Ministry of Science and Higher Education of the Republic of Kazakhstan

D.Serikbayev EKTU

APPROVED:
Dean of ISoE:
Onalbaeva Z.S.
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HYDRAULIC AND THERMAL SYSTEMS IN MOBILE MACHINES

Syllabus

Programme of Study: 6B07107 Transport, Transport Equipment and Technologies
Course code: GTSMM2205
Number of credits: 5
Cycle: BD
Component: UC

Ust-Kamenogorsk, 2026

The syllabus was developed at «ISoE» on the basis of the State General Educational Standard for Higher Education approved by the Minister for Education and Science of the Republic of Kazakhstan (Order No. 604 dated 10.31.2018), Rules for organizing educational process based on academic credit system approved by the Minister for Education and Science of the Republic of Kazakhstan (Order No. 563 dated 12.10.2018), Education Program, Work Curriculum, and the Catalog of Elective Courses.

Approved by the Quality Assurance Commission

Chairperson Date 26.08.2026 y. Protocol №1	Mukhamedova R.O.
Head of the educational program	Muzdybayev M.S. 6B07107
Library employee	Drozdova O.N.
Developed by	Muzdybayev M.S. Professor Myrzabekova D.M. Associate professor Eserkegenova B.Z. Senior lecturer Mukhamedova A.I. Senior lecturer

1 COURSE DESCRIPTION. ITS PLACE IN THE ACADEMIC PROCESS

1.1 Course Overview

The discipline studies the basics of hydraulics and the types of hydraulic systems in mobile machines. Students analyze the principles of operation of hydrostatic and hydrodynamic systems and drives, their main units and assemblies, and also study the designs of hydrostatic drive and hydromechanical gears. The fundamentals of heat engineering and heat exchange processes are analyzed. They study the designs and principles of operation of thermal control systems for units and assemblies in mobile machines.

1.2 Goals and Objectives of the Course

Goals of the course:

Study of the fundamental laws and principles on which hydraulic and thermal systems and their components are based.

Objectives of the course:

- Mastering the fundamental principles of hydraulic and thermal system operation, including the laws of hydraulics, heat transfer, and thermodynamics.

1.3 Sustainable Development Goals

Goal 4. Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all

Goal 8. Promote inclusive and sustainable economic growth, employment and decent work for all

Goal 9. Build resilient infrastructure, promote sustainable industrialization and foster innovation

Goal 16. Promote just, peaceful and inclusive societies

1.4 Learning Outcomes

Learning outcomes are determined based on Dublin Descriptors for the appropriate educational level and are expressed through competencies.

Core competencies to be formed	Learning outcomes (units of core competencies)	
	Programme of study	Course
	PO5 - Possess practical skills in the selection of materials and alloys for car assemblies and assemblies, their hydraulic and thermal engineering systems, batteries, justify the use of technological methods of their processing and methods of assessing their properties to ensure high efficiency of transport equipment	

Core competencies to be formed	Learning outcomes (units of core competencies)	
	Programme of study	Course
		operation of mobile machines, influencing their performance and reliability. - Being able to clearly and accurately explain the technical aspects of hydraulic and thermal system operation, both orally and in writing, which is especially important when interacting with colleagues and clients. - Skills in preparing and formatting technical documentation, including reports, operating instructions, and diagrams, which enable the effective transfer of information and knowledge.

1.5 Educational Technologies Used in the Course

1.5.1 Modern Educational Technologies

The following educational technologies are used during the training:

- Interactive teaching methods. Lecture-discussions, business games, and problem-based and case-based learning methods are used. These approaches enable students to independently analyze the operation of hydraulic and thermal systems and to develop their operating diagrams and algorithms. Multimedia and digital technologies. Electronic presentations, 3D models of hydraulic systems and thermal circuits, instructional videos, and simulators of hydraulic drives and thermal installations are utilized. During the course, students master key software tools for modeling hydraulic and thermal processes, such as MATLAB Simulink, FluidSIM, Automation Studio, and ANSYS Fluent. Practice-oriented learning. The main focus is on solving real engineering problems — designing, analyzing, and calculating hydraulic drives and cooling and heating systems. Project-based and research technologies. Students develop individual mini-projects (e.g., “hydraulic system for dump body lifting,” “engine thermal balance”) and present the results in the form of a report or presentation. Modular-competence approach. Training is aimed at developing key competencies such as system thinking, engineering analysis, and the use of software for calculations and modeling. Online and blended learning. For remote interaction, platforms such as Moodle, Microsoft Teams, Zoom, and the university’s electronic resources are used.

1.5.2 Adaptive Learning Technologies (Inclusive Education)

The following Learner-adaptive educational technologies can be used in education for persons with special needs:

- Individualization of learning. The instructor takes into account each student’s level of preparation, learning pace, and perceptual characteristics. The materials are presented in an adapted form — diagrams, illustrations, videos, electronic simulators, and interactive tasks. Accessible learning environment. Electronic resources, visual models of hydraulic and thermal systems, audio materials, and text summaries are used. This ensures that the learning material is accessible to students with limited visual, hearing, or motor abilities. Flexible forms of interaction. Students who require special conditions are provided with the opportunity to participate in lectures and practical classes remotely via Moodle, Microsoft Teams, and Zoom platforms, as well as to receive individual consultations.

1.6 Prerequisites

- Physics

1.7 Postrequisites

- Automotive Internal Combustion Engines and Traction Electric Motors

1.8 Course Workload

Types of classes	hours
Lectures	30
Practical classes	15
SAWTG (Student Autonomous Work under Teacher Guidance)	30
SAW (Student autonomous work)	75
Final assessment method	Exam

2 COURSE CONTENT

2.1 Course Topics

№	Topic, content	Workload (hours)	Intended CDIO Learning Outcomes	Teaching Methods	Reading
	Lectures				
1	**Lecture 1.** Introduction. The importance of hydraulic and thermal systems in mobile machines. – Purpose and objectives of the course. – General structure and functions of hydraulic systems.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
2	**Lecture 2.** Classification and operating principles of hydraulic systems. – Open and closed circuits. – Static and dynamic characteristics.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
3	**Lecture 3.**	2	Advanced knowledge of the basics of	interactive method	5.1.1-5.2.8

№	Topic, content	Workload (hours)	Intended CDIO Learning Outcomes	Teaching Methods	Reading
	Hydraulic fluids and their properties. – Viscosity, pressure, density, temperature effects. – Criteria for selecting hydraulic fluids.		engineering, methods and tools (depending on the program)		
4	**Lecture 4.** Hydraulic pumps. Types and operating principles. – Gear, vane, and piston pumps. – Pump characteristics and efficiency.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
5	**Lecture 5.** Hydraulic motors and cylinders. – Types of motion: rotary and linear. – Calculation of force and speed.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
6	**Lecture 6.** Control and regulation elements. – Hydraulic valves, throttles, and distributors. – Principles of pressure, flow, and directional control.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
7	**Lecture 7.** Filtration and cleaning devices in hydraulic systems. – Causes and effects of contamination. – Types of filters and maintenance requirements.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
8	**Lecture 8.** System stability and cavitation phenomena. – Causes of cavitation and preventive measures. – Assessment of dynamic stability of the system.	2	Advanced knowledge of the basics of engineering, methods	interactive method	5.1.1-5.2.8

№	Topic, content	Workload (hours)	Intended CDIO Learning Outcomes	Teaching Methods	Reading
			and tools (depending on the program)		
9	**Lecture 9.** Characteristics and applications of hydraulic drives. – Types of drives in mobile machines: lifting, slewing, and travel drives. – Energy efficiency and overall efficiency (η).	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
10	**Lecture 10.** Diagnostics and maintenance of hydraulic systems. – Types of faults, their causes, and troubleshooting methods. – Diagnostic instruments and test benches.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
11	**Lecture 11.** Heat transfer processes and fundamental laws. – Conduction, convection, and radiation. – Transport equations and energy balance.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
12	**Lecture 12.** Structure of cooling and heating systems. – Radiators, heat exchangers, heat carriers. – Principles of cooling engines and hydraulic systems.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
13	**Lecture 13.** Thermoregulation and thermal management systems. – Automatic temperature control elements. – Sensors and control algorithms.	2	Advanced knowledge of the basics of engineering, methods and tools (depending	interactive method	5.1.1-5.2.8

№	Topic, content	Workload (hours)	Intended CDIO Learning Outcomes	Teaching Methods	Reading
			on the program)		
14	**Lecture 14.** Energy efficiency of thermal engineering systems. – Energy losses and heat balance. – Recuperative and closed-loop systems.	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
15	**Lecture 15.** Integration of complex hydraulic and thermal systems. – Combined control of hydraulics and thermal engineering. – Examples of application in mobile machines (excavators, combines, tractors).	2	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
TOTAL		30			
	Practical classes				
1	**Topic 1.** Introduction to the structure and components of hydraulic systems in mobile machines. – Familiarization with structural diagrams of hydraulic drives. – Identifying the functions of main components (pump, hydraulic motor, distributor/valve, filter, tank).	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
2	**Topic 2.** Designation and classification of hydraulic system components in schematic diagrams. – Studying standard graphical symbols according to GOST. – Constructing a simple hydraulic drive diagram.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
3	**Topic 3.** Calculation of properties and characteristics of hydraulic fluids. – Determining viscosity, density, and temperature coefficient. – Calculating pressure loss in a pipeline.	1	Advanced knowledge of the basics of engineering, methods and tools	interactive method	5.1.1-5.2.8

№	Topic, content	Workload (hours)	Intended CDIO Learning Outcomes	Teaching Methods	Reading
			(depending on the program)		
4	**Topic 4.** Hydraulic pumps: calculation of flow rate and power. – Determining flow rate, efficiency, and power consumption. – Plotting the pump characteristic curve.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
5	**Topic 5.** Hydraulic motors and cylinders. – Calculating force, speed, and piston stroke. – Comparing the characteristics of different types of hydraulic motors.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
6	**Topic 6.** Hydraulic distributors and valves. – Studying the operating principles of pressure- and flow-control valves. – Analyzing pressure-control and directional-control circuits.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
7	**Topic 7.** Filtration of working fluid and calculation of filters. – Determining the level of contamination and selecting the filter flow capacity. – Calculating pressure drop across the filter.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
8	**Topic 8.** Study of cavitaion and system stability. – Determining the conditions under which cavitation occurs. – Plotting the relationship between pressure and flow rate.	1	Advanced knowledge of the basics of engineering, methods and tools (depending	interactive method	5.1.1-5.2.8

№	Topic, content	Workload (hours)	Intended CDIO Learning Outcomes	Teaching Methods	Reading
			on the program)		
9	**Topic 9. – Building a mathematical model of the selected system (hydraulic circuit, cooling system, pump station).** – Performing a virtual experiment: adjusting parameters (pressure, flow rate, temperature) and analyzing the results. – Evaluating system stability and determining optimal operating conditions.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
10	**Topic 10.** Diagnostics and maintenance of hydraulic systems. – Identifying major faults and their causes. – Developing a maintenance plan for a hydraulic drive.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
11	**Topic 11.** Heat transfer processes and calculation of thermal conductivity. – Determining the heat transfer coefficient and temperature difference. – Calculating the heat flux.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
12	**Topic 12.** Analysis of cooling and heating systems of mobile machines. – Determining the efficiency of radiators and heat exchangers. – Constructing a thermal cycle diagram.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
13	**Topic 13.** Calculation of the engine heat balance. – Determining heat losses and efficiency. – Constructing the heat balance based on test results.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8

№	Topic, content	Workload (hours)	Intended CDIO Learning Outcomes	Teaching Methods	Reading
14	**Topic 14.** Automatic control of thermal processes and thermoregulation. – Studying the operation of thermostats, temperature sensors, and controllers. – Developing a structural diagram of a temperature control system.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
15	**Topic 15.** Integrated project: combining hydraulic and thermal engineering systems. – Developing a functional diagram of the integrated system. – Calculating key parameters and presenting (defending) the project.	1	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)	interactive method	5.1.1-5.2.8
TOTAL		**15**			

2.2 Tasks for Student Autonomous Work (SAW)

Topic	Content	Assessment method	Submission date, week	Workload (hours)	CDIO Learning Outcomes
Structure and operating principles.	Types of hydraulic systems, their main components, and interconnections.	spoken survey	2	12	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)
Hydraulic pumps and motors used in mobile machines.	Types, operational features, and ways to improve efficiency.	spoken survey	4	13	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)
Heat transfer processes and their calculation methods.	Types of conduction, convection, and radiation, and related engineering calculations.	spoken survey	6	13	Advanced knowledge of the basics of engineering, methods and tools

Topic	Content	Assessment method	Submission date, week	Workload (hours)	CDIO Learning Outcomes
					(depending on the program)
Improving the efficiency of cooling and heating systems.	Radiators, heat exchangers, and their structural features.	spoken survey	9	13	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)
Diagnostics and maintenance of hydraulic and thermal engineering systems.	Main types of faults, preventive measures, and technical monitoring tools.	spoken survey	11	12	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)
The role of hydraulics and thermal engineering in improving the energy efficiency of mobile machines.	Energy-saving technologies and modern solutions.	spoken survey	13	12	Advanced knowledge of the basics of engineering, methods and tools (depending on the program)
TOTAL				**75**	

2.3 Schedule of Course Task Submission

Types of tasks	Academic period, week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Knowledge															
1 task				+											
2 task							+								
test								+							+
3 task											+				
4 task														+	
Comprehension															
1 task				+											
2 task							+								
test								+							+
3 task											+				
4 task														+	
Application															

Types of tasks	Academic period, week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 task				+											
2 task							+								
3 task											+				
4 task														+	
Analysis															
1 task				+											
2 task							+								
3 task											+				
4 task														+	

3 ASSESSMENT OF STUDENT KNOWLEDGE

Teacher oversees various tasks related to ongoing assessment and determines students' current performance twice during each academic period. Ratings 1 and 2 are formulated based on the outcomes of this ongoing assessment. The student's learning achievements are assessed using a 100-point scale, and the final grades P1 and P2 are calculated as the average of their ongoing performance evaluations. The teacher evaluates the student's work throughout the academic period in alignment with the assignment submission schedule for the discipline. The assessment system may incorporate a mix of written and oral, group and individual formats.

Period	Type of work	Final Assessment
First rating	1 task	0-100
	2 task	
	test	
Second rating	3 task	0-100
	4 task	
	test	
Final control	Exam	0-100

3.1 The evaluating policy of learning outcomes by work type

Type of work	90-100	70-89	50-69	0-49
	Excellent	Good	Satisfactory	Unsatisfactory
	1. The work is completed in full, accurately, and with necessary explanations. The initial data, calculation results, units of measurement, and conclusions are provided. 2. Calculation diagrams (figures, drawings) are	1. The work is completed in full, with only minor comments, accurately, and with necessary explanations. The initial data, calculation results, units of measurement, and conclusions are provided. 2. Calculation diagrams	1. The work is poorly executed and inaccurate; necessary explanations are missing; source data, calculation results, units of measurement, or conclusions are missing. 2. Calculation diagrams (figures, drawings) are poorly	1. The work is completed with serious errors and is sloppy; necessary explanations are missing; the original data, calculation results, units of measurement, or conclusions are missing. 2. The work contains missing or

	accurately completed using drawing tools or graphics programs. 3. When defending the work, the student is well-versed in the material, has a command of the terminology, and fully answers additional questions.	(figures, drawings) are accurately completed using drawing tools or graphics programs. 3. When defending the work, the student is not sufficiently familiar with the material, makes inaccuracies in terminology, and has difficulty answering additional questions.	executed or contain errors. 3. When defending the work, the student is poorly versed in the material, has poor command of the terminology, and makes errors in answering questions about the work.	incorrectly executed calculation diagrams (figures, drawings). 3. When defending the work, the student is unoriented in the material, does not know the terminology, and does not answer questions about the work.

The student's final grade in the course is calculated on a 100 point grading scale, it includes:
- 60% of current academic performance results;
- 40% of the result obtained on the exam.

The final grade is calculated by the formula:

$$И = 0{,}6\frac{P_1+P_2}{2} + 0{,}4Э \quad (1)$$

where P1, P2 are numerical values of Rating 1 and Rating 2 correspondingly;
Э is the numerical value of the examination grade.

:

Alphabetical grade	Numerical value	Points (%)	Traditional grade
A	4.0	95-100	Excellent
A-	3.67	90-94	
B+	3.33	85-89	Good
B	3.0	80-84	
B-	2.67	75-79	
C+	2.33	70-74	
C	2.0	65-69	Satisfactory
C-	1.67	60-64	
D+	1.33	55-59	
D	1.0	50-54	
FX	0.5	25-49	Unsatisfactory
F	0	0-24	

4 COURSE POLICY

Student is required to:

The course is aimed at developing students' knowledge of the operating principles, design, calculations, and maintenance of hydraulic and thermal engineering systems used in mobile machines (construction, agricultural, transport, and special equipment). The course policy defines the rules for instruction, interaction, and the evaluation of students' learning outcomes.

5 RECOMMENDED READING

5.1 Key reading

1. Kulagin V. A. Hydraulic and Pneumatic Systems of Mobile Machines. — Moscow: Mashinostroenie, 2019. — 368 p.

2. *Hydraulic Drives and Hydraulic Systems of Mobile Machines: Textbook for Universities. Edited by V. I. Filippov. — Moscow: Academia, 2020. — 412 p.

3. Pupkov K. A., Kartashev S. V. Fundamentals of Hydraulics and Hydraulic Drives. — Saint Petersburg: BHV-Petersburg, 2018. — 352 p.

4. Klimenko A. V. Thermal Engineering and Thermal Processes in Technical Systems. — Moscow: Forum, 2017. — 320 p.

5. Baikov A. P. Fundamentals of Thermal Engineering and Heat Transfer. — Moscow: Academia, 2016. — 288 p.

5.2 Further reading

1. Gerasimov M. G., Chirkov V. A. Hydraulic and Thermal Engineering Systems of Transport Machines. — Yekaterinburg: UGLTU, 2021. — 298 p.
2. Soldatov V. G. Hydraulic Drives of Mobile Machines and Installations. — Moscow: Mashinostroenie, 2018. — 340 p.
3. *Thermal Engineering Systems and Energy Efficiency of Machines. Edited by A. V. Kravtsov. — Moscow: Academia, 2022. — 295 p.
4. Dell T. W. Hydraulic Systems of Mobile Equipment. — Translated from English. — Moscow: Technosphere, 2021. — 360 p.
5. Polyakov Yu. I. Thermal Processes and Cooling Systems in Mobile Machines. — Novosibirsk: NSTU, 2020. — 274 p.
6. IPR SMART http://www.iprbookshop.ru
7. ScienceDirect - http://www.sciencedirect.com.
8. EBSCO Discovery Service (EDS) - http://search.ebscohost.com