National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"

Department
biomedical engineering

MATERIAL SCIENCE AND STRUCTURAL MATERIALS

Working program of basic discipline (Syllabus)

Requisites for basic discipline	
Level of higher education	***First (bachelor's)***
Branch of knowledge	*16 Chemical and Bioengineering*
Specialty	*163 Biomedical Engineering*
Educational program	*Medical Engineering*
Discipline status	*Mandatory discipline*
Form of study	*full-time*
Year of preparation, semester	*2nd year, autumn semester*
The scope of discipline	*4.5 ECTS credits*
Semester control / Control measures	*Test, Modular Control Work*
Lessons schedule	*According to the schedule on the site http://rozklad.kpi.ua/*
Language of instruction	*English*
Information about course leader / teachers	***Lecturer**: Yurii Yavorskyi* ***Practical**: Yurii Yavorskyi*
Course placement	*https://campus.kpi.ua* *https://www.youtube.com/channel/UClcevlTnjMp4xMvyJhr6FjA*

Curriculum of the discipline

1. Description of the discipline, its purpose, subject of study and learning outcomes

The Purpose of the Discipline.

"Materials Science and Structural Materials" is one of the important special subjects of the curriculum of the specialty 163 "Biomedical Engineering". The importance of this course is due to the need to train specialists with basic knowledge and competencies in the field of biomedical engineering, to formulate and substantiate medical and technical requirements for medical products, to analyze the dependence of the properties of medical material on various parameters, to make the choice of material in accordance with the technique in order appointment.

Given that the discipline is mandatory, it is necessary to be proficient in:

- ***skills:** basic knowledge of mathematics, physics, chemistry and biochemistry;*
- ***competencies:** apply statistical methods of analysis of communication and dynamics of phenomena; collect, process and analyze source data; analyze and interpret data; solve mathematical, physical and materials science problems.*

General competencies (OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):

- ***GC 1** - Ability to apply knowledge in practical situations.*
- ***GC 2** - Knowledge and understanding of the subject area and understanding of professional activity.*
- ***GC 3** - Ability to communicate in the state language both orally and in writing.*
- ***GC 4** - Skills in the use of information and communication technologies.*

- ***GC 5*** *- Ability to perform research at the appropriate level.*
- ***GC 6 -*** *Ability to search, process and analyze information from various sources.*
- ***GC 7 -*** *Ability to generate new ideas (creativity).*
- ***GC 8 -*** *Ability to make well-grounded decisions.*
- ***GC 9*** *- Ability to communicate with representatives of other professional groups of different levels (with experts from other fields of knowledge / types of economic activity).*
- ***GC 10*** *- Safe activities skills.*

Special (professional) competencies *(OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):*

- ***PC 2*** *- Ability to provide engineering expertise in the process of planning, development, evaluation and specification of medical equipment.*
- ***PC 6*** *- Ability to effectively use tools and methods for analysis, design, calculation and testing in the development of biomedical products and services.*

The program learning outcomes after studying the discipline" Material science and structural materials" are *(OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):*

- ***PLO 2 -*** *Possession of engineering methods for calculation of elements of devices and systems of medical use and a choice of classical and newest constructional materials.*
- ***PLO 7 -*** *Understanding of scientific and technical principles that underlie the latest advances in biomedical engineering.*
- ***PLO 24 - A****pply knowledge of the basics of mathematics, physics and biophysics, bioengineering, chemistry, engineering graphics, mechanics, resistance and strength of materials, properties of gases and liquids, electronics, computer science, obtaining and analyzing signals and images, automatic control, systems analysis and decision making methods at the level required to solve the problems of biomedical engineering.*
- ***PLO 32 -*** *Understanding of theoretical and practical approaches to creation and application of artificial biological and biotechnical objects and materials of medical appointment.*
- ***PLO 41 -*** *Apply knowledge of chemistry and bioengineering for the creation, synthesis and application of artificial biotechnical and biological objects.*

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

The discipline "Material science and structural materials" is an interdisciplinary study that integrates according to its subject knowledge from other disciplines: physics, biochemistry, mathematics, etc. Following the structural and logical scheme of the training program, the discipline "Material science and structural materials" is closely related to other disciplines of general and professional training: "Biomaterials and biocompatibility", "Radiation safety and dosimetry", "Devices for control of person's physiological parameters", etc. It is preceded by the discipline "Biochemistry".

The acquired practical skills and acquired theoretical knowledge during the study of the discipline "Material science and structural materials" can be used in the disciplines:

- from the cycle of professional training (educational-professional program "Medical Engineering"): "Biomaterials and biocompatibility", "Radiation safety and dosimetry", "Devices for control of person's physiological parameters;

- in elective disciplines (educational-professional program "Medical Engineering"): some disciplines;

- undergraduate practice and diploma design.

3. The content of the discipline

The main sections and topics considered in the course:

Section 1. Metal science

Subject 1.1. *Structure of metals. Properties of metals and their alloys*

Subject 1.2. *Phase transitions. Diagrams of states*

Subject 1.3. *Metals and alloys*

Subject 1.4. *Carbon alloys with carbon*

Section 2. Heat treatment of metals and alloys.

Subject 2.1. *Annealing. Steel bending and tempering.*

Subject 2.2. *Surface hardening of metals and alloys*

Section 3. Construction materials.

Subject 3.1. *Alloy steels*

Subject 3.2. *Metals and alloys with special properties*

Subject 3.3. *Non-ferrous metals and alloys*

Subject 3.4. *Non-metallic materials*

Subject 3.5. *Methods of processing structural materials*

4. Training materials and resources

Basic literature:

1.Афтанділянц Є.Г., Зазимко О.В., Лопатько К.Г. Технологія конструкційних матерілів і матеріалознавство. – К.: Видавничий центр НАУ, 2007. –356 с.

2.Кузін О.А., Яцюк Р.А. Металознавство та термічна обробка металів. – Л.: "Афіша", 20024. – 300 с.

3.Котречко О.О., Зазимко О.В. та ін. Практикум з матеріалознавства. - Херсон: Олді-Плюс, 2013. – 499 с.

4. Roger Narayan editor. Biomedical Materials. – USA: Springer, 2009 – 569 c. ISBN 978-0-387-84871-6

5.G. F. Carter, Giles F. Carter and Donald E. Paul, editors. Materials Science and Engineering. – USA: ASM International, 1991 – 369.

Additional literature:

1.Бялік О.М. та ін. Металознавство: Підручник. - К ІВЦ «Політехніка». 2001.-375 с. - ISBN 966-622-053-9.

2.Лахтин Ю.М., Леонтьева В.П. Металловедение: Учебник — 3-є изд., перераб. и доп. -М.: ЗКОЛИМ, 2011. - 528 с. - ISBN 978-5-4365-0025-6.

3.Матеріалознавство та технологія матеріалів. Конспект лекцій Уклад 1 М. Курська, Г.О. Чернобай, С.Б. Єрьоменко. - Х.: УЦЗУ. 2008. - 136 с.

4.Опальчук А.С., Котречко О.О. Роговський Л.Л. Лабораторний практикум з технології конструкційних матеріалів і матеріалознавства: Навч. посібник / За ред. А.С. Опальчука. — К.: Вища освіта, 2006. - 287 с.

Educational content

5. Methods of mastering the discipline (educational component)

Contents of lectures

Lecture 1*. Introduction. Material science as a science. The main historical stages. General characteristics of metals. The main criteria for evaluation and selection of materials.*

Lecture 2. *Polymorphism. Mechanical mixtures. Solid solutions. Chemical compounds. Crystallization of mixtures of substances. Diagrams of status I - IV kind. Eutectic and eutectoid*

transformations. Gibbs phase rule. Rule of segments.

Lecture 3. *Anisotropy. Crystal lattice. Crystalline systems. The structure of real crystals. Single crystals and polycrystals. Elimination. Dendrites.*

Lecture 4. *Texture. Defects in the crystal structure and their effect on the properties of metals. Dislocation mechanism of plastic deformation by sliding. Deformation strengthening.*

Lecture 5. *Principles of analysis of double alloy state diagrams. Components and phases. Eutectic, eutectoid and pretectic transformation.*

Lecture 6. *Diagrams of Fe-Fe3C (iron-cementite) and Fe-C (iron-graphite). Cementite, ferrite, austenite. Perlite, ledeburit. Isothermal transformations in the state diagram of iron-carbon alloys. Fe-C (iron-graphite) state diagram.*

Lecture 7. *Advantages and disadvantages of cast iron. Cast iron products. Classification by chemical composition and structure, method of smelting, degree of deoxidation, quality, purpose. "Steel area" of the Fe-Fe3C state diagram, Structure, properties, classification and marking of steels. Advantages and disadvantages of steels.*

Lecture 8. *The theory of heat treatment of steel. Phase transformations when heated. Annealing forks, temperature limits. The concept of tempering and tempering of steel. Diagram of isothermal transformation.*

Lecture 9. *Methods of quenching. Conversion of martensite into perlite. Vacation. Influence of heat treatment on mechanical properties of steel.*

Lecture 10. *Basic types of surface hardening. Technological processes of chemical-thermal treatment. Types of modes and their purpose. Advantages and areas of use of cementation, nitriding, different types of diffusion metallization.*

Lecture 11. *Classification of steel alloys. The influence of alloying elements on the change in the structure and properties of steel. Classification and marking of steels.*

Lecture 12. *Structure, properties and application of corrosion-resistant (non-corrosion-proof), heat-resistant (scale), heat-resistant, wear-resistant steels and alloys with special physical and chemical properties.*

Lecture 13. *Classification of copper alloys, their composition, marking system, properties and applications. Mechanical properties of copper and brass.*

Lecture 14. *Aluminum and its alloys. Classification, marking, purpose. Technological methods of manufacturing aluminum alloy products.*

Lecture 15. *Thermoplastic and thermosetting polymers, their physical and mechanical properties and applications. Characteristics of the most common thermoplastic and thermosetting plastics. The aging process of plastics.*

Lecture 16. *The basic types of metal processing by pressure, rolling, drawing, pressing, forging, punching volume and sheet.*

Lecture 17. *The main ways of forming plastic products.*

Lecture 18. *Prospects for development and creation of new materials.*

Contents of practical's

Practical 1. *Microstructural analysis of metals and alloys. Acquaintance with work of the equipment.*

Practical 2. *Microstructural analysis of metals and alloys. Carrying out of research of microstructure of ferrous and non-ferrous metals.*

Practical 3. *Macrostructural analysis of metals and alloys. Determination of the macrostructure of metals. The method of fractures.*

Practical 4. *Macrostructural analysis of metals and alloys. Determination of the distribution of sulfur in the casting by the Bauman method.*

Practical 5. *Plastic deformation and recrystallization of metals.*

Practical 6. *State diagrams of binary systems, basic principles.*

Practical 7. *Analysis of transformations occurring in alloys during cooling and heating, determination of phase and structural state of alloys depending on their composition and temperature.*

Practical 8. *State diagram of the iron-carbon system.*

Practical 9. *Phase transformations in Fe-Fe_3C alloys.*

Practical 10. *Steel and white cast iron. The structure of steels.*

Practical 11. *Steel and white cast iron. The structure of white cast iron.*

Practical 12. *Marking and principles of classification of alloy steels.*

Practical 13. *Gray, malleable and high-strength cast iron.*

Practical 14. *Defects in the structure of metals.*

Practical 15. *Heat treatment of steels. Hardening, tempering and annealing.*

Practical 16. *Chemical and heat treatment of metal products. Introduction to the processes of cementation, nitriding and diffuse saturation.*

Practical 17. *Aluminum-based alloys. Classification and labeling.*

Practical 18. *Heat treatment of aluminum alloys.*

Practical 19. *Copper-based alloys. Structures and properties of brass.*

Practical 20. *Copper-based alloys. Structures and properties of bronzes.*

Practical 21. *Antifriction alloys.*

Practical 22. *Titanium-based alloys.*

Practical 23. *Properties of thermoplastic and thermosetting plastics. Features of physical and mechanical characteristics of plastics.*

Practical 24. *Module control work.*

6. Independent student work

Independent work of students (total duration of 40 hours) on the discipline is:

- self-study of literary sources to expand the understanding of lecture topics - at the rate of 0.5 hours per lecture = 9 hours;

- preparation for practical work and formulation of conclusions - at the rate of 1 hour for 1 practical work = 23 hours;

- preparation for home control work (HCW) - 3 hours;

- preparation for module control work (MCW) - 3 hours;

- preparation for the final test - 3 hours.

Policy and control

7. Policy of academic discipline (educational component)

Attending classes

The system of requirements for students:

• Elaboration of material on all topics of lectures and practical classes is mandatory.

• Attendance at all classes is optional.

- The student must work off the missed lecture by writing a lecture synopsis of the missed topic.

- The student must complete the task of the missed practical lesson within the time agreed with the professor.

• It is forbidden to use mobile phones in audio mode during all classes. It is allowed to use a mobile phone only to perform the tasks set by the teacher in practical or lecture classes or to obtain additional information on the topic of the lesson.

• It is forbidden to use any gadgets when writing tests, tests and tests.

•The results of practical work are presented in the form of reports. The report consists of a theoretical part, a practical part and conclusions. The theoretical part of the report can be printed, the practical part and conclusions should be drawn up by hand. Direct defense takes the form of interviews, questions or answers.

• Incentive points can be awarded for special learning achievements - the application of a creative approach to practical work, including the use of data for work on their own research.

• Deadline policy stipulates the need for timely completion of tasks. The syllabus for the missed lecture must be provided to the teacher no later than 2 weeks from the time of the missed lecture. Reports on practical work are performed and submitted for inspection no later than 2 weeks after completion. All written documents must be defended before the end of the theoretical training in the semester.

Academic integrity

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". Read more: https://kpi.ua/code.

Norms of ethical behavior

Normative principles of behavior of students and employees, defined in sections 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more: https://kpi.ua/code.

Procedure for appealing the results of control measures

Students have the opportunity to raise any issue related to the control procedure and expect it to be addressed according to predefined procedures.

The student has the right to appeal the results of the control measure according to the approved provision on appeals in the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (approved by the order №NON/128/2021 from 20.05.2021) - https://osvita.kpi.ua/index.php/node/182

Inclusive education

The discipline "Biophysics" can be taught to most students with special educational needs, except for students with severe visual impairments who do not allow to perform tasks using personal computers, laptops and / or other technical means.

Distance learning

Distance learning is conducted by communication between teacher and students in a telegram group. Lectures are conducted with the help of Google Meet or ZOOM resources.

Practical classes with the help of Google Meet or YouTube resources. To perform a practical task, the student must draw up a protocol and send a scanned copy to the teacher. To get the final grade for a practical task, the student needs to take a test through the Google form or take an online interview with the teacher.

Modular control work is carried out in the form of an online interview between teacher and student.

Learning the discipline in a foreign language

Teaching in English is carried out only for foreign students.

At the request of students, it is allowed to study the material with the help of English-language online courses on topics that correspond to the topics of specific classes.

***8*. Monitor and evaluate the system of evaluation of learning outcomes (Rating System of Evaluation)**

Evaluation system (current control):

Table. 2. *Calculation of the final score*

№ s/n	*Control measure*	*Weight points*	*Number*	*Total*
1.	*Active participation in lectures*	*7*	*1*	*7*
2.	*Work on practical classes*	*3*	*23*	*69*
3.	*Home control work (HCW)*	*12*	*1*	*12*
4.	*Modular control work (MCW)*	*12*	*1*	*12*
	Total			*100*

- keeping notes and active participation in lectures (incentive points) - 7 points.

- Work on practical classes (PC) 69 points - a maximum of 3 points for each work. Criteria for evaluating the results of work in practical classes (SO) table 2.

- home control work is carried out once within a semester on the subject of practical classes. The maximum score for HCW is 12 points. Criteria for evaluating the results written by the HCW are presented in tables 2.

- modular control work is conducted once a semester on the topics of lectures and practical classes. The maximum score for the MCW is 20 points. Criteria for evaluating the results written by the MCW are presented in tables 2.

Table. 2. *Evaluation criteria and the number of points for work in PC, HPW and MPW*

Criteria	*PC*	*HPW*	*MPW*
full answer (excellent)	*3*	*10-12*	*10-12*
incomplete answer (good)	*2*	*7-9*	*7-9*
incomplete answer (satisfactory)	*1*	*5-6*	*5-6*
unsatisfactory answer	*Less than 1*	*Less than 1*	*Less than 1*

Calendar control (CC) *- is carried out twice a semester as monitoring of the current state of compliance with the requirements of the syllabus. To get a positive result in the first calendar control, you must have at least 20 points, the second - at least 50 points.*

Semester certification of students

The semester certification of students is test. Conditions of admission to semester control: semester rating not less than 60 points. If the student is satisfied with the number of points he received for the semester, he can get a test "automatically", but if the student wants to increase his rating, you need to have all the credited practical and calculation and graphic work and write a test. The rating for the semester is canceled, the test is 100 points, the total rating is evaluated on a university scale, the table of knowledge assessment of which is presented in table 3.

Optional conditions for admission to closure:

1. *Activity during practical classes.*
2. *Positive result of the first attestation and the second attestation.*
3. *Attending lectures.*

Table 3. *Table of translation of rating points to grades on a university scale.*

Total rating points	***Grades according to the university scale***
100-95	*Excellent*
94-85	*Very good*
84-75	*Good*
74-65	*Satisfactory*
64-60	*Passed*
Below 60	*Unsatisfactory*
Violation of passing requirements	*Not passed*

9. Additional information on the discipline (educational component)

For a more in-depth study of the discipline, I recommend dealing with the following issues:

1. *Physical, mechanical, chemical, technological, operational and special properties of materials.*
2. *Thermodynamic equilibrium and metastable states. Martensitic transformation.*
3. *Mechanical properties and methods for determining their quantitative characteristics Brinell hardness. The Rockwell Method. Vickers Method.*
4. *Shore dynamic method. Influence of temperature. Methods for evaluating viscosity. Evaluation of viscosity by type of fracture. Technological properties. Performance properties*
5. *The process of graphitization. Structure, properties, classification and marking of cast iron.*
6. *Steel products. Features of pearlitic, intermediate and martensitic transformations occurring in the upper, middle and lower temperature regions, respectively.*
7. *Structure and properties of perlite, sorbitol, trostite, martensite.*
8. *Influence of alloying elements on kinetics and character of transformation in perlite, intermediate and martensitic regions.*
9. *Thermo-mechanical treatment of steel. Technological processes of thermomechanical processing. Types of modes and their purpose. Defects arising from the heat treatment of steel.*
10. *Chemical-thermal treatment in solid, liquid and gas environments. Dissociation, adsorption and diffusion processes.*
11. *Basic performance of each group. Selection of suitable alloy steels for production of certain parts and tools.*
12. *Heat resistant copper alloys and their purpose. Nickel and its alloys. Alloys for thermocouples and electric heaters.*
13. *Magnesium alloys, their properties and applications. Allotropic titanium modifications.*
14. *The influence of alloying elements and impurities on the mechanical properties of titanium. Heat treatment of titanium alloys. Marking system and field of use.*
15. *Anti-friction (bearing) alloys. Powder materials.*
16. *Rubber technical materials. Composition and classification of tires. General purpose tires and their characteristics. Special-purpose tires and their applications. Adhesives, paints and varnishes, their application.*
17. *Inorganic materials: glass, ceramics, corundum ceramics.*

18. *Materials obtained by powder metallurgy. Principles of creation of basic types of composite materials.*
19. *Casting properties of alloys and foundry production. Injection molding - using fusible and gasified models; - in metal forms; - under pressure and other casting methods.*

Work program of the discipline (syllabus):

Compiled by

Approved by *the Department of Biomedical Engineering (protocol № ___ from 25 June 2021)*

Approved by *the Methodical Commission of the Faculty of Biomedical Engineering (protocol № __ from 27 August 2021)*