SCIENCE 808
LEVERS, PULLEYS, GEARS, AND THINGS

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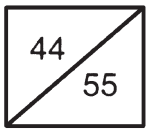
e. What is the efficiency of the lever?



III. WHEEL AND AXLE, PULLEYS, AND GEARS

The invention of the **wheel** was a major step in the histories of man and of the machine. The Sumerians used the wheel as early as 3500 B.C. Their chariots were wooden and have since decomposed. The evidence of wooden-wheeled chariots exists today in pictures and molds. Evidence exists that by 2000 B.C. use of the wheel and **axle** had spread from China to the British Isles.

To make a wheel, man first had to learn to draw and cut an accurate circle. That step, in itself, was a major one. The wheel is generally viewed as a means of transportation, but it also was used horizontally as a potter's wheel. This application, too, was a major step forward.

The pulley came a little later in history, in the Middle East, as an outgrowth of the wheel and axle. Gears are one of the oldest methods of transmitting motion.

SECTION OBJECTIVES

Read these objectives. When you have completed this section, you should be able:

7. To list the uses of the wheel and axle, pulley, and gears.
8. To calculate the mechanical advantage of the wheel and axle and pulleys.

VOCABULARY

Study these words to enhance your learning success in this section.

axle (ak' sul). The shaft on which a wheel turns.

axis (ak' sis). An imaginary or real line that passes through an object, about which the object turns.

block and tackle (blok and tak' ul). A system of pulleys designed to lift a large weight with a small effort force.

gear (gir). A wheel with teeth that fit into the teeth of another wheel of the same kind to transmit motion.

pulley (půl' ē). A wheel having a grooved rim in which a rope can run to change direction of effort, or with a set of these wheels to increase the effort force.

wheel (hwēl). A round frame turning on a shaft in its center.

WHEEL AND AXLE

A wheel and axle is a device that increases the effect of the effort force. The wheel and axle have the same **axis**.

Types. The idea of the wheel and axle is sometimes expressed as an axle with a crank, or lever, instead of a wheel. The effort distance moves through a larger circle than does the resistance distance. The wheel is attached to an axle or drum that has the same axis.

Mechanical advantages. The ideal mechanical advantage is found by dividing the circumference of the wheel (the effort distance) by the circumference of the axle (the resistance distance). The same quotient is arrived at by dividing the wheel radius by the axle radius.

$$\text{IMA} = \frac{\text{circumference/radius of wheel}}{\text{circumference/radius of axle}}$$

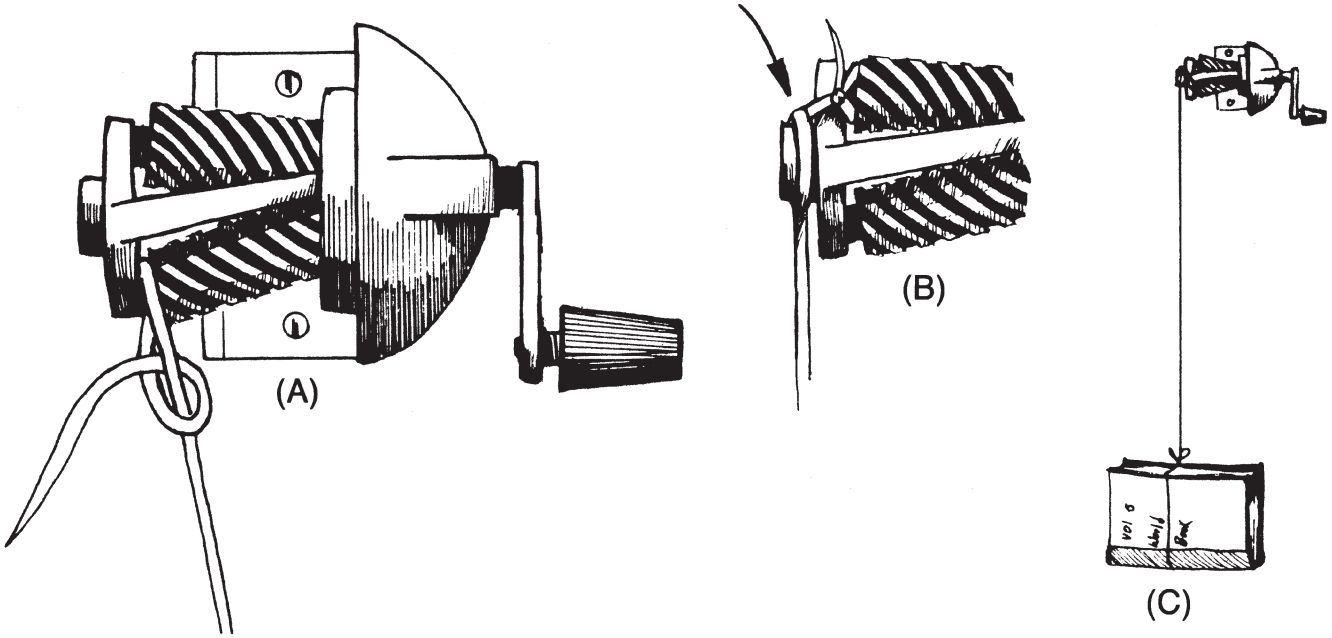
Try this investigation.

These materials are needed:

pencil sharpener (wall-mounted)
book
$2\frac{1}{2}$ metres of string

Follow these directions and complete the sentence. Put a check in the box when each step is completed.

- ☐ 1. Remove the cover of the pencil sharpener.
- ☐ 2. Tie one end of the string around the book.
- ☐ 3. Tie the other end of the string around the axle of the pencil sharpener as shown in the drawing in (A). Then loop string around the end of the axle as in (B).



☐ 4. Turn the handle of the sharpener and raise the book to the level of the sharpener.

☐ 5. Untie the book and lift it the same distance by hand.

3.1 Using the wheel and axle (pencil sharpener) to raise the book required less _____ force.

The IMA can be increased by increasing the radius of the wheel and/or decreasing the radius of the axle.

The actual mechanical advantage for the wheel and axle, as for the lever, is the resistance force divided by the effort force.

The efficiency, as in other machines, is found by dividing the AMA by the IMA.

$$\text{AMA} = \frac{\text{resistance force}}{\text{effort force}} \qquad \text{efficiency} = \frac{\text{AMA}}{\text{IMA}}$$

Uses. The steering wheel of a car is an example of a wheel and axle. A small turn of the steering wheel turns the steering column of the heavy car. A water wheel is also a wheel and axle. Before steam power, the water wheel ground grain, sawed lumber, and powered machines by transforming the energy of falling water into mechanical energy. A door handle is a wheel that turns the small axle, or shaft. A small force moves through a large distance in order to make the larger resistance force move.

Wheels are a part of our transportation system. They are found on everything from bicycles to eighteen-wheel trucks. When the axle turns the wheel, distance is increased for the amount of force applied.

Write *true* **or** *false.*

3.2 _____ When using the wheel and axle, the effort force moves through a greater distance than the resistance force.

3.3 _____ A wheel and its axle have the same axis.

3.4 _____ The efficiency of the wheel can be found by dividing the IMA by the AMA.

Complete this activity.

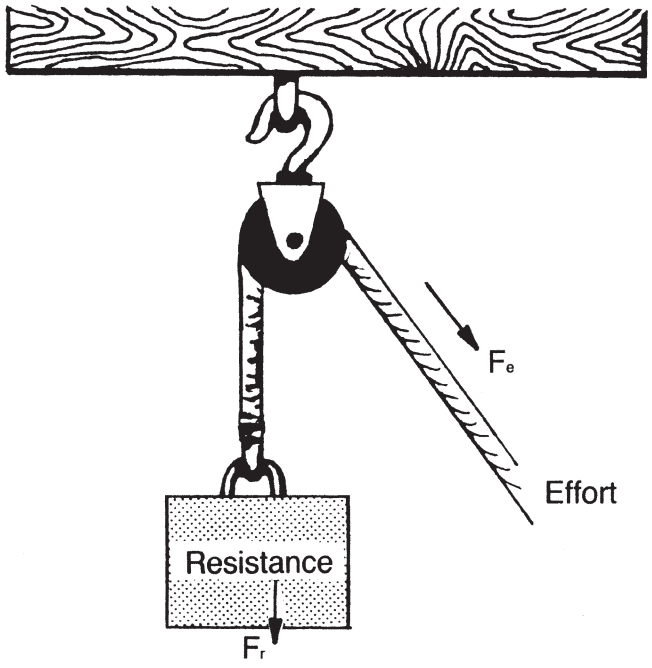
3.5 A wheel with a radius of 25 centimetres has an axle with a radius of 5 centimetres. The IMA of this wheel is _____.

3.6 The IMA of a wheel and axle could be increased by increasing the size of the a. _____ and/or b. _____ the size of the axle.

PULLEYS

Before 200 B.C., Archimedes designed systems of **pulleys** to lift large weights. The original pulley was probably a rope passing over a roller, which might have developed from using a rope over a tree branch to lift weights.

Types. A single pulley, fixed in position, simply changes the *direction* of force.



Try this investigation.

These materials are needed:

book	string (1 metre long)
sturdy coat hanger	wire cutters
spool	chair

Follow these directions and complete the sentence. Put a check in the box when each step is completed.

- ☐ 1. Using the wire cutters, cut the long, straight wire from the coat hanger.
- ☐ 2. Bend it like the letter "L."
- ☐ 3. Slip the spool onto short leg of the "L."
- ☐ 4. Bend the end of the wire so the spool cannot slip off.
- ☐ 5. Tie the string around the book.
- ☐ 6. Pick up the book by the string.
- ☐ 7. Bend the top of the "L" so it can be hooked over the back of a chair.
- ☐ 8. Pass the string over the spool.
- ☐ 9. Pull the string to move the book.

3.7 A single fixed pulley simply changes the _____ of the effort.

A movable single pulley multiples the effort. The IMA of a single movable pulley is 2; that is, the effort force (F_e) of this system is half the resistance force (F_r), but the effort distance (d_e) is twice the resistance distance (d_r).

In a pulley system a 5-newton weight is to be lifted 2 metres. The rope is pulled 10 metres. The IMA is then 10 metres divided by 2 metres.

$$\text{IMA} = \frac{10\ \text{m}}{2\ \text{m}} = 5$$