometimes pollute water systems. Strip-mining causes difficulty in the replacement and regrowth of topsoil in the lithosphere. (By 1985, three million acres in the U.S. will have been used for strip-mining.) Uranium mining for nuclear industries releases radiation into the atmosphere and hydrosphere. Oil spills at both on-shore and off-shore drilling sites are dangerous to the environment. Obtaining natural gas from the earth can cause explosions or burning of gas. However, renewable energy sources—such as solar, wind, thermal and tidal power, hydropower, and biomass—cause little, if any, harm to the environment.

The **conversion** (change) of extracted fuels into usable form can also cause problems. When coal is washed and sorted, the resulting waste heaps sometimes burn or add to local pollution when wind and water erosion spread the coal dust. Also, the refining of petroleum products affects the hydrosphere and lithosphere with oil leaks and chemical wastes. Uranium processing causes radioactive waste.

After fuels have been processed, they must be **distributed** to the areas in which they are used. Transportation of fuels makes possible petroleum spills, leaks, and fires in the water and on the land. Oil spills make coastal waters uninhabitable for fish and wildlife, which are necessary to maintain the balance of life in the lithosphere.



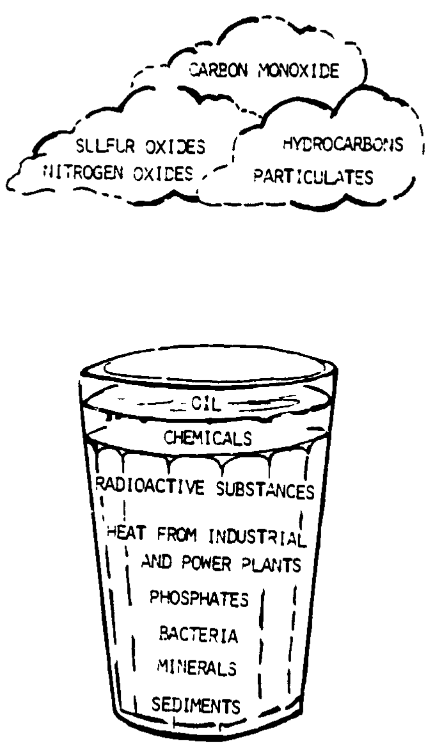
Fuels are **used** in various ways to provide power. Coal is burned for power, heat, and electricity. Burning coal puts sulfur oxide, nitrogen oxide, and fly-ash particles in the air. These cause respiratory and heart diseases in humans. Mixing with water in the atmosphere, sulfur oxide causes acid rain. This can corrode metal, stone, and fabrics. It also kills fish. Lakes and rivers are becoming more acidic. Burning petroleum and coal products adds hydrocarbons and sulfur to the air. Radiation is pollution we cannot see, smell, or taste. Radiation can leak from nuclear reactors used to make electricity.

WASTE PRODUCTS

The waste by-products of energy production can also be hazardous to the environment. One of the most serious waste products is high-level radioactive material generated by nuclear power. These wastes, such as plutonium, must be stored safely for 25,000 years to avoid contamination of living things. Wastes from petroleum fuels pollute the lithosphere, hydrosphere, and atmosphere. Natural gas is a clean-burning fuel, but it is becoming scarce.

THERMAL POLLUTION

As they produce power, energy industries create large amounts of heat. Many industrial processes also require high degrees of heat. When heat is wasted, it results in **thermal pollution** of the environment. Water is used in large quantities as a cooling agent, and also to produce steam to run generators in power plants. A surplus of heat in the atmosphere can cause changes in the climate of the earth. The aquatic ecosystems can be harmed if heated water is allowed to change the sensitive balance of the hydrosphere.



Causes of Air and Water Pollution

There are ways of keeping the environment free from pollution. Government regulations, such as the Clean Air Act, require equipment such as scrubbers to remove particles from the exhausts of power plants which burn fossil fuels. Laws and devices can aid in reduction of pollution to our environment. Now, do you have the picture?

However, energy consumption need not create negative effects on our environment beyond the point where nature can correct the problem. New technologies may result in obtaining energy with a consideration toward the environment. Conservation will help in the meantime, while many potential energy sources are being explored.

The relationship between energy and the environment is a complex one. Factors such as pollution, animal food chains, and fuel consumption create an interrelation of people, technology, and the environment. We can have a better life if we understand how these things work together.

The next time you hear a discussion on the high cost of fuels, think about the high cost to the environment of the use of some of these fuels. As fossil fuel supplies begin to diminish, it is time to look at other possible fuel sources. But in choosing fuels to power us in the future, it is important to look at the future of the environment where we live, breathe, play, and work. With good planning, we can have a healthy environment for all living creatures.

Now, how aware are you of energy and the environment? Using your own paper, write the answers to the following quiz.

SELF-QUIZ

1. What are the names of the three basic parts of the environment?
2. List the five terms for the stages in the process of obtaining and using energy.
3. Name some of the problems to the environment when fuels are extracted from the earth.
4. What parts of the environment can be harmed by accidents while transporting fuels? Give examples.
5. What are some of the causes of thermal pollution?

Turn this page upside down; you will find the answers at the bottom of the page. Go back and read again about the ones you missed.

THINGS TO DO

- Build a model of a supertanker. Show where the oil is located and how much oil a supertanker can hold. How are supertankers loaded and unloaded? Discuss the precautions that must be taken to prevent spills.
- Collect current newspaper and magazine clippings about pollution from the extraction, transportation, and use of fossil fuels.
- Compare the renewable energy sources with alternative energy sources (solar, wind, biofuels, hydro, etc.). List the economic, environmental, and energy advantages and disadvantages of each.

FOR FURTHER STUDY

Fowler, J. M. *Energy-environment source book.* Washington, D.C.: National Science Teachers Association, 1980.

Energy: Facing up to the problem, getting down to the solutions. Washington, D.C.: National Geographic Society, 1981.

White, D.C. Energy choices for the 1980s. *Technology Review*, August/September 1980.

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Answers

1. lithosphere, hydrosphere, atmosphere
2. extraction, conversion, distribution, use, waste
3. strip-mining/oil drilling pollute hydrosphere and lithosphere
4. lithosphere, hydrosphere, atmosphere
5. energy industries put out heated air and water to the environment; atmosphere traps heat of the earth

History of Transportation

We live in a technologically advanced nation. One of the advantages of living in the United States is that we have a truly impressive transportation network at our disposal. Our modern transportation system has been developed over successive generations to move people and goods quickly and efficiently. The development of this transportation network has come about through a number of technical inventions and innovations. Let's look at how transportation technology has developed.

After studying this unit you will be able to:

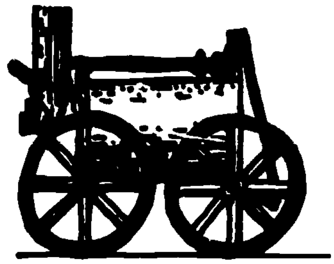
- Define transportation technology.
- Explain several major inventions and the role they played in the development of transportation.
- Identify the three major types of transportation systems.

First, let's look at LAND TRANSPORTATION . . .

Early transportation began with the use of pack animals, sledges, and wheeled carts. Camels, donkeys, and horses were used to carry goods. Pack "trains" of horses were extensively used in Europe well into the seventeenth century. Dragging devices made of poles with cross braces allowed pack animals to carry twice the load they could carry on their backs. You probably have seen pictures of North American Indians using a version of the sledge called a "**travois.**"

No one knows for sure when the wheel was invented, but the best guess is that it occurred in Asia between 8000 B.C. and 4000 B.C. From Asia, the use of wheels probably spread (or rolled) to Egypt and Greece. The first wheels may have been made of flat pieces of wood fastened together with a hole cut into the center. Solid wooden wheels are still used today in developing countries, such as Laos and Bangladesh. It may be obvious to you that the wheel made a great contribution to transportation because rolling friction is less than sliding friction. With wheels, greater loads can be carried more quickly over longer distances.

James Watt is credited with developing the steam engine, but the railroad system was born in England in 1825. It was then that a group of British businessmen, frustrated by the high cost of moving goods by canal, sponsored a competitive event to select the fastest railroad locomotive. George Stephenson's steam-powered locomotive astonished crowds at the competition by travelling at a top speed of 24 MPH. The railroad opened officially several years later, and the first commercial run carried 52 tons of freight between Liverpool and Manchester. Railroading grew rapidly. Between 1829 and 1837, 1,450 miles of locomotive-powered railroad had been built by the U.S. By 1869, when the golden spike was driven marking the completion of the first coast-to-coast railroad, more than 50,000 miles of track had been laid.

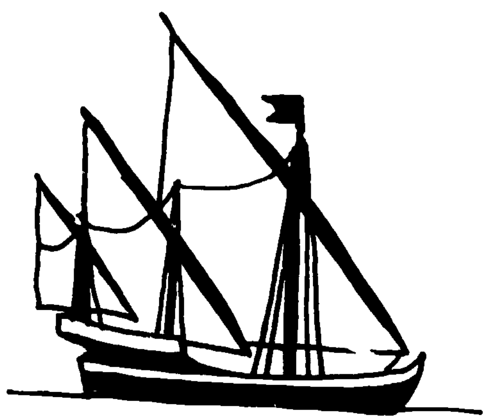


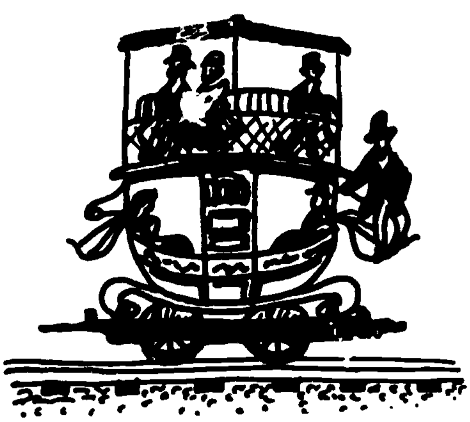
The year 1880 saw the beginning of a technology that was to revolutionize transportation. No, it was not the automobile; it was the bicycle. Between 1880 and 1900, the bicycle evolved from the "highwheel ordinary" design to the modern "safety bicycle." By 1900, U.S. workers were manufacturing 1 million bicycles each year. Why was the development of the bicycle so important? As bicycles developed, so did the precision-bearing industry, the roller-chain industry, and the pneumatic-tire industry. Later, all of these came into use on automobiles and aircraft.

Also, there was WATER TRANSPORTATION . . .

Early humans used logs, bark canoes, waterproof baskets, and skin-covered frameworks to float their goods downstream. As boats were developed, people used poles, oars, and eventually sails for power. The first recorded use of the sea for shipping goods occurred about 2800 B.C. when the Egyptians sailed the Mediterranean Sea to Phoenicia. Their ships carried papyrus and grain, which were bartered for wood. Inventions, such as the compass, made navigation more reliable and meant that vessels could take more direct, open-ocean routes. Inventions over the next few hundred years included the sternpost rudder that enabled vessels to be larger and more easily controlled.

Certainly, boats and ships were useful, but they were somewhat limited until ports, harbors, locks, and canals were developed. By the time Columbus discovered America in 1492, parts of the Old World had developed shipping canals and locks to control water levels. In fact, Leonardo da Vinci is credited with inventing the double-mitering gate lock. Like many of his inventions, it was rediscovered many centuries later.





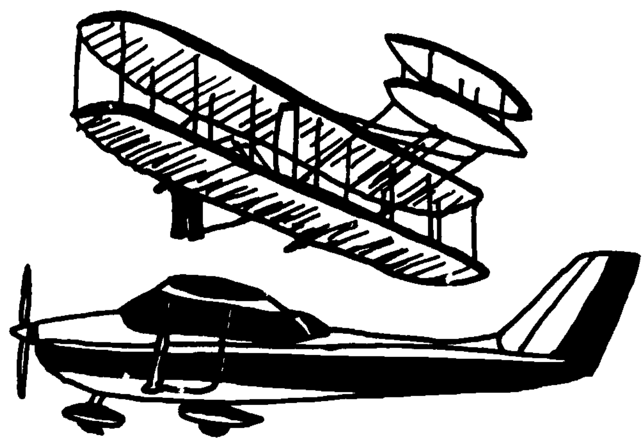
A canal lock is a chamber in which a vessel, while afloat, can be raised or lowered from one stage of a canal to the next. This is very important in inland waterways connecting lakes or rivers of differing heights (elevations). In the operation of a lock, a boat enters the chamber, doors are closed, and the water level inside the chamber is raised or lowered, whichever is needed. The invention of the canal lock made it practical to build canals large enough to accommodate large boats. Perhaps the most famous is the Panama Canal.

But, what about . . . AIR TRANSPORTATION?

For as long as humans have looked at the clouds, they have dreamed of flying with the birds. Perhaps y' 'I have read elsewhere about Icarus in Greek mythology. According to the my , Icarus flew toward the heavens with feathers glued to his arms. You can guess what happened when he got too close to the sun. When studying technology, it is often fun to think about "what if" questions. For example, we know that Ancient Egyptians had the technology to fly. What if they had used available cloth, thread, rope, and basketry to fashion hot-air ballons? Apparently no one had the idea, and human flight remained a myth for centuries. Or, what if Leonardo da Vinci had spent his time watching birds that soared instead of birds that flapped their wings? The technology for construction of human-carrying gliders certainly existed at that time, but no one developed it. Instead, Leonardo drew designs for flying machines requiring sophisticated technology that was not yet available.

Air transportation (aviation) probably got its start with model gliders during the nineteenth century. The lowly elastic band may have been a significant factor leading to the development of powered flight. It provided the first power source that was light enough to propel model aircraft, allowing for experimentation with airfoil design. Kite-building and bicycle technology also played an important role in the history of aviation. In the 1880s and 1890, aviation pioneers, such as Germany's Otto Lilienthal, proved that gliders could provide enough lift to keep a human off the ground.

Wilbur and Orville Wright combined their talent for kite-building, model airplane experience, and knowledge of bicycle drives to achieve manned flight in 1903. The Wright brothers realized that the internal combustion engine was more suited for flight than the gasoline-powered engine and installed it in a glider. It weighed 180 pounds and developed 16 horsepower. The flight lasted only 12 seconds, and the plane flew 120 feet.



Today, transportation technology is responsible for moving people and goods all over the world. Modern means of transportation allow workers to get to and from their jobs. Raw materials are transported to factories, and the finished goods are shipped to retail stores.

Now, try a SELF-QUIZ . . .

SELF-QUIZ

On your own sheet of paper, write your answers to these questions.

1. What technological advances were contributed to by the development of the bicycle?
2. What role do canal locks play in inland water transporation?
3. Name three major kinds of transportation systems.
4. Why didn't aviation pioneers use steam engines to power their aircraft?
5. Why do wheels play such an important role in land transportation devices?

The answers are upside down on the bottom of the page. Go back and read again about the ones you missed.

THINGS TO DO

- Build a device to carry a raw egg from one end of your lab to the other in the shortest possible time without breaking the egg.
- Select a historically significant transportation device and build a working model. Consider some of Leonardo da Vinci's inventions.
- Study a modern transportation system, such as a railroad or a bus system where you live. Show how it could be improved in the future.

FOR FURTHER STUDY

Sharp, D. *Looking Inside: Machines on the move.* London: Hampton, 1968

Cooper, M. *The Inventions of Leonardo da Vinci.* New York: Macmillan, 1965.

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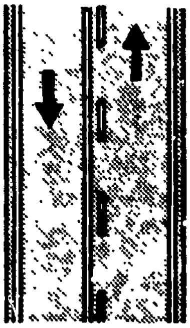
Answers:

1. Chain drives, precision bearings, pneumatic tires.
2. They create a chamber that allows water level to be adjusted up or down.
3. Land, air, water.
4. Steam engines were too heavy.
5. They reduce friction.

Transportation Control Devices

Transportation systems require control devices to ensure their safe operation and to maximize their efficiency. Each transportation mode (highway, railway, marine, air) has developed a variety of control devices and systems.

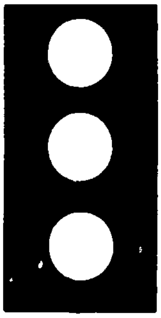


HIGHWAY MARKINGS

The white line down the center of the pavement is the simplest form of highway traffic control device. It is inexpensive, easily changed, and does not obstruct traffic. Some common types of markings are center lines, lane lines, no-passing lines, pavement edge lines, and stop lines. Although most are painted, some pavement markings consist of adhesive-backed strips of rubber.

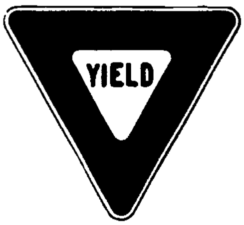
TRAFFIC SIGNS

Traffic signs provide a simple method of traffic control. Stop signs and speed limit signs are used to regulate traffic. Warning signs are used to alert drivers of such hazards as railroad crossings or intersections. Guide signs give general information about the location of hospitals, gas stations, and other services.

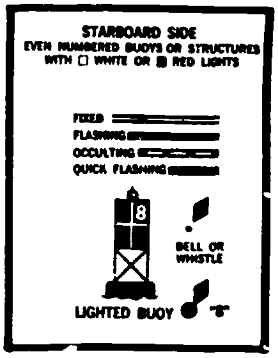


TRAFFIC SIGNALS

Stop lights and other traffic signals provide for order and safety. Most visual traffic signals require that the vehicle operator see them and react accordingly. However, the electronic signals can be used to automatically control the vehicle without depending on an operator to respond. For example, railroads use a system of electronic signals to automatically route one train to a siding if another should approach on the same track.



MARINE BUOYS

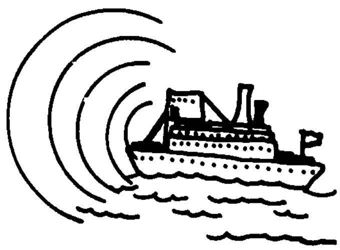


Marine navigation aids permit vessels to know their exact location at all times. Various types of buoys are used much like highway signs to mark ship channels and hazards near ports. Numbers, lettering, colors, bells, and whistles are used as part of the warning system. Radar and optical reflectors on some buoys help make them easier to locate in poor weather.

MARINE RADIO BEACONS

Electronic aids are becoming increasingly important to marine navigation because they can operate in all kinds of weather. The radio beacon system is the simplest of these. It requires only an inexpensive receiver similar to a transitor radio. Radio beacons can provide information about direction but not about distance. Because it is inexpensive, many small fishing boats and pleasure craft use the radio beacon system.

MARINE LORAN AND RADAR



Long-range radio navigation (LORAN) provides both directional and distance information through triangulation. Radio direction and ranging (RADAR) provides information about location and movement of objects within range. An on-board transmitter sends out a radar signal that is reflected by all objects in its path. A receiver picks up the reflected signals and displays them on a screen much like a television monitor.

AIR NAVIGATION AIDS

Pilots use various types of navigation aids, including automatic direction findings (ADF), very-high-frequency omnidirectional range (VOR), distance measuring equipment (DME), transponders, and radar. When an aircraft is operating under instrument flight rules, its position is monitored at all times by air traffic control centers. Some airports are now installing a new microwave landing system (MLS) similar to the one developed for space shuttle flights. The system allows for very accurate landings under poor visibility.

FOR FURTHER STUDY

Innovation in public transportation. Washington, D.C.: U.S. Department of Transportation, 1981.

Schefter, J. Safer skies into the 21st century: FAA's revolutionary control systems. *Popular Science*, October 1982, pp. 80–83.

History of Communication

Inventions in technical communication systems have changed the shape of phonograph records, provided dial telephones, and created video games that can "outsmart" the player. Other inventions have resulted in many new and improved communication devices. Change continues to occur very rapidly in the world of technology. You may want to hold onto your cassette tape player—it will be an antique someday.

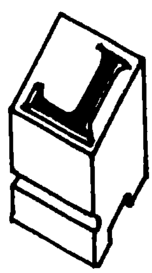
After reading this unit you will be able to:

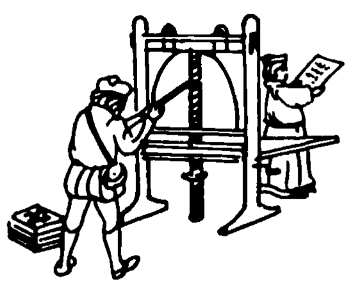
- List 3 systems in which information might be stored.
- Explain the difference between real-time and stored communication.
- Briefly explain how radio developed.
- Explain the difference between computer and other communication systems.

PRINTING PRESS

Before the year 1455, books were very rare. Printing systems were not yet developed. If you had lived in those times it would have been highly unlikely that you would have owned even one book because they were very expensive. Why? Scribes had to copy manuscripts by hand. Going to school would have been a lot different without books. In fact, many things would have been a lot different without today's communication devices, such as the printing press.

The development of printing systems using movable type is considered to be one of civilization's most important accomplishments. Improved printing techniques enabled a press to reproduce more information in one day than a scribe copyist could accomplish in a whole year. The printing system using movable type in 1455 was the beginning of a modern printing system that can reproduce visual information in multicolors as fast as you can blink. The early printing systems, as well as modern ones, make printed information available to the masses.

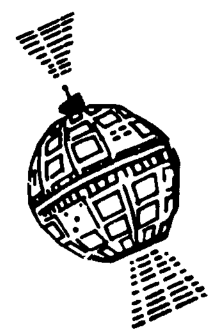




MASS COMMUNICATION

This idea of making information available to the masses has taken many twists in more modern times. If you think about the techniques used today for mass communication, you would have to include radio and television technology. There is a long line of inventions and developments that has contributed to these forms of communication. Take your radio for example.

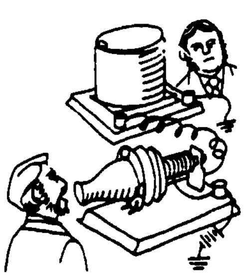
Scientists and ordinary people contributed insight into such fields as magnetism and electric storage batteries in the late 1800s. Building on the work of many others, a man named Guglielmo Marconi created in 1894 the first successful radio to send coded signals through the electromagnetic spectrum. Using a crude spark-gap transmitter, a grounded antenna, and a sensitive tube filled with iron filings, he was able to transmit radio signals over a two-mile distance. A few years later, voice communication signals could be sent over great distances by using a microphone to encode the human voice. Developments in radio transmitters and receivers through the next 70 years evolved from crystal and vacuum tubes to the transistor and microelectronic circuits of today. Because of these improvements, more and more people have become influenced by radio technology. Today, satellites 22 500 miles above the earth can relay radio signals to many millions of people.

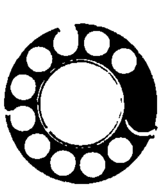


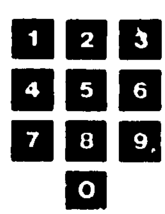
The following question is probably on your mind: If printing, radio, and television technology has improved means to provide information to the masses, what type of systems have improved long-distance communication from one point to another (person-to-person)? Read on and you will see.

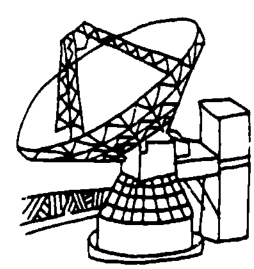
THE TELEPHONE

In 1876, Alexander Graham Bell combined the existing technical system of the telegraph (which sent messages only in *code*) with a new technical device that could change the human voice into electrical signals—the flexible diaphragm microphone. He created the telephone! How could you live without a telephone today? Expanded telephone network switching and microwave links have created a comprehensive communication network in the U.S. in just 100 years.

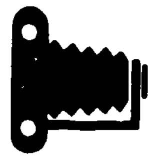


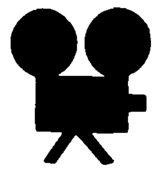






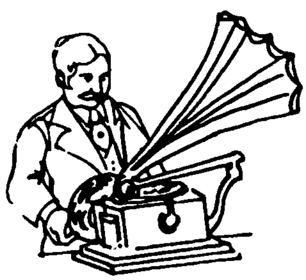
INFORMATION STORAGE





The long-distance transmission of information by radio and telephone generally occurs as "real-time" communications. That is, the messages are sent and received without any delay. This is fine if you are able to participate in the process. But, what if you wanted to communicate to people at different times in different places? Well, this involves storing information. How did one store the image of a Civil War battle scene or the sound of a great musical performance? Technical means were developed to store this type of information. Today we have still cameras, television, audiotapes, and discs.

The first permanently stored visual images were achieved by Daguerre in about 1830. Photography was born! Improvements followed by people like George Eastman, who created flexible film that could be put onto a roll or cartridge. Color and motion picture capability expanded the limits of storing visual images.

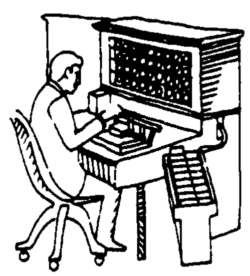


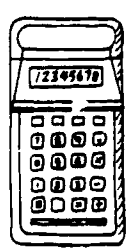
It was during the late 1800s (remember the telephone, 1876; the radio, 1894; and flexible film, 1884) that one of the most prolific inventor/developers in history contributed what he claimed to be his favorite invention—the phonograph. Good old Thomas Edison found a way to store and retrieve sound on wax cylinders. It was 10 years later (1899) that Emile Berliner changed the shape of the storage device from a cylinder to a disk. Berliner must have foreseen the shape of modern stereo cabinet furniture. Original wax cylinders and phonographs are now valuable antiques.

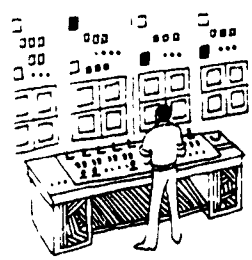
COMPUTERS

The ability to create technical systems to transmit and store information was now the final aspect of humankind's technological feats. The ability to process information was next. After early beginnings with mechanical calculators which could process (add, subtract, multiply, and divide) information, the era of electronic computers rocketed into existence in 1939. Using vacuum tubes for the internal "thinking" circuitry and capacitors for memory, John Atanasoff developed the first working model of an electronic computer. It was huge and used lots of electricity. Since the application of transistors and later microelectronic integrated circuits, the computer has evolved to be one of the most influential devices ever developed by humans.

All of these foundational technical developments in communication have been made more efficient in the past few decades by the application of new, improved components. Transistors and integrated circuits have improved the speed of information flow in technical systems. New dish antennas have increased the clarity of radio signals from space; while lasers and fiber-optic guideways have increased the capacity of signal channels. Communication devices have become smaller, less expensive, and more efficient; yet, things look even better for the future.







SELF-QUIZ

Now that you have worked through this, try a SELF-QUIZ. On your own sheet of paper, write the answers to these questions.

1. What development is considered to be one of civilization's most important accomplishments?
2. Radio and telephone generally occur as __________ communications.
3. Photography and recording are __________ information systems.
4. Computers are used to __________ information.
5. The key breakthrough that allows for more efficient and improved systems is referred to as the __________.

Turn this page upside down and you will find the answers at the bottom of the page. Go back and read again about the ones you missed.

THINGS TO DO

- ✪ Do a lineage study tracing the development of a communication device (radio, telegraph, photography, etc.) or one component of one of these devices.
- ☆ Construct a crystal radio.
- ✪ Hold an antique show of "historical" communication devices.
- ☆ Conduct an oral history of older community members' impressions of the first radio, television, computer, and so forth that they saw or owned.

FOR FURTHER STUDY

Boettinger, H. M. *The telephone book: Bell, Watson, Vail and American life 1876-1976.* Croton-on-Hudson, N.Y.: Riverwood, 1977.

DuVall, J. B.; Maughan, G. R.; & Berger, E. G. *Getting the message: The technology of communication.* Worcester, Mass.: Davis, 1981.

Science February 12, 1982, p. 4534.

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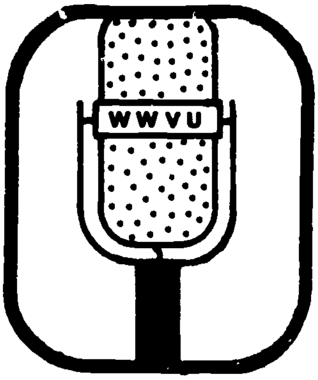
Answers.
1. printing system
2. real-time
3. stored
4. process
5. foundational technical development

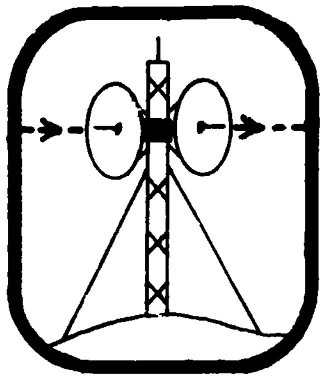
Communication Devices



MICROPHONE

A microphone is a device that converts sound (acoustical energy) into electrical energy. When the sound waves strike the microphone, it causes a diaphragm (a thin membrane) or a thin ribbon of metal to vibrate. The vibrating action causes a change in the electrostatic field that passes through the microphone. The electronic signal can then be easily sent to its destination by wire.

MICROWAVE TRANSPONDER



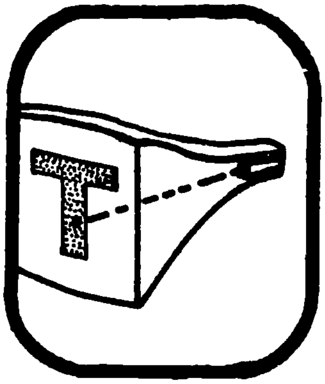
A microwave transponder receives and transmits microwave radio signals. It is used as a relay to keep a signal going toward its destination. Being very short radio signals, microwaves are deflected very little when passing through the air. Transponders are usually placed on towers located on hilltops to maintain the line of sight transmission that is necessary to keep the waves from traveling into space. They typically transfer telephone and computer signals.

VIDEO DISC

The video disc is a storage device. It contains both visual and acoustical information. Video and audio information is encoded into electron signals which are frequency modulated (FM). This FM wave is then used in conjunction with a computer and a laser to form a series of indentations or pits in a spiral fashion on the surface of the disc, much like a conventional record. The engraved disc contains about 26 billion indentations that are used to reconstruct the original sound and picture during playback.

LASER

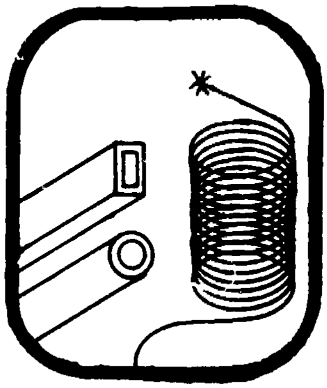
Lasers are used to produce a beam of coherent light. Through modulation (regulation, usually controlled by a computer) information can be added to the lightwaves. The laser beam can be used to carry telephone, radio, or television signals. Since lightwaves may be scattered by the atmosphere and cannot pass through solid objects, they are usually transmitted through glass fibers to avoid interruption.



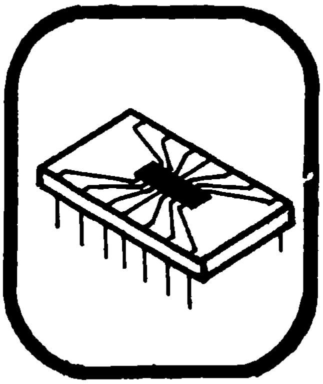
TV RECEIVER/CRT

A television receiver or CRT (cathode ray tube) is a decoding device that converts electrical signals into a visual image. The electrical signal causes a beam of electrons to be emitted that flow toward the positively charged face of the CRT. The strength of the electrical signal controls how many electrons hit the surface and how hard they strike. When the electrons hit, they strike the phosphorescent material that is coated on the inside surface of the screen. These dots glow and blend together to reproduce the original image. A synchronizing signal aligns each bit of information of the screen to reconstruct the image as our eyes see it.

WAVEGUIDES



A waveguide controls and guides light or radio waves as they are transmitted from one point to another. Radio (micro) waves travel very easily through the air and can transmit great quantities of information. However, once they have been collected by an antenna, they must be transported to a decoder to be useful. Microwaves are transported through a waveguide made of round or square tubing. Microwave guides are generally made of metal. Lightwave guides are made of glass fibers.



MICROPROCESSOR

A microprocessor is an ultraminiature integrated circuit. It contains conductors, resistors, capacitors, transistors, diodes, and coils that are all connected during manufacturing. Because of its tiny size, a microprocessor works very quickly while using very little current. The result is efficiency and savings of energy. A microprocessor is used to control and amplify electronic signals. It is found in computers, video games, calculators, and most modern communication systems.

TV CAMERA

A television camera is a device that converts a visual signal into an electrical signal. When light from the original image is reflected, it is picked up by the camera lens and focused on the vidicon (camera pick-up) tube. The surface of the tube is light sensitive and causes a change in an electrical signal depending upon how bright the image is at any particular point. The camera adds a sync (synchronizing) signal so that when the message is decoded, it can be reconstructed properly.

FOR FURTHER STUDY

Mabon, P. C. *Mission communications: The story of Bell Laboratories*. Murray Hill, N.J.: Bell Laboratories, 1976.

Mann, C. C. Videodisc. *Technology Illustrated*, October/November 1981, 102–103.

Renner-Smith, S. "Data-display TV links your home with huge info banks. *Popular Science, 218*(1), 72–75.

MAGNETIC STORAGE OF INFORMATION

Many machine tools, entertainment devices, and information-processing devices require the storage of information. Sets of operating instructions for modern drill presses and lathes are frequently stored with the machine in order to repeat operations over and over again. For decades, computers have used external storage devices to hold data and control programs for later use or to interact with specific processing operations. The most flexible and cost-effective medium to store large amounts of information for these applications is by magnetic tape or magnetic disc.

After studying this unit you will be able to:

- Describe the process of storing information on a magnetic medium.
- Identify characteristics of magnetic tape and disc storage systems used with machine tools and computing devices.
- Trace the history of magnetic storage devices used with machine tools and computing devices.

The story begins . . .

External storage mediums for machine tools and computers have gone through a number of evolutionary changes since punched cards and paper tapes were used to store simple codes. During the late 1950s, a fast and efficient storage medium that could be reused was found in magnetic tape. A number of years later, the magnetic medium was placed on a disc to overcome some disadvantages of the tape. Basically, the storage of data and control information on a magnetic surface for machine tools and computers work on the same principle as storing music on a cassette tape. There are, however, enough critical variations in the storage and retrieval process and the equipment to warrant a look at contemporary techniques and devices.

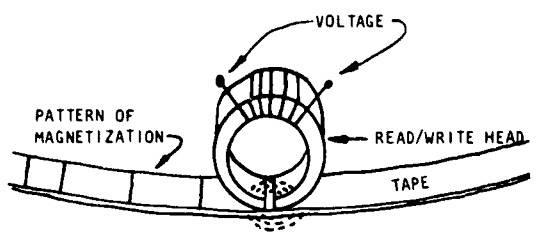
MAGNETIC TAPE

Early tape storage systems were reel-to-reel. If you have ever seen a reel-to-reel tape recorder begin to spill tape in ever-increasing lengths across a room before someone could turn it off, you can appreciate one of the dangers of this format. As machine tools and computers became smaller and smaller, this means of storage did not seem to be very practical. The reel-to-reel format was also too large and expensive. Thus, the tape format that evolved was the cassette or cartridge.

The cassette is distinguished from the cartridge tape format by the manner of tape movement within the case. The cassette permits tape to be driven in either direction with tape taken up or removed from both reels. The cartridge requires tape to be driven in one direction only. Because the cartridge tape is an endless loop, there is no need for rewinding.

The flexible magnetic tape used in cartridges and cassettes is inexpensive and durable. The tape consists of a base material of polyester. This is a relatively stable medium because it has good tensile strength and can stop and start repeatedly without breaking. The polyester also reduces the tendency to shrink or stretch when tension is applied. The polyester is made in wide ribbons coated with an iron oxide surface that is very sensitive to magnetic fields. The polyester base with the magnetically sensitive coating is then slit into tape widths and applied to take-up reels. The cassette drive is the most important element of the mass storage capability of microcomputer systems that use magnetic tape.

The two critical functions of the cassette tape drive are the reading and writing of information onto the tape and the tape transport mechanism. The magnetic head in a cassette tape drive is the device that actually records and retrieves information from the magnetic tape. The iron oxide on the surface of the tape comprises many needle-like magnetic particles. The particles are not aligned in any particular order when the iron oxide coating is applied to the tape's base material.



Let's take a close look at what occurs when information is recorded onto a cassette tape. In order to store information on the magnetic surface, it is necessary to align the magnetic particles into a pattern. The magnetic head aligns the magnetic particles to represent zeros and ones by using a tiny electromagnet to create a magnetic field.

The conventional magnetic head consists of a split ring-like substance, wound like a coil. The gap on the front of the head is where the magnetic field is generated when current is applied to the winding.

When the cassette drive is in the record mode and information is being stored on tape, data in the form of binary signals are sent to the windings around the core. As the signals activate the magnetic core, a magnetic field is generated at the gap of the core. As the magnetic tape presses the head, this magnetic field aligns the particles on the tape in a form that can later be distinguished as the binary code.

STANDARD SIZES OF MAGNETIC STORAGE MEDIUMS FOR SMALL COMPUTER SYSTEMS

DISCS		TAPE	
Rigid	8"	Cassette	1/8"
Floppy	8"	Cartridge	1/4"
Rigid	5-1/4"	Cartridge	1/2"
Minifloppy	5-1/4"		
Semirigid	3-1/2"		

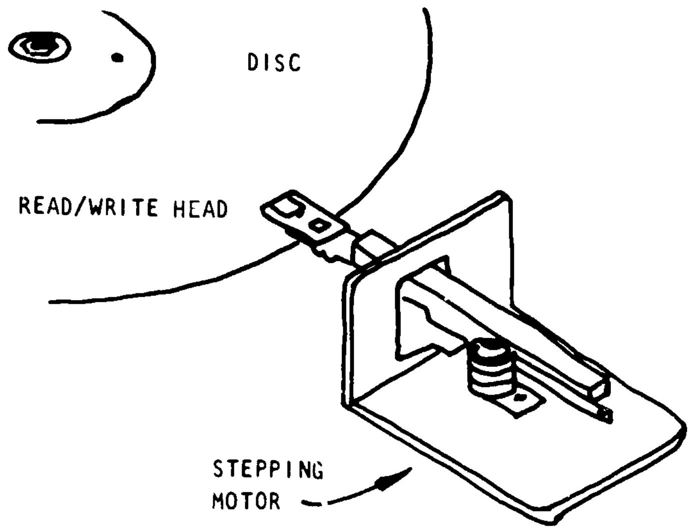
Each character, such as the character "A" followed by the character "B," followed by the character "C," and so on, follows an order indicating that a character serial technique is used. It is this very recording technique of bit serial, character serial, that the magnetic tape cassette drive storage system uses to record each track of the tape. This method ensures more accurate information retrieval because the alignment of read-write heads is not critical. This tolerance is the reason why cassette tape drivers are so useful as an inexpensive storage medium.

MAGNETIC DISC

The physical characteristics of the magnetic disc medium, as well as the characteristics of the disc drive, are engineered to provide efficient information storage and transfer. To understand how data are stored and retrieved on a magnetic disc, it is necessary to investigate what the read/write head is and how it works.

The reading and writing of data on discs are accomplished by a small, cylindrical device similar in principle to a tape recorder. The head is at the end of a movable arm. The arm, powered by an electric motor, slides in and out along the same axis. This permits the head to be positioned above any of the tracks of stored data that are on the surface of the disc. The movement of the head is controlled by the disc controller card or circuit. Accurate positioning of the head, in relation to specific tracks of data, is extremely important.

Once in position to read or write data, the head is activated. To read data, the head must be able to discriminate between patterns of magnetic fields represented by the arrangement of magnetic particles. The head of a floppy-disc storage system actually makes contact with the surface of the disc. This is necessary because the flexible nature of the disc would create uneven distances between the head and the disc as it rotated. The head moves up and down with the disc to maintain accurate data transfer.



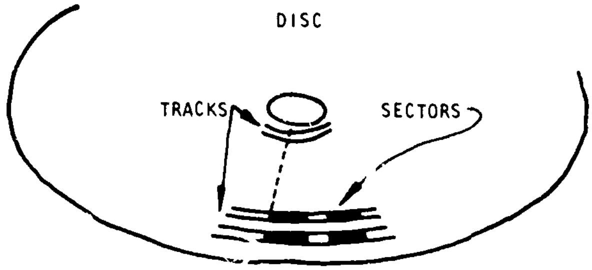
The more traditional rigid disc is stable enough to maintain a uniform rotational distance from the head. This enables the head to float on a cushion of air between the head and the disc surface. This type of head configuration is commonly referred to as a "Winchester" head. The Winchester-type head design has been manufactured by many firms since its introduction in 1973.

Disc storage systems differ from manufacturer to manufacturer. During the early 1980s, the Apple II microcomputer system recorded data onto 5¼ inch floppy diskettes which contained 35 concentric bands called "tracks." These tracks were numbered from the outermost to the innermost track. When the read/write head needs access to a certain track on the diskette, the head moves back and forth into position. Each track is divided into numerous sectors.

Now back to the rotating disc. As the sectors pass beneath the head, one after another, the head fills each sector with information by alternating the arrangement of magnetic particles. If a sector can hold up to 256 bytes of information, then 256 bytes are stored at one time exactly filling one sector.

Because the disc is spinning when the disc drive is activated, the head will store information in the first vacant sector it finds. This frees the head from having to search for a particular starting point and track through sectors until it finds an empty one. That process would have to be repeated each time storage occurs. As the method of random storage continues, the head may search for empty sectors on any track to continue to store information. This process continues until all sectors have been filled.

The disc operating system records the location of each data file according to the track and sector it is stored in while it stores the information. This creates something of a directory of tracks and sectors. This track sector directory is also stored in an empty sector, usually located in one of three tracks reserved for use by the disc operating system. These procedures enable the random storage and access of information to occur very quickly—a major characteristic of disc storage mediums.



Now, try a SELF-QUIZ

On your own sheet of paper, write your answers to these questions.

1. What were the major disadvantages of reel-to-reel magnetic tape storage units for machine tools and computers?
2. The characteristic of magnetic tape to store information one character/bit after another is referred to as ______________
3. Magnetic disc mediums are considered to be random access in terms of storage and retrieval of information. This is because the format of most discs includes some type of ______________ and ______________.
4. What happens to a magnetic surface when information is stored?
5. What are the two physical forms of magnetic discs for machine tools and small computers?

Turn this page upside down and you will find the answers. Go back and read again about the ones you missed.

THINGS TO DO

- Create a "click" track on a reel-to-reel magnetic tape by laying out the tape and passing a magnet across the width of the tape at different lengths (2, 3, 6 . . . inches).
- Using a specific microcomputer, determine the format of the external storage medium including tape or disc tracks, sectors, or channels. Try to create a program that will store your name in a given location only.
- Using paper/tape from a desk-top calculator, design and construct a device that will control a low-voltage electrical circuit. Consider using punched holes in the tape as a machine code. Can you make your device automatically turn on and off a power tool?

FOR FURTHER STUDY

Bethune, R. W. Getting along with cassette storage. *Popular Computing*, 1983, *2*(8), 190–192.
Waite, M., & Pardee, M. *Your own computer*. Indianapolis, Ind.: Howard W. Sams. 1981.
White, R. M. Disk-storage technology. *Scientific American* 1980, *243*(2), 138–148.

ANSWERS

1. too large and expensive
2. bit serial, character serial
3. track, sector
4. an alignment of magnetic particles into specific patterns represents information
5. rigid and floppy

COMPUTER LOGIC DEVICES

Taking a look inside a microcomputer when you are not prepared for what you will see can be pretty risky business. On first impression, it's possible to see families of black caterpillars with silver legs sitting in rows. A closer look reveals that those black objects are made of plastic and are really electrical components plugged into a green printed circuit board. It's what happens inside these black plastic cases that enables a computer to work.

Obviously, electricity runs around inside the cases. But, how electricity represents letters and numbers in binary code and how it is processed inside these components are not quite as obvious. One major processing function typical to these components is to control the combination of binary signals (0 or 1) to create a certain output. This type of processing control is called gating. The devices used to accomplish this are called gates. All gates use a form of logic to ensure consistent results. By studying this unit, you can begin to understand this function of computer circuitry.

After studying this unit, you will be able to:

- Describe how electricity is controlled in computer logic devices.
- Determine outputs from computer logic devices by using truth tables.
- Identify the pin-out configuration of a SN7400 NAND gate.
- Explain the two voltage levels necessary for digital logic devices (TTL devices).

To understand the magic of computers, we need to begin to understand what really goes on inside the circuitry. In a house or apartment, electricity powers the appliances by supplying 110 volts. This voltage is used by the appliances to run motors or to heat coils. Electricity is used in computer circuits to generate clock pulses and activate counters, switches, and gates, among other things. Most of these microcomputer circuit components require 5 volts. Actually, because microcomputers use a binary code, it is important to have two levels of voltage, 0 volts or 5 volts. The 0 volts (+0.0 to 0.8 volts) represents the binary 0, and the 5 volts (+2.8 to 5.0 volts) represents the binary 1.

This idea of using binary codes as two different voltage levels represents digital electronics. When applied to components, such as gates that provide some control of the flow of voltage, this activity is called transistor, transistor logic, or TTL.

LOGIC GATES

There are four basic types of gates. To help you understand the concept of logic gates, this unit will emphasize the NAND gate. A basic NAND gate provides an output when the two inputs are applied simultaneously.

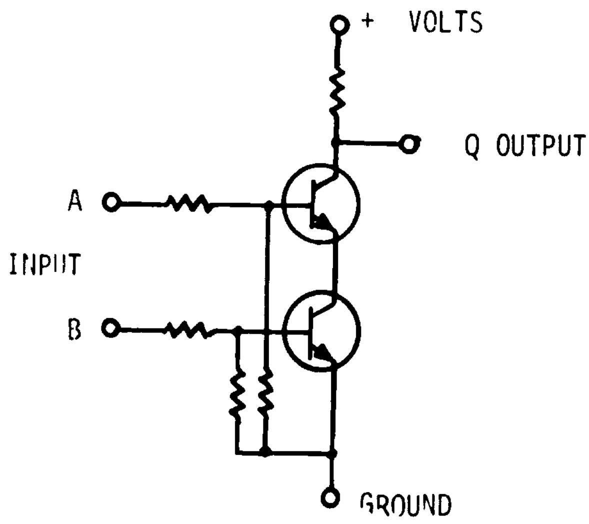
For example, in the block diagram of a gate, the two inputs are A and B. The output is identified as Q. Remember, the two inputs can be either 0 volts or 5 volts (0 or 1 in binary). One input can have a different input than the other. The output is basically determined by the type of gate.

NAND gates respond differently than other types of gates. A NAND gate always responds in a certain way. If input A is 0 and input B is also an 0, then the output Q is a 1. You can check the drawing to the right to see the rest of the gate responses. In all but one combination of inputs, the output is 1. The one combination of inputs that produces a unique output is when A is 1 and B is 1, the output is 0. The table that shows this type of information about logic gates is called a truth table.

AB	Q
00	1
01	1
10	1
11	0

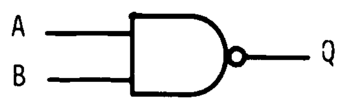
TTL was used with circuit components before the development of those chips inside the black "caterpillar" cases. In fact, transistors were used along with resistors for many years to create logic gates.

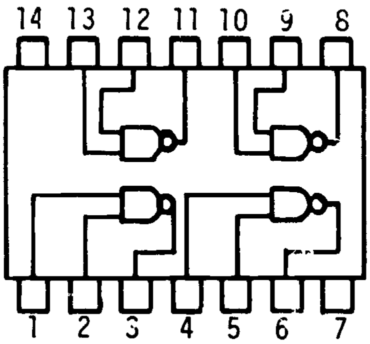
When very large-scale integrated circuits evolved in the late 1960s and early 1970s, it became possible to fabricate TTL devices within small chips of doped silicon crystals. This drastically reduced the size of the device. In fact, it became common practice to fabricate a number of TTL gates on a single integrated circuit housed inside a black plastic package with tiny connecting wires attached to the silver leg pins.



BASIC CIRCUIT NAND GATE

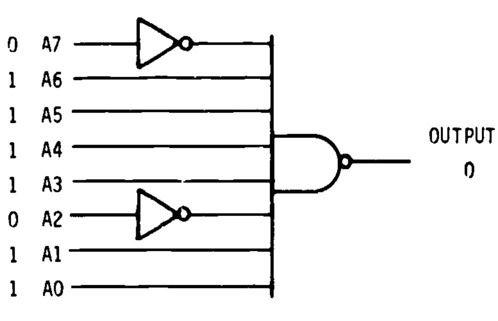
A basic NAND gate, such as the SN7400, has four logic gates built into a single chip. Each NAND gate works according to the truth table presented earlier. One gate uses the connecting pins 1 and 2 for input, and provides output to pin 3. Correspondingly, each of the remaining three gates uses three pins. Pin 14 connects to a +5 volt power supply, and pin 7 goes to ground.





INTEGRATED CIRCUIT NAND GATE DEVICE #SN7400

NAND gate devices can have 2, 3, 4, 8, or 13 inputs and still provide only one output. A NAND gate device used to decode an 8-line address bus would have 8 inputs. The unique output state for a NAND gate occurs only when all of the inputs are logic 1's. If this gate were used to decode address 123, we see that input A2 and A7 are logic state 0. This means the gate device would *not* provide a logic 0 output unless the logic state inputs were inverted to logic 1. For this gate to decode address 123, the inputs A2 and A7 are inverted by a tiny divide before the input reaching the logic gate. Consequently, this gate is useful only to decode a single address. When you recall that many storage locations exist in a solid state memory, it's possible to see that this specific type of decoding is inflexible and would require many NAND gates. In reality, a slightly different type of NAND gate decoding is used in actual microcomputer circuits. The actual gate, however, works the same.



NAND GATE WITH 8 INPUTS

In a way, logic gates provide a means of recognizing and decoding patterns of 0's and 1's for input and output devices. As you know 0's and 1's are used to represent characters and numbers in a variety of patterns on an address bus. To be able to accommodate a variety of 0 and 1 patterns, a programmable gating circuit is used. The use of a programmable gate also permits the distinction of address information of input/output devices from address information for solid state memory locations inside the computer.

At this point it's easy to see that a single component such as a NAND logic gate only *contributes* to the operation of a very sophisticated computer circuit. To simplify the complexity of the overall circuit, it's important to understand the principles and concepts involved in a fashion similar to what you have done with computer logic devices.

SELF-QUIZ

On your own sheet of paper, write your answers to these questions.

1. What are the two voltage levels necessary for digital logic devices (TTL devices)?
2. What is the unique output state of a NAND gate? What inputs provide this unique output state?
3. How many pins are there on an integrated circuit #SN7400 that contains four two-input NAND gates?
4. What does TTL stand for?
5. What two electronic components did a basic circuit NAND gate contain (before integrated circuits)?

Turn this page upside down and you will find the answers to this Self-Quiz. Go back and read again about the ones you missed.

THINGS TO DO

- Determine the values of resistors and the type of transistors necessary to construct a NAND gate logic device. Construct the device as a means to verify the NAND gate truth table.
- Purchase logic switches and TTL devices (AND, NAND, OR, NOR) and create breadboarding experiments to teach about transistor logic devices to junior high school students.
- Open the case of a microcomputer and draw a diagram of the circuit boards identifying the type and position of logic devices.

FOR FURTHER STUDY

Camp, R. C.; Smay, T. A.; & Triska, C. J. *Microprocessor systems engineering*. Oregon: Matrix, 1979.

Osborne, A. *Introduction to microcomputers: Vol. 0, the beginner's book*. Berkeley, Calif.: Osborne & Associates, 1977.

Titus, J. A. *TRS-80 interfacing book I*. Indianapolis: Howard W. Sams, 1979.

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ANSWERS

1. 0 logic state = 0.0 to 0.8 volts; 1 logic state = 2.8 to 5.0 volts
2. 0; 1,1
3. 14 pins
4. transistor, transistor logic
5. resistors and transistors

Resources in Technology

NONIMPACT COMPUTER PRINTERS

You've seen computer-type printouts for years: letters, cash register slips at fast food places, or graphic posters. At times, it is difficult to determine if the printed information has been generated by a typewriter, a printing press, or someone with a bunch of little dots who sticks them together to form letters and numbers. What is clear is that more computer-type printed material will be generated in the near future because of the application of more small computers in businesses, homes, and schools. Along with printing techniques that require a character (A, B, C, etc.) or plunger impacting a ribbon and paper, there are a number of nonimpact type of printers. It is the intent of this unit to review the different techniques associated with nonimpact printing.

After studying this unit, you will be able to:

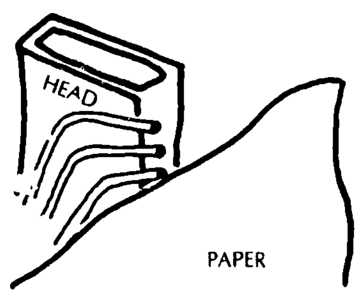
- Describe three types of nonimpact printing techniques.
- Discuss the advantages and disadvantages of nonimpact printing.
- Identify common dot matrix sizes used to form printed character images.

NONIMPACT PRINTERS

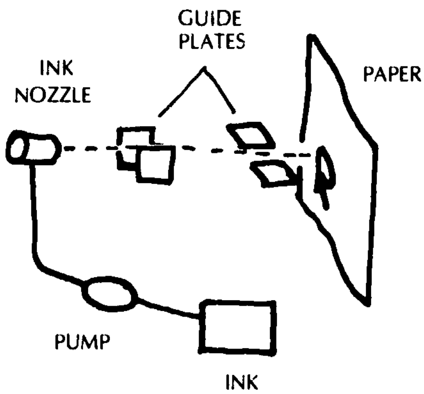
Nonimpact printers create images on paper *without* striking a ribbon or paper. Because there is no physical impact, nonimpact printers employ either a heating element or a fine jet of ink sprayed onto paper to generate images. Because of these techniques, nonimpact printers are very quiet. They are also very reliable because they have few moving parts.

There are two kinds of print techniques that use heat. They are thermal and electrosensitive. Both methods use a print head that generates tiny areas of heat in a dot matrix pattern.

THERMAL PRINTING WIRE



The most common way to direct heat is to quickly heat tiny wires that are close to a specially treated paper. The print head is only half of the system necessary to generate images. The specially treated paper is the second half. Thermal printing paper is a sandwich of normal paper base coated with a thin layer and a colorless dye stuff. When heat is applied, the two elements in the coating fuse together, causing a color to appear. The color is dependent on the dye in the coating. When the heat is directed in a dot matrix pattern, it is possible to create characters and graphic patterns.



LIQUID INK-JET

Electrosensitive print heads work in a slightly different manner. Instead of fusing elements together to form dots that create character patterns, the electrosensitive print head vaporizes dots of a metallized coating to reveal a dark paper base. These dots then form character patterns similar to the patterns formed by thermal printing.

We will discuss the formation of dot matrix characters in more detail later. . . . BUT let's continue with an overview of ink-jet printing.

Ink-jet printers represent pretty fancy technology. Ink-jet printers spray drops of ink onto paper. The tiny ink drops are arranged to overlap in order to form character patterns. Some printers can print only black and therefore contain only one spray nozzle and a cassette filled with black ink, other printers contain a four-nozzle print head to print colors. One nozzle for each of the primary colors and one nozzle for black can create as many as seven colors. Obviously a reservoir for each of the four nozzles is necessary.

A new type of ink-jet print head sprays a fine graphic powder instead of liquid ink. Used in the Irwin/Olivetti JP101, the print head is a glass nozzle that contains a solid graphite ink rod. An electric spark in the head vaporizes the rod's tip into fine graphic powder that is pulled onto the paper by a charged plate. The charged plate, located behind the paper, represents character images that are created on the paper.

Get the image???

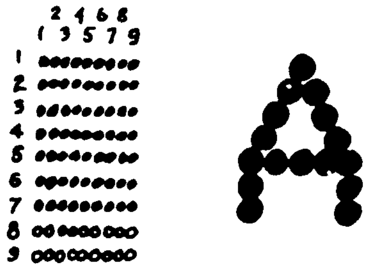
COMMON SMALL NONIMPACT PRINTERS

Name	Technology	Color	Matrix
Alpacom VP42	Thermal	No	5 × 7
Axiom EX401	Electrosensitive	No	5 × 8
Canon A-1210	Drop-on-demand ink-jet	4 mixable	5 × 7
Gulton Microprint-20	Thermal	No	5 × 7
Irwin/Olivetti JP101	Solid ink-jet	No	7 × 7

DOT MATRIX IMAGES

Creating a character image with dots, whether it is an alphabetic letter or a number, is really pretty simple. To be able to do this accurately and consistently requires that a pattern be established. This pattern is created by the formation of a matrix. A matrix is a carefully designed way to divide space. Consider a grid used to play the game of X's and O's. By drawing a box around the grid, you have formed a matrix 3 spaces wide and 3 spaces tall. This could be called a 3 × 3 matrix. By shading in the appropriate spaces, one could create the letter "C" very easily.

Typical matrix patterns for nonimpact printers are 5 × 7 for capital letters only. A matrix of 7 × 9 or 9 × 9 for upper and lowercase characters is also typical. The vertical dimension of the matrix determines the number of thermal heat wires in the print head. For example, the 5 × 7 matrix thermal printer has a vertical column of 7 wires aligned above one another. As the head moves across the paper 5 matrix spaces, there is an opportunity for the entire 5 × 7 matrix to be covered by the printer. This enables any alphanumeric character of the type font to be printed in that 5 × 7 character space.



DOT MATRIX 9 × 9 OVERLAP

A 7 × 9 matrix would require a vertical column of 9 wires, as would a 9 × 9 matrix. The larger matrix configuration enables lowercase characters to be printed with ascenders below the guideline. The 9 × 9 matrix also permits underlining. The pattern of dots to create characters is usually established by the American National Standard Code for Information Interchange (ASCII) character set.

PRINTER FEATURES

Beyond the basic techniques incorporated in microcomputer printers, there are a number of printer features that often determine the type of printer used with computer systems. Printer manufacturers hope to provide equipment that is inexpensive, fast, and flexible in use and easily interfaced with a variety of computers.

In addition to character type and speed, one of the most important features of printers is the method of paper handling. The type of paper feed determines what flexibility the printer offers. A friction feed can handle almost any type of paper that can be placed into the rollers. On the other hand, the pin feed, or tractor feed, ensures consistent paper placement in relation to the printing head but cannot accommodate paper without pinfeed holes. Many printers designed for use with microcomputers can feed paper both ways. Of course, thermal printers have little flexibility in paper selection because a special thermal coating is necessary to generate an image. Most thermal printers incorporate a friction-type paper handling system.

Another factor is the ability to print multipart forms. Business applications often require printers to print forms of two, three, four, or more copies. The impact printers are capable of printing multicopy forms. Because the nonimpact printer heads do not strike a ribbon or paper, they are not capable of printing multicopies.

SELF-QUIZ

Now that you have worked through this, try a Self-Quiz. On your own sheet of paper, write the answers to these questions.

1. What are the three types of nonimpact printing techniques?
2. What is the advantage of nonimpact printing? A disadvantage?
3. What are 3 common dot matrix sizes used to form printed images?
4. Ink-jet printer heads can produce images with two forms of ink material. What are they?

Answers are upside down on the bottom of this page. Go back and read about the ones you missed.

THINGS TO DO

Collect and label samples of a variety of computer-type print material. Compare the characteristics of nonimpact printer quality with other print techniques.

Using small electromagnets, construct a demonstration model of a matrix by which patterns of letter characters could be generated with graphite powder. (To create a permanent image, the powder must have a binder mixed with it.)

Conduct tests on thermal printer paper to determine its sensitivity to heat and light.

FOR FURTHER STUDY

Bradbeer, R.; DeBono, P.; & Laurie, P. *The beginners guide to computers*. Reading, Mass.: Addison-Wesley, 1982.

Covvey, H. D., & McAlister, N. *Computer choices*. Reading, Mass.: Addison-Wesley, 1982.

Powell, D. The top 40 low cost printers. *Popular Computing*, July 1983, pp. 106–136.

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ANSWERS

1. thermal, electrosensitive, ink jet
2. very reliable, little flexibility in paper selection
3. 5 × 7, 7 × 9, 9 × 9
4. liquid ink and a solid ink rod

History of Production

Production is the use of land, labor, and capital to create goods and services. In prehistoric times hunting animals and gathering food were full-time jobs for everyone. Through the centuries, as more efficient tools and methods for food production were discovered, some people had time to produce extra food, clothing, and shelters for sale or barter. Today, modern production systems provide us with a degree of comfort and convenience beyond our forebearers' wildest dreams. How have production systems developed? Let's look at the two major subsystems of production: manufacturing and construction.

After studying this unit, you will be able to

- Define the term "production."
- Describe the difference between manufacturing and construction.
- Give examples of types of constructed products.
- Explain how manufacturing systems depend upon major power sources.

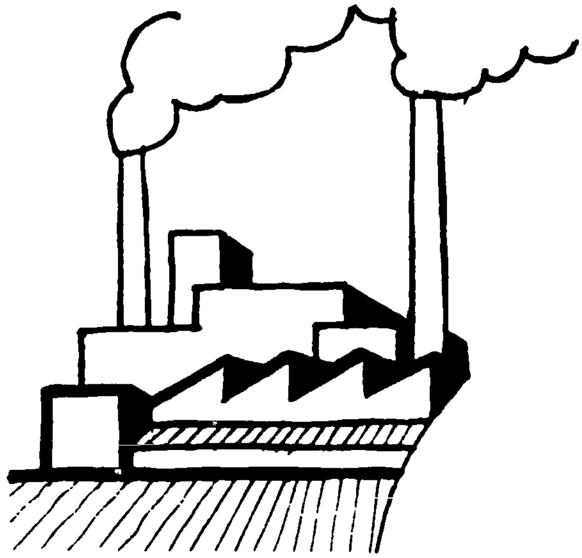
First, let's look at MANUFACTURING . . .

Modern manufacturing technology generally occurs at a central location, sometimes called a factory or plant. Materials are formed and assembled to produce finished goods. Throughout history, manufacturing technology passed through several stages:

Phase	Date	Worker's Role
Handcraft Era	1000–1784	Worker made complete item
Machine Era	1785–1869	Specialist at one job
Power Era	1870–1914	Machine operator
Mass Production	1915–1951	Assembler, engineer
Automation Era	1952–now	Technician, engineer

During the Handcraft Era, manufactured goods were almost always produced from start to finish by one person. A cooper in the 1600s, for example, might make an entire barrel alone—hoops, staves, everything. The Colonial American home during this period was often a center of production for the family's clothing, food, housing, tools, and weapons. Any excess products made in these "home manufactories" were sold or bartered to neighbors.

The Industrial Revolution began in England in 1750, and new production methods soon spread to America. The Industrial Revolution was made possible by a series of important inventions. For example, Robert Fulton's steam engine made it easier to ship raw materials and finished goods to centrally located plants. Steam engines also provided power for the manufacturing machines, such as Hargeave's spinning jenny and Jacquard's automated loom. Factories were no longer dependent on water power and could be built in inland cities where a large supply of labor was available.



During the Power Era (also called the Second Industrial Revolution), electricity, coal, and oil became the prime sources of much needed power for factories. In recent decades, we have progressed through the Mass Production Era and are now in what is called the Automation Era. Today, much of the "hand" labor in manufacturing plants is being done by automatic machinery controlled by computers.

Now, let's look at CONSTRUCTION . . .

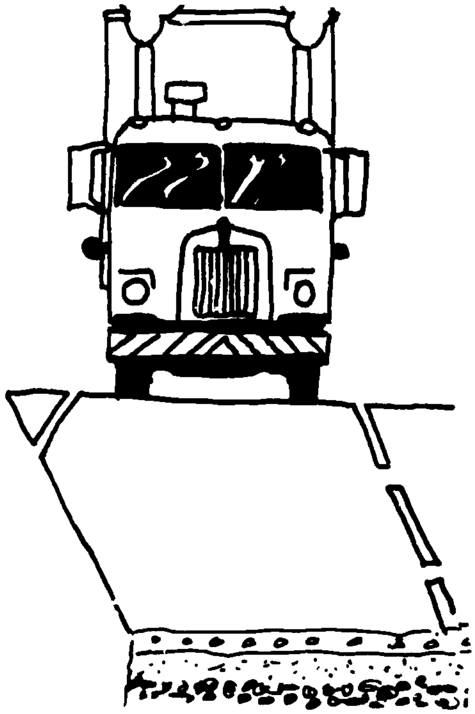
In contrast to manufactured goods, constructed products are made at the site where they will be used. People who use constructed products come to the site to use them. Bridges, buildings, and roads are examples. Constructed products are called—you guessed it—"structures."

Humans began to construct homes of timber in Europe around 5000 B.C. By 2000 B.C., builders were using sophisticated mortise and tenon joints to make their buildings stronger. In the Near East and the Nile Valley, where timber was scarce, homes and temples were built of sun-dried mud brick, mortar, and stone.

Early Romans used a kind of cement called *pozzulana*, but the secret for making it was lost with the fall of the Roman Empire. Construction materials remained much the same until the 19th century, when Portland cement was developed. Because it is an excellent bonding agent (adhesive), Portland cement makes it possible to build very large structures of stone and brick.

Also in the 19th century, steel beams began to replace wood, stone, and brick as the main structural support material. Today, tall office buildings are erected with a steel skeleton covered with a brick and glass "skin" called a facade. The result is a relatively light framework. If our modern sky skyscrapers were made entirely of stone, they would be so heavy they would slowly sink into the ground. Why do you think the Leaning Tower of Pisa is leaning?

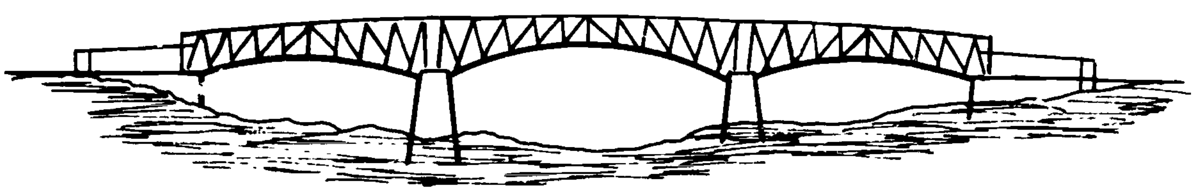
The earliest roads simply happened to be wherever people drove their wagons. The Romans built the world's first major road system. There were 29 major roads connecting the city of Rome with other cities of the empire. The greatest of these roads was the Appian Way. It was 360 miles long and paved with large stone slabs. For centuries after, crushed stone was used as road paving material. The first concrete road was constructed in Austria in the 1850s. Asphalt, although experimented with in about 1830, was not systematically used as a paving material until the 1870s.

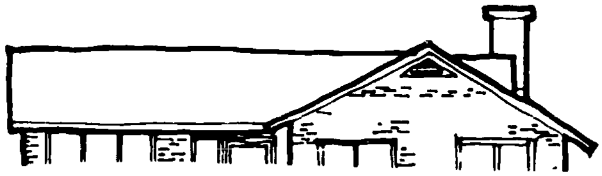


The first known use of a bridge to cross a river occurred in 900 B.C., when the Assyrians used pontoon bridges. The Romans built bridges of timber around 600 B.C. By the second century B.C., the Romans were constructing stone arch bridges. Caesar's engineers constructed a wooden trestle bridge over the Rhine in 55 B.C. in only 10 days.

Cantilever and suspension bridges were first constructed during the 16th century. The world's first iron bridge was built by Abraham Darby across the Severn River in Coalbroakdale, England, in 1779. Suspension bridge construction received a giant boost with the development, by John Augustus Roebling in 1844, of a means for continuous spinning of wire suspension cable.

Through the ages, new construction materials and techniques have been developed to dam giant rivers, tunnel under mountains, and span great chasms. Similarly, new manufacturing machines have evolved which increase our ability to produce great quantities of goods and services to satisfy people's wants and needs.





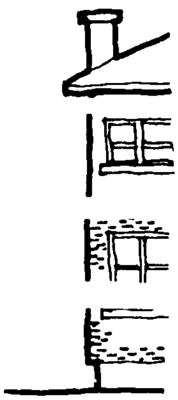
SELF-QUIZ

On your own sheet of paper, write your answers to these questions.

1. Constructed products are usually produced on the site where they will be used. True or false?
2. When was the Handcraft Era?
3. How did the development of steam engines help the Industrial Revolution?
4. What role has the development of Portland cement played in modern construction techniques?
5. What is a facade?

Turn this page upside down and read the answers. Go back and read again about the ones you missed.

THINGS TO DO



Design a product to be mass produced in your lab; organize and produce copies for everyone in your class.

Investigate alternative construction methods, and build a geodesic dome or inflatable shelter.

Visit a local museum or antique shop and identify tools that were used in your region 50 years ago, 100 years ago. Take photographs or make sketches of these tools.

Study the role children and young adults played in manufacturing plants during the Industrial Revolution.

FOR FURTHER STUDY

Pannell, J.P.H. *Man the builder.* New York: Crescent, 1964.
Sloane, E. *An age of barns.* New York: Ballentine, 1967.

Answers:
1. True.
2. 1000 to 1784 A.D.
3. Factories could be built wherever labor was available.
4. It made it possible to build very large structures.
5. The masonry and glass covering on buildings.

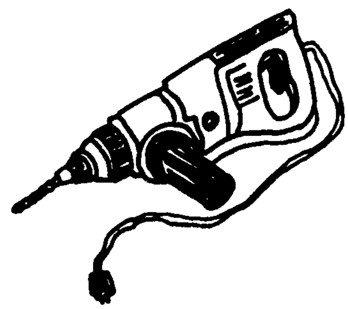
Production Tools & Processes

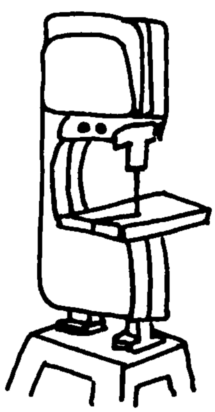
HAND TOOLS

Hand tools multiply the power of our muscles. The simplest tools, such as the hammer, have no moving parts. Other kinds, such as the socket wrench, employ moving gears and cams to make the tool more effective. Because they are normally small and lightweight, hand tools can be easily carried to wherever they are needed.

POWER HAND TOOLS

When a motor or other power source is added to a hand tool, the result is called a power hand tool. The addition of a motor saves a great deal of muscle power and allows the tool to be used much longer without tiring the worker. Electric hand drills, circular saws, and portable sanders are common examples of power hand tools. Sometimes air motors or small gasoline engines are used as power sources.





MACHINES

In many instances, machines are merely complicated power hand tools. Unlike hand tools, which are light and portable, most machines are bulky structures with large, powerful motors. The increased size and power of machines allow them to tackle heavier jobs. But because they are so heavy, machines are usually kept in one place and the raw materials are transported to the machines.

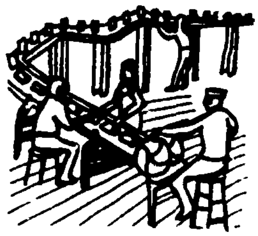
MACHINE SYSTEMS

In some production situations, several machines are linked together in a system. Automobile engine blocks, for example, are drilled, bored, and reamed to size by a group of machines arranged in one location. Machine systems allow a number of processes to be done while the material or product remains in one place. Often, machine systems are controlled by microprocessors or other automatic devices. Workers need only to monitor the process to make sure all machines are functioning properly.

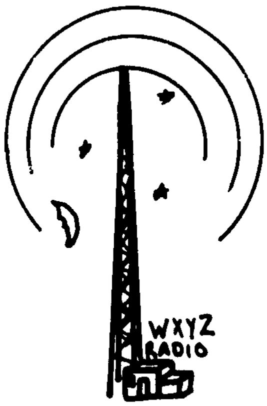
HANDCRAFT PROCESSES

If only limited numbers of products are to be made, each one may be produced entirely by hand. Each handmade product is unique and often reflects the individual style of the crafter. Because each item is unique, consumers may consider it to be more valuable than a machine-made item.

LINE PRODUCTION



Line production is used where large numbers of identical products must be assembled. Each worker is assigned a specific task that is done repeatedly throughout the process. Portable radios are produced in this way. As the radio cases move down the line, component parts, called subassemblies, are installed. At the end of the line, completed radios are boxed and labeled for shipment.



AUTOMATION

Automation is a form of line production in which there is little need for human workers. Once the automated system is begun, self-regulating machines operate until they are programmed to switch off. Many modern radio stations use automation to broadcast taped music for days at a time without the need for anyone to be at the station. Automatic tape players insert commercials or a disk jockey's prerecorded chatter on cue.

CYBERNATION

The word "cybernetics" means to steer, guide, or govern. Cybernetics is an advanced form of automation in which computers control the production machines. During cybernetic production processes, sensing devices on the machine continuously send information to the computer. The computer guides the machine to accomplish the work it has been programmed to do. Industrial robots in automobile assembly plants are cybernetic devices.

FOR FURTHER STUDY

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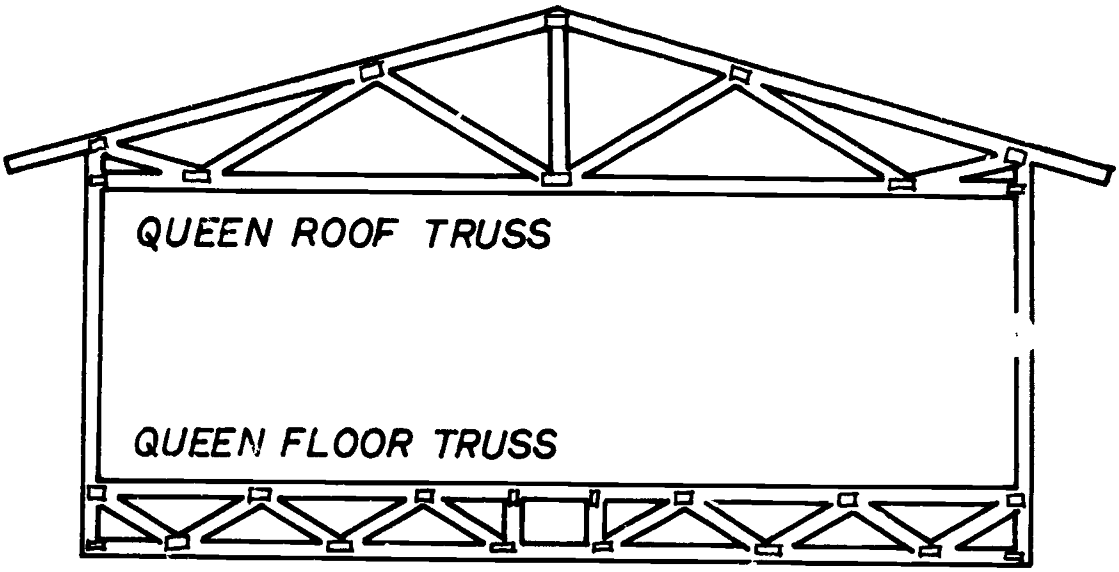
TRUSS-FRAMES IN HOME CONSTRUCTION

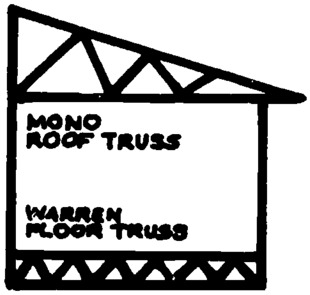
In this age of high technology, it may seem as though new materials, products, and techniques are being developed so fast we cannot keep up with them. But, we know that in the housing industry the same old construction methods are still being used, right? Wrong! Although it may not seem as exciting to you as the latest development in electronic music, the home construction industry is undergoing some changes too. "Show me," you say. Okay, read on and you shall see.

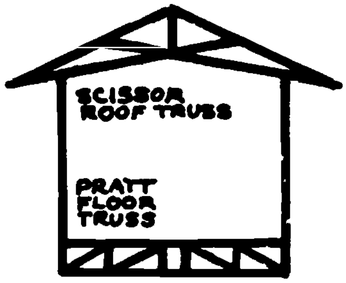
After studying this unit, you will be able to:

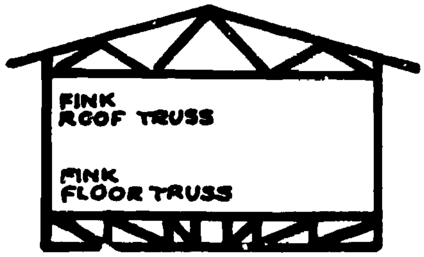
- Explain why truss-framing saves construction time and materials.
- Describe at least two types of trusses.
- List at least two advantages truss-framing has over stick-built construction methods.

For many years, homes, apartments, offices, and other small buildings were constructed by the "stick-built" method. Individual pieces of lumber sually two-by-fours and two-by-sixes, were nailed in place one at a time. These jois rafters, and wall studs were a embled in the same manner that one might build a model out of toothpicks. As you might guess, the stick-built method required lots of time and a considerable amount of material. Today, builders are still using sticks of lumber, but in a different way. The same type of two-by-fours and two-by-sixes used years ago are now assembled at a factory into frames called "trusses." The preassembled trusses are then shipped from the factory and erected at the building site.







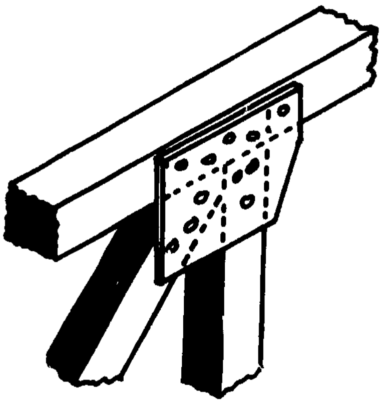


TRUSSES

In its basic form, a truss is simply a number of sticks assembled in triangular shapes. You probably know that the triangle is the strongest geometric shape. One major advantage of a truss is its ability to span a greater distance than the individual sticks with which it is made. Another advantage is that a truss can be made up of shorter and lighter pieces of lumber. If you have seen an old barn, with its huge timbers and beams, you may understand how difficult and expensive it would be to construct all of our homes with such large structural members. By using smaller pieces of lumber, builders can also use more of each tree. Can you guess why this is so?

ROOF TRUSSES

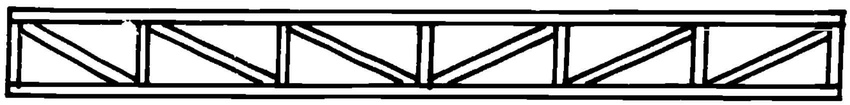
One of the recent changes in home construction began several years ago when builders started using roof trusses. Roof trusses are triangle-shaped structures built at lumber yards by joining rafters, ceiling joists, and bracing, all in one [illegible]. Metal plates, called "gussets," are used to fasten the pieces together. You may have seen roof trusses being shipped upside down on flatbed trucks. At the building site, roof trusses are hoisted on top of the walls and spaced 24 inches apart. Temporary bracing holds the trusses in place until plywood roof sheathing is nailed or stapled on top. Because they span entirely across the house, roof trusses need no load-bearing wall for support. Although they were used centuries ago, roof trusses became popular in modern home construction when builders found that trusses saved time and materials over stick-built methods.


GUSSET PLATE

FLOOR TRUSSES

Another relatively new development in building construction is the flat floor truss. Before floor trusses were used, individual sticks called "floor joists" were used to span across the foundation walls of the house. Because the width of the house is almost greater than the longest lumber available, it is necessary with the stick-built method to place a beam or load-carrying wall through the center of the basement or crawl space. Floor joists were then placed across the span from each wall to the center beam. Spaced 16 inches apart, nearly 100 joists are needed for each floor of a modest-sized home.

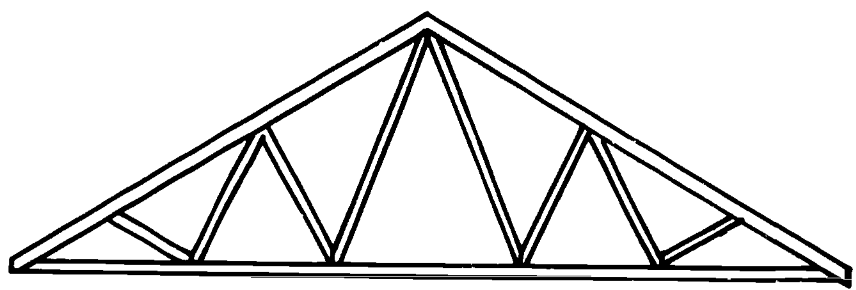
Flat floor trusses are assembled at the factory much the same as are triangular roof trusses. Floor trusses can span all the way across from one foundation wall to the other, thus no center beam is required. One result is a clear, open basement area with no beam or posts to get in the way. And, because floor trusses can be spaced 24 inches apart, less lumber is needed for each house. They have another advantage in that insulation, plumbing, wiring, and heating/cooling ductwork can more easily be run under the floor than with traditional floor joist systems.



FLAT TRUSS: 16'-48' SPAN

TRUSS-FRAMED CONSTRUCTION

In the newest development, roof trusses, wall studs, and floor trusses are joined together to form assemblies called "truss-frames." Only about 26 trusses are needed for a typical house. The truss-frame units are hoisted onto the foundation wall by light crane or forklift. Like roof trusses, they are positioned 24 inches apart. Standard sheathing or insulation board is then fastened on walls and roof for strength. This new method requires less construction time and less lumber than conventional methods.



DOUBLE FINK TRUSS: 20'-60' SPAN

Materials and labor for truss-framed construction reportedly cost 10 to 25% less than traditional stick-built construction. If a home costs $50,000 to build the traditional way, you can see that a contractor might save as much as $12,500 if the home were constructed with truss-frames. That could mean that the truss-framed house could be sold for much less, and more people might be able to afford it. In addition, each truss-framed house would use less lumber, thus reducing our use of natural resources.

SELF-QUIZ

Now try a Self-Quiz. On your own sheet of paper, write your answers to these questions.

1. What is another name for the traditional, "toothpick" method of home construction?
2. Are trusses usually constructed on-site or assembled in factories?
3. One advantage of truss-framing is that no center beam or wall is required. Name another advantage.
4. Metal plates are often used to fasten structural members of trusses. What are these plates called?
5. Trusses are usually spaced how many inches apart?

Answers are at the bottom of this page. Go back and read about the ones you missed.

THINGS TO DO

- Design and construct the frame of a model home using modern truss-frames. See if this new structural method allows more flexibility for more efficient and more interesting shelter design.
- Locate a construction project in your community where truss-framed methods are being used. Talk with the workers, take pictures if possible, then report to your class on the project.
- Using actual two-by-fours, test the stress and load theories of truss-framed construction versus traditional stick-built methods. Are trusses actually stronger? Do they really use less lumber?

FOR FURTHER STUDY

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Miller, C. Truss-framed construction: A fast, cheap technique for your next house. *Popular Science,* June 1983, pp. 110–112.

ANSWERS

1. stick-built
2. assembled in factories
3 less material, cheaper
4. gussets
5. 24 inches apart

SPACE FRAMES AND GEODESIC DOMES

Have you noticed how many of today's sports stadiums, shopping centers, and exhibit halls are constructed with thin metal framing that looks like a giant version of Tinker-Toys? These large, open-space structures have huge, lightweight rooms that require little or no interior support. Some of them look as though they might not be very strong. How can so little structural material hold up such a large roof? Can they be strong enough to withstand high winds or snow loads? Read on and you will see.

After studying this unit, you will be able to:

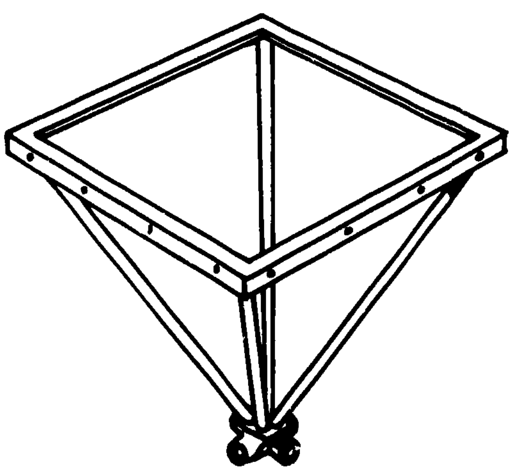
- Explain why space frames and geodesic domes can span long distances while using relatively little structural materials.
- Describe the basic geometric units used in space frames and geodesic domes.
- Name two American inventors who played an important role in the development of space frames and geodesic domes.

For centuries, buildings were constructed using either the post and lintel method or the arch method. Arched structures could be built out of stone and brick. During the Reformation, the arch method was used to construct churches, which were among the largest buildings of the time. The post and lintel method used wooden beams placed on top of posts in a "T" arrangement. This method was useful for constructing houses and barns.

Both types of construction were strong and could hold up very heavy roof loads. On the other hand, the support materials used in both methods needed to be quite large, which meant that construction was difficult and time consuming. In recent years, as architects and engineers searched for ways to conserve building materials and shorten construction time, new types of structural methods have been developed. Two of the newest structural designs are the space frame and the geodesic dome.

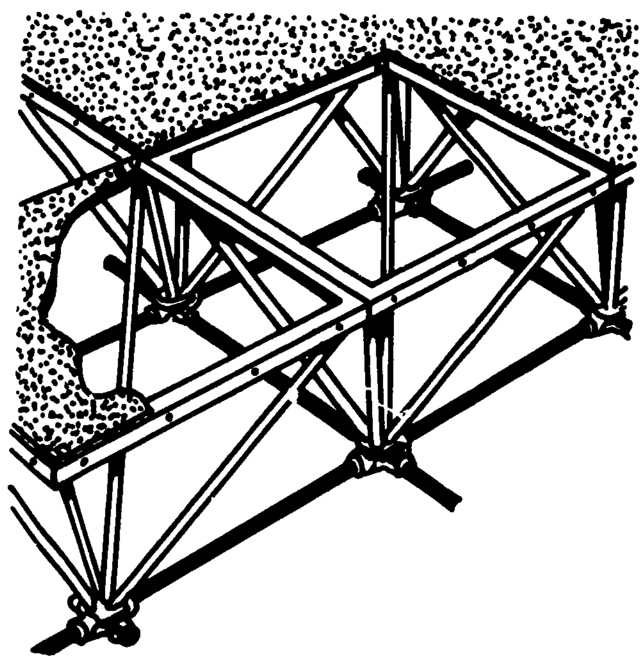
SPACE FRAMES

Space frames are rigid, load-supporting structural roof systems made with lightweight struts joined with connector plates. The basic structural unit of the space frame is the pyramid. A pyramid has a square base and four triangular sides joined at the top. When the tops of several pyramid-shaped units are joined with additional struts, the result is a space frame grid.



The position of the struts distributes loads evenly throughout the frame. This makes the space frame very light but strong enough to support a roof over very long spans. The space frame roof can be cantilevered, so it does not need load-bearing walls around the perimeter for support. And, because it requires only a few vertical supports or legs, a space frame roof is an excellent choice for large, open-plan buildings.

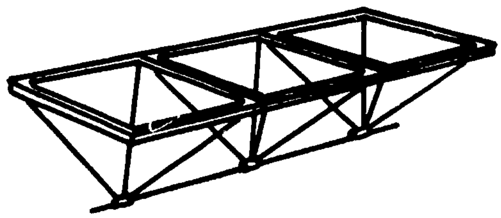
Space frames are usually designed so that all the struts are the same size. That way, the struts may be produced in factories to reduce costs. Also, construction workers can easily and quickly assemble the structure on site. In practice, several of the pyramid units are usually connected to one another on the ground. Bolts or pins are used to fasten the struts to the connector plates. Sometimes, several pyramid units are connected together at the factory and shipped to the building site in sections.

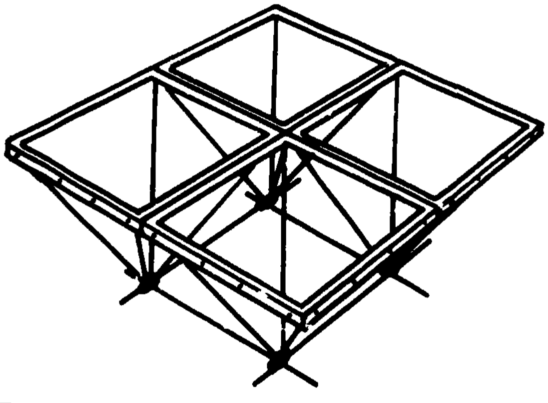


The prebuilt sections are then lifted onto the building and connected to others already in place. Space frames are often installed with the bases of the pyramid units on top. This results in a stronger surface for roofing applications. Many different types of roofing materials can be used on top of the space frames. In multistory buildings, the space between the top and bottom of the grid can be used for installation and maintenance of heating, cooling, and ventilating services.

Did you know that Alexander Graham Bell was one of the first Americans to experiment with space frame structures? In 1907, Bell built a space frame observation tower that was 80 feet (24 meters) tall. The struts and connectors for Bell's tower were mass produced in a factory. Wide use of space frame structures has come only in the past 20 to 30 years as new materials and connecting devices have been developed.

Today, space frames are used extensively for industrial and commercial buildings. Besides being used for roofs, space frame designs are also used to construct radio transmitters, microwave relay stations, and giant highway signs. Space frame struts can be made from steel, aluminum, wood, and even plastic tubing. Space frames may someday be used in outer space, although that's not how the structural system got its name. Its lightweight and fast assembly make space frames a promising choice for building structures outside the earth's atmosphere.

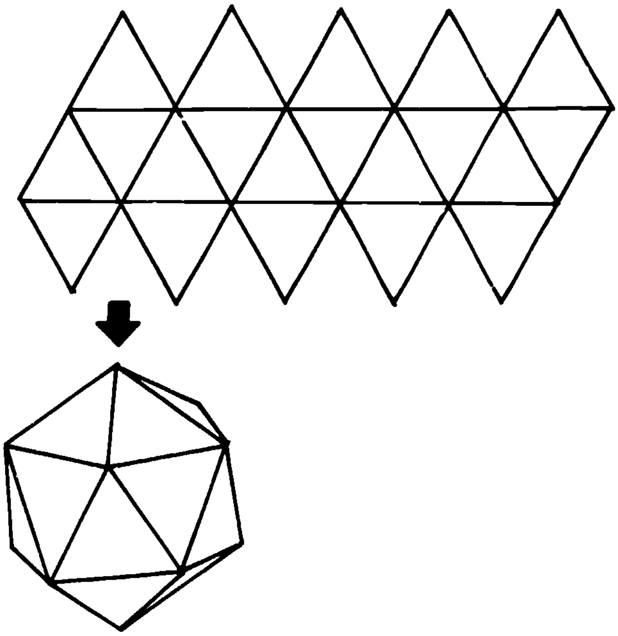


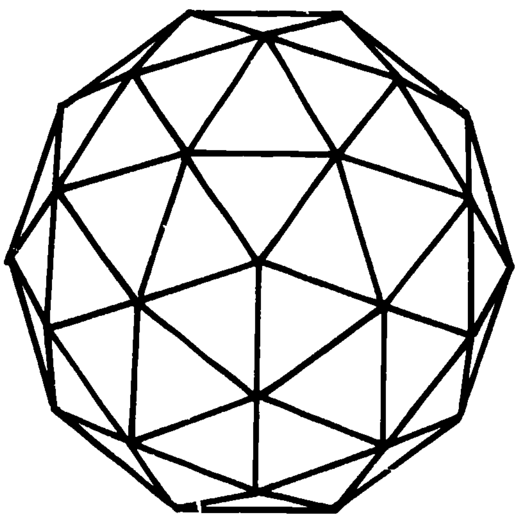


GEODESIC DOMES

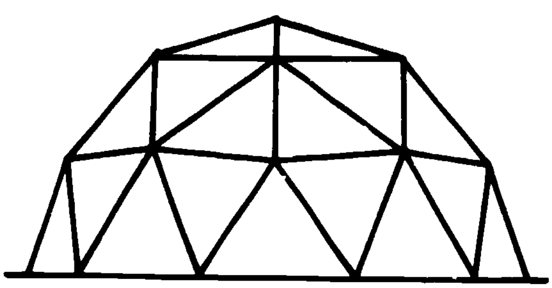
Geodesic domes are really types of space frames formed into spherical (ball) shapes. The basic structural unit of most geodesic domes is the tetrahedron. A tetrahedron is a pyramid with four triangular faces. Because every strut in a tetrahedron braces every other strut, the tetrahedron is very strong. When tetrahedron units are connected together, the result is a framework that is light, but strong.

Tetrahedrons are often joined to form a sphere or part of a sphere. The result is a geodesic dome. Domes are great for enclosing large, open spaces. The curvature of the dome actually makes the frame stronger because all of the struts share the structural load. The term "geodesic" was coined by American inventor–engineer Buckminster Fuller. Fuller's designs have inspired construction of space frame domes around the world. Geodesic domes are used for many kinds of structures, including tents, radar housings, exhibit halls, sports arenas, and greenhouses. Besides saving in structural materials, geodesic domes require no internal columns for support. So, they are excellent choices for structures where unobstructed interior space is needed.





One of the world's first space frame domes, called the Dome of Discovery, was built in London in 1951. It is 360 feet (110 meters) in diameter. In 1953, Buckminster Fuller built one of his patented geodesic domes at the Detroit Ford plant. The hemisphere has a diameter of 95 feet (28 meters) and weights only 8.5 tons, which is unusually light for a building that large. Perhaps the most famous geodesic dome is the U.S. Pavilion constructed in Canada for the Montreal World Exhibit (Expo 1967). It is a three-quarter spherical dome with a heigth of 200 feet (61 meters) and a diameter of 250 feet (76 meters).



In the past two decades, geodesic domes and space frame roofs have been constructed all over the world. Some are big, housing sports arenas or entertainment centers. Others are small, and serve as homes or storage sheds. Regardless of their size, space frame structures provide open-space shelter with fewer materials and less weight than traditional building methods.

Now, try a SELF-QUIZ

On your own sheet of paper, write your answers to these questions.

1. Name two inventors noted for their experiments with space frames or geodesic domes.
2. What is the basic structural unit of the space frame roof?
3. Name at least two common uses for space frame structures.
4. What is the basic structural unit of the geodesic dome?
5. What are the major advantages to using space frames and geodesic domes?

Turn this page upside down and you will find the answers. Go back and read again about the ones you missed.

THINGS TO DO

- Using round toothpicks and glue, design and construct a model of a space frame roof. Experiment with different designs. See if one type of design is stronger than the others.
- Locate a building in your community where space frame or geodesic dome construction was used. Find out what type of material was used for the struts and what types of connectors hold the struts together.
- Design and build a playground climbing tower using geodesic dome construction. Electrical conduit can be used to make struts, although other materials may work just as well. To connect metal tubing, try crushing the tips with a vise or a hydraulic jack. Drill holes and use bolts as connectors.

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ANSWERS

1. Buckminster Fuller, Alexander Graham Bell
2. pyramid
3. roofs, towers, sign supports
4. tetrahedron
5. lightweight, open space, economy of materials

FIBER COMPOSITE MATERIALS

For a long time, conventional aircraft structures were made entirely from alloys of aluminum, magnesium, titanium, and steel. Years ago, people would have thought it impossible that airplane and helicopter parts could be made of plastic. Yet today, unconventional plastics called fiber composites are used not only for aircraft parts but also for engines, boat hulls, tennis rackets, and many other products. Fiber composites are the result of recent research and development to meet the extreme and exacting requirements of space programs, oceanography, and supersonic flight. Let's see what makes fiber composites so special.

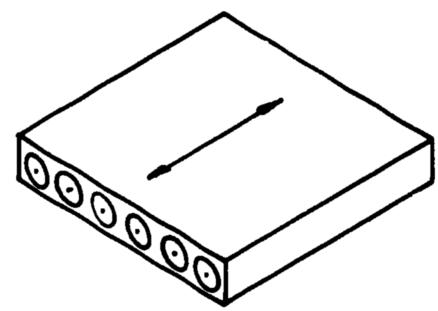
After studying this unit, you will be able to:

- Explain what materials are combined to form fiber composites.
- Describe the major design characteristics of fiber composites and why they exist.
- Explain at least two ways composite materials may be fabricated.
- Name at least four kinds of products made from composites.

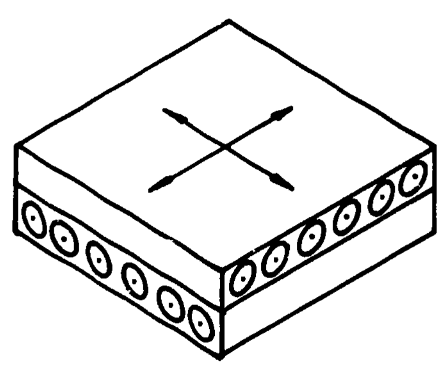
The technology of high-performance fiber composites has been known for only about 20 years. Although fiberglass has been available for a long time, the discovery of boron fiber in the early 1960s, followed quickly by graphite and other fibers, ushered in a new era of structural composites.

At present, there are several hundred advanced composite structures, and the technology developed primarily for aerospace is being quickly adapted to commercial applications, including machinery, sporting equipment, and storage tanks, among others.

Fiber composites consist of filaments—long fibers—of graphite, glass, boron, or polymer arranged in a matrix material to hold them together. The matrix material is normally either epoxy, which is similar to that used in autobody fiber glass repair kits, or a polymide similar to Krazy Glue. Matrix material also provides protection from corrosion and helps spread load stress over a wider area of the product's surface.

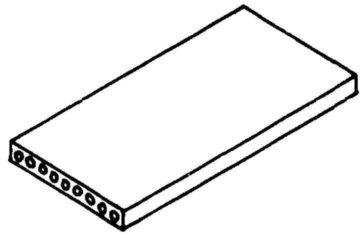


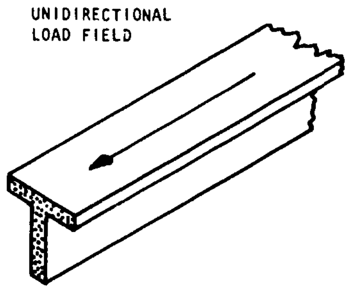
UNIDIRECTIONAL



BIDIRECTIONAL

Composites are light, yet strong and stiff. Their strength and stiffness can be concentrated longways, crossways, or diagonally, depending how the layers of fibers are arranged. In a tennis racket, for example, fibers are oriented to provide tailored stiffness needed for maximum power. Composites have a very high strength-to-weight ratio, which means they are quite strong, even though they are also very light. When composites are used in place of metals, they can reduce weight by as much as 25%.





FIBERS

Reinforcing fibers used in composites generally belong to the glass, boron, or carbon families of materials. Fibers with different sets of properties are available within each family.

Glass is the least expensive of fibers used in composite materials, costing about $1 per pound. Glass fibers are made by extruding molten glass through a small orifice and then rapidly drawing the fibers to a small size, usually about .0004 inches in diameter. Commercially, it is often supplied in the form of slightly twisted yarns or rovings consisting of groups of parallel strands of fibers. In some composite applications, glass fibers are woven into "yarn goods" similar to glass drapery fabric. Glass is the strongest of the three commonly used fibers. Because glass becomes soft at very high temperatures, it is used mostly in low temperature composite applications, such as boat hulls, autobodies, and recreational equipment.

Boron is almost as strong as glass but can withstand extremely high temperatures. It costs about $300 per pound. Boron fibers are made by thermally decomposing boron hydrides on a heated tungsten wire. It is furnished as a single filament, usually about .005 inches in diameter.

Carbon or graphite fibers, at about $350 per pound, are the most expensive of the commonly used fibers. They are made from textile fibers—usually rayon. During processing, the rayon fibers are carefully "burned" so that the carbon bonds align themselves along the fiber's axis. The resulting graphitized fibers are furnished as untwisted course threads called tows. The tows are very fine, about .0003 inches in diameter. Carbon fibers, because they are very strong and light, are used to make aircraft parts.

MATRIX MATERIALS

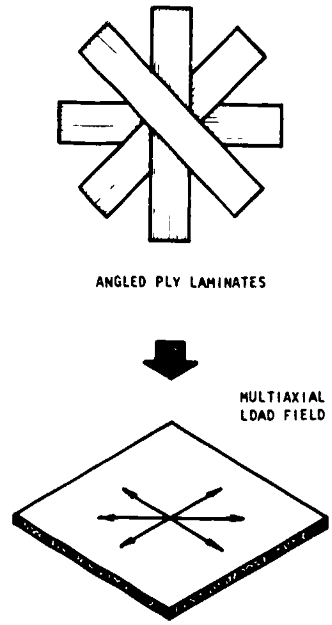
Individual fibers are useless for high-strength applications, so a binder material called a matrix must be used. The matrix material holds the fibers together, distributes load stress, and protects the fibers from corrosion.

Two kinds of matrix materials are used: epoxies and polymides. Although they are both plastics, epoxies and polymides have different characteristics. Epoxies are cheaper to produce but can break down under very high temperatures. Polymides remain strong under high temperatures. They are used in rocket motors, jet engines, and other similar applications.

Epoxy and polymide matrix materials have a crystalline structure and are made inherently stiffer and stronger than compounds formed through metallic or ionic bonds. Furthermore, most are abundant and, therefore, potentially inexpensive. Unfortunately, these matrix materials are brittle and by themselves would not be suitable for use in high technology applications. However, when combined with glass, boron, or carbon fibers, the resulting composite material is both strong and flexible.

FABRICATION

Fabrication with composite materials is accomplished either by using preprocessed rolls of material called tapes or by custom building the product by using the hand lay-up technique. The hand lay-up technique is similar to building a fiberglass boat or car body. A slippery paper is first spread out, then a thick layer of epoxy matrix material is spread out on the paper. Next, a layer of fiber material is placed on top of the first layer of epoxy. The fiber material (spun glass, carbon, graphite) is often used in the form of a woven fabric similar to fiber glass drapery material. Then, another layer of epoxy is spread over the fiber cloth and the sequence is repeated to form the desired thickness. The layed-up part is then allowed to cure.



Some products lend themselves to assembly from preformed tapes. The "tapes" are rolls of composite material which have been layed-up and cured. Tapes are available in widths from less than an inch to several feet in width. Parts of an assembly can be cut from the tapes or sheets and then fastened together with an adhesive. Fabrication skills for composite materials can be learned more quickly than sheet metal fabrication techniques. Because composites are easier to assemble than sheet metal, they can also save money in fabrication costs. Also, composites require fewer fasteners.

For some high-stress applications, such as in aircraft, the fabricated parts are put in an autoclave or vacuum bag to cure. An autoclave is a strong metal box in which air is forced under high pressure—as much as 100 pounds per square inch. This forces out any air bubbles and results in a stronger material. In a vacuum bag, the air is drawn out. The results are virtually the same. If air bubbles were allowed to remain in the composite, the resulting weak spot might crack under use.

APPLICATIONS

Just as people sometimes do, some materials can become tired. The technical word for "tiredness" of materials is **fatigue**. Engineers have noticed that composites are slow to fatigue and when they do, cracks grow slowly and can be found in routine inspections. In many applications, parts made of composite materials are virtually indestructible. This characteristic makes composites a promising material for use in aircraft and other devices where failure of a part might be disastrous.

One of the major advantages of composite materials is their resistance to corrosion. With the exception of some plastic solvents that can dissolve the matrix material, composites are not affected by chemicals. This characteristic makes composites especially useful for marine applications, in fuel tanks, and as fasteners where dissimilar metals might cause electrolysis. Among many applications, composites are currently being used in tennis rackets, golf clubs, canoes, aircraft tail and wing surfaces, ultralight aircraft, and flywheels.

CUTTING COSTS

Composite materials cost less to produce than aluminum. Aluminum production requires electricity. Compared with aluminum, an equal amount by weight of composites takes only one-eleventh of the total energy required. Composites take one-fourth as much energy to produce as does steel with the same strength.

Because composites weigh less than most metals, aircraft made with composites require less fuel and can carry heavier payloads. The savings can be substantial. Engineers are continuing to find out how composite materials behave in actual use. One day soon we may fly in an aircraft made almost entirely of composite materials—a plastic airplane.

SELF-QUIZ

On your own sheet of paper, write your answers to these questions.

1. What are the two most useful characteristics of fiber composites?
2. What are the two common methods of fabricating products using fiber composites?
3. Name at least four different kinds of products made at least in part from composite materials.
4. What are the two kinds of matrix materials used in composites?

Turn this page upside down and you will find the answers. Go back and read again about the ones you missed.

THINGS TO DO

- Collect sample products made from fiberglass and other composites. Try to determine how many layers and what kind of matrix material was used. A materials microscope will be useful. If one is not available, use a magnifying glass.
- Experiment with hand lay-up fabrication methods by using cotton cloth as a fiber and white glue as a matrix material. Even paper towels will work. Doing your lay-up on wax paper will prevent it from sticking to the work surface. If you use a mold, make sure to use petroleum jelly or some other slippery substance to keep the matrix material (glue) from sticking to the mold.
- Design a product to be made with fiberglass. Experiment with samples to determine the best arrangement of the glass cloth and the number of layers. Produce one prototype and test it; if you are satisfied, go into production.

FOR FURTHER STUDY

Materials & Structures/ACEE. *NASA facts.* National Aeronautics and Space Administration, NF-117, August 1981.

McCullough, R. *Concepts of fiber-resin composites.* New York: Marcel Dekker, 1971.

Salkind, M. *Applications of composite materials.* Philadelphia: American Society for Testing and Materials, 1973.

ANSWERS

1. Strength and light weight
2. Lay-up assembly with prefabricated rolls
3. Tennis rackets, boat hulls, airplane parts, golf clubs, hang glider frames, etc.
4. Epoxies and polyimides

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