SYSTEM DYNAMICS MODELLING IN SUSTAINABLE DEVELOPMENT OF WORLD

(Problems and perspectives in Education: theoretical and applied aspects)

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"Gouverner c'est prévioir"

Bonapart Napoleon

"Every knowledge is taking the beginning from sensations"

Yan Komenskiy
(GREAT DIDACTICS)

Preface

Our aim is the investigation of important problems related to Education in whole. Because as it is noted by **Bernard Shaw**:

"The owning the information and Knowledge, own the World…".

From this point the Education System without problems is very actual for SD trends
So, for SD of our World we must, firstly, – to develop the Education System, – to understand the problems and methods of its solving.
Here I show it on example of discipline of "Mechanics". Why – from Mechanics? The reasons:
The discipline of "Mechanics" is main base, background for our knowledge in whole; and Mechanics (with mathematics as constructive "tool" for it, with its specific role as an effective "transport" (pulling) means) will be able to provide considerable advance in the understanding of the essence of complex phenomena of the surrounding world, with the deep penetration of its methods into all fields, including non-traditional for it.
And exactly Mechanics, with its areas promoting development of the dynamic systems theory, of A.M.Lyapunov stability theory (which 120-th Anniversary is celebrated in 2012), plays in all this the major role, providing joint efforts of theorists and engineers, with development and synthesis of methods for the solving problems in interdisciplinary spheres of a science, education and engineering practice, for the researches on nonlinear problems in general, in the whole diversity of fundamental and applied sciences, including the disciplines of natural science and the Humanities (among them also the problems from economics and financial mathematics; nanoscience and nanotechnology; problems of stability and sustaining development; problems of risks and information security, operation research, …).
And on this direction, in process of training, as it is noted by Academician of RAS A.N.Krylov:
"The Specialist (engineer) must not only get the knowledge, but also – "understand" (to be able to know how); …
The Specialist (engineer) must develop not only the mind, but also their own feelings so that they did not deceive him; …
he must not only be able to look, but also – "to see";
he must be able not listen, but also – "hear", not only smell, but also – "feel";

Good illustration of these statements is "Mechanics" and – Education process of this field.
Besides important research topic for SD is "the decision-making process in the area of EDUCATION in MECHANICS that is VERY important basic FOUNDATION for any ENGINEERING area (including: health, water and other basic services, technology, resource use (physical or financial), infrastructure, agricultural/industrialization or environmental sustainability…)". Good Education in this domain "MECHANICS" will be helping to optimize the development in view of constraints and

limited resources also... . Very many students have elementary mistakes in MODELLING of different processes, because they did not obtain GOOD TEACHING in main basic domain – MECHANICS in first!
So, how it is possible to organize the process of teaching students for training good specialists in Engineering ("engineering" in extended sense – not only for traditional technique, but - for all areas in whole, because MECHANICS is MAIN discipline for our KNOWLEDGE).

After this preliminary "WORD" we present our paper.

Abstract – This research is devoted to the specific problems of Mechanics Foundations and Engineering Education in High School. The actual questions are considered, that are connected with the level and quality of fundamental Knowledge on Theoretical Mechanics in training-teaching of specialists (Engineers-Mechanicians) both in general and aviation engineering domain. The principles of subject teaching are discussed, that are led to the activating and governing methods of learning in High Engineering Education. In regard to this statement the general aspects of the peculiarities, inherent to the Theoretical Mechanics subject, that are distinguishing it from another basic disciplines of Engineering Education, are studied. Also of the special difficulties in the understanding and the education, that are generated by these peculiarities, are analyzed. The objective causes, having systematic character, are selected and discovered. The general tenets are illustrated on the examples from the experience of our National Education System in the Mechanical Engineering domain [1-7]. This area is subject of deep theoretical investigation, beginning from early National Scientific-Educational Engineering Schools of Russia (Soviet Union) – S.P.Chebyshev, S.A.Chaplygin, N.E.Zhukovskiy, A.M.Lyapunov, N.G.Chetayev, A.N.Krylov …
Besides we note, this study is connected also with important trend: "System dynamics modelling in sustainable development of world in whole", *in extended sense* from view point of *nonlinear analysts* (*operations researchers*) [8-12].
Also it is very important contribution that systems thinking and system dynamics applied to complex nonlinear systems can bring for a more sustainable world, including objects of various nature of multidisciplinary character. From this point it is very interesting the development of constructive approximate asymptotic methods that are very effective for modelling nonlinear systems of general nature on the basis of the Lyapunov theory and the Chetayev stability postulate, with generalizing herewith the concepts of parametric stability and singularity Also for multidisciplinary systems this systemic techniques, based on developed here methodology, will be providing the stable solutions in dynamics for such complex systems on long-term tracks.

Introduction

The work is dedicated to actual problems that are related to the questions of study effectiveness in Mechanics (Theoretical Mechanics) domain in High School [1-6]; to the search of such methods of theme Education that could be at the same time both the teaching, evolving and controlling ones in process of educating activity. It was paramount subject for specific discussions of famous Mechanicians, Scientists-Teachers, well-known in Russia (SU) and in World in whole (A.N.Krylov, A.P.Minakov, N.G.Chetayev, A.Yu.Ishlinskiy, P.V.Kharlamov,…). The some general aspects of the peculiarities of Theoretical Mechanics subject are considered; the difficulties in education and understanding that are caused by these specific peculiarities are investigated. Moreover special analysis [7] is showing, that these peculiarities have systematic character; and also it is revealed, that they are attributed by objective causes.

And it is the source of hindrance in the knowing of mechanics laws, and it is leading to prolonged adaptation process in the education in domain of Theoretical Mechanics.

Theoretical Mechanics (it is Science about the motion of macrobodies in space and time) has the relation to *all phenomena* of Nature and Engineering Products; it is connected with *all natural-scientific subjects* (disciplines).

The study of Mechanics in High School (University) has great importance and paramount significance to the forming skills and mentality of future specialist. Main aim of Theoretical Mechanics is discovery, cognition and practical application of general basic laws of mechanical motion. The modern Engineering and University Education are impossible without knowing Mechanics. This leading principle was laid the foundations for teaching in Engineering School by classical traditions of well-known Russian School of Mechanics, developed by fundamental researches of N.E.Zhukovskiy, S.A.Chaplygin, N.G.Chetayev, A.N.Krylov,…

Main problems statements

Principle task of Theoretical Mechanics is to give the general maturity-level, necessary skills, and – to learn to study. How?

"The difficulties are not in the question *that* it is necessary to do, but – *how* is it possible to do", A.S.Makarenko.

All organizing of educational-teaching process on Theoretical Mechanics was always dedicated to this task; and it is caused the subject peculiarities that are distinguishing this discipline among another scientific-educational subjects; it is connected with the specific difficulties during learning of some sections – questions of subject.

A.P.Minakov: "On first stage…it seems to Professor, teaching of students, that he pulls "breaked up cart" on the road incredibly pitted (full of potholes). But he must understand – remember, that it is the property of expounded subject".

What is the crux of these peculiarities?

1. Mechanics axioms are requiring for their understanding the certain trainingness of mind, the necessary intellect level.
2. Fundamental conceptions of Mechanics and its laws are based on results of observations, and they are understand via our senses organs; but our sensations may be erroneous (sensation of force, visual perception, …).
3. Theoretical Mechanics is studying the mechanical motion, but the phenomena that are related to it are complex.

All that is leading to the serious obstacle in studying, and it is not easy to overcome. The special investigations of the scientists-psychologists were ascertaining that 80% from all learned students are faced with this.

Among main causes of persistent non-understanding of Mechanics principles and of the difficulties of studying it is necessary indicate:

1. Student is badly possessing elementary knowledge and skills from physics, he is do not connecting it with the phenomena of mundane reality.
2. He has not necessary training-level in Mathematics.
3. In the textbooks the main concepts on Mechanics are not expounded clearly and in all details, but they are stated only primitively-oversimplifiedly.
4. There is real the nonconformity between intuitional ideas of students about motion, based on sense perception, and physical reality, corresponding to Newton's axioms – laws. Exactly this nonconformity creates (on first stages of teaching) the incredibly complexities (as "breaked up cart on the road full of pot-holes").

Our teaching experience, also as the investigations carried out in American Universities, confirm these conclusions.

General scientific psychological-pedagogical aspects

The special psychological analysis ascertained:

- many people have incorrect ideas about the objects motion;
- but on a basis of these ideas they are forming intuitional theory about motion, that is contradicting the fundamental Newtonian laws.

For instance, the question was stated for students: let man is moving (fig.1);
please, draw the trajectory of ball, that is falling out from hand of running man (please, draw your visualizing).

There are different answers; and the distribution of answers is shown on fig.1:
"parabola" – 45% (right answer);
"vertical line" – 49% (non-right answer);
"motion backward" – 6% (non-right answer).

These answers are revealing very interesting problems, that are very important from the point view of education methodics:

- why there are such errors in notions about mechanical motion?
- why are a non true notions?
- what is "true"?
- how it is necessary understand – "true"?

The special investigations showed that these mistakes have not occasional type, but *ones have systematic character*. These errors are caused by wrong notions that are created by the reflection of environment action on the senses organs, via sense perception, and fixed in the mind. It appears that, these perceptions are very close to before Newtonian theory that was accepted earlier, before Newton time.

As example, the students were giving answers in problem about motion of stone (mass point) flinged with horizontal initial speed (in case of motion without air resistance). The answers distribution is shown on fig.2:
A – 28% (right answer),
B – 35% (non-right answer),
C – 5% (non-right answer),
D – 32% (non-right).

Besides the solving of this question was accompanied by explanations of students; in these explanations the conception of before-Newtonian Mechanics was clearly felt(!) (on those earlier notions three phases (1; 2; 3) in the trajectory of cannon-ball flying were separated (fig.3); similarly our students are doing).

Such similarity (in perceptions of medieval scientists and our contemporaries) allows to suppose, that there are objective reasons for this:
these perceptions are *the result of observations* of motion in Earth conditions. Also probably, the cause is in that, what frequently the subject motion is perceived incorrectly (relative motion is apprehended for absolute motion); and wrong perception is consolidating the erroneous notion about motion (that the subjects really move so, as it seams…).

The special investigations of visual recognizing of motion were carried out, and the results were examined. It is shown:
the observation of object against moving reference system is able to lead to the optical illusion. The motion relatively the moving reference system (observed motion) may be incorrectly perceived as the motion relatively the motionless reference system – inertial system.
This supposition about mistaken visual perception was also confirmed by experiments.

As example, let point is situated inside rectangle. Let this point is motionless in regard to the observer; and let the rectangle is moving respectively observer to the right (translationally). In this case for observer it *seems* (it will be able to seem), that this point is moving to the left (fig.4).

Next experiment. For students it was shown the videotape recording of man motion that during motion is droping the ball (fig.5). After this film preview it was proposed the students to draw the ball trajectory (to draw that, *what* they have *seen*). The answers distribution is shown on fig.5:

22% of students have *seen*, what the ball droping is moving forward (it is absolute trajectory);
56% of students have *seen* the ball motion on vertical line (it is relative trajectory);
22% of students have *seen* the ball motion back (?…).

So, in same time the different students have *seen* these *different* motions!

Additional similar experiment (it is shown on fig.6). There is the rectangle, moving relatively the screen. On top side of rectangle there is the small circle that was in rest relatively the rectangle until, when this rectangle did not pass the distance ~1/3 of length of screen. After this the circle has "droped" on line, *imitating its absolute trajectory*, and the rectangle contained its former motion.

After viewing it was suggested the students to draw the *observed* trajectory of circle. Only 22% of students were *seen* the real motion (absolute trajectory); 78% of students were *seen* the circle fall on vertical line (*apparent motion*).

So: the mistaken perceptions may be the caused of wrong notions about motion and, as consequence, – about Mechanics laws(!).

Methodics problems

So: non-true notions about objects motion lead to the forming of intuitional theory of motion; and it is leading to the errors in the actions in real situation.

How it is possible to destroy these wrong notions? It seems, that it is very easy –
by way of education-teaching of Newton Mechanics.

But (and it is conformed by special analytical and experimental investigations) it is very complex problem – to change these intuitional notions. Many students, graduated University with studying of the subject of Theoretical Mechanics can not give up these intuitional ideas about motion. From the education psychology view point, probably, the educational material is adjusted by students to fixed (in their mind) intuitional ideas, and it is interpreted non-correctly by them. So, it is very important to develop *the aim-directed methods* of teaching *in engineering education* that take into consideration the specific peculiarities for such Science as Theoretical Mechanics.

Our scientific and teaching experience allows to develop good effective manners that are based on "problemic education" method in the combination with activating of original work of students during process of getting to know.

Also our psychological-educational experience is conforming for Theoretical Mechanics, that it is very important during teaching period, during explanation of Mechanics principles to give the time period for students adaptation ("better go very slowly, than hasty teaching…").

So, it is asymptotic process…(the good illustration in this: the comparison of Newton Mechanics model and Aristotle Mechanics model for systems with friction…).

It is necessary to give the exhaustive, deep, through expounding of fundamentals, on which Mechanics is based.

The investigations of intuitional ideas and the analysis of psychological processes of their forming will be able to permit to improve the methodics of teaching in Theoretical

Mechanics, to help to introduce to systemic method of Teaching. Our national (in Russia-Soviet Union) experience of Teaching in Engineering Education is allowing to elaborate:

- the skill to get into essence of examined phenomena;
- the skill to generalize and to extend the concepts;
- the skill to think by analogies and to model.

It is very actual for Theoretical Mechanics, for that "the all difficulty in whole is contained in what, that it is necessary on motion phenomena to understand the forces of Nature, and after on these forces – to explain the another phenomena", – **Isaak Newton**.

Conclusion

As illustration of presented meditations and results, as short resume of these complex problems, we repeat here again the interesting quotation from poem of well-known Russian Poet A.S.Pushkin (that is reflecting the underlying idea, essence of principal peculiarities of Theoretical Mechanics subject) and also – Academician of RAS N.N.Moiseev, specialist in area of Mechanics, Mathematics, operation research (nonlinear analyst):

«There is no motion», - the Sage bearded said;
Another person stopped saying, and took up
in front of him to go;
He could not powerfully to disagree;
All praised the intricate reply.
But, gentlemen, this fanny case brings
another example on memory to me:
After all Sun goes every day in front of us,
However THE RIGHT is stubborn Galileo!

A.S.Pushkin

"…I think, that a key, capable to open a door in the future of Mankind, will turn out to be THE SYNTHESIS of reason (mind) and that irrational beginning which is mortgaged in people … ;

The science can formulate necessary definitions, create the whole system of a taboo, but – will be able Mankind to accept them? "

N.N.Moiseev

In final remark of this paper as confirmation of our (National Educational and Scientific Schools) positive results in this experience we would like to present here the opinion of USA Vice-President (Josef Byden):

"…we value cooperation with Russia…
since **in Russia it is World Sharpest Engineers,**…"

Josef Byden (2011).

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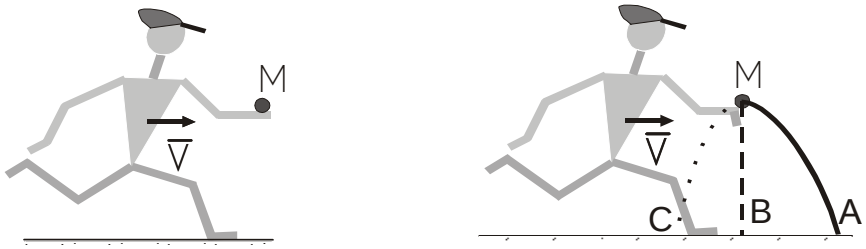
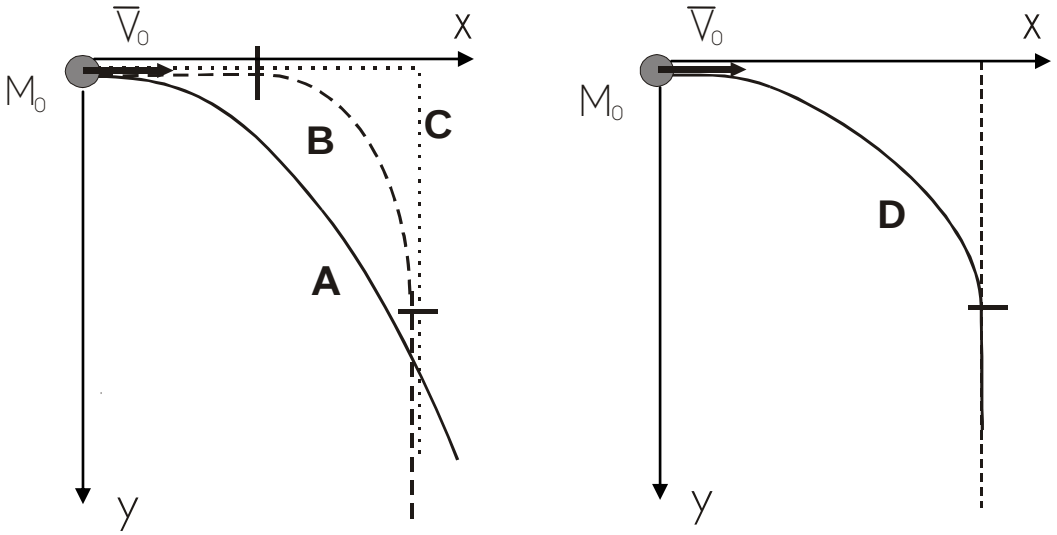
Figures



A (parabola) — 45%
B (vertical line) — 49%
C (motion backward) — 6%

Fig.1



A (parabola) - 28%
B - 35%
C - 5%

D - 32%

Fig.2

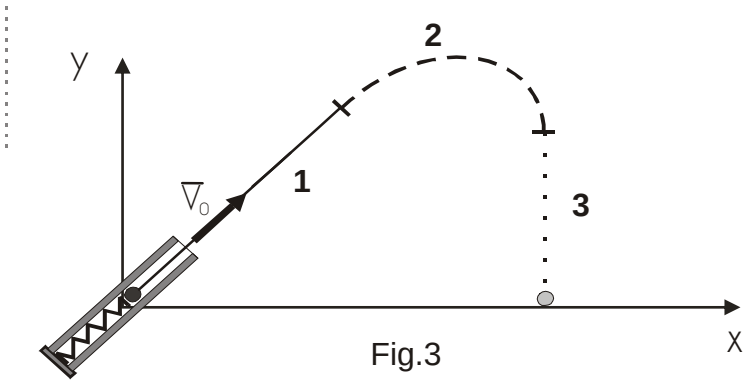
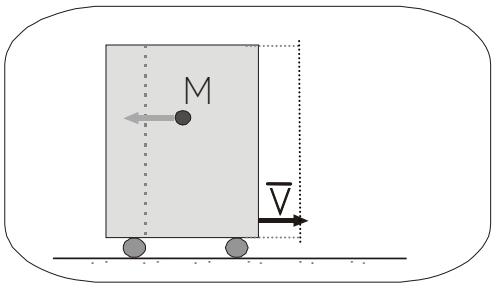
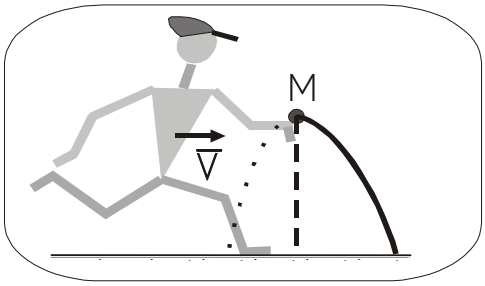


Fig.3



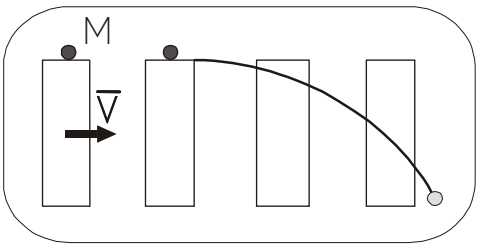
Real motion (rest) – 20%
Apparent motion
(to the left) – 80%

Fig.4

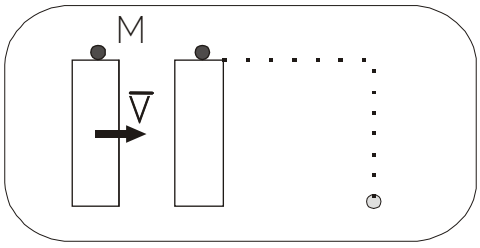


Motion forward – 22%
Motion on vertical line – 56%
Motion backward – 22%

Fig.5



Real motion – 22%



Apparent motion – 78%

Fig.6