Forces on and in the body

 What is a "Force?" Force is a push or a pull exerted on a body which tends to change the state of motion of the body.

MASS is the measure of the amount of matter in an object, It is measured in Kilograms .

 A force causes something with mass to move (accelerate).
 From Newton's Second Law of Motion F = m x a
Weight (force) = mass x gravity (Earth)
 The unit of force is Newton "N"

Newton's First Law: Objects in motion tend to stay in motion and objects at rest tend to stay at rest unless acted upon by an unbalanced force.

Newton's Second Law: Force equals mass times acceleration (F = ma)

Newton's Third Law: For every action there is an equal and opposite reaction.

All forces can be described by four fundamental forces:
1. Gravity: Newton low which states that "there is a force of attraction between any two object which is proportion to the product of their masses and inversely proportional to the square of the distance between them"
2. Electromagnetic: responsible for many electrical, magnetic and EM wave phenomena.
3. Weak nuclear: short range, radioactive decay.
4. Strong nuclear: short range.

Rigid Bodies: An object extend in space that does not change its size or shape when subjected to a force ,In real life nobody is perfectly rigid
External and Internal forces:

External forces on a rigid body are due to causes that are external to the body. They can cause the body to move or remain at rest as a whole. For example: force of gravity, applied external force on an object.

Internal forces develop in any body (not just rigid bodies) that keep all the particles of a body together. For example: Internal TENSION or COMPRESSION in a bar, bending moment in a beam.

1-Static forces

Statics is the study of forces acting on an object that is in equilibrium and at rest.

A body is in static equilibrium if

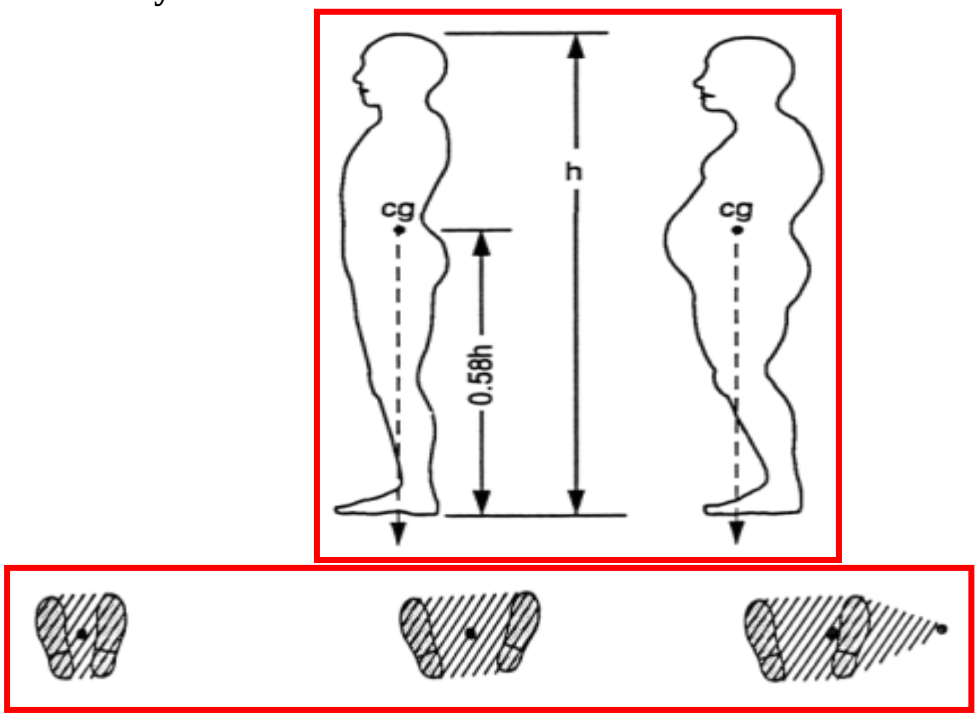
- **the vector sum of the forces acting on the body is zero i.e., $\Sigma F = 0$**
- **the vector sum of all the moments about any arbitrary point is zero i.e.** $\sum \tau = 0$

The main force acting on the body is the gravitational force

(W= weight!) → $W = m \cdot g$

Stability of the body against the gravitational force is maintained by the bone structure of the skeleton!

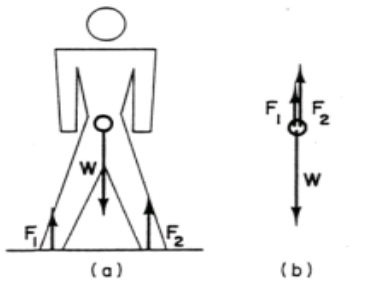
Gravitational force W applies at the center of gravity CG of the body!



CG depends on body mass distribution! to maintain stability CG must be located between feet, if feet are far apart forces in horizontal direction F_x have to be considered

To maintain stability the vector sum of all forces applying at the CG must be zero!

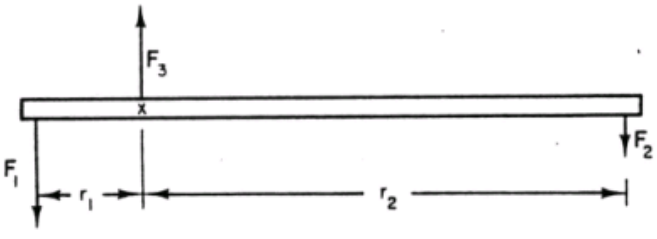
$$\sum \vec{F}_i = 0$$



$$\vec{F}_1 + \vec{F}_2 = \mathrm{W}$$

$\vec{F}_1$, $\vec{F}_2$ are the forces the ground applies to the feet

The torque r causes a rotational movement around a pivot point!



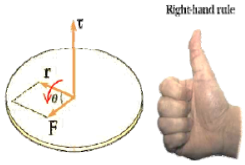
$$\sum_i \vec{\tau}_i = \sum_i \vec{r}_i \times \vec{F}_i = 0$$

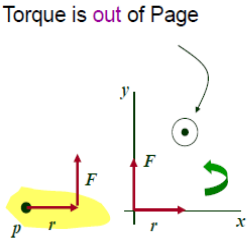
Torque is defined by the force *F* applied at the distance *r* from the pivot point.

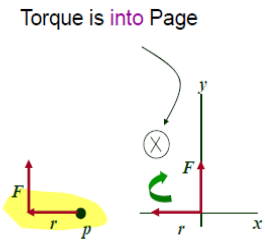
- The torque is a vector quantity and its direction is determine by the right hand rule,

If the turning tendency of the force is counterclockwise, the torque will be positive

If the turning tendency is clockwise, the torque will be negative



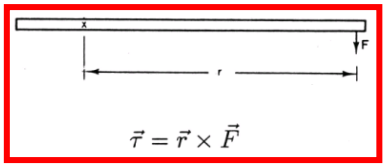


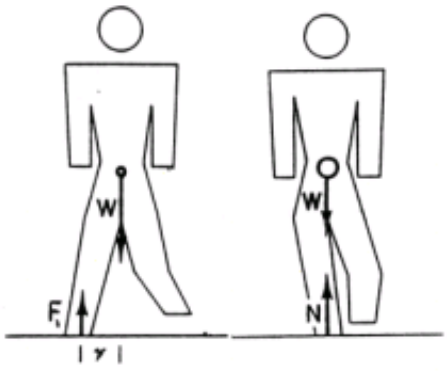


In rotational equilibrium (no rotation, constant rotation) to maintain stability for a person standing on one leg the torque requires to shift **CG** of body so, that:

$\sum_i \vec{\tau}_i = 0$

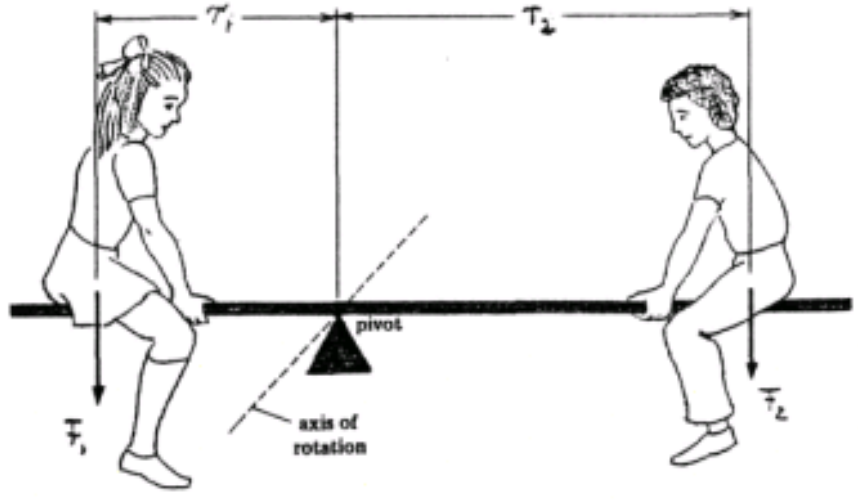
$\vec{F}_1 = \vec{W}$





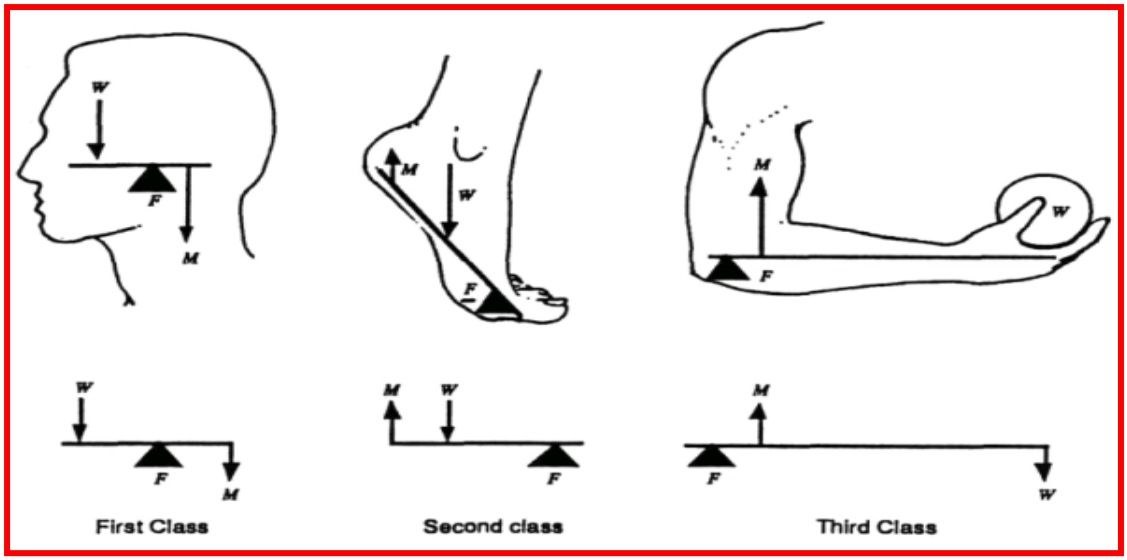
torque for an average person of weight $\vec{W}$=80 kg·9.81 m/s^2 and $\vec{r}$=20cm, $\vec{\tau}$ ≈16 N·m

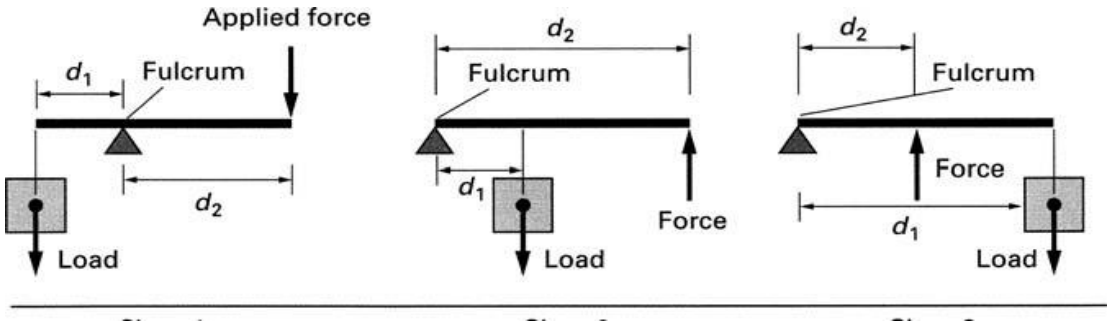
Body movements are controlled by muscle forces, initiated by contraction or extension of the muscles. Skeletal muscles control the movements of the body limbs. **Most of the muscle forces involve levers!**



for the lever at rest: $\sum_i \tau_i = 0$

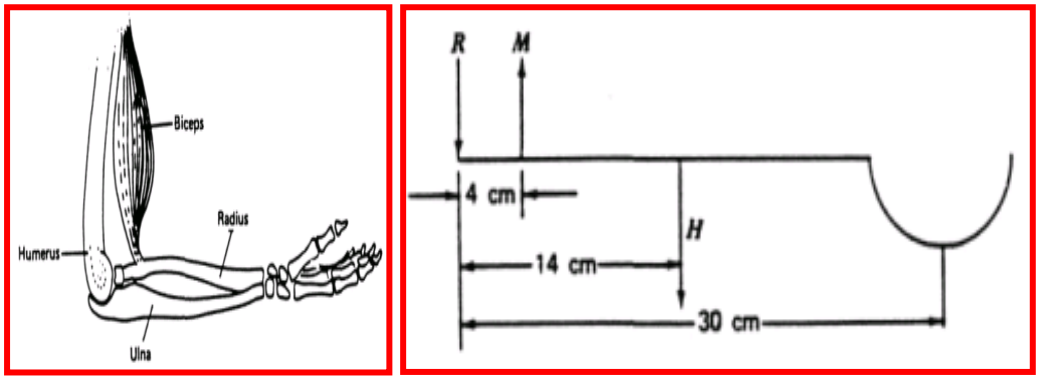
Three examples for lever systems, W is the applied weight, F is the force supporting the pivot point of the lever system, and M is the muscles force.





EXAMPLE: THE FOREARM AS LEVER SYSTEM

The biceps muscle pulls the arm upwards by muscle contraction with a force M the opposing force is the weight of the arm H at its center of gravity (CG)!



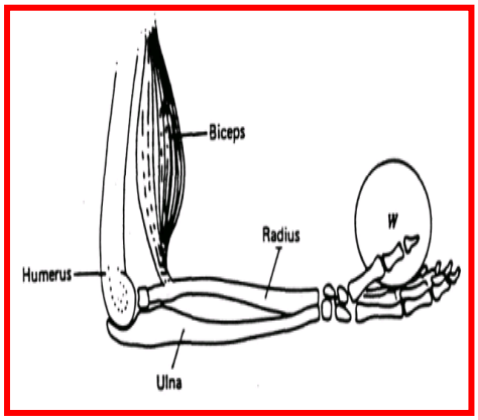
$$\sum_i \vec{r}_i = \vec{r}_1 \times \vec{M} + \vec{r}_2 \times \vec{H} = 0$$

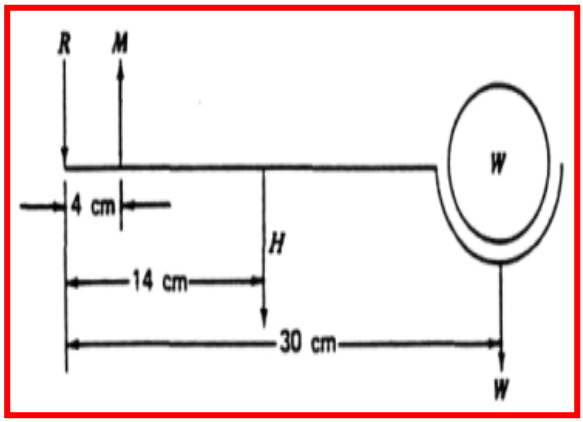
$$r_1 \cdot M - r_2 \cdot H = 4cm \cdot M - 14cm \cdot H = 0$$

(all forces apply perpendicular to the lever arm)
with H≈15N (mass of the lower arm is approximately 3.3 lb)

$$M = 52.5\ N$$

Biceps can be strengthened by weight W lifting this adds another force which has to be compensated by the muscle force.





$$\sum_i \vec{r}_i = \vec{r}_1 \times \vec{M} + \vec{r}_2 \times \vec{H} + \vec{r}_3 \times \vec{W} = 0$$

$$r_1 \cdot M - r_2 \cdot H - r_3 \cdot W = 4cm \cdot M - 14cm \cdot H - 30cm \cdot W = 0$$

$$M = (14/4 \cdot H + 30/4 \cdot W) = 52.5\ N + 7.5\ W$$

muscle force increases linearly with weight

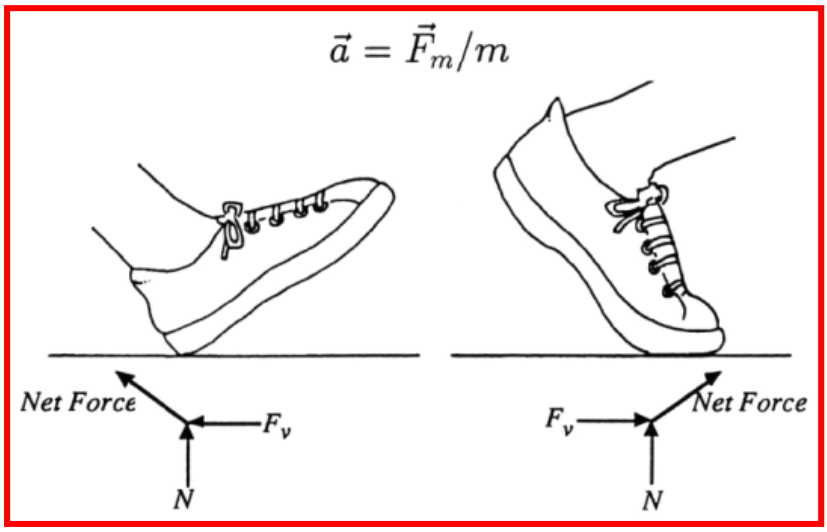
for W = 100N (22lb); M = 802.5 N

2 – Frictional Forces :

If a body of mass *m* is in constant motion no acceleration or deceleration occurs !

$$\vec{v} = d\vec{x}/dt = \text{const}$$

Acceleration *a* can be caused by leg muscle force *F* !



Deceleration can be caused by friction, muscle force or external forces (by running into a wall for example).

Friction occurs between a moving surface and a surface at rest:

$$\vec{F}_f = \mu_k \vec{N}$$

N is the normal force!

μk is coefficient for kinetic friction:

for rubber-concrete: $\mu_k \approx 0.8$

joints between bones: $\mu_k \approx 0.003$

As smaller the coefficient as less resistance by frictional forces!

For a walker of N ≈ W ≈ 800 N (m=82kg):

Friction force: $F_f \approx 640$ N

deceleration: $a \approx 7.8$ m/s^2

Accelerating muscle forces maintain a constant walking speed!

3 – Dynamic Forces : When the body bumps into a solid object (like a wall) rapid deceleration *a* occurs:

$$\vec{a} = d\vec{v}/dt \approx \Delta\vec{v}/\Delta t$$

The decelerating force F_d applied by the wall to the body (or to whatever body part which hits first) causes pressure P_d which causes deformation:

$$\vec{F}_d = m \cdot \vec{a} \quad \vec{P}_d = \vec{F}_d/\mathrm{A}$$

A is the surface area of the body or body part exposed to the force

Force is only applied over the time period *Dt* until complete stop

$$\Delta\vec{v} \approx \vec{v}_i$$

$\vec{v}_i$ is the velocity at impact

This force is important when the body is moving and hitting another body . Therefore this force is used in forensic medicine

Example of dynamic force in the body is apparent increase of weight when the heart beats (systole) is increase .

Example : 60 gm of blood is given upward of about 0.1 sec in a velocity nearly 1m / sec , the force is equal to :

$F = m\,\Delta v/\Delta t = (60\times10^{-3}kgm)\times(1m/\text{ sec})/\ 0.1\text{ sec} = 0.6$ N

($kgm.m/\text{sec}^2$)

Principles of centrifugation

Centrifugation is a separation technique where different components of mixture are separated based on their density or particle size. The separation of different substances is based on centrifugal force that is produced by high speed rotation. Centrifugal force causes denser components to be directed away from the axis of rotation whereas lighter components travel towards it.

Centrifugation is generally utilized with separation of insoluble particles from liquids, but it is utilized as well in the separation of two immiscible liquids. For example, in industrial milk processing the centrifugal separation of the cream from milk is based on the density

differences of the components. Centrifuges that are utilized in industrial setting, can be classified into two different categories: sedimentation and filter centrifuges. The classification is based on the general operation principles of the centrifuges, but the continuous and batch feeding type of centrifuge is also taken into consideration in classification.

Sedimentation centrifuges separate insoluble particles from liquids based on different sedimentation features, such as size, shape, density and centrifugal force . Sedimentation is a process where molecules or particles sediment downward due to gravitational force.

Larger and denser particles sediment faster. Centrifugation facilitates sedimentation with centrifugal force, separating the particles into solid pellet (sudden) and liquid solvent (supernatant).

In comparison to sedimentation centrifuges, centrifugal filtration utilizes filtration material to separate the components from the mixture .

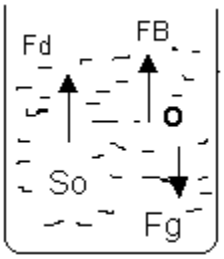
Sedimentation

A sedimentation of small spherical objects of radius (a) and Density (ρ) insulation of density (ρ_o) , and his viscosity (η in Pascal) , in gravitational field , and when his object is moving of constant speed (ν) , the retarding force is :

$F_d = 6 \Pi a \eta \nu$ is in equilibrium with difference downward gravitational force and upward buoyant force :

$F_d = F_g - F_B$

$F = mg \Rightarrow \rho = m/v$



$= \rho v g = 4/3 \pi a^3 \rho g$

ν = Terminal velocity

(sediment action velocity)

$6\pi a \eta \nu = 3/4 \pi a^3 \rho g - 4/3 \pi a^3 \rho_o g$

$= 3/4 \pi a^3 (\rho - \rho_o) g$

$\therefore \nu = (2a^2/9\eta) g (\rho - \rho_o)$

$\therefore$ sedimentation velocity depend on :

1. size of particle .
2. viscosity of liquid .
3. acceleration of gravitation

In some diseases (**rheumatic fever, rheumatic heart disease and gout**) the red blood cells (RBC's) clump together and the effective radius increases; thus, the sedimentation velocity (rate) is **faster than normal**. In other diseases: (**hemolytic jaundice and sickle cell anemia**), the RBCs change shape or break. The radius decreases; thus, the rate of sedimentation is **slower than normal**. Determining the RBCs sedimentation rate is a simple and routine clinical laboratory test that enables the hematologist to diagnose the above mentioned blood diseases.