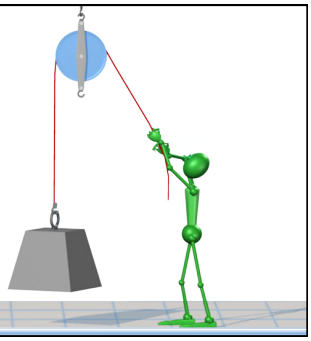
Ideal mechanical advantage



Objectives

- Describe the difference between the ideal and actual mechanical advantage of a system.
- Calculate the ideal mechanical advantage of a machine.

Assessment

Jasmine uses a block and tackle system, pulling with 10 N of force for 5 m. Doing so, she lifts a 40 N weight by 1 m.

1. What is the ideal mechanical advantage of her block and tackle system?
2. What is the (actual) mechanical advantage?
3. Explain the difference.

Physics terms

- ideal mechanical advantage
- actual mechanical advantage

Equations

$$MA = \frac{F_o}{F_i}$$ Actual mechanical advantage

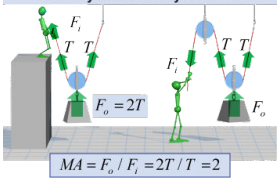
$$MA_{ideal} = \frac{d_i}{d_o}$$ Ideal mechanical advantage

Ideal mechanical advantage

The *ideal mechanical advantage* is the mechanical advantage of a machine with no inefficiencies.

The *actual mechanical advantage* is the mechanical advantage of a real machine *with* all of the inefficiencies.

Two ways to double your force

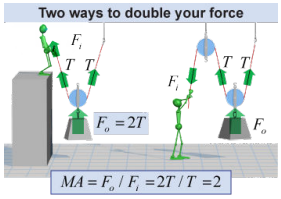


$MA = F_o / F_i = 2T / T = 2$

Ideal mechanical advantage

If these pulleys are ideal (frictionless and massless) the mechanical advantage is $MA_{ideal} = 2$.

In real life, some of the force is used to overcome friction and added weight: MA_{actual} is < 2.



Ideal mechanical advantage

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

The *actual* mechanical advantage is the ratio of the output force to the input force.

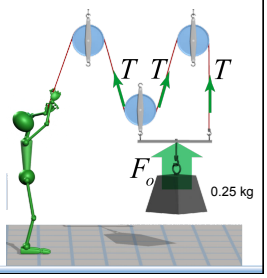
$$MA_{ideal} = \frac{d_i}{d_o}$$

The *ideal* mechanical advantage is the mechanical advantage in an ideal world. It equals the input distance divided by the output distance.

Ideal mechanical advantage

A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

1. What is the ideal mechanical advantage of the machine?
2. What is the actual mechanical advantage of the machine?
3. What is the machine's efficiency?



Ideal mechanical advantage

Use this interactive calculator on page 341 to solve the problem.

The ideal mechanical advantage of a machine assumes an efficiency of 100% (no energy losses). The ideal *MA* is the ratio of the distance moved at the machine's input to the distance moved by the output.

Calculator

(12.4) $MA_{ideal} = \frac{d_i}{d_o}$

MA_{ideal} = ideal mechanical advantage
d_i = input distance (m)
d_o = output distance (m)

Ideal mechanical advantage

Measuring forces or distances

The ideal mechanical advantage of a system is determined from the input and output *distances* moved. For the (actual) mechanical advantage, however, you measure the input and output *forces*. To determine efficiency, you need both force *and* distance!

Ideal mechanical advantage

A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

What is the ideal mechanical advantage of this pulley system?

Ideal mechanical advantage

Ideal mechanical advantage ____ (dimensionless) MA_{ideal} = $\frac{d_i}{d_o}$

Input distance 0.45 (meters, m)

Output distance 0.15 (meters, m)

Solve for: Ideal mechanical advantage

Ideal mechanical advantage

A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

What is the ideal mechanical advantage of this pulley system? 3

$$MA_{ideal} = \frac{d_i}{d_o} = \frac{0.45\text{ m}}{0.15\text{ m}} = 3$$

Ideal mechanical advantage

Ideal mechanical advantage 3 (dimensionless) MA_{ideal} = $\frac{d_i}{d_o}$

Input distance 0.45 (meters, m)

Output distance 0.15 (meters, m)

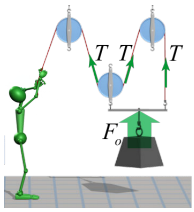
Solve for: Ideal mechanical advantage

Ideal mechanical advantage

A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

What is the ideal mechanical advantage of this pulley system? **3**

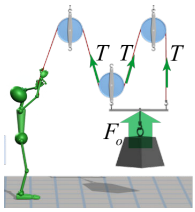
Notice: the MA_{ideal} also equals the number of rope strands lifting the mass.



Ideal mechanical advantage

A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

What is the actual mechanical advantage of the machine?



Ideal mechanical advantage

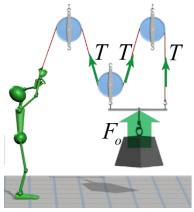
A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

What is the actual mechanical advantage of the machine?

F_o = (9.8 m/s^2)(0.25 kg) = 2.45 N

$$MA = \frac{F_o}{F_i} = \frac{2.45\text{ N}}{0.95\text{ N}} = 2.6$$

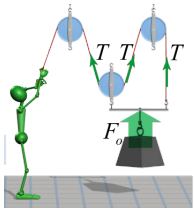
The actual mechanical advantage is always less than the ideal value.



Ideal mechanical advantage

A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

What is the machine's efficiency?



Ideal mechanical advantage

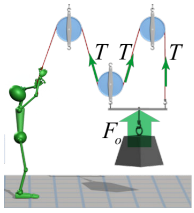
A robot constructs a pulley system to lift a 0.25 kg mass by 15 cm. It pulls the input string down 45 cm with a force of 0.95 N.

What is the machine's efficiency?

$$W_o = F_o d_o = (2.45\text{ N})(0.15\text{ m}) = 0.37\text{ J}$$
$$W_i = F_i d_i = (0.95\text{ N})(0.45\text{ m}) = 0.43\text{ J}$$

$$\eta = \frac{W_o}{W_i} = \frac{0.37\text{ J}}{0.43\text{ J}} = 0.86$$

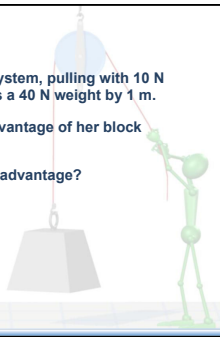
The efficiency is 86%.



Assessment

Jasmine uses a block and tackle system, pulling with 10 N of force for 5 m. Doing so, she lifts a 40 N weight by 1 m.

1. What is the ideal mechanical advantage of her block and tackle system?
2. What is the (actual) mechanical advantage?
3. Explain the difference.



Assessment

Jasmine uses a block and tackle system, pulling with 10 N of force for 5 m. Doing so, she lifts a 40 N weight by 1 m.

1. What is the ideal mechanical advantage of her block and tackle system? 5
2. What is the (actual) mechanical advantage?
3. Explain the difference.

Assessment

Jasmine uses a block and tackle system, pulling with 10 N of force for 5 m. Doing so, she lifts a 40 N weight by 1 m.

1. What is the ideal mechanical advantage of her block and tackle system? 5
2. What is the (actual) mechanical advantage? 4
3. Explain the difference.

Assessment

Jasmine uses a block and tackle system, pulling with 10 N of force for 5 m. Doing so, she lifts a 40 N weight by 1 m.

1. What is the ideal mechanical advantage of her block and tackle system? 5
2. What is the (actual) mechanical advantage? 4
3. Explain the difference.

   Friction and other losses require her to use extra force to lift the block.

Ideal mechanical advantage (advanced)

The *ideal mechanical advantage* is equal to the ratio of input distance to output distance.

$$MA_{ideal} = \frac{d_i}{d_o}$$

Can you explain why this is so?

Ideal mechanical advantage (advanced)

Mechanical advantage is the ratio of output force to input force. Losses dues to friction, etc. effect these forces, so the measured forces give you the *actual* mechanical advantage.

However, most machines don't *stretch* much. The actual distances moved are very close to the distances objects would move if there were no losses.

Thus, the distances can be used to calculate the *ideal* mechanical advantage.