Syllabus
of educational component

Inverse measurement problems

Discipline name:	**Inverse measurement problems**
Higher education level:	**second (master's)**
Course page in Moodle:	***https://dl.khadi.kharkov.ua/course/view.php?id=2851***
The scope of the educational component:	**4 credits (120 hours)**
Final control form:	**Test**
Consultations:	**according to the schedule**
Name of the department:	**department of metrology and life safety**
Teaching language:	**English**
Head of the course:	**Oleksandr Poliarus, Doctor of Eng. Science., professor**
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Brief content of the educational component:

The goal is for applicants to acquire competence, knowledge, abilities and skills of mathematical description of input actions of measurement information systems based on output signals.
Subject: theoretical and methodological foundations of methods for solving inverse problems in measuring information systems and metrological support of these problems.
The main tasks of studying the academic discipline are:
- formation of systems of knowledge, skills and ideas about the current state of development of methods for solving inverse problems;
− assessment of the possibilities of applying methods of solving inverse problems in measurement information systems and automobile and road engineering;
- development of system analysis skills;
- formation of skills for evaluating metrological support of methods for solving inverse problems.
Prerequisites for studying the educational component:
Measuring information systems, Fundamentals of scientific research.

Competencies that the student acquires:

General competences:

Knowledge and understanding of the subject area and understanding of professional activity.
Skills in using information and communication technologies.
Ability to conduct research at an appropriate level.
Ability to identify, pose and solve problems.
The ability to evaluate and ensure the quality of the work performed.

Special (professional) competences:

The ability to apply suitable mathematical methods, computer technologies, as well as approaches to standardization and certification to solve tasks in the field of metrology and information and measurement technology.
Knowledge and understanding of scientific facts, concepts, theories, principles and methods of experimental informatics.

The ability to apply a systematic approach to solving scientific and technical tasks of metrology and information and measurement technology.
The ability to apply a comprehensive approach to solving experimental tasks using information and measurement equipment and application software.
The ability to demonstrate knowledge and understanding of mathematical principles and methods necessary for the creation of virtual means of measurement and information-measuring technology.
The ability to apply modern computer technologies in the design and research of intelligent measuring equipment.

Learning results:

Know and understand modern methods of conducting scientific research, organization and planning of experiments, computerized methods of research and processing of measurement results.
Know and understand the basic concepts of measurement theory, apply in practice and in computer modeling of objects and phenomena.
Understand the interdisciplinary connections and specialty contexts.
Be able to perform analysis of engineering products, processes and systems according to established criteria; choose and apply the most appropriate analytical, calculation and experimental methods for conducting research; interpret research results.

Topical plan

№ of the topic	Name of topics (lectures, laboratory works, practical lessons, independent work)	Number of hours	
		full-time	correspondence
1	LC Methodological problems of the inverse measurements theory.	2	2
	PL Compilation of the inverse measurement equation.	2	2
	IW Philosophical and methodological aspects of direct and inverse measurements.	12	14
2	LC Methods of exact solution of inverse measurement problems in linear inertial systems.	2	-
	PL The task of accurately restoring the input signal of the sensor.	2	-
	IW Methods of solving ill-posed inverse measurement problems.	12	-
3	LC Methods of approximate solution of inverse measurement problems in linear inertial systems.	2	-
	PL The problem of approximate restoration of the sensor input signal.	2	-
	IW Methods of dynamic errors reducing for input signals restoration.	12	14

4	LC Models of Volterra, Wiener and Hammerstein for nonlinear inertial systems.	2	-
	PL Comparison of the effectiveness of Volterra, Wiener and Hammerstein models.	2	-
	IW Limits of application of Volterra, Wiener and Hammerstein models.	12	14
5	LC Methods of approximate solution of inverse measurement problems in nonlinear inertial systems.	2	-
	PL Solving inverse measurement problems for nonlinear inertial problems with a quadratic transformation function.	2	-
	IW Quality criteria for solving inverse measurement problems.	12	14
6	LC Methods for solving inverse problems based on singular SVD decomposition and Koopman operators.	2	-
	PL The technique of transition from nonlinear to equivalent linear inertial systems using Koopman modes.	2	-
	IW Linear representation of a nonlinear system.	12	14
7	LC Applied inverse problems	2	-
	PL Image restoration with blind deconvolution.	2	-
	IW Areas of application of inverse problems.	8	14
8	LC Metrological support of inverse measurement problems.	2	2
	PL Standardization and determination of dynamic characteristics of measuring devices for qualitative solution of inverse measurement problems.	2	2
	IW Requirements for uncertainty sources in solving inverse measurement problems.	8	14
Разом	LC	16	4
	PL	16	4
	IW	88	112

Individual educational and research task (if available):

Solve the inverse measurement problem for a simple electronic circuit.

Teaching methods:

1) verbal: 1.1 traditional: lectures, explanations, stories, etc.;

1.2 interactive (non-traditional): problem lectures, discussions, etc.;

2) visual: method of illustrations, method of demonstrations;

3) practical: 3.1 traditional: practical classes, seminars;

3.2 interactive (non-traditional): trainings, brainstorming method.

Knowledge assessment system and requirements:

Current success rate

1 The current success of applicants for the performance of educational types of work in training classes and for the performance of independent work tasks is evaluated using a four-point rating scale with subsequent transfer to a 100-point scale. During the evaluation of the current academic performance, all types of work provided by the educational program are taken into account.

1.1 Lecture classes are evaluated by determining the quality of performance of specified tasks.

1.2 Practical classes are evaluated by the quality of performance of a control or individual task, performance and design of practical work.

2 The evaluation of the current academic performance of students of higher education is carried out at each practical session on a four-point scale ("5", "4", "Z", "2") and is entered in the journal of academic performance.

– “excellent”: the applicant mastered the theoretical material flawlessly, demonstrates deep knowledge of the relevant topic or academic discipline, the main provisions;

- "good": the applicant has mastered the theoretical material well, has the main aspects from primary sources and recommended literature, presents it in a reasoned way; has practical skills, expresses his thoughts on certain problems, but certain inaccuracies and errors are assumed in the logic of the presentation of theoretical content or in the analysis of practical ones;

- "satisfactory": the applicant has basically mastered the theoretical knowledge of the educational topic or discipline, orients himself in primary sources and recommended literature, but answers unconvincingly, confuses concepts, answers additional questions uncertainly, does not have stable knowledge; when answering questions of a practical nature, reveals inaccuracy in knowledge, does not know how to evaluate facts and phenomena, connect them with the future profession;

- "unsatisfactory": the applicant has not mastered the educational material of the topic (discipline), does not know scientific facts, definitions, hardly orients himself in primary sources and recommended literature, lacks scientific thinking, practical skills are not formed.

3 The final score for the current activity is determineded as the arithmetic mean sum of points for each lesson, for individual work, current test works according to the formula:

$$K^{current} = \frac{K1 + K2 + ... + Kn}{n},$$

where $K^{current}$ – final evaluation of success based on the results of current control; $K1, K2, ..., Kn$ – evaluation of the success of the n current control measure;

n – the number of measures of current control.

Estimates are converted into points according to the conversion scale (table 1).

Table 1 – Recalculation of the average grade for the current activity into a multi-point scale

4-point scale	100-point scale	4-point scale	100-point scale	4-point scale	100-point scale	4-point scale	100-point scale
5	100	4,45	89	3,90	78	3,35	67
4,95	99	4,4	88	3,85	77	3,3	66
4,9	98	4,35	87	3,80	76	3,25	65
4,85	97	4,3	86	3,75	75	3,2	64
4,8	96	4,25	85	3,7	74	3,15	63
4,75	95	4,20	84	3,65	73	3,1	62
4,7	94	4,15	83	3,60	72	3,05	61
4,65	93	4,10	82	3,55	71	3	60

4,6	92	4,05	81	3,5	70	from 1,78 to 2,99	from 35 to 59
						retaking	
4,55	91	4,00	80	3,45	69	від 0 до 1,77	від 0 до 34
4,5	90	3,95	79	3,4	68	repeated study	

Final assessment

1 A student of higher education receives a credit in the last lesson in the discipline based on the results of the current assessment. The average score for the current activity is converted into points on a 100-point scale, according to the conversion table (table 1).

Applicants for higher education who have a current grade point average in the discipline lower than "3" (60 points) can increase their current grade by taking tests in the discipline in the last session.

Assessment of the knowledge of applicants through testing is carried out according to the following scale:

– "Excellent": at least 90% of correct answers;
– "Very good": from 82% to 89% of correct answers;
– "Good": from 74% to 81% of correct answers;
– "Satisfactory": from 67% to 73% of correct answers;
– "Satisfactory enough": from 60% to 66% of correct answers;
– "Unsatisfactory": less than 60% of correct answers.

2 The condition for obtaining credit is:

- making up for all missed classes;
– the average current grade in the discipline is not lower than "3" (60 points).

3 For performing individual independent work and participating in scientific events, winners are awarded additional points.

3.1 Additional points are added to the sum of points scored by the student of higher education for the current educational activity (for disciplines for which the final form of control is a credit), or to the final grade in the discipline for which the final form of control is an exam.

3.2 The number of additional points awarded for different types of individual tasks depends on their volume and significance:

- prizes in the discipline at the international / all-Ukrainian competition of scientific student works - 20 points;
- prize places in the discipline at the All-Ukrainian Olympiads - 20 points;
- participation in the international / all-Ukrainian competition of scientific student works - 15 points
- participation in international / all-Ukrainian scientific conferences of students and young scientists - 12 points;
- participation in all-Ukrainian Olympiads in the discipline - 10 points
- participation in Olympiads and scientific conferences of the Khnadu in the discipline - 5 points;
- performance of individual scientific and research (educational and research) tasks of increased complexity - 5 points.

3.3 The number of additional points cannot exceed 20 points.

4 The learning result is evaluated on a two-point scale (passed/failed) according to table 2;

The final grade together with additional points cannot exceed 100 points.

Table 2 – Scale of transfer of points to the national assessment system

On a 100-point scale	On a national scale
from 60 points to 100 points	credited
less than 60 points	not credited

Table 3 - Scale for assessing the knowledge of applicants for the results of final control of academic discipline

Score in points	Evaluation according to the national scale		Evaluation according to the ECTS scale	
	екзамен	залік	Estimation	Criteria
90-100	**Excellent**	**Credited**	**A**	The theoretical content of the course has been mastered in its entirety, without gaps, the necessary practical skills for working with the mastered material have been formed, all educational tasks provided for in the training program have been completed, the quality of their performance has been assessed with a number of points close to the maximum
80–89	**Good**	**Credited**	**B**	The theoretical content of the course has been mastered in its entirety, without gaps, the necessary practical skills for working with the mastered material have mainly been formed, all educational tasks provided for by the training program have been completed, the quality of most of them has been assessed with a number of points close to the maximum
75-79			**C**	The theoretical content of the course has been mastered in its entirety, without gaps, some practical skills of working with the mastered material have not been formed enough, all educational tasks provided for by the training program have been completed, the quality of none of them has been assessed with a minimum number of points, some types of tasks have been completed with errors
67-74	**Satisfactorily**		**D**	The theoretical content of the course is partially mastered, but the gaps are not of a significant nature, the necessary practical skills for working with the mastered material are basically formed, most of the educational tasks provided by the training program have been completed, some of the completed tasks may contain errors
60–66			**E**	The theoretical content of the course has been partially mastered, some practical work skills have not been formed, many educational tasks provided by the training program have not been completed, or the quality of some of them has been assessed with a number of points close to the minimum.

Score in points	Evaluation according to the national scale		Evaluation according to the ECTS scale	
	екзамен	залік	Estimation	Criteria
35–59	**Unsatisfactorily**	**Not credited**	**FX**	The theoretical content of the course has been partially mastered, the necessary practical work skills have not been formed, most of the prescribed training programs of educational tasks have not been completed, or the quality of their implementation has been assessed with a number of points close to the minimum; with additional independent work on the course material, it is possible to improve the quality of the performance of educational tasks (with the possibility of retaking)
0–34	**Unacceptable**		**F**	The theoretical content of the course has not been mastered, the necessary practical work skills have not been formed, all completed educational tasks contain gross errors, additional independent work on the course material will not lead to any significant improvement in the quality of the performance of educational tasks (with a mandatory repeat course).

Course policy:

– the course involves working in a team, the environment in the classroom is friendly, creative, open to constructive criticism;

- mastering the discipline involves mandatory attendance of lectures and practical classes, as well as independent work;

- independent work involves the study of individual topics of the academic discipline, which are assigned in accordance with the program for independent study or were considered briefly;

– all tasks provided for by the program must be completed within the set time;

- if the student of higher education is absent from classes for a good reason, he presents the completed tasks during independent preparation and consultation of the teacher;

- while studying the course, students of higher education must adhere to the rules of academic integrity set forth in the following documents: "Rules of academic integrity of participants in the educational process of the KhNAHU" (https://www.khadi.kharkov.ua/fileadmin/P_Standart/pologeniya/stvnz_67_01_dobroch_1.pdf), "Academic integrity. Checking the text of academic, scientific and qualification works for plagiarism" (https://www.khadi.kharkov.ua/fileadmin/P_Standart/pologeniya/stvnz_85_1_01.pdf), "Moral and ethical code of participants in the educational process of the KhNAHU (https://www.khadi.kharkov.ua/fileadmin/P_Standart/pologeniya/stvnz_67_01_MEK_1.pdf).

- in case of detection of plagiarism, the applicant receives 0 points for the task and must repeat the tasks provided for in the syllabus;

- writing off during tests and exams is prohibited (including using mobile devices). Mobile devices are allowed to be used only during online testing.

Recommended literature: (literature no later than 10 years old, except for 1 fundamental classical textbook or monograph)

1. 1. Poliarus O. V., Poliakov E. O. Approximate solution of the inverse measurement problem and its metrological support. - Monograph. - Kh.: "Leader" publishing house, 2014. - 120 p.
2. 2. V. P. Babak, V. S. Yeremenko, Yu. V. Kuts, M. V. Myslovych, L. M. Shcherbak/Edited by V. P. Babak, correspondent member of the National Academy of Sciences of Ukraine. Models and measures in measurements. - Kyiv: Naukova dumka, 2019. - 208 p.
3. Konstantin Semenov, Gennady N. Solopchenko, Vladik Kreinovich. Inverse problems in theory and practice of measurements and metrology. – In book: Advanced Mathematical and Computational Tools in Metrology and Testing - World Scientific, 2015.- pp.330-339.
4. Albet Tarantola. Inverse Problems Theory and Methods for Model Parameter Estimation. – SIAM (Society for Industrial and Applied Mathematics), Philadelphia, 2005. – 358 p.
5. Guillaume Bal. Introduction to Inverse Problems. - University of Chicago, Chicago, 2019. – 235 p.
6. 6. Poliarus O. V., Brovko Y. S., Poliakov E. O., Yanushkevich S. D. Metrological support of inverse measurement problems in nonlinear inertial systems. – Ukrainian Metrological Journal, 2017, No. 4, p. 23-28.
7. 7. Models and measures in measurements: Monograph / V. P. Babak, V. S. Eremenko, Yu. V. Kuts, M. V. Myslovych, L. M. Shcherbak; under the editorship member-cor. NAS of Ukraine V. P. Babak. - K.: Naukova dumka, 2019. - 192 p.
8. 8. Poliarus O. V., Brovko Y. S., Maletska O. E. Peculiarities of the application of regulatory documents to inverse measurement problems. – Metrology and devices, 2018, No. 5, p. 40-46.
9. Victor A. Kovtunenko* and Kohji Ohtsuka. Inverse problem of shape identification from boundary measurement for Stokes equations: Shape differentiability of Lagrangian. - Journal of Inverse and Ill-posed Problems, 2020, pp. 15-20.
10. Abdel Hamid Ismail Mourad and József Kázmér Tar. Approximate Evaluation of Exact Solutions of Measurements Inverse Problems. - Applied Mechanics and Materials, 2014, vol. 527, pp. 326-331.

Additional sources:

1. distance course: https://dl.khadi.kharkov.ua/course/view.php?id=2851
2. https://lutsk-ntu.com.ua/sites/default/files/06_norma_0.pdf
3. https://journal-me.com/archive-ukr/vol23-2020-iss2-paper2/?print=print
4. https://studopedia.org/12-99505.html
5. http://mcm-tech.kpnu.edu.ua
6. https://journals.indexcopernicus.com/api/file/viewByFileId/683129.pdf
7. http://www.numdam.org/item/COCV_2013__19_1_190_0/
8. https://iopscience.iop.org/article/10.1088/0957-0233/9/6/001
9. https://uwaterloo.ca/waterloo-laboratory-for-inverse-analysis-and-thermal-sciences/research/inverse-problem

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