Національний технічний університет
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ І
імені ІГОРЯ СІКОРСЬКОГО»

Department of the
Computer Engineering

COMPUTER SYSTEMS
(Syllabus)

Details of the academic discipline

Level of higher education ***First (bachelor)***

Branch of knowledge	*12 Information technologies*
Specialty	*123 Computer engineering*
Educational program	*Computer systems*
Discipline status	*Normative*
Form of education	*(full-time) internal/external*
Year of training, semester	*4th year, autumn semester*
Scope of the discipline	*5.5 credits/165 hours*
Semester control/ control measures	*Examination*
Timetable	*http://roz.kpi.ua*
Language of teaching	*Ukrainian*
Information about head of the course / teachers	Lecturer: Ph.D., associate professor, Rusanova Olga Veniaminivna., olga.rusanova.v@gmail.com Labs: Ph.D., associate professor, Rusanova Olga Veniaminivna., olga.rusanova.v@gmail.com
Placement of the course	//comsys.kpi.ua

Program of educational discipline

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

The main indicator of the level of development of computer technology is the performance indicator of computer systems. In this regard, the traditional sequential nature of information processing has practically exhausted itself. Currently, the issues of further significant increase in the productivity of computer systems are being solved on the basis of the principles of parallel information processing. Therefore, this credit module is devoted to the study of the principles of parallelism, methods and means of organization and implementation of parallel processing and parallel systems of high and ultra-high productivity. The discipline provides the following program learning outcomes of the educational and professional program Computer Systems and Networks: ФК1, ФК3-ФК9, ФК18, ФК18, ПРН1, ПРН3, ПРН4, ПРН7, ПРН9-11, ПРН13, ПРН15. ПРН22, ПРН24.

The purpose of the discipline is to study the methods and means of building effective parallel and distributed computing systems of general and special purpose and issues of organization of parallel computing processes.

The subject of the discipline is:

- approaches, methods and ways of building effective high-performance and ultra-high-performance centralized and distributed computer systems;

Levels, methods, types and organization of parallelization of computing processes;Classification of parallel systems from the point of view of parallelism;

Topological organization of parallel computing systems of high and ultra-high performance;

Organization of input-output of information of high-performance computer systems;Interfaces of computer systems;

Main learning outcomes

As a result of studying the discipline, students should **know:**

1. The essence of problems and limitations associated with the sequential nature of information processing.
2. Goals and objectives of multiprogramming systems.
3. Goals and objectives of systems with multiprocessor information processing.
4. Problems of parallel processing and the main approaches to solving these problems.
5. Methods of determining the productivity and efficiency of parallel computing systems.
6. Ways of organizing parallelism, levels and types of parallelization of computing processes.
7. Classifications of computer systems according to Flynn, according to Krishnamarfa, according to Dazgupta, according to Baz, according to Shore.
8. Structural and algorithmic organization of matrix, vector, associative, conveyor and systolic processors.
9. Structural and algorithmic organization of multiprocessor, multicomputer, cluster, NUMA computing systems, as well as distributed GRID and CLOUD systems.
10. Structural and algorithmic organization of computing systems SOLOMON, ILLIAS-I4, UNIVAC, 8TAR-100, PS-2100, Elbrus, Vshtoughs, Sgau-1, СДС-6600 (6700).
11. Topological features of parallel computing systems focused on mass parallelization of computing processes.
12. Basic topological organizations of systems with a fixed system of connections (directly connected networks), their properties, topological characteristics, optimality criteria.
13. Topologies with flexible connection systems or with reconfigurable connection systems (switched networks).
14. RISC architectures.
15. Transputer and transputer-like computer systems.
16. Structural and algorithmic organization of computer systems controlled by data flow
17. Structural and algorithmic organization of universal homogeneous computer systems with individual handling of elements.
18. Synchronous and asynchronous methods of parallelization of computing processes.
19. Organization of high-performance data input - output.
20. Functions of input - output channels.
21. I/O management organization: direct control from the application program, I/O buffering, direct access to memory, I/O channel organization, I/O management using I/O processors.
22. Classification of input-output channels according to the degree of autonomy, according to the method of connection to peripheral devices, according to the degree of decentralization of channel functions between system devices.
23. Priority maintenance of external devices.

24. Computer system interfaces.
25. Synchronous and asynchronous methods of data transmission, addressing and identification.
26. Organization of bus interfaces.
27. Methods and means of integrating devices and computers into a single computing system.
28. Methods and means of building distributed computing systems.
29. Methods and means of access to data transmission channels in computer systems.
30. Methods and means of assignment, planning and distribution in parallel computing systems.
31. Algorithms and methods of implementing message routing tasks in parallel computing systems.
32. Methods of building fault-tolerant parallel computing systems.

As a result of studying the discipline, students should **be able to:**

1. On the basis of knowledge of the main criteria of optimality of topological organization, choose and develop optimal topologies of fault-tolerant parallel computing systems with an arbitrary level of parallelization of computing processes, solve the issue of effective routing of messages taking into account the peculiarities of topological organization.
2. On the basis of the introduced conceptual and theoretical foundations of the construction of parallel computing systems, select and design effective structural organizations of high-performance computing equipment of general and special purpose.
3. On the basis of the considered and researched synchronous and asynchronous methods and means of parallelization of computing processes, develop effective organizations of parallel computing systems with specified parameters of user and system productivity, solve issues of planning and distribution of tasks in the system.
4. On the basis of knowledge of the main trends in the development of parallel computing systems, solve the issue of creating new non-traditional options for building high-performance and super-performance means of computing equipment.
5. Based on the study of the main methods and means of data input-output organization, solve the issue of building effective data input-output subsystems, taking into account the productivity of the processor elements of the system.
6. Based on the study of algorithms and methods of interaction of subsystems, methods and means of data transmission, develop effective interfaces of parallel computing systems.
7. Based on the study of methods and means of integrating devices and computers, create centralized and distributed computing complexes, develop effective methods of accessing data transmission channels.

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

Knowledge is necessary for successful mastery of the discipline:

- basics of mathematical analysis, graph theory, matrix theory, theory of functions and mathematical statistics;
- the basics of the operation of operating systems;
- basics of parallel programming.

According to the educational program, it is necessary to acquire knowledge in the following disciplines: "Programming", "Computer Architecture", "Data Structures and Algorithms", "Operating Systems", Algorithms and Calculation Methods", "Discrete Mathematics", "Parallel Programming".

Competences, knowledge and skills acquired within the framework of studying this discipline can be applied in the design of modern computer systems and in the development of parallel programs.

3. Content of the academic discipline

Chapter 1. Computer systems and parallel processing of information.

Topic 1.1. *Computer systems and their efficiency.*

Basic approaches to improving the productivity of computer systems. Evolution of computer systems. Generation of computing systems. Basic methods of improving the efficiency of computer systems and means of their implementation. Modes of multiprogram organization of calculations and time division General structural organization of computer systems of different structural generations.

The fourth and fifth generation of computer systems. Objectives of parallelism. General organization of parallel processing of information.

Productivity of computing systems. Basic concepts and definitions. Levels of parallelization. System and user efficiency. Local and global types of parallelism. Natural, private and general types of parallelism. Parallelism of independent branches. Parallelism of adjacent operations. Artificial parallelism. Parallelism at the level of micro- and nanocommands

Loosely coupled and strongly coupled computing systems, centralized and distributed computing systems.

Topic 1.2. *Memory organization in high-performance computing systems.*

Hierarchical memory structures. Hierarchical memory. Hierarchical memory optimization issue. Virtual memory systems. The concept of virtual memory. Segmental organization of memory. Segmented - page organization of memory. Memory management. Memory organization strategy. Memory management systems.

CACHE memory. Characteristics of buffer memory (CACHE memory). Organization of CACHE memory. Design of systems with cache memory. Choice and strategy of memory update. Movement strategy. Evolution of hierarchical memory systems.

Multiprogramming is the first step on the way to parallel information processing.
Trends in the development of parallel information processing.

Topic 1.3. *Classification of parallel computing systems.*

Classification of computer systems according to Flynn, according to Krishnamarfa, according to Dazgupta, according to Baz, according to Shor. Number of command and data streams. Systems with different relationships of command and data flows: Single Instruction Flow - Single Data Flow (SISD); Single Instruction Flow – Multiple Data Flow (SIMD); Multiple Instruction Flow – Single Data Flow (MISD); Multiple Instruction Flow - Single Data Flow (MIMD), General organization and features of systems with different relationships of flow of instructions and data.

Chapter 2. Parallel structures of computer systems.

Topic 2.1. *SISD class systems and their limitations.*

Basic uniprocessor architectures. Means of organizing quasi-parallel information processing in single-processor architectures. Confluent systems. Limitations of SISD class systems.

Topic 2.2. SIMD class systems.

Matrix computing systems. Problematic orientation of matrix systems. The structure and organization of matrix systems. Unger system, SOLOMON system, ILLIAC-IV system, PS-2000 system, VSR system. Allocation of RAM in SIMD class systems. Mechanism of data masking and routing. Organization of connections between processor elements. Switching networks in computer systems of the SIMD class. Performance analysis of matrix processors. Organization of multiple computer systems with SIMD class organization.

Examples of the organization of parallel calculations in matrix systems. Productivity of matrix systems. Advantages and disadvantages of matrix systems. The field of use of computer systems of the SIMD class.

Vector computing systems. The method of dividing computing processes into multiple parts and their distribution in space and time. Spatio-temporal multi-layered organization of vector calculations. Inertia of vector systems. Structural organization of vector systems. Examples of the organization of parallel calculations based on vector systems. Productivity of vector systems. Advantages and disadvantages of vector systems.

Systolic processors. The principle of proximity and immersion of control functions in the processor structure. Structural organization of systolic processors. Examples of the organization of parallel calculations based on systolic processors. Productivity of systolic processors. Advantages and disadvantages of systolic processors.

Associative systems. Organization of parallel processing based on the principles of matrix organization using associative memory as a working memory. Structural organization of associative systems. Purpose, structure and organization of associative memory. Types of associative memory. Data processing using associative memory. Associative processors of computing systems.

Examples of organization of parallel calculations based on associative systems. Associative system STARAN and RERE. Algorithms of associative search.

Topic 2.3. MISD class systems.

Pipeline systems. The principle of multi-layer vector data processing with the possibility of performing different functions on different layers of processing devices. Architecture of pipeline systems. Operations pipeline. Command pipeline. Macro pipeline. A multi-level pipeline is a pipeline of pipelines. Pipeline system Star-100. Cray-1 pipeline system. The TI-ASS pipeline system. Examples of the organization of parallel calculations based on pipeline systems. Assessment of productivity and functioning of pipeline computing systems.

Topic 2.4. MIMD class systems.

Parallel systems with common (collective) and individual (distributed) memory. Limitations of systems with collective memory. Advantages and possibilities of systems with distributed memory. Problems of interaction in systems with distributed memory. Multi-processor computer systems. Multicomputer computing systems. Systems with non-uniform access to RAM (NUMA). Cluster systems. GRID-systems. CLOUD systems. Performance of parallel computing systems.

Chapter 3. Multiprocessor computer systems.

Topic 3.1. *Variants of the organization of multiprocessor systems.*

Switching networks. Spatial switching, temporal switching, spatial-temporal switching. Memory organization of multiprocessor systems. Multiport types of memory. Features of processors of multiprocessor architectures. Features of operating systems for multiprocessor organizations. Classification of operating systems for multiprocessor organizations. Software requirements for multiprocessor systems. Requirements for operating systems of multiprocessor organizations. Organization of parallelism in multiprocessor systems.

Topic 3.2. *Means of organization of multiprocessor systems.*

Bus organization, organization with a matrix switch, multi-port (multi-bus organization).

CISC and RISC architectures. Organization of high-level multiprocessor systems with a matrix switch: Elbrus, Burroughs. Features of the Elbrus and Burroughs systems, their advantages and disadvantages.

Organization of CRAY C90 multiprocessor system. Features of the CRAY C90 system, its advantages and disadvantages. Organization of the UNIVAC multiport multiprocessor system.

Topic 3.3. *Features of operating systems for multiprocessor organizations.*

Classification of operating systems for multiprocessor organizations. Software requirements for multiprocessor systems. Requirements for operating systems of multiprocessor organizations. Organization of parallelism in multiprocessor systems.

Chapter 4. Topological organization of multicomputer systems.

Topic 4.1. *Directly connected networks.*

The main indicators of the topology with a fixed system of connections (**directly connected networks**). Metrics of topological constructions. Optimality criteria of the topology of systems with a fixed system of connections. Means of minimizing the degree of topological organizations. Means of minimizing the diameter of topological organizations. Basic topologies of computing systems.

Topic 4.2. *Switched networks.*

Topologies with a reconfigured communication system (**switched networks**). Organization of switched

networks for scalable computer systems. Single-stage and multi-stage switched networks. Multi-cascade non-blocking networks. Close network. Benes network. Multi-cascade blocked networks. A network with a Banyan topology. Network with Omega topology. Network with binary n-cubic topology. Baseline topology. Advantages and disadvantages of networks with different topological organizations. An example of implementing a fast Fourier transform based on a single-cascade Omega topology. Delta topological organization. Topologies with a combined system of connections.

Chapter 5. Scalable systems.

Topic 5.1*. Structural organization of multicomputer systems.*

Cray T3D/T3E multicomputer system. Cray T3E communication array. Features of Cray T3D/T3E systems.

Topic 5.2*. Symmetrical multiprocessors.*

System with massive parallel processing. Parallel-vector systems (Parallel vector processor (PVP)). System structure with massively parallel processing.

Topic 5.3*. Cluster systems.*

Architecture of cluster systems with common (collective) disks. Architecture of cluster systems with individual (distributed) disks. Cluster topology: topology of cluster pairs, N+1 topology, N*N topology, fully distributed access topology.

TheHIVE cluster system (Highly-parallel Integrated Virtual Environment. Cluster organization of the Ministry of Internal Affairs=1000M. Structure of the Cm computer system. Structure of the BBN Butterfly computer system.

Topic 5.4. Non uniformmemory access systems (NUMA-systems).

Conceptual principles of NUMA systems. Features of NUMA systems. Structural organization of the Cm computing system. Structural organization of the BBN Butterfly computing system. General organization of the HP Superdome computer system.

Topic 5.5. Systems with massive parallel processing (MPP).

Conceptual principles of MPP systems. General structural organization of MPP systems. Features of MPP systems.

Topic 5.6. GRID-systems.

Conceptual principles and features of GRID systems. Intermediate software support of GRID systems. The place of GRID systems in the system of various parallel organizations General structural organization of GRID systems. Protocol stacks of GRID systems and network model.
Basic GRID services. Interaction of services in SOA environments.

Topic 5.7. CLOUD computing.

Conceptual principles and features of CLOUD computing. The overall structural organization of CLOUD is computing. Cloud technologies and data storage. Opportunities of cloud technologies. Advantages and disadvantages of useless calculations.

Chapter 6. High-performance systems with unconventional architecture.

Topic 6.1. *Computing environments – Universal homogeneous systems with individual behavior of elements.*

Basic principles of computing environments. Versatility. Scalability. Homogeneity of elements and connections. The method of forming the appropriate optimal architecture of a computer system based on a single construct for each individual task. The principle of proximity is the exclusion of physical connections.

Structural organization of the computing environment and its cells. Functions of the cells of the computing environment. Implementation examples.

Topic 6.2. *Transputer systems.*

Structural organization of the transputer and its features. Transputer is an effective element for building computing environments. Transputer set of elements and methods of building transputer systems.

Topic 6.3. *Dataflow systems*

Computational model of stream processing. Architecture of streaming computing systems. Static dataflow computing systems. Dynamic dataflow computing systems. Computing systems with on-demand computing management.

Topic 6.4. *Quantum computers.*

Conceptual foundations of building quantum computers. A qubit is a unit of quantum information. State of cells and registers. Physical implementation of the qubit, memory cells and registers. Work of a quantum computer processor. Quantum logic elements are gates. An example of quantum parallel computing.

Topic 6.5. *Computer systems with very long instruction word (VLIW).*

VLIW is a solution to parallelism issues at the command level. The concept and features of computer systems with an extra long command word. Processor architecture with VLIW organization. Advantages and disadvantages of VLIW systems.

Chapter 7. Organization of high-performance input-output.

Topic 7.1. *Organization of input-output in evolutionary development.*

Impossibility of direct connection of input-output devices and RAM. Using a central processor as an intermediate element between input-output devices and RAM. Disadvantages of using the central processor as an intermediate element.

Topic 7.2. *I/O channel.*

Input-output channel functions. A computer system with memory as the central element. I/O processors and their purpose.

Topic 7.3. *Organization of input-output management.*

Direct I/O management. I/O buffering. Occupancy of the RAM cycle (direct memory access). Structural organization of input-output channels.

Topic 7.4. *Elements of classification of input-output channels.*

According to the degree of autonomy of input-output channels: built-in channels, non-autonomous channels, partially non-autonomous channels, autonomous channels. Channels with cross connections. Input-output selector channels. Multiplex input-output channels. Functioning of selector and multiplex input-output channels.

Input-output operations. I/O control commands. I/O addressing. Address word of the channel. Control word of the channel. Signs of the channel control word: latching by data, latching by commands, indication of incorrect length indication suppression, write blocking, software-controlled interrupt. An example of the use of features of the control word of the input-output channel. I/O states. I/O execution sequence. I/O status word. External device status byte. I/O channel status byte.

Centralized and decentralized input-output channels. Variants of the structural organization of centralized and decentralized input-output channels. Priority maintenance of external devices.

Chapter 8. Interfaces of computer systems.

Topic 8.1. *Standard means of connection and their importance in the construction, modification and restoration of computer systems.*

Concept of interfaces. Requirements for interfaces at different levels of structural organization of computer systems. Methods of data transmission. Synchronous and asynchronous methods of data transmission and their features and conditions of use.

Topic 8.2. *Organization of interfaces.*

Organization of interfaces based on individual buses. Organization of interfaces based on combined buses. Organization of interfaces based on collective buses. Structural organization of the interface with a collective bus and algorithms of its operation when performing addressing and identification operations of external devices.

Topic 8.3 *Organization of parallel memory.*

Structural organization of parallel memory and corresponding interfaces for accessing it when writing and reading from memory. CDC-6600/6700 computer system. Organization of memory in the CDC-6600/6700 computer system. Multisystem means of computer systems and methods of their use for combining computers into complexes.

4. Educational materials and resources

Basic:

1. Loutsky G., Zhukov I., Korochkin A. Parallel Computing. – Kyiv, Kornechuk, 2007. -216 pp. //comsys.kpi.ua
2. H.M. Loutskii, O. V. Rusanova, O. O. Honcharenko COMPUTER SYSTEMS. LABORATORY WORK INSTRUCTIONS. Study guide. – Kyiv, «IHOR SIKORSKY KYIV POLYTECHNICAL INSTITUTE», 2022. - 47 pp. //comsys.kpi.ua
3. V.Kumar, A.Grama, A.Gupta, GKarypis. Introduction to Parallel Computing.Design and Analysis of Algorithms- Benjamin/Cummings Pub.Co, 1995.-597 p.

Additional:

1. Korochkin O. Multicore programming in Ada. Навч. посібник з гріфом НТУУ "КПІ" [Електроний ресурс]., Київ, НТУУ-КПІ, 2018.- 114 с. //comsys.kpi.ua
2. Hesham El-Rewini, Ted G.Lewis. Distributed and Parallel Computing-Manning Publications Co., 1997.-447 p.

Full-time education

Names of sections, topics	Number of hours			
	Total	Including		
		Lectures	Labs	CPC
Chapter 1. Computer systems and parallel processing of information.	**16**	**7**		**9**
Topic 1.1. Computer systems and their efficiency. Basic approaches to increasing the productivity of computing systems. Evolution of computing systems. Generation of computing systems. Basic methods of improving the efficiency of computer systems and means of their implementation. Modes of multiprogram organization of calculations and time division. General structural organization of computer systems of different structural generations.				

The fourth and fifth generation of computer systems. Goals of parallelism. General organization of parallel information processing. Productivity of computing systems. Basic concepts and definitions. Levels of parallelization. System and user efficiency. Local and global types of parallelism. Natural, private and general types of parallelism. Parallelism of independent branches. Parallelism of adjacent operations. Artificial parallelism. Parallelism at the level of micro- and nanocommands Loosely coupled and tightly coupled computer systems, centralized and distributed computer systems.				
Topic 1.2. Memory organization in high-performance computing systems. Hierarchical memory structures. Hierarchical memory. Hierarchical memory optimization issue. Virtual memory systems. The concept of virtual memory. Segmental organization of memory. Segmented - page organization of memory. Memory management. Memory organization strategy. Memory management systems. CACHE memory. Characteristics of buffer memory (CACHE memory). Organization of CACHE memory. Design of systems with cache memory. Choice and strategy of memory update. Movement strategy. Evolution of hierarchical memory systems. Multiprogramming is the first step on the way to parallel information processing. Trends in the development of parallel information processing.				
Topic 1.3. Classification of parallel computing systems. Classification of computer systems according to Flynn, according to Krishnamarfa, according to Dazgupta, according to Baz, according to Shor. Number of command and data streams. Systems with different relationships of command and data flows: Single Instruction Flow - Single Data Flow (SISD); Single Instruction Flow – Multiple Data Flow (SIMD); Multiple Instruction Flow – Single Data Flow (MISD);				

Multiple Instruction Flow - Single Data Flow (MIMD), General organization and features of systems with different relationships of flow of instructions and data				
Chapter 2. Parallel structures of computer systems	**24**	**7**	**8**	**9**
Topic 2.1. SISD class systems and their limitations. Basic uniprocessor architectures. Means of organizing quasi-parallel information processing in single-processor architectures. Confluent systems. Limitations of SISD class systems.				
Topic 2.2. SIMD class systems Matrix computing systems. Problematic orientation of matrix systems. The structure and organization of matrix systems. Unger system, SOLOMON system, ILLIAC-IV system, PS-2000 system, VSR system. Allocation of RAM in SIMD class systems. Mechanism of data masking and routing. Organization of connections between processor elements. Switching networks in computer systems of the SIMD class. Performance analysis of matrix processors. Organization of multiple computer systems with SIMD class organization. Examples of the organization of parallel calculations in matrix systems. Productivity of matrix systems. Advantages and disadvantages of matrix systems. The field of use of computer systems of the SIMD class. Vector computing systems. The method of dividing computing processes into multiple parts and their distribution in space and time. Spatio-temporal multi-layered organization of vector calculations. Inertia of vector systems. Structural organization of vector systems.				

Examples of the organization of parallel calculations based on vector systems. Productivity of vector systems. Advantages and disadvantages of vector systems. Systolic processors. The principle of proximity and immersion of control functions in the processor structure. Structural organization of systolic processors. Examples of the organization of parallel calculations based on systolic processors. Productivity of systolic processors. Advantages and disadvantages of systolic processors. Associative systems. Organization of parallel processing based on the principles of matrix organization using associative memory as a working memory. Structural organization of associative systems. Purpose, structure and organization of associative memory. Types of associative memory. Data processing using associative memory. Associative processors of computing systems. Examples of organization of parallel calculations based on associative systems. Associative system STARAN and RERE. Algorithms of associative search.				
Topic 2.3. MISD class systems Pipeline systems. The principle of multi-layer vector data processing with the possibility of performing different functions on different layers of processing devices. Architecture of pipeline systems. Operations pipeline. Command pipeline. Macro pipeline. A multi-level pipeline is a pipeline of pipelines. Pipeline system Star-100. Cray-1 pipeline system. The TI-ASS pipeline system. Examples of the organization of parallel calculations based on pipeline systems. Assessment of productivity and functioning of pipeline computing systems.				

Topic 2.4. MIMD class systems. Parallel systems with common (collective) and individual (distributed) memory. Limitations of systems with collective memory. Advantages and possibilities of systems with distributed memory. Problems of interaction in systems with distributed memory. Multi-processor computer systems. Multicomputer computing systems. Systems with non-uniform accessto RAM (NUMA). Cluster systems. GRID-systems. CLOUD systems. Performance of parallel computing systems.				
Chapter 3. Multiprocessor computer systems	**17**	**4**	**4**	**9**
Topic 3.1. Variants of the organization of multiprocessor systems. Switching networks. Spatial switching, temporal switching, spatial-temporal switching. Memory organization of multiprocessor systems. Multiport types of memory. Features of processors of multiprocessor architectures. Features of operating systems for multiprocessor organizations. Classification of operating systems for multiprocessor organizations. Software requirements for multiprocessor systems. Requirements for operating systems of multiprocessor organizations. Organization of parallelism in multiprocessor systems.				
Topic 3.2. Means of organization of multiprocessor systems. Bus organization, organization with a matrix switch, multi-port (multi-bus organization). CISC and RISC architectures. Organization of high-level multiprocessor systems with a matrix switch: Elbrus, Burroughs. Features of the Elbrus and Burroughs systems, their advantages and disadvantages.				

Organization of CRAY C90 multiprocessor system. Features of the CRAY C90 system, its advantages and disadvantages. Organization of the UNIVAC multiport multiprocessor system.				
Topic 3.3. Features of operating systems for multiprocessor organizations. Classification of operating systems for multiprocessor organizations. Software requirements for multiprocessor systems. Requirements for operating systems of multiprocessor organizations. Organization of parallelism in multiprocessor systems.				
Chapter 4. Topological organization of multicomputer systems	**14**	**5**		**9**
Topic 4.1. Directly connected networks. The main indicators of the topology with a fixed system of connections (directly connected networks). Metrics of topological constructions. Optimality criteria of the topology of systems with a fixed system of connections. Means of minimizing the degree of topological organizations. Means of minimizing the diameter of topological organizations. Basic topologies of computing systems.				
Topic 4.2. Switched networks. Topologies with a reconfigured communication system (switched networks). Organization of switched networks for scalable computer systems. Single-stage and multi-stage switched networks. Multi-cascade non-blocking networks. Close network. Benes network. Multi-cascade blocked networks. A network with a Banyan topology. Network with Omega topology. Network with binary n-cubic topology. Baseline topology. Advantages and disadvantages of networks with different topological organizations.				

An example of implementing a fast Fourier transform based on a single-cascade Omega topology. Delta topological organization. Topologies with a combined system of connections				
Chapter 5. Scalable systems.	**19**	**10**		**9**
Topic 5.1. Structural organization of multicomputer systems. Cray T3D/T3E multicomputer system. Cray T3E communication array. Features of Cray T3D/T3E systems.				
Topic 5.2. Symmetrical multiprocessors. System with massive parallel processing. Parallel-vector systems (Parallel vector processor (PVP)). System structure with massively parallel processing..				
Topic 5.3. Cluster systems. Architecture of cluster systems with common (collective) disks. Architecture of cluster systems with individual (distributed) disks. Cluster topology: topology of cluster pairs, N+1 topology, N*N topology, fully distributed access topology. TheHIVE cluster system (Highly-parallel Integrated Virtual Environment. Cluster organization of the Ministry of Internal Affairs=1000M. Structure of the Cm computer system. Structure of the BBN Butterfly computer system.				
Topic 5.4. Non uniformmemory access systems(NUMA-systems). Conceptual principles of NUMA systems. Features of NUMA systems. Structural organization of the Cm computing system. Structural organization of the BBN Butterfly computing system.				

General organization of the HP Superdome computer system				
Topic 5.5. Systems with massive parallel processing (MPP). Conceptual principles of MPP systems. General structural organization of MPP systems. Features of MPP systems.				
Topic 5.6. GRID-systems Conceptual principles and features of GRID systems. Intermediate software support of GRID systems. The place of GRID systems in the system of various parallel organizations General structural organization of GRID systems. Protocol stacks of GRID systems and network model. Basic GRID services. Interaction of services in SOA environments.				
Topic 5.7. CLOUD computing.				
Conceptual principles and features of CLOUD computing. The overall structural organization of CLOUD is computing. Cloud technologies and data storage. Opportunities of cloud technologies. Advantages and disadvantages of useless calculations				
Chapter 6. High-performance systems with unconventional architecture.	**24**	**9**	**6**	**9**
Topic 6.1. Computing environments – Universal homogeneous systems with individual behavior of elements. Basic principles of computing environments. Versatility. Scalability. Homogeneity of elements and connections. The method of forming the appropriate optimal architecture of a computer system based on a single construct for each individual task. The principle of proximity is the exclusion of physical connections.				

Structural organization of the computing environment and its cells. Functions of the cells of the computing environment. Implementation examples				
Topic 6.2. Transputer systems. Structural organization of the transputer and its features. Transputer is an effective element for building computing environments. Transputer set of elements and methods of building transputer systems.				
Topic 6.3. Dataflow systems Computational model of stream processing. Architecture of streaming computing systems. Static dataflow computing systems. Dynamic dataflow computing systems. Computing systems with on-demand computing management.				
Topic 6.4. Quantum computers. Conceptual foundations of building quantum computers. A qubit is a unit of quantum information. State of cells and registers. Physical implementation of the qubit, memory cells and registers. Work of a quantum computer processor. Quantum logic elements are gates. An example of quantum parallel computing.				
Topic 6.5. Computer systems with very long instruction word (VLIW). VLIW is a solution to parallelism issues at the command level. The concept and features of computer systems with an extra long command word. Processor architecture with VLIW organization. Advantages and disadvantages of VLIW systems.				
Chapter 7. Organization of high-performance input-output.	**16**	**7**		**9**

Topic 7.1. Organization of input-output in evolutionary development. Impossibility of direct connection of input-output devices and RAM. Using a central processor as an intermediate element between input-output devices and RAM. Disadvantages of using the central processor as an intermediate element.				
Topic 7.2. I/O channel. Input-output channel functions. A computer system with memory as the central element. I/O processors and their purpose.				
Topic 7.3. Organization of input-output management. Direct I/O management. I/O buffering. Occupancy of the RAM cycle (direct memory access). Structural organization of input-output channels.				
Topic 7.4. Elements of classification of input-output channels.. According to the degree of autonomy of input-output channels: built-in channels, nonautonomous channels, partially non-autonomous channels, autonomous channels. Channels with cross connections. Input-output selector channels. Multiplex input-output channels. Functioning of selector and multiplex input-output channels. Input-output operations. I/O control commands. I/O addressing. Address word of the channel. Control word of the channel. Signs of the channel control word: latching by data, latching by commands, indication of incorrect length indication suppression, write blocking, software-controlled interrupt.				

An example of the use of features of the control word of the input-output channel. I/O states. I/O execution sequence. I/O status word. External device status byte. I/O channel status byte. Centralized and decentralized input-output channels. Variants of the structural organization of centralized and decentralized input-output channels. Priority maintenance of external devices-				
Chapter 8. Interfaces of computer systems.	**14**	**5**		**9**
Topic 8.1. Standard means of connection and their importance in the construction, modification and restoration of computer systems. Concept of interfaces. Requirements for interfaces at different levels of structural organization of computer systems. Methods of data transmission. Synchronous and asynchronous methods of data transmission and their features and conditions of use.				
Topic 8.2. Organization of interfaces. Organization of interfaces based on individual buses. Organization of interfaces based on combined buses. Organization of interfaces based on collective buses. Structural organization of the interface with a collective bus and algorithms of its operation when performing addressing and identification operations of external devices.				
Topic 8.3 Organization of parallel memory. Structural organization of parallel memory and corresponding interfaces for accessing it when writing and reading from memory. CDC-6600/6700 computer system. Organization of memory in the CDC-6600/6700 computer system. Multisystem means of computer systems and methods of their use for combining computers into complexes.				
Examination	**30**			**30**
Total in the semester	**165**	**54**	**18**	**93**

External form of education

Names of sections, topics	Number of hours			
	Total	У тому числі		
		Лекції	Лабораторні роботи	СРС
Chapter 1. Computer systems and parallel processing of information.	**16**	**7**		**9**
Topic 1.1. Computer systems and their efficiency. Basic approaches to increasing the productivity of computing systems. Evolution of computing systems. Generation of computing systems. Basic methods of improving the efficiency of computer systems and means of their implementation. Modes of multiprogram organization of calculations and time division. General structural organization of computer systems of different structural generations.				
The fourth and fifth generation of computer systems. Goals of parallelism. General organization of parallel information processing. Productivity of computing systems. Basic concepts and definitions. Levels of parallelization. System and user efficiency. Local and global types of parallelism. Natural, private and general types of parallelism. Parallelism of independent branches. Parallelism of adjacent operations. Artificial parallelism. Parallelism at the level of micro- and nanocommands Loosely coupled and tightly coupled computer systems, centralized and distributed computer systems.				

Topic 1.2. Memory organization in high-performance computing systems. Hierarchical memory structures. Hierarchical memory. Hierarchical memory optimization issue. Virtual memory systems. The concept of virtual memory. Segmental organization of memory. Segmented - page organization of memory. Memory management. Memory organization strategy. Memory management systems. CACHE memory. Characteristics of buffer memory (CACHE memory). Organization of CACHE memory. Design of systems with cache memory. Choice and strategy of memory update. Movement strategy. Evolution of hierarchical memory systems. Multiprogramming is the first step on the way to parallel information processing. Trends in the development of parallel information processing.				
Topic 1.3. Classification of parallel computing systems. Classification of computer systems according to Flynn, according to Krishnamarfa, according to Dazgupta, according to Baz, according to Shor. Number of command and data streams. Systems with different relationships of command and data flows: Single Instruction Flow - SingleData Flow (SISD); Single Instruction Flow – Multiple Data Flow (SIMD); Multiple Instruction Flow – SingleData Flow (MISD);				
Multiple Instruction Flow - Single Data Flow (MIMD), General organization and features of systems with different relationships of flow of instructions and data				
Chapter 2. Parallel structures of computer systems.	**24**	**7**	**8**	**9**

Topic 2.1. SISD class systems and their limitations Basic uniprocessor architectures. Means of organizing quasi-parallel information processing in single-processor architectures. Confluent systems. Limitations of SISD class systems.				
Topic 2.2. SIMD class systems. Matrix computing systems. Problematic orientation of matrix systems. The structure and organization of matrix systems. Unger system, SOLOMON system, ILLIAC-IV system, PS-2000 system, VSR system. Allocation of RAM in SIMD class systems. Mechanism of data masking and routing. Organization of connections between processor elements. Switching networks in computer systems of the SIMD class. Performance analysis of matrix processors. Organization of multiple computer systems with SIMD class organization. Examples of the organization of parallel calculations in matrix systems. Productivity of matrix systems. Advantages and disadvantages of matrix systems. The field of use of computer systems of the SIMD class. Vector computing systems. The method of dividing computing processes into multiple parts and their distribution in space and time. Spatio-temporal multi-layered organization of vector calculations. Inertia of vector systems. Structural organization of vector systems. Examples of the organization of parallel calculations based on vector systems. Productivity of vector systems. Advantages and disadvantages of vector systems. Systolic processors. The principle of proximity and immersion of control functions in the processor structure. Structural organization of systolic processors. Examples of the organization of parallel calculations based on systolic processors. Productivity of systolic processors. Advantages and disadvantages of systolic processors. Associative systems.				

Organization of parallel processing based on the principles of matrix organization using associative memory as a working memory. Structural organization of associative systems. Purpose, structure and organization of associative memory. Types of associative memory. Data processing using associative memory. Associative processors of computing systems. Examples of organization of parallel calculations based on associative systems. Associative system STARAN and RERE. Algorithms of associative search.				
Topic 2.3. MISD class systems. Pipeline systems. The principle of multi-layer vector data processing with the possibility of performing different functions on different layers of processing devices. Architecture of pipeline systems. Operations pipeline. Command pipeline. Macro pipeline. A multi-level pipeline is a pipeline of pipelines. Pipeline system Star-100. Cray-1 pipeline system. The TI-ASS pipeline system. Examples of the organization of parallel calculations based on pipeline systems. Assessment of productivity and functioning of pipeline computing systems.				

Topic 2.4. MIMD class systems Parallel systems with common (collective) and individual (distributed) memory. Limitations of systems with collective memory. Advantages and possibilities of systems with distributed memory. Problems of interaction in systems with distributed memory. Multi-processor computer systems. Multicomputer computing systems. Systems with non-uniform accessto RAM (NUMA). Cluster systems. GRID-systems. CLOUD systems. Performance of parallel computing systems.				
Chapter 3. Multiprocessor computer systems.	**17**	**4**	**4**	**9**
Topic 3.1. Variants of the organization of multiprocessor systems. Switching networks. Spatial switching, temporal switching, spatial-temporal switching. Memory organization of multiprocessor systems. Multiport types of memory. Features of processors of multiprocessor architectures. Features of operating systems for multiprocessor organizations. Classification of operating systems for multiprocessor organizations. Software requirements for multiprocessor systems. Requirements for operating systems of multiprocessor organizations. Organization of parallelism in multiprocessor systems.				
Topic 3.2. Means of organization of multiprocessor systems. Bus organization, organization with a matrix switch, multi-port (multi-bus organization). CISC and RISC architectures. Organization of high-level multiprocessor systems with a matrix switch: Elbrus, Burroughs. Features of the Elbrus and Burroughs systems, their advantages and disadvantages.				

Organization of CRAY C90 multiprocessor system. Features of the CRAY C90 system, its advantages and disadvantages. Organization of the UNIVAC multiport multiprocessor system.				
Topic 3.3. Features of operating systems for multiprocessor organizations. Classification of operating systems for multiprocessor organizations. Software requirements for multiprocessor systems. Requirements for operating systems of multiprocessor organizations. Organization of parallelism in multiprocessor systems.				
Chapter 4. Topological organization of multicomputer systems.	**14**	**5**		**9**
Topic 4.1. Directly connected networks. The main indicators of the topology with a fixed system of connections (**directly connected networks**). Metrics of topological constructions. Optimality criteria of the topology of systems with a fixed system of connections. Means of minimizing the degree of topological organizations. Means of minimizing the diameter of topological organizations. Basic topologies of computing systems.				
Topic 4.2. Switched networks. Topologies with a reconfigured communication system (switched networks). Organization of switched networks for scalable computer systems. Single-stage and multi-stage switched networks. Multi-cascade non-blocking networks. Close network. Benes network. Multi-cascade blocked networks. A network with a Banyan topology. Network with Omega topology. Network with binary n-cubic topology. Baseline topology. Advantages and disadvantages of networks with different topological organizations. An example of implementing a fast Fourier transform based on a single-cascade Omega topology.				

Delta topological organization. Topologies with a combined system of connections				
Chapter 5. Scalable systems	**19**	**10**		**9**
Topic 5.1. Structural organization of multicomputer systems. Cray T3D/T3E multicomputer system. Cray T3E communication array. Features of Cray T3D/T3E systems.				
Topic 5.2. Symmetrical multiprocessors. System with massive parallel processing. Parallel-vector systems (*Parallel vector processor* (**PVP**)). System structure with massively parallel processing				
Topic 5.3. Cluster systems. Architecture of cluster systems with common (collective) disks. Architecture of cluster systems with individual (distributed) disks. Cluster topology: topology of cluster pairs, N+1 topology, N*N topology, fully distributed access topology. TheHIVE cluster system (Highly-parallel Integrated Virtual Environment. Cluster organization of the Ministry of Internal Affairs=1000M. Structure of the Cm computer system. Structure of the BBN Butterfly computer system.				
Topic 5.4. Non uniformmemory access systems(NUMA -systems Conceptual principles of NUMA systems. Features of NUMA systems. Structural organization of the Cm computing system. Structural organization of the BBN Butterfly computing system.				

General organization of the HP Superdome computer system				
Topic 5.5. Systems with massive parallel processing (MPP). Conceptual principles of MPP systems. General structural organization of MPP systems. Features of MPP systems.				
Topic 5.6. GRID-systems. Conceptual principles and features of GRID systems. Intermediate software support of GRID systems. The place of GRID systems in the system of various parallel organizations General structural organization of GRID systems. Protocol stacks of GRID systems and network model. Basic GRID services. Interaction of services in SOA environments.				
Topic 5.7. CLOUD computing.				
Conceptual principles and features of CLOUD computing. The overall structural organization of CLOUD is computing. Cloud technologies and data storage. Opportunities of cloud technologies. Advantages and disadvantages of useless calculations				
Chapter 6. High -performance systems with unconventional architecture.	**24**	**9**	**6**	**9**
Topic 6.1. Computing Environments – Universal homogeneous systems with individual behavior of elements. Basic principles of computing environments. Versatility. Scalability. Homogeneity of elements and connections. The method of forming the appropriate optimal architecture of a computer system based on a single construct for each individual task. The principle of proximity is the exclusion of physical connections.				

Structural organization of the computing environment and its cells. Functions of the cells of the computing environment. Implementation examples				
Topic 6.2. Transputer systems Structural organization of the transputer and its features. Transputer is an effective element for building computing environments. Transputer set of elements and methods of building transputer systems.				
Topic 6.3. Dataflow systems Computational model of stream processing. Architecture of streaming computing systems. Static dataflow computing systems. Dynamic dataflow computing systems. Computing systems with on-demand computing management..				
Topic 6.4. Quantum computers. Conceptual foundations of building quantum computers. A qubit is a unit of quantum information. State of cells and registers. Physical implementation of the qubit, memory cells and registers. Work of a quantum computer processor. Quantum logic elements are gates. An example of quantum parallel computing.				
Topic 6.5. Computer systems with very long instruction word (VLIW). VLIW is a solution to parallelism issues at the command level. The concept and features of computer systems with an extra long command word. Processor architecture with VLIW organization. Advantages and disadvantages of VLIW systems..				
Chapter 7. Organization of high -performance input-output.	**16**	**7**		**9**

Topic 7.1. Organization of input-output in evolutionary development Impossibility of direct connection of input-output devices and RAM. Using a central processor as an intermediate element between input-output devices and RAM. Disadvantages of using the central processor as an intermediate element.				
Topic 7.2. I/O channel. Input-output channel functions. A computer system with memory as the central element. I/O processors and their purpose				
Topic 7.3. Organization of inputoutput management. Direct I/O management. I/O buffering. Occupancy of the RAM cycle (direct memory access). Structural organization of input-output channels.				
Topic 7.4. Elements of classification of input-output channels. ng to the degree of autonomy of input-output channels: built-in channels, nonautonomous channels, partially non-autonomous channels, autonomous channels. Channels with cross connections. Input-output selector channels. Multiplex input-output channels. Functioning of selector and multiplex input-output channels. Input-output operations. I/O control commands. I/O addressing. Address word of the channel. Control word of the channel. Signs of the channel control word: latching by data, latching by commands, indication of incorrect length indication suppression, write blocking, software-controlled interrupt.				

An example of the use of features of the control word of the input-output channel. I/O states. I/O execution sequence. I/O status word. External device status byte. I/O channel status byte. Centralized and decentralized input-output channels. Variants of the structural organization of centralized and decentralized input-output channels. Priority maintenance of external devices				
Chapter 8. Interfaces of computer systems.	**14**	**5**		**9**
Topic 8.1. Standard means of connection and their importance in the construction, modification and restoration of computer systems. Concept of interfaces. Requirements for interfaces at different levels of structural organization of computer systems. Methods of data transmission. Synchronous and asynchronous methods of data transmission and their features and conditions of use.				
Topic 8.2. Organization of interfaces. Organization of interfaces based on individual buses. Organization of interfaces based on combined buses. Organization of interfaces based on collective buses. Structural organization of the interface with a collective bus and algorithms of its operation when performing addressing and identification operations of external devices.				
Topic 8.3 Organization of parallel memory. Structural organization of parallel memory and corresponding interfaces for accessing it when writing and reading from memory. CDC-6600/6700 computer system. Organization of memory in the CDC-6600/6700 computer system. Multisystem means of computer systems and methods of their use for combining computers into complexes.				
Examination	**30**			**30**
Total in the semester	**165**	**6**	**4**	**15**

13. Independent work of the student.

The purpose of conducting a cycle of laboratory work is for students to acquire the necessary practical skills in the use of methods and ways of presenting and processing data to obtain hidden information, methods of researching mathematical models for describing the information sought, technology of data extraction for the development of forecasts regarding researched objects and processes.

The main tasks of the cycle of laboratory classes (computer workshop) are the acquisition of practical skills related to the operation of parallel computer systems with different architectures.

№ з/п	Name of laboratory work (computer workshop)	Number of aud. hours
1	STUDY OF OPERATION OF MULTIPROCESSOR CS(SMP) WITH SHARED MEMORY	4
2	STUDY OF WORK OF PIPELINE CS	4
3	STUDYING THE WORK OF MATRIX COMPUTER SYSTEMS	4
4	STUDYING THE OPERATION OF DATAFLOW COMPUTER SYSTEMS	6
	Total:	18

Policy and control

14. Policy of academic discipline (educational component)

During classes in the educational discipline "Computer systems", graduate students must adhere to certain disciplinary rules:

- it is forbidden to be late for classes;
- at the entrance of the teacher, as a sign of greeting, persons studying at KPI named after Igor Sikorsky should stand up;
- extraneous conversations or other noise that interferes with classes are not allowed;
- leaving the classroom during the lesson is allowed only with the teacher's permission.
- the use of mobile phones and other technical means is not allowed without the teacher's permission.

The following factors are taken into account when enrolling and evaluating laboratory work (LW).:

- the completion of the LW task
- timeliness of execution LW
- independent performance of LW according to the schedule
- answers to questions about the content of LW during its defense

During the first and second attestation, the number of LW enrolled at the time of the attestation is taken into account.

15. Types of control and rating system for evaluating learning outcomes (RSO)

Types of control in the educational discipline "Computer systems" include:
Labs: independent implementation of four LW is planned. LW topics are aligned in time and content with lecture topics. Completing LW in its entirety allows you to acquire practical skills in the discipline.

Current control: testing with closed tests.

Calendar control: is conducted twice a semester as a monitoring of the current state of meeting the requirements of the syllabus.

Semester control: examination

The student's semester rating consists of the points he receives for the types of work according to Table 1.

Type of educational work	*Total by type of work*
Implementation and protection of laboratory work #1	15
Implementation and protection of laboratory work #2	15
Implementation and protection of laboratory work #3	15
Implementation and protection of laboratory work #4	15
Rп	**60**
Examination (Re)	**40**
Total for the semester (**R = Rп + Re)**	**100**

The student's **individual rating** consists of the points he receives for performing laboratory work. During the semester, students perform four laboratory works. The maximum number of points for each work is 15. Points are awarded for:

- theoretical component - 7 points;
- practical component - 8 points.

A necessary condition for a student's admission to the semester control is his individual rating (Rp), not less than 59 points, and the absence of debt from laboratory work. If the mentioned requirements are not met, the student will not be admitted to the exam.

Conditions for crediting additional points.

As part of the study of the educational discipline "Computer systems", it is allowed to credit the points obtained on the basis of independent study of new approaches to significantly increasing the productivity of computer systems and preparation of an essay with original conclusions, provided that the program of this study has been agreed with the teacher in advance.

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

Scores	***Rating***
100-95	Perfectly
94-85	Very well
84-75	Well
74-65	Satisfactorily
64-60	Enough
Less than 60	Unsatisfactorily

Admission conditions not met	Not admitted

16. Additional information on the discipline (educational component)

The list of questions submitted for semester control.

1. The concept of the problems of significantly increasing productivity in modern conditions.
2. Concept of mass parallelization systems.
3. Concept of scalable systems.
4. Multiprocessor and multicomputer systems, their advantages and disadvantages.
5. NUMA systems.
6. Cluster systems.
7. GRID – systems.
8. CLOUD -systems.
9. Data-Flow – systems.
10. Associative memory and modern approaches to its organization.
11. Modern approaches to building effective systems that are controlled by the flow of data.
12. Prospects for building ultra-high-performance computer systems that are controlled by the flow of data.

Working program of the academic discipline (syllabus):

Folded, Ph.D., associate professor, Rusanova Olga Veniaminivna
Approved by the Department of Computer Engineering (protocol No. 10 dated 05.25.2022)

Agreed by the methodical commission of the faculty (protocol No. 10 dated 09.06.2022)

……