ICP - Simple Machines Notes & Worksheet

There are six types of simple machines: levers, pulleys, wheel & axle, inclined planes (ramps), wedges, and screws. The first three all fall under the general category of levers, and the second three all fall under the general category of inclined planes. A simple machine is a device that can provide one of the two following benefits:

1. It can increase the force that is applied to the machine, so that the output (resistance) force is bigger than the input (effort) force.

OR

2. It can increase the speed at which a task is performed.

A simple machine can never provide both of the benefits listed above at the same time. If the force is increased, the speed at which the task is performed will decrease. If the speed of the task is increased, the output (resistance) force will be smaller than the input (effort) force.

In addition, a simple machine can also change the direction of the force, so that the direction of the effort force is different than the direction of the resistance force. A simple machine can change the direction of the force at the same time it is providing either of the benefits listed above.

Listed below are terms commonly used when describing simple machines. These terms have the same definition for all types of simple machines.

Input:

Effort Force (F_e) – the force applied to the machine (usually by you!)
Effort Distance (d_e) – the distance over which the effort force is applied (how far you push or pull)
Work In (W_{in}) – the amount of work that is applied to the machine ($W_{in} = F_e \times d_e$)

Output: (load)

Resistance Force (F_r) – the weight of the object that is being lifted
Resistance Distance (d_r) – the distance that the object being lifted is moved
Work Out (W_{out}) – the amount of work done by the machine ($W_{out} = F_r \times d_r$)

In addition to these terms, there are three common measurements used to describe simple machines. These terms are defined and discussed below.

The **mechanical advantage** of a machine is a number that is used to represent how much a machine increases the force that is applied to it. The number for the mechanical advantage is a factor that you can multiply by the effort force in order to determine the output force from the machine. For example, if a machine had a mechanical advantage of 3, then applying an effort force of 100 N would result in an output force of 300 N. If a machine had a mechanical advantage of ½, then applying an effort force of 100 N would result in an output force of 50 N.

In real machines, some of the work that you put in is used to overcome things like friction, which are taking some of the energy away from the system. An ideal machine is a perfect machine. All of the work that is put into the machine will be used to lift the object, and none of it will be wasted on "energy stealers", like friction. (These ideal machines don't really exist!)

It is common to look at the mechanical advantage from two perspectives:

1. What is the actual mechanical advantage (AMA) of the machine (in the real world)?
2. What would be the ideal mechanical advantage (IMA) if the machine had no friction?

The actual mechanical advantage of a machine is defined to be the resistance force divided by the effort force $AMA = \frac{F_r}{F_e}$.

The ideal mechanical advantage of a machine is defined to be the effort distance divided by the resistance distance $IMA = \frac{d_e}{d_r}$.

It is also common to look at the efficiency of a machine, or how much work you get out compared to how much work was input. The efficiency is given as a percentage, where a 100% efficient machine is one in which $W_{out} = W_{in}$. An 80% efficient machine only uses 80% of the work you put in to actually lift the object (i.e. if W_{in} = 100J then W_{out} = 80J). An ideal machine has an efficiency of 100%. Real machines will always have an efficiency that is less than 100%. The higher the efficiency, the closer the machine is to being ideal. The efficiency can be calculated in two ways:

$$\text{efficiency} = \frac{W_{out}}{W_{in}} \times 100 \qquad \text{OR} \qquad \text{efficiency} = \frac{AMA}{IMA} \times 100$$

1. A force of 100 N is applied to a simple machine in order to lift a box that weighs 300 N. The effort force is applied over a distance of 4 meters, causing the box to rise 1 meter.
   a. What is the effort force? What is the effort distance?
   b. What is the resistance force? What is the resistance distance?
   c. What is the work in? What is the work out?
   d. Determine the IMA, AMA, and efficiency for the machine.

2. A force of 300 N is applied to a machine to lift a 90 kg object. What is the effort force? What is the resistance force? Determine the AMA for this machine. Can you determine the machine's efficiency? Why or why not?

3. Forty-five Joules of work is input to a lever that provides 30 Joules of work out. The effort force is 15 N and the resistance force is 30 N. What is the effort distance? What is the resistance distance? Determine the IMA, AMA, and efficiency for this machine.

4. A machine with an AMA of 5 is used to lift an object that weighs 2500 N. What effort force is needed to lift the object?

5. An effort force is applied over a distance of 20 cm. If the machine has an IMA of 4, how far will the object be lifted?

6. A 75% efficient machine is used to lift a 60 kg mass. The machine has an IMA of 4. What is the AMA of this machine? How much effort force is required to lift the mass?

1. 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?

2. 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?

3. 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? If the input force is 200N and the box weighs 90 kg, determine the efficiency of the lever.

4. What is the mechanical advantage of a lever that has an input arm of 3 meters and an output arm of 2 meters? If the load weighs 165 kg and the machine is 83.3% efficient, determine the actual mechanical advantage of the lever.

5. A lever with an input arm of 2 meters has a mechanical advantage of 4. What is the output arm's length? If the W_{in} is 100J and the efficiency of the machine is 60%, determine the weight of the load.

6. A lever with an output arm of 0.8 meter has a mechanical advantage of 6. What is the length of the input arm? Determine the W_{out} if the machine is 80% efficient and effort force is 25 N.

7. 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? What type of lever is a rake? Explain your answer.

8. 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?

9. 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)?

10. 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? Determine the W_{out} if the machine is 80% efficient and effort force is 25 N.

11. A 5-meter ramp lifts objects to a height of 0.75 meters. What is the mechanical advantage of the ramp? If the input force is 300N and the box weighs 120 kg, determine the efficiency of the ramp.

12. A 10-meter long ramp has a mechanical advantage of 5. What is the height of the ramp? If the load weighs 150 kg and the machine is 90% efficient, determine the actual mechanical advantage of the lever.

13. A ramp with a mechanical advantage of 8 lifts objects to a height of 1.5 meters. How long is the ramp? If the W_{in} is 2450J and the efficiency of the machine is 75%, determine the weight of the load.

14. 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? What assumption are you making?

ICP - Mechanical Advantage, Work and Efficiency Worksheet

For each of the following questions include the following:

- a diagram if possible
- the formula
- any workings required
- the answer with the correct units

1. A lever is used to lift a load weighing 200N. The force needed was 600N. What is the mechanical advantage of this first class lever?

2. Another first class lever is used to lift a T.V. Into the back of a truck. The force arm is 6m and the load arm is 3m. What is the mechanical advantage of this lever?

3. A lever is used to lift a load. The load is 5m from the pivot points and the force is applied 15m from the pivot. What is the mechanical advantage of this lever?

4. An inclined plane is used to lift a box into a moving truck. The ramp is 6m long and 1.5m from the ground. What is the mechanical advantage of the inclined plane?

ICP - Mechanical Advantage, Work and Efficiency Worksheet

5. What is the mechanical advantage of the following pulley? The pulley has six supporting ropes but the force end is down.

6. The work output of a lever used to lift books is 30 Joules and the work input is 60 Joules. What is the efficiency of this lever?

7. Scott needs to split a chunk of wood for the fire. There is a crack in the chunk. If he uses an axe it will use 200 Joules of energy. He receives 100 Joules of work out of the machine.

   A) What type of simple machine has he used?
   B) What is the efficiency of the machine?

8. David and Aaron were snowmobiling after school. David's snowmobile ran out of gas. He needs to lift the snowmobile into his father's truck. He decides to use an inclined plane to push it up to the truck. The snowmobile weighs 1500N. If they push the snowmobile 8m to the ramp, how much work have they completed?

ICP - Mechanical Advantage, Work and Efficiency Worksheet

9. Would you do more work moving 100 boxes weighing 12N for 1m or moving a 1000N box, 30cm? Support your answer.

10. A person needs to lift his/her book bag onto the desk. How much work is completed if the desk is 90 cm high and the book bag has a mass of 3kg?

11. A ramp is used to lift a box into a truck. The distance it is lifted is 1.5m. The box has a mass of 5kg. What amount of work must be completed in order to lift the box?

12. How much work is needed to lift the books unto a shelf. The books weigh 25N and the shelf is 500 cm high.