Name:

Skill Sheet 4-A 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 apply 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:

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

or

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

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. Since units behave like numbers in mathematical calculations:

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

The units cancel each other, leaving the value for mechanical advantage as a unit-less quantity.

2. Calculating mechanical advantage

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

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

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

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

3. An input force of 35 N 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)?

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

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, which is 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). This can be helpful in two ways. First, the object will move farther and faster than the input force; second, you can handle a very delicate object that the force of your fingers might damage. Therefore, knowing a machine's *MA* 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 N is applied to a machine to move 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

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

2. An input force of 50 N is applied to a machine with a mechanical advantage of 3 to move the object 3 meters. If 450 joules of work output is accomplished, what is the output force applied by the machine to the object?

3. 200 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 *MA* of the machine?