A nutcracker is a machine that converts the input force applied to it into a larger force capable of cracking a nut.

Because it increases force, the nutcracker has a mechanical advantage greater than 1.

# Mechanical Advantage

**How does the actual mechanical advantage of a machine compare to its ideal mechanical advantage?**

The **mechanical advantage** of a machine is the number of times that the machine increases an input force.

**Because friction is always present, the actual mechanical advantage of a machine is always less than the ideal mechanical advantage.**

# Mechanical Advantage

## Actual Mechanical Advantage

The mechanical advantage determined by measuring the actual forces acting on a machine is the actual mechanical advantage.

The **actual mechanical advantage** (AMA) equals the ratio of the output force to the input force.

# Mechanical Advantage

A loading ramp is a machine used to move heavy items into a truck.

The mechanical advantage of a ramp with a rough surface is less than that of a similar smooth ramp because a greater force is needed to overcome friction.

## Actual Mechanical Advantage

$$\text{Actual mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

# Mechanical Advantage

## Ideal Mechanical Advantage

The **ideal mechanical advantage** (IMA) of a machine is the mechanical advantage in the absence of friction.

Because friction reduces mechanical advantage, engineers often design machines that use low-friction materials and lubricants.

# Calculating Mechanical Advantage

## Ideal Mechanical Advantage

$$\text{Ideal mechanical advantage} = \frac{\text{Input distance}}{\text{Output distance}}$$

# Calculating Mechanical Advantage

Math Practice

**1.** A student working in a grocery store after school pushes several grocery carts together along a ramp. The ramp is 3 meters long and rises 0.5 meter. What is the ideal mechanical advantage of the ramp?

# Calculating Mechanical Advantage

Math Practice

**1.** A student working in a grocery store after school pushes several grocery carts together along a ramp. The ramp is 3 meters long and rises 0.5 meter. What is the ideal mechanical advantage of the ramp?

Answer:

IMA = Input distance/Output distance

IMA = 3 m/0.5 m = 6

# Calculating Mechanical Advantage

Math Practice

**2.** A construction worker moves a crowbar through a distance of 0.50 m to lift a load 0.05 m off of the ground. What is the IMA of the crowbar?

# Calculating Mechanical Advantage

Math Practice

**2.** A construction worker moves a crowbar through a distance of 0.50 m to lift a load 0.05 m off of the ground. What is the IMA of the crowbar?

Answer:

IMA = Input distance/Output distance

IMA = 0.5 m/0.05 m = 10

# Calculating Mechanical Advantage

Math Practice

**3.** The IMA of a simple machine is 2.5. If the output distance of the machine is 1.0 m, what is the input distance?

# Calculating Mechanical Advantage

Math Practice

**3.** The IMA of a simple machine is 2.5. If the output distance of the machine is 1.0 m, what is the input distance?

Answer:

Input distance = (IMA)(Output distance)

Input distance = (2.5)(1.0 m) = 2.5 m

# Efficiency

**Why is the efficiency of a machine always less than 100 percent?**

The percentage of the work input that becomes work output is the **efficiency** of a machine.

**Because there is always some friction, the efficiency of any machine is always less than 100 percent.**

# Efficiency

Efficiency is usually expressed as a percentage.

**Efficiency**

$$\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}} \times 100\%$$

For example, if the efficiency of a machine is 75 percent, then you know that 75 percent of the work input becomes work output.

## Efficiency

If a machine requires 10.0 J of work input to operate, then the work output is 75% of 10.0 J.

$$\text{Work output} = \frac{\text{Work input} \times \text{Efficiency}}{100\%}$$

$$\text{Work output} = \frac{10.0\ \text{J} \times 75\%}{100\%} = 7.5\ \text{J}$$

# Assessment Questions

1. Which statement about the actual mechanical advantage of a machine is true?

   a. The actual mechanical advantage is greater than one if the input force is greater than the output force.

   b. The actual mechanical advantage of a machine is greater than its ideal mechanical advantage when the output force is greater than the input force.

   c. The actual mechanical advantage of a machine is always less than its ideal mechanical advantage.

   d. The actual mechanical advantage of a machine is never affected by friction.

# Assessment Questions

1. Which statement about the actual mechanical advantage of a machine is true?

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   c. The actual mechanical advantage of a machine is always less than its ideal mechanical advantage.

   d. The actual mechanical advantage of a machine is never affected by friction.

   ANS: C

## Assessment Questions

2. If a lever raises a large rock 0.1 meters when the other end of the lever moves downward 2 meters, what is the ideal mechanical advantage of the lever?
   a. 0.05
   b. 0.5
   c. 2
   d. 20

## Assessment Questions

2. If a lever raises a large rock 0.1 meters when the other end of the lever moves downward 2 meters, what is the ideal mechanical advantage of the lever?

   a. 0.05
   b. 0.5
   c. 2
   d. 20

   ANS: D

## Assessment Questions

3. A machine is used to accomplish 300 J of work. If the efficiency of the machine is 60 percent, what is the necessary work input?
   a. 180 J
   b. 360 J
   c. 500 J
   d. 750 J

## Assessment Questions

3. A machine is used to accomplish 300 J of work. If the efficiency of the machine is 60 percent, what is the necessary work input?

   a. 180 J
   b. 360 J
   c. 500 J
   d. 750 J

   ANS: A

## Assessment Questions

1. The efficiency of any machine is less than 100% because of losses due to friction.

   True
   False

## Assessment Questions

1. The efficiency of any machine is less than 100% because of losses due to friction.

   True
   False

   ANS: T