Innovative ICT Education for Social-Economic Development (IESED)
574283-EPP-1-2016-1-LT-EPPKA2-CBHE-JP

TECHNOLOGIES OF DESIGNING 3-D OBJECTS

Minsk 2017

1. PLAN OF EDUCATIONAL DISCIPLINE

Course code	Year of study	Semester	Total	Auditor hours			Independent work	Course hours	Course volume	Number of hours
				lec-tures	Laborato-ry works	Practi-cal and seminar				
	3	5	108	16	48	-	16	28	4	Д.О
	3	5	108	8	10	-	62	28	4	З.О

2. COMPETENCIES

1 Apply basic scientific and theoretical knowledge to solve practical problem
8 Generate new ideas focusing on creativity, critical thinking, communication and collaboration

3. COURSE GOALS

The goal of course is to form skills in the modeling of solid objects; form skills in 3D objects visualization.
The tasks of studying the academic course:
- design of assignments of various components of three-dimensional data visualization;
- design of components of three-dimensional systems;
- use of principles and criteria for testing computer data visualization systems;
- development of visualization systems for specific tasks of medicine, industry, trade, training;
- test and evaluation of data visualization systems;
- analysis of system faults and shortcomings.

4. COURSE OUTCOMES

Will be able to
– develop model of real world physics using appropriated software
– organize efficient team work;
– analyze and enable use data from external sources.

5. EDUCATIONAL AND METHODICAL MAP for full-time education

Section number, topics, classes	Title of the section, topics, classes; list of issues to be studied	Number of classroom hours				Form of knowledge control
		lectures	Practical (seminar) classes	Laboratory works	Managed (controlled) Independent work	
1	2	3	4	5	6	7
1	Theoretical basis of computer graphics (1, 2)	2		4	2	Protection of laboratory work
2	Methods of 3-D object visualization and virtual reality cognitive technologies (3)	2		4	2	Protection of laboratory work
3	Systems of solid-state modeling in automated production preparation (4, 7, 10)	2		8	2	Protection of laboratory work

4	Methods of programming in the creation of parametric models (9)	2		4	2	Protection of laboratory work
5	Visualization of the calculation of engineering properties and geometric methods for solving problems (6)	2		4	2	Protection of laboratory work
6	Projecting a 3-D model onto a plane (8, 12)	2		10	2	Protection of laboratory work
7	Fractal geometry (10)	2		4	2	Protection of laboratory work
8	Prototyping and animation of 3-D objects (11, 13)	2		10	2	Protection of laboratory work
Total per semester		16		48	16	
Course work					28	Protection of course work
Total		16		48	44	Exam

6. EDUCATIONAL AND METHODICAL MAP for correspondence form of education

Section number, topics, classes	Title of the section, topics, classes; list of issues to be studied	Number of classroom hours				Form of knowledge control
		lectures	Practical (seminar) classes	Laboratory works	Managed (controlled) Independent work	
1	2	3	4	5	6	7
1	Theoretical basis of computer graphics (1, 2)	1			7	Testing
2	Methods of 3-D object visualization and virtual reality cognitive technologies (3)	1			7	Testing
3	Systems of solid-state modeling in automated production preparation (4, 7, 10)	1		2	9	Protection of laboratory work
4	Methods of programming in the creation of parametric models (9)	1		4	3	Protection of laboratory work
5	Visualization of the calculation of engineering properties and geometric methods for solving problems (6)	1			7	Testing
6	Projecting a 3-D model onto a plane (8, 12)	1		2	11	Protection of laboratory work
7	Fractal geometry (10)	1			7	Testing
8	Prototyping and animation of 3-D objects (11, 13)	1		2	11	Protection of laboratory work
Total per semester		8		10	62	
Course work					28	Protection of course work
Total		8		10	90	Exam

8. CONTENTS OF THE LECTURE TEMPLATES

№	Topic Title	Content
1	Theoretical basis of computer graphics (1, 2)	Spheres of application of 2-D projections of volumetric bodies and spatial geometric images. Projecting 3-D objects on the plane of the screen, the methods of projection. Realistic display. Perspective. Cognitive methods of simulating volume. Using 4-D abstractions in math, physics, programming. Ways to visualize 4-D abstractions. Projecting 4-D geometric images on a three-dimensional space, on a plane, n-dimensional abstractions in physics. The main directions of computer graphics. Areas of application of computer graphics. Methods of representation of graphic images. Graphics data storage formats: raster, vector, three-dimensional (wireframe, polygonal, solid-state), fractal Principle of operation and application of laser 3-D scanner. 3-D profilometry and profiloscopy. Use of holo-graphy in flaw detection. Visualization in nanotechnology. The principle of the atomic force microscope in the mode of topography and in phase contrast mode. Graphic modeling in medicine, magnetic resonance imaging, 3-D visualization of internal organs. Physiological features of human sight. Structure of the organs of vision. The etymology of the concept of "Cognitive technologies". Two-dimensional visualization. The history of the development of two-dimensional data visualization. Methods of two-dimensional visualization
2	Methods of 3-D object visualization and virtual reality cognitive technologies (3)	Technological prerequisites for the transition to visualization of 3-D objects. Stereoscopy. The concept of a stereo effect. Methods of parallel and cross-sights. Mirror image separation. The Stereo Effect of Pulfrich. Streopsis, the technique of its creation. Methods and means of evaluating stereopsis. Systems of artificial reality. Types of virtual reality. Visual and audio-visual technologies for providing the effect of presence. Systems with tactile feedback. Desktop VR-systems. Visually consistent display. The effect of interaction and the technique of its re-creation. Types of 3D visualization displays. Single-screen 3-D systems, multi-display systems (video walls), CAVE-systems, augmented reality systems, HR3D displays - the principles of operation. The device and principle of the virtual reality helmet. Areas of application of modern cognitive technologies. The use of virtual reality tools in cognitive technologies. Trainers and manipulators of data visualization in medicine. Simulators of three-dimensional visualization of scenes on transport. Three-dimensional visualization in simulators for the Ministry of Emergency Situations. Three-dimensional visualization in aviation and astronautics. Visualization in geoinformation systems. Cognitive visualization in management and marketing. Cognitive models of infocommunication and social systems
3	Systems of solid-state modeling in automated production preparation (4, 7, 10)	Frame, polygonal and solid modeling - the main differences and areas of application. The mathematical apparatus of polygonal and solid 3-D graphs. Principles of shape formation in solid-state modeling. The concept of a constructive element and the accompanying sketch. Geometric primitives. Classification of geometric primitives according to the number of sketches underlying them The logic of constructing a model (adding, subtracting, re-multiplying geometric forms). Stages construction of a complex solid model. Automated systems for design, engineering analysis, production preparation, and production information management. Industries, applications, structure of technical support of computer-aided design systems. CAD / CAM-systems of high, medium, low levels. Object-oriented interactive environment. Formats of inter-program and cross-platform exchanges. CALS-technology. Visualization in product life cycle management. Automated logistical systems. Features of the organization of the file system of the project, which contains a composite product. The degrees of freedom of the constituent parts in the product. Applying rela-

		tionships and dependencies. Dynamic dependencies. Creating a level of detail. Creating a part in the context of the collection. Editing details by direct manipulation
4	Programming methods in the creation of parametric models (9)	The protocol of the automated modeling system, model associativity, connection management, adaptive technology. Geometry parameters of the solid model. Editing the parameters. Mathematical equations, relationships and dependencies between parameters. The application programming interface (API), the specification of the hierarchy of objects, their properties and methods. The diagram of the object model. Enter the text of the VBA program. The syntax of the API. Auxiliary geometry: points, surfaces, bodies, curves, vectors, transformation matrices. Interaction with the user. External calls to the API functionality. Masters of design in standard engineering calculations. Systems of preliminary engineering calculations. Operative editing of parameters and decision-making
5	Visualization of the calculation of engineering properties and geometric methods for solving problems (6)	Finite element method. The scope of the finite element method. The basic concept of the finite element method. The partition of the calculated domain into finite elements. Visualization of the results of the calculation and modeling of the finite element method. Examples of visualization of the calculation of the distribution of thermal fields in the nodes of radioelectronic engineering. Examples of visualization of strength calculation and finding the "dangerous section" in the design. Examples of CAE modeling systems in mechanics, heating engineering, radio electronics. Geometric abstractions in physics, information communication systems, in statistics. Geometric (graphical) methods for solving engineering problems. Vozioshnosti 3-D modeling in the application of geometric methods. Static and kinematic methods for solving geometric problems
6	Projecting the 3-D model on the plane (8, 12)	Transformation of the 3-D model into a flat image by rectangular parallel projection methods. Creation of a drawing in accordance with the requirements of ESKD. Creation of isometric projections of products. Export images to raster and vector formats. Materials and representations. Textures. Colour. Styles for visualization and animation. Local and global styles. Lighting styles and virtual light sources. Local sources of light. Rendering. Factors affecting the time of visualization. Composition in graphic design. Laws of interaction of objects, information architecture. Visual hierarchy in web design. The effect of empty space on the perception of elements. Color harmony. Theory of color, contrasts, color schemes. Introduction to the concept of adaptive design. Principles of prototyping for mobile devices. Tools for adaptive prototyping. Preparing an adaptive layout for frontend development
7	Fractal Geometry (10)	Introduction to the fractal geometry of nature. Self-similar and self-affiliated structures. Methods of fractal graphic analysis in engineering and scientific and scientific calculations. Methods of fractal imaging, fractal compression and storage of graphic information
8	Prototyping and animation of 3-D objects (11, 13)	Prototyping, as a stage of design development. The process of creating a prototype. Types of prototypes. Rapid prototyping. Stereolithography, modeling by fusing, laser sintering of powders, fabber technology, three-dimensional printers. Areas of application of rapid prototyping. The advantages and disadvantages of the method. Visualization and animation commands. Timeline of animate. Types of created animation. Creation of motionless and animated images of parts. Animation of components. Animation of camera trajectory. Create video presentations using one or more cameras. Create and save multiple animations in one detail file

9. CONTENTS THEMES OF LABORATORY WORKS

№	Topic	Title
1	Create and edit a 2-D sketch	Creating a tool palette to create a flat image (sketch), as an integral step in the creation of any solid model
2	Working with constructive elements (primitives)	Creation of 3-D models of the simplest geometric bodies by extrusion and rotation of a planar closed contour
3	Visualization of solving the problems of descriptive geometry	Creating models of pairs of geometric bodies for the purpose of 3-D visualization of the line of their intersection. Solving this problem using solid modeling (Autodesk Inventor) and analytical geometry (MathLab)
4	Creation of solid models of complex geometric shapes	Creation of solid-state models of household and technical products (mobile phones, ergonomic seats, dishes)
5	Export of vector graphics and data arrays to the 3-D model	Export vector drawings to their Corel Draw, Illustrstor, AutoCAD for using them as 2-D sketches in the solid modeling environment. Drawing on the surface of the product by engraving
6	Relations and kinematic relationships between bodies	Creating a composite product (a node consisting of several parts). Assignment of connections between components (the disk rotates on the axis, the wheels roll along the rails)
7	Convert a 3-D model to a drawing	Acquaintance with technologies of transformation of 3-D models into flat images by methods of rectangular projection
8	Creation of a parametric model of a geometric body	Familiarization with the principles of parametric modeling. Adjustment of the parametric series and mathematical dependencies between the geometric dimensions of the elements of the 3-D model
9	Programming a Parametric Model	Basic principles of using the application programming interface (API). Analysis of the code of the simplest program (creating a 3-D model of a geometric primitive)
10	Working with a design studio, rendering	Setting up external lighting sources, saving the model as a raster image of high quality
11	Visualization of engineering calculations in Nastran	Programs that visualize engineering calculations. Finite element method. Calculation of the strength of the product according to its solid model
12	Creating a composite product model	Implementation of an individual project: the creation of parametric 3-D models of several parts, their combination into a composite product, the assignment of dynamic links and dependencies
13	The device and principle of operation of a 3-D printer	Creation of a prototype of a geometric body from a previously specified 3-D model on a Cubex printer

10. EXAMPLE LIST OF ASSIGNMENTS OF MANAGED SELF-WORKING TRAINING

No. topics by article 4	Name individual practical work	Content	Corresponding completeness (List of computer programs, visual aids, methodical instructions, technical means for performing work on the article10)
3	Creation of a parametric model of a geometric body	Familiarization with the principles of parametric modeling. Adjustment of the parametric series and mathematical dependencies between the geometric dimensions of the elements of the 3-D model	1
4	Programming a Parametric Model	Basic principles of using the application programming interface (API). Analysis of the code of the simplest program (creating a 3-D model of a geometric primitive)	1
6	Working with a design studio, rendering	Setting up external lighting sources, saving the model as a raster image of high	1

		quality	
8	Visualization of engineering calculations in Nastran	Programs that visualize engineering calculations. Finite element method. Calculation of the strength of the product according to its solid model	1

11. EXAMPLE LIST OF COURSE WORKS

№	Topic title
1	Vector Graphics
2	Solid modeling
3	Structure of automatic design systems
4	Functions, characteristics and examples of CAE / CAD / CAM-systems
5	Simulation of the body of the Power tool
6	Simulation of products of Microsystem technology: Microbeam
7	Simulation of products of Microsystem technology: Micromembrane
8	Simulation of robotic systems
9	Investigation of the fractal properties of the nanostructure of the vacuum coating surface
10	Visualization of engineering calculations at the rate of technical mechanics
11	Creation and visualization of the parametric model of the computer equipment node
12	3-D visualization of surface topography according to AFM data
13	Evaluation of the accuracy of the product model performed by rapid prototyping on a 3-D printer
14	Visualization of numerical methods of solving geometric problems
15	Investigation of the fractal properties of the nanostructure of the vacuum coating surface
16	Visualization of engineering calculations at the rate of technical mechanics
17	Creating a parametric 3-D composite product model
18	Evaluation of the accuracy of the product model performed by rapid prototyping on a 3-D printer
19	Visualization of numerical methods for solving geometric problems
20	Modeling of a rough surface according to 3-D profilometry
21	Simulation of a rough surface according to atomic force microscopy
22	Development of the algorithm for creating a stereogram for the 3-D model
23	Design of a stereoscope based on the principle of parallel view
24	Designing a stereoscope design based on the mirror split image method
25	Development of the algorithm for scanning three-dimensional scenes by triangulation
26	Development of an interactive three-dimensional model of the solar system
27	Creating a 3D visualization of mechanical stresses in a deformable solid body
28	Creating a three-dimensional visualization of temperature fields in a solid
29	Development of a methodology for testing the effectiveness of trackers (sensors) to provide 3D visualization
30	Development of a simulator for laboratory work at the course "Technical mechanics"

12. CRITERIA FOR EVALUATION OF RESULTS BY THE TEN-SECOND SCALE

A ten-point scale, depending on the magnitude of the score and the mark, includes the following criteria:

10 (ten) points, credits:
systematized, in-depth and complete knowledge of all sections of the curriculum of higher education institutions on the subject of academic discipline, as well as on major issues that go beyond it;
accurate use of scientific terminology (including in a foreign language), competent, logically correct statement of the answer to questions;
perfect knowledge of the tools of the academic discipline, the ability to use it effectively in the formulation and solution of scientific and professional problems;
the expressed ability independently and creatively to solve difficult problems in a non-standard situation;

complete and profound mastering of the basic, additional literature, on the studied discipline;
the ability to freely navigate in theories, concepts and directions on the studied discipline and give them an analytical assessment, use the scientific achievements of other disciplines;
creative independent work on practical, laboratory classes, active creative participation in group discussions high level of the culture of performance of tasks.

9 (nine) points, credits:
systematized, deep and complete knowledge of all sections of the curriculum of higher education institutions on the subject of discipline;
exact use of scientific terminology (including in a foreign language), competent, logically correct presentation of the answer to questions;
possession of the tools of the academic discipline, the ability to use it effectively in the formulation and solution of scientific and professional problems;
ability to independently and creatively solve complex problems in an unconventional situation within the curriculum of an institution of higher education in the discipline;
complete mastering of the basic and additional literature recommended by the curriculum of the institution of higher education in the discipline;
the ability to navigate in theories, concepts and directions on the studied discipline and give them an analytical assessment;
systematic, active independent work on practical, laboratory classes, creative participation in group discussions, high level of the culture of performance of tasks.

8 (eight) points, credits:
systematized, in-depth and complete knowledge of all sections of the curriculum of the institution of higher education in the academic discipline in the scope of the curriculum of the institution of higher education for academic discipline;
the use of scientific terminology (including in a foreign language), a competent, logically correct presentation of the answer to questions, the ability to make informed conclusions and generalizations;
possession of the tools of the academic discipline (complex analysis methods, information technology technology), the ability to use it in the formulation and solution of scientific and professional tasks;
ability to independently solve complex problems within the framework of the curriculum of higher education institutions in the field of academic discipline;
assimilation of basic and additional literature recommended by the curriculum of the institution of higher education in the discipline;
the ability to navigate in theories, concepts and directions on the studied discipline and give them an analytical assessment;
active independent work on practical, laboratory classes, systematic participation in group discussions, high level of the culture of performance of tasks.

7 (seven) points, credits:
systematized, deep and complete knowledge of all sections of the curriculum of higher education institutions on the subject of discipline;
the use of scientific terminology (including in a foreign language), a competent, logically correct presentation of the answer to questions, the ability to make informed conclusions and generalizations;
possession of the tools of the academic discipline, the ability to use it in the formulation and solution of scientific and professional tasks;
free possession of standard solutions in the framework of the higher education curriculum for academic discipline;

assimilation of basic and additional literature recommended by the curriculum of the institution of higher education in the discipline;
the ability to navigate in the basic theories, concepts and directions on the studied discipline and give them an analytical assessment;
independent work on practical, laboratory employment, participation in group discussions, high level of the culture of performance of tasks.

6 (six) points, credits:
sufficiently complete and systematized knowledge in the volume of the curriculum of the institution of higher education in the discipline;
use of necessary scientific terminology, competent, logically correct statement of the answer to questions, ability to make generalizations and well-grounded conclusions;
possession of the tools of the academic discipline, the ability to use it in solving educational and professional problems;
the ability to independently apply standard solutions within the curriculum of a higher education institution for academic discipline;
assimilation of the main literature recommended by the curriculum of the institution of higher education in the discipline;
the ability to navigate in the basic theories, concepts and directions of the discipline and give them a comparative assessment;
active independent work on practical, laboratory classes, periodic participation in group discussions, high level of culture of performance of tasks.

5 (five) points, credits:
sufficient knowledge in the curriculum of the institution of higher education in the discipline;
the use of scientific terminology, competent, logical-correct presentation of the answer to questions, the ability to draw conclusions;
possession of the tools of the academic discipline, the ability to use it in solving educational and professional problems;
the ability to independently apply standard solutions within the framework of the higher education institution's curriculum for academic discipline;
assimilation of the main literature recommended by the curriculum of the institution of higher education in the discipline;
the ability to navigate in the basic theories, concepts and directions on the studied discipline and give them a comparative assessment;
independent work in practical, laboratory classes, fragmentary participation in group discussions, sufficient level of culture of performance of tasks.

4 (four) points, credits:
sufficient knowledge within the educational standard of higher education;
assimilation of the main literature recommended by the curriculum of the institution of higher education in the discipline;
the use of scientific terminology, the logical presentation of the answer to questions, the ability to draw conclusions without significant errors;
possession of the tools of the academic discipline, the ability to use it in solving standard (typical) tasks;
the ability, under the guidance of the teacher, to solve standard (typical) tasks;
ability to navigate in the basic theories, concepts and directions on the studied discipline and give them an assessment;
work under the guidance of the teacher in practical, laboratory classes, the permissible level of the culture of performance of tasks.

3 (three) points, not credited:
insufficiently full knowledge within the educational standard of higher education;
knowledge of a part of the main literature recommended by the curriculum of the institution of higher education in the discipline;
the use of scientific terminology, the presentation of the answer to questions with significant, logical errors;
weak possession of the tools of the academic discipline, incompetence in solving standard (typical) tasks;
inability to navigate in the basic theories, concepts and directions of the studied discipline;
passivity in practical and laboratory studies, low level of the culture of performance of tasks.

2 (two) points, not credited:
fragmentary knowledge within the educational standard of higher education;
knowledge of individual literary sources recommended by the curriculum of the higher education institution for academic discipline;
inability to use the scientific terminology of the teaching discipline, the presence of coarse, logical errors in the answer;
passivity in practical and laboratory studies, low level of the culture of performance of tasks.

1 (one) point, not credited:
lack of knowledge and (competencies) in the educational, higher education standard, refusal of response, failure to attend the certification without valid reason.

13. METHODS AND MEANS OF IMPLEMENTATION OF THE CONTENT OF THE TRAINING PROGRAM AND TRAINING OF EDUCATIONAL, TRAINING-METHODICAL MATERIALS

In the classroom, students will learn the discipline directly in the computer class. The following software (software) will be used during the training:

№	Software System	System requirements to the specified software	№ Theme from the educational-methodological map for the support of which the specified software will be used	Purpose of using the software
1.	Autodesk Inventor	Processor: Pentium® III 700 MHz minimum RAM: 384 MB RAM or more recommended Video: DirectX 9 32MB of VRAM is minimal Sound: not needed	8-22	For modeling and visualization of 3D-objects

14. INFORMATION-METHODICAL PART

Basic Literature

1 Гузненков В.Н., Журбенко П.А., Винцулина Е.В. Autodesk Inventor 2016. Трёхмерное моделирование деталей и выполнение электронных чертежей.: ДМК, 2016, 126 стр.
2 Аббасов И.Б. Основы трехмерного моделирования в графической системе 3ds Max 2018. Учебное пособие. : ДМК, 2017, 188 с.
3 Голованов Н. Н. Геометрическое моделирование.—М.: Издательство Физико-математической литературы, 2002, — 472 с.
4 Коичи Мацура, Роджео Ли. WebGL: программирование трёхмерной графики. / пер с англ. Киселёв А.Н. _М.: ДМК Пресс, 2015. – 494 с.
5 Киселевский О.С. Твердотельное трёхмерное моделирование в Autodesk Inventor: учеб.-метод. пособие / О.С. Киселевский. – Минск: БГУИР, 2017. – 92.
6 Егоров В. В. Когнитивные технологии : учебное пособие [доп. МО РБ]. - Минск : БГУИР, 2017. - 240 с. : ил.

Additional literature

7 Dunn Fletcher. 3D math primer for graphics and game development / by Fletcher Dunn and Ian Parberry, 2002, 449 p.
8 С. Красноперов. Самоучитель Autodesk Inventor. Спб: БХВ-Петербург, 2008
9 Фураев Э.В. Компьютерные технологии в приборостроении : учеб. пособ. для студ. ВУЗов / Э.В. Фураев, Л.И. Фураева. – М: Изд. центр «Академия», 2009. – 336 с.
10 Ушаков Д.М. Введение в математические основы САПР: курс лекций. – М: ДМК, 2011. – 208 с.