Chater 02:

Generalities and Basic Definitions

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1. Introduction

It is clear that a good knowledge of the forces acting on a mechanical system is the key to better understanding and solving problems related to mechanics (statics, kinematics, and dynamics).

For this reason, this chapter is devoted to studying forces, more precisely the mechanical force, its definition, representation, composition, as well as its classification according to their origin (internal or external).

2. Definition and Representation:

A force represents the interaction between a body and another, as well as the interactions that occur at a distance. In mechanics, forces are often used to model the effects of different physical actions (pressure, friction, contact force, etc.).

The force is represented by a vector. A vector force has the general properties of vectors (already seen in the previous chapter), namely:

* A direction
* A line of action
* A magnitude or value calculated in newtons and sometimes called intensity
* A point of application

Example:
The force corresponding to the weight of an object is vertical, directed downward, and its value is obtained thanks to the relation $P = m \times g$

3. Composition and Decomposition of a Force:

→ Composition of forces

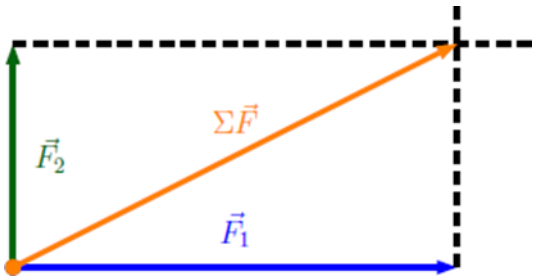
If a body is subject to several forces $\vec{F_1}, \vec{F_2}, \ldots, \vec{Fn}$ at the same time, the resultant is equivalent to the single force equal to the vector sum $\vec{\sum F_i}$, called the resultant force.

This applied force is equivalent to the vector sum of all the forces acting on a body.

$$\vec{F} = \vec{F_1} + \vec{F_2} + \ldots\ldots \vec{Fn}$$

Example: Addition of two perpendicular forces:

$$\vec{F} = \vec{F_1} + \vec{F_2}$$



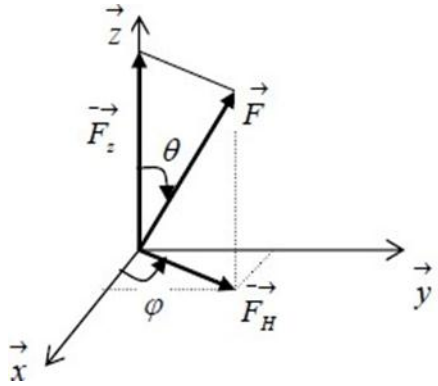
→ Decomposition of Forces

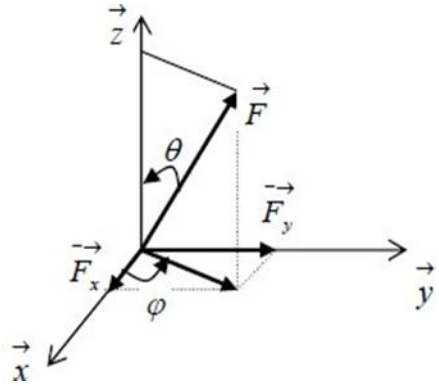
In the study of mechanical systems, it is often advantageous to replace a force $\vec{F}$ with two forces F_1 and F_2, whose combined action is identical to that of F. The forces $\vec{F1}$ and $\vec{F2}$ are then the components of the resultant $\vec{F}$:

$$\vec{F} = \vec{F1} + \vec{F2}$$

Example:

Let a force F be applied at the origin O of an orthonormal frame R(O, x, y, z).
The components of this force are defined by:





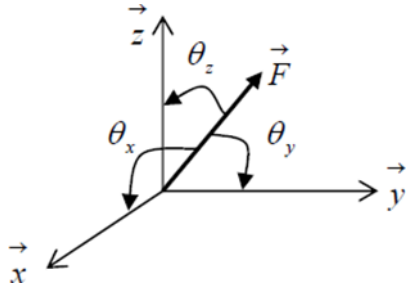
$$\vec{F} = Fx\,\vec{i} + Fy\,\vec{j} + Fz\,\vec{k}$$

$Fx = F \sin\theta \cos\varphi$, $Fy = F \sin\theta \sin\varphi$, $Fz = F \cos\theta$

Hence: $\vec{F} = F \sin\theta \cos\varphi\,\vec{i} + F \sin\theta \sin\varphi\,\vec{j} + F \cos\theta\,\vec{k}$

4. Direction Cosines:

The projections of vector $\vec{F}$ on the three axes Ox, Oy, Oz give respectively the angles: θx, θy, θz.



We then have:

$Fx = F\cos(\theta x), \quad Fy = F\cos(\theta y), \quad Fz = F\cos(\theta z)$

$\vec{F} = Fx\,\vec{i} + Fy\,\vec{j} + Fz\,\vec{k} = F(\cos(\theta x)\,\vec{i} + \cos(\theta y)\,\vec{j} + \cos(\theta z)\,\vec{k})$

Thus, $\vec{F} = F\,\vec{Up}$ where $\vec{Up} = (\cos(\theta x), \cos(\theta y), \cos(\theta z))$

5. Systems of Forces in Space

Force systems in space are classified into three categories:

• Concurrent forces: The lines of action of all forces in the system pass through a single point. This point is called the point of concurrency of the forces.

• Parallel forces: The lines of action of the forces are all parallel to each other, whether in the same or opposite directions.

• Non-concurrent and non-parallel forces: The forces are neither concurrent nor parallel; they form a general system of forces.

6. Classification of Forces According to Their Origin

Whatever their systems, forces are classified as either external or internal.

6.1. Internal Forces

Internal forces are those that exist between the parts of the same structure. There are several types of internal forces, such as tension, compression, torsion, and shearing.

6.2. External Forces

External forces are those exerted on structures by gravity or other external agents.
On Earth, gravity always acts vertically downward. Gravity is therefore an external force acting