# Machine

## Introduction

Machine is a device that can be used to do work. Machines are designed to make life easier for us. Some machines perform tasks that would be impossible to do without them. We use machines all the time. Industries use drill presses, lathes, and grinding machines to make products we use. Businesses depend on computers, copying machines, and fax machines. Automobiles, buses, and airplanes transport people swiftly over great distances. Trucks, railroads, and ships haul goods to and from markets. Without machines, the residents of our cities would find it more difficult to live, and farmers could not raise enough food to feed us.

People have constructed a wide variety of machines to satisfy their needs. Early people made stone axes that served as weapons and tools. The machines that were gradually developed gave people great control over their environment (physical surroundings). To operate these improved machines, people harnessed the energy of falling water and of such fuels as coal, oil, and the atom. Today, we use so many machines that the age we live in is often called the machine age.

## Principles of machines

A machine produces or transmits force and controls the direction and the motion of force. But it cannot create energy. A machine can never do more work than the energy put into it. It only transforms one kind of energy, such as electrical energy, and passes it along as mechanical energy. Some machines, such as diesel engines or steam turbines, change energy directly into mechanical motion. For example, the energy of steam rushing through the wheels of a turbine produces rotary motion. The mechanical energy of the turbine can be used to drive a generator that produces electric power. Other machines simply transmit mechanical work from one part of a device to another part. They include the six simple machines that are described below.

A machine's ability to do work is measured by two factors. They are (1) efficiency and (2) mechanical advantage.

Efficiency. The efficiency of a machine is the ratio between the energy it supplies and the energy put into it. No machine can operate with 100 per cent efficiency because the friction of its parts always uses up

some of the energy that is being supplied to the machine. Although friction can be decreased by oiling any sliding or rotating parts, all machines produce some friction. For this reason, a perpetual-motion machine is impossible (see Perpetual motion machine ).

A simple lever is a good example of a machine that has a high efficiency (see Lever ). The work it puts out is almost equal to the energy it receives, because the energy used up by friction is quite small. On the other hand, an automobile engine has an efficiency of only about 25 per cent, because much of the energy supplied by the fuel is lost in the form of heat and noise that escapes into the surrounding air. See Efficiency .

Mechanical advantage. In machines that transmit only mechanical energy, the ratio of the force exerted by the machine to the force applied to the machine is known as mechanical advantage. Mechanical advantage can be demonstrated with a crowbar, which is a type of lever. When one end of the crowbar is directly under the weight, a part of the crowbar must rest on a fulcrum (support). The closer the fulcrum is to the load, the less the effort required to raise the load by pushing down on the handle of the crowbar, and the greater the mechanical advantage of the crowbar. For example, if the load is 2,000 newtons, and the distance from the load to the fulcrum is one fourth of the distance from the handle to the fulcrum, it will take 500 newtons of effort to raise the load. Therefore, the mechanical advantage will be 4 to 1. But the distance the load will be moved will be only one-fourth of the distance through which the effort is applied.

## Six simple machines

Most machines consist of a number of elements, such as gears and ball bearings, that work together in a complex way. But no matter how complex they are, all machines are based in some way on six types of simple machines. These six types of machines are (1) the lever, (2) the wheel and axle, (3) the pulley, (4) the inclined plane, (5) the wedge, and (6) the screw.

Lever. There are three basic types of levers, depending on where the effort is applied, on the position of the load, and on the position of the fulcrum. In a first-class lever, such as a crowbar, the fulcrum is between the load and the applied force. In a second-class lever, such as a wheelbarrow, the load lies between the fulcrum and the applied force. In a third-class lever, the effort is applied between the load and the fulcrum. For example, when a person lifts a ball in the palm of the hand, the load is at the hand and the fulcrum is at the elbow. The forearm supplies the upward force that lifts the ball. See Lever .

Wheel and axle. The wheel and axle is essentially a modified lever, but it can move a load farther than a lever can. In a windlass used to raise water from a well, the rope that carries the load is wrapped around the axle of the wheel. The effort is applied to a crank handle on the side of the wheel. The center of the axle serves as a fulcrum. The mechanical advantage of the windlass depends upon the ratio between the radius of the axle and the distance from the center of the axle to the crank handle. The wheel-and-axle machine has important applications when it is used to transport heavy goods by rolling rather than by sliding. The wheel itself is regarded as one of the most important inventions of all time. It is widely used in all types of machinery and motor vehicles. See Wheel and axle .

Pulley. A pulley is a wheel over which a rope or belt is passed. It is a form of the wheel and axle. The mechanical advantage of a single pulley is one, because the downward force exerted on the rope equals the weight lifted by the other end of the rope that passes over the pulley. The main advantage of the single pulley is that it changes the direction of the force. For example, to lift a load, a person can conveniently pull down on a rope, using the weight of the body. When one pulley is attached to a support and another is attached to the load and allowed to move freely, a definite mechanical advantage is obtained. See Pulley .

Inclined plane. The inclined plane is such a simple device that it scarcely looks like a machine at all. The average person cannot raise a 200-pound box up 2 feet into the rear of a truck. But by placing a 10-foot plank from the truck to the ground, a person could raise the load easily. If there were no friction, the force required to move the box would be exactly 40 pounds. The mechanical advantage of an inclined plane is the length of the incline divided by the vertical rise. The mechanical advantage increases as the slope of the incline decreases. But the load will then have to be moved a greater distance. By adding rollers, it is possible to make a roller conveyor that will reduce friction and have great efficiency. See Inclined plane .

Wedge. The wedge is an adaptation of the inclined plane. It can be used to raise a heavy load over a short distance or to split a log. The wedge is driven by blows from a mallet or sledge hammer. The effectiveness of the wedge depends on the angle of the thin end. The smaller the angle, the less the force required to raise a given load. See Wedge .

Screw. The screw is actually an inclined plane wrapped in a spiral around a shaft. The mechanical advantage of a screw is approximately the ratio of the circumference of the screw to the distance the screw advances during each revolution.

A jackscrew, such as those used to raise homes and other structures, combines the usefulness of the screw and the lever. The lever is used to turn the screw. The mechanical advantage of a jackscrew is quite high, and only a small effort will raise a heavy load. See Screw .

## Designing machines

By combining the principles of simple machines, engineers develop new and specialized machines. They choose materials for the various parts of the machine that resist stress, friction, and corrosion (wear from chemicals). Engineers also design machines to be safe and efficient.

**Contributor**
Gregory S. Chirikjian, Ph.D., Professor, Department of Mechanical Engineering, Johns Hopkins University.