Physics for the Computer Science Students

Lecture 1: Laws of Physics

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1 Introduction

The word "*physics*" (***fysike***) has the origin in the Greek language and means the knowledge of our environment.

Citation from the encyclopedia: "Physics deals with the most general properties and the structure of the inanimate matter (atoms, particles, crystals, liquids, gases etc.) and with the main forms of its motions and changes (mechanical, thermal, electromagnetic, gravitational, nuclear and other processes)."

Method of physics : experiment → theory → verification → experiment …

To have a good physical theory one needs mathematics. Mathematics is a language of physics. Mathematics, at its origin, was the experimental science and next it converts into the pure speculative science. One says that mathematics it is the art of using the notions, which were on purpose to manipulate with them.

Nowadays the spectacular return to the roots of mathematics is observed, because with the development of the computer science the experimental mathematics has appeared again.

The view that mathematics is the set of ideas, abstract and unconnected with the real life, is very naive.

Is the contemporary physics really very difficult and impossible to understand even for the well educated persons?

2 Laws of physics

The very great number of physical phenomena is observed. Everyone can list hundreds of them. Aspiration to introduce the order in the picture of our very complicated world is very natural. One can ask the questions: in what all that phenomena are similar and in what all that phenomena are different? These questions have been asked since the thousands of years. And only during the last four - five hundreds of years they were reasonably formulated and ordered. This process is still not finished, because the new laws, e.g. in elementary particles physics, are continuously discovered.

The laws of physics are formulated in the following ways:

1. as conclusions from observations, e.g. the energy conservation law;

2. as conclusions from the constructed theories (e.g. the energy conservation law resulting from the Emma Noether theorem as applied to the Lagrange approach).

It is very well known that every theory can be falsificated, and we conclude that (probably) the development of the science is the never ended story.

The mathematics used below has an informative meaning only in order to give the reader the ideas what kinds of equations are used to describe the physical phenomena in the contemporary physics.

3 Conservation laws

The conservation laws (principles) play a very important role in physics. They say that:

No thing can come into existence from nothing, and no thing can vanish without any trace.

This idea is described by the (local) partial differential equation

$$a(x,\,t)\frac{\partial\rho(x,\,t)}{\partial t} + b(x,\,t)\nabla\,\boldsymbol{j}(x,\,t) = Q(x,\,t), \qquad (1)$$

where $\rho(x,\,t)$ - density, $\boldsymbol{j}$ - flux, $Q(x,\,t)$ - source.

Let's try to read what is written above: at any point of the physical space and in the arbitrary instant of time, the change in time of the density of the quantity under consideration (e.g. mass, energy, etc.) has to be compensated the influx or outflow of that quantity or can be generated the the source of production or annihilation of that quantity. Now, some special cases can be considered, e.g. source vanishes, or the density is constant in time, or flux vanishes or is constant, etc.

Equation (1) is written sometimes in the more general and simpler form, in the form of the **continuity equation:**

the loss of a certain quantity occupying the volume V has to be compensated by the flux of that quantity through the surface S around that volume.

Using the divergence theorem the surface integral can be transformed into the volume integral, and we have that

$$\frac{\partial}{\partial t}\int_V r(x,\,t)\mathrm{dV} \;=\; -\oint_S \rho(x,\,t)\,\boldsymbol{v}(x,\,t)\,dS \;=\; -\int_V \nabla\rho(x,\,t)\,\boldsymbol{v}(x,\,t)\,\mathrm{dV}. \qquad (2)$$

The equality has to be fulfilled for any volume V, and it follows that the functions in integrals have to equal too, and the equation in the local form, i.e. in the differential equation form, is obtained:

$$\frac{\partial\ \rho(x,\ t)}{\partial t} + \nabla \cdot (\rho(x,\ t)\ \boldsymbol{v}(x,\ t)) = 0, \tag{3}$$

or in the more compact form

$$\frac{D\rho(x,\ t)}{D\,t} + \rho(x,\ t)\ \nabla \cdot \boldsymbol{v}(x,\ t) = 0, \tag{4}$$

where

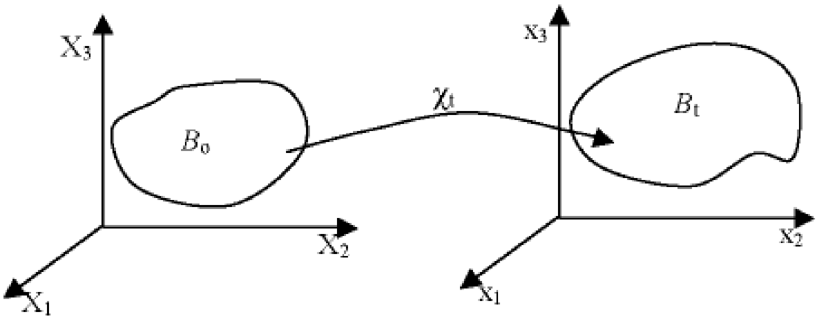
$$\frac{D}{D\,t} = \frac{\partial}{\partial t} + \boldsymbol{v} \cdot \nabla, \tag{5}$$

is the so called material time derivative. Let us observe that in the continuity equation the source term is absent.

3.1 Mass conservation law

The certain scalar quantity m, called the **mass** of the body, can be ascribed to the body. The mass is a nonnegative and an additive quantity. This quantity describes the inertia of the body: the greater the mass is, so the inertia is greater too. And the inertia describes the magnitude of the force which must be applied to the body to give the body a certain needed velocity. The velocity is not the absolute quantity, it has a physical meaning in respect to an arbitrarily chosen, but exactly defined, frame of the reference only.

Notice: observe the difference between the frame of reference and the system of coordinates - in one frame of the reference many different systems of coordinates can coexist.



Rysunek 1: Reference configuration B_0 in the Lagrange description X_1, X_2, X_3 and the actual configuration in the Euler description x_1, x_2, x_3

In physics two methods of description of the motion of a body are used:

- in which the actual state of a body is compared with the starting situation, in which the trace of a material point is observed (Lagrange description), or
- in which the point of a physical space is observed (Euler description).

The second one is more frequently used in the hydrodynamics.

The total mass of a body does not depend of the choice of description, of course. The total mass is identical in both configurations: in the reference configuration and in the actual configuration:

$$m = \int_{B_0} \rho_0 \, dV = \int_{B_t} \rho(x,\, t)\, dv\,, \qquad 0 \le \rho \le \infty, \tag{6}$$

ρ_0 - density of the mass in the reference configuration, $\rho(x,\, t)$ - density of the mass in the actual configuration.

The way of description of the body motion is a way of taste or convenience. Let us have a look how the actual configuration is seen from the point of view of the reference configuration (material Lagrange description):

$$\int_{B_0} (\rho_0 - \rho\, J)\, dV = 0, \tag{7}$$

where

$$J = \det\left|\frac{\partial x_i}{\partial X_K}\right|, \tag{8}$$

is the Jacobian of transformation. The reciprocal transformation exists too.

Integral (7) equals zero, iff

$$\rho_0 = \rho\, J. \tag{9}$$

In that way **the local law of the mass conservation** in the material description was obtained. **The global mass conservation law** in the actual (Euler) configuration has the form:

$$\frac{d}{d\,t}\int_{B_t} \rho(x,\, t)\, dv = 0. \tag{10}$$

We read that equation that the total mass of the body does not depend on time, it is constant in time.

It follows from Eqn. (10) that the local mass conservation law is fulfilled too: it is true for any instant of time t and for any actual configuration B_t, so

$$\frac{d}{d\,t}\rho(x,\, t) = \frac{\partial}{\partial t}\rho(x,\, t) + \rho(x,\, t)\,\mathrm{div}\,\boldsymbol{v}\,(x,\, t) = 0. \tag{11}$$

If the body is incompressible then its volume does not change, and consequently its mass density as well. In such a case

$$\frac{\partial}{\partial t}\rho(x,\, t) = 0, \tag{12}$$

what means that $\rho(x,\, t) = \rho(x)$. In such a situation it follows simultaneously from Eqn. (11) that the velocity of the body fulfills the following equation

$$\operatorname{div} \boldsymbol{v}(x, t) = 0. \tag{13}$$

The velocity field $\boldsymbol{v}(x, t)$ fulfilling Eqn. (13) is called the sourceless field (not divergent). It follows from the known mathematical identity (div rot(·) = 0) , that in such a case the velocity $\boldsymbol{v}$ can be represented in the form

$$\boldsymbol{v}(x, t) = \operatorname{rot} \boldsymbol{u}(x, t), \tag{14}$$

where $\boldsymbol{u}$ - the vector potential of the velocity field $\boldsymbol{v}$.

The motion of the body is called rotationless, iff

$$\operatorname{rot} \boldsymbol{v}(x, t) = 0, \tag{15}$$

and in such a case there exists the scalar potential φ for the velocity field, i.e.

$$\boldsymbol{v}(x, t) = \operatorname{grad} \varphi(x, t), \tag{16}$$

because rot grad (·) = 0.

Remark:

Every vector field, and the velocity field as well, can be unambiguously decomposed into the sum of two fields:

$$\boldsymbol{v} = \boldsymbol{v}_1 + \boldsymbol{v}_2 = \operatorname{grad} \varphi + \operatorname{rot} \boldsymbol{u}, \text{ with the condition that } \operatorname{div} \boldsymbol{u} = 0,$$

where φ - scalar potential, $\boldsymbol{u}$ - vector potential. It follows from that decomposition that

$$\operatorname{rot}\boldsymbol{v}_1 = \operatorname{rot} \operatorname{grad} \varphi, \qquad \operatorname{div} \boldsymbol{v}_2 = \operatorname{div} \operatorname{rot} \boldsymbol{u} = 0.$$

The field $\boldsymbol{v}_1$ is called ***the sourceless field*** *(axial field), and the $\boldsymbol{v}_2$ is called* *the wireless **field** (solenoidal field).*

The equation of continuity for the wireless motion can be now presented in the form

$$\dot{\rho} + \rho \, \Delta \varphi = 0. \tag{17}$$

For the incompressible bodies Eqn. (17) reduces to the well known Laplace equation

$$\Delta \varphi = 0. \tag{18}$$

It is seen, that looking for the solutions of the differential equation (11) , one can make use of many simplifications making our calculations significantly easier.

3.2 Momentum conservation law

Momentum it is a vector quantity defined for the body B at the instant t by the formula:

$$\boldsymbol{P} = \int_{B_t} \rho \, \boldsymbol{v} \, dv. \tag{19}$$

The momentum conservation law it is in fact nothing else but the Newton second law of dynamics that says that any change of the momentum can be triggered only by the acting forces on the body

$$\dot{\boldsymbol{P}} = \boldsymbol{F}, \tag{20}$$

where

$$\boldsymbol{F} = \int_{B_t} \rho\, \boldsymbol{f}\, dv + \int_{\partial B_t} \boldsymbol{t}_n\, ds, \tag{21}$$

$\boldsymbol{f}$ - density of the mass forces acting in the all volume of a body (gravitation force is a good example), and $\boldsymbol{t}_n$ - forces acting on the border ∂B_n of a body.

Remark

$$\boldsymbol{f}_n = \boldsymbol{\sigma}\, \boldsymbol{n},$$

$\boldsymbol{\sigma}$ - stress tensor, $\boldsymbol{n}$ - vector normal to the surface of the border of a body.

Gauss-Ostrogradzki Theorem

$$\int_V a_{i\,,\,j}\, dv = \oint_S a_i\, n_j\, ds,$$

allows to transform the volume integral into a surface integral and vice versa.

Equation (20) can be written in the form

$$\int_{B_t} (\rho\, \dot{\boldsymbol{v}} - \rho\, \boldsymbol{f} - \operatorname{div} \boldsymbol{\sigma})\, dv = \boldsymbol{0}\,. \tag{22}$$

This equation is valid for any body B and for any of its configuration B_t, so the integral function have to vanish too. From these consideration follows the local momentum conservation law in the form of the differential equation

$$\operatorname{div} \boldsymbol{\sigma} + \rho\, \boldsymbol{f} = \rho\, \dot{\boldsymbol{v}}, \tag{23}$$

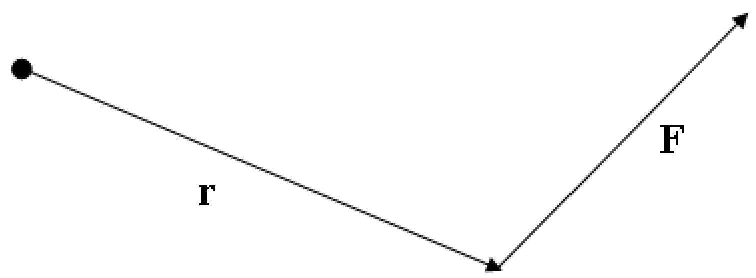
The above description it is in the absolute form. In the Cartesian coordinate system one has

$$\sigma_{i\,j,i} + \rho\, f_j = \rho\, \dot{v}_j. \tag{24}$$

3.3 Moment of momentum conservation law

The vector product of (the shortest) vector ***r*** starting from the rotation axis and connecting the beginning of the another vector ***F*** (e.g. force, momentum...) is called the moment of the vector ***F*** and is denoted as ***m***:

$$\boldsymbol{m} = \boldsymbol{r}\times\boldsymbol{F}. \tag{25}$$



Rysunek 2: Moment of a force

Remark

*The result of the vector product of two not collinear vectors a and **b** is the third vector **c** perpendicular to a and **b**:*

$$\boldsymbol{c} = \boldsymbol{a}\times\boldsymbol{b} = \det\begin{bmatrix} \boldsymbol{i} & \boldsymbol{j} & \boldsymbol{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{bmatrix},$$

i, ***j***, ***k*** *- unit vectors (versors) of the Cartesian coordinate system,*

Remark

$$|\boldsymbol{a}\times\boldsymbol{b}| = |\boldsymbol{a}|\,|\boldsymbol{b}|\sin(\boldsymbol{a},\,\boldsymbol{b}),$$

or in the coordinates

$$(\boldsymbol{a}\times\boldsymbol{b})_i = \varepsilon_{ijk}\, a_j\, b_k\,,$$

where ε_{ijk} - Levi-Civita permutation symbol

$$\varepsilon_{ijk} = \begin{cases} -1 & \text{odd permutation of } i,\ j,\ k \\ 1 & \text{even permutation of } i,\ j,\ k \\ 0 & \text{repeated indices} \end{cases}$$

Let us make some remarks about the volume and surface quantities in the body B in configuration B_t. The following notation is introduced: ∂B_t - surface of the body B, $\boldsymbol{t}_n$ - density of the surface stresses, $\boldsymbol{m}_n$- density of the surface momentum, $\boldsymbol{n}$ - unit vector normal to the surface. We have:

1. Total surface force:

$$\boldsymbol{F}_s = \int_{\partial B_t} \boldsymbol{t}_n\, ds, \tag{26}$$

2. Total surface momentum:

$$\boldsymbol{M}_s = \int_{\partial B_s} \boldsymbol{m}_n\, ds + \int_{\partial B_t} \boldsymbol{r}\times\boldsymbol{t}_n\, \mathrm{ds}. \tag{27}$$

In the classical theory of elasticity the surface moments $\boldsymbol{m}_n$ are absent. It means that there exists the non classical elasticity theory of the continuous media in which the points of a body have the internal structure and posses the three additional rotational degrees of freedom. The theory was developed by

Cosserat brothers more than one hundred years ago.

3. Resultant moment acting on a body:

$$\boldsymbol{M} = \int_{B_t} (\rho\, \boldsymbol{r}\times\boldsymbol{f} + \rho\, \boldsymbol{m})dv + \int_{\partial B_t} (\boldsymbol{r}\times\boldsymbol{t}_n + \boldsymbol{m}_n)ds, \tag{28}$$

ρ - mass density, $\boldsymbol{r}$ - radius vector from the chosen point, $\boldsymbol{f}$ - force density vector, $\boldsymbol{m}$ - mass (volume) moments density vector.

4. Moment of momentum W of the body B at instant t:

$$\boldsymbol{W} = \int_{B_t} \rho \times \boldsymbol{v}\, dv, \tag{29}$$

$\boldsymbol{v}(x,\ t)$ - velocity of a point $P(\boldsymbol{r})$ of a body.

The moment of momentum conservation law says that the rate of change of the total moment of momentum of a body B with respect to the arbitrary chosen point equals to the resultant momentum counted with respect of the same point at the same instant of time t, i.e.

$$\dot{\boldsymbol{W}} = \boldsymbol{M}, \tag{30}$$

what means that

$$\int_{B_t} \rho\, \boldsymbol{r}\times\dot{\boldsymbol{v}}\ \mathrm{dv} = \int_{B_t} (\rho\, \boldsymbol{r}\times\boldsymbol{f} + \rho\, \boldsymbol{m})dv + \int_{\partial B_t} (\boldsymbol{r}\times\boldsymbol{t}_n + \boldsymbol{m}_n)ds. \tag{31}$$

After transformation to the volume integrals one obtains the local moment of momentum conservation law

$$\rho\, \boldsymbol{m} + \mathrm{div}\, \boldsymbol{M} + \boldsymbol{e} \cdot \boldsymbol{\sigma} = \boldsymbol{0}, \tag{32}$$

where $\boldsymbol{m}_n = \boldsymbol{n}\,\boldsymbol{M}$ (M - tensor of moment stresses), and $\boldsymbol{e}$ - third order tensor. In coordinates it looks like:

$$\rho\, m_i + M_{j\,i,\,j} + e_{i\,j\,k}\,\sigma_{j\,k} = 0. \tag{33}$$

3.4 Mechanical energy conservation law

The equation $E = m\,c^2$ gives the maximal value of the energy accumulated by the body with mass m. This energy is a sum of a considerable partial energies like:

- intrinsic energy,
- free energy,
- interaction energy,
- kinetic energy,
- thermal energy,
- potential energy,
- electromagnetic energy
- and many others.

We consider here the mechanical energy conservation law only, what means that other kinds of energy are excluded.

Let us multiply Eqn. (23) by the velocity and integrate the result over the all volume occupied by the body B_t. We obtain

$$\int\limits_{B_t} \operatorname{div} \boldsymbol{\sigma}\cdot\boldsymbol{v}\,dv + \int\limits_{B_t} \rho\,\boldsymbol{f}\cdot\boldsymbol{v}\,dv = \int\limits_{B_t} \rho\,\boldsymbol{v}\cdot\dot{\boldsymbol{v}}\;dv. \tag{34}$$

Applying Gauss - Ostrogradzki theorem gives

$$\int_{B_t} \operatorname{div} \boldsymbol{\sigma} \cdot \boldsymbol{v} \, dv = \int_{B_t} (\operatorname{div}(\boldsymbol{\sigma} \, \boldsymbol{v}) - \boldsymbol{\sigma} \cdot \operatorname{grad} \boldsymbol{v} \, \mathrm{dv} = \int_{\partial B_t} n \sigma v \, ds - \int_{B_t} \boldsymbol{\sigma} \cdot \boldsymbol{D} \, dv, \qquad (35)$$

where the second order tensor grad $\boldsymbol{v} = \boldsymbol{D} + \boldsymbol{W}$, and $\boldsymbol{D}$ - rate of the deformation tensor

$$\boldsymbol{D} = \frac{1}{2}(\boldsymbol{L} + \boldsymbol{L}^T),$$

and $d\boldsymbol{v}$ = (grad $\boldsymbol{v}$) $d\,\boldsymbol{x} = \boldsymbol{L}\, d\,\boldsymbol{x}$.

Another tensor constructed from the gradient of the velocity $\boldsymbol{L}$, it is the antisymmetric tensor $\boldsymbol{W}$ - tensor of the momentary rotational velocity (material spin tensor)

$$\boldsymbol{W} = \frac{1}{2}(\boldsymbol{L} - \boldsymbol{L}^T). \qquad (36)$$

Kinetic energy of a body

The kinetic energy of a body B_t is given by the volume integral

$$K = \int_{B_t} \frac{1}{2} \rho \, \boldsymbol{v} \cdot \boldsymbol{v} \, dv. \qquad (37)$$

It follows that

$$\dot{K} = \int_{B_t} \rho \, \dot{\boldsymbol{v}} \cdot \boldsymbol{v} \, dv. \qquad (38)$$

Making use of equations (32) and (37), Eqn. (34) obtains the form

$$\dot{K} = L - \int_{B_t} \boldsymbol{\sigma} \cdot \boldsymbol{D} \, dv. \tag{39}$$

where L is the power of the work of the external forces acting on the body B_t

$$L = \int_{B_t} \rho \, \boldsymbol{f} \cdot \boldsymbol{v} \, dv + \int_{\partial B_t} \boldsymbol{t}_n \cdot \boldsymbol{v} \, ds. \tag{40}$$

This is the mechanical energy conservation law:

the material derivative of the kinetic energy equals to the work of external forces reduced by the power of internal forces, i.e. the power of the work done by stresses on the rate of deformation.

In the case when the deformation is absent, e.g. in the case of a rigid body, Eqn. (39) takes a form

$$\dot{K} = L. \tag{41}$$

4 Some historical remarks on the physical theories

- Nicolaus Copernicus (19.02.1473 - 24.05.1543)
- Claudius Ptolemaeus (Ptolemy) (about AD 90 - after AD 161)
- Gaspard-Gustave de Coriolis (21.05.1792 in Nancy - 19.09.1843 in Paris)
- Jean Bernard Léon Foucault (18.09.1819 - 11.02.1868)

4.1 Nicolaus Copernicus

Nicolaus Copernicus (19.02.1473 - 24.05.1543) studied at the Cracow

University in years 1491-1495 and next moved to Italy to study at the Universities in Bologna, Padova and Ferrara. He got his doctor title in 1503 in Canon Law. He studied in Poland from 18 to 22 year of his life, but without any diploma. And it was not the reason that he was not enough clever. He confided to his uncle and protector Luke Watzenrode about his ideas on the astronomy, and the uncle waiting for the bishopric did not want to have troubles and send the nephew abroad.

After he came back to Poland he lived in Lidzbark Warmiński, Frombork (1510) and Olsztyn (1520-1521, during the war Poland - the Order of the Teutonic Knights). He started to work on his Opus Magna entitled "De revolutionibus" about 1515 . Actually he worked on it till the end of his life and constantly introduced the corrections. Joachim von Lauchen, called Retyk, the young German scientist, came to Frombork in 1539. He took the Copernicus' manuscript to Nürnberg, where it was printed in 1543 under the title "De revolutionibus orbium coelestium libri VI", and was dedicated to the Pope Paul III. The first edition of 1000 copies, consisted of six books and 203 cards. The title was changed without the permission of Copernicus, because the shorter title was considered as too revolutionary.

4.2 Claudius Ptolemaeus (Ptolemy)

Ptolemy (about AD 90 - after AD 161), the eminent Greek-Egyptian astronomer, astrologer, mathematician, geographer and optics specialist, probably born in Promemaid (Tebaid), lived and worked in the northern Egypt. He conducted his astronomical research in years AD 125-141. The works of Ptolemy had the huge impact on the astronomy and astrology in the next several hundreds of years. He summarized the earlier works of Greek astronomer in the work of 13 books and entitled them "Megale syntaxis" (or "Megiste syntaxis" or "Mathematiké sýntaksis"). This work, has survived to our days, and is known as "Almagest" (the title was distorted in Middle Ages). It has been a canon of the astronomical knowledge for over 15 hundreds of years until the work of Copernicus became recognized.

Ptolemy believed that the Sun, Moon, planets, and stars were attached to crystalline spheres, centred on Earth, which turned to create the cycles of day and night, the lunar month, and so on. In order to explain retrograde motion of the planets, he refined a complex geometric model of cycles within cycles that was highly successful at predicting the planets' positions in the sky. His Geography contained an estimate of the size of Earth, a description of its surface, and a list of places located by latitude and longitude. Ptolemy also dabbled in mechanics, optics, and music theory.

4.3 Gaspard-Gustave de Coriolis

The arguments of Copernicus that Earth really rotates, although supported by calculations, have to wait more then three hundreds years to be confirmed by the experiment. These works began Gaspard-Gustave de Coriolis, (borned 21.05.1792 in Nancy, and died 19.09.1843 in Paris), the French physicist and mathematician. All the story began, when he was a small boy. He was a very dynamic child, and when his mother was very tired of him, she let him to ride on a merry-go-round. After half an hour small Gaspard-Gustave was a very polite boy. After he became older, in years 1816-1838, he was a deputy professor of mathematics at the École Polytéchnique, the most prominent French technical college. He was a member of the French Academy of Sciences. He studied the laws of motions, especially on the surface of the Earth, to make clear why the merry-go-round made him so calm. He introduces the term "work", and gave the formula for the change of rate as a result of the performance of the work (today it is called the kinetic energy). The physical phenomenon, today called the Coriolis effect, occurs in the rotating reference systems, and consists on the perturbation of the trajectory of bodies moving in such systems. This perturbation looks like it was caused by any force, and that is why this effect is sometimes called the Coriolis force, but in fact it is caused by the movement of the reference system. The value if this ostensible force equals

$$\boldsymbol{F}_C = 2\,m\,\boldsymbol{v}\times\boldsymbol{\omega}, \tag{42}$$

where m - mass of a body, $\boldsymbol{v}$ - its velocity, $\boldsymbol{\omega}$ - angular velocity of a system.

Let the reference system rotates with the angular velocity $\boldsymbol{\omega}$. According to Eqn. (42), if the body moves away from rotation axis along a certain radius with the velocity v, then it experiences the force acting perpendicular to the radius and in the opposite direction to the rotation. If it moves in the direction of the rotation axis, then the force acts in the direction of the rotation.

Accordingly, if the body will be thrown away along the radius it will turn opposite to the direction of rotation. If it will be thrown to the center of rotation, it will turn in the direction of rotation.

If the Earth rotates, then the Coriolis effect should appear quite frequently.

(Question: do the Earth rotates from the West to the East of from the East to the West?)

It is observed that to the North from the equator the Coriolis force drives the moving objects to the right, and to South from the equator the Coriolis force drives the moving objects to the left (from the point of view of the observer looking in the direction of the equator). Usually this effect is rather weak, but there are some cases when it is very important. Here some examples:

1. On the north hemisphere the wind tends to turn to the right, and on the south hemisphere - to the left.
2. On the north hemisphere rivers washes over the right banks usually stronger than left banks (on the south hemisphere the left banks accordingly).
3. On the north hemisphere water whirlpools and anticyclones moves clockwise (on the south hemisphere anticlockwise).

Rysunek 3: Hurricane Rita (24.09.2005)

Some other examples:

1. If from the determined point on the north hemisphere the mass of air starts to move in the direction of the North Pole, then coming to areas with the smaller linear velocity it will be flowing on not from the South, but from the South-East. From the point of view of the observer on the Earth it seems like the result of the force acting from the East to the West. Exactly this force is called the Coriolis force.

2. The body thrown down from the Tour Eiffel (273 m height) drops down moved to the East about 6,505103512 cm.

3. The Coriolis effect have to be taken into account by the artillerist and by the navigators of airplanes, rockets, etc., too. E.g. the Coriolis effect made an unpleasant surprise to the war ships of Great Britain during the Falkland armed conflict with Argentine. The English artillerists did not take into account the fact that they are on the south hemisphere (the Coriolis alterations have different signs on the north and the south hemispheres) and they lost two ships.

4.4 Jean Bernard Léon Foucault

The first experimental confirmation of the Coriolis effect on the Earth was done by Jean Bernard Léon Foucault (18.09.1819 - 11.02.1868) - French physisist, the discoverer of the eddy currents (called also Foucalt currents). He was one of the first who measured the velocity of the light in the air and in the water; he constructed the polarizing prism, the photometer and the gyroscope. And what is of our interest, he proofed in 1851 that the Earth really rotates, using the suspended in the Paris Pantheon pendulum of 67 meter long, having the possibility to oscillate in an arbitrary vertical plane.

After the certain time of observation one can notice that the pendulum has changed its plane of oscillations.

The pendulum placed on the geographic pole of the Earth does not change its plane of oscillations, after 24 hours it makes a rotation of 360°.

On the equator, where the latitude $\varphi = 0°$, the Foucault pendulum does not rotate at all.

For the latitudes between $\varphi = 0°$and $\varphi = 360°$, the velocity of the rotation of the oscillation plane depends on the sinus of the latitude and equals $15° \cdot \sin\varphi$ /hour.

The Foucault pendulum demonstrates its interesting properties in many places: in Pantheon in Paris, in USA, in many places important for the science, culture and politics, like universities, museums, congress centers,... and also in Poland, e.g. in Cracow and Frombork.

5 Computer and the physical theory

Physics is a part of science. The goal of the science is to explain the world, i.e. to describe and try to understand the phenomena and to undertake the attempts to predict the future events. As far all the attempts to describe the world in details fails: there are too many details. One have to simplify, i.e. to select the most important elements. Such a simplified description is the model of the phenomenon only. One has to be very careful not to confuse the model with the reality. Unfortunately it happens too often. Our mind also "thinks using models".

The main goal of a researcher is to isolate the most important (decisive) factors influencing the observed phenomenon. One can observe the most rapid progress of science occurred when the researchers succeeded in making proper models. The methodology "from very simple to more complicated" may be very useful.

If we are going to ask the computer to help us in studying the real world, we have to start with the construction of the mathematical model (usually it is a set off integro-differential equations with well posed initial-boundary conditions), and next to look for numerical solutions.The obtained solutions can be visualized in the form of plots or (what sometimes is much better) beautiful animations. The most important however is the interpretation of the obtained results. Let us remember that computer helps and not substitute the human being thought.

The End of the Lecture 1

6 Problems to think about

1. Make a choice of your answers to the following problems and justify them in short essays:

i. Conservation laws deal with the invariance of the values of the all physical quantities independently of the processes in the all phenomena:

a. always,

b. sometimes,

c. from time to time and from the phenomenon to the phenomenon.

ii. The law of the conservation of the velocity is the fundamental law of physics

a. always,

b. sometimes,

c. from time to time and from the phenomenon to phenomenon,

d. not the case

iii. The most important conservation law is:

a. the mass conservation law,

b. the energy conservation law,

c. the momentum conservation law,

d. the moment of momentum conservation law,

e. the moment of force conservation law,

f. the energy-momentum conservation law.

iv. The scalar potential φ of the velocity field exists, if:

a. the medium is incompressible,

b. the motion of the medium is rotationlless,

c. exists always.

2. Order with respect to the date of birth the following scientists: Gaspard-Gustave de Coriolis, Jean Bernard Léon Foucault, Nicolaus Copernicus, Ptolemy.