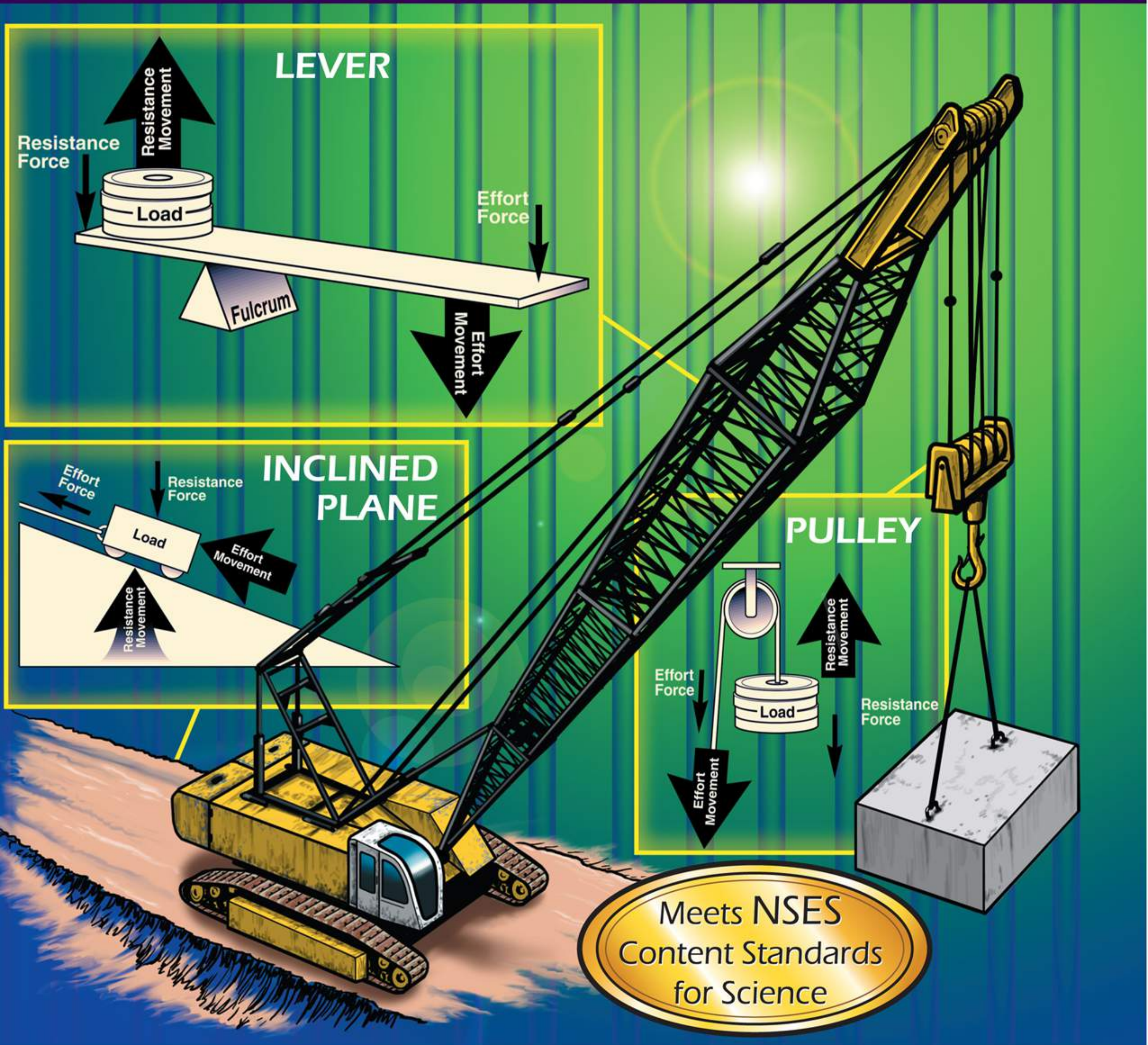
CD-1558

Teacher Resource & Student Activity Book

GRADES 5-8+

SIMPLE MACHINES

CONNECTING STUDENTS TO SCIENCE SERIES



By Dr. Barbara R. Sandall

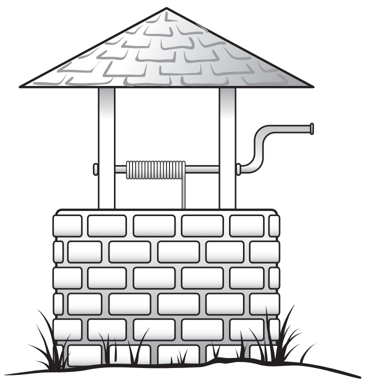
Mark Twain Media/Carson-Dellosa Publishing Company, Inc.

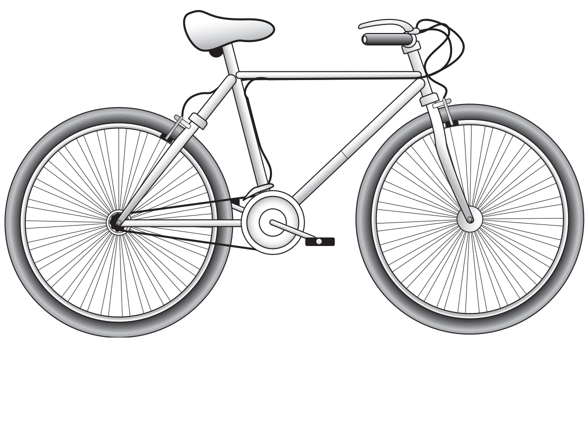
Introduction to the Series

The Connecting Students to Science Series is designed for grades 5–8+. This series will introduce the following topics: Simple Machines, electricity and Magnetism, rocks and Minerals, atmosphere and Weather, Chemistry, light and Color, The Solar System, and Sound. each book will contain an introduction to the topic, naive concepts and terminology, inquiry activities, content integration, children's literature connections, curriculum resources, assessment documents, and a bibliography and materials list. all of the activities will be aligned with the national Science education Standards and the national Council of Teachers of Mathematics Standards.

This series is written for classroom teachers, parents, families, and students. The books in this series can be used as a full unit of study or as individual lessons to supplement existing textbooks or curriculum programs. activities are designed to be pedagogically sound hands-on, minds-on science activities that support the national Science education Standards (nSeS). Parents and students could use this series as an enhancement to what is being done in the classroom or as a tutorial at home.

The procedures and content background are clearly explained in the introductions of the individual activities. Materials used in the activities are commonly found in classrooms and homes. If teachers are giving letter grades for the activities, points may be awarded for each level of mastery indicated on the assessment rubrics. If not, simple check marks at the appropriate levels will give students feedback on how well they are doing.





Introduction to the Concepts: Historical Perspective

Tools date back to 6000 B.C. when bows and arrows and spears were used for hunting. Dugout boats were used for transportation. Wheeled vehicles were first used in Mesopotamia in 3500 B.C. In 3000 B.C., levers and ramps were used to move heavy loads, and sailboats and wooden ships traveled the seas. In 2000 B.C., horse-drawn vehicles were used, and spoke wheels were invented. In 1500 B.C., pulleys were used by the assyrians, and in 1000 B.C., woodworking lathes, cranes, and complex pulleys were used.

From A.D. 1 to A.D. 500, there were waterwheels, r oman wood planes, and Chinese cranks. The wheelbarrow was created in China during this time. archimedes (287–212 B.C.) discovered the laws of levers and pulleys. he also invented the archimedian screw and the catapult. The **Archimedian screw** was a device invented to raise water. It consisted of a screw snugly fit into a cylindrical casing and was used in the nile valley for irrigation. The **catapult** is a machine that works like a slingshot and is capable of launching heavy objects.

Introduction to the Concepts: Simple Machines

a **machine** is a device that increases or decreases a force or changes the direction of the force. Simple machines are all around us. **Simple machines** change the amount, distance, or direction of a force needed to do work. The scientific definition of **work** is the force needed to move an object through a distance. **Work** is the product of the **effort force** multiplied by the **distance** through which the object is moved. **W** = Work, **f** = effort force, and **d** = distance the object is moved: **W = f x d**

Simple machines also offer mechanical advantage. **Mechanical advantage** compares the force produced by a machine with the force applied to the machine. It can be found by dividing the force of resistance by the force of the effort.

$$\textbf{Mechanical Advantage} = \frac{\textbf{force of Resistance (Load)}}{\textbf{force of Effort}}$$

This formula calculates an ideal mechanical advantage and does not take into consideration the friction involved. **friction** is a force that resists motion. It can reduce the amount of work that can be done with a given force. another force involved with machines is **inertia**, the resistance of an object to change its motion.

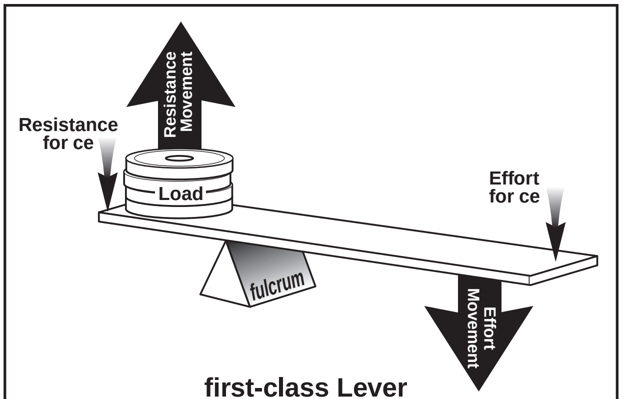
Isaac newton's three **Laws of Motion** include the laws of Inertia, acceleration, and action and reaction. The **first Law** is the **Law of Inertia**, which states an object at rest stays at rest until acted upon by another force; it stays in motion in a straight line at a constant speed until acted upon by another force. The **Law of Acceleration**, the **Second Law**, states that acceleration produced by a force on a body is directly proportional to the magnitude of the net force, is in the same direction as the force, and is inversely proportional to the mass of the body. newton's **Third Law**, the **Law of Action and Reaction** states that for every action there is an equal and opposite reaction.

Introduction to the Concepts: Simple Machines (cont.)

Simple machines can be divided into two main groups. The first group is **levers**, and the second is **inclined planes**.

Levers

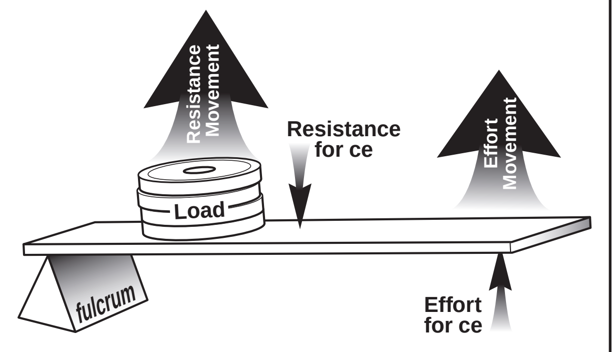
The simplest machine is a lever. a **lever** is a bar that can turn on a fixed point, the **fulcrum**. a lever can be used to multiply the force or change the direction of the force. a lever has a **resistance or load** (the object being moved), a **fulcrum or pivot point** for the bar, and a **force** (any push or pull on an object) to move the object. as shown in the diagrams, the effort force and effort movement are in the same direction. The resistance force is in the direction of gravity, and the resistance motion is in the opposite direction. The resistance on a machine may be due to the force of gravity, friction, and inertia. In order to simplify the discussion, the **resistance force** referred to in this book is the force of gravity.



first-class Lever

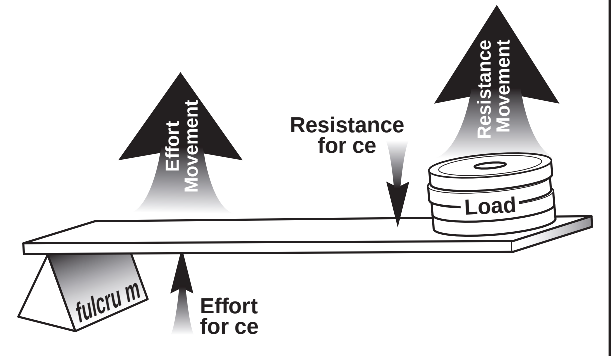
There are three classes of levers. Using a **first-class lever**, the force changes directions. The load is on one side of the fulcrum, and the forces are on the other side of the lever. When the force pushes down on one end, the load (resistance) moves up. an example of this would be using a crowbar to pry the lid off a box.

In a **second-class lever**, the load is placed between the force and the fulcrum. The direction of the force stays the same as the load. The force on the load is increased; however, the load will not move as far. an example of this is a wheelbarrow.



Second-class Lever

The **third-class lever** is similar to the first-class lever with the fulcrum at one end and the load on the other end. however, a third-class lever has the force applied between the fulcrum and the load. The effort force and the load are moving in the same direction. an example of this type of lever is your elbow and your lower arm. The fulcrum is your elbow, and the load is your hand. The force is applied in the middle by your biceps muscles.



Third-class Lever

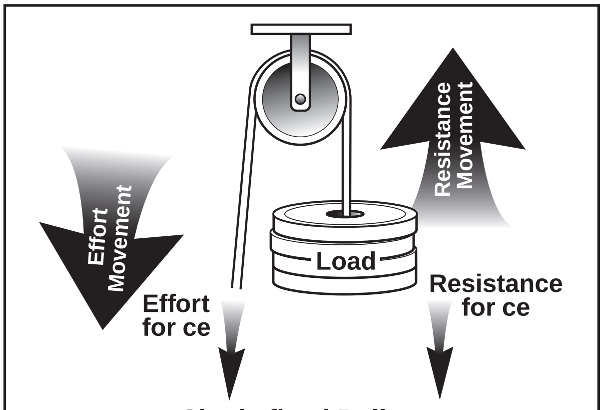
Introduction to the Concepts: Simple Machines (cont.)

Some of the machines we use every day are knives, forks, spoons, needles, scissors, pliers, screws, screwdrivers, hammers and nails, etc. This book will introduce you to simple machines and how they work.

a **pulley** is a kind of lever that can change the direction of a force and/or multiply force. as shown in the diagrams below, the effort force and effort movement are in the same direction. The resistance force is in the direction of gravity, and the resistance motion is in the opposite direction.

Pulleys can be set up in three different ways: a **single fixed pulley**, a **moveable pulley**, or a **block and tackle**.

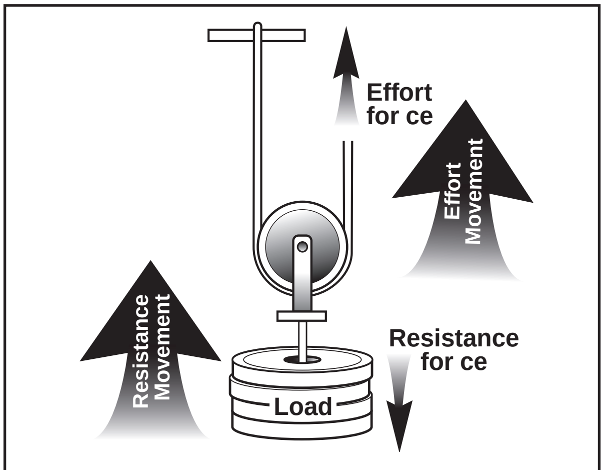
a **single fixed pulley** behaves like a first-class lever with the fulcrum (axis of the pulley) between the force and the load. The load moves up as the force goes down. This type of pulley only changes the direction of the force.



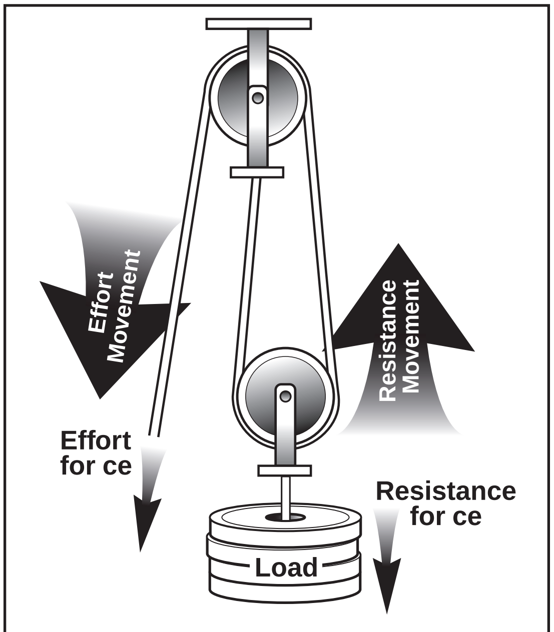
Single fixed Pulley

a **moveable pulley** is set up so the force and load move in the same direction. a moveable pulley resembles a second-class lever. The fulcrum is at the end of the lever where the supporting rope touches the pulley. The load is suspended from the pulley between the fulcrum and the force. The force in this type of pulley is multiplied.

In a **block and tackle system**, pulleys can change the direction of a force and multiply the force. The block and tackle system consists of a fixed and a moveable pulley. In a block and tackle system, the effort force moves downward as the load moves up. The number of lines determines how much the force is amplified.



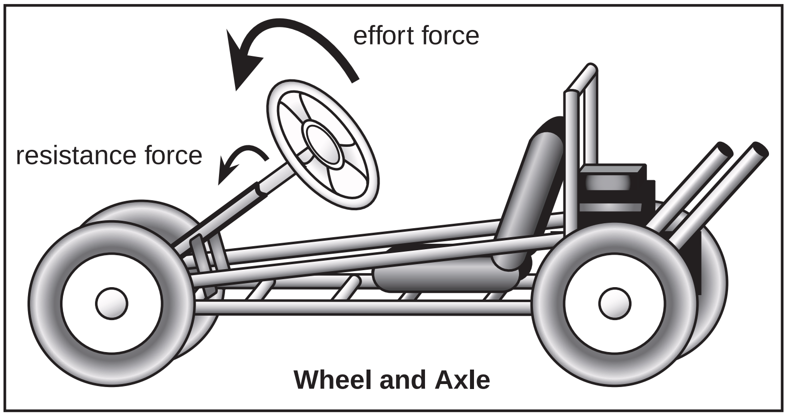
Moveable Pulley



Block and Tackle System

Introduction to the Concepts: Simple Machines (cont.)

The **wheel and axle** is another form of a lever. The bar is changed into a circle moving around a fulcrum. In the example pictured here, the steering wheel (wheel) is rigidly attached to the steering wheel column (axle). The radius of the steering wheel represents one lever and the radius of the steering wheel column represents a second lever. hence, we have two wheels of unequal diameter, fastened so they turn together. In the steering wheel assembly, the effort force is applied to the steering wheel and the steering wheel column represents the resistance force. Ideal mechanical advantage is equal to the diameter of the wheel (D) divided by the diameter of the axle (d). **IMA = D/d**.



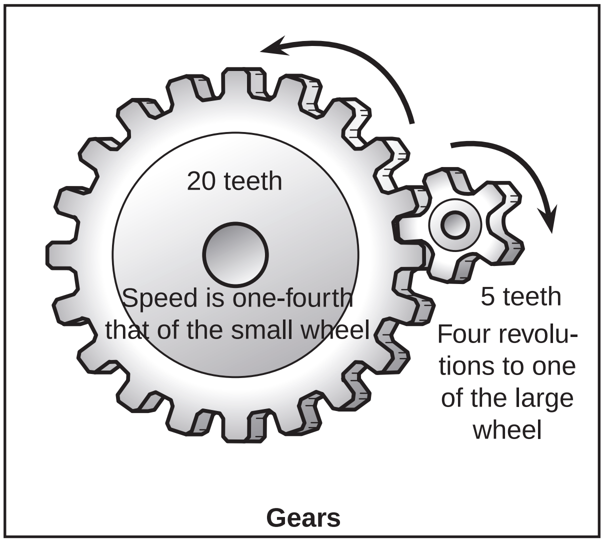
Wheel and Axle

examples of a wheel and axle include a playground merry-go-round, a screwdriver, a hand drill, a wrench, a faucet, and a steering wheel.

Gears are toothed wheels and axles. like all other machines, the gears can change the direction in which the force is applied, or it can increase or decrease the force or distance over which the force is applied. **Gear wheels** are compound machines made of a wheel and axle and a lever. Gears need to work in pairs—a combination of two simple machines working together. When two or more simple machines work together to perform one task, it becomes a **compound machine**.

Two or more gears meshed together are called a **gear train**. The gear on which the force is applied is the **driver**, and the other gear is the **driven gear**. any gears between the driver and the driven gear are called **idlers**. The gear wheels are meshed together to make one turn the other, so they will turn in opposite directions. The number of teeth on the gear will determine the number of rotations it takes to turn the other gear. If a large gear has 20 teeth and is meshed with a smaller gear with 5 teeth, the smaller gear turns four times for every one turn of the larger gear. The larger gear multiplies the force. Doing the same amount of work, it takes one-fourth less force to move the same distance. examples of machines using gears are bicycles, cars, clocks, and music boxes.

Gear wheel combinations of different diameters, as in the diagram at right, are used to increase or decrease speed. If we apply the effort force to the larger wheel we gain speed, since the second wheel will make four revolutions while the first is making one.

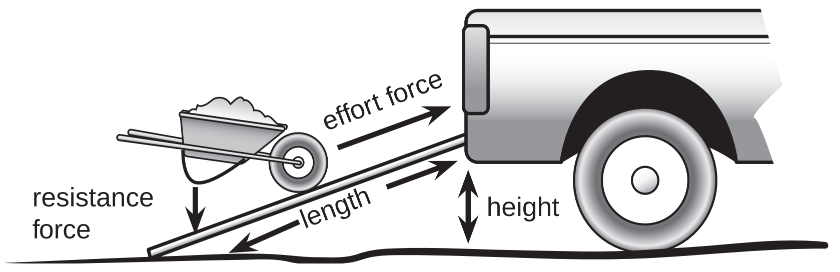


Gears

Introduction to the Concepts: Simple Machines (cont.)

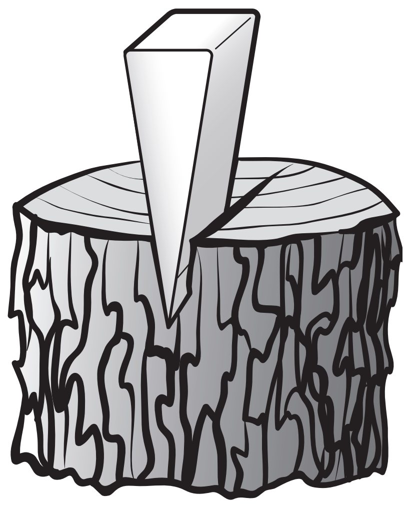
Inclined Planes

The second group of simple machines is the **inclined plane**. an inclined plane is a flat, sloping surface over which objects can be moved to a higher level. Inclined planes can be divided into three different types: the ramp, the wedge, and the screw or bolt. an inclined plane can be used to form a ramp. a **ramp** spreads the force over a longer distance, so it takes less force to lift an object. as shown in the diagram above, the effort force and effort movement are in the same direction. The resistance force is in the direction of gravity, and the resistance motion is in the opposite direction. examples are stairs, escalators, handicap ramps, and skateboard ramps.

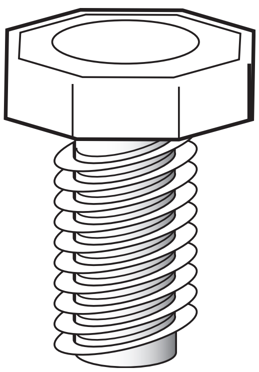


Inclined Plane

a **wedge** is two inclined planes put back-to-back. like the ramp, the wedge spreads the force needed to move the load over a longer distance. examples are a knife, an ax, the point of a needle, a nail, and scissors blades.


Wedge

a **bolt** or **screw** is an inclined plane wrapped around a central point or a winding inclined plane. examples of winding inclined planes are a winding staircase, drill bit threads, wood screw threads, bolts, and pigtail curves in the mountains. The wood screw and drill bit are compound machines because the threads are inclined planes, but there is a wedge on the points.


Bolt

This book will discuss simple and compound machines, real-life examples of machines, and how they work. Some common machines include toothbrushes, hair dryers, light switches, faucet handles, cars, trains, and buses.

Naive Concepts and Terminology

Introduction

our understanding of the natural world is directly related to everyday experience, including experiences in and out of the science classroom. however, the everyday descriptions of phenomena may lead to concepts that are either incomplete or inaccurate. For example, we may observe a glass of iced tea with water collecting and running down the outside of the glass and state, “The glass is sweating.” Such a statement may lead us to inaccurately infer as to the source of the moisture on the outside of the glass. a careful and thoughtful analysis of this phenomena will lead us to infer that the moisture on the outside of the glass is condensation and that the source of the moisture is the water vapor from the surrounding air.

We may refer to our developing conception of the world and the way things work or the way life works as being in the process of development. In this way, some of our ideas may be naive. Some authors prefer referring to these developing concepts as misconceptions; however, we will refer to them as **naive ideas**.

Some Naive Ideas Related to Simple Machines

o ne area for potential naive ideas is related to the terminology used. Many commonly-used words have a specific and alternative meaning in science. a second area that may serve as a source for naive conceptions occurs when intuitive ideas gained through everyday experience are contrary to the more formal structure of scientific concepts. In order to reduce the confusion caused by naive ideas, definitions for important scientific concepts will be included here.

- **Work** in everyday language has many meanings, including some of the following. It might mean that we are exerting muscular effort, or it may simply refer to our daily duties related to job or school. In physical science, the word *work* has a particular meaning. Work is done when a force acts on a body and moves it. For instance, no matter how long you hold a 20-kilogram load on your shoulder, you are not doing any work according to the scientific definition of the term. You are merely exerting an upward force, which supports the downward force of the 20-kilogram load. You do work when you raise the 20-kilogram load to your shoulder, or when you carry the load up a flight of stairs, or push it across the floor.

  Two factors must be considered then when measuring work: (1) the force applied, and (2) the distance through which the force acts. In work, **distance** is the change of position of an object.
- In science, **work** is the product of a force and the distance through which it acts or that which is done when a force acts on matter and moves it. **W = f x d** , **W** = work, **f** = Force, and **d** = distance.

  - **English System:** a force of one pound acting through a distance of one foot does one foot-pound of work.

  - **Metric System:** a force of one newton acting through a distance of one meter, does one joule of work. note that on earth, we must exert a force of about 9.8 newtons to lift a mass of 1.0 kg. hence, a rough equivalent exists. 1 nt = 100 g., newton = nt

Naive Concepts and Terminology (cont.)

Example A: a box weighs 150 pounds. how much work is done when carrying the box up a flight of stairs 20 feet high?

W = fd W = 150 lb. X 20 ft. W = 3,000 ft-lb.

Example B: a force of 600 newtons is required to carry a box up a flight of stairs 5 meters high. how much work is done?

W = fd W = 600 nt X 5 m W = 3,000 joules of work

- **force** may be defined as a push or a pull in a particular direction or that which produces or prevents motion. The measure of the attractive force of the earth for a body is called the **weight** of the body. The measure of the quantity of matter that a body contains is called **mass**.

  In the metric system, force is measured in **newtons**. a newton is used because it includes both mass and acceleration of the mass. note that acceleration includes distance and time or rate of change of velocity. Force then equals mass times acceleration. one kilogram meter/sec^2.
- **Acceleration:** net Force/mass
- **Energy:** The ability to do work
  - **Potential energy** is stored energy or energy due to the position of a mass.
  - **Kinetic energy** is energy due to the motion of a mass.
- **Harder/Easier**: Simple machines help us do work; they don't do the work for us. They allow us to change the amount of force required to do work, and they can change the distance or the direction through which a force acts. In this way, they allow us to do things that we otherwise would not be able to do.
- **Power** is the time rate of doing work or the rate of doing work. hence, power equals work divided by time or **P = W / t**.
- **Effort** is represented by the force that you apply to move a load (resistance). effort is sometimes referred to as **effort force**.
- **Resistance** is represented by the force of the load or object being moved. resistance is sometimes referred to as **resistance force**.
- **fulcrum:** a pivot point in a lever
- **Inertia:** resistance of an object to change its motion
- **Load:** resistance or what is being moved
- **Advantage** is related to resistance and effort. The ratio of the resistance force to the effort force is called **ideal mechanical advantage**.
- **Mechanical advantage** has two definitions: ideal mechanical advantage and actual mechanical advantage.

Naive Concepts and Terminology (cont.)

- **Ideal Mechanical Advantage** is the ratio of the distance the effort force moves to the distance the resistance force moves.
- **Actual Mechanical Advantage** is the ratio of the resistance force to the effort force.

- **Torque** is a moment of force that causes a rotation. Moment of force refers to mass x distance. levers, pulleys, and the wheel and axle all involve torque.

- **Simple Machine:** Changes the amount, distance, or direction of a force needed to do work. Simple machines may be classified into two groups: levers and inclined planes. **Levers** include the lever, the pulley, and the wheel and axle. **Inclined planes** include the inclined plane, the wedge, and the screw. other machines are either modifications of a simple machine or combinations of two or more of these.

  We use machines to help us do work. Machines can change the direction in which a force acts; they can change force; or they can change the distance through which the force acts.

- **Simple machines** are designed to do specific jobs:
  - a **lever** is a rigid bar that is free to rotate about a point called a fulcrum.
  - The **pulley** is a wheel that turns readily on an axle. The axle is usually mounted on a frame.
  - The **wheel and axle** is a wheel rigidly fixed to an axle.
  - The **inclined plane** is a device that allows us to increase the height of an object without lifting it vertically.
  - The **wedge** is a double inclined plane.
  - The **screw** is an inclined plane wound around a cylinder.

- **Compound Machine:** Two or more simple machines working together

- **Newton's Laws of Motion**
  - **Law 1 (Law of Inertia):** an object at rest stays at rest unless acted upon by another force; an object in motion stays in motion in a straight line at a constant speed until acted upon by another force.
  - **Law 2 (Law of Acceleration):** acceleration produced by a force on a body is directly proportional to the magnitude of the net force, is in the same direction as the force, and is inversely proportional to the mass of the body.
  - **Law 3 (Law of Action and Reaction):** For every action, there is an equal and opposite reaction.