**Syllabus**
Course Program

# Modeling of Liquid and Gas Flow

Specialty
113 – Applied Mathematics

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer and mathematical modeling

Department
Mathematical Modeling and Intelligent Computing in engineering (161)

Level of education
Master's level (1 year 4 months)

Course type
Special (professional), Elective

Semester
2

Language of instruction
English

## Lecturers and course developers


**Lyudmyla ROZOVA (lecturer and practical lessons)**

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More about the lecturer on the department's website



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## General information

### Summary


The discipline is aimed at studying the basic laws of fluid and gas mechanics and the features of modeling the flow of liquid and gas using modern multi-purpose software systems for design and analysis in order to solve computational and research problems in future professional activities. The discipline is presented in the 2nd semester and provides: 32 hours of lectures, 16 hours of laboratory classes, 72 hours of independent work.


### Course objectives and goals

The purpose of the discipline is to obtain knowledge on the basic laws of fluid and gas mechanics, modern methods, approaches and understanding in the flow of liquid and gas modeling, skills and abilities to apply them in solving practical problems of a computational and research nature. The goals of teaching the discipline are to provide students with in-depth knowledge about the features of using software for flow modeling, specifying the necessary input data, constructing a mesh, selecting a solver, interpreting calculation results and their further use. The acquisition of skills and abilities to apply the received knowledge occurs by solving practical problems in flow modeling to study the main characteristics of liquid and gas flow by the use of ANSYS software package, its interactive platform ANSYS Workbench and a special module for flow modeling ANSYS Fluent. in their realization in the student version in free access.

### Format of classes

Lectures, laboratory classes, independent work. Final control in the form of credit.

### Competencies

PC1. Ability to solve tasks and problems that can be formalised, require updating and integrating knowledge, in particular in conditions of incomplete information.
PC3. Ability to develop methods and algorithms for the construction, research and software implementation of mathematical models in engineering, physics, biology, medicine and other fields and to analyse them.
PC4. Ability to develop and research mathematical and computer models, conduct computational experiments and solve formalised problems using specialised software.
PC9. The ability to mathematically formalise the formulation of scientific and practical problems, to choose a mathematical analytical or numerical method of its solution, which ensures the required accuracy and reliability of the result.
PC10. Ability to develop mathematical methods and algorithms for computer modelling of nonlinear physical phenomena and processes in innovative technological systems.

### Learning outcomes

LO4. Build mathematical models of complex systems and choose methods of their research, implement the built models in software and check their adequacy using computer technologies.
LO14. To have the knowledge to mathematically formalise the formulation of scientific and practical problems, to choose a mathematical analytical or numerical method of its solution, which ensures the required accuracy and reliability of the result.
LO16. Be able to develop mathematical methods and algorithms for computer modelling of nonlinear physical phenomena and processes in innovative technological systems

### Student workload

The total volume of the course is 120 hours (4 ECTS credits): lectures - 32 hours, laboratory classes - 16 hours, self-study - 72 hours.

### Course prerequisites

Methods of mathematical modeling and data analysis, Modeling in CAE systems, Nonlinear processes and models.

### Features of the course, teaching and learning methods, and technologies

Classes are provided interactively using multimedia technologies. To master practical skills, the following software components are used: ANSYS software package, its interactive platform ANSYS Workbench and a special module for flows modeling ANSYS Fluent, in their realization in the student version in free access.

## Program of the course

### Topics of the lectures

Topic 1. Introduction to fluid and gas mechanics. Basic physical properties and parameters of the liquid

The concept of density, compressibility, viscosity of a liquid. Forces acting on a fluid. Basic equations of hydrostatics.

Topic 2. Fundamentals of fluid kinematics.

Stable and unstable movement of fluid. Current line and current tubes. Fluid velocity vector. Vortex and irrotational motion. Fundamental theorem of kinematics. Strain rate tensor.

Topic 3. Equation of motion of liquid and gas.

Equation of continuity and state. System of equations of motion of a viscous incompressible fluid. Stokes equation. Limit conditions. Heat transfer. Conduction. Convective heat transfer. Forced convection. Total amount of heat. Law of energy conservation.

Topic 4. Equation of motion of ideal and non-ideal fluid.

Tension in an ideal fluid. Euler's equation of motion of an ideal fluid. Hydrodynamics of a viscous fluid. Viscous fluid model. Hypothesis of linearity, homogeneity, isotropy. Equation of motion of a viscous fluid. Navier-Stokes equation.

Topic 5. Classification of water flows.

Laminar flow. Laminar flow in round pipes. Turbulent flow. General information. Turbulence models. Introduction to the finite volume method for modeling liquid and gas flow.

Topic 6. Introduction to modeling in the ANSYS Workbench software package.

Basic approaches and features. Graphical user interface (GUI) ANSYS Workbench. ANSYS Workbench Modules. Approaches for constructing model geometry.

Topic 7. Setting material properties.

Using existing ANSYS material libraries. Materials database. Material properties specified by the user. Properties of materials, depending on the physical model. Features of setting the properties of materials as functions of temperature, mass fraction, pressure.

Topic 8. An introduction to fluid and gas flow modeling in ANSYS Fluent.

Features of modeling liquid and gas flow. Transport equation for liquid. Introduction to the finite volume method for modeling liquid and gas flow. ANSYS Fluent graphical user interface (GUI).

Topic 9. The steps of modeling in ANSYS Fluent.

Basic stages of modeling in ANSYS Fluent. Selecting the modeling area. 2D or 3D modeling approach. Features of creating flow geometry. Creating a mesh. Selecting an element type. Features. Setting material properties.

Topic 10. The steps of modeling in ANSYS Fluent. Continuation

Selection of a physical flow model. Setting initial and boundary conditions, operating conditions for the flow. Specifying the decoupler type and convergence accuracy for calculation. Studying of the obtained results (post-processing). Conclusions from the calculations.

Topic 11. Creation of a mesh of finite volumes.

Meshing. Creation of Cell zones. Fluid cell zones, solid cell zones. Creating boundary zones.

Topic 12. Setting boundary and operating conditions for the flow.

Types of boundary conditions. Internal and external boundary conditions. Selection of boundary conditions zone. Flow input and output. Changing boundary conditions. Setting the boundary layer. Conditions of symmetry. Features of setting operating pressure and flow speed.

Topic 13. ANSYS Fluent Solvers.

Pressure-based solver. Density-based solver. Selection and features. Algorithms used in the solvers. Calculation convergence. Acceleration of convergence.

Topic 14. Flow turbulence.

Features of specifying turbulence in a flow model. Turbulence models, used in ANSYS Fluent.

Topic 15. Postprocessing in ANSYS Fluent.

Possibility of presenting analysis results. Type of results. Isosurfaces, isolines, vectors of quantities. Creating a flow animation. Obtaining results for user-defined quantities. Create a report.

Topic 16. Postprocessing. Review the course.

Setting up graphical display of results, cutting plane, diagrams. Further application and processing of calculation results. Conclusions about the course.

## Topics of the laboratory classes

Topic 1. Laboratory work 1.

Simulation of 2D laminar flow in a pipe.

Topic 2. Laboratory work 2.

Simulation of 3D laminar flow in a pipe.
Topic 3. Laboratory work 3.
Simulation of flow in a sinusoidal pipe.
Topic 4. Laboratory work 4.
Simulation of turbulent flow in a pipe.
Topic 5. Laboratory work 5.
Bridge Flow Analysis.
Topic 6. Laboratory work 6.
Modeling the flow around a wing 2D.
Topic 7. Laboratory work 7.
Modeling the flow around a wing 3D. P.1.
Topic 8. Laboratory work 8.
Modeling the flow around a wing 3D. P.2.

### Self-study

Processing of lecture material. Preparation for laboratory classes. Independent study of topics and questions not covered in lecture classes. Performing individual tasks for laboratory work.

## Course materials and recommended reading


1. Lee H.H. Finite Element Simulations with ANSYS Workbench 2021.-SDC Publications, 2021. (https://www.sdcpublications.com/Textbooks/Finite-Element-Simulations-ANSYS-Workbench/ISBN/978-1-63057-456-7/)
2. Currie, I.G. Fundamental mechanics of fluids / I.G. Currie. –New York ; Basel: Marcel Dekker, Inc., 2003. – 525 p.
3. Shaughnessy, Edward J., Jr. Introduction to fluid mechanics / Edward J. Shaughnessy, Jr., Ira M. Katz, James P. Schaffer. – New York ; Oxford: Oxford University Press, 2005. 1018 p.
4. Rajput R.K. A Textbook of Heat and Mass Transfer. - S Chand Publishing, 2015. 771 p.
5. Ansys Student - Free Software Download. ANSYS, Inc., 2023.
URL: https://www.ansys.com/academic/students


## Assessment and grading

### Criteria for assessment of student performance, and the final score structure

Points for the test are added according to the rating:
Completing laboratory works – 80 points
Theoretical survey – 20 points

### Grading scale

| Total points | National | ECTS |
|---|---|---|
| 90–100 | Excellent | A |
| 82–89 | Good | B |
| 75–81 | Good | C |
| 64–74 | Satisfactory | D |
| 60–63 | Satisfactory | E |
| 35–59 | Unsatisfactory (requires additional learning) | FX |
| 1–34 | Unsatisfactory (requires repetition of the course) | F |

## Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.

Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU "KhPI" are available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

## Approval

| Approved by | Date<br>August 30, 2023 | Head of the department<br>Oleksiy VODKA |
| --- | --- | --- |
| | Date<br>August 30, 2023 | Guarantor of the educational and professional program (1 year 4 months)<br>Oleksiy LARIN |