Physical bases of biophysics

Statics – changes of shape, forces, mechanical stress, pressure

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Mechanics: Statics és dynamics

Kinematics: Describes the motion of bodies (without investigating the causes).

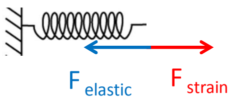
Statics: forces acting on a body are in equilibrium, thus the body is at rest .

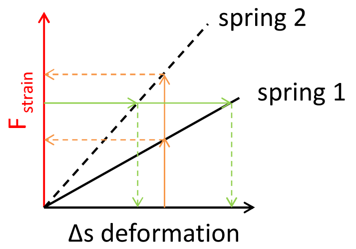
Eqilibrium: An object remains in equilibrium if the net force acting on it is ΣF = 0. Consequently, its acceleration will be zero, thus it is either moving in a straight line with uniform velocity or is at rest. The latter, special case is studied by the field of statics.

Dynamics: study of forces acting between bodies and their effect on their motion.
$\Sigma F \neq 0$

Force laws

I. Elastic force





The stronger spring is, where:

- The same deformation requires higher force
- The same force causes less deformation

Hooke's law:

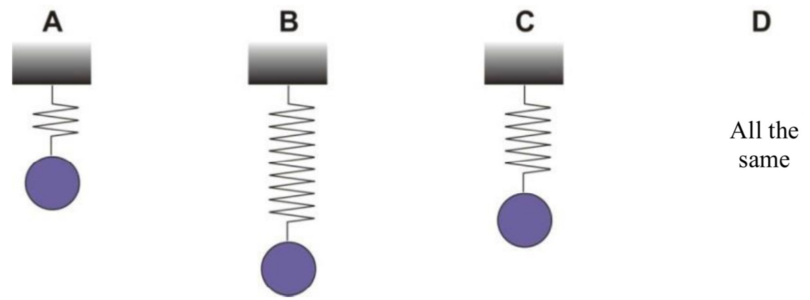
$$k = -\frac{\Delta F_{elastic}}{\Delta s}$$

k: spring constant [N/m]
— : ΔF and Δs oposite direction

11. I pull a spring with 20 N force. Its extension after equilibrium is 25 cm. Calculate the spring constant.

10. Let us consider the Achilles tendon as a simple spring with a spring constant of $3 \cdot 10^5$ N/m. Calculate the force needed to stretch the tendon by 2 mm.

12. All the springs shown in the figures are extended by 10 % when we hang the same mass on them. Which spring has the highest spring constant? Or do all have the same spring constant?



Force laws

II. Law of universal gravitation

$$F_{grav} = G \cdot \frac{m_1 \cdot m_2}{r^2}$$

F_{grav}: gravitational force acting between two bodies [N]

G: gravitational constant: $6{,}7 \cdot 10^{-11}\ [\frac{N \cdot m^2}{kg}]$

m_1, m_2: mass of the bodies [kg]

r: distance between the bodies [m]

8. Calculate the gravitational force between two asteroids (masses 200 000 and 300 000 tons) when they pass by each other at a distance of 2 km.

Force laws

II/b Gravity: the force that accelerates and object falling freely towards the Earth.

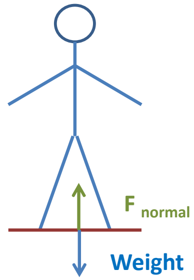
$$\overrightarrow{F_{gravity}} = m \cdot \vec{g}$$

$\overrightarrow{F_{gravity}}$: gravity force[N]

m: mass [kg]

$\vec{g}$: gravitational acceleration: $9{,}81\ \frac{m}{s^2}$

II/a Weight: Weight is the force with which an object is pressing or pulling the surface that holds it.



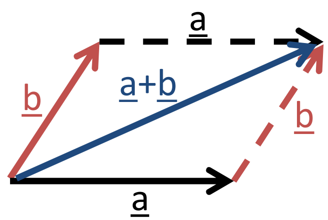
9. A sandbag with a mass of 40 kg hangs from a rope.
a) Calculate the gravity pulling the bag.
b) Calculate the force with which the bag pulls the rope (its weight)

* A paratrooper with 60 kg is falling with a constant velocity. Calculate the gravity force acting on it! What is the weight or the mass of this paratrooper?

Vectoral addition of Forces

Forces acting on the same path: e.g. bottle on the table
choose a + and – direction and summarise

Addition of forces in a given angle:
summation of vectors, paralellogram method
More than 2 forces are present: construct the resultant force of a choosen force pair, then summarise the resultant force with the third force



Pressure: force applied perpendicular to a surface

$$p = \frac{F}{A}$$

F: force [N]

A: area (m^2)

p: pressure [N/m^2=**Pa**]

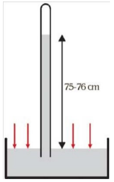
1 bar = 105 Pa

1 atm = $1{,}01 \cdot 10^5$ Pa

1 mmHg = 133 Pa.

3. a) Calculate the pressure that a 70-kg-person exerts on the floor while standing. Assume that the total surface of the two soles is 200 cm^2.
b) Calculate the pressure this man exerts on the surface of ice during skating! Assume that the total surface of the blades is 4 cm^2.
c) And if we increase the area to 1000 cm^2 with a snow shoe?

2. Atmospheric pressure (barometric pressure)



Torricelli-experiment

750-760 Hgmm= 1 atm= 101 kPa

3. Partial pressure

hypothetical pressure of that gas if it alone occupied the volume of the mixture at the same temperature.

E.g. Atmospheric pressure is 760 Hgmm, O_2 is 21% of the air: 760 Hgmm·0,21= =159 Hgmm partial pressure

The sum of the partial pressures of each individual gas in the mixture gives the total pressure of the mixture

4. Pressure of gases

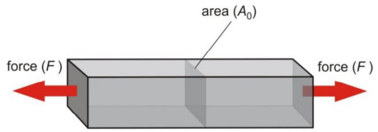
$$p = F/A$$

$$F = \Delta I/\Delta t$$

$$\Delta I = m \cdot \Delta v$$

(Mechanical or tensile) stress: stress, that emerges in solid bodies when they are deformed

$$\sigma = \frac{F}{A_0}$$



F: force [N]
A_0: original cross section (m^2)
σ: stress [N/m^2=**Pa**]

Mechanics- Dynamics and statics

Newton I: law of inertia
Every object remains at rest or moves in a straight line with uniform velocity until another object will compel it to change its motion.

Describes the state of motion:
- velocity
- momentum

Describes the CHANGE in the motion state:
- Acceleration
- Force

Inertial frame of reference: frame of reference in which a body with zero net force acting upon it is not accelerating. (braking train: traveller can measure an inertial force so they are not in the inertial frame of reference)

Momentum

„the quantity of motion of a moving body” (push, toss)

When do we feel a stronegr push? If a bee or a bottle hits us?
We are standing at the red light. When do we feel a stronger push? If a walker or a runner runs against us?

$$\vec{I} = m \cdot \vec{v}$$

m: mass[kg]
$\vec{v}$: velocity (vector quantity) [m/s]
$\vec{I}$: momentum (vector quantity, same direction as the velocity) [$kg \cdot \frac{m}{s}$]

Conservation law of momentum: In a closed system the total momentum is consant
(closed system: one that does not exchange any matter with its surroundings and is not acted on by external forces)

Force

Quantity of the ability to change the motion state

1. ***Change in the momentum in a given time***

$$\vec{F} = \frac{\Delta\vec{I}}{\Delta t}$$

$\Delta\vec{I}$: change in the momentum (vector quantity) $[kg \cdot \frac{m}{s}]$

Δt: time $[s]$

$\vec{F}$: Force $[\frac{kg \cdot \frac{m}{s}}{s} = kg \cdot \frac{m}{s^2} = \mathbf{N}]$

2. ***Newton's second law (fundamental law of dynamics)***

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

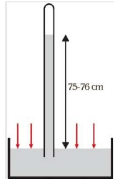
$\vec{a}$: acceleration (vector quantity) $[\frac{m}{s^2}]$

m: mass $[kg]$

$\vec{F}$: force $[kg \cdot \frac{m}{s^2} = \mathbf{N}]$

How will the speed, momentum and the force change, if a ball is bounced back from a wall?

2. Atmospheric pressure (barometric pressure)



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The sum of the partial pressures of each individual gas in the mixture gives the total pressure of the mixture

4. Pressure of gases

$$p = F/A$$

$$F = \Delta I/\Delta t$$

$$\Delta I = m \cdot \Delta v$$

Newton' third law (law of equal action and reaction):

When object A exerts a force of F on object B, then object B exerts a force of F on object B. The two forces are in equilibrium, if:

- They have equal magnitude
- They act in an opposite direction but on the same path

Two forces acting on one body are in equlibrium, if:

- They have equal magnitude
- They act in an opposite direction but on the same path
- They act on the same body

Equilibrium: An object remains in equilibrium if the net force acting on it is ΣF = 0. Consequently, it's acceleration will be zero, thus it is either moving in a straight line with uniform velocity or is at rest. The latter,special case is studied by the field of statics.

2. A racecar (m=1 500 kg) accelerates from rest with uniform acceleration. It reaches the 100 km/h velocity in3.1 s.

a) Calculate the force accelerating the car.

b) Calculate the distance in which the car reaches the 100 km/h velocity.

9. A sandbag with a mass of 40 kg hangs from a rope.

c) Calculate the gravity and the weight if we hang the bag in an elevator that is accelerating with 2 m/s^2 downwards.

4. . The acceleration of a paratrooper (m = 70 kg) at a given moment during its fall is 0.5 m/s^2 . What kind of forces act on the paratrooper at this moment? Calculate the value of these forces!

5. A father is pulling a sled for 5 seconds starting from rest with a constant force of 105 N. The mass of the sled together with the child on it is 25 kg. The friction force acting on the sled is 15N.

a) Calculate the acceleration of the sled.

b) What will be the final velocity of the sled after 5s?

c) How far can dad pull the sled during this time?

6. A man is pulling a sled with constant velocity (m = 20 kg). The rope suddenly breaks. The sled slides on for
6,1 seconds with uniform decelaration and stops after traveling 9.2 m.
a) Calculate the velocity of the sled at the moment when the rope breaks.
b) Calculate the acceleration (in fact, deceleration) of the sled.
c) Calculate the force that slows the sled.

13. The figures show the change in force as a function of time
a) We throw a ball straight up. Which figure shows correctly the change of gravity acting on the ball?
b) We slowly compress a spring uniformly. Which figure shows correctly the change of spring force during compression?
c) A ball falls freely towards the ground. Which figure shows correctly the change in the ball's weight?