Name ____________________ Class ________________ Date ____________

Chapter 14 **Work, Power, and Machines**

Summary

14.1 Work and Power

Work is the product of force and distance. Work is done when a force moves an object over a distance. For example, you do work when you lift a textbook. If an object does not move, no work is done.

You can calculate work by multiplying the force exerted on the object times the distance the object moves:

$$\text{Work} = \text{Force} \times \text{Distance}$$

The joule (J) is the SI unit of work. One joule is the amount of work done when a force of 1 newton moves an object a distance of 1 meter in the direction of the force.

Power is the rate, or speed, of doing work. To do work faster, you must use more power. To increase power, you can do more work in the same time or you can do the same work in less time.

You can calculate power by dividing the amount of work done by the time needed to do the work:

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

The watt (W) is the SI unit of power. One watt equals one joule per second.

Another unit of power is the horsepower (hp). One horsepower equals about 746 watts. The horsepower was invented by Scottish engine builder James Watt around 200 years ago. Watt defined one horsepower as the power output of a very strong horse.

14.2 Work and Machines

A machine is something that changes a force and makes work easier. Machines may change a force in three ways. They may

- increase the size of the force
- change the direction of the force
- increase the distance over which the force acts

The force you put into a machine is the input force. The distance over which the input force acts is the input distance. The work you do on the machine is the work input. The work input equals the input force times the input distance. You can increase the work input by increasing the input force, the input distance, or both.

The force a machine produces is the output force. The distance over which the output force acts is the output distance. The work the machines does is the work output. The work output equals the output force times the output distance. The only way to increase the work output is to increase the work input. You cannot get more work out of a machine than you put into it.

The moving parts of a machine must use some of the work input to overcome friction. Recall that friction acts against any moving object. Because of friction, the work output of a machine is always less than the work input.

14.3 Mechanical Advantage and Efficiency

Many machines increase the size of the input force. The number of times a machine increases the size of the input force is called its mechanical advantage. For example, a machine that increases the input force by a factor of three has a mechanical advantage of 3. There are two types of mechanical advantage: actual mechanical advantage and ideal mechanical advantage.

The actual mechanical advantage (AMA) of a machine is the ratio of output force to input force. You can calculate the actual mechanical advantage by dividing the output force by the input force:

$$\text{AMA} = \frac{\text{Output force}}{\text{Input force}}$$

The ideal mechanical advantage (IMA) of a machine is the mechanical advantage without friction. Friction is always present, so the actual mechanical advantage of a machine is always less than the ideal mechanical advantage. You can calculate ideal mechanical advantage by dividing input distance by output distance:

$$\text{IMA} = \frac{\text{Input distance}}{\text{Output distance}}$$

Some of the work input to any machine must be used to overcome friction. The percentage of work input that becomes work output is the efficiency of a machine. The efficiency of a machine is always less than 100 percent. The formula for calculating efficiency is

$$\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}} \times 100\%$$

If the efficiency of a machine is 75 percent, then 75 percent of the work input becomes work output. The other 25 percent of work input is used to overcome friction. Reducing friction increases the efficiency of a machine. With less friction, more of the work input becomes work output.

14.4 Simple Machines

There are six different types of simple machines: lever, wheel and axle, inclined plane, wedge, screw, and pulley.

A lever is a stiff bar that can move around a fixed point. The fixed point is called the fulcrum. A seesaw is an example of a lever. To calculate the ideal mechanical advantage of a lever, you divide the input arm by the output arm. The input arm is the distance between the input force and the fulcrum. The output arm is the distance between the output force and the fulcrum. Based on the locations of the input force, the output force, and the fulcrum, levers are classified into three categories:

- First-class levers—fulcrum between input force and output force (example: seesaw)
- Second-class levers—output force between input force and fulcrum (example: wheelbarrow)
- Third-class levers—input force between fulcrum and output force (example: baseball bat)

A wheel and axle is made up of a larger outer disk attached to a smaller inner cylinder. The outer disk is the wheel, and inner cylinder is the axle. A steering wheel is an example of a wheel and axle. When you turn the large wheel, the narrow axle also turns. To calculate the mechanical advantage of a wheel and axle, you divide the radius of the disk or cylinder where the input force is applied by the radius of the disk or cylinder where the output force is produced.

An inclined plane is a slanted surface used to move an object to a different height. A wheelchair ramp is an example of an inclined plane. To calculate the ideal mechanical advantage of an inclined plane, you divide the distance along the inclined plane by its change in height. For example, a 6-meter-long ramp that gains 1 meter of height has an ideal mechanical advantage of 6.

A wedge is a V-shaped object. The two sides of the V are inclined planes that slope toward each other. An example of a wedge is a knife blade. The ideal mechanical advantage of a wedge depends on its shape. A thin wedge has a greater ideal mechanical advantage than a thick wedge of the same length.

A screw is an inclined plane wrapped around a cylinder. The turns of the inclined plane around the cylinder are called threads. The ideal mechanical advantage of a screw depends on the closeness of the threads. The closer the threads are, the greater the ideal mechanical advantage is.

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A pulley is a simple machine that consists of a rope that fits into a groove in a wheel. It is used to help lift objects. A pulley may be fixed or movable. In a fixed pulley, the wheel is attached in a fixed location. A fixed pulley changes the direction, but not the size, of the input force. An example of a fixed pulley is the pulley at the top of a flag pole. In a movable pulley, the pulley is attached to the object being moved. A movable pulley changes both the direction and the size of the input force. A pulley system is made up of two or more individual pulleys, both fixed and movable. To calculate the ideal mechanical advantage of a pulley or pulley system, you add the number of rope sections supporting the object being lifted. A pulley system made up of several individual pulleys can have a large ideal mechanical advantage.

Most of the machines you use every day are made up of more than one simple machine. A combination of two or more simple that operate together is called a compound machine. Scissors are an example of a compound machine. Each blade of a pair of scissors is a wedge, and the two blades work together as levers. Some compound machines, such as washing machines and clocks, contain dozens of simple machines.