New Look on Training the General Physics

Nakhchivan Yusub oglu Safarov

Department of Physics, Azerbaijan Technical University, Baku, Azerbaijan.

ABSTRACT

In this paper the System of training the General Physics with a unified approach is construed. The technique of creation of this pedagogical system is explained. Having established analogy between elements of system and elements of a natural tree, training process is designed in the form of the natural tree ("Training tree"). The analogy of evolutions of the "Training Tree" and a natural tree have been established. A synergism of the developed training system is shown, it is established that it adequately meets the criteria of the training technology.

Key words: Training system; Unified approach; Evolution; Synergism; Training technology

INTRODUCTION

Physical knowledge of the modern engineer should meet requirements of fundamentality, professional orientation and technological effectiveness. The General Physics is the base of the engineering sciences. It should be taught in conformity with the future profession of the student of Technical high school. Training the General Physics should be carried out at technological level.

Studies show that the existing methodology of training the General Physics not fully meets the specified requirements. In its training one can see the following shortages:

1. Escalating from year to year innovations of theoretical and applied physics unceasing increase volume of the training material and complicate its perception. Training term remains invariable, and in many cases decreases. The existing methodology of training cannot meet the requirements of training material of great volume and complexity.

2. Concepts, terms of the General technical disciplines and the General Physics differ, different symbols are used, forms of record of laws and the equations differ. In these disciplines physical quantities and their units often are not similar to one another.

3. A source for the fundamental knowledge, promoting understanding of non-equilibrium open systems, existence in systems of self-organization and spontaneous anti-dissipative processes in them, synergistic effects, operating principle of the "alternators" concerning to "fuel-free" power generation and operating on field energy, a creation principle of nanomaterial's should be the General Physics. These important problems concerning the modern technics and technologies cannot be included in the content of the existing programs on the General Physics.

4. The existing methodology creates a condition for mechanical cramming without assimilation. And it does not promote formation of the substantive, long-term knowledge necessary for studying of special disciplines.

5. In present-day methodology actually prevails an inclination on studying only the knowledge concerning the physics itself.

6. This shortage is associated with such abstractions as a material point, conservative system, instantaneous velocity, etc., introduced in physics from mathematics. For example, the concept "a material point" is mathematical abstraction. In this case spatial dimensions conditionally are reduced to zero. It means that at movement of the material point there cannot be an external friction force. Besides, absence of the spatial
dimensions does senseless think about rigidity of the system. Finally, a material point does not have the rotary motion form.

These revealed shortages can be eliminated by realization of new approaches in training the General Physics by modification its content and structure.

In our opinion, listed above difficulties can be eliminated by using in training the General Physics modern theories, laboratory experiments and applying analogy as a method, means. On the basis of this idea we have created the System of training the General Physics with a unified approach [Safarov N.Y., 2014]. This system is created by generalisation of physical analogues of various groups for identical motion forms.

A technique of creation of the System of training the General Physics with a unified approach

Training the General Physics is process. A main condition for the process to become a system is that it must be consist of the stages connected with each other. Therefore process of training the General Physics we divide on stages (Table 1).

At all stages the problems concerning identical forms of motion are studied. Forms of motion "bring together", connect stages with each other.

Each stage consists of elements – physical analogues

<table>
<thead>
<tr>
<th>Ordinal number</th>
<th>Stages</th>
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<tr>
<td>I.</td>
<td>Definition of forms of the interaction (motion) entering into the content of the General Physics</td>
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<td>II.</td>
<td>Definition for each form of motion a property with attributes of extensiveness [Cengel Y. A. et al., 2006] and generalization of the extensive property for all forms of motion</td>
</tr>
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<td>III.</td>
<td>Definition for each form of motion a property with attributes of intensity [Cengel Y. A. et al., 2006] and generalisation of the intensive property for all forms of motion</td>
</tr>
<tr>
<td>IV.</td>
<td>Definition of the equilibrium criteria for separate properties, generalisation of these criteria. Definition of the distribution moment of the extensive quantity (Z) as absolute extensive measure of spatial heterogeneity of the system [Etkin V.A., 2011] with respect to one of the system properties, generalisation of the distribution moment of the extensive quantity. Analyzing expression of full differential of function Z, for one form, all p processes running in heterogeneous systems can be divided into three groups: uniform, redistribution and reorientation processes. Generalisation of this proposition for all forms of motion.</td>
</tr>
<tr>
<td>V.</td>
<td>Definition of expression for forces proportional to a potential gradient, considering that the reason for the occurrence of processes in the system is the potential gradient on the one hand, and force on the other hand.</td>
</tr>
<tr>
<td>VI.</td>
<td>Understanding work as a quantitative measure of the process associated with overcoming any forces, its definition on presence or absence of the resultant at overcomable forces (ordered or unordered) [Etkin V.A., 2011]. Definition of expressions of separate unordered works in uniform processes and their generalisation.</td>
</tr>
<tr>
<td>VII.</td>
<td>Definition expressions for separate ordered works in redistribution and reorientation processes and their generalisation.</td>
</tr>
<tr>
<td>VIII.</td>
<td>Accepting a total energy as a quantitative measure for all ordered and unordered works which the system can make, record of change of the total energy in the form of the sum of the ordered and unordered works and their generalisation: dE_{total} = \sum_i \psi_i d\theta_i - \sum_i \phi_i d\psi_i</td>
</tr>
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<td>IX.</td>
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<td>X.</td>
<td>Definition of physical analogs characterizing subsystems of capacitive, resistive and inductive behavior involved in the transition processes</td>
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<td>Subsystems of capacitive behavior, generalised formula for a potential difference in subsystems of capacitive behavior: ( \psi_c = \frac{\theta}{\theta_c} )</td>
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<tr>
<td>X.2</td>
<td>Subsystems of the resistive behavior, generalised formula for a potential difference in subsystems of the resistive behavior: ( \psi_R = RI = R\theta )</td>
</tr>
<tr>
<td>X.3</td>
<td>Subsystems of the inductive behavior, generalised formula for a potential difference in subsystems of the inductive behavior: ( \psi_I = -L\theta )</td>
</tr>
<tr>
<td>XI.</td>
<td>The transient processes. A generalised differential equation, characterising transient processes: ( \frac{\theta}{\theta_c} + R\theta + L\theta = \psi_c + \psi_R + \psi_I = \psi(t) )</td>
</tr>
</tbody>
</table>
| XII.           | The transport processes. They are associated with a subsystem of the resistive behavior arising in the transient processes: \( J = -k [d\psi_R/dt] \); k – transport coefficient.
Under physical analogue we mean physical objects which have at least one identical physical property (quantity, formula, etc.). Stages are physical analogues of one group, while intra-stage elements are those of other group.

**Table 2: Intra-stage elements of training the General Physics**

<table>
<thead>
<tr>
<th>Number and the name of the stage</th>
<th>Intra-stage elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Forms of motion</td>
<td>1. Linear motion. 2. Rotation around a fixed axis. 3. Laminar flow, a gas flow. 4. Mass exchange. 5. Move the mass in the gravitational field. 6. Heat interaction. 8. Magnetic interaction</td>
</tr>
<tr>
<td>III. Intensive properties (( \Psi_i ))</td>
<td>1. Projections of the linear velocity ( (v_x, v_y, v_z) ). 2. Angular velocity (( \omega )). 3. Pressure of the liquid, gas (P). 4. Chemical potential (( \mu )). 5. Gravitational potential ( (\omega_0) ). 6. Absolute temperature (T). 7. Electric potential (( \phi )). 8. Magnetic potential (( \phi_m ))</td>
</tr>
<tr>
<td>IV. Processes, generalized expression: ( \frac{dZ}{dR} = R_d \Theta_i + \Theta_i dR )</td>
<td>(terms I characterize uniform processes, terms II characterize redistribution processes)</td>
</tr>
<tr>
<td>Y. Forces, general: ( - \Theta_i \text{grad}q )</td>
<td>1. Newton force: ( -p \text{grad}q ). 2. Rotating force: ( -L \text{grad}q ). 3. Force acting on the volume element of the liquid, gas: ( -V \text{grad}q ). 4. Force in a fuel element (dialyzer): ( -N \text{grad}q ). 5. Force of gravity: ( -M \text{grad}q ). 6. Thermoelectromotive force: ( -S \text{grad}q ). 7. Coulomb force: ( -q \text{grad}q ). 8. Lorentz force: ( -q \text{grad}q )</td>
</tr>
<tr>
<td>YI. Unordered work, general: ( \Psi_i d\Theta_i )</td>
<td>1. Work of input of a linear momentum in the body with average speed ( v ): vdp. 2. Work of input of an angular momentum in the body with average angular speed ( \omega ): ( \omega dL ). 3. Work of uniform input of the liquid, work of expansion of gas: ( PdV ). 4. Work of input of the substance in the system (mass transfer): ( \mu dN ). 5. Work of input of the mass in the gravitational field with average potential ( \Phi_m ): ( \Phi_m dM ). 6. Heat exchange: ( TdS ). 7. Work of input of the electric charge in the electric field with average potential ( \Phi ): ( \Phi dq ). 8. Work of input of the &quot;magnetic charge&quot; in the magnetic field with average potential ( \Phi_m ): ( \Phi_m dq_m )</td>
</tr>
<tr>
<td>YIII. Change of the total energy of the system having five degrees of freedom</td>
<td>(terms in the top line show unordered works, while terms in the bottom line show ordered works) ( dE_{\text{total}} = vdp + TdS + \mu dN + \Phi dM + \Phi dq )</td>
</tr>
<tr>
<td>IX. Laws of conservation of linear momentum, angular momentum, electric charge</td>
<td>1. ( dE_{\text{total}} = vdp ); for isolated system ( dE_{\text{total}} = 0 ); vdp = 0; p = const. 2. ( dL = \omega dL ); for isolated system ( dE_{\text{total}} = 0 ); ( \omega dL = 0 ); ( L = ) const. 3. ( dq ); for isolated system ( dE_{\text{total}} = 0 ); ( \Phi dq = 0 ); ( q = ) const.</td>
</tr>
</tbody>
</table>
System is a set of interconnected elements that perform a common function [Krutitskiy A.N. et al., 2006]. From the tables presented by us one can see that process of training the General Physics with a unified approach has complex structure and consists of elements. This training process has the overall goal. This goal is to improve the basic and specialized training in physics for engineering students, getting education at bachelor level. In order to achieve the common goal each element performs its role, function. For example, items such as the definition of ordered and unordered works related to extensive, intensive properties and their changes have a peculiar role and function. These elements are connected among themselves by certain relation. Elements within the set

| X. Subsystems participating in transient processes | a) Subsystems of the capacitive behaviour  
b) Subsystems of the resistive behaviour  
c) Subsystems of the inductive behaviour  

X.1. Subsystems of capacitive behaviour  
1. \( V_c = \frac{L}{m} \); in linear moving the mass is also linear momentum capacity of the body [Herrmann F, 2000].  
2. \( \omega_c = \frac{L}{j} \); in rotation around a fixed axis the moment of inertia is also angular momentum capacity of the body.  
3. \( \frac{F}{C} = \frac{V}{k_c} \); in a liquid flow in the closed pipe a capacity is defined as change of the volume which creates 1 Pa additional pressure \( \Delta V / \Delta P \) - \( K_c \) or \( V / P = K_c \) [Hans U. Fuchs, 2010].  
7. \( U_c = \frac{Q}{C} \); in electricity a capacity is defined as change of the charge which creates 1 V additional voltage

X.2. Subsystems of resistive behaviour  
1. \( v_n = -R \cdot F; R\) - resistance to linear momentum current.  
2. \( \omega_R = -R \cdot I; R\) - resistance to angular momentum current.  
3. \( P = R \cdot \frac{T}{l}; R = \frac{8 \eta l}{\pi r^4}\) the resistance defined under the Poiseuille's law \( \eta\) - fluid viscosity, \( l\) - pipe length, \( r\) - pipe radius [Hans U. Fuchs, 2010].  
7. \( U_R = R \cdot I\); Ohm's law, \( R\) - Ohmic resistance

X.3. Subsystems of inductive behaviour  
1. \( v_L = -\frac{d}{dt} \frac{I}{k}; \) a difference of the linear velocities (voltage drop) is proportional to rate of change of the linear momentum current (force), inductive subsystem is a spring, \( k\) - spring constant.  
2. \( \omega_L = -\frac{1}{m \cdot gb}; \) a difference of angular velocities (voltage drop) is proportional to rate of change of the angular momentum current (torque), inductive subsystem is a body of the physical pendulum.  
3. \( P_l = L \cdot \frac{dV}{dt}\) [Hans U. Fuchs, 2010]; a difference of pressure is proportional to rate of change of the liquid volume current, inductive subsystem is a liquid in the connecting pipe.  
7. \( U_L = -L \cdot \frac{dI}{dt}; \) in the inductive coil voltage drop is proportional to rate of change of the electric current.

XI. Transient processes  
1. Discharge (from extensive property) of subsystem of capacitive behaviour (capacitor discharge): \( \psi_C + \psi_F = 0; \quad (U_C + U_K = 0) \)  
2. Charging (with extensive property) of subsystems of capacitive behaviour (capacitor charging): \( \psi_C + \psi_R = \psi_0; \quad (U_C + U_K = U_0) \)  
3. Disappearance of the current of extensive value in the chain in series connected subsystems of resistive and inductive behaviour (disappearance of the electric current): \( \psi_R + \psi_L = 0; \quad (U_R + U_I = 0) \)  
4. Current establishment (electric current establishment): \( \psi_R + \psi_L = \psi_0; \quad (U_R + U_I = U_0) \)  
5. Damped oscillations (damped oscillations in the spring pendulum): \( \psi_C + \psi_R + \psi_L = 0; \quad (\frac{v_0}{m} + \frac{v_0}{m} + \frac{v_0}{m} = 0) \)  
6. Forced oscillations (forced oscillations in a spring pendulum): \( \psi_C + \psi_R + \psi_L = \psi_0 \sin \omega t; \quad (\frac{v_0}{m} + \frac{v_0}{m} + \frac{v_0}{m} = \psi_0 \sin \omega t) \)

XII. Transport phenomena  
1. \( j = -\kappa \frac{dT}{dx}; \) Fourier's law  
2. \( j = -D \frac{\partial c}{\partial x}; \) Fick's law  
3. \( j = -\eta \frac{\partial E}{\partial x}; \) Newton's law  
4. \( j = -\rho_0 \frac{\partial q}{\partial x}; \) Ohm's law

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occupy no any desired place, but a definite place in accordance with their role and function. Relationships between them are not arbitrary, but defined.

Arrangement in a defined order of the elements linked to certain bonds forms a definite structure. The structure is defined as a significant, sustained, stable connection between the elements of the system. Each of the elements in turn also may have elements; for example, the training of the transition process associated with the study of elements of capacitive, resistive and inductive nature. These elements are also connected with both the external and internal elements. Eventually, it is seen that all components of the system in a particular order associated with each other. These associations have a peculiar direction, logic and they have a mutual submission; properties and their extensive spatial and temporal changes include, one can say, in all relationships. Each new element acts as the successor of the previous elements. An arrangement of elements in the order described by us forms hierarchical complex structure.

Hence, presented by us process of training the General Physics with a unified approach has properties of the system and therefore, is a system. This is ideal (theoretical, conceptual) system. In the given system elements (stages) are coordinated, connected with each other by the "forms of motion". Hence, sheaves of system defined by us are on the one hand "forms of interaction - forms of motion", on the other hand - the analogy used as a method and means.

There is an analogy between elements of the System of training the General Physics with a unified approach and elements of the natural tree (Table 3). This analogy gives an idea to design this process of training in the form of a natural tree (Training Tree).

Table 3: Natural tree and constructive analogy of the "Training Tree"

<table>
<thead>
<tr>
<th>Natural tree</th>
<th>Training Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root</td>
<td>Phoenomena studied in the General Physics</td>
</tr>
<tr>
<td>Trunk</td>
<td>Forms of motion</td>
</tr>
<tr>
<td>Branches</td>
<td>Training stages of the General Physics content</td>
</tr>
<tr>
<td>Leaves</td>
<td>The elements entering into stages</td>
</tr>
<tr>
<td>Hierarchy of branches</td>
<td>Hierarchy of training stages</td>
</tr>
</tbody>
</table>

A design of the process of training created on the basis of this idea (Training Tree) is shown in Fig. 1. "Forms of motion" designed in the form of a trunk connects with each other stages of training and intra-stage elements. Also each branch (training stage) binds together its leaves (intra-stage elements). Thus, elements of the system construed by us are connected by double bonds.

An ordered sequence of branches shows hierarchy of the training stages.

**Analogy of evolutions of the “Training Tree” and a natural tree**

Let's investigate conformity of evolution of the named trees to Darwin's principles of adaptation, variability, hereditary.

A natural tree is non-equilibrium biological system. It is located in non-equilibrium environment. Non-equilibrium state of the system leads to occurrence a thermodynamic force inside it. Such force exists within the system and within the outer environment. The system is located within the environment and they interact. Therefore force in the system can be balanced by force in the environment. It is external balance. Precisely such balancing processes are responsible for bio-system evolution. They proceed in a direction of establishing balance between the system and the environment. External balance is not complete equilibrium (internal and external). The aspiration to such balance in any way does not deprive system of possibilities to execute external useful work, to transform energy within itself.

During balancing processes the natural tree acquires new properties (new degrees of freedom). New branches, leaves are formed. This is variability. But occurring changes are not casual. Changes occur pursuant to environmental impacts. This is adaptation.

Let’s explain also hereditary in evolution. Assume that in biosystem external balance with respect to some degree of freedom is achieved (one leaf of the tree has ripened). This balance can remain for a long time. It can be transferred from generation to generation. This is hereditary.

Now let’s examine the evolution of the "Training Tree". "Training Tree" is a non-equilibrium theoretical, conceptual system. For this system environment is the information medium necessary for provision physical knowledge of the engineer. The information system also is non-equilibrium. The training system is surrounded by the information medium and they interact. Analogue of thermodynamic force in the system of the natural tree is the offer to study in training system (on "Training Tree") a certain training material (for example, one branch). This offer can be expressed as a negative gradient of the potential difference of knowledge of the teacher and the student. Analogue of thermodynamic force in the information environment is the requirement to teach student certain information. This requirement also can be expressed as a negative gradient of the potential difference in the information medium and knowledge of the student. The training system is in interaction with the
information environment. Therefore the offer can coincide with the requirement. Being expressed in terms of physics, the force in training system can be balanced by the force within the information environment. For evolution of the training system just processes of convergence of requirements and offers are responsible. These processes do not interfere with deeper, wider explanation of any question at training.

In the training system offered by us necessity of studying of the training material relating to certain stage makes it necessary to study also the materials relating to intra-stage elements. This is analogue of the origination of new leaf from a branch and shows variability of the training system. These changes occur not casually, but according to requirements of the information environment. This is adaptation.

In the System of training the General Physics with a unified approach hereditary is obviously visible. Each subsequent training stage is based on the preceding stage and is its successor. For example, for studying of intensive properties it is necessary to study extensive properties before. Let’s explain in other words. Assume that one of the training stages has been completed. It means that the offer corresponding to this stage is counterbalanced by the requirement. This balance can remain till the end of the training term, can be a basis for studying of subsequent stages. This is hereditary.

Thus, the system of training offered by us occurs according to natural processes.

**Synergism of the System of training the General Physics with unified approach**

Attributes of synergism of the system is its complexity, openness, non-equilibrium, non-linearity, self-organisation.

The system proposed by us is complex. This system of training includes training numerous different issues related with each other. Being a single whole, the training system assumes study of the General physics on the basis of relations of stages and intra-stage elements entering into system. It is an indicator of the synergism. For the sake of clarity we note that also in statistical physics we deal with complex systems formed of numerous subsystems (atoms, molecules). But the main difference between a synergistic approach and statistical physics is that the static physics studies the system based on the properties of their constituent elements, whereas synergy studies of the system on the basis of inter-element relationships.

The training system developed by us is organised not on the basis of a superposition principle, but on the basis of an interference principle. This is clearly seen in the evolution of the tree. With growth of number of branches a trunk thickens. With passage of the stages in the training system the quality of the knowledge on the forms of motion (trunk) increases. That fact that the system is not organised on the basis of superposition principle indicates its nonlinearity.

The system of training with a unified approach is open system. The system can accept new scientific information. Necessity of introduction new information changes the requirement. For evolution of the system the offer should be counterbalanced by the requirement. For an equilibration in system a change corresponding to the offer occurs. A necessity to install in the system a new stage (branches) or intra-stage element (leaf) arises. Origin in the system new degrees of freedom as a result of impact of new forces arising in environment is a bifurcation. Hence, introduction in the system of training a new stage, an element is a bifurcation.

Accompanying bifurcation new stage (branch), new element (leaf) being counterbalanced with environment can "live" during long time. Origin and "existence" of a new stage, an element means self-organising of the system.

Herein above we noted that the training system has a hierarchical structure. In other words, being single whole, the training system assumes consecutive performance in the necessary (coordinated) sequence associated with each other training stages. It is very close to definition of the synergy formulated by Haken [Hermann Haken, 1978].

In evolution of the training system it is seen a creation an order from “chaos”. Before the origin of the training system the materials concerning a content of the General Physics are in a “chaos” form. At evolution of the training system one stage arises, and the offer corresponding to this stage is counterbalanced by the requirement of the information environment. Origin and "existence" of the stage means creation an order from the “chaos”. It corresponds to Prigogine's explanation [Prigogine Ilya et al, 1984].

**The System of training the General Physics with a unified approach as a training technology**

Lets examine, whether the methodical system offered by us satisfies to criteria of training technologies. Training the General Physics with a unified approach is process. In its training aid V.Y) Vilenskiy et al, 2004) underlined that technology being accepted as process is characterised by following three attributes:
Fig. 1. Training Tree
• division of process into the interconnected stages;
• stage-by-stage execution of the actions directed on obtaining the desired result (goal achievement);
• univocal implementation of the operations entered into technology; it is important, decisive condition for achievement of the results adequate to object in view.

Having investigated numerous technologies of training, (Selevko.G.K, 2000) has defined criteria on which pedagogical process is pedagogical technology. These include: consistency (complexity, integrity), scientific character (conceptual, creative character), structuring (hierarchy and continuity, logicality, etc.), controllability (diagnosing, forecasting, efficiency, optimality, reproducibility).

The satisfaction of pedagogical process – training process to structure criteria was already explained above.

In the system offered by us there is one algorithm - division on separate content areas occurring in a certain order. Depending on conditions of implementation of technology it is possible to change the sequence, the period of elements. For example, at X and XI stages change of sequence of elements does not lead to changes in result.

Scientific character in system is explained by resting on such scientific theories, as the classical physics, classical thermodynamics, thermokinetics, energodynamics and modern practical achievements.

Efficiency, optimality of the training system is embodied in generalisation of the important concepts – process, force, ordered work, unordered work, etc. for the considered forms of movement. It shows that process satisfies criteria of controllability.

From stated it is clear that the training system offered by us along with requirements of consistency adequately satisfies also to criteria of the training technology.

We come to conclusion that prepared by us the System of training the General Physics based on Unified Approach can be realised at the level of training technologies.

CONCLUSION

The System of training the General Physics with a unified approach for Technical high schools have been developed. The system consists of the training stages and intra-stage elements and meets the criteria of the system. There is an analogy between elements of the developed ideal system and elements of the natural tree. Therefore the training system is designed in the form of a tree. The analogy of evolutions of this tree and a natural tree is established. It is shown that the training system is opened, non-equilibrium, nonlinear, polyvariant, self-organizing system and is established its synergism. Realisation of the developed training system as technology of training is offered.

A unified approach saves time in the teaching of processes, allows gaining system knowledge, correctly understanding the processes, generalizing, drawing conclusions and simplifying the process of remembering.

REFERENCES


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