Newton's Laws

- Forces & Motion
- Gravity

The four currently understood forces in nature
- Gravity
- Electro-Magnetic (Maxwell, 1862)
- Weak Nuclear
- Strong Nuclear

Not understood
- Dark Energy & Accelerating expansion of our universe
- Nature of Dark Matter, the dominant form of matter

Energy Budget of Our Universe:
- Dark Energy (68%)
- Dark Matter (27%)
- Atoms (5%)
  + Ns, Hs, etc.

Physics as we know it, chemistry, engineering...
- Dogs, cats, tables, you, we...
MCA.2

**Newton's 1st Law**

A **object** which **keeps** or **starts** to **move** with a **constant** velocity experiences a **net force** only while being **accelerated**.

\[
\text{Net Force} = m \cdot \text{Acceleration} \]

**Newton's 2nd Law**

The **resulting force** equals the **mass** times the **acceleration**.

\[
f_{\text{net}} = m \cdot \vec{a}
\]

**Newton's 3rd Law**

For every **force** there is an equal and **opposite** **force** acting on the **other object**.

\[
f_{AB} = -f_{BA}
\]

Many of our exercises will involve finding the **net force** on an object, given the **forces** acting on it.
We already know a lot for how to use Newton's laws:

* Kinematics, 1-D & 2/3-D motion.

This is the answer for a constant force on an object:

\[ \mathbf{r}(t) = \mathbf{r}_0 + \mathbf{v}_0 t + \frac{1}{2} \mathbf{a} t^2 \]

Constant acceleration due to a constant net force.

* We will encounter non-constant forces, including friction.

* Additional essential concepts:
  * Energy & Conservation of Energy
  * Momentum & Conservation of Momentum
  * Rotation
  * Angular Momentum & Conservation of Angular Momentum
  * Gravity for large distances & when not close to surface of the earth.
Another essential concept

**Inertial Frame of Reference**

Newton's laws work only in an

**Inertial Reference Frame**

We will take the surface of Earth as an inertial
frame of reference, but
this is not quite true!
Earth spins, Foucault
pendulum

Inertial

- outer space, far from everything
- your dorm room
- a car moving straight on a flat road, w/o vibrations

* Not really inertial, but close!

Non-Inertial

- a car rounding a curve at constant speed
- a child on a swing
- a plane landing in rough weather.
- a spaceship in outer space far from everything, accelerating
- the top floor of a tall building swaying gently in a strong wind
Some Forces:

- Gravity near the surface of the Earth: $\vec{F}_g = mg = \text{Weight}$

- Normal Force

- Contact forces, due to electromagnetic force

- Friction

Ball of mass $M$ on floor: Weight, due to gravity.

$\vec{F} = \text{upward force counteracting gravity.}$

Box on ramp:

$\vec{F}_f = \text{Friction at surface keeps box from sliding down ramp, or slows progress of a sliding box.}$

Let's talk about all the forces on the box:

- Gravity (Weight)
- Friction
- Normal
\[ W = -m \sin \phi \]
Some forces, continued:

Springs: Force opposite compression / extension

\[ F_{\text{spring}} = -kx \]

Book uses \( F = -kx \), which is the same as \( F = -kx \) with \( x_{\text{equilibrium}} = 0 \)

(Signed distance from equilibrium position)

Compressed

\( F = 10 \)

Equilibrium

\( F = 0 \)

Extension

Equilibrium position

Any small motion about a point of equilibrium with a (pure) spring

Strings - take a force around a corner.
\[ F = \text{Tension} \]

\[ \sum F_y = m g \]

\[ \sum F_x = \text{Force} \]

\[ \text{Pulley} \]