Syllabus
of elective component of EC
Rapid prototyping technologies

Name of discipline:	**Rapid prototyping technologies**
Higher Education Level:	**First (Bachelor)**
Course page in Moodle:	https://dl2022.khadi-kh.com/course/view.php?id=2863
The scope of the educational component	**4 credits (120 hours)**
The form of the summary control	**test**
Consultations:	**on schedule**
Name of the department:	**Department of Machine Elements and Theory of mechanisms and machines**
Teaching language:	**English**
Course leader:	**Pavlo Yehorov, Doctor of Philosophy, Associate Professor**
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Brief content of the educational component:

The aim is to form the set of knowledge, skills and abilities to solve mechanical engineering problems related to automated product design and manufacturing technologies using modern tools, in particular additive manufacturing and CNC machines.

Subject: theoretical, methodological and practical foundations of product development and preparation for their production using modern technologies.

The main tasks of studying an academic discipline are:

- development of skills in using CAD and CAM software;
- familiarization with the structure, technological capabilities and technical characteristics of devices for rapid prototyping;
- acquiring skills in using rapid prototyping devices;
- acquiring skills in rational design taking into account manufacturing technology.

Prerequisites for studying the educational component:

Basic knowledge of computer science and engineering and computer graphics.

Competencies acquired by the applicant:

General competencies (GC):

Knowledge and understanding of the subject area and professional activity.
Ability to evaluate and ensure the quality of work performed.
Ability to work in a team.
Ability to work autonomously.

Professional competencies (special, subject) (PC):

The ability to apply typical methods for solving professional, technical and practical problems in the field of mechanical engineering, effective methods of mathematics, physics, engineering sciences, as well as appropriate software.

The ability to rationally choose rapid prototyping technologies and appropriate materials in order to optimize the speed of obtaining prototypes while ensuring the necessary parameters of accuracy and operability.

Ability to use knowledge and practical skills in the field of design and technological preparation of production.

Ability to perform technical measurements, obtain, analyze and evaluate measurement results.

Ability to use computer systems to solve technical problems in the field of mechanical engineering.

Ability to present the results of one's activities in compliance with generally accepted norms and standards.

Program learning outcomes (PLO):

Select and apply the necessary methods, equipment, and tools for manufacturing parts using rapid prototyping technology.

Thematic plan

Topic No	Title of topics (Lectures LC, Practical classes PC, Laboratory work LW, Independent work IW)	Number of hours
1	LC Introduction. Design of industrial products. Evolution of design technologies. Rapid prototyping technologies.	2
	PC Introduction to the Autodesk Fusion 360 environment. Modeling simple parts.	2
	IW History and trends of industrial revolutions.	6
2	LC Alternative methods for obtaining three-dimensional models. Using CAE systems for engineering calculations to improve structures.	2
	PC Obtaining a three-dimensional model of a part from photographs. Using the CAE module Autodesk Fusion 360.	2
	IW Using photogrammetry to obtain a three-dimensional model of a part.	8
3	LC CNC machines, classification and technical capabilities. Additive manufacturing technologies.	2
	PC	
	IW New and promising machines for additive and extractive molding.	10
4	LC Manufacturing of parts using FDM technology. Design of 3D printers.	2
	PC Using Autodesk Fusion 360 add-ins and libraries.	2
	IW Recycling and disposal of printing waste.	6
5	LC CAM systems. Control programs.	2
	PC Design review and printing using a 3D printer using FDM technology. Working with the Autodesk Fusion 360 CAM module.	2
	IW Comparison of CAM system capabilities from different manufacturers.	8
6	LC Polymer materials and raw materials for FDM printing. Mechanical properties of materials for printing.	2
	PC	
	IW New materials and raw materials for FDM printing.	6
7	LC Defects that occur when printing using FDM technology and ways to eliminate them.	2
	PC Preparation for printing and optimization of models taking into account the features of FDM technology.	2
	IW Preparing your own model for printing using FDM technology.	8

Topic No	Title of topics (Lectures LC, Practical classes PC, Laboratory work LW, Independent work IW)	Number of hours
8	LC 3D printing using vat polymerization technology (SLA/DLP/LCD). Design and types of devices.	2
	PC Preparation of a model and control program for printing using LCD vat polymerization technology.	2
	IW Familiarization with slicer software.	6
9	LC 3D printing using vat polymerization technology. Post-processing. Device maintenance.	2
	PC	
	IW Preparing your own model for printing using vat polymerization technology.	6
10	LC Materials for SLA printing. Selection of materials and printing parameters.	2
	PC Using slicer software to create control programs.	2
	IW Market research of existing raw materials and the specifics of their application.	6
11	LC Printing of complex and large-sized objects. Post-processing of printed parts.	2
	PC Preparing complex and large-sized objects for printing.	2
	IW Preparing complex models for printing.	6
12	LC 3D printing using SLS technology. Materials and features of the technology.	2
	PC	
	IW Overview of devices and the latest developments related to SLS technology.	4
Total	LC	**24**
	PC	**16**
	IW	**80**

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.

Evaluation system and requirements:
Current performance
1 The current success of applicants for the performance of educational types of work in training sessions 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 current performance of higher education applicants is assessed at each practical session (laboratory or seminar) on a four-point scale ("5", "4", "Z", "2") and entered in the journal of academic performance.
– **"Excellent"**: the winner 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;
– **"Satisfactorily"**: 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;
– **"Unsatisfactorily"**: 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 recognized as the arithmetic mean sum of points for each lesson, for individual work, current control works according to the formula:

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

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

Assessments are converted into points according to the calculation 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 a course assessment	
4,55	91	4,00	80	3,45	69	from 0 to 1,77	from 0 to 34
4,5	90	3,95	79	3,4	68	Re-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 participation in scientific events, additional points are awarded to the winners.

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 importance:

- 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 KhNAHU 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 outcome is evaluated:

– on a 100-point scale (for differentiated assessment) according to table 2.

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

Table 2 – The scale for evaluating the knowledge of students based on the results of the final control of the academic discipline

Score in points	Evaluation on a national scale		Evaluation according to the ECTS scale	
	examination	course assessment	Rating	Criteria
90-100	**Excellent**	**Pass**	**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**		**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 on a national scale		Evaluation according to the ECTS scale	
	examination	course assessment	Rating	Criteria
35–59	**Unsatisfactorily**	**Fail**	**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, as well as independent work;
– independent work involves the study of individual topics of the academic discipline, which are presented in accordance with the program for independent study, or were considered briefly;
– all tasks provided 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 comply with 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 papers for plagiarism" (https://www.khadi.kharkov.ua/fileadmin/P_Standart/pologeniya/stvnz_85.1-02.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

Basic literature

1. Gibson, I., Rosen, D., Stucker, B., “Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing”, 2nd ed.; Springer-Verlag: New York, NY, USA, 2015.

2. Godec, D., Gonzalez-Gutierrez, J., Nordin, A., Pei, E., & Alcázar, J. U. (Eds.) (2022). A Guide to Additive Manufacturing. (1 ed.) (Springer Tracts in Additive Manufacturing). Springer Cham.

Supplementary literature

1. Холодняк Ю. В. Комп'ютерне проєктування промислових виробів: конспект лекцій. Мелітополь: ТДАТУ, 2021. 140 с.

2. Ковальов В.А., Гаврушкевич А.Ю., Гаврушкевич Н.В. Конструктивні особливості та основи програмування верстатів з числовим програмним керуванням: Навч. посіб. К.: КПІ ім. Ігоря Сікорського, 2020. 158с.

3. Коваленко А. В. Конспект лекцій з дисципліни «Технологічні основи програмування для верстатів з ЧПК». Краматорськ, 2016. 143 с.

4. Люта А. В. Автоматизоване проєктування складних об'єктів і систем: конспект лекцій. Краматорськ: ДДМА, 2020. 124 с.

5. САПР ТП: Конспект лекцій / К. С. Барандич, С. П. Вислоух, М. В. Філіппова. Київ: КПІ ім. Ігоря Сікорського, 2023. 201 с.

6. Voropay A. V., Karpenko V. A., Koriak O. O., Povaliaiev S. I., Sharapata A. S. Theory of mechanisms and machines: Lecture notes (digital edition, https://dspace.khadi.kharkov.ua/dspace/bitstream/123456789/17395 /5/TheoryofMechanismsandMachines23.pdf) Kharkiv National Automobile and Highway University. Kharkiv: KhNAHU, 2023. 95 p.

7. Воропай О. В. Методичні вказівки до лабораторних робіт за курсом «Деталі машин» для студентів напряму підготовки G3 «Електрична інженерія»; G9 «Прикладна механіка»; G11 «Машинобудування»; J8 «Автомобільний транспорт» / О. В. Воропай, Д. І. Богдан, П. А. Єгоров, В. О. Карпенко, А. С. Шарапата. Харків : ХНАДУ, 2025. 123 с.

8. Онофрейчук Н. В. Основи обробки та програмування на верстатах з числовим програмним керуванням : підруч. Львів : Світ, 2019. 352 с. ISBN 978-966-914-229-0

9. Voropay, A., Yehorov, P., Gnatenko, G., Povalıayev, S. & Sharapata, A. (2022). OPTIMIZATION OF MACHINE PARTS MODELS FOR 3D PRINTING. International Journal of 3D Printing Technologies and Digital Industry, 6 (3), 511-520. DOI: 10.46519/ij3dptdi.1187111

10. Voropay A., Yehorov P., Koriak O., Sharapata A., Gnatenko G. Restoring the Functionality of Gears Using Rapid Prototyping. (2025) Lecture Notes in Networks and Systems, 1315 LNNS, pp. 173 - 183. DOI: 10.1007/978-3-031-85751-5_13 ISSN: 23673370, ISBN: 978-303185750-8

Additional sources:

1. Course page in Moodle:
https://dl2022.khadi-kh.com/course/view.php?id=1802

2. Course page in Moodle:
https://dl2022.khadi-kh.com/course/view.php?id=1917

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