Dynamics Pt.I

- Forces
- First Law of Motion (Law of Inertia)
- Second Law of Motion
- Hooke's Law
- Law of Universal Gravitation
- Newton’s Third Law of Motion

FORCES

A FORCE is the pushing or pulling effort that one body exerts on another.

LONG-RANGE forces: active over large distances

SHORT-RANGE forces: active only when there is **contact**

fundamental interactions:

- gravitational interaction
- weak interaction
- electromagnetic interaction
- strong interaction

DEFINITION OF FORCE AND UNIT OF MEASUREMENT

Force is a vector quantity.

Force has the same direction and the same sense as acceleration; its magnitude is proportional to that of acceleration

The *magnitude* of the force *does not* fully describe the force itself; it is also necessary to consider its *direction* and its *sense*.

$$[F] = [MLT^{-2}]$$

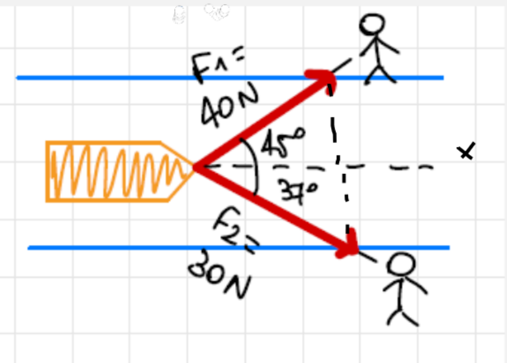
unit of measurement:

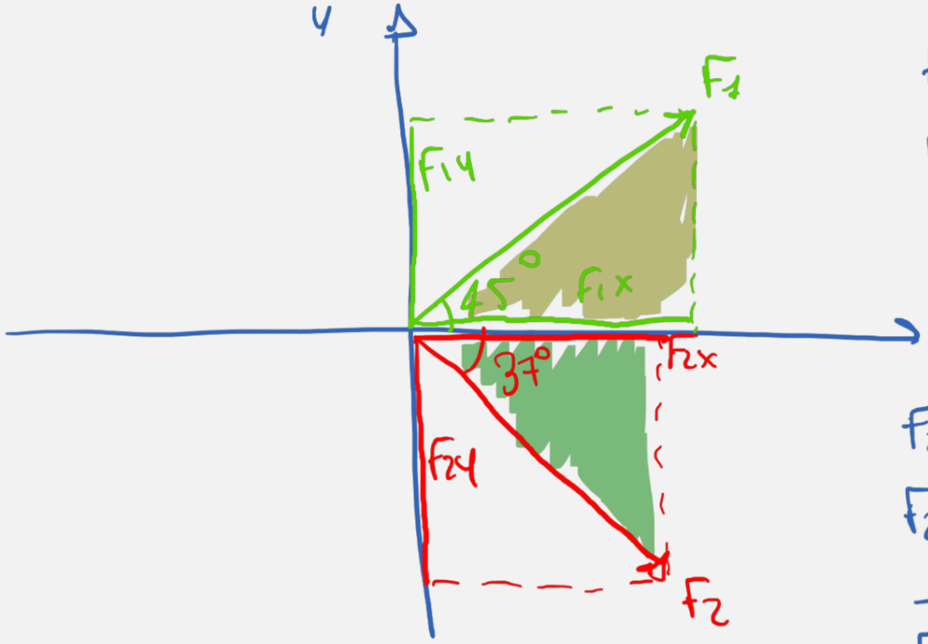
$$Newton\,(N) = kg \cdot m \cdot s^{-2}$$

DEFINITION OF FORCE AND UNITS OF MEASUREMENT

Example

Calculate the resultant of the two forces acting on the boat shown in the figure. F1=40N, F2=30N. The angles formed by F1 and F2 are 45° and 37°, respectively.





$$F_{1x} = F_1 \cdot \cos 45° = 28.3\,N$$

$$F_{1y} = F_1 \cdot \sin 45° = 28.3\,N$$

$$F_{2x} = F_2 \cdot \cos 37° = 24\,N$$

$$F_{2y} = -F_2 \cdot \sin 37° = -18.1\,N$$

$$\vec{F}_{TOT} = F_{TOT_x} + F_{TOT_y}$$

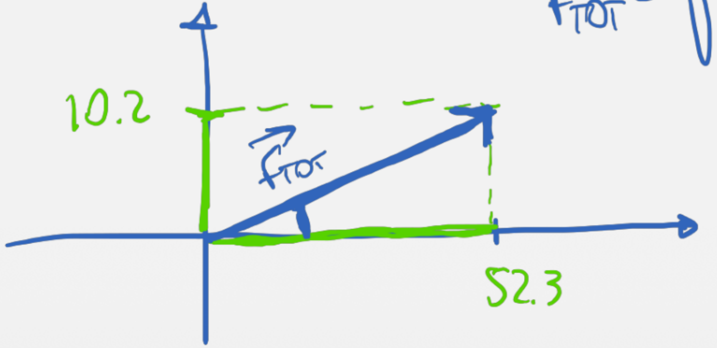
$$F_{TOT_x} = F_{1x} + F_{2x}$$

$$F_{TOT_y} = F_{1y} + F_{2y}$$

$$F_{TOT_x} = 52.3\,N \qquad F_{TOT_y} = 10.2\,N$$

$$\vec{F}_{TOT} = \sqrt{F_{TOT_x}^2 + F_{TOT_y}^2} = 53.3\,N$$

$$\theta = \tan^{-1} \frac{F_{TOT_y}}{F_{TOT_x}} = \frac{10.2\,N}{52.3\,N} = 11°$$



DEFINITION OF FORCE AND UNIT OF MEASUREMENT

Total force (net force or resultant of forces)

When multiple forces act on an object, the motion of the object is determined by the total force (or net force or resultant of forces) acting on the object.

The total force is the vector obtained by summing all forces acting on the object.

$$\vec{F}_{TOT} = \sum_{i=1}^{n} \overrightarrow{F_i}$$

FIRST LAW OF MOTION (LAW OF INERTIA)

In an inertial system, a body remains in its state of rest or in its state of uniform rectilinear motion if it is not subjected to forces, or if it is subjected to forces whose resultant is zero.

$$\vec{F} = 0 \Leftrightarrow \vec{v} = \text{constant}$$

In physics, inertia means **resistance to changes in velocity**.

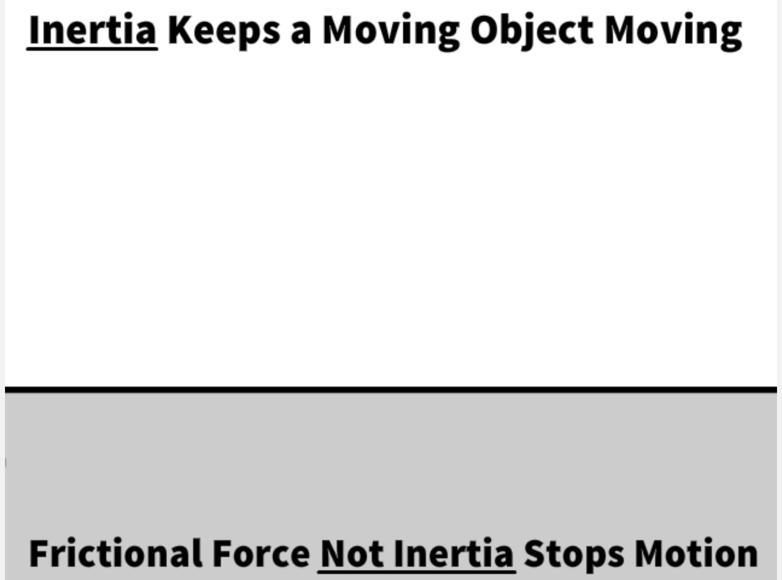
The reference frames in which Newton's first law holds are called INERTIAL REFERENCE FRAMES

CONCEPT OF MASS

CONCEPT OF MASS: a measure of a body's inertia

The more mass a body has, the more difficult it is to change its motion. It is more difficult to stop it when it is moving, or to deflect its path, or to set it in motion when it is at rest

In the SI, the unit of mass is the KILOGRAM (kg)



SECOND LAW OF MOTION

$$\vec{F} = m\vec{a}$$

A force produces an acceleration

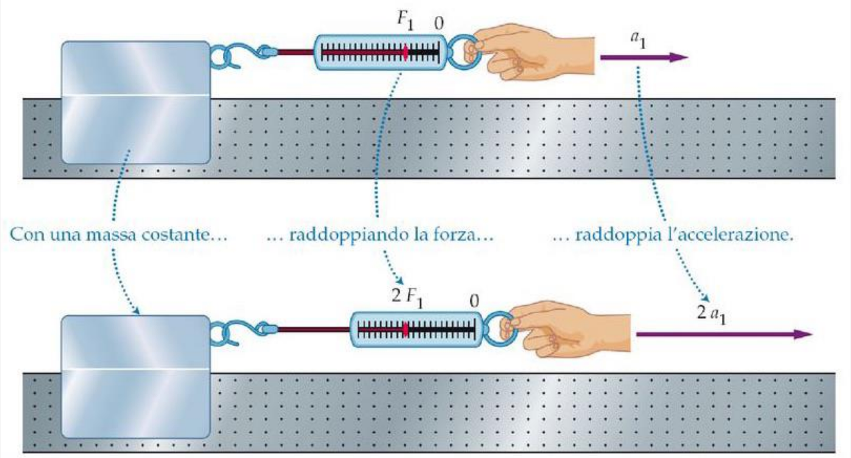
$$|\vec{F}| \quad |\vec{a}|$$

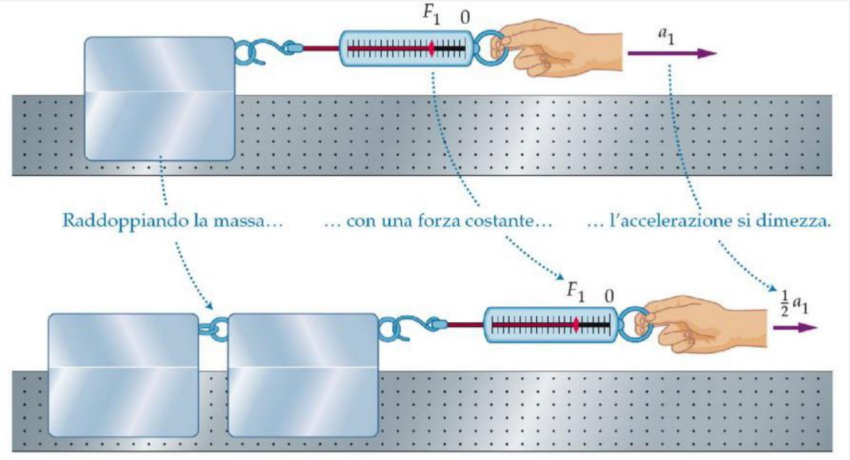
They are proportional, up to a constant that is the mass, or inertial mass.

Different bodies, subjected to the action of the same force, acquire different accelerations.

SECOND LAW OF MOTION

$$\vec{F} = m\vec{a}$$





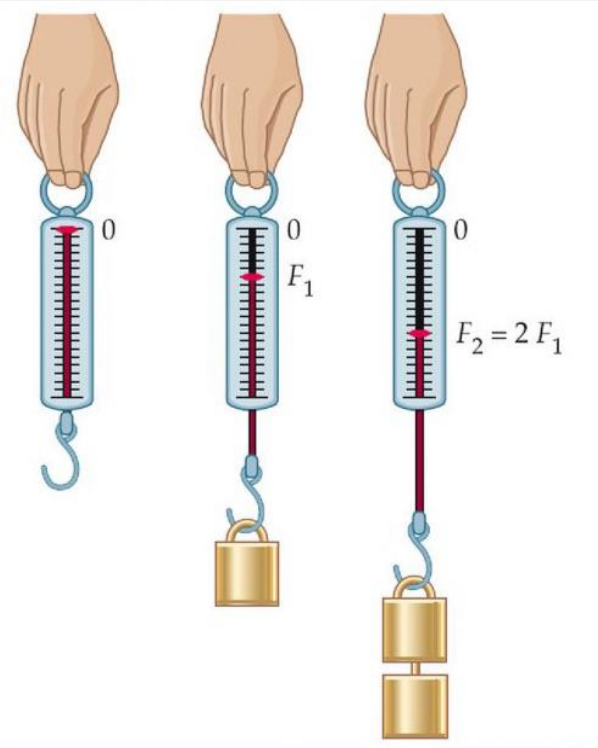
$$\vec{a} \propto \vec{F} \qquad \vec{a} \propto \frac{1}{m}$$

$$\vec{\boldsymbol{a}} = \frac{1}{m}\sum \vec{\boldsymbol{F}} \quad \text{and} \quad \sum \vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$$

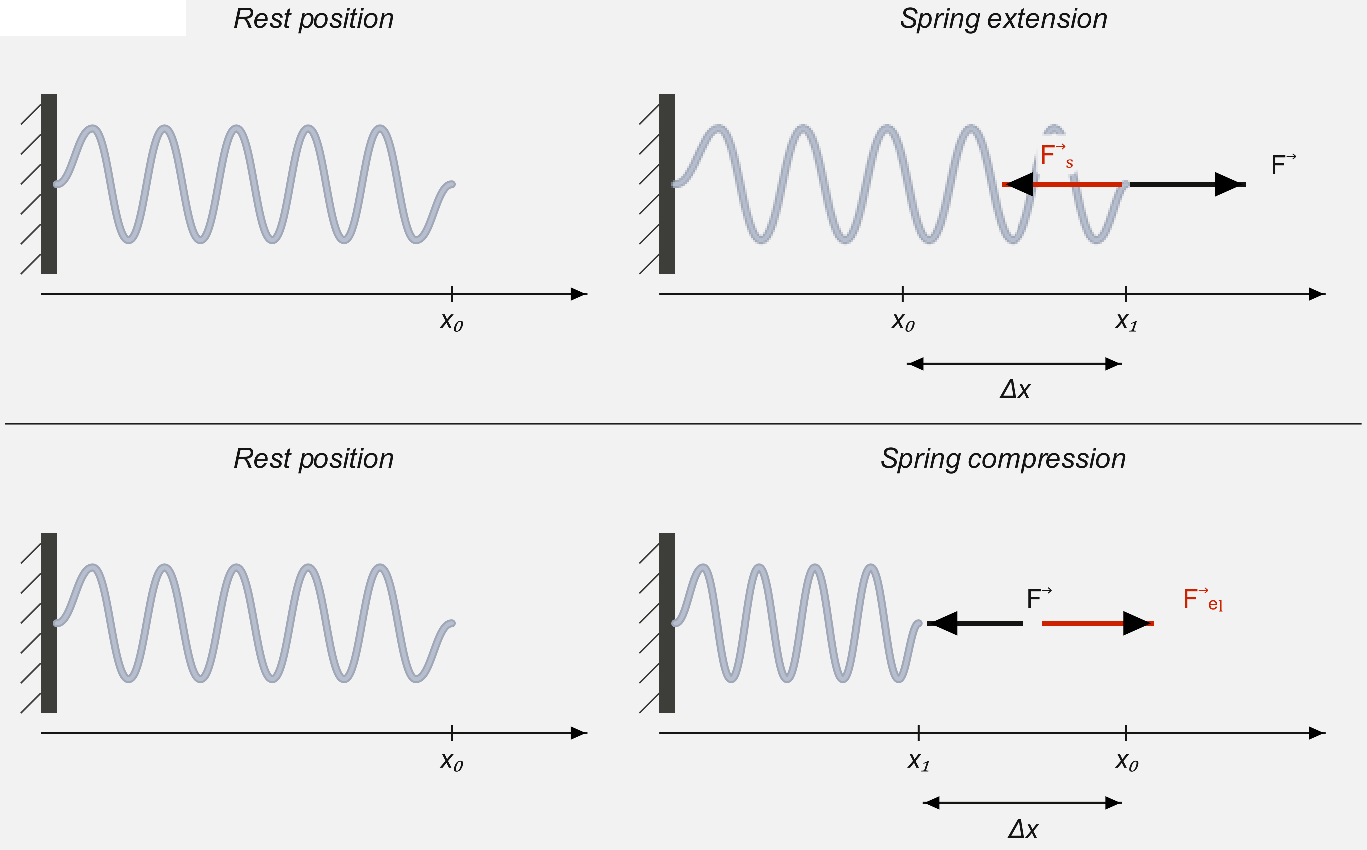
The acceleration of an object is directly proportional to the resultant force acting on it and is inversely proportional to its mass

The direction and sense of the acceleration are the same direction and the same sense as the resultant force acting on the object

MEASURING A FORCE: HOOKE'S LAW



$$\vec{F} = -k\overrightarrow{\Delta x}$$



LAW OF UNIVERSAL GRAVITATION

$$F = -G\frac{m_A m_B}{r^2}, \quad G = 6.67 \cdot 10^{-11}\frac{N \cdot m^2}{Kg^2}$$

$$\vec{F} = G\frac{m_A m_B}{r^2}\hat{r}$$

Body in the vicinity of the Earth's surface: the distance between the body and the center of the Earth is practically identical to the mean value of the Earth's radius $R_T = 6.37 \cdot 10^6\ m$. The Earth's mass is $M_T = 5.97 \cdot 10^{24}\ kg$

$$F = G\frac{M_T m}{R_T^2} = m\left(\frac{GM_T}{R_T^2}\right)$$

Constant values for any body in the vicinity of the Earth's surface

LAW OF UNIVERSAL GRAVITATION

$$\frac{GM_T}{R_T^2} = g$$

Gravitational field g near the Earth's surface

$$g = \frac{GM_T}{R_T^2} = \frac{(6.674 \cdot 10^{-11} Nm^2 kg^{-2}) \cdot (5.97 \cdot 10^{24} kg)}{(6.37 \cdot 10^6 m)^2} \approx 9.8 N/kg = 9.8\, m/s^2$$

How many N of gravitational force are exerted on a body for each kg of the body's mass

$$\frac{kg \cdot m/s^2}{kg}$$

$$F = m\left(\frac{GM_T}{R_T^2}\right) = mg$$

$$\vec{P} = m\vec{g}$$

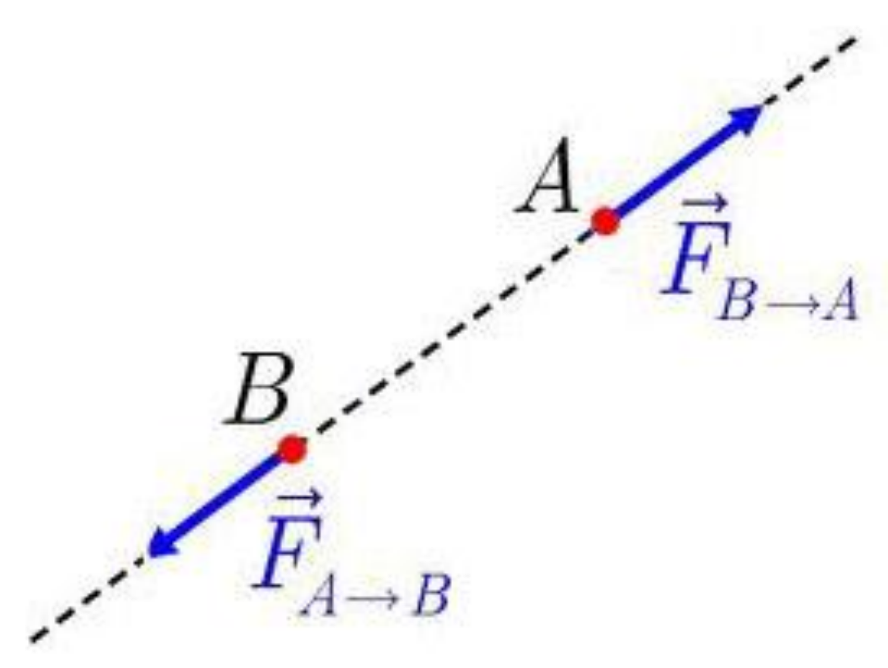
$\vec{F_p}$

The WEIGHT FORCE (or WEIGHT) is the force associated with the gravitational attraction exerted by the Earth on bodies near the Earth's surface; it is directed along the vertical and oriented downward

NEWTON'S THIRD LAW OF MOTION

If an object A exerts a force F on an object B, then B will exert on A a force of

equal magnitude and direction, but opposite sense.



FORCE PAIR: action force and reaction force.

When an object exerts a force on a second object, the second exerts a force equal in magnitude and direction, but opposite in sense, on the first

NEWTON’S THIRD LAW OF MOTION