# Classical Mechanics 2

I) A body on which no forces act remains at rest or moves at a constant velocity.
II) The rate of change of momentum of a body is proportion to the force applied.
III) For every force that body A exerts on body B, body B exerts an equal and opposite force on body A.

Law 1
This can be viewed as a special case of law 2. Contrasts to aristotlian view. From the point of view of an accerating observer, stationary objects appear to be accelerating in the opposite direction ∴ Law 1 only holds in inertial frames of reference.

A modern viewpoint views newton's first law as stating that inertail frames exist (no fictious forces).

If frame F is inertail, so is any frame moving at constant velocity with respect to F.

We don't live in an inertial frame, the earth is rotating about it's own axis and the sun. i.e. fictious forces do act but are often so small we can ignore them and get a good approximation.

## The Galilean Principle of Relativity

If two bodies move at a constant relative velocity, it is impossible to tell which is at rest and which is moving.

## The Einsteinian Principle of Relativity

The laws of physics have the same mathematical form in all inertial frames ($c = \text{const}$).

## Law 2

Why the rate of change of momentum instead of $ma$? In classical mechanics, $\dot{p} = ma$, so we can use $ma$. However in special relativity we find that

$$p \triangleq \frac{mv}{\sqrt{1 - v^2/c^2}}$$

so we cannot say $F = ma$.

We note that newton's second law hold for each of the $>10^{27}$ atoms in my body. But it also holds for my body as a whole. Let's prove this.

For two external particles:

$$\frac{dp_1}{dt} = f_1^{ext} + f_{2on1} \qquad \frac{dp_2}{dt} = f_2^{ext} + f_{1on2}$$

$$\frac{dp_1}{dt} + \frac{dp_2}{dt} = f_1^{ext} + f_2^{ext} + \underbrace{f_{2on1} + f_{1on2}}_{\text{law 3 states that this equals } 0}$$

$$\frac{dP}{dt} = F^{ext}$$

where $P \triangleq p_1 + p_2 \qquad F^{ext} = f_1^{ext} + f_2^{ext}$

We can generalise this to n particles.

$$\frac{dp_n}{dt} = f_n^{ext} + \sum_{i=1}^{\infty} f_{ionn} \qquad \frac{dp_i}{dt} = f_i^{ext} + f_{noni}$$

$$f_{noni} = -f_{ionn}$$

$$\frac{dp_n}{dt} = f_n^{ext} + \sum_{i=1}^{\infty} f_i^{ext} - \sum_{i=1}^{\infty} \frac{dp_i}{dt}$$

$$\frac{dp_n}{dt} + \sum_{i=1}^{\infty} \frac{dp_i}{dt} = f_n^{ext} + \sum_{i=1}^{\infty} f_i^{ext}$$

∴ the total rate of change equals to total force.

It follows that the momentum of any isolated system of bodies is always conserved. The total KE may change (eg. turned into heat), but the total momentum does not.

Question 1

A woman pulls on a 6kg crate, which is in turn connected to a 4kg crate by a light rope. The rope remains taught.

The lighter crate feels a smaller net force but with the same acceleration.

Question 2

A ball sits on a horizontal table. The gravitational force on the ball is one half of an action-reaction pair.

~~The upwards force that the table exerts on the ball is the other side of the pair.~~
The upwards force the ball exerts on the earth.

Take home message

Two forces acting on the same body are never an action-reaction pair.

The reaction for exerted by the table on the ball is equal and opposite to the mg force but it is not an action reaction pair.

## Types of Forces

### Gravity

$$F = \frac{Gm_1m_2}{r^2} \qquad G = 6.674\times10^{-11}\, m^3 kg^{-1} s^{-2}$$

- very weak
- import at large distances or near large masses.

### Electromagnetism

$$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$$

- much stronger then gravity
- Irrelivent at large distances because large objects are almost always charge neutral.
- responcible for nearly all the forces we feel.

### Strong Force

- very strong but very short ranged.
- binds quarks together to form nucleons.
- holds nuclei together despite EM force

### Weak Force

- weaker than EM, stronger than gravity
- shorter range than strong force
- responcibl for radioactive decay.

## Common Mechanical Forces

- Weight (pull of gravity on object)
- Tension (pull on object from rope)
- Normal force ( surfaces push back on object)
- Friction (parralel to surface)

## Friction

- arises from electromagnetic interactions between molecules (lumps on surface on objects).

Static friction acts when sliding has not yet started. $F_s \approx \mu_s n$

Kinetic friction acts after sliding has begun. $F_k \approx \mu_k n$

Usually $\mu_s > \mu_k$ (n = normal force)

## Tension

Kinda obvious

## Ficticous Forces

- If you live in an accelerating frame of reference, eg. surface of the earth, you feel forces that are not real.
- for example, centrifugal force when on a roundabout
- closley related is the coriolis force, ficticous but strong enough to cause hurricanes

# Inertial and Gravitational Mass

→ the m in $F=ma$ tells you about inertia: how much force produces an acceleration of $1ms^{-2}$.

→ the m in

$$F = \frac{Gm_1m_2}{r^2}$$

is a 'gravitational charge' analogous to the electrical charge.

Why should the inertial $m_I$ and the gravitational mass $m_G$ be the same?

We find that the inertial & the gravitational masses are indeed the same.