Unit D: Mechanical Systems

Lesson 2: Work, Force and Efficiency

Outcomes

- identify work input and work output in joules for a simple machine or mechanical system (e.g., use a device to lift a measured mass an identified distance, then calculate the work output)
- analyze a mechanical device, by:

− describing the overall function of the device

− describing the contribution of individual components or subsystems to the overall function of the device

− identifying components that operate as simple machines

- evaluate the design and function of a mechanical device in relation to its efficiency and effectiveness, and identify its impacts on humans and the environment
- compare theoretical and actual values of force ratios, and propose explanations for discrepancies (e.g., identify frictional forces, and estimate their effect on efficiency)
- develop and apply a set of criteria for evaluating a given mechanical device, and defend those criteria in terms of relevance to social and environmental needs
- analyze mechanical devices to determine force ratios

What is a Machine?

A machine is any device that is used to help us do work or perform a particular task.

A machine can be as simple as a ramp, or complex like a lawnmower!

All complex machines are usually variations of 2 simple ones:

- The Inclined plane and the Lever

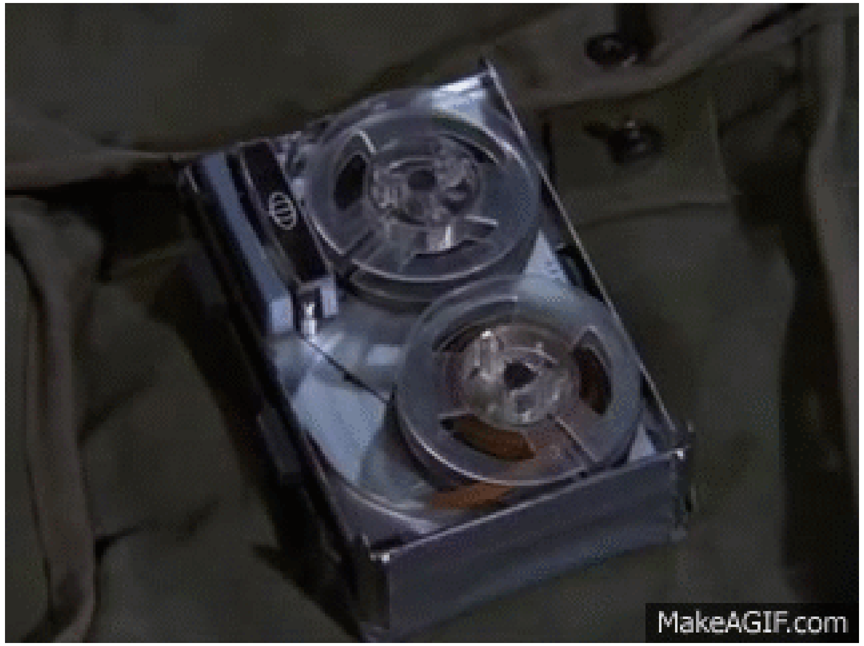
We use machines to convert the energy added to it **(which we call energy input)**

to a different form of energy **(useful energy output)** that we may need in order to do work.

WHEN A MACHINE TRANSFORMS ENERGY, SOME ENERGY WILL ALWAYS BE LOST AS…
Heat
Sound
Light
Wobbly wheels (unnecessary movement)

Or some other form of energy

Friction is usually the force that causes this loss of energy



In other words, the useful energy input is never equal to the useful energy output.

A *perfect machine*, which is 100% efficient in converting energy, does not exist.

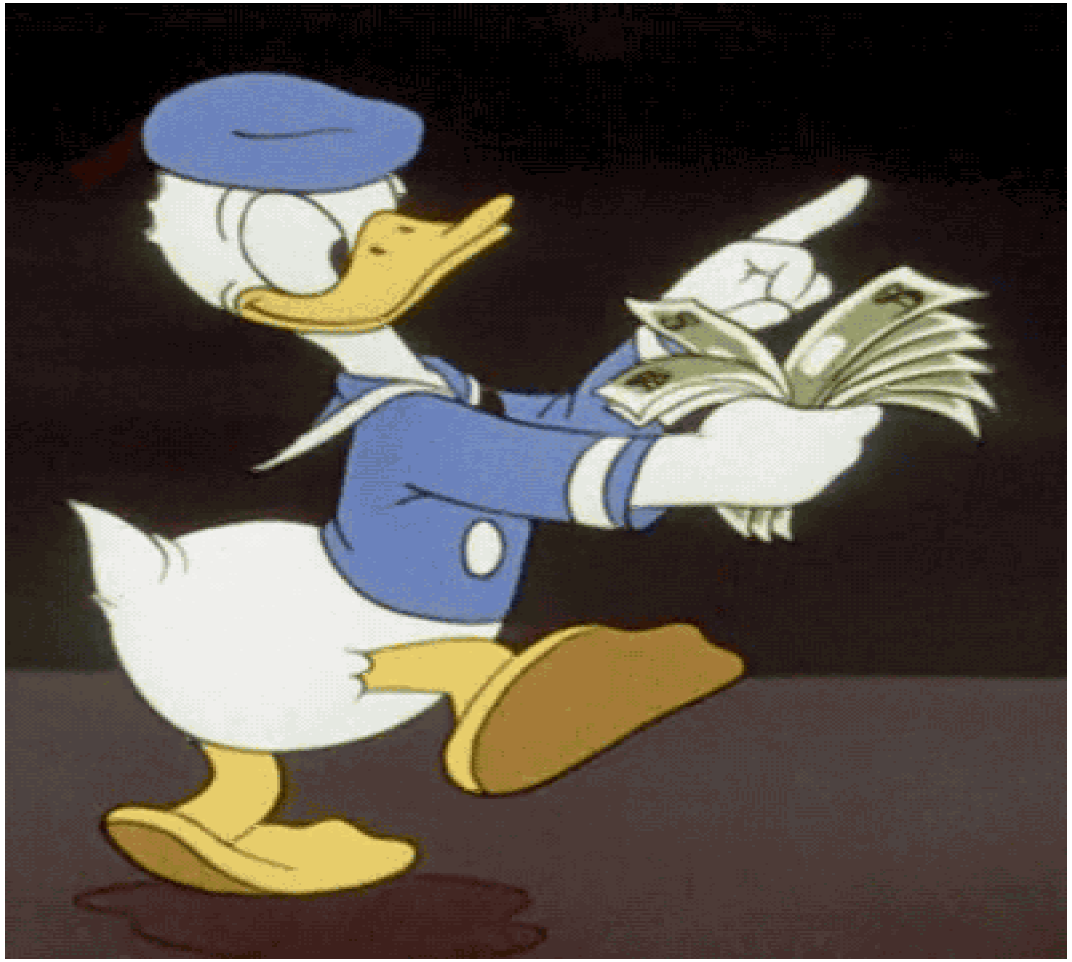
Efficiency

Efficiency is a measurement of how effectively a machine converts input energy into useful energy output.

The *efficiency* of a machine tells you how much of the energy you gave to the machine is actually transferred to the load.

$$\text{percent efficiency} = \frac{\text{total work output}}{\text{total work input}} \times 100\%$$

% Efficiency Is Like Money Earned vs. Saved.



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- Say you earned $100. On your way to the bank, you spent $20 on Slurpees and candy. Now you only have $80 remaining.
- Since you have $80/$100, that works out to 80% efficiency.
- That means you were 80% efficient with your money.
- 100% efficiency would've meant you did not spend any money.

<u>100% Efficiency Is Impossible</u>

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- **100 % efficiency would mean that you WASTED NONE of your money on anything. Hey, you need to eat. There is no such thing as a machine that uses 100 % of the energy that you give it for useful motion. Friction always will find a way to waste some of it.**

How to Boost Efficiency

Quite Simple Actually….Just Reduce Friction

Lubricants, reduces the surface area where parts rub together. This reduces friction.

Wobbly areas on moving parts create a lot of friction. Tighten wiggly areas.

Friction is a thief because it steals useful energy. Following all of this advice will reduce friction so that more energy can be used for useful purposes.

Sometimes We Need Friction

There are many places where friction is useful, including:

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Bicycle – tires create friction with the road surface to give you grip

Baseball – ***rosin*** is used to form a stronger grip with the bat. Pitchers use it for better grip on ball.

Gymnasts – also use ***rosin*** to provide grip on slippery metal surfaces (like rings or bars)

Curlers – sweep the ice in front of the rock to decrease friction with the ice surface and then they sometimes stop sweeping to increase friction so that the rock slows down.

Increase Friction Where it is needed. Reduce friction where its not needed.
Doing So will MAXIMIZE EFFICIENCY!

- Large Rear Tires maximize friction where thrust is created. This creates enough traction.
- Small Front Tires minimize friction in the front (where it is not needed) so that more energy can be used to accelerate the car as opposed to wasting it as friction and heat.

You do 222 J of work pushing a box up a ramp. If the ramp does 200 J of work, what is the efficiency of the ramp?

$$\text{Efficiency} = \frac{\text{Work done by machine}}{\text{Work done to make the machine operate}} \times 100\%$$

$$= \frac{200\ J}{222\ J} \times 100\%$$

$$= 0.9 \times 100\%$$

$$= 90\%$$

If the ramp required only 200 J of energy, then why did we have to apply 222 J ? What was the extra 22 J used for?

Force

A **force** can be described as a 

or a 

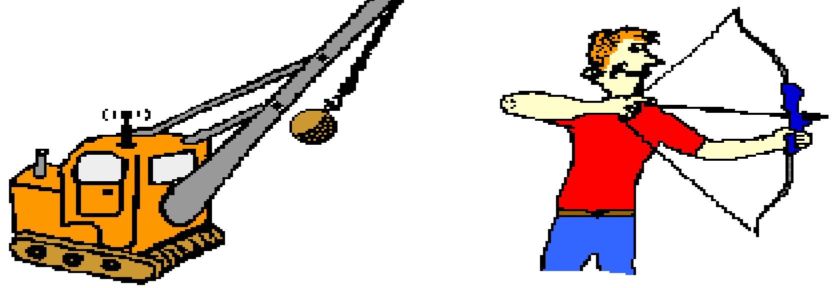
on an object

Sir Isaac Newton

Measured in Newtons

symbol: N

Energy?



The massive ball of a demolition machine and the stretched bow possesses stored energy of position - potential energy.

Energy is defined as the ability to do work or cause a change in the direction, of an object

Kinetic Energy is when WORK is actually being done.

Potential Energy is when the work is waiting to be done, when there is the potential for work to be performed.

The amount of kinetic energy or potential energy is measured in **joules** (J)

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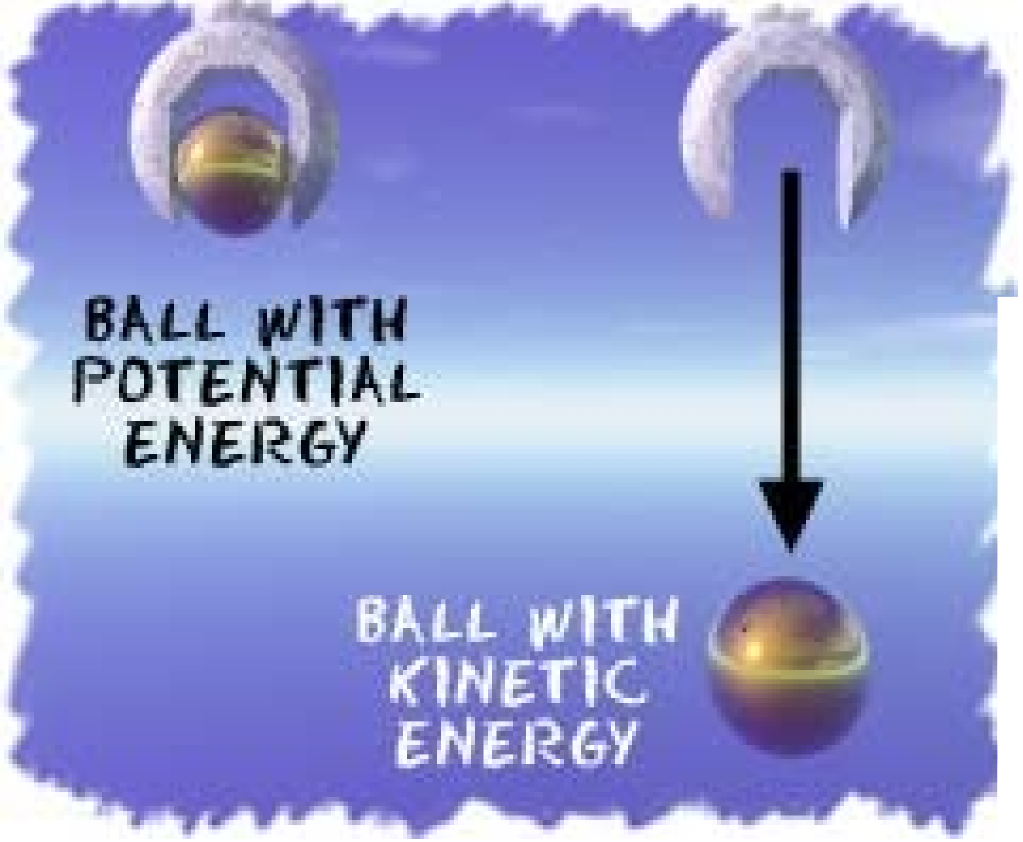
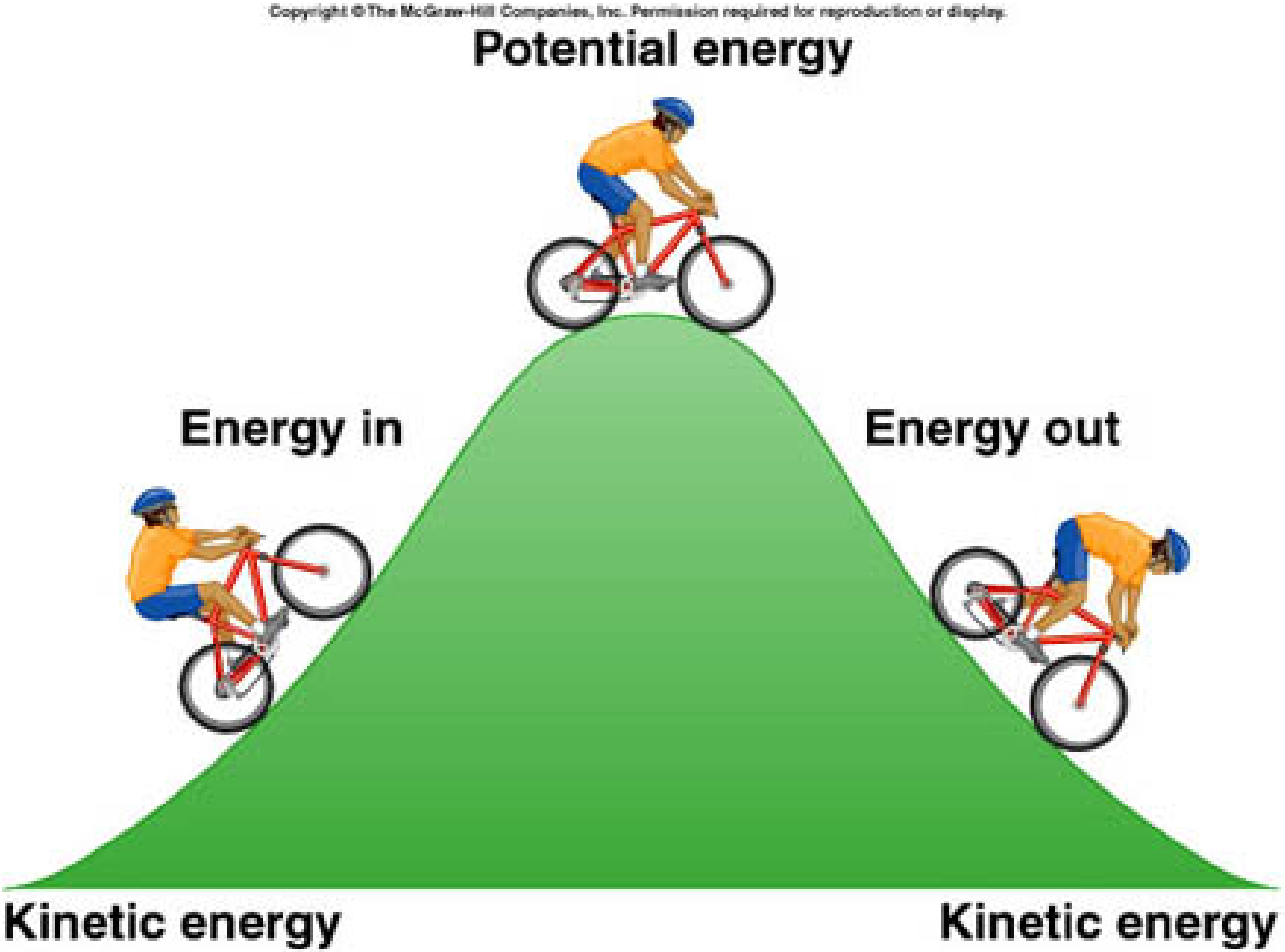

BALL WITH POTENTIAL ENERGY
BALL WITH KINETIC ENERGY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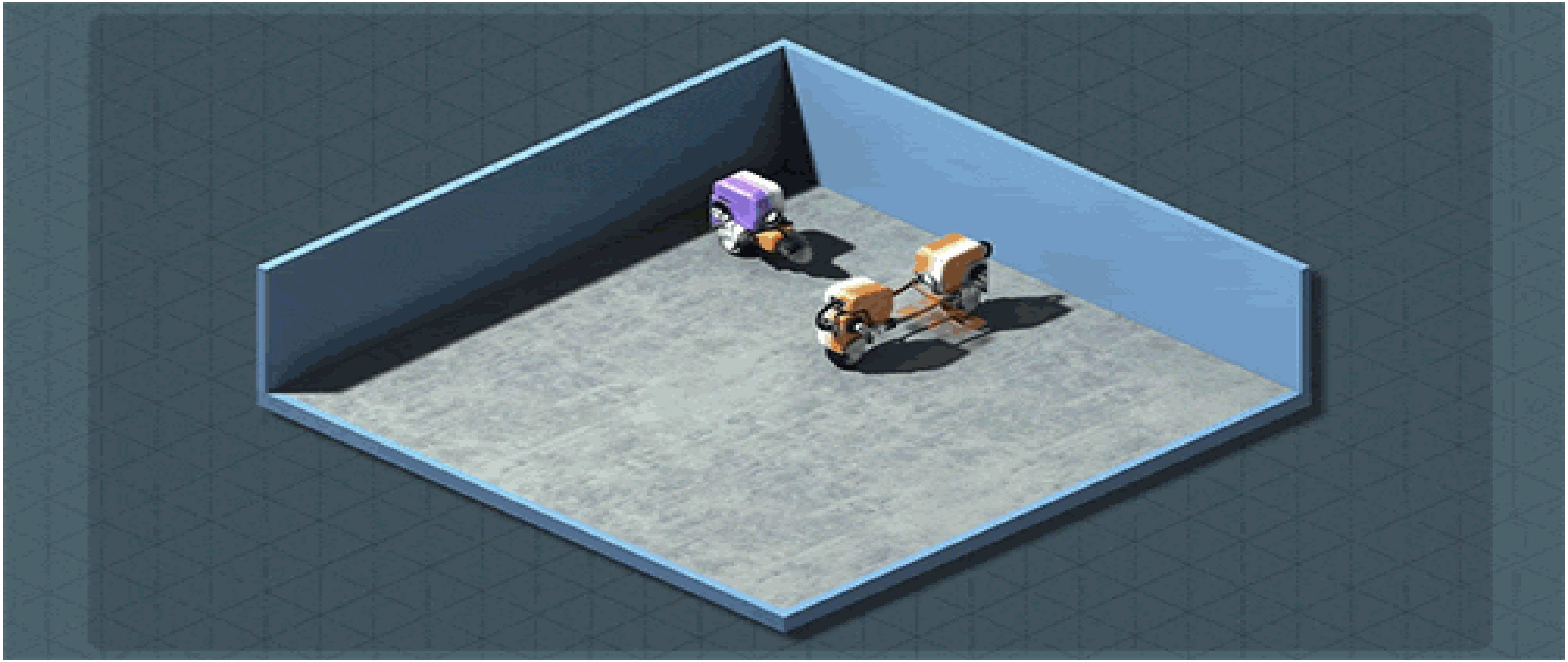
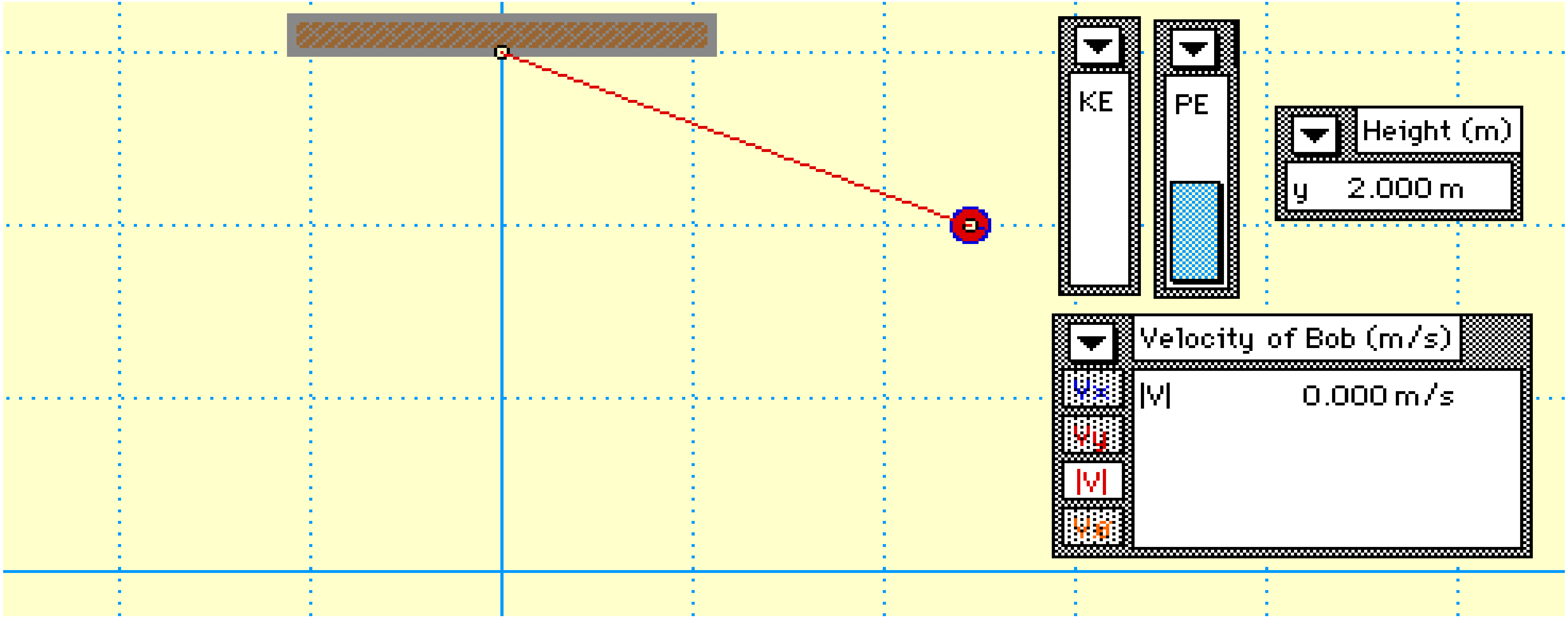
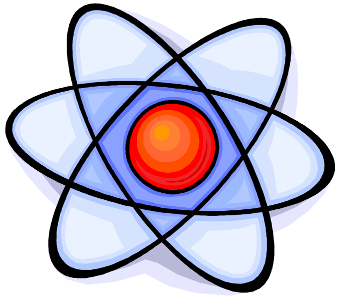
Potential energy
Energy in
Energy out
Kinetic energy
Kinetic energy

Potential Energy Is Stored Energy
Kinetic Energy Is Activated Energy

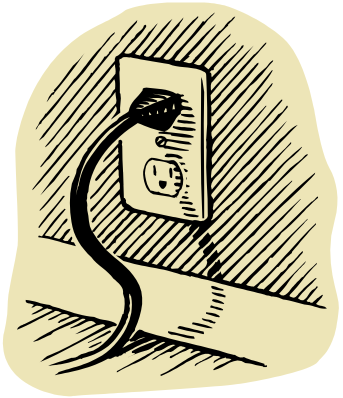


Potential Energy (PE) → At the very top
Kinetic Energy (KE)→ As it swings down





Work & Energy



Work and energy are two concepts which are very closely related to one another.

energy: the ability to do work. Kinetic Energy, Thermal Energy, Potential Energy, Electrical Energy.

work: A force applied over a distance.

$$W = \vec{F}d$$

W = work (J)

$\vec{F}$ = applied force (N)

d = distance the object moves (m)

Work and Energy

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

Work is a transfer of energy.

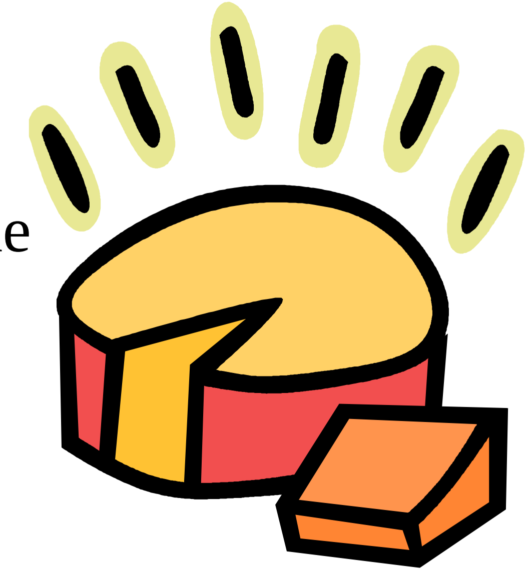
In the example of the bicycle – your energy (chemical energy from your food) is transferred to the pedals giving them **kinetic energy**, or energy of motion. The pedals transfer this energy to the sprockets and chain, and then to the wheels.

The <u>Force</u> and the <u>motion</u> must be in the same direction, or <u>no work is being done</u>.

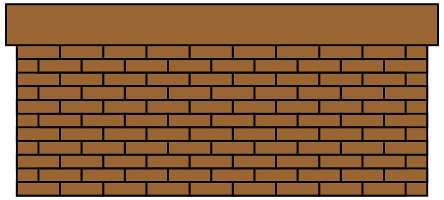
For each of the following examples, do I do any work?

1) I lift a 2.0 kg wheel of cheese from the ground to the top of a table.

The direction of the displacement is the same as the direction as the applied force.



2) I push against a wall with a force of 130 N for 10.0 s.



The wall did not move.

3) I carry a 2.0 kg wheel of cheese 12.0 m across the room.

The force that I apply to hold the cheese up is vertical, and the cheese only moves horizontally.

These directions are perpendicular

Connor McDavid Demonstrating Work

Remember: Work is a Force applied over a distance.

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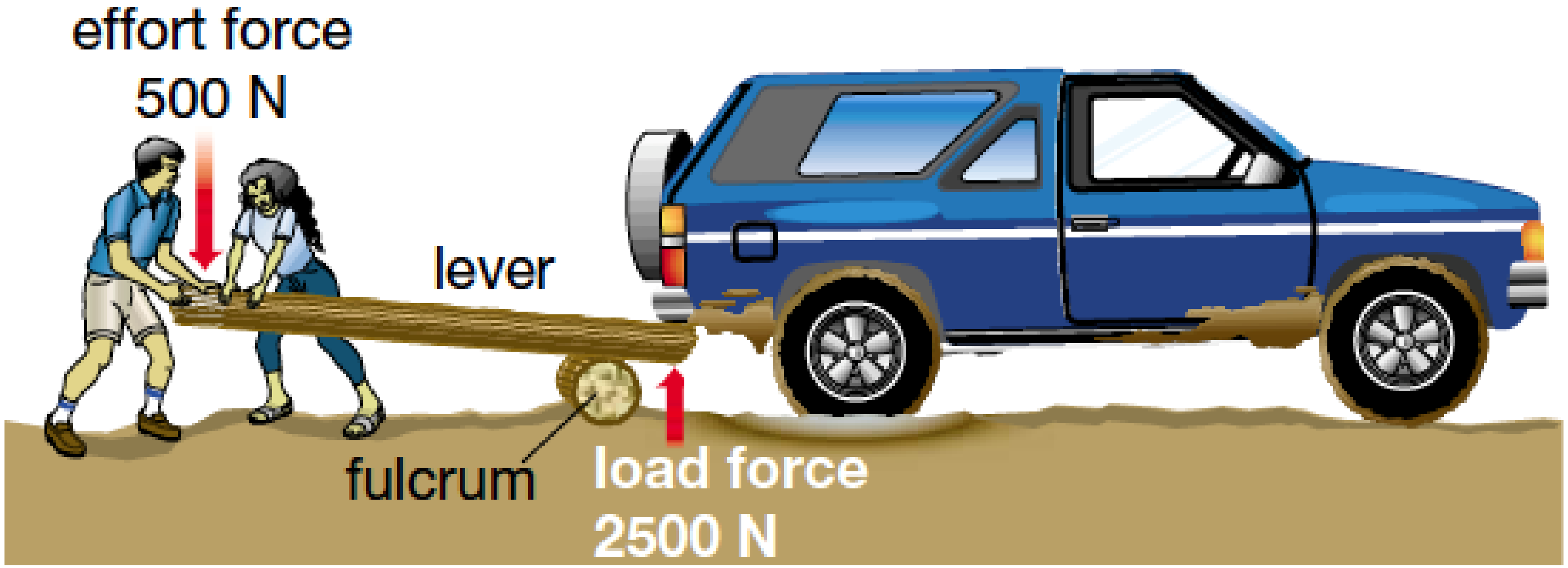
Mechanical Advantage

- Mechanical Advantage is when a machine increases the force that you give it to make you feel like superman.
- This makes makes it easy to lift heavy things.
- The larger the M.A, the greater the machine will magnify your force.

$$\text{Mechanical Advantage} = \frac{\text{Load Force}}{\text{Effort Force}}$$

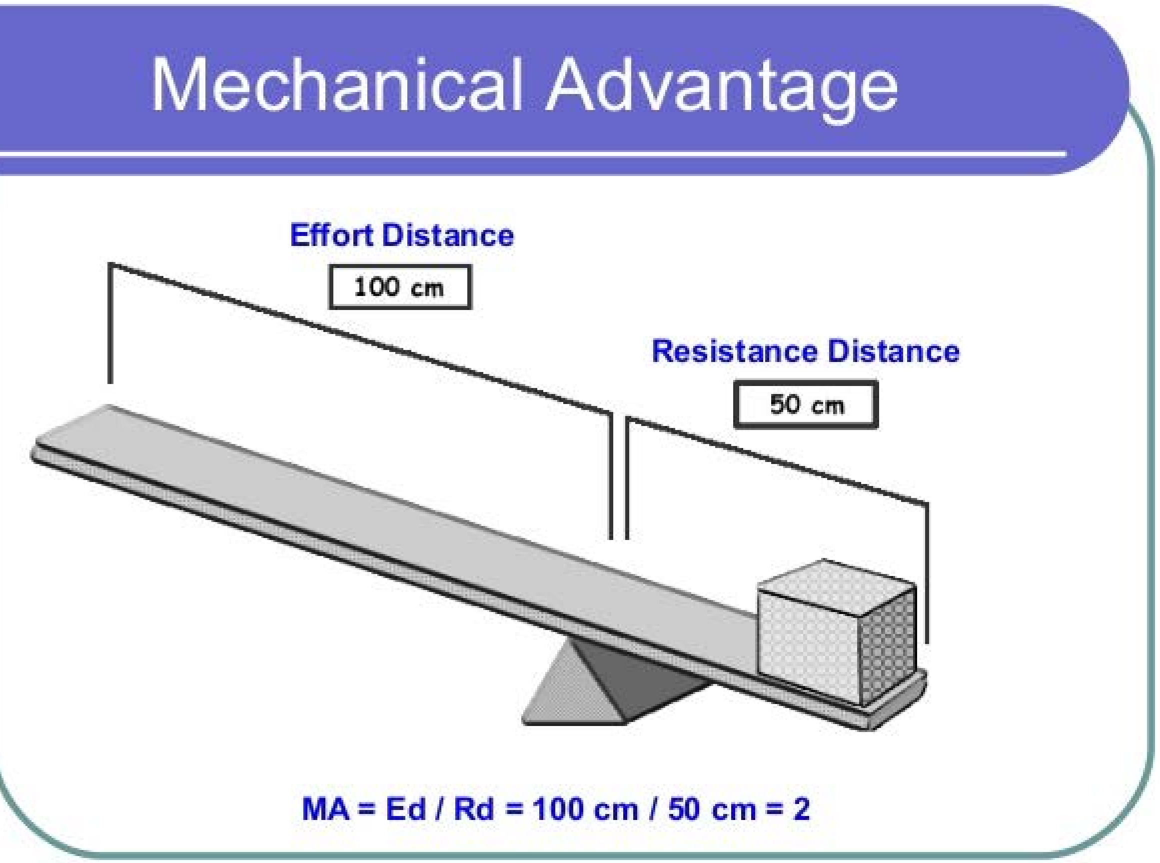
Mechanical Advantage



$$\text{Mechanical Advantage } (MA) = \frac{\text{Load force } (F_L)}{\text{Effort force } (F_E)} = \frac{2500 \text{ N}}{500 \text{ N}} = 5$$

This means that this lever will magnify your force 5X. #superman

Mechanical Advantage of a Lever



$$MA = \frac{\text{Effort Distance}}{\text{Load Distance}} = \frac{100cm}{50cm} = 2$$

The 2 means that this lever will make you multiply your force by 2.

If the box weighs 40 pounds, how much mass would you need on the other end to lift it?

If the Effort Distance is 1000cm, then what is the M.A?

How much mass would you need to lift a 40 pound box with a 1000 cm long effort arm?

Therefore,

$$\text{Mechanical Advantage} = \frac{\text{Load Force}}{\text{Effort Force}} \quad \text{or} \quad \frac{\text{Length of Effort Arm}}{\text{Length of Load arm}}$$

Mechanical advantage

a) can be 1 (No Advantage),

b) less than 1(converts into less force)

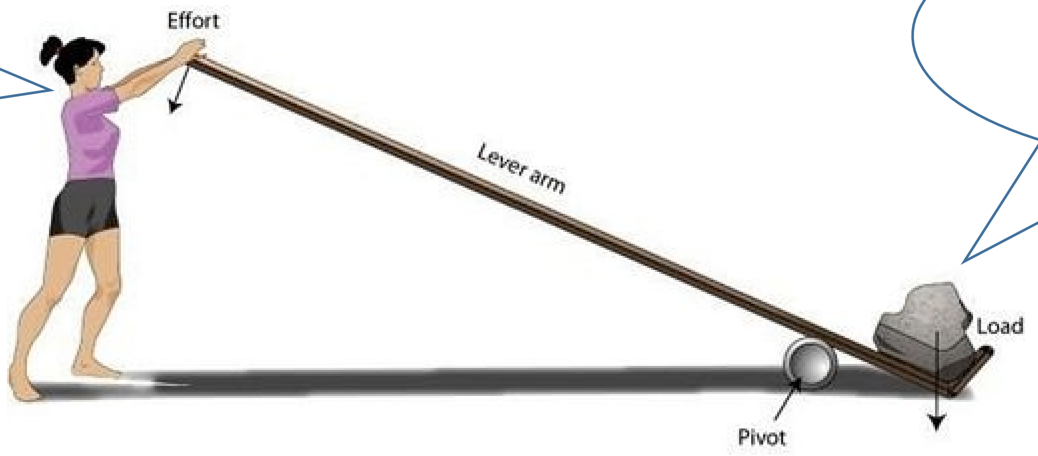
c) or greater than 1 (magnifies your force)

MA has **no units** because it is a ratio.

Too Good To Be True?

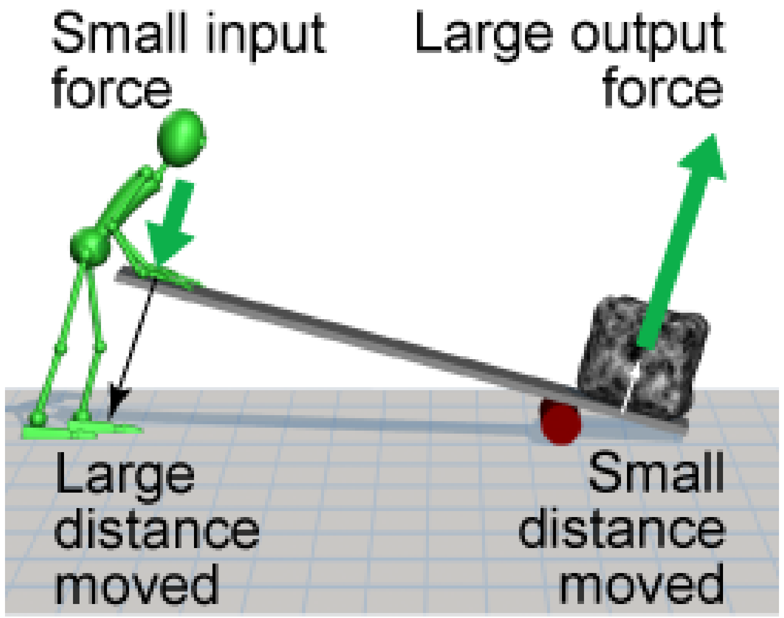
- A machine that takes your force and converts it to superman levels sounds too good to be true!
- Not so fast! There is a trade off.
- You always trade force for distance.
- The greater the force generated, the greater distance the machine makes you move. #itsatradeoff

I'm gonna easily lift this heavy rock. But I have to move this arm so far to do so. #Fairtrade.



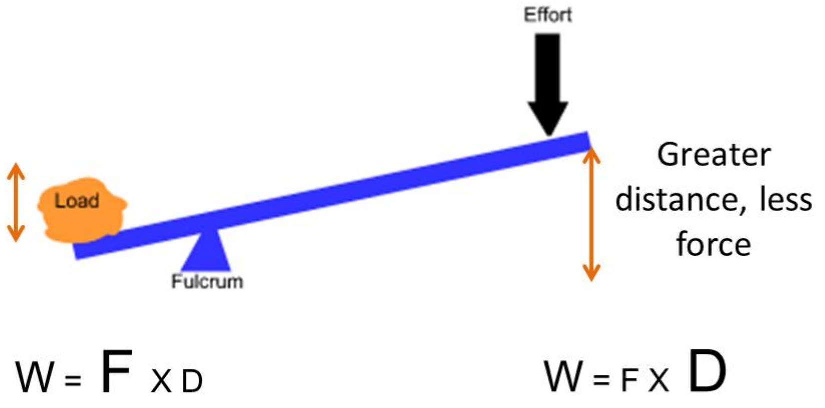
Sure, you can lift me, but you aint gonna lift me very high…lady.

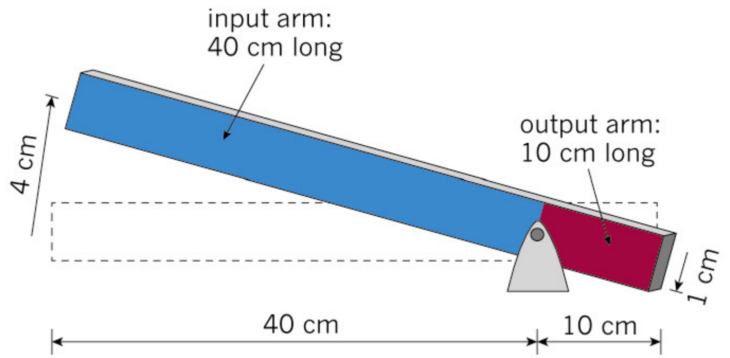
You Always Trade Force For Distance



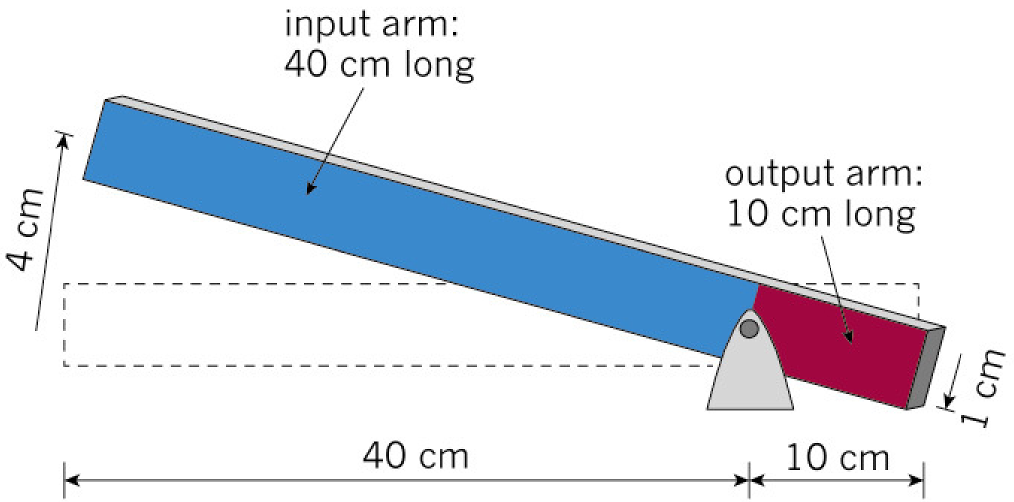
Simple machine force – distance trade-off:

A simple machine **does not** reduce the amount of Work you do.
A simple machine makes work easier by allowing you to apply a **smaller force** over a **greater distance.**

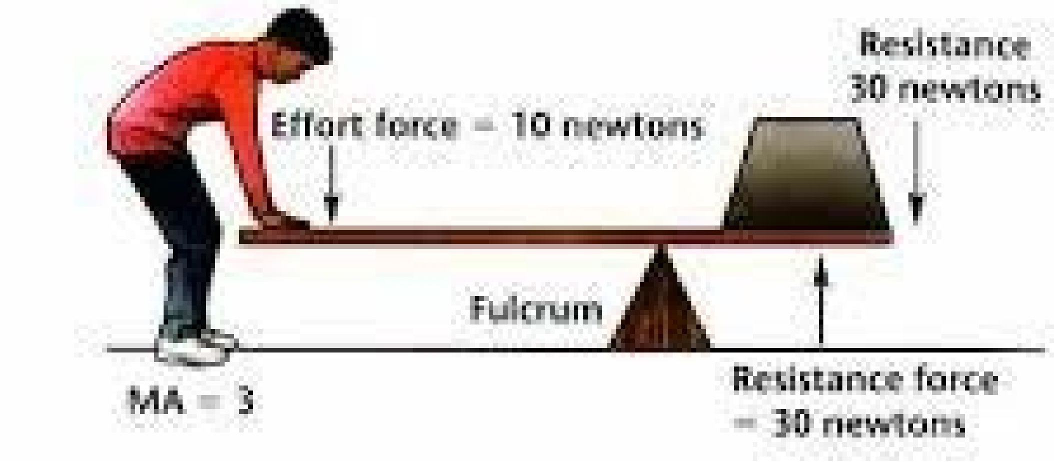




Calculate the Mechanical Advantage of These Levers.



Click here to reveal solution



MA = Effort Arm Length/Load Arm Length
MA = 40 cm / 10 cm
MA = 4