MECHANICAL PROPERTIES OF MATTER

This chapter deals with the behavior of materials used in construction of structures (e.g. bridges, vehicles, dams, roofs etc.) under the action of external forces.
These materials include;

- Timber
- Rubber
- Metals
- Glass
- Concrete
- Bricks
- Plastics
- Stones

Before these materials are used, they are tested under different conditions to see whether they can withstand weather conditions and the action of external forces. The behavior of these materials under test are called mechanical properties.

Definition:
Mechanical properties of matter are the behavior of matter when acted upon by external forces.

These mechanical properties include;

a) STRENGTH:
This is the ability of a material to withstand an applied force before it breaks.

Materials that have this property are said to be strong.

- A **strong material** is a material that can withstand a large force before breaking.
  Strong materials include; concrete, metals, etc.

Factors that affect the strength of a material

- **Magnitude of applied force:**
  It is easier for a material to withstand a small force than a large force. Therefore, strength of a material increases when a small force is applied than when a large force is applied.
- **Cross-sectional area of a material:**
  A material of large diameter (large cross-sectional area) is able to withstand a large force than a material of small diameter.
  Therefore, materials with large cross-sectional areas are stronger than material with small cross-sectional areas.
- **Nature of the material:**
  Different materials withstand different forces before breaking e.g. a steel rod is able to withstand large forces than a piece of wood.

b) STIFFNESS:
This is the ability of a material to resist any force that try to change its shape and size.
OR
This is the ability of a material to resist bending when a force is applied on it.

Materials that have this property are said to be stiff.

- A **stiff material** is a material that resists any forces that try to change its shape and size.
  Stiff materials are not flexible and they require a large force to be bent.
  Stiff materials include; concrete, steel, iron etc.

How to increase the stiffness of a material:

- By reducing the length of a material.
- By reducing the temperature of a material.

c) DUCTILITY:

This is the ability of a material to be changed or molded into different shapes and sizes without breaking.

Materials that have this property are said to be ductile.

- A **ductile material** is a material that can be changed or molded into different shapes and sizes without breaking.
  Ductile materials are flexible and they can be bent greatly before they break.
  Ductile materials include; copper wire, plasticine, rubber etc.

d) BRITTLENESS:

This is the ability of a material to break suddenly without bending when a force is applied on it.

Materials that have this property are said to be brittle.

- A **brittle material** is a material that breaks suddenly without bending when a force is applied on it.
  Brittle materials are not flexible and they cannot be molded into other shapes. They break easily (fragile) without undergoing plastic deformation.
  Brittle materials include; chalk, glass, bricks, dry biscuits, concrete, charcoal, etc.

e) ELASTICITY:

This is the ability of a material to regain its original shape and size when a stretching force is removed.

Materials that have this property are said to be elastic.

- An **elastic material** is a material that can regain its original shape and size when a stretching force is removed.
  Elastic materials include; rubber springs, etc.

The extension of an elastic material depends on;

→ Nature of a material.
→ Magnitude of stretching force.

f) PLASTICITY:

This is the ability of a material not to regain its original shape and size when a stretching force is removed.

Materials that have this property are said to be plastic (inelastic).

- A **plastic material** is a material that cannot regain its original shape and size when a stretching force is removed.
  Plastic materials include; plasticine, clay, etc.

HOOKES'S LAW

It states that the extension of a material is directly proportional to force applied provided that the elastic limit is not exceeded.

$\boldsymbol{Force\ (F)\ is\ directly\ proportional\ to\ extenstion\ (e)}$

$$F \propto e$$

$$\boxed{F = Ke}$$

Where;

F → Force applied
e → Extension
K → Spring constant / Proportionality constant / Elastic constant

The SI unit of the spring constant, K is Nm^{-1}.

$\boldsymbol{Extension = New\ length\ (l_2) - Original\ length\ (l_1)}$

Examples:

1. A force of 3N is applied on an elastic wire of length 10cm. If its new length after the application of force is 12cm, calculate;
   a) Extension.
   $l_2 = 12cm, \quad l_1 = 10cm,$
   $e = l_2 - l_1$
   $e = 12 - 10$
   $e = 2cm$
   b) Elastic constant.
   $e = 2cm = \frac{2}{100} = 0.02m, \quad F = 3N$
   $F = Ke$
   $3 = K \times 0.02$
   $K = \frac{3}{0.02}$
   $K = 150Nm^{-1}$

2. A spring extends by 0.5cm when a load of 0.4N hangs on it.
   i) Calculate the spring constant.
   $e = 0.5cm = \frac{0.5}{100} = 0.005m, \quad F = 0.4N$
   $F = Ke$
   $0.4 = K \times 0.005$
   $K = \frac{0.4}{0.005}$
   $K = 80Nm^{-1}$
   ii) Find the force required to cause an extension of 0.06m.
   $F = Ke$
   $F = 80 \times 0.06$
   $F = 4.8N$

NOTE:

- If force, F_1 acts on an elastic material, and produces an extension, e_1 and then force, F_2 acts on the same elastic material and produces an extension, e_2, then;

$$\boxed{\frac{F_1}{e_1} = \frac{F_2}{e_2} \quad or \quad \frac{F_1}{F_2} = \frac{e_1}{e_2}}$$

Examples:

There is no need of converting units for extension if the two extensions have the same units.

3. A force of 50N causes an extension of 5mm on stretched material. Calculate its extension if a force of 150N is applied.

$F_1 = 50N, \quad e_1 = 5mm, \quad F_2 = 150N, \quad e_2 = ?$

$$\frac{F_1}{F_2} = \frac{e_1}{e_2}$$
$$\frac{50}{150} = \frac{5}{e_2}$$
$$e_2 = \frac{150 \times 5}{50}$$
$$e_2 = 15mm$$

4. A mass of 10kg is hang on a spring and it produces an extension of 2cm. What will be the extension if a force of 150N is applied?

$F_1 = mg = 10 \times 10 = 100N, \quad e_1 = 2cm, \quad F_2 = 150N, \quad e_2 = ?$

$$\frac{F_1}{F_2} = \frac{e_1}{e_2}$$
$$\frac{100}{150} = \frac{2}{e_2}$$
$$e_2 = \frac{150 \times 2}{100}$$
$$e_2 = 3cm$$

5. When a force of 1N is applied on a spring, the length of the spring increases from 7.4cm to 8.4cm. Calculate;

a) The elastic constant of the spring.

$$e = (8.4 - 7.4) = 1cm = \frac{1}{100} = 0.01m, \quad F = 1N$$

$$F = Ke$$
$$1 = K \times 0.01$$
$$K = \frac{1}{0.01}$$
$$K = 100Nm^{-1}$$

b) The extension produced when a force of 50N is applied.

$$F = Ke$$
$$50 = 100 \times e$$
$$e = \frac{50}{100} = 0.5m$$

6. A spring has a natural length of 12cm. When a load P is suspended from it, its length increases to 22cm and when a load of 250N is attached to it, its length increases to 27cm. Find the value of P.

$$F_1 = P, \quad e_1 = (22 - 12) = 10cm, \quad F_2 = 250N, \quad e_2 = (27 - 12) = 15cm$$

$$\frac{F_1}{F_2} = \frac{e_1}{e_2}$$

$$\frac{P}{250} = \frac{10}{15}$$

$$P = \frac{250 \times 10}{15}$$

$$P = 166.8N$$

7. A mass of 500g causes an extension of 2cm. Calculate the mass that can cause an extension of 0.5cm.

$$m_1 = 500g, \quad e_1 = 2cm, \quad m_2 = ?, \quad e_2 = 0.5cm$$

$$\frac{F_1}{F_2} = \frac{e_1}{e_2}$$

$$\frac{m_1 g}{m_2 g} = \frac{e_1}{e_2}$$

$$\frac{500}{m_2} = \frac{2}{0.5}$$

$$m_2 = \frac{500 \times 0.5}{2}$$

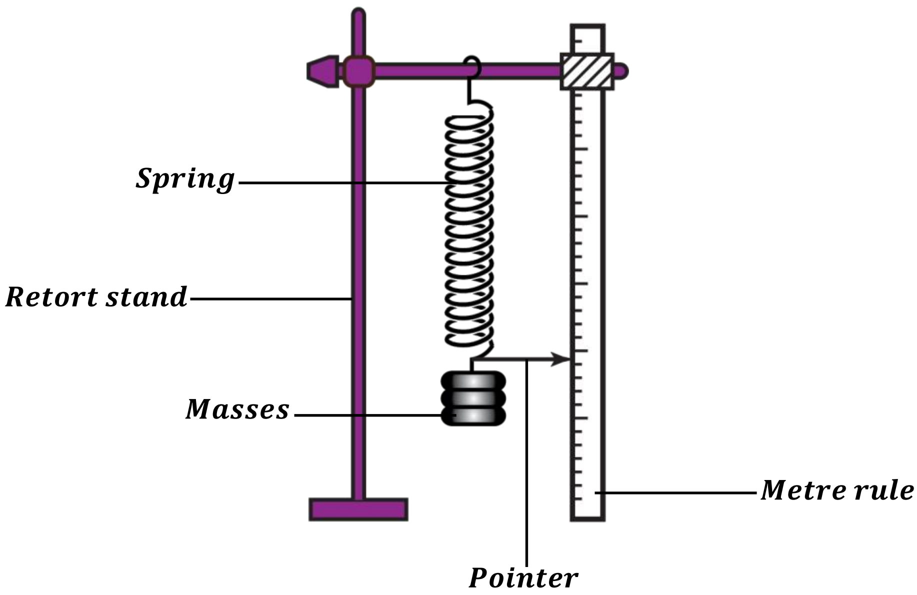
$$m_2 = 125g$$

EXERCISE:

1. A mass of 0.5kg causes a spiral spring to extend by 4cm. Calculate the mass that would cause an extension of 6cm.
2. A force of 10N extends a wire by 2cm.
   i) Find the constant of proportionality.
   ii) Find the extension produced by the force of 50N.
3. A spring produces an extension of 6mm when a load of 9N is hung from its free end. What load would cause the same spring to stretch by 16mm?
4. A metallic cube suspended freely from the end of the spring caused it to stretch by 5cm. 500g mass suspended from the same spring stretched it by 2cm.
   a) Find the weight of the metallic cube.
   b) By what length will the spring stretch if a mass of 1.5kg is attached to its end?
5. A spring stretches by 4mm when supporting a mass of 15kg. By how much would it stretch when supporting a load of 55N?
6. A spring increase its length from 20cm to 25cm when a force is applied. If the spring constant is $100Nm^{-1}$, calculate the force applied.
7. A 5.0cm long spring was used in an experiment. When a load of 2000N is suspended from it, its length increases to 6.5cm and when a load Q is attached to it, its length increases to 8.0cm. Find the value of Q.

8. A vertical spring of length 30cm is stretched to 36cm when an object of mass 100g is placed in the pan attached to it. The spring is stretched to 4ocm when a mass of 200g is placed in the pan. Find the mass of the pan.
9. A spring of natural length $8.0 \times 10^{-2} m$ extends by $2.5 \times 10^{-2} mm$ when a weight of 10N is suspended on it.
   i) Find the spring constant.
   ii) Determine the extension when a weight of 15N is suspended on the spring.
10. A force of 500N extends a wire by 2mm. If the force is reduced by a half, what will be the new length of the wire if the original length is 10cm.

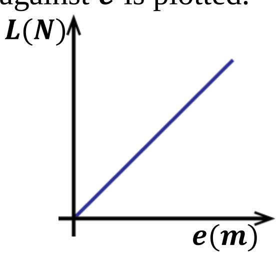
<u>An experiment to verify Hooke's law</u>



- The experiment is set up as shown above.
- The initial position of the pointer, $\boldsymbol{P_1}$ is read and recorded.
- A standard mass, $\boldsymbol{m}$ is attached at the end the spring.
- The new position of the pointer, $\boldsymbol{P_2}$ is read and recorded.
- The extension, $\boldsymbol{e}$ of the spring is determined from the expression, $\boldsymbol{e = P_2 - P_1}$.
- The above procedures are repeated with different masses.
- The results are then put into a suitable table including values of the load (force) i.e. $L = mg$.

$m(kg)$	$L(N)$	$P_2(cm)$	$e(cm)$

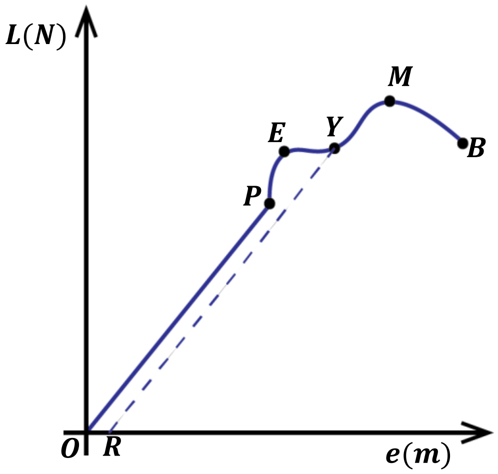
- A graph of $\boldsymbol{L}$ against $\boldsymbol{e}$ is plotted.



- A straight-line graph through the origin is obtained.
- This shows that $\boldsymbol{L}$ is directly proportional to $\boldsymbol{e}$ hence verifying Hooke's law.

NOTE:
- In order to get accurate results in the above experiment, the elastic limit of the spring should not be exceeded.

A graph of load against extension for copper wire (ductile material):



$P -$ ***Proportional limit***
$E -$ ***Elastic limit***
$Y -$ ***Yield point***
$M -$ ***Maximum stress (Breaking stress)***
$B -$ ***Breaking point***
$OR -$ ***Region of permanent deformation***

Between O and P:
The extension, e is directly proportional to applied force (Load, L) hence Hooke's law is obeyed in this region. In this region, the material can regain its original shape and size when the stretching force is removed.

Between P and E:
In this region, the material undergoes elastic deformation until it reaches the elastic limit, E.
In this region, Hooke's law is not obeyed but the material can regain its original shape and size when the stretching force is removed.

Beyond E:
Point, E, is the elastic limit of the material. Therefore, beyond E, the material undergoes plastic deformation whereby it cannot regain its original shape and size when the stretching force is removed.
The material is permanently stretched between Y an M.

Beyond M:
This point represents the maximum stress a material can withstand (i.e. the maximum load it can handle). Addition of any extra load (force) at this point makes the wire to break on reaching the breaking point B.

IMPORTANT DEFINITIONS
- **Proportional limit:**
  This is a point beyond which Hooke's law is not obeyed.
- **Elastic limit:**
  This is a point beyond which a material cannot regain its original shape and size when a stretching force is removed.
- **Yield point:**
  This is a point beyond which a material is permanently stretched and there is a permanent increase in length when the stretching force is removed.

- **Elastic deformation**:
  This is a temporary deformation which occurs before the elastic limit and the material can regain its original shape and size when the stretching force is removed.

- **Plastic deformation**:
  This is a permanent deformation which occurs after the elastic limit and the material cannot regain its original shape and size when the stretching force is removed.

TENSILE STRESS, TENSILE STRAIN AND YOUNG'S MODULUS

TENSILE STRESS:
This is the ratio of force applied to the cross-sectional area of a material.

OR

This is the force acting per unit cross-sectional area of a material.

$$Stress = \frac{Force}{Cross - sectional\ area}$$

$$\boldsymbol{Stress = \frac{F}{A}}$$

The SI unit of tensile stress is $\boldsymbol{Nm^{-2}}$ $(Pascals)$.

Question: Distinguish between Pressure and Tensile stress.
Pressure is the force acting normally per unit surface area of a material.

WHILE

Tensile stress is the force acting per unit cross-sectional area of a material.

TENSILE STRESS:
This is the ratio of extension to the original length of the material.

$$Strain = \frac{Extension}{Original\ length}$$

$$\boldsymbol{Strain = \frac{e}{l_1}}$$

Tensile strain has no units since extension and original length have the same units.

YOUNG'S MODULUS:
This is the ratio of tensile stress to tensile strain of a material.

$$\boldsymbol{Young's\ modulus = \frac{Tensile\ stress}{Tensile\ strain}}$$

$$Young's\ modulus = \frac{F/A}{e/l_1}$$

$$Young's\ modulus = \frac{Fl_1}{Ae}$$

The SI unit of Young's modulus is $\boldsymbol{Nm^{-2}}$ $(Pascals)$.

Examples:

1. A copper wire of length 10cm is subjected to a force of 2N. If its cross-sectional area is $5cm^2$ and a force causes it to extend by 0.2cm, calculate;
   i) Tensile stress.
   ii) Tensile strain.
   iii) Young's modulus.

$$l_1 = 10cm, \quad F = 2N, \quad A = 5cm^2, \quad e = 0.2cm$$

i) Tensile stress

$$A = 5cm^2 = \frac{5}{10000} = 0.00005m^2$$

$$Stress = \frac{F}{A}$$

$$Stress = \frac{2}{0.00005}$$

$$Stress = 40,000Nm^{-2}$$

ii) Tensile strain

$$Strain = \frac{e}{l_1}$$

$$Strain = \frac{0.2}{10}$$

$$Strain = 0.02$$

iii) Young's modulus

$$Young's\ modulus = \frac{Stress}{Strain}$$

$$Young's\ modulus = \frac{0.02}{40000}$$

$$Young's\ modulus = 5 \times 10^{-7}Nm^{-2}$$

2. A mass of 2.4kg is attached to the end of a long vertical wire 2m long and produces an extension of 0.5mm. If the diameter of the wire is 0.78mm, calculate;
   i) Tensile stress.
   ii) Tensile strain.
   iii) Young's modulus.

$$m = 2.4kg, \quad l_1 = 2m, \quad r = \frac{d}{2} = \frac{0.78}{2} = 0.39mm, \quad e = 0.5mm$$

i) Tensile stress

$$A = \pi r^2 = \frac{22}{7} \times 0.39^2 = 0.478mm^2$$

$$A = 0.478mm^2 = \frac{0.478}{1000000} = 4.78 \times 10^{-7}m^2$$

$$F = mg = 2.4 \times 10 = 24N$$

$$Stress = \frac{F}{A}$$

$$Stress = \frac{24}{4.78 \times 10^{-7}}$$

$$Stress = 5.02 \times 10^7 Nm^{-2}$$

ii) Tensile strain

$$e = \frac{0.5}{1000} = 5 \times 10^{-4}m$$

$$Strain = \frac{e}{l_1}$$

$$Strain = \frac{5 \times 10^{-4}}{2}$$

$$Strain = 2.5 \times 10^{-4}$$

iii) Young's modulus

$$Young's\ modulus = \frac{Stress}{Strain}$$

$$Young's\ modulus = \frac{5.02 \times 10^7}{2.5 \times 10^{-4}}$$

$$Young's\ modulus = 2.0 \times 10^{11}Nm^{-2}$$

3. A mass of 2000g is placed at the end of the wire 15cm long and cross-sectional area $0.2cm^2$. If the mass causes an extension of 1.5cm, calculate;
   i) Stress.
   ii) Strain.
   iii) Young's modulus.

$$m = 2000g, \quad l_1 = 15cm, \quad A = 0.2cm^2, \quad e = 1.5cm,$$

i) Stress

$$A = 0.2cm^2 = \frac{0.2}{10000} = 2.0 \times 10^{-5}m^2$$

$$F = mg = \frac{2000}{1000} \times 10 = 20N$$

$$Stress = \frac{F}{A}$$

$$Stress = \frac{20}{2.0 \times 10^{-5}}$$

$$Stress = 1 \times 10^6 Nm^{-2}$$

ii) Strain

$$Strain = \frac{e}{l_1}$$

$$Strain = \frac{1.5}{15}$$

$$Strain = 0.1$$

iii) Young's modulus

$$Young's\ modulus = \frac{Stress}{Strain}$$

$$Young's\ modulus = \frac{1 \times 10^6}{0.1}$$

$$Young's\ modulus = 1.0 \times 10^7 Nm^{-2}$$

4. A piece of wire of diameter 0.64mm and length 12m is stretched through 2.5cm by a 5kg mass.
   a) Determine the;

$$A = \pi r^2 = \frac{22}{7} \times \left(\frac{0.64}{2}\right)^2 = 3.218 \times 10^{-1}mm^2$$

$$A = 3.218 \times 10^{-1}mm^2 = \frac{3.218 \times 10^{-1}}{1000000} = 3.218 \times 10^{-7}m^2$$

$$F = mg = 5 \times 10 = 50N$$

$$Stress = \frac{F}{A}$$

$$Stress = \frac{50}{3.218 \times 10^{-7}}$$

$$Stress = 1.554 \times 10^8 Nm^{-2}$$

   b) What force will stretch the wire through 4cm?

$$\frac{F_1}{F_2} = \frac{e_1}{e_2}$$

$$\frac{50}{F_2} = \frac{2.5}{4}$$

$$F_2 = \frac{50 \times 4}{2.5}$$

$$F_2 = 80N$$

5. A material stretched by 6cm develops a strain of 4.8×10^{-2}. Find the original length of the material.

$$e = 6cm, \qquad strain = 4.8 \times 10^{-2}$$

$$Strain = \frac{e}{l_1}$$

$$4.8 \times 10^{-2} = \frac{6}{l_1}$$

$$l_1 = 125cm$$

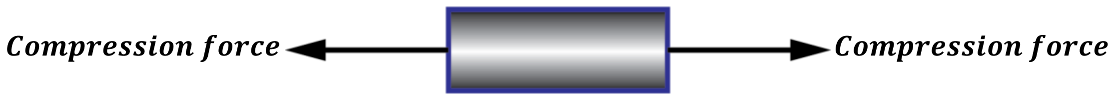
EXERCISE:

1. Calculate the tensile stress when a force of 25N acts on a wire of cross-sectional area $5m^2$.
2. The breaking stress of a material is $4.0 \times 10^6 Nm^{-2}$. Calculate the force required to break a piece of material of cross-sectional area $10m^2$.
3. A string 4mm in diameter has original length 2m. The string is pulled by a force of 200N. If the final length of the spring is 2.02m, determine;
   a) Stress.
   b) Strain.
   c) Young's modulus.
4. A piece of wire of diameter 0.32mm and length 14m is stretched through 2.8cm by a 10kg mass.
   i) Determine the young's modulus of the material.
   ii) What force will stretch the wire through 12cm?
5. An elastic material of cross-sectional area $32m^2$ is 4m long. When a force of $1.6 \times 10^5 N$ is applied to the material, its length increases by 1mm. Calculate;
   a) The stress in the material.
   b) The strain in the material.
6. A mass of 200kg is placed at the end of the wire 15cm long and cross-sectional area $0.2cm^2$. If the mass causes an extension of 1.5cm, calculate the young's modulus of the material.

COMPRESSION AND TENSILE FORCES

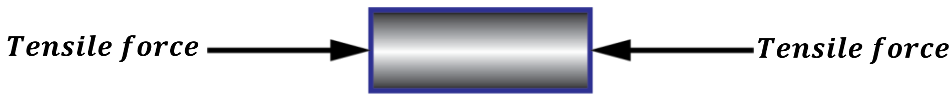
<u>Compression forces</u>:

When compression forces act on a material, they cause the particles of the material to be pressed more closely together. This causes a decrease in length of a material but the thickness of the material increases.



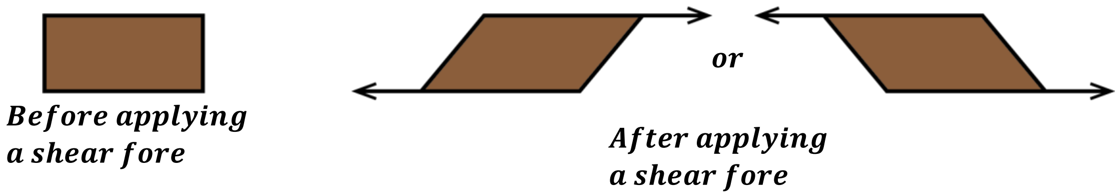
<u>Tensile forces</u>:

When tensile forces act on a material, they cause the particles of the material to be pulled further apart from one another. This causes an increase in length of a material but the thickness of the material decreases.



SHEAR FORCE:

A shear force is the force needed to fracture the material in direction parallel to applied force.
A shear force is produced when two equal but opposite forces are applied on the body. Shear forces causes a body to be twisted and deformed.



CONSTRUCTION MATERIALS

In Uganda, some of the important building or construction materials today are natural stones, timber, glass, bricks, concrete, iron bars, iron sheets, etc.

NATURAL STONES:

These are inorganic minerals quarried from the earth's surface.
These natural stones occur in form of basalt, flint, granite, limestone, marbles, sand stones, slate, quartzite, limestone, etc.

BRICKS OR BLOCKS:

Bricks are made by mixing clay and water together. The mixture is then molded into different shapes and then fired in a kiln at high temperatures.
Bricks are hard, stiff, brittle and strong under compression.

MORTAR:

Mortar is a mixture of sand and cement made into paste by adding water. It is used for bonding bricks

METALS:

These are used in construction of different structures e.g. ships, vehicles, buildings, etc.
Metals can be deformed into different shapes and sizes depending on the construction to be made.
Metals are usually stronger and durable when compared to timber.
Common metals used in construction include; iron for making iron sheets and nails, steel, etc.

TIMBER:

It is used for making furniture used to make scaffolds, bridges, bodies of vehicles, ceiling boards, etc.

Advantages of timber as a construction material

→ It is cheap.
→ It is durable when seasoned and treated well.
→ It is easy to work with.

Disadvantages of timber as a construction material

→ It is not fire resistant.
→ It can get rotten if not treated and seasoned well.

Glass:

Glass is a magical construction material as it has various applications in doors and windows because of its desirable properties.

Properties of glass that make it a desirable building material:

- It is transparent.
- It is weather resistance i.e. it can withstand the effects of rain, sun, wind.
- It is heat resistant i.e. its an insulator to heat.
- It is chemical resistant i.e. few chemicals can react with it.
- Its surface is hard and difficult to scratch.
- It is fire resistant.

Disadvantages of timber as a construction material

→ Glass is brittle i.e. it can break immediately when a maximum force is applied.

CONCRETE:

Concrete is a proportioned mixture of cement, sand, gravel (small stones) and water.

Concrete is used where heavy loads have to be supported e.g. in foundations of tall buildings, dams, etc.

- Since concrete is a brittle material it is weak under tension (tensile forces) but strong under compression.

Properties of concrete which make it a desirable building material

- It is weather resistant.
- It is fire resistant.
- It is strong under compression.
- It is durable i.e. it can be used for a long period of time.

NOTE:

- Although concrete is a desirable building material, it is unsuitable for use in structures under tension since it has a small tensile strength (weak under tension). Therefore, to increase the tensile strength of concrete, it has to be reinforced.

REINFORCED CONCRETE:

Reinforced concrete is concrete obtained by combining concrete with materials that have a high tensile strength e.g. steel or iron bars, wire mesh, wooden strands, etc.

Question: State any materials that maybe used to reinforce concrete.

- ***Steel rods***
- ***Iron bars***
- ***Wire mesh***
- ***Wooden stands***

Advantages of reinforced concrete

→ It is strong under compression and under tension.
→ It is weather resistant.
→ It is fire resistant.
→ It is durable.
→ It has much greater ductility when still wet.

STRUCTURES AND BEAMS

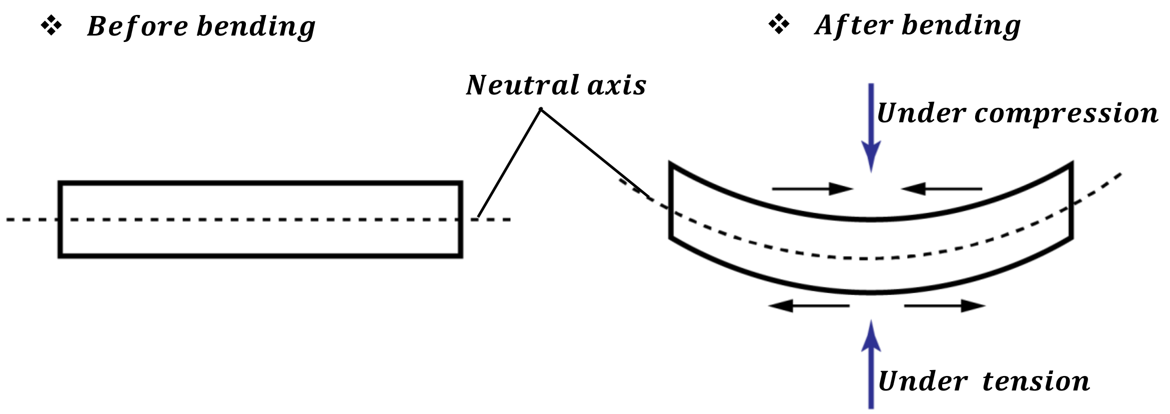
A **structure** is a make-up which consists of pieces of materials that are joined together.
In order to construct a structure that will be durable, beams and girders are put into use.

BEAMS:

A **beam** is a large and long piece of material used to provide main support to the structure.
Without a beam, a structure is unable to withstand the compressional and tensile forces.

NOTE:

- When a beam bends, one side of the beam is compressed (under compression) and the other side is stretched out (under tension) but the centre of the beam is not stretched or compressed (neutral).



From the diagram, the neutral axis is the central region of a beam that is not affected by either compression or tensile forces. Therefore, if removed, the tensile and compressive strength of the beam increases since less material is stuck in the middle.
This explains why pipes used in construction of structures are made hollow.

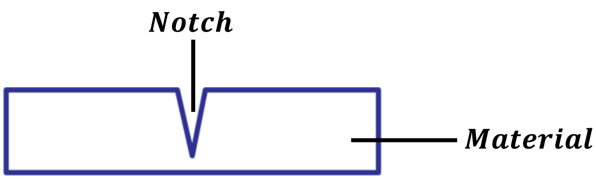
Advantages of hollow beams:

(Why are pipes used in construction of structures like bicycles and bridges are made hollow?)

→ They can withstand both compression and tensile forces.
→ Notches cannot spread easily thus there is less risk of breaking.
→ They are light.
→ They are economical since less material is used for construction.
→ Structures can expand and contract easily.

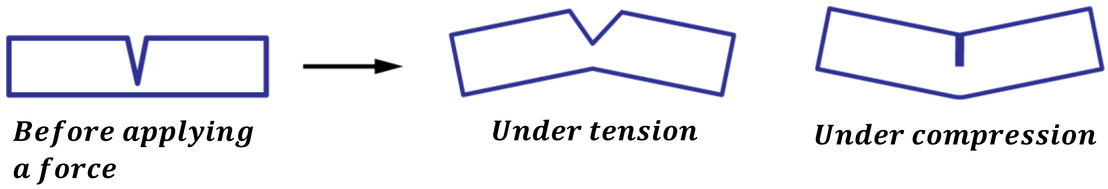
NOTCHES AND CRACKS:

A **notch** is a cut or a weak point on a material.



Notches and cracks spread more easily when a material is under tension than when it is under compression.

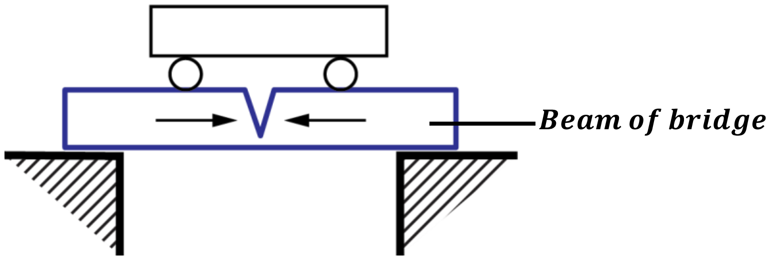
How a notch weakens a beam of a brittle material:



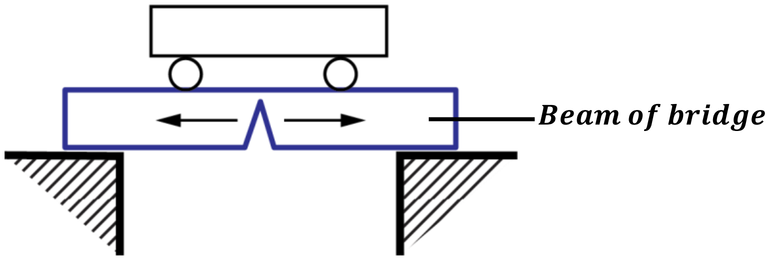
When a tensile (tensional) file is applied on a brittle material like glass with a notch, it will cause a notch to be stretched (under tension) causing it to widen further hence weakening the material.

Question: Explain why in bridge, a beam with a notch lasts longer when a notch is on the top surface than when the notch is on the lower surface.

When a notch is on the top surface of beam, it is under compression. Therefore, it doesn't spread easily since it can withstand compressional forces thus making it stronger in this case.



When a notch is the lower surface of the beam, it is under tension. Therefore, it spreads easily since it cannot withstand tensional forces thus making it weak in this state.



Methods of reducing notch effect:

- Structures are designed in such a way that all parts are under compression.
- Structures are laminated. i.e. layers of a structure are joined together e.g. tables are covered with plywood on their top surfaces and pieces of timber are glued to get a stronger one.
- Surfaces of structures e.g. made as smooth as possible

Applications of the notch effect:

→ Some papers like bank slips are designed in such a way that they perforations (notches) to separate them easily.

→ Notches or cracks are put on glass so that it can easily cut into pieces.

STRENGTH AND TYPES OF STRUCTURES

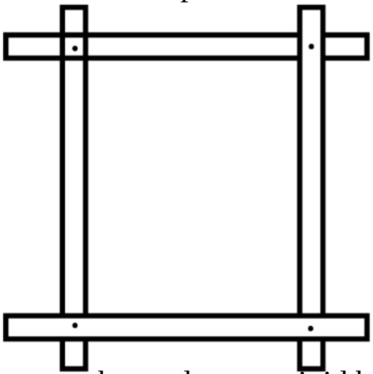
There are many types and shapes of structures commonly used in Uganda. The type and shape of a structure determines its strength.

The common types of structures include;

a) Rectangular structures:

These are made in form of a rectangle.

They are less rigid and weak compared to others. Therefore, they can easily collapse.

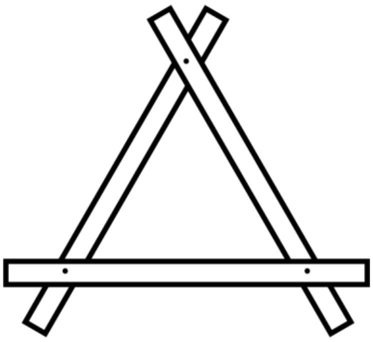


Rectangular structures can be made more rigid by placing a beam along one of its diagonals.

b) Triangular structures:

These are made in form of a triangle.

They are more rigid and strong compared to others. Therefore, they cannot easily collapse.



Since triangular structures are strong and rigid, this explains why structures like doors, house roofs, water tanks are made with triangular shapes.

GIRDERS

A girder is a piece of material which strengthens a structure.
In a structure, some girders are under tension and others are under compression.

TIES AND STRUTS:

Tie: This is a girder under tension.
Ties can be replaced by strings.

Strut: This is a girder under compression.

How to identify ties and struts in a given structure:

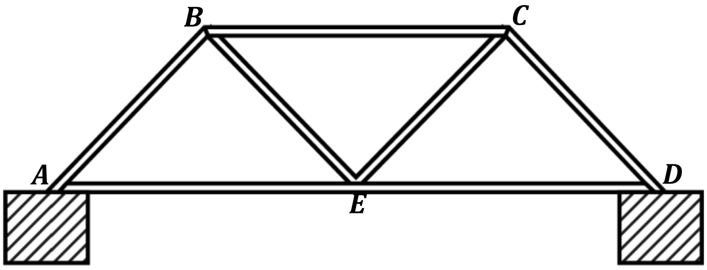
- Remove each of the girder one at a time from the structure and observe the effect it causes on the points that were joined by that girder.
- If the points that were joined by the girder move further apart, then the girder is a tie.
- If the points that were joined by the girder move closer together, then the girder is a strut.
- Always note that the weight of the structure acts downwards.

NOTE:

- Therefore, the functions of ties prevent the points they join from moving further away and struts prevent the points they join from moving closer together.

Examples:

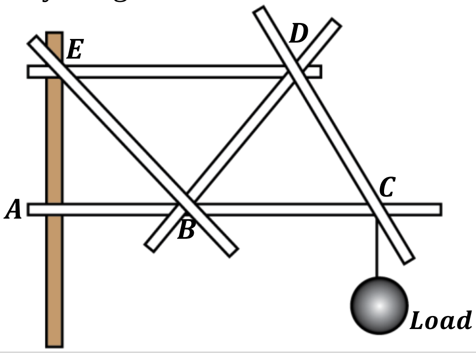
1. The figure below shows a structure of a bridge. Identify the ties and struts in the structure.



In order to determine each of the girders whether they are struts or ties, each of the girders is removed and the effect noted.

- When BC is removed, point B moves close to point C. Then girder BC is a strut.
- When AB is removed, point A moves close to point B. Then girder AB is a strut.
- When CD is removed, point C moves close to point D. Then girder CD is a strut.
- When BE is removed, point E moves further away from point B. Then girder BE is a tie.
- When CE is removed, point E moves further away from point C. Then girder CE is a tie.
- When AE is removed, point A moves further apart from point E. Then girder AE is a tie
- When ED is removed, point E moves further apart from point D. Then girder ED is a tie

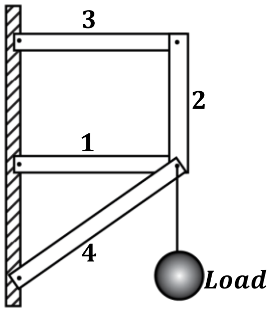
2. Identify the girders in the structure below.



ED – Tie
DC – Tie
BC – Strut
AB – Strut
EB – Strut
BD – Strut

- When ED is removed, the structure will bend at B. Therefore, D moves further away from E. Then ED is a tie.
- When DC is removed, the load pulls point C downwards. Therefore, C moves further away from D. Then DC is a tie.
- When BC is removed, the load pulls point C to come close to point B. Then BC is a strut.
- When AB is removed, the structure bends at E. Therefore, point B moves close to A. then AB is a strut.
- When BD is removed, points E, D, C will become straight thus making point D to come closer to B. Then BD is a strut. Similarly, BE is a strut.

3. The diagram below shows a structure firmly fixed on the wall. Identify the ties and struts.



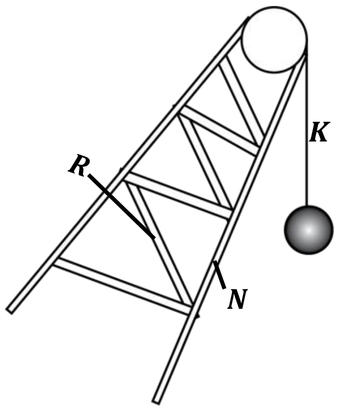
$1 - \textbf{\textit{Strut}}$

$2 - \textbf{\textit{Tie}}$

$3 - \textbf{\textit{Tie}}$

$4 - \textbf{\textit{Strut}}$

4. The diagram below shows an arm of a crane used to carry a load. Name the forces acting on the structure.



K – Strut force

R – Compression force

N – Compression force

5. The diagram shows the framework of a bicycle.

Which of the parts labelled M, N, R and Q would be in;

a) tension.

Q and R

b) compression when a heavy person sits on the seat.

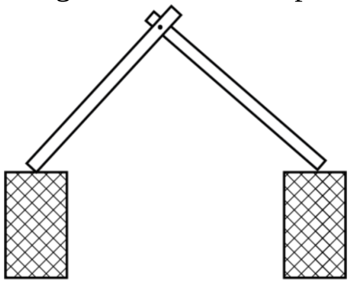
M and N

Applications of struts and ties:

→ They are used in roof supports.
→ They are used in communication masts.
→ They are used in construction of bridges.
→ They are used to support water tanks.

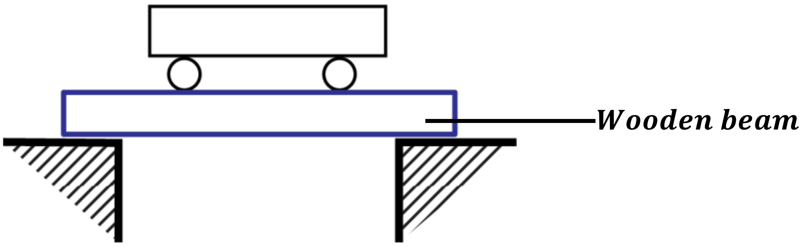
EXERCISE:

1. The figure below shows part of a roof structure.



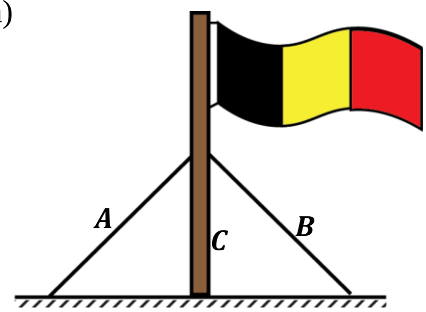
a) Copy the diagram and on it show how the structure can be strengthened by using two other girders.
b) Label one tie and one strut on your diagram.

2. Explain the functions of the following girders in a structure.
   a) Struts.
   b) Ties.
3. The diagram below shows a structure of a simple bridge.

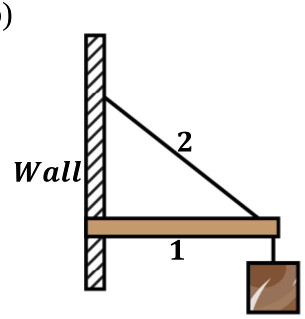


   i) Mark the neutral axis of the beam.
   ii) Explain the mechanical state of the beam.
   iii) What would be the effect on the beam if a notch is made on the lower side of the beam.
   iv) Indicate on the diagram how the bridge can be strengthened.
4. a) With the aid of a diagram, describe the effect of a shear force on the body.
   b) State any three characteristics of concrete which make it a desirable building material.
   c) State any three reasons why the pipes used in the structures of bicycles are made hollow.
5. a) Many construction materials are commonly used in Uganda.
      i) State one advantage of glass as a construction material.
      ii) Explain briefly how concrete maybe improved so that it can withstand tensional forces.
   c) In construction of bridges, hollow cubes of strong metals are used instead of the solid ones. What advantages do those bridges have?
6. Identify the ties and struts in the following diagrams.

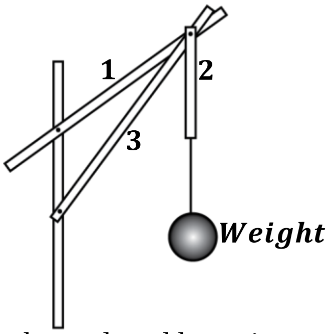
a)



b)

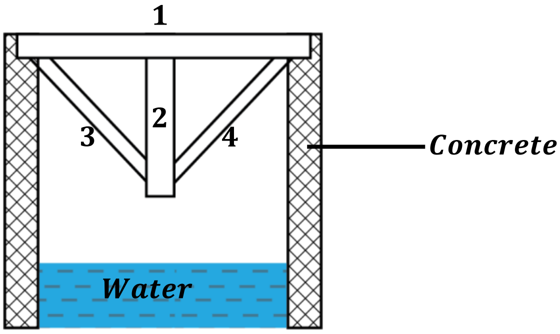


7. The figure below shows an arrangement of three planks on a vertical frame.



State the planks that can be replaced by strings or ropes.

8. The diagram below shows the structure of a bridge.



a) Name the types of force that acts along the parts 1, 2, 3 and 4 when the bridge has been loaded at the centre.
b) Name one material in each case that can be used to construct parts 2 and 4. Give a reason for your answer.

9. a) Define the term "notch" as used in construction.
b) State three ways of reducing notches in beams.
c) Describe the advantages of reinforcing concrete.

10. The following readings were obtained in an experiment to verify Hooke's law when a spring was extended by hanging various masses on it.

Mass (g)	0	25	50	75	100	125
Extension (cm)	10.0	11.5	12.5	13.5	14.4	16.0

Plot a graph of mass against extension and use it to determine.
a) The mass when the extension is 12cm.
b) The extension for 0.02kg.