

Mathematical and Physical Basis of Medical Biophysics

Lecture 1

Mathematics Necessary for Understanding Physics
Physical Quantities and Units

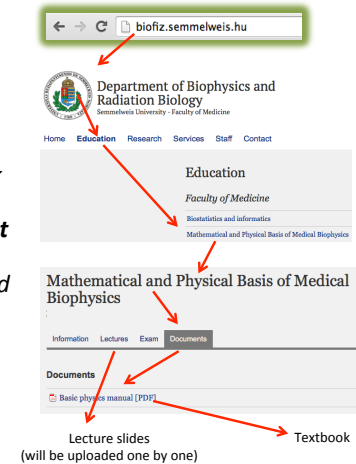
10th September 2018

Gergely AGÓCS

1

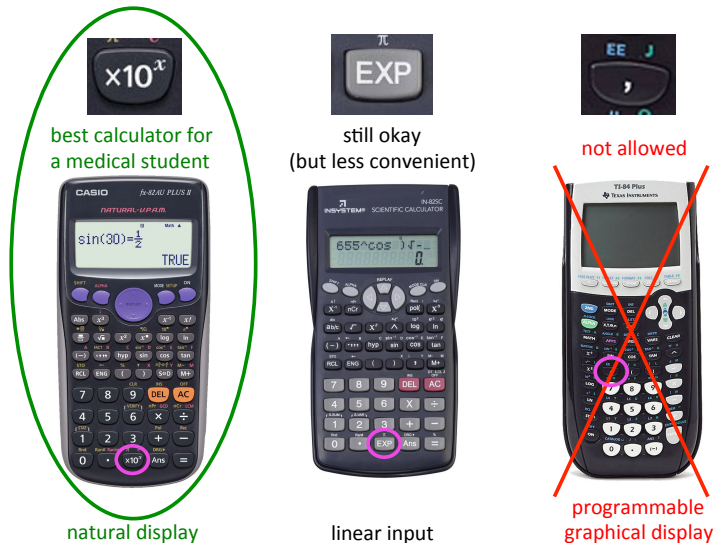
How to Get Prepared?

- university = **autonomous learning**
- sources:
 - **your** notes made in the lectures (*Monday 19³⁰–20⁵⁰; Friday 16¹⁰–17³⁰; EOK "Szent-Györgyi Albert" lecture hall; **only in the first four weeks***)
 - Tölgyesi: *Mathematical and Physical Basis of Medical Biophysics* (2016)
 - homepage: biofiz.semmelweis.hu
 - subject requirements
 - lecture schedule and slides
 - textbook



2

How to Use Scientific Notation?

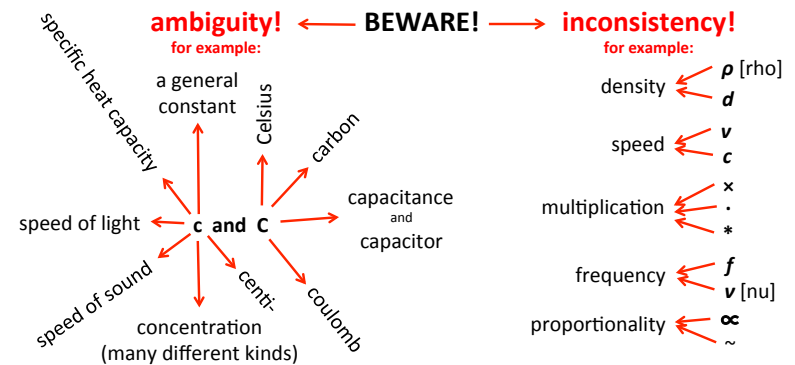


3

Use of Symbols in Science

In science we use a large number of **Latin** and **Greek** letters (and their combinations) as symbols, so it is inevitable to learn the Greek alphabet.

However, the number of quantities and units is much greater than the number of available letters, and this can lead to confusion. Your help: CONTEXT



4

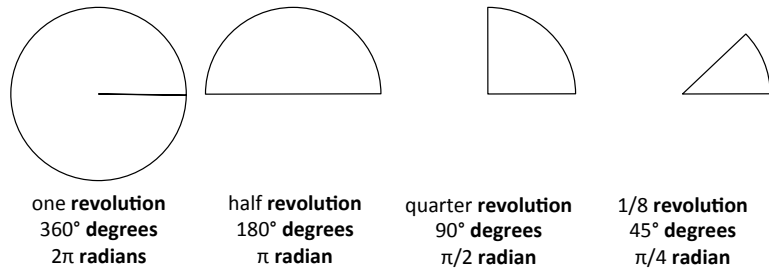
Angles

D: degrees mode
R: radians mode

revolution: one turn
degree: practical, traditional unit
radian: scientific unit, arc/radius

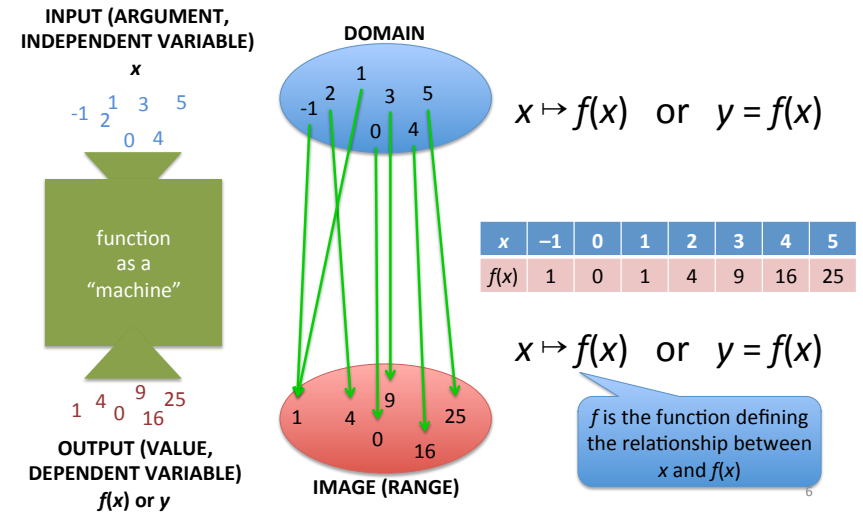
1 revolution = $360^\circ = 2\pi$ rad
 $1^\circ = 60' = 3600''$

~ shift
~ setup
~ 3 (for degrees)
~ 4 (for radians)



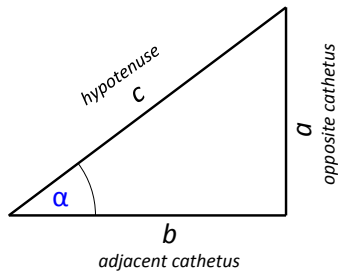
What is a Function?

Unambiguous assignment of one set of values to another set of values



Trigonometric Functions

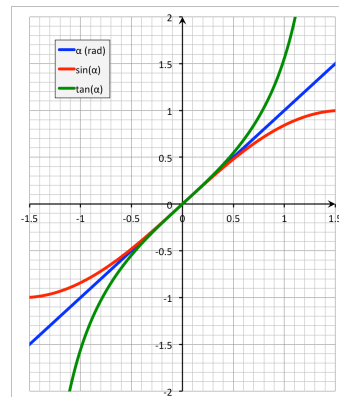
degree: practical, traditional unit
radian: scientific unit, arc/radius
1 revolution = $360^\circ = 2\pi$ rad



sine: $\sin(\alpha) = a/c$
cosine: $\cos(\alpha) = b/c$
tangent: $\tan(\alpha) = tg(\alpha) = a/b$

for small angles ($<10^\circ \approx 0.2$ rad):

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



Linear Function

INTEGRAL FORM

VARIABLES: dependent variable, independent variable

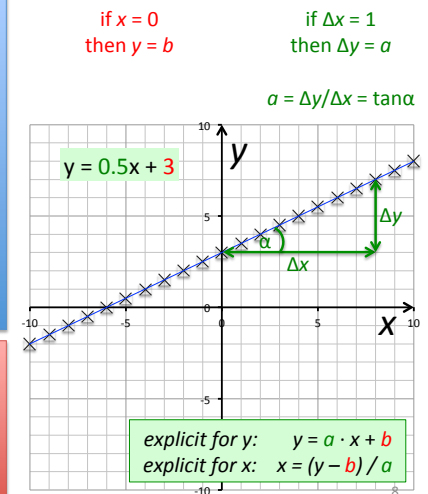
$y = a \cdot x + b$

PARAMETERS: slope (gradient, increment), y-axis intercept

"DIFFERENTIAL" FORM

$\Delta y \propto \Delta x$

The **change** of the dependent variable is proportional to the **change** of the independent variable



Linear Function: Some Examples from the Biophysics Formula Collection

#1: The ideal gas law
(I.35)
 $pV = nRT$ (if n & V are constant)
 $p = nR/V \cdot T + 0$
 $y = a \cdot x + b$

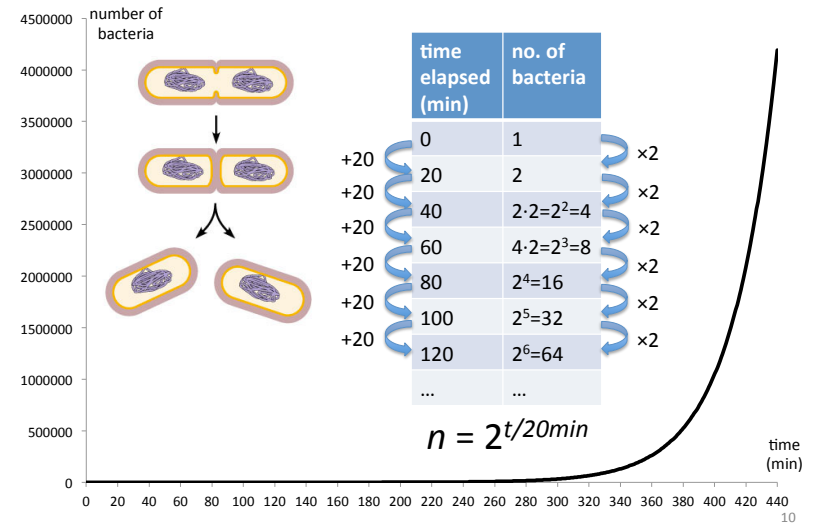
#2: Photoelectric effect
(II.37)
 $E_{\text{kin}} = hf - W_{\text{em}}$
 $E_{\text{kin}} = h \cdot f + (-W_{\text{em}})$
 $y = a \cdot x + b$

#3: Attenuation coefficient
(II.85)
 $\mu = \mu_m \cdot \rho$
 $\mu = \mu_m \cdot \rho + 0$
 $y = a \cdot x + b$

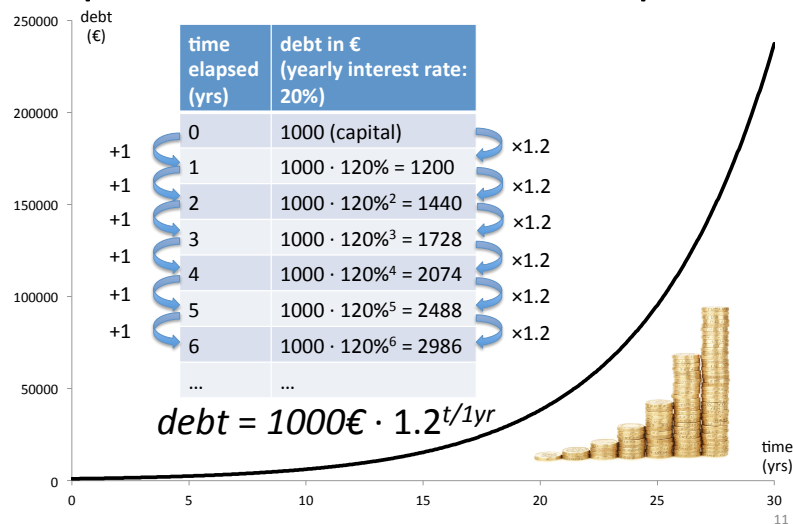
#4: Ohm's law
(II.85)
 $R = U/I$
 $I = 1/R \cdot U + 0$
 $y = a \cdot x + b$

9

Exponential Function: Example #1

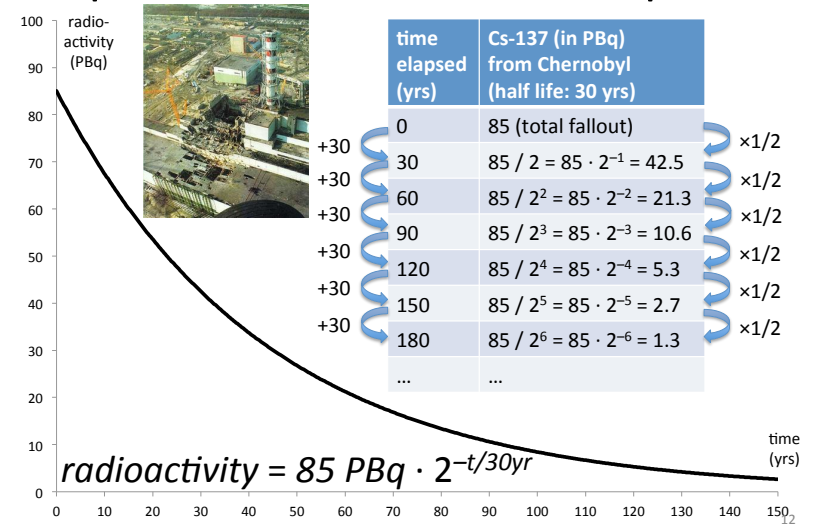


Exponential Function: Example #2



11

Exponential Function: Example #3



Exponential Function

INTEGRAL FORM

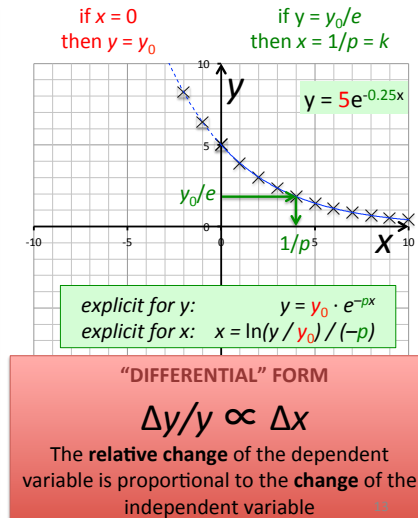
$$y = b \cdot a^x$$

PRACTICAL MODIFICATIONS:

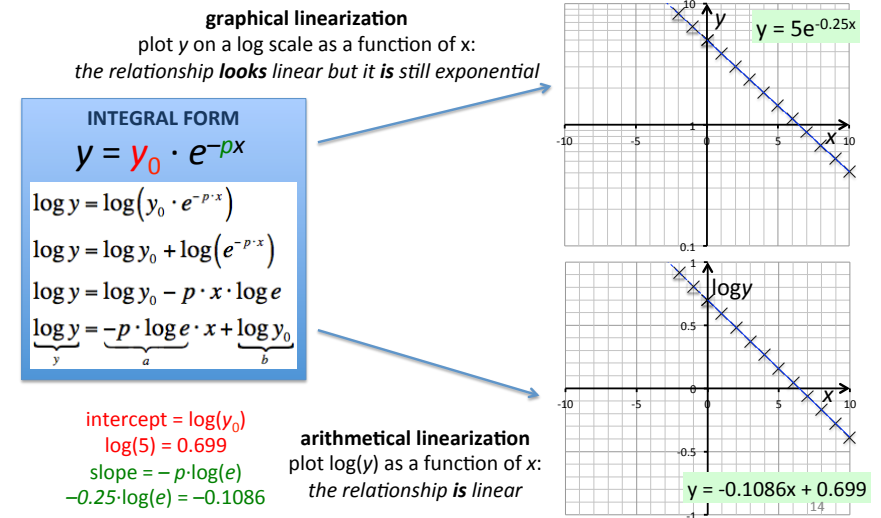
- the base number is preferred to be e
- a new factor parameter p (or $1/k$) is necessary in the exponent
- use a negative sign in the exponent
- b is rather denoted by y_0

VARIABLES: dependent variable y , independent variable x

PARAMETERS: exponential coefficient y_0 , pre-exponential coefficient p (or $1/k$)

$$y = y_0 \cdot e^{-px} = y_0 \cdot e^{-x/k}$$


Exponential Function: Linearization



Exponential Function: Some Examples from the Biophysics Formula Collection

#1: Law of radiation attenuation (II.11)

$$J = J_0 \cdot e^{-\mu x}$$

$$y = y_0 \cdot e^{-px}$$

#2: Boltzmann's distribution (I.25)

$$n_i = n_0 \cdot e^{-\Delta \epsilon / (kT)}$$

$$y = y_0 \cdot e^{-x/k}$$

#3: Decay law (II.96)

$$N = N_0 \cdot e^{-\lambda t}$$

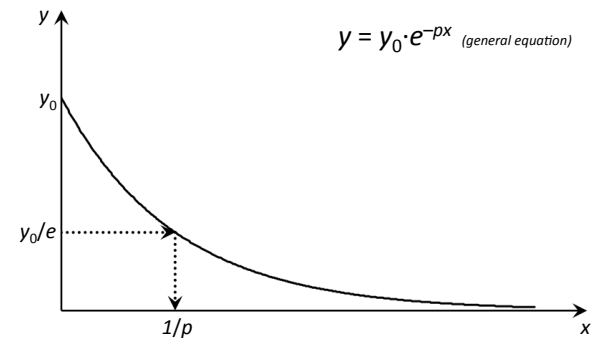
$$y = y_0 \cdot e^{-px}$$

#4: Discharging an RC circuit (VII.2)

$$U = U_0 \cdot e^{-t/(RC)}$$

$$y = y_0 \cdot e^{-x/k}$$

Graph of Exponential Functions from the Biophysics Formula Collection



Graph of Exponential Functions

from the Biophysics Formula Collection

