Al-FARABI KAZAKH NATIONAL UNIVERSITY
FACULTY MECHANICS AND MATHEMATICS
Educational program on specialty «050603-Mechanics»

Approved
at the meeting of Academic Council
of the faculty of Mechanics and Mathematics

Protocol №___from « ____»_______ 2016
Dean of the Faculty ______ Bektemesov M.A.

SYLLABUS
"APPLIED PROBLEMS OF GAS AND FLUID MECHANICS"
CH 4313, COMPUTATIONAL FLUID MECHANICS

4th year bachelor students «05060300-Mechanics»,
Spring semester, 3 credits

Lecturer/Labs Teacher: Yerzhan Belyayev, Doctor PhD
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Activities under the program of the course is set in the form of lectures. Practical fastening of the lecture materials is carried out in a laboratory studies and IWST (independent work of a student with a teacher) in accordance with the schedule and the program. Tasks for IWS (independent work of a student) and verification of IWS is carried out by lecturer. Midterm exams takes Labs teacher.

Aim of the course. To teach students the fundamentals of Computational Fluid Mechanics (Dynamics), the basic research methods of CFD, to teach them to understand the basic equations and to introduce the fundamental axioms, hypotheses and modern approach of numerical modeling. The purpose of discipline is familiarize students with the methods of solution for hyperbolic, parabolic and elliptic type of equations, which are covered with practical applications. Concept of the course is based on the book "Computational Fluid Dynamics" by Klaus A. Hoffmann and Steve T. Chiang. As a result of studying the course, students should know the basic numerical methods, to be able to recognize and simulate problems in Fluid Mechanics and Gas Dynamics.

Objectives of the course. Computational Fluid Dynamics (CFD) - a branch of science that emerged at the intersection of Computational Mathematics and Theoretical Fluid Mechanics. The subject of this branch of science is a numerical simulation of a variety of liquid and gas flows, and the obtained solution of problems on computers. Among the many areas of the subject can be specified for calculating the motion of a viscous fluid, numerical study of gas flows with the physical and chemical transformations, the study of the propagation of shock waves in various media, the solution gas-dynamic problems in the presence of radiation, etc. The proposed discipline, we limit our discussion to just one of these areas - numerical calculation of viscous fluid flows described by the Navier-Stokes equations.

Learning outcomes. Necessary knowledge in the basics of Computational Fluid Mechanics, CFD and skills to solve the problems of Fluid Mechanics and Gas Dynamics.

General competence:

- instrumental – the ability to assess the methodological approaches to carry out their critical analysis;
- interpersonal – ability to independently develop and deepen their knowledge and acquire new skills in a professional manner; knowledge of a foreign language in an amount sufficient to communicate freely in arbitrary topics;
- system – the ability to plan the steps of solving professional problems and implement them in time; demonstrate independence and original approach to problem solving, the ability to justify and make decisions.

Subject specific competences: owning a deep fundamental theoretical knowledge in the CFD, modern problems of Fluid Mechanics and Gas Dynamics.

Prerequisites: “Fluid Mechanics”, “Continuum Mechanics”, “Differential Equations”, “Mathematical Physics”, “Programming Languages”.

Post requisites: “Numerical Methods”, “CFD”.

STRUCTURE AND CONTENT OF THE SUBJECT

Week	Title of the theme	Hour	Grade
1	**Lecture 1.** Classification of partial differential equations. **Lab.1.** Elliptic, parabolic, hyperbolic equations. **IWM 1.** Initial and boundary conditions.	2 1	14
2	**Lecture 2.** Finite difference formulations. **Lab.2.** Taylor series expansion. **IWM 2.** Test problems.	2 1	14
3	**Lecture 3.** Parabolic partial differential equations. **Lab.3.** Explicit and implicit methods. **IWM 3.** Example problem.	2 1	14
4	**Lecture 4.** Stability analysis. **Lab.4.** Von Neumann Stability analysis. **IWM 4.** Artificial viscosity.	2 1	14
5	**Lecture 5.** Finite difference formulations of elliptic equations. **Lab.5.** Solution algorithms. The Jacobi iteration method, PSOR. **IWM 5.** Test problem. The Gauss-Seidel iteration method.	2 1	14
6	**Lecture 6.** Hyperbolic equations. **Lab.6.** Explicit and implicit methods. **IWM 6.** Linear test problem.	2 1	14
7	**Lecture 7.** Hyperbolic equations. Nonlinear problem. **Lab.7.** Monotone schemes formulations. **IWM 7.** TVD formulations.	2 1	16
	1st control test	1	**100**
	Midterm exam	1	**100**
8	**Lecture 8.** Scalar representation of Navier-Stokes equations. **Lab.8.** Numerical algorithms. **IWM 8.** Applications: nonlinear problem.	2 1	12
9	**Lecture 9.** Incompressible Navier-Stokes equations.	2	12

	Lab.9. Primitive variable formulations. **IWM 9.** Vorticity-stream function formulations.	 1	
10	**Lecture 10.** Numerical algorithms: primitive variables. **Lab.10.** Steady flows. Crank-Nicolson implicit. **IWM 10.** Boundary conditions.	2 1	12
11	**Lecture 11.** Numerical-algorithms: vorticity-stream function formulation. **Lab.11.** Boundary conditions. **IWM 11.** Temperature field.	2 1	12
12	**Lecture 12.** Grid generation – structured grids. **Lab.12.** Grid generation techniques. **IWM 12.** Elliptic grid generators.	2 1	12
13	**Lecture 13.** Hyperbolic grid generation techniques. **Lab.13.** Parabolic grid generators. **IWM 13.** Problems.	2 1	12
14	**Lecture 14.** An introduction to theory of characteristics: wave propagation. **Lab.14.** Basic equations. **IWM 14.** Problems.	2 1	12
15	**Lecture 15.** Engineering applications. **Lab.15.** Commercial software examples. **IWM 15.** Prepare a presentation.	2 1	16
	2nd control test	1	100
	Exam		**100**
	TOTAL		**(1CT+2CT)/2*0.6 +0.1*MT+0.3*EXAM**

LIST OF LITERATURE

Main:

1. Klaus A. Hoffmann and Steve T. Chiang Computational Fluid Dynamics // 4th Edition, Volume 1 Engineering Education Systems, First print August 2000, ISBN 0-9623731-0-9, P. 486.
2. П. Роуч Вычислительная гидродинамика. Москва «Мир» 1980, 616 с.
3. Д. Андерсон, Дж. Таннехилл, Р. Плетчер Вычислительная гидромеханика и теплообмен. Том 1-2, Москва «Мир» 1990. – 726 с.
4. К. Флетчер Вычислительные методы в динамике жидкостей. Том 1-2, Москва «Мир» 1991. Том 1 – 502 с., Том 2 – 552 с.

Additional:

1. T. J. Chung Computational Fluid Dynamics. Cambridge University Press, 2002, p. 1012
2. Хейгеман Л., Янг Д. Прикладные итерационные методы. Мир. 1996г, 446 с.

3. Роже Пейре, Томас Д. Тейлор. Вычислительные методы в задачах механики жидкости.//Ленинград, 1986г, 350 стр.
4. Марчук Г.И. Методы вычислительной математики. М.: Наука. 1980г.
5. Самарский. Теория разностных схем. Наука. 1980г.
6. OpenFOAM User Guide. 2014.

GUIDLINES

All the assignments must be completed until due date. Students, who could not earn 50% out of 100% during first or second midterm and final, will be able to work off during an additional term. Late assignment is not accepted except for extenuating circumstances (e.g. field trip, hospitalization). Student, who failed to meet all kinds of work, is not allowed for passing an exam. In addition, the assessment takes into account the activity and attendance of students during class.

Be tolerant and respect other people's opinions. The objections should be formulated in a correct manner. Plagiarism and other forms of cheating are not allowed. Cheating is not accepted during independent work of student (IWS), midterm and final exam, copying solved problems from others, passing the exam to another student are not allowed also. Student convicted of falsifying any information about the course, any unauthorized upload to the “Intranet” using cheat sheets, will be graded with a final grade «F». For advice on the implementation of IWS, submitting and defending, as well as additional information on the studied material and all the other issues that arose upon studying the course, contact the instructor during his office hours.

Letter grade	Numerical equivalency	% (percentage)	Grading in a traditional way
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	Satisfactory
C	2,0	65-69	
C-	1,67	60-64	
D+	1,33	55-59	
D-	1,0	50-54	
F	0	0-49	Unsatisfactory
I (Incomplete)	-	-	«The course is incomplete» (this isn’t taken into account when calculating the *GPA)*
P (Pass)	-	-	«Passed» (this isn’t taken into account when calculating the *GPA)*
NP (No Pass)	-	-	«Not passed» (this isn’t taken into account when calculating the *GPA)*
W	-	-	«the course is withdrawn»

(Withdrawal)			(this isn't taken into account when calculating the *GPA)*
AW (Academic Withdrawal)			Withdrawn because of academic issues (this isn't taken into account when calculating the *GPA)*
AU (Audit)	-	-	«Audit» (this isn't taken into account when calculating the *GPA)*
Att.		30-60 50-100	Attested
Not att.		0-29 0-49	Not attested
R (Retake)	-	-	Retaking the course

Considered in department meeting
Protocol № __ from «__» ___________

Head of the department of Mechanics ____________________ Z. Rakisheva

Lecturer ____________________ Ye. Belyayev