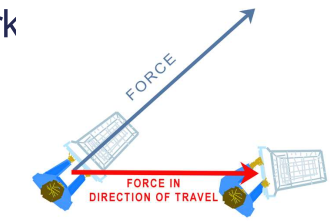
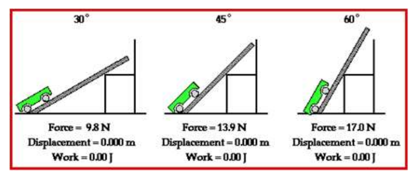
CHAPTER 13.1 & 13.2

Work, Power and Machines

Work

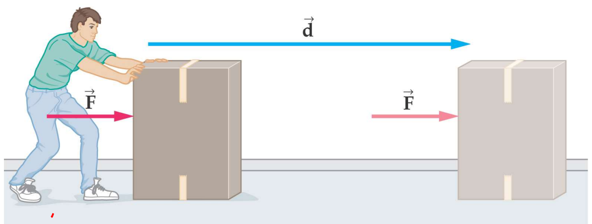
- What is work?
  - Work is done when changing motion
- The product of the force applied to an object and the distance through which that force is applied.
- Work is zero when an object is not moving





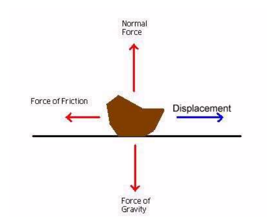
Video

Work is force times distance…but!



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

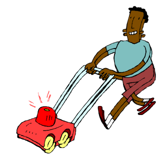
- All or part of the force must act in the direction of the movement.

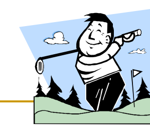


Is work being done or not?

- Mowing the lawn
- Dragging a bag of books
- Moving furniture up a flight of stairs
- Pushing against a locked door
- Swinging a golf club
- Sitting on a chair

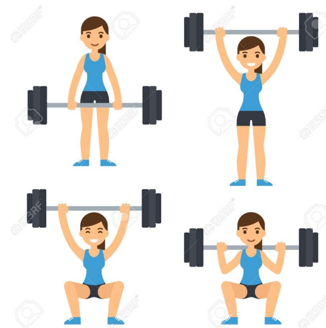
- YES
- YES
- YES
- NO
- YES
- NO





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



Calculating Work

- Work= force x distance
- W = F x d
- Unit of work is Joules

work = force x distance

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

Units of work

- Force= Newton
- Distance= meters
- Work= Newton x meter (N·m)
- N·m= 1Joules (J)
- Or kg·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 Or W= 1.3×10^5 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 or W = 1.75×10^3 J

Practice Problem (Work)

3. A mechanic uses a hydraulic life 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 9.8 m/s^2

F= 11760 N

W= F x d

W= 11760 N x 0.50 m

W= 5880 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?

27200

W = 2.72×10^4 J
F=715 N
d= ?

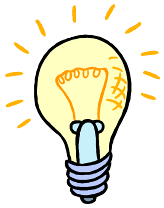
d= W/F

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

d= 38.04 m

Power

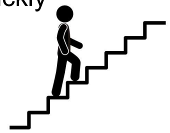
- What is Power?
  - It is the rate at which work is done.
  - How quickly work is done.
  - Quantity that measures work in relation to time.
  - Watts are units of Power
    - Used to measure power of light bulbs and small appliances
    - An electric bill is measured in kW/hrs.
    - 1 kilowatt = 1000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



Understanding Power

- 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

Calculating Power

- Power is work divided by time
- Power = work/time
  - Units for power is watts

- Power = Watts (W)
- Work= Joules
- Time= s

- 1 watt is the power to do 1 J of work in 1 s

What is the formula when solving for work?

W= p x t

What is the formula when solving for time?

T= w/p

Practice Problem (Power)

1. A student lifts a 12 N textbook 1.5 m of the floor in 1.5 s.

How much work did he do?

W = f x d   W = 12 N x 1.5 m   W = 18 J

How much power did he use?

P = W/t   P = 18 J/ 1.5s   P = 12 W

Practice Problem (Power)

2. A 43 N force is exerted through 2.0 m distance for 3.0 s.
   How much work was done?

W= ?
F= 43 N
d= 2.0 m

W = f x d   W =43 N x 2.0 m   W = 86 J

How much power was used?

P= ?
W= 86 J
t= 3.0 s

P = W/t

P = 86 J / 3.0 s

P = 28.66 W

P = 29 W

Practice Problem (Power)

3. While rowing across the lake during a race, John does 3,960 J of work on the oars in 60.0 s. What is his power output in watts?

P= ?
W= 3,960 J
t= 60.0 s

P= W/t

P= 3960 J / 60.0 s

P= 66 W

Practice Problem (Power)

4.Anna walks up the stairs on her way to class. She weighs 565 N, and the stairs go up 3.25 m vertically.

a. If Anna climbs the stairs in 12.6 s, what is her power output?

P= ?
W= 1836.25 J
t= 12.6 s

P=W/t

P=1836.25 J /12.6 s

P=145.73 W

b. What is her power output if she climbs the stairs in 10.5 s?

P= ?
W= ?
t= 10.5 s

Figure out work first

W= ?
F= 565 N
d= 3.25

W= F x d

W= 1836.25 J

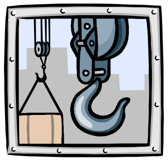
P=W/t

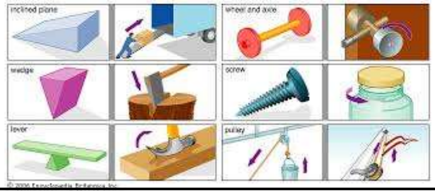
P=1836.25 J / 10.5 s

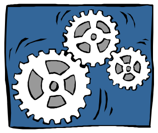
P=174.88 W

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.







Mechanical Advantage

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

Forces involved:

- Input Force
  - F_I
  - Force applied to a machine
- Output Force
  - F_O
  - Force applied by a machine

Calculating Mechanical Advantage

2 Formula: 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

Determine if you are using force or distance first.

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

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

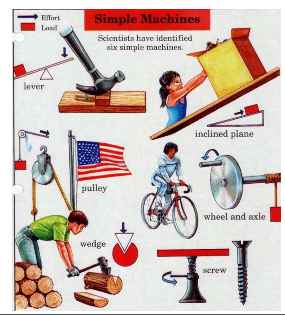
MA = 4.0

- So, what was increased? Force, because it was great than 1

What is a Simple Machine?

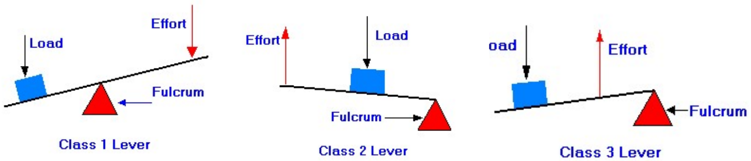
- A simple machine has few or no moving parts.
- Simple machines make work easier
- Six types
  - Levers, Incline Plan, Pulley, Wheel & Axel, Wedge, Screw

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



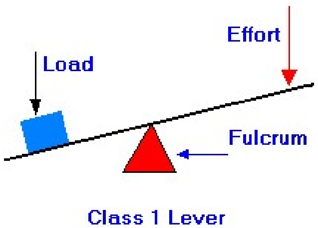
1. THE LEVER

- 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.

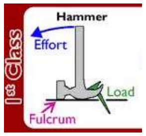


Lever Family-1st Class

- 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.

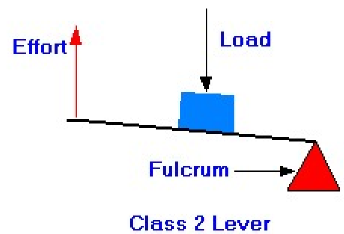


Ex. See-saw, Hammer

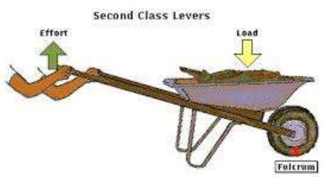


Lever Family-2nd Class

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

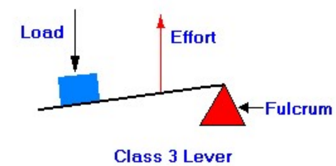


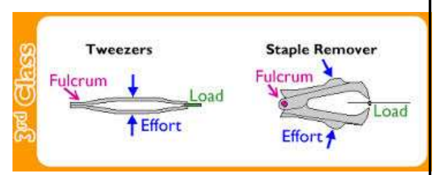
Ex: wheelbarrow

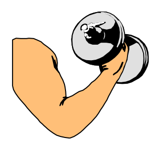


Lever Family- 3rd Class

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



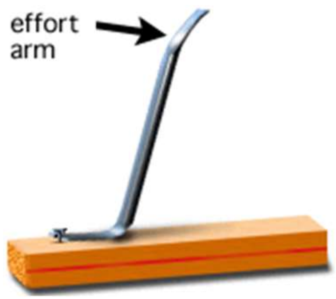




Ex: tweezers

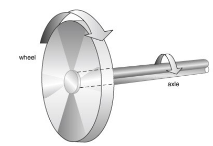
Mechanical advantage of levers.

- 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



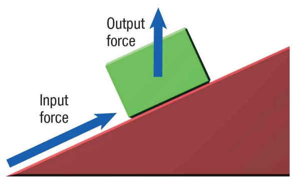
2.Wheels and Axles

- 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.

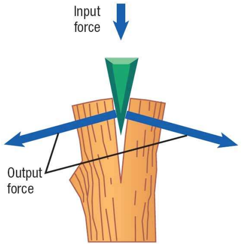
3. Inclined Planes



- 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

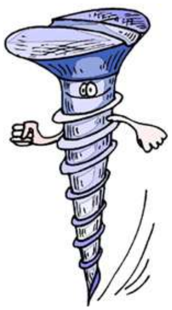
4. Wedges

- 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.

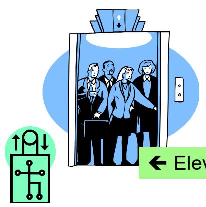


6. Pulleys

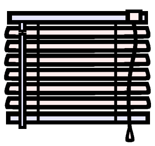
- Pulley are wheels with a groove around the outside
- A pulley needs a rope, chain or belt around the groove to make it do work
- They redirect force
  - Enables us to use gravity to help us (it is usually easier to pull down to lift something up)
- One end of rope has a force applied

Who has seen pulleys?

…Pulleys are all around us…



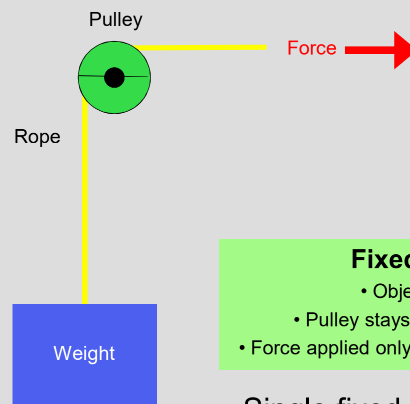
← Elevator

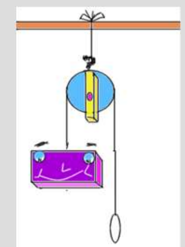


← Window shades and blinds

Flagpole →

Pulley Type: Fixed Pulley



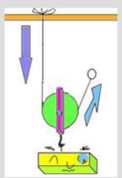


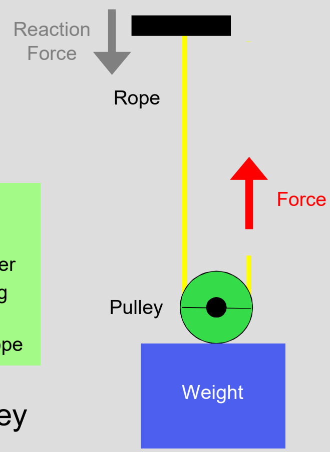
Fixed Pulley

- 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

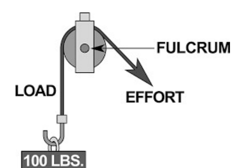
- Pulley is attached to object
- Pulley and object move together
- Rope is attached to something that does not move
- Force applied to other end of rope

- Single moveable pulley
  MA = 2

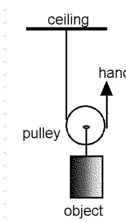
Pulley types

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

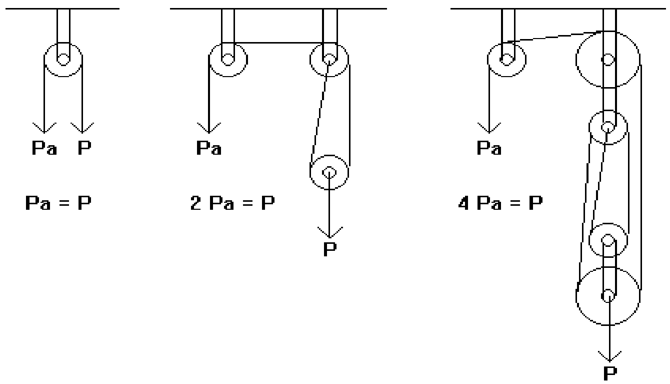
- MOVABLE
- Can multiply an effort force, but cannot change direction.
- MA > 1



IMA= Number of supporting ropes



MA = Count # of ropes that apply an upward force (note the block and tackle!)



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