

## Lesson 3

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# 1 Newton's Laws

- Philosophiae Naturalis
- Principia Mathematica in 1687

## 1.1 Newton's First Law

An object in motion moves in straight lines at constant speed unless acted upon by an external force

- **Inertia** - "Resistance to change" in velocity
- **mass (m)** - Inertia of a physical object
  - More mass = More resistance to change

## 1.2 Newton's Second Law

A force is the change in momentum (p) per unit time

**force (F)** – first derivative of *momentum* WRT *time*

\* *WRT* – *With respect to*

$$\sum \vec{F}_{ext} = \frac{d\vec{p}}{dt}$$

$$g(x, t)$$

$$g' = \frac{dg}{dx}$$

$$\dot{g} = \frac{dg}{dt}$$

$$\vec{p} = m \vec{v}$$

$$\begin{aligned} \sum \vec{F}_{ext} &= \vec{\dot{p}} \\ &= m \overrightarrow{dot{v}} + \dot{m} \vec{v} \end{aligned}$$

$$\boxed{\sum \vec{F}_{ext} = m \frac{d\vec{v}}{dt}}$$

There are only a handful of forces. There are two broad categories:

Long Range	Contact
Gravity (1A)	Friction
Electromagnetic (1C)	Normal
Strong (1D)	Applied
Weak (1D)	Tension
	Orange
	Drag (1B)

*\* Text within parenthesis refers to physics courses where the force is covered in detail*

Force definitions

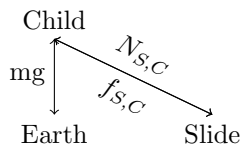
- **Normal force (N)** - Perpendicular to surface of contact, and always points away from the surface
- **friction (f)** - Parallel to contact surface
  - $f = \mu N$
  - $\mu$  – “coefficient of friction”
- **Tension ( $F_T, T$ )** - Carried along a rope or chain & points away from the object
  - Tension is not uniform if: rope has mass, massive pulley

### 1.3 Newton’s Third Law

Every force creates a reaction force which acts on a different object. These forces are equal in magnitude and opposite in direction.

Drawing a diagram

1. Draw a simplified diagram
2. Identify points of contact
3. List all relevant forces
4. Draw a free body diagram

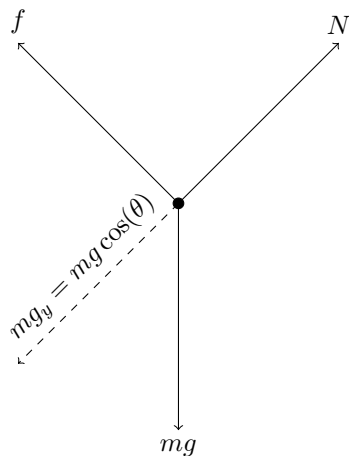


**Static -**

$$\frac{d\vec{v}}{dt} = 0$$

$$\sum F_{ext} = 0, \text{ if } m = 0$$

What value does  $\mu$  have if  $m$ ,  $g$ , &  $\theta$  are known?



$$f = \mu N$$

Always start with a  $\sum F$  statement

$x$  Direction:

$$\sum F_x^{(m)} = 0$$

\* Where  $x$  is direction and  $(m)$  is the object

$$mg \sin(\theta) - f = 0$$

$$f = mg \sin(\theta)$$

$y$  Direction:

$$\sum F_y^{(m)} = 0$$

$$N - mg \cos(\theta) = 0$$

$$f = \mu N$$

$$mg \sin(\theta) = \mu(mg \cos(\theta))$$

$$\mu = \frac{\sin(\theta)}{\cos(\theta)} = \tan(\theta)$$

## 2 Density

Density:

$$\frac{dm}{dy} = \frac{M}{L}$$

$$dm = \frac{M}{L} dy$$

$$dT = g dm$$

$$\int_0^T dT = \int_0^y \frac{Mg}{L} dy$$

$$T = \frac{Mg}{L} y$$