Name: _____ Date: _____

CONTENT 9.2

9.2 Mechanical Advantage of Simple Machines

READ 

We use simple machines to make tasks easier. While the output work of a simple machine can never be greater than the input work, a simple machine can multiply input forces OR multiply input distances (but never both at the same time). You can use this skill sheet to practice calculating mechanical advantage (MA) for two common simple machines: levers and ramps.

The general formula for the mechanical advantage (MA) of levers:

$$MA_{lever} = \frac{F_o \text{ (output force)}}{F_i \text{ (input force)}}$$

Or you can use the ratio of the input arm length to the output arm length:

$$MA_{lever} = \frac{L_i \text{ (length of input arm)}}{L_o \text{ (length of output arm)}}$$

Most of the time, levers are used to multiply force to lift heavy objects.

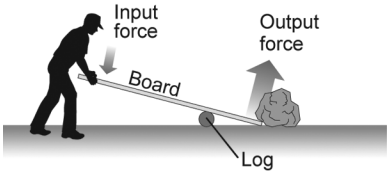
The general formula for the mechanical advantage (MA) of ramps:

$$MA_{ramp} = \frac{\text{ramp length}}{\text{ramp height}}$$

A ramp makes it possible to move a heavy load to a new height using less force (but over a longer distance).

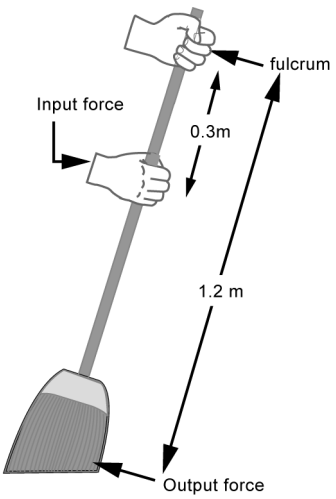
EXAMPLE

Example 1: A construction worker uses a board and log as a lever to lift a heavy rock. If the input arm is 3 meters long and the output arm is 0.75 meters long, what is the mechanical advantage of the lever?



$$MA = \frac{3 \text{ meters}}{0.75 \text{ meter}} = 4$$

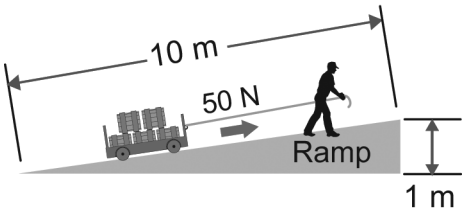
Example 2: Sometimes levers are used to multiply distance. For a broom, your upper hand is the fulcrum and your lower hand provides the input force: Notice the input arm is shorter than the output arm. The mechanical advantage of this broom is:



$$MA = \frac{0.3 \text{ meter}}{1.2 \text{ meters}} = 0.25$$

A mechanical advantage less than one doesn't mean a machine isn't useful. It just means that instead of multiplying force, the machine multiplies distance. A broom doesn't push the dust with as much force as you use to push the broom, but a small movement of your arm pushes the dust a large distance.

Example 3: A 500-newton cart is lifted to a height of 1 meter using a 10-meter long ramp. You can see that the worker only has to use 50 newtons of force to pull the cart. You can figure the mechanical advantage in either of these two ways:



$$MA_{ramp} = \frac{\text{ramp length}}{\text{ramp height}} = \frac{10 \text{ meters}}{1 \text{ meter}} = 10$$

Or using the standard formula for mechanical advantage:

$$MA = \frac{\text{output force}}{\text{input force}} = \frac{500 \text{ newtons}}{50 \text{ newtons}} = 10$$

$$\text{Mechanical advantage} = \frac{\text{ramp length}}{\text{height}} = \frac{10}{1}$$

PRACTICE

Lever problems

1. A lever used to lift a heavy box has an input arm of 4 meters and an output arm of 0.8 meters. What is the mechanical advantage of the lever?
2. What is the mechanical advantage of a lever that has an input arm of 3 meters and an output arm of 2 meters?
3. A lever with an input arm of 2 meters has a mechanical advantage of 4. What is the output arm's length?
4. A lever with an output arm of 0.8 meter has a mechanical advantage of 6. What is the length of the input arm?
5. A rake is held so that its input arm is 0.4 meters and its output arm is 1.0 meters. What is the mechanical advantage of the rake?
6. A broom with an input arm length of 0.4 meters has a mechanical advantage of 0.5. What is the length of the output arm?
7. A child's toy rake is held so that its output arm is 0.75 meters. If the mechanical advantage is 0.33, what is the input arm length?

Ramp problems

8. A 5-meter ramp lifts objects to a height of 0.75 meters. What is the mechanical advantage of the ramp?
9. A 10-meter long ramp has a mechanical advantage of 5. What is the height of the ramp?
10. A ramp with a mechanical advantage of 8 lifts objects to a height of 1.5 meters. How long is the ramp?
11. A child makes a ramp to push his toy dump truck up to his sandbox. If he uses 5 newtons of force to push the 12-newton truck up the ramp, what is the mechanical advantage of his ramp?
12. A ramp with a mechanical advantage of 6 is used to move a 36-newton load. What input force is needed to push the load up the ramp?
13. Gina wheels her wheelchair up a ramp using a force of 80 newtons. If the ramp has a mechanical advantage of 7, what is the output force (in newtons)?
14. **Challenge!** A mover uses a ramp to pull a 1000-newton cart up to the floor of his truck (0.8 meters high). If it takes a force of 200 newtons to pull the cart, what is the length of the ramp?

Name: _____ Date: _____

CONTENT 9.2

9.2 Mechanical Advantage

READ 

Mechanical advantage (MA) is the ratio of output force to input force for a machine.

$$MA = \frac{F_o}{F_i}$$

or

$$MA = \frac{\text{output force (N)}}{\text{input force (N)}}$$

Did you notice that the force unit involved in the calculation, the newton (N) is present in both the numerator and the denominator of the fraction? These units cancel each other, leaving the value for mechanical advantage unitless.

$$\frac{\text{newtons}}{\text{newtons}} = \frac{\text{N}}{\text{N}} = 1$$

Mechanical advantage tells you how many times a machine multiplies the force put into it. Some machines provide us with more output force than we applied to the machine—this means MA is greater than one. Some machines produce an output force smaller than our effort force, and MA is less than one. We choose the type of machine that will give us the appropriate MA for the work that needs to be performed.

EXAMPLE ▶

Example 1: A force of 200 newtons is applied to a machine in order to lift a 1,000-newton load. What is the mechanical advantage of the machine?

$$MA = \frac{\text{output force}}{\text{input force}} = \frac{1000\ \text{N}}{200\ \text{N}} = 5$$

Machines make work easier. Work is force times distance ($W = F \times d$). The unit for work is the newton-meter. Using the work equation, as shown in example 2 below, can help calculate the mechanical advantage.

Example 2: A force of 30 newtons is applied to a machine through a distance of 10 meters. The machine is designed to lift an object to a height of 2 meters. If the total work output for the machine is 18 newton-meters (N-m), what is the mechanical advantage of the machine?

$$\text{input force} = 30\ \text{N} \qquad \text{output force} = (\text{work} \div \text{distance}) = (18\ \text{N-m} \div 2\ \text{m}) = 9\ \text{N}$$

$$MA = \frac{\text{output force}}{\text{input force}} = \frac{9\ \text{N}}{30\ \text{N}} = 0.3$$

PRACTICE

1. A machine uses an input force of 200 newtons to produce an output force of 800 newtons. What is the mechanical advantage of this machine?

2. Another machine uses an input force of 200 newtons to produce an output force of 80 newtons. What is the mechanical advantage of this machine?

3. A machine is required to produce an output force of 600 newtons. If the machine has a mechanical advantage of 6, what input force must be applied to the machine?

4. A machine with a mechanical advantage of 10 is used to produce an output force of 250 newtons. What input force is applied to this machine?

5. A machine with a mechanical advantage of 2.5 requires an input force of 120 newtons. What output force is produced by this machine?

6. An input force of 35 newtons is applied to a machine with a mechanical advantage of 0.75. What is the size of the load this machine could lift (how large is the output force)?

7. A machine is designed to lift an object with a weight of 12 newtons. If the input force for the machine is set at 4 newtons, what is the mechanical advantage of the machine?

8. An input force of 50. newtons is applied through a distance of 10. meters to a machine with a mechanical advantage of 3. If the work output for the machine is 450 newton · meters and this work is applied through a distance of 3 meters, what is the output force of the machine?

9. 200. newton·meters of work is put into a machine over a distance of 20. meters. The machine does 150. newton·meters of work as it lifts a load 10. meters high. What is the mechanical advantage of the machine?

10. A machine has a mechanical advantage of 5. If 300. newtons of input force is used to produce 3,000. newton·meters of work,
    a. What is the output force?
    b. What is the distance over which the work is applied?