



3D printing

Work program of the educational component (Syllabus)

Educational component details

Higher education level	<i>First (bachelor's)</i>
Field of knowledge	<i>13 Mechanical Engineering</i>
Specialty	<i>131 Applied mechanics</i>
Educational program	<i>Packaging and packaging equipment engineering</i>
Educational component status	<i>selective</i>
Form of study	<i>full-time (day)</i>
Training year, semester	<i>4 course, spring semester</i>
The scope of the educational component	<i>4(120)</i>
Semester control/control measures	<i>test</i>
Class schedule	<i>6 hours per week (2 hours of lectures, 2 hours of practical classes, 2 hours of laboratory classes)</i>
Teaching language	<i>Ukrainian</i>
Information about head of the course / teachers	Lecturer: Asst., Oleksyshen Vitalii Oleksandrovych Practical: Asst., Oleksyshen Vitalii Oleksandrovych
Course placement	<i>Sikorsky Platform</i>

Educational component program

1. Description of the educational component, its purpose, subject matter and learning outcomes

The syllabus "3D Printing" is compiled in accordance with the educational and professional program for training bachelors in specialty 131 - Applied Mechanics under the educational program "Engineering of equipment for the production of polymer and building materials and products." The educational component belongs to the selective educational components.

Subject of the educational component – development of equipment and software for additive manufacturing.

Purpose of the educational component «3D printing»

The purpose of the educational component is the manufacture of polymer parts using the 3D printing method.

In accordance with the purpose, the training of bachelors in this specialty requires the strengthening of the formation of the following competencies:

Integral competence: The ability to solve complex specialized tasks and practical problems in applied mechanics or in the process of learning, which involves the application of certain theories and methods of mechanical engineering and is characterized by the complexity and uncertainty of the conditions.

1.1. According to the requirements of the educational component "3D Printing", after mastering it, students must strengthen the following program learning outcomes:

- the ability to make the optimal choice of technological equipment, complete technical complexes, have basic ideas about the rules of their operation (FC4);
- ability to use computer-aided design (CAD), manufacturing (CAM), engineering research (CAE) systems and specialized application software to solve engineering problems in applied mechanics (FC7).

And also to form additional provisions:

- use software and additive manufacturing equipment to manufacture functional parts and structures from polymer materials.

1.2. According to the requirements of the educational and professional program, students after mastering the academic discipline must demonstrate the following learning outcomes:

Knowledge:

- basics of information technology, programming, practical use of application software for performing engineering calculations, processing information and results of experimental research (PH8);
- designs, selection and calculation methods, basics of maintenance and operation of drives for machine tool and robotic equipment (RN10);

Skills:

- develop technological processes for manufacturing parts, assembling technological equipment, develop lubrication schemes and maps (PH20).

Additional learning outcomes will also contribute to:

- create functional parts and prototypes based on modern production methods.

2. Prerequisites and postrequisites of the educational component (place in the structural and logical scheme of training according to the relevant educational program)

This educational component is an applied development of the educational components that were taught to students: "Informatics", "Engineering and Computer Graphics", "Engineering Calculations on PCs".

3. Content of the educational component

3D printing: additive technologies - history of development, current state and development prospects. Fused Deposition Modeling (FDM) - 3D printing with polymer materials and compositions. Overview of materials for FDM: from the simplest thermoplastics to promising intelligent materials. Creating an executive program (G-code) in the most popular slicing programs. Using additive technologies in business: 3D printing as a main activity or a component of engineering services.

4. Educational materials and resources

Basic literature

1. Ian Gibson, David Rosen, Brent Stucker. Additive Manufacturing, Technologies, 3D Printing, Rapid Prototyping and Direct Digital Manufacturing – Springer New York Heidelberg Dordrecht London, 2015. - 510 c.
ISBN 978-1-4939-2112-6, DOI 10.1007/978-1-4939-2113-3.
2. Brook Drumm, James Floyd Kelly, John Edgar Park, Brian Roe, John Baichtal, Rick Winscot, Steven Bolin, Nick Ernst, and Caleb Cotter. Make: 3D Printing Projects – Maker Media, Inc., 2015.– 283 c.
ISBN: 978-1-4571-8724-7

Additional literature

1. Kaushik Kumar, Chikesh Ranjan, J. Paulo Davim. Understanding CATIA – CRC Press, 2021, DOI:10.1201/9781003121657, ISBN: 9781000370805.

2. ДСТУ ГОСТ 2.051:2006 Єдина система конструкторської документації. Електронні документи. Загальні положення (ГОСТ 2.051-2006, IDT) К. : Держспоживстандарт України, 2007. - 19 с.

Educational content

5. Methods of mastering the educational component

Lecture classes

Lectures are aimed at:

- providing modern, holistic, interdependent knowledge on the educational component “3D printing”, the level of which is determined by the target setting for each specific topic;
- ensuring the creative work of students together with the teacher during the lecture;
- educating students in professional and business qualities and developing their independent creative thinking;
- forming the necessary interest in students and providing a direction for independent work;
- determining the current level of development of science and technology in the field of additive technologies, forecasting their development for the coming years;
- reflecting the methodological processing of the material (highlighting the main ideas and provisions, emphasizing conclusions, repeating them in different formulations);
- acquiring visibility, combining it, if possible, with the demonstration of audiovisual materials, models, models and samples;
- teaching in a clear and understandable language, explaining all newly introduced terms and concepts;
- accessibility for perception by the given audience.

No	6. Title of the lecture topic and list of main questions (list of didactic aids, references to literature and tasks for the SRS)	Hours
1	Topic 1. 3D printing: additive technologies – history of development, current state and development prospects Lecture 1. History of the emergence of 3D printing. Types and principles of spatial printing. Overview of schematic diagrams of additive manufacturing equipment. Literature: [base 1, add. 1]. Tasks for the SRS: Principles of printing depending on additive technology.	4
2	Topic 2. Fused Deposition Modeling (FDM) – 3D printing with polymer materials and compositions Lecture 2. Schematic diagram of an FDM 3D printer. Basic designs. Types of extrusion heads. Literature: [bas. 1, add. 1]. Task on the SRS: Dual-extruder scheme of an FDM 3D printer.	4
3	Topic 3. Overview of materials for FDM: from the simplest thermoplastics to promising intellectual materials Lecture 3. Basic materials. Engineering plastics and compositions. Post-processing and modification of printed products. Literature: [bas. 1,2, add. 1]. Tasks for the SRS: Overview of the main domestic and global manufacturers.	4
4	Topic 4. Creating an executive program (G-code) in the most popular slicing programs Lecture 4. The slicing process. Basic settings and 3D printing modes. The influence of the properties of the working material on the parameters of the movement of the executive bodies.	2

	<i>Literature: [bas. 1, add. 1]. Tasks for the SRC: Slicing for different 3D printing technologies.</i>	
5	Topic 5. Using additive technologies in business: 3D printing as the main activity or a component of engineering services <i>Lecture 5. Additive technologies market. Review of global and domestic companies. Promising directions for the development of spatial printing. Literature: [base 1]. Tasks for the SRS: Review of global startups and companies.</i>	4
	Total	18

Practical classes

The system of professional training of applicants for the educational component provides for practical classes. Being a supplement to the lecture course, they lay and form the foundations of the bachelor's qualification in the field of mechanical engineering. The content of these classes and the methodology of their conduct should provide knowledge of methods, the ability to perform calculations, and allow you to check your knowledge. Therefore, this type of work is an important means of operational feedback. Practical classes should perform not only cognitive and educational functions, but also contribute to the growth of applicants as creative workers in the field of computer modeling.

Main tasks of the practical training cycle:

- - to help applicants systematize, consolidate and deepen theoretical knowledge in the field of modern 3D printing methods;
- - to teach applicants techniques for solving practical problems, to help them master the skills and abilities of programming, maintenance and improvement of additive equipment;
- - to teach them to work with technical and reference literature and diagrams.

№	Title of the topic of the practical lesson and list of main questions (list of didactic support, references to literature and tasks on the VTS)	Годин
1	Safety briefing and familiarization of students with the practical work program.	1
2	Schematic diagrams of additive devices. <i>Literature: [base 1,2]. Tasks for the SRS: Preparation and study of the protocol for laboratory work.</i>	2
3	Design of print heads of FDM 3D printer. <i>Literature: [basic 1,2]. Tasks for SRS: Preparation and study of the protocol for laboratory work.</i>	3
4	Comparative characteristics of different groups of consumables. <i>Literature: [base 1,2]. Tasks for the SRS: Preparation and study of the protocol for laboratory work.</i>	2
5	Creating an executable code for printing a functional part. <i>Literature: [basic 1,2]. Tasks for the SRS: Preparation and study of the protocol for laboratory work.</i>	2
6	Business plan project. <i>Literature: [base 1,2]. Tasks for the SRS: Preparation and study of the protocol for laboratory work.</i>	4
7	MCW	2
8	Debt collection classes	2
	Total	18

Laboratory classes

No	Name of the laboratory work topic	Number of SRS hours
1	Topic 1. Study of technological parameters of the 3D printing process <i>Literature: [base 1, add. 1].</i>	4
2	Topic 2. 3D printing of complex geometry using support structures <i>Literature: [bas. 1, add. 1, 2].</i>	2
3	Topic 3. Features of printing basic and special plastics <i>Literature: [base. 1,2, add. 1].</i>	2
4	Topic 4. Spatial scanning of a physical object <i>Literature: [bas. 1, add. 1].</i>	2
5	Topic 5. The process of implementing 3D printing of scanned objects <i>Literature: [base 2, add. 1].</i>	2
6	Laboratory work protection	4
	Total	18

7. Independent work of a student/postgraduate student

Independent work takes up 55% of the time of studying the educational component, including preparation for the test. The main task of independent work of applicants is to master scientific knowledge in areas that are not included in the list of lecture questions through personal search for information, the formation of an active interest in a creative approach to educational work. In the process of independent work within the educational component, the applicant must learn to deeply analyze modern approaches to the development and implementation of the latest packaging technologies, based on the characteristics of water and requirements for the quality of packaged products. He must be able to create the most effective methods and means of packaging.

No	Title of the topic to be studied independently	Number of SRS hours
1	Topic 1. 3D printing: additive technologies – history of development, current state and prospects for development <i>Literature: [base 1, add. 1].</i> <i>Tasks for the SRS: Promising technologies of additive manufacturing.</i>	14
2	Topic 2. Fused Deposition Modeling (FDM) – 3D printing with polymer materials and compositions <i>Literature: [base 1, add. 1, 2].</i> <i>Tasks for the SRS: 3D printing with silicones and clays.</i>	12
3	Topic 3. Overview of materials for FDM: from the simplest thermoplastics to promising intellectual materials <i>Literature: [base 1,2, add. 1].</i> <i>Tasks for the SRS: Promising structural materials</i>	12
4	Topic 4. Creating an executive program (G-code) in the most popular slicing programs <i>Literature: [base 1, add. 1].</i> <i>Task on the SRS: Slicing for multi-extruder printers.</i>	8
5	Topic 5. Use of additive technologies in business: 3D printing as the main activity or component of engineering services <i>Literature: [base 2, add. 1].</i> <i>Task for the CTC: Review of Ukrainian companies.</i>	10

6	Preparation for the ICR	4
7	Preparation for the test	6
	Total	66

8. Individual lessons

According to the working curriculum, no individual tasks are provided.

Policy and control

9. Educational component policy

Rules for class attendance and behavior in class

Attendance at classes is a mandatory component of assessment. Applicants are required to actively participate in the learning process, not be late for classes or miss them without a valid reason, not interfere with the teacher conducting classes, and not be distracted by activities unrelated to the learning process.

Rules for assigning incentive and penalty points

- incentive points are not provided*
- penalty points are not provided within the educational component.*

Policy of deadlines and rescheduling

In the event of arrears for the educational component or any force majeure circumstances, applicants must contact the teacher via the available (provided by the teacher) communication channels to resolve problematic issues and agree on an algorithm of actions for working out.

Academic Integrity Policy

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the lack of references when using printed and electronic materials, quotes, opinions of other authors. Hints and copying when writing tests, conducting classes are unacceptable; taking a test for another applicant; copying materials protected by the copyright system without the permission of the author of the work.

The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". More: <https://kpi.ua/code>

Academic Conduct and Ethics Policy

Applicants must be tolerant, respect the opinions of others, formulate objections in a correct form, and constructively support feedback in classes.

The norms of ethical behavior of students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". More: <https://kpi.ua/code>

10. Types of control and rating system for assessing learning outcomes (RSO)

Distribution of study time by types of classes and tasks from the educational component according to the working curriculum:

Semester	Study time		Distribution of teaching hours					Control measures		
	Credits	Acad. hours	Lectures	Practical	Lab work	CPC	Ind	MCW	RR	Semester Control
8	4	120	18	18	18	66	0	1	–	test

A student's rating for the educational component consists of the points he receives for work in practical, laboratory classes and the completion of MCW.

Semester control is a credit.

Current control: *Reports on practical classes, laboratory classes, modular test work.*

Calendar control: *carried out twice a semester as a monitoring of the current status of implementation of the syllabus requirements.*

A student's rating for the educational component consists of the points he receives for:

- 1) completion and defense of practical work (total of 5 works);*
- 2) completion and defense of laboratory work (total of 5 works);*
- 3) completion of modular test work.*

Rating (weighting) points system and evaluation criteria

1. Practical classes:

Weighted score – 8. The maximum number of points for all practical classes

is: $8 \text{ points} \times 5 = 40 \text{ points}$.

Evaluation criteria:

A score of 8 is awarded if the problem is solved without errors;

Scores of 6 and 7 are awarded if the problem is solved with a minor error;

Scores of 3, 4 and 5 are awarded if the problem is solved with several errors;

Score 0 is awarded if the problem is solved with a significant error or if the student is absent from the practical session without a valid reason.

2. Laboratory classes

Weighted score – 8. The maximum number of points for all practical classes

is equal to: $8 \text{ points} \times 5 = 40 \text{ points}$.

Evaluation criteria:

a score of 8 is given if the problem is solved without errors;

a score of 6 and 7 is given if the problem is solved with a minor error;

a score of 3, 4 and 5 is given if the problem is solved with several errors;

a score of 0 is given if the problem is solved with a significant error or if the practical class is absent without a valid reason.

3. Modular test:

Weighted score – 10. The maximum number of points for the test is $10 \text{ points} \times 2 \text{ questions} = 20 \text{ points}$.

A score of 20 is awarded if at least 95% of the questions are answered;

A score of 17-19 is awarded if at least 85% of the questions are answered;

A score of 15-16 is awarded if 75% of the questions are answered;

A score of 12-14 is awarded if 60% of the questions are answered;

A score of 0 is awarded if less than 60% of the questions are answered.

There are no incentive points.

There are no penalty points.

According to the results of the academic work for the first 7 weeks, the "ideal student" should score 20 points. At the certification (8th week), the student receives "passed" if his current rating is at least 10 points.

According to the results of 15 weeks, the "ideal student" should score 40 points. At the second certification (week 14), the student receives "passed" if his current rating is at least 20 points.

The maximum sum of points for the RC semester is 100:

$$RC = R_{pz} + R_{lab} + R_{mkr} = 40 + 40 + 20 = 100 \text{ points.}$$

Conditions for admission to semester control: passing all practical work, laboratory work and the starting component of the semester rating of at least 20 points.

Students who have scored $R_c = 60$ points or more per semester can receive a credit automatically based on the points they have scored. Students who have not scored a semester rating of 60 points and have at least 20 points or students who wish to increase their scores in the educational component, complete a written credit work and their semester scores are canceled. At the credit test, students complete a written credit test on 2 credit questions. Each task contains two theoretical questions. The list of questions is given in the methodological recommendations for mastering the academic discipline. Each theoretical question is estimated at 50 points.

Question evaluation system:

- "excellent", complete answer (at least 95% of the required information) - 48-50 points;
- "good", fairly complete answer (at least 75% of the required information or minor inaccuracies) - 40-47 points;
- "satisfactory", incomplete answer (at least 60% of the required information and some errors) - 30-39 points;
- "unsatisfactory", unsatisfactory answer - 0 points.

The maximum rating of the final test is

$$R_z = R_{T1} + R_{T2} = 50 + 50 = 100 \text{ points.}$$

The sum of the starting points and the points for the credit test is converted into the credit score according to the table:

Table of correspondence of rating points to grades on the university scale:

Number of points	Rating
100-95	Excellent
94-85	Very good
84-75	Good
74-65	Satisfactory
64-60	Sufficient
Less than 60	Unsatisfactory
Admission conditions not met	Not allowed

Additional information on the educational component

QUESTIONS FOR THE EXAM

1. Define the concept of additive technologies.
2. Define the concept of 3D printer and 3D printing.
3. List the main characteristics of an FDM 3D printer.
4. List the main characteristics of an SLA 3D printer.
5. List the classification of the main circuits of FDM 3D printers.
6. List a typical electronic circuit of an FDM 3D printer.
7. List the schematic diagrams of the print heads of an FDM 3D printer.
8. Explain the principle of Fused Deposition Modeling (FDM) technology.

9. Explain the principle of Stereolithography (SLA) technology.
10. Explain the principle of Selective Laser Sintering and Melting (SLS & SLM) technology.
11. Explain the principle of Electron Beam Melting (EBM) technology.
12. Explain the principle of Laminated Object Manufacturing (LOM) technology.
13. Explain the principle of Multi Jet Fusion (MJF) technology.
14. Give examples of the use of additive technologies in prototyping.
15. Give examples of the use of additive technologies in prototyping.
16. Give examples of the use of additive technologies in construction.
17. Give examples of the use of additive technologies in medicine.
18. Give examples of the use of additive technologies in jewelry.
19. Give examples of the use of additive technologies in the aerospace industry.
20. Give basic polymer materials for 3D printing and their characteristics.
21. Give structural polymer materials for 3D printing and their characteristics.
22. Give composite polymer materials for 3D printing and their characteristics.
23. Give elastomeric polymer materials for 3D printing and their characteristics.
24. Explain the principle of preparing a model for printing.
25. Explain the principle of operation of slicers.
26. List of popular slicers and their main differences.
27. List the main print settings.
28. Explain the effect of layer thickness on the quality and productivity of 3D printing.
29. Explain the effect of the filling scheme on the quality and productivity of 3D printing.
30. Explain the effect of print speed on the quality and productivity of 3D printing.
31. Explain the need for cooling depending on the material.
32. Explain the effect of the environment on the 3D printing process.
33. List methods for increasing the fixation of the product on the work platform.
34. List the principles of printing thin-walled parts.
35. List the principles of printing large-sized parts.
36. List the method of hardening printed products.
37. List the method of correcting the dimensions of the mating surfaces of printed parts.
38. Give a classification of the main defects of 3D printing.
39. Give the main reasons for the appearance of 3D printing defects.
40. Give a methodology for determining the economic feasibility of using 3D printing.

SET OF TASKS FOR MODULAR CONTROL WORK

TASK 1

1. Define the term additive manufacturing.
2. Give examples of additive manufacturing in prototyping.

TASK 2

1. Define the concept of 3D printer and 3D printing.
2. Explain the principle of Stereolithography (SLA) technology.

TASK 3

1. List the main characteristics of an FDM 3D printer.
2. Explain the principle of Multi Jet Fusion (MJF) technology.

TASK 4

1. *Give a classification of the main schemes of FDM 3D printers.*
2. *Explain the principle of operation of slicers.*

TASK 5

1. *Explain the principle of Fused Deposition Modeling (FDM) technology.*
2. *Explain the need for cooling depending on the material.*

TASK 6

1. *Provide schematic diagrams of the print heads of an FDM 3D printer.*
2. *Provide methods for increasing the fixation of the product on the work platform.*

TASK 7

1. *Give a typical electronic circuit diagram of an FDM 3D printer.*
2. *Give the basic print settings.*

TASK 8

1. *Explain the impact of print speed on the quality and productivity of 3D printing.*
2. *State the principles of printing thin-walled parts.*

TASK 9

1. *Explain the principle of Electron Beam Melting (EBM) technology.*
2. *Give examples of the use of additive technologies in medicine.*

TASK 10

1. *List the main characteristics of an SLA 3D printer.*
2. *List the basic polymer materials for 3D printing and their characteristics.*

TASK 11

1. *Explain the principle of Selective Laser Sintering and Melting (SLS & SLM) technology.*
2. *List popular slicers and their main differences.*

TASK 12

1. *Explain the principle of Laminated Object Manufacturing (LOM) technology.*
2. *Give examples of the use of additive technologies in prototyping.*

TASK 13

1. *List the structural polymer materials for 3D printing and their characteristics.*
2. *Explain the principle of preparing a model for printing.*

TASK 14

1. *Explain the effect of layer thickness on the quality and performance of 3D printing.*
2. *State the principles of printing large-sized parts.*

TASK 15

1. *Give examples of the use of additive technologies in construction.*
2. *Give elastomeric polymer materials for 3D printing and their characteristics.*

TASK 16

1. *Explain the impact of the fill pattern on the quality and productivity of 3D printing.*
2. *Give examples of the use of additive technologies in jewelry.*

TASK 17

1. *Give a method for correcting the dimensions of the mating surfaces of printed parts.*
2. *Give a method for hardening printed products.*

TASK 18

1. *List the composite polymer materials for 3D printing and their characteristics.*
2. *List the main causes of 3D printing defects.*

TASK 19

1. *Give a classification of the main defects of 3D printing.*
2. *Give examples of the use of additive technologies in the aerospace industry.*

TASK 20

1. *Explain the impact of the environment on the 3D printing process.*
2. *Provide a methodology for determining the economic feasibility of using 3D printing.*

List of questions for the modular test

1. *Define the concept of additive technologies.*
2. *Define the concept of 3D printer and 3D printing.*
3. *List the main characteristics of an FDM 3D printer.*
4. *List the main characteristics of an SLA 3D printer.*

5. List the classification of the main circuits of FDM 3D printers.
6. List a typical electronic circuit of an FDM 3D printer.
7. List the schematic diagrams of the print heads of an FDM 3D printer.
8. Explain the principle of Fused Deposition Modeling (FDM) technology.
9. Explain the principle of Stereolithography (SLA) technology.
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21. Give structural polymer materials for 3D printing and their characteristics.
22. Give composite polymer materials for 3D printing and their characteristics.
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27. List the main print settings.
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40. Give a methodology for determining the economic feasibility of using 3D printing.

The work program of the educational component (syllabus):

Compiled by Assistant., PhD Oleksyshen V.O.

Approved by the department CPSM (protocol № 17 from 04.06.2025)

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