Simple Machines

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What is Engineering?

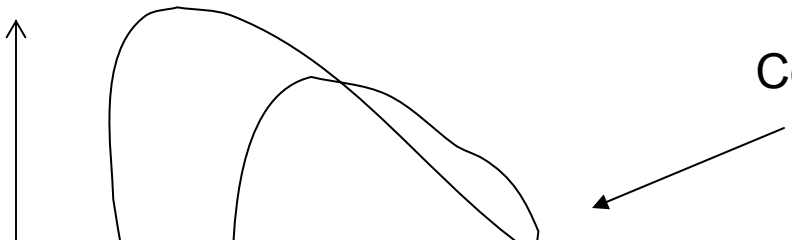
- To different people, it means different things
- To me, it's an "Art" (constructive imagination) and sometimes it means making "Toy"

"the use of skill and imagination in the creation of aesthetic objects, environments, or experiences that can be shared with others"

What is difference between engineering and science?

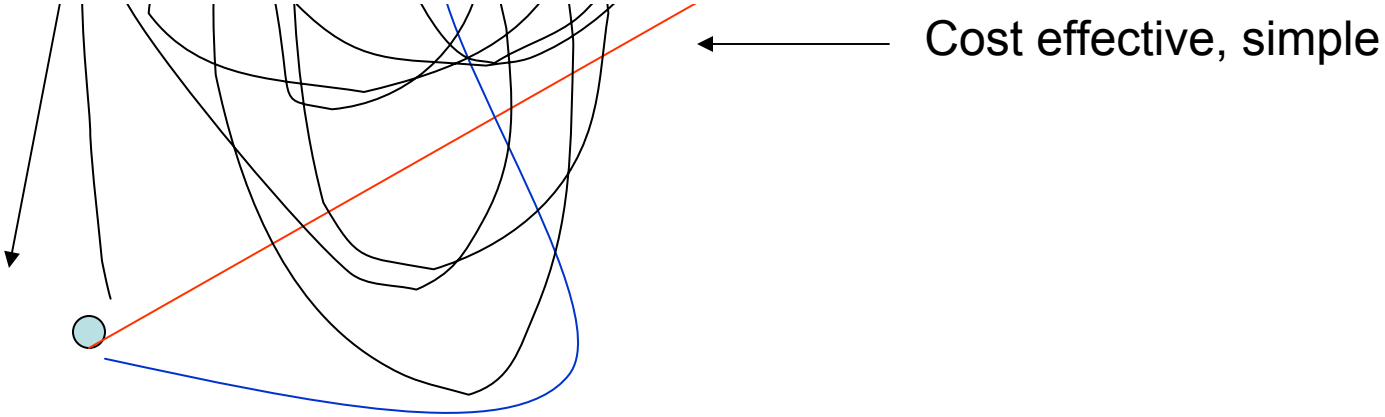
- Engineering is an application of science
- Methodical way of solving a particular large class of problems.
- Engineering solution is different from solving a Physics or Math problem where there are infinitely many different solution.

How to solve it?



There is no right way or wrong way of solving an engineering problem…..

It all depends on situation…….

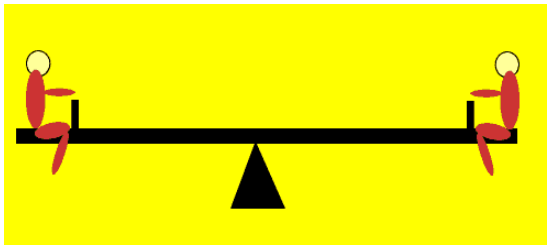


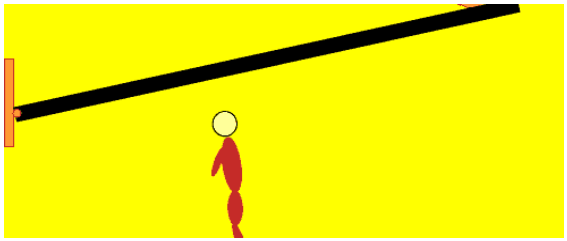
Extra credit tips

- Pick a design based on some of the topics we talked about in class. It does not have to be very complicated.
- Utilizing conventional literature search and online resources
- Observe your surrounding
- Use what you know
- Use What you have

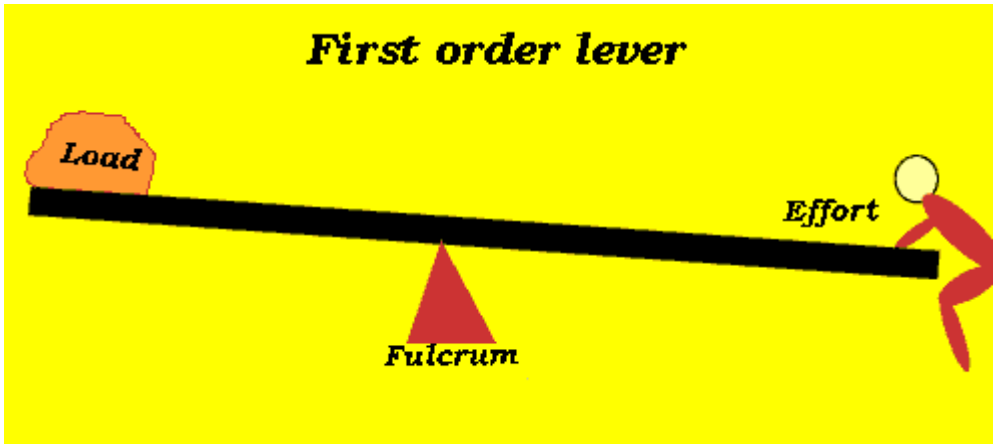
Simple Machine

Lever

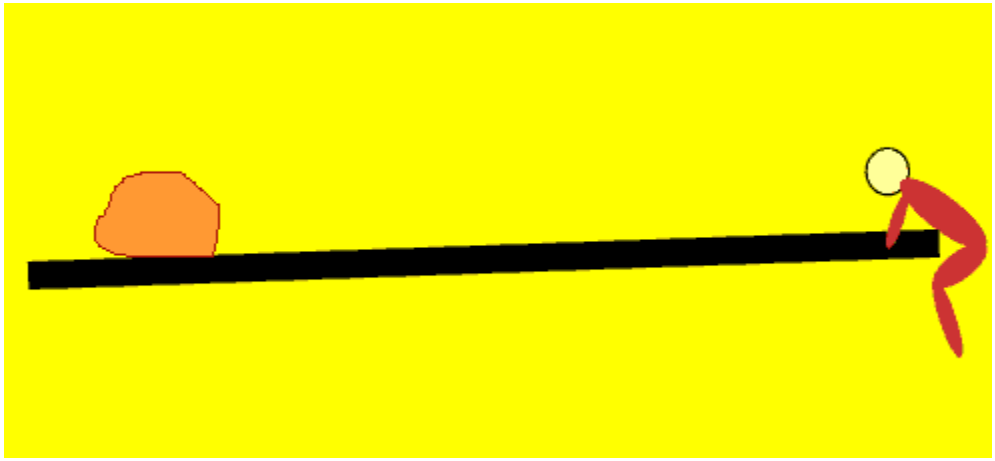




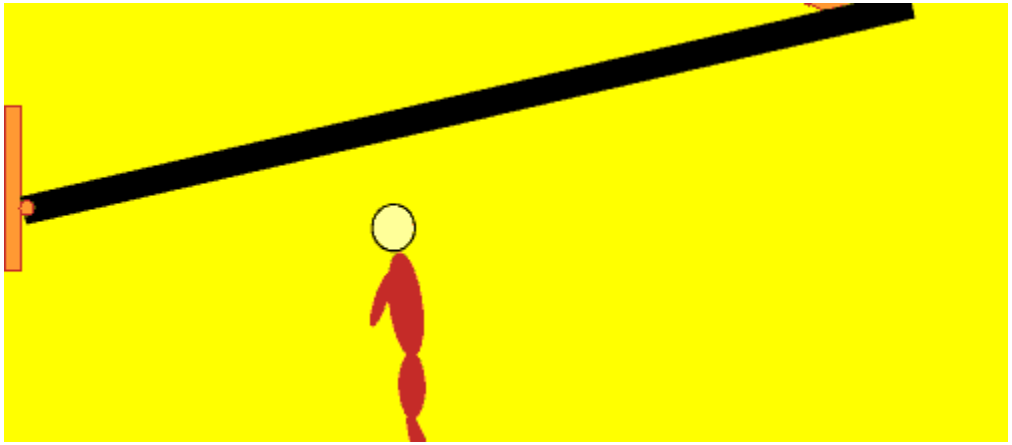
The most simplest of machines is the common lever. A simple log can act to magnify forces and shift objects heavier than the person holding the log. All levers have a ***fulcrum*** (turning point), ***effort*** (the force provided to do the work) and the ***load*** (the force we are pushing against).There are three classes of levers, ***first order, second order*** and ***third order***. They differ in the position of the fulcrum, load and effort.



First order levers have the turning point(fulcrum) between the load and the effort.



A lever that has the load between the fulcrum and the effort is known as a ***second order lever.***

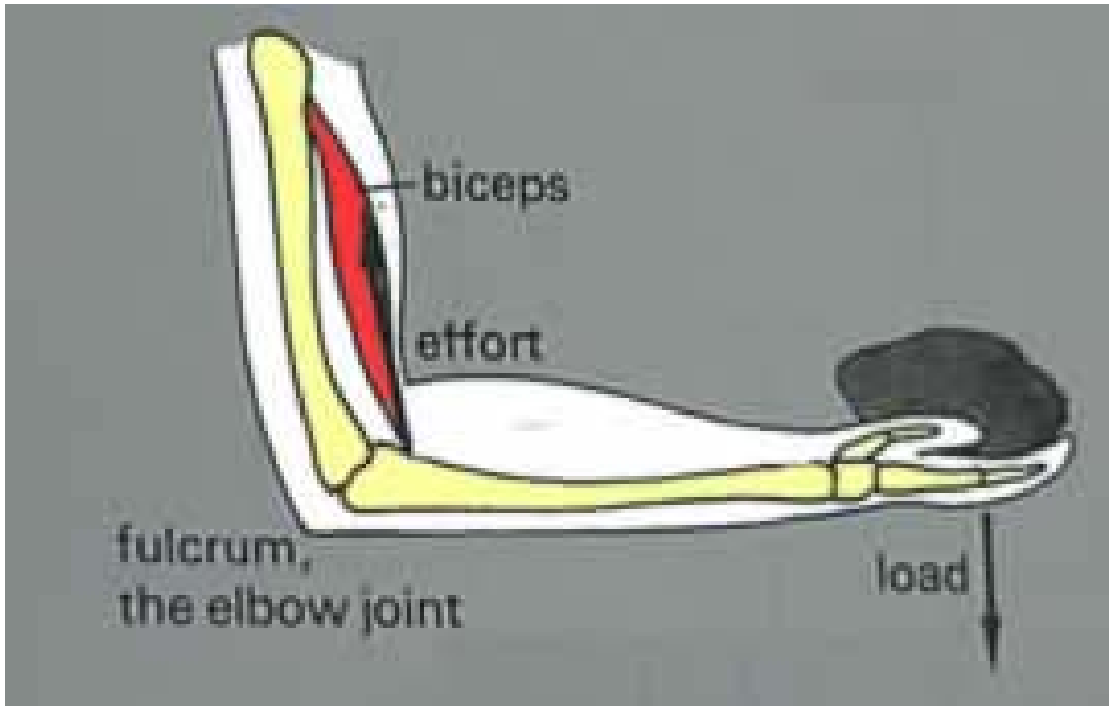


A third order lever is one which has the effort between the fulcrum and the load.

Such levers do not have good mechanical advantage. In fact they have ***mechanical disadvantage.*** The effort is closer to the fulcrum than the load. The effort is always greater than the load. However, one advantage of such levers is that the distance moved by the load is greater than the distance moved by the effort.

Cranes such as the one on the left are examples of third order levers. As you can see the effort is between the load, at the top, and the fulcrum. The advantage of this lever system is that the load moves through a greater distance than the effort. This is desirable when the crane needs to lift loads high above the ground.

Tweezers are another example of a third order lever.
Look at the image on the left. Identify the fulcrum, load and effort.

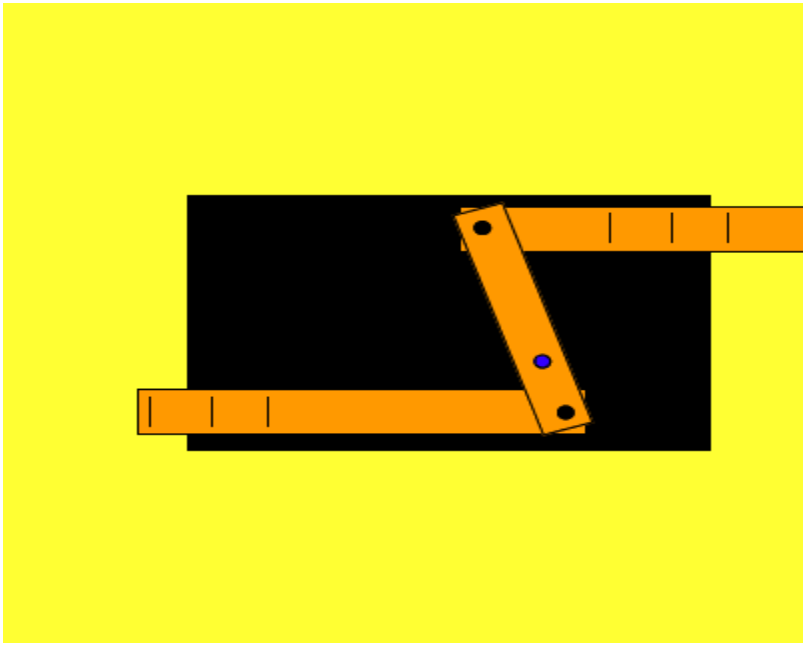


Is the arm an example of a third order lever? Explain.

- You have just learn the Physics problem “Moment”

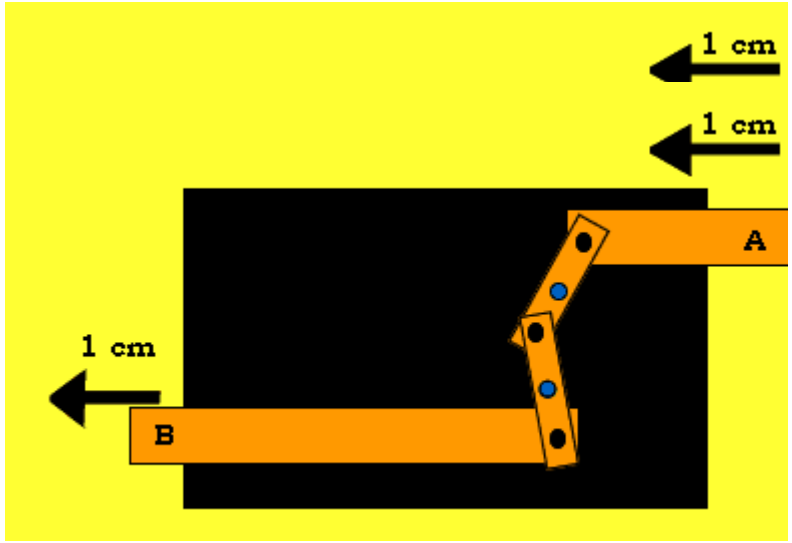
$$M_1R_1 = M_2 R_2$$

Lever use to move another lever in different distance



When lever "A" is pushed in 2 cms Lever "B" moves in 1cm.

Lever use to move another lever in different distance

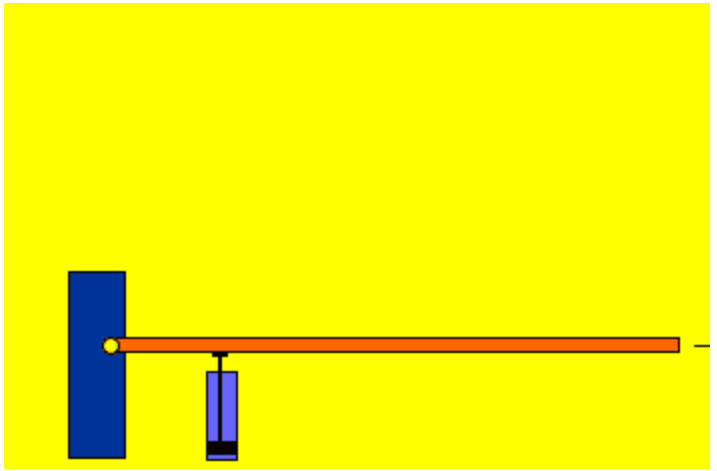


Design a set of levers housed in the black box that will carry out the following functions When lever "A" is pushed in 1 cms Lever "B" moves in 1cm in the same direction.

Distance and velocity ratio

- Look at the lever on the right. The effort(piston) moves up 10cms while the end of the lever moves 30cms over the same time period. The distance and velocity ratios are therefore the same and can be calculated by the expression below.

$$\text{velocity ratio} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$



- In this case the velocity ratio is 1/3.

Angular velocity

When on the same stick, ω angular velocity is same, but tangential velocity at the tip of the stick is different.. It's a function of the length of the arm

$V_1 = R_1 \times \omega_1$

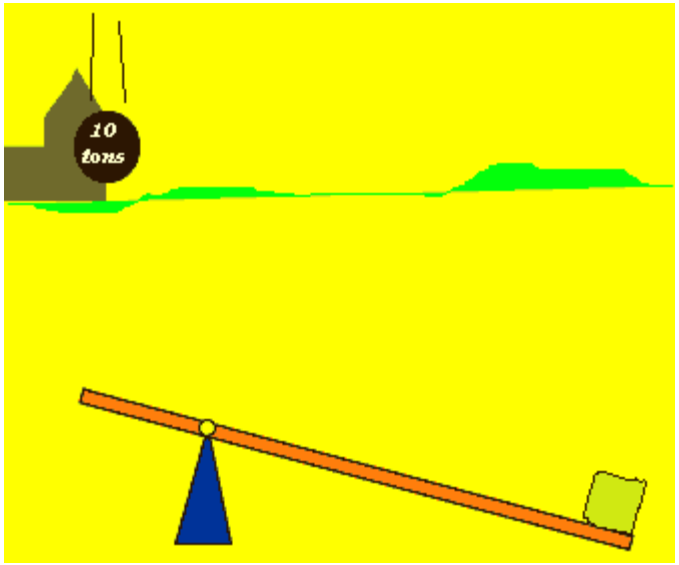
$V_2 = R_2 \times \omega_1$

$V_3 = R_3 \times \omega_2$

$V_4 = R_4 \times \omega_2$

How to use lever to increase velocity

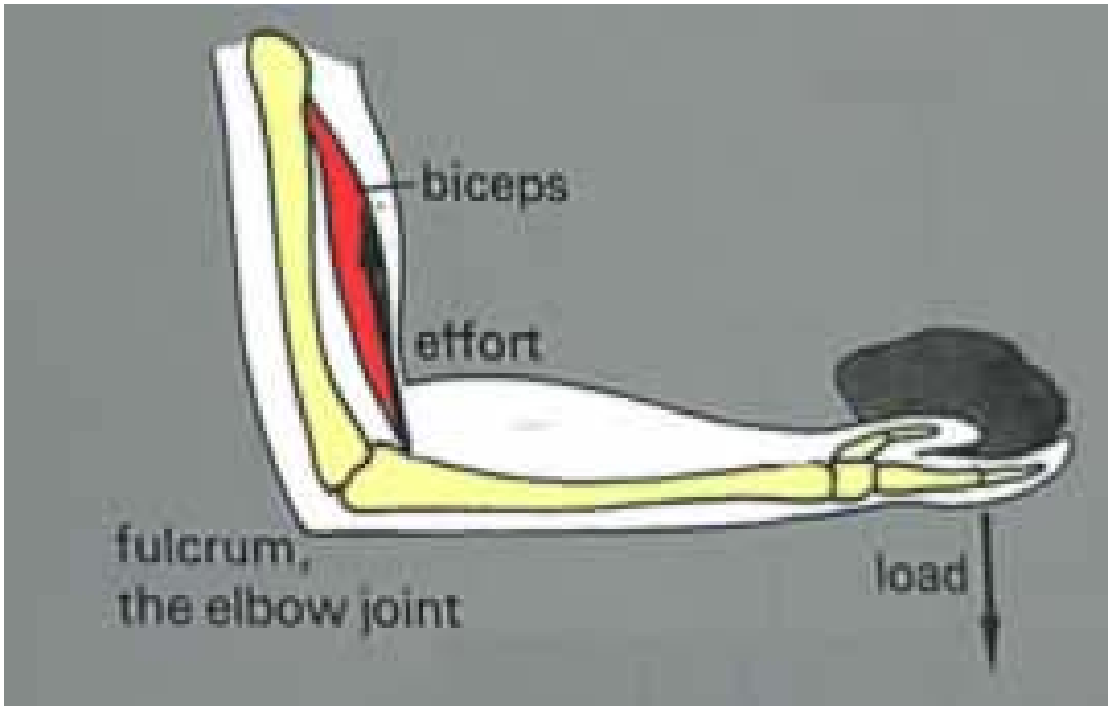
- Using levers to multiply the velocity of the load was used to great effect in medieval siege weapons. Huge boulders were hurled at castles with devastating effect.



What is one advantage and disadvantage of putting the hydraulic piston so close to the fulcrum?

Increase speed at the top

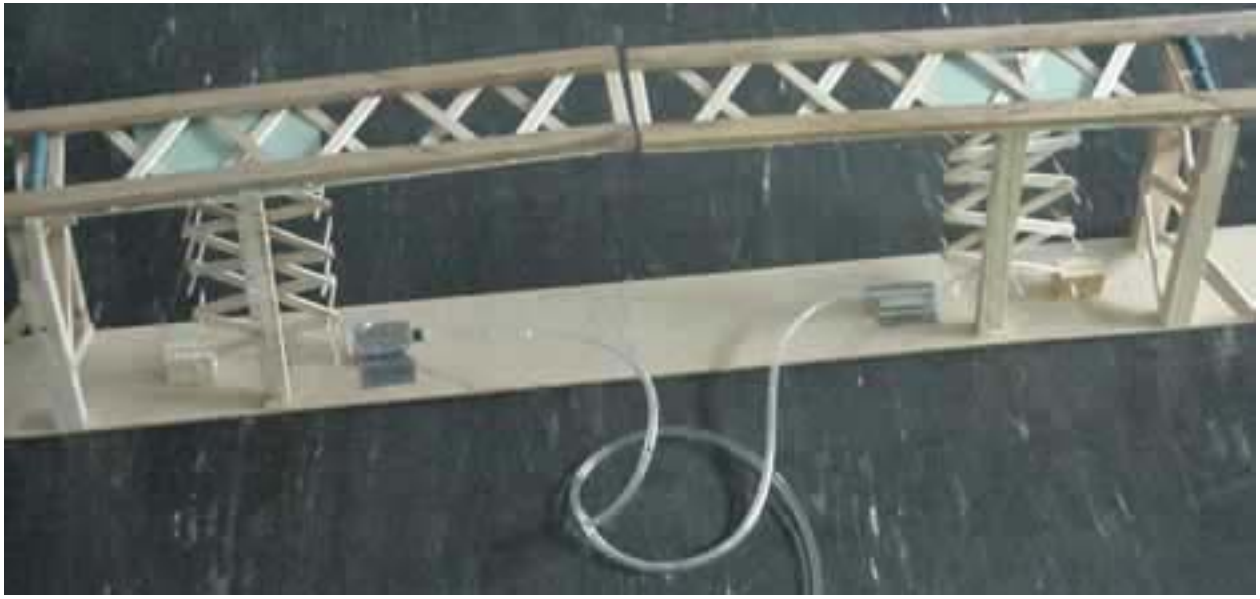
Harder to lift heavyweight



Why is the biceps muscle connected to the forearm so close to the elbow joint?

Lift faster

Combine with hydraulic with lever



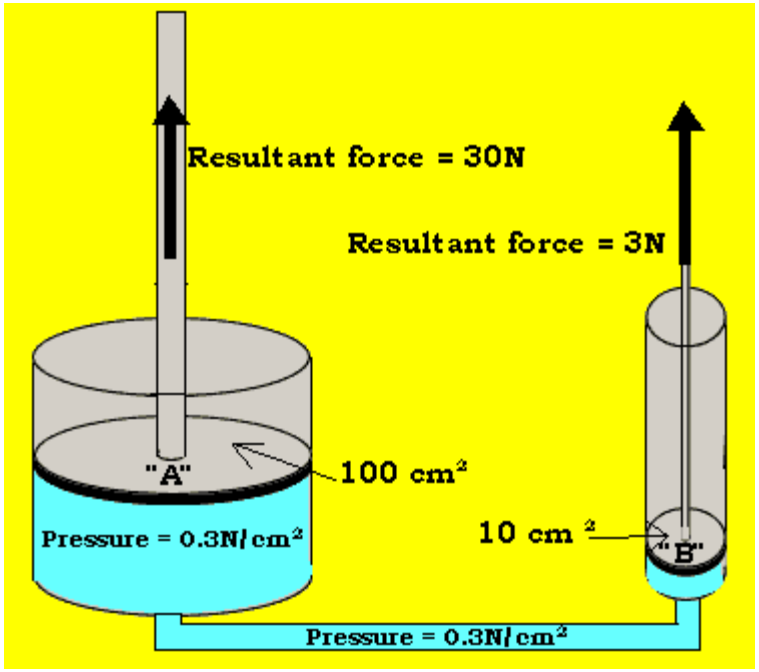
Conservation of momentum

$$M_1V_1 = M_2V_2 = M_1R_1\,\omega_1 = M_2\,R_2\,\omega_1$$

Momentum always conserve

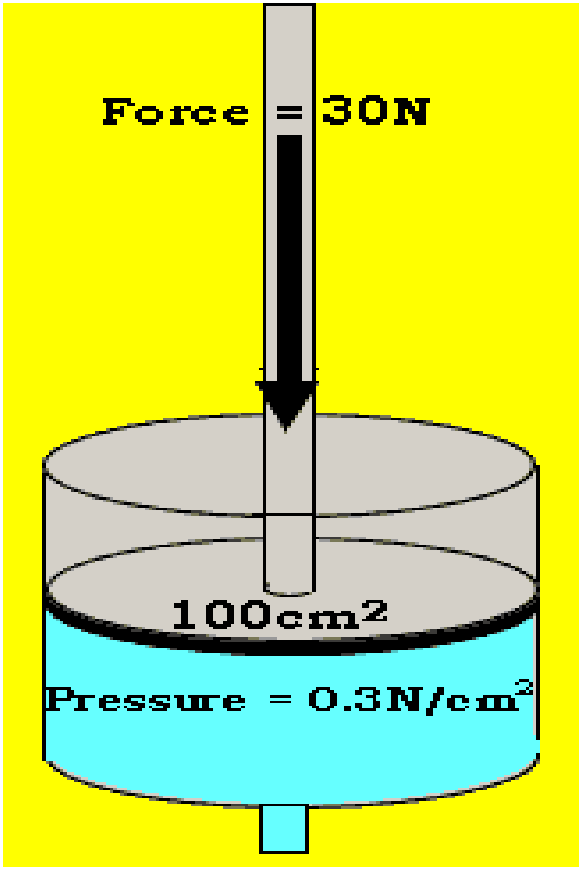
Hydraulic
Force, work and energy

- The force produced by a piston depends on the pressure the liquid inside the piston is under and the surface area of the piston.
- The force can be calculated according to the expression below.
- ***Force = pressure X area***
- Look at the single pistons on the right. Piston "A" has a surface area of 100 cm2 and fluid at a pressure of 0.3N / cm2. The resultant force is calculated as follows
- ***Force = 0.3N/cm2 X 100cm2***
  Force = 30N



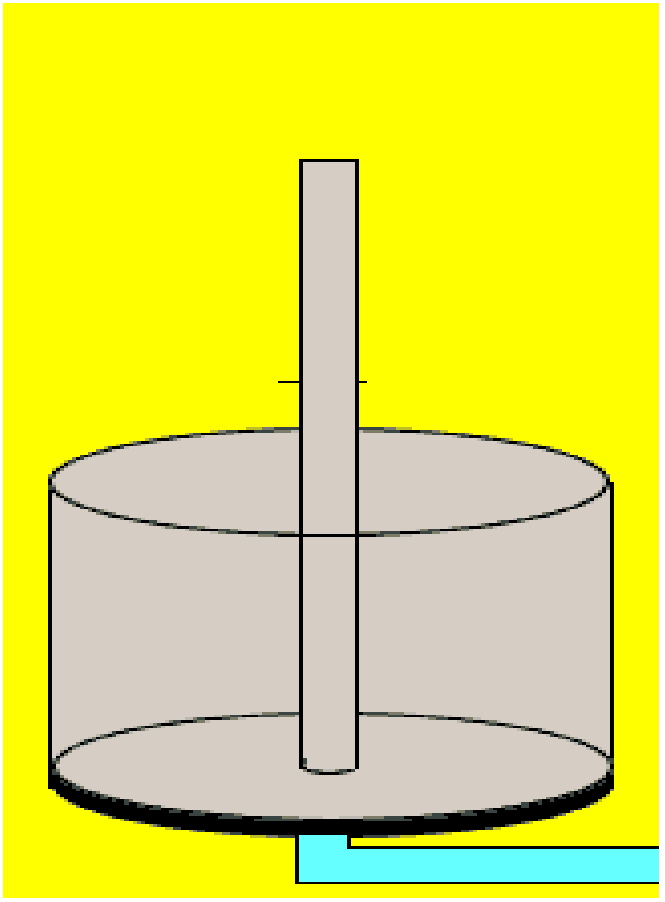
Pressure

- Pressure is the force exerted per unit area. Obviously the greater the force exerted over a small area the greater the pressure. The piston on the left has a surface are of 100 cm2and is pushed down with a force of 30 N. The pressure that the fluid inside the piston is under can be calculated by the expression below
  Pressure = force / area
  Pressure = 30N / 100 = 0.3N/cm2



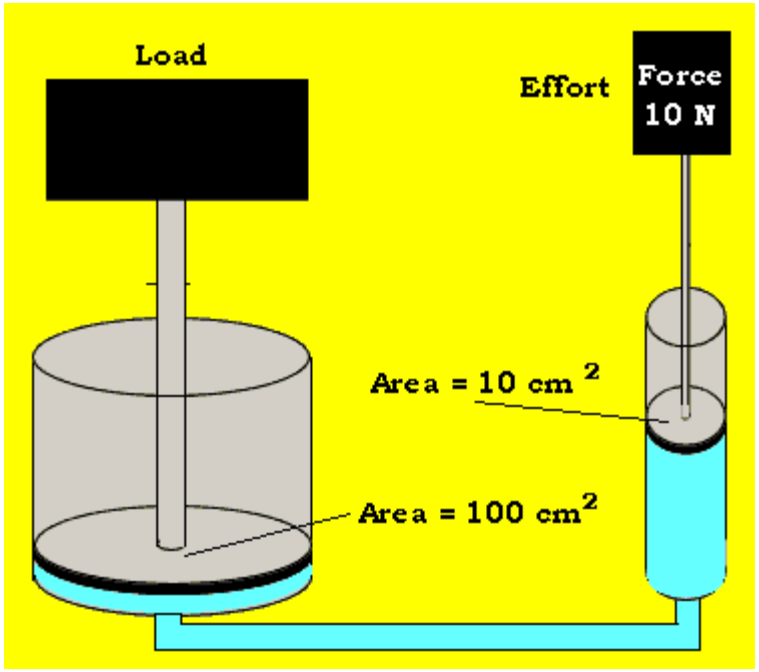
Work

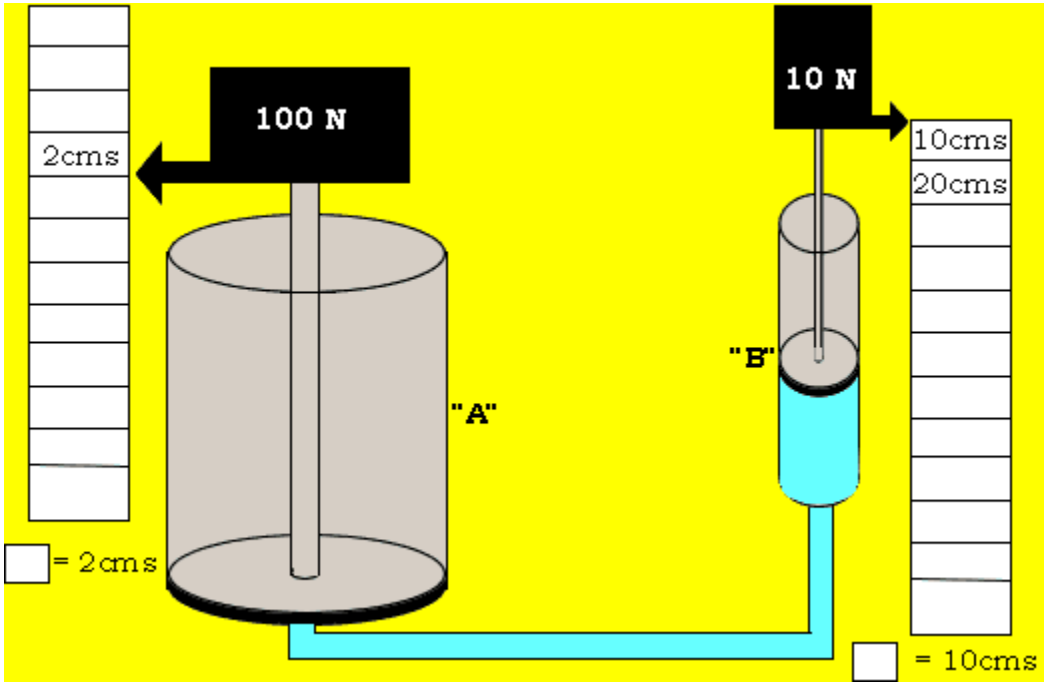
- Consider carrying 25 Kg of bricks 25 metres along the road. You can say you have done some work. Now try carrying 25Kg of bricks 50 metres along the road. You can now say you have done more work than before. ***Work*** is a concept defined by the expression below.
- ***Work = force***(N) ***X distance***(m).
- So the work done on the bricks to carry them 25 metres along the road is the product of the force, exerted by the man to lift the bricks against gravtiy and the distance travelled.
- The unit for work is the ***joule***.
- *One joule of work is done when a force of one Newton is applied over a distance of one metre.*
  Consider the piston on the left. If a force of 3N is applied to lift an object resting on the piston 3m high the work done on the object is
- Work = 3N X 3m = 9Nm = 9Joules



Multiplying forces using hydraulic

Pistons of different sizes can be used to magnify forces. Now how can this happen? It seems remarkable that we get something for nothing. Is this possible? No! You see the amount of work is the same. The work done in pushing the smaller piston down is exactly the work done in lifting the heavier weight up.
Consider the setup pictured on the right. If a force of 10N is applied to the smaller piston it generates a force of 100N to lift the load on the larger piston.
Note the different cross sectional areas of each piston. Pushing down on the smaller piston with a force of 10N generates a pressure in the liquid given by the expression below.
Pressure = force / Area = 10N/10cm2
Pressure = 1N/ cm2
This means that a force of 1N acts on every square centimetre of exposed surface. This pressure is transmitted through the fluid to the larger piston.
The large surface area of the other piston plays a critical role in multiplying the force. Now remember that a force of 1N acts on every square centimetre of exposed surface area. The larger piston with 100cm2 of exposed area will have a force exerted on it according to the expression below.
Force = pressureXarea = 1N/cm2 X 100cm2
Force = 100N





Look at the operation of the two pistons above of a 10N force being multiplied to become a 100N force. Notice how the smaller piston with a force 10N travels 20cms down the grid, while the larger pistons travels 2cms up the grid. Now lets calculate the work done by each piston.

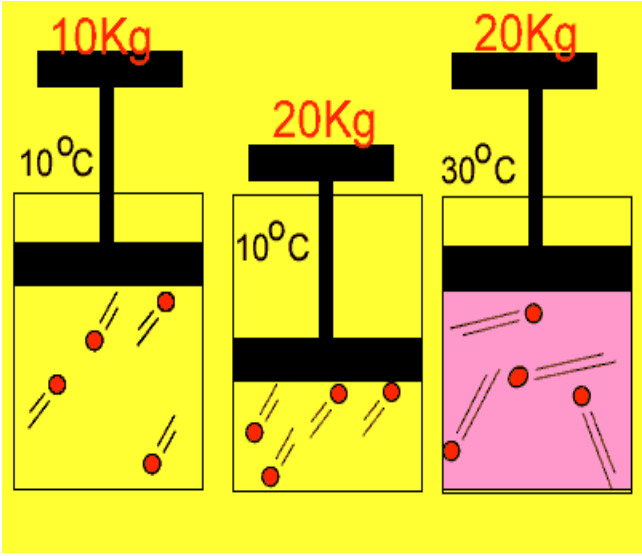
Piston "A" = Force X Distance = 100N X 0.02m = 2 Joules

Piston "B" = Force X Distance = 10N X 0.2m = 2 Joules.

Notice how the work is the same. The law of conservation of energy (***"Energy can not be created or destroyed"***) is not violated. The increase in force is compensated by a decrease in distance travelled.

Gas pressure and the kinetic theory

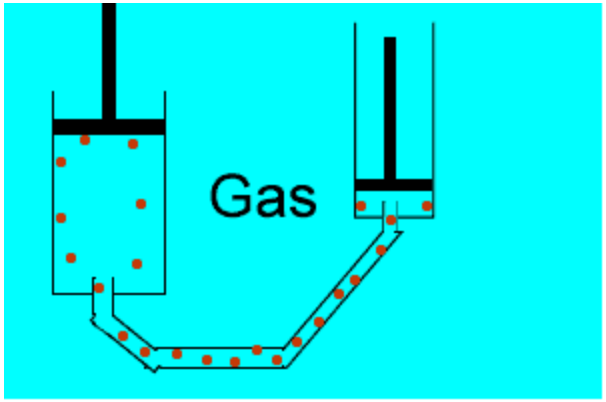
Gases are made of molecules in constant, high speed, random motion. The molecules collide frequently with the walls of their container, exerting pressure with every collision. **Pressure** is simply caused by billions of tiny collisions on the wall of the container every second. Pressure is the force applied over a known area. Collisons of molecules with the walls of the container exert a force on the wall surface. The bigger the surface the lower the pressure. Pressure is given by the formula
force/area

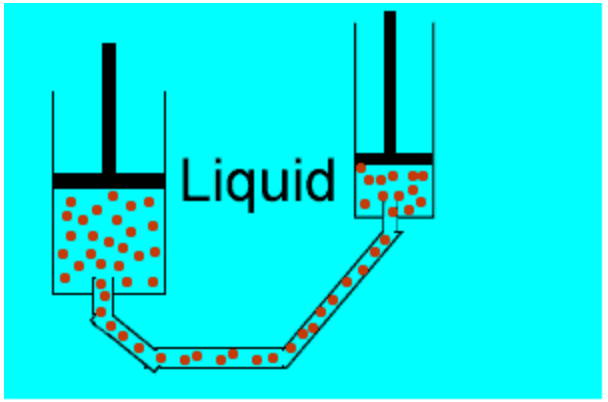


If we compress the volume in which the molecules are placed in the pressure rises. Why? Simply because the molecules have less distance to travel to collide with the wall so the number of collisions increases. With an increase in collisions comes an increase in pressure.

Temperature also has an effect on pressure. Have you noticed how the pressure in the tyres of the family car increases on a hot day? As the gas molecules absorb heat they increase in speed and this causes them to collide more often with the walls of the container and exert a greater pressure.

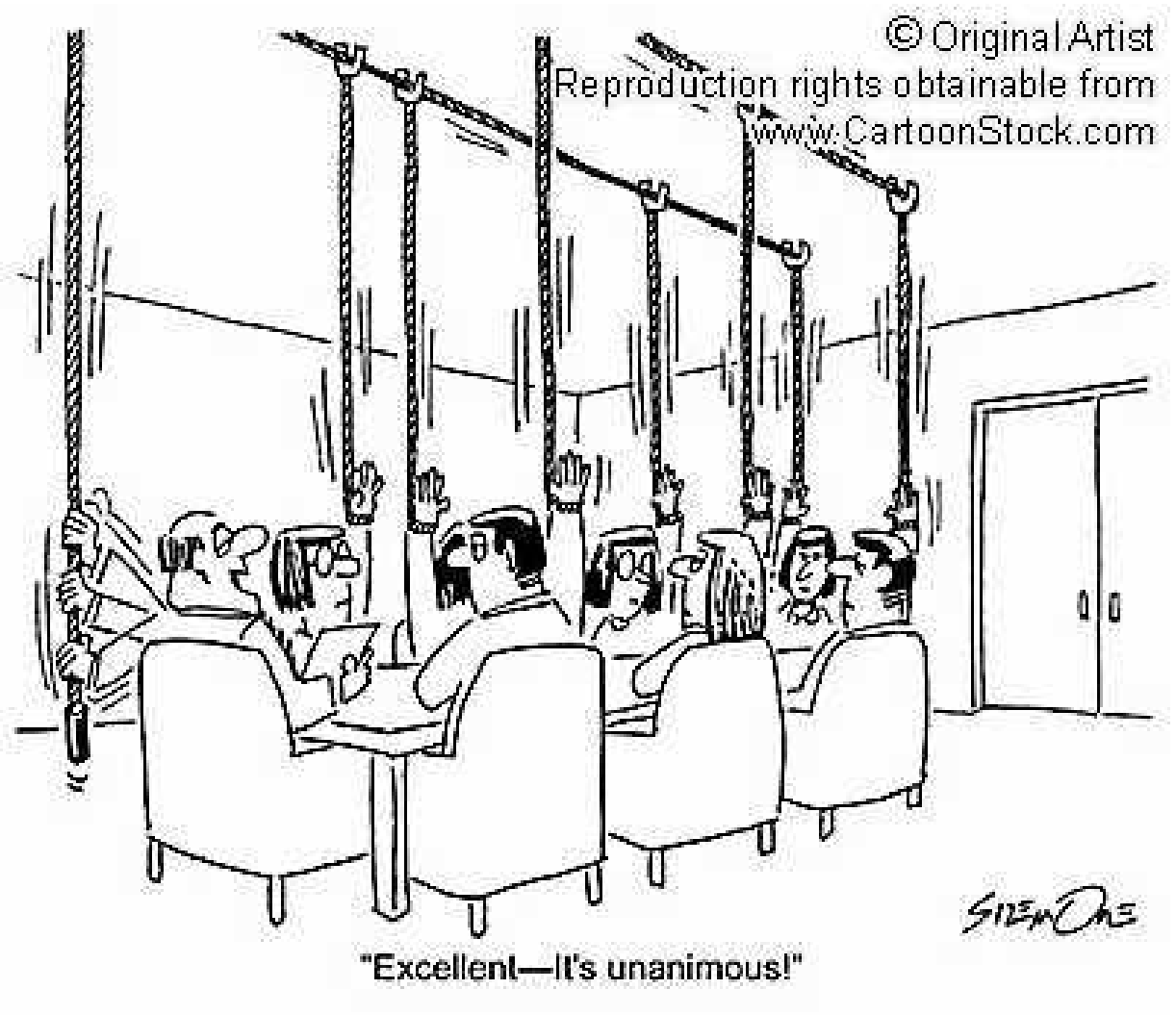
States of matter and hydraulics

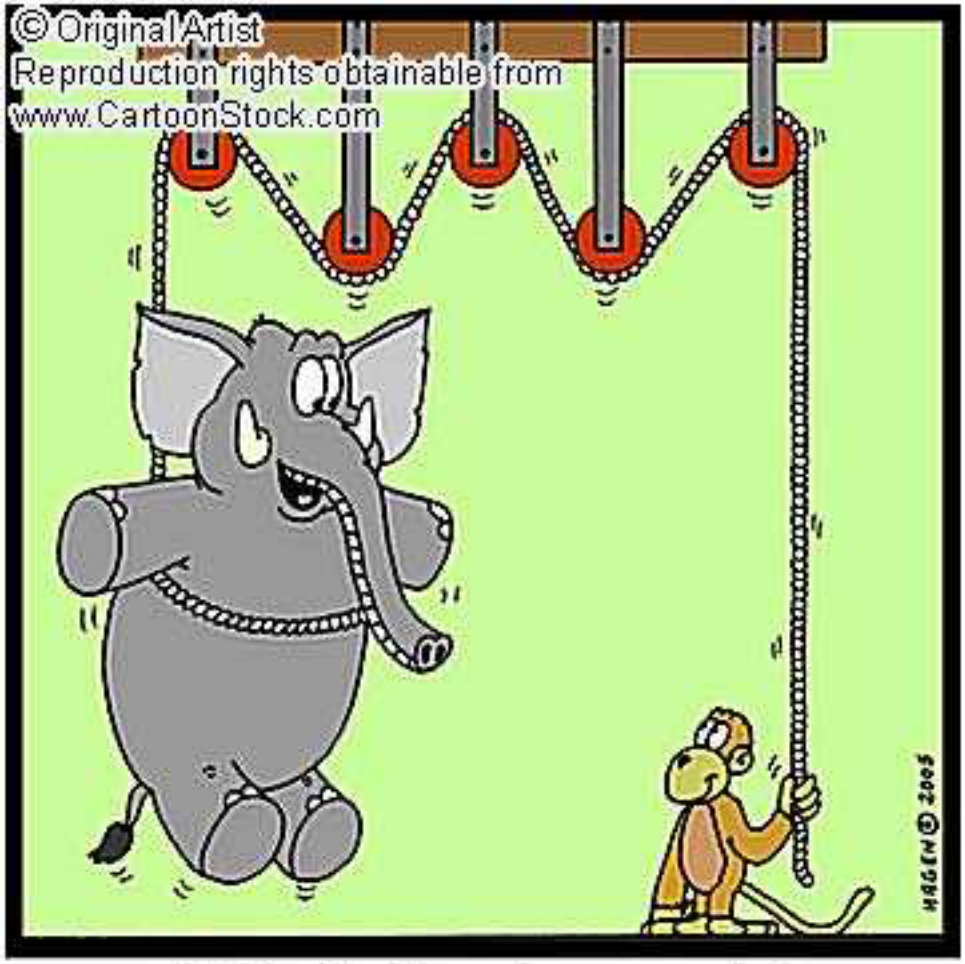




Look at the animations above. Notice how far the piston on the right moves as a result of pushing the piston on the left all the way down. Gases are composed of molecules with immense amount of space between them. As a result these gases can be compressed more than liquids. As you can see from the animation above, liquids are composed of molecules where the space between them is not as great as that found in gases. As a result liquids can not be compressed as much as gases. You will find that the hydraulic mechanisms in Hydraulicus respond better with fluids rather than gases.

Pulley Systems

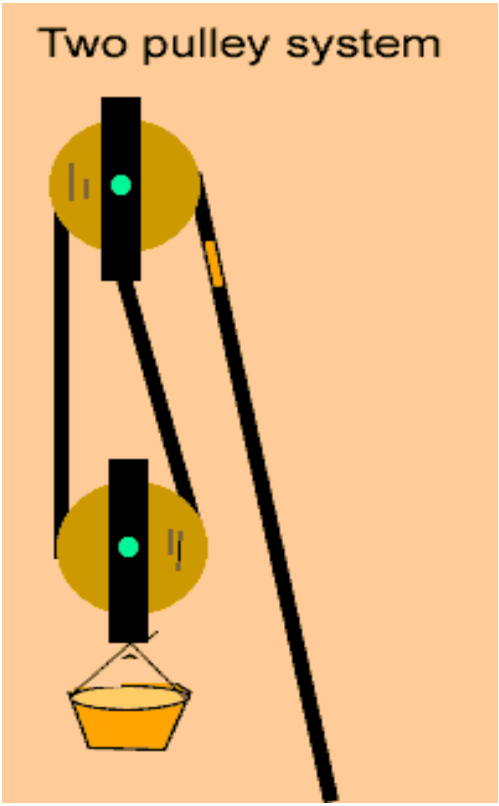




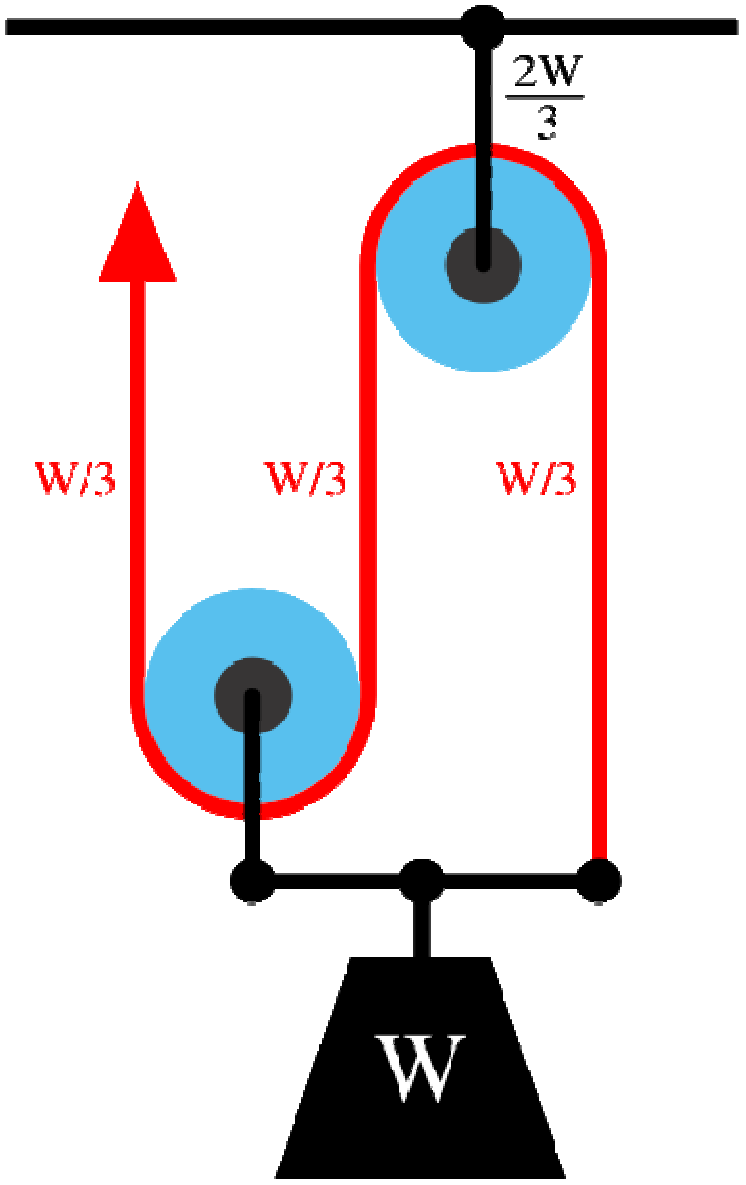
Alright, alright, you've won your bet:
You can lift me with one hand...

Pulley

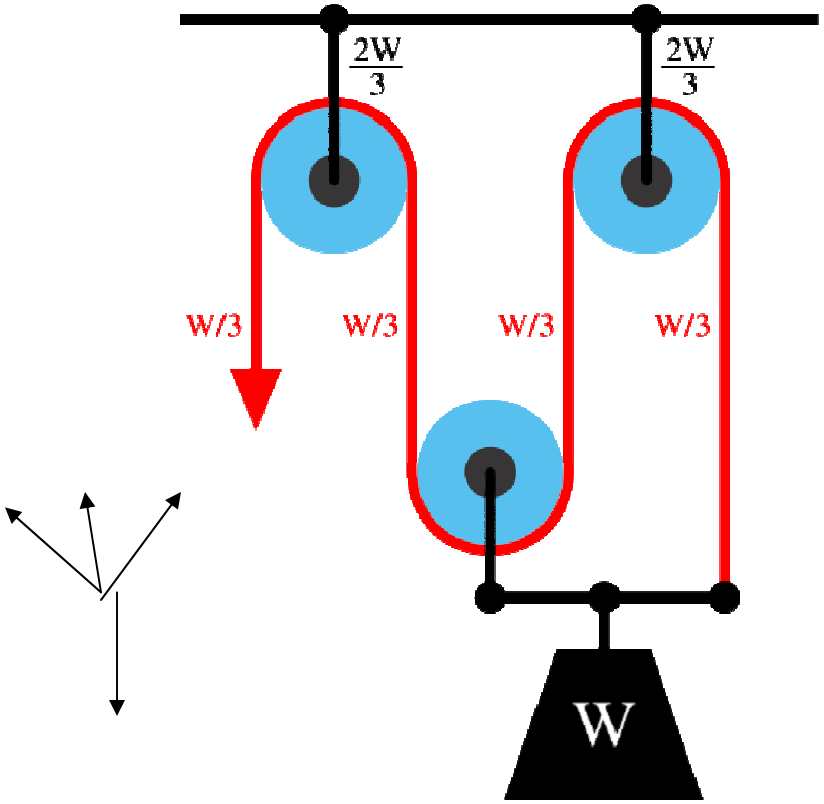
- The more pulleys we have the easier it is to lift heavy objects. As rope is pulled from the top pulley wheel, the load and the bottom pulley wheel are lifted. If 2 metres of rope are pulled through the bucket (load) will only rise 1 metre (there are two ropes holding the bucket and both have to shorten).

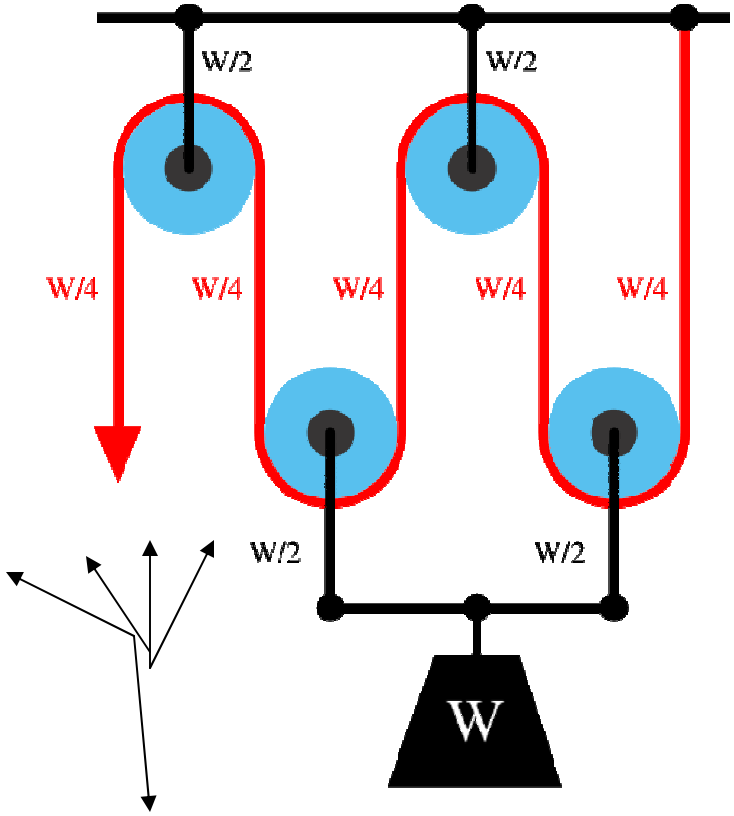


If you add a second pulley, the amount of effort to lift the heavy object is much less .
For example, to lift a box weighing 150 N, one would need to exert 150 N of force without the help of pulleys.
However, by using just two pulleys, the person would only need to use 50 N of force.



Fix and movable pulleys



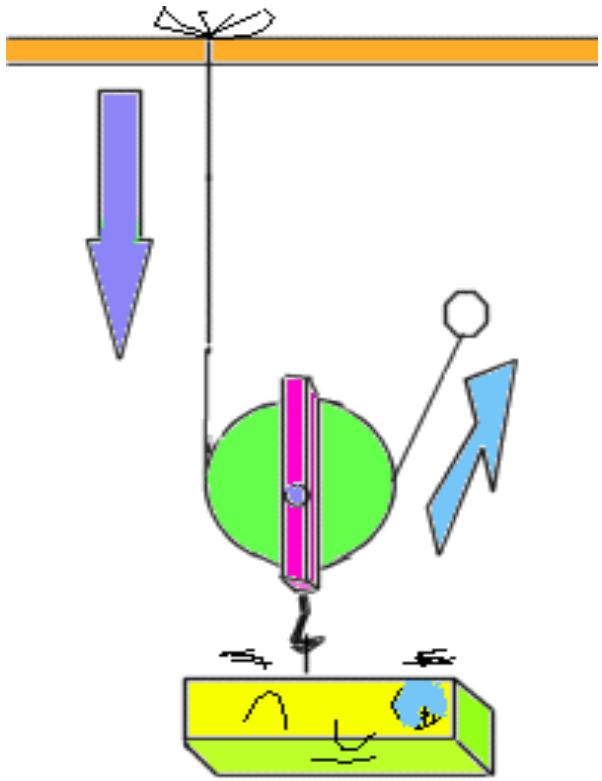


Look at direction of supporting forces elative to load before summing

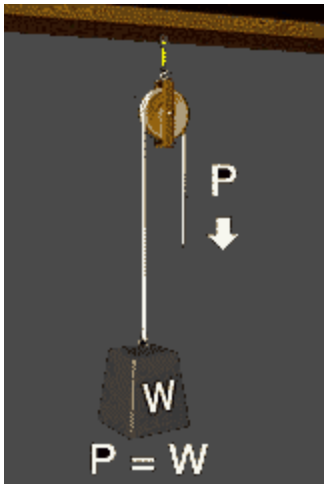
Pulley system

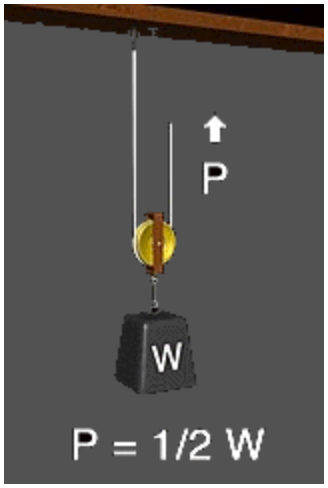
The movable pulley allows the effort to be less than the weight of the load. The movable pulley also acts as a second class lever. The load is between the fulcrum and the effort.
The main advantage of a movable pulley is that you use less effort to pull the load. Take less space.

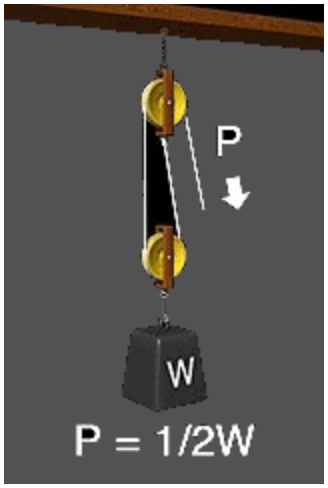
The main disadvantage of a movable pulley is that you have to pull or push the pulley up or down.

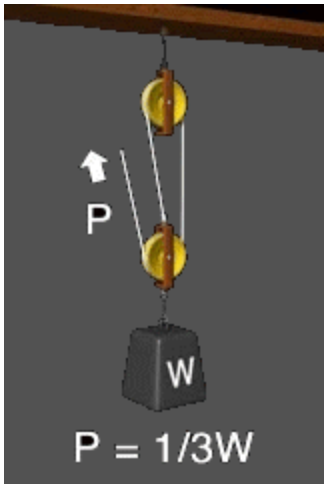


Different Movable Pulley system









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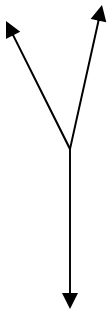
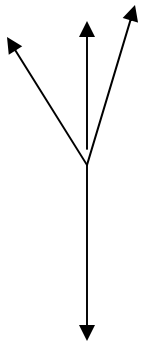
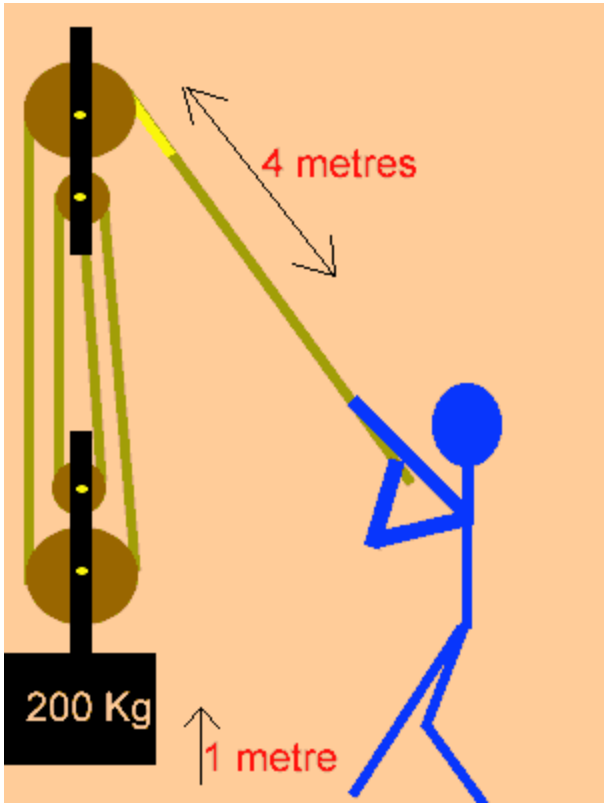
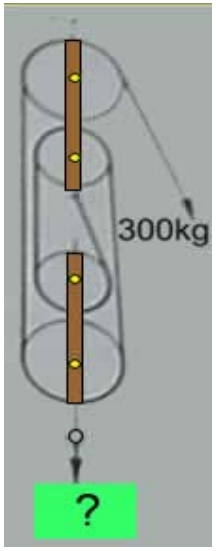




Pulley

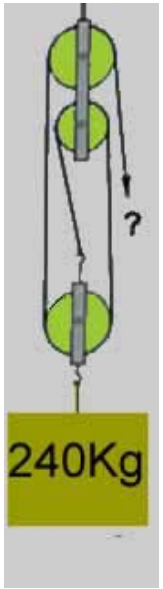
- To calculate the effort required to lift the load we divide the load by the number of ropes (do not count the rope that goes to the effort). The image on the right shows a four pulley system. The person lifting the 200kg load experiences a pull equal to only 50kg (200kg/4).
- Using the four pulley system on the right, the person certainly experiences an advantage. We call this advantage the ***mechanical advantage*** and is calculated by dividing the load by the effort (load/effort). The pulley system offers a mechanical advantage of 4.





What is the maximum load that can be lifted with this system?

For every 2 meters the rope is pulled through what height does the load rise off the ground?
What is the mechanical advantage?



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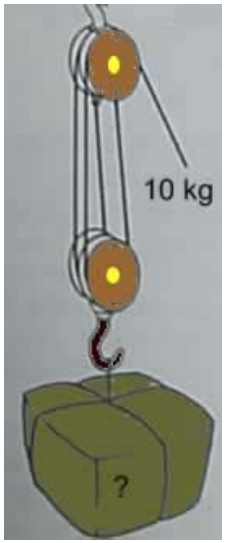

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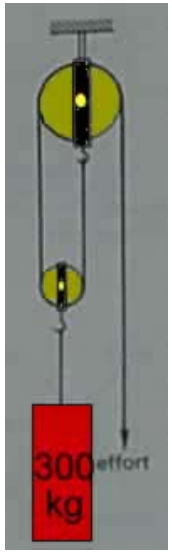
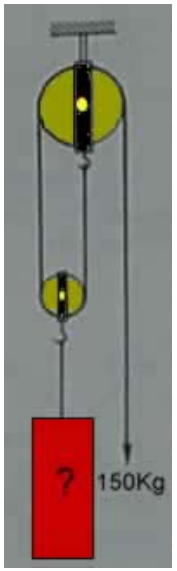


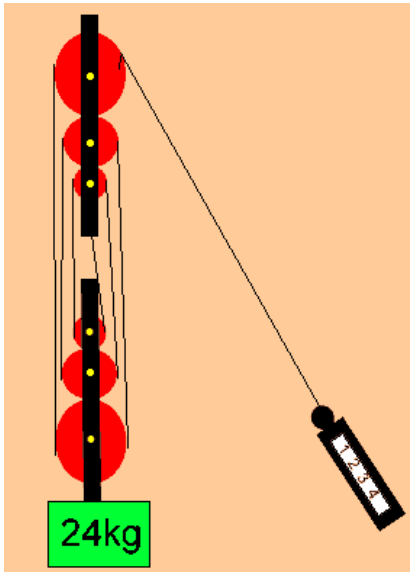
What is the minimum effort that must be applied to lift the load?

For every 2 meters the rope is pulled through, what height does the load rise off the ground?
What is the mechanical advantage?



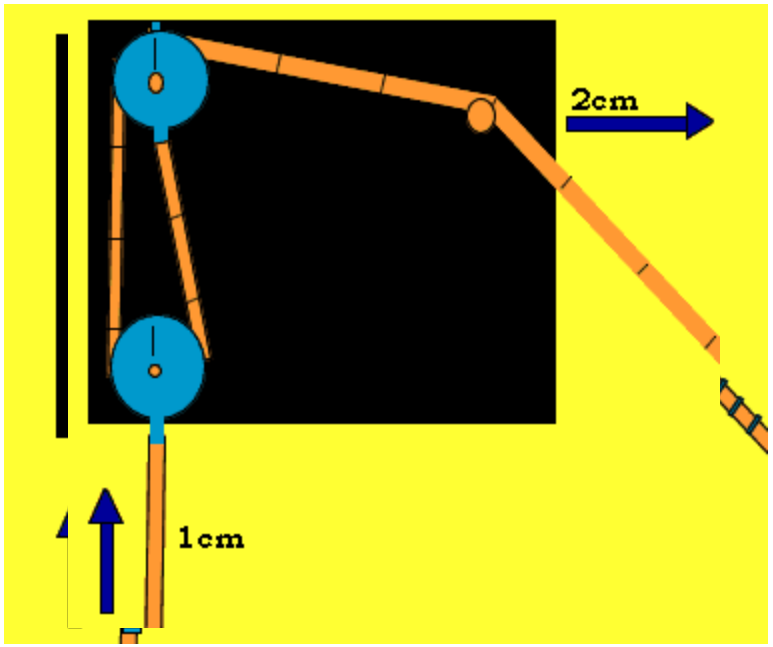
What is the maximum load that can be lifted with this system?

For every 2 meters the rope is pulled through, what height does the load rise off the ground?
What is the mechanical advantage?

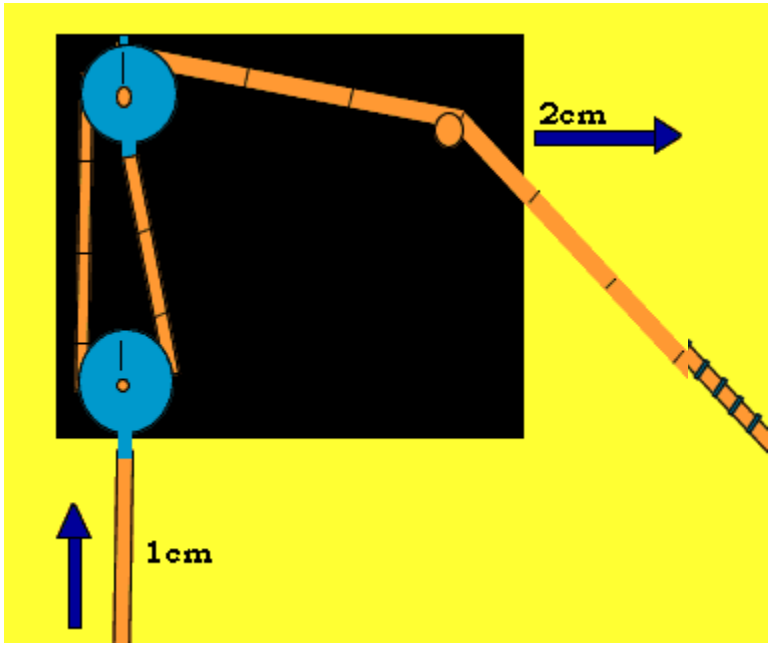


What is the reading on the spring balance attached to the rope where the effort is applied?

For every 2 meters the rope is pulled through, what height does the load rise off the ground?
What is the mechanical advantage?



Describe a pulley system that allows the string on the right to be pulled through 10cms while the string at the bottom is pulled up 5cms.



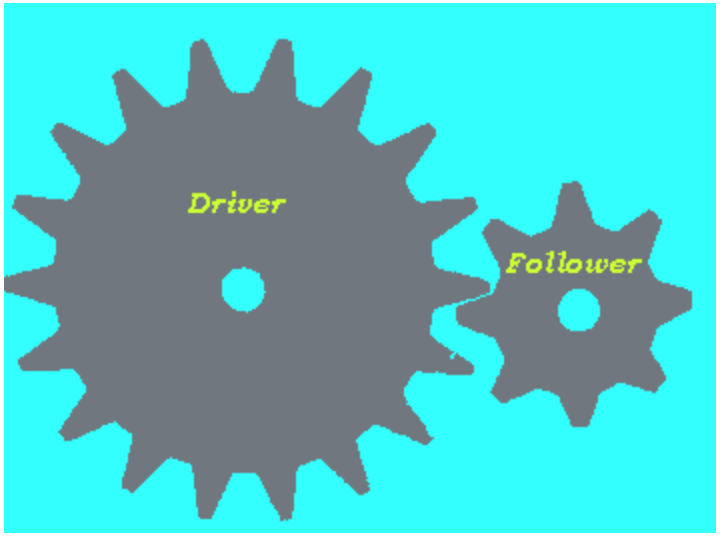
Describe a pulley system that allows the string on the right to be pulled through 40cms while the string at the bottom is pulled up 10cms.

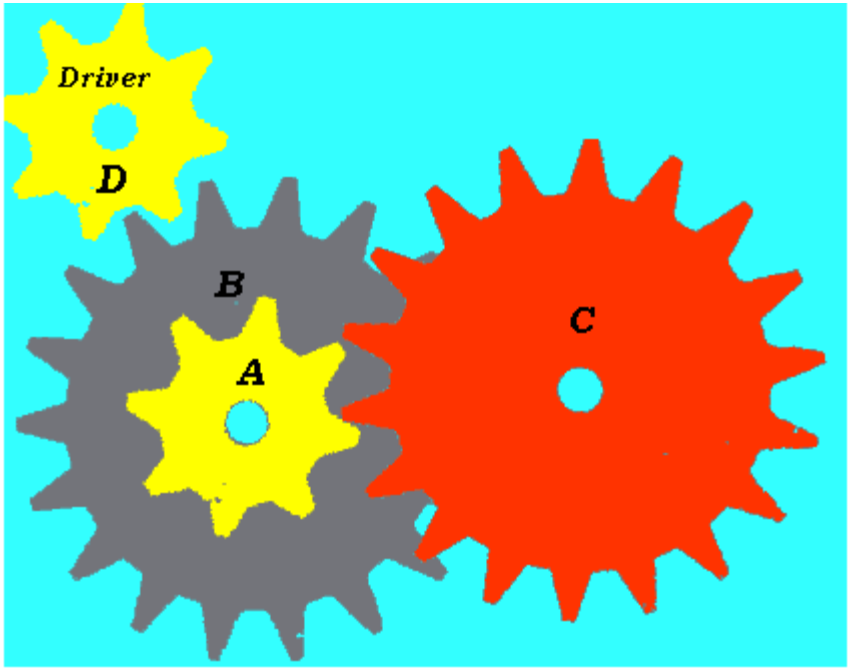
Summation of force

- Free body diagram
- Summation of force = 0 when the body is not moving
- Use conservation of momentum to figure out velocity and distance

Gear system

- Intermeshing gears are used to transmit motion and force. A series of intermeshing gears is called a **gear train.** Intermeshing gears turn in opposing directions.
- We often talk about a ***gear ratio***. The gear ratio of a gear train is the number of teeth on the follower divided by the number of teeth on the driver. In the gear train above the driver has 18 teeth while the follower has 8 teeth. Therefore the gear ratio is 8/18 or 4/9. For every 4 turns of the driver the follower turns 9 times. This gear train can be used to multiply speed on a bicycle if the follower was connected to a wheel and the driver connected to the paddles

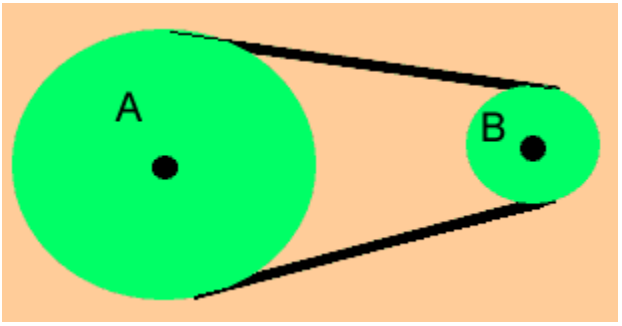




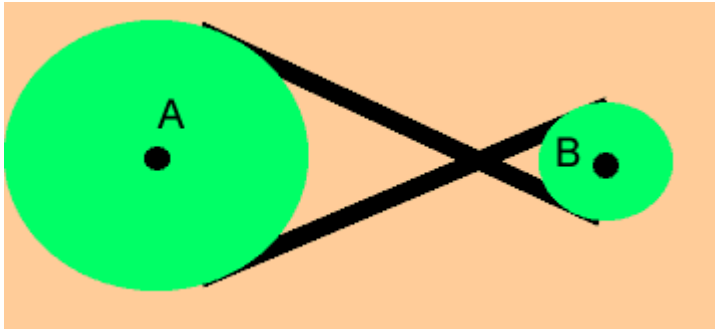
Find Gear Ratio of gear A to gear D

This gear configuration allow you to create more torque at C but speed will be reduce

We can connect pulleys to each other with a belt and have one pulley drive the other. In this manner we can magnify the force, increase the number of turns or change the direction of the force applied. For example, have a look at the diagram on the right, pulley "A" being twice as big as pulley "B" increase the rate of rotation of pulley "B" two fold.

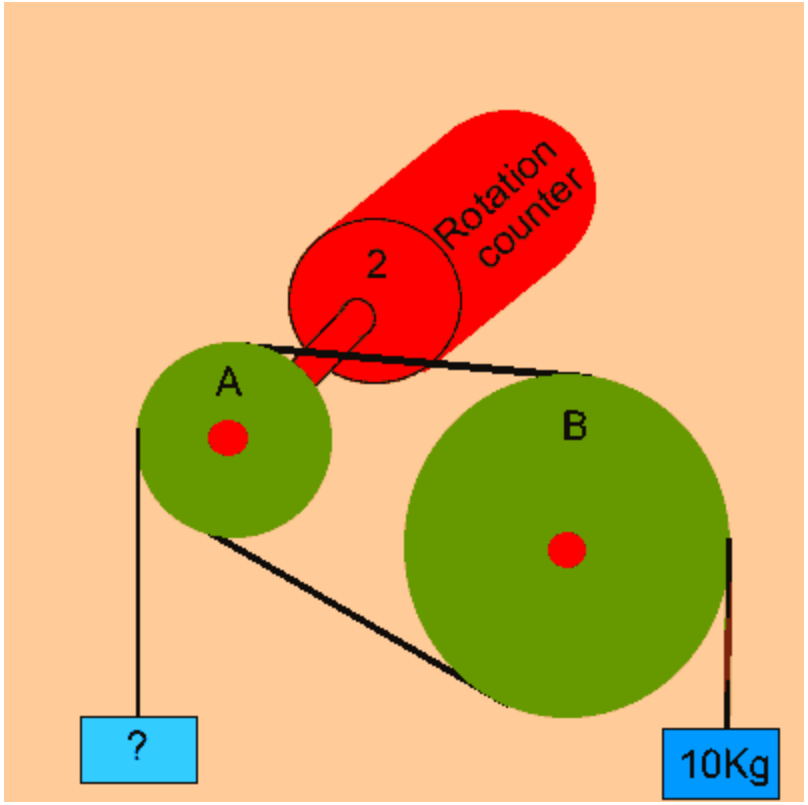


By connecting a large driving pulley to a smaller driven pulley we can increase the number of rotations, change the direction of rotation and reduce the force that is exerted by the driven pulley.



Look at the direction of rotation!

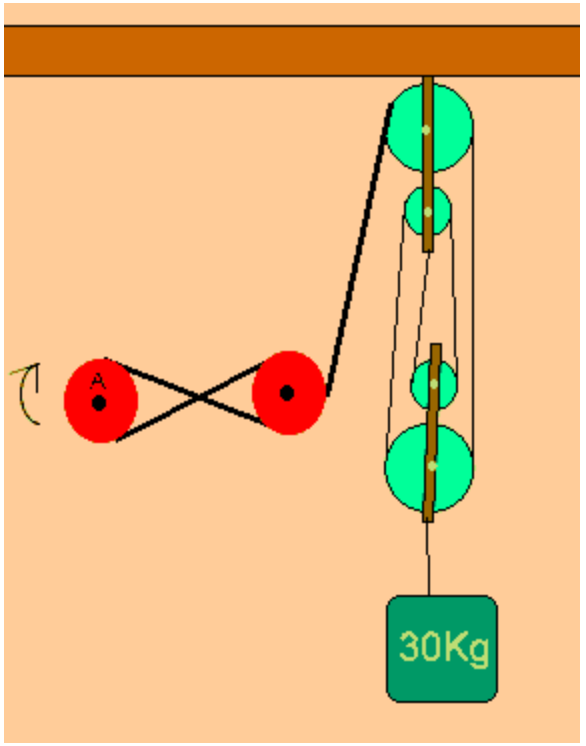
Pulley "A" is half the size of pulley "B" and rotates a full circle twice.
What is the minimum weight that can hang from pulley "A" to just balance the 10kg mass hanging from pulley "B"?
How many times will pulley "A" make a full rotation?
Will the 10kg mass hanging from pulley "B" rise or fall?



Pulley "A" is connected to the shaft of a motor. The motor can generate enough force to just lift a 8kg mass off the ground when the mass is tied around the shaft of the motor. The motor is connected to the pulley system pictured on the right through pulley "A". Pulley "A" rotates in the direction of the arrow.

Is the system of pulleys on the right sufficient to provide enough force to lift the 30kg mass off the ground?

Will the 30kg mass be lifted off the ground by the motor? Explain.



Gear Ratio

$$R_1 \omega_1 = R_2 \omega_2$$

Conservation of energy

$$KE_o + PE_o = KE_f + PE_f$$

Torque

$$\tau = R \times F$$

How to create large potential energy

- Mechanical system:
  - increase height
  - pulley
  - lever
  - spring (loaded spring, mouse trap)
  - hydraulic
  - acoustic wave (speaker)
  - flow (air current water current- fan, balloon, helium, water mill)
- Electromagnetic energy:
  - magnet, electric coil, relay, speaker, microphone, electrical motor, linear actuator
  - battery (rechargeable battery, 110v house hold outlet, etc)
  - piezoelectric, thermal electric, photoelectric, etc.
- Chemical energy:
- - exothermic reaction, endothermic reaction (gaseus water, acid-base reaction)

In class exercise

- Can you come up with a design and application using a simple mouse trap? (group of 4, 1 hour, present your idea in the second hour)