	University of Belgrade Technical faculty in Bor		
	ACCREDITATION OF THE STUDY PROGRAMME		
	DOCTORAL ACADEMIC STUDIES	**METALLURGICAL ENGINEERING**	

BOOK OF COURSES

STUDY PROGRAM:
METALLURGICALENGINEERING

DOCTORAL ACADEMIC STUDIES
(3RD LEVEL OF THE ACADEMIC STUDIES)

Bor, 2023.

NO. LIST OF COURSES

Course: METHODOLOGY OF THE SCIENTIFIC-RESEARCH ACTIVITIES			
Lecturer/s: Dr. Nada Štrbac, full professor			
Status of the course: Elective for the study program in Metallurgical Engineering			
ECTS: 15			
Prerequisite: Entered the first semester of doctoral academic studies			
Course goals: The participants of doctoral studies will theoretically and practically improve the previously acquired knowledge from the basis of the methodology of scientific research.			
Learning outcomes: The student will obtain adequate knowledge for the implementation of research proceedings and the research methodology of defined case testing and acquires the ability for the independent presentation of the obtained results during applied research.			
Course description: Lectures: Introductory considerations. Basic concepts in scientific research. Tasks, goals, roles and types of research. Planning the research. Methods of research. Scientific hypothesis. Validity and reliability of measurement. Research composition. Work publishing. The concept of intellectual property. Application of ethical principles in the research. Practice: Demonstration of individual methods and techniques on concrete research issues.			
Literature: Recommended: 1. M. Vuković, N.Štrbac, Metodologija naučnih istraživanja, TF Bor, Bor, 2019. *(in Serbian)* 2. J. Stanić, Metod inženjerskih merenja, Mašinski fakultet, Beograd, 1986. *(in Serbian)* 3. M. Sarić, Opšti principi naučnog rada, Naučna knjiga, 1990. *(in Serbian)* Ancillary: 1. D. Mihailović, Metodologija naučnih istraživanja, FON Beograd, Beograd, 2012. *(in Serbian)* 2. Ž. Adamović, G. Milošević, S. Ristić, Osnovi metodologije naučno-istraživačkog rada, Društvo za tehničku dijagnostiku Srbije, Beograd, 2005. 3. Papers published in the international journals.			
Number of classes per week	**Lectures: 6**	**Practical classes: 4**	
Teaching methods Oral lecturing.			
Knowledge evaluation (maximum 100 points)			
Activity during the lecture	Points	Final exam	Points
Independent work	20	Written exam	40
		Oral exam	40

Course: Project Management		
Lecturer/s: dr. Nenad N. Milijić, Associate professor		
Status of the course: Elective		
ECTS: 15		
Prerequisite: Required knowledge of Statistics, Quality Management, Project Management and Economics of business, Portfolio project management.		
Course goals: The course presents the fundamental concepts of project management. Students will be enabled to understand range and variety of project types, understanding key variables in project management as well as studying methods, techniques and approaches that are important for successful project management in order to achieve objectives in a wide range of contexts.		
Learning outcomes: Students' ability to use basic techniques and tools as well as communication and information technology and their application in the project management process. The expected outcome is knowledge of the critical success factors in project management, but also the ability to create project reports.		
Course description: Lectures: The place of projects in modern organizations: project definition, project life cycle. Initiation project: strategic management and project selection, project portfolio process. Project manager; special requirements of project managers, selection of project managers, multicultural communication and management behavior. Project organization; as part of a functional organization, a purely project organization, matrix organization, Human factor and project team. Project planning: initial coordination project, system integration, WBS and maps of linear responsibility. Conflicts and negotiation. Project budget and cost estimation; project budget estimation, improvement of the cost estimation process. Network Planning: structure analysis, time and cost analysis, PERT and CPM. Resource allocation. Project monitoring and information systems. Project control. Project audit. Project completion process.		
Literature: Recommended: 1. J.R.Meredith, S.J.Mantel, Project Management-a managerial approach, John Wiley and Sons, Inc, 5th Edition, Haboken, NJ, USA, 2002. 2. 2. H.A. Levine, Project portfolio management, HB Printing, John Wiley and Sons, New York, USA, 2005. 3. 3. J. M. Nikolas, H. Steyn, Project management for engineering, business and technology, Routledge, 4th Edition, USA, 2012. 4. 4. H. Kerzner, Project management, John Wiley & Sons, Inc, 10th Edition, New Jersy, 2009. Ancillary: 1. M.W.Carter, C.C.Price, Operations research-a practical introduction, CRC Press, International edition, 2001. 2. Articles from international journals.		
Number of classes per week	**Lectures: 6**	**Scientific research work: 4**
Teaching methods Classic lectures, case studies, practical exercises, creation of collective and individual seminar paper.		
Knowledge evaluation (maximum 100 points) - Seminar work - 20 - Written part of the exam – 40 - Oral part of the exam – 40		

Course: PYROMETALLURGICAL PROCESSES		
Lecturer/s: Dr. Dragan Manasijević, full professor		
Status of the course: Elective for the study program in Metallurgical Engineering		
ECTS: 15		
Prerequisite: Knowledge of metallurgical thermodynamics, theory of pyrometallurgical processes theory, metallurgy of ferrous metals, iron and steel metallurgy and thermodynamics of materials.		
Course goals: The aim of the subject is the synthesis of current knowledge about the pyrometallurgical processes of obtaining metals with special reference to the equilibrium states in certain systems of type Metal-O, Metal-S-O, Metal-Slag, MeS-Slag.		
Learning outcomes: Gained knowledge should enable active recognition of phenomena in particular metallurgical systems and competent decision-making in order to keep the process going to the projected goals.		
Course description: Theoretical basics of pyrometallurgical processes. Oxidation of metals. Reduction process. Sulphides. Carbonates. Halides. Silicates. Systems Me-X-O (Me = Cu, Ni, Fe, Pb, X = S, C, Cl, Si). Metallurgical slag. Molecular Theory. Ionic Theory. Temkin Theory, Polymerization Models. Masson Theory. Slag structure. Reactions in the metal-slag and slag-matte systems. Refining role of slag. Methods of metal refining.		
Literature: Recommended: 1. M. SHAMSUDDIN, PHYSICAL CHEMISTRY OF METALLURGICAL PROCESSES,John Wiley & Sons, Inc., Hoboken, New Jersey, 2016. 2. S. Seetharaman (Ed.), Treatise on Process Metallurgy, Elsevier, 2014. 3. C. B. Alcock, Principles of Pyrometallurgy, Academic Press, 1976. 4. F. Habashi, Textbook of Pyrometallurgy, Laval University, Quebec, 2002.		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Classical lectures and student research work in the fields of thermal analysis, X-ray analysis and electronic microscopy, as well as modern metallurgical software. Case study from metallurgical practice.		
Knowledge evaluation (maximum 100 points) 50% exam, 40% seminar, 10% activity through student research work.		

Course: HYDRO AND ELECTROMETALLURGICAL PROCESSES		
Lecturer/s: Dr. Vesna Grekulović, full professor; Dr. Milan Gorgievski, associate professor		
Status of the course: Elective for Metallurgical Engineering (Module: Extractive Metallurgy)		
ECTS: 15		
Prerequisite: Knowledge from physical chemistry, electrochemistry and theory of hydro and electrometallurgical processes		
Course goals: Hydro and electrometallurgical processes are one of fundamental theoretical subjects in extractive metallurgy and in production of metallic materials. The goal of the subject is to enlarge students' knowledge in the area, to introduce them with contemporary scientific achievements in the theory of hydro and electrometallurgical processes and to make them capable for further individual scientific and engineering work.		
Learning outcomes: Expected outcome are intellectual, professional, engineering and teaching capabilities to apply knowledge and skills acquired during this course for managing and controlling in different processes in the field of hydro and electrometallurgy, the capability to develop new technologies as well as to perform researches in these areas.		
Course description: Lectures: Physical and chemical fundamentals of hydro end electrometallurgical processes. Theoretical principles of leaching of different materials. Leaching devices. Fundamentals of metallic ions concentration and purification of leaching solutions – ionic exchange, solvent extraction, adsorption-desorption. Methods for obtaining compounds of metals from solutions. Methods for obtaining pure metals from solutions – chemical reduction and cementation. Most important hydrometallurgical processes. Thermodynamics of electrochemical systems. Conductivity of electrolytes. Chemical effects of direct current in electrolytes. Kinetics of electrode processes. Theoretical aspects of solutions and melts electrolysis. Most important anodic and cathodic processes in metallurgy (electrowinning and electro refining of metals, electrochemical synthesis of metallic powders, oxides and other compounds, corrosion and passivity of metals, direct electrochemical oxidation of sulfides). Measuring methods and diagnostic criteria in electrochemistry.		
Literature: Recommended: 1. N. Pacović, Hidrometalurgija, ŠRIF, Bor, 1980. (*in Serbian)* 2. F. Habashi, A Textbook of Hydrometallurgy, Metallurgy Extractive, Quebec, 1993. 3. F. Habashi, Principles of Extractive Metallurgy - Amalgam and Electrometallurgy, Laval University, Quebec, 1998. 4. S. Venkatachalam, Hydrometallurgy, Narosa Publishing House, 1998. 5. M. Rajčić-Vujasinović, V. Grekulović, Teorija hidro i elektrometalurških procesa, TF Bor, 2017. (*in Serbian)* 6. C.M.A. Brett and A.M.O. Brett, ELECTROCHEMISTRY, Principles, Methods, and Applications, Oxford University Press, 1994. 7. A. Despić, Osnove elektrohemije, Zavod za udžbenike i nastavna sredstva, Beograd, 2003. (*in Serbian)* 8. A. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley, 2000.		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Lectures with interactive discussions, independent research work, study research, its presentation		
Knowledge evaluation (maximum 100 points) 50% exam, 40% seminar, 10% activity through student research work.		

Course: PHYSICAL METALLURGY 4		
Lecturer/s: Dr Ivana Markovic, Associate Professor		
Status of the course: Elective subject for study program Metallurgical Engineering		
ECTS: 15		
Prerequisite: Required knowledge in Physical Metallurgy 1,2,3		
Course goals: The course goal is to acquire modern fundamental knowledge about the structure of metallic materials, the structure of alloys, phase transformations and the properties of metals and alloys.		
Learning outcomes: The expected learning outcome is intellectual, professional-practical and transferable abilities for the application of this knowledge as a foundation for further individual improvement in the field of foundry, processing of metals in a plastic state, characterization of materials and synthesis of new materials.		
Course description: Structure of atoms and crystals. Electronic structure of atoms. Chemical bonds in crystals. Typical metal structures. Electronic theory of metals. Free electron theory. Theory of energy zones. Electrical properties of metals. Magnetic properties of metals. Structure of alloys. Solid solutions. Intermediate stages. Arranged solid solutions. Lattice defects. Point defects. Dislocations. Grain and subgrain boundaries. Sequence defects. Diffusion. Diffusion theories. Experimental study of diffusion. Crystallization of metals. Phase transformations in the solid state. Diffusion and non-diffusion phase transformations. Nanostructured materials. Mechanical properties of metals and alloys. Strengthening mechanisms. Creep. Superplasticity. Fatigue. Fracture of metallic materials. Recovery and recrystallization. Texture. Deformation texture. Annealing texture.		
Literature: Recommended: 1. R.E. Smallman, P.J. Bishop, Modern Physical Metallurgy and Materials Engineering (Sixt edition), Elsevier Butterworth-Heinemann, 1999. 2. R.W. Cahn, P. Haansen, Physical Metallurgy, V1-3, Elsevier North Holland, 1996. 3. P. Papon, J. Leblond, P.H.E. Meijer, The Physics of Phase Transitions, Second revised edition, Springer-Verlag, Berlin, Heidelberg, 2006. 4. J. Schijve, Fatigue of Structures and Materials, Kluwer Academic Publishers, New York, 2001. 5. J. Lemaitre, R. Desmorat, Engineering Damage Mechanics, Ductile, Creep, Fatigue and Brittle Failures, Springer-Verlag, Berlin, Heidelberhg, 2005. 6. Z. L. Wang, Y. Liu, Z. Zhang, Handbook of Nanophase and Nanostructured Materials, Springer US, 2002.		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Preparation and defense of a seminar with a consulting approach to the student's independent work (mentor work of the teacher).		
Knowledge evaluation (maximum 100 points) Exam 55%; Seminar 45%		

Course: METALLURGICAL THERMODYNAMICS 2		
Lecturer/s: Dr. Dragan Manasijević, full professor, ; Dr Ljubiša Balanović, associate professor		
Status of the course: Elective for the study program in Metallurgical Engineering		
ECTS: 15		
Prerequisite: Knowledge of metallurgical thermodynamics 1, thermodynamics of materials and physical metallurgy.		
Course goals: The aim of the course is to get acquainted with the principles, methods and current trends of metallurgical thermodynamics, using a modern approach, concrete examples and modern software in this area.		
Learning outcomes: The expected outcomes represent intellectual, professional-practical and transferable capabilities for the application of this knowledge in the management of various metallurgical processes in the field of pyro-, hydro- and electrometallurgy, and are the basis for further individual development.		
Course description: Lectures: Thermodynamics of solutions. Multicomponent solutions. Interaction parameters. Solubility of gases in metals. Graphical interpretation of thermodynamic functions of the state. Thermodynamic models of solution. Experimental methods in metallurgical thermodynamics. Calorimetric methods. Methods based on EMF measurement. Gas phase equilibrium. Experimental determination of phase diagrams. Methods of thermodynamic prediction. Methods by Toop, Hillert, Kohler, Muggianu, RKM and GSM Method. Estimation of thermodynamic data. Examples of applications of metallurgical thermodynamics for various metallurgical processes. Application of modern software in the field of metallurgical thermodynamics. Pandat, ThermoCalc, and others. Practice: Thermodynamic calculations using the Pandat Software. Laboratory experimental work.		
Literature: Recommended: 1. D.R.Gaskell, Introduction to Metallurgical Thermodynamics, McGraw-Hill Co., New York., 1985. 2. S. Seetharaman (Ed.), Treatise on Process Metallurgy, Elsevier, 2014. 3. O.Kubaschewski, C.B. Alcock, Metallurgical Thermochemistry, Pergamon Press, Oxford, 1979. 4. S. Stolen, T. Grande, N. L. Allan, Chemical Thermodynamics of Materials: Macroscopic and Microscopic Aspects, John Wiley & Sons Ltd,2004. 5. Y.K.Rao, Stoichiometry and Thermodynamics of Metallurgical Processes, Cambridge University Press, New York, 1985. 6. R.Hultgren, R.L.Orr, P.D.Anderson, K.K.Kelley, Selected Values of Thermodynamic Properties of Metals and Alloys, John Willey&Sons, New York, 1963. 7. D.Minić, D.Manasijević, D.Živković, Ž.Živković, Fazna ravnoteža i termodinamika sistema Pb-Sn-(In,Ga), TF Bor, 2007. (in Serbian) 8. A.Kostov, D.Živković, Hemijska termodinamika i karakterizacija legura Ga-Ge-Sb sistema, Grafomedtrade, Bor, 2008. (in Serbian)		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Classical lectures with consultant approach to independent student work, seminar work and student research work.		
Knowledge evaluation (maximum 100 points) Exam 40% + presentation and presentation of seminar work 40% + student research work 20%.		

Course: METALLURGICAL REACTORS

Lecturer/s: Dr. Milan Gorgievski, assistant professor, Dr. Miroslav Sokić, senior research associate

Status of the course: Elective for the study program in Metallurgical Engineering

ECTS: 15

Prerequisite: Basic knowledge in metallurgical thermodynamics, theory of pyrometallurgical processes, heat technique, and basic processes of ferrous and non-ferrous metallurgy is required.

Course goals: The objective of the course is to provide students with adequate knowledge about the reactor technology. Students should be familiar with alternative types and design of metallurgical reactors according to the types of metallurgical processes and production capacities.

Learning outcomes: After the course, students are able to independently, with a wide-ranging project approach, perform an adequate selection of metallurgical reactors, calculate characteristic parameters of the reactor process, as well as the thermal and material balance of the process under consideration.

Course description:

Lectures:

Transfer of heat and mass in gas/solid systems. Types and application of gas/solid rectifiers: fluidized bed reactors, suspension reactors, mobile batch reactors, rotary columns, multi-columns, endless belt sintering machines, vibration and pulsation reactors. Reactors for the vapor phase: flame and plasma reactors, vapor decomposition reactors. Reactor design: reactor types according to design and characteristics, reactor design methods, research and development in reactor technology. Application of reactors in the most important pyrometallurgical processes: blast furnace in ferrous metallurgy, shaft furnace, reverberatory and electric furnace in non-ferrous metallurgy, bottling processes, reactor for salt dissolution in extractive metallurgy, pneumatic processes (converting), reactor processes in a vacuum, reactors for the refinement of metallurgical slag. Contemporary approach to calculations of the material and thermal balance of metallurgical reactors. Refractory materials as a component of metallurgical reactors.

Practice:

Literature research and project task on a subject in the field of matter.

Literature:

Recommended:

1. High temperature chemical reaction engineering: solids conversions processes, Edited by F. Roberts, R.F.Taylor, T.R.Jankins, The institution of chemical engineers, London, 1971.

2. O. Levenspiel, Osnovi teorije i projektovanja hemijskih reaktora, Univerzitet u Beogradu, Tehnološko metalurški fakultet, Beograd, 1991. (in Serbian)

3. Heat and Mass transfer in process metallurgy, Edited by A.W.D.Hills, The institute of Mining and Metallurgy, London, 1967.

4. C. A. Kayode, Modeling of Chemical Kinetics and Reactor Design, Boston, Gulf Professional Publishing, 2001.

Number of classes per week	**Lectures: 6**	**Practical classes: 4**

Teaching methods

Classical lectures with consultant approach to developing an individual project task for students.

Knowledge evaluation (maximum 100 points)

Exam 50% + creation and presentation of individual project 50%

Course: PHYSICS OF THE STRENGTH AND PLASTICITY OF METALS
Lecturer/s: dr Saša R. Marjanović, Associate Professor
Status of the course: Elective for Module: Processing metallurgy
ECTS: 15
Prerequisite: Required knowledge of physical chemistry and physical metallurgy.
Course goals: To provide students with adequate knowledge about the strength, elasticity and plasticity of metals.
Learning outcomes: The expected outcome is intellectual, practical and transferable abilities to apply these knowledge in the management of metallurgical processes in the field of metal processing in the plastic state.
Course description: Lectures: Elasticity and plasticity of crystals. Dislocations and sliding. Doppelgangers and doppelgangers. Borderline surface. Deformation strengthening of crystals. Deformation and strengthening of polycrystalline aggregates. Deformation and strengthening of solid solutions. Precipitation and dispersion strengthening. Energy change at deformation. Recovery. Recrystallization. Grain growth. Texture. Fracture of metallic materials. Stress and deformation. Mechanical scheme of deformation and its effect on plasticity. Shaping metal in a plastic state. Deformation of metal during rolling. Deformation of metal during extraction. Deformation during pressing. Metal deformation during forging. Practice:
Literature: Recommended: 1.D. Drobnjak, Fizika čvrstoće i plastičnosti, TMF, Beograd, 1981. 2. B. Perović, Fizička metalurgija, MTF, Podgorica, 1997. 3. C.E.Dieter, Mechanical Metallurgy, Thiko ed., Mc Graw - Hil, N.Y., 1986. 4. Microstructure evolution in metal forming processes, Jianguo Lin, 2012. 5. R.W.K. Honeycombe, The Plastic Deformation of Metals, Edvard Arnold, London, 1984. 6. H.S.Valberg, Applied Metal Forming, Cambridge University Press, New York, 2010. 7. D. Broek, Osnovu mehaniki razrušenija, prev. sa engl., Moskva 1980. 8. N.P.Gromov, Teorija obrabotki metallov davleniem, Metallurgija, Moskva, 1967. 9. W.F.Hosford, R.M.Caddell, Metall Forming - Mechanics and Metallurgy, Prentice - Hall, 2nd ed. 1993. 10. A. Tselikov, Stress and Strain in Metal Rolling, University Press, L.A., 2003. Ancillary: 1.

Number of classes per week	**Lectures: 4**	**Practical classes: 6**

Teaching methods Classic lecture and consulting approach to the creation of an individual seminar assignment.
Knowledge evaluation (maximum 100 points) Project assignment 40%, final exam 60%.

Course: MECHANICAL BEHAVIOR OF METALS		
Lecturer/s: Dr. Uroš Stamenković, assistant professor		
Status of the course: Elective for Module: Processing metallurgy		
ECTS: 15		
Prerequisite: Required knowledge of the theory of plastic deformation, physical metallurgy, thermal treatment of metals.		
Course goals: The aim of the course is to familiarize with the interaction of the structure and the conditions under which a metal is deformed, in order to achieve optimal processing conditions that ensure the shaping of the material without breakage and with appropriate performance in exploitation. Acquired knowledge in this area, the development of experimental methods of testing metals and the establishment of a correlation between the structure and properties of metals represent the basis for the design of metal materials. Within the course, the ability to apply this knowledge in concrete practical examples should be acquired, which form the basis for further learning and improvement.		
Learning outcomes: The acquired knowledge in this area, the development of experimental methods of testing metals and the establishment of the correlation between the structure and the properties of metals represent the basis for the design of metal materials. Within the scope of the course, the ability to apply this knowledge in concrete practical examples should be acquired, which form the basis for further learning and improvement.		
Course description: Lectures: Behavior of materials under stress. Linear elastic behavior; nonlinear elastic behavior; inelastic behavior; viscous behavior; elastic-plastic behavior. Deformation-mechanical properties of metals. Deformation strengthening. Uniaxial tension. The influence of the rate of deformation on the mechanical properties. Plastic instability and strain rate sensitivity. Deformation of metals at elevated temperatures. Effect of temperature on the mechanical properties of metals. Heat treatment of metals. Special cases of deformation behavior at elevated temperatures: creep; superplasticity. Metal forming by bending, deep drawing, stretching, compression. Practice:		
Literature: Recommended: 1. Е. Ромхањи, Механика и металургија деформације метала, Технолошко-металуршки факултет, Београд, 2001. 2. Ђ. Дробњак, Физика чврстоће и пластичности 1, Технолошко-металуршки факултет, Београд, 1981. 3. H.S. Valberg, Applied Metal Forming, Cambridge University Press, New York, 2010. 4. M. Kazeminezhad, Metal Forming-Process, Tools, Design, In Tech, Croatia, 2012. 5. M.L. Bernstein and V.A. Zaimovsky, Mechanical properties of metals, English translation, Mir Publishers, Moscow, 1983. 6. В.Г. Зубчанинов, Основы теории упругости и пластичности, Москва, 1990. 7. W.F. Hosford, R.M. Caddell, Metal Forming-Mechanics and Metallurgy, Englewood Cliffs, N.J.: Prentice-Hall, 2007. 8. М.Ю. Лахтин, Металловедение и термическая обработка металлов, Металлургия, Москва, 1984. 9. D.W. A. Rees, Mechanics of Solids and Strengths, McGraw-Hill UK Ltd., 1990. 10. H. Ford, J.M. Alexander, Advanced Mechanics of Materials, Ellis Horwood Pub., New York, 1977. 11. М.Л. Бернштейн, Термомеханическая обработка металлов и сплавов, том 1и 2, Металлургия, Москва, 1968. 12. C.H. Hamilton, C.C. Bampton, N.E. Patton, Superplastic Forming of Structural Alloys, TMS-AIME, Warrendale, PA, 1982.		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Theoretical lessons with a consulting approach to students' independent work, preparation of a seminar paper.		

Knowledge evaluation (maximum 100 points)

Exam 50%, preparation and presentation of a seminar paper 40%, activity during classes and SIR 10%.

Course: METALLURGICAL KINETICS		
Lecturer/s: Dr. Nada Štrbac, full proffesor; Dr. Vesna Grekulović, full professor		
Status of the course: Elective for the study program in Metallurgical Engineering		
ECTS: 15		
Prerequisite: Knowledge in Physical chemistry and Theory of pyrometallurgical processes is required		
Course goals: The objective of the course is to introduce students to the basic principles of metallurgical kinetics and to study the ongoing and mechanism of reactions, physical and energy changes and the speed of product creation, as well as the basic factors that influence the speed of processes in homogeneous and heterogeneous systems.		
Learning outcomes: The expected outcome of the course is the development of knowledge and understanding of the application and use of metallurgical reactions for industrial purposes, with the aim of developing a general design strategy for different homogeneous and heterogeneous systems.		
Course description: Lectures: Theories of reaction kinetics. Dependence of reaction rate on concentration. Dependence of reaction rate on temperature. Determination of the metallurgical reaction mechanism. Possibilities for theoretical predictions of the reaction rate. Kinetics of heterogeneous reactions. Model selection in heterogeneous systems. Nonisothermal kinetics. Isothermal kinetics. Experimental and analytical methods for testing kinetic parameters. Kinetics of phase transformations in metals.		
Literature: Recommended: 1. G.Hammes, Principles of chemical kinetics, Academic press, London, 1996. 2. E.Koch, Non-isothermal reaction analysis, Academic press, London, 1977. 3. S.W.Benson,Thermochemical kinetics, Second edition, John Wiley Sons,New York, 1976. 4. F.Habashi, Kinetics of Metallurgical Processes, Laval University, Quebec, 1999. 5. E.N.Eremin, The foundations of chemical kinetics, Mir Publishers, Moskow, 1979. 6. J.Бурке, Kinetika faznih transformacija u metalima, Tehnološko-metalurški fakultet, Beograd, 1980. *(in Serbian)* 7. W.Wendlant, Thermal methods of analysis, Second Edition, John Wiley Sons, New York, 1974. 8. C. A. Kayode, Modeling of Chemical Kinetics and Reactor Design, Boston, Gulf Professional Publishing, 2001.		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Classic lectures, study research work and seminar work - concrete calculation of individual kinetic parameters of a particular metallurgical process.		
Knowledge evaluation (maximum 100 points) Exam 50% + preparation and presentation of seminar work 40% + activity within study research work 10%		

Course: MODERN METAL MATERIALS		
Lecturer/s: Dr. Vladan Ćosović, senior research associate; Dr Ljubiša Balanović, associate professor		
Status of the course: Elective for the study program in Metallurgical Engineering		
ECTS: 15		
Prerequisite: Required knowledge of physical metallurgy, thermodynamics of materials, basic processes of ferrous and nonferrous metallurgy and materials characterization.		
Course goals: The aim of the course is for students to gain a comprehensive knowledge of modern metal materials, procedures for their preparation, their structural, physical, mechanical, corrosion and functional properties, as well as areas of application through a multidisciplinary approach to materials and engineering materials.		
Learning outcomes: Forming a solid foundation of integrated knowledge on modern metal materials and modern processing techniques for independent scientific research works for further scientific and professional development.		
Course description: Lectures: This course provides insight into the principles of modern scientific knowledge about materials from their design and functionality point of view, methods of research and practical results in the field of modern metal materials with a focus on the connection between the processes of obtaining and processing of these materials, and their properties, with reference to the most common areas of application. The covered classes of materials include micro and nanostructural multi-component metal systems and composites with a metal matrix that include carbon and alloy steels – perlitic, ledeburite, martensitic, ferrite, austenitic, with nickel, manganese, chromium, molybdenum, silicon, chromium and nickel, HSLA steels, DP steels, MA steels, iron – white cast iron, gray cast iron, nodular cast iron, tempered cast iron, alloyed iron, aluminum and aluminum alloys; copper and copper alloys; nickel and nickel alloys; silver and silver alloys; magnesium and magnesium alloys.		
Literature: Recommended: 1. B.S.Mitchell, An Introduction to Materials Engineering and Science, John Willey&Sons, New Jersey, 2004. 2. F.C. Campbell, Ed., Elements of Metallurgy and Engineering Alloys, ASM International, 2008. 3. P. A. Schweitzer, Metallic Materials: Physical, Mechanical, and Corrosion Properties, CRC Press, 2003. 4. J.F. Shackelford, W. Alexander, Materials Science and Engineering Handbook, CRC Press, New York, 2001. 5. D. D. L. Chung, Applied Materials Science, Chapman and Hall, CRC Press lnc, 2001. 6. W.D.Callister, Fundamentals of Material Science and Engineering,Wiley, 2012.		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Classical lectures with consultant approach to independent student work, and seminar work.		
Knowledge evaluation (maximum 100 points) Exam 50% + preparation and presentation of seminar work 40% + student research work 10%.		

Course: MODERN METHODS OF MATERIALS CHARACTERIZATION		
Lecturer/s: Dr. Ljubiša Balanović, associate professor; Dr. Milan Gorgievski, associate professor		
Status of the course: Elective for the study program in Metallurgical Engineering		
ECTS: 15		
Prerequisite: Knowledge in physics, physical chemistry, materials testing and materials characterization is required.		
Course goals: The aim of the course is to introduce students to modern methods of characterization of solids and liquids from the point of view of these methods outcomes, to devices used for the purpose and fundamentals of their functioning		
Learning outcomes: As the main outcome it is expected that students become able to make independently the choice of optimal method for some investigation or specific application, as well as assistant methods which will provide the needed parameters; this implies the knowledge about the limits of selected methods and basics of functioning of used devices and instruments		
Course description: Lectures: Spectroscopic methods (UV, VIS, IR and Raman spectroscopy). Mass spectrometry. Characterization of solid materials. Investigations of structures by X-ray, electrones and neutrons diffraction (scanning electron microscopy, transmissive electron microscopy and other modern methods). Auger spectroscopy. Physical methods of determining properties. Mechanical testing materials using static and mechanical force. Thermochemical methods (TG, DTA, DSC). Practice: Characterization of powders and sintered materials. Electrochemical methods of characterization. Characterization of liquids. Measurement of viscosity of melts. Ideal and non-ideal liquid mixtures and solutions.		
Literature: Recommended: 1. C. R. Brundle, C. A. Evans, S. Wilson, Encycloped ia of Materials Characterization, Butterworth Heinemann, Boston, London, 1992. 2. H. R. Verma, Atomic and Nuclear Analytical Methods, Springer Verlag, Berlin, Heidelberg, 2007. 3. П.П. Арсентев и други, Физико-химические методи иследованија метллургических процессов, Металлургија, Москва, 1988. (*in Russian*) 4. J.P. Sibilia, A Guide to Materials Characterization, VCH Publishers, 1988. 5. G.M. Crankovic, ASM Handbook, Volume 10: Materials Characterization, 1986. 6. Yu. Lyalikov et al. Problems in Physicochemical Methods of Analysis, Mir Publishers, Moscow, 1974. 7. Ј. Мишовић, Т. Аст, Инструменталне методе хемијске анализе, ТМФ, Београд, 1978. (*in Serbian*) 8. С. Ђорђевић, В. Дражић, Физичка хемија, 4. издање, ТМФ, Београд, 2000. (*in Serbian*) 9. C.M.A. Brett and A.M.O. Brett, ELECTROCHEMISTRY, Principles, Methods, and Applications, Oxford University Press 1994 10. V. K.Pecharsky, P. Y. Zavalij, Fundamentals of powder diffraction and structural characterization of materials, Springer science and Business media, 2003. 11. B. S. Mitchell, An Introduction to Materials Engineering and Science, John Wiley & Sons, Inc, 2004. 12. D. B. Murphy, Fundamentals of Light Microscopy and Electronic Imagin, Willey-Liss, 2001.		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Classical lectures and individual research work from the framework of applying different methods of characterization and familiarization with devices for characterization of materials in laboratories of other institutions (other faculties, institutes and industrial laboratories) and their way of functioning, processing of results and possibilities.		
Knowledge evaluation (maximum 100 points) Exam 50% + seminar work 40% + student research work 10%.		

Course: TRANSPORT PHENOMENA 2		
Lecturer/s: Dr. Vesna Grekulović, full professor; Dr. Milan Gorgievski, associate professor		
Status of the course: Elective for the study program in Metallurgical Engineering		
ECTS: 20		
Prerequisite: Knowledge in Mathematic, Physical Chemistry and Transport Phenomena 1 is required		
Course goals: Providing students the knowledge momentum, mass and heat transfer, as well as mathematical interpretation of the transport ways, so that they can explain and interpret a phenomenon under they consideration.		
Learning outcomes: Students gain a certain level of knowledge from the basic transport phenomena that would help them to identify, solve problems in the subject area and manage processes that are limited by the transport rate of a specific phenomenon.		
Course description: Physical and mathematical basics of transport phenomena: transport mechanisms, fluid flow modes, boundary layer; differential equations of mass and energy conservation and transport; partial solutions of differential equations of transport - theory of similarity. Transport in one's own field: diffusion, diffusion in own field, own field and flux. Convective transport. Transport models. Transport analogues. Equations of convective transfer - some partial solutions for natural and forced convection. Transport across phases interface: contact of phases, transfer rate and resistance through phases interface, contactors. Transfer of heat and mass with a chemical reaction.		
Literature: Recommended: 1. S.D. Cvijović, N. M. Bošković-Vragolović; Fenomeni prenosa; TMF Beograd, 2001. (*in Serbian*) 2. J. M. Coulson & J. F. Richardson, Chemical Engineering vol. 1 and 2, Butterworth-Heinemann; 2002. 3. J. Szekely & N.J. Themelis; Rate Phenomena in Process Metallurgy; John Wiley & Sons; New York; 1971. 4. G.H. Geiger & D.R. Poirier; Transport Phenomena in Metallurgy; Addison-Wesley publ. Co. MA USA;1973. 5. V. Stanković, Fenomeni prenosa i operacije u metalurgiji 1, Univerzitet u Beogradu, Tehnički fakultet Bor,1998. *(in Serbian)* 6. V. Stanković, Fenomeni prenosa i operacije u metalurgiji 2, Univerzitet u Beogradu, Tehnički fakultet Bor,1998. *(in Serbian)* 7. M. Sovilj; Difuzione operacije; Tehnološki fakultet Univerziteta u Novom Sadu; 2004. *(in Serbian)* 8. F. Zdanski; Mehanika fluida; Tehnološko-metalurški fakultet, Univerziteta u Beogradu; 1995. *(in Serbian)*		
Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods Classical lectures, consultations and experimental work.		
Knowledge evaluation (maximum 100 points) Exam 50% + preparation and presentation of individual work 50%		

Course: MODERN PROCEDURES OF CASTING AND MODELING IN FOUNDRY
Lecturer/s: :Dr. srba A. Mladenović, full prof.
Status of the course: Elective for Metallurgical Engineering
ECTS: 20
Prerequisite: Required knowledge of physical metallurgy, foundry theory and foundry
Course goals: Familiarization with the principles, methods, and current trends in the field of contemporary procedures of liquid metal shaping and modeling in the foundry.
Learning outcomes: Intellectual, professional, and practically applicable abilities for the use of this knowledge in organizing and managing processes in the field of the foundry. They form the basics for further learning and improvement
Course description: Properties of liquid metals and alloys. Structure of one-component and two-component melts. Casting melts into molds. Solidification of multiphase alloys and metals. Examination of liquid metals. Contemporary casting procedures. General characteristics and classification of castings. Modern ways of controlling the casting process and casting quality. Systems and methods of modeling in the foundry. Modeling the structure and properties of (amorphous) metals and alloys. Interaction of particles in liquid metal. Modeling of the casting process and crystallization processes. Statistical analysis of castings Lectures: Practice:
Literature: Recommended: 1. Different papers and scientific articles from the course field. 2. Ancillary: 2.

Number of classes per week	**Lectures: 6**	**Practical classes: 4**
Teaching methods		
Knowledge evaluation (maximum 100 points) Exam 50%, seminar work 40% and activity in classes 10%.		

Course: SINTERED METALLIC MATERIALS AND COMPOSITES
Lecturer/s: Dr Ivana Markovic, Associate Professor
Status of the course: Elective subject for study program Metallurgical Engineering
ECTS: 15
Prerequisite: Required knowledge from Physical Metallurgy and Powder Metallurgy
Course goals: The aim of the course is to acquire and improve knowledge in the field of modern processes of powder forming and syntheses by sintering of metal and composite materials.
Learning outcomes: The expected outcome is that fundamental knowledge in the field of solid state sintering theory and liquid-phase sintering be applied in the design and characterization of the materials which were obtained using powder metallurgy technology. Within the course, the ability to apply this knowledge in concrete practical examples that form the basis for the synthesis of materials by sintering and further scientific and professional improvement should be acquired.
Course description: **Lectures:** Examination and characterization of metal powders. Technologies for obtaining metal powders: physical-chemical and mechanical methods for obtaining metal powders. Shaping of powders: under pressure at room temperature, under pressure at elevated temperature, without application of pressure. Theoretical foundations of the sintering process: sintering in the solid state, sintering in the presence of a liquid phase, sintering under pressure. New sintering techniques. Infiltration. Sintered metal materials and composites. Sintered materials based on iron and non-ferrous metals and their alloys. High alloyed sintered materials with high density. Sliding materials and bearings. Friction materials. Highly porous materials and filters. Materials based on metals with a high melting point (W, Mo, Re), W-Cu composite material, W-Ag composite material. High-temperature metals and alloys: tungsten, molybdenum and tantalum - sintering and processing of sintered parts. Sintered magnets - production of sintered parts from AlNiCo, heat treatment, structure and properties. Hard materials and composites of hard materials. Metal-graphite composites. Silver-graphite composites, copper-graphite composites. Dispersion-strengthened materials: dispersion-strengthened copper based alloys, dispersion-strengthened aluminum alloys, dispersion-strengthened silver-based materials. Cermets: the influence of the properties of the constituents, application and future development. **Practice:** Examination of sintered materials: density, porosity, shrinkage, mechanical properties and indicators of plasticity, thermal (DTA, DSC and TG) and physical properties. Microstructural examination of sintered materials: quantitative and qualitative analysis of microstructure and phase composition using SEM-EDS analysis.
Literature: 1. W. Schatt, K.P.Wieters, Металургија праха, Прерада и материјали, EPMA,1994. 2. F. Lenel, Powder Metallurgy Principles and Aplications, Princeton, USA, 1980. 3. R.M. German, Sintering Theory and Practice, John Wiley & Cons, 1996. 4. S.J.L. Kang, Sintering - Densification, Grain Growth and Microstructure, Elsevier, 2005. 5. O. Neikov, Stanislav S. Naboychenko, G. Dowson, Handbook of Non-ferrous Metal Powder, Elsevier, 2009. 6. S.J.L. Kang, Sintering - Densification,Grain Growth, and Microstructure, Elsevier, 2005. 7. Z.Z. Fang, Sintering of Advanced Materials Fundamentals and Processes, Woodhead Publishing Limited, 2010. 8. F. Thummler, R.Oberacker, An Introduction to Powder Metallurgy, The Institute of Materials, 1993. 9. R.M. German, Powder Metallurgy & Particulare Materials Processing, EPMA, 2005. 10. P. Beiss, K. Dalal, R. Peters, International Atlas of Powder Metallurgical Microstructures, MPIF, 2002. 11. М. Митков, Д. Божић, З. Вујовић, Металургија праха, БМГ, Завод за уџбенике и наставна средства, Винча,1998.

Number of classes per week	**Lectures: 6**	**Practical classes: 4**

Teaching methods Classical lectures with consultant approach to independent work of students, study research work, and elaboration of seminary work.
Knowledge evaluation (maximum 100 points) **Exam 60% and Seminary 40%**

<table>
<tr><td colspan="3">Course: DOCTORAL DISSERTATION – DEFINING THEME</td></tr>
<tr><td colspan="3">Lecturer/s: All professors from study program, eligible to be a mentor</td></tr>
<tr><td colspan="3">Status of the course: Compulsory</td></tr>
<tr><td colspan="3">ECTS: 10</td></tr>
<tr><td colspan="3">Prerequisite: All exams at the PhD level successfully passed</td></tr>
<tr><td colspan="3">Course goals: Applying new theoretically – methodological, scientific and vocational applicable knowledge, methodology and contemporary methods, available in the SCI listed journals, in solving concrete tasks in frame of the PhD level subjects.</td></tr>
<tr><td colspan="3">Learning outcomes: The student will be trained to become capable to carry on analysis and synthesis of the doctoral level subject level, on his/her own. Also, to apply gained knowledge in structuring the research problem and defining the potential directions of its solution. Independent application of the literature resources from the available data bases with the purpose of complete overview of the predefined research problem.</td></tr>
<tr><td colspan="3">Course description:
The course content is to be prepared for each student individually, in line with requirements of his/her future work.
Student will review scientific literature aiming the solution of concrete research task, through:
a) defining the methodology of research that will be applied in the work on the doctoral thesis (dissertation),
b) clearly defined basic scientific contributions that will result from the doctoral thesis,
The work on above tasks will result with written report – seminar work, that will be defended in front of the three members commission, appointed through Scientific-educational council of Technical faculty in Bor. The members of the commission will be initially proposed at the departments level.</td></tr>
<tr><td colspan="3">Literature:
Available scientific journal publications from the „Kobson“ list, as well as the available library literature.</td></tr>
<tr><td>Number of classes per week</td><td>Lectures: 0</td><td>Practical classes: 10</td></tr>
<tr><td colspan="3">Teaching methods
Mentor is assigning the research task, in consultations with the student, for defining the research elaborate, which will present the scientific validation of the proposed doctoral dissertation theme. Preliminary literature is to be defined by the mentor. All further research of available literature resources will be completed by the student. During students work on the final elaborate, the mentor can be involved with adequate suggestions and instructions that will result with high quality of explanation of the scientific contribution and adequacy of selected theme of the dissertation.
During his/her work on the elaborate, student shell conducts all necessary experiments, measurements, analysis and other research work, with the aim to define and explain the research problem, as better as possible. After defending the elaborate, mentor will start the procedure for official acceptance of the doctoral dissertation theme.</td></tr>
<tr><td colspan="3">Knowledge evaluation (maximum 100 points)</td></tr>
</table>

Course: DOCTORAL DISSERTATION – RESEARCH WORK 1		
Lecturer/s: All professors from study program, eligible to be a mentor		
Status of the course: Compulsory		
ECTS: 30		
Prerequisite: All exams at the PhD level successfully passed		
Course goals: Applying basic theoretically – methodological, scientific and vocational applicable knowledge, methodology and contemporary methods, available in the SCI listed journals, in solving concrete tasks in frame of the subject of the doctoral dissertation. Through defined theme of the doctoral dissertation student study the problem, its structure and complexity, conducts analysis and synthesis and defines the potential directions for its solution. The goal of students activities, at this study level is in acquiring of necessary experience for independent structuring of the research problem and finding the solutions for solving it.		
Learning outcomes: The student will be trained to become capable to practically apply the knowledge generated through the subjects of this study program and use it in solving the defined practical problem. Through independent application of the literature resources from the available data bases, student will expand his/her knowledge and will become capable in using the contemporary methods and tools in solving the predefined research problems.		
Course description: The course content is to be prepared for each student individually, in line with requirements of his/her future work. Student will review scientific literature and conduct necessary research work, which are connected with the subject of the doctoral thesis theme (laboratory research, field work research, etc.).		
Literature: Available scientific journal publications from the „Kobson“ list.		
Number of classes per week	**Lectures: 0**	**Practical classes: 20**
Teaching methods Mentor is assigning the research task, with proposition of main research directions, that resulted from the defined and defended research elaborate, during the definition of the doctoral dissertation theme course. During students work on the doctoral thesis, the mentor can be involved with adequate suggestions and instructions that will result with high quality of final content of the doctoral dissertation.		
Knowledge evaluation (maximum 100 points)		

Course: DOCTORAL DISSERTATION – RESEARCH WORK 2		
Lecturer/s: All professors from study program, eligible to be a mentor		
Status of the course: Compulsory		
ECTS: 30		
Prerequisite: All exams at the PhD level successfully passed		
Course goals: Applying basic theoretically – methodological, scientific and vocational applicable knowledge, methodology and contemporary methods, available in the SCI listed journals, in solving concrete tasks in frame of the subject of the doctoral dissertation. Through defined theme of the doctoral dissertation student study the problem, its structure and complexity, conducts analysis and synthesis and defines the potential directions for its solution. The goal of students activities, at this study level is in acquiring of necessary experience for independent structuring of the research problem and finding the solutions for solving it.		
Learning outcomes: The student will be trained to become capable to practically apply the knowledge generated through the subjects of this study program and use it in solving the defined practical problem. Through independent application of the literature resources from the available data bases, student will expand his/her knowledge and will become capable in using the contemporary methods and tools in solving the predefined research problems.		
Course description: The course content is to be prepared for each student individually, in line with requirements of his/her future work. Student will review scientific literature and conduct necessary research work, which are connected with the subject of the doctoral thesis theme (laboratory research, field work research, etc.). Dominant resources to be used by the student, through his/her individual research work are journals from the SCI list.		
Literature: Available scientific journal publications from the „Kobson“ list.		
Number of classes per week	**Lectures: 0**	**Practical classes: 20**
Teaching methods Mentor is assigning the research task, with proposition of main research directions, that resulted from the defined and defended research elaborate, during the definition of the doctoral dissertation theme course. During students work on the doctoral thesis, the mentor can be involved with adequate suggestions and instructions that will result with high quality of final content of the doctoral dissertation.		
Knowledge evaluation (maximum 100 points)		

Course: DOCTORAL DISSERTATION – RESEARCH WORK 3		
Lecturer/s: All professors from study program, eligible to be a mentor		
Status of the course: Compulsory		
ECTS: 5		
Prerequisite: All exams at the PhD level successfully passed		
Course goals: Applying basic theoretically – methodological, scientific and vocational applicable knowledge, methodology and contemporary methods, available in the SCI listed journals, in solving concrete tasks in frame of the subject of the doctoral dissertation. Through defined theme of the doctoral dissertation student study the problem, its structure and complexity, conducts analysis and synthesis and defines the potential directions for its solution. The goal of students activities, at this study level is in acquiring of necessary experience for independent structuring of the research problem and finding the solutions for solving it.		
Learning outcomes: The student will be trained to become capable to practically apply the knowledge generated through the subjects of this study program and use it in solving the defined practical problem. Through independent application of the literature resources from the available data bases, student will expand his/her knowledge and will become capable in using the contemporary methods and tools in solving the predefined research problems.		
Course description: The course content is to be prepared for each student individually, in line with requirements of his/her future work. Student will review scientific literature and conduct necessary research work, which are connected with the subject of the doctoral thesis theme (laboratory research, field work research, etc.). Dominant resources to be used by the student, through his/her individual research work are journals from the SCI list.		
Literature: Available scientific journal publications from the „Kobson“ list.		
Number of classes per week	**Lectures: 0**	**Practical classes: 20**
Teaching methods Mentor is assigning the research task, with proposition of main research directions, that resulted from the defined and defended research elaborate, during the definition of the doctoral dissertation theme course. During students work on the doctoral thesis, the mentor can be involved with adequate suggestions and instructions that will result with high quality of final content of the doctoral dissertation.		
Knowledge evaluation (maximum 100 points)		

Course: DOCTORAL DISSERTATION – REALIZATION AND DEFENSE OF THESIS		
Lecturer/s: All professors from study program, eligible to be a mentor		
Status of the course: Compulsory		
ECTS: 25		
Prerequisite: All exams at the PhD level successfully passed		
Course goals: Successful defending the doctoral thesis of the student.		
Learning outcomes: After successful and independent work on the doctoral dissertation and its preparation in the written form, from the scientific field of technical sciences which was selected by the student after enrollment, the candidate acquires the right to defend his doctoral dissertation.		
Course description: The student chooses a theme for the doctoral dissertation in the field covered by the elective courses. Doctoral dissertation should include common chapters: title, introduction, literature review, work hypothesis and research, material and methods, performance, discussion, conclusion and literature.		
Literature: All available domestic and foreign literature referring to the scientific field from which the PhD dissertation was submitted.		
Number of classes per week	**Lectures:**	**Practical classes:**
Teaching methods Analysis of experimental data obtained using predefined methods, and results processing, followed by writing the dissertation, accompanied by continuous consultations with the mentor and commission members.		
Knowledge evaluation (maximum 100 points)		