

# Physical basis of biophysics

**1st Lecture**

**Mathematics Necessary for Understanding Physics  
Physical Quantities and Units**

**11st September 2018**

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Information about the lectures:

Tuesday: 16:30-17:50 Hevesy György Hall

Friday: 17:00-18:20 Békésy György Hall

Sources for the course:

Notes made on the lectures

Tölgyesi: *Mathematical and Physical Basis of Medical Biophysics* )

Website of the department

(<http://biofiz.semmelweis.hu/>)



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**Closing test of the course:** 9th of October (Tuesday) at 16:30. Location to be announced later.

# Number theory basics

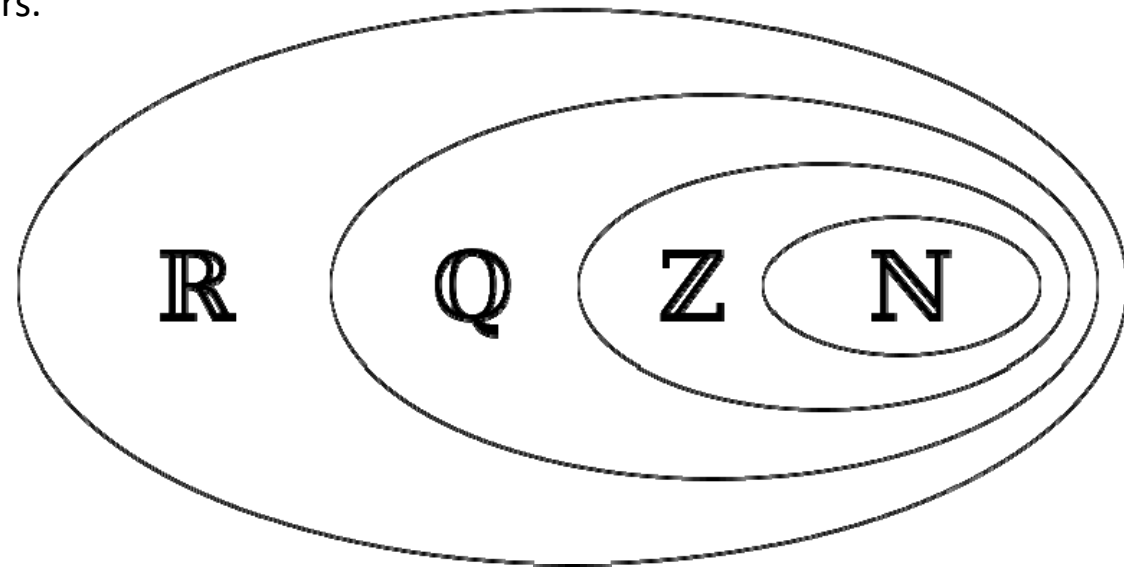
$\mathbb{N}=\{0,1,2,\dots,n,\dots\}$  not negative integers

$\mathbb{Z}=\{-3,-2,-1,0,1,2,3,\dots\}$  integer numbers

$\mathbb{Q}=\{p/q \mid p,q \in \mathbb{Z}, q \neq 0\}$

$\mathbb{Q}^*$ = all real numbers which are not rational numbers.

$\mathbb{R}=\{\mathbb{Q} \cup \mathbb{Q}^*\}$  real numbers



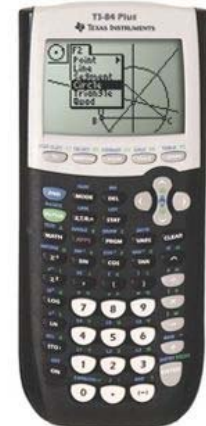
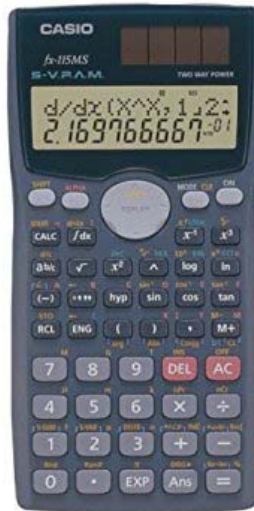
# Normalized notation

$$M \times 10^n$$

M= mantissa  $1 \leq M < 10$   $M \in \mathbb{R}$

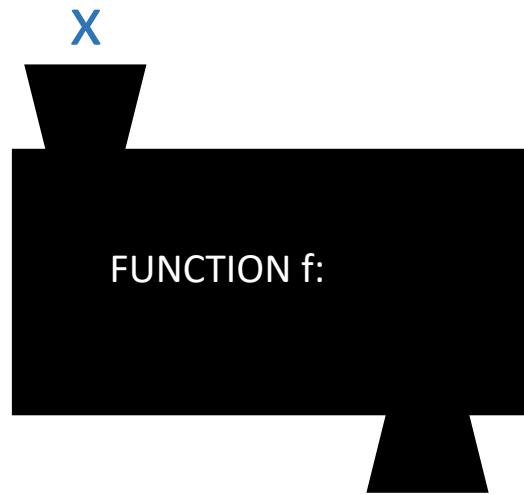
n= an integer  $n \in \mathbb{Z}$

n gives the order of magnitude of the number



# Functions

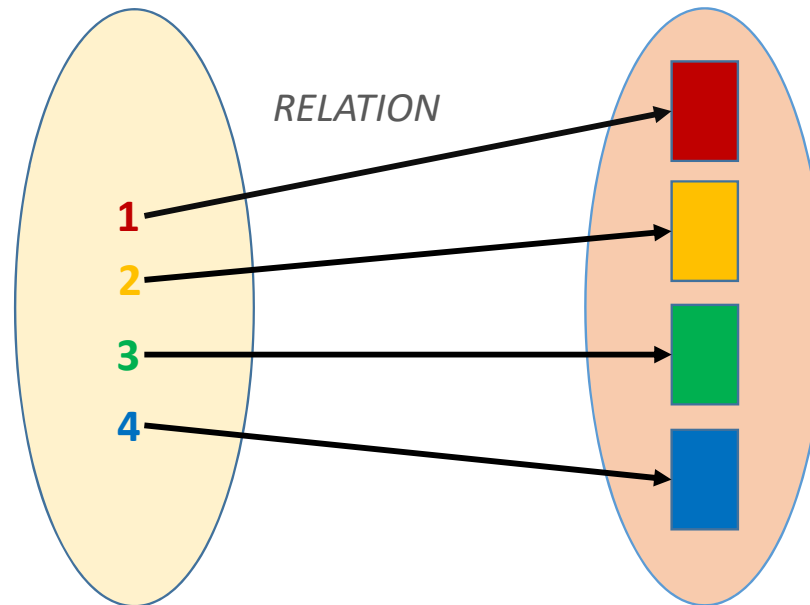
*Independent variable*  
**INPUT**



**f(x) y**  
*Dependent variable*  
**OUTPUT**

**Domain  $D_f$**   
(the possible values for the independent variable)

**Range of the function  $R_f$**   
(the possible values that we can get with our function)



x	f(x) or y
1	Red
2	Orange
3	Green
4	blue

# Linear function

There is only one variable in the equation, the variable is at the first power

$\mathbb{R} \rightarrow \mathbb{R} \quad x \mapsto ax+b \quad a, b \in \mathbb{R} \quad a \neq 0$

The graph of a linear function is a straight line

Rises the same rate everywhere

$y = ax + b$

*slope* (points to  $a$ )

*y axis intercept* (points to  $b$ )

**Dependent variable** (points to  $y$ )

**Independent variable** (points to  $x$ )

x axis intersect

$$0 = ax + b$$

$$x = -\frac{b}{a}$$

In the case of the plotted function

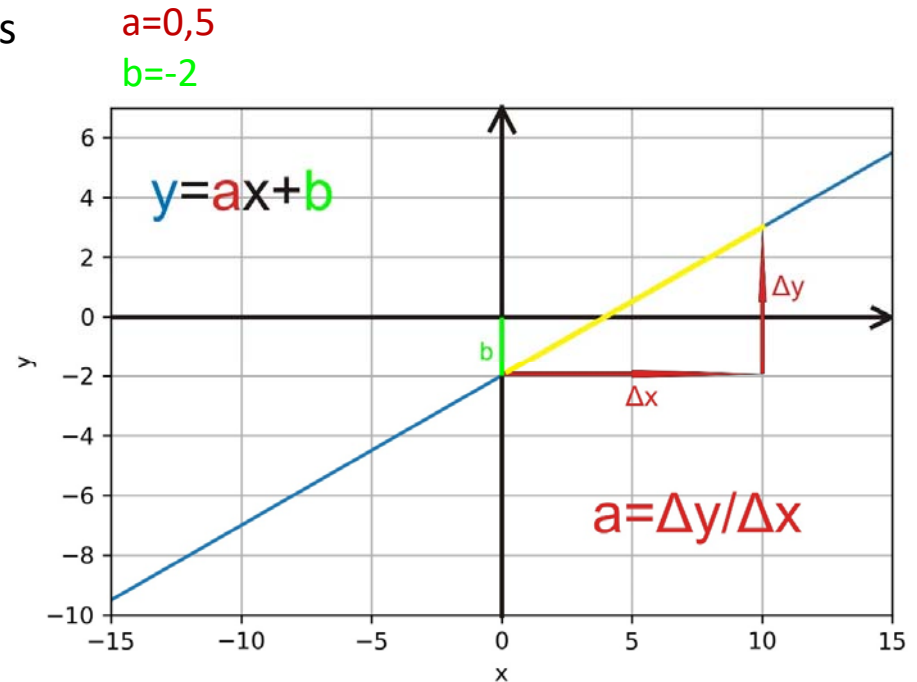
$$0 = 0,5 \cdot x + (-2)$$

$$2 = 0,5x$$

$$x = 4$$

If  $a=0$   
Then  $y=b$

If  $b=0$   
Then  $y=ax$



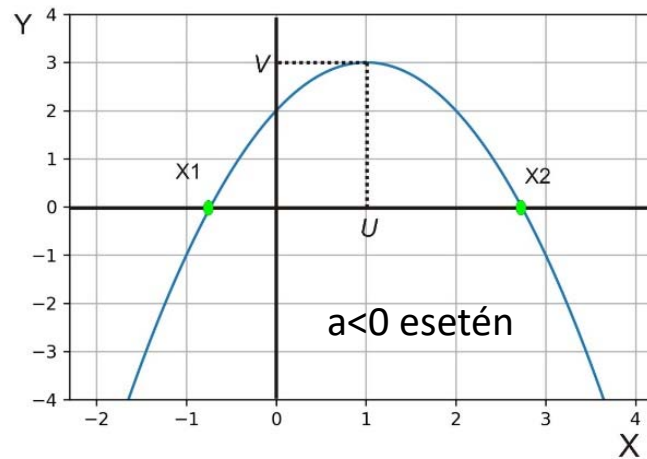
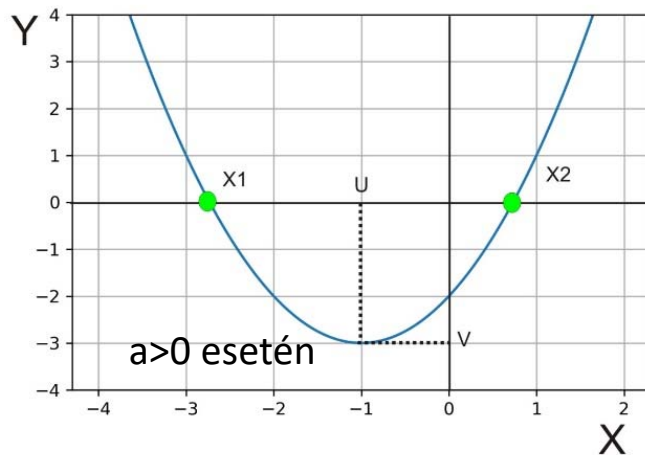
$$a = \Delta y / \Delta x = \tan(\alpha)$$

# Quadratic function

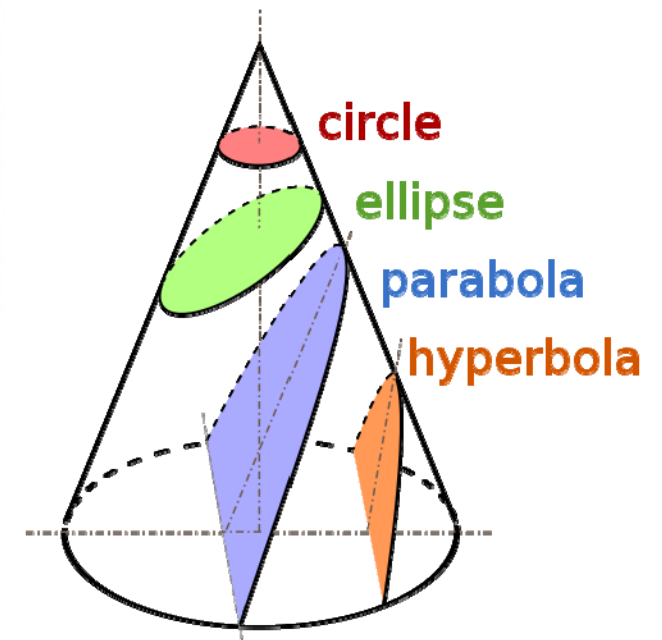
$\mathbb{R} \rightarrow \mathbb{R}, x \mapsto ax^2 + bx + c$   $a, b, c \in \mathbb{R}, a \neq 0$  if  $a=0$  the the function is linear

The graph of a quadratic equation with one variable is a PARABOLA .

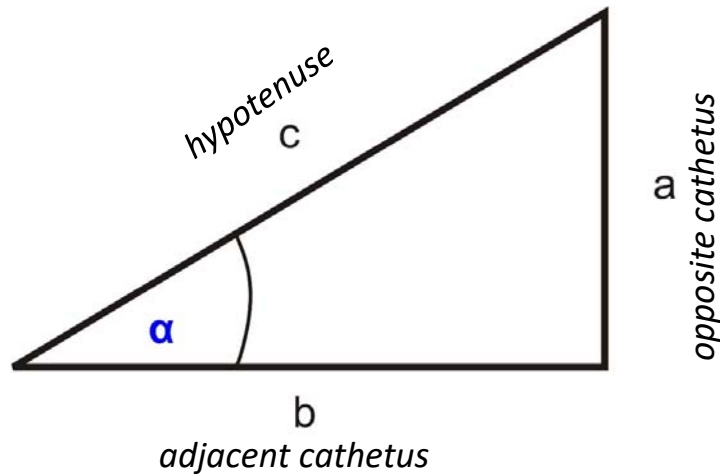
$ax^2 + bx + c = a(x-u)^2 + v$   $u$  and  $v$  gives the coordinates for the vertex of the parabola this is where the curve is the steepest



$U$  and  $V$  are the coordinates for the vertex of the parabola



# Trigonometric functions

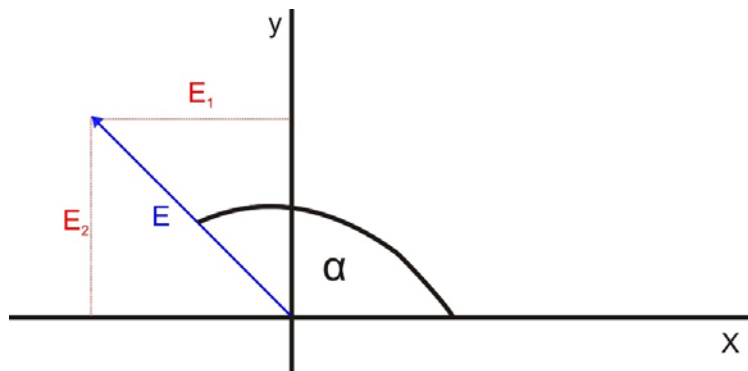


$$\sin(\alpha) = a/c$$

$$\cos(\alpha) = b/c$$

$$\text{tg}(\alpha) = \tan(\alpha) = a/b$$

$$\text{ctg}(\alpha) = b/a$$

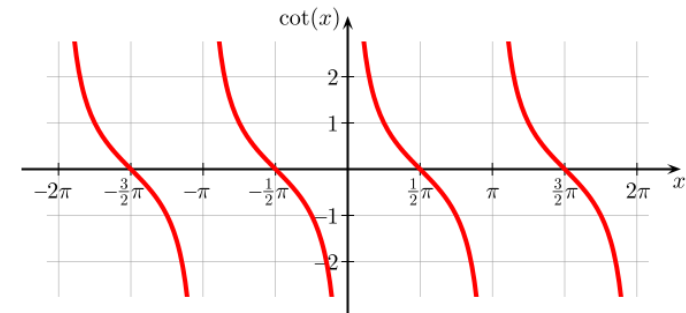
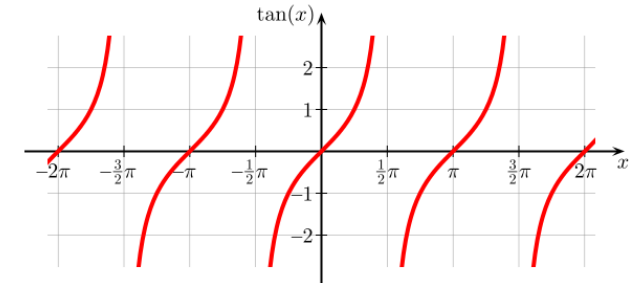
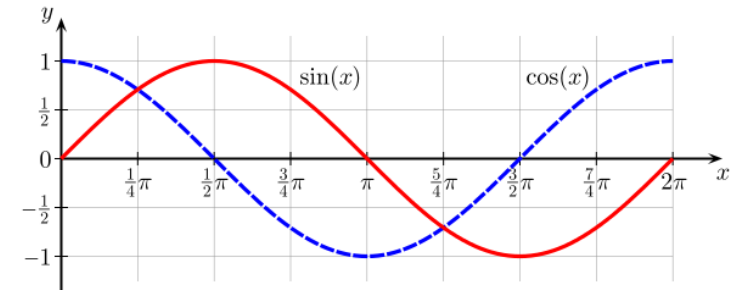


$E$  is a unit vector  
rotated with  $\alpha$  angle

$$\sin(\alpha) = E_2$$

$$\cos(\alpha) = E_1$$

$$\text{tg}(\alpha) = E_2/E_1$$



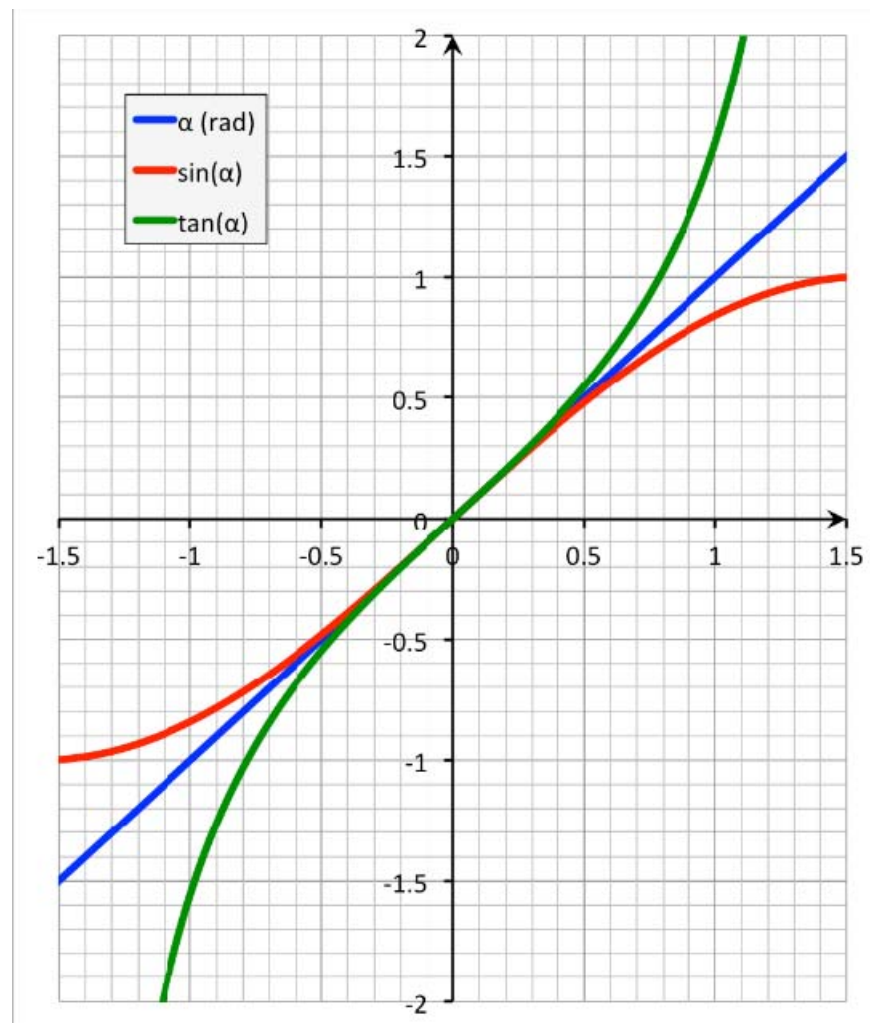


## Trigonometric functions

In case of small angles ( $<10^\circ \approx 0.2$  rad)

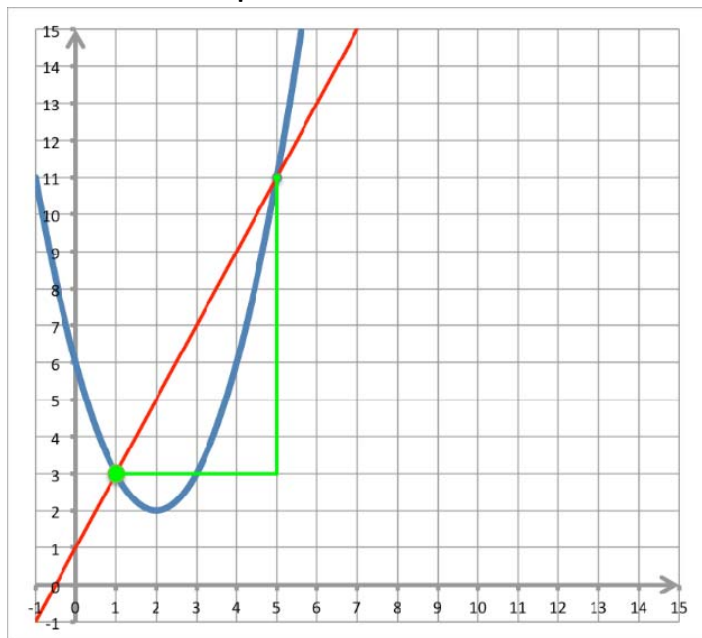
$$\sin(\alpha) \approx \alpha[\text{rad}] \approx \tan(\alpha)$$

szög(°)	radián(rad)	$\sin(\alpha)$	$\tan(\alpha)$
1	0,01745	0,01745	0,01745
2	0,03491	0,03490	0,03492
3	0,05236	0,05233	0,05241
4	0,06981	0,06976	0,06993
5	0,08727	0,08716	0,08749
10	0,1745	0,1736	0,1763



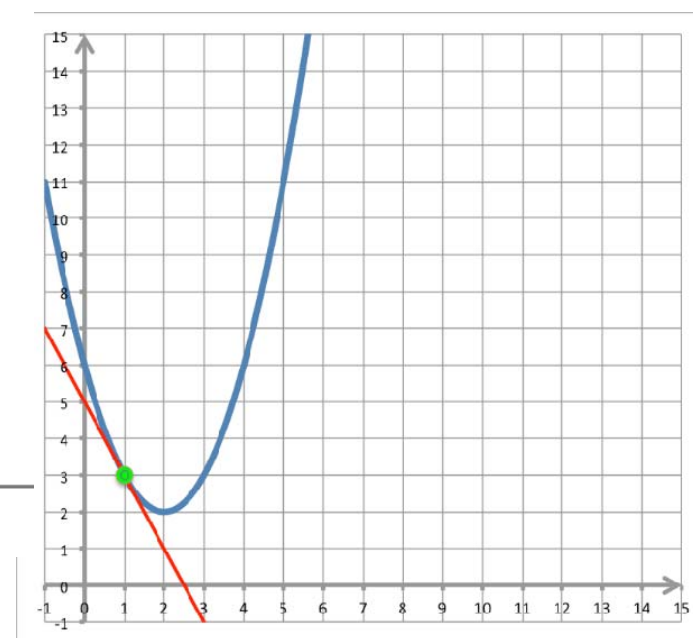
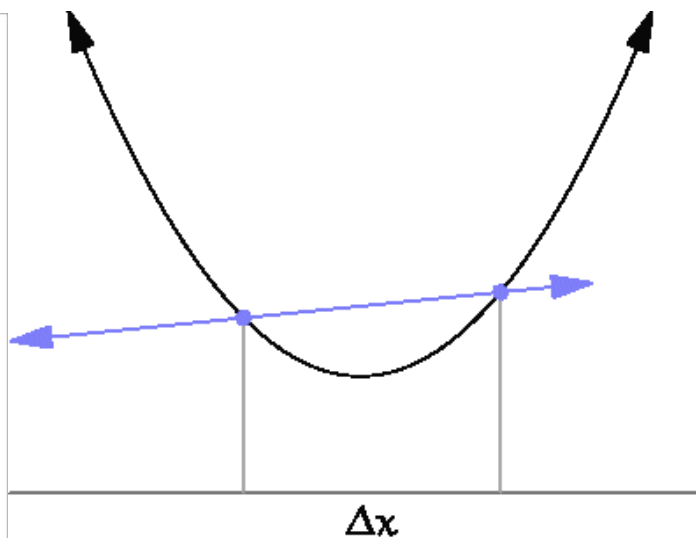
# Differentiation

Difference quotient



$$\frac{f(x) - f(x_0)}{x - x_0}$$

Derivative when the difference quotient is calculated for  $\delta x \rightarrow 0$

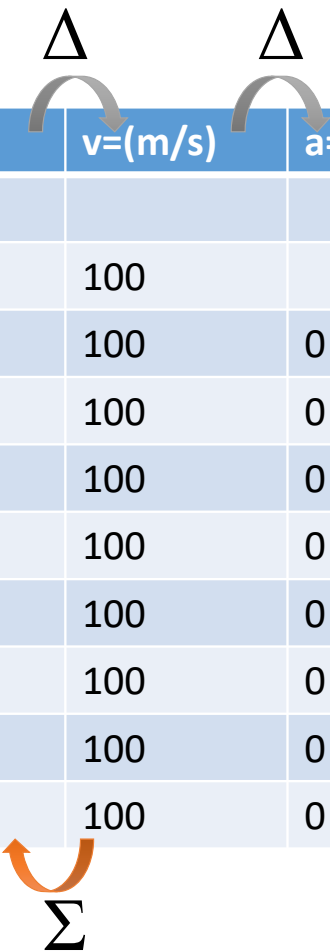


$$\lim_{x \rightarrow x_0} \frac{f(x) - f(x_0)}{x - x_0}$$

## Derivation in the case of simple kinematic problems

Rectilinear Motions  $v=\text{const.}$

Example:  $v=100\text{m/s}$




$t(\text{s})$	$s(\text{m})$	$v(\text{m/s})$	$a(\text{m/s}^2)$
0	0		
1	100	100	
2	200	100	0
3	300	100	0
4	400	100	0
5	500	100	0
6	600	100	0
7	700	100	0
8	800	100	0
9	900	100	0

## 2.Example

Rectilinear Motion with Uniform Acceleration  $a = \text{const.}$

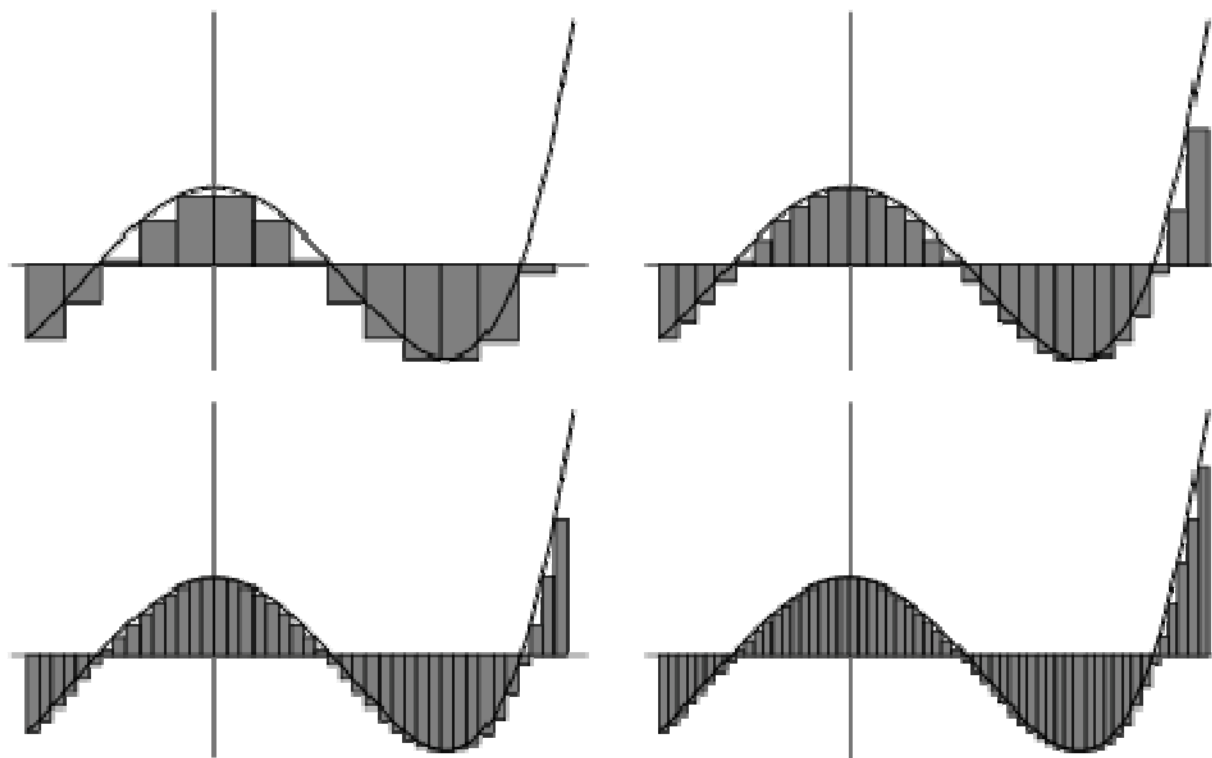
$$a = 2 \text{ (m/s}^2\text{)} \quad v_0 = 100 \text{ m/s}$$



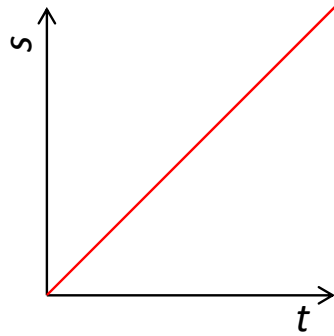
t	s	v (m/s) $\delta t=1\text{s}$	v (m/s) $\delta t=0.01\text{s}$	a (m/s <sup>2</sup> )
0	0	100	100	
1	101	103	102,001	2
2	204	105	104,001	2
3	309	107	106,001	2
4	416	109	108,001	2
5	525	111	110,001	2
6	636	113	112,001	2
7	749	115	114,001	2
8	864	117	116,001	2

## How to calculate an Integral

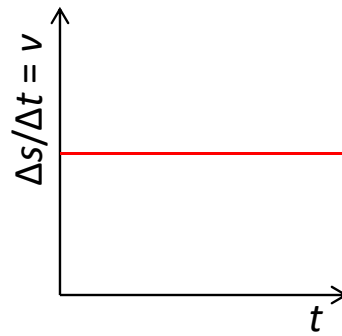
$$\Sigma \rightarrow \int$$



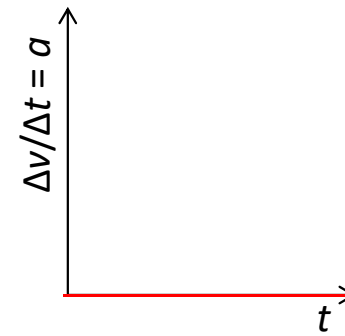
### Uniform Rectilinear Motion:



$$s = v \times t$$

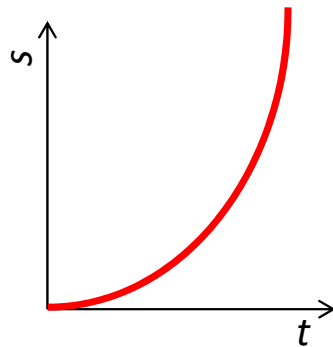


$$v = \text{const.}$$

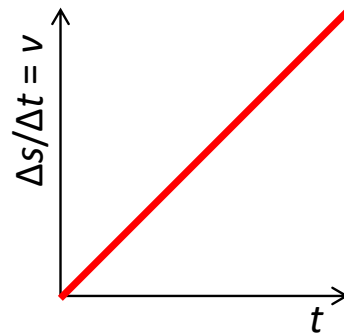


$$a = 0$$

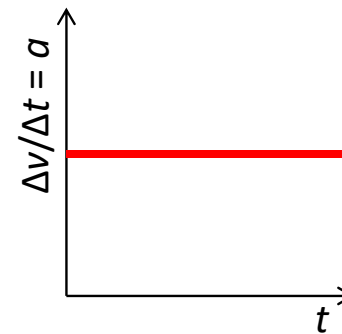
### Rectilinear Motion with Uniform Acceleration:



$$s = v_o \times t + \frac{1}{2} a \times t^2$$



$$v = a \times t$$



$$a = \text{const.}$$

# Physical quantities SI units

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

Types of physical units:

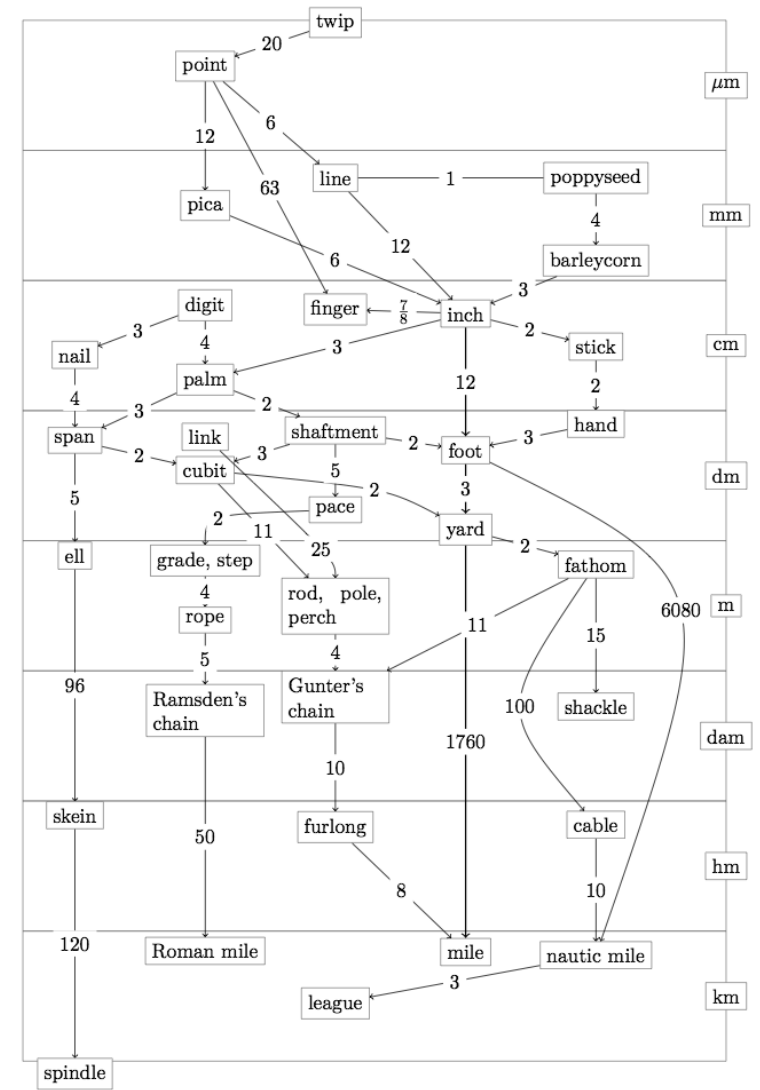
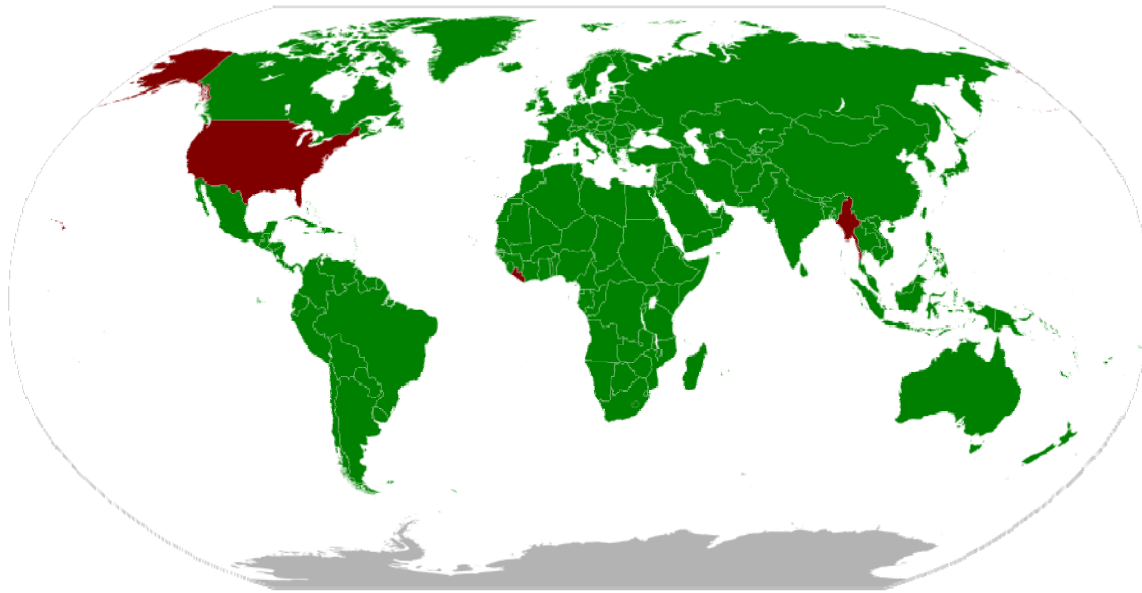
Scalar quantities: a quantity without spatial direction (mass, temperature)

Vektor 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

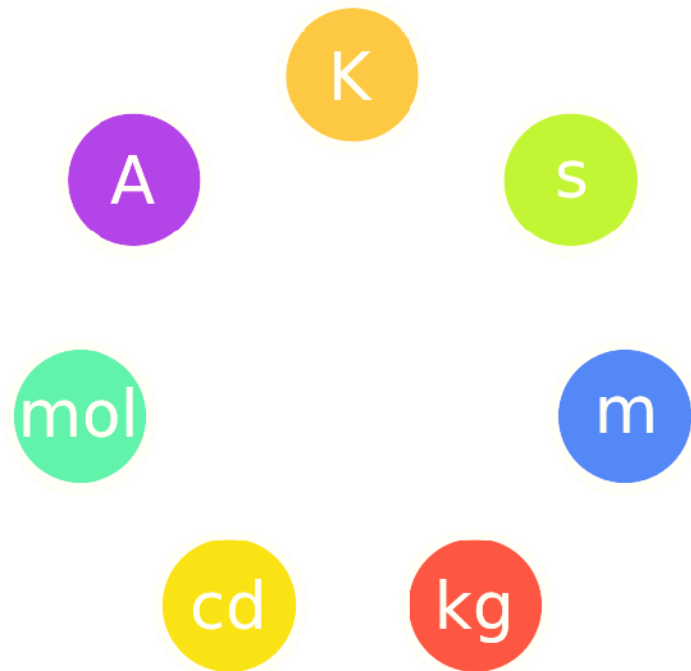
- Speed of light in vacuum ( $3 \cdot 10^8$  m/s)
- Velocity of wave [m/s]
- concentration [mol/m<sup>3</sup>]
- Specific heat capacity [J/kg]

Α α	Β β	Γ γ	Δ δ	Ε ε	Ζ ζ	Η η	Θ θ
ἄλφα	βῆτα	γάμμα	δέλτα	ἔνιλον	ζῆτα	ἦτα	θῆτα
alpha	beta	gamma	delta	epsilon	zeta	eta	theta
a	b	g	d	e	z	ē	th
[a/a:]	[b]	[g]	[d]	[e]	[zd/dz]	[ε:]	[t <sup>h</sup> ]
Ι ι	Κ κ	Λ λ	Μ μ	Ν ν	Ξ ξ	Ο ο	Π π
ἰῶτα	κάππα	λάμβδα	μῦ	νῦ	ξεῖ	ὀμικρόν	πεῖ
iota	kappa	lambda	mu	nu	xi	omikron	pi
i	k	l	m	n	ks/x	o	p
[i/i:]	[k]	[l]	[m]	[n]	[ks]	[o]	[p]
Ρ ρ	Σ σ/ς	Τ τ	Υ υ	Φ φ	Χ χ	Ψ ψ	Ω ω
ῥῶ	σίγμα	ταῦ	ὑνιλον	φεῖ	χεῖ	ψεῖ	ὠμέγα
rho	sigma	tau	upsilon	phi	chi	psi	omega
r/rh	s	t	u/y	ph	kh/ch	ps	ō
[r]	[s/z]	[t]	[y/y:]	[p <sup>h</sup> ]	[k <sup>h</sup> ]	[ps]	[ɔ:]





# 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	$n, N, \nu$ [nu]	mole	mol
luminous intensity	$I_v$	candela	cd

The SI base units

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

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	$\mu$	$10^{-6}$
nano	N	$10^{-9}$
pico	P	$10^{-12}$
femto	F	$10^{-15}$
atto	A	$10^{-18}$
zepto	z	$10^{-21}$
yocto	y	$10^{-24}$