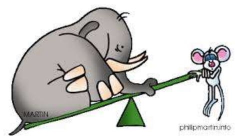
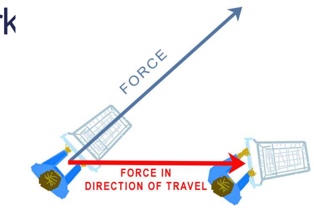
CHAPTER 13.1 & 13.2

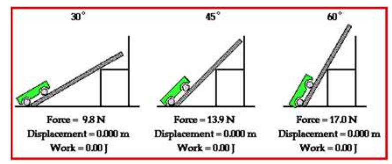
Work, Power and Machines



Work

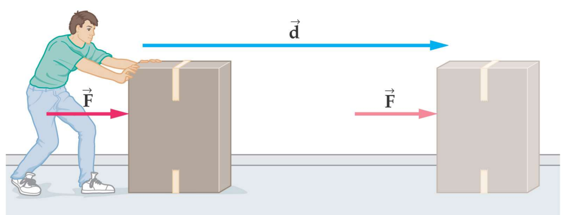
- What is work?
  - Work is done when changing motion
  - Form of energy
- The product of the force applied to an object and the distance through which that force is applied.
- Work is zero when an object is not moving





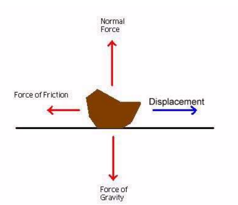
Video

Work is force times distance…but!



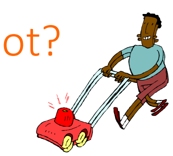
- Only the force component in the direction of motion counts!

- All or part of the force must act in the direction of the movement.



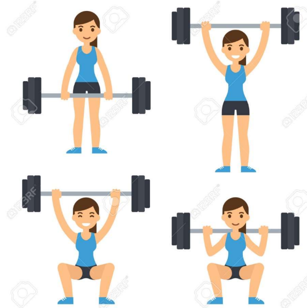
Is work being done or not?

Mowing the lawn	YES
Dragging a bag of books	YES
Moving furniture up a flight of stairs	YES
Pushing against a locked door	NO
Swinging a golf club	YES
Sitting on a chair	NO



Work

- When an Olympic weight lifter presses a barbell over his head? he is doing work
- When he has to hold it there until the judges say he can put it down? he is not doing work
  - Big force but no distance

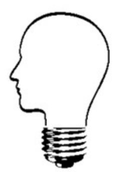


Do you do more work when you finish a job quickly?

- Work does NOT involve time, only force and distance.
- No work is done when you stand in place holding an object.

What do you think?

- You push a stationary wall with a force of 1000N. How much work was done to the wall?



Calculating Work

- **Work= force x distance**
- W = F x d

- Energy is expressed in JOULES (J)
- Energy can be expressed more specifically by using the term **WORK(W)**

- Unit of work is Joules

Units of work
- Force= Newton
- Distance= meters
- Work= Newton x meter (N·m)
- N·m= 1Joules (J)
- Or kg·m²/s² → Or $kg \cdot m^2/s^2$

What is the formula when solving for force?

F= work/distance

What is the formula when solving for distance?

D= work/force

So if an apple weighs about 1 N and you lift it 1 meter.

That is 1 N·m of work or 1 J of work

Practice Problem (Work)

1. A crane uses an average force of 5,200 N to lift a girder 25 m. How much work does the crane do on the girder?

W = ?
F=5,200 N
d= 25 m

W= F x d

W= 5,200 N x 25 m

W= 130000 J

2. A bicycle's brakes apply 125 N of frictional force to the wheels as the bike moves 14.0 m. How much work do the brakes do?

W = ?
F= 125 N
d= 14.0 m

W = F x d

W = 125 N x 14.0 m

W = 1,750 J

Practice Problem (Work)

3. A mechanic uses a hydraulic lift to raise a 1,200 kg car 0.50 m off the ground. How much work does the lift do on the car?

W = ?
F= ?
d = 0.50 m

F= m x a

F= 1,200 kg x 10 m/s²

F= 12000 N

W= F x d

W= 12000 N x 0.50 m

W= 6000 J

4. A car has run out of gas. Fortunately, there is a gas station nearby. You must exert a force of 715 N on the car in order to move it. By the time you reach the station, you have done 2.72 x 10^4 J of work. How far have you pushed the car?

W = 2.72 x 10^4 J
F=715 N
d= ?

d= W/F

d= $\frac{2.72 \times 10^4 \text{ J}}{715 \text{ N}}$

d= 38.04 m

1. You must exert a force of 4.5 N on a book to slide it across a table. You move it .5 meters. How much work have you done?

2. Your roller blade brakes apply 5.6 N of frictional force as you travel 2 meters. How much work have the brakes done?

3. The world's most powerful tugboats are built in Finland. One of these boats can do 9.8 x 10^7 J of work through a distance of 35 m. What is the force exerted by the tugboat?

4. A child pulls a sled up a snow-covered hill. In the process, the child does 405 J of work on the sled. If she walks a distance of 15 m up the hill, how large a force does she exert on the sled?

5. What requires more work? Lifting a 50 kg sack a vertical distance of 2 m or lifting a 25 kg sack a vertical distance of 4 m?

6. A mover is loading a 253 kg crate of hammers onto a truck. The upward force on the crate is 2470 N, and 3650 J of work are required to raise the crate from the pavement to the truck bed. How far is the crate lifted?

7. A popular and dangerous circus act is the human cannonball, in which a person is shot from a cannon. Suppose the cannon has a barrel that is 3.05 m long and 1.67 x 10^4 J of work is done to accelerate the acrobat. What is the force exerted by the cannon on the acrobat?

8. Mrs. Spalla exerts a force of 25 N in order to push a cart through the hallway. How much work is done when she pushes the cart 40 m between classes?

9. You must exert a force of 4.5 N on a book to slide it across a table. You move it 0.5 meters. How much work have you done?

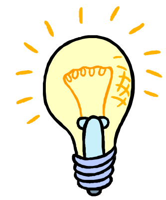
10. Your roller blade brakes apply 5.6 N of frictional force as you travel 2 meters. How much work have the brakes done?

11. A car has run out of gas. Fortunately, there is a gas station nearby. You must exert a force of 715 N on the car in order to move it. By the time you reach the station, you have done 2.72 x 10^4 J of work. How far have you pushed the car?

Power

$P = \frac{W}{t}$

- What is Power?
  - It is the rate at which work is done.
  - How quickly work is done.
  - Quantity that measures work in relation to time.
  - Watts are units of Power
    - Used to measure power of light bulbs and small appliances
    - An electric bill is measured in kW/hrs.
    - 1 kilowatt = 1000 W



Understanding Power

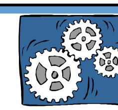
$P = \frac{W}{t}$

- Running up stairs is harder than walking up stairs

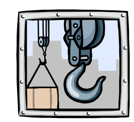
  Why?
  - Running does the same work more quickly
- Your power output would be greater than if you walked up the stairs.

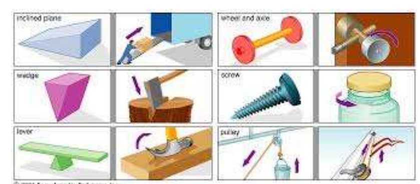
- If two people mow two lawns of equal size and one does the job in half the time, who did more work?
  - Same work
  - Different power exerted

Machines



- A device that makes work easier.
- A machine can change the size, the direction, or the distance over which a force acts.
- They multiply force by using a small force to go a long distance
- Things like ramps, levers, etc.

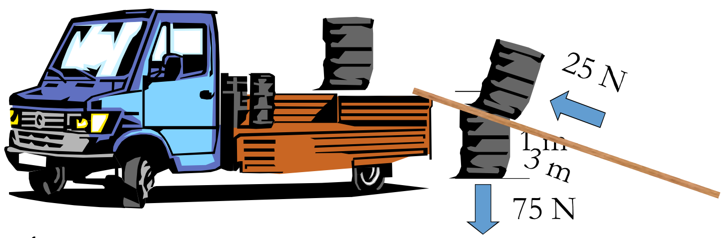




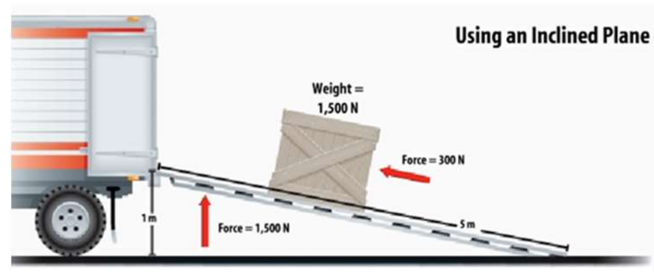
W = 75 N x 1 m = 75 J

W = 25 N x 3 m = 75 J

What increased in this scenario?
What decreased in this scenario?



Mechanical Advantage (MA)



Mechanical Advantage (MA)

- How many times a machine multiplies the input force
- Mechanical advantage greater than 1 multiplies force
- Less than 1 it multiplies distance, less force

Mechanical Advantage (MA)

Mechanical Advantage = output force / input force

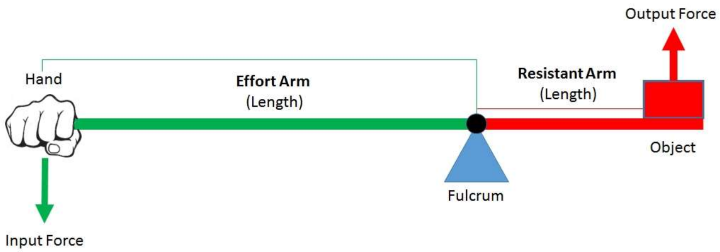
Forces involved:

- Input Force
- F_I
- Effort Force
  - Force applied to a machine

- Output Force
- F_O
- Resistance Force
  - Force applied by a machine

Mechanical Advantage

Mechanical Advantage = $\frac{\text{output force}}{\text{input force}}$



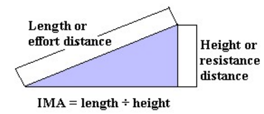
Forces involved:

- Input Force
- F_I
- Effort Force
  - Force applied to a machine

- Output Force
- F_O
- Resistance Force
  - Force applied by a machine

Mechanical Advantage

Mechanical Advantage = $\frac{\text{input distance}}{\text{output distance}}$



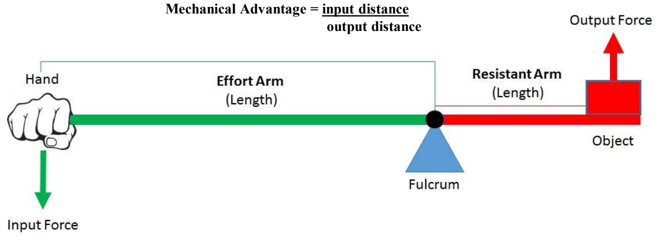
Distance involved:

Input Distance
- D_I
- Length distance
- Effort distance

Output Distance
- D_o
- Height distance
- Resistance distance

Mechanical Advantage

Mechanical Advantage = $\frac{\text{input distance}}{\text{output distance}}$



Distance involved:

Input Distance
- D_I
- Length distance
- Effort distance

Output Distance
- D_o
- Height distance
- Resistance distance

Calculating Mechanical Advantage

2 Types of MA

Calculating Mechanical Advantage

1. Mechanical Advantage = $\frac{\text{output force}}{\text{input force}}$
2. Mechanical Advantage = $\frac{\text{input distance}}{\text{output distance}}$

- MA = has no unit
- Force= Newtons
- Distance = meter

Calculating Mechanical Advantage

What does the formula look like if you are looking for output force?

What does the formula look like if you are looking for input force?

What does the formula look like if you are looking for output distance?

What does the formula look like if you are looking for output distance?

Mechanical Advantage

The force that you apply on a machine is known as the _____.

Answer

The force that you apply is the input force. The force the machine applies is the output force.

Practice Problem (Mechanical Advantage)

1. Find the mechanical advantage of a ramp that is 6.0 m long and 1.5 m tall.

MA = input distance/output distance

MA = 6.0 m/1.5 m

MA = 4.0

- So, what was increased?

Force, because it was great than 1

Practice Problem (Mechanical Advantage)

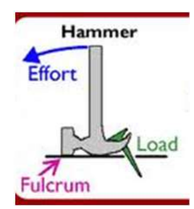
2. Alex pulls on the handle of a claw hammer with a force of 15 N. If the hammer has a mechanical advantage of 5.2, how much force is exerted on the nail in the claw?

F out= ?
MA =5.2
F in = 15 N

F out= MA x F in

F out= 5.2 x 15 N

F out= 78 N



Practice Problem (Mechanical Advantage)

3. If an input force of 202 N is applied to the handles of the wheelbarrow with a mechanical advantage of 2.2. How large is the output force that just lifts the load?

MA= 2.2
F_{out}= ?
F_{in}= 202 N

F_{out}= MA x F_{in}

F_{out}= 2.2 x 202 N

F_{out}= 444.4 N

4. Suppose you need to remove a nail from a board by using a claw hammer. What is the input distance for a claw hammer if the output distance is 2.0 m and the mechanical advantage is 5.5?

MA= 5.5
D_{out}= 2.0 m
D_{in}= ?

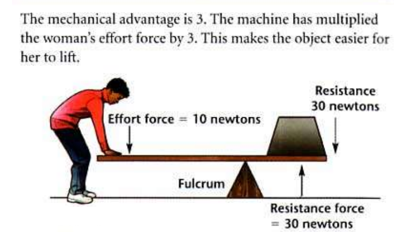
D_{in}= MA x D_{out}

D_{in}=5.5 x 2.0 cm

D_{in}= 11 m

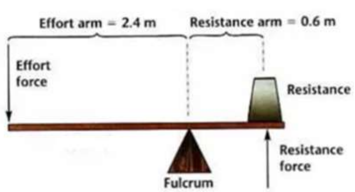
Mechanical Advantage

5. What is the MA for the example below?



Mechanical Advantage

6. What is the MA for the example below?



Mechanical Advantage Question?

As an inclined plane becomes longer, the force needed to move an object over it becomes _______.

Answer

The force needed becomes smaller. This is the advantage of using a ramp, which is an inclined plane, instead of lifting objects.

Mechanical Advantage Worksheet

1. Mechanical Advantage = $\dfrac{\textbf{output force}}{\textbf{input force}}$ **2. Mechanical Advantage =** $\dfrac{\textbf{input distance}}{\textbf{output distance}}$

1. The power steering in an automobile has a mechanical advantage of roughly 75. If the input force on the steering wheel is 49 N, what is the output force that turns the car's front wheels?

2. An axe used to split wood is driven into a piece of wood for an input distance of 3.0 cm. If the mechanical advantage of the axe is 0.85, how far apart (output distance) is the wood split?

3. The mechanical advantage of an automobile's wheel and axle is 0.0893. If the wheel's output force is 2220 N, what is the input force that turns the axle?

4. You apply a force of 18 N on to the end of a lever to open a paint can lid. The resistance of the lid is 9 N. Calculate the MA.

5. An Archimedean screw is a screw within a closely fitting cover, so that water can be raised when the screw is turned. Suppose the screw has a mechanical advantage of 12.5. If the screw is turned several times, so that the input distance is 15.7 m, how much has water been lifted upward by the screw?

6. A mover uses a ramp to load a crate of nails onto a truck. The crate, which must be lifted 1.4 m from the street to the bed of the truck, is pushed along the length of the ramp. If the ramp is 4.6 m long and friction between the ramp and crate can be ignored, what is the mechanical advantage of the ramp?

7. A complex arrangement of pulleys forms what is called the block in a block and tackle. The rope used to lift the pulleys and the load is the tackle. A block and tackle is used to lift a truck engine uses a force of nearly 7406 N. The required force to lift this weight using the block and tackle is 308.6 N. What is the mechanical advantage of the block and tackle?

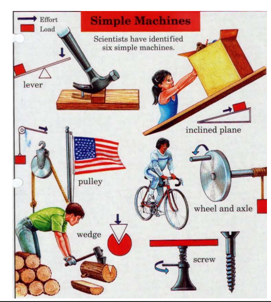
8. It has been proposed that the stones of the Pyramids in Egypt were raised by using ramps. Suppose one of these ramps had a mechanical advantage of 3.86. If an input force of 6350 N was provided by laborers, what would the output force on the stone have been?

9. A wedge with a mechanical advantage of 0.78 is used to raise a house corner from its foundation. If the resistance force is 7500 N, what is the effort force?

What is a Simple Machine?

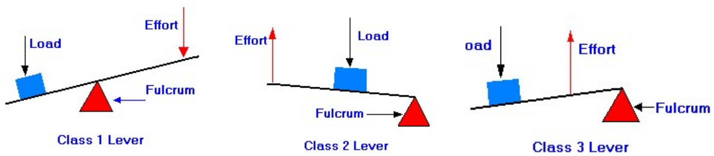
- A simple machine has few or no moving parts.
- Simple machines make work easier
- Six types
  - Levers, Incline Plan, Pulley, Wheel & Axel, Wedge, Screw

- **2 Families**
  - **Lever** (Levers, Wheel & Axel, Pulley)
  - **Incline Plan** (Incline plan, wedge, screw)



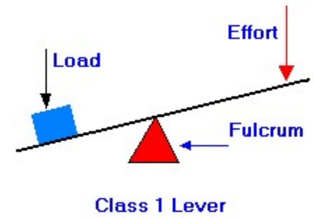
1. THE LEVER

- A bar that is free to pivot, or move about a fixed point when an input force is applied.
- *Fulcrum* = the pivot point of a lever.
- There are three classes of levers based on the positioning of the effort force, resistance force, and fulcrum.

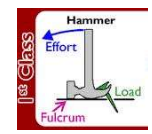


Lever Family-1st Class

- The fulcrum is in the middle and the load and effort is on either side
- Makes work easier by multiplying the effort force AND changing direction.

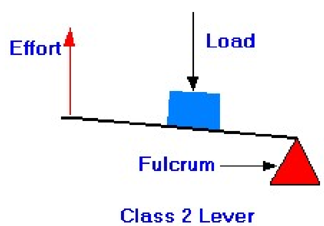


Ex. See-saw, Hammer

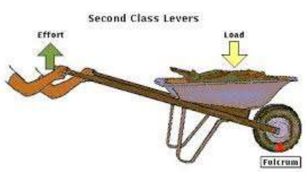


Lever Family-2nd Class

- The fulcrum is at the end, with the load in the middle
- Makes work easier by multiplying the effort force, but NOT changing direction.

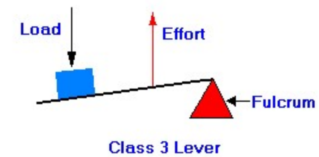


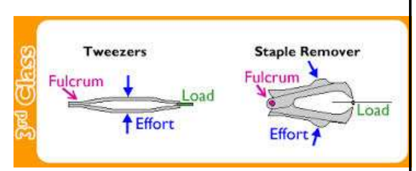
Ex: wheelbarrow

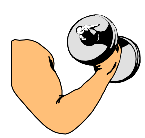


Lever Family- 3rd Class

- The fulcrum is again at the end, but the effort is in the middle
- Does NOT multiply the effort force, only multiplies the distance.

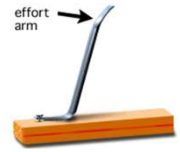




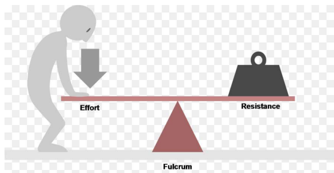


Ex: tweezers

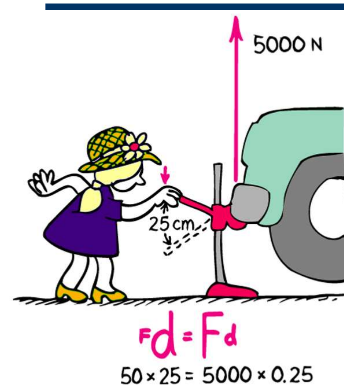
Mechanical advantage of levers.



- Ideal = input arm length/output arm length
- *input arm* = distance from input force to the fulcrum
- *output arm* = distance from output force to the fulcrum

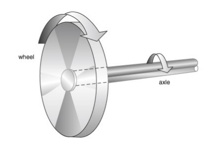


Levers



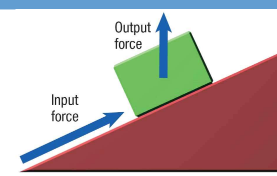
2.Wheels and Axles

- A lever that rotates in a circle.
- A combination of two wheels of different sizes.
- Smaller wheel is termed the axle.
- IMA = radius of wheel/radius of axle

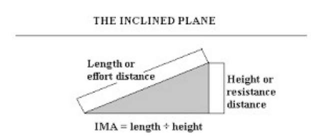


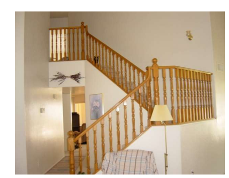
THE WHEEL AND AXLE IS A WHEEL CONNECTED TO A RIGID POLE.

3. Inclined Planes



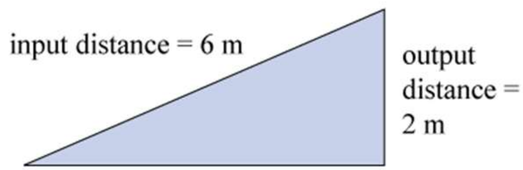
- An inclined plane is a flat surface that is higher on one end
- Inclined planes make the work of moving things easier
- Reduces input force
- Ramp





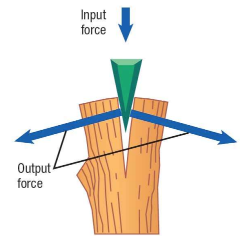
MA on ramp

Mechanical Advantage = $\frac{\text{input distance}}{\text{output distance}}$



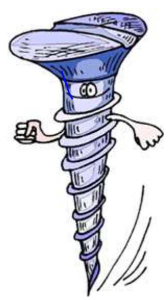
4. Wedges

- Two inclined planes joined back to back.
- Wedges are used to split things.



5. Screws

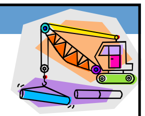
- A screw is an inclined plane wrapped around a shaft or cylinder.
- The inclined plane allows the screw to move itself when rotated.



6. Pulleys- Lever family

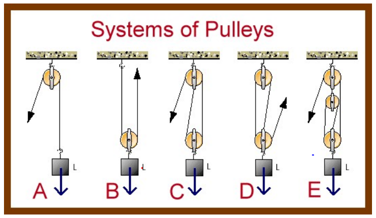
- Pulley are wheels with a groove around the outside
- A pulley needs a rope, chain or belt around the groove to make it do work
- They redirect force
  - Enables us to use gravity to help us (it is usually easier to pull down to lift something up)
- One end of rope has a force applied

Why use pulleys?



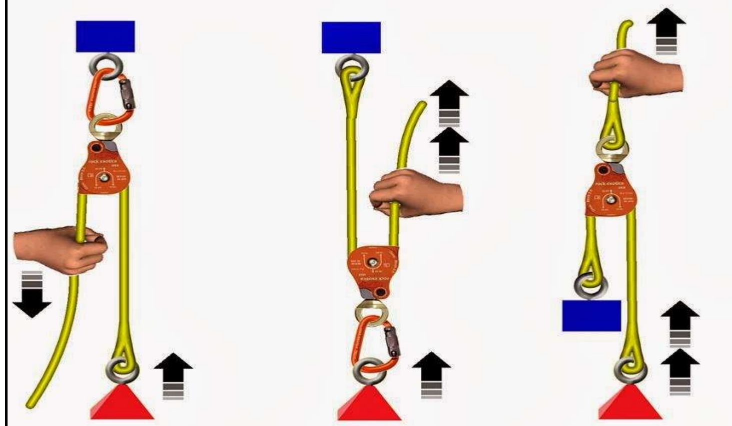
- Using several pulleys reduces the force required to lift an object
  - We have to use more rope and make the rope go further
  - Mechanical Advantage: More distance traveled, but less force required

The mechanical advantage of a pulley system is equal to the number of sections of rope pulling up on the object.



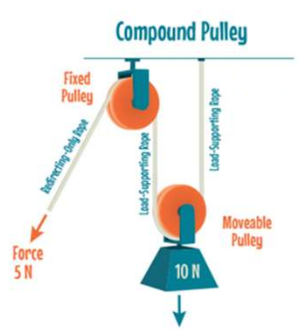
Count the number of rope segments on each side of the pulley, including the free end. If the free end is to be pulled down, subtract 1 from this number. This number is the mechanical advantage.

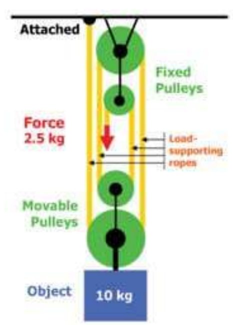
Pulleys as levers



Class 1 Class 2 Class 3

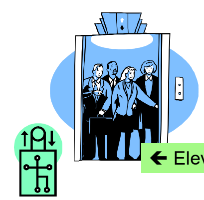
Pulleys Systems



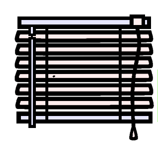


Who has seen pulleys?

…Pulleys are all around us…



← Elevator



← Window shades and blinds

Flagpole →

More examples

← Cranes ↓

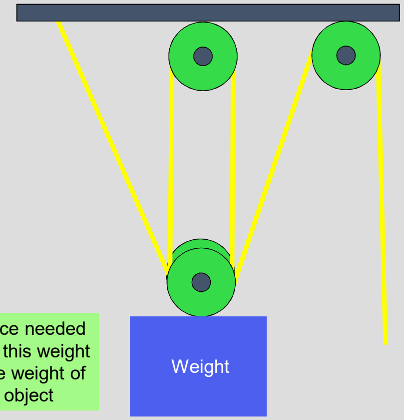
← Sails and fishing nets

+ clothes lines

+ gym training equipment

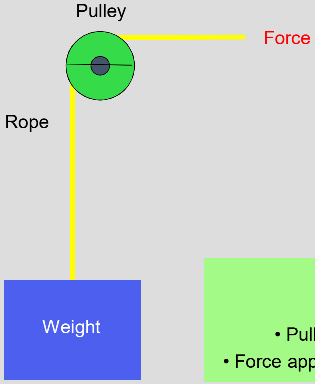
+ rock climbing gear

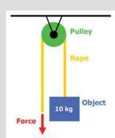
System of Pulleys

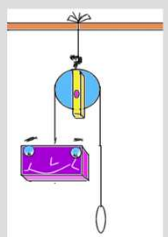


The force needed to raise this weight is ¼ the weight of the object

Pulley Type: Fixed Pulley





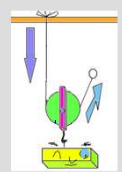


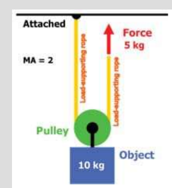
Fixed Pulley

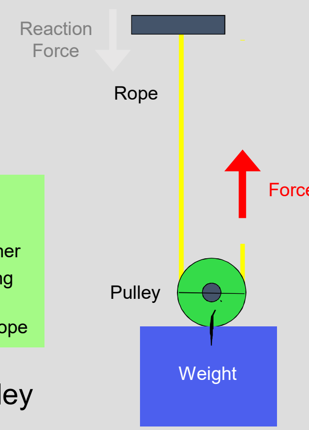
- Object moves
- Pulley stays in the same spot
- Force applied only on one end of the rope

- Single fixed pulley MA = 1

Pulley Type: Movable Pulley







Movable Pulley

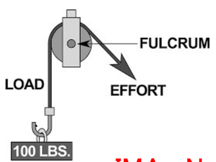
- Pulley is attached to object
- Pulley and object move together
- Rope is attached to something that does not move
- Force applied to other end of rope

- Single moveable pulley MA = 2

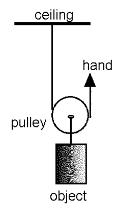
Pulley types

- FIXED
- Can only change the direction of a force.
- MA = 1

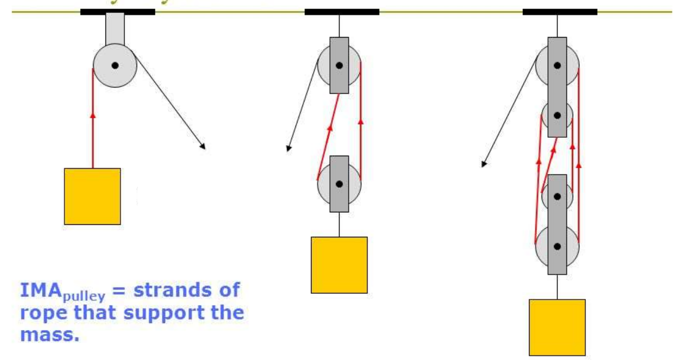
- MOVABLE
- Can multiply an effort force, but cannot change direction.
- MA > 1



IMA= Number of supporting ropes



Pulley Systems



IMA_{pulley} = strands of rope that support the mass.

5/5/2015

Mechanical Advantage

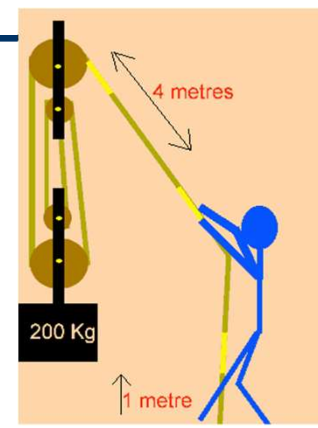
There are three main advantages to using a machine. In what three ways does a machine make work easier?

Answer

A machine makes work easier by changing the amount of force you need to exert, changing the distance over which the force is exerted, and changing the direction in which you exert the force.

Mechanical Advantage

- How many supporting strands are there ?
- What is the Mechanical advantage here equal to?
- What is the input force required to lift the 200kg object?



Compound Machines

- Compound machine: a machine that combines **more than one** simple machine.
- Simple Machines can be put together in different ways to make complex machinery