MACHINE THEORY
Bachelor in Mechanical Engineering

INTRODUCTION TO MACHINE DESIGN

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Machine Definition

Machine - any mechanical or electrical device that transmits or modifies energy to perform any type of work

- Historically, a machine required to have moving parts to be classified as a machine
- Nowadays, electronics technology has led to the development of devices without moving parts that are often referred as machines

Machine Elements

Classification by working principle:

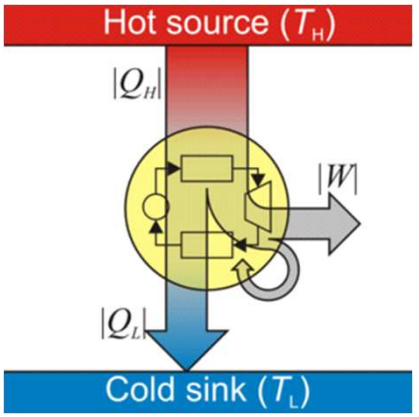
1. Mechanical components (bolts, nuts, shafts, gears, clutches, bearings etc.) ⇦
2. Non-mechanical components (electrical, optical, electronical etc.)
3. Combined components (sensors, engines, converters etc.)

Mechanical Components (I)

Engine - converts heat or other forms of energy into mechanical energy

- Electric motor - transforms electrical energy into mechanical energy

- Heat engine - converts heat energy into mechanical energy

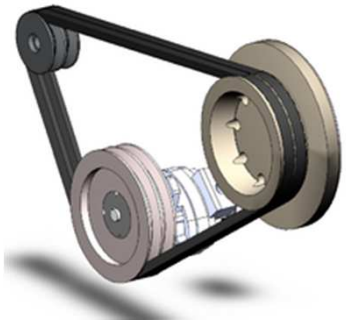


Source: Wikipedia

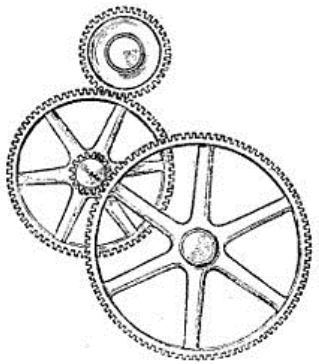
Mechanical Components (II)

Power transmission - provides speed and torque conversions from a rotating power source to another device. Achieved by:

- Belt drives
- Chain drives
- Gear trains



Belt drive
Source: Wikipedia



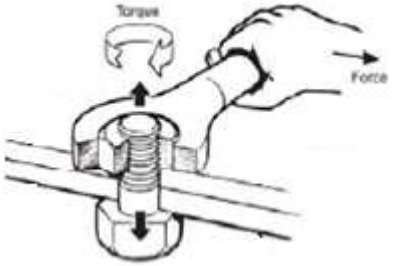
Gear train
Source: Wikipedia

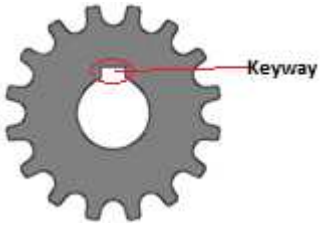
Mechanical Components (III)

Fasteners and connectors - elements that mechanically join or affix two or more objects together

Classification:

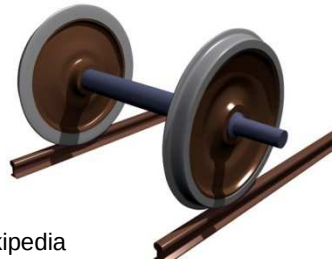
- Permanent fasteners (weldments, rivets)
- Detachable fasteners (bolts, screws, pins, keys etc.)





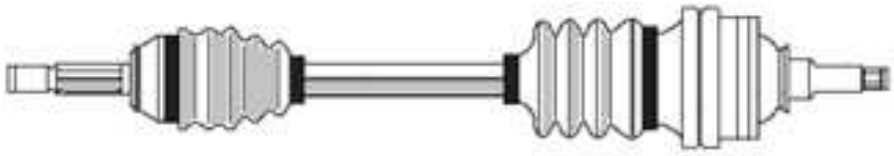
Mechanical Components (IV)

- **Axles and shafts** – to support rotating elements in a machine and fix their rotation axis
  - Axle – can be fixed in position or rolle.



Source: Wikipedia

  - Drive shaft - mechanical component for transmitting torque and rotation, used to connect other components of a drive train



Source: Wikipedia

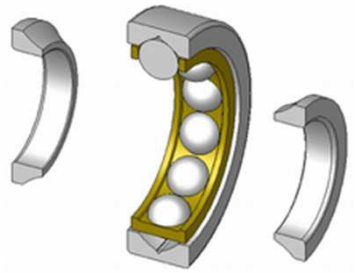
Mechanical Components (V)

Bearings - allow constrained relative motion between two or more parts, typically rotation or linear movement

- Plain bearing - comprises just a bearing surface and no rolling elements

A solid sleeve bushing | A flanged bushing | A clenched bushing

- Rolling-element bearing - permits relative motion between two machine members while minimizing frictional resistance

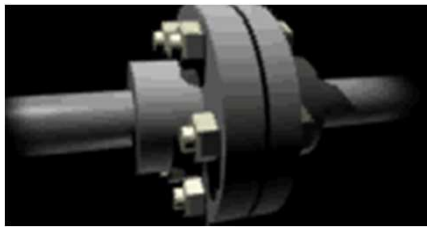


Mechanical Components (VI)

- **Clutches and couplings** – to connect shafts and to transmit movement and torque
  - Clutch - allows connecting and disconnecting the shafts during their operation

Source: Wikipedia

  - Coupling – permanent connection between shafts, does not allow disconnection of shafts during their operation

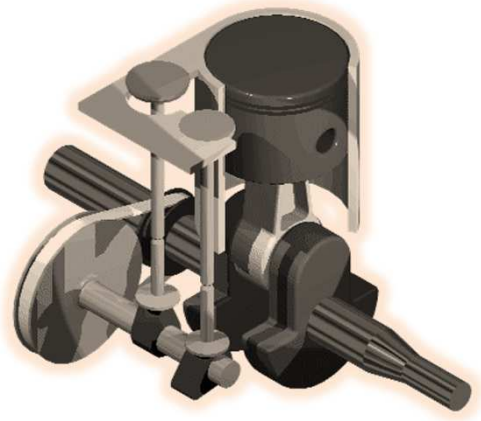


Rotating coupling
Source: Wikipedia

Beam coupling
Source: Wikipedia

Mechanical Components(VII)

- **Cams and followers**
  - Cam – an irregularly shaped element which serves as a driving link and imparts motion to a driven link called the follower.
    Enables transformation of rotation to linear motion or vice-versa.



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Mechanical Components (VIII)

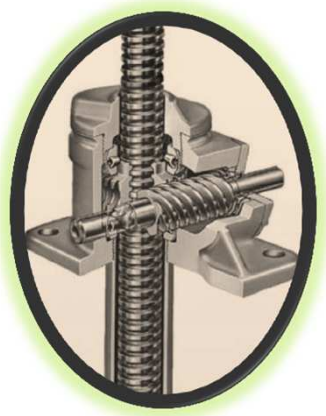
- **Brakes** – a machine element that inhibits motion by absorbing kinetic energy

Disc Brake. Source: Wikipedia

- **Springs** – a machine element that stores energy or provides a force over a distance by elastic deflection

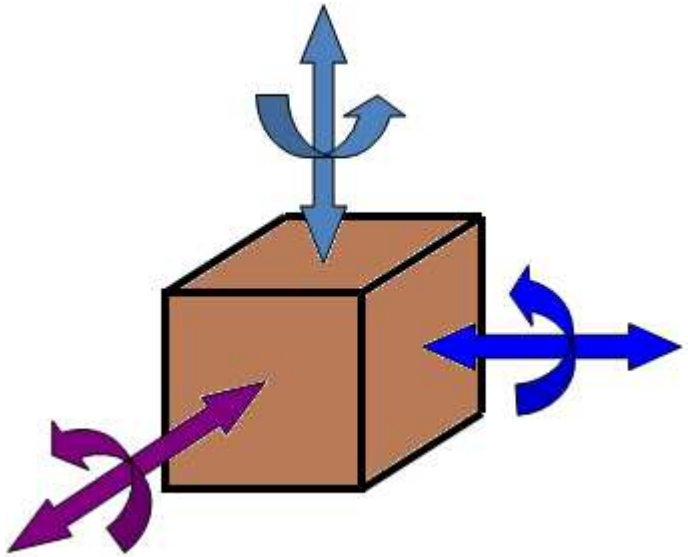
Spring. Source: Wikipedia

- **Power screws** – a machine element that translates rotary motion into uniform longitudinal motion



Degrees of Freedom (DOF)

- The minimum number of independent parameters to define the geometric configuration of a system in space
- An element in space has 6 DOF:
  - 3 translations.
  - 3 rotations.



Number of Degrees of Freedom

- GRÜBLER equation (GRUEBLER):

$$G = 3 \cdot (N-1) - 2 \cdot f_1 - f_2$$

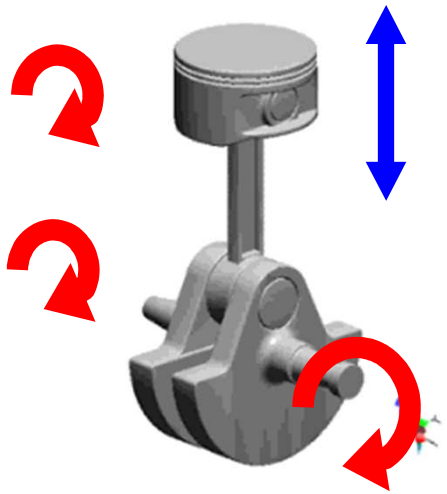
f_1 = nº pairs 1 DOF
f_2 = nº pairs 2 DOF
N = nº of elements

- If G>1 mechanism having G - DOF.
- If G=1 desmodromic mechanism.
- If G=0 statically determined structure.
- If G<0 hyper-static structure.

Kinematic Pairs

- **Kinematic pair** - two contiguous members that are in permanent contact and have a relative motion between them
  Kinematic pairs are classified as:
  - Lower pair – two links having a surface contact between them
  - Higher pair – two links having line or point contact between them

- **Joint** - guarantees the contact between two members and constrains their relative motion



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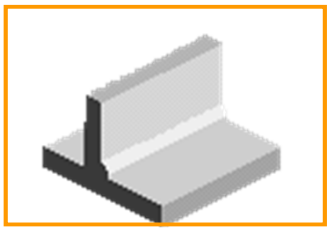
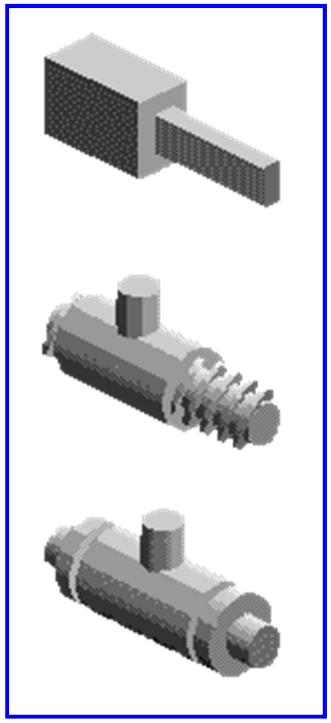
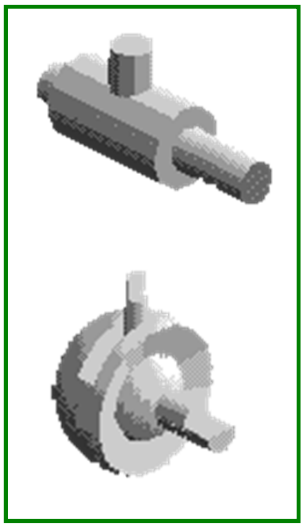
Classification of Kinematic Pairs by Degrees of Freedom



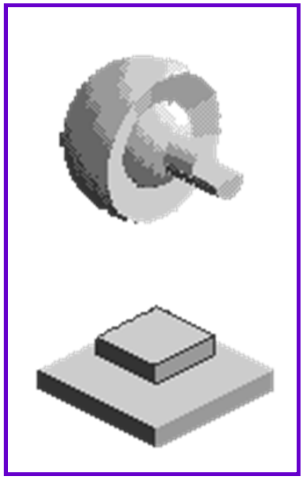
0 DOF



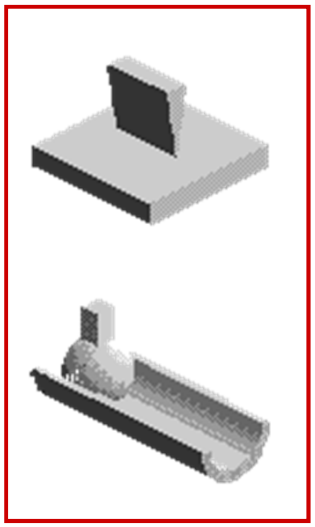
1 DOF



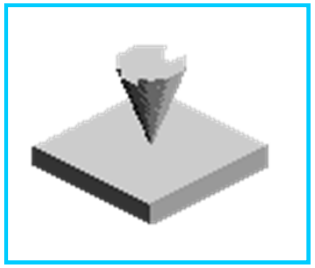
2 DOF



3 DOF



4 DOF



5 DOF