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**FOCUS**: Simple Machines

**ESSENTIAL QUESTION:** Can you explain the difference between Ideal and Actual Mechanical Advantage? Can you calculate the Ideal Mechanical Advantage of a machine? Can you evaluate a machine's efficiency and develop ways to make that machine more efficient?

**What do we already know?**

- Machines make work easier by changing the amount, distance or direction of your force.
- The output work done by a machine can be calculated by multiplying the output force by the output distance
- The output work done by a machine can not exceed the input work you put into the machine.

**How can we measure how useful a machine is?**

- How much easier and faster a machine makes your work is the mechanical advantage of that machine.
- Scientifically, a machine's mechanical advantage is the number of times a machine increases a force exerted on it.
- Can be found by comparing the output force to the input force.
- Two different ways of measuring:
  - The Ideal mechanical advantage (IMA), or *theoretical mechanical advantage*, is the mechanical advantage of an ideal machine (a machine with no friction).
    - Calculated using physics principles because no ideal machines actually exist.
    - Formula:

$$IMA = \frac{\text{Output force}}{\text{Input force}} = \frac{F_o}{F_i}$$

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- The Actual Mechanical Advantage (AMA) is the mechanical advantage of a real machine.
  - AMA takes into consideration real world factors such as energy lost due to friction.

**Calculating Mechanical Advantage**

- If you exert a force of 10N on a can-opener and the can-opener exerts a force of 30N on the can, what is the Ideal Mechanical Advantage (IMA) of this machine?

input output force

$$IMA = \frac{F_o}{F_I} = \frac{30N}{10N} = 3$$


- If you exert a force of 20N on a pair of chopsticks and the chopsticks exert a force of 10N on a piece of sweet-and-sour chicken, what is the IMA of this machine?

$$IMA = \frac{10N}{20N} = .5$$

- There are No Units because:
  - The units cancel out.
  - The answer simply telling you how many times the machine multiplies your input force.

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**Mechanical Advantage Conclusions:**

- If the machine increases your force, then the mechanical advantage will be > 1.
- If the machine increases your distance, then the mechanical advantage will be < 1.
- If the machine changes the direction of your force, then the mechanical advantage will be = 1.

**Machine Efficiency**

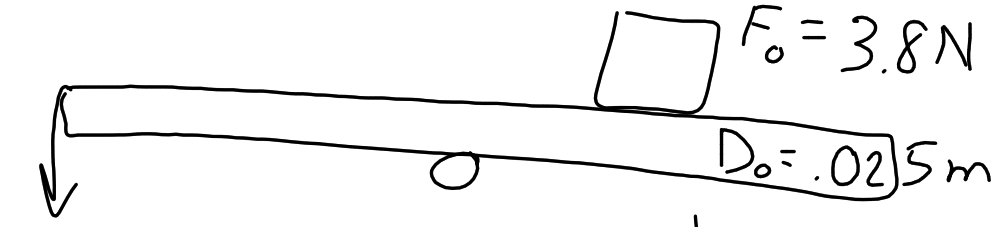
- Earlier I said "in all machines, output work = input work." This is only true for ideal machines, which don't actually exist.
- In the real world, all machines are slowed down by friction.
- Therefore, Output Work is *always* less than Input Work.
- The efficiency of a machine compares the output work to the input work, and is expressed as a %.
- The higher the percent, the more efficient the machine is.
- Calculate with the following formula:

$W_i = 5J$

$W_o = 4J$

$$\text{Efficiency} = \frac{\text{Output Work}}{\text{Input work}} \times 100\%$$

$$= \frac{4J}{5J} \times 100\% = 80\%$$




$F_i = 1.3N$

$D_i = .065m$

$W_i = .085J$

$W_o = .095J$

$M.A. = \frac{3.8N}{1.3N} = 2.92$

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**Let's Practice:**

1) You do 250,000 J of work to cut a lawn with a hand mower. If the work done by the mower is 200,000 J, what is the efficiency of the lawn mower?

$\frac{W_o}{W_i} = \frac{200{,}000\,J}{250{,}000\,J} \times 100\% = 80\%$ → $.8 \times 100\% = 80\%$

$0.50

2) You left your lawn mower outdoors all winter. Now it's rusty. Of your 250,000 J of work, only 100,000 J go to cutting the lawn. What is the efficiency of the lawn mower now?

$\frac{100{,}000\,J}{250{,}000\,J} = .4 \times 100\% = 40\%$

3) Suppose the efficiency of a manual pencil sharpener is 58%. If the output work needed to sharpen a pencil is 4.8 J, how much input work must you do to sharpen the pencil?

$E = \frac{W_o}{W_i}$ $W_i = \frac{W_o}{E} = \frac{4.8\,J}{.58} = 8.28\,J$