National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Department of space engineering

NAME OF THE COURSE

Hydrogasdynamics and thermodynamics

Working program of the academic discipline (Syllabus)

Details of the academic discipline

Level of higher education	***First (undergraduate)***
Branch of knowledge	*13 Mechanical engineering*
Specialty	*134 Aviation and rocket and space technology*
Educational program	*Engineering of aviation and rocket-space systems*
Discipline status	*Normative*
Form of education	*Ochna (daytime)*
Year of training, semester	*2nd year, autumn semester*
Scope of the discipline	*6.5 ECTS credits, 195 hours (lectures – 54 hours, practical classes – 18 hours, laboratory – 18 hours, independent work – 105 hours)*
Semester control/ control measures	*Exam*
Lessons schedule	*The schedule presents lectures according to the curriculum - 3 hours, 1 hour. practical classes, 1 hour laboratory: http://rozklad.kpi.ua*
Language of teaching	*Ukrainian*
Information about head of the course / teachers	*Lecturer: candidate of technical sciences, senior researcher, Oleksandr Petrovych Lobunko, tel. +380675957591, e-mail: Lobunko_IAT@ukr.net* *Practical training: candidate of technical sciences, senior researcher, Oleksandr Petrovych Lobunko, tel. +380675957591, e-mail: Lobunko_IAT@ukr.net*
Placement of the course	*A link to a remote resource (Moodl, Google classroom)*

Program of educational discipline

1. Description of the educational discipline, its purpose, subject of study and learning outcomes

Determination and research of the spatial change of the flow parameters in different operational and structural conditions is one of the key components of the justification of the external forms of aircraft, profiling of the internal components of engines, system units. Calculation of frictional resistance, velocity and temperature fields, construction of the flow pattern around structural elements, clarification of the force and thermal interaction of the working body and component parts of aircraft, and many other tasks are solved using the relevant theoretical provisions, mathematical and scientific-methodological apparatus.

This requires specialists to have in-depth knowledge of disciplines focused on the problems of improving the conditions of interaction of aerospace objects with a moving liquid environment, the parameters of which are changing. One of these disciplines is "Hydrogasdynamics and Thermodynamics". It provides basic knowledge in the field of laws of movement and equilibrium of gas flow and liquids, energy transformation into various forms. The study of the discipline is necessary to understand and calculate the characteristics of the processes occurring in the elements of aircraft and their power plants, to visualize the results of modeling flow parameters, to analyze the perfection of the design, to determine and control the thermal state of stressed parts of aerospace structures.

The purpose of studying the academic discipline "Hydrogasdynamics and Thermodynamics" is the formation of students' basic theoretical knowledge regarding the understanding of principles and regularities of fluid and gas mechanics, features of energy conversion, working and thermal processes in aviation and rocket and space technology systems.

The subject of the discipline is hydrodynamic, gas-dynamic, thermodynamic, thermal processes in aviation and rocket-space engineering.

As a result of training, students of higher education acquire knowledge and practical skills regarding the principles of fluid and gas mechanics, peculiarities of work processes in functional systems of aviation and rocket and space technology.

2. Pre-requisites and post-requisites of the discipline (place in the structural and logical scheme of training according to the relevant educational program)

Prerequisites for the discipline "Hydrogasdynamics and Thermodynamics" are the disciplines of bachelor's training "Higher Mathematics", "Physics", "Chemistry".

Postrequisites of the discipline "Hydrogasdynamics and Thermodynamics" are the disciplines "Design of energy installations of rockets and spacecraft", "Aerodynamics of aircraft", "Design of aircraft", "Dynamics of flight".

3. Content of the academic discipline

The theoretical course of the discipline consists of 54 academic hours and includes the following sections and topics:

CHAPTER 1. Hydrogas dynamics.

Topic 1.1. Physical properties and models of liquids and gases.
Topic 1.2. Dynamics of liquids and gases.
Topic 1.3. Basic laws of fluid movement.
Topic 1.4. One-dimensional gas movement.
Topic 1.5. Two- and three-dimensional fluid movement.
Topic 1.6. Features of compressible fluid flow.
Topic 1.7. Flat to and supersonic gas flow with small disturbances.
Topic 1.8. Characteristics method for two-dimensional supersonic flow.
Topic 1.9. Compression jumps in the gas flow.
Topic 1.10. Boundary layer.
Topic 1.11. Current in the elements of power plants.

CHAPTER 2. Thermodynamics and heat exchange.

Topic 2.1. Thermodynamic system and its characteristics.
Topic 2.2. Basic laws of thermodynamics.
Topic 2.3. Thermodynamic processes in elements of power plants and systems.
Topic 2.4. Thermodynamic analysis of engines.
Topic 2.5. Theory of heat exchange, thermal conductivity.
Topic 2.6. Convective heat exchange.
Topic 2.7. Heat exchange by radiation.
Topic 2.8. Heat transfer through walls, thermal protection methods.
Topic 2.9. Unsteady heat exchange.

4. Educational materials and resources

Basic literature:

1. Turyk V.M. Basics of gas dynamics. - K.: NTUU KPI named after Igor Sikorskyi, 2022. – 139 p.

2. Khalatov A.A., Gilchuk A.V., Kohtych L.M. Thermodynamics of gas flow. - K.: NTUU KPI named after Igor Sikorskyi, 2019. – 219 p.

3. Boyko A.V. Hydrogas dynamics. - Kh.: NTU KhPI, 2008. - 444 p.

4. Theory of thermal conductivity / A.V. Gilchuk, A.A. Khalatov, T.V. Donyk. KPI named after Igor Sikorsky. –Kyiv: KPI named after Igor Sikorskyi, 2020. – 153 p.

Additional literature:

1. Calculation of the cooling system of the nozzle of a liquid rocket engine: methodical recommendations for course work / comp.: A.A. Khalatov, N.A. Panchenko, A.Zh. Meiris. - To: NTUU "KPI", 2016. - 34 p.

2. Basics of convective heat transfer: method. instructions for practice. classes / N.A. Panchenko, A.A. Khalatov - To: NTUU "KPI named after Igor Sikorsky", 2017. - 32 p.

3. Methodological instructions for coursework from the credit module "Heat and mass transfer - 2". O. V. Semenyako, E. V. Novakivskyi - K.: "KPI named after Igor Sikorsky", 2017. - 31 p.

4. Turyk V.M. Hydrogas dynamics. - K.: NTUU KPI named after Igor Sikorskyi, 2021. – 145 p.

5. Rusanov A.V., Solovei V.V., Zipunnikov M.M., Shevchenko A.A. Thermogas dynamics of physical and energy processes in alternative technologies in 3 volumes - Kh.: Technological Center, 2018. - 336 p.

6. Fundamentals of gas dynamics. M.E.H. van Dongen, A. Hirschberg, D.M.J. Smeulders. 2015. – 123 p.

7. Kolchunov V.I. Theoretical and applied hydromechanics. - K.: NAU, 2004. - 336 p.

8. Turyk V.M. Hydrogas dynamics. Practicum - K.: NTUU KPI named after Igor Sikorskyi, 2021. – 38 p.

Electronic resources:

1. http://kpi.ua.
2. http://iat.kpi.ua.
3. http://www.nkau.gov.ua.
4. http://www.nasa.gov.
5. http://www.esa.int.

Mandatory reading are the sections from the listed basic and additional literature that thematically correspond to the lecture material.

Educational content

5. 5. Methods of mastering an educational discipline (educational component)

The discipline is designed for one semester. The lecture load of the discipline "Hydrogasdynamics and Thermodynamics" consists of lectures - 54 ac. hours, practical classes - 18 ac. hours, laboratory work - 18 ac. hours Auditory classes are evenly distributed throughout the semester, which allows students of higher education to systematically organize and plan their work.

The theoretical part consists of 2 logically connected sections: 1 – Hydrogas dynamics (topics 1.1-1.11); 2 – Thermodynamics and heat exchange (topics 2.1-2.9).

The purpose of lectures on the discipline "Hydrogasdynamics and Thermodynamics" is to obtain theoretical knowledge about hydrodynamic, gasdynamic, thermodynamic, thermal processes and the conditions of interaction of aerospace objects with a moving gas and liquid medium. Approximate topics of lectures:

CHAPTER 1. HYDROGAS DYNAMICS

Lecture 1: Introduction. Physical properties and models of liquids and gases (topic 1.1).
Lecture 2: Dynamics of liquids and gases (topic 1.2).
Lecture 3: Basic laws of fluid movement (topic 1.3).
Lecture 4: One-dimensional movement of gas (topic 1.4).
Lecture 5: Fundamentals of physical flow modeling (topic 1.4).
Lecture 6: Two- and three-dimensional fluid movement (topic 1.5).
Lecture 7: Basics of the theory of vortices (topic 1.5).
Lecture 8: Method of conformal transformation (topic 1.5).
Lecture 9: Features of compressible fluid flow (topic 1.6).
Lecture 10: Flat to and supersonic gas flow with small disturbances (topic 1.7).
Lecture 11: Method of characteristics for two-dimensional supersonic flow (topic 1.8).

Lecture 12: Compression jumps in a gas flow (topic 1.9).
Lecture 13: Boundary layer (topic 1.10).
Lecture 14: Flow in the elements of power plants (topic 1.11).

CHAPTER 2. Thermodynamics and heat exchange

Lecture 15: Concept of thermodynamic system, its varieties, characteristics (topic 2.1).
Lecture 16: Essence, formulation, application of the first law of thermodynamics (topic 2.2).
Lecture 17: Essence, formulation, application of the second law of thermodynamics (topic 2.2).
Lecture 18: Entropy of thermodynamic systems (topic 2.2).
Lecture 19: Thermodynamic processes in elements of power plants (topic 2.3).
Lecture 20: Thermodynamic cycles of heat engines (topic 2.3).
Lecture 21: Thermodynamic analysis of engines (topic 2.4).
Lecture 22. Basic provisions of the theory of heat transfer, thermal conductivity (topic 2.5).
Lecture 23: Convective heat transfer (topic 2.6).
Lecture 24: Radiation heat transfer (topic 2.7)
Lecture 25: Heat transfer through walls, thermal protection methods (topic 2.8).
Lecture 26: Heat exchangers (topic 2.8).
Lecture 27: Unsteady heat transfer (topic 2.9).

Tasks of practical classes and laboratory work are performed using basic and additional literature, relevant electronic resources, lecture materials, modern software tools for numerical modeling (laboratory work 2-9) of work processes and the state of elements and are oriented towards independent understanding. The performance of the tasks of practical classes and laboratory works is preceded by theoretical preparation and control of knowledge. Approximate topics of practical classes:

practical session 1. Methods of measuring parameters and characteristics of liquids and gases (topic 1.1);

practical session 2. Solving problems using the basic laws and equations of hydrogas dynamics (topic 1.2, 1.3);

practical lesson 3. Calculations of flow parameters when flowing around bodies, application of the lifting force formula (topic 1.4, 1.5);

practical lesson 4. Calculations of boundary layer parameters (topic 1.6-10);

practical session 5. Study of flow and thermal effects on flow parameters, determination of Laval nozzle parameters (topic 1.7-1.11);

practical lesson 6. Calculations of parameters of working thermodynamic processes in elements of power plants of aircraft (topic 2.1, 2.2);

practical session 7. Thermodynamic analysis of aircraft engine sample parameters (topic 2.3, 2.4);

practical session 8. Calculation of heat transfer when moving gas at high speed and during free convection (topic 2.5, 2.6);

practical lesson 9. Solving problems related to heat transfer through single-layer and multi-layer flat and cylindrical walls (topic 2.7, 2.8).

Approximate topics of laboratory works:

laboratory work 1. Study of methods of measuring the main parameters and characteristics of liquids and gases;

laboratory work 2. Mastering the method of creating a project for numerical modeling of laminar flow parameters of viscous liquid and gas;

laboratory work 3. Mastering the technique of creating a sketch (building a grid, specifying grid nodes) for numerical modeling of laminar flow parameters of viscous liquid and gas;

laboratory work 4. Mastering the method of setting initial data, boundary conditions and numerical modeling of laminar flow parameters of viscous liquid and gas;

laboratory work 5. Mastering the method of processing the results of numerical modeling of parameters of laminar flow of viscous liquid and gas;

laboratory work 6. Mastering the method of creating a project and a sketch for numerical modeling of the parameters of the turbulent flow of a viscous incompressible liquid;

laboratory work 7. Mastering the methodology of setting initial data, boundary conditions, conducting numerical modeling of turbulent flow parameters of a viscous incompressible fluid, processing results;

laboratory work 8. Mastering the methodology of numerical modeling of the development of a compressible supersonic flow of gas with an oblique compression jump;

laboratory work 9. Mastering the methodology of numerical modeling of thermal processes in elements of aerospace systems.

The calendar plan for the organization of the educational process is presented in Table 1.

Table 1.

№ Week	№ Lectures	№ Practice session	№ Laboratory work
1	Lecture 1, 2	Practice session 1	
2	Lecture 3		laboratory work 1
3	Lecture 4, 5	Practice session 2	
4	Lecture 6		laboratory work 2
5	Lecture 7, 8	Practice session 3	
6	Lecture 9		laboratory work 3
7	Lecture 10, 11	Practice session 4	
8	Lecture 12		laboratory work 4
9	Lecture 13, 14	Practice session 5	
10	Lecture 15		laboratory work 5
11	Lecture 16, 17	Practice session 6	
12	Lecture 18		laboratory work 6
13	Lecture 19, 20	Practice session 7	
14	Lecture 21		laboratory work 7
15	Lecture 22, 23	Practice session 8	
16	Lecture 24		laboratory work 8
17	Lecture 25, 26	Practice session 9	
18	Lecture 27		laboratory work 9

6. Independent work of the student

The volume of independent work during the semester is 105 credits. hours The approximate structure of independent work is as follows.

Preparation for lectures (15 academic hours).

Preparation and implementation of tasks of practical classes (15 academic hours).

Preparation and performance of laboratory tasks (25 ac. hours).

Performance of control work (25 acc. hours).

Preparation for the exam (25 credit hours).

Policy and control

7. Policy of academic discipline (educational component)

Attending lectures and practical classes is mandatory and is carried out according to the approved schedule or according to the individual plan of the student of higher education. In case of missing lectures, the student works on its electronic version and explains the main provisions in a short essay. Missed practical classes are made up at the end of the semester according to a separate approved schedule.

Mobile phones must be switched off during classroom sessions. Complex moments of the topics presented at the lectures can be entrusted to the students of higher education to prepare short reports for discussions in order to increase the activity of the listeners.

Assignments of practical classes are issued to each student individually, defended at the next scheduled practical class. Tasks are drawn up in the form of reports.

The test is issued at the beginning of the semester individually to each individual and is defended in the form of a written work containing calculations and the necessary graphic material (drawings, graphs, etc.) individually according to a separate schedule.

In practical classes, educational materials of the relevant subject are demonstrated, including those prepared with the participation of students of higher education and with their support and comments.

Issues that are debatable or can be resolved by various methods, methods, and technologies are subject to discussion at practical classes. Each of the options for solving the problem is prepared by the relevant speaker, and the best option is determined in the process of group discussion.

The following rules of incentive and penalty points are used.

5 points are awarded for participation in the olympiad in the discipline, 5 points are awarded for the work on improving the didactic material in the discipline, 3 points are awarded for the preparation and support of the educational video. 3 points are awarded for the preparation of a mini report on a variable and discussion question, for a creative approach to work, active participation in the discussion of topics, independent search for topics: +1...4 points.

2 points will be deducted for absence from a practical session without valid reasons. In case of detection of plagiarism during the performance of the control work, or non-independent performance of tasks of practical classes, their results are annulled.

8. Types of control and rating system for evaluating learning outcomes

The student's rating in the discipline consists of the points he receives for the following:

- performance of tasks and answers in practical classes;
- performance of control work;
- exam answers.

System of rating (weighted) points and evaluation criteria.

1. Practical classes.

Weight score – 2.

The maximum number of points is equal to 2 points x 16 = 32 points.

Evaluation criteria:

complete completion of the task – 2;

performance, but theoretical knowledge is insufficient – 1;

not prepared – 0.

2. Control work.

Weight score – 12.

The maximum number of points is equal to 12 points x 1 = 12 points.

Evaluation criteria:

complete completion of the task – 12;

incomplete completion of the task – 5...11;

unsatisfactory performance – 0.

Penalty and incentive points:

creative approach to work, active participation in discussion of topics, search for topics: +1...4 points;

absence from a practical session without a valid reason: – 2 points.

The maximum number of incentive and penalty points is 4.

Calculation of the rating scale (R):

the sum of weighted points of control measures during the semester is:

RC = 32 + 12 = 44 points.

A necessary condition for admission to the exam is the timely completion of the tasks of all practical classes, the Control work and the provision of relevant reporting materials to the teacher

3. Examination.

The credit component of the scale is equal to 56% of R, namely 56 points, and consists of a theoretical part containing two questions on different topics.

For each question, subject to fluency in the material, answers to all additional questions – 28 points;

fairly confident mastery of the material, incomplete answers to additional questions – 20 points;

uncertain answer to the main question, no answer to additional questions – 10 points;

does not have an answer to the main question – 0 points.

Thus, the rating scale of the discipline is:

R = RS + RE = 44 + 56 = 100 points.

Conditions for a positive intermediate certification in the semester.

In order to receive "credited" from the first intermediate certification (8th week), the student will have at least 12 points (provided that at the beginning of the 8th week, according to the control activities calendar, the "ideal" student must receive 20 points).

In order to receive "credited" from the second intermediate certification (week 14), the student will have at least 24 points (provided that at the beginning of week 14, according to the calendar of control activities, the "ideal" student must receive 40 points).

Table of correspondence of rating points to grades on the university scale:

Scores	Rating
100-95	Perfectly
94-85	Very good
84-75	Fine
74-65	Satisfactorily
64-60	Enough
Less 60	Unsatisfactorily
Admission conditions not met	Not allowed

9. Additional information on the discipline (educational component)

The questions for the semester control (examination) are:

1. The essence and characteristics of the movement of a continuous medium.
2. Methods of studying the movement of a continuous medium.
3. Explanation of the concepts tube, trickle, flow intensity.
4. The essence of the universal law of conservation of substance (mass, momentum, energy).
5. One-dimensional equations of gas dynamics.
6. Gasodynamic functions of temperature, pressure, density.
7. Models of the formation of a direct jump of compaction and a shock wave.
8. Explanation of the equation and the law of inverse influence.
9. Features of possible effects on gas flow.
10. Description of the model of vortex-free motion of an ideal incompressible fluid.
11. Method of conformal mappings and its application.
12. Formula M.E. Zhukovsky for lifting power.
13. Features of the description of planar potential gas flows.
14. Description of the finite disturbance model in supersonic flows.
15. Laminar, turbulent and mixed boundary layer on a flat wall.
16. Concept of thermodynamic system, its varieties.
17. The essence and formulation of the first law of thermodynamics.
18. The essence and formulation of the second law of thermodynamics.
19. Models of isoparametric processes;

20. Processes in elements of energy installations.
21. Analysis of thermodynamic processes of heat engines.
22. Basic concepts and laws of heat transfer.
23. Stationary and non-stationary thermal conductivity.
24. Natural and forced convection.
25. Physical similarity of heat exchange objects.
26. Methods of describing radiant heat transfer.
27. Complex heat exchange.

The discipline "Hydrogasdynamics and thermodynamics" is constantly updated and improved. The modern stage is characterized by the possibility of active creative influence of developers on the further development of the discipline, appropriate educational and methodical material, scientific and experimental base. Such conditions provide for the use of modern scientific achievements, works, dissertations, monographs and other new sources of information for mastering the discipline, and not only the proposed literature and electronic information resources.

Working program of the academic discipline (syllabus):

Compiled by the associate professor of the Department of Space Engineering, candidate of technical sciences, senior researcher Lobunko Oleksandr Petrovych

Adopted by the Department of Space Engineering (protocol № 15 07.06.2023).

Agreed by the Methodical Commission of the Educational and Scientific Institute of Aerospace Technologies (protocol № 6 22.06.2023).