SARSEN AMANZHOLOV EAST KAZAKHSTAN UNIVERSITY

APPROVED
Chairman of the Council of the Higher School of IT and Natural Sciences

____________________ Adikanova S.
Protocol
№ from « » 2022 year

DISCIPLINE PROGRAM (SYLLABUS)

COMPUTER SIMULATION OF PHYSICAL PROCESSES

Name of the academic discipline

6B01509 – Physics-Computer Science
6B01502 – Physics
(code and name of the EP)

Form of study / full-time distance (fd/f) on the base of Higher education
(full-time)

Course 3
Term 6
Number of credits 5
Lectures 20
Practical (seminar) classes 30
Laboratory classes 0
IWST 25
IWS 75
Exam 6 semester

Ust-Kamenogorsk, 2022 year

The compiler: ________ Maulet Meruyert, lecturer of the Department of Physics and Technology Master

Discipline program (Syllabus)
Discipline program developed on the basis of standard curricula of the cycle of general education disciplines for organizations of higher and (or) postgraduate education (Order ME RK from 31.10.2018 year. № 603) (*for general education discipline*);

Discipline program (Syllabus) developed on the basis of the curriculum approved at the meeting of the Academic Council of the University
Protocol №___ «___» ___________202 year. (*for basic and profile disciplines*)

Recommended at the meeting of the Department of Physics and Technology
Protocol № «___» 202 year.

Head of the Department of Physics and Technology ________ Sakenova R.E.

1. Information about the discipline

<table>
<tr><td>Name of the discipline:
Methods of teaching physics in English</td><td>Discipline code
MOFAYa-2204</td><td>Number of credits
6</td><td>Course 2
Term 3</td></tr>
<tr><td>Code EP:
6B01509

6B01502</td><td>Title EP:
Physics-Computer Science
Physics</td><td>Department of Physics and Technology</td><td>Higher School of IT and Natural Sciences</td></tr>
<tr><td colspan="4">Time and place of the discipline
according to the schedule</td></tr>
<tr><td colspan="4">Consultation time - according to the schedule</td></tr>
<tr><td colspan="4">Rating schedule: 7 and 15 weeks</td></tr>
<tr><td colspan="2">Full name of the teacher, academic degree, academic title, activity /
Maulet Meruyert, lecturer of the Department of Physics and Technology Master</td><td colspan="2">Contact details (telephone, e-mail)
+7-705-214-15-88
maulet_meruert@mail.ru</td></tr>
</table>

2. Brief description of the discipline:

This discipline is intended for mastering the practical course of mathematical and computer modeling of physical processes. At present, mathematical modeling is one of the most rapidly developing branches of modern applied and computational mathematics. A mathematical model is an approximate description of a physical phenomenon or an object of the real world with the help of a mathematical apparatus. The course includes the study of methods for the numerical solution of problems associated with research of natural-physical and physical-technological processes on the basis of mathematical modeling. It is important to note that modeling is also a method of cognition of the surrounding world, which makes it possible to study in detail the processes taking place in it, since it is not always possible to carry out a full-scale experiment.

Purpose:

The goal of the course is to provide students with skills in using physical processes with mathematical equations, using of numerical methods as a main tool in solving of those equations and their graphic processing for achieving results.

Tasks:

Students successfully completing the course will be able to:

- Construction of mathematical models of physical processes
- Discretization of differential equations of mathematical physics
- Select the correct numerical method
- Write code to construct mathematical models
- Plotting and animation for the results obtained
- Develop personal qualities self-study, to expand their knowledge of mathematical and computer modeling of physical processes
- Ability to deter a rational solution to the problem
- The ability to use scientific, reference, methodological literature on the subject

- The choice and use of information technology for applications.

Competencies

As a result of mastering the discipline, students develop the following competencies:

- the ability to use natural science and mathematical knowledge for orientation in the modern information space;
- ability to self-organize and self-education;
- willingness to implement the educational process in physics in accordance with the requirements of educational standards;
- willingness to use systematized theoretical and practical knowledge to formulate and solve research problems in the field of education;
- the ability to use the opportunities of the educational environment to achieve personal, meta-subject and subject learning outcomes and to ensure the quality of teaching physics;
- willingness to interact with participants in the educational process;

Result of training

By the end of the course, the leaner should be able to:

- select and use appropriate instruments to carry out measurements in the physical environment;
- use the knowledge acquired to discover and explain the order of the physical environment
- use the acquired knowledge in the conservation and management of the environment
- apply the principles of Physics and acquired skills to construct appropriate scientific devices from the available resources
- develop capacity for critical thinking in solving problems in any situation
- contribute to the technological and industrial development of the nation
- appreciate and explain the role of Physics in promoting health in society
- observe general safety precautions in all aspects of life
- acquire and demonstrate a sense of honesty and high integrity in all aspects of Physics and life in general
- acquire positive attitude towards Physics

Acquire adequate knowledge in Physics for further education and/or training.

Prerequisites

№	Name of the discipline, sections (topics)
1	School physics course
2	Mathematics
3	General and Theoretical Physics course
4	Computer science
5	Psychology

6	Pedagogy
7	English language

List of post-requisites

№	**Name of the discipline, sections (topics)**
1	Workshop on solving physical problems
2	Pre-graduate practice

5. Calendar and thematic plan

№	**Name of the discipline topics**	**weeks**	**Number of classroom hours by type of classes**		**Number of extracurricular hours by type of occupation**		**Total (hours)**
			Lecture (hours)	**Pract/sem/ lab/stud (hours)**	**IWST (hours)**	**IWS (hours)**	
1	Introduction to finite-difference time-domain method	**1**	**1**	**2/0/0**	**1**	**5**	**9**
2	Numerical stability and dispersion	**2**	**1**	**2/0/0**	**1**	**5**	**9**
3	Building objects in the Yee grid	**3**	**1**	**2/0/0**	**1**	**5**	**9**
4	Active and passive lumped elements	**4**	**1**	**2/0/0**	**1**	**5**	**9**
5	Source waveforms and time to frequency domain transformation	**5**	**1**	**2/0/0**	**1**	**5**	**9**
6	S-Parameters	**6**	**1**	**2/0/0**	**2**	**5**	**10**
7	Perfectly matched layer absorbing boundary	**7**	**1**	**2/0/0**	**2**	**5**	**10**
8	Advanced PML formulations	**8**	**1**	**2/0/0**	**2**	**5**	**10**
9	Near-field to far-field transformation	**9**	**1**	**2/0/0**	**2**	**5**	**10**
10	Thin-wire modeling	**10**	**1**	**2/0/0**	**2**	**5**	**10**
11	Scattered field formulation	**11**	**2**	**2/0/0**	**2**	**5**	**11**
12	Total field/scattered field formulation	**12**	**2**	**2/0/0**	**2**	**5**	**11**
13	Dispersive material modeling	**13**	**2**	**2/0/0**	**2**	**5**	**11**
14	Analysis of periodic structures	**14**	**2**	**2/0/0**	**2**	**5**	**11**
15	Nonuniform grid. Graphics processing unit acceleration of FDTD method	**15**	**2**	**2/0/0**	**2**	**5**	**11**
	Total		**20**	**30/0/0**	**25**	**75**	**150**

6. Content of lectures

Topic 1. Introduction to finite-difference time-domain method

The finite-difference time-domain method basic equations, Approximation of derivatives by finite differences, FDTD updating equations for three-dimensional problems, FDTD updating equations for two-dimensional problems, FDTD updating equations for one-dimensional problems.

Literature: [1,2,5].

Topic 2. Numerical stability and dispersion

Numerical stability, Stability in time-domain algorithm, CFL condition for the FDTD method, Numerical dispersion, Creation of the material grid, .

Literature: [1,2,5].

Topic 3. Building objects in the Yee grid

Definition of objects, Material approximations, Subcell averaging schemes for tangential and normal components, Defining objects snapped to the Yee grid, Improved eight-subcell averaging.

Literature: [1,2,5].

Topic 4. Active and passive lumped elements

FDTD updating equations for lumped elements, Definition, initialization, and simulation of lumped elements, Simulation examples

Literature: [5].

Topic 5. Common source waveforms for FDTD simulations

Common source waveforms for FDTD simulations, Definition and initialization of source waveforms for FDTD simulations, Transformation from time domain to frequency domain, Simulation examples.

Literature: [1,2,5].

Topic 6. S-Parameters

Scattering parameters, S-Parameter calculations, Simulation examples.

Literature: [1,2,5].

Topic 7. Perfectly matched layer absorbing boundary

Theory of PML, PML equations for three-dimensional problem space, PML loss functions, FDTD updating equations for PML and MATLAB implementation, Simulation examples.

Literature: [7,4,5].

Topic 8. Advanced PML formulations

Formulation of CPML, The CPML algorithm, CPML parameter distribution, MATLAB implementation of CPML in the three-dimensional FDTD method, Simulation examples, CPML in the two-dimensional FDTD method, MATLAB implementation of CPML in the two-dimensional FDTD method, Auxiliary differential equation PML.

Literature: [1,2,5,6].

Topic 9. Near-field to far-field transformation

Implementation of the surface equivalence theorem, Frequency domain near-field to far-field transformation, MATLAB implementation of near-field to far-field transformation, Simulation examples.

Literature: [1,2,5,6].

Topic 10. Thin-wire modeling

Thin-wire formulation, MATLAB implementation of the thin-wire formulation, Simulation examples, An improved thin-wire model, MATLAB implementation of the improved thin-wire formulation, Simulation example.

Literature: [1,2,5,6].

Topic 11. Scattered field formulation

Scattered field basic equations, The scattered field updating equations, Expressions for the incident plane waves, MATLAB implementation of the scattered field formulation, Simulation examples.

Literature: [1,2,5,3].

Topic 12. Total field/scattered field formulation

Introduction, MATLAB implementation of the TF/SF formulation, Simulation examples.

Literature: [1,2,5,3].

Topic 13. Dispersive material modeling

Modeling dispersive media using ADE technique, MATLAB implementation of ADE algorithm for Lorentz medium, Simulation examples.

Literature: [1,2,5].

Topic 14. Analysis of periodic structures

Periodic boundary conditions, Constant horizontal wavenumber method, Source excitation, Reflection and transmission coefficients, MATLAB implementation of PBC FDTD algorithm, Simulation examples.

Literature: [5]

Topic 15. Nonuniform grid Graphics processing unit acceleration of finite-difference time-domain method.

Introduction, Transition between fine and coarse grid subregions, FDTD updating equations for the nonuniform grids, Active and passive lumped elements, Defining objects snapped to the electric field grid, MATLAB implementation of nonuniform grids, Simulation examples. GPU programming using CUDA, CUDA implementation of two-dimensional FDTD, Performance of two-dimensional FDTD on CUDA

Literature: [5]

7. The content of practical (seminar) classes

Topic 1. Introduction to finite-difference time-domain method

The finite-difference time-domain method basic equations, Approximation of derivatives by finite differences, FDTD updating equations for three-dimensional problems, FDTD updating equations for two-dimensional problems, FDTD updating equations for one-dimensional problems.

Literature: [1,2,5].

Topic 2. Numerical stability and dispersion

Numerical stability, Stability in time-domain algorithm, CFL condition for the FDTD method, Numerical dispersion, Creation of the material grid, .

Literature: [1,2,5].

Topic 3. Building objects in the Yee grid

Definition of objects, Material approximations, Subcell averaging schemes for tangential and normal components, Defining objects snapped to the Yee grid, Improved eight-subcell averaging.

Literature: [1,2,5].

Topic 4. Active and passive lumped elements

FDTD updating equations for lumped elements, Definition, initialization, and simulation of lumped elements, Simulation examples

Literature: [5].

Topic 5. Common source waveforms for FDTD simulations

Common source waveforms for FDTD simulations, Definition and initialization of source waveforms for FDTD simulations, Transformation from time domain to frequency domain, Simulation examples.

Literature: [1,2,5].

Topic 6. S-Parameters

Scattering parameters, S-Parameter calculations, Simulation examples.

Literature: [1,2,5].

Topic 7. Perfectly matched layer absorbing boundary

Theory of PML, PML equations for three-dimensional problem space, PML loss functions, FDTD updating equations for PML and MATLAB implementation, Simulation examples.

Literature: [7,4,5].

Topic 8. Advanced PML formulations

Formulation of CPML, The CPML algorithm, CPML parameter distribution, MATLAB implementation of CPML in the three-dimensional FDTD method, Simulation examples, CPML in the two-dimensional FDTD method, MATLAB implementation of CPML in the two-dimensional FDTD method, Auxiliary differential equation PML.

Literature: [1,2,5,6].

Topic 9. Near-field to far-field transformation

Implementation of the surface equivalence theorem, Frequency domain near-field to far-field transformation, MATLAB implementation of near-field to far-field transformation, Simulation examples.

Literature: [1,2,5,6].

Topic 10. Thin-wire modeling

Thin-wire formulation, MATLAB implementation of the thin-wire formulation, Simulation examples, An improved thin-wire model, MATLAB implementation of the improved thin-wire formulation, Simulation example.

Literature: [1,2,5,6].

Topic 11. Scattered field formulation

Scattered field basic equations, The scattered field updating equations, Expressions for the incident plane waves, MATLAB implementation of the scattered field formulation, Simulation examples.

Literature: [1,2,5,3].

Topic 12. Total field/scattered field formulation

Introduction, MATLAB implementation of the TF/SF formulation, Simulation examples.

Literature: [1,2,5,3].

Topic 13. Dispersive material modeling

Modeling dispersive media using ADE technique, MATLAB implementation of ADE algorithm for Lorentz medium, Simulation examples.

Literature: [1,2,5].

Topic 14. Analysis of periodic structures

Periodic boundary conditions, Constant horizontal wavenumber method, Source excitation, Reflection and transmission coefficients, MATLAB implementation of PBC FDTD algorithm, Simulation examples.

Literature: [5]

Topic 15. Nonuniform grid Graphics processing unit acceleration of finite-difference time-domain method.

Introduction, Transition between fine and coarse grid subregions, FDTD updating equations for the nonuniform grids, Active and passive lumped elements, Defining objects snapped to the electric field grid, MATLAB implementation of nonuniform grids, Simulation examples. GPU programming using CUDA, CUDA implementation of two-dimensional FDTD, Performance of two-dimensional FDTD on CUDA

Literature: [5]

8. Content of laboratory classes

Laboratory work is not provided for in the curriculum

9. IWST and IWS tasks

№	Name of topics	Content of tasks for IWST and IWS	Form of control	Deadline for delivery
Topic 1	Introduction to finite-difference time-domain method	Students' work with literature	Protection of the abstract	1
Topic 2	Numerical stability and dispersion	Students' work with textbooks, notes	oral explanation of the material	3
Topic 3	Building objects in the Yee grid	Students' work with physical devices	demonstration of a physical experiment with an explanation	4
Topic 4	Active and passive lumped elements	Student work with problem books, notes	Protection of the selection of tasks and methods of their solution	5-6
Topic 5	Source waveforms and time to frequency domain transformation	Students' work with textbooks, notes	Explanation of the material with the use of the outline	7-8
Topic 6	S-Parameters	Students' work with textbooks, notes	Explanation of new material with the creation of a problem situation	9
Topic 7	Perfectly matched layer absorbing boundary	Students work on computers	Explanation of the new material with the use of slides	10-11
Topic 8	Advanced PML formulations	Students' work with textbooks, notes	Protect task selection	12-13
Topic 9	Near-field to far-field transformation	Students' work with textbooks, notes	Conducting an extracurricular activity in physics	14
Topic 10	Thin-wire modeling	Students' work with textbooks, notes	Written outline	15

Consultation on all issues - on schedule.

10. Evaluation policy and criteria *(choose in the language of instruction)*

One of the elements of the organization of the educational process in the conditions of credit technology of training is the use of a point-rating system for assessing the educational achievements of students. The grading policy is based on the principles of objectivity, transparency, flexibility and high differentiation.

The study of the discipline ends with an exam in various forms (written or oral exam, testing), which covers all the material passed. A prerequisite for admission to the exam is the completion of all the tasks provided in the program.

Each task is rated 0-100 points.

№	**Type of work**	Score (max point) for one task	Number of tasks	The amount
Rating 1				
1	individual tasks	100	1	100
2	performing and protecting laboratory work	100	5	500
…	test papers and colloquiums	100	2	200
			Total	800/8 = 100
Rating 2				
1	individual tasks	100	1	100
2	performing and protecting laboratory work	100	5	500
…	test papers and colloquiums	100	2	200
			Total	800/8 = 100

The assessment of the admission rating, which is calculated as the arithmetic mean of the sum of all the assessments of the current and boundary controls received during the academic period:

$$AR = (CC_1 + CC_2 + CC_3 + \ldots + CC_n + BC_1 + BC_2) / (n+2),$$

where, AR – admission rating; CC – current control; BC – border control; n – number of current controls; 2 – number of boundary controls.

Students who have fulfilled all the requirements of the discipline program (execution and delivery of all practical (seminar, laboratory) works and tasks on IWST, IWS), who have scored an admission rating (at least 50 points) are allowed to the final control (FC) in the discipline. Students who do not have a positive assessment of the admission rating in the discipline (at least 50%) are not allowed to take the exam.

The final grade for the discipline is calculated automatically according to the formula:

$$T = (R_1+R_2)/2*0,6+ \text{ex. assessment} *0,4,$$

where, R_1 – evaluation of the first boundary control; R_2 – evaluation of the second boundary control.

The final grade in the discipline is calculated only if the student has positive grades, both according to the admission rating and according to the final control. If you do not show up for the final control for a valid or disrespectful reason, "0" (zero) is set in the "Exam score" column. The results of the intermediate certification in the discipline are brought to the students on the same day.

A letter-based system for evaluating students' academic achievements, corresponding to the digital equivalent of a four-point system

Rating by letter system	Digital equivalent of points	% content	Assessment according to the traditional system
A	4,0	95-100	Great
A-	3,67	90-94	
B+	3,33	85-89	Well
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	0-49	

11. Teacher requirements *(choose in the language of instruction)*

The policy of evaluating students' academic achievements is based on the principles of academic honesty, unity of requirements, objectivity and fairness, openness and transparency.

At the first training session, the teacher introduces students to the content of the syllabus of the discipline, the planned results of training in the academic discipline and the procedures for their assessment.

In case of academic dishonesty on the part of university students:

- *during classroom and extracurricular activities*: after the first violation committed, the established commission conducts a conversation with the student; the act records the warning issued and the measure taken (reduction of the assessment for the work being evaluated; cancellation of the student's written work, recommendation to re-conduct the control event, etc.). In case of repeated admission of the facts of academic dishonesty during the academic year, a commission is created again, an act is drawn up and submitted to the Disciplinary and Anti-Corruption Council (hereinafter referred to as ACC) for further decisions;

- *during the intermediate or final certification:* a student who has shown academic dishonesty is removed from the classroom without the right to retake the exam during the same academic period. At the same time, an entry "Removed from the exam for academic dishonesty" is entered in the examination sheet with an indication of its type. Repeated passing of the exam is carried out in the Summer semester or in the next academic semester on a paid basis. At the same time, the student re-enrolls in this academic discipline, attends all types of training sessions, performs all types of academic work according to the working curriculum and passes the exam. In case of repeated removal from the exam (during the entire period of study at the university), the student is expelled without the right to further reinstatement to the university.

Attendance by students of all classroom classes without delay is mandatory. In case of missing classes, they are worked out in accordance with the procedure established by the dean's office.

The presence of outsiders at lectures who are not a contingent of the student of this course is prohibited.

The work should be handed in by the specified deadline. The deadline for all assignments is 5 days before the exam session.

Repetition of the topic and rehearsal of passed material on each training session is mandatory. The degree of mastery of the study materials is checked by tests or written work. A student may be tested without warning.

When performing independent work of a student under the guidance of a teacher (IWST), consider the following main functions:

- The first - involves the implementation of the active perception of the students of the teacher's information received during the introductory classes in the academic discipline;

- the second function assumes that students independently, based on the recommendations of the teacher, study educational and methodological manuals, literary sources, do homework, tests and coursework, etc. At this stage, the student is required to know the methods of work, fix their difficulties, self-organization and self-discipline;

- the third function is to analyze and systematize their difficult situations, identify the causes of difficulties in understanding and mastering the learning material, performing other learning activities. Students translate insoluble difficulties into a system of questions for the teacher (rank them, arrange them, design them), and build their own versions of answers to these questions;

- The fourth function is to ask the teacher for appropriate explanations, advice, and counseling.

11. Exam questions

1. The finite-difference time-domain method basic equations
2. Approximation of derivatives by finite differences
3. FDTD updating equations for three-dimensional problems
4. FDTD updating equations for two-dimensional problems
5. FDTD updating equations for one-dimensional problems
6. Stability in time-domain algorithm
7. CFL condition for the FDTD method
8. Numerical dispersion
9. Defining the problem space parameters
10. Defining the objects in the problem space
11. Material approximations
12. Subcell averaging schemes for tangential and normal components

13. FDTD updating equations for lumped elements
14. Definition, initialization, and simulation of lumped elements
15. Common source waveforms for FDTD simulations
16. Definition and initialization of source waveforms for FDTD simulations
17. Transformation from time domain to frequency domain
18. Scattering parameters
19. S-Parameter calculations
20. Theory of PML at the vacuum–PML interface
21. PML equations for three-dimensional problem space
22. FDTD updating equations for PML and MATLAB implementation
23. PML in stretched coordinates
24. MATLAB implementation of CPML in the two-dimensional FDTD method Reflecting on your own assessment experiences
25. Implementation of the surface equivalence theorem
26. Frequency domain near-field to far-field transformation
27. MATLAB implementation of the thin-wire formulation
28. Scattered field basic equations
29. Total field/scattered field formulation
30. Modeling dispersive media using ADE technique
31. Periodic boundary conditions
32. Reflection and transmission coefficients
33. Transition between fine and coarse grid subregions
34. Defining objects snapped to the electric field grid
35. Graphics processing unit acceleration of finite-difference time-domain method

12. References

1. Atef Z., Veysel D. The Finite-Difference Time-Domain Method for Electromagnetics with MATLAB Simulations / SeiTech Publishing. — 2015. — 559p.
2. Michalowski T. Applications of MATLAB in science and engineering / InTech. — 2011. — 552p.
3. Vasilios N. K. MATLAB – A fundamental tool for scientific computing and engineering applications – volume 1 / InTech. — 2012. — 533p.
4. Vasilios N. K. MATLAB – A fundamental tool for scientific computing and engineering applications – volume 3 / InTech. — 2012. — 598p.
5. Barth T.J., Griebel M., Keyes D.E., Nieminen R.M., Roose D., Schlick T. Programming for Computations – MATLAB/Octave / This book is published open access. DOI 10.1007/978-3-319-32452-4
6. Blain J.M. The Complete Guide to Blender Graphics Computer Modeling & animation 3rd Edition / Taylor&Francis Group. — 2016. — 610p.
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Additions and changes to the discipline program (Syllabus) for the discipline_ Computer simulation of physical processes
_20 ____ /____ academic year

The following changes are made to the discipline program:
1. ____
2. ____
3. ____
4. ____
5. ____

The discipline program (**Syllabus**) has been revised, the changes made were approved at a meeting of the Department of Physics and Technology

Protocol № _________ «________»__________________20 year.

Teacher _____________ Maulet Meruyert.

Head of the Department of Physics and Technology ________ Sakenova R.E.

The changes made have been agreed:

Chairman CHS IT NS___________________ Adikanova S.
signature

Protocol № ______ «________»________________20 year