2.0 – An understanding of mechanical advantage and work helps in determining the efficiency of machines

2.1 –Machines Make Work Easier

Machines help people do things that they normally couldn't do on their own.

Mechanical Advantage
A machine makes work easier for you by increasing the amount of force that you exert on an object. This produces a **mechanical advantage**, which is the amount of force that is multiplied by the machine. The force applied to the machine (by you) is the ***input force***. The force that is applied to the object (by the machine) is the ***output force***.

Calculating Mechanical Advantage
The mechanical advantage of a machine is the output force divided by the input force.

$$MA = \frac{\text{Output Force}}{\text{Input Force}}$$

The mechanical advantage is the *force ratio* of a machine.

$$MA = \frac{F_{output}}{F_{input}}$$

F = Force in Newtons (**N**)

The more a machine multiplies the force, the greater is the mechanical advantage of the machine.

Speed Ratio
Speed measures the distance an object travels in a given amount of time. The measure of how a machine affects speed is called the **speed ratio**. It is calculated by dividing the ***input distance*** by the ***output distance***.

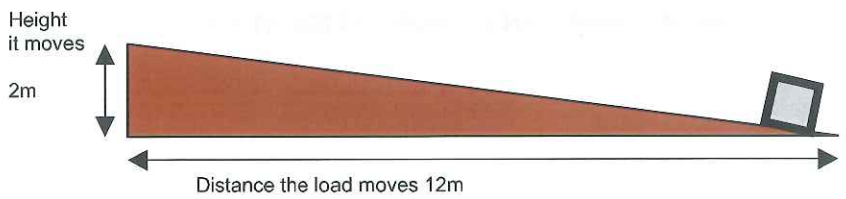
$$SR = \frac{\text{Input distance}}{\text{Output distance}}$$

$$SR = \frac{d_{input}}{d_{output}}$$

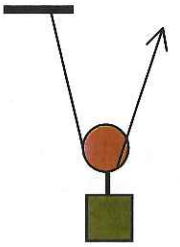
d = distance (**m**)

Using the formula provided, you can calculate the speed ratio of any device.

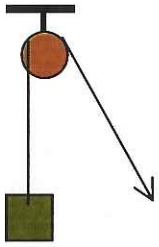
Less Force But Greater Distance
You do not get something for nothing when using a machine. The *advantage* to **gaining force** is offset by the *disadvantage* of **losing distance.**
An inclined plane makes it possible to lift heavy objects using a smaller force (examples: loading ramp, wheelchair access ramp), but you have to move the object over a much longer distance.



A **Pulley system** consists of one or more combinations of wheels and ropes, which can be fixed in place or movable. Pulleys help you lift larger loads. To calculate the **MA** of a pulley, count the number of ropes/cables **supporting the load.**



A single movable pulley
MA = **2**



A single fixed pulley
MA = **1**

Pulley System
MA = **4**

Pulley System
MA = **3**

A Mechanical Advantage Less Than 1
In the case of machines where the mechanical advantage is greater than 1 the machine is multiplying the input force to create a larger output force. If a machine has a mechanical advantage that is **less than 1**, it is useful for tasks that don't require a large output force. A bicycle is a machine with a mechanical advantage of less than 1. Even though it has a mechanical advantage of less than 1, the output force causes the bicycle to move faster than the rider could walk, so it is a very useful machine.

Comparing Real Mechanical Advantage With Speed Ratio
When people calculate mechanical advantage and speed ratio they may find that they are the same. In real situations however, when they are calculated, they can be very different. This is because of friction.

The Effect of Friction
The difference between the calculated value and the real (actual) value of mechanical advantage is friction, which is **a force that opposes motion**. Friction is caused by the roughness of materials. Because friction is a force in any device, additional force must be applied to overcome the force of friction. The mechanical advantage of the device will be less because of this added force that must be overcome. The speed ratio will not be affected. In fact, the speed ratio represents the *ideal mechanical advantage* of a machine – as if friction didn't exist. Friction in a system also causes heat, which can cause additional concerns.

Efficiency
Efficiency is a measure of how well a machine or a device uses energy. The more energy that is lost, the less efficient a machine is. Efficiency is represent in %.

$$\text{Efficiency} = \frac{\text{Mechanical Advantage}}{\text{Speed Ratio}} \times 100$$

In complex machines, there are many subsystems that are affected by friction and other factors. Because of this, most complex machines are not very efficient.

NO MACHINE CAN BE 100% EFFICIENT !!!!