Subject: Physics 1 (2 lectures/1 exercise)

Lecture topic nr. 1: Introduction into physics

prof. Roman Pašteka, PhD.
Department of engineering geology, hydrogeology and applied geophysics

E-mail: roman.pasteka@uniba.sk

Lecture 1: Introduction into physics

Basic info:

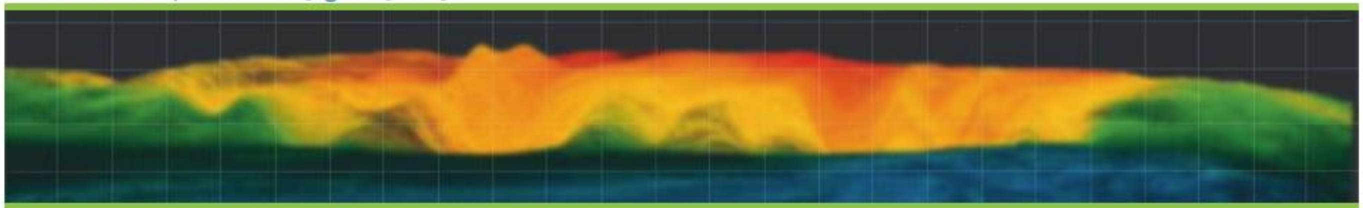
Organisation of the term (semester), study material and evaluation of the subject:

- all lectures are on the website www.kaeg.sk
- evaluation of the subject – 100% final examination (few definitions and solution of exercises), list of all possible questions is on www.kaeg.sk.
- during exercises every week 1 home work exercise will be given to you – this should be evaluated and sent to hamekhani1@uniba.sk. (our PhD. student M.Sc. Farhad Hamekhani), it is a basic condition - to have done all these home work exercises before attending of final examination, on www.kaeg.sk will be published a table with done home work problems.

www.kaeg.sk

Prírodovedecká fakulta Univerzity Komenského v Bratislave

Katedra inžinierskej geológie, hydrogeológie a aplikovanej geofyziky
Oddelenie aplikovanej geofyziky



O nás | Novinky | Zaujímavosti | Výskum | Zamestnanci | Súbory | Fotogaléria

Workshop na tému alpsko-karpatskej gravimetrie

Napísal Kaeg-Doktorand, 21. mája 2024 v Uncategorized @sk

22. a 23. mája sme organizovali medzinárodný workshop "Alpine-Carpathian Gravimetry," počas ktorého sme na našej fakulte privítali odborníkov na gravimetriu z rôznych kútov Európy.

Slovenčina
Angličtina

Hľadať

zadajte výraz...

Rýchla navigácia

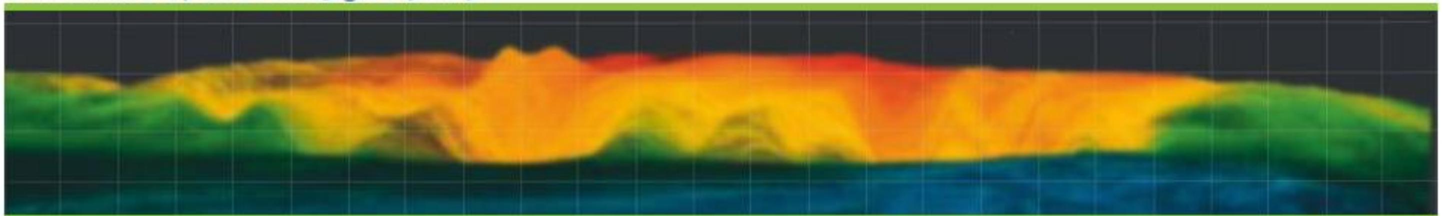
- Fotogaléria
- Novinky
- O nás
- Súbory
  - Učebné texty
  - Iné
- Výskum
  - Projekty APVV
    - Project APVV-0194-10

study materials

www.kaeg.sk

Prírodovedecká fakulta Univerzity Komenského v Bratislave

Katedra inžinierskej geológie, hydrogeológie a aplikovanej geofyziky
Oddelenie aplikovanej geofyziky



O nás | Novinky | Zaujímavosti | Výskum | Zamestnanci | Súbory | Fotogaléria

Učebné texty

Slovenčina

Predmet: Fyzika, 1. roč. bak. Geológia a Geológia vo využívaní krajiny

in the bottom part of the page

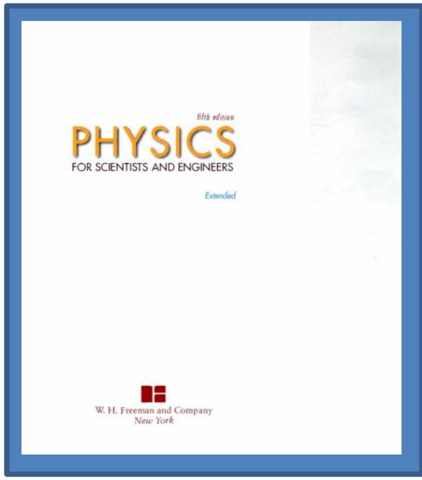
Subject: Physics 1 (Biological Chemistry)

1. Introduction: Physics for BCH – topic 1
2. Mechanics: Physics for BCH – topic 2
3. Oscillations and waves: Physics for BCH – topic 3
4. Thermodanymics: Physics for BCH – topic 4
5. Electricity: Physics for BCH – topic 5
6. Magnetism: Physics for BCH – topic 6

List of Fundamental physical constants and values

Physics 1: possible questions

Lecture 1: Introduction into physics



Basic literature:

Tipler P.A. and Mosca G., 2014 :
Physics for scientists and engineers. Freeman and Co, New York

Schiller Ch., 2016:
Motion Mountain, The adventure of physics – vol. I – VI.
(free download under „Physics - free and fun“)

- lectures from this class (www.kaeg.sk)
- Additional literature + internet sources:
Feynman lectures on physics, Physics - free and fun, wiki, …

For Slovak students we recommend a Slovak text-book for terminology:
Zemanová A., 2014: Anglický jazyk pre študentov FMFI UK, Fyzika, UK v Bratislave

Lecture 1: Introduction into physics

Content:

- introduction into physics
- branches in physics
- basic forces in physics (nature)
- physical quantities and their units
- basic units (SI system)
- formalism: calculus, scalars, vectors, tensors
- problem solving strategy

Introduction into physics

Physics is the natural science that involves the study of **matter and its motion through space and time**, along with related concepts such as energy and force.

It is one of the most fundamental scientific disciplines, the main goal of physics is to understand how the universe behaves.

The word physics has been derived from the from ancient Greek: φυσική = phusiké , which means the **knowledge of nature**.

Comment: What means Biology? (Bios-life, logos- the study of). So biology is the study of life.

Introduction into physics

Physics – two main branches:

Classical physics:

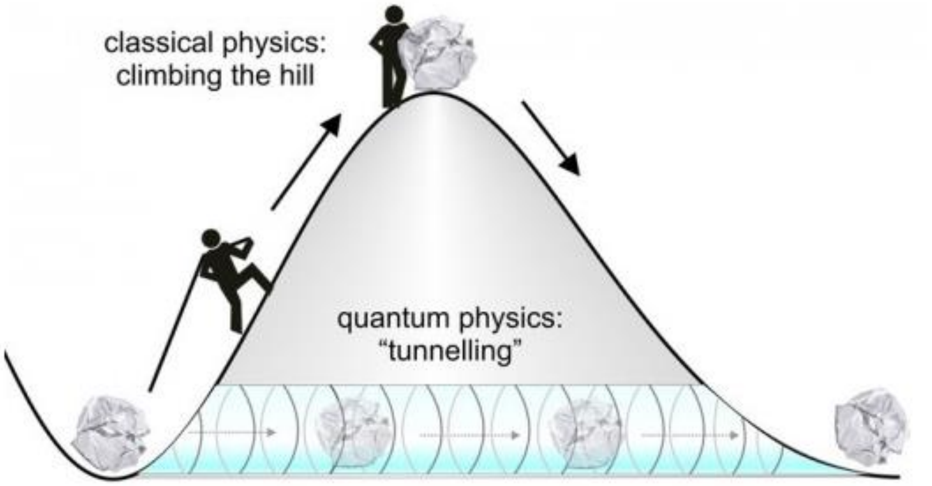
- is mainly concerned with the laws of motion and gravitation, kinetic theory, thermodynamics and classical electromagnetism,
- important contributors: I. Newton and J. C. Maxwell,
- **energy and matter** are **considered as separate entities,**
- **understands time as independent and stable entity,**

Modern physics:

- is mainly concerned with the theory of relativity and quantum mechanics,
- important pioneers: Albert Einstein, Max Plank, Nils Bohr…,
- energy and matter are not considered as separate entities; rather **they are considered as different forms of each other.**
- **time is a more complicated topic, often part of the time-space,**

Physics – main topics in this term:

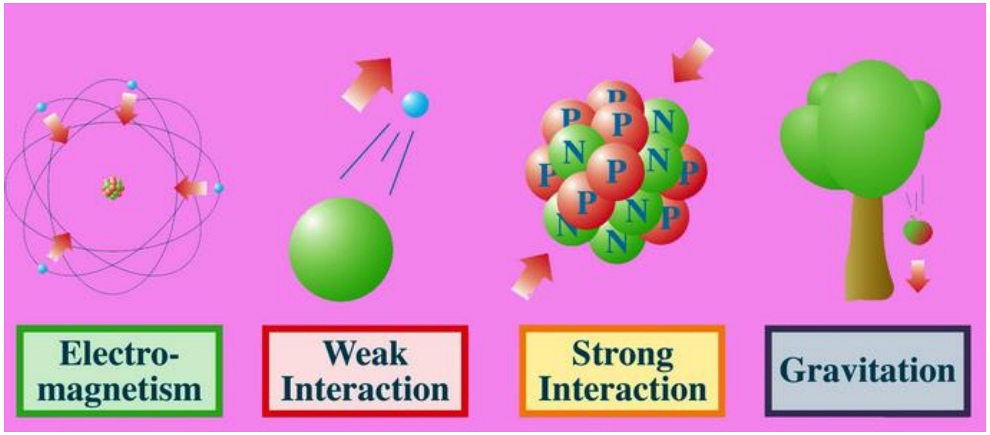
- mechanics,
- acoustics,
- thermodynamics,
- electrics,
- magnetism.



Fundamental forces (interactions) in physics:

1. Gravitational: interaction of mass objects.
2. Electromagnetic: acting of electrically charged objects and influence of electric/magnetic fields.
3. Strong nuclear: binds protons and neutrons (nucleons) together to form the nucleus of an atom.
4. Week nuclear: acting of light elementary particles (leptons) among each other.

Discussed is also the so called 5th force (kind of gravitational force, which could be dependent on the kind of matter).



Fundamental forces (interactions) in physics:

The four fundamental interactions of nature

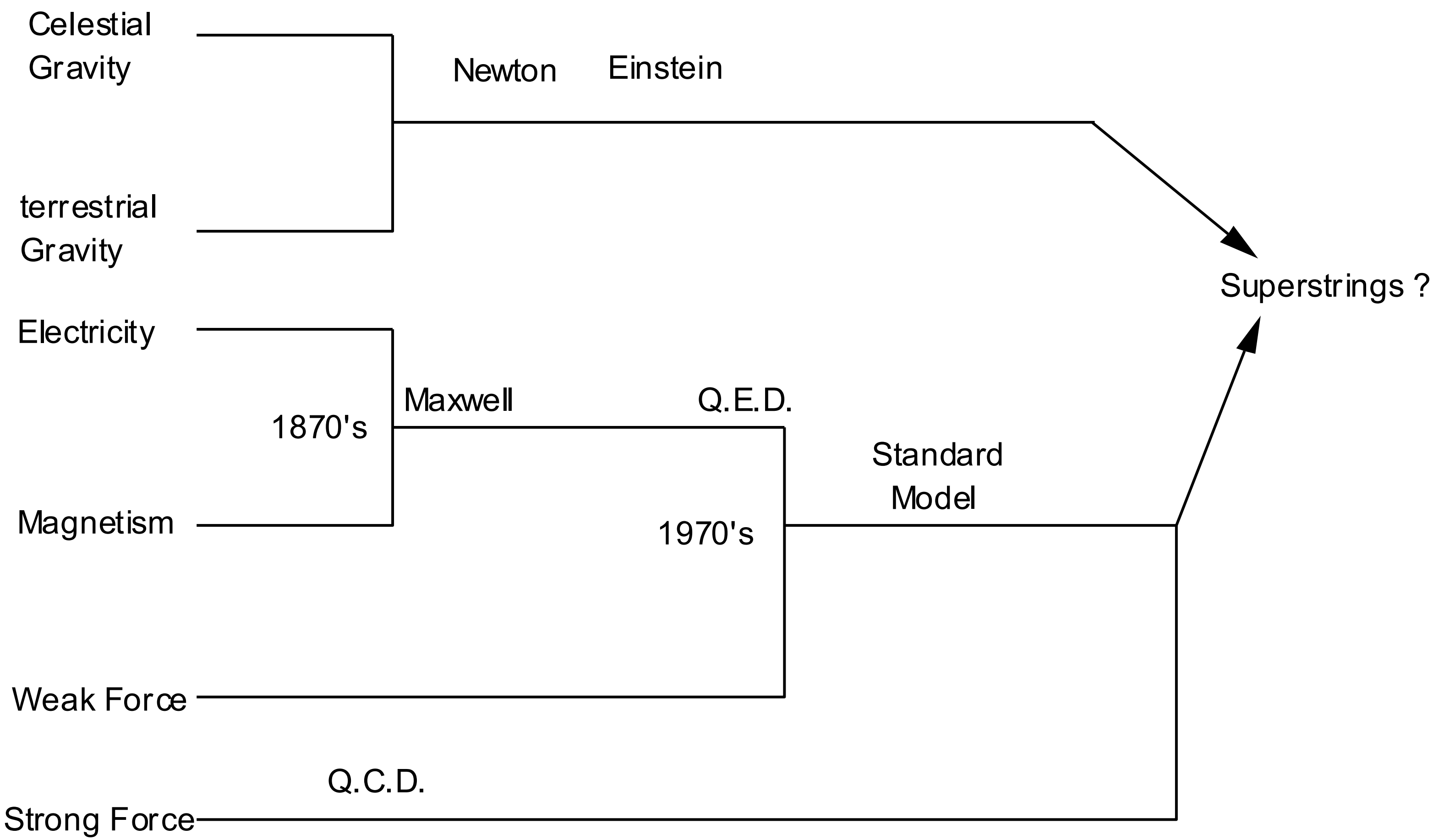
Property/Interaction	Gravitation	Weak	Electromagnetic	Strong	
		(Electroweak)		Fundamental	Residual
Acts on:	Mass - Energy	Flavor	Electric charge	Color charge	Atomic nuclei
Particles experiencing:	All	Quarks, leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Not yet observed (Graviton hypothesised)	$W^+ W^- Z^0$	γ (photon)	Gluons	Mesons
Strength at the scale of quarks:	10^{-41}	10^{-4}	1	60	Not applicable to quarks
Strength at the scale of protons/neutrons:	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

Some theoretical physicists seek to quantize the gravitational field – theory of **quantum gravity** (QG).

Other theorists seek to unite the electroweak and strong fields within a **Grand Unified Theory** (GUT).

Trials to put everything together - so called **Theory of Everything** (ToE).

Fundamental forces (interactions) in physics:



Comment: Q.E.D. - Quantum Electrodynamics, Q.C.D. - Quantum Chromodynamics,

From the history:

1930: Bohr, after learning of the Dirac equation (for the electron), said, *"Physics as we know it will be over in six months.“*

Physical quantities and units:

Physical quantities must always have ***units (dimensions).***

We know basic and derived units.

Units often carry the name of some important physicist.

Units will be often given in brackets [ ], in this lecture.

Physical quantities and units:

Physical quantities must always have ***dimensions (units).***

Units will be often given in brackets [ ] in this lecture.

We can only compare quantities with the same dimensions

$v = s/t$

unit = length/time = [m/s] or [km/h]

Or:

$v = v(0) + a \cdot t$

unit = length/time + length/time^2 · time

Comparing quantities with <u>different</u> <u>dimensions</u> is <u>nonsense</u>

$v = a \cdot t^2$

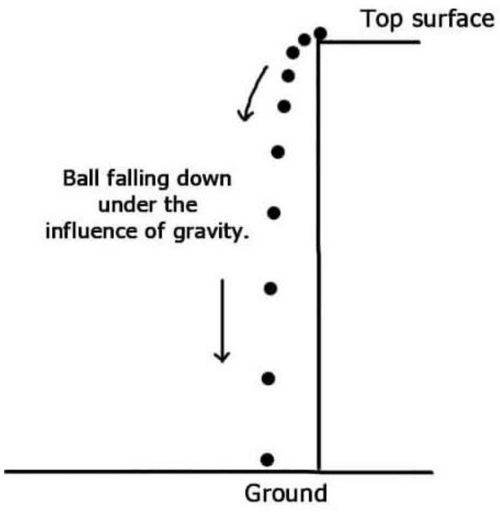
unit = length/time^2 · time^2 = length…???

<u>Meaning of symbols in this example</u>:

v – velocity, s – length, t – time, a – acceleration.

Physical quantities and units:

next example (free fall equation):

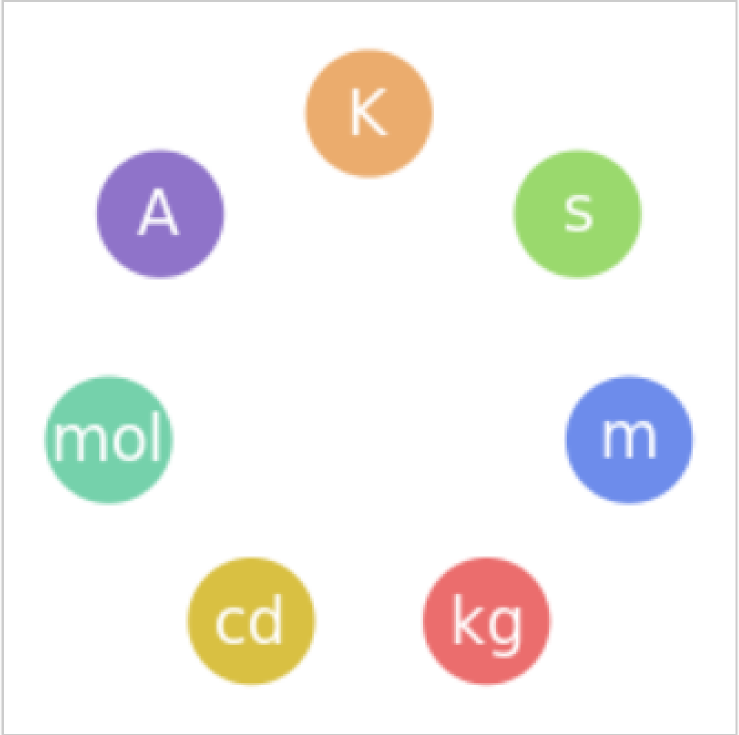


$$h_2 - h_1 = vt + \frac{1}{2}at^2$$

- $h_2 - h_1$: length
- vt: length/time·time = length
- $\frac{1}{2}at^2$: length/time^2·time^2 = length

International System of Units (SI) in physics:

There are several units systems, the most important is the SI system:



The seven base units in the International System of Units

7 basic units

International System of Units (SI) in physics:

SI base units

Unit name	Unit symbol	Quantity name	Definition (incomplete)[n 1]
metre	m	length	• **Original** (1793): $\frac{1}{10\,000\,000}$ of the meridian through Paris between the North Pole and the Equator.[FG] • **Interim** (1960): 1 650 763.73 wavelengths in a vacuum of the radiation corresponding to the transition between the $2p^{10}$ and $5d^{5}$ quantum levels of the krypton-86 atom. • ~~**Current**~~ (1983): The distance travelled by light in vacuum in $\frac{1}{299\,792\,458}$ second.
kilogram[n 2]	kg	mass	• **Original** (1793): The **grave** was defined as being the weight [mass] of one cubic decimetre of pure water at its freezing point.[FG] • ~~**Current**~~ (1889): The mass of the international prototype kilogram.
second	s	time	• **Original** (Medieval): $\frac{1}{86\,400}$ of a day. • **Interim** (1956): $\frac{1}{31\,556\,925.9747}$ of the tropical year for 1900 January 0 at 12 hours ephemeris time. • ~~**Current**~~ (1967): The duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom.

basic units

International System of Units (SI) in physics:

Unit name	Unit symbol	Quantity name	Definition (incomplete)[n 1]
ampere	A	electric current	• **Original** (1881): A tenth of the electromagnetic CGS unit of current. The [CGS] electromagnetic unit of current is that current, flowing in an arc 1 cm long of a circle 1 cm in radius creates a field of one oersted at the centre.[39] IEC • ~~**Current**~~ (1946): The constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newtons per metre of length.
kelvin	K	thermodynamic temperature	• **Original** (1743): The **centigrade scale** is obtained by assigning 0 °C to the freezing point of water and 100 °C to the boiling point of water. • **Interim** (1954): The triple point of water (0.01 °C) defined to be exactly 273.16 K.[n 3] • ~~**Current**~~ (1967): $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water
mole	mol	amount of substance	• **Original** (1900): The molecular weight of a substance in mass grams.ICAW • ~~**Current**~~ (1967): The amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12.[n 4]
candela	cd	luminous intensity	• **Original** (1946): The value of the new candle is such that the brightness of the full radiator at the temperature of solidification of platinum is 60 new candles per square centimetre. • ~~**Current**~~ (1979): The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of $\frac{1}{683}$ watt per steradian.

basic units

Named units derived from SI base units

Name	Symbol	Quantity	Expressed in terms of other SI units	Expressed in terms of SI base units
radian	rad	angle		$m \cdot m^{-1}$
steradian	sr	solid angle		$m^2 \cdot m^{-2}$
hertz	Hz	frequency		s^{-1}
newton	N	force, weight		$kg \cdot m \cdot s^{-2}$
pascal	Pa	pressure, stress	N/m^2	$kg \cdot m^{-1} \cdot s^{-2}$
joule	J	energy, work, heat	$N \cdot m$	$kg \cdot m^2 \cdot s^{-2}$
watt	W	power, radiant flux	J/s	$kg \cdot m^2 \cdot s^{-3}$
coulomb	C	electric charge or quantity of electricity		$s \cdot A$
volt	V	voltage (electrical potential difference), electromotive force	W/A	$kg \cdot m^2 \cdot s^{-3} \cdot A^{-1}$
farad	F	electric capacitance	C/V	$kg^{-1} \cdot m^{-2} \cdot s^4 \cdot A^2$
ohm	Ω	electric resistance, impedance, reactance	V/A	$kg \cdot m^2 \cdot s^{-3} \cdot A^{-2}$
siemens	S	electrical conductance	A/V	$kg^{-1} \cdot m^{-2} \cdot s^3 \cdot A^2$
weber	Wb	magnetic flux	$V \cdot s$	$kg \cdot m^2 \cdot s^{-2} \cdot A^{-1}$
tesla	T	magnetic field strength	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
henry	H	inductance	Wb/A	$kg \cdot m^2 \cdot s^{-2} \cdot A^{-2}$
degree Celsius	°C	temperature relative to 273.15 K		K
lumen	lm	luminous flux	$cd \cdot sr$	cd
lux	lx	illuminance	lm/m^2	$m^{-2} \cdot cd$
becquerel	Bq	radioactivity (decays per unit time)		s^{-1}
gray	Gy	absorbed dose (of ionizing radiation)	J/kg	$m^2 \cdot s^{-2}$
sievert	Sv	equivalent dose (of ionizing radiation)	J/kg	$m^2 \cdot s^{-2}$
katal	kat	catalytic activity		$mol \cdot s^{-1}$

Notes

1. The radian and steradian, once given special status, are now considered dimensionless derived units.[33]:3
2. The ordering of this table is such that any derived unit is based only on base units or derived units that precede it in the table.

derived units

repetition – prefixes of units:

Prefix	Symbol	10^n	Decimal	Short scale	Long scale	Since
yotta	Y	10^{24}	1 000 000 000 000 000 000 000 000	Septillion	Quadrillion	1991
zetta	Z	10^{21}	1 000 000 000 000 000 000 000	Sextillion	Trilliard	1991
exa	E	10^{18}	1 000 000 000 000 000 000	Quintillion	Trillion	1975
peta	P	10^{15}	1 000 000 000 000 000	Quadrillion	Billiard	1975
tera	T	10^{12}	1 000 000 000 000	Trillion	Billion	1960
giga	G	10^{9}	1 000 000 000	Billion	Milliard	1960
mega	M	10^{6}	1 000 000	Million		1960
kilo	k	10^{3}	1 000	Thousand		1795
hecto	h	10^{2}	100	Hundred		1795
deca	da	10^{1}	10	Ten		1795
		10^{0}	1	One		–
deci	d	10^{-1}	0.1	Tenth		1795
centi	c	10^{-2}	0.01	Hundredth		1795
milli	m	10^{-3}	0.001	Thousandth		1795
micro	µ	10^{-6}	0.000 001	Millionth		1960
nano	n	10^{-9}	0.000 000 001	Billionth	Milliardth	1960
pico	p	10^{-12}	0.000 000 000 001	Trillionth	Billionth	1960
femto	f	10^{-15}	0.000 000 000 000 001	Quadrillionth	Billiardth	1964
atto	a	10^{-18}	0.000 000 000 000 000 001	Quintillionth	Trillionth	1964
zepto	z	10^{-21}	0.000 000 000 000 000 000 001	Sextillionth	Trilliardth	1991
yocto	y	10^{-24}	0.000 000 000 000 000 000 000 001	Septillionth	Quadrillionth	1991

International System of Units (SI) in physics:

New definitions – from 20 May 2019 !

Problems with the international *kg* prototype,

- made in 1889, saved in BIPM close to Paris,
- alloy of Platinum (90%) and Iridium (10%)
- 40 copies all around the world
- checked in 1946 and 1989

The international prototype of the kilogram is inside three nested bell jars at the Bureau International des Poids et Mesures in Paris.

- it has lost its mass (in 1989 approx. -100 μg!)
- unknown reasons (lost of hydrogen atoms?,
  wearing away atoms during manipulation?,
  sticking molecules of air on the copies?...)
- definition of *kg* is influencing also other units..

There was an urgent need to accept new definitions!

constants:

Table of universal constants

Quantity V·T·E	Symbol	Value[8][9]	Relative Standard Uncertainty
speed of light in vacuum	c	299 792 458 $m \cdot s^{-1}$	defined
Newtonian constant of gravitation	G	6.674 08(31) × 10^{-11} $m^3 \cdot kg^{-1} \cdot s^{-2}$	4.7 × 10^{-5}
Planck constant	h	6.626 070 040(81) × 10^{-34} J·s	1.2 × 10^{-8}
reduced Planck constant	$\hbar = h/(2\pi)$	1.054 571 800(13) × 10^{-34} J·s	1.2 × 10^{-8}

...electromagnetic constants, atomic and nuclear constants, physico-chemical constants, adopted values (elementary charge, Boltzman const., Avogadro const.,...)

New definitions of SI units are founded on basic physical constants!

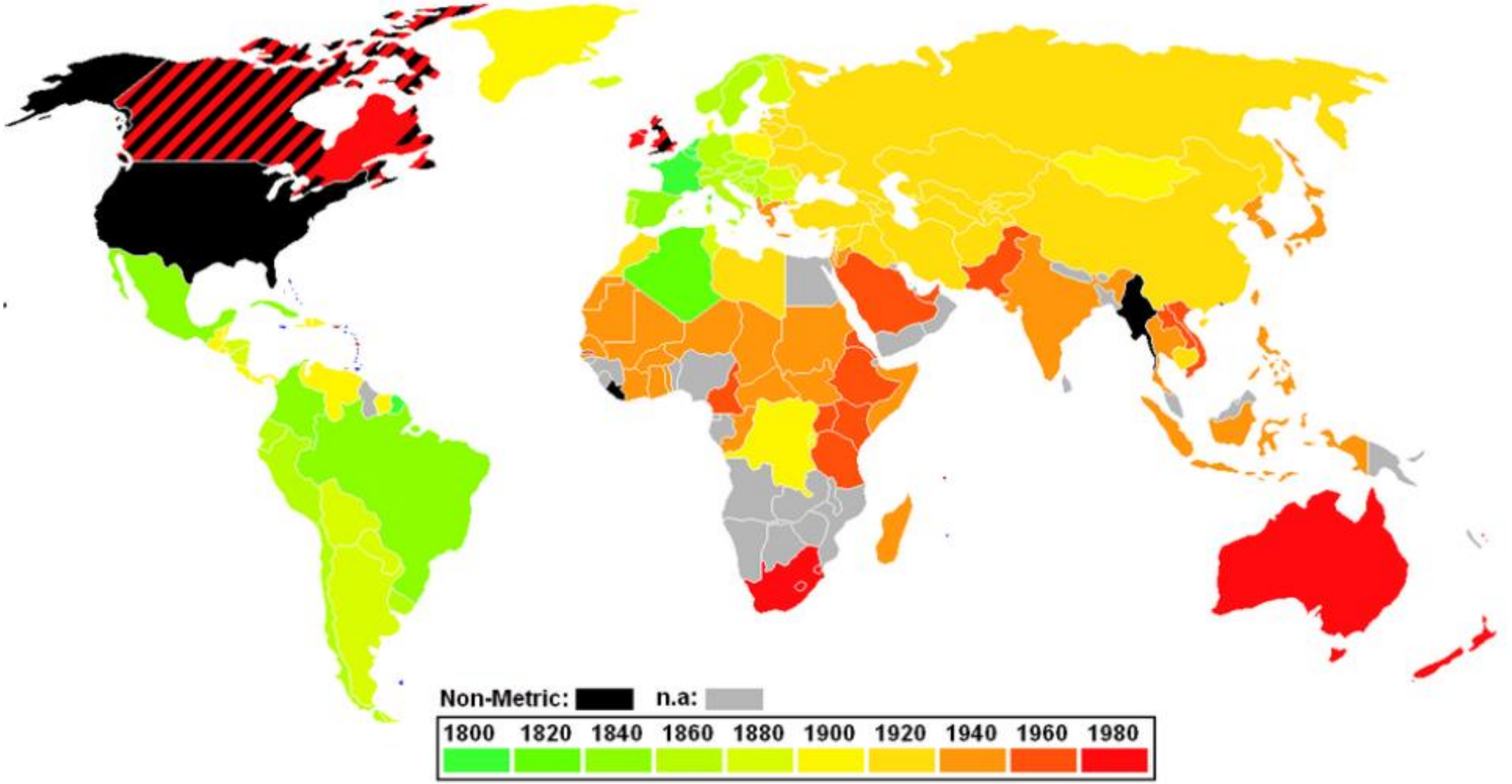
Physical constant

A physical constant (sometimes fundamental physical constant or universal constant) is a physical quantity that is generally believed to be both universal in nature and have constant value in time.

It is distinct from a mathematical constant, which has a fixed numerical value, but does not directly involve any physical measurement.

c	velocity of light in vacuum
h	Planck's constant
$\hbar$	$(= h/2\pi)$
e	electronic charge
μ_e	electron magnetic moment
μ_B	Bohr magneton
μ_N	nuclear magneton
m_e	electron mass
m_P	proton mass
m_N	neutron mass
k_B	Boltzmann's constant
N_A	Avogadro's constant
R	molar gas constant
F	Faraday constant

International System of Units (SI) in physics:



World map showing metrication, colour-coded by year of conversion: from ca 1800 (green) to 1980 (red).

Black indicates the nations that have not yet adopted the SI-system: Burma, Liberia, and the United States. Canada and the United Kingdom both have fairly common use of previously used units.

mathematical apparatus in physics

don't be scared !

Calculus – derivatives and integrals express in a much better way the infinitesimal properties of various parameters.

e.g.: velocity – when it is constant, then v = s/t

but when it is not a constant value...(?)

$$v = \frac{ds}{dt} = s' \quad \left[\mathrm{m \cdot s^{-1}}\right]$$

e.g.: work – when the force is constant, then A = F·s, when not:

$$A = \int_S \vec{F} \cdot d\vec{s} \quad [\mathrm{J}] = [\mathrm{N \cdot m}]$$

mathematical apparatus in physics

scalars (they do have only size/magnitude
(time, temperature,...)

t

vectors (they have size and direction)
(strength, velocity, ...)

$\vec{F}$ or $\mathbf{F}$

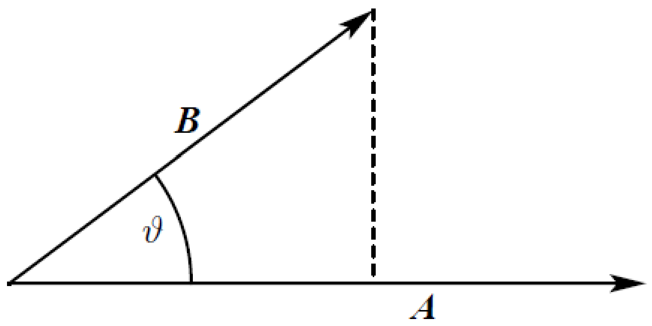
tensors (generalisation of a vector –
they have several dimensions)
(press, susceptibility...)

$\overline{T}$

mathematical apparatus in physics

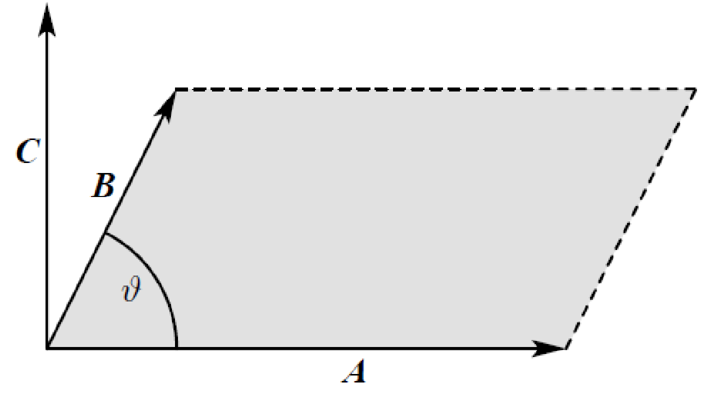
Multiplication of vectors

scalar product (result is scalar): $\boldsymbol{A} \cdot \boldsymbol{B} = |\boldsymbol{A}|\,|\boldsymbol{B}| \cos\vartheta,$



vector product (result is vector):

$\boldsymbol{A} \times \boldsymbol{B} = \boldsymbol{C} \qquad |\boldsymbol{C}| = |\boldsymbol{A}|\,|\boldsymbol{B}| \sin\vartheta,$



mathematical apparatus in physics

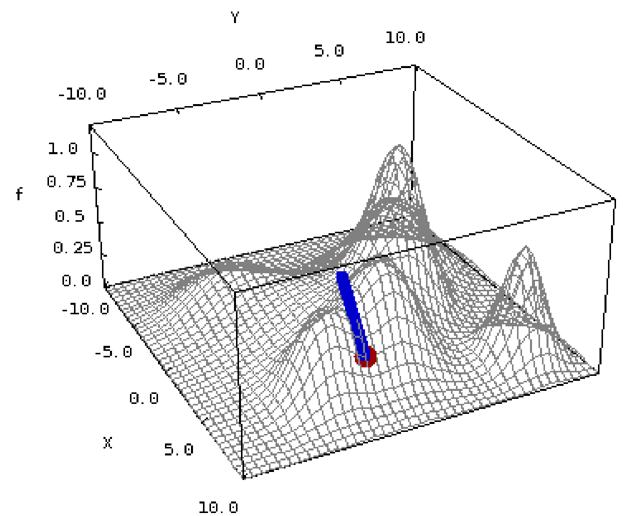
Differential operators - gradient:

Gradient – show the direction and size of the greatest change of a scalar field in each point of its domain,

input of the operation: scalar field

output of the operation: vector field

$$gradU = \frac{\partial U}{\partial x}\vec{i} + \frac{\partial U}{\partial y}\vec{j} + \frac{\partial U}{\partial z}\vec{k}$$

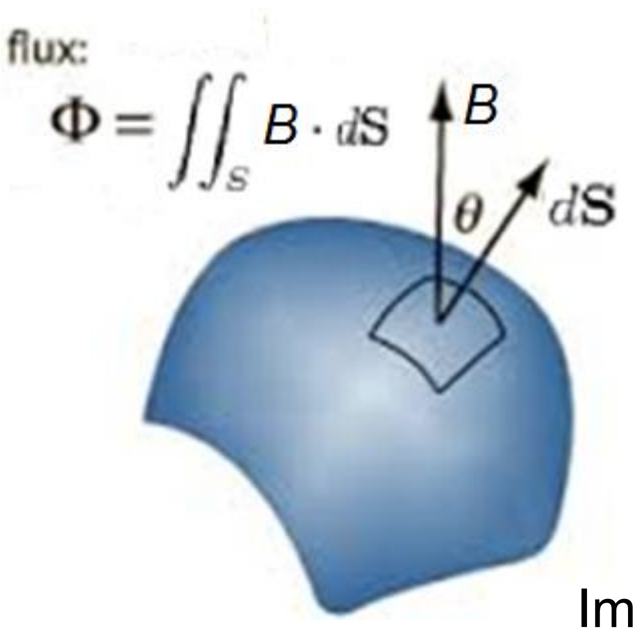


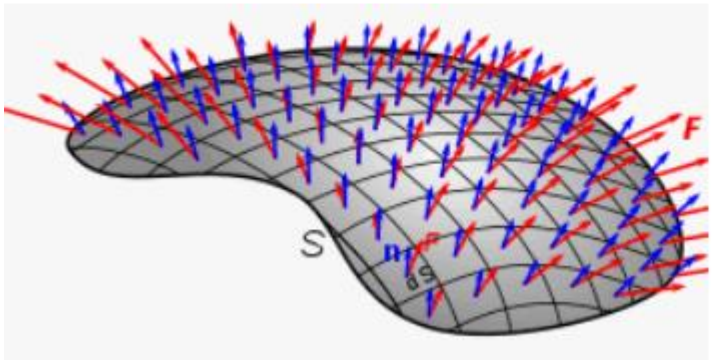
where $\vec{i}, \vec{j}, \vec{k}$ are elementary vectors (pointing in the direction of each coordinate axis – see 2. lecture, 26.slide)

mathematical apparatus in physics

integral operators (flux):

Flux describes any effect that appears to pass or travel (whether it actually moves or not) through a surface.





Important is the scalar product in the integral.

Comment: Similar operation is so called circulation (1D integration is used).

So why do we need physics in biology and chemistry?

- to learn a kind of analytical thinking, which is used in natural sciences
- to get answers about the principles of many fundamental processes and reactions:

How a biological membrane works?

How the heart pumps blood?

How muscles contract?

How plants use light for grow in photosynthesis?

How genes are switched on and off?

How does the atomic structure influence chemical reactions?

So why do we need physics in biology, chemistry and medicine?

Physics	**Medicine**
Statics (mechanics)	Orthopaedics
Dynamics (mechanics)	Heart motion
Elasticity and strength of materials	Orthopaedics
Fluid statics	Blood pressure
Fluid dynamics	Blood flow in vascular system
Surface tension	Capillary action
Sound and acoustics	Stethoscope, ultrasound, acoustic microscope
Electricity	All life processes, ion transfer at membranes
Magnetism	Nuclear magnetic resonance imaging
Light and optics	Light microscopy, laser therapy, fibre optics
Heat and thermodynamics	Heat balance
Kinetic theory and statistical mechanics	Brownian motion, osmosis, diffusion of gases
Atomic physics and spectroscopy	"Chemical shift" in NMR imaging, lasers in medicine
Molecular physics	Genetics, antibodies, protein structure, electron microscope
Ultraviolet and infrared energy	Skin treatment and imaging
X-rays	Radiology, CT imaging
Quantum mechanics	Electron diffraction microscope
Relativity	Synchrotron radiation imaging
Crystallography	Structure of proteins
Solid-state physics and semiconductors	Computers in medicine, scintigraphy
Nuclear physics	Radioisotope labelling, nuclear medicine, radiation therapy
Radioactivity	Positron emission tomography (PET)
Elementary particle physics	Pion therapy
Accelerators, cyclotrons, etc	Tumour therapy, Hodgkin's disease
Astronomy and astrophysics	Discovery of helium, treatment of asthma (obsolete)

Physical quantities span an immense range

Length	size of nucleus	$\sim 10^{-18}$ m
	size of universe	$\sim 10^{26}$ m
Time	nuclear vibration	$\sim 10^{-20}$ s
	age of universe	$\sim 10^{18}$ s
Mass	electron	$\sim 10^{-30}$ kg
	universe	$\sim 10^{28}$ kg

interesting video: https://www.youtube.com/watch?v=bhofN1xX6u0

Solving Problems
(in physics)

Problem Solving Strategy

- Each profession has its own specialized knowledge and patterns of thought.
- The knowledge and thought processes that you use in each of the steps will depend on the discipline in which you operate.
- Taking into account the specific nature of ***physics***, we choose to label and interpret the ***five steps*** of the general problem solving strategy as follows:

Problem Solving Strategy

A. Everyday language:

1) Make a sketch.
2) What do you want to find out?
3) What are the physics ideas?

B. Physics description:

1) Make a physics diagram (figure).
2) Define your variables.
3) Write down general equations.

C. Combine equations:

1) Select an equation with the target variable.
2) Which of the variables are not known?
3) Substitute in a different equation.
4) Continue for all of the unknown variables .
5) Solve for the target variable.
6) Check units.

D. Calculate solution:

1) Plug in numerical values.

E. Evaluate the answer:

1) Is it properly stated?
2) Is it reasonable?
3) Answered the question asked?

An attempt at a physics joke ;-)

Laplace, Newton and Pascal are playing hide and seek.

Laplace is the first to close his eyes, Pascal jumps behind the bushes, but Newton just stands still and uses a wooden stick to dig a 1 x 1 m square in the ground around him. When Laplace finishes counting and opens his eyes, he sees Newton and shouts 'Newton!' But Newton replies: 'No, no, Newton per square metre, that is, Pascal !''

$1\ Pa = N/m^2$