Physical bases of biophysics

2nd Lecture
Kinematics
13th September 2019.
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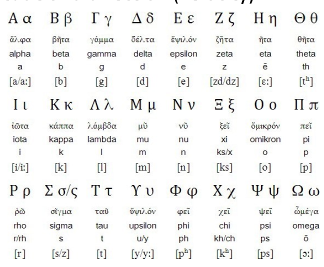
Physical quantities SI units

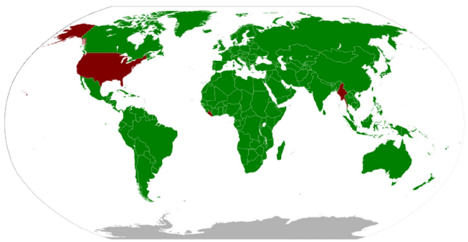
$$\boldsymbol{physical\ quantity = numerical\ number * unit}$$

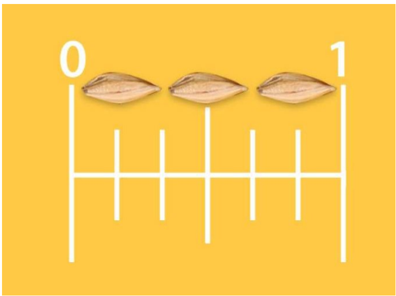
Types of physical units:
Scalar quantities: a quantity without spatial direction (mass, temperature)
Vector quantities: represent physical quantities that have both magnitude and direction (velocity)

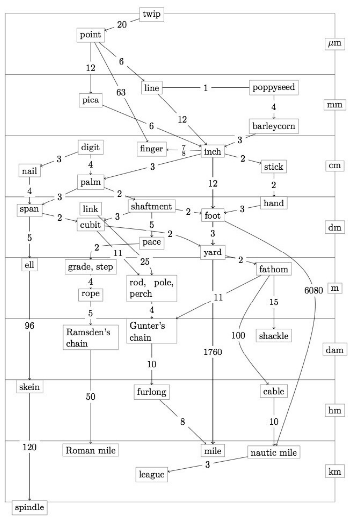
c-can stand for depending on the context for a lot of physical quantities or constants

- Speed of light in vacuum ($3 \times 10^8 \frac{m}{s}$)
- Velocity of wave [$\frac{m}{s}$]
- concentration [$\frac{mol}{m^3}$]
- Specific heat capacity [$\frac{J}{kg}$]

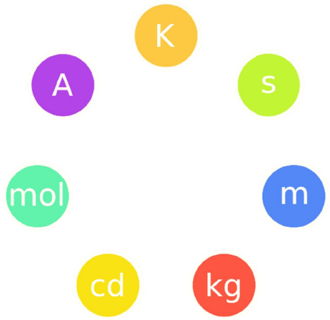








SI units



physical quantity	symbol	unit	symbol
length	*l, x, s, d*	meter	m
mass	*m*	kilogram	kg
time	*t*	second	s
temperature	*T*	kelvin	K
electric current	*I*	ampere	A
amount of substance	*n, N*, ν [nu]	mole	mol
luminous intensity	I_v	candela	cd

The SI base units

physical quantity	symbol	unit	symbol	derivation
speed	*v, c*	–	–	$m \cdot s^{-1}$
acceleration	*a*	–	–	$m \cdot s^{-2}$
force	*F*	newton	N	$kg \cdot m \cdot s^{-2}$
energy	*E*	joule	J	$kg \cdot m^2 \cdot s^{-2}$
power	*P*	watt	W	$kg \cdot m^2 \cdot s^{-3}$
intensity	*I*	–	–	$kg \cdot s^{-3}$
pressure	*p*	pascal	Pa	$kg \cdot m^{-1} \cdot s^{-2}$

Some SI derived units

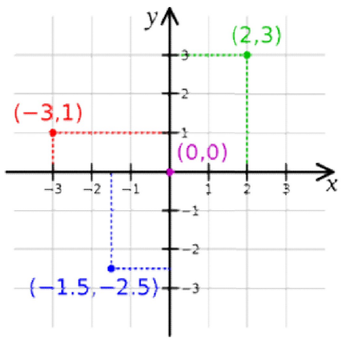
SI prefixes

prefix	symbol	value
deka	da	10^1
hekto	h	10^2
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^12
peta	P	10^15
exa	E	10^18
zetta	Z	10^21
yotta	Y	10^24

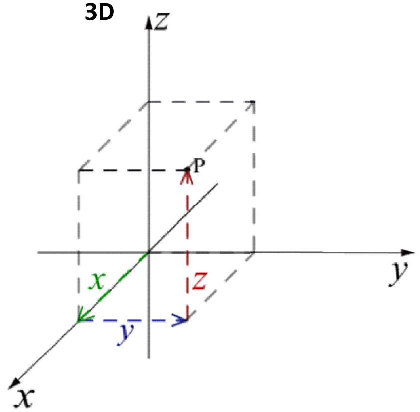
prefix	symbol	value
deci	d	10^-1
centi	c	10^-2
mili	m	10^-3
mikro	µ	10^-6
nano	n	10^-9
pico	p	10^-12
femto	F	10^-15
atto	a	10^-18
zepto	z	10^-21
yocto	y	10^-24

Cartesian coordinate system

2D

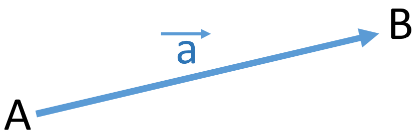


3D



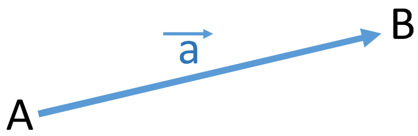
Eucleadean vector

A vector is given if we now:
direction:
magnitude:

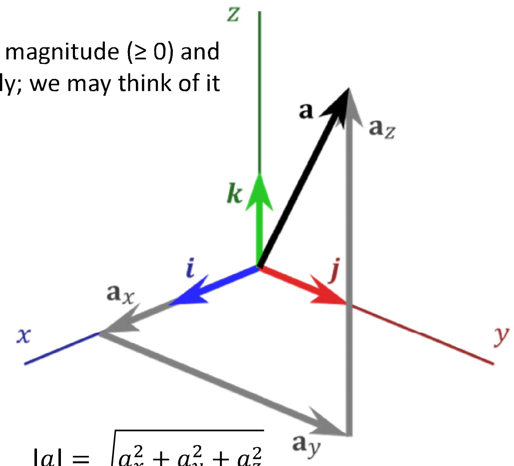


Vectors

A vector is a quantity that requires both a magnitude (≥ 0) and a direction in space to specify it completely; we may think of it as an arrow in space



$$|\boldsymbol{a}| = \sqrt{a_x^2 + a_y^2}$$



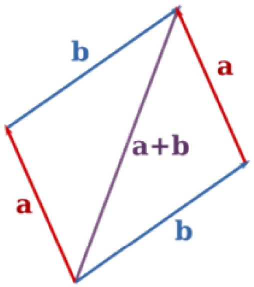
$$|a| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

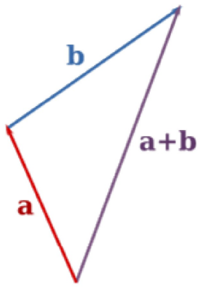
Vector algebra

Addition of vectors

$$\boldsymbol{a} + \boldsymbol{b} = \boldsymbol{b} + \boldsymbol{a}$$

$$(\boldsymbol{a} + \boldsymbol{b}) + \boldsymbol{c} = \boldsymbol{a} + (\boldsymbol{b} + \boldsymbol{c}) = \boldsymbol{a} + \boldsymbol{b} + \boldsymbol{c}$$



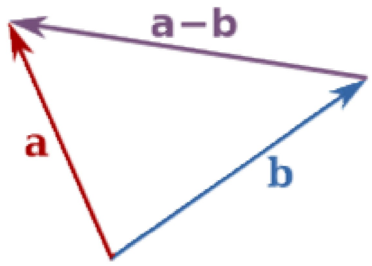


$$\boldsymbol{a} + \boldsymbol{b} = (a_1 + b_1)\boldsymbol{i} + (a_2 + b_2)\boldsymbol{j}$$

$$|\boldsymbol{a}| = \sqrt{a_x^2 + a_y^2}$$

Vector algebra

Substraction of vectors



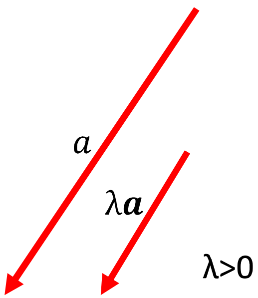
-b is a vector with the same magnitude of **b** but with opposite directions
Place the tails of the vectors **a b** together draw an arrow rom the head of the substracted arrow towards the vector from which you substracted from THIS will give the **resultant vector**

$$\boldsymbol{a} - \boldsymbol{b} = \boldsymbol{a} + (-\boldsymbol{b})$$

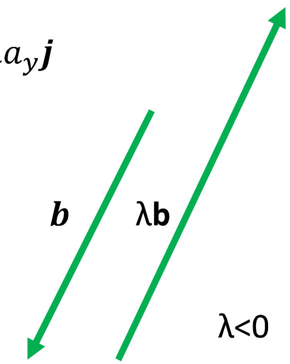
$$\boldsymbol{a} - \boldsymbol{b} = (a_x - b_x)\boldsymbol{i} + (a_y - b_y)\boldsymbol{j}$$

Vector Algebra

Multiplication by a scalar

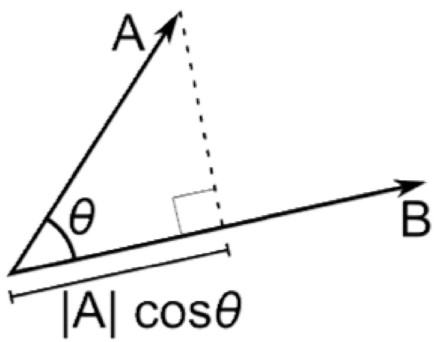


$$\lambda\boldsymbol{a} = \lambda a_x\boldsymbol{i} + \lambda a_y\boldsymbol{j}$$



Vector algebra

Scalar product of two vectors



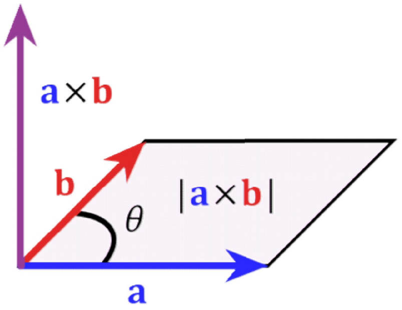
$$\boldsymbol{ab} = |a||b| \times cos\Theta$$

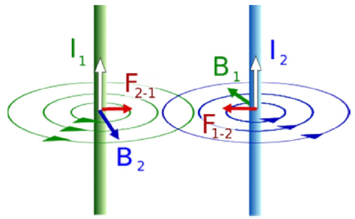
$$\boldsymbol{a} \cdot \boldsymbol{b} = a_x b_x + a_y b_y$$

Vector algebra

Vector product

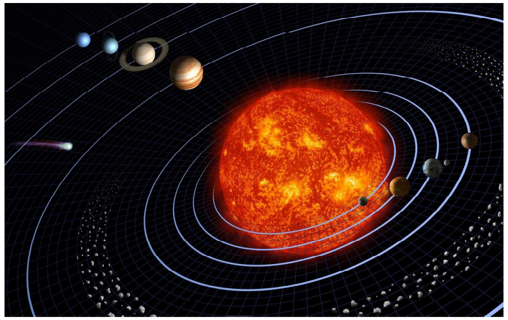
$$|a \times b| = |a||b| \sin\theta$$

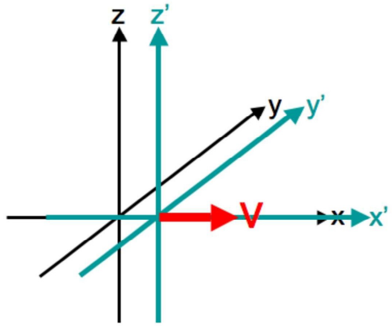




Frame of reference

A point of view from which we are measuring from

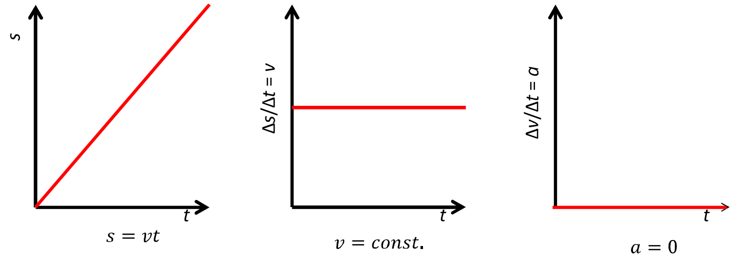




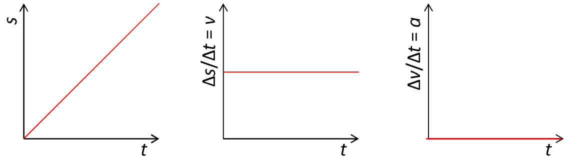
Kinematics

Kinematics is a branch of classical mechanics that describes the motion of points, bodies (objects), and systems of bodies (groups of objects) without the causes.
Describes the motion of a point in space and time.

Uniform Rectilinear Motion:

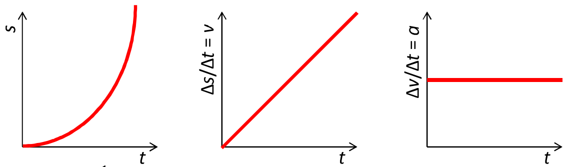


Uniform Rectilinear Motion:



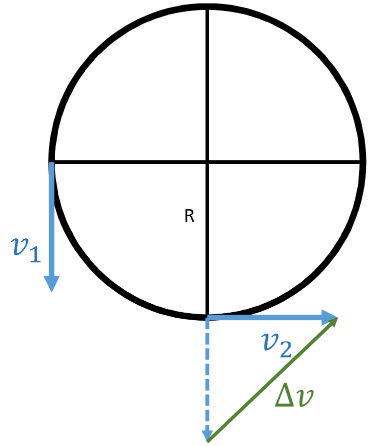
$s = vt$ $\quad v = const.$ $\quad a = 0$

Rectilinear Motion with Uniform Acceleration:



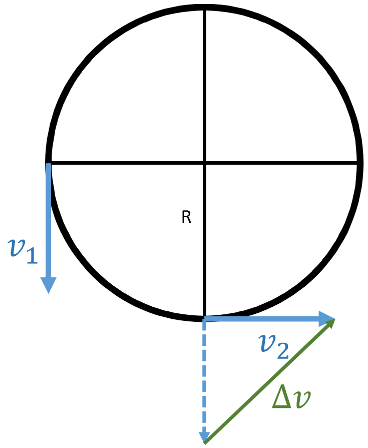
$s = v_o t + \frac{1}{2}at^2$ $\quad v = at$ $\quad a = const.$

Circular motion



T= **Period** The duration of one cycle in a repeating event [s]
f=1/T **Freuqency** is the number of occurences of a repeating event per unit of time [Hz=1/s]
ω= Δα/Δt = 2π/T **angular velocity** [rad/s]
B= Δω/Δt **angular acceleration** [rad/s^2]

Circular motion



Uniform circular motion

Arc quantities

$$s = \varphi R$$

$$v = \omega R$$

$$a_t = \beta R$$

$$a_{cp} = R\omega^2 = \frac{v^2}{R}$$

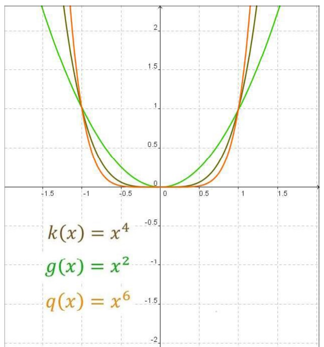
Angular quantities

φ [rad]

$$\omega = \frac{\Delta\varphi}{\Delta t}\left[\frac{rad}{s}\right]$$

$$\beta = \frac{\Delta\omega}{\Delta t}\left[\frac{rad}{s^2}\right]$$

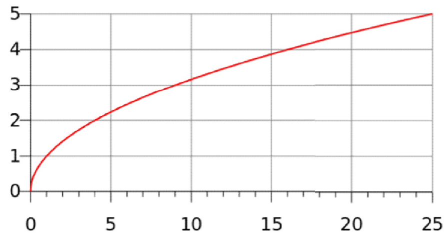
Power function



if n= is an even integer then at [0, ∞] the function is monotonically increasing so the function can be inverted. The inverse of the function is $\sqrt[n]{x}$

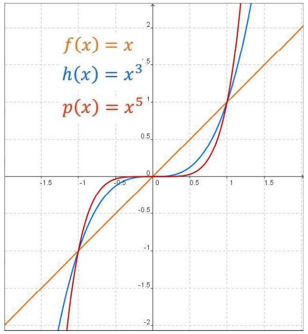
$f(x) = a\,x^n$

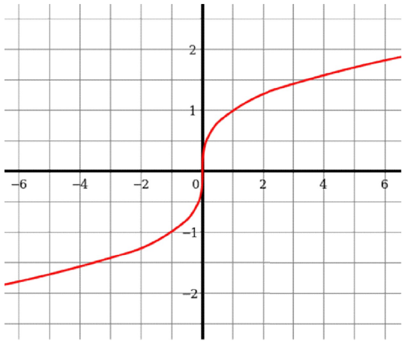
Squareroot function



$[0, \infty] \rightarrow \mathbb{R},$

Power function





The f(x)= x^3
function is invert*able its inverse is*: $f^{-1}(x)$= $\sqrt[3]{x}$

Exponential function

$$f(x) = b^{x+c}$$

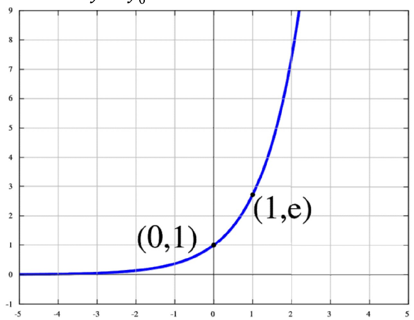
For any positive number b>0 there is a function $f\colon \mathbb{R} \to [0, \infty]$ called an exponential function that is defined as $f(x) = b^{x+c}$

$b^x b^y = b^{x+y}$

$\frac{b^x}{b^y} = b^{x-y}$

$(b^x)^y = b^{xy}$

Ha $x = o$
Akkor $y = y_0$

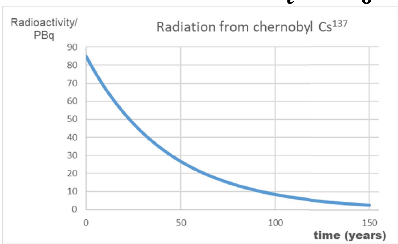


$b > 1$ monotonically increases
$0 < b < 1$ monotonically increases

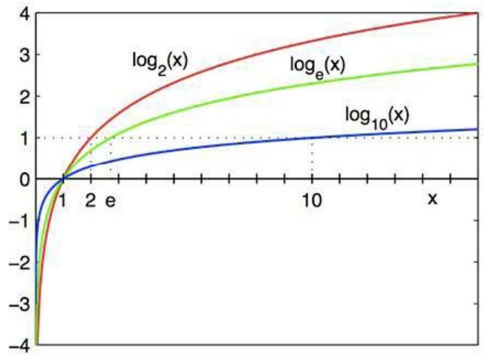
Physical example

Spontaneous decay of radioactive atomic nuclei:
Each nuclei have the same chance to decay in each moment of time.

$$N_t = N_0 2^{\frac{-t}{T_{\frac{1}{2}}}}$$



Logaritmic function



a>1

b is usually 2, e, or 10

$\mathbb{R}^+ \to \mathbb{R}, x \to log_a x$; a>0

The inverse function for the exponential function

$$e^{lna} = a \iff ln(e^x) = x$$

$$log_b(xy) = log_b(x) + log_b(y)$$

$$log_b(x^p) = p\, log_b(x)$$

$$log_b(x) = \frac{log_k(x)}{log_k(b)}$$

Linearizing a power relation

$$y = m\,x^{n}$$

$$\log(y) = n\,log(x) + \log(m)$$

y=ax+b

Log-log method for lineariznig power relations

Linearizing an exponential function

$$y = Ae^{kx}$$

$$\ln(y) = kx + lnA$$

Semi-log method for exponential relations