Ministry of Education and Science of the Russian Federation

National Research University – Novosibirsk State University (NRU NSU)

Department of Mechanics and Mathematics

MASTER EDUCATIONAL PROGRAMME
FOR TEACHING FOREIGN STUDENTS IN ENGLISH

Mathematical and Computer Modeling in Mechanics

qualification (degree) of the graduate
Master of Mechanics and mathematical modeling

Full-time tuition

Supervisor: **Lapin Vasiliy N.**, senior tutor of the
Chair of Mathematical modeling NRU NSU,
Lazareva Galina G., assistant professor of the
Chair of Mathematical modeling NRU NSU

Novosibirsk, Russia
2013

Contents

Introduction

National Research University – Novosibirsk State University.

Department of Mechanics and Mathematics

Novosibirsk State University (NSU; see the site http://www.nsu.ru/exp/index.jz?lang=en) was established in 1958. NSU was growing up together with world known Novosibirsk Scientific Center (Akademgorodok) focusing on training highly qualified specialists for science and education.

The Department of Mechanics and Mathematics (DMM; see the site http://www.nsu.ru/exp/en/education/mechanics_and_mathematics) is one of the leading divisions of NSU. It was founded in 1961. The DMM has three levels of education: for Bachelor degree, for Master degree and postgraduate study. Students get trained in the following fields: Mathematics, Mathematics and Computer Science, Applied Mathematics and Information Science, Mechanics and Mathematical Simulation.

The main courses on DMM are held by outstanding scientists from institutes of Siberian Branch (SB) of Russian Academy of Sciences (RAS). Apart from attending the courses students have an opportunity to join leading scientific schools in these institutes. Both professors and students take an active part in corporative projects along with researchers from the world's and Russia leading universities and scientific organizations. Working in RAS research institutes senior students carry out research in modern fields of mathematics and its applications (including various fundamental and modern issues of mathematical model construction and computer science). Such specialization diversity allows students to prepare both for carrying out research in scientific institutes and for practical work in many areas applying the latest information technologies.

Every year the International student scientific conference "Students and the Progress in Science and Technologies" takes place in NSU (see the site http://issc.nsu.ru/index.php?lang=1), where students and young scientists can deliver talks on their researches and get acquainted with the results of their colleagues.

At 2009, after the complete selection among the leading Russian universities, the Novosibirsk State University got the category National Research University (NRU). This category was awarded by the Government of the Russian Federation on the basis of special Development Program of NSU for the period 2009-2018 (see the site http://www.nsu.ru/exp/en/university/national_research_university). The strategy goal of the Program is (quote): *"to form a research-educational system of national and global importance…which will be able to provide an advised specialist training based on science, education and business integration".*

At 2013 NRU NSU became one of 15 Russian universities that had won in the competition the right to get a subsidy that will favour the university advancement in the world ratings.

Chair of Mathematical Modeling DMM NRU NSU

Chair of Mathematical modeling was founded in 1964 at the Novosibirsk state University. The main purpose of the foundation was the training of specialists in computational and applied mathematics. The first name of the Chair was "Computing methods in continuum mechanics". The name was changed at 1997 because of generalization of the Chairs field of interests.

The Chair was founded and headed by an outstanding Soviet mathematician and mechanic, the Hero of Socialist labor Academician N. N. Yanenko (1921-1984). From 1984 to 1989 the Chair was headed by Corresponding Member of the Russian Academy of Sciences (RAS) V. G. Dulov (1928-

2001). From 1989 the Chair is headed by Professor V. M. Kovenya.

Now the Chair employs about 30 teachers including 14 professors and 10 assistant professors. At the same time they work in scientific institutes of SB RAS as researchers. The majority of Chair staff members have scientific degrees (Ph.D. of higher). One of the most known members of the Chair is Academician Professor Yu. I. Shokin.

The Chair is based on the following research institutes of Siberian Branch of the Russian Academy of Sciences (SB RAS)

- Institute of Computational Technologies (the main institute for the Chair),
- Khristianovich Institute of Theoretical and Applied Mechanics,
- Lavrentyev Institute of Hydrodynamics,
- Institute of Thermophysics.

The Chair provides students the opportunity to specialize in the following scientific directions

- Numerical methods of continuum mechanics
- Application of mathematical methods and mathematical modeling in scientific researchers
- Mechanics of fluid, gas and plasma
- Computational mathematics
- Differential equations

For student with keen interest in modern numerical methods the Chair offers a wide range of advanced professional optional courses. It should be noted that several dozens of students and postgraduate students of the Chair have become diploma and prize-winners of various research competitions and conferences held among the young scientists.

Chair of mathematical modeling has a great experience in research and education. More than 800 students have graduated the Chair (and have got BSc. or MSc.), more than 300 of them have defended candidate dissertations (PhD thesis) and more than 30 have got Doctor Degree (similar to Dr. habil. or Doctor of Science).

Chair graduates work in the industrial and academic scientific research institutes, on the mathematics departments of universities, in computer centers and companies engaged in science-intensive production. The graduates and former tutors of the Chair occupy the leading scientific and administrative positions in various institutions and firms.

Chair’s students make theirs researchers and prepare Bachelor’s or Master’s thesis in one of the basic institutes under the supervision of one of leading researchers. That fact makes SB RAS and NSU computational resources and scientific experience open for the students. These circumstances provide a good environment for high quality education and opportunities for the students to participate in up-to date scientific projects and industrial developments.

Development of the Master Educational Program (MEP)

“Mathematical and Computer Modeling in Mechanics”

The Development Program of NRU NSU for the period 2009-2018 implies that individual educational pathways based on the University Master Training Center will be introduced and English-speaking training groups will be organized. Elaboration of the Master Educational Program (MEP) “Mathematical and Computer Modeling in Mechanics” for teaching foreign students in English (author – assistant professor the Chair of Mathematical modeling NRU NSU G.G. Lazareva and senior tutor V.N. Lapin) is a certain contribution to development of the Center. This MEP complies the State Master Standard (SMS) for preparation direction 010800 – “Mechanics and mathematical modeling” (approved by the Order № 40 of Ministry of Education and Science of the Russian Federation on January, 14; 2010). So MEP gives foreign student an opportunity to get Russian state diploma at the end of education.

Invention of a computer has opened the way for mathematical methods application to study the laws of nature and the development of new technical devices. Due to that mathematical modeling has become the third method (after an experiment and theoretical analysis) of investigation of the world and new technologies development. The goal of Master Educational program «Mathematical and Computer Modeling in Mechanics» is to provide knowledge and experience in the field of mathematical modeling of complex physical processes in solids, fluids, gases and plasma.

The Master Educational program includes courses that developed by scientists experienced in mathematical modeling and numerical methods: Academician of RAS Professor Yu. I. Shokin: Professor V.M. Kovenya, Professor S.G. Cherny, Professor Yu.N. Grigoriev, Professor V.P. Shapeev, senior tutor V.N. Lapin. Educational program is complemented by courses, developed by the specialists in the field of programming and HPC, researches from ICM&MG, SB RAS and IIS, SB RAS Professor V.A. Vshivkov, assistant professor G.G. Lazareva, assistant professor P.G. Emelyanov, assistant professor M.A. Bulyonkov and N.N. Filatkina. All of authors of the courses also hold professor’s or tutor’s positions DMM NRU NSU. These researches have well-known, published in international press, world-class scientific results.

The MEP includes courses required by educational standard SMS 010800 – “Mechanics and mathematical modeling”. Some courses from overall Master Educational program of Department of Mechanics and Mathematics NRU NSU are also included in described program. It should be noted that MEP includes research work in the ICT, SB RAS.

The MEP “Mathematical and Computer Modeling in Mechanics” is essentially updated and revised version of the master program of the same title in Russian, which was elaborated in 2011 (author – Professor S.G. Cherny and senior tutor V.N. Lapin).

Information about the supervisor of the programme – G.G. Lazareva

Scientific biography

Galina Lazareva is a senior researcher of the Laboratory of Parallel Algorithms for Complex Problem Solutions in the Institute of Computational Mathematics and Mathematical Geophysics SB RAS. She was born at May, 24, 1971 in Novosibirsk, Russia. In 1988 he graduated the 130-th Novosibirsk secondary school with special courses in mathematics and English. She obtained her BSc and MSc degrees in Mathematics from the Novosibirsk State University, Russia. She got her PhD in Mathematical Modelling and Computational Technology in Science from the Special Scientefic Committee (chaired by Yu.I. Shokin) at the Institute of Computational Technologies SB RAS (Russia). She has been working at the Department of Mechanics and Mathematics in the Novosibirsk State University since 2002. She has been working there as a Senior Lecturer since June, 2007, and as an associate dean in education since February, 2008. She was the supervisor of several magistrate dissertations and student degree works. In 2012 she got her Doctor of Sciences in Mathematical Modelling, Numerical Methods and Program Complexes from the Dissertation Council (chaired by B.G. Mikhailenko) at the Institute of Computational Mathematics and Mathematical Geophysics SB RAS.

Research intersts of Galina Lazareva include numerical methods, equations of the nonlinear differential gravitational gas dynamics, mathematical and computational 3-D nonstationary modelling in astrophysics, geophysics, biology and plazma physics. She is an author of more than 60 papers in scientific journals and conference proceedings, a co-author of 3 textbooks. Galina Lazareva took part in many international and all-Russian conferences. She also worked in organizing committees of conferences on numerical mathematics. She was one of the most active executors of scientific projects,

supported by Russian Fund for Fundamental Research (RFFR), International Scientific Fund and funds of the Higher School.

Main scientific works: papers in international journals

1. Kedrinskii V.K., Vshivkov V.A., Dudnikova G.I., Shokin Yu.I., Lazareva G.G. Focusing of an Oscillating Shock Wave Emitted by a Toroidal Bubble Cloud // J. Exper. and Theor. Physics. 2004. V. 98. N. 6. P.1138-1145.
2. Korneev V.D., Lazareva G.G., Vshivkov V.A, Kedrinskii V.K. The Parallel Implementation of the Algorithm Solution of Model for Two-phase Cluster in Liquids // Parallel Comp. Technologies, Proc. PaCT-2006, Springer, LNCS 3606. 2005. P. 433-445.
3. VshivkovV.A. , Lazareva G.G., Kulikov I.M. A modified fluids-in-cell method for problems of gravitational gas dynamics // Optoelectronics, Instrumentation and Data Processing. 2007. V. 43. N 6. P. 530-537.
4. G.G. Lazareva, V. V. Mironova, N. A. Omelyanchuk, I. V. Shvab, V. A. Vshivkov, D. N. Gorpinchenko, S. V. Nikolaev, N. A. Kolchanov Mathematical modeling of plant morphogenesis // Numerical Analysis and Applications 2008. V. 1. N. 2. P. 123-134.
5. Kulikov, G. Lazareva, A. Snytnikov, V. Vshivkov Supercomputer Simulation of an Astrophysical Object Collapse by the Fluids-in-Cell Method // PaCT 2009, LNCS 5698, pp. 414-422, 2009.
6. Vshivkov V., Lazareva G., Snytnikov A., Kulikov I., Tutukov A. Computational methods for ill-posed problems of gravitational gasodynamics // Journal of Inverse and Ill-posed Problems. 2011. V. 19, I. 1. P. 151-166.
7. V.A. Vshivkov, G.G. Lazareva, A.V.Snytnikov, I.M.Kulikov, A.V.Tutukov Hydrodynamical Code for Numerical Simulation of the Gas Components of Colliding Galaxies // The Astrophysical Journal Supplement Series. 2011. V. 194. N. 2. P. 46-57.

Information about the supervisor of the programme – V.N. Lapin

Scientific biography

Lapin Vasiliy Nicolaevich graduated Mechanic Department of Mechanics and Mathematics of Novosibirsk State University at 2000. He defended his Ph.D thesis in "Mathematical modelling, numerical methods and program complexes" at 2006. Now he works in Institute of Computational Technologies SD RAS as a researcher.

Lapin Vasiliy has working in Chair of mathematical modelling of Novosibirsk State University since 2004 as senior tutor. He gives lessons on "Linear algebra and numerical analysis" and "Numerical methods".

Lapin Vasiliy is experienced tutor and qualified scientist. His fields of interests are development of mathematical models and numerical methods for coupled problems in fluid and solid mechanics. He is an author of about 30 scientific papers.

Main scientific works: papers in international journals

1. Cherny S.G., Chirkov D.V., Lapin V.N., Lobareva I., Sharov S., Skorospelov V. 3D Euler flow simulation in hydro turbines: unsteady analysis and automatic design // Notes on Numerical Fluid Mechanics and Multidisciplinary Design. - 2006. - Vol. 93. - P. 33-51.

2. Cherny S.G., Chirkov D.V., Lapin V.N., Skorospelov V.A., Turuk P.A. Numerical simulation of a turbulent flow in Francis hydroturbine // Russian Journal of Numerical Analysis and Mathematical Modelling. - 2006. - Vol. 21. - No 5. - P. 425-446.

3. Cherny S.G., Chirkov D.V., Lapin V.N., Muranov A., Bannikov D.V., Miller M., Willberg D., Medvedev O., Alekseenko O. Two-dimensional modeling of the near-wellbore fracture tortuosity effect // International Journal of Rock Mechanics and Mining Sciences. - 2009. - Vol. 36. - No 6. - P. 992-1000.

4. Alekseenko O.P., Potapenko D.I., Cherny S.G., Esipov, D.V., Kuranakov D.S., Lapin V.N. 3-D Modeling of fracture initiation from perforated non-cemented wellbore // Paper SPE. - 2012. - No 151585. - P. 1-16.

5. Cherny S.G., Lapin V.N., Chirkov D.V., Alekseenko O.P., Medvedev O.O. 2D Modeling of Hydraulic Fracture Initiating at a Wellbore with or without Microannulus // Proc. of the SPE Hydraulic Fracturing Technology Conference (The Woodlands, Texas, USA, 19-21 January 2009). - Woodlands. - 2009. - P. SPE 119352.

Brief description of the MEP

"Mathematical and Computer Modeling in Mechanics"

Definition of the Master Educational Programme (MEP)

The ***master educational programme (MEP) "Mathematical and Computer Modeling in Mechanics"*** is a system of educational documents based the State Master Standard (SMS) for training direction 010800 – "Mechanics and mathematical modeling" (approved by the Order № 40 of Ministry of Education and Science of the Russian Federation on January, 14; 2010; see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian]) and the requirements for graduates of master program of Department of Mechanics and Mathematics (DMM) of National Research University – Novosibirsk State University (NRU NSU). The MEP includes curriculum, programs of courses, conditions for admission to the MEP and acquired knowledge and skills of graduates.

Aims and objectives of the MEP

Aims and objectives of the MEP "Mathematical and Computer Modeling in Mechanics" are related with training of highly qualified specialists in the field of numerical statistical modelling and simulation, who are able to work productively in research institutes, programming firms, engineering companies, etc. The training is based on requirements of the SMS 010800 and NRU NSU.

The **main goal** of the MEP is to train highly qualified specialists who are able to perform full cycle of mathematical modeling in mechanics and natural science for solution of fundamental scientific problems and development of new industrial technologies.

The key objectives of education are

- to acquaint with methodology of numerical simulation as a method of nature investigation.
- to give theoretical knowledge of mathematical models that are currently used in mechanics, physics and natural sciences
- to give an experience in creation of mathematical models, their validation and application to generate new information about the nature
- to train practical skills in numerical methods development, implementation and verification
- to teach to analyze the results of numerical simulations

MER gives knowledge in modern numerical methods theory, problem-oriented programming, up to date numerical simulation results in fundamental sciences (mechanics, aero and hydrodynamics, plasma physics, geophysics, astrophysics, mining).

Student graduated in MER will able to solve practical problems and develop new technologies in aircraft and turbomachine design, gas and petroleum production, laser technologies etc. He can be employed in educational, science and industrial sector.

Training period of the MEP

The training period of the MEP "Mathematical and Computer Modeling in Mechanics" is equal to two academic years. One academic year includes two semesters ("autumn" and "spring" semesters), two test and examination sessions ("winter" and "summer" sessions), see below the section "Approximate curriculum of the MEP". Two "winter" holydays and one "summer" holydays are also provided.

An academic year begins at September, 1. The "autumn" semesters (the first and the third semesters of the MEP) proceed 18 weeks: from September, 1 till the end of December. The "winter" test sessions (after the first and the third semesters of the MEP) occur at the end of December. The "winter" examination sessions proceed in January.

The "winter" holydays (after the first and the third semesters of the MEP) proceed one week at the beginning of February.

The second "spring" semester proceeds 16 weeks: from February till the end of May. The second "summer" test and examination sessions proceed in June. The "summer" holydays (after the second semester of the MEP) proceeds two months: from July, 1 till August, 31.

The fourth "spring" semester proceeds 14 weeks: from February till May. The fourth "summer" test and examination sessions proceed at the end of May. Then (in June) the procedures of final state certification (including the defending the master dissertation) are carried out.

Training capacity of the MEP

Training capacity for training within the MEP "Mathematical and Computer Modeling in Mechanics", including classroom work, independent and research student's work and the time taken for quality control, is equal to 120 credits (units of study); one credit (unit) is equal to 36 academic hours – see below the section "Approximate curriculum of the MEP".

Conditions for admission to the MEP

"Mathematical and Computer Modeling in Mechanics"

Educational level of the entrant

The MEP "Mathematical and Computer Modeling in Mechanics" provides participation in it both foreign students and graduates of the Russian higher education institutions (including bachelor graduates of NRU NSU).

The entrant to the MEP should have an educational diploma (certificate or some analogous document) on programme of level of a bachelor degree in the field of mathematics, natural science (physics, chemistry, biology, geology, etc.) or economics. This programme must include an advanced mathematical course (courses) with basic elements of mathematical and functional analysis, linear algebra, mathematical physics, numerical analysis, numerical methods of linear algebra, fluid, gas and solid body mechanic. Desirable knowledge of English language: TOEFL Internet based equivalent score 50-70 (intermediate or upper intermediate). Some knowledge of Russian language (for scientific and household communication) is also useful (but not necessary).

For passing of the program the Russian entrants can be accepted (including graduates of NRU NSU). For Russian entrants the submission of the bachelor's degree diploma is obligatory.

Selection procedure to the MEP (the major dates)

Till ***May, 15*** the applicant send the following copies of documents by electronic mail to the supervisor of the program associate dean Lazareva Galina Gennadievna (e-mail: lazareva@ssd.sscc.ru):

1. Diploma (or some analogous document) on programme of level of a bachelor degree or certificate (ordering) about passing at the moment such programme.
2. TOEFL certificate (score 50-70: intermediate or upper intermediate level).
3. Recommendation of the professor of mathematics or applied mathematics.
4. Biography of the applicant.
5. Motivational letter (1-2 pages) on entrance to the MEP.

Till ***June, 1*** the procedure of selection of applicants for testing passing is carried out.

Till ***June, 10*** the interview with committee of leading professors of the Chair of Mathematical

Modeling NRU NSU is carried out (in internal form or by Skype). Features of this interview are reflected in the following section of the programme.

Till ***June, 25*** the Russian entrants (and wishing foreign applicants; except bachelor graduates of DMM NRU NSU having the special admission to the master program – see the site http://mmf.nsu.ru/applicants/magistracy [in Russian]) additionally pass the admission test. The examples of admission test are shown in the Appendix 2 of this program; see also the site http://mmf.nsu.ru/applicants/master-entexams [in Russian]**).**

Till ***July, 1*** the admittance to the MEP occurs.

Interview on the Chair of Mathematical Modeling NRU NSU

The interview with committee of leading professors of the Chair of Mathematical Modeling NRU NSU includes control questions and simple tests on basics of mathematical and functional analysis, linear algebra, mathematical physics, probability theory and mathematical statistics, numerical mathematics and programming, fluid, gas and solid body mechanic. Examples of interview control questions are presented below in the Appendix 2.

In case the committee makes the decision on acceptance of the applicant, the entrant's scientific supervisor (one of the professors of the Chair of Mathematical Modeling NRU NSU) is nominated. This person defines the choice of training courses, the direction of scientific research for preparation of term and dissertations works during training time of the MEP. The committee can also determine an individual additional leveling educational list of basic courses (in the case when the applicant shows insufficiently profound knowledge during the interview).

Concerning the organization of interview it is necessary to address to associate dean Lazareva Galina Gennadievna; e-mail: lazareva@ssd.sscc.ru.

Formal reception to the MEP. Training payment

In case of successful passing of interview, the testing committee of the Chair of Mathematical Modeling NRU NSU formulates the written recommendation for the entrant to the MEP (this document must be signed by the Head and Secretary of the Chair and also by the nominated scientific supervisor of the entrant) and sends it to dean's office of Department of Mechanics and Mathematics (DMM) NRU NSU.

The training for master on DMM NRU NSU is paid (in 2014-2015 the corresponding price is equal to 5200 dollars for one year). For the students having a high rating, possibility of receiving a state or NSU grant is provided (see the sites www.russia.edu.ru, http://www.nsu.ru/exp/university/oms/magistratura and http://www.nsu.ru/exp/magistratura/pravila_priema [in Russian]).

The detailed conditions of training can be found from associate dean Lazareva Galina Gennadievna; e-mail: lazareva@ssd.sscc.ru.

Learning outcomes of the MEP

"Mathematical and Computer Modeling in Mechanics"

General comments

As the result of training the graduates of the MEP "Mathematical and Computer Modeling in Mechanics" students gain knowledge and skills of qualified specialist (experts) in the field of mathematical modeling of complex physical processes in solids, fluids, gases and plasma. They become able to construct and analyze modern mathematical and computer models for solution of actual applied problems, to realize these algorithms on the modern supercomputer technique and to create corresponding scientific reviews, reports and articles.

The graduates of the MEP can choose the following kinds of activity:

- *postgraduate study of NRU NSU and scientific institutions of Siberian Branch of RAS (in particular, in ICT SB RAS);*
- *research work in laboratories of NRU NSU and scientific institutions of SB RAS;*
- *teaching in higher education institutions:*
- *work in research divisions of factories and firms;*
- *business and advisory activity.*

Acquired knowledge and skills (according to the MEP curriculum)

In accordance to the SMS for training direction 010800 – "Mechanics and mathematical modeling" (see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian]) the MEP "Mathematical and Computer Modeling in Mechanics" includes the following cycles and parts (see below the section "Approximate curriculum of the MEP"):

– M.1-B General scientific cycle – basic part;
– M.1-V General scientific cycle – variable part;
– M.2-B Professional cycle – basic part;
– M.1-V Professional cycle – variable part;
– M.3 Scientific practice and research work;
– M.4 Final state certification.

In ***the section M.1-B "General scientific cycle – basic part"*** the competences ***GCC-1,2,4,7,10*** and ***PC-10,13,17*** (see the Appendix 1) are formed. As the results of mastering courses of this part ***the MEP graduate student***

should know modern concepts of science, the place of natural sciences, and mathematics in the development of the scientific worldview, history, modern tendencies of development and achievements in mathematical modelling and mechanics;

should be able to perform a conceptual analysis and the formation of the ontological basis for solving scientific and applied problems of mechanics and mathematical modelling;

should possess basics of methodology of computational experiment as a general method of mathematical modeling for mechanics actual problems and others.

In ***the section M.1-V "General scientific cycle – variable part"*** the competences ***GCC-5-9*** and ***PC-1,2,5,8-10,14*** (see the Appendix 1) are formed. As the result of the part's study ***the MEP graduate student***

should know modern concepts of basic mathematical courses (such as mathematical and functional analysis, numerical methods), programming technologies;

should be able to perform basic mathematical analysis of modern problems, develop appropriate algorithms for analytical and numerical solutions;

should possess methodology of development and application numerical approaches for solving mathematical and applied problems.

In ***the section M.2-B "Professional cycle – basic part"*** the competences ***GCC-3,5-7,9,10*** and ***PC-1,2,4-11,13,14,16*** (see the Appendix 1) are formed. As the result of the part's study ***the MEP graduate student***

should know fundamental concepts and professional results, system methodologies in the area of mathematical modelling and mechanics, the current state and the principal features of modern programming languages and systems;

should be able to use new knowledge and apply them in professional activity; use of modern theories, methods, systems and means of mathematical modeling for solutions of research and application problems in mechanics and adjacent fields .

In ***the section M.2-V "Professional cycle – variable part"*** the competences ***GCC-1,2,3,6,10*** and ***PC-1,2,4-7,9-11*** (see the Appendix 1) are formed. As the result of the part's study ***the MEP graduate student***

should know modern concepts of mathematics and mechanical courses related to the area of numerical modelling and simulation;

should be able to analyze studied applied problems, develop appropriate mathematical and numerical models, construct and implement algorithms for numerical solution, set and perform computational experiment;

should possess methodology of numerical methods development and computational experiment for solving applied problems in the chosen area of research.

In ***the section M.3 "Scientific practice and research work"*** the competencies ***GCC-3-10*** and ***PC-3,8,12-19*** (see the Appendix 1) are formed. In accordance to the SMS for training direction 010800 – "Applied Mathematics and Information Science" ***the MEP graduate student must get the following skills*****:**

- *skills* for usage of numerical methods and mathematical modelling technology for solution of applied problems;
- *skills* for working with modern software and hardware information technologies during scientific research;
- *the ability* to carry out scientific research and obtain scientific results in the area of mechanics and mathematical modeling;
- *the ability* to speak publicly in front of different audiences with reports or messages about problems and solutions;
- *the ability* to work in research teams and in a companies.

In ***the section M.4 "Final state certification" the MEP graduate student should be able*****:**

- *to use* modern methods for research and solving of scientific and applied problems in the area of mathematical modelling and mechanics;
- *to apply* numerical methods and computational experiment to problem of mechanics and other fields of science.

Professional characteristics of the MEP graduates

The area professional activities of MEP graduates includes scientific and applied aspects of mathematical modelling and simulation. This area corresponds to the SMS for training direction 010800 – "Mechanics and mathematical modeling" (see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian]). Applied aspects of graduate's activities can be related to mathematical modeling of complex physical processes in solids, fluids, gases and plasma.

The objects of research scientific activity of the MEP graduates may be modern mathematical models of actual processes and phenomena in the sense of elaboration and modification of these models together with usage or proof of hypotheses, theorems, methods and development of corresponding analytical systems and software modules. These objects correspond to the SMS for training direction 010800 – "Mechanics and mathematical modeling" (see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian]).

The MEP students are preparing for the following main ***types of professional activity***:

- *scientific and research activities* (within the MEP, this training is provided by probation periods at the Chair of Mathematical Modeling NRU NSU and laboratories of Institute of Computational Technologies – ICT SB RAS);
- *project, production and technological activities* (within the MEP, this training is provided by the participation in execution of scientific projects in ICT SB RAS);

- *social and personal improvement*.

Additional professional activities of the graduate may be:

- *educational activities;*
- *consulting and consortium activities;*
- *organizational and management activities;*
- *normative and methodological activities;*
- *socially-oriented activities.*

These types of professional activity correspond to the SMS for training direction 010800 – "Mechanics and mathematical modeling" (see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian]).

The purposes of professional activities of MEP graduates are related to effective use of algorithms, theoretical and computational technologies of mathematical modelling and simulation for elaboration, modification and presentation of numerical schemes for solving of actual scientific and applied problems. These purposes of professional activity correspond to the SMS for training direction 010800 – "Mechanics and mathematical modeling" (see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian]).

Structure and features of the MEP

"Mathematical and Computer Modeling in Mechanics"

Approximate curriculum of the MEP

index	Course title	Credits	In total hours	Class-room work	Indepen-dent work	1 sem.	2 sem.	3 sem.	4 sem.	Sertifica-tion form
M.1	**General scientific cycle**	**30**	**1080**	**15**	**15**	**16**	**10**	**4**		
M.1-B	**Basic part**	**14**	**504**	**7**	**7**	**6**	**4**	**4**		
M.1-B-1	Philosophy and methodology of science. Philosophy problem of mathematics. [1]	2	72	1	1			2		Exam
M.1-B-2	Physics [2,3]	8	288	4	4	4	4			Exam
M.1-B-3	Numerical models of random functions with applications in geophysics [3]	2	72	1	1			2		Exam
M.1-B-4	History of mathematics [4]	2	72	1	1	2				Test
M.1-V	**Variable part** (courses at the choice of the student)	**16**	**576**	**8**	**8**	**10**	**6**			
	List of optional courses									
M.1-V-1	Numerical methods [6]	10	360	5	5	6	4			Exam/ test
M.1-V-2	Stochastic models of meteorological processes [1, 3]	2	72	1	1	2				Exam
M.1-V-3	Basic Programming Technologies	2	72	1	1	2				Exam
M.1-V-4	Compressible flow modeling [5]	2	72	1	1	2				Exam
M.1-V-5	Numerical modelling of discrete random processes and fields	2	72	1	1	2				Exam
M.1-V-6	Number theory	2	72	1	1	2				Exam
M.1-V-7	Monte Carlo methods for solving boundary value prob-	2	72	1	1		2			Exam

	lems of mathematical physics									
M.1-V-8	Theory of Programming	2	72	1	1		2			Exam
M.1-V-9	English academic writing	2	72	1	1		2			
M.2	**Professional cycle**	**30**	**1008**	**15**	**15**	**2**	**8**	**14**	**6**	
M.2-B	**Basic part**	**12**	**432**	**6**	**6**		**4**	**8**		
M.2-B-1	Numerical methods of simulation and optimization in mechanics [5, 6]	6	216	3	3		4	2		Exam/ test
M.2-B-2	Additional chapters of numerical methods [5]	4	108	2	2			4		Exam
M.2-B-3	Methods of discrete simulation [5]	2	72	1	1			2		Exam
M.2-V	**Variable part** (courses at the choice of the student)	**18**	**648**	**9**	**9**	**2**	**4**	**6**	**6**	
	Courses (at the choice of the student)	10	360	5	5		2	4	4	
	Scientific seminar (at the choice of the student)	8	288	4	4	2	2	2	2	
	List of courses									
M.2-V-1	Parallel numerical methods	6	216	3	3		2	2	2	Exam/ test
M.2-V-2	Method of differential approximation	4	144	2	2			2	2	Exam
M.2-V-3	Mathematical models of plasma technologies of microelectronic	2	72	1	1				2	Exam
M.2-V-4	Modern methods of computational mathematics	2	72	1	1			2		Exam
M.2-V-5	The method of collocations and the least residuals for solving boundary problems for systems of differential equations	2	72	1	1		2			Exam
M.2-V-6	Numerical methods in aerodynamics [5]	2	72	1	1				2	Exam
	List of scientific seminars									
M.2-V-7	Mathematical modeling of large-scale problems. Scientific seminar **([i])**	4	144	2	2	2	2			Test
M.2-V-8	Informational and computational technologies in problems of decision-making support. Scientific seminar.	4	144	2	2	2			2	Test
M.2-V-9	Informational technologies. Scientific seminar **([i])**	4	144	2	2			2	2	Test
M.2-V-10	Informational and computational technologies. Scientific seminar [1] **([i])**	4	144	2	2		2	2		Test
M.3	**Scientific practice and research work**	**48**	**1728**	**4**	**44**	**12**	**12**	**12**	**12**	
M.3-1	Preparation and presentation of two reports at scientific seminar “Informational and computational technologies in problems of decision-making support” [7, 8]	6	216		6	3			3	Test
M.3-2	Preparation and defending the term paper [7,8]	10	360		10		7	3		Test
M.3-3	Research work in a SB RAS institute [7]	18	648	4	14	9	5	4		Test
M.3-4	Report at scientific conferences: annual International student scientific conference “Students and the progress in science and technologies” or annual conference of young researchers of ICT SB RAS or others [7,8]	4	144		4			1	3	
M.3-5	Development of the master dissertation [8]	10	360		10			4	6	
M.4	**Final state certification**	**12**	**432**	**2**	**10**				**12**	
M.4-1	Passing the state exam [9]	8	288	2	6				8	Grade
M.4-2	Preparation and defending the master thesis [8]	4	144		4				4	Grade

	TOTAL:	**120**	**4320**	**36**	**74**	**30**	**30**	**30**	**30**	

[1] – materials of the course correspond to the obligatory course “Philosophy and methodology of science knowledge” of the State Master Standard (SMS) for training direction 010800 – “Mechanics and mathematical modelling” (see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian])
[2] – materials of the course correspond to the obligatory course “Theoretical physics” of the SMS for training direction 010800
[3] – materials of the course correspond to the obligatory course “Natural science courses” of the SMS for training direction 010800
[4] – materials of the course correspond to the obligatory course “History and methodology of mechanics” of the SMS for training direction 010800
[5] – materials of the course correspond to the obligatory course “Modern problems of mechanics” of the SMS for training direction 010800
[6] – materials of the course correspond to the obligatory course “Computer mechanic practice” of the SMS for training direction 010800
[7] – this course corresponds to the obligatory course “Scientific research work” of the SMS for training direction 010800
[8] – this course corresponds to the obligatory course “Preparation and defending the master dissertation” of the SMS for training direction 010800
[9] – this course corresponds to the obligatory course “State examination” of the SMS for training direction 010800
(*) – course of the MEP “Probability and Statistics”
(**) – course of the MEP “Mathematical and Computer Modelling in Mechanics”
(***) – course of the MEP “Modern Trends in Discrete Mathematics and Combinatorial Optimization”
(i) – the seminar can be taken at any education semester (position mentioned here is preferable, but is not obligatory)

Semester programs of the MEP

THE FIRST (“AUTUMN”) SEMESTER

Obligatory courses of the section M.1-B “General scientific cycle. Basic part”; total volume – 6 credits (units)

M.1-B-2 Physics – the first part of the course; 4 credits (units)

M.1-B-4 History of mathematics – full course; 2 credits (units)

Elective courses of the section M.1-V “General scientific cycle. Variable part”; minimal total volume – 10 credits (units)

M.1-V-1 Numerical methods – the first part of the course; 6 credits (units)

M.1-V-2 Stochastic models of meteorological processes – full course; *2* credits (units)

M.1-V-3 Basic Programming Technologies – full course; *2* credits (units)

M.1-V-4 Compressible flow modeling – full course; *2* credits (units)

M.1-V-5 Numerical modelling of discrete random processes and fields – full course; *2* credits (units)

M.1-V-6 Number theory – full course; *2* credits (units)

Elective courses of the section M.2-V “Professional cycle. Variable part”; minimal total volume – 2 credits (units)

M.2-V-7 Informational and computational technologies in problems of decision-making support. Scientific seminar – the first part of the course; *2* credits (units)

M.2-V-8 *Informational Mathematical modeling of large-scale problems. Scientific seminar* – the first part of the course; *2* credits (units)

Obligatory courses of the section M.3 "Scientific practice and research work"; total volume – 10 credits (units)

M.3-1 Preparation and presentation of two reports at scientific seminar "Informational and computational technologies in problems of decision-making support" - the first part of the course; 3 credits (units)

M.3-3 Research work in a SB RAS institute – the first part of the course; 9 credits (units)

TOTAL MINIMUM – 30 CREDITS (UNITS)

THE SECOND ("SPRING") SEMESTER

Obligatory courses of the section M.1-B "General scientific cycle. Basic part"; total volume – 4 credits (units)

M.1-B-2 Physics – the second part of the course; 4 credits (units)

Obligatory courses of the section M.2-B "Professional cycle. Basic part"; total volume – 4 credits (units)

M.2-B-1 Numerical methods of simulation and optimization in mechanics – the first part of the course; 4 credits (units)

Elective courses of the section M.1-V "General scientific cycle. Variable part"; minimal total volume – 6 credits (units)

M.1-V-1 Numerical methods – the second part of the course; 4 credits (units)

M.1-V-7 Monte Carlo methods for solving boundary value problems of mathematical physics – full course; *2* credits (units)

M.1-V-8 Theory of Programming – full course; *2* credits (units)

M.1-V-9 English academic writing – full course; *2* credits (units)

Elective courses of the section M.2-V "Professional cycle. Variable part"; minimal total volume – 4 credits (units)

M.2-V-1 Parallel numerical methods – the first part of the course; *2* credits (units)

M.2-V-5 The method of collocations and the least residuals for solving boundary problems for systems of differential equations – full course; *2* credits (units)

M.2-V-7 Mathematical modeling of large-scale problems. Scientific seminar – the second part of the course; *2* credits (units)

M.2-V-10 Informational and computational technologies. Scientific seminar – the first part of the course; *2* credits (units)

Obligatory disciplines of the section M.3 "Scientific practice and research work"; total volume – 12 credits (units)

M.3-2 Preparation and defending the term paper – the first part of the course; 7 credits (units)

M.3-3 Research work in in a SB RAS institute – the second part of the course; 5 credits (units)

TOTAL MINIMUM – 30 CREDITS (UNITS)

THE THIRD ("AUTUMN") SEMESTER

Obligatory courses of the section M.1-B "General scientific cycle. Basic part"; total volume – 6 credits (units)

M.1-B-1 Philosophy and methodology of science. Philosophy problem of mathematics – full course; *2* credits (units)

M.1-B-3 Numerical models of random functions with applications in geophysics – full course; *2* credits (units)

Obligatory courses of the section M.2-B "Professional cycle. Basic part"; total volume – 8 credits (units)

M.2-B-1 Numerical methods of simulation and optimization in mechanics – the second part of the course; 2 credits (units)

M.2-B-2 Additional chapters of numerical methods – full course; 4 credits (units)

M.2-B-3 Methods of discrete simulation – full course; 2 credits (units)

Elective courses of the section M.2-V "Professional cycle. Variable part"; minimal total volume – 6 credits (units)

M.2-V-1 Parallel numerical methods – the second part of the course; *2* credits (units)

M.2-V-2 Method of differential approximation – the first part of the course; *2* credits (units)

M.2-V-4 Modern methods of computational mathematics – full course; *2* credits (units)

M.2-V-9 Informational technologies. Scientific seminar – the first part of the course; *2* credits (units)

M.2-V-10 Informational and computational technologies. Scientific seminar – the second part of the course; *2* credits (units)

Obligatory courses of the section M.3 "Scientific practice and research work"; total volume – 12 credits (units)

M.3-2 Preparation and defending the term paper – the first part of the course; 3 credits (units)

M.3-3 Research work in in a SB RAS institute – the second part of the course; 4 credits (units)

M.3-4 Report at scientific conferences…:– the first part of the course; 1 credits (units)

M.3-4 Development of the master dissertation – the first part of the course; 4 credits (units)

TOTAL MINIMUM – 30 CREDITS (UNITS)

THE FOURTH ("SPRING") SEMESTER

Elective courses of the section M.2-V "Professional cycle. Variable part"; minimal total volume – 6 credits (units)

M.2-V-1 Parallel numerical methods – the third part of the course; 2 credits (units)

M.2-V-2 Method of differential approximation – the second part of the course; *2* credits (units)

M.2-V-3 Mathematical models of plasma technologies of microelectronic – full course; *2* credits (units)

M.2-V-6 Numerical methods in aerodynamics – full course; *2* credits (units)

M.2-V-8 Informational and computational technologies in problems of decision-making support. Scientific seminar – the second part of the course; *2* credits (units)

M.2-V-9 Informational technologies. Scientific seminar – the second part of the course; *2* credits (units)

Obligatory courses of the section M.3 "Scientific practice and research work"; total volume – 12 credits (units)

M.3-1 Preparation and presentation of two reports at scientific seminar "Informational and computational technologies in problems of decision-making support" - the second part of the course; 3 credits (units)

M.3-4 Reports at scientific conferences – the second part of the course; 3 credits (units)

M.3-5 Development of master dissertation – the first part of the course; 6 credits (units)

Obligatory courses of the section M.4 "Final state certification"; total volume – 12 credits (units)

M.4-1 Passing the state exam – full course; 8 credits (units)

M.4-2 Preparation and defending the master dissertation – full course; 4 credits (units)

TOTAL MINIMUM – 30 CREDITS (UNITS)

Contents of courses of the MEP

“Mathematical and Computer Modeling in Mechanics”

M.1 GENERAL SCIENTIFIC CYCLE

M.1-B BASIC PART

Title of the course:

M.1-B-1 Philosophy and methodology of science. Philosophy problem of mathematics

Information about the author:

Sychova Ludmila Sergeevna

- Full Professor, doctor of philosophy;
- professor of Chair of philosophy of Philosophy Department NSU; see http://philos.nsu.ru/;

Course description

The course contents include detailed analysis of problem of essence and development of the science, laws of science genesis and self estimation. Along with questions that concern whole science, the course is focused on the philosophical problems of mathematics. It helps to make general conception of the science more specific and perform reflection under mathematics as a subject of professional knowledge.

The *aim* of the course is to acquire knowledge in philosophy and methodology of science and philosophical problems of mathematics, in particular knowledge of problems of essence and development of science, laws of science genesis, self estimation, features of mathematics as a science. The following *objectives* are important to achieve course goal

- understanding of definition of conceptions “philosophy”, “philosophy of science”, “philosophy of mathematics”, “methodology of science”;
- knowing of historical stages of science formation, science genesis and function as a social institution;
- specific of math as a science. Philosophy and mathematic interaction in theirs historical development;
- analysis of philosophical problems of mathematics: type mathematic objects existence; paradoxes in mathematic development scientific revolutions.

Learning outcomes of the course

As a result of learning the course “Philosophy and methodology of science. Philosophy problem of mathematics” the student should:

• *understand* specific of philosophy of science, philosophy of mathematics;

• *know* content of philosophical problems of mathematics, essence of mathematics innovations and scientific revolutions;

• *be able* to operate philosophical categories “science”, “system with reflection”, “innovations and traditions in science development”, and apply them to analysis of genesis and development of mathematic courses.

Course content

Conceptions "science ", "philosophy of science", "methodology of science".
Appearing of science and main stages of its historical evolution. Genesis of mathematics as a science.
Science as social institution. Science worth Science and power.
Mathematics and reality. Relation of mathematics and other sciences.
Philosophy and mathematic interaction in theirs historical development
Innovations and traditions in science development. Science revolutions. Science as a system with reflection. Science revolutions in mathematics.
Paradoxes in mathematics development. Problem of mathematics foundation.

Method of assessment

In the program of the course, the carrying out the test is provided. The detailed grades for the examination are presented in the working program of the course.

Basic literature

1. *Van der Waerden B.L.* , Science awakening. – Oxford University Press, New York, 1961
2. *Weil H.* The Mathematical Way of Thinking. M., The World of Mathematics – 1956, – Vol 3. – pp. 1832-1851
3. *Hylbert D.* Foundations of Geometry. Open Court – 1999 – 226p

Title of the course:

M.1-B-2 Physics

Information about the author:

Vasiliev Anatoliy Aleksandrovich

- Full Professor, Doctor of Science in Physics and Mathematics;
- professor of Chair of general physics of Physics Department NSU; see http://professorrating.ru/kafedra.php?id=2994;
- director of Lavrentyev Institute of Hydrodynamics; see http://hydro.nsc.ru/estruktura.php

Information about the author:

Ershov Alexandr Petrovich

- Full Professor, Doctor of Science in Physics and Mathematics;
- associate professor of Chair of general physics of Physics Department NSU; see http://professorrating.ru/kafedra.php?id=2994;
- head of laboratory in Lavrentyev Institute of Hydrodynamics; see http://hydro.nsc.ru/estruktura1.php

Course description

The course contents cover basis of modern physics, include fundamental essence, knowledge about contemporary picture of the world, main approaches of physics. Basic *goal* of the course is to give students basic essence, results and approaches of the fundamental physics.

The following *objectives* are important to achieve course goal

- to study theory of electromagnetic fields, special theory of relativity, physical optics, basic quantum mechanics, thermodynamics, statistical physics;
- train skills in problem solutions in field of physics mentioned above;
- provide understanding of fields and mechanisms of physical theories applications.

Course duration is two semester. Course includes both lections and seminars. Overall complexity of the course is 8 credits divided equally among the all forms of training.

Learning outcomes of the course

As a result of learning the course “Physics” the student should:
- *understand* main issues and essence of physical theories;
- *know* definitions of main essence, formulation of main subjects of the course;
- *be able* solve problems based on the equations refer to various physics parts.

Course content

Physics object of investigation
Electromagnetic fields
Theory of relativity
Wave physics and optics
Thermodynamics and statistical physics

Method of assessment

In the program of the course, the carrying out one test and one examination are provided. The detailed grades for the examination and test are presented in the working program of the course.

Basic literature

1. *L.D. Landau, E.M. Lifshitz.* Quantum Mechanics:– Pergamon Press – 1977.
2. *L.D. Landau, E.M. Lifshitz.* Electrodynamics of Continuous Media:– Pergamon Press – 1984.

Title of the course:

M.1-B-3 Numerical models of random functions with applications in geophysics

Information about the author:

Prigarin Sergey Mikhailovich

- Full Professor, Doctor of physical and mathematical sciences;
- Professor of CCM DMM NSU, see http://mmfd.nsu.ru/mmf/kaf/cm/prep.asp;
- Leading Researcher of LSP ICM&MG SB RAS, see http://osmf.sscc.ru/mixa/bak.html;
- see also the section “Information about the author” in working program of the course **M.2-V-12;**
- e-mail: sergeim.prigarin@gmail.com, smp@osmf.sscc.ru.

Course description

The developed course M.2-V-12 “Numerical models of random functions with applications in geophysics” is a course for section M.2-V “Professional cycle – variable part” of the MEP “Numerical Statistical Modelling and Simulation. Monte Carlo Methods” and intends for studying at the fourth semester of the MEP. The course “Numerical models of random functions with applications in geophysics” can be considered as continuation of the course M.1-B-2 “Random process simulation and continuous stochastic models” **(**the third semester of the MEP, section M.1-B “General cycle – basic part”).

Recently, methods of numerical modelling of random functions are being effectively developed and the area of stochastic models application is rapidly expanded. Nowadays stochastic simulation is extensively used in the atmosphere and ocean optics, turbulence theory, analysis of pollution transport for porous media, astrophysics, meteorology and other fields of science. The aim of the course is to acquaint students with up-to-date numerical methods to simulate stochastic structure of geophysical processes and fields. In particular, stochastic models of the sea surface undulation, extreme ocean waves, and atmospheric clouds are presented in the course. One of the objectives of the course is to teach students to apply general simulation methods and specific techniques to construct stochastic models of geophysical objects.

Various preparation levels of Russian and foreign students in probability theory, mathematical statistics, Monte Carlo methods, and stochastic processes will be taken into account within the course. Extensive teaching experience of Prof. S.M. Prigarin, material of his text-books published in the Novosibirsk State University and research papers are used in the development of the course.

The course "Numerical models of random functions with applications in geophysics" can be used in realization of the Joint Master Programme "Applied Mathematics and Energy Strategies" (MINES Paris Tech, France – NRU NSU, Russia) and international master programs "Probability and Statistics", "Mathematical and Computer Modelling in Mechanics" and "Modern Trends in Discrete Mathematics and Combinatorial Optimization" of DMM NRU NSU.

Learning outcomes of the course

As a result of study of the course "Numerical models of random functions with applications in geophysics" a student *should know* the basic methods of stochastic simulation of geophysical random fields, *should be able* to perform analysis and to construct numerical models of geophysical time series and random fields, *should possess* techniques of theoretical study and numerical realization of stochastic models in geophysics.

Course content

1. A review on stochastic simulation methods
2. Numerical stochastic models of the sea surface undulation (mathematical models, correlation functions and spectra of the wind-driven waves and swell, simulation of the sea level by ARMA schemes, spectral time-space models of the sea surface, conditional spectral models of the extreme ocean waves)
3. Simulation of stochastic structure of clouds in the atmosphere (models of cloud boundaries and optical thickness, quasi-Gaussian model of broken cloudiness, stochastic model for generating broken cloud optical depth and cloud-top height fields)
4. Additional examples of stochastic models in geophysics (simulation and prediction of the relative sunspot numbers, stochastic fields of granules on the photosphere of the Sun, turbulence)
5. Simulation of random fractal objects (definitions of dimension, algorithms to estimate dimension, stochastic fractal models)

Method of assessment

According to the program of the course, an examination is provided. The details on the examination are described in the working program of the course **M.2-V-12**.

Basic literature

Prigarin S.M., Spectral Models of Random Processes in Monte Carlo Methods, Novosibirsk, 2013 (electronic version).

Title of the course:

M.1-B-4 History of mathematics

Information about the author:

Savelief Lev Yakovlevich

- Professor, Candidate of Science in Physics and Mathematics (PhD);
- professor of Chair of High mathematics of MMD NSU; see http://mmf.nsu.ru/person/861;
- senior researcher of Sobolev institute of mathematics; see http://a-server.math.nsc.ru/IM/sotrudl.asp?CodID=493

Course description

The course gives a vision of mathematics and mechanics development, conditions of their genesis and evolution, peoples that gives a direction of the evolution. Various fields of mathematics are described in the course. Some important problem (Fermat's Last Theorem, Riemann hypothesis, Poincaré conjecture). The *aim* of the course is to give a understanding of ways of mechanics and mathematics evolution, modification of math approaches in time, understanding of current state of mathematic science.

Course duration is one semester. Course includes lections only. Overall complexity of the course is 2 credits.

Learning outcomes of the course

As a result of learning the course “History of mathematics” the student should:
• *understand* main issues of mathematics and mechanics evolution ;
• *be able* analyze methods and approaches in terms of main ways of science evolution.

Course content

1. History of Russian academy of science and Siberian Branch of RAS.
2. History of Novosibirsk State University and its place in mathematics evolution.
3. History and main results of Lavrentiev institute of hydrodynamics.
4. History and main results of Sobolev institute of mathematics.
5. History of algebra .
6. History of geometry.
7. History of mathematical analysis.
8. History of number theory.
9. History of mechanics (ancient).
10. History of mechanics (contemporary).
11. Fermat's Last Theorem.
12. Riemann hypothesis.
13. Poincaré conjecture.

Method of assessment

In the program of the course, the carrying out examination is provided.

Basic literature

Kolmogorov A.N. Mathematics in its historical development. M.: Nauka, 1991. [in Russian]
Rybnikov K.A. The history of mathematics. M.: MSU, 1994. [in Russian]

M.1-V VARIABLE PART (courses at the choice of the student)

Title of the course:

M.1-V-1 Numerical methods

Information about the author:

Cherny Sergey Grigorievich
- Full Professor, doctor of physical and mathematical sciences;
- professor of CMM DMM NSU; see http://www.ict.nsc.ru/matmod/index.php?file=prepods;
- head of laboratory of mathematical modeling of ICT SB RAS; see http://www.ict.nsc.ru/staffall.php:

Lapin Vasiliy Nikolaevich
- candidate of physical and mathematical sciences (PhD);
- senior tutor, of CMM DMM NSU; see http://www.ict.nsc.ru/matmod/index.php?file=prepods;
- researcher of ICT SB RAS; see http://www.ict.nsc.ru/staffall.php:

Course description

The course M.1-V-1 “Numerical methods” is a fundamental course for all sections M.2 «Professional cycle» of the MEP «Mathematical and Computer Modelling in Mechanics» and intends for studying at the first two semesters of the MEP. When developing the course the possibility for control of various preparation levels of Russian and foreign students in the fields of analysis, functional analysis, numerical analysis, numerical methods of linear algebra, programming, mathematical modeling is provided.

The course presents detailed descriptions for approaches to develop numerical methods for ordinary and partial differential equations, train students skills in creation, development, and realization of the methods. The course also familiarizes students with methodic of computational experiment, provides the experience in its performing. Lections, practical seminars, laboratory works, report writing and presentations are planned within the course.

The *aim* of the course “Numerical methods” is to teach students to use numerical methods to solve partial differential equations.

The corresponding *objectives* of the course “Numerical methods” are:

- to give to students knowledge of numerical methods theory, methodology of computational experiment.
- train theirs practical skills in development and implementation of numerical method;
- to teach students to investigate numerical methods in terms of their efficiency and to use these algorithms for numerical solution of actual applied problems;

When developing the course, the vast experience of the author in teaching at Mechanical-Mathematical Department of NRU NSU the courses concerned the theory and practice of numerical method and mathematical modelling, are used.

The course “Numerical methods” can be used in realization of the international master programmes “Probability and Statistics”, “Numerical Statistical Modelling and Simulation. Monte Carlo Methods” and «Modern Trends in Discrete Mathematics and Combinatorial Optimization» of DMM NRU NSU.

Learning outcomes of the course

As the result of study of the course “Numerical methods” the student

should know various types of numerical methods of partial differential equation solution, their properties and features.

should be able to know most popular finite difference and finite volume methods for problems with ordinary and partial difference equations.;

should be able to develop numerical algorithms, implement in computer code typical numerical methods, pose and perform computational experiment, analyze and present computation results.

Course content

1. Mathematical models and numerical experiment
2. Numerical methods for Cauchy problem for ordinary differential equation (ODE).
3. Numerical methods for boundary problems for ODE
4. Finite difference schemes for parabolic equations
5. Finite difference schemes for elliptic equations
6. Finite difference schemes for hyperbolic equations

Method of assessment

In the program of the course, the carrying out the examination, tests laboratory work and reports are provided. The detailed grades for the laboratory work, tests and examination are presented in the working program of the course **M.2-V-1**.

Basic literature

Khakimzyanov G.S., Cherny S.G. Numerical methods. Novosibirsk, 2013 (electronic version).

Title of the course:

M.1-V-2 Stochastic models of meteorological processes

Information about the author:

Ogorodnikov Vasilii Aleksandrovich

- Associate Professor, Doctor of physical and mathematical sciences;
- professor of CCM DMM NSU; see http://mmfd.nsu.ru/mmf/kaf/cm/prep.asp;
- major researcher of LSP ICM&MG SB RAS; see http://osmf.sscc.ru/mixa/bak.html;
- see also the section «Information about the author» of working program of the course **M.2-V-13**;
- e-mail: ova@osmf.sscc.ru

Course description

The proposed course examines issues related to the construction of stochastic models of hydrometeorological processes, fields, and their complexes based on real observations. Approaches to the construction of these models are based on the use of simulation algorithms of Gaussian and non-Gaussian processes and fields with a given one-dimensional distributions and correlation functions. Due to the specificity and complexity of real meteorological processes (fields) which as a rule are not stationary (heterogeneous) the need arises to adapt the existing algorithms to real process or develop new special algorithms. This course considers approaches to solving these problems, as well as methods of verification of models and algorithms for the calculation of different characteristics associated with extreme weather events with the help of model samples. The issues related with stochastic interpolation of meteorological fields from stations in the grid nodes and approaches to building dynamic-stochastic models of atmospheric processes are discussed.

Course “Stochastic models of meteorological processes” will meet high international level in the field of scientific research on the theory and applications of algorithms for discrete stochastic numerical simulations. The course will also help master student to receive research skills. The course program will include a review of new research results on the use of statistical modelling for the study of real processes. This will contribute to the further development of the Master Education Programme “Numerical Statistical Modelling. Monte Carlo Methods”.

The course is associated with the implementation of Development Program NRU NSU in 2009-2018 years and related to program sections “Discrete and Computational Mathematics”, “Modelling and analysis of the results of physical experiments”, “Technologies of distributed and high-performance computing and systems” of the direction “Mathematics, fundamental basis of computer science and information technology”.

Learning outcomes of the course

After studying of the course “Stochastic models of meteorological processes” a master student will know modern methods of investigation of real processes with the help of numerical stochastic models. He will be also familiar with the modern approaches to the construction of stochastic models of real meteorological processes and be able to build stochastic models of different processes by the real data. He will know the methods of verification of models and methods for the numerical studies using models of different statistical characteristics of investigated process.

Course content

1. Principles of construction of numerical stochastic models of real meteorological processes
2. Assignment of the input data for models. Approximation of empirical probability distributions of meteorological time series
3. Stochastic models of scalar meteorological time series

4. Models of vector time series of wind speed
5. Models of joint non-Gaussian time series of several different meteorological elements
6. Periodically correlated meteorological stochastic processes
7. Simulation of spatial and spatial-temporal fields of meteorological elements
8. Specific of modelling of time series and fields of precipitation sums
9. Numerical simulation of indicators of an output of meteorological process for the given levels on the basis Markov chain
10. Study the characteristics of extreme meteorological events on the basis of numerical stochastic models
11. Numerical models of conditionally distributed meteorological fields. Stochastic interpolation of meteorological fields
12. Stochastic dynamic models of meteorological processes
13.Control questions, tests

Method of assessment

In the program of the course, the carrying out an examination is provided. The detailed grade for this examination is presented in the working program of the course **M.2-V-13**.

Basic literature

Ogorodnikov V.A. Stochastic Models of Meteorological Processes. Novosibirsk, 2013 (electronic version).

Title of the course:

M.1-V-3 Basic Programming Technologies

Information about the author:

Pavel Emelyanov

- Associate Professor, Candidate of physical and mathematical sciences;
- associate professor of Programming DMM NSU; see http://mmfd.nsu.ru/mmf/kaf;
- senior researcher of IIS SB RAS; see http://www.iis.ru.

Course description

A course program “Basic Programming Technologies” is compiled in accordance with requirements to the structure and results of master educational programs “Professional cycle. Free electives”. It is an item of educational master program in English “Mathematical and Computer Modeling in Mechanics”. A course program is compiled in accordance with Novosibirsk State University tasks of implementing the NSU development Program.

To make researches in mathematical modeling more effective and to embed their results into the industry first of all program systems implementing numerical methods should be well-written programs and well-organized information systems. It is especially important for industrial applications having long life cycle and intended for risk-sensitive systems. Therefore numerical analysts should have strong skills in programming technologies which supply creation of reliable and effective software.

The course topics cover the essential issues associated with modern methods and concepts of programming and technological aspects of software development such that object-oriented programming and design, basic data structures and programming techniques, as well as the problems of man-computer interaction through a graphical computer interfaces and the organization of large information repositories.

The developed course “Basic Programming Technologies” belongs to the section “Varying part (courses at the choice of the student)” and designed to study during the first year of the MEP “Mathematical and Computer Modeling in Mechanics”. The course provides the following forms of training: lectures, labs (program projects) and tests (theoretical material testing), and individual work as well. Accomplishing of program projects and testing results are taken into account to integrally estimate student’s course progress. The Faculty Academic Council can set additional forms of the control. Overall complexity of the course is 6 credits divided equally among the all forms of training.

Learning outcomes of the course

As a result of learning the course “Basic Programming Technologies” the student should:

- be able to analyze basic information about the phenomena of the world and to take design and project decisions based on own knowledge;
- have an understanding of the various aspects of programming and their relationship;
- know the basic concepts of object-oriented programming and projecting, the requirements for the organization of user interfaces, and data warehousing;
- build object-oriented models;
- be able to identify the benefits of using object-oriented programming techniques for application development.
- develop adequate ways of human-computer interaction through user interfaces;
- analyze the information needed for the design and implementation of data warehouses;be skilled in solving problems encountered in the design, implementation and maintenance of software projects.

Course content

1. Programming as a scientific and technological courses: customer programming, system programming, programming technology, theoretical programming.
2. The life cycle of the software product and its models. Traditional models on the software life cycle. Technological aspects of development of software systems in the models of the life cycle.
3. The concept of programming system: compiler (source/object code translator), linker, loader, target program. Additional software development tools: help system, a debugger, testing tools, profiler, documentation tools, source code analyzers, bug-tracker, versioning and refactoring tools.
4. Development of a new programming language as a response to new technological challenges. Disadvantages of C-language. What is C and is not C++.
5. Boolean type. Constants. Pointers and constants. References.
6. Data encapsulation. Concept of class. Objects (instances) of the class. Access to parts of the class. The static part of the class.
7. Constructors in C++. Constructing objects of the class. The default constructor. The copy constructor.
8. Overloading function names. Resolution of conflicts. Operator overriding. The default assignment operator. Overriding assignment operator.
9. Scopes in C++. Friends of classes. Namespaces. The standard namespace. The use of namespaces for design and redesign of legacy program systems.
10. Exceptions in C++. Why this is needed? Exceptions handling. Exceptions in constructors and destructors. Specification of exceptions. Standard exceptions. Exceptions as a programming style and its critics.
11. Generic programming. Templates for function. Class templates. STL. Basic principles of construction. Issues of efficiency.
12. Inheritance in C++. Base and derived classes. Virtual methods. Abstract classes and methods.

Implementation of virtual methods.

13. Multiple inheritance. Constructing objects under multiple inheritance. The use of inheritance in design of software systems.
14. Technological reasons for introducing new concepts. The virtual machine and the managed heap (MS CLR). Heap dispatching algorithms (allocation, tracking, compactification).
15. Language level constructions in C++/ CLI to work with the managed heap: ref-descriptors, gcnew, internal and pinned pointers.
16. Other concepts: abstract specifier, interface classes, value classes, properties, delegates, override/partial/sealed.
17. Aspects of the interaction between man and machine. Classification of user interface controls. Standards for user-interfaces. The interface style. Methodology to evaluate user interfaces.
18. Basic controls in the GUI. Practical aspects of the user interface. IBM recommendations.
19. System messages in the computer. Message handling loop. Event-driven programming. The main types of events for controls. Event handlers.
20. Information storage requirements: data type definitions, data validity and consistency, data manipulation, performance issues. File system: advantages and disadvantages.
21. Standard XML. The hierarchical organization of data.
22. Data type definition. XML schema is an example of DTD. The main types of restrictions for elements and attributes. The definition of entities. Validating XML-processor to control data consistency.
23. XPath: XML Query Language. Path axis, tests for nodes, function manipulators. The effectiveness of queries.
24. XML DOM: a standard for program interface. The main interfaces. MSXML API. Examples of usage.

Method of assessment

There a final exam to assess the student work will be held in the end of the course. Also, students will be given the homework during the course.

Basic literature

1. Alfred V. Aho, Monica S. Lam, Ravi Sethi, and Jeffrey D. Ullman. Compilers: Principles, Techniques, & Tools. Pearson Education, Inc, 2006.
2. Alfred V. Aho, John E. Hopcroft, and Jeffrey D. Ullman. Data Structures and Algorithms. Addison-Wesley, 1983.
3. Robert T. Futrell, Donald F. Shafer, Linda I. Shafer. Quality Software Project Management. Prentice Hall, 2002.
4. Grady Booch, Robert A. Maksimchuk, Michael W. Engle and Bobbi J. Young. Object-Oriented Analysis and Design with Applications (3rd Edition). Addison-Wesley, 2007.
5. Hector Garcia-Molina, Jeff Ullman, and Jennifer Widom. Database Systems: The Complete Book (Second edition). Prentice-Hall, 2008.
6. Nicolai M. Josuttis. The C++ Standard Library: A Tutorial and Reference. Addison-Wesley, 2000.
7. A.G. Kalinin and I.V. Marcinkevitch. Universal Programming Languages: Semantical Approach. Radio i svyaz, 1991.
8. Theo Mandel. The Elements of User Interface Design. John Wiley and Sons, 1997.
9. Robert W. Sebesta. Concepts of Programming Languages (10th Edition), Addison-Wesley, 2012.
10. Bjarne Stroustrup. Programming: Principles and Practice Using C++. Addison-Wesley, 2008.

11. Bjarne Stroustrup. The C++ Programming Language (4th edition). Addison-Wesley, 2013.
12. Bjarne Stroustrup. The Design and Evolution of C++. Addison-Wesley, 1994.
13. Robert J. Torres. Practitioner's Handbook for User Interface Design and Development. Prentice Hall, 2001.
14. IBM, Systems Application Architecture: Common User Access: Guide to User Interface Design, Document SC34-4289-00. 1991.
15. IBM, Systems Application Architecture: Common User Access: Advanced Interface Design Reference, Document SC34-4290-00. 1991.

Title of the course:

M.1-V-4 Compressible flow modeling

Information about the author:

Lazareva Galina Gennadievna

- Assistant Professor, Candidate of physical and mathematical sciences;
- Assistant Professor of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- senior researcher of ICMaMG SD RAS; see http://sscc.ru;
- see also the section «Information about the supervisor of the programme» of this programme.

Course description

Course program "Compressible flow modeling" is compiled in accordance with requirements to the structure and results of master educational programs "Professional cycle. Free electives". It is an item of educational master program in English "Mathematical and Computer Modeling in Mechanics". Course program is compiled in accordance with Novosibirsk State University tasks of implementing the NSU development Program.

Compressible flow is the area of fluid mechanics that deals with fluids in which the fluid density varies significantly in response to a change in pressure. Compressibility effects are typically considered significant if the Mach number (the ratio of the flow velocity to the local speed of sound) of the flow exceeds 0.3, or if the fluid undergoes very large pressure changes. The most distinct differences between the compressible and incompressible flow models are that the compressible flow model allows for the existence of shock waves and choked flow. Compressible flow describes the behavior of fluids that experience significant variations in density. For flows in which the density does not vary significantly, the analysis of the behavior of such flows may be simplified greatly by assuming a constant density. This is an idealization, which leads to the theory of incompressible flow. However, in the many cases dealing with gases (especially at higher velocities) and those cases dealing with liquids with large pressure changes, the significant variations in density can occur, and the flow should be analyzed as a compressible flow if accurate results are to be obtained.

Allowing for a change in density brings an additional variable into the analysis. In contrast to incompressible flows, which can usually be solved by considering only the equations from conservation of mass and conservation of momentum. Usually, the principle of conservation of energy is included. However, this introduces another variable (temperature), and so a fourth equation (such as the ideal gas equation) is required to relate the temperature to the other thermodynamic properties in order to fully describe the flow. Solutions of these problems are presented in the developed course "Compressible flow modeling". The course also provides an overview of modern applications of numerical modelling and simulation in astrophysics, acoustics and geodynamics.

Note that the presented program is essentially updated and revised version of the program of the course "Mathematical simulation of compressible fluid dynamics and gas" (in Russian, elaborated in 2012 by G.G. Lazareva) of the MEP "Mechanics and mathematical modeling" (in Russian, elaborated in 2011 by Professor S.G. Cherny and senior lecturer V.N. Lapin).

The developed course “Compressible flow modeling” belongs to the section “Variable part (courses at the choice of the student)” and designed to study during the second year of the MEP “Mathematical and Computer Modeling in Mechanics”. When developing the course the possibility for control of various preparation levels of Russian and foreign students in the fields of probability theory, functional analysis and numerical statistical modelling and simulation is provided.

Learning outcomes of the course

As a result of learning the course “Compressible flow modeling” the student should:

• Know the main approaches to astrophysics mathematical models construction and numerical methods for their solving;

• Apply the obtained knowledge to the solution of scientific modelling problems;

• Be award of the following skills: choice of the effective numerical method and approaches to the development of the realization of an algorithm in the process of mathematical modelling of mechanics of continua problems.

Course content

1.Mathematical models of natural phenomena in astrophysics. Gravitational gasodynamics equations. Self-consistent gravitational field allowance. Star-dust component kinetic models. Modern gravitational gas dynamics numerical methods. The carbuncle effect. General approaches. Comparative analysis.

2. Lagrangian methods. Method of Smooth Particle Hydrodynamics. The ideology of the smoothing particles method. Algorithm for solving a problem. Smooth Particle Hydrodynamics approximation. Approximation error estimate. Conservation laws. Artificial viscosity. Adaptive smoothing step.

3. Allowance of the effect of gravitational field onparticle motion. Hierarchical method of computing gravitational force. Gravitational force smoothing at small distances. Truncation error and efficiency of hierarchical method. Parallel implementation of the method of Smooth Particle Hydrodynamics. Parallel implementation of the hierarchical search method of neighboring particles.

4. Euler methods. Adaptive mesh and grids. Redefining in the cells. Block-structured redefining. 5. Godunov’s method for acoustic equations with one spatial variable. Conservation laws. General solution formula. Riemann’s problem in acoustics. Differential formulas for Godunov's method. Solution construction with help of Riemann solvers. Data averaging and conservation laws. Difference scheme construction using the relations based on characteristics.

6. Godunov’s method for gasodynamic equations with one spatial variable. Riemann’s problem in linearized gas dynamics. Possible configurations. Finite-difference scheme. Godunov’s method for gasodynamic equations with two spatial variables. Modification for moving computational mesh. Parallel implementation of Godunov’s method for gravitational gasodynamics.

7. Eulerian-Lagrangian methods. Belotserkovsky-Davydov’s large particle-in-cell method for gasodynamic equations with one spatial variable. Large particle-in-cell method stability. Large particle-in-cell method for gasodynamic equations with three spatial variables. Parallel implementation of the large particle-in-cell method. Choice of the decomposition method.

8. Modern numerical methods for gravitational gasodynamic equations.

9. General introduction to the particle-in-cell method (PIC). Particle collision model. Description of star-dust component by the PIC method. Description of interaction between gas and dust phases.

10. Parallel implementation of the PIC method. Link-level numerical noise with a number of model particles. Intra-tie parallelism method. Different ways of parallel implementation: P2, PM, Treecode. Parallel processors data communications.

11. Numerical simulation of dynamics of shock waves in a passive bubble systems. IKV model and solution methods. Selection of the geometry of bubble cluster. Energy conservation laws. Method to determine the error of the focus area pressure maximal amplitude.

12. Parallel version of the algorithm. Parallel data processing. Acceleration and efficiency of parallel

algorithm. Size of the bubble cluster effect on acceleration and efficiency of the parallel algorithm. Formation and shock wave amplification in the issue of plane shock wave interaction with bubble cluster.
13. Shock wave dynamics in passive bubble systems: computer simulation and experiment.
14. Modern numerical models and methods for mantle flows. Approach to parallel algorithm design for computing with distributed memory.
15. Classical Oberbeck–Boussinesq approximation model for the heat gravitational convection description.
16. Numerical simulation of dynamics of non-stationary mantle flows in the approximation of weakly compressible liquid. Upwelling light substances dynamic as the result of underplating high temperature magma under the base of crust.
17. Additional physical factors (multiphase mixture, self-consistent gravitational field, cooling processes, heat transfer, melting, availability of greatly varying rheological and transport properties, etc.) in hydrodynamic applications. Introduction to the gasodynamic equations of new members. Inclusion of additional equations into the gasodynamic equations.
18. Modern mathematical models of compressible flows and numerical methods of implementation**.**

Method of assessment

In the program of the course, the carrying out the examination is provided. The detailed grades for the examination are presented in the working program of the course.

Basic literature

1. Grigoriev Yu.N., Vshivkov V.A., Fedoruk M.P. NUMERICAL "PARTICLE-IN-CELL" METHODS THEORY and APPLICATIONS // Utrecht, Boston, 2002.
2. Lazareva G.G. Compressible flow modeling. Novosibirsk, 2013 (electronic version).

Title of the course:

M.1-V-5 Numerical modelling of discrete random processes and fields

(course of the MEP "Numerical Statistical Modelling and Simulation. Monte Carlo Methods")

Information about the authors:

Ogorodnikov Vasilii Aleksandrovich

- Associate Professor, Doctor of physical and mathematical sciences;
- professor of CCM DMM NSU; see http://mmfd.nsu.ru/mmf/kaf/cm/prep.asp;
- major researcher of LSP ICM&MG SB RAS; see http://osmf.sscc.ru/mixa/bak.html;
- see also the section «Information about the author» of working program of the course **M.2-B-5**;
- e-mail: ova@osmf.sscc.ru

Course description

Some questions connected with the construction and study of algorithms for simulation of Gaussian processes and fields of discrete argument based on the method of conditional distributions are considered in the given course. For the given Toeplitz and block-Toeplitz covariance matrices some special recursive algorithms for simulation of scalar and vector stationary processes and homogeneous fields on uniform grids are considered. Some questions of regularization and estimation the accuracy of the simulation are explored.

The application of these algorithms for scalar and vector autoregression process with a given correlation structure is considered, the conditions of their stationarity are studied. Special attention is paid to the modelling of non-Gaussian random processes and fields of discrete argument and also to the problems of numerical simulation of periodically correlated processes and conditional random fields.

The course “Numerical modelling of discrete random processes and fields” will meet high international level in the field of scientific research on the theory and applications of algorithms for discrete-stochastic numerical simulations.

The course is associated with the implementation of Development Program NRU NSU in 2009-2018 years and related to program sections “Discrete and Computational Mathematics”, “Modelling and analysis of the results of physical experiments”, “Technologies of distributed and high-performance computing and systems” of the direction “Mathematics, fundamental basis of computer science and information technology”.

Learning outcomes of the course

After studying of the course “Numerical modelling of discrete random processes and fields” a master student will know the methods and algorithms for the numerical modelling random Gaussian and non-Gaussian scalar and vector stationary and periodically correlated processes, homogeneous and homogeneous isotropic fields of discrete argument. A master student will also know the methods and algorithms for modelling the conditionally distributed Gaussian and non-Gaussian processes and fields of discrete argument, as well as methods of stochastic interpolation of random processes and fields.

Course content

1. Gaussian processes and fields of discrete argument with Toeplitz’s covariance matrixes
2. Method of conditional distributions for modelling normal vectors with Toeplitz’s correlation matrixes
3. Regularization of the algorithm, control of calculation accuracy
4. Modelling of autoregressive processes with the given correlation structure
5. Simulation of stationary Gaussian vector sequences with a given correlation structure
6. Simulation of homogeneous and homogeneous isotropic Gaussian fields on the regular grid
7. Modelling of stationary vector autoregressive sequences
8. Modelling of periodically correlated processes of discrete argument
9. Algorithms of modelling of non-Gaussian processes of discrete argument
10. Modelling of conditionally distributed Gaussian and non-Gaussian processes and fields of discrete argument
11. Combined models of non-Gaussian random processes and fields
12. Tasks, control questions

Method of assessment

In the program of the course, the carrying out an examination is provided. The detailed grade for this examination is presented in the working program of the course **M.2-B-5**.

Basic literature

Ogorodnikov V.A. Numerical Modelling of Discrete Random Processes and Fields. Novosibirsk, 2013 (electronic version).

Title of the course:

M.1-V-6 Number theory

(course of the MEP “Numerical Statistical Modelling and Simulation. Monte Carlo Methods”)

Information about the authors:

Vdovin Evgenii Petrovich

- Associate professor, Doctor of physical and mathematical sciences;
- professor of Chair of algebra and mathematical logic (CAML) in DMM NSU; see http://mmfd.nsu.ru/mmf/kaf/aml/aml-e.html;

- deputy director of IM SB RAS; see http://math.nsc.ru/str/dir.htm;
- e-mail: vdovin@math.nsc.ru

Kolesnikov Pavel Sergeevich

- Doctor of physical and mathematical sciences;
- associate professor of CAML DMM NSU; see http://mmfd.nsu.ru/mmf/kaf/aml/aml-e.html;
- head of the Laboratory of ring theory of IM SB RAS; see http://math.nsc.ru/LBRT/a1/;
- e-mail: pavelsk@math.nsc.ru

Course description

The course contains a series of classical topics in number theory which can be informally divided into three parts: algebraic and transcendental numbers, distribution of primes, and p-adic numbers and their applications. The first section is partially motivated by the famous problem of “squaring the circle” known since the ancient times. Being unsolvable by means of straightedge and compass, this problem had been inspiring the development of algebra and geometry for centuries until it was proved in 1882 that the number □ is transcendental. The course covers the definitions and basic properties of algebraic complex numbers and algebraic integers, the Liouville’s theory of Diophantine approximations, and complete proofs of the theorems by C. Hermite and F. Lindemann that the fundamental constants *e* and □ are transcendental.

In the second section, we study the foundations of the analytic number theory. Founded by P. Dirichlet and B. Riemann in the middle of XIX century, this theory remains one of the most important branches of contemporary mathematics. The main idea of the analytic number theory is to apply well-developed techniques of advanced complex analysis to the arithmetic of natural numbers. The course focuses on two famous problems of this kind: determine the asymptotic behavior of the ratio of primes in the series of natural numbers and prove that each arithmetic progression of the form $a_n = a + nd$ with relatively prime a and d contains infinitely many primes. Solutions of these problems are given by the famous Prime Number Theorem and the Dirichlet Theorem, respectively. The course contains complete proofs of these statements based on the properties of the Riemann zeta-function, Dirichlet series, and Chebyshev functions.

The third section contains the basics of *p*-adic number theory which plays an important role in contemporary geometry and mathematical physics, as well as in the general theory of Diophantine equations. We observe the theory of fields equipped with a valuation, classify the valuations on the field of rational numbers, and state the construction of the field of *p*-adic numbers. Finally, we establish the principal properties of *p*-adic numbers and shortly review some of their applications.

Prerequisites assumed to the students taking the course include: elementary number theory (division algorithm, fundamental theorem of arithmetic, Euclidean algorithm), basic algebra (ring of polynomials, structure of finite abelian groups), advanced complex-valued calculus (convergence of functional series and of parametrized improper integrals, Cauchy integral theorem), and basic topology (definition of a topological space, convergence, and topological complements).

Learning outcomes of the course

Course content

1. The field of algebraic numbers and the ring of algebraic integers
2. Diophantine approximation of a real number by rational numbers. The Dirichlet Theorem on rational approximation. An example of a transcendental number
3. The numbers e and π are transcendental
4. The distribution of primes: statement and history. Chebyshev functions
5. Discrete convolution and the product of Dirichlet series for arithmetic functions. Mobius inversion formula
6. Euler identity. Riemann zeta-function in the half-plane Re(z)>1

7. The connection between the integral Chebyshev function and the logarithmic derivation of the Riemann function

8. The analytic extension for the Riemann function in the half-plane Re(z)>0. Zeros of the Riemann function in Re(z)□1

9. Proof of the asymptotic law for the distribution of primes. An asymptotic formula for the n^{th} prime

10. Group of characters for a finite abelian group. Orthogonality relations

11. Dirichlet theorem for the number of primes in an arithmetic progression

12. Valuation fields. The classification of valuations on the field of rational numbers. Complement of a valuation field

13. The construction and properties of the ring of integer p-adic numbers and of the field of p-adic numbers

Method of assessment

In the program of the course, the carrying out the examination is provided. The detailed grade for this examination is presented in the working program of the course **M.1-V-8**.

Basic literature

Vdovin E.P., Kolesnikov P.S. Number Theory. Novosibirsk, 2013 (electronic version).

Title of the course:

M.1-V-7 Monte Carlo methods for solving boundary value problems of mathematical physics

(course of the MEP "Numerical Statistical Modelling and Simulation. Monte Carlo Methods")

Information about the authors:

Shalimova Irina Aleksandrovna

- Associate Professor, Candidate of physical and mathematical sciences;
- associate professor of CCM DMM NSU; see http://mmfd.nsu.ru/mmf/kaf/cm/prep.asp;
- senior researcher of LSP ICM&MG SB RAS; see http://osmf.sscc.ru/mixa/bak.html;
- see also the section "Information about the author" of working program of the course **M.2-V-6**;
- e-mail: ias@osmf.sscc.ru

Course description

This course is devoted to algorithms of statistical modeling for solving the boundary value problems of mathematical physics in classic and stochastic forms. Such problems are appeared in different branches of science, for example, in a crystallography (modelling of dislocations), bioinformatics, financial mathematics, elasticity theory. The essence of the studied methods is in general statistical approach. It means that the solution of a problem is constructed as the expectation of random estimator defined in a functional space of trajectories. In this approach either the probabilistic representations for original boundary problem or the equivalent integral representations are used.

The course "Monte Carlo methods for solving boundary value problems of mathematical physics" *is aimed* to expand basic educational knowledge of the undergraduate students, namely, to study the non deterministic approach for solving the boundary value problems. Despite growing technical capacity of computer systems, Monte Carlo methods have become a convenient, effective and sometimes unique way to solve most of up-to-date problems.

The course "Monte Carlo methods for solving boundary value problems of mathematical physics" corresponds to the obligatory course “Discrete and probabilistic mathematical models” of the State Master Standard (SMS) for training direction 010400 – “Applied Mathematics and Information Science”. Also some materials of the course concern to the obligatory courses “Modern problems of applied mathematics and information science” and “Continuous mathematical models” of the SMS for training direction 010400 (see the MEP “Numerical Statistical Modelling and Simulation. Monte Carlo Methods”).

Course content

1. Algorithms of statistical modeling for integral equations of second kind. Integrated equations. Markov chains. Basic estimator. Adjoint estimator. Absorption estimator. Variance of random estimators. Systems of algebraic equations. Analytical continuation on parameter. Computational complexity of Monte Carlo algorithms.

2. The Random Walk on Boundary Method for the problems of potential theory. Newton potentials: single and double layer potentials. Boundary integral equations of electrostatics. Interior Dirichlet and exterior Neumann problems. Properties of single and double layer potentials. Random Walk on Boundary algorithms for solving the Laplace equation. Convergence conditions. Analytical continuation of the resolvent. Isotropic walk on boundary. Variance, bias and computational complexity of walk on boundary algorithms.

3. Random walk on spheres process for Dirichlet problem. Scalar algorithms. Dirichlet problem for the diffusion equation. Mean value theorems. Green functions. Integral equations with generalized kernels. Random walk on spheres algorithm. Random estimator. Bias, variance and cost of Monte Carlo algorithms. Global algorithm for solving boundary value problems in all domain decisions. Method of double randomization. Random walk on spheres process for Neumann problem.

4. Boundary value problems for system of elasticity theory. Vector algorithms. Dirichlet problem for biharmonic equation. Mean value relation. Poisson integrated formula for biharmonic equation. Random Walk on Spheres process for system of integral equations. Vector estimator. Variance and bias of random estimator and computational complexity of the algorithm.

5. Lame’s equation. Lam'e equation. Generalized Poisson formula for Lam'e equation. Standard estimator. Random walk on spheres algorithm for Dirichlet problem of Lam'e equation in special class of domains. Walking on fixed spheres algorithms.

6. Monte Carlo methods for problems with random data. First boundary value problem with random loads. Double randomization.

Method of assessment

In the program of the course, the carrying out the examination is provided. The detailed grade for this examination is presented in the working program of the course **M.2-V-6**.

Basic literature

Shalimova I.A. Monte Carlo Methods for Boundary Value Problems. Novosibirsk, 2013 (electronic version).

Title of the course:

M.1-V-8 Theory of Programming

Information about the author:

Bulyonkov Mikhail Alekseevich

- Candidate of Physics and Math Sciences;
- Senior Lecturer of the Chair of Programming of the DMM NSU; see http://programming.iis.nsk.su/;
- Head of laboratory in IIS SD RAS; see http://www.iis.nsk.su:

Filatkina Natalya Nikolaevna

- Magister of Mathematics from NSU;
- Tutor of the Chair of Programming of the DMM NSU; see http://programming.iis.nsk.su/;
- Scientific researcher in IIS SD RAS; see http://www.iis.nsk.su .

Course description

The objective of the course is the student comprehension of basic concepts of theoretical programming, which in their turn are essential for understanding of modern technologies and methodology of software engineering and development. The purpose of the course “Theory of Programming” is to realize more in-depth learning of the section “Professional Cycle. Varying part (courses at the choice of the student)” of the MEP “Mathematical and Computer Modeling in Mechanics” and to study fundamental theory of program design and understanding. Notice that the course “Theory of Programming” corresponds to the obligatory course “Modern methods of computational mathematics” of the State Master Standard (SMS) for specialty 010800 – “Mechanics and mathematical modeling”.

The first part of the course is devoted to the elements of complexity theory as a mean for estimation of essential properties of computational models. This distinguishes the course from the course “Theory of Algorithms” that concentrates on the questions of existence of algorithms. Familiarity with various models and their comparative analysis on the basis of simulation gives the student the understanding of program implementation of a model and its complexity. The methods of estimation are demonstrated on the widely used search and sorting algorithms as well as the task of matrix-vector multiplication. The course provides a machine-independent complexity theory that allows to estimates the applicability limits of the concepts related to the complexity of algorithms.

The second part of the course considers a different aspect of program model analysis. The high level abstraction is leverage to uniform definition of various program characteristics, and dynamic transition systems in general, which allows applying the method of analysis to a wide range of problems. A student will obtain a conception of the very fundamental notions such as control and data flows, informational dependences, invariants, etc. The usefulness of these notions is demonstrated on the formulation of conditions for application of program transformations, which are used in a constructive proof of the decidability of logical-term equivalence.

The concluding part of the course addresses the theory of mixed computation – a generic method for improving program efficiency based on some knowledge of its input data. Many of the concepts, which were discussed earlier in the course, are shown to be useful for realization o mixed computations. On the other hand, mixed computation and its close relation to interpretation and compilation is a good link to implementation of programming languages. Finally, since the main purpose of mixed computation is program efficiency it utilizes many fundamental concepts of complexity theory.

The course “Theory of Programming” provides a systematic knowledge about the main directions of computer science. The course acquaints students with a wide range of problems arising in the scope of reliable and effective software development.

Learning outcomes of the course

As a result of learning the course “Theory of Programming” the student should:

- know basic concepts of algorithm complexity theory, program models, and mixed computation,
- be able to analyze complexity of algorithms and program models, and to apply mixed computation methods for compilation,
- be skilled in solving the problems related to algorithm design and program manipulation,

- have a solid reasoning for choice of adequate data structure and storage for a task being solved.

Course content

1. The concept of Turing machine (MT). The concept of RAM. Time and space complexity. The concept of complexity in average.
2. Simulation of MT on RAM and of RAM on MT. Complexity estimation.
3. Theorem of linear speed-up. The concept of complexity measure. Tseitin and Rabin theorems.
4. Lower bounds of complexity. Unbranching programs as a computation model. The theorems of lower complexity bounds of matrix-vector multiplication for the cases of rows and columns.
5. The concept of finite state machine (FSM). The concept of regular expression and its language. The theorem of equivalence of FSM and regular languages. Pumping lemma.
6. The problems of emptiness and equivalence for FSM. The concept of minimal automaton and its construction by the roughest splitting method.
7. Search in informational space. Bit scales: constant time inclusion and search. Linear search, time complexity estimation in the worst case and in average. Binary search and binary search trees. Balanced trees. 2-3-trees: complexity estimation, insertion and deletion. B-trees as a generalization of 2-3-trees: complexity estimation. AVL-trees. Hash tables.
8. Sorting. Classification of sorting methods. The concept of decision tree. Complexity estimation in the worst case or sorting based on comparison. Merge sort and quick sort: time complexity estimation. The concept of digital search.
9. The concept of marking algorithm. The formulation of global analysis problem (GAP). Exact solution of GAP, Non-deterministic marking process. Stable marking and the proof of its existence. Safe marking. The theorem of safe and unique stable marking. Estimation of complexity of GAP.
10. The theorem of existence of exact GAP solution for distributive case. Example of GAP for detecting loops in graphs. Methods of minimization of marking steps. The theorem of impossibility of construction of exaction GAP solution in monotonic case.
11. The concept of standard scheme: basis, terms, operators. The concept of interpretation: the value of term, protocol, results of computation. Free interpretations. Functional equivalence of standard schemes. Logical-term (LT) equivalence of standard schemes: LT-history, determinant. The theorem of LT-equivalence correctness.
12. The concept of informational relationships and informational graph. Construction of informational graph by formulation of GAP. Connected components of informational graph, and their interrelationship.
13. The concept of invariant equation. Functional nets as a representation of a set of invariant equations. Solution of detecting of invariant equation by GAP.
14. The concept of a system of transformations. Σ_{lt} system. Correctness of Σ_{lt}. Completeness of Σ_{lt}: matching of standard schemes, L-graphs. Estimation of complexity.
15. The concept of mixed computation (MC): programs as data, static and dynamic computation, basic MC equation. Relationship of MC with Kleene S-m-n theorem. Condition of expedience of MC. Relationship of MC, interpretation, and compilation of programs. Futamura projections. The concepts of meta-interpreter, self-interpreter, Jones optimality. Potential application of MC.
16. MC on the example of x^n program. Interpretive approach to MC implementation. The concept of generating extension. Transformational approach.
17. The problem of dynamic control in MC. Polyvariant MC. Methods of program transformation to improve its MC.
18. The concept of binding time analysis (BTA). Reduction of BTA to GAP. Solution of BTA by

fixed point iteration. Reduction of BTA to the solution of linear inequation system. The concept of polyvariant BTA. Transformation of program during its analysis.

Method of assessment

The course provides the following forms of training: lectures, seminars and control tests, and individual work as well. Accomplishing of program projects and testing results are taken into account to integrally estimate student’s course progress. The Faculty Academic Council can set additional forms of the control. Overall complexity of the course is 4 credits divided equally among the all forms of training.

Basic literature

1. Aho, Hopcroft, J., Ullman Data Structures and Algorithms. Springer-Verlag, Berlin., 2000.
2. T. Cormen, Charles E. Leiserson, Rivest R. Algorithms: construction and analysis. The Mit Press, 1999.
3. Motwani, R. Hopcroft, J. Ullman, J. Introduction to Automata Theory, Languages, and Computation. Pearson Publication, 2000. - 521 pages. 2nd Edition.
4. Handbook of Theoretical Computer Science. Volume A: Algorithms and Com-plexity. Volume B: Formal Models and Semantics / Edited by J. van Leeuwen. - Cambridge, MA: The MIT Press and - Amsterdam, New York, Oxford, Tokyo: Elsevier, 1996.

Title of the course:

M.1-V-9 English academic writing

Course description

Training on this course will be carried out in the form of special seminars under the chairmanship of leading researchers of ICM&MG SB RAS. Participation of leading members of editorial boards of “Siberian Journal of Numerical mathematics” (see the site http://www.sscc.ru/), “Siberian Mathematical Journal” (see the site http://www.springer.com/mathematics/journal/11202), journal “Monte Carlo Methods and Applications” (see the site http://www.degruyter.com/view/j/mcma) and others is also supposed. The course provides the student’s practice in analyzing and writing mathematical texts in English.

Learning outcomes of the course

As the result of course students gain skills for analyzing and writing mathematical texts in English (including texts on numerical statistical modelling and simulation).

Method of assessment

In the program of the course, the carrying out the test is provided.

Basic literature

Kutateladze S.S. Russian-English in writing. Novosibirsk, 2013 (electronic version).

M.2 PROFESSIONAL CYCLE

M.2-B BASIC PART

Title of the course:

M.2-B-1 Numerical methods of simulation and optimization in mechanics

Information about the author:

Cherny Sergey Grigorievich

- Full Professor, doctor of physical and mathematical sciences;
- professor of CMM DMM NSU; see http://www.ict.nsc.ru/matmod/index.php?file=prepods;
- head of laboratory of mathematical modeling of ICT SB RAS; see http://www.ict.nsc.ru/staffall.php:

Lapin Vasiliy Nikolaevich

- candidate of physical and mathematical sciences (PhD);
- senior tutor, of CMM DMM NSU; see http://www.ict.nsc.ru/matmod/index.php?file=prepods;
- researcher of ICT SB RAS; see http://www.ict.nsc.ru/staffall.php:

Course description

The course M.2-V-1 "Numerical methods of simulation and optimization in mechanics" is a fundamental course for all sections M.2 «Professional cycle» of the MEP «Mathematical and Computer Modelling in Mechanics» and intends for studying at the second and third semesters of the MEP. When developing the course the possibility for control of various preparation levels of Russian and foreign students in the fields of analysis, functional analysis, numerical analysis, numerical methods of linear algebra, programming, mathematical modeling is provided.

The main *goal* of the course is to acquaint students with on date results in solution of direct and inverse problems in aerodynamics, hydrodynamics, geophysics and solid body mechanics, and to teach them to solve actual scientific problems in these field of science.

The corresponding *objectives* of the course "Numerical methods of simulation and optimization in mechanics" are:

- to give knowledge of theory of methods in simulation and optimization, methodology and procedure of computational experiment.
- train practical skills in problem statement, development and implementation of mathematical models, using of self-developed and commercial program complexes for simulation;
- to teach students to investigate mathematical models in terms of their efficiency, applicability and validity;

Course duration is two semester. Lections, practical seminars, laboratory works, report writing and presentations are planned within the course. Overall complexity of the course is 6 credits (4 in the first semester and two in the second) divided equally among the all forms of training.

Learning outcomes of the course

As the result of study of the course "Numerical methods" the student should

know basic types of modern methods of mathematical modelling and optimization, theirs properties and features;

have an idea of actual achievements in mathematical modelling and optimization

know most popular mathematical models and numerical methods applied for problem of mechanics.
be able to implement numerical methods of simulation and optimization in program code
be able to use contemporary program complexes (ANSYS, Fluent, etc)
be able to independently solve problems of simulation in mechanics, analyze and present obtained results

Course content

1. General approaches to complex mechanical problems simulations
2. Mathematical modeling in mechanics of solids and rock mechanics
3. Mathematical modeling of hydro and gas dynamic
4. Mathematical modeling of fluid filtration
5. Mathematical modeling of hydraulic fracturing
6. Optimization of engineering system and technological procasses

Method of assessment

In the program of the course, the carrying out two examination, tests laboratory work and reports are provided. The detailed grades for the laboratory work, tests and examination are presented in the working program of the course **M.2-B-1**.

Basic literature

Cherny S.G., Chirkov D.V., Lapin V.N, Skorospelov V.A., Sharov S.V. Numerical simulation of flows in turbo machines. Novosibirsk, 2013 (electronic version).

Title of the course:

M.2-B-2 Additional chapters of numerical methods

Information about the authors:

Kovenya Viktor Mikhailovich

- full Professor, doctor of physical and mathematical sciences;
- Professor of Chair of Mathematical modeling in DMM NSU; see http://www.ict.nsc.ru/matmod/;
- chief researcher in Institute of Computational Technologies SB RAS; see http://www.ict.nsc.ru.

Lazareva Galina Gennadievna

- candidate of physical and mathematical sciences;
- associate professor of Chair of Mathematical modeling in DMM NSU; see http://www.ict.nsc.ru/matmod/;
- senior researcher in Institute of Computational Mathematics and Mathematical Geophysics SB RAS; see http://www.ict.nsc.ru.

Course description

The course «Additional chapters of numerical methods» is a logical continue of the basic course «Computational methods», read in Department of Mechanics and Mathematics of NRU NSU. It is devoted to the construction and analysis of modern efficient numerical methods for the solution of multi-dimensional equations of mathematical physics. The main emphasis is done to equations of compressible and incompressible fluid dynamics.

The course presents a detailed description of modern approaches in computational fluid dynamics, such as finite volume method, upwind approximation of convective terms, monotonization of numerical schemes, efficient implementation of implicit schemes, and so on. Great attention is paid to investigation accuracy and stability of the algorithms. The aspect of efficient computer implementation is also considered. Several commonly used numerical schemes for Navier-Stokes equations (compressible and incompressible case) are presented and analyzed.

The teaching is carried out by lectures and seminars. Independent student's work together with the fulfillment of several home tasks is also planned within the course.

The course is intended to prepare specialists in computational methods of fluid dynamics, able to construct and program numerical schemes for their own applications, as well as to competent using of existing computational software. *The aims and objectives* of the course «Additional chapters of numerical methods» are:

- to give to students the basic methods and techniques for numerical solution of real physical problems, described by partial differential equations;
- to give to students the understanding of modern trends in computational methods for fluid dynamics;
- to teach students to analyze the accuracy, stability and realizability of different methods;
- to train students to construct the economical numerical algorithms for solution of multi-dimensional equations of mathematical physics;
- to provide the understanding of the basic methods used in the core of commercial simulation software, such as ANSYS Fluent, CFX, and so on.

When developing the course, the vast scientific experience of the authors, as well as their experience in teaching «Computational methods» in Department of Mechanics and Mathematics of NRU NSU is used.

Learning outcomes of the course

As the result of study of the course «Additional chapters of numerical methods» the student

- *should know* the basic computational techniques for solving multi-dimensional partial differential equations;
- *should know* modern computational methods for fluid dynamics;
- *should be able to* construct and analyze finite-difference and finite-volume methods for general nonlinear hyperbolic and parabolic equations.

Course content

1. Technological workflow of mathematical modeling.
2. Main equations of mathematical physics.
3. Basic concepts and approaches for investigation of finite difference schemes.
4. Approximation, stability and convergence of finite difference schemes. Convergence theorem.
5. Investigation of stability. Von Neumann's spectral criterion of stability.
6. Scalar, vector and matrix tri-diagonal matrix algorithms. Economy of finite-difference schemes.
7. Explicit schemes. Runge-Kutta schemes.
8. The concept of conservativity. Conservative schemes.
9. Finite volume method.
10. Basic approaches to implementation of boundary conditions.
11. Upwind approximation of convective terms.
12. Nonlinear Riemann problem. Godunov scheme. Upwind schemes based on the solution of linearized Riemann problem.
13. Implicit schemes. Linearization of implicit schemes.
14. Fractional step method.
15. Approximate factorization method.
16. Gauss-Seidel method.

17. Predictor-corrector method.
18. Techniques for increasing accuracy of the numerical solution.
19. High resolution schemes.
20. Compact schemes.
21. Solution on adaptive grid.
22. The concept of monotonicity. Monotonic schemes.
23. Finite-difference and finite volume schemes for gas dynamics equations.
24. Schemes for compressible Navier-Stokes equations.
25. Schemes for incompressible Navier-Stokes equations.
26. Artificial compressibility method.

Method of assessment

For the assessment of students one colloquium and final exam are provided. Students are also offered to carry out several written home tasks.

Basic literature

1. Fletcher C. A. J., Computational Techniques for Fluid Dynamics: Vol. I, II. 2nd Ed., Springer-Verlag, Berlin, 1991.
2. Ferziger J., Peric M. Computational Methods for Fluid Dynamics: 3rd Ed., Springer, 2002.
3. Toro E. F. Riemann Solvers and Numerical Methods for Fluid Dynamics: 2nd Ed., Springer-Verlag, 1999.

Title of the course:

M.2-B-3 Methods of discrete simulation

Information about the authors:

Grigoriev Yuriy Nikolalevich

- full Professor, doctor of physical and mathematical sciences;
- Professor of Chair of Mathematical modeling in DMM NSU; see http://www.ict.nsc.ru/matmod/;
- chief researcher in Institute of Computational Technologies SB RAS; see http://www.ict.nsc.ru.

Lapin Vasiliy Nikolaevich

- candidate of physical and mathematical sciences (PhD);
- senior tutor, of CMM DMM NSU; see http://www.ict.nsc.ru/matmod/index.php?file=prepods;
- researcher of ICT SB RAS; see http://www.ict.nsc.ru/staffall.php:

Course description

Corse gives an introduction in numerical method of discrete particles. Universal formal approach to particle-in-cell algorithms construction is described. Most popular models of discrete particles are investigated. Specific errors of method are analyzed. General scheme of particle-in-cell method applications to problems in gas dynamics, vorticity dynamic in incompressible and compressible fluids plasma physics rear gas dynamic is proposed.

For each application typical problem solution are considered and new ways of the method application are shown.

The course *goals* are *to give a conception* about numerical particle methods as an alternative of finite difference methods, *teach to construct* algorithms of particle-in-cell method based on mathematical problem formulation, to improve methods (increase methods efficiency and reduce typical errors), *to implement* the methods for parallel computers.

Course duration is one semester. Lections are planned within the course. Overall complexity of the course is 2 credits divided equally among the all forms of training.

Learning outcomes of the course

As the result of study of the course « Methods of discrete simulation » the student should

- *know* the basic of theory and applications of particle-in-cell methods;
- *be able* to build particle-in-cell method for particular problem ;
- *be able* to use universal blocks and specific procedures of the method and reduce typical method errors.

Course content

1. Particle-in-cell methods in mathematical modelling.
   1.1. General properties
   1.2. Some applications
2. Particle-in-cell methods.
   2.1. General scheme
   2.2. Model particles and theirs properties
   2.3. Errors of particles in cells schemes.
3. Method of particles in gas dynamics
   3.1. Equations of gas dynamic in divergent form
   3.2. Scheme Harlow
   3.3. Method of super particles (FLIC method)
4. Vortexes in cells methods
   4.1. Vorticity dynamic in plane flows
   4.2. Vortexes in cells methods for incompressible floes
   4.3. Vortexes in cells methods for compressible floes
5. Particle-in-cell methods in plasma mechanics
   5.1. Kinetic equation with self-consistent field
   5.2. General scheme and computational cycle
6. Statistical particle-in-cell methods
   6.1. Kinetic equations of rear gas
   6.2. Some approaches of Monte-Carlo methods
   6.3. Bird’s algorithm

Method of assessment

In the program of the course, scientific report writing and carrying out an examination are provided

Basic literature

Yu.N. Grigoryev, V.A.Vshivkov and M.P.Fedoruk. Numerical-Particle-in-Cell Methods - Theory and Applications. - Utrecht: VSP BV.-2002. P.250+viii, ISBN 90-6764-368-8.

M.2-V VARIABLE PART (courses at the choice of the student)

Title of the course:

M.2-V-1 Parallel numerical methods

Information about the author:

Vitaly Andreevich Vshivkov

- Full Professor, Doctor of Physical and Mathematical sciences;
- Professor of CS DMM NSU; see http://mmfd.nsu.ru/mmf/kaf;
- Head of the Laboratory of ICMMG SB RAS; see http://www.sscc.ru.

Course description

The course «Parallel numerical methods» is a fundamental course within the field of education «Applied mathematics and informatics». It is a one year course (two semesters). To succeed in the course it is assumed that students are familiar with the university level courses such as linear algebra, logic theory and programming using any algorithmic language including the tools of programming on parallel computers. However, the course is built in such a way that the main definitions from these courses will be provided to the students. Therefore, it allows to the students of different level of preparation to take this course.

The objectives of the course «Parallel numerical methods» are to teach students to master all components of the methodology of the mathematical modeling on parallel computers, to give them the universal scientific tool which can be applied to the very different fields of the natural science, technology and social science. Along with the lectures, the practical seminars (laboratories) and independent student's work are planned within the course.

The aim of the course is the learning by the students of the modern parallel methods in the computational mathematics and, also, the forming of practical skills in the implementation of the mathematical methods to solve different practical problems by parallel computers and estimation of the parallel algorithm efficiency. Besides the classical sorting methods, number summation by obtaining partial sums, the solving of the systems of linear algebraic equations, the inversion of a square matrix and the determinant computation, the parallel methods to solve the systems of ordinary differential equations and partial differential equations of different types are considered. Using the theoretical knowledge obtained on the lectures the students carry out the parallelization of one-processor algorithms, estimate its efficiency, implement the algorithm on a parallel computer and proof the validity of the obtained numerical solution.

When preparing the course, the vast experience of the author in teaching the computer simulation courses at the Department of Mechanics and Mathematics and the Department of Physics of NRU NSU was used.

Learning outcomes of the course

After completing the course «Parallel numerical methods» a student

will know the basic parallel algorithms and the main parallelization techniques for problems of the linear algebra and the mathematical physics;

will be able to develop elementary parallel algorithms to solve different mathematical problems, to implement the developed algorithms on parallel computers using programming languages, to control a validity of obtained results, to estimate an accuracy of the results and to estimate an efficiency of the developed algorithm and the parallel code.

Course content

1. Basic definitions of the parallel algorithm theory.
2. Examples of parallelization for the bubble sort and number summation.
3. The Batcher sort algorithm.
4. General parallel algorithms. Descent and ascend parallel algorithms.
5. Reduction of different parallel algorithms to the general algorithms.
6. Parallelization of the matrix product.
7. Definition and properties of the matrix determinant.
8. Definition and properties of the vector and matrix norms. Standard vector norms.
9. Definitions and properties of the matrix eigenvalues and eigenvectors.

10. Eigenvalues of the similar and inverse matrices.
11. Theorems on the connection of the matrix and vector norms.
12. Computation of the matrix norms.
13. Parallelization of the iterative Jacobi method.
14. Parallelization of the successive overrelaxation method.
15. Definitions of the ordering and successive ordering of the matrix.
16. Red-black ordering of the matrix.
17. Successive ordering of the matrix when solving the Poisson equation.
18. Splitting algorithm to solve the heat equation.
19. Double-sweep method.
20. Parallelization of the double-sweep method.
21. Power series methods.
22. Inverse matrix for the triangular matrix.
23. The Pan-Reif algorithm for the inverse matrix computation. A sufficiently good estimation for the inverse matrix.
24. Parallel algorithm to find the matrix determinant.
25. The discrete Fourier transform.
26. Fast algorithm for obtaining the convolution product of two sequences.
27. Solving the Poisson equation by the Fourier transform.
28. Algorithm for the fast Fourier transform.
29. One example of the parallel code carrying out the fast Fourier transform.
30. Time estimation to implement an algorithm on parallel processors.

Method of assessment

There a final exam to assess the student work will be held in the end of the course. Also, students will be given the homework during the course.

Basic literature

V.A. Vshivkov. Introduction to parallel numerical methods. Novosibirsk, 2013 (electronic version).

Title of the course:

M.2-V-2 Method of differential approximation

Information about the author:

Khakimzyanov Gayaz Salimovich

- Full Professor, doctor of physical and mathematical sciences;
- professor of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- leading researcher of ICT SD RAS; see http://www.ict.nsc.ru/showpers.php?uid=37 .

Lazareva Galina Gennadievna

- Assistant Professor, PhD in Mathematical Modelling and Computational Technology in Science;
- senior lecturer of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- senior researcher of ICMaMG SD RAS; see http://sscc.ru;
- see also the section «Information about the supervisor of the programme» of this programme.

Course description

Course program “Method of differential approximation” is compiled in accordance with requirements to the structure and results of master educational programs “Professional cycle. Free electives”. It is an item of educational master program in English “Mathematical and Computer Modeling in Mechanics”. Course program is compiled in accordance with Novosibirsk State University tasks of implementing the NSU development Program.

The developed course “Method of differential approximation” belongs to the section “Variable part (courses at the choice of the student)” and designed to study during the second year of the MEP “Mathematical and Computer Modeling in Mechanics”. When developing the course the possibility for control of various preparation levels of Russian and foreign students in the fields of probability theory, functional analysis and numerical modelling and simulation is provided.

The presented program is new. It is based on the latest achievements of recent years in the field of computational mathematics. For the first time the possibility of using differential approximations in the study of difference schemes specified by A. I. Zhukov. In 1968, N.N. Yanenko and Yu.I. Shokin formulated the concept of the first differential approximations for the difference scheme with constant coefficients. They proved the first theorems on the connection stability of difference schemes and their correctness of the first differential approximation for the hyperbolic system of first order equations. Subsequently, the idea of using differential approximations was widely developed in the works of other Russian and foreign mathematicians. Early achievements in the theory of method of differential approximation and its applications reflected in the book Yu.I. Shokin, N.N. Yanenko, «Method of differential approximation. Application to gas dynamics». - Novosibirsk: Nauka, 1985, and the textbook Yu.I. Shokin, G.S. Khakimzyanov «Introduction to the method of differential approximation». - Novosibirsk: NSU, 1997. The results of the last 15 years are reflected only in journal articles, including numerous foreign publications. This creates difficulties both for undergraduates studying and mastering the modern tools of computational mathematics. Therefore, students will be useful and convenient to have on hand material. In its present and future research students have the knowledge contained the single style, give an idea of the method of investigation of difference schemes, the method of differential approximation.

Finite difference method is one of the most used numerical methods of solution of initial-boundary value problems for differential equations with partial derivatives. Described in these lectures method of differential approximation can be used to study the properties of existing difference schemes for the construction of new schemes with predefined properties, and for designing of the automated systems of design and analysis of difference schemes.

Method of differential approximation is that the finite-difference approximation is replaced by a differential equation of infinite order, differential representation of the difference scheme. Differential representation of the difference scheme is a record of this scheme in terms of differential operators. It carries the complete information about the differential scheme. If you leave the differential representation of a certain number of senior members, you can get a differential approximation of the difference scheme of a different order. It occupied an intermediate position between the original differential equation and the approximating its difference circuit. Differential approximation contains some information about both the equation and finite-difference scheme. This can be used to study the properties of stability, dissipation, dispersion, monotonicity, equivalence, invariance of difference schemes and some other properties.

Lecture course aims to

• give the students basic knowledge in the field of the modern method of research of finite-difference schemes by method of differential approximation;
• teach students to write a differential approximation of difference schemes;
• teach students to research the finite-difference schemes by method of differential approximation.

The course consists of a set of four interconnected modules. The first one is an introduction. It provides necessary for further presentation of the information from the theory of differential equations and difference schemes. It defines the concept of differential representation and a differential approximation of the difference scheme.

The second module is devoted to the analysis of stability of difference schemes by method of differential approximation. It provides the analysis of such important properties of difference schemes as dissipation and dispersion of difference schemes. A significant place is given to examples that will help students master the technique of method of differential approximation in the amount sufficient for its use in their tasks of mathematical modeling.

In the third module, given the peculiarities of application of method of differential approximation for the analysis of algebraic equivalence and fully conservative difference schemes. For the analysis of the monotonicity of difference schemes including schemes on adaptive grids. Introduces a new approach to building TVD schemes. Examples of study of difference schemes.

The final module is devoted to research of the invariance of difference schemes. Reminded of information from the theory of group properties of differential equations. Deduces the conditions of invariance of difference schemes in terms of their first differential approximations. Deduces the conditions of invariance of difference schemes for one-dimensional equations of gas .

Learning outcomes of the course

As a result of learning the course “Method of differential approximation” the student should:

• Know techniques for constructing differential approximation for difference scheme;

• Be able to apply method of differential approximation for research of finite-difference scheme properties (stability, dissipation, dispersion, save the monotony of the numerical solution).

Course content

1. Some information from the theory of linear differential equations and the theory of difference schemes.
2. Differential representation of difference schemes.
3. Differential approximation of the difference scheme.
4. Analysis of the difference scheme stability on the basis of its differential representation.
5. Stability of some difference schemes with fixed factors.
6. Definition of properties of K difference schemes. Research the properties of simple difference schemes.
7. K - property is three-point difference schemes. K -property of the predictor-corrector scheme and some implicit schemes.
8. Shallow water equations. About schemas, preserving hydraulic jump.
9. Dissipation and dispersion of difference schemes.
10. Geometric illustration of dissipation and dispersion of difference schemes.
11. Analysis of the monotonicity of difference schemes. TVD-scheme. Theorem on necessary and sufficient condition of monotonicity of difference schemes. Strong monotonicity.
12. Monotonication the predictor-corrector scheme for one-dimensional linear transport equation.
13. On difference schemes in arbitrary frame.
14. Research of the properties of the predictor-corrector scheme on the moving grid for a one-dimensional linear transport equation.
15. Monotonication the predictor-corrector scheme for a nonlinear transport equation. The use of differential approximation to the study of entropic conditions.
16. Algebraic equivalence of difference schemes.
17. Conservative difference schemes. The conservative scheme for mobile grid. Conservative difference schemes on adaptive grids for equations of shallow water.
18. Fully conservative difference schemes.
19. Some information from the theory of batch properties of differential equations.
20. The conditions of the invariance of difference schemes for one-dimensional equations of gas dynamics

Method of assessment

In the program of the course, the carrying out the examination is provided. The detailed grades for the examination are presented in the working program of the course.

Basic literature

Khakimzyanov G.S. Lectures on methods of differential approximation. Novosibirsk, 2013 (electronic version).

Title of the course:

M.2-V-3 Mathematical models of plasma technologies of microelectronic

Information about the author:

Gorobchuk Aleksei Gennad'evich
- Candidate of physical and mathematical sciences;
- Associate professor of MMC DMM NSU; see http://www.ict.nsc.ru/matmod;
- Scientist of ICT SB RAS; see http://www.ict.nsc.ru.

Lapin Vasiliy Nikolaevich
- Candidate of physical and mathematical sciences;
- Secretary of MMC DMM NSU; see http://www.ict.nsc.ru/matmod;
- Scientist of ICT SB RAS; see http://www.ict.nsc.ru.

Course description

The course M.2-V-3 «Mathematical models of plasma technologies in microelectronics (special course)» is an important course for the senior students assigning a specialization in the field of the "mathematical modeling". The special course is devoted to the detailed descriptions for numerical modeling of perspective plasma technologies in microelectronics. The up-to-date mathematical models and numerical methods for modeling of plasma-chemical etching processes implied in the microelectronic device production are presented. The problem of RF-discharge modeling, computation of hydrodynamics, multicomponent chemical kinetics, heat and mass transfer are sequentially considered. The modern numerical methods for these problems are discussed. The final lecture includes the actual problems of silicon technology and corresponding effective methods of numerical modeling.

The aims and objectives of the course «Mathematical models of plasma technologies in microelectronics (special course)» are:
- to give to students the widen knowledge in the applications of mechanics of continuum (fluid, gas and plasma) and numerical methods;
- to train students to construct the numerical algorithms for modeling of similar problems.

The course «Mathematical models of plasma technologies in microelectronics (special course)» can be used in realization of international master program «Mathematical and Computer Modelling in Mechanics» of DMM NRU NSU.

Learning outcomes of the course

The student should know the general mathematical models of mechanics of continuum (hydrodynamics, heat and mass transfer) and plasma physics (kinetic equations, models of multicomponent plasma kinetic). They should use the actual numerical methods and technologies for solving such problems.

Course content

1.1. Perspective technologies in micro- and nanoelectronics. Classification of etching processes.
1.2. Widespread constructions of plasma-chemical etching reactors.
2.1. Mathematical models of plasma-chemical etching reactors. RF-discharge models.
2.1.1. Kinetic equations of low-temperature plasma.

2.1.2. Hydrodynamic approach.
2.1.3. Combination of kinetic and hydrodynamic descriptions.
2.1.4. Simple analytical models.
2.2. Plasma-chemical kinetics.
2.2.1. Binary approach for gas mixture.
2.2.2. Multicomponent gas mixture.
2.2.3. Excited and charged plasma components.
2.3. Hydrodynamics in the plasma reactors.
2.3.1. Continuum approach.
2.3.2. Viscous, diffusion and temperature sliding at the lower pressure.
2.4. Heat transfer.
2.4.1. Energy balance equation.
2.4.2. Radial heat exchange in the optical thin layer.
2.4.3. Approximate calculation of absorb ability.
2.4.4. Effect of temperature jump at the lower pressure.
2.5. Mass transfer.
2.5.1. Convective and diffusion transfer.
2.5.2. Thermodiffusion.
2.6. Transport and thermodynamic characteristics of multicomponent gas mixture.
2.7. Numerical methods.
2.7.1. Numerical peculiarities.
2.7.2. Finite-difference splitting schemes.
2.7.3. Approximation of boundary conditions.
3.1. Advance of mathematical models of plasma-chemical etching reactors. Virtual reactor. Optimal controller in the feedback circuit.
3.2. Conjugate heat transfer on the processing wafer.
3.2.1. Finite-difference methods for numerical solve of energy balance equations in the wafer and gas.
3.3. Thermoelastic deformations of wafer.
3.3.1. Lame equations and boundary conditions.
3.3.2. Finite-difference schemes with two order of approximation.

Method of assessment

The main method of assessment is the examination.

Basic literature

Yurii N. Grigoryev and Aleksey G. Gorobchuk (2009). Numerical Simulation of Plasma-Chemical Processing Semiconductors, Micro Electronic and Mechanical Systems, Kenichi Takahata (Ed.), ISBN: 978-953-307-027-8, InTech, DOI: 10.5772/7012. Open Access.
Available from: http://www.intechopen.com/books/micro-electronic-and-mechanical-systems/numerical-simulation-of-plasma-chemical-processing-semiconductors.

Title of the course:

M.2-V-4 Modern methods of computational mathematics

Information about the author:

Khakimzyanov Gayaz Salimovich

- Full Professor, doctor of physical and mathematical sciences;
- professor of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- leading researcher of ICT SD RAS; see http://www.ict.nsc.ru/showpers.php?uid=37 .

Lazareva Galina Gennadievna

- Assistant Professor, PhD in Mathematical Modelling and Computational Technology in Science;
- senior lecturer of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- senior researcher of ICMaMG SD RAS; see http://sscc.ru;
- see also the section «Information about the supervisor of the programme» of this programme.

Course description

Course program "Modern methods of computational mathematics" is compiled in accordance with requirements to the structure and results of master educational programs "Professional cycle. Free electives". It is an item of educational master program in English "Mathematical and Computer Modeling in Mechanics". Course program is compiled in accordance with Novosibirsk State University tasks of implementing the NSU development Program.

The developed course "Modern methods of computational mathematics" belongs to the section "Basic part" and designed to study during the second year of the MEP "Mathematical and Computer Modeling in Mechanics". When developing the course the possibility for control of various preparation levels of Russian and foreign students in the fields of probability theory, functional analysis and numerical statistical modelling and simulation is provided.

Note that the presented program is new. It is based on the latest achievements of recent years in the field of computational mathematics. A distinctive feature of the presented program is that the material of the lectures is not stated previously in textbooks and manuals. Lecture material is spread out over numerous journal articles. This creates difficulties both for undergraduates for self-study and development of modern tools of computational mathematics. Therefore, students will be useful and convenient to have on hand material. In its present and future research students have the knowledge contained the single style, give an idea of the current state of Affairs in computational mathematics.

Lecture course aims to

• give the students basic knowledge in the field of the theory and applications of modern numerical methods;

• teach students to choose the most effective numerical methods for solution of actual applied problems;

• teach students to conduct modern level computing experiments.

The course consists of a set of four interconnected modules. The first one is connected with the modern finite-difference methods on adaptive grids. Students learn the concept of adaptive mesh, some methods of construction of adapting to the solution of one-dimensional nets and multidimensional curved grids. Students learn the General principles of constructing finite-difference schemes on adaptive grids. Special attention is paid to the development of schemes on adaptive grids for the Poisson equation, equations of shallow water and gas dynamics.

The second module focuses on the finite-element approximations. This course focuses on mastering the masters' modern methods of triangulation areas with complex geometry borders.

In the third module outlines the features of such rapidly developing recently numerical methods as methods of control volumes of fictitious areas, boundary elements, spectral methods and various algorithmic method implementations «particles-in-cells». Maked an examples of problems solved by these methods.

The final module deals with some special issues of the modern computational mathematics. The theory TVD schemes, specific features of the development non-oscillating schemes for multidimensional problems are considered. Modern methods of monotonization of hyperbolic equations numerical solution and algorithms for accelerating the iterative convergence are studied.

Learning outcomes of the course

As a result of learning the course "Modern methods of computational mathematics" the student should:

• Know techniques for constructing and theoretical methods of research of modern numerical methods;
• Be award of the following skills: choice from a set of known numerical methods of the most effective numerical method for the particular class of applied problems;
• Know the modern technology of computing experiments.

Course content

1. Adaptive mesh refinement for solving second-order ordinary differential equations. The error of approximation on non-uniform mesh. General principles of constructing finite-difference schemes on adaptive grids.
2. Equidistribution method for building adaptive moving grids in the one-dimensional problems.
3. Predictor–corrector method on an non-uniform moving mesh for a one-dimensional linear transport equation. Schema properties.
4. The geometric conservation law and divergent schemes on the moving grid.
5. The concept of curvilinear net in a multidimensional region. Algebraic methods of construction of grids.
6. Differential methods of construction of adaptive meshes and their numerical realization.
7. Finite-difference scheme on an adaptive grid for the solution of a boundary-value problem for the Poisson equation. Integro- interpolation method of obtaining difference equations. Properties of differential operator.
8. Difference schemes on adaptive grids for shallow water equations. Schemes research.
9. Adaptive meshes in gas dynamics problems.
10. Finite element method for the second-order ordinary differential equations. Energy space. Generalized problem-solving.
11. Generalized solving of the Dirichlet problem for the Poisson equation. Finite element method for finding approximate generalized solution.
12. Domain triangulation. Methods of construction of unstructured triangular grids in the two-dimensional domains with complex geometry borders.
13. Control volume approach. Application.
14. Fictitious domains method. Hydrodynamic problems.
15. Boundary-element method. Free boundary problems.
16. Spectral methods. Meteorology problems.
17. Numerical methods «particles-in-cells». Wave hydrodynamics problems.
18. Theory TVD schemes. Theorem on necessary and sufficient condition of monotony of difference schemes with constant and variable coefficients.
19. Modern methods of monotonization for numerical solution of hyperbolic equations. Monotonization the predictor-corrector scheme for one-dimensional linear transport equation.
20. The design features of the non-oscillating schemes for multidimensional problems.
21. Modern algorithms for accelerating the iterative convergence. Algorithms for accelerating the iterative convergence using the least square technique.
22. Schemes of high order of approximation, based on the Runge-Kutta method. Multigrid schemes.
23. General principles of computing experiment organization. Mathematical model hierarchy and research methods. Computational algorithms hierarchy. Accuracy, stability, efficiency, parallelism numerical algorithms. Some principles of software engineering. Design, programming, debugging, software testing. Processing method of the results of calculations.

Method of assessment

In the program of the course, the carrying out the examination is provided. The detailed grades for the examination are presented in the working program of the course.

Basic literature

Khakimzyanov G.S. Modern methods of computational mathematics. Novosibirsk, 2013 (electronic

version).

Title of the course:

M.2-V5 The method of collocations and the least residuals for solving boundary problems for systems of differential equations

Information about the author:
Shapeev Vasily Pavlovich

- Full Professor, doctor of physical and mathematical sciences;
- professor of DMM NSU;
see http://www.nsu.ru/exp/mmf/kafedra_matematicheskogo_modelirovaniya
- leading researcher of ITAM SD RAS; see http://itam.nsc.ru/en/search/?q=Shapeev

Course description

The method of collocations and least residuals (CLR) is an universal method for numerical solution of boundary-value problems for the systems of ordinary differential equations (ODE) and partial differential equations (PDE). It combines two methods of computational mathematics: the method of collocations and a version of the least-squares method. The CLR method differs from all advanced methods for solving the PDEs in that it minimizes the functional of the residual of numerical solution of a boundary-value problem. This peculiarity of the method conditions a number of its good properties. The method was initially applied for solving the boundary-value problems for ODEs. One has started relatively recently applying and developing the method for solving the PDEs. The method has been applied for the PDE systems for the first time by the author of the present suggested course together with his colleagues from the NSU.

In the CLR method, the region of problem solution is discretized by a difference grid. The problem solution is sought in the form of a linear combination of the basis functions of a linear functional space. The space of polynomials is taken most frequently as the latter. An overdetermined system of linear algebraic equations (SLAE) is written for the indeterminate coefficients of the sought combination. Since the equations in the overdetermined system can be taken with different weights, there arise in solution formulas the parameters, which affect the solution properties. Controlling their values one can affect, within some limits, the smoothness of the sought solution, its accuracy, and the conditionality of the SLAE determining the solution. Increasing the number of vectors in the space basis one can increase the accuracy of problem solution. The CLR method is applied relatively simply on the adaptive and irregular grids. Unlike the existing courses of the given profile, the techniques of using the advanced systems of computer algebra will be shown in the proposed lecture course, which facilitate greatly and speed up the work of a numerist at the derivation of the numerical algorithm formulas, at the machine code verification. This enables one to avoid many errors at the realization of the computational algorithm on computer and increases the reliability of the results of the method application. Unlike most other courses it will be shown in the given course how significantly the iterative processes of the numerical solution of boundary-value problems are accelerated at the application of the Krylov's subspaces, the original techniques for increasing the efficiency of this approach in the region of small solution residuals, the use of the domain decomposition method enabling an efficient parallelization of the problem solution on advanced computer complexes.

The **objectives and the tasks of the course** "The method of collocations and least residuals for solving boundary-value problems for systems of differential equations":

— to give students the skills of the development of variants of the CLR method for solving the

boundary-value problems for the ODE and PDE systems;
— to teach students to analyze the properties of the different variants of the CLR method from the viewpoint of the efficiency of problem solution with its aid on computer;
— acquaint students with modern mathematical and computer facilities for the development and implementation on a computer of the versions of the CLR method.

The basis of the course consists of original research results on the CLR method, which were obtained by the author of the course and other researchers. The proposed course will differ significantly from the conventional ones, but it will give at the same time a certain set of information about the computational mathematics, which is used in other methods.

Learning outcomes of the course

As a result of studying the course "The method of collocations and least residuals for solving boundary-value problems for systems of differential equations" the student
must know the fundamentals of the theory of projection methods for solving the systems of differential equations;
must be able to analyze the properties of different variants of the CLR method from the viewpoint of their efficiency for modeling various problems of the mathematical physics and continuum mechanics by this method;
must master the technology of the development of a version of the numerical algorithm for solving the boundary-value problem for a given PDE system.

Course content

1. The algorithm and properties of the least-squares method at the approximation of discretely given functions with a random relatively small error.
2. The methods of collocation and CLR for the solution of ODEs.
3. Basic elements and specific details of the CLR method for solving the boundary-value problem for PDE.
4. Versions of the CLR method for solving the Poisson equation.
5. Control parameters of the method and their influence on the properties of the problem solution.
6 The application of the method on an irregular adaptive grid.
7. The conservative version of the method.
8. The application of computer algebra systems for deriving the formulas of the numerical algorithm of the method, their verification and translation into a machine code.
9. The application of the Krylov' subspaces for accelerating the iteration process of the SLAE solution.
10.The S-criterion for a stable construction of the Krylov's subspace in the region of small residuals of the SLAE solution.
11. The versions of the CLR method for solving the convection-diffusion equation.
12. The versions of the CLR method for solving the boundary-value problems for 2D and 3D Navier–Stokes equations.
13. Solution of the benchmark problem of the viscous fluid flow in the 2D and 3D cavities. The overview of the literature on the results of the solution of this problem.
14. The application of the CLR method to the problem of laser welding of metal plates.

Method of assessment

In the program of the course, the carrying out the colloquium and the examination is provided.

Basic literature (electronic version).

1. V.P. Shapeev and E.V. Vorozhtsov. Symbolic-numeric implementation of the method of collocations and least squares for 3D Navier--Stokes equations // Lecture Notes in Computer Science. -- 2012. -- Vol. 7442. -- P. 321--333.
2. V.P. Shapeev, V.I. Isaev and V. Idimeshev. The collocations and least squares method: application to numerical solution of the Navier-Stokes equations, CD-ROM Proceedings of the 6th European

Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), September 10-14, 2012, Vienna, Austria, Eds.: Eberhardsteiner, J.; Bohm, H.J.; Rammerstorfer, F.G., Publisher: Vienna University of Technology, Austria, ISBN: 978-3-9502481-9-7.
3. Saad Y. Numerical methods for large eigenvalue problems. Manchester University Press, 1991. 358 pp.

Title of the course:

M.2-V-6 Numerical methods in aerodynamics

Information about the authors:

Cherny Sergey Grigorievich

- Candidate of physical and mathematical sciences (PhD);
- associate professor of CMM DMM NSU; see http://www.ict.nsc.ru/matmod/index.php?file=prepods;
- senior researcher ICT SB RAS; see http://www.ict.nsc.ru/staffall.php:

Lapin Vasiliy Nikolaevich

- candidate of physical and mathematical sciences (PhD);
- senior tutor, of CMM DMM NSU; see http://www.ict.nsc.ru/matmod/index.php?file=prepods;
- researcher of ICT SB RAS; see http://www.ict.nsc.ru/staffall.php:

Course description

The purpose of the course “Numerical methods in aerodynamics” is to realize more in-depth learning of the section M.2-V “Professional Cycle Variable part (courses at the choice of the student)” of the MEP “Mathematical and Computer Modelling in Mechanics” and to study modern directions for development of the numerical method development and its application to computational fluid dynamic. These methods discover wide applications in solution of problems of mathematical physics and industrial mathematics.

Note that the course “Numerical methods in aerodynamics” is an extension of courses “Numerical methods” and “Numerical methods Additional chapters”. The theory of numerical methods described in these courses is applied to fluid and gas mechanics here.

The contents of the course “Numerical methods in aerodynamics” covers the circle of questions tied with modern development of theory and applications of algorithms of numerical methods and their applications to gas and fluid flow problems. Numerical experiment takes leading role in nature investigation, technology development. Its role increases due to increasing of computers productivity and computer science evolution. The course is mostly focused on the second part of “Samarskiy's triad” (model-algorithm-program) that is the basis of mathematical simulation methodology. Numerical method theory is evolved in the course and applied to problems of computational fluid and gas dynamic. The methods and approaches described in the course are based both on classical schemes (to provide students the logic of the theory) and on modern scientific results (to acquaint students with contemporary state of the theory)

The *aim* of the course “Numerical methods in aerodynamics” is to describe methodology of numerical methods development in case of computational fluid and gas dynamics.

The corresponding *objectives* of the course “Numerical methods in aerodynamics” are:

- to give to students basic knowledge in methodology of mathematical modelling and computational experimenting

- the theory and applications of for numerical solution of problems of computational fluid and gas dynamics;
- to teach students to investigate numerical methods in terms of their efficiency and to use these algorithms for numerical solution of actual applied problems;

Course duration is two semester. Lections are planned within the course. Overall complexity of the course is 2 credits divided equally among the all forms of training.

Learning outcomes of the course

As the result of study of the course "Numerical methods in aerodynamics" the student

should know methodology of mathematical modelling and computational experimenting, the theory and applications of for numerical solution of problems of computational fluid and gas dynamics.

should be able to analyze and investigate (theoretically and numerically) the Numerical methods in aerodynamics in terms of their efficiency and possibility of their use in numerical solution of actual applied problems;

should possess the technologies for construction of effective numerical schemes and mesh generation for solution of actual applied problems .

Course content

1. Physical and mathematical models
2. Basic ideas of finite difference schemes
3. Finite difference schemes for convection equation and system of hyperbolic equations
4. Finite difference schemes for parabolic equations and system of equations
5. Finite difference schemes for compressible Navier-Stokes equations
6. Numerical mesh as a part of numerical algorithm

Method of assessment

In the program of the course, the carrying out the examination is provided. The detailed grades for the laboratory work, tests and examination are presented in the working program of the course **M.2-V-6**.

Basic literature

1. C. A. J. Fletcher Computational Techniques for Fluid Dynamics. Vol 1-2 – Springer –1991.
2. Cherny S.G., Lapin V.N. Numerical methods in aerodynamics. Novosibirsk, 2013 (electronic version).

Title of the course:

M.2-V-7 Scientific seminar "Mathematical modeling of large-scale problems"

Information about the authors:

Vitaly Andreevich Vshivkov

- Full Professor, Doctor of Physical and Mathematical sciences;
- Professor of CS DMM NSU; see http://mmfd.nsu.ru/mmf/kaf;
- Head of the Laboratory of ICMMG SB RAS; see http://www.sscc.ru.

Course description

The scientific seminar is one of the most important elements of famous Russian research schools. Seminars are held every week. The reports of leading specialists in the field of mathematical modeling of large-scale problems are presented.

Learning outcomes of the course

As the result of studying the scientific seminar "Mathematical modeling of large-scale problems", student gets the new ideas about modern concepts and applications of the theory of mathematical modelling and supercomputer simulation. He also gets examples of presentation of reports and articles on actual scientific topics, experience in scientific discussions, asking questions, etc.

Method of assessment

The grade of the course "Scientific seminar 'Mathematical modeling of large-scale problems'" depends on student's attendance and activity on the seminar. The excellent mark is guaranteed to those students who are invited to give a rigorous scientific report on the seminar.

Title of the course:

M.2-V-8 Scientific seminar "Informational and computational technologies in problems of decision-making support"

Information about the authors:

Shokin Yuri Ivanovich

- Academician of Russian Academy of Sciences (RAS), Full Professor, Doctor of physical and mathematical sciences;
- Director of the Institute of Computational Technologies SB RAS; see http://www.ict.nsc.ru/sitepage.php?PageID=136.

Fedoruk Mikhail Petrovich

- Full Professor, Doctor of physical and mathematical sciences;
- Rector of NSU; see http://www.nsu.ru/exp/en/university/governance;
- Head of Laboratory of computational technologies ICT SB RAS; see http://www.ict.nsc.ru/showpers.php?uid=33.

Chubarov Leonid Borisovich

- Full Professor, Doctor of physical and mathematical sciences;
- professor of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- Major researcher of Center for monitoring of socio-economic and environmental situation ICT SB RAS; see http://www.ict.nsc.ru/showpers.php?uid=49&showcv=y.

Course description

The scientific school of Academician Yu.I. Shokin (Novosibirsk scientific center, ICT SB RAS) continues the traditions of academician Nikolai Nikolaevich Yanenko. The main direction of research developed in the present scientific school of Academician Yu.I. Shokin, connected with the development of information and computing technologies for decision support in the design and operation of complex technical systems and facilities, environmental monitoring, prediction of consequences of disasters and catastrophes. Scientific-methodical seminar of the Institute of computational technologies SB RAS was founded in 2004 Workshop is designed to promote the establishment of young researchers, to promote youth involvement in the work on research projects and programmes for the control over fulfillment of plans of research works of students, graduate students, doctoral candidates. Seminars are held every week – see http://www.ict.nsc.ru/seminar/dp/info.html (in Russian). The reports of leading specialists, young researches and students in problems of decision-making support are presented.

Learning outcomes of the course

As the result of studying the course "Informational and computational technologies in problems of decision-making support", student gets the new ideas about modern technologies. He also gets examples and train skills in presentation of scientific reports and articles on actual scientific topics, experience in scientific discussions, asking questions, etc.

Method of assessment

The seminar “Informational and computational technologies in problems of decision-making support” is obligatory speeches of the participants with messages about the contents of tasks and their results in order to develop the skills of presentation of the research results, participate in scientific discussions. Student should make two presentations of his/her scientific researches. The first in the first year of educational should contain problem statement, chosen method of solution and some problem/method features. The second presentation in 3-4 semester should be based on master dissertation results. Also lectures of the leading scientists of the Department and the base of the Institute are there in the seminar.

Title of the course:

M.2-V-9 Scientific seminar “Informational technologies”

Information about the authors:

Shokin Yuri Ivanovich

- Academician of Russian Academy of Sciences (RAS), Full Professor, Doctor of physical and mathematical sciences;
- Director of the Institute of Computational Technologies SB RAS; see http://www.ict.nsc.ru/sitepage.php?PageID=136.

Fedotov Anatoliy Mikhaylovich

- Corresponding Member of Russian Academy of Sciences (RAS), Full Professor, Doctor of physical and mathematical sciences;
- Head of the department of Information Technology of NSU; see http://www.nsu.ru/exp/en/education/information_technologies;
- Deputy Director on scientific work ICT SB RAS; see http://www.ict.nsc.ru/showpers.php?uid=1.

Chubarov Leonid Borisovich

- Full Professor, Doctor of physical and mathematical sciences;
- professor of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- Major researcher of Center for monitoring of socio-economic and environmental situation ICT SB RAS; see http://www.ict.nsc.ru/showpers.php?uid=49&showcv=y.

Course description

Seminar "Information technologies" was founded in 2000 by Professor Fedotov A.M. scope of the workshop is to exchange experience in the field of development and creation of information systems, design and building information models, design of distributed databases remote access. The seminar is addressed to specialists, postgraduates and students of NSU. Seminars are held every week – see http://www.ict.nsc.ru/seminar/it/ (in Russian). The reports of leading specialists in the field of numerical stochastic modeling are presented.

Learning outcomes of the course

As the result of studying the course “Informational technologies”, student gets the new ideas about modern concepts and applications of the theory of informational technologies. He also gets examples of presentation of reports and articles on actual scientific topics, experience in scientific discussions, asking questions, etc.

Method of assessment

The grade of the course “Informational technologies” depends on student’s attendance and activity on the seminar. The excellent mark is guaranteed to those students who are invited to give a rigorous scientific report on the seminar.

M.2-V-10 Scientific seminar

“Informational and computational technologies”

Information about the authors:

Shokin Yuri Ivanovich

- Academician of Russian Academy of Sciences (RAS), Full Professor, Doctor of physical and mathematical sciences;
- Director of the Institute of Computational Technologies SB RAS; see http://www.ict.nsc.ru/sitepage.php?PageID=136 ;

Kovenya Viktor Mikhailovich

- full Professor, doctor of physical and mathematical sciences;
- Head of Chair of Mathematical modeling in DMM NSU; see http://www.ict.nsc.ru/matmod/;
- chief researcher in Institute of Computational Technologies SB RAS; see http://www.ict.nsc.ru.

Course description

In 1964 by academician N. Yanenko was held the first seminar at NSU. In those years it was called "Numerical methods in continuum mechanics". Nikolai Nikolaevich invited to the seminar all employees. Often spoke visitors. There are 2--3 lecturer happened two or more sessions per week, because no time to listen to all comers. It was considered an honorary give a seminar and get an assessment of Yanenko, she was always objective.

The range of reports was always famous for its breadth. The distinctive feature of this workshop is that it gives speak to anyone, regardless supporter of what school, what direction he is.

On the basis of the seminar appeared the circle of all-Union: "Numerical methods of mechanics of viscous fluid", "Models of continuum mechanics" and some other.

The seminar became an important scientific school for participants: here are Ph.D. and doctoral theses are graduates, post-graduate students. One of the traditions is the constant participation of students. The seminar was always the consortium: Institute plus the chair of mathematical modeling of NSU, and is now added and Department of computing technologies of Novosibirsk state technical University. Seminars are held every week – see http://www.ict.nsc.ru/seminar/ict/info.html, http://www-sbras.nsc.ru/HBC/1999/n39/f7.html (in Russian).

Learning outcomes of the course

As the result of studying the course “Informational and computational technologies”, student gets the new ideas about modern concepts and applications of the theory of informational and computational technologies. He also gets examples of presentation of reports and articles on actual scientific topics, experience in scientific discussions, asking questions, etc.

Method of assessment

The grade of the course “Informational and computational technologies” depends on student’s attendance and activity on the seminar. The excellent mark is guaranteed to those students who are invited to give a rigorous scientific report on the seminar.

M.3 SCIENTIFIC PRACTICE AND RESEARCH WORK

M.3-1 Scientific seminar “Preparation and presenting scientific two reports at scientific seminar “Informational and computational technologies in problems of decision-making support”

Information about the authors:

Shokin Yuri Ivanovich

- Academician of Russian Academy of Sciences (RAS), Full Professor, Doctor of physical and mathematical sciences;
- Director of the Institute of Computational Technologies SB RAS; see http://www.ict.nsc.ru/sitepage.php?PageID=136.

Fedoruk Mikhail Petrovich

- Full Professor, Doctor of physical and mathematical sciences;
- Rector of NSU; see http://www.nsu.ru/exp/en/university/governance;
- Head of Laboratory of computational technologies ICT SB RAS; see http://www.ict.nsc.ru/showpers.php?uid=33.

Chubarov Leonid Borisovich

- Full Professor, Doctor of physical and mathematical sciences;
- professor of MM DMM NSU; see http://www.ict.nsc.ru/matmod;
- Major researcher of Center for monitoring of socio-economic and environmental situation ICT SB RAS; see http://www.ict.nsc.ru/showpers.php?uid=49&showcv=y.

Course description

The scientific school of Academician Yu.I. Shokin (Novosibirsk scientific center, ICT SB RAS) continues the traditions of academician Nikolai Nikolaevich Yanenko. The main direction of research developed in the present scientific school of Academician Yu.I. Shokin, connected with the development of information and computing technologies for decision support in the design and operation of complex technical systems and facilities, environmental monitoring, prediction of consequences of disasters and catastrophes. Scientific-methodical seminar of the Institute of computational technologies SB RAS was founded in 2004 Workshop is designed to promote the establishment of young researchers, to promote youth involvement in the work on research projects and programmes for the control over fulfillment of plans of research works of students, graduate students, doctoral candidates. Seminars are held every week – see http://www.ict.nsc.ru/seminar/dp/info.html (in Russian). The reports of leading specialists, young researches and students in problems of decision-making support are presented.

Learning outcomes of the course

As the result of studying the course “Informational and computational technologies in problems of decision-making support”, student gets the new ideas about modern technologies. He also gets examples and train skills in presentation of scientific reports and articles on actual scientific topics, experience in scientific discussions, asking questions, etc.

Method of assessment

The seminar “Informational and computational technologies in problems of decision-making support” is obligatory speeches of the participants with messages about the contents of tasks and their results in order to develop the skills of presentation of the research results, participate in scientific discussions.

Student should make two presentations of his/her scientific researches. The first in the first year of educational should contain problem statement, chosen method of solution and some problem/method features. The second presentation in 3-4 semester should be based on master dissertation results. Also lectures of the leading scientists of the Department and the base of the Institute are there in the seminar.

M.3-2 Preparation and defending the term paper

Course description

The term paper represents printing scientific work which includes introduction sections of student's research work (main concepts, problem definition, plan of researches, etc.) description of the first student's scientific achievements (the proved statements, results of numerical experiments, etc.). The performance of the term paper is defined and is constantly inspected by the student's scientific supervisor.

Learning outcomes of the course

As the result of the course "Preparation and defending the term paper" the student receives initial skills in carrying out research and design of scientific reports and works.

Method of assessment

The defending the term paper is made by analogy with the same preliminary procedure for master dissertation (see the site http://mmf.nsu.ru/education/thesis [in Russian]). Meeting of special committee of the Chair of Mathematical Modeling DMM NSU is carried out. The grade depends on the quality of student's report and subsequent discussion on this report. The supervisor's review of the term work also plays the big role in evaluation of the paper.

M.3-3 Research work in a laboratory of ICT SB RAS

Course description

In frames of the course "Research work in a laboratory of ICT SB RAS" the research work in one of the laboratories of Institute of Computational Technologies (ICT) of Siberian branch (SB) of Russian Academy of Sciences (RAS) is provided. As a rule, the concrete laboratory is defined by working place of the student's supervisor.

The course includes ongoing consultations with student's supervisor and other experts of Chair of Mathematical modeling, realization of numerical experiments (including calculations on equipment of the Information-computing center NSU (see the site http://www.nusc.ru/), participation in scientific seminars and conferences, visits to scientific libraries and specialized classes of ICT and other institutes SB RAS (Khristianovich Institute of Theoretical and Applied Mechanics, see http://www.itam.nsc.ru/en/, Lavrentyev Institute of Hydrodynamics, see http://www.hydro.nsc.ru/, Institute of thermal physics SB RAS – see http://www.itp.nsc.ru/, etc.).

There are also example of student's research work in frames of some scientific projects (in the case, this work is paid).

Learning outcomes of the course

As the result of the course "Research work in a laboratory of ICT SB RAS" the student receives initial skills in carrying out actual theoretical research and numerical experiments (including using of modern computer techniques).

Method of assessment

The gradation for the course "Research work in a laboratory of ICT SB RAS" is defined by the student's scientific supervisor. He must declare the corresponding requirements at the beginning of every training semester.

M.3-4 Reports at scientific conferences

Course description

Every year the International student scientific conference "Students and the Progress in Science and Technologies" takes place in NSU (see the site http://issc.nsu.ru/index.php?lang=1), where students and young scientists can deliver talks on their researches and get acquainted with the results of their colleagues. The Chair of Mathematical Modeling DMM NRU NSU organizes the sections "Mathematical Modeling" on this conference. As a rule, the students, who specialized in mathematical modeling, participate these sections and make scientific reports.

The most interesting reports are marked with diplomas and prizes. These student's achievements are taken into account in assessment procedures of courses M.3-2 "Preparation and defending the term paper" and M.4-2 "Preparation and defending the master dissertation" of the MEP "Mathematical and Computer Modeling in Mechanics".

The best student's works in the field of mathematical modeling of complex physical processes in solids, fluids, gases and plasma are also recommended for presentation on the annual Conference of young researchers of ICT SB RAS. There are also examples of student's reports on other scientific forums (as a rule, these reports are made in collaboration with the student's scientific supervisor).

In exceptional cases, the course "Reports at scientific conferences" can be replaced by one of the courses of the section M.2-V "Variable part (courses at the choice of the student" of the part M.2 "Professional cycle" of the MEP "Mathematical and Computer Modeling in Mechanics".

Learning outcomes of the course

As the result of the course "Reports at scientific conferences" the student receives initial skills in preparation and carrying out scientific reports, conducting scientific debates, asking questions, etc.

Method of assessment

The gradation for the course "Reports at scientific conferences" is defined by the student's scientific supervisor. The opinions of chairmen of corresponding scientific meetings are also taken into account.

M.3-5 Development of the master dissertation

Course description

As a rule, dissertation work is the continuation of research work related with the term paper (see above the presentation of the course M.3-2 "Preparation and defending the term paper"). In development of the master dissertation, the student's achievements in research (see above the presentation of the course M.3-3 "Research work in a laboratory of ICT SB RAS") and presentation of corresponding results (see above the presentation of the course M.3-4 "Reports at scientific conferences") are used. The course M.3-5 "Development of the master dissertation" is realized in the third and fourth semesters of the MEP "Mathematical and Computer Modeling in Mechanics" (the second year of training).

Learning outcomes of the course

As the result of the course "Development of the master dissertation" the student receives initial skills in carrying out research and design of sections of scientific reports and printed works.

Method of assessment

The gradation for the course "Development of the master dissertation" is defined by the student's scientific supervisor. He must declare the corresponding requirements at the beginning of every training semester.

M.4 FINAL STATE CERTIFICATION

M.4-1 Passing the state exam

Course description

The realization of the course M.4-1 “Passing the state exam” is realized with respect to common rules of the master state exam on DMM NRU NSU (see the site http://mmf.nsu.ru/education/state-exams [in Russian]). Questions and tasks for the state exam are prepared by the lecturers of the obligatory courses of the first three semesters of the MEP “Mathematical and Computer Modeling in Mechanics”. These courses are:

M.1-B-2 Physics

M.2-B-1 Numerical methods of simulation and optimization in mechanics

M.2-B-2 Additional chapters of numerical methods

M.2-B-3 Methods of discrete simulation

The preliminary list of exam committee is: Prof. V.M. Kovenya, Prof. Yu.N. Grigoriev, Prof. G.S. Khakimzyanov, Prof. S.G. Cherny, Prof. V.P. Shapeev, Dr. G.G. Lazareva, Dr. V.N. Lapin.

The style of possible questions and tasks is reflected on the site http://mmf.nsu.ru/education/state-exams [in Russian].

The master state exam is carried out at the second Sunday of Fabruary (the beginning if the fourth semester of the MEP “Mathematical and Computer Modeling in Mechanics”). The week before, the short intensive training course on preparation to the state exam is carried out.

Learning outcomes of the course

As the result of the course “Passing the state exam”, the students demonstrate knowledge and slills on the main courses of the first training year of the MEP “Mathematical and Computer Modeling in Mechanics”.

Method of assessment

The gradation for the course “Passing the state exam” is defined by exam committee and announced at the end of preparation course at the beginning of the fourth semester of the MEP “Mathematical and Computer Modeling in Mechanics”.

M.4-2 Preparation and defending the master dissertation

Course description

The master dissertation represents printing scientific work which includes detailed review on student’s research work (see the site http://mmf.nsu.ru/education/thesis [in Russian]). The performance of the master dissertation is defined and is constantly inspected by the student’s scientific supervisor.

Learning outcomes of the course

As the result of the course “Preparation and defending the master dissertation” the student receives skills in development of final reviews on volume scientific projects and defending this review in the face of expert commitees.

Method of assessment

The procedure for defending the master dissertation is the following (see the site http://mmf.nsu.ru/education/thesis [in Russian]). The “pre-defending” is realized on the meeting of special committee of the Chair of Mathematical Modeling DMM NSU: the recommended grade and the name of the reviewer are defined.

The final defending the master dissertation is carried out on the meeting State Validation Committee.

The grade depends on corresponding marks given by the “pre-defending” committee and the reviewer, and also by the quality of student's report and subsequent discussion on this report. The supervisor's review of the term work also plays the specific role in evaluation of the dissertation.

APPENDIX 1. List of competencies of the graduates of the MEP

(according to the SMS for training direction 010800 –

"Mechanics and mathematical modeling";

see the site http://www.edu.ru/db/mo/Data/d_09/prm771-1.pdf [in Russian]**)**

General cultural competences (GCC)

GCC-1 ability to work in multidisciplinary team
GCC-2 ability to interact with others fields specialists
GCC-3 ability to active social mobility and work in international environment
GCC-4 ability to use advanced knowledge of rules of law and ethical standards in the evaluation of own professional activities, and also in the development and implementation of social projects.
GCC-5: ability generate new ideas
GCC-6 ability to work independently with quality and result motivation
GCC-7 ability to organize researches, to lead scientific groups
GCC-8 ability to demonstrate initiative
GCC-9: ability to organizing and planning
GCC-10 ability to analyze the information including that is concern with new fields of knowledge

Professional competences (PC)

Scientific and research activities
PC-1: be master of mathematical modeling to analyze global problems using knowledge in fundamental mathematic disciplines and computer science
PC-2: be master of mathematical modeling to analyze problems in technics and natural science
PC-3: ability to intensive scientific and research activities
PC-4: ability to develop and analyze new models of real bodies and constructions
PC-5: to understand the theory of experiment
PC-6: ability to determine basic parameters of real bodies and materials models from experimental data
PC-7: ability to independent analysis of physical aspects in classical statements of mathematical and mechanical problems
PC-8: to understand modern algorithms of computational mathematics to be able to develop and evolve theory of mathematics and physical and mathematical models.
Project, industrial and technological activities
PC-9: be familiar with modern algorithms of computational mathematics, be able to develop and improve mathematical theory and physical-mathematical models that it based on
PC-10: ability to independent view on applicability of mathematical formulations
PC-11: ability to apply implement and develop complex mathematic algorithms in modern program complexes
Organizational and management activities

PC-12: ability to determine general forms, laws and instruments for disciplines groups

PC-13: ability to construct main picture of discipline independently

PC-14: be master of mathematical modeling to analyze global problems using knowledge in fundamental mathematic disciplines and computer science

PC-15: ability to adapt and present mathematical knowledge taking in to account auditory level

PC-16: ability to lead and management of scientific work of the team

PC-17: be able to formulate in problem-task form non mathematical types of knowledge (including humanitarian ones)

Educational activities

PC-18: ability to carry out physical and mathematical subjects in secondary, professional and high schools using fundamental education

PC-19: ability to obtain actual scientific information form electronic libraries and journals.