Name: _____

Skill Sheet 10.1 Mechanical Advantage

Mechanical advantage (MA) can be defined as the ratio of output force to input force for a machine In other words, MA 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.

1. What is mechanical advantage?

Mathematically, mechanical advantage may be expressed using either of the following equations:

$$MA = \frac{\text{output force}}{\text{input force}} = \frac{F_o}{F_i}$$

or

$$MA = \frac{\text{input lever arm}}{\text{output lever arm}} = \frac{L_i}{L_o}$$

If we look at the force unit involved in the calculation, the newton (N), we see that it is present in both the numerator and the denominator of the fraction. Units behave like numbers in mathematical calculations. They can cancel each other, leaving the value for mechanical advantage as a unit-less quantity.

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

2. Calculating mechanical advantage

The following set of problems is designed to provide you with practice using the mechanical advantage formula. The first one is done for you.

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?

$$MA = \frac{\text{output force}}{\text{input force}} = \frac{1{,}000\ \text{N}}{200\ \text{N}} = 5$$

2. 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?

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3. 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, or how large is the output force?

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

5. A lever has an input arm of 1.5 meters, an output arm of 0.5 meters. What is the mechanical advantage?

6. A person with a mass of 80 kilograms wants to lift a stone with a mass of 600 kilograms. The person wants to use a steel bar 2 meters long. Calculate the minimum ratio of the input to the output arm and the maximum output lever arm.

3. Looking ahead

Machines make work easier. Remember that work is force times distance ($W = F \times d$). The unit for work is the newton-meter, or often called the joule. Remembering that a joule is the same as a newton-meter will help you cancel units as you work through the problems in this section.

We put work into a machine (work input) and the machine produces work for us in return (work output). The work output is never greater than the work input. In fact, work output is always less than work input because of *friction*. Friction reduces the amount of energy available to the machine. Less energy for the machine means less work done by the machine.

In spite of the loss of work due to friction, the machine still makes work easier because machines can provide mechanical advantage (*MA*).

Machines can multiply your input force (when *MA* is greater than 1) so that you can lift a very heavy object. Machines can also diminish your input force (when *MA* is less than 1) so that you can handle a very delicate object that the force of your fingers could damage. Therefore, knowing a machine's mechanical advantage helps us choose a machine to perform a specific task.

Use the equations for work and mechanical advantage to solve the following problems. The first one is done for you.

1. 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 joules, what is the mechanical advantage of the machine?

   input force = 30 N output force= (work ÷ distance)= (18 J ÷ 2 m)= 9 N

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

2. 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 joules and this work is applied through a distance of 3 meters, what is the output force of the machine?

3. Two hundred joules of work is put into a machine over a distance of 20 meters. The machine does 150 joules of work as it lifts a load 10 meters high. What is the machine's mechanical advantage (*MA*)?