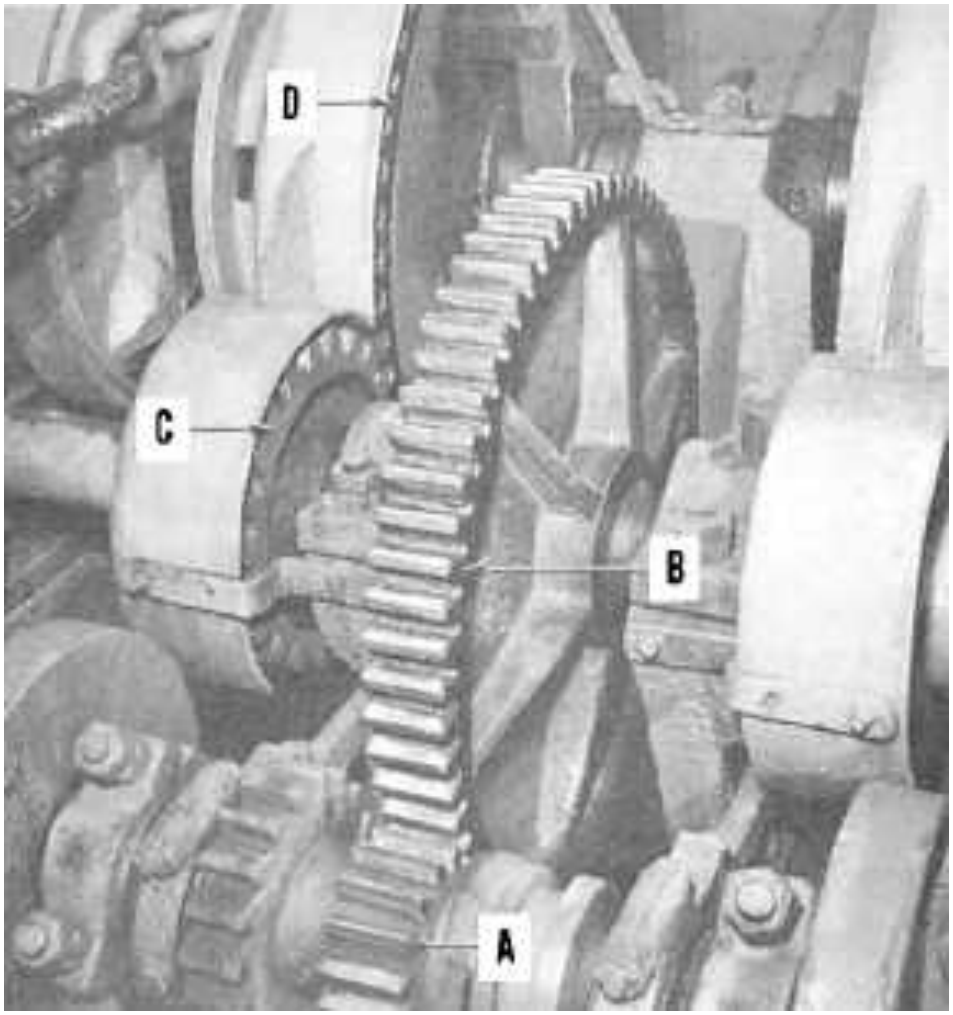
Do Now:

What are the 3 ways a machine helps make work easier?

Mechanical Advantage and Efficiency of Machines



Mechanical Advantage

- If you compare the input force to the output force, you can find the advantage of using a machine
- A machine's mechanical advantage is the number of times a machine increases a force exerted on it
- Finding the ratio of output force to input force gives you the **mechanical advantage** of a machine

$$\text{Mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

Increasing Force

- When the output force is greater than the input force, the mechanical advantage of a machine is greater than 1
- Suppose you exert an input force of 10 newtons on a hand-held can opener, and the opener exerts an output force of 30 Newtons on a can
- The mechanical advantage of the can opener is: $\frac{\text{Output force}}{\text{Input force}} = \frac{30\ \text{N}}{10\ \text{N}} = 3$
- The can opener triples your input force!

Without the mechanical advantage of the can opener, opening the can would be very difficult.

Increasing Distance

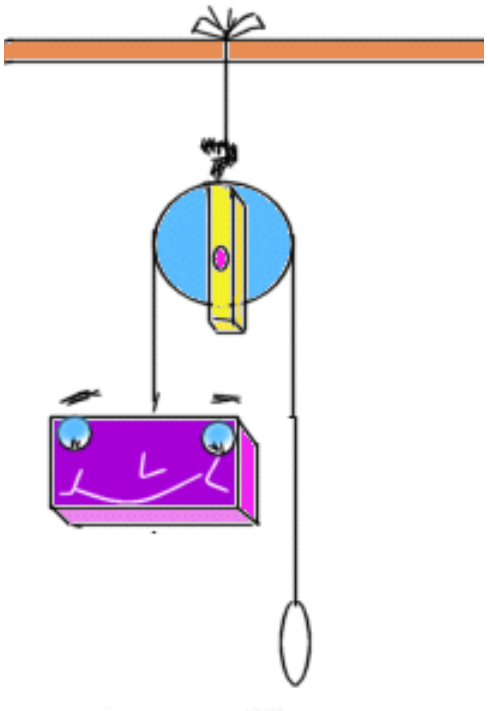
- If the output force is less than the input force, the mechanical advantage of the machine is less than 1
- This type of machine exerts that force over a long distance
- For example, suppose your input force is 20 Newtons and the machine's output force is 10 Newtons
- The mechanical advantage is:

$$\frac{\text{Output force}}{\text{Input force}} = \frac{10\ \text{N}}{20\ \text{N}} = 0.5$$

- The output force of the machine is half your input force, but the machine exerts that force over a longer distance

You need to apply a lot of force to the spoon in order to hold it, but the spoon applies little force to hold the cereal. You move the spoon a short distance in the cereal but the spoon moves the cereal a great distance to your mouth.

Changing Direction



- What can you predict about the mechanical advantage of a machine that changes the direction of the force?
- If only the direction changes, the input force will be the same as the output force
- The mechanical advantage will always be 1

Closure:

Calculate the mechanical advantage of a machine that has an input force of 15 N and an output force of 60 N.

Do Now:

Suppose that with a pulley system, you need to exert a force of 1,400 N to lift a heavy object. But without the pulley system, you need to exert 4,200 N to lift the object. What is the mechanical advantage of the pulley system?

Efficiency of Machines

- So far, you have learned that the work you put into a machine is exactly equal to the work done by the machine
- In an ideal situation, this equation is true
- In real situations, however, the output work is always less than the input work

Friction and Efficiency

- If you have ever tried to cut something with scissors that barely open and close, you know that a large part of your work is wasted overcoming the tightness, or friction, between the parts of the scissors
- In every machine, some work is wasted overcoming the force of friction
- The less friction there is, the closer the output work is to the input work
- To calculate the efficiency of a machine, divide the output work by the input work and multiply the result by 100 percent
- This is summarized by the following formula

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

- The **efficiency** of a machine compares the output work to the input work
- Efficiency is expressed as a percent
- The higher the percent, the more efficient the machine is
- If you know the input work and output work for a machine, you can calculate a machine's efficiency

- If the rusty, tight scissors (left) have an efficiency of 60%, only a little more than half of the work you do goes into cutting the paper
- The rest is wasted overcoming the friction in the scissors

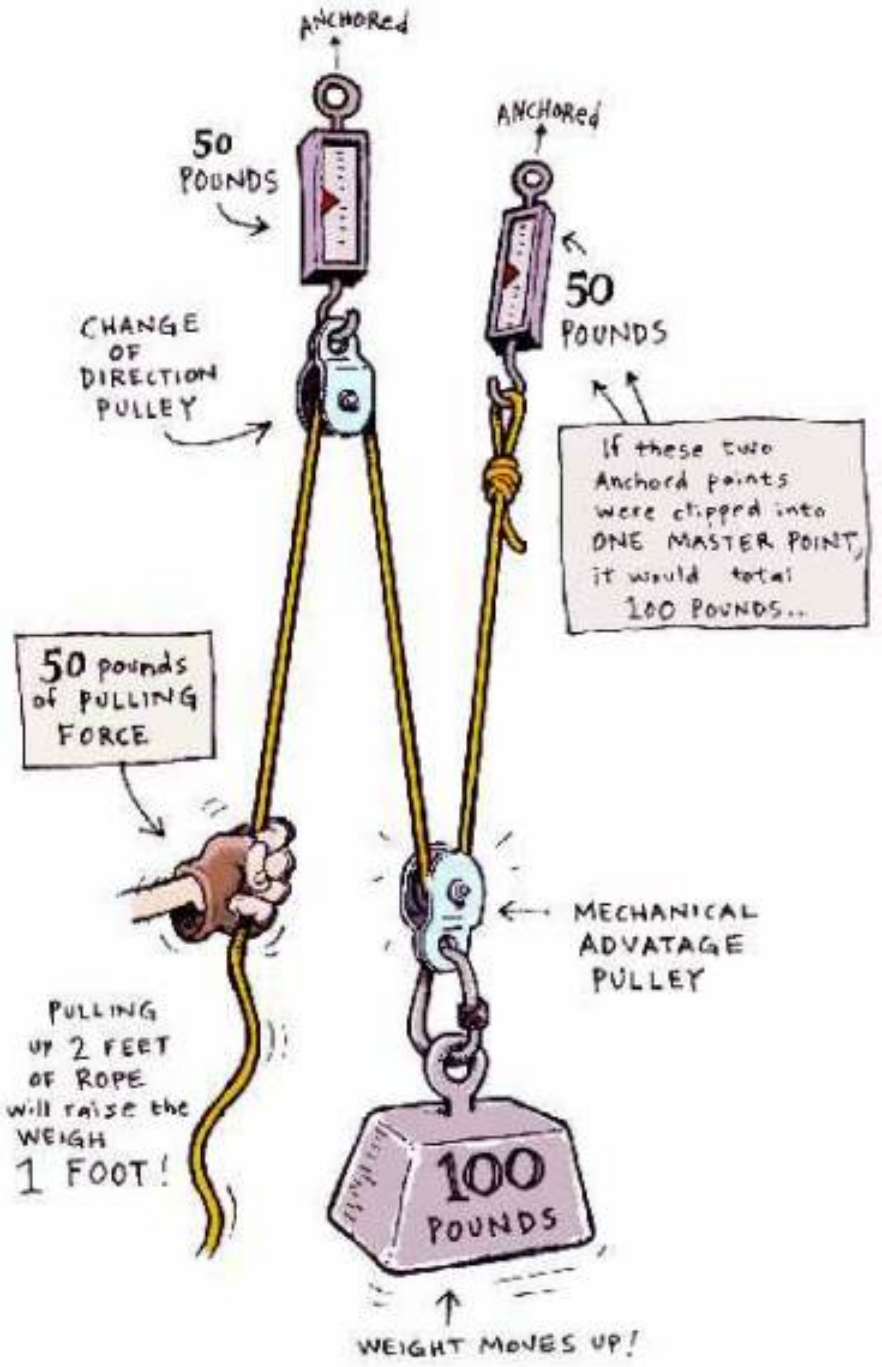
Journals:

- **Calculating Efficiency** You do 20 J of work while using a hammer. The hammer does 18 J of work on a nail. What is the efficiency of the hammer?
- **(2) Calculating Efficiency** Suppose you left your lawn mower outdoors all winter. Now it's rusty. Of your 250,000 J of work, only 100,000 J go to cutting the lawn. What is the efficiency of the lawn mower now?

Real and Ideal Machines

- If you could find a machine with an efficiency of 100%, it would be an ideal machine
- Unfortunately, such a machine does not exist

- In all machines, some work is wasted due to friction
- So all machines have an efficiency of less than 100%
- The machines you use every day, such as scissors, screwdrivers, and rakes, lose some work due to friction



A machine's ideal mechanical advantage is its mechanical advantage with 100% efficiency.

However, if you measure a machine's input force and output force, you will find the efficiency is always less than 100%.

A machine's measured mechanical advantage is called actual mechanical advantage.

Closure:

What is the difference between Ideal and Actual mechanical advantage?