UNIVERSITY OF LEICESTER

School of Engineering

Simple Engineering Structures and Mechanical Equilibrium

Gebril El-Fallah

EG1101 – Mechanical Engineering – Mechanics of Materials

gmae2@leicester.ac.uk

What is a structure?

- A Structure is an object or a collection of objects put together in a particular way to withstand load.

Examples of man-made structures:

Clare Bridge, built in 1640, is Cambridge's oldest surviving bridge

Heydar Aliyev cultural center, Baku, 2012

Examples of structures in nature:

Snails shell

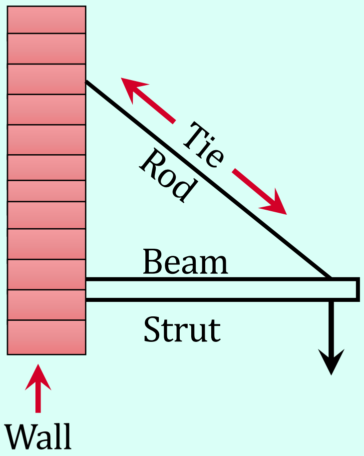
Trees

Cob-webs

Types of Structural and Solid Body Components: Struts and Ties

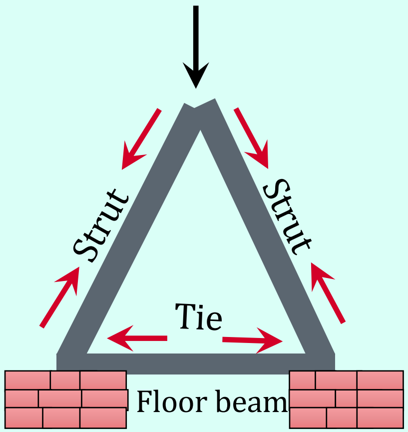
Wall

The beam is held in position by a steel rod. The weight of the beam is stretching (pulling) the rod (tensile force).

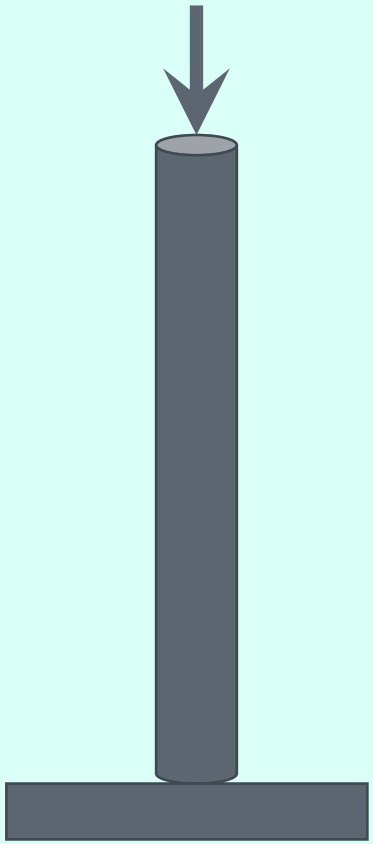


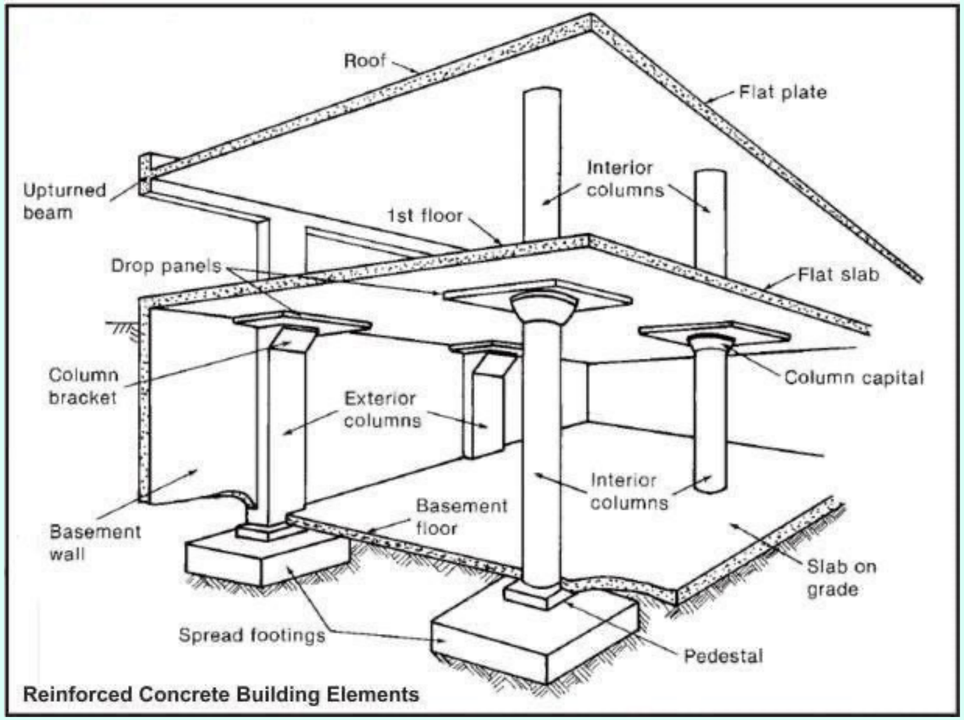
Roof

The roof beams are under pressure from the weight of the tiles on the roof (compressive force). The floor beam is being stretched (tensile force).

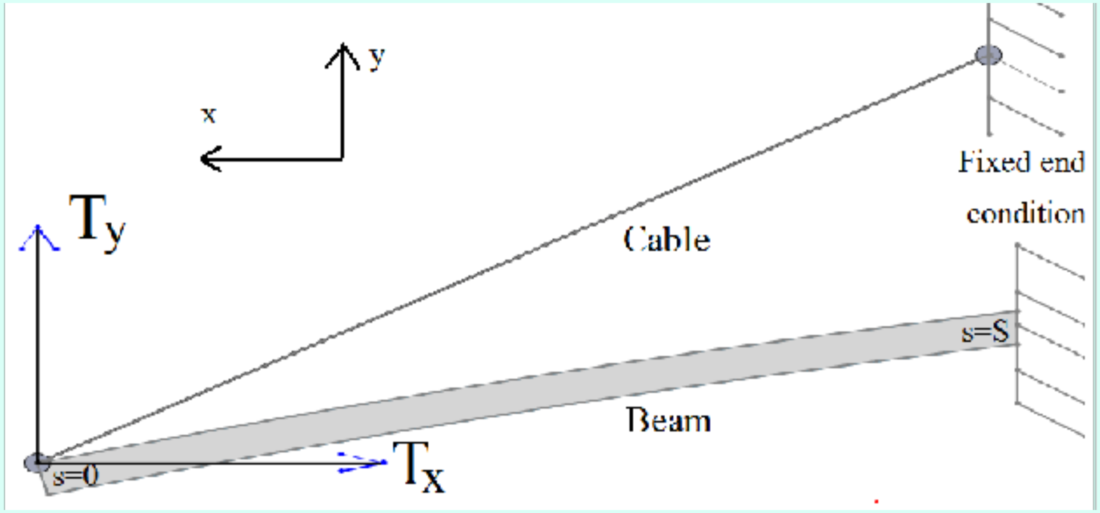


Types of Structural and Solid Body Components: Column



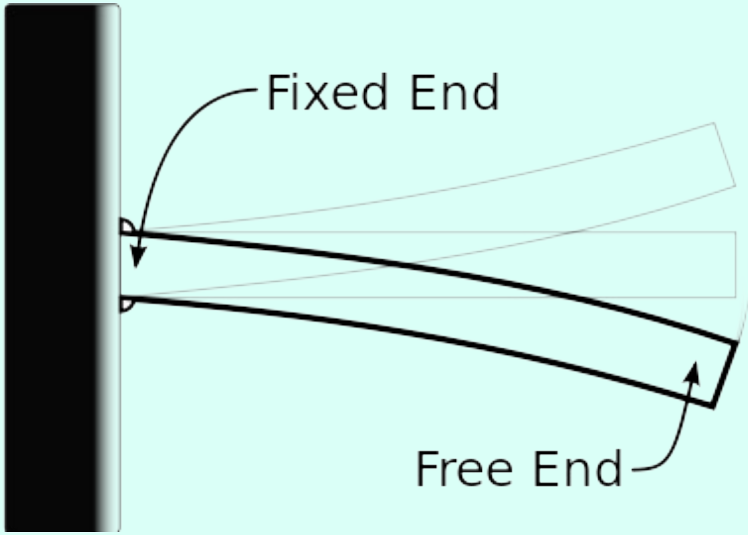


Types of Structural and Solid Body Components: Cable – Flexible Component (Wire)

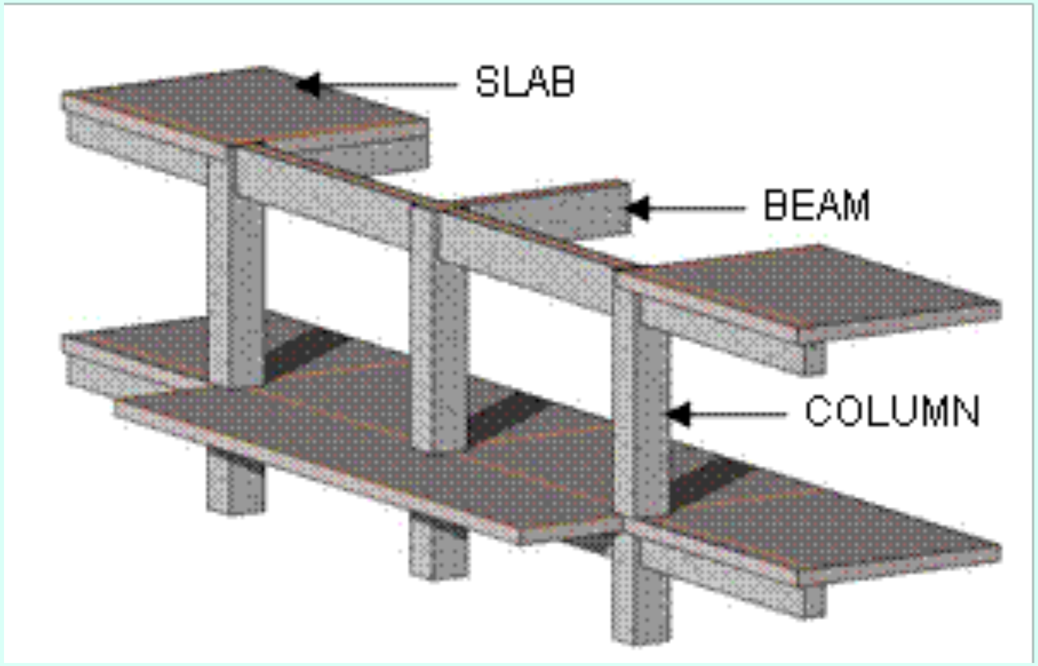


Types of Structural and Solid Body Components: Simply Supported Beam

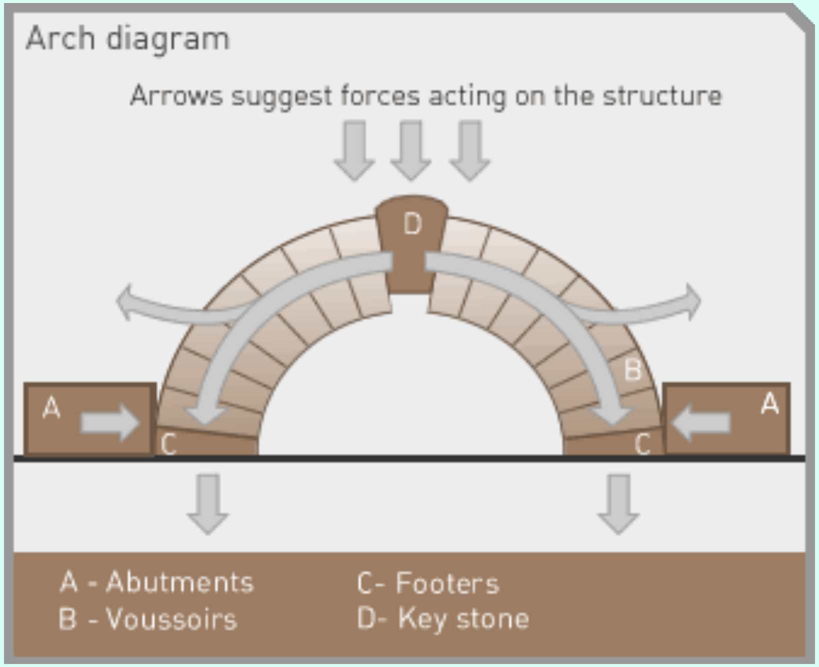
Types of Structural and Solid Body Components: Cantilever Beam



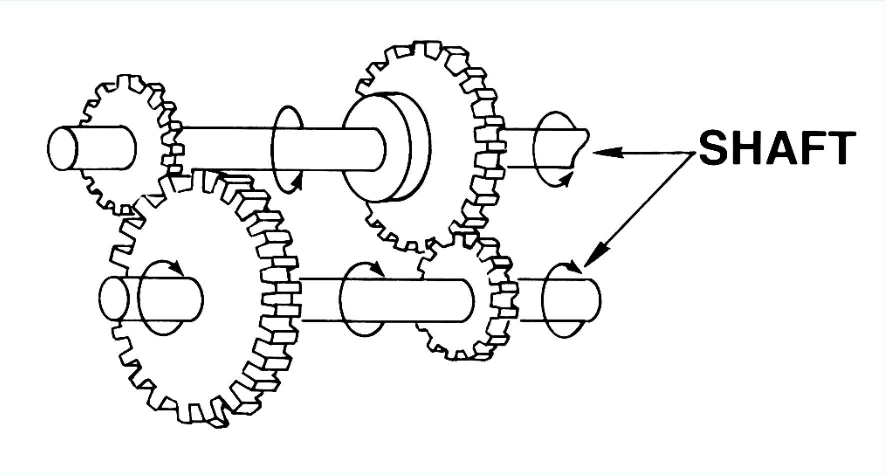
Types of Structural and Solid Body Components: Beam – Column



Types of Structural and Solid Body Components: Arch



Types of Structural and Solid Body Components: Shaft



Units and Dimensions

Dimensions

- **Elimination of Errors**
  - **When performing Derivations and Calculations**
- **Check correct units being used**

- 3 Fundamental Dimensions

  Mass ($\boldsymbol{M}$)

  Length ($\boldsymbol{L}$)

  Time ($\boldsymbol{T}$)

- One Derived Dimension

  Force ($\boldsymbol{F}$)

  where Dimensions of Force are MLT^{-2}

ALL Engineering Quantities are based on these Dimensions

Units and Dimensions

International System (SI) Units

- 3 Fundamental Units

  Mass: kilogram (*kg*)

  Length: meter (m)

  Time: second (*s*)

Units and Dimensions

Basic Derived Units

Velocity	m/s
Acceleration	m/s^2
Area	m^2
Volume (solids)	m^3
Volume (liquids) (**Litre**)	$10^{-3}\mathrm{m}^3$
Density	kg/m^3
Frequency (**Hertz**)	s^{-1}
Force (Newton) (N)	$kg.\mathrm{m}/s^2$

Units and Dimensions

Some Useful Derived Units

Force	Newton (N)	$kg.\mathrm{m}/s^2$
Energy, Work	Joule (J)	$N.\mathrm{m}$
Power	Watt (W)	$J/s = N.\mathrm{m}/s$
Pressure, Stress	Pascal (Pa)	N/m^2

Statics: Definition of Force

"**Force** is any interaction that, when unopposed, will change the motion of an object"

Force can cause an object with mass ($\boldsymbol{m}$) to change its velocity i.e. accelerate ($\boldsymbol{F = m.a}$)

Force Properties

- Magnitude
- Direction
- Vector Quantity
- SI Unit: **Newtons (N) (kg.m/s^2)**
- Represented by symbol $\boldsymbol{F}$
- Dimensions of Force are: MLT^{-2}

Statics: Concept of Force

2 Types of External Forces acting on a Body:

- ***Surface Forces***
  - Distributed on the **surface** of a body
    - Pressure
    - Hydrostatic Pressure
- ***Body Forces***
  - Forces distributed over the **volume** of a body
    - Gravity
    - Magnetic Forces
    - Inertial Forces (for a body in motion)

Statics: Concept of Force

Forces can be thought of as:

PUSH or PULL (in one direction)

THRUST → Increase in Velocity

DRAG → Decrease in Velocity

TORQUE → Change in Rotational Speed

Pressure → Distribution of Force over a Surface of a Body

Newton’s Laws of Motion

Sir Isaac Newton

Physicist and Mathematician

1643 – 1727

Formulated Laws to explain Planetary Motion

The three laws of motion were first compiled by Isaac Newton in his Philosophiæ Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy), first published in 1687

Newton's Laws of Motion: First Law

If the sum of the Forces acting on a body is zero then the body has a constant velocity or is stationary

"In an inertial frame of reference, an object either remains at rest or continues to move at a constant velocity, unless acted upon by a force"

$$\sum \boldsymbol{F} = \boldsymbol{0} \;\Rightarrow\; \boldsymbol{v} = \boldsymbol{const}$$

Newton’s Laws of Motion: Second Law

Force is equal to the mass times acceleration

“In an inertial reference frame, the vector sum of the forces $\boldsymbol{F}$ on an object is equal to the mass m of that object multiplied by the acceleration $\boldsymbol{a}$ of the object (It is assumed here that the mass *m* is constant)”

$$\boldsymbol{F} = \boldsymbol{m}\,\boldsymbol{a}$$

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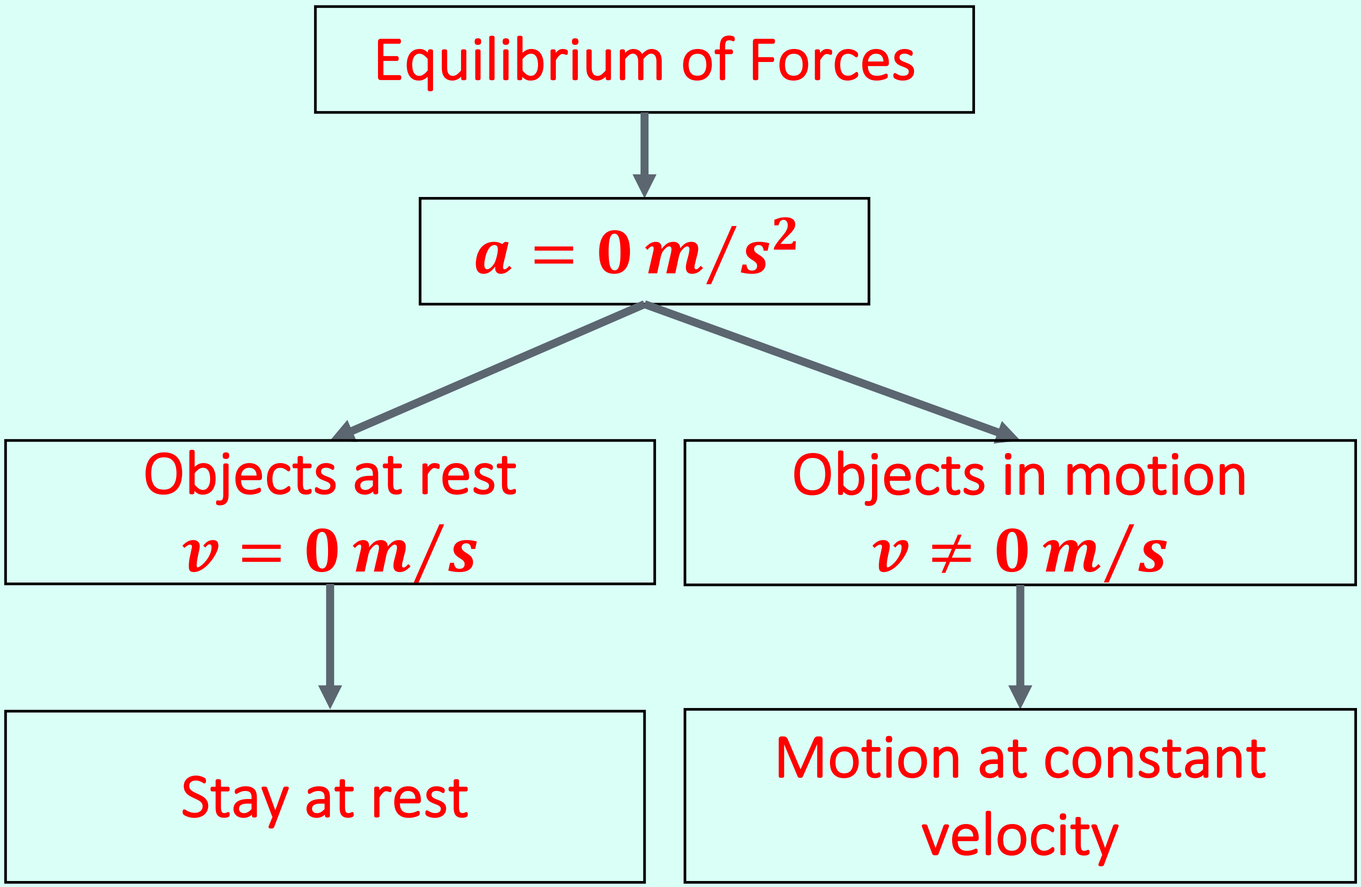
Newton's Laws of Motion: Third Law

Every Force has an equal and opposite Reaction Force

"When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body"

$$\boldsymbol{F_A} = -\boldsymbol{F_B}$$

Newton’s Laws of Motion



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Statics: Concept of Force

Distribution of Forces <u>WITHIN</u> a Body

→ Internal Mechanical Stress

Internal Mechanical Stresses do <u>NOT</u> cause acceleration of Body

as Forces (and Moments) over the body balance themselves

i.e. $\sum_i \underline{F}_i = \tilde{0}$

but individual force components $\underline{F}_i \neq 0$

Note: $\underline{F}_i$ **are Vectors**

Stresses →

Deformation of Solid Materials

Flow in Liquids

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Statics: Force Components

Resolve Forces into components

(Depending on Coordinate system used)

- Cartesian
- Axisymmetric
- 2D Planar

Normally Cartesian Coordinates used

x, *y*, and *z* directions

Force Components

F_x, F_y, F_z

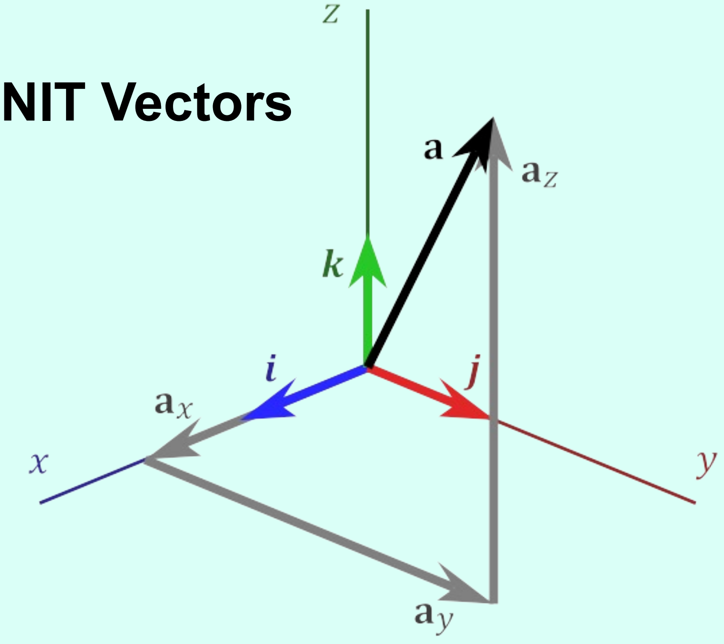
Statics: Force Components

In Cartesian Coordinates a Force Vector $\underline{\boldsymbol{F}}$ is given by:

$$\underline{F} = F_x\underline{i} + F_y\underline{j} + F_z\underline{k}$$

where $\underline{i}$, $\underline{j}$ and $\underline{k}$ are ORTHOGONAL UNIT Vectors

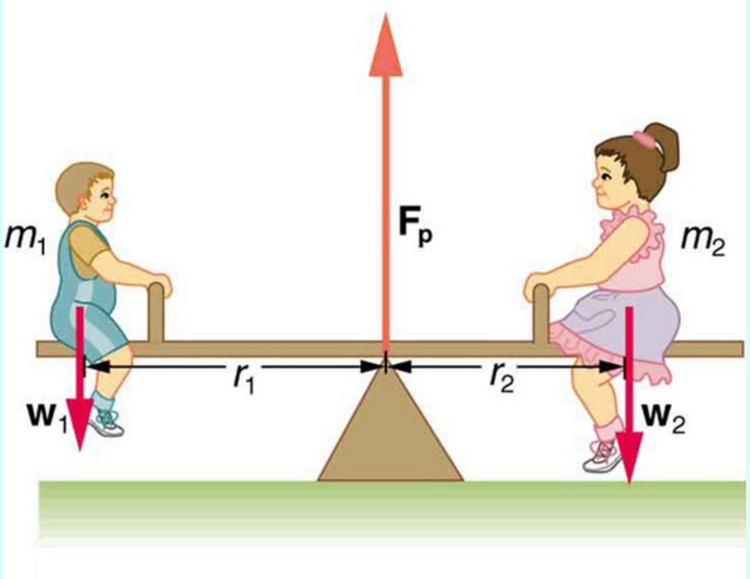
in the ***x***, ***y*** and ***z*** directions, respectively



Conditions for Equilibrium

An object is in equilibrium if:

1. **The resultant force acting on the object is zero**
2. **The sum of the moments acting on an object is zero**



https://courses.lumenlearning.com/boundless-physics/chapter/conditions-for-equilibrium

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