Dynamics

1.- Introduction: forces

A ***force*** is any action which causes an object to change its shape or its state of motion. ***Dynamics*** is a branch of Physics which studies the forces.

2.- Hooke´s law

When a force is applied to matter, it can produce a change of its shape or ***deformation***. We can classify this deformation into two different types: elastic or plastic.

An ***elastic deformation*** is a temporary change of shape in which the original shape can be restored when the force is removed. It is usually produced when the strengh of the force is low. The elastic deformation is described by Hooke´s law which states:

"***The extension of a spring is directly proportional to the force which is applied upon it***"

$$F = K.x$$

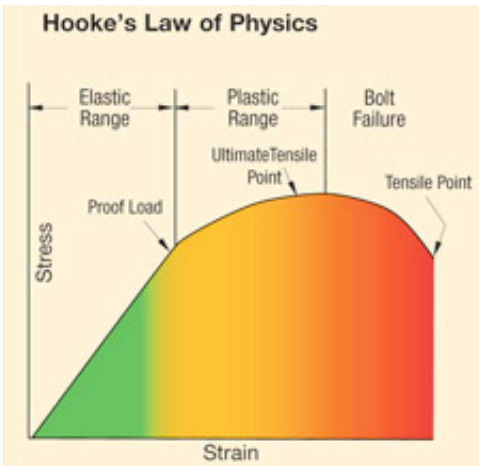
- F: represents a force, measured in Newtons (N)
- x: extension of the spring, measured in metres
- K: constant of the spring, measured in $N.m^{-1}$.

The constant of the spring refers to the stiffness of the spring. In other words, the greater the constant, the lower the stretching is. Elastic range can be recognized plotting a graph force (or stress) against stretching (or strain), because the graph is a straight line. The constant of the spring is the slope of the graph.

When the force applied is greater, the spring cannot recover its original length when the force is removed. Therefore we say it undergoes a ***plastic deformation***. The ***elastic limit*** is the force from which matter cannot recover its elastic properties and it undergoes a permanent deformation.

Matter can be stressed more and more until it reaches its ***tensile point***, which is the force where matter breaks.

The following diagram represents the graph of force against stretching (stress vs. strain)



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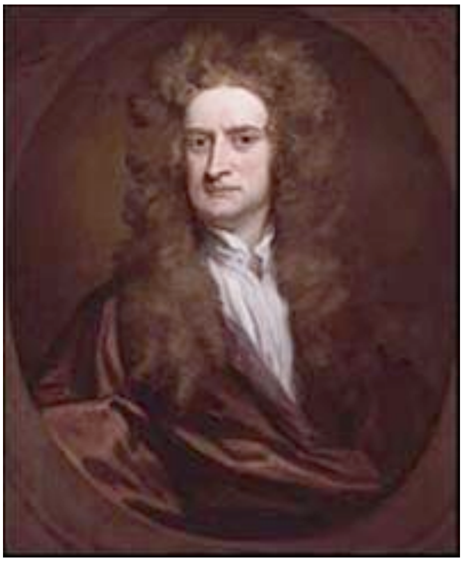
3.- Newton laws

Isaac Newton stated his three laws of Dynamics in 1687. They represent the foundations of Classical Mechanics and can be stated as follows:



1. ***Inertia law***: ***An object will remain at rest or continue with its linear uniform motion, unless an unbalanced force is applied to it.***

This law is quite important because people thought that objects try always to remain at rest when there is no net force applied upon them. However, objects also tend to move at constant speed if they were moving before. This trend is not so clear because of the friction forces, but it can be observed moving on ice or another non-friction surface

2. ***The net force applied to an object is proportional its acceleration***. In other words:

$$\sum F = m.a$$

The constant of proportionality, mass, is also called ***inertia***. It measures the resistance, which an object has to change its motion. In other words, how difficult or easy is to throw the object: the greater the inertia, the greater force required to push the object (or to stop it).

It is important to repeat that a force is not required to keep an object in motion, but to change its state of motion or velocity. When a object is thrown in the outer space, it will continue moving forever, unless a force of friction acts on it.

You can notice that the unit for force must be the same of mass and acceleration, which is called ***Newton***

3. ***Action-reaction law: Every action has an equal and opposite reaction***.

In other words, when an object applies a force to a second object, the second one applies another force upon the first object, which has the same magnitude but opposite direction.

Action-reaction law is usually misunderstood: forces always occur by pairs but they are applied to different objects, which can move freely. For instance, the Earth attracts an apple, so the apple applies the same opposite force to the Earth. However, as the mass of the Earth is huge, we don´t observe any motion of the Earth, but it is clear that the apple falls down to the ground.

4.- Types of forces

1. ***Weight***

The weight is the atraction force applied by the Earth upon an object. It can be calculated taking into account that every body falls down at the same acceleration, which is gravity

Newton´s Second law $F = m.a \Rightarrow$ **Weight = m.g**

It is very important to distinguish between mass and weight, which are different quantities in Physics. Mass is a quantity which measures the amount of matter of an object and it is the same no matter its position or conditions. On the other hand, weight is a force which depends on gravity.

2. *Normal reaction force*

The normal force is a support force applied upon any object which rests on a surface. As the object remains at rest and there is no vertical motion, forces must be balanced so the weight must be cancelled by another upward force applied by the surface

Generally speaking, the normal force measures the degree to which two surfaces are pressed together and it is always applied perpendicularly to the surfaces in contact.

3. *Force of friction*

Frictional forces are contact forces applied upon an object, which is moving along a surface. Frictional forces often opposes to the motion of the object.

If we consider that the motion is not very fast, frictional forces don´t depend on the surface area in contact with each other nor the velocity of the object. They just depend on the normal force between the body and the surface and a quantity, which is called ***coefficient of friction***.

$$F = \mu . N$$

The coefficient of friction is an adimensional quantity, greater than zero and usually less than one, which depends on the types of materials which are in contact. There are two coefficients of friction: static and kinetic. The ***static coefficient of friction*** has to do with the force required to accelerate a body form rest and starts to move it. On the other hand, kinetic coefficient of friction refers to the force needed to keep the object in motion. The static coefficient of friction is usually greater than the kinetic one.

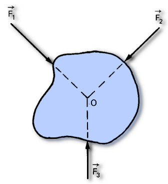
surface-on-surface	μ_s	μ_k	
hook velcro-on-fuzzy velcro	>6.0	>5.9	Sticky
avg tire-on-dry pavement	0.9	0.8	↓
grooved tire-on-wet pavement	0.8	0.7	↓
glass-on-glass	0.9	0.4	↓
metal-on-metal (dry)	0.6	0.4	↓
smooth tire-on-wet pavement	0.5	0.4	↓
metal-on-metal (lubricated)	0.1	0.05	↓
steel-on-ice	0.1	0.05	↓
steel-on-Teflon	0.05	0.05	Slippery

5.- Equilibrium. Moment of a force

A body is at ***equilibrium*** when all the forces which are applied on it are balanced. In other hand, the net force aplied to it is equal to zero.

$$\text{Equilibrium} \quad \Rightarrow \quad \sum \vec{F} = 0$$

Statics is a branch of Physics whic studies the systems which are at equilibrium. It is quite important for bridges, structures and all kind of buidings.



Concurrent forces are those which are applied to the same point. When concurrent forces are applied to a body, it is at equilibrium if the net force is equal to zero.

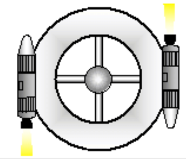


Figure 2

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Parallel forces are those which are applied to different points of an object. Parallel forces make an object to turn about a point. Archimedes, a greek scientist, discovered that this motion depends on the force but also on the distance between the point and the centre, which is called ***fulcrum***. This law is called ***lever law***.

Consequently, we have to define a new quantity which is called ***moment of a force*** or ***torque***, the product of the distance between centre and the point where the force is applied and the force. Torque refers to the turning effect produced by a force applied at a distance of the fulcrum.

$$\vec{M} = \vec{r} \times \vec{F}$$

On a general basis, a system is at equilibrium when all the forces and torques are balanced. In other words, the net force and the net moment of every force are equal to zero.

$$\sum \vec{F} = 0 \qquad \sum \vec{M} = 0$$

Examples this kind of systems are a ladder leaning on a wall, or two children sitting on a seesaw.

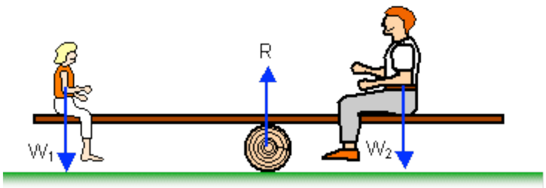

Figure 5

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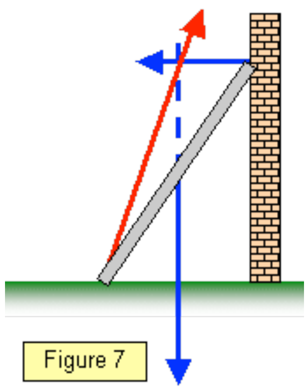

Figure 7