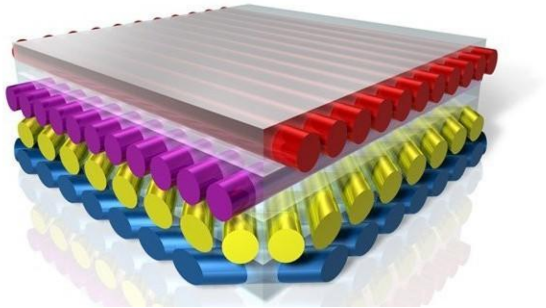
Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Department of Applied Radio Electronics

[RE-26] CONSTRUCTION AND RADIO MATERIALS



Work program of the academic discipline (Syllabus)

Course details

Level of higher education	First (bachelor's)
Field of knowledge	17 - Electronics, Automation, and Electronic Communications
Specialization	172 - Electronic Communications and Radio Engineering
Educational program	All educational programs
Discipline status	Elective (F-catalog)
Form of higher education	Full-time
Year of training, semester	Available for selection starting from the 2nd year, fall semester
Course load	4 credits (Lectures 16 hours, Practical classes 30 hours, Laboratory work 30 hours, Independent work 74 hours)
Semester Control/control measures	Credit
Class schedule	https://schedule.kpi.ua
Language of instruction	Ukrainian
Information about the course coordinator/teachers	Lectures: Nepochatych Y. V., Labs: Nepochatych Y. V., Independent work: Nepochatych Y. V.
Course location	

Curriculum

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

The professional training discipline "Construction and Radio Materials" is a primary component of the set of disciplines that prepare students for their future design, construction, and technological activities.

The purpose of teaching the discipline is to develop students' abilities to: •

assess the conditions of material use;

- draw up requirements for materials in accordance with their operating conditions;
- make informed choices about materials according to their purpose, operating conditions, and technology.

Subject of the discipline: properties of structural and radio engineering materials, their parameters and the influence of various factors on them. The discipline provides specific knowledge and understanding of the effects of various technological and operational factors on the properties of materials, the characteristics of their behavior in different production and use conditions and, if necessary, the mechanisms for purposeful modification of material properties.

Program learning outcomes:

knowledge:

- composition and structure of materials;
- properties of materials;
- the influence of external factors on the properties of materials;
- parameters and possibilities of using materials;
- classification of materials, material grades;

skills:

- link the properties of a material to its composition, structure, production technology, and shaping;
- predict the dependence of material properties on operating conditions;
- measure material parameters;

experience:

- use a combination of knowledge and skills to select materials for use in radio-electronic devices.

Program outcomes of the educational program:

PLO 4: explain the results obtained from measurements in terms of their significance and relate them to the relevant theory;

PLO 18: find, evaluate, and use information from various sources necessary for solving professional tasks, including reproducing information through electronic search;

PLO 28: apply methods and means of influencing the parameters of the physical environment;

PLO 31: apply ... the latest materials in the design of radio-electronic equipment for intelligent systems.

2. Prerequisites and post-requisites of the discipline (place in the structural-logical scheme of training under the relevant educational program)

Interdisciplinary connections:

The study of the discipline requires knowledge acquired by students in the study of physics (at the level of the first year of study), chemistry (at least at the level of the school course), mathematics (at the level of the first year of study), and the basics of circuit theory.

The knowledge is provided by the following disciplines: "Electronic Components," "Applied Mechanics," "Mechatronics", "Design of Intelligent Radio-Electronic Equipment", "Elements of Intelligent Radio-Electronic Equipment", "Technology of Radio-Electronic Equipment Production", "Technology of Electronic Equipment Production: Technologies assembly, installation, adjustment, control, and testing."

3. Contents of the academic discipline

Section and topic names	Number of hours				
	Total	including			
		Lectures	Practical (seminar)	Laboratory (computer workshop)	SRC
1	2	3	4	5	6
Section 1. Construction materials					
Topic 1.1. *General provisions. Crystallization of simple substances*	*8*	*4*			*4*
Topic 1.2. *Complex substances*	*23*	*8*		*4*	*11*
Topic 1.3. The effect of heat treatment and plastic deformation on properties of substances	*16*	*8*			*8*
Section 2. Radiomaterials					
Topic 2.1. *General provisions. Classification of materials*	*8*	*4*			*4*
Topic 2.2. *Dielectrics*	*22*	*8*		*6*	*8*
Topic 2.3. *Magnetic materials*	*10*	*2*		*4*	*4*
Topic 2.4. *Conductive materials*	*8*	*2*		*4*	*2*
Modular test	*4*				*4*
Home test	*15*				*15*
Preparation for the exam	*6*				*6*
Total hours	120	36		18	66

4. Teaching materials and resources

Recommended reading

Basic

1. Buzylo V.I. Materials Science: Textbook / V.I. Buzylo, V.P. Serdyuk, A.V. Yavorsky, O.A. Haidai / Ministry of Education and Science of Ukraine, National Technical University "Dnipro Polytechnic" — Dnipro
2. : NTU "DP", 2021. — 243 p.
3. Vlasenko A.M. Materials Science and Metal Technology: Textbook for Vocational Education Students / A.M. Vlasenko. — Kyiv: Litera LTD, 2019. — 224 p.
4. Shapoval S. V. Lecture notes on the discipline "Materials Science" (for 2nd-year full-time students of the educational level "bachelor" in specialty 185
5. "Oil and Gas Engineering and Technology") / S. V. Shapoval; Kharkiv National University of Municipal Economy named after O. M. Beketov. — Kharkiv: KNUCE named after O. M. Beketov, 2017. — 122 p.
6. Afanasyeva O.V. Materials Science and Structural Materials. Textbook. — Kharkiv: KhNURE, 2016. — 188 p.
7. Materials Science and Materials Technology. Lecture Notes / Compiled by T.M. Kurskaya, G.O. Chernobay, S.B. Yeromenko. — Kharkiv: UCSU, 2008. — 136 p.
8. V. M. Garnets, V. M. Kovalenko G20 Structural Materials Science: Textbook. — Kyiv: Lybid, 2007. — 384 p.
9. Poplavko Yu. M. Physical Materials Science: Textbook / Yu. M. Poplavko, S. O. Voronov. — Kyiv: Internet Publishing House of the National Technical University of Ukraine, 2015. — 699 p.
10. Materials for Radioelectronic Equipment and Telecommunication Systems. Lecture Course: Textbook / Igor Sikorsky Kyiv Polytechnic Institute; comp.: A. P. Miroshnychenko, G. V. Ivannik. — Electronic network educational publication — Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2022. 242 p.
11. Electrical engineering materials: Course lectures. Part 1. Dielectric materials.
12. [Electronic resource]: textbook for students of all forms of education in specialty 141 "Electric Power Engineering, Electrical Engineering and Electromechanics" / Igor Sikorsky KPI; comp.: V.M. Kyrylenko, K.V. Kyrylenko. V.M. Golovko. — Electronic text data (1 file: 6.698 MB). — Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. — 224 p.
13. Lyshuk V. V. Electrical and Radio Materials: Textbook / V. V. Lyshuk. — Lutsk: 2016. — 324 p.
14. Leontiev V. O. Electrical Engineering Materials: Textbook / V. O. Leontiev, S. V. Bevz, V. A. Vydmish. — Vinnytsia: VNTU, 2013. — 122 p.
15. Electrical and Radio Materials: Laboratory Practicum [Electronic resource]: textbook for students

majoring in 172 "Electronic Communications and Radio Engineering" / Igor Sikorsky KPI; compiled by: Yu. V. Nepochatykh. — Electronic text data (1 file: 1.17 MB). — Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2023. — 72 p.

16. Methodological guidelines for completing homework assignments, calculations, drawings, and tests in the discipline "Materials Science of Radio Electronic Devices" for students majoring in
17. "Design and Technology of Radioelectronic Devices" of all forms of training / compiled by V. A. Bidenko, S. V. Ogurtsov, M. F. Bogomolov. — Kyiv: KPI, 1990. — 32 p.

Additional

1. Structural Materials Technology and Materials Science: Reference Dictionary / V. V. Popovich, V. V. Popovich. — Lviv: Svit, 2010. — 304 p.
2. Bovsunovsky, A. P. Electrical Materials: A Brief Reference Guide / A. P. Bovsunovsky. — Kyiv: NUHT, 2012.
   a. 36 p.

3. DSTU 2825-94. Strength calculations and tests. Terms and definitions of basic concepts. [Effective from 1996-01-01]. Official publication. Kyiv: DP "UkrNDNC," 1994. 22 p.
4. DSTU 2824-94 Strength calculations and testing. Types and methods of mechanical testing. Terms and definitions. [Effective from 1996-01-01]. Official publication. Kyiv: DP
5. UkrNDNC, 1994. 18 p.

6. DSTU 3715-98. Metals. Types of fracture surfaces (breaks). Terms and definitions. [Effective from 1999-01-01]. Official publication. Kyiv: DP "UkrNDNC", 1998. 24 p.
7. DSTU 2651-94. Carbon steels of ordinary quality. Grades. [Effective from 1996-01-01]. Official publication. Kyiv: State Enterprise "UkrNDNC", 1994. 27 p.
8. DSTU 3054-95. Cast iron and steel. Methods of analysis. Terms and definitions. [Effective from 1996-07-01]. Official publication. Kyiv: DP "UkrNDNC", 1995. 43 p.
9. DSTU 2439:2018. Chemical elements and simple substances. Terms and definitions of basic concepts, names, and symbols. [Effective from 2019-10-01]. Official publication. Kyiv: State Enterprise "UkrNDNC," 2018. 15 p.
10. DSTU 3002-95. Calculations and strength tests. Methods for testing the fatigue of materials under high-frequency axial loading. [Effective from 1996-01-01]. Official publication. Kyiv: State Enterprise "UkrNDNC", 1995. 29 p.
11. DSTU 2843-94. Electrical engineering. Basic concepts. Terms and definitions. [Effective from 1996-01-01]. Official publication. Kyiv: DP "UkrNDNC", 1994. 36 p.
12. DSTU 2725-94. Magnetic materials. Terms and definitions. [Effective from 1995-07-01]. Official publication. Kyiv: State Enterprise "UkrNDNC", 1994. 34 p.
13. DSTU 2815-94 Electrical and magnetic circuits and devices. Terms and definitions. [Effective from 1996-01-01]. Official publication. Kyiv: State Enterprise "UkrNDNC", 1994. 58 p.

Educational content

5. Methodology for mastering the academic discipline (educational component)

Lectures

<u>Section 1. Construction materials.</u>

Topic 1.1. General provisions. Crystallization of simple substances.

Lecture 1. Terminology. Thermodynamic systems. Parameters of construction materials.

List of key issues: *component, main component, impurity, contamination, alloying component, degree of alloying, simple metal, traces (of impurities, contamination). Thermodynamic systems: isolated, uninsulated, homogeneous, heterogeneous, equilibrium, non-equilibrium.*
Phase definition. Helmholtz free energy. Determining the direction of the process. [4, pp. 9–15; 28, pp. 163, 187–

193]

Assignments for independent study: *Mechanical stress. Strength, hardness, plasticity, brittleness. Laws of thermodynamics. Clausius' postulate.*

[4, pp. 9–15; 1, pp. 87–110]

Lecture 2. Crystallization of simple substances.

List of main topics: *Primary and secondary crystallization. Cooling curve. Degree of supercooling. Latent heat. Crystal lattice. Elementary crystal cell. Crystal lattices of metals. Anisotropy, quasi-isotropy, texture and its use. Defects in crystal structure. Dislocations. Dislocation slip. Dislocation annihilation. Crystal size. The principle of thin-walled design. Quasi-amorphous state. Glass, sitalloy, amorphous metal. Polymorphism. Modification.*

[1, pp. 7–27; 3, pp. 390–393, 401–406; 7, pp. 18–19]

Assignments for independent study: *Types of bonding. Critical radius of crystallization nucleus. Brave lattices. Coordination number. Packing density. Indexing of crystallographic direction and crystallographic plane. Point defects. Cottrell clouds. Burgers vector.*
Dislocation creep. Surface defects. Metallographic analysis. [20, pp. 29–44; 1, pp. 11–24;

18, pp. 52–56]

Topic 1.2. Complex substances.

Lecture 3. Phases of complex substances. Phase diagram.

List of main *topics: Solid solutions, chemical compounds, mixtures of different phases. Gibbs' rule. Variability of a thermodynamic system. Phase diagram. Expression of component concentrations.*
Kurnakov's principles. Methods of constructing diagrams. Methods of analyzing complex substances. Phase diagram of the 1st kind. Konoda. Lever rule. Concentration rule. Eutectic.

[4, pp. 19–21, 38–51; 2, pp. 93–105]

Assignments for independent study: *Chemical potential of a component. Method of geometric thermodynamics in constructing phase diagrams. Differential method of analysis. X-ray structural analysis (Laue and Debye methods).*

[3, pp. 23–24; 18, pp. 52–101; 4, pp. 40–51]

Lecture 4. Unlimited solubility of components. Non-equilibrium states.

List of main questions: *Phase diagram with unlimited solubility of components. Dendritic liquidation. Solubility gap. Non-equilibrium states. Hardening and aging. Processing and application of dispersion-hardening alloys.*

[1, pp. 51–63; 2, pp. 97–105; 3, pp. 118–129]

Assignments for independent study: *Density segregation. Homogenization. Zone refining. Zone formation and retention. Mechanism of zone refining.*

[1, pp. 55–61; 6, pp. 41–43, 84–85, 346–350; 18, pp. 47–49]

Lecture 5. Limited solubility of components. Relationship between phase diagrams and material properties.

List of main topics: *Phase diagram with limited solubility of components. Eutectic and peritectic reactions. Phase diagrams with allotropy of components. Eutectoid transformation. Use of phase diagrams. Relationship between phase diagrams and material properties. Additive and nonlinear dependencies. Strength and plasticity.*
Fluidity and its dependence on the crystallization interval. Deformable alloys and alloys for casting. [1,

pp. 56–65; 3, pp. 145–149; 6, pp. 50–54]

Assignments for independent study: *Diagrams for chemical compounds. Multicomponent systems. Concentration triangle. Concentration tetrahedron.*

[1, pp. 65–68; 3, pp. 129–141, 149–152]

Lecture 6. Iron–carbon system.

List of main questions: *Transformations in iron with temperature change, hysteresis of transformations. Solid solutions of carbon in iron modifications. Chemical compound of iron with carbon. Iron-carbon phase diagram. Peritectic, eutectic, and eutectoid regions of the diagram. Distribution of iron-carbon alloys. Effect of carbon on the properties of steel. Effect of alloying components on the properties of steel.*

[1, pp. 118–144; 3, pp. 152–173; 6, pp. 55–65]

Assignment for independent study: *Deciphering the structure of steel or cast iron for any phase field of the iron-carbon diagram. The influence of accompanying components on the properties of steel. Austenitic and ferritic steels. The system of steel grade designations.*

[3, pp. 133–141, 161–173; 1, pp. 132–134; 141–144]

Topic 1.3. The effect of heat treatment and plastic deformation on the properties of substances.

Lecture 7. TTT diagram. Martensite. Austenite grain size.

List of key questions: *Isothermal diagram. Incubation period. Slowing down and suppression of carbon diffusion. Construction of the TTT diagram. Diffusion, non-diffusion, and intermediate regions of the TTT diagram. Properties of non-equilibrium structures. Martensitic transformation.*
Critical cooling rate. Transformation during continuous cooling. Martensite decomposition. [1,

pp. 165–189; 3, pp. 195–217; 6, pp. 85–103]

Assignment for independent study: *Transformations in steel during heating and cooling. Austenite grain growth. Widmanstätten structure. Heredity of steel.*

[1, pp. 156–165; 3, pp. 190–195; 6, pp. 89–91]

Lecture 8. Heat treatment of steel. Thermomechanical treatment. Chemical-thermal treatment of steel.

List of main issues*: Types and technology of heat treatment of steel. Heating and cooling environments. Internal stresses. Their influence and determination. Hardenability and temperability of steel. Tempering of steel. Cold treatment of steel. Thermomechanical treatment. General overview of heat treatment of structural materials; classification of its types according to Bochvar.*

[1, pp. 191–228; 3, pp. 223–257]

Assignments for independent study: *Chemical-thermal treatment of steel. Dependence of the diffusion layer thickness on the treatment mode. Carburizing. Nitriding. Cyaniding. Diffusion metallization.*

[1, pp. 228–249; 3, pp. 257–269; 6, pp. 110–122]

Lecture 9. The effect of plastic deformation on the properties of substances.

List of key issues: *Mechanical properties determined by static tests. Tensile curve. Elastic and plastic deformation. Schmid's law. Dislocation mechanism of plastic deformation. Frank-Ried source. Bausinger effect. Whiskers. Deformation strengthening (work hardening) during plastic deformation. Bochvar diagram. Ways to increase strength.*

[1, pp. 87–98, 110–118, 68–77; 3, pp. 45–56, 62–69, 110–118; 6, pp. 66–74]

Assignment for independent study: *Mechanical properties determined by dynamic, variable, and extended tests. Impact toughness. Endurance limit. Creep.*

[1, pp. 98–110; 3, pp. 69–75]

Lecture 10. Plastic deformation and recrystallization.

List of main questions: *Reversibility and recrystallization. Recrystallization diagram. Hot and cold plastic deformation. Bochvar's formula. Plastic deformation diagrams. Diagram of comprehensive compression under high pressure; its practical implementation.*

[1, pp. 81–87; 3, pp. 56–62; 6, pp. 74–79]

Assignment for independent study: *Application of plastic deformation in production. Drawing and pressing.*

[29]

Section 2. Radiomaterials.

Topic 2.1. General provisions. Classification of materials.

Lecture 11. Parameters of radio engineering materials.

List of key issues: *The relationship between the properties, composition, and structure of materials. Maxwell's equations as the basis for the macroscopic study of radio engineering materials. Basic parameters of radio engineering materials. Complex parameters. Parameters characterizing losses. [7,*

pp. 15–19, 200–211; 8, pp. 130–144; 9, pp. 213–225; 10, pp. 14–16, 21–31]

Assignment for independent study: *Elements of zone theory of solids. Types of chemical bonds. Glassy state – the most important type of amorphous state.*

[7, pp. 19–26, 9–15, 18–19; 8, pp. 195–199; 3, pp. 397–406]

Lecture 12. Classification of radio engineering materials.

List of main issues: *Classification of materials depending on the nature of their reaction to the influence of an electromagnetic field: dielectrics, semiconductors, conductors, magnetic materials. Consideration of the criteria for dividing materials into dielectrics, semiconductors, and conductors. The vagueness of the classification*

boundaries. [7, pp. 7–9; 8, pp. 5–10; 10,

pp. 10–14; 9, pp. 25–34]

Assignment for independent *study*: *Classification of radio engineering materials according to their response to electromagnetic parameters: linear and nonlinear, isotropic and anisotropic.*

[7, pp. 188–189; 9, pp. 69–73]

Topic 2.2. Dielectrics.

Lecture 13. Polarization of dielectrics.

List of key questions: *Key parameters characterizing polarization. Elastic and thermal polarization mechanisms. Polarization models. Strong and weak bonds between material particles. Hydrogen atom. Ammonia molecule. Relaxation period. Types of polarization. Electronic elastic polarization. Dipole elastic and thermal polarization.*

[7, pp. 182–188; 8, pp. 108–112, 114–117; 9, pp. 42–55, 93–98, 104–108, 117–122]

Assignments for independent study: *Ionic elastic polarization. Ionic thermal polarization. Migration polarization.*

[9, pp. 98–104, 122–127; 7, p. 188]

Lecture 14. Polarization arising without the influence of an electric field.

List of main questions: *Spontaneous polarization. Pyroelectrics. Ferroelectrics. Domain structure. Hysteresis. Main polarization curve. Parameters of ferroelectrics. Mechanical polarization. Piezoelectrics. Direct and inverse piezoelectric effects. Electrostriction.*

[7, pp. 188–189, 261–281; 8, pp. 208–224, 227–245; 9, pp. 167–182, 185–196]

Assignments for independent study: *Residual polarization. Electrets. Conditions for the formation of electrets. Types of electrets.*

[7, pp. 281–283; 8, pp. 267–272; 9, pp. 182–185]

Lecture 15. Electrical conductivity of dielectrics. Breakdown of dielectrics.

List of main questions: *Main parameters characterizing the electrical conductivity of dielectrics. Mechanisms of* *electrical conductivity of dielectrics. Electronic, ionic, and molionic electrical conductivity of dielectrics. Specific volume and surface resistivity of dielectrics.*

[7, pp. 193–200; 8, pp. 122–130; 9, pp. 196–208]

Assignments for independent study: *Breakdown of dielectrics. Types of breakdown. Influence of external factors on the electrical strength of dielectrics. Streamer theory of breakdown. Electronic, electrothermal, electrochemical breakdown. Breakdown of gaseous, liquid, and solid dielectrics. [7, pp. 211– 224; 8, pp. 144–154]*

Lecture 16. Types of dielectrics.

List of main topics: *High-frequency and low-frequency dielectrics. Spatial and linear polymers. Composite powder plastics. Layered plastics.*

Inorganic glass. The effect of the chemical composition of glass on its properties. Alkali-free glass. Alkali glass without heavy oxides. Alkali glass with a high content of heavy oxides.

Sital. Features of manufacturing technology. Structure of sital and its properties. Types of sital. Installation and capacitor sital.

[7, pp. 225–240, 243–252; 8, pp. 172–184, 188–200; 10, pp. 121–141, 147–153, 169–207]

Assignment for independent study: *Ceramics. Features of manufacturing technology. Structure of ceramics and its properties. Types of ceramics. Installation and capacitor ceramics.*

[7, pp. 252–260; 8, pp. 200–204; 10, pp. 207–230]

Topic 2.3. Magnetic materials.

Lecture 17. Magnetic materials.

List of main questions: *Classification of magnetic materials. The nature of ferro- and ferrimagnetism. Classification of strong magnetic materials. Hysteresis loop. Initial and main magnetization curves. Parameters of high-magnetic materials. Magnetization by an alternating field. Types of soft magnetic materials. Materials for high and ultra-high frequencies (ferrites, magnetodielectrics).*

[7, pp. 296–344; 8, pp. 273–304; 10, pp. 352–384]

Assignments for independent study: *Magnetically hard materials (features of manufacturing technology and types). Special-purpose materials (materials with a rectangular hysteresis loop, magnetostrictive materials).*

[7, pp. 344–358; 8, pp. 304–314, 317–327; 10, pp. 384–396]

Topic 2.4. Conductive materials.

Lecture 18. Conductive materials.

List of key issues: *Classification of conductor materials. Parameters of conductive materials (specific resistance, thermoelectric force, temperature coefficients of specific resistance and linear expansion) and the influence of external factors on them. High conductivity materials. Superconductors and cryoconductors. High resistance alloys.*

[7, pp. 27–74; 8, pp. 11–32, 36–40; 10, pp. 231–283]

Assignments for independent study: *Alloys for thermocouples. Strain gauge alloys. Contact materials. Solders and fluxes.*

[7, pp. 74–86; 8, pp. 40–43; 10, pp. 283–289]

Laboratory classes

The main purpose of laboratory classes:

- *to test acquired theoretical knowledge in practice;*
- *acquiring skills in working with measuring instruments and equipment;*
- *mastering methods for measuring parameters and recording characteristics;* • *acquiring skills in evaluating experimental data and drawing conclusions.*

No.	Name of laboratory work	Number Class hours
Section 1. Construction materials		
1	***Topic 1.2. Complex substances*** **Laboratory work 3***. Determination of transition temperatures (critical points) of metals and alloys [12, pp. 15–20].* Independent work assignment: *prepare a report on the work; prepare answers to the test questions [12, pp. 19–20].*	*4*
2	***Topic 1.3. The effect of heat treatment and plastic deformation on the properties of substances*** **Laboratory work 1***. Mechanical properties of materials. Tensile testing [13, pp. 4–10].* Independent work assignment: *prepare a report on the work; prepare answers to the control questions [13, pp. 9–10].*	
3	***Topic 1.3. The effect of heat treatment and plastic deformation on the properties of substances*** **Laboratory work 2***. Investigation of the mechanical properties of materials. Brinell hardness testing [13, pp. 10–17].* Independent work assignment: *prepare a report on the work; prepare answers to the test questions [13, p. 17].*	
Section 2. Radioactive materials		
4	***Topic 2.2. Dielectrics*** **Laboratory work 3.** *Electrical conductivity of radio engineering materials [14, pp. 24–33].* Independent work assignment: *prepare a report on the work; prepare answers to test questions [14, p. 33.*	*2*
5	***Topic 2.2. Dielectrics*** **Laboratory work 4***. Investigation of piezoelectrics [14, pp. 34–49].* Independent work assignment: *prepare a report on the work; prepare answers to the test questions [14, p. 49].*	
6	***Topic 2.2. Dielectrics*** **Laboratory work 5.** *Investigation of ferroelectrics [14, pp. 50–62].* Independent work assignment: *prepare a report on the work; prepare answers to the control questions [14, pp. 61–62].*	*4*
7	***Topic 2.3. Magnetic materials*** **Laboratory work 2.** *Investigation of the effect of elastic deformations on the properties of magnetically soft materials [14, pp. 17–23].* Independent work assignment: *prepare a report on the work and prepare answers to the test questions. [14, p. 23].*	
8	***Topic 2.3. Magnetic materials*** **Laboratory work 6.** *Investigation of the dispersion of magnetic permeability of ferrites [14, pp. 63–72].* Independent work assignment: *prepare a report on the work and prepare answers to the test questions. [14, pp. 71–72].*	*4*
9	***Topic 2.4. Conductive materials*** **Laboratory work 3.** *Electrical conductivity of radio engineering materials [7, pp. 24–33].* Independent work assignment: *prepare a report on the work and prepare answers to the test questions. [14, p. 33].*	*4*

6. Independent work by students

Students complete assignments that are given for independent study. In addition, students *complete homework assignments (**HA**). The purpose of this work is to reinforce lecture material, broaden horizons in the field of materials science, and develop skills in solving practical problems and grapho- analytical constructions. Homework assignment options are outlined in the methodological guidelines [13] (100 options). Each student receives an individual option consisting of 4 tasks and theoretical questions. Tasks are given to students in the 6th week. The 16th week is the last week for completing the calculation and graphic work.*

Title of the topic for independent study Section 1. Construction

materials

Topic 1.1. General provisions. Crystallization of simple substances (4 hours)

Mechanical stress. Strength, hardness, plasticity, brittleness. Laws of thermodynamics. Clausius'

postulate. [4, pp. 9–15; 1, pp. 87–110]

Types of bonding. Critical radius of a crystallization nucleus. Brave lattices. Coordination number. Packing density. Indexing of crystallographic directions and crystallographic planes. Point defects. Cottrell clouds. Burgers vector. Dislocation creep. Surface defects. Metallographic analysis.

[20, pp. 29–44; 1, pp. 11–24; 18, pp. 52–56]

Topic 1.2. Complex substances (11 hours)

Chemical potential of a component. Method of geometric thermodynamics in constructing phase diagrams. Differential method of analysis. X-ray structural analysis (Laue and Debye methods).

[3, pp. 23–24; 18, pp. 52–101; 4, pp. 40–51]

Liquidation by density. Homogenization. Zone refining. Zone formation and maintenance. Zone refining mechanism.

[1, pp. 55–61; 6, pp. 41–43, 84–85, 346–350; 18, pp. 47–49]

Diagrams for chemical compounds. Multicomponent systems. Concentration triangle. Concentration tetrahedron.

[1, pp. 65–68; 3, pp. 129–141, 149–152]

Deciphering the structure of steel or cast iron for any fragment of the phase fields of the iron-carbon diagram. The influence of accompanying components on the properties of steel. Austenitic and ferritic steels. System of steel grade designations.

[3, pp. 133–141, 161–173; 1, pp. 132–134; 141–144]

Topic 1.3. The effect of heat treatment and plastic deformation on the properties of substances (8 hours)

Transformations in steel during heating and cooling. Austenite grain growth. Widmanstätten structure. Heredity of steel.

[1, pp. 156–165; 3, pp. 190–195; 6, pp. 89–91]

Chemical and thermal treatment of steel. Dependence of the diffusion layer thickness on the treatment mode. Carburizing. Nitriding. Cyaniding. Diffusion metallization.

[1, pp. 228–249; 3, pp. 257–269; 6, pp. 110–122]

Mechanical properties determined by dynamic, variable, and extended tests. Impact toughness. Endurance limit. Creep.

[1, pp. 98–110; 3, pp. 69–75]

The use of plastic deformation in manufacturing. Drawing and pressing. [29]

Section 2. Radioactive materials

Topic 2.1. General provisions. Classification of materials (4 hours)

Elements of zone theory of solids. Types of chemical bonds. Glassy state — the most important type of amorphous state.

[7, pp. 19–26, 9–15, 18–19; 8, pp. 195–199; 3, pp. 397–406]

Classification of radio engineering materials according to their reaction to electromagnetic parameters: linear and nonlinear, isotropic and anisotropic.

[7, pp. 188–189; 9, pp. 69–73]

Topic 2.2. Dielectrics (8 hours)

Ionic elastic polarization. Ionic thermal polarization. Migration polarization. [9, pp.

98–104, 122–127;7, p. 188]

Residual polarization. Electrets. Conditions for the formation of electrets. Types of electrets. [7, pp. 281–283; 8,

pp. 267–272; 9, pp. 182–185]

Breakdown of dielectrics. Types of breakdown. Influence of external factors on the electrical strength of dielectrics. Streamer theory of breakdown. Electronic, electrothermal, and electrochemical breakdowns. Breakdown of gaseous, liquid, and solid dielectrics.

[7, pp. 211–224; 8, pp. 144–154]

Ceramics. Features of manufacturing technology. Structure of ceramics and its properties. Types of ceramics. Installation and capacitor ceramics.

[7, pp. 252–260; 8, pp. 200–204; 10, pp. 207–230]

Topic 2.3. Magnetic materials (4 hours)

Magnetically hard materials (features of manufacturing technology and types). Special-purpose materials (materials with a rectangular hysteresis loop, magnetostrictive materials).

[7, pp. 344–358; 8, pp. 304–314, 317–327; 10, pp. 384–396]

Topic 2.4. Conductive materials (2 hours)

Alloys for thermocouples. Strain gauge alloys. Contact materials. Solders and fluxes. [7, pp. 74–86; 8,

pp. 40–43; 10, pp. 283–289]

Policy and control

7. Policy of the academic discipline (educational component)

Classroom sessions are mandatory.

Students are required to demonstrate their knowledge of the material from missed lectures during scheduled consultations.

A laboratory class missed for a valid reason must be made up by prior agreement with the instructor.

Admission to laboratory classes is granted by the teacher after an interview with the students. The defense of the report on the laboratory work is held during the next scheduled laboratory class.

The teacher conducts the defense of the calculation and graphic work after the 16th week of study according to the consultation schedule or by agreement with the students.

The rules for awarding incentive and penalty points are set out below in section 8.

8. Types of control and rating system for assessing learning outcomes

The teacher carries out ongoing assessment by communicating with students during the admission and defense of laboratory work and based on the results of the modular control work (MCW) before the second attestation. The MCW assignment consists of the questions listed in (section 9).

Teaching the credit module "Construction and Radio Materials" involves the following learning outcome assessment rating system (LOAS).

The student's rating for the credit module is made up of points (on a 100-point scale) that they receive for:

1. *completion and defense of 4 laboratory works;*
2. *a modular control work (**MCW**);*
3. *calculation and graphic work (**CGW**).*

Rating (weighting) point system and assessment criteria

1. Laboratory work

*Weighting score — 10. The maximum number of points for all laboratory work is: 10 points*4=40*

points.

Each laboratory work is evaluated for:

a) preparedness for work:

- fluency in theoretical material, availability of a prepared protocol 4 points;

- poor command of theoretical material 2 points;

- unpreparedness for work -1 point;

b) completion of laboratory work:

- report formatting in accordance with requirements 4 points;

- work performed with errors or sloppiness 2 points;

- work not completed -1 point;

c) defense of the work:

- full answer during defense 2 points;

- incomplete answer during defense 0 points;

- work defended on a day other than the day of completion and the following lab day 0 points.

2. *Modular control*

Weighting score —

20. Assessment

criteria:

- *"excellent", the topic of the assignment is fully disclosed (at least 90% of the required information) 20–18 points;*

- "good," sufficiently complete answer (at least 75% of the required information), or complete answer with inaccuracies 17–15 points;

- *"satisfactory", incomplete answer (at least 60% of the required information), there are errors 14–10 points;*

- *"unsatisfactory," unsatisfactory response (does not meet the requirements for "satisfactory")*

0 points.

3. *Calculation and graphic work*

Weighting

— 40.

Assessment

criteria:

- *"excellent," all requirements for the work have been met 40–35 points;*
- *"good," almost all requirements for the work have been met, or there are minor errors 34–28 points;*
- *"satisfactory," there are shortcomings in meeting the requirements for the work and certain errors*

27–22 points;

- *"sufficient," there are noticeable shortcomings in meeting the requirements for the work and errors*

21–10 points;

- *"unsatisfactory," does not meet the requirements for "adequate," many errors 0 points.*
- *for each week of delay in submitting the calculated work for review -1 point.*

Penalty points for:

-denial of admission to laboratory work due to unsatisfactory initial control……..-1 point;

-failure to complete laboratory work . ..-1 point;

-absence from laboratory classes without a valid reason ....-2 points;

-for each week of delay in submitting the calculated work for review...-1 point.

The total number of penalty points shall not exceed 10 points. *Bonus points for:*

-preparation of notes for the competition..8 points;

-preparation of an abstract 10 points;

-improvement of teaching materials 8 points.

The total number of incentive points shall not exceed 10 points.

The rating scale is R = 100 points. Calculation of the rating scale (R)

The sum of the weighted points for control measures (items 1-3) during the semester is:
R= 40 + 20 + 40 = 100 points.

Conditions for a positive interim assessment

- To receive a "pass" on the first interim assessment (week 8), the student must score at least 10 points ("ideal" student – 20 points).
- To receive a "pass" on the second interim assessment (week 14), the student must earn at least 30 points ("perfect" student – 60 points).

The maximum number of points is 100. A prerequisite for admission to the exam is the completion of all laboratory work and calculation work. To receive a credit for the credit module "automatically," you must have a rating of at least 60 points and complete all laboratory work and calculation work.

Students who have a rating of less than 60 points at the end of the semester, as well as those who want to improve their grade, take a credit test. In this case, the points for the test should be added to the points for the calculation work, and this rating is final. The test consists of four questions from different sections of the work program from the list provided in Appendix 1 to the work program.

For each question, the student can receive points according to the grading system: –

"excellent," complete answer (at least 90% of the required information)
15–13 points;

–"Good," sufficiently complete answer (at least 75% of the required information, possible inaccuracies)
12–10 points;

–"Satisfactory," incomplete answer (at least 60% of the required information, possible errors)
9–7 points;

–"unsatisfactory", unsatisfactory answer
0 points.

The sum of points for the student's academic activity to receive a credit for the credit module "automatically", or the sum of points for the calculation work and credit test should be transformed into a credit grade according to the table.

Table of correspondence between rating points and grades on the university scale

Number of points	Grade
10	Excellent
94	Very good
84	Good
74-65	Satisfactory
64-60	Sufficient
Less than 60	Unsatisfactory
Admission requirements not met	Not admitted

9. Additional information on the discipline (educational component)

List of questions to check the level of mastery of the educational material for modular control and for semester control.

1. *X-ray structural analysis.*
2. *Laue method.*
3. *Debye method.*
4. *Phase diagram for a mechanical mixture of component crystals.*
5. *Transformation of martensite during heating.*
6. *Unlimited solid solutions. Phase diagram.*
7. *Liquidation.*
8. *Solubility gap of solid solutions*
9. *Eutectic diagram of solid solutions.*
10. *Peritectic diagram of solid solutions.*
11. *Phase diagrams for chemical compounds.*
12. *Phase diagram with allotropy of a component.*
13. *Zone refining.*
14. *Three- and multi-component phase diagram.*
15. *Relationship between phase diagrams and properties of complex substances.*
16. *Critical points of iron. Construction of an iron-carbon diagram.*
17. *Eutectic region of the iron-carbon diagram.*
18. *Peritectic region of the iron-carbon diagram.*
19. *Eutectoid region of the iron-carbon diagram.*
20. *Distribution of iron-carbon alloys.*
21. *The effect of carbon on the properties of steel.*
22. *The effect of accompanying impurities and contaminants on the properties of steel.*
23. *The effect of alloying components on the properties of steel.*
24. *Transformations in steel under the influence of heating.*
25. *Construction of a TTT diagram.*
26. *Pearlite region of the TTT diagram.*
27. *Intermediate region of the TTT diagram.*
28. *Martensitic region of the TTT diagram.*
29. *Martensitic points. Martensitic curve.*
30. *TTT diagram for continuous cooling.TTT diagram for hypoeutectoid and hypereutectoid steels.*
31. *Martensite transformation during heating.*
32. *Explain why soldering a resistor lead in a metallized hole in a printed circuit board requires a small radial gap of no more than 50 μm.*
33. *Calculate the relative change in volume during the transition of high-purity iron from the BCC to the FCC modification. The radius of an iron atom in the BCC is 1.27 Å, and in the FCC is 1.24 Å.*
34. *Draw the directions of the main axes of the dendrite during the growth of the iron crystal.*
35. *Grain fineness 7 corresponds to the number of grains per 1 mm^2 , which is equal to 1024. Find the area of the boundaries between grains in a volume of 1 mm^3 .*
36. *Find the possible number of diffraction orders if the minimum Bragg angle is 30 .*
37. *Describe cases of crystallization of two-component alloys without a change in temperature.*
38. *Draw the dependence of free energy on concentration for several temperatures when constructing a eutectic phase diagram of type III using the method of geometric thermodynamics.*

39. Draw the cooling curves for several informative concentrations when constructing a eutectic phase diagram of the third kind using the method of thermal analysis.
40. How and why does the crystallization temperature of eutectics depend on time when the external temperature and pressure change?
41. What system and number of phases and components does hypoeutectoid carbon steel have? What phase equilibrium can exist in this case?
42. Name and explain the advantages and disadvantages of eutectic solders.
43. Name and explain the advantages and disadvantages of eutectic alloys for castings.
44. A study of the structure of hypereutectoid steel has established that it contains 30% pearlite. Find the carbon content.
45. On a micrograph of hypereutectoid tool carbon steel, it has been calculated that approximately 7% of the area belongs to cementite. Find the steel grade.
46. On a micrograph of carbon steel, the area belonging to cementite is equal to ρ%. Find the carbon content.
47. Name and explain the significance of the temperatures at which iron carbide appears during slow cooling of steel 05, steel 08, steel 65, and tool steel U80.
48. Find the amount of pearlite in steel 40, which was slowly cooled from 900 °C. The mass of steel is 100 kg.
49. Find the amount of ferrite and cementite in steel 30 at 723 °C and room temperature.
50. Find the relative mass of phases in steel 60 at 723 °C and room temperature.
51. What will be the expected structure of eutectoid carbon steel if it is cooled from
52. a temperature of 800 °C at a rate of 100 °C/sec?
53. What factors determine the time of isothermal decomposition of austenite?
54. What is the carbon content in martensite steel 60?
55. Explain the meaning of eutectoid reaction.
56. Explain the dispersibility of eutectics.
57. Explain the fluidity of eutectic alloys.
58. Determine the diameter of the X-ray diffractometer chamber if the distance between symmetrical lines on the diffractogram, measured in mm, is numerically equal to twice the Bragg angle in degrees.
59. After manufacturing parts by stamping and bending steel sheet, some of them turned out to be defective. Analysis revealed that the cause of the defect was the arbitrary placement of the blanks on the sheet during cutting. Explain this phenomenon.
60. The casting is subjected to considerable pressure P. The design of the die-cast part must be changed so as not to violate the principle of thin-walledness. (see corresponding drawing).
61. Provide a graph showing the dependence of the length of a high-purity iron test sample on temperature during heating from 0 to 1500 degrees Celsius.
62. How and why does the degree of supercooling of a metal (alloy) depend on the degree of purity of the metal (alloy)?
63. On the same fragment of the crystal lattice, show the positive and negative edge dislocations belonging to the same slip plane with a distance of 6a between them. Describe their interaction. What will happen when a shear stress parallel to the slip plane is applied to this lattice?
64. The temperature of transformation from Mebto Meaduring cooling is 1025°C. The energy of the interface between phases a and b is 500 erg/cm2. The value of DF(V) is minus 100 cal/cm3 for 1000°C and minus 500 cal/cm3 for 900°C. Find the critical radius of the crystallization nucleus for these temperatures.
65. Plot a graph of the dependence of magnetic permeability m on t° for high-purity iron from 0° to 1500°.
66. Describe your understanding of the entropy of a thermodynamic system.
67. Find the angle between the directions [011] and [111] of the cubic lattice.
68. Fig. 3 shows the phase diagram of water. Find the number of degrees of freedom at points 1, 2, 3, and 4. (corresponding figure).
69. Calculate the relative change in volume during the transition of high-purity iron from the BCC to the FCC modification. The radius of the iron atom in the BCC is 1.27 Å, and in the FCC is 1.24 Å.
70. Find the possible number of diffraction orders if the minimum Bragg angle is 30°.
71. Describe the possible advantages and disadvantages of switching from electrical steels to magnetically soft amorphous alloys for the production of power transformers (mass production, high power).
72. Calculate the relative packing density for iron at room temperature.
73. Describe the interaction for metallic bonding.
74. Describe and explain the difference between the processes of glass and silicate production.
75. Draw the directions of the main axes of the dendrite during the growth of an iron crystal.
76. Prove the action of the surfactant modifier.

77. Draw the plane (211) in the BCC crystal cell.
78. The given Debye diagram corresponds to the distance d111 of the copper BCC crystal lattice. Find the lattice parameter if the wavelength of X-rays is 1.5 Å. (see Figure 4).
79. Find the filling coefficient of the crystal lattice for the coordination number K12.
80. Grain size 7 corresponds to the number of grains per 1 mm2 , which is equal to 1024. Find the area of the grain boundaries in a volume of 1 mm3 .
81. The dependence of temperature on furnace time for studying a copper sample is shown. On the same graph, show the dependence for the sample under study. (corresponding figure).
82. Explain the dependence of the degree of supercooling on the cooling rate.
83. The negative ion of component A has a radius of 1.53A. Find the value of the radius of the smallest monovalent positive ion for coordination number K6.
84. The specific surface energy of glass at 650°C is 0.3 J/m2. How much energy ΔE must be released if a glass thread 100 mm long and 0.02 mm in diameter is transformed into a ball (spheroidization process)?
85. Explain why vacancies and dislocated atoms exist simultaneously in a crystal lattice at room temperature.
86. Find the angle Qcbetween the directions [011] and [101] of a cubic crystal lattice.
87. 1 mole of table salt (58 g) has a volume of 27 cm3. Find the average value of interatomic distances in the crystal. Avogadro's number is 6x1023.
88. When designing parts for casting, for which casting methods should the principle of thin- walledness be followed most strictly?
89. Explain why the use of an amorphous soft magnetic alloy for the manufacture of a tape recorder head increases the dynamic range of the device.
90. Give a definition of packing density.
91. How is packing density related to the coordination number?
92. Give a geometric definition of the concepts of long-range and short-range order in a substance.
93. Give examples of homogeneous and heterogeneous systems.
94. Describe the difference between the definitions of "solid body" and "solid phase."
95. Give examples of the manifestation of the law of anisotropy.
96. Describe the phenomenon of polymorphism. Give examples.
97. Formulate the difference between monocrystalline, polycrystalline, and amorphous phases.
98. Define a crystal lattice.
99. Define an elementary crystal cell.
100. What are point defects in real crystals? Give examples.
101. Give examples of linear defects in crystal structure.
102. Formulate Moseley's law.
103. Describe the four quantum numbers and the Pauli principle.
104. Define a phase diagram.
105. Define liquidus and solidus lines.
106. How is thermal analysis implemented?
107. What is the Bragg angle?
108. Write the electronic formula for a titanium atom.
109. How does the electronic structure of transition metal atoms differ from that of simple metals?
110. Which particles interact to form metallic bonds?
111. Which crystal cells of metals have the maximum packing density?
112. Give examples of materials that are simultaneously in a solid state and in a liquid phase.
113. What is the absolute condition for the transition of a substance from one phase to another?
114. define the degree of supercooling.
115. What means can be used to regulate the degree of dispersion of a crystallizing substance?
116. What factors determine the speed of the crystallization process?
117. Describe the processes that occur during secondary crystallization.
118. What determines the number of lines on a debaygram?
119. What determines the width of a Debye diagram line?
120. Define and characterize thermodynamic systems.
121. Formulate Gibbs' rule.
122. Define the distribution coefficient.
123. Under what load conditions can brittle materials such as gray cast iron be reliably used?
124. What do plasticity indicators allow a designer who is selecting a material to determine?
125. What do plasticity indicators allow a designer who is selecting a material to determine?
126. What do plasticity indicators allow a technologist selecting a material to determine?

127. *How does the conditional strength limit differ from the true strength limit?*
128. *Define the physical meaning of yield strength.*
129. *A metal part in a structure is subjected to cyclic loading. What mechanical characteristics of the material are important for assessing its strength under such loading conditions?*
130. *What are the most radical means of combating metal fatigue?*
131. *What is called the stratification (fastening) of a metal material?*
132. *Define temporary and internal stresses.*
133. *Explain the strengthening of metal material during plastic deformation.*
134. *Describe the action of the Frank-Ried source during plastic deformation.*
135. *Explain the formation of a Frank network during plastic deformation.*
136. *What phases are included in the structure of iron-carbon alloys at room temperature according to the phase diagram?*
137. *In what cases should alloyed structural steels be used instead of carbon steels for the manufacture of structural parts?*
138. *The glassy state of a substance is a type of amorphous state. Purely amorphous state.*
139. *Residual polarization. Electrets. Classification of electrets.*

1. *Active dielectrics. Use of active dielectrics.*
2. *Types of polarization that occur without the influence of an electric field.*
3. *Initial polarization curve, main polarization curve.*
4. *Electrical breakdown of dielectrics. Types of electrical breakdown.*
5. *Streamer breakdown.*
6. *Ionic and molionic electrical conductivity of dielectrics.*
7. *Pyroelectrics. Ferroelectrics (classification, properties).*
8. *Classification of materials according to their behavior in an electric field.*
9. *Classification of materials according to their behavior in a magnetic field.*
10. *Dependence of the dielectric permeability of polar dielectrics on temperature.*
11. *Migration polarization.*
12. *The effect of moisture on the electrical conductivity of dielectrics.*
13. *Mechanical models of elastic and thermal (relaxation) polarizations.*
14. *The nature of the electrical conductivity of solid dielectrics.*
15. *Limit and partial hysteresis cycles. Material parameters determined by the limit hysteresis loop.*
16. *Piezoelectric effect.*
17. *Dipole elastic polarization.*
18. *Clausius–Mosotti formula.*
19. *Ionic thermal polarization.*
20. *Isotropy, anisotropy, quasi-isotropy.*
21. *Polarization of dielectrics. Main parameters characterizing it.*
22. *Electrical conductivity of liquid dielectrics.*

Description of material, technical, and informational support for the discipline

Three laboratory works devoted to structural materials are proposed, which familiarize students with the mechanical properties of these materials and methods for determining them, as well as with one of the methods for experimentally determining the temperatures of phase transitions in materials.

Five more laboratory works are devoted to radio materials and allow students to familiarize themselves with certain properties of metal conductors, passive and active dielectrics, ferro- and ferrimagnets, which these materials exhibit under the action of an electromagnetic field.

The working program of the academic discipline (syllabus):
Compiled by Nepochatych Y. V.;
Approved by the PRE Department (Minutes No. 06/2025 dated 06/24/2025)
Approved by the methodological commission of the faculty/research institute (protocol No. 06/2025 dated 25.06.2025)