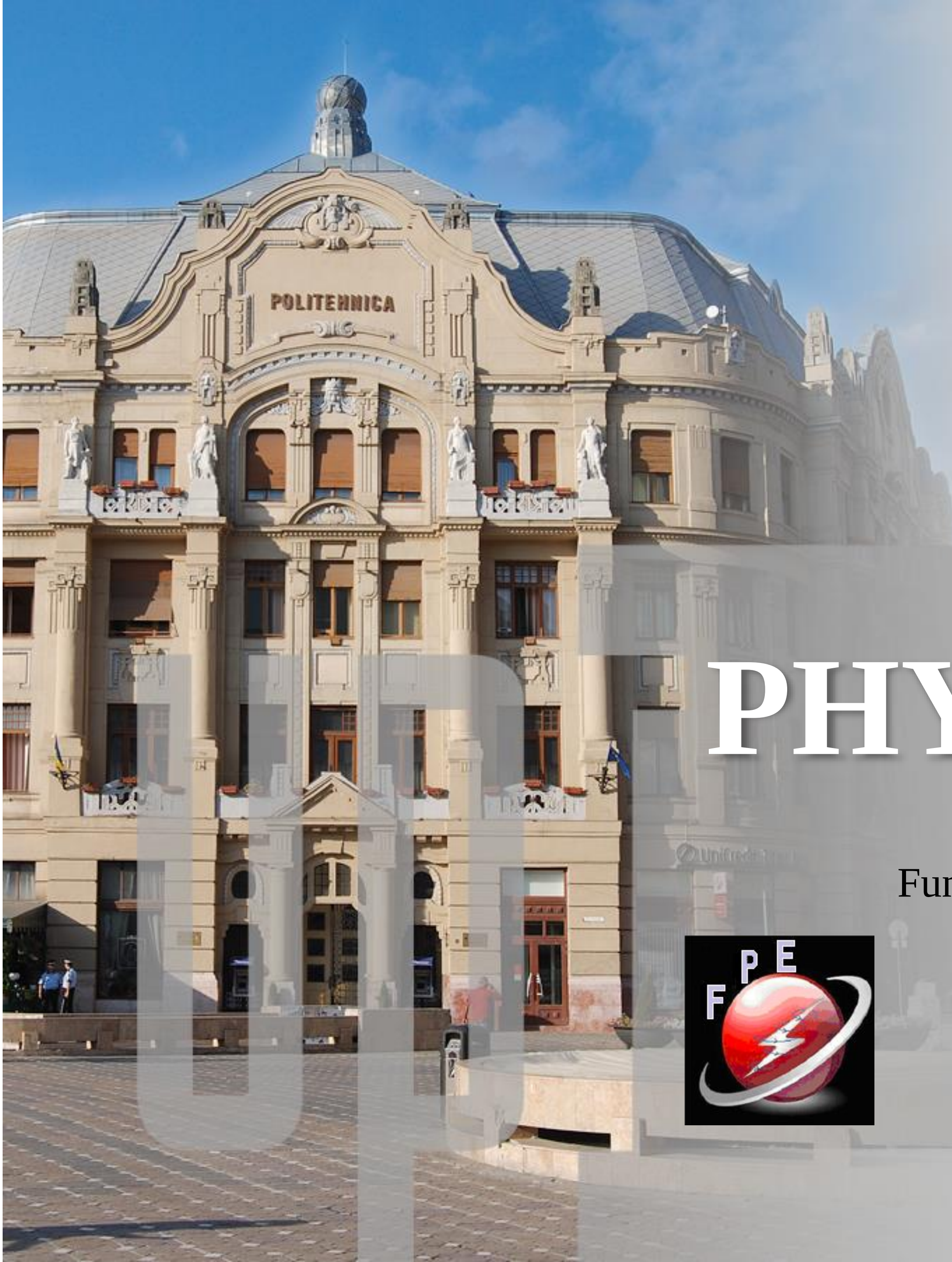


Universitatea Politehnica Timişoara

Pia]a Victoriei nr. 2
RO 300006 - Timi[oara
Tel: +40 256 403000
Fax: +40 256 403021
rector@upt.ro
www.upt.ro

Politehnica University of Timisoara

PHYSICS

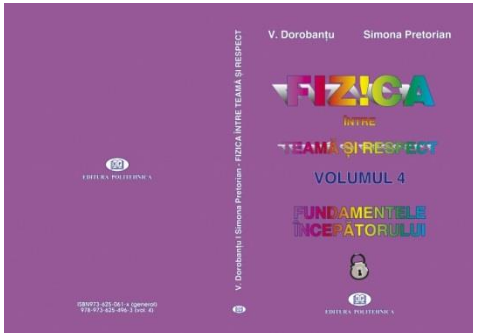
Lect. Dr. Pretorian Simona
Fundamental of Physics for Engineers
02 V. Pârvan C 209b
Timişoara, 300223, România
simona.pretorian@upt.ro

https://www.youtube.com/watch?v=ZihywtixUYo The Map of Physics
https://www.youtube.com/watch?v=OmJ-4B-mS-Y The Map of Mathematics

PHYSICS BETWEEN FEAR and RESPECT, vol.3, V. Dorobanţu, Simona Pretorian, Ed. Politehnica Timişoara, 2009;
QUANTUM MECHANICS, vol. 1, V. Dorobanţu, Ed. Politehnica Timişoara, 2005;

Contents:

NEWTONIAN MECHANICS
THERMODYNAMICS
ELECTRODYNAMICS
QUANTUM MECHANICS



The Feynman lectures on physics : Mainly mechanics, radiation, and heat, Richard P. Feynman, Robert B. Leighton, Matthew Sands, Addison-Wesley 1963, Central Library of the Politehnica University of Timisoara
https://www.feynmanlectures.caltech.edu/
HyperPhysics hosted by Georgia State University and authored by Georgia State faculty member Rod Nave http://hyperphysics.phy-astr.gsu.edu/hbase/index.html

EVALUATION FOR PHYSICS

Seminar and laboratory -Continuous assessment= activity during the semester (33.33%) :

Seminar (50% for Continuous assessment)

- 2 tests (week 5/6 and 13/14)
- involvement in seminars sessions (extra points)

Lab (50% for Continuous assessment)

- 5 lab reports on conducted subjects
- involvement in lab sessions and small experiments to be conducted at home on a voluntary basis (extra points)

Distributed assessment (66.66%)

- Attendance and involvement in lectures, homework assignments (extra points)
- First part exam (50%) 1-8 Nov. (date subject to changes)
- Second part exam (50%) 18-22 Dec. (date subject to changes)

MODEL in PHYSICS

MODEL = **"**a surrogate (object), a conceptual representation of a real thing"

D. Hestenes

WHY???

In order to **describe** and **explain** observed physical phenomena and to **predict** the outcomes of new phenomena.

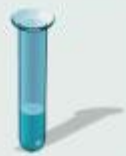
For a study - ONLY the **relevant** aspects (or variables) of the system for that study.

NO model **~** include all the characteristics of the real system,
~must include all the entities of the real system.

"in order to understand physical laws you must understand that they are all some kind of approximation" Feynman

International System of Units

The seven base units

	Definition	Symbol	New definition
	**Current: ampere** The current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in a vacuum, would produce between these conductors a force equal to 2×10^{-7} newtons per metre of length	A	**Current: ampere** The ampere is such that the elementary charge is exactly $1.60217653 \times 10^{-19}$ coulombs (1 coulomb = 1 ampere second)
	**Time: second** The time equal to 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	s	**Time: second** UNCHANGED
	**Temperature: kelvin** The fraction 1/273.16 of the thermodynamic temperature of the triple point of water	K	**Temperature: kelvin** The kelvin is such that the Boltzmann constant is exactly $1.3806505 \times 10^{-23}$ joules per kelvin
	**Amount of substance: mole** The amount of substance that contains as many elementary units as there are atoms in 0.012 kilograms of carbon-12	mol	**Amount of substance: mole** The mole is such that the Avogadro constant is exactly 6.0221415×10^{23} per mole
	**Luminous intensity: candela** The intensity, in a given direction, of a light source that emits monochromatic radiation of frequency 540×10^{12} hertz with a radiant intensity in that direction of 1/683 watts per steradian	cd	**Luminous intensity: candela** UNCHANGED
	**Length: metre** The length of the path travelled by light in a vacuum during a time interval of 1/299,792,458 of a second	m	**Length: metre** UNCHANGED
	**Mass: kilogram** The mass of the international prototype kept in Sèvres, France	kg	$\boxed{\textbf{Mass: kilogram} \text{ The kilogram is such that the Planck constant is exactly } 6.6260693 \times 10^{-34} \text{ joule seconds}}$

International System of Units

https://www.nist.gov/pml/special-publication-330/sp-330-section-2#2.3.1

THE five CONSTANTS are chosen in such a way that any unit of the SI (since 2019) can be written either through a defining constant itself or through products or quotients of defining constants.

The International System of Units, the SI, is the system of units in which

- **the unperturbed ground state hyperfine transition frequency of the cesium 133 atom $\Delta\nu_{Cs}$ is 9 192 631 770 Hz,**
- **the speed of light in vacuum c is 299 792 458 m/s,**
- **the Planck constant h is 6.626 070 15 × 10^{-34} (J s = ...),**
- **the elementary charge e is 1.602 176 634 × 10^{-19} C,**
- **the Boltzmann constant k is 1.380 649 × 10^{-23} J/K,**
- **the Avogadro constant N_A is 6.022 140 76 × 10^{23} mol^{-1},**
- **the luminous efficacy of monochromatic radiation of frequency 540 × 10^{12} Hz, K_{cd}, is 683 lm/W,**

Det. h, k, e ---Lab experiments C217

International System of Units

The 11th CGPM (1960, Resolution 12) adopted a series of prefix names and prefix symbols to form the names and symbols of the **decimal multiples and submultiples** of SI units, ranging from 10^{12} to 10^{-12}. Prefixes for 10^{-15} and 10^{-18} were added by the 12th CGPM (1964, Resolution 8), for 10^{15} and 10^{18} by the 15th CGPM (1975, Resolution 10), and for 10^{21}, 10^{24}, 10^{-21} and 10^{-24} by the 19th CGPM (1991, Resolution 4).

Table of all approved SI prefix names and symbols.

Factor	Name	Symbol	Factor	Name	Symbol
10^{1}	deca	da	10^{-1}	deci	d
10^{2}	hecto	h	10^{-2}	centi	c
10^{3}	kilo	k	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	µ
10^{9}	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

CLASSICAL MECHANICS

There are three equivalent approaches for the Classical Mechanics:

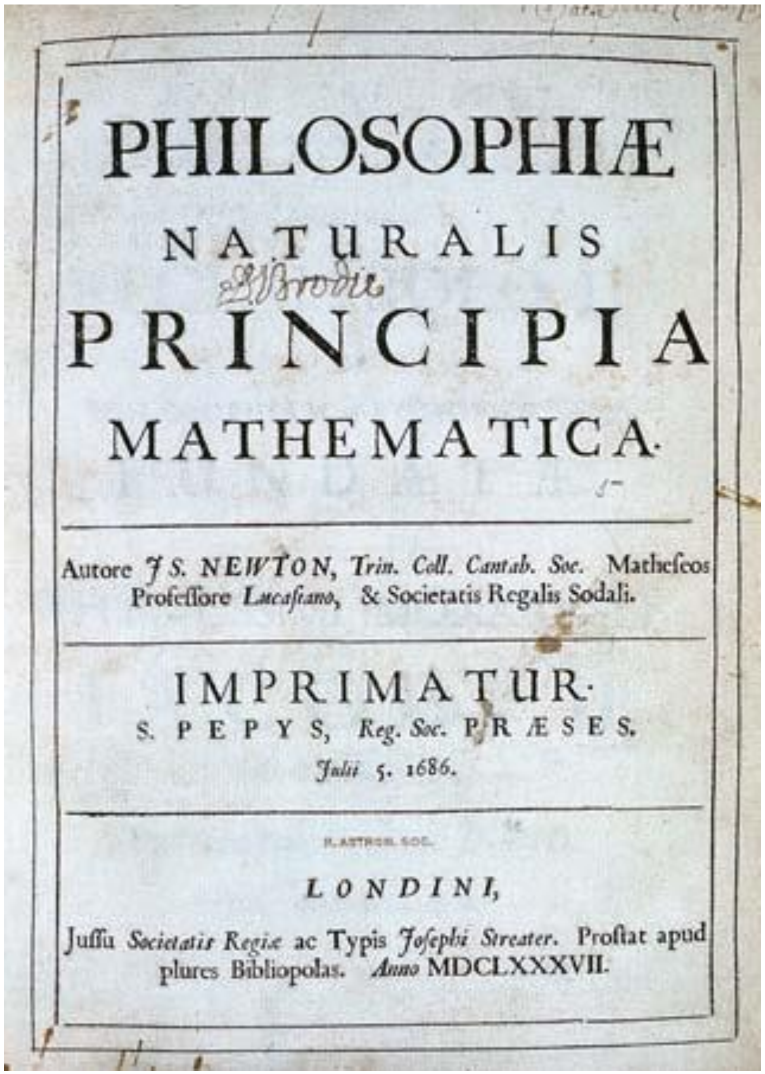
1.1 Newtonian Mechanics;
1.2 Lagrangean Mechanics;
1.3 Hamiltonian Mechanics.

Every approach consists in **a set of differential equations**, and by solving them, when it is possible, we can know **the state of motion**.

Kinematics is the study of motion without regard for the cause (forces).
Dynamics is the study of motions studying also the causes of motion (how the motion arrive from forces).

NEWTONIAN MECHANICS

***PHILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA*, Isaac Newton,** a fundamental book for the humanity published in Latin language in **1687**, republished in **1713** and **1726**


PHILOSOPHIÆ

NATURALIS

PRINCIPIA

MATHEMATICA.

Autore *J S. NEWTON*, *Trin. Coll. Cantab. Soc.* Mathefeos Profeffore *Lucafiano*, & Societatis Regalis Sodali.

IMPRIMATUR.

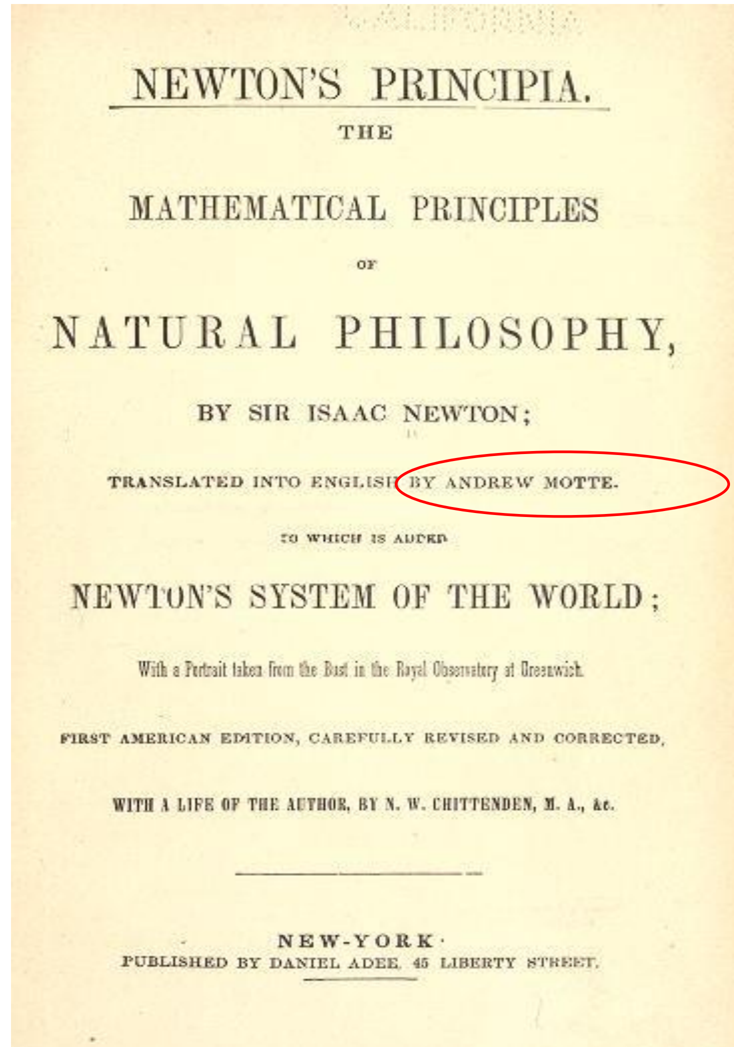
S. PEPYS, *Reg. Soc.* PRÆSES.

Julii 5. 1686.

R. ASTRON. SOC.

LONDINI,

Juffu *Societatis Regiæ* ac Typis *Jofephi Streater.* Proftat apud plures Bibliopolas. *Anno* MDCLXXXVII.


NEWTON'S PRINCIPIA.

THE

MATHEMATICAL PRINCIPLES

OF

NATURAL PHILOSOPHY,

BY SIR ISAAC NEWTON;

TRANSLATED INTO ENGLISH BY ANDREW MOTTE.

TO WHICH IS ADDED

NEWTON'S SYSTEM OF THE WORLD;

With a Portrait taken from the Bust in the Royal Observatory at Greenwich.

FIRST AMERICAN EDITION, CAREFULLY REVISED AND CORRECTED,

WITH A LIFE OF THE AUTHOR, BY N. W. CHITTENDEN, M. A., &c.

NEW-YORK.

PUBLISHED BY DANIEL ADEE, 45 LIBERTY STREET.

NEWTONIAN MECHANICS

Concepts

•A finite region of space, bordered from surroundings, having as essential quality the *mass* ⟺ ***BODY*.**
A body whose dimensions can be neglected in *its motion* ⟺ ***MASS POINT*.**

•***Mass*** ⟺ the substance quantity existing *inside* a body .
•**FOR CLASSICAL PHYSICS**, ***the space*** ⟺
the scene where the bodies evolve;
independent of what happens inside it;
with *Euclidian geometry.*
•**According to Newton**, “absolute, true, and mathematical ***time*** , of itself, and from its own nature *flows equably without regard to anything external*”

The **motion** of a particle is completely specified if we know, at every moment, the spatial COORDINATES and its velocity.
COORDINATES are, naturally, related with the ***frame of reference.***

Reference frame: System of axis bound to an observer and equipped with a clock to measure time.
Obs. If we ignore Earth’s astronomical motion then the ground can be usually assumed an inertial frame.
If we ignore Sun’s astronomical motion then the Sun can be assumed an inertial frame.

NEWTONIAN MECHANICS
Velocity

Position VECTOR relative to the ***frame of reference***

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k} \quad (m)$$

Motion law $\boxed{\vec{r}(t);}$

Average velocity

$$\vec{v}_{av} = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} = \frac{\Delta\vec{r}}{\Delta t} \quad (m/s)$$

$\Delta\vec{r}$=**displacement**=the final position $\vec{r}_2$ relative to initial position $\vec{r}_1$

"the rate at which an object changes its position."

https://www.youtube.com/watch?time_continue=195&v=pfTTHx9kCHk

If we go to the limit, for $\Delta t \to 0 \Longrightarrow$ ***instantaneous velocity***
=the first derivative of the position vector with respect to time= the time rate of change of the position vector.

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

Velocity law $\boxed{\vec{v}(t);}$

The magnitude of velocity is called **speed**.

If we know the velocity law $\vec{v}(t)$ we have the average velocity

$$\vec{v}_{av} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \vec{v}(t)\,dt$$

The motion law from velocity law

$$\vec{r} = \int \vec{v}dt + \vec{c}_1$$

From initial conditions

Displacement vector magnitude can be different from the travelled distance!!!!!!!!

https://www.youtube.com/watch?v=79WW8RcuSL0

NEWTONIAN MECHANICS
Acceleration

Position vector relative to the *frame of reference* $\vec{\mathbf{r}} = \mathbf{x}\vec{\mathbf{i}} + \mathbf{y}\vec{\mathbf{j}} + \mathbf{z}\vec{\mathbf{k}}$ (m)

Motion law $\boxed{\vec{r}(t);}$

Average acceleration $$\vec{\mathbf{a}}_{\mathbf{av}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta\mathbf{t}}$$ (m/s^2)

Instantaneous acceleration $$\vec{\mathbf{a}} = \lim_{\Delta t \to 0} \frac{\Delta\vec{\mathbf{v}}}{\Delta\mathbf{t}} = \frac{\mathbf{d}\vec{\mathbf{v}}}{\mathbf{dt}}$$ (m/s^2)

=the first derivative of the velocity with respect to time

$$\vec{a} = \frac{d\ \vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2} \iff \vec{a} = \dot{\vec{v}} = \ddot{\vec{r}}$$

The velocity law from acceleration law

$$\vec{v} = \int \vec{a}dt + \overrightarrow{c_2}$$

From initial conditions

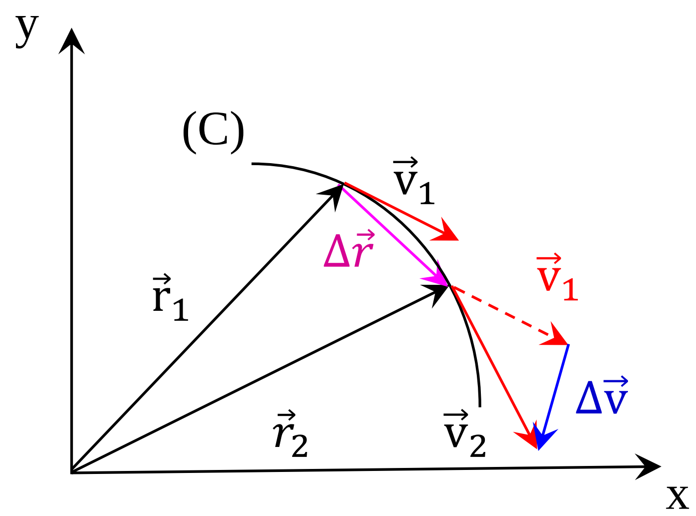
http://hyperphysics.phy-astr.gsu.edu/hbase/acca.html#c1

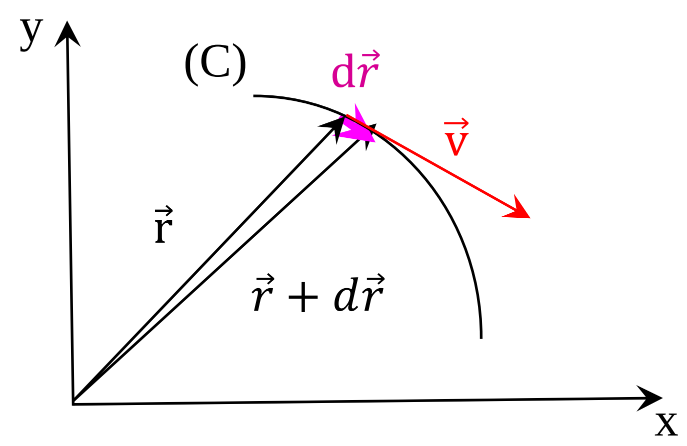
NEWTONIAN MECHANICS

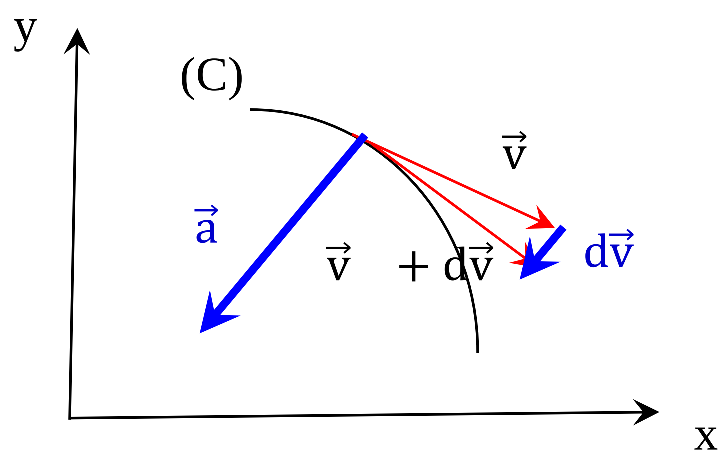
The directions of velocity and acceleration -kinematics

The velocity ***always*** *has the direction of* $\Delta\vec{r}$ ($d\vec{r}$) , meaning it permanently follows the “road”, in other words is *tangent in every point of the trajectory*

The acceleration has the direction of $\Delta\vec{v}$ ($d\vec{v}$)

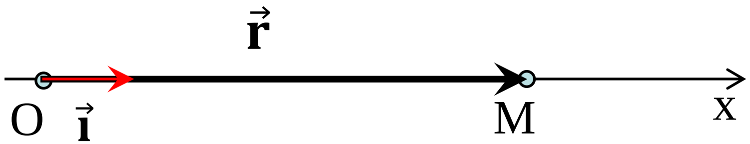






http://physics.info/motion-graphs/

MOTION ALONG A STRAIGHT LINE (the one-dimensional case : Ox)



$$\vec{r}(t) = x\vec{i}$$

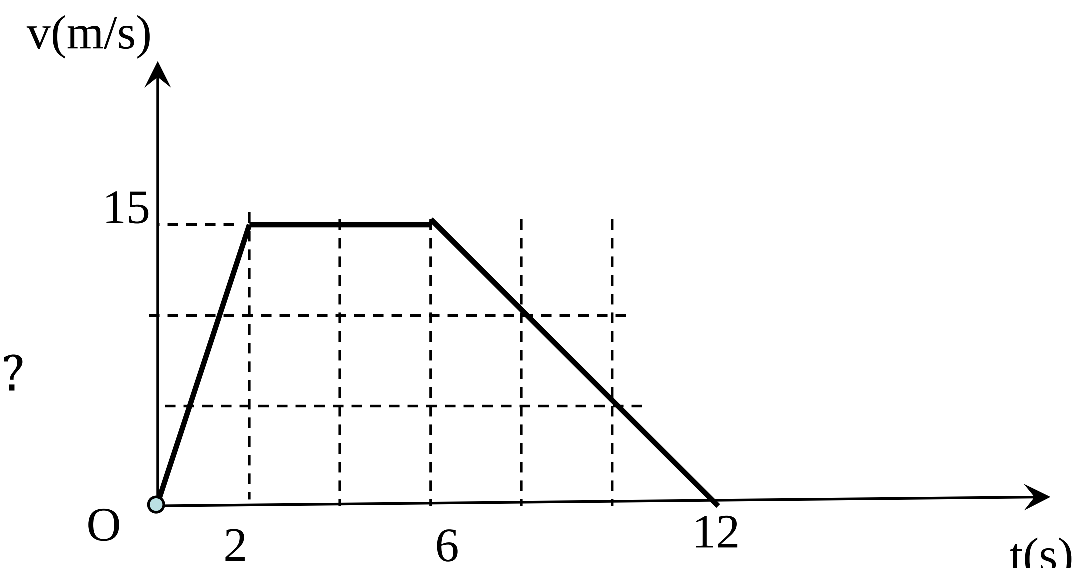
$$v_{av} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}, \qquad v = \frac{dx}{dt}$$

Ex. –uniform linear motion $x(t) = 4 + 3t$

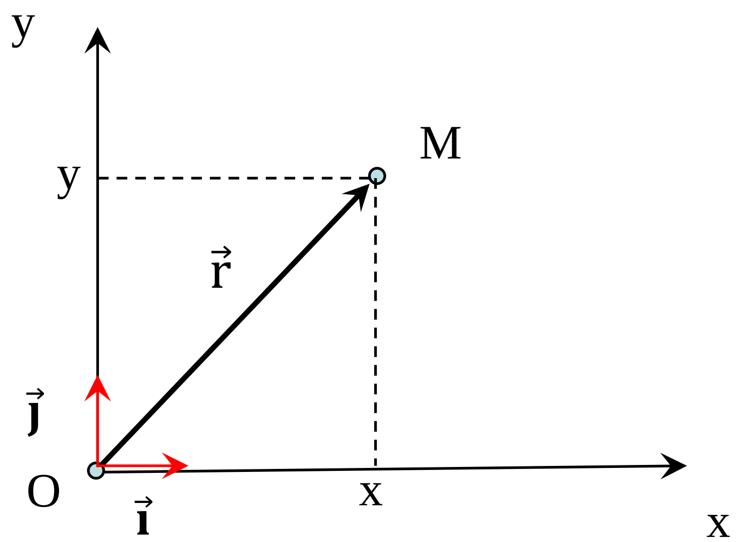
-Uniformly accelerated linear motion $x(t) = 2 + 3t - 10t^2$

Exercise:

$$v_{av} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} v(t)dt = ????$$



PLANAR MOTION (two-dimensional case : XOY)



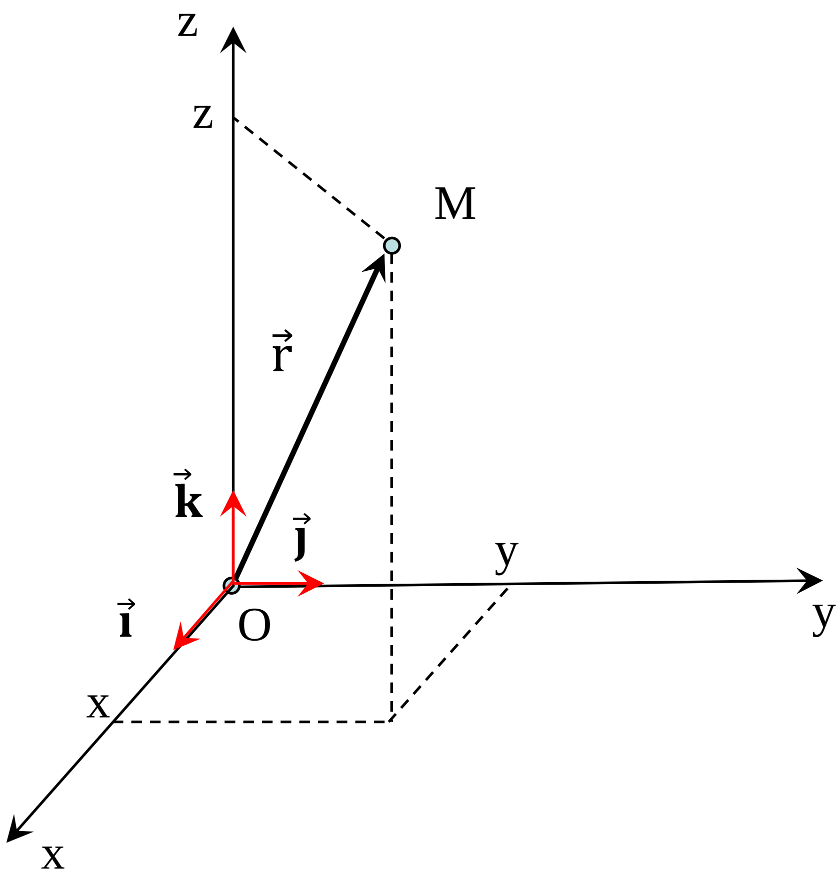
$$\vec{r}(t) = x\vec{i} + y\vec{j}$$

$$\vec{v}(t) = \frac{dx}{dt}\vec{i} + \frac{dy}{dt}\vec{j}$$

Ex. circular uniform motion $\vec{r}(t) = 3\cos 4t\,\vec{i} + 3\sin 4t\,\vec{j}$ (m)

relativ motion (boat Crossing a River– reference)
https://www.surendranath.org/GPA/Kinematics/Boat/Boat.html
https://www.surendranath.org/GPA/Kinematics/RelativeMotion/RelativeMotion.html

THREE –DIMENSIONAL CASE



$$\vec{r}(t) = x\vec{i} + y\vec{j} + z\vec{k}$$

$$\vec{v}(t) = \frac{dx}{dt}\vec{i} + \frac{dy}{dt}\vec{j} + \frac{dz}{dt}\vec{k}$$

$$r^2 = \vec{r} \cdot \vec{r} = x^2 + y^2 + z^2$$

$$v^2 = \vec{v} \cdot \vec{v} = {v_x}^2 + {v_y}^2 + {v_z}^2$$

Ex. helical Motion $\vec{r}(t) = 3\cos 4t\,\vec{i} + 3\sin 4t\,\vec{j}$ +5t (mm)

NEWTONIAN MECHANICS
Trajectory

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$$

If we know, **at every moment**, the spatial coordinates of a body with respect to a frame of reference, then we can find **the trajectory or the path** of the body by eliminating time between them.

$\vec{r}(t)$ $\Leftrightarrow$ **x(t)**

y(t)

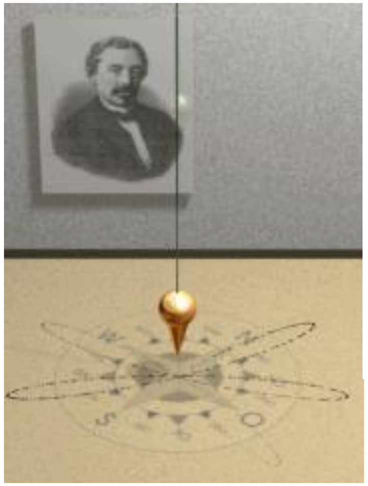
z(t)

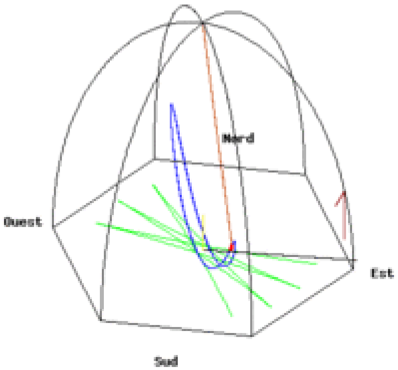
$\Rightarrow$ **f (x, y, z)=0**

trajectory equations

The path is univocal determined only if we know the **INITIAL CONDITIONS**, namely $\vec{r}(t=0)$ and $\vec{v}(t=0)$

If the movement is **planar**, then the path means the **y(x)** graphic.





Foucault pendulum http://demonstrations.wolfram.com/TrajectoryOfFoucaultsPendulum/

Trajectories-examples

Hidden (additional) slide !!!!!!

http://mathworld.wolfram.com/topics/RadialCurves.html

Straight line, circle, ellipse, parabola, hyperbola

Trochoid

A **trochoid** is the locus of a point at a distance   from the center of a circle of radius r rolling on a fixed line

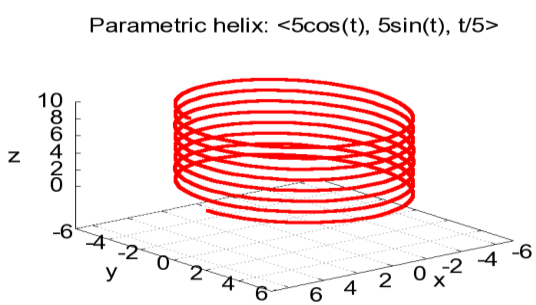
$$x = at - r \sin t$$
$$\mathrm{y = a - r\,cost}$$

Cycloid (a=r)

Curtate cycloid (a<r)

Prolate cycloid (a>r)

Hellix



NEWTONIAN MECHANICS

Degrees of freedom

The number of **independent** coordinates, which characterize the *mass point* position, represent the degrees of freedom for that *particle*.

The *particle*'s number of degrees of freedom is equal to the difference between the number of coordinates and the number of constraints between these coordinates.

For a rigid body …….

NEWTONIAN MECHANICS

First Newton’s law

An object will remain at rest or in uniform linear motion unless acted upon by an external force (net force).

“Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus illud a viribus impressis cogitur statum suum mutare.”

The Andrew Motte’s translation from the original statement (1729) is
“Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon”.

https://archive.org/stream/100878576#page/82/mode/2up

*The tendency of a body to maintain its state of rest or of uniform motion in a straight line is called **inertia**, and the first law is sometimes called **the law of inertia**.*

Net force is the overall force acting on an object.

NEWTONIAN MECHANICS

DYNAMICS -FORCES AND MOTION

- ***Force?*** An impressed force is ***an action*** exerted upon a body, in order to change its state

"If you insist upon a precise definition of force, you will never get it!" Feynman

Action at a distance

Gravitational force

Electromagnetic force

("are fundamental forces- we analyze these forces by means of the field concept")

The gravitational/electric field is the "condition" produced by a source (mass/electric charge) and the force is the response of a probe (mass/electric charge) to the field.

Contact forces

Friction force

(ex. when one solid body slides on another $F_f = \mu N$)

"Molecular forces are forces between the atoms, and are the ultimate origin of friction. Molecular forces have never been satisfactorily explained on a basis of classical physics" Feynman

The resistant force

(ex. air resistance for fast movement in air of a solid body $F_r = -\alpha\ v$)

"this law is not in the same class as the *basic* laws of physics, and further study of it will only make it more and more complicated" Feynman

Elastic force

(ex. in a deformed spring $F_{el} = -k_{el}x$)

Tension force (ex. string tension)

Action force (upon a body)

Reaction force (ex. normal reaction force)

All contact forces arise from electromagnetic interactions between the charged particles in the bodies making contact.

• ***Force?*** An impressed force is ***an action*** exerted upon a body, in order to change its state

"If you insist upon a precise definition of force, you will never get it!" Feynman

"In analyzing forces by the use of fields, we need two kinds of laws pertaining to fields.

The first is the response to a field, and that gives the equations of motion. For example, the law of response of a mass to a gravitational field is that the force is equal to the mass times the gravitational field; or, if there is also a charge on the body, the response of the charge to the electric field equals the charge times the electric field.

The second part of the analysis of nature in these situations is to formulate the laws which determine the strength of the field and how it is produced. These laws are sometimes called the *field equations*. " Feynman

"In nuclear analysis **we no longer think in terms of forces**, and in fact we can replace the force concept with a concept of the energy of interaction of two particles", "the forces disappear as soon as the particles are any great distance apart, although they are very strong within the 10^{-13}cm range"

NEWTONIAN MECHANICS

The Newton's Second Law

The rate of change of momentum of an object is directly proportional to the resultant force applied and is in the direction of the resultant force.

$$\boxed{\vec{\mathbf{F}} = \frac{\mathbf{d}(\mathbf{m} \cdot \vec{\mathbf{v}})}{\mathbf{dt}}}$$

$[F]_{SI}$=Newton
1N=1kg·m/s^2

"Mutationem motus proportionalem esse vi motrici impressae, et fieri secundum lineam rectam qua vis illa imprimitur."

The Andrew Motte's translation:

"The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed".

motus, the quantity of motion was later called the **momentum,**

$$\boldsymbol{\Delta}(\mathbf{m} \cdot \vec{\mathbf{v}}) = \vec{\mathbf{F}} \cdot \boldsymbol{\Delta}\mathbf{t}$$

Only if the mass is constant in time:

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

NEWTONIAN MECHANICS

Concepts: linear momentum and impulse

Linear momentum $\vec{\mathbf{p}} = \mathbf{m}\vec{\mathbf{v}}$ (N·s)

An **impulse** occurs when a force $\vec{F}$ acts over an interval of time $\Delta t = t_2 - t_1$, and it is given by **Impulse=**$\int_{\mathbf{t_1}}^{\mathbf{t_2}} \vec{\mathbf{F}}\mathbf{dt}$ or

$$\mathbf{Impulse} = \vec{\mathbf{F}}_{\mathbf{average}}(\mathbf{t_2} - \mathbf{t_1}).$$

The second Newton law is a relation between impulse and momentum variation:

$$\mathbf{Impulse} = \Delta\vec{\mathbf{p}}$$

Momentum is dimensionally equivalent to impulse N·s

NEWTONIAN MECHANICS

Conclusions to the Newton’s Second Law

• Newton’s first law says that the motion state (or the rest state) changes only if a force is applied, and the Newton’s second law says **how** we make the changing, namely the force change the body’s momentum;

• Knowing the force expression, we have a second order differential equation and solving it – when it is possible - we find the time dependence of velocity $\vec{v}(t)$, respectively of the radius vector $\vec{r}(t)$;

•The linear momentum conservation law for an isolated physical system;

NEWTONIAN MECHANICS

Newton's Third Law

When two objects interact they exert equal and opposite **forces** on each other.

$$\vec{\mathbf{F}}_{12} = -\vec{\mathbf{F}}_{21}$$

" Actioni contrariam semper et aequalem esse reactionem: sive corporum duorum actiones in se mutuo semper esse aequales et in partes contrarias dirigi."

"To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts".

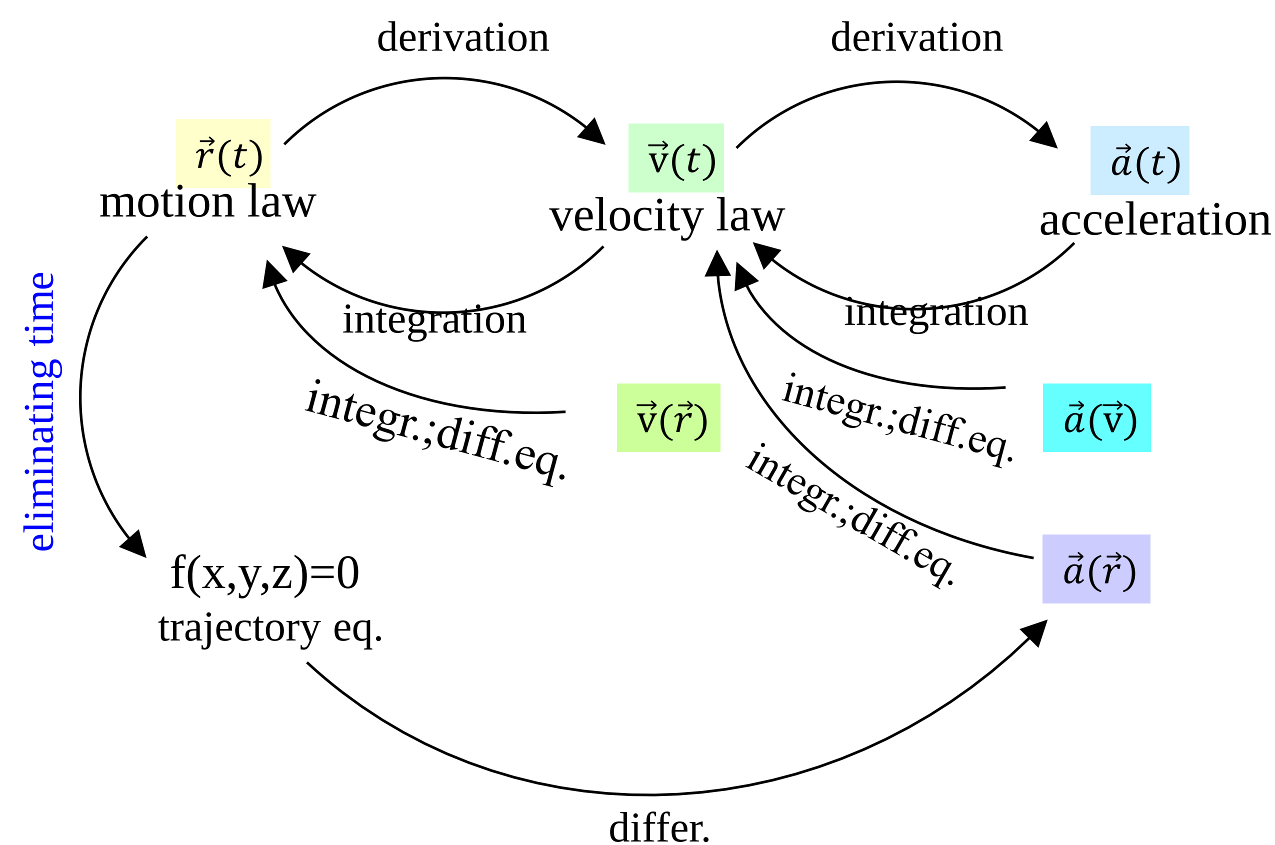
Examples ?

In principle, every problem for* point masses *can be solved using Newton's laws, but they are not sufficient for the motions of rigid and fluid bodies.

YUVAL NOAH HARARI –SAPIENS A brief History of Humankind (The Scientific Dogma p.284)

NEWTONIAN MECHANICS

In principle, every problem can be solved using Newton's laws.



Using the Newton's Second Law – dynamics of bodies that can be considered mass points

$\vec{G}$ -freefall in the gravitational field of Earth

-vertical throw (down/up) in the gravitational field of Earth

-oblique throw in the gravitational field of Earth

$\Updownarrow$ -free sliding on an horizontal/inclined plane in the gravitational field of Earth without/with F_f

$\overrightarrow{F_g}$ -satellite in the gravitational field of a planet

F_{el} Harmonic oscillations

resistant force

ex. $\overrightarrow{F_r} = -\alpha\,\vec{v}$

-throw with initial velocity in a viscous medium

-damped oscillations

-oblique throw in the gravitational field of Earth through a viscous medium

$\overrightarrow{F} = q\,\vec{E}$ -motion of an electron in a constant electric field similar with……..

$\overrightarrow{F} = q\vec{v}\times\vec{B}$ -motion of an electron in a constant magnetic field

NEWTONIAN MECHANICS

1. International System of Units; The seven base units; The decimal multiples and submultiples;
2. Definitions for average and instantaneous velocity and acceleration; The directions of velocity and acceleration;
3. The Newton's laws: The first Newton's law; Inertia and inertial frames of reference; The second Newton law; Conclusions to the Newton's Second Law; The third Newton law;

PHYSICS BETWEEN FEAR and RESPECT, vol.3, V. Dorobanţu, Simona Pretorian, Ed. Politehnica Timişoara, 2009; p.16-30