MECHANISMS

TO TRANSMIT MOTION AND FORCE

UNIT 4 TECHNOLOGY IES Villa de Vícar

Mechanisms are devices that allow machines to move or to transmit the motion from one part of the machine to another one.

CLASSIFICATION

- **Linear transmission mechanisms.**

They transmit the movement from a part to another but always linear. Ex: levers, pulleys.

- **Circular transmission mechanisms.**

They do the same of the ones above but in this case the movement is circular. Ex.: pulleys and belts, friction pulleys, gears ...

- **Circular movement transformation to linear.**

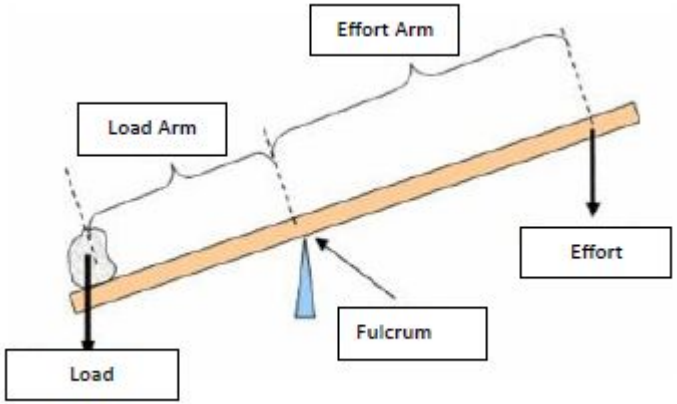
One part of the machine produces rotary movement and it is transformed into circular in another part of it. Ex.: Rack and pinion, nut and screw, winch.

- **Circular movement transformation to alternative linear**. Ex. Crank-connecting rod system, crankshafts, cams, eccentrics

LINEAR TRANSMISSION MECHANISMS

1) LEVERS (PALANCAS)

A lever is a bar which pivots around a fixed point called the fulcrum or pivot (fulcro o punto de apoyo).



The **elements in a lever** are:

- **Load "L"** (carga o resistencia): is the force we have to lift or overcome.
- **Effort "E"** (esfuerzo o potencia): is the force exerted by the user.
- **Load arm "La"** (brazo de resistencia): distance between the load application point and the fulcrum.
- **Effort arm "Ea"** (brazo de potencia): distance between the effort application point and the fulcrum.

Levers balance equation is:

$$E \times Ea = L \times La$$

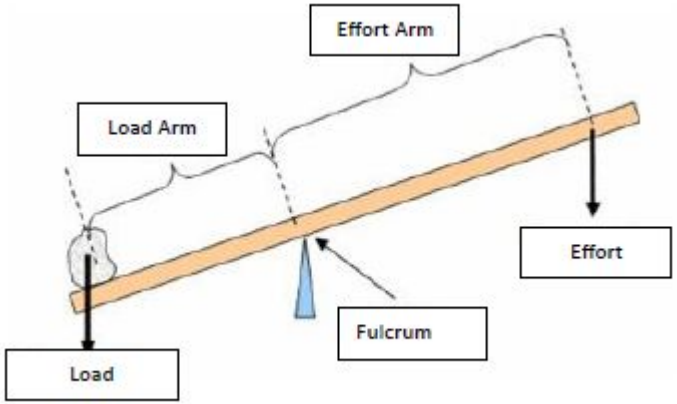
We usually employ Newton or Kilos as the unit for forces (effort and load) and metres, cm or millimetres for the arms, but we have to pay attention to apply always the same units.

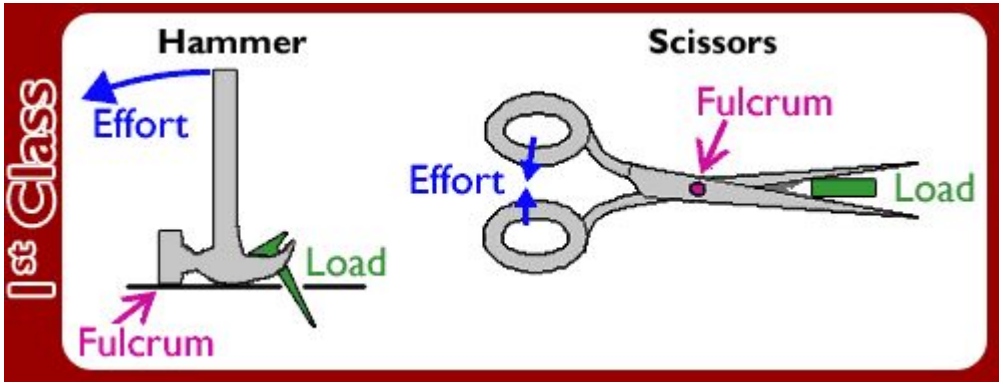
In all levers, if the effort arm is longer than the load arm, we've got **mechanical advantage**. That means that it amplifies the force exerted by the user, so the force needed to lift the load is smaller than the weight of that load. In exchange, the speed and then the movement of the effort have to be higher than the one of the load.

TYPES OF LEVERS

★ FIRST CLASS LEVER (PALANCA DE 1ER GRADO)

In these levers the **fulcrum** is placed **between the load and the effort**. Examples: the see-saw, scissors, hammer claws, pliers, etc.

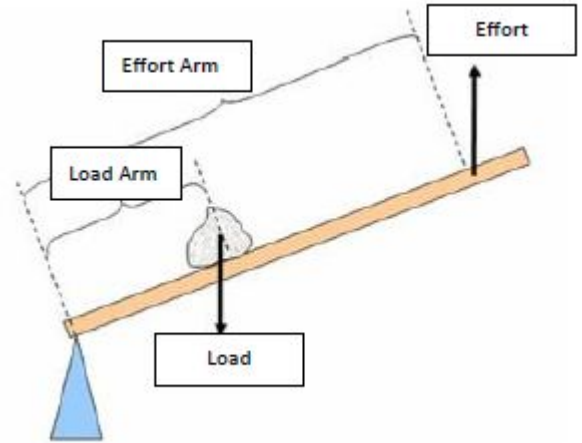


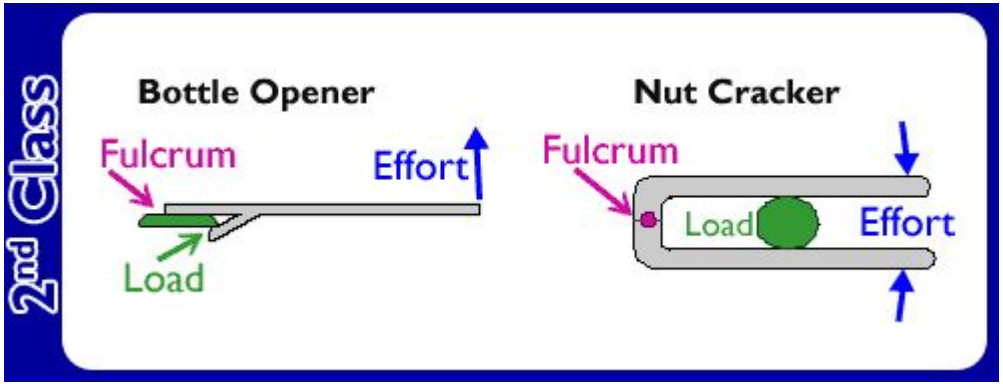


★ SECOND CLASS LEVER (PALANCA DE 2° GRADO)

In these levers the **load** is placed **between the fulcrum and the effort**. Examples: the wheelbarrow, the bottle opener, the nutcracker, etc.

With these levers **we always get mechanical advantage** as the effort arm is always longer than the load arm.

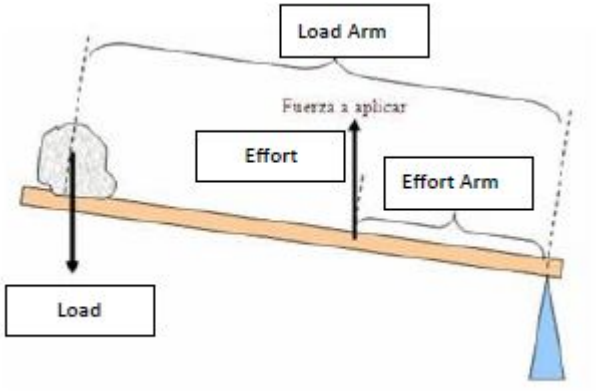


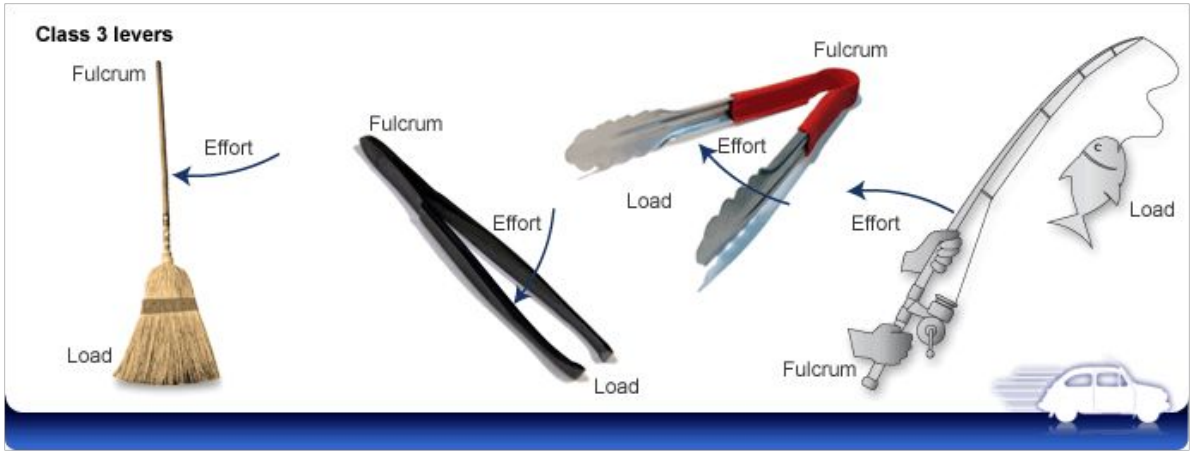


★ THIRD CLASS LEVER (PALANCA DE 3er GRADO)

In these levers the **effort** is placed **between the fulcrum and the load**. Examples: the shovel (pala para cavar), a stapler, the hockey bat, a fishing rod, a broom, the tweezers, the ice holder, etc.

With this kind of lever no mechanical advantage is obtained as the effort arm is always shorter than the load arm. Instead, we gain in speed of the load or movement of it.



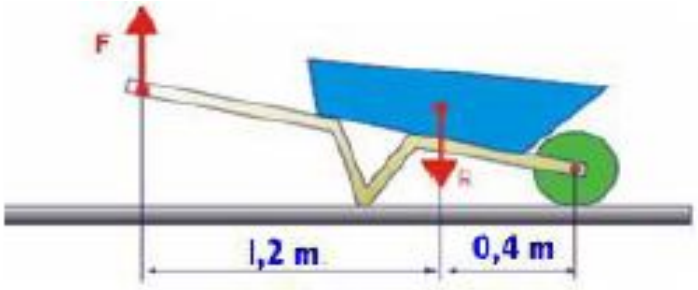


EXERCISES OF LEVERS

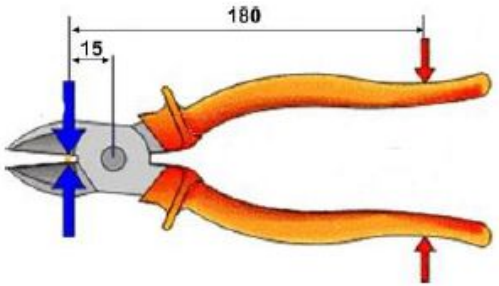
1. To raise a load of 50 kg we have a lever whose bar is 2.5 m length. The Load arm is 0,50 m and the effort arm is 2 m. Find out the force we have to apply. Draw a sketch of it.
2. A see-saw of a playground has a bar of 4 metres. Two children are playing with it. One of the children weighs 50 kg and the other one 40 kg. If the 40 kg boy is sitting on one seat (2 metres from the fulcrum), calculate the distance from the fulcrum the other boy has to seat down to balance the see-saw. Draw a sketch of it.
3. We want to carry two 50 kgs packets of cement with the wheelbarrow shown in the drawing.

   a) Indicate the type of lever

   b) Calculate the force we need to apply to lift the weight up.



EXERCISES OF LEVERS



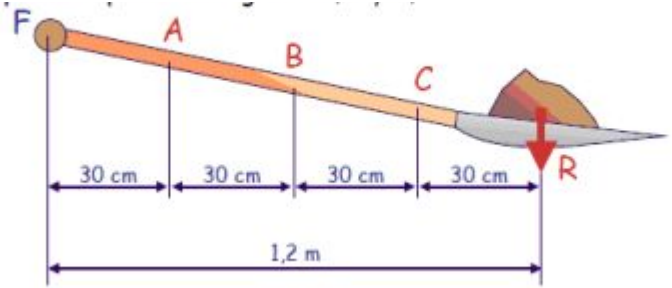
4. Using the pliers shown in the photo, we want to cut a wire that resists a 2 Kg force.

Answer these questions:

a) What type does the lever belong?

b) Calculate the force that will be necessary for cutting it?.

5. The shovel in the drawing is used to lift a sand load of 20 N. The shovel can be hold by three possible points (A, B or C). Note: F is the fulcr



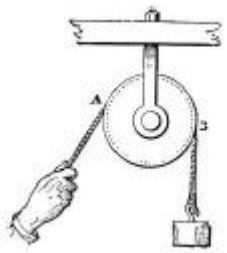
a) Which class of lever is the shovel?

b) In which point do we have to hold the shovel to lift the load with the minimum effort?. How much is this effort?

2) PULLEYS (POLEAS)

A pulley is a wheel with a groove (canal) that turns around a fixed axle.

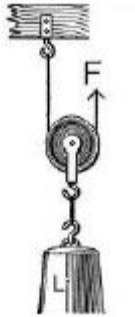
The drive element of a pulley mechanism is usually a rope, cable, belt or chain that runs over the pulley inside the groove.



A **simple pulley** (also called **fixed pulley**) **doesn't** increase the speed of the rope nor **reduce the effort needed to move a load.** **E = L**

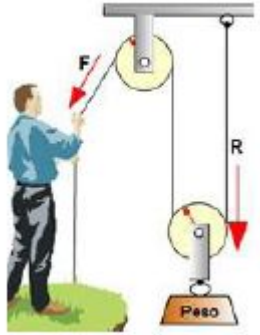
The only advantage is to reduce friction and to change the direction of the rope to help us with our own weight.

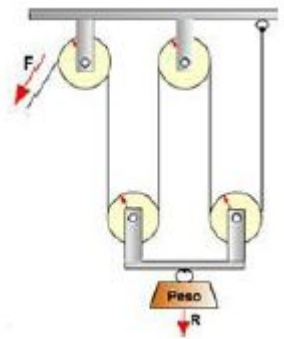
A **movable pulley** is a normal pulley but in this case the load is hanging from its axle .



With this mechanism we get mechanical advantage of 2 because the load is hanging from two parts of rope and we just pull on one of them, the other one is tied to a fixed point. In exchange, we'll have to pull the rope two metres if we want to lift the load 1 meter.

Usually, the moving pulley is used in combination with another fixed to get the advantages of both of them. This mechanism is called **block and tackle** (polipasto o aparejo)



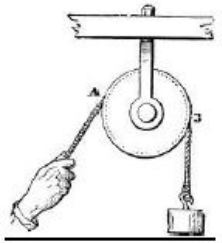


Mechanical advantage = 2

Mechanical advantage = 4

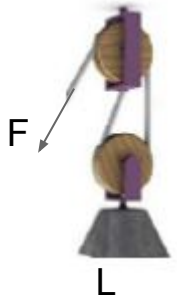
EXERCISES OF PULLEYS

1. Using the pulley on the right, calculate the force we have to exert to lift the load of 50 Kg. How many metres do we have to pull the rope to raise the load 2 metres?.



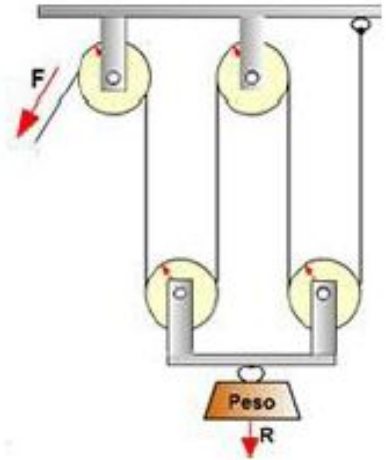
2. Considering the pulley below, calculate the force we have to exert to lift the load of 50 Kg. To raise 3 metres the load, how many metres do we have to pull the rope?

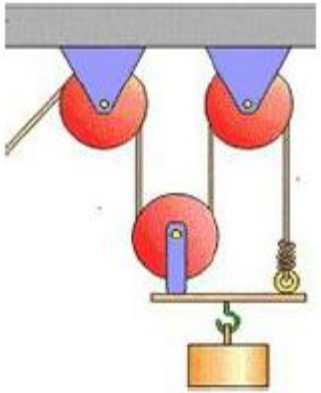
3. Considering the gun and tackle below. Calculate the force we have to exert to lift the load of 50 Kg. Why this pulley system is better than the one of the exercise 2?. How many metres do we have to pull the rope if the load is going up 3 metres?.



EXERCISES OF PULLEYS

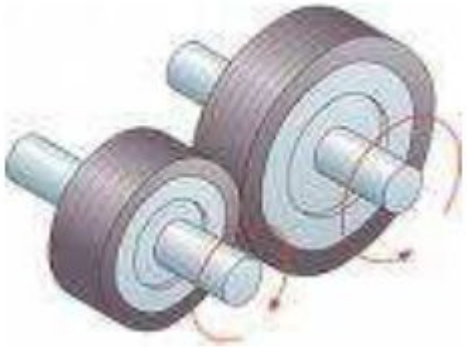
4. Look at the pulleys shown in these drawings. If the load is 120 N, how much force will it necessary to apply to lift the load?





CIRCULAR TRANSMISSION MECHANISMS

1) FRICTION WHEELS (RUEDAS DE FRICCIÓN)



Driver wheel (rueda motriz o conductora) is the wheel moved directly by a motor or a crank.

Driven wheel (rueda conducida) is the one to which the motion is transmitted.

The motion to the driven wheel is transmitted by means of friction existing in the contact of both wheels. Consequently, both wheels rotate in opposite direction.

To calculate the speed of the driven wheel we use the equation:

$$N1 \times D1 = N2 \times D2$$

D1 = diameter of the driver wheel.

D2 = diameter of the driven wheel.

N1 = speed of the driver wheel or input speed, usually in rpm (revolutions per minute)

N2 = speed of the driven wheel or output speed, usually in rpm (revolutions per minute)

This mechanism is **reversible,** which means that we can use both wheels as driven or driver wheels.

The **gear ratio or transmission ratio** (relación de transmisión) for the mechamism is calculated as follows:

$$\text{Gear or transmission ratio} = \text{Output speed/Input speed} = N2/N1$$

<u>This equation can be used for all the circular transmission mechanisms</u>

EXERCISES OF FRICTION WHEELS

1. In a friction wheel mechanism, the driving wheel rotation speed is 5000 rpm. Figure out the rotation speed of the driven wheel if the diameters are the following ones: 10 cm for the driver wheel and 5 cm for the driven wheel. Draw the diagram.
2. Calculate the diameter of a driven wheel in a friction wheel transmission system if its rotation speed is 3000 rpm. The driver wheel rotates at a speed of 500 rpm and its diameter is 15 cm. Draw the diagram.
3. The gear ratio in a friction drive system is 2.5. Calculate the speed of the driver wheel by knowing the speed of the driven wheel is 250 rpm.

2) BELT AND PULLEYS (CORREA Y POLEAS)

In this mechanisms, a belt passes around two pulleys. When the driver pulley moves, it moves the belt and the belt moves the driven pulley. Both pulleys rotate in the same direction. This mechanism is reversible, which means that we can use both wheels as driven or as driving wheels.

The transmission speed ratio is the same as in the friction wheels. So the equation is exactly the same:

$$N1 \times D1 = N2 \times D2$$

D1 = diameter of the driver wheel.

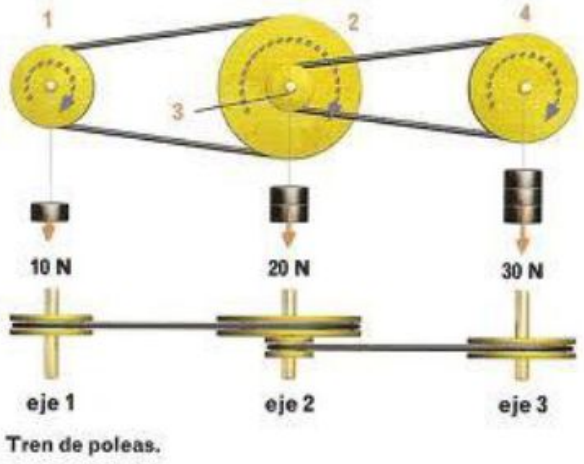
D2 = diameter of the driven wheel.

N1 = speed of the driver wheel, usually in rpm (revolutions per minute).

N2 = speed of the driven wheel, usually in rpm.

In this type of mechanism slipping may be a problem. To avoid slipping, **toothed pulleys and belts** are used.

BELTS AND PULLEYS TRAINS (TREN DE POLEAS Y CORREA).



Tren de poleas.

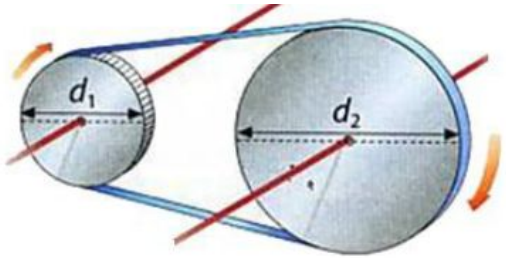
This consists of two pairs of pulleys with belts working together.

As shown in the picture, the central shaft is made up with two pulleys built together. To study this mechanism we have to divide it in parts. First of all we analyze the first two pulleys and then the other two, considering the same speed for both central pulleys.

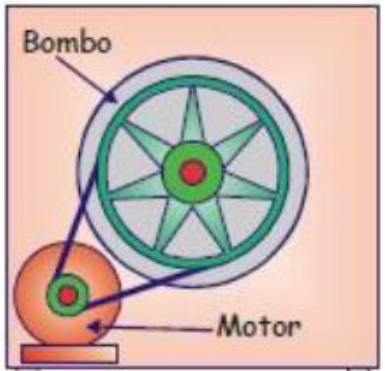
EXERCISES OF BELT AND PULLEYS

1. Calculate the speed of the driver wheel (1) shown in this sketch as well as the gear ratio. Finally indicate the type of system (Multiplying-Reducing-Constant)

d1= 20 cm d2= 30 cm n2= 1200 rpm

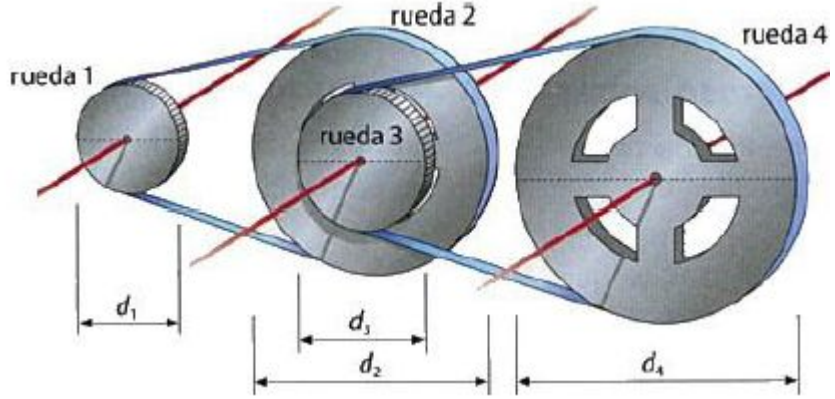


2. The engine of a washing machine is connected to a 8cm diameter pulley, whereas the tumble is joined to a 32cm diameter pulley. The fastest speed the tumble spins, is 1200 rpm. What speed will the engine turn?

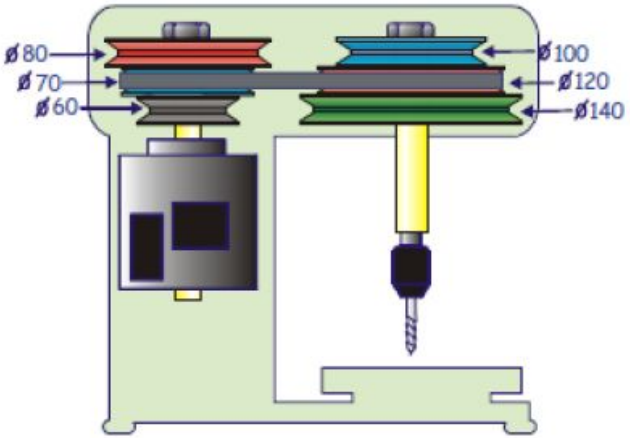


EXERCISES OF BELT AND PULLEYS

3. Calculate the gear ratio of the system and the speed of each pulley if the driving wheel (1) rotates at 100 rpm.
d1= 10 cm d2= 20 cm d3= 15 cm d4= 30 cm



4. The figure shows the pulley trains with belt of a power drill. Depending on the pulleys combination we select, we can get different speeds in the drill bit.
If the engine spins at 1400 rpm, what's the minimum speed the drill bit can rotate?

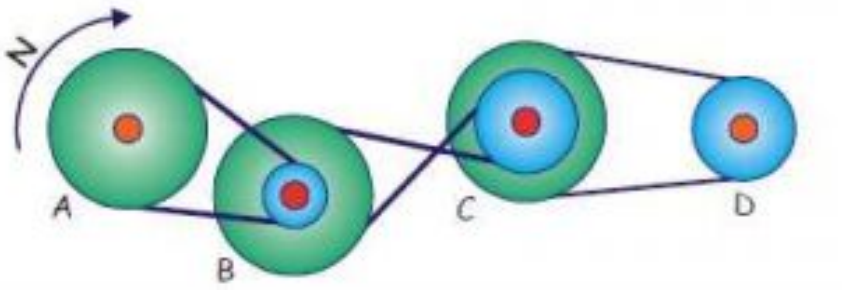


EXERCISES OF BELT AND PULLEYS

5. In a belt and pulleys mechanism, we want the driven shaft spins at 1000 rpm when the driver shaft does it at 500 rpm. Propose two possible solutions:

	Solution 1	Solution 2
Diameter driver pulley		
Diameter driven pulley		

6. Indicate with arrows the turning direction for each pulley, considering the turning direction of the driver pulley (A)



3) GEARS (ENGRANAJES)

Gears are toothed wheels that mesh each other to transmit the circular motion or to change the speed between two axles. The gears rotate in opposite direction. The speed of the driven gear depends on the number of teeth of both gears:

$$N1 \times Z1 = N2 \times Z2$$

Where

Z1 = number of teeth of the driver wheel.

Z2 = number of teeth of the driven wheel.

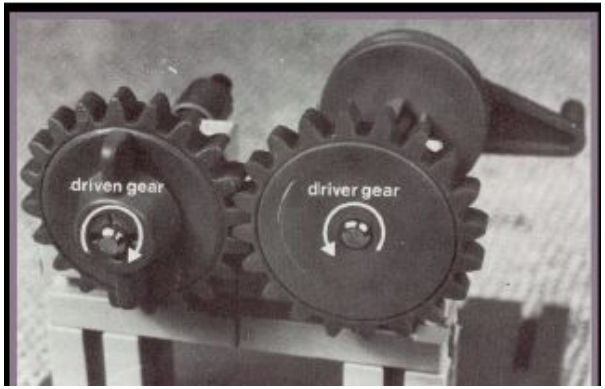
N1 = speed of the driver wheel, usually in rpm (revolutions per minute)

N2 = speed of the driven wheel, usually in rpm.

Sometimes the driver gear is called pinion.

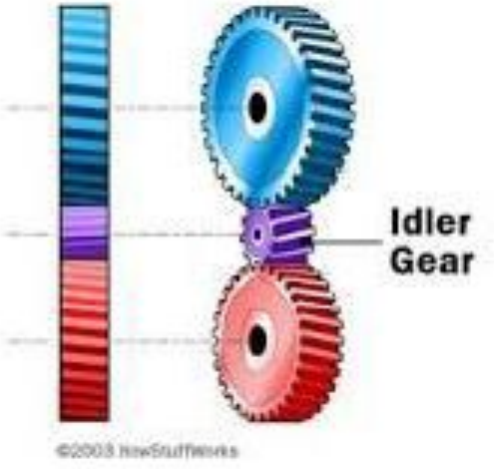
SPUR GEARS (ENGRANAJES CILINDRICOS)

They are the most common type of gears. No possibility of slipping with this mechanism, so great strengths can be transmitted.



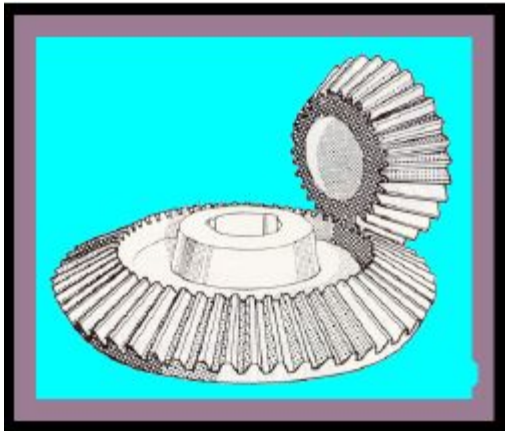
The gears rotate in opposite direction. If we need them to rotate in the same direction, an **idler gear** (engranaje loco) should be used. With the idler gear, the speed transmission is not affected.

Spurs gears are reversible, which means that we can use both gears as driven or as driving gears.



BEVEL GEARS (ENGRANAJES CÓNICOS)

These gears have teeth cut on a cone instead of a cylinder. They are used in pairs to transmit rotary motion where the bevel gear shafts are at right angles (90 degrees) to each other.



For the speed transmission we use the same equation we know from spur gears. Bevel gears are reversible as well.

WORM GEAR (ENGRANAJE DE TORNILLO SINFÍN Y RUEDA DENTADA)

It is constituted by a screw (worm) and a spur gear. As the worm turns, it pulls the gear. For every revolution of the worm, it will pull one of the gear's teeth. Therefore, worm gears have a great speed reduction ratio, they are used when you want to slow down a movement considerably. The two axles (the one of the worm and the gear) are 90°.

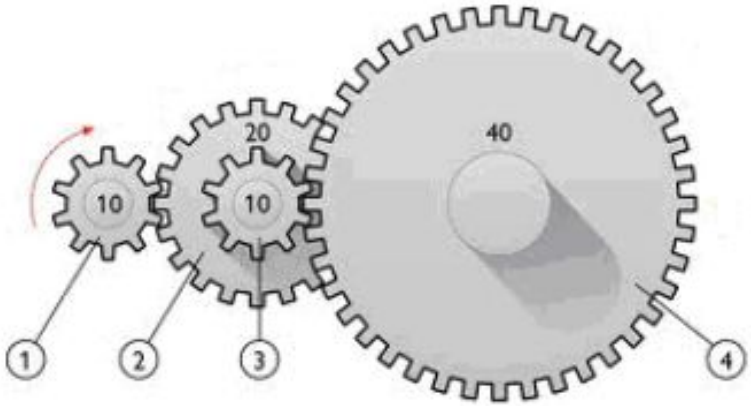
For the speed transmission we use the same equation seen for spur gears, considering that the worm is a gear with only one teeth (Z=1). So:

$$N1 = N2 \times Z2 \rightarrow N2 = N1 / Z2$$

This mechanism is not reversible. The **driver element** has to be always **the worm**, whereas the gear will always be the driven element.

COMPOUND GEAR TRAIN (TREN DE ENGRANAJES)

This consists of two pairs of gears working together. It is used when we need large changes in speed of rotation. This mechanism must be calculated the same as we saw in the belts and pulleys train.



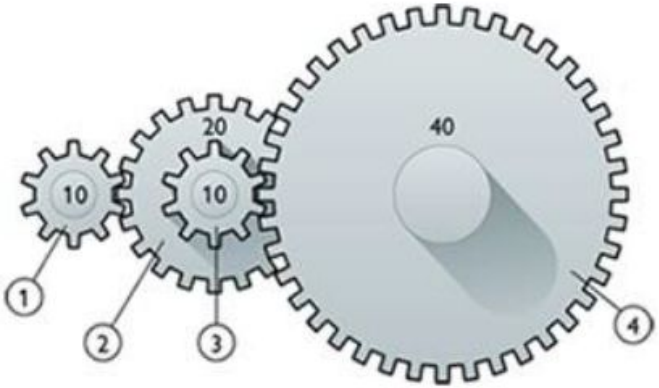
EXERCISES OF GEARS

1. In the diagram below the bigger wheel has 40 teeth, whereas the pinion 20.

a) Calculate the gear ratio.

b) At what velocity will the pinion rotate if the other moves at 300 rpm?

2. Calculate the gear ratio of the system and the speed of each gear if the driving gear (4) rotates at 800 rpm.(clockwise)



4) CHAINS AND SPROCKETS (SISTEMA DE PIÑONES Y CADENA)

It is a system similar to the belts and pulleys but built in toothed wheels and a chain. The driver toothed wheel meshes with the chain and pulls it as it rotates. As the chain moves, the driven wheel turns.

Bicycles and motorbikes use sprockets and chains because of their greater strength and the fact that they do not slip.

The speed ratio is the same as with the spur gears.
As well as the spur gears it is a reversible mechanism.

EXERCISES OF CHAINS AND SPROCKETS

The bicycle shown on the picture below has 2 chain rings (platos) with 44 and 56 teeth and 5 cassettes (piñones) with 14, 16, 18, 20 and 22 teeth.

a) Calculate the gear ratio in the following situations:

Combination	Gear Ratio
Biggest chain ring & cassette	
Biggest chain ring & smallest cassette	
Smallest chain ring & Biggest cassette	
Smallest chain ring & Smallest cassette	

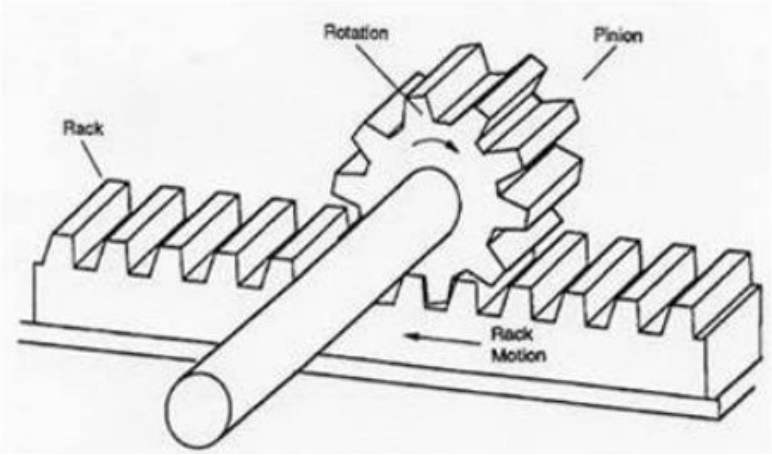
MECHANISMS THAT TRANSFORM THE MOVEMENT

1) RACK AND PINION GEAR (ENGRANAJE DE PIÑÓN Y CREMALLERA)

A rack and pinion consists of a pair of gears which convert rotational motion into linear motion.

When the pinion (circular gear) turns, it meshes with the teeth of a linear "gear" bar, so it moves linearly.

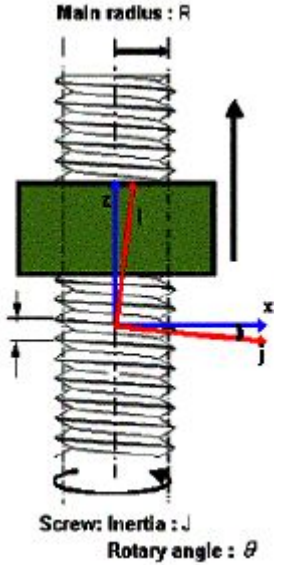
This mechanism is reversible, which means that the rack can also make the pinion turn.



2) NUT AND SCREW (MECANISMO TORNILLO Y TUERCA)

If we turn the screw while locking the nut, then the screw will move back or forth depending on the turning direction of it.

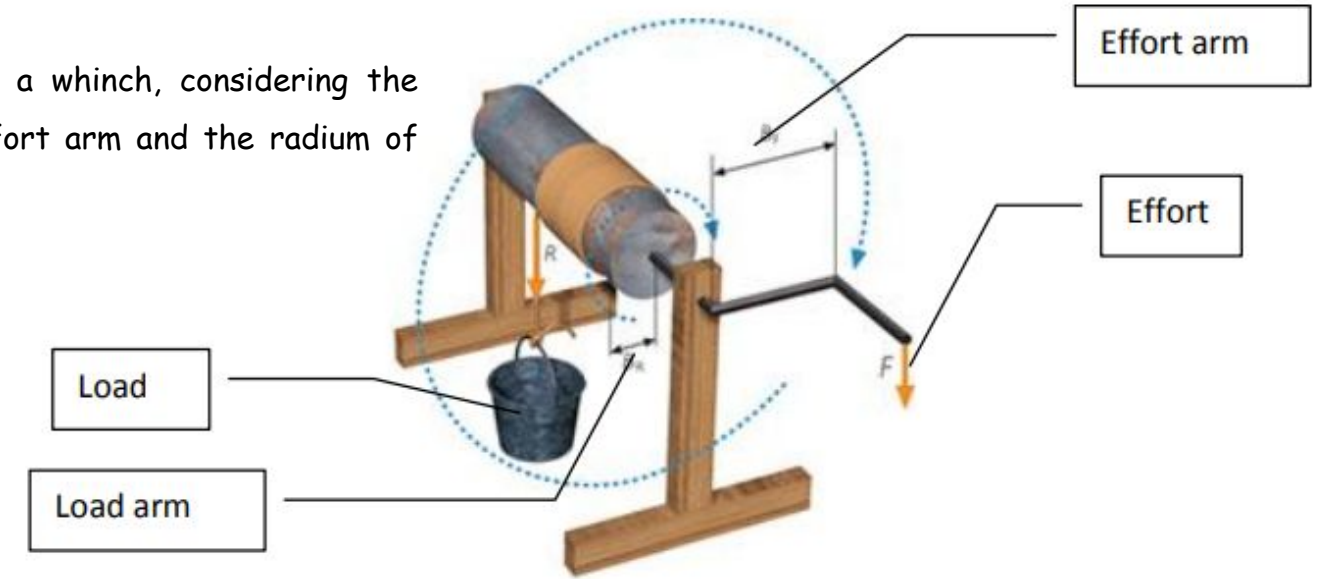
And if we turn the nut while locking the screw, then the nut will move back or forth depending on the turning direction of it.



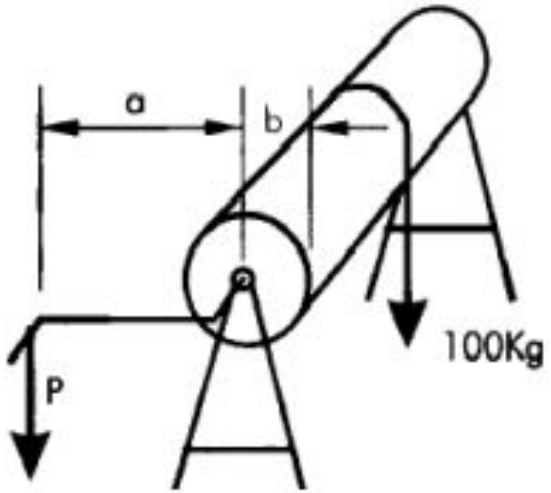
3) THE WHINCH (TORNO)

A winch is made up of a spool with a rope or cable and a crank. When we make the crank turn, the rope will roll up or unroll depending on the turning direction to the crank. This way, the load attached to the rope will move up or down. It is the system used to lift buckets in water wells or in fishing rods.

We can use the lever's law in a whinch, considering the length of the crank as the Effort arm and the radium of the spool as the Load arm

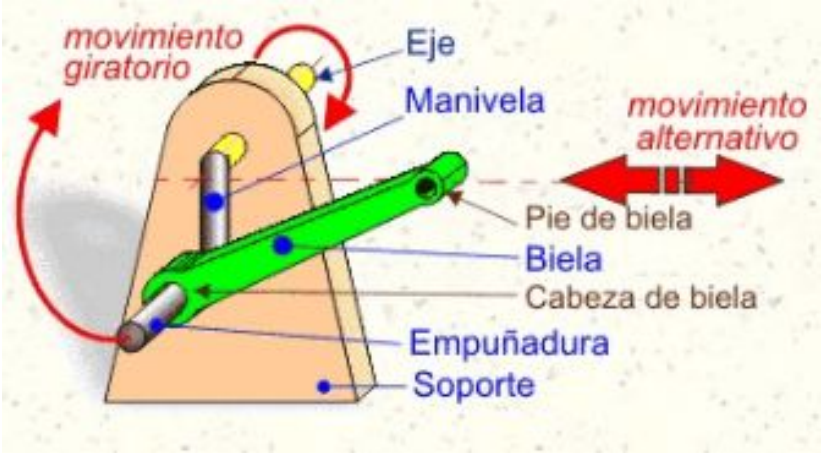


Disponemos de un torno cuyo tambor de enrollamiento tiene un radio de b=10 cm. y la manivela es de a=1 m. Para mover una carga de 100 Kg. ¿Qué fuerza tendremos que aplicar en el extremo de la manivela?



4) CRANK-ROD MECHANISM (MECANISMO DE BIELA-MANIVELA)

It transforms a rotary movement in the crank (manivela) or an eccentric axle (eje excéntrico) into alternative linear movement in the rod (biela). It is a reversible mechanism, so if we make the rod move back and forth, we will get a rotary motion in the crank or the eccentric.



5) CAM OR ECCENTRICS AND FOLLOWER (LEVA O EXCÉNTRICA Y SEGUIDOR)

A cam (leva) is a specially shaped piece of material, which is fixed to a rotating shaft. The follower is an element designed to move up and down as it follows the edge of the cam. The same function of the cam can do it an eccentrics (excéntrica)