SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2016 **Issue:** 1 **Volume:** 33

Published: 30.01.2016 http://T-Science.org

Gennady Evgenievich Markelov
Candidate of Engineering Sciences,
associate professor,
Bauman Moscow State Technical University,
Moscow, Russia
markelov@bmstu.ru

**SECTION 21. Pedagogy. Psychology.
Innovations in the field of education.**

TEACHING THE BASICS OF MATHEMATICAL MODELING. PART 1

Abstract: *The article outlines some important aspects related to teaching the basics of mathematical modeling. It provides recommendations for the development of content and framework of the discipline teaching the basics of mathematical modeling. The application of such aspects and guidelines enhances the quality of graduates' training and increases their competitiveness.*

Key words: *mathematical modeling, quality training, competitiveness.*
Language: *English*
Citation: Markelov GE (2016) TEACHING THE BASICS OF MATHEMATICAL MODELING. PART 1. ISJ Theoretical & Applied Science, 01 (33): 69-71.
Soi: http://s-o-i.org/1.1/TAS-01-33-14 ***Doi***: crossref http://dx.doi.org/10.15863/TAS.2016.01.33.14

1. Introduction

Mathematical modeling is frequently used in many knowledge-intensive industries, such as machine and instrumentation engineering. Continuous development of these industries requires highly qualified experts with necessary skills who are able to address any arising research and engineering challenges by rational application of mathematical modeling. In this context, it is critical to teach the basics of mathematical modeling focused on studying advanced methods of building mathematical models, ways of quantitative and qualitative analysis of mathematical models, methods of rational use of mathematical modeling in machine and instrumentation engineering.

The purpose of this article is to outline some important aspects of development of content and framework of the discipline teaching the basics of mathematical modeling. The application of such aspects and guidelines improves the quality of graduates' training for work in different sectors of machine and instrumentation engineering and increases their competitiveness.

These aspects are outlined to include guidelines described in [1; 2].

2. The Entry Level of Students

Mathematical modeling of advanced machine and instrumentation engineering objects relies on the knowledge of science and technology and uses almost all branches of mathematics. Thus, the content of the discipline teaching the mathematical modeling basics is closely connected to the mathematical, science and engineering disciplines within the main education program, or their modules. In this context, it is worth looking at the Mathematics at a Technical University [3–23] set of textbooks that reflect extensive experience of the Bauman Moscow State Technical University in teaching the fundamentals of mathematics, its specific areas and a range of mathematical disciplines required in machine and instrumentation engineering.

Successful teaching of basics of mathematical modeling requires knowledge, skills and abilities gained from studying the preceding disciplines (or their modules), in particular, physics; mathematical analysis; analytical geometry; linear algebra; integrals and series; differential equations; theory of functions of a complex variable; probability theory, mathematical statistics and theory of stochastic processes; computing techniques; equations of mathematical physics; and mechanics and electrodynamics of continuous media.

3. Content and Structure of the Teaching Discipline

The content of the teaching discipline should cover various mathematical, science and engineering disciplines as well as establish a common and unbroken connection between them. Such a discipline should look at mathematical models of various engineering systems with a special focus on mechanical, thermal, hydraulic and pneumatic systems. For this purpose, it is a good idea to build a hierarchy of mathematical models of the same object.

The Basics of Mathematical Modeling course is described below as an example of such a teaching discipline. The author delivered the relevant lecture series at the Department of Applied Mathematics of the Bauman Moscow State Technical University. The content is based on the final, 21st issue of the Mathematics at a Technical University series [23] and comprises four modules: Fundamentals of Mathematical Modeling, Macro-Level Mathematical Models, Non-Linear Macro-Level Mathematical Models, and Micro-Level Mathematical Models.

3.1. Fundamentals of Mathematical Modeling

Mathematical Modeling and Technical Progress.

Main Stages of Mathematical Modeling.

Mathematical Model of a Technical Object. Definition, Structure and Properties of Mathematical Models. Requirements for Mathematical Models. Principles of Building Mathematical Models.

Classification of Mathematical Models.

Decomposition Principle. Hierarchy of Mathematical Models and Their Presentation Forms (Micro-Level Mathematical Models, Macro-Level Mathematical Models, and Meta-Level Mathematical Models).

Introduction to Dimension Theory. Governing, Definable and Basic Parameters of Technical Objects. Pi Theorem. Examples of Use of Dimension Theory.

Mathematical Model Presentation in a Dimensionless Form. Similar Processes. Example Problems.

3.2. Macro-Level Mathematical Models

Equation of the State of a Standard Element. Features of Building Mathematical Models of Systems Consisting of a Large Number of Interrelated Standard Elements.

Primitive Elements of Technical Systems. Electromechanical, Electrothermal, Electrohydraulic and Electropneumatic Analogies.

Using Mathematical Models of Primitive Standard Elements. Mathematical Model of the Resistor, Which Resistance and Total Specific Heat Depends on Its Temperature. Mathematical Model of the Capacitor, Which Loses Its Electrical Charge Due to Imperfect Insulation.

Equivalent Scheme of a Technical System. Dual Electric Circuits. Correlation Between the Voltage Drop Law and Current Intensity Law in Dual Circuits.

Duality of Electromechanical Analogy. Building Mathematical Models of Mechanical Systems by Using the Second Variant of Electromechanical Analogy.

Mathematical Models of a Linear Oscillator and Their Analysis.

Using Lagrange Equations of the Second Kind to Build Mathematical Models of Technical Systems.

3.3. Non-Linear Macro-Level Mathematical Models

Examples of Problems Leading to Building of Non-linear Macro-Level Mathematical Models of Technical Systems.

Static and Stationary Mathematical Models. Some Non-Stationary Mathematical Models. Primitive Dynamical Mathematical Models.

Conservative System. Behavior of Some Conservative Systems.

Mathematical Models of Some Dissipative Systems.

Self-Oscillating Systems.

Approximate Analytical Methods for Dynamical Model Analysis.

3.4. Micro-Level Mathematical Models

Micro-Level Mathematical Models of Primitive Elements of Electrical Systems. Mathematical Model of a Long Linear Conductor with a Circular Cross-Section. Mathematical Model of a Flat Electric Capacitor. Analysis of Created Mathematical Models.

One-Dimensional Stationary Models of Thermal Conductivity. Building Stationary Models of Thermal Conductivity in a Porous Heat Protection Layer. Building One-Dimensional Stationary Models of Thermal Conductivity in a Curved Surface Wall. Building One-Dimensional Stationary Models of Thermal Conductivity in a Curved Surface Wall with Internal Heat Release. Analysis of Created Mathematical Models. Thermal Explosion.

One-Dimensional Non-Stationary Models of Thermal Conductivity. Building Non-Stationary Mathematical Models of Thermal Conductivity in a Flat Wall. Building Non-Stationary Mathematical Models of Thermal Conductivity in a Two-Layer Flat. Analysis of Created Mathematical Models.

One-Dimensional Non-Stationary Models of Hydraulic Systems. Building Mathematical Models of a Horizontal Pipeline Section. Boundary Conditions at Pipeline Ends. Examples of Building Mathematical Models of Hydraulic Systems. Analysis of Created Mathematical Models. Water Hammer.

Features of Using Mathematical Models. Examples of Using Mathematical Models of Thermal Conductivity for Solving Problems of Selecting Optimal Parameters for a Two-Layered Spherical Shell.

4. Conclusion

Thus, developing the contents and structure of the discipline teaching the basics of mathematical modeling should take into account students' entry level and guidelines focused on establishing a common and unbroken connection of mathematical, science, and engineering disciplines.

The abovementioned features and guidelines improve students' training for their future employment in the machine and instrumentation engineering industries and enhance their competitiveness.

References:

1. Markelov GE (2015) Content of the Course «Fundamentals of Mathematical Modeling». ISJ Theoretical & Applied Science 05 (25): 59–61. Soi: http://s-o-i.org/1.1/TAS*05(25)12 Doi: http://dx.doi.org/10.15863/TAS.2015.05.25.12
2. Markelov GE (2015) Particular Aspects of Teaching the Fundamentals of Mathematical Modeling. ISJ Theoretical & Applied Science 05 (25): 69–72. Soi: http://s-o-i.org/1.1/TAS*05(25)14 Doi: http://dx.doi.org/10.15863/TAS.2015.05.25.14
3. Morozova VD (2014) Vvedenie v analiz. Izd-vo MGTU im. N.E. Baumana, Moscow.
4. Ivanova EE (2014) Differentsial'noe ischislenie funktsii odnogo peremennogo. Izd-vo MGTU im. N.E. Baumana, Moscow.
5. Kanatnikov AN, Krishchenko AP (2014) Analiticheskaya geometriya. Izd-vo MGTU im. N.E. Baumana, Moscow.
6. Kanatnikov AN, Krishchenko AP (2015) Lineinaya algebra. Izd-vo MGTU im. N.E. Baumana, Moscow.
7. Kanatnikov AN, Krishchenko AP, Chetverikov VN (2007) Differentsial'noe ischislenie funktsii mnogikh peremennykh. Izd-vo MGTU im. N.E. Baumana, Moscow.
8. Zarubin VS, Ivanova EE, Kuvyrkin GN (2015) Integral'noe ischislenie funktsii odnogo peremennogo. Izd-vo MGTU im. N.E. Baumana, Moscow.
9. Gavrilov VR, Ivanova EE, Morozova VD (2008) Kratnye i krivolineinye integraly. Elementy teorii polya. Izd-vo MGTU im. N.E. Baumana, Moscow.
10. Agafonov SA, German AD, Muratova TV (2011) Differentsial'nye uravneniya. Izd-vo MGTU im. N.E. Baumana, Moscow.
11. Vlasova EA (2006) Ryady. Izd-vo MGTU im. N.E. Baumana, Moscow.
12. Morozova VD (2009) Teoriya funktsii kompleksnogo peremennogo. Izd-vo MGTU im. N.E. Baumana, Moscow.
13. Volkov IK, Kanatnikov AN (2015) Integral'nye preobrazovaniya i operatsionnoe ischislenie. Izd-vo MGTU im. N.E. Baumana, Moscow.
14. Martinson LK, Malov YuI (2011) Differentsial'nye uravneniya matematicheskoi fiziki. Izd-vo MGTU im. N.E. Baumana, Moscow.
15. Vlasova EA, Zarubin VS, Kuvyrkin GN (2004) Priblizhennye metody matematicheskoi fiziki. Izd-vo MGTU im. N.E. Baumana, Moscow.
16. Attetkov AV, Galkin SV, Zarubin VS (2003) Metody optimizatsii. Izd-vo MGTU im. N.E. Baumana, Moscow.
17. Van'ko VI, Ermoshina OV, Kuvyrkin GN (2006) Variatsionnoe ischislenie i optimal'noe upravlenie. Izd-vo MGTU im. N.E. Baumana, Moscow.
18. Pechinkin AV, Teskin OI, Tsvetkova GM, Bocharov PP, Kozlov NE (2006) Teoriya veroyatnostei. Izd-vo MGTU im. N.E. Baumana, Moscow.
19. Goryainov VB, Pavlov IV, Tsvetkova GM, Teskin OI (2008) Matematicheskaya statistika. Izd-vo MGTU im. N.E. Baumana, Moscow.
20. Volkov IK, Zuev SM, Tsvetkova GM (2006) Sluchainye protsessy. Izd-vo MGTU im. N.E. Baumana, Moscow.
21. Belousov AI, Tkachev SB (2015) Diskretnaya matematika. Izd-vo MGTU im. N.E. Baumana, Moscow.
22. Volkov IK, Zagoruiko EA (2004). Issledovanie operatsii. Izd-vo MGTU im. N.E. Baumana, Moscow.
23. Zarubin VS (2010) Matematicheskoe modelirovanie v tekhnike. Izd-vo MGTU im. N.E. Baumana, Moscow.