Basic Definitions for Force

force is that which causes an object to move or to prevent it from moving.. Common types are: gravity force, spring force, and friction force.
The mechanics of force is based on Newton's Laws of Motion.
A force is a vector quantity that satisfies the rules of vector algebra.
Use of the principle of equilibrium is a fundamental tool in structural mechanics

Characteristics of force include:

- To change the velocity of a body it is necessary to apply a force to it - i.e. Newton's First Law
- When a body is subject to forces that do not result in movement, the body is in *static equilibrium.*
- The application of a non-uniform system of forces to a body causes it to deform, i.e. to change its shape - see spring force.

Forces are defined along a line i.e. direct forces and about an axis i.e. moments.
Forces are considered to be applied to a body if they come from an external source and are considered to be internal forces if they are caused by the body's properties.
Pressure is applied force per unit area. Stress is internal force per unit area.

Newton's laws of motion

The **first law** is that for a body to change from being at rest or in constant motion a force needs to be applied to it.

The **second law** defines the relationship between a force and the change in momentum of a body. Momentum is mass times velocity. In structural engineering, changes in mass is not normally an issue and therefore only change in velocity, i.e. acceleration is considered. The second law implies that the in order to accelerate a mass, a force: mass times acceleration , needs to be applied to it. This relationship is used to assess the effect of oscillations/vibrations on structures.

Third law 'To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal and directed to contrary parts.' This is a translation from Newton's statement in Latin. The third law is the basis of 'equilibrium' that is a central principle in structural mechanics. It is used by structural engineers with the wider definition that it applies not only to 'mutual actions of two bodies', but also applies to single bodies, to parts of bodies, to any system that is subject to force.

The principle of equilibrium

A **force action** can be a direct force or a moment. A *direct force* acts along a line. A *moment* is a turning effect of a force about an axis.

When a body is subject to force actions that do not result in movement, the body is in *static equilibrium.*

For a body, or for part of a body, and at the interface between bodies, this means that the vector sum of all force actions is zero i.e.

$$\sum F = 0, \quad \sum M = 0 \qquad (1)$$

Where F is a direct force and M *is a moment*

An *applied force* acts on a body that may or may not cause the body to move. A *resisting force* tends to limit or prevent motion. Equation (1), for forces in a given direction, is often stated as:

Sum of the applied forces = Sum of the resisting forces (2) or:

Sum of forces in one direction = sum of forces in the opposite direction

This implies that forces come in equal and opposite pairs (Newton's third law). If there is a force in one direction, there is always an equal force in the opposite direction.

Equations (1) and (2) are different ways of expressing this principle.

There are no uncertainties involved in the principle of equilibrium (i.e. there are always an equal and opposite forces) but there may be uncertainties as to whether all relevant force terms have been included and there will be uncertainty about the values o9 the forces used.

Standard for defining force

The standard for defining force is based on the force required to accelerate a mass. The SI unit of force, the Newton, is that force which will accelerate a mass of one kilogram by one metre per second per second ($1N = 1kgm/s^2$) (see Newton's Second Law). This force has units of MLT^{-2} and therefore all types of force have these units whether or not they are associated with a mass or with an acceleration.

Gravity Force

The interaction between a mass *m* at the surface of the Earth and the mass of the Earth causes a gravity force:

$$F_{gravity} = m*g$$

where *g* is a gravity constant for forces at the surface of the Earth. The value in normal use is:

$g = 9.8\ m/sec^2$

The use of *g* is a special case of Newton's Universal Law of Gravity

Weight

The word 'weight' is used in the following ways:

- In a scientific / engineering context: **Weight** is the force of gravity acting on a body = mass of body*g, where mass is in kilograms and weight is in Newtons
- In a day-to-day context: **Weight** is the mass of a body in kilograms typically measured by standing on a set of scales.

Spring force

In a spring-mass system, the strain energy in the spring provides a resistive force. This is known as the spring force. The strain energy is from atomic action in the material.

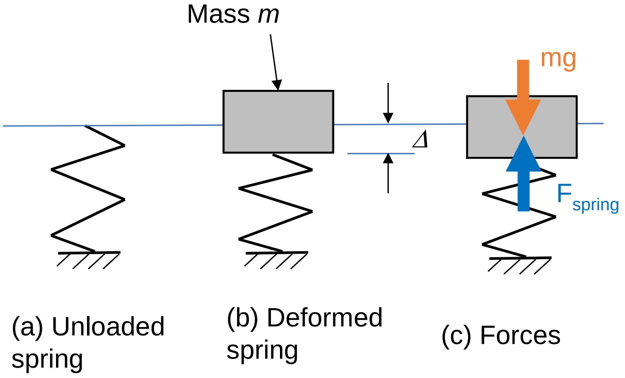
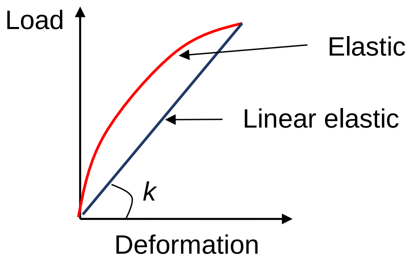


Figure (a) shows an unloaded spring.
In (b) a mass *m* has deflected the spring by an amount Δ.
The loaded spring resists the downward gravity force from the mass (mg) by an upward force due to strain energy in the spring - Figure (c).



Elastic behaviour means that when a load is removed, the spring returns to its original position. This is because the strain energy has not been dissipated by plastic deformation - see material properties. Most structural materials behave in a way that can be modelled as linear elastic in the initial part of the load deformation curve. For this condition:

$$F = k\Delta$$

Where F is the spring force and k is the linear stiffness, the force per unit deformation. This equation is known as Hooke's Law.

In a structural mechanics context, when a load is applied to a structure or to a foundation, strain energy in the material provides a resisting force - a type *spring force.* This is a main characteristic of a structure.

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