**Al-Farabi KAZAKH NATIONAL UNIVERSITY**

**Faculty of mechanics and mathematics**

**Educational program for the specialty « Mathematical and computer modelling»**

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|  | Approved by the Faculty Scientific Council meetingProtocol №\_\_\_ from \_\_\_\_\_\_\_\_\_\_\_\_ 2013 **Dean of the faculty**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_A. Kadyrbekuly** |

**SULLABUS**

**Module No. \_\_\_ “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_”**

**«\_\_\_\_\_\_\_\_\_» «Numerical methods   
for mathematical physics inverse problems»**

master degree, 2 course, autumn semester, 2 credits

**Serovajsky Simon, Doctor of Science, Professor, Professor**

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**Aim and problems of the course:**

**Aim:**

Practical solving of mathematical physics inverse problems.

**Problems:**

Numerical methods for mathematical physics inverse problems.

**Results:**

Knowledge of the numerical methods for mathematical physics inverse problems.

**Pre Essential Elements**:

Numerical methods. Calculus of variational and optimization methods. Differential equations. Mathematical physics equations.

**Post** **Essential Elements**:

Identification of mathematical models.

**STRUCTURE AND CONTENT OF THE COURSE**

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| --- | --- | --- | --- |
| **week** | **subject** | **hours** | **maximal mark** |
| **Module 1. Introduction** | | | |
| **1** | **Lecture 1. Conception of inverse problems. Examples:** the fall of the body, the synthesis of the hydrochloric acid, “the predator-prey” model. Direct and inverse problems. Basic idea of solving of the inverse problems. Well-posedness of problems. | 1 | 0 |
| **Practical work 1**. Examplesof easiest inverse problems. | 1 | 3 |
| **Homework 1**. Examplesof easiest inverse problems. | 1 | 10 |
| **Module 2. Basic optimization control theory** | | | |
| **2** | **Lecture 2. Minimization of functions.** Stationary condition. Gradient method. | 1 | 1 |
| **Practical work 2**. Minimization of functions. | 1 | 3 |
| **Homework 2**. Minimization of functions. | 1 | 10 |
| **3** | **Lecture 3. Differentiation of functionals.** Gateaux derivative. Examples. | 1 | 2 |
| **Practical work 3**. Calculation of Gateaux derivatives. | 1 | 3 |
| **Homework 3.** Calculation of Gateaux derivatives. | 1 | 10 |
| **4** | **Lecture 4. Minimization of functionals.** Stationary condition. Gradient method. | 1 | 1 |
| **Practical work 4**. Minimization of functionals. | 1 | 3 |
| **Homework 4**. Minimization of functionals. | 1 | 10 |
| **Module 3. Inverse problems for elliptic equations** | | | |
| **5** | **Lecture 5. Source inverse problem for Poisson equation.** Stationary conditions and gradient method. | 1 | 2 |
| **Practical work 5**. Source inverse problem for Poisson equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 5**. Source inverse problem for Poisson equation. Gradient method. | 1 | 10 |
| **6** | **Lecture 6. Boundary inverse problem for Poisson equation.** Stationary conditions and gradient method. | 1 | 1 |
| **Practical work 6.** Boundary inverse problem for Poisson equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 6.** Boundary inverse problem for Poisson equation. Calculation of the functional gradient. | 1 | 10 |
| **7** | **Lecture 7. Coefficient inverse problem for Helmholtz** **equation.** Stationary conditions and gradient method. | 1 | 2 |
| **Practical work 7.** Coefficient inverse problem for Helmholtz equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 7.** Coefficient inverse problem for Helmholtz equation. Calculation of the functional gradient. | 1 | 10 |
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| **Border control 1** |  | **100** |
|  | | | |
| **Module 4. Inverse problems for parabolic equations** | | | |
| **8** | **Lecture 8. Source inverse problem for the heat equation**. Stationary conditions and gradient method. | 1 | 1 |
| **Practical work 8.** Source inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 8.** Source inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 8 |
| **9** | **Lecture 9. Time inverse problem for the heat equation**. Stationary conditions and gradient method. | 1 | 2 |
| **Practical work 9.** Time inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 9.** Time inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 8 |
| **10** | **Lecture 10. Boundary inverse problem for the heat equation**. Stationary conditions and gradient method. | 1 | 1 |
| **Practical work 10.** Boundary inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 10.** Boundary inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 8 |
| **11** | **Lecture 11. Coefficient inverse problem for the heat equation**. Stationary conditions and gradient method. | 1 | 2 |
| **Practical work 11.** Coefficient inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 11.** Coefficient inverse problem for the heat equation. Calculation of the functional gradient. | 1 | 8 |
| **Module 5. Module 4. Inverse problems for parabolic equations** | | | |
| **12** | **Lecture 12. Source inverse problem for the wave equation**. Stationary conditions and gradient method. | 1 | 1 |
| **Practical work 12.** Source inverse problem for the wave equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 12.** Source inverse problem for the wave equation. Calculation of the functional gradient. | 1 | 8 |
| **13** | **Lecture 13. Boundary inverse problem for the wave equation**. Stationary conditions and gradient method. | 1 | 2 |
| **Practical work 13.** Boundary inverse problem for the wave equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 13.** Boundary inverse problem for the wave equation. Calculation of the functional gradient. | 1 | 8 |
| **14** | **Lecture 14**. **Coefficient inverse problem for the wave equation**. Stationary conditions and gradient method. | 1 | 1 |
| **Practical work 14**. Coefficient inverse problem for the wave equation. Calculation of the functional gradient. | 1 | 3 |
| **Homework 14.** Coefficient inverse problem for the wave equation. Calculation of the functional gradient. | 1 | 8 |
| **Module 5. Well-posedness of the optimization control problems and regularization methods** | | | |
| **15** | **Lecture 15. Well-posedness of the optimization control problems and regularization methods.** Example of Tihonov’s ill-posed problem.Example of Hadamard’s ill-posed problem.Regularization methods. | 1 | 2 |
| **Practical work 15.** Regularization methods for the concrete problems. | 1 | 3 |
| **Homework 15.** Regularization methods for the concrete problems. | 1 | 8 |
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| **Border control 2** |  | **100** |
|  | **Examination** |  | **100** |
|  | **TOTAL** |  | **100** |

**LITERATURE**

**Basic:**

1. Кабанихин С.И. Обратные и некорректные задачи. – Новосибирск, Сибирское научное изд-во, 2009.
2. Серовайский С.Я. Оптимизация и дифференцирование. – Алматы, Prinr-S, 2006.
3. Serovajsky S. Practical Course of the Optimal Control Theory with Examples. – Almaty, Қазақ университеті, 2011.
4. Алексеев В. М., Тихомиров В. М., Фомин С. В. Оптимальное управление. – М., Наука, 1979.
5. Kirk D. E. Optimal Control Theory: An Introduction. – New Jersey, Englewood Cliffs, 2004. <http://www.amazon.com/Optimal-Control-Theory-Introduction-Engineering/dp/0486434842>

**Additional:**

1. Serovajsky S. Counterexamples in optimal control theory. – Utrecht-Boston, VSP, 2004.
2. Серовайский С.Я. Контрпримеры в теории оптимального управления. – Алматы, Қазақ университеті, 2001.
3. Васильев Ф.П. Методы оптимизации. В двух томах. – М.: МЦНМО, 2011.
4. Канторович Л. В., Акилов Г. П. Функциональный анализ. – М., Наука, 1977.

АКАДЕМИЧЕСКАЯ Политика курса

Все виды работ необходимо выполнять и защищать в указанные сроки. Студенты, не сдавшие очередное задание или получившие за его выполнение менее 50% баллов, имеют возможность отработать указанное задание по дополнительному графику. Студенты, пропустившие лабораторные занятия по уважительной причине, отрабатывают их в дополнительное время в присутствии лаборанта, после допуска преподавателя. Студенты, не выполнившие все виды работ, к экзамену не допускаются. Кроме того, при оценке учитывается активность и посещаемость студентов во время занятий.

будьте толерантны, уважайте чужое мнение. Возражения формулируйте в корректной форме. Плагиат и другие формы нечестной работы недопустимы. Недопустимы подсказывание и списывание во время сдачи СРС, промежуточного контроля и финального экзамена, копирование решенных задач другими лицами, сдача экзамена за другого студента. Студент, уличенный в фальсификации любой информации курса, несанкционированном доступе в Интранет, пользовании шпаргалками, получит итоговую оценку «F».

За консультациями по выполнению самостоятельных работ (СРС), их сдачей и защитой, а также за дополнительной информацией по пройденному материалу и всеми другими возникающими вопросами по читаемому курсу обращайтесь к преподавателю в период его офис-часов.

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| --- | --- | --- | --- |
| Letter mark | Number mark | % | Traditional mark |
| А | 4,0 | 95-100 | Very good |
| А- | 3,67 | 90-94 |
| В+ | 3,33 | 85-89 | Good |
| В | 3,0 | 80-84 |
| В- | 2,67 | 75-79 |
| С+ | 2,33 | 70-74 | Satisfactory |
| С | 2,0 | 65-69 |
| С- | 1,67 | 60-64 |
| D+ | 1,33 | 55-59 |
| D- | 1,0 | 50-54 |
| F | 0 | 0-49 | Non satisfactory |
| I  (Incomplete) | - | - | «The course is not finished»  (*do not take into consideration of GPA)* |
| P  (Pass) | **-** | **-** | «given a credit»  (*do not take into consideration of GPA)* |
| NP  (No Рass) | **-** | **-** | «did not give a credit»  (*do not take into consideration of GPA)* |
| W  (Withdrawal) | - | - | «renunciation of the course»  (*do not take into consideration of GPA)* |
| AW  (Academic Withdrawal) |  |  | Renunciation of the course by academic cause  (*do not take into consideration of GPA)* |
| AU  (Audit) | - | - | «the course is listen»  (*do not take into consideration of GPA)* |
| Атт. |  | 30-60  50-100 | Attested |
| Не атт. |  | 0-29  0-49 | No attested |
| R (Retake) | - | - | Retake the course |

Session № \_\_ of « \_\_ » \_\_\_\_\_\_\_\_\_\_\_ 2013.

**Head of the Department**

**Lecturer S. Serovajsky**