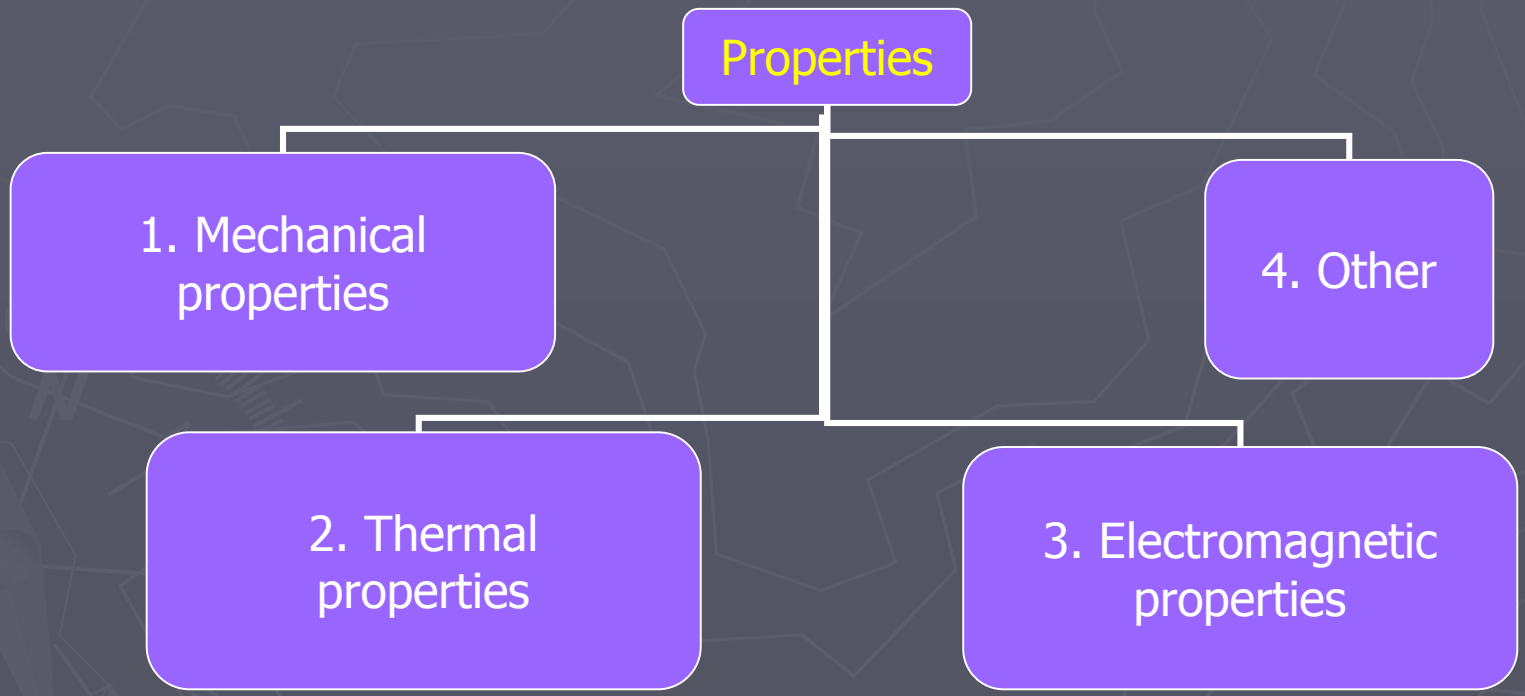
Properties of industrial materials

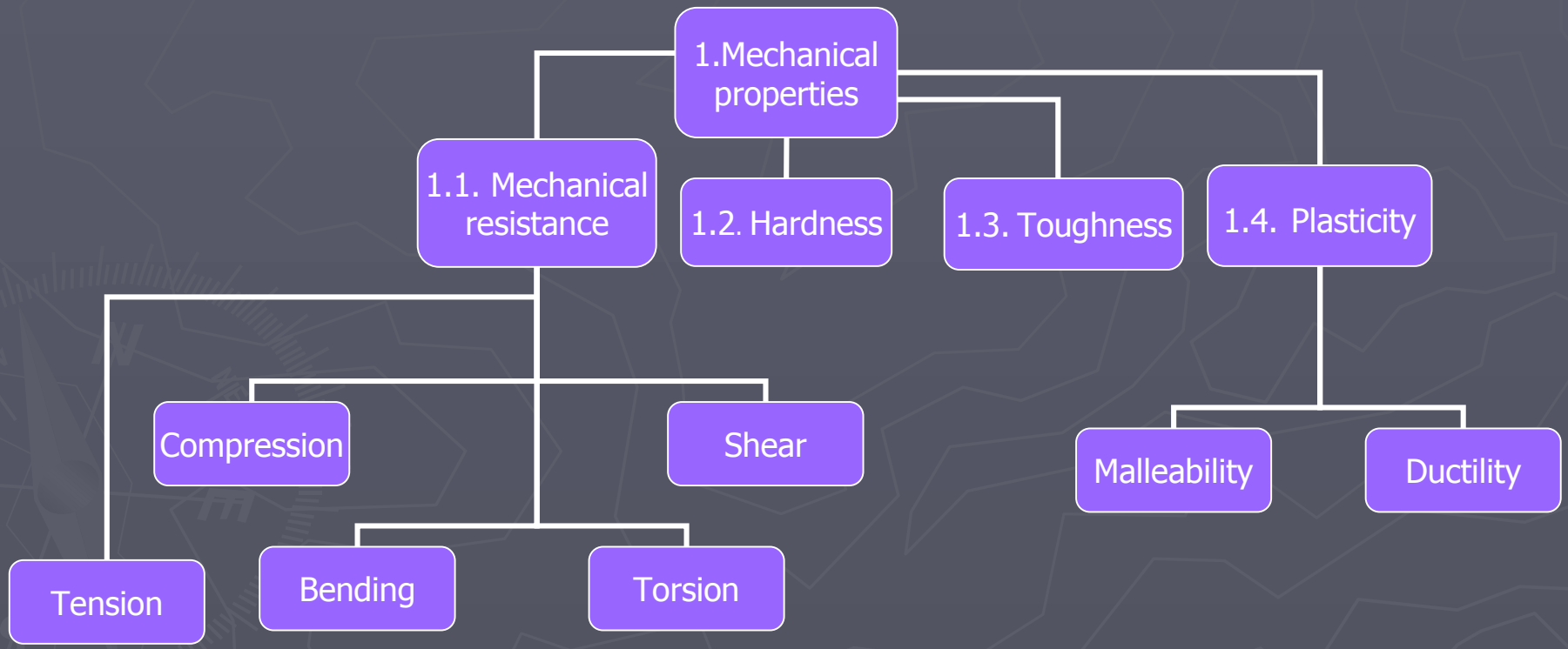
Different materials exhibit different working properties. In the following slides we will find the key properties which determine how materials behave

Josep Poch March 07

Properties of industrial materials

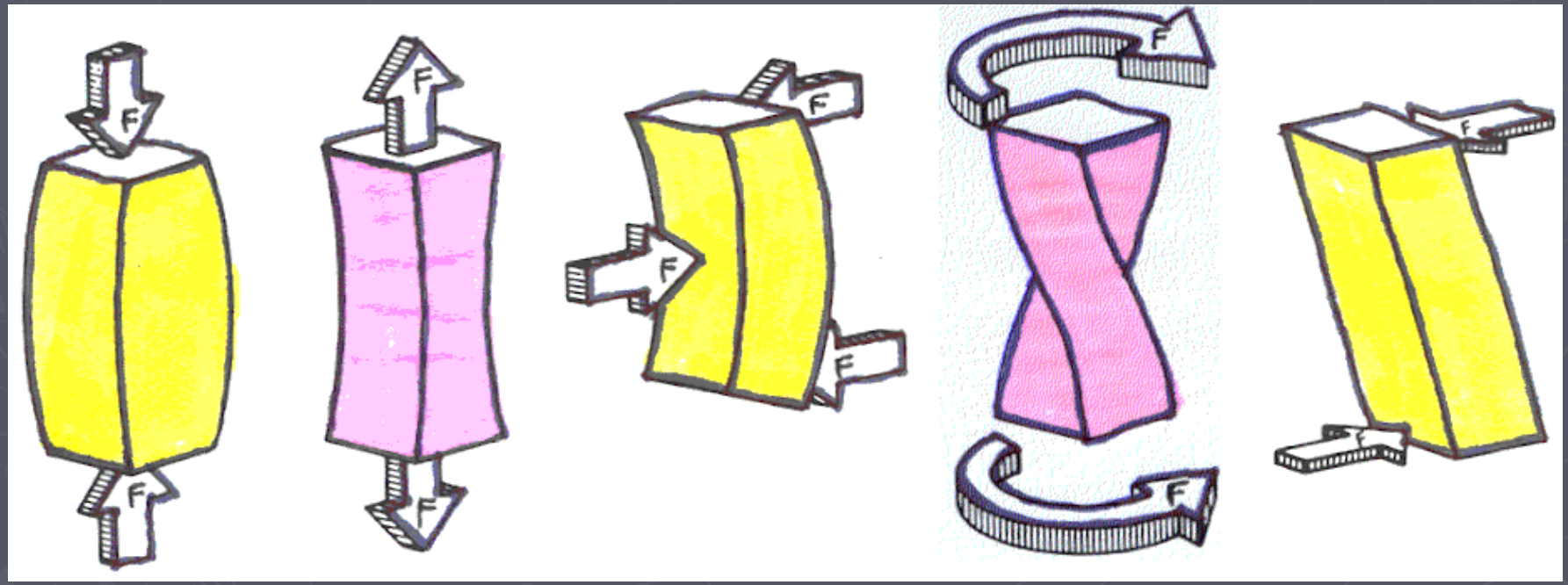


1. Mechanical properties



1.1. Mechanical resistance

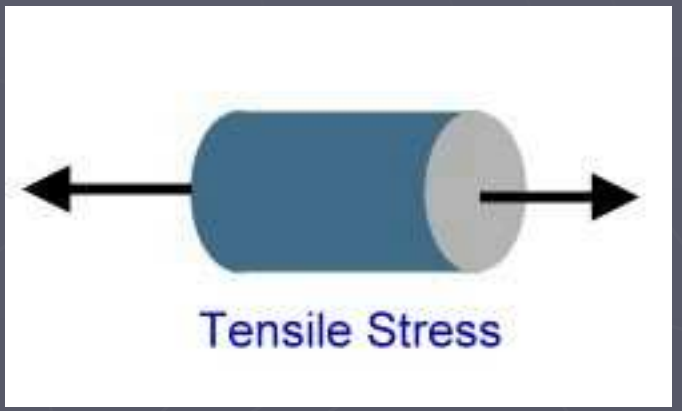
- Mechanical forces (stresses) that can be exerted on a piece of material (usually in a structure):

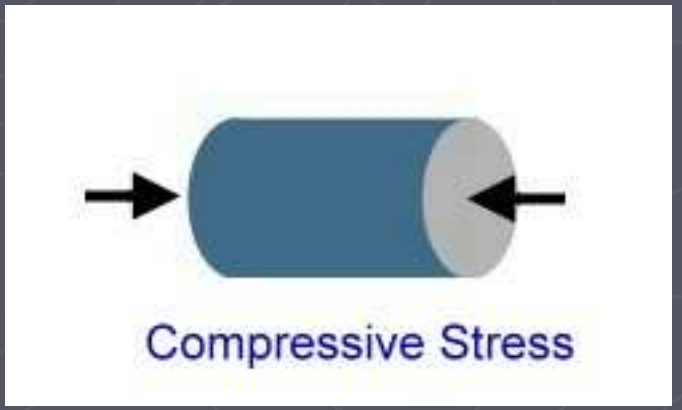


Compression ***Tension*** ***Bending*** ***Torsion*** ***Shearing***

Tension and compression

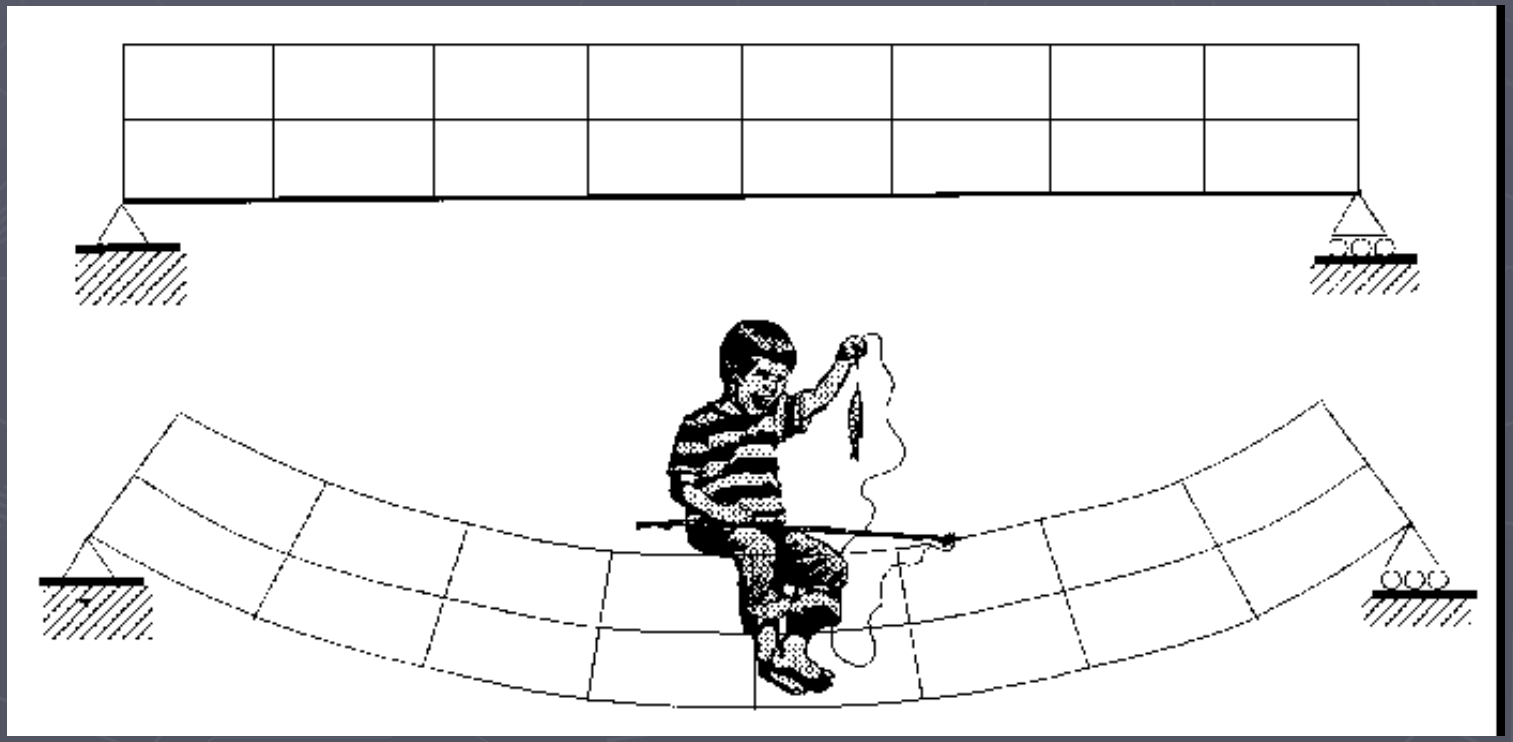
- Tensile stress: the force is applied perpendicular to the body and takes it apart. The body tends to be elongated in the direction of the applied forces
- Compressive stress: the force is applied perpendicular to the body and puts it together. The body tends to be shrunk in the direction of the applied forces





Bending stress

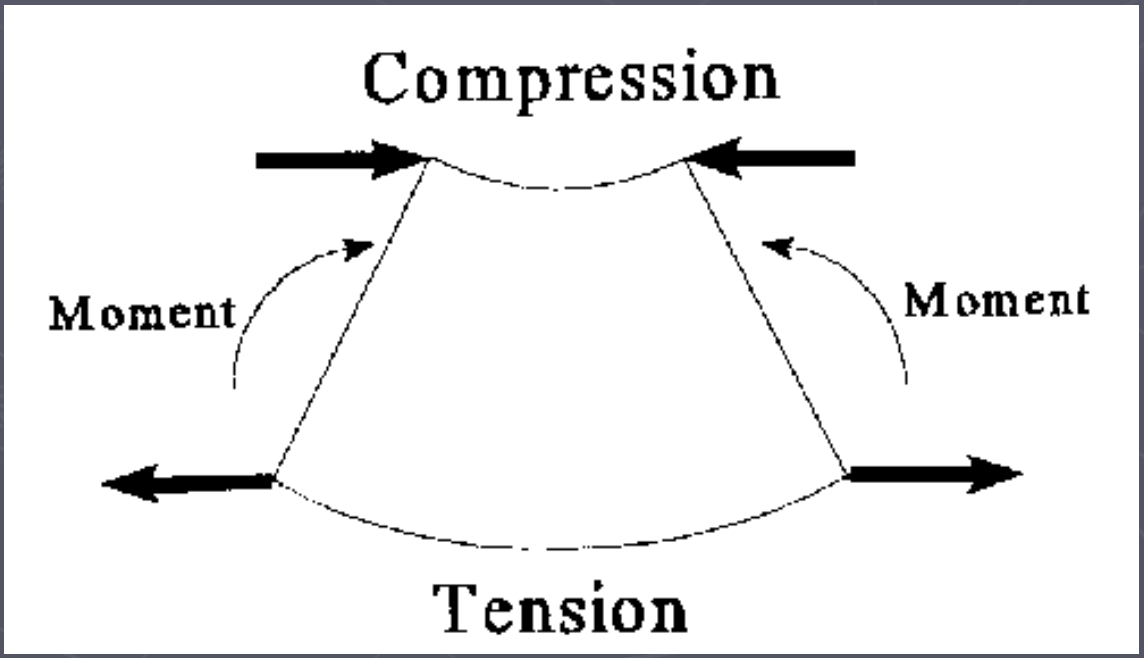
- It is the stress that is induced at a point in a body subjected to loads that cause it to bend



The child is bending the beam

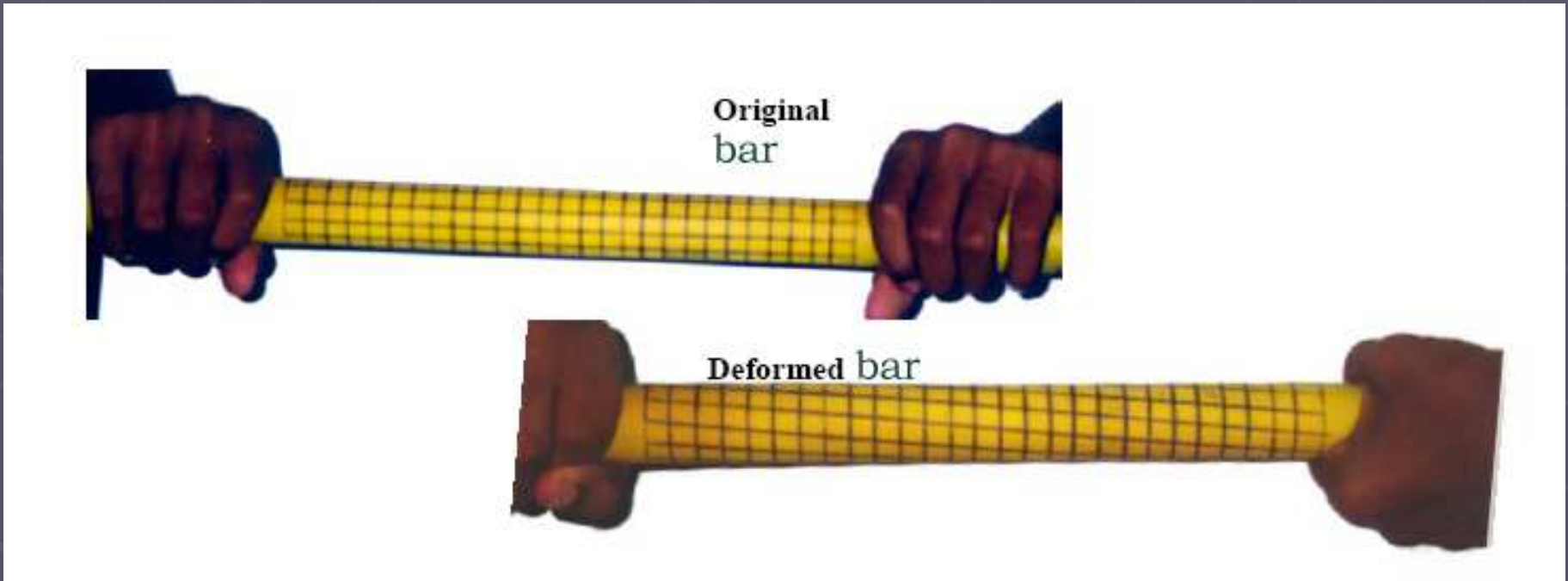
Bending stress

- Close-up view of a short segment of the beam is shown below. The top part of the beam is being squeezed in *compression* and the bottom part of the beam is in *tension*.



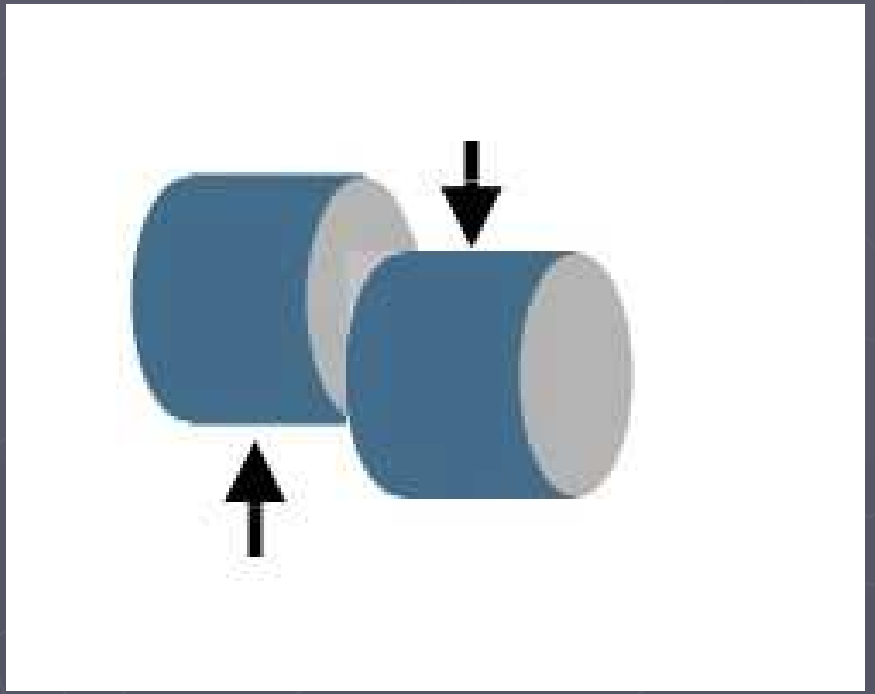
Torsion stress

- Torsion is the twisting of an object due to an applied rotational force

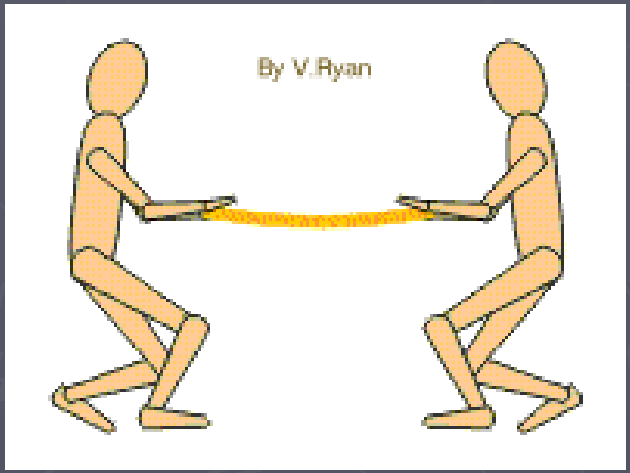


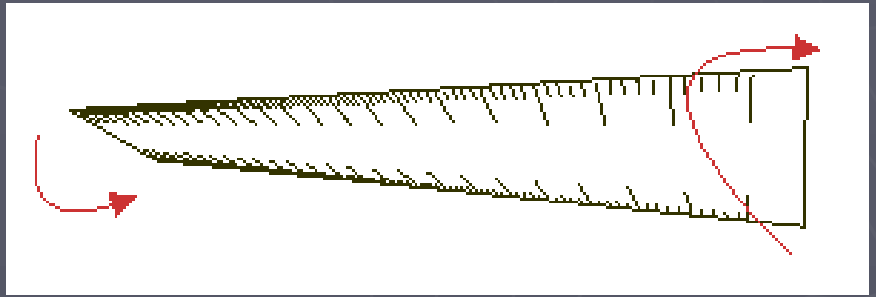
Shear stress

- Shear stress: the force acting in directions tangent to the area resisting the force, also named as tangential force
- The body tends to be cut off in two parts
- This is the physical principle of a pair of scissors cutting a piece of paper



What kind of stresses are being exerted?

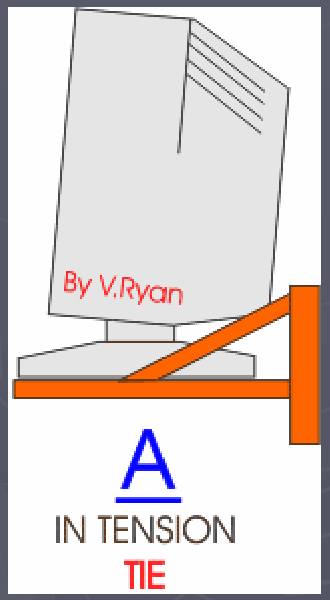


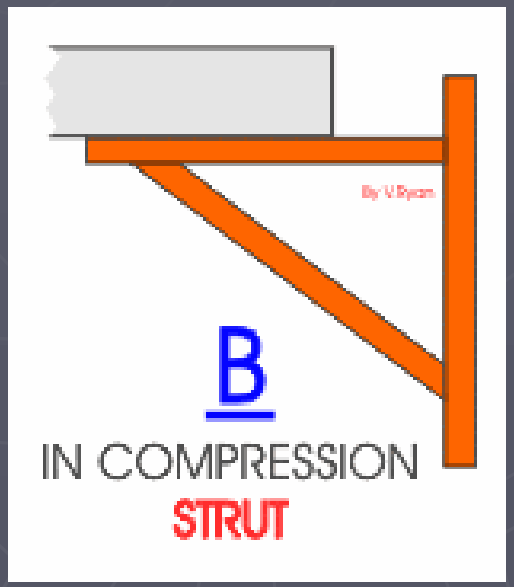


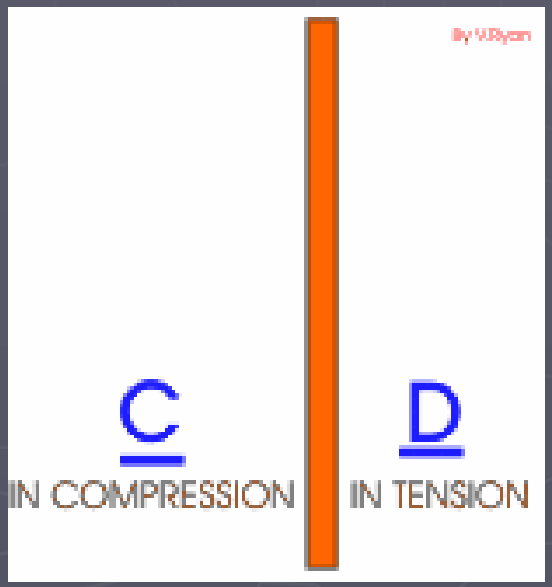
1. _____

2. _____

What kind of stresses are being exerted?







- A: the tie is in tension
- B: the strut is in compression
- C-D: the piece is being bent (compression/tension)

1.2. Hardness

A material that can't be scratched is hard

A material that can be easily scratched is soft

Wood is soft. Glass is hard

1.3 Toughness and brittleness

- **Toughness** is the ability of a material to withstand blows or sudden shocks without breaking

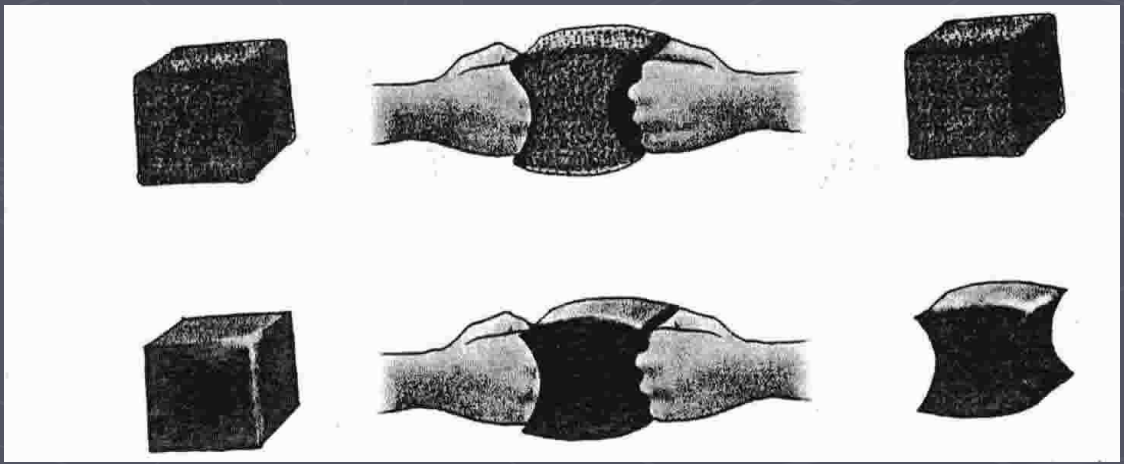
This piece of wood is very **tough**

1.3 Toughness and brittleness

- A material is **brittle** if it is susceptible to fracture when a sudden force is exerted on it
- The property is called **brittleness**
- It is generally applied to materials when there is no plastic deformation before breaking

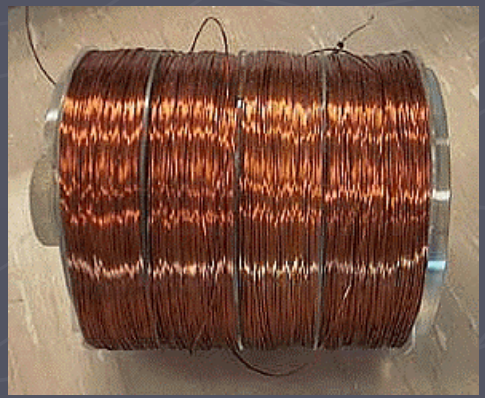
1.4. Plasticity and Elasticity

- Elastic deformation. When the stress is removed, the material returns to the dimension it had before it was applied. Deformation is *reversible, non permanent*
- The first material is elastic
- Plastic deformation. When the stress is removed, the material does not return to its previous dimension but there is a *permanent*, irreversible deformation
- The second material is plastic



Ductility

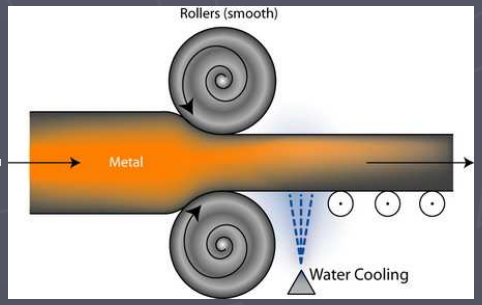
- **Ductility** is the physical property of being capable of sustaining large plastic deformations without fracture
- A **ductile** metal can be drawn into a very thin wire



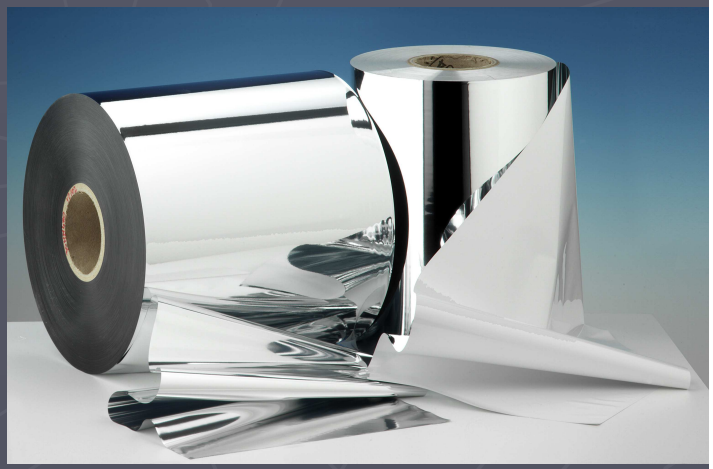
Malleability

- A **malleable** metal can easily be deformed, especially by rolling, without breaking
- It can be used to obtain a **foil** from a **plate** reducing its thickness through a **rolling process**

Plate



Rolling process



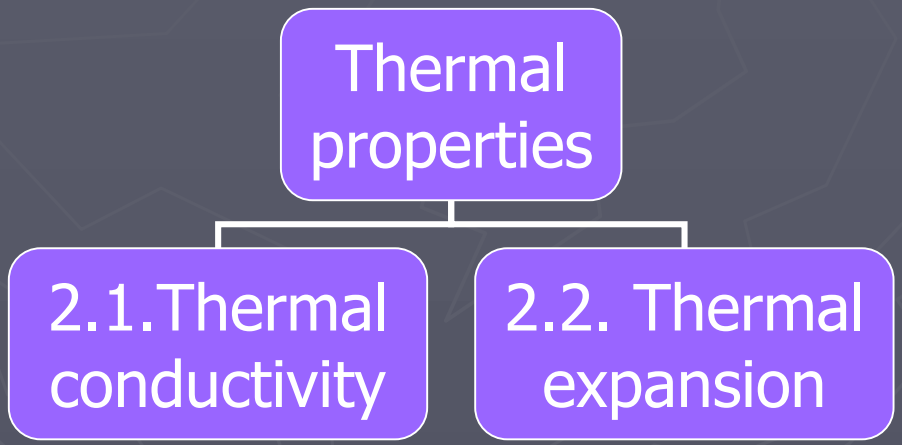
Foil

Stiffness or rigidity

- **Stiffness** is the resistance of a body to deformation by an applied force
- In general it refers to an object that is not easily bent (no deformations occur before breaking): it is **rigid** or **stiff**

This beam is NOT STIFF at all! It can be bent very easily, it is FLEXIBLE

2. Thermal properties



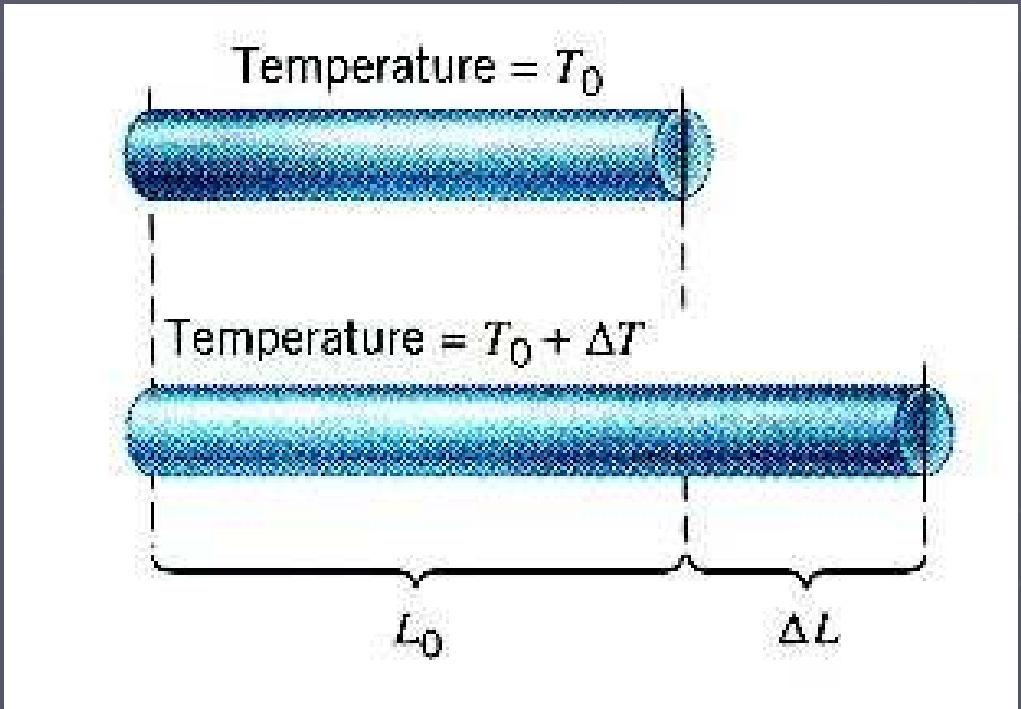
2.1. Thermal conductivity

- **Thermal conductivity** is the ability of a material to conduct heat
- A material with good thermal conductivity is a **thermal conductor**

Copper pipes are widely used in central heating systems

2.2. Thermal expansion

- Thermal expansion is the tendency of matter to increase in volume when heated
- When an object is long (a bar, a wire) its length increases when heated. The phenomenon is called linear expansion



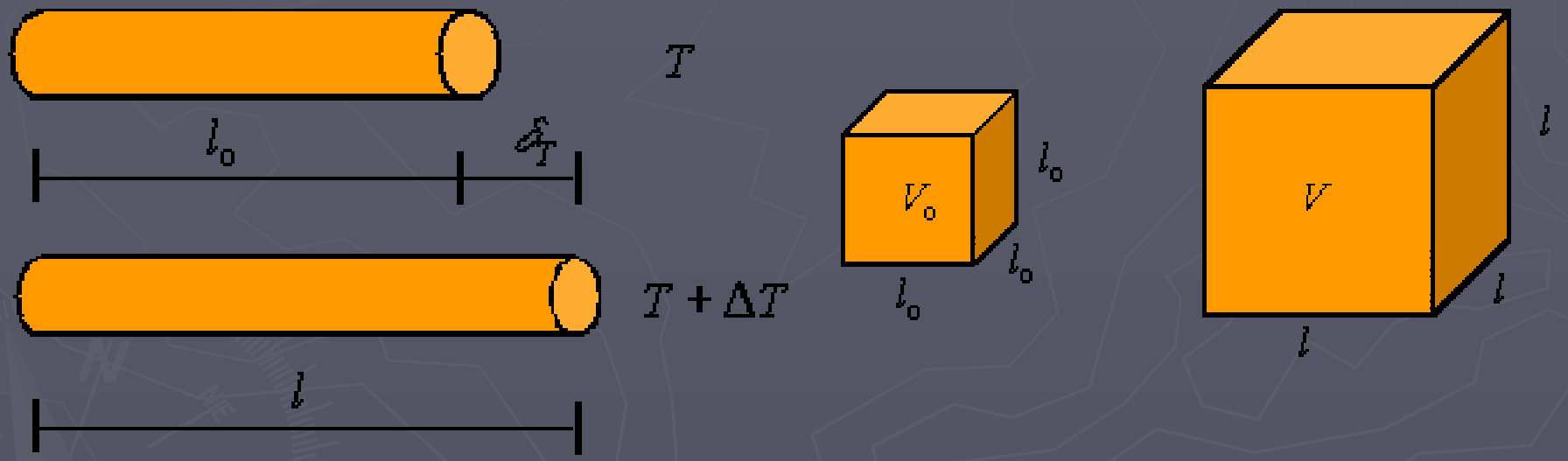
Lo = initial length

ΔL = change in length

To = initial temperature

ΔT = change in temperature

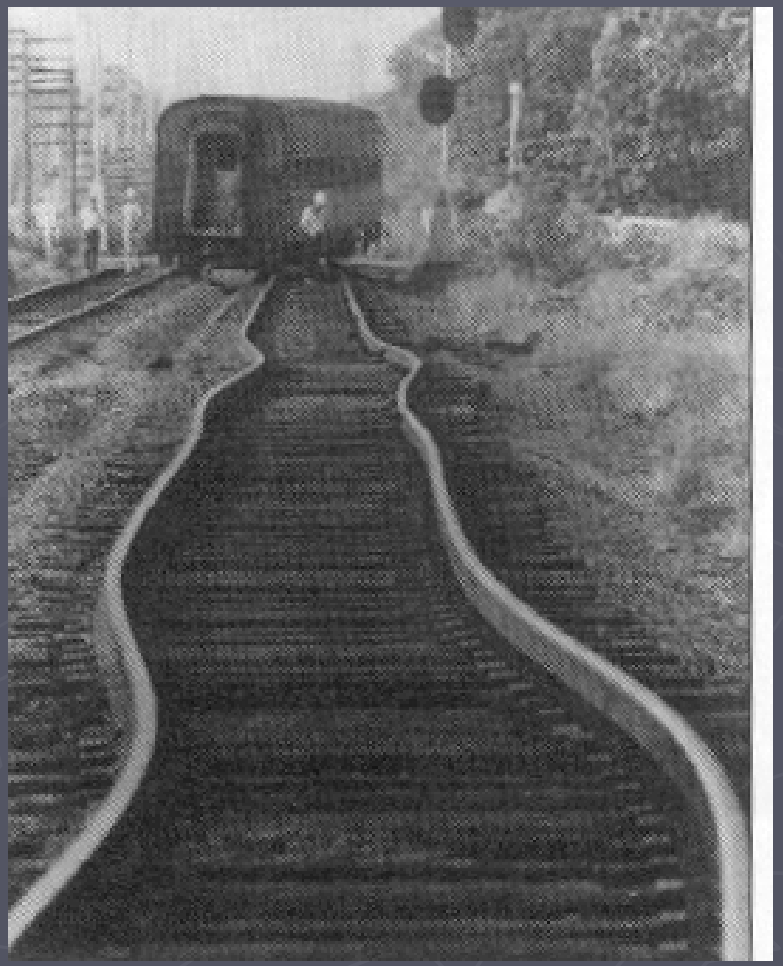
2.2. Thermal expansion



- Linear expansion and volume expansion

Linear expansion

- Rail track expansion joints are necessary. In summer the length of the tracks increase



Tracks with no expansion joints become distorted in summer

Linear expansion

- For solid materials with a significant length like rail tracks or cables, the amount of thermal expansion can be described by the ratio $\varepsilon_{thermal}$
- α is the coefficient of thermal expansion in $^{o}K^{-1}$ (or $^{o}C^{-1}$)

$$\epsilon_{thermal} = \frac{(L_{final} - L_{initial})}{L_{initial}}$$

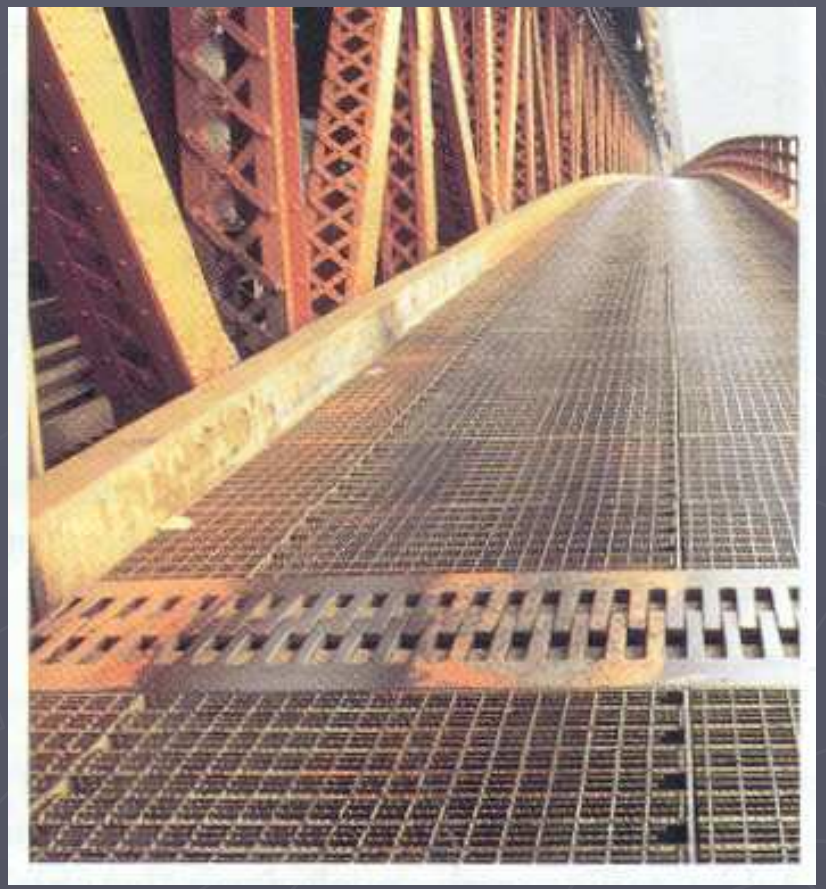
$$\epsilon_{thermal} = \alpha \Delta T$$

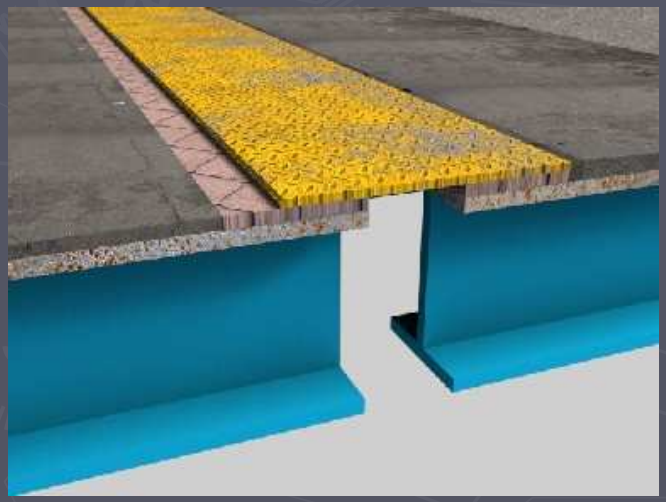
Coefficients of Linear Expansion (α) of some materials

Material	$^{o}K^{-1}$
Aluminium	23.6×10^{-6}
Copper	16.5×10^{-6}
Steel	13.0×10^{-6}
Glass	5.9×10^{-6}
Wood	5.0×10^{-6}

Linear expansion

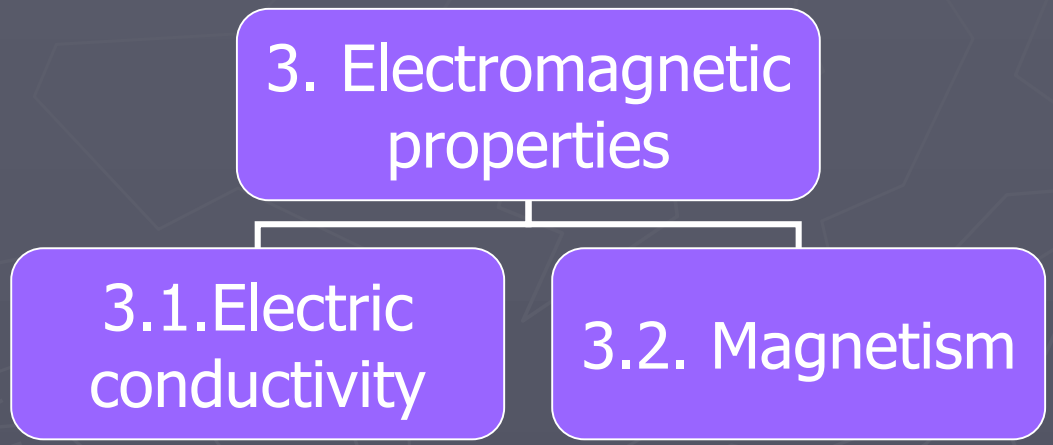
- Bridge expansion joint. In summer the teeth link together





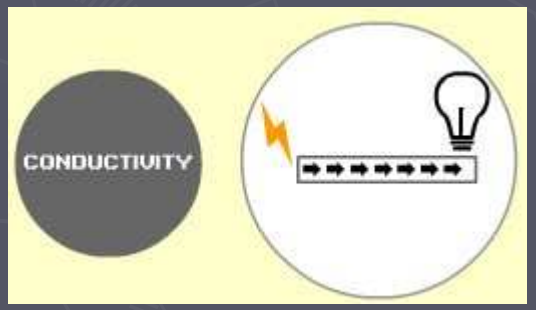
- Another bridge expansion joint. In summer the beams get closer

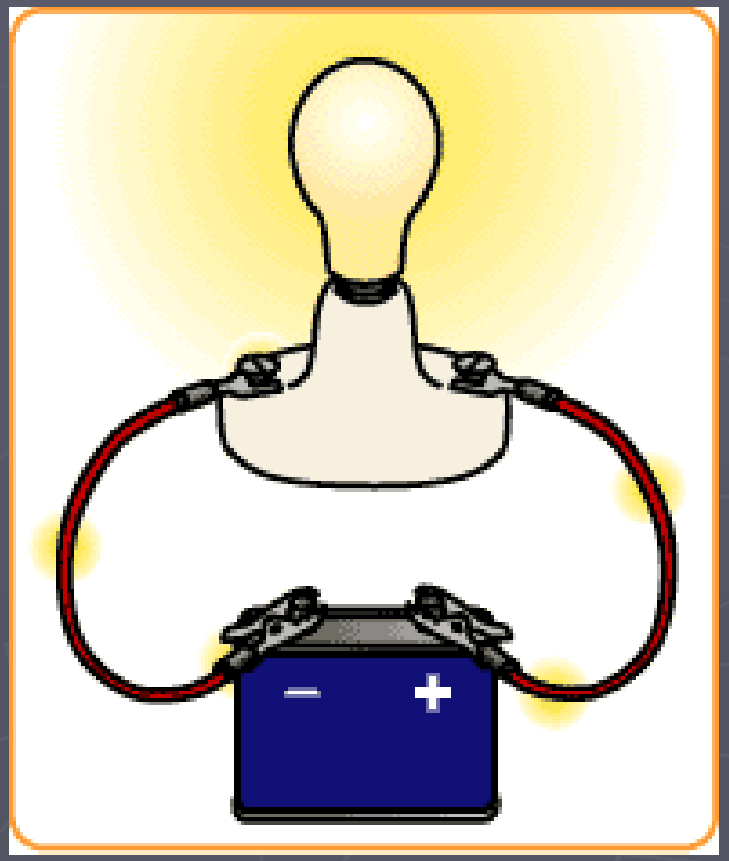
3. Electromagnetic properties



3.1. Electrical conductivity

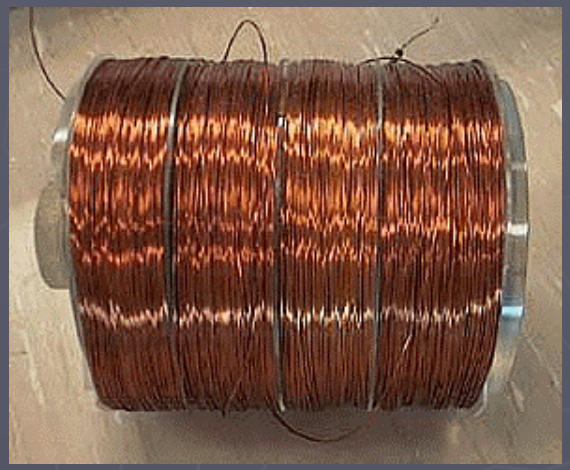
- **Electrical conductivity** is the ability of a material to conduct electrical energy





3.1. Electrical conductivity

- **Conductor:** material that transmits electricity



Copper is a conductor

- **Insulator:** *a material with negligible electrical conductivity*

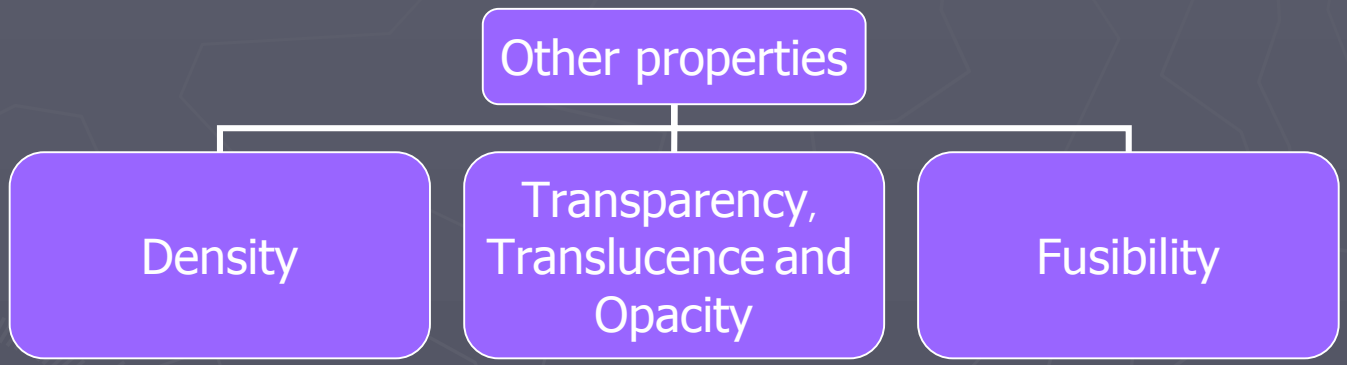
Timber is an insulator

3.2. Magnetism

- **Magnetism** is one of the phenomena by which materials exert an attractive or repulsive force on other materials
- Ferromagnetic materials (such as iron) are attracted by magnets
- Non-ferromagnetic materials (such as aluminium) are not

Magnets on a fridge. There is an attractive force between them and the fridge (made of steel)

4. Other properties



Density

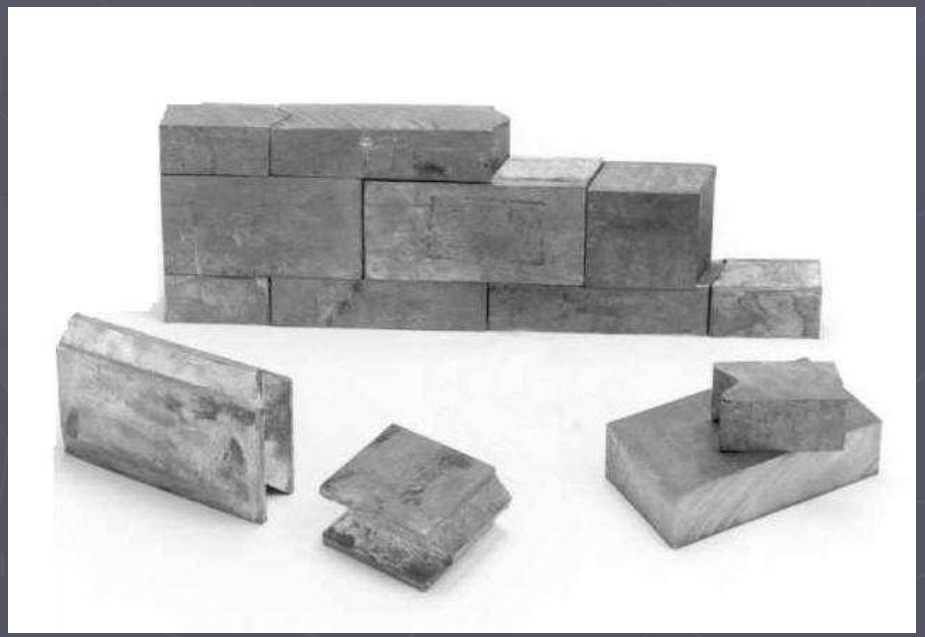
- **Density** is a measure of mass per unit volume
- An object made from a comparatively **dense material** (such as iron) will have more mass than an equal-sized object made from some **less dense substance** (such as aluminium)

$$\rho = \frac{m}{v}$$

Substance	Density (kg/m^3)
Gold	19300
Copper	8960
Iron	7870
Steel	7850
Aluminium	2700

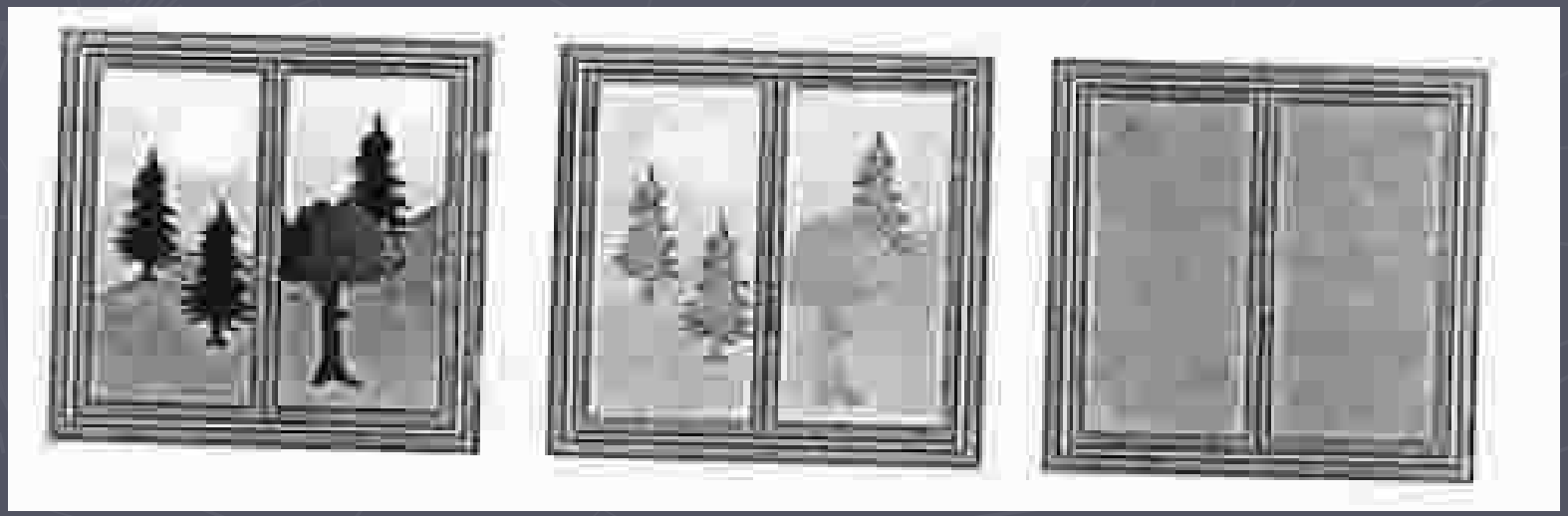
Density

- These bricks made of lead (left) are heavier than the aluminium plates (right). Lead has a higher density than aluminium



Transparency, Translucence and Opacity

- **Transparent** materials let light go through them and objects at the other side can be clearly seen
- **Translucent** materials let light go through them but objects at the other side can't be clearly seen
- **Opaque** materials don't let light go through them and objects at the other side can not be seen



Fusibility

- **Fusibility** is the ability of a material to change into a **liquid** or **molten state** when heated to its melting point

Pouring molten aluminium into a **cast** or **mould**