METALLURGICAL ENGINEERING

DOCTORAL ACADEMIC STUDIES

BOOK OF COURSES

2013.

List of courses:

Study program: Metallurgical Engineering	
Level of study: Doctoral Academic Studies	
Course: METHODOLOGY OF THE SCIENTIFIC-RESEARCH ACTIVITIES	
Lecturer: Dr. Nada Štrbac, full professor	
Status of the course: Elective course	
ECTS: 15	
Prerequisites: Graduated with Master's academic degree	
Course goals: Mastering the basic knowledge of scientific research methods and research techniques in order to select adequate research activity, depending on the nature of the examined phenomenon (process).	
Learning outcome: Adequate knowledge of the research procedure application and research methodology of the defined tested course.	
Course description: *Lectures:* Introduction to the methodology (understanding the progress in science, qualitative and quantitative research). Basic methods (experimental method, axiomatic method, modeling method and statistical method). Thinking-logical operations in research (induction and deduction, analysis and synthesis, generalization and specialization, abstraction and concretization, role of definitions in the cognitive process). Theoretical and systemic methods and research techniques. Phases of the methodological procedure; research question, theory, data and data usage. Conceptualization and operationalization; validity and reliability of measurement. Demonstration of specific methods and techniques for concrete research problems.	
Literature Recommended: 1. M. Vuković, Ž. Živković, Metodologija naučno-istraživačkog rada, Grafožig, Beograd, 2005. *(in Serbian)* 2. P. Ghauri, K. Gronhaug, Research Methods in Business Studies, Prentice Hall, England, 2005. 3. A. H. Kvanli, R. J. Pavur, K. B. Keeling, Concise Managerial Statistics, Thomson Learning, USA, 2007. 4. B. Render, R. M. Stair, M. E. Hanna, Quantitative analysis for management, Person Prantice Hall, New Jersey, USA, 2006. Supplementary: Papers published in the international journals.	
Lectures: 6	Study research work: 4
Methods of teaching Oral lectures.	
Grading system (max. number of points 100)	
Independent work	20
Written exam	40
Oral exam	40

Study program: Metallurgical Engineering, Engineering Management			
Level of study: Doctoral Academic Studies			
Course: PROJECT MANAGEMENT			
Lecturer: Dr. Nenad Milijić, assistant professor			
Status of the course: Elective course			
ECTS: 15			
Prerequisites: Knowledge in the field of Statistics, Quality Management and Business Economics			
Course goals: The course represents the fundamental concepts of project management. Students will be able to understand the scope and variations of project types, understand the key variables in the project management, as well as study of methods, techniques and approaches that are important for successful project management in order to achieve goals across a wide range of contexts.			
Learning outcome: The expected outcome is knowledge of critical success factors in project management, as well as the ability to produce project reports.			
Course description: 1. Location of projects in contemporary organizations: project definition, life cycle of the project. 2. Project Initiation: strategic management and project selection, project portfolio process. 3. Project manager: special project manager requirements, project manager selection, multicultural communication and managerial behavior. 4. Project organization as a part of a functional organization, pure project organization, matrix organization. 5. Human factor and project team. 6. Project planning: initial coordination of the project, system integration, WBS and linear liability maps. 7. Conflicts and Negotiations. 8. Project budget and cost estimates; assessment of the project budget, improvement of the cost estimation process. 9. Network planning: structure, time and cost analysis, PERT and CPM. 10. Resource allocation. 11. Project monitoring and information systems. 12. Project control. 13. Project audit. 14. Project completion process.			
Literature Recommended: 1. Meredith, J.R., Mantel, S.J., Project Management – A Managerial Approach, John Wiley and Sons, Inc, 7th Edition, Haboken, NJ, USA, 2009. 2. Levine, H.A., Project portfolio management, HB Printing, John Wiley and Sons, New York, USA, 2005. 3. Carter, M.W., Price, C.C., Operations research-a practical introduction, CRC Press, International edition, 2001. Supplementary: Articles from international journals.			
Number of classes per week: 10	Lectures: 6	Study research work: 4	
Methods of teaching Traditional lectures, case studies, practical classes, production of collective and individual term papers			
Grading system (max. number of points 100)			
Pre-examination requirements	**Number of points**	**Final examination**	**Number of points**
Term paper – 20 Written exam – 40 Oral exam – 40			

Study program: Metallurgical Engineering				
Level of study: Doctoral Academic Studies				
Course: PYROMETALLURGICAL PROCESSES				
Lecturer: Dr. Dragan Manasijević, full professor				
Status of the course: Elective course				
ECTS: 15				
Prerequisites: Knowledge of metallurgical thermodynamics, pyrometallurgical processes theory, metallurgy of ferrous metals, iron and steel metallurgy, and thermodynamics of materials.				
Course goals: The aim of the course is the synthesis of the current knowledge about the pyrometallurgical processes of obtaining metals with a special reference to the equilibrium states in certain systems of type Metal-O, Metal-S-O, Metal-Slag.				
Learning outcome: 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. C. B. Alcock, Principles of Pyrometallurgy, Academic Press, 1976. 2. F. Habashi, Textbook of Pyrometallurgy, Laval University, Quebec, 2002. 3. B.Dobovišek, Metalurške žlindre, FNT, Ljubljana, 1989. 4. Y.K.Rao, Stoichiometry and thermodynamics of metallurgical processes, Cambridge University Press, New York, 1985. 5. K.Hauffe, Oxidation of Metals, Plenum Press, New York, 1965. 6. Ž. Živković, V. Savović, Teorija pirometalurških procesa, Bakar, Bor, 1994. (*in Serbian)* 7.P.P. Arsentiev et al., Fizikohemičeskie metodi isledovania metalurgičeskih procesov, Metalurgija, Moskva, 1988. (*in Russian)* 8. N. Štrbac, D. Živković, Ž. Živkovič, I. Mihajlović, Sulfidi - termijska, termodinamička i kinetička analiza, Punta, Niš, 2005. (*in Serbian)*				
Number of classes per week				Other classes:
Lectures: 6	Practical classes:	Other forms of teaching:	Study research work: 4	
Methods of teaching Traditional lectures and student research work in the fields of thermal analysis, X-ray analysis and electronic microscopy, as well as modern metallurgical software. Case studies from metallurgical practice.				
Grading system (max. number of points 100)				
50% exam, 40% seminar, 10% activity through student research work.				

Study program: Metallurgical Engineering				
Level of study: Doctoral Academic Studies				
Course: HYDRO AND ELECTROMETALLURGICAL PROCESSES				
Lecturer: Dr. Mirjana M. Rajčić Vujasinović, full professor				
Status of the course: Elective course in Metallurgical Engineering				
ECTS: 15				
Prerequisites: Knowledge from physical chemistry, electrochemistry and theory of hydro and electrometallurgical processes				
Course goals: Hydro and electrometallurgical processes are one of the fundamental theoretical courses in extractive metallurgy and in the production of metallic materials. The course goals are to enlarge students' knowledge in the area, to introduce them with the contemporary scientific achievements in the theory of hydro and electrometallurgical processes and to make them capable for further individual scientific and engineering work.				
Learning outcome: Expected outcomes are intellectual, professional, engineering, and teaching capabilities to apply knowledge and skills acquired during this course in order to manage and control 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: 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. Н. Пацовић, Хидрометалургија, ШРИФ, Бор, 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. З. Станковић, М. Рајчић-Вујасиновић, Теорија електрометалуршких процеса, Ауторизована предавања, ТФ Бор. (*in Serbian)* 6. C.M.A. Brett and A.M.O. Brett, ELECTROCHEMISTRY, Principles, Methods, and Applications, Oxford University Press, 1994. 7. А. Деспић, Основе електрохемије, Завод за уџбенике и наставна средства, Београд, 2003. (*in Serbian)* 8. A. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley, 2000.				
Number of classes per week				Other classes:
Lectures: 6	Practical classes:	Other forms of teaching:	Study research work: 4	
Methods of teaching Interactive teaching, independent research work, study research and its presentation				
Grading system (max. number of points 100)				
50% exam, 40% seminar, 10% activity through student research work.				

Study program: Metallurgical Engineering

Level of study: Doctoral Academic Studies

Course: PHYSICAL METALLURGY 4

Lecturer: Dr. Desimir D. Marković, full proffesor

Status of the course: Elective course

ECTS: 15

Prerequisites: Requires knowledge of Physical Metallurgy 1, 2, 3

Course goals:
The course goal is to gather modern fundamental knowledge about the structure of metallic materials, the structure of alloys, phase transformations and properties of metals and alloys.

Learning outcome:
The expected outcome is to gather the intellectual, professional and practical transferable skills in order to implement the learned material in this course. These skills are later used for improvement in other metallurgical courses: casting, mechanical treatment of metals, and synthesis of new materials and characterization of materials.

Course description:
Structure of atoms and crystals. Electronic structure of atoms. Chemical bonds in crystals. Typical metallic structures. Electron theory of metals. Theory of free electrons. Theory of energy zones. Electronic band theory. Magnetic properties of metals. Alloys structure. Solid solutions. Intermediate phases. Ordered solid solutions. Crystal defects. Point defects. Dislocations. Grain and sub grain boundaries. Order defects. Diffusion, theory of diffusion. Experimental study of diffusion process. Crystallization of metals. Phase transformations in solid state. Diffusional and non-diffusional phase transformations. Microstructure. Elements of microstructure. Nanostructured materials. Mechanical properties of metals and alloys. Strengthening mechanisms. Creep. Super plasticity. 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. M. F. Ashby, D.R.H. Jones, Engineering Materials 1, Second Edition, Butterworth-Heinemann, Oxford, 1996.
4. David R.H. Jones, Michael Ashby, Engineering Materials, Volume 2: An Introduction to Microstructures, Processing and Design (Second Edition), Elsevier Butterworth-Heinemann, 1998.
5. Philippe Knauth, Joop Shoonman, Nanostructured Materials: Selected Synthesis Methods, Properties, and Applications, Electronic Materials: Science & Technology, MA Kluwer Academic Publishers, Boston, 2002.
6. W.R. Farhner, Nanotechnology and Nanoelectronics: Materials, Devices, Measurement Techniques, Springer Science & Business Media, New York, Berlin, 2005.
7. P. Papon, J. Leblond, P.H.E. Meijer, The Physics of Phase Transitions, Second revised edition, SpringerVerlag, Berlin, Heidelberg, 2006.
8. J. Schijve, Fatigue of Structures and Materials, Kluwer Academi Publishers, New York, 2004.
9. J. Lemaitre, R. Desmorat, Engineering Damage Mechanics, Ductile, Creep, Fatigue and Brittle Failures, Springer-Verlag, Berlin, Heidelberhg, 2005.
10. S. L. Kakani, A. Kakani, Material Science, New Age International (P) Ltd., Publishers, New Delhi, 2004.
11. R.E. Smallman, A. H. W. Ngan, Physical Metallurgy and Advanced Materials (seventh edition), Elsevier Butterworth-Heinemann , 2007.

Number of classes per week				Other classes:
Lectures:6	Practical classes:	Other forms of teaching:	Study research work: 4	

Methods of teaching
Traditional lectures with a consultative approach to students' independent work, study research work.

Grading system (max. number of points 100)

50% exam, 40% seminar, 10% activity through student research work.

Study program: Metallurgical Engineering
Level of study: Doctoral Academic Studies
Course: METALLURGICAL THERMODYNAMICS 2
Lecturer: Dr. Dragan Manasijević, full professor
Status of the course: Elective course
ECTS: 15
Prerequisites: 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 outcome: 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: 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. HSC, ThermoCalc, MTData, and others.
Literature Recommended: 1. D.R.Gaskell, Introduction to Metallurgical Thermodynamics, McGraw-Hill Co., New York., 1985. 2. O.F.Devero, Problemi metalurgičeskoi termodinamiki, Metalurgija, Moskva, 1986. 3. O.Kubaschewski, C.B. Alcock, Metallurgical Thermochemistry, Pergamon Press, Oxford, 1979. 4. Y.K.Rao, Stoichiometry and Thermodynamics of Metallurgical Processes, Cambridge University Press, New York, 1985. 5. 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. 6. Comprehensive Handbook of Calorimetry and Thermal Analysis, John Willey&Sons, Chichester, 2004. 7. Ž.Živković, V.Savović, Principi metalurške termodinamike, TF Bor, 1997. (*in Serbian*) 8. D.Minić, D.Manasijević, D.Živković, Ž.Živković, Fazna ravnoteža i termodinamika sistema Pb-Sn-(In,Ga), TF Bor, 2007. (*in Serbian*) 9. A.Kostov, D.Živković, Hemijska termodinamika i karakterizacija legura Ga-Ge-Sb sistema, Grafomedtrade, Bor, 2008. (*in Serbian*)

Number of classes per week				Other classes:
Lectures: 6	Practical classes:	Other forms of teaching:	Study research work: 4	

Methods of teaching Traditional lectures with a consultative approach to independent students' work, term paper and student research work.
Grading system (max. number of points 100)
Exam 40% + presentation and presentation of term paper 40% + student research work 20%.

Study program: Metallurgical Engineering	
Level of study: Doctoral Academic Studies	
Course: METALLURGICAL REACTORS	
Lecturer: Dr. Aleksandra Mitovski, assistant professor	
Status of the course: Elective course	
ECTS: 15	
Prerequisites: 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 the adequate knowledge about the reactor technology. Students should be familiar with the alternative types and design of metallurgical reactors according to the types of metallurgical processes and production capacities.	
Learning outcome: 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: 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.	
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.	
Lectures: 6	Study research work: 4
Methods of teaching Traditional lectures with a consultative approach to developing an individual project task for students.	
Grading system (max. number of points 100) Exam 50% + creation and presentation of an individual project 50%	

Study program: Metallurgical Engineering				
Level of study: Doctoral Academic Studies				
Course: PHYSICS OF STRENGTH AND PLASTICITY OF METALS				
Lecturer: Dr. Dragoslav Gusković, full professor				
Status of the course: Elective course				
ECTS: 15				
Prerequisites: Required knowledge in physical chemistry and physical metallurgy.				
Course goals: To provide students with the adequate knowledge about the strength, elasticity and plasticity of metals.				
Learning outcome: The expected outcome is intellectual, practical and transferable skills for applying this knowledge in the management of metallurgical processes in the field of metal processing in plastic state.				
Course description: Elasticity and plasticity of crystals. Dislocations and sliding. Twins and twining. Border surfaces. Deformation crystal strengthening. Deformation and strengthening of polycrystalline aggregates. Deformation and strengthening of solid solutions. Precipitating and dispersing strengthening. Change of energy in deformation. Recovery. Recrystallization. Grain growth. Texture. Breaking of metal materials. Stress and deformation. Mechanical scheme of deformation and its influence on plasticity. Metal forming in plastic state. Metal deformation during rolling. Deformation of metal in drawing. Deformation during pressing. Deformation of metal in forging.				
Literature Recommended: 1.D. Drobnjak, Fizika čvrstoće i plastičnosti, TMF, Beograd, 1981. (*in Serbian*) 2. B. Perović, Fizička metalurgija, MTF, Podgorica, 1997. (*in Serbian*) 3. C.E.Dieter, Mechanical Metallurgy, Thiko ed., Mc Graw - Hil, N.Y., 1986. 4. Chakrabaty, Theory of Plasticity, Mc Graw - Hil, N.Y., 1987. 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. (*in Russian*) 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.				
Number of classes per week				Other classes:
Lectures: 4	Practical classes:	Other forms of teaching:	Study research work: 6	
Methods of teaching Traditional lectures and a consultative approach to the development of an individual seminar task.				

Grading system (%)	
Project assignment	**Final examination**
40	60

Study program: Metallurgical Engineering
Level of study: Doctoral Academic Studies
Course: MECHANICAL BEHAVIOR OF METALS
Lecturer: Dr. Svetlana Lj. Ivanov, associate professor
Status of the course: Elective course
ECTS: 15
Prerequisites: Requires knowledge in Theory of metal forming, Physical metallurgy, Heat treatment of metals
Course goals: The course goal is to provide an introduction to the fundamental and advanced aspects of the mechanical and deformation behavior of metals under different stress states.
Learning outcome: The learning outcomes are that the students will be able to understand and analyze mechanical and deformation behavior of metals, as well as the development of capabilities for the further independent scientific and professional work.
Course description: Course "Mechanical behavior of metals" covers various fundamental and advanced aspects of the mechanical and deformation behavior of metals: deformation mechanics, principles of analysis of strain hardening, the elements of the theory of elasticity and plasticity, the specific behavior of metals such as creep and superplasticity. It deals with the analysis of plastic instability and the possibilities of defining the formability limits of materials.
Literature Recommended: 1. Е. Ромхањи, Механика и металургија деформације метала, Технолошко-металуршки факултет, Београд, 2001. (*in Serbian*) 2. Ђ. Дробњак, Физичка металургија / Физика чврстоће и пластичности 1, Технолошко-металуршки факултет, Београд, 1981. (*in Serbian*) 3. M. Kazeminezhad, Metal Forming - Process, Tools, Design, In Tech, Croatia, 2012. 4. G.E.Dieter, Mechanical Metallurgy - SI Metric ed./adapted by David Bacon, McGraw-Hill Book Co-Singapore, 1988. 5. K. Bowman, Mechanical Behavior of Materials, John Wiley and Sons, 2003. 6. W.F. Hosford, Mechanical Behavior of Materials, Cambridge University Press, England, 2010. 7. N.E. Dowling, Mechanical Behavior of Materials, Pearson Company, Harlow, UK, 2013. 8. D.W. A. Rees, Mechanics of Solids and Strengths, McGraw-Hill UK Ltd., 1990. 9. H. Ford, J.M. Alexander, Advanced Mechanics of Materials, Ellis Horwood Pub., New York, 1977. 10. М.Ю. Лахтин, Металловедение и термическая обработка металлов, Металлургия, Москва, 1984. (*in Russian*) 11. C.H. Hamilton, C.C. Bampton, N.E. Patton, Superplastic Forming of Structural Alloys, TMS-AIME, Warrendale, PA, 1982.

Number of classes per week				Other classes:
Lectures: 6	Practical classes:	Other forms of teaching:	Study research work: 4	

Methods of teaching Discussions, individual study, consultations, independent term paper (literature review, research project, term paper, presentation)

Grading system (max. number of points 100)			
Pre-examination requirements	**Number of points**	**Final examination**	**Number of points**
Exam 50% + preparation and presentation of the term paper 40% + activity within study research work 10%			

Study program: Metallurgical Engineering	
Level of study: Doctoral Academic Studies	
Course: METALLURGICAL KINETICS	
Lecturer: Dr. Nada Štrbac, full proffesor	
Status of the course: Elective course	
ECTS: 15	
Prerequisites: 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 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 outcome: The expected learning outcome 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: 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.	
Lectures: 6	Study research work: 4
Methods of teaching Traditional lectures, study research work and term paper - concrete calculation of individual kinetic parameters of a particular metallurgical process.	
Grading system (max. number of points 100) Exam 50% + preparation and presentation of the term paper 40% + activity within study research work 10%	

Study program: Metallurgical Engineering

Level of study: Doctoral Academic Studies

Course: MODERN METAL MATERIALS

Lecturer: Dr. Vladan Ćosović, senior research associate

Status of the course: Elective course

ECTS: 15

Prerequisites: 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 to acquire basic knowledge about modern metallic materials, the structural, physical, mechanical, corrosion properties, and applications.

Learning outcome:
The expected outcome is the ability to apply this knowledge in the existing practical examples, and form the basis for further scientific and professional improvement.

Course description:
Classification of modern metal materials. Carbon and alloy steels - perlite, ledeburite, martensite, ferrite, austenitic, with nickel, manganese, chromium, molybdenum, silicon, with chromium and nickel, HSLA steels, DP steels, MA steels. Iron - white cast iron, gray cast iron, nodular cast iron, temper cast iron, alloyed cast iron. Nickel and nickel alloys. Titanium and titanium alloys. Intermetallic compounds - nickel aluminides, titanium aluminides.
Aluminum and aluminum alloys. Copper and copper alloys. Magnesium and magnesium alloys.
Lead-free solder materials. Synthesis of modern metal materials. Structural, physical, mechanical, corrosion properties of modern metal materials.

Literature
Recommended:

1. B.S.Mitchell, An Introduction to Materials Engineering and Science, John Willey&Sons, New Jersey, 2004.
2. R.E. Smallman, R.J. Bishop, Modern Physical Metallurgy and Materials Engineering, Butterworth - Heinemann Oxford, 1999.
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				Other classes:
Lectures: 4	Practical classes:	Other forms of teaching:	Study research work: 6	

Methods of teaching
Traditional lectures with a consultative approach to independent student work, term paper.

Grading system (max. number of points 100)

Exam 50% + preparation and presentation of the term paper 40% + student research work 10%.

Study program: Metallurgical Engineering
Level of study: Doctoral Academic Studies
Course: MODERN METHODS OF MATERIALS CHARACTERIZATION
Lecturers: Dr. Mirjana M. Rajčić Vujasinović, full professor and Dr. Ljubiša T. Balanović, assistant professor
Status of the course: Elective course
ECTS: 15
Prerequisites: Knowledge in physics, physical chemistry, materials testing and materials characterization is required.
Course goals: The aim of the course is to introduce students to the modern methods of characterization of solids and liquids considering these methods' outcomes, as well as to devices used for the purpose, and the fundamentals of their functioning
Learning outcome: The students are expected to become capable of making independent choice of optimal methods for some investigations or specific applications, as well as the choice of assistant methods which will provide the needed parameters; this implies the knowledge about the limits of selected methods and the basics of functioning of devices and instruments used.
Course description: Spectroscopic methods (UV, VIS, IR and Raman spectroscopy). Mass spectrometry. Characterization of solid materials. Investigations of structures by X-ray, electrons 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). 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. Yu. Lyalikov et al. Problems in Physicochemical Methods of Analysis, Mir Publishers, Moscow, 1974. 6. J. Мишовић, Т. Аст, Инструменталне методе хемијске анализе, ТМФ, Београд, 1978. (*in Serbian*) 7. С. Ђорђевић, В. Дражић, Физичка хемија, 4. издање, ТМФ, Београд, 2000. (*in Serbian*) 8. C.M.A. Brett and A.M.O. Brett, ELECTROCHEMISTRY, Principles, Methods, and Applications, Oxford University Press 1994 9. V. K.Pecharsky, P. Y. Zavalij, Fundamentals of powder diffraction and structural characterization of materials, Springer science and Business media, 2003. 10. B. S. Mitchell, An Introduction to Materials Engineering and Science, John Wiley & Sons, Inc, 2004. 11. D. B. Murphy, Fundamentals of Light Microscopy and Electronic Imagin, Willey-Liss, 2001.

Number of classes per week				Other classes:
Lectures: 6	Practical classes:	Other forms of teaching:	Study research 4work:	

Methods of teaching Traditional lectures and individual research work within the framework of applying different methods of characterization, and familiarization with the devices for the characterization of materials in the laboratories of other institutions (other faculties, institutes and industrial laboratories) and their way of functioning, processing of results and possibilities.
Grading system (max. number of points 100)
Exam 50% + term paper 40% + student research work 10%.

Study program: Metallurgical Engineering
Level of study: Doctoral Academic Studies
Course: TRANSPORT PHENOMENA 2
Lecturer: Dr. Vesna Grekulović, assistant professor
Status of the course: Elective course for the study program in Metallurgical Engineering and Obligatory course for the study program in Mining Engineering
ECTS: 8
Prerequisites: Knowledge in Mathematic, Physical Chemistry and Transport Phenomena 1 is required
Course goals: Providing students with the knowledge of momentum, mass and heat transfer, as well as with the mathematical interpretation of the transport ways, so that they can explain and interpret a phenomenon under consideration.
Learning outcome: Students gain a certain level of knowledge from the basic transport phenomena that would help them to identify and solve problems in the course area, and to 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 and 2, Univerzitet u Beogradu, Tehnički fakultet Bor,1998. *(in Serbian)* 6. M. Sovilj; Difuzione operacije; Tehnološki fakultet Univerziteta u Novom Sadu; 2004. *(in Serbian)* 7. F. Zdanski; Mehanika fluida; Tehnološko-metalurški fakultet, Univerziteta u Beogradu; 1995. *(in Serbian)*

Number of classes per week				Other classes:
Lectures: 6	Practical classes:	Other forms of teaching:	Study research work: 4	

Methods of teaching Traditional lectures, consultations and experimental work.
Grading system (max. number of points 100)
Exam 40% + preparation and presentation of individual work 40% + preparation and presentation of term paper 20%

Study program: Metallurgical Engineering				
Level of study: Doctoral Academic Studies				
Course: CONTEMPORARY PROCEDURES IN MODELING AND CASTING TECHNOLOGY				
Lecturer: Dr. Srba Mladenović, associate professor				
Status of the course: Elective course				
ECTS: 15				
Prerequisites: Basic knowledge from physical metallurgy, casting process				
Course goals: Basic knowledge about modeling in casting technology.				
Learning outcome: Using of casting simulation software				
Course description: Properties of liquid metals and alloys. Structure of one phase and two phase melts. Casting of metals in to the patterns. Solidification of multiphase alloys and metals. Contemporary procedures of casting production. Characteristics and classification of castings. 3D modeling. 3D modeling of castings process.				
Literature Recommended: 1. Laurentiu Nastac, Modeling and Simulation of Microstructure Evolution in Solidifying Alloys, Kluwer Academcs Publishers, New York, 2004. 2. Brian Cantor, K OReilly Solidification and casting Supplementary: 1. С. Марковић Principles of metalcasting, Научна књига, Београд 1999.				
Number of classes per week				Other classes:
Lectures: 3	Practical classes: 1	Other forms of teaching: 2	Study research work:4	
Methods of teaching Lectures, practical classes and other forms of interactive teaching.				
Grading system (max. number of points 100)				
Pre-examination requirements	**Number of points**	**Final examination**	**Number of points**	
Exam 50% + term paper 40% + student research work 10%.				

Study program: Metallurgical Engineering

Level of study: Doctoral Academic Studies

Course: SINTERED METALLIC MATERIALS AND COMPOSITES

Lecturer: Dr. Ivana Markovic, assistant professor

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

ECTS: 15

Prerequisites: Required knowledge from Powder Metallurgy, Sintering Theory and Physical 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 outcome:
The expected outcome is that the fundamental knowledge in the field of solid state sintering theory and liquid-phase sintering should be applied in the design and the characterization of the materials obtained by 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:
Testing and characterization of metal powders. Powder forming. Theoretical basis for sintering process. New sintering techniques. Sintered metallic materials and composites. Sintered materials of non-ferrous metals. High alloyed sintered materials with high density. Sliding bearings. Friction materials. Highly porous materials and filters. Materials for electrical contacts. 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: sintering of tungsten, molybdenum and tantalum and processing of sintered parts. Sintered magnets-production of sintered parts from AlNiCo, thermal treatment, structure and properties. Hard materials and composites from hard materials. Metal-graphite composites. Silver-graphite composites, copper-graphite composites. Dispersion hardened materials: dispersion hardened copper alloys, dispersion hardened aluminum alloys, dispersion hardened silver-based materials. Cermets: influence of constituent properties, application and future development of cermets. Testing of sintered materials: density, porosity, shrinkage, hardness, strength, elastic moduli. Microstructure testing of sintered samples: quantitative and qualitative analysis of microstructure and phase composition by modern methods.

Literature

1.Werner Schatt, Claus-Peter Wieters, Technical University Dresden, Germany, Powder Metallurgy, Processing and Materials, EPMA, 1997.
2. Randall M.German, Sintering Theory and Practice, The Pennnsylavnia State University, University Park, Pensilvania, U.S.A. 1996.
3. P. Beiss, K. Dalal, R. Peters, International Atlas of Powder Metallurgical Microstructures, MPIF, 2002.
4. A. P. Savitskii, Liquid Phase Sintering of Sistem with Interacting Compoments, EPMA, 2005.
5. R M. German, Particle Packing Characteristics, EPMA 2005.
6. R.M. German, Powder Metallurgy and Particulare Materials Processing, EPMA, 2005.
7. О.В. Роман, И.Н. Габриелов, Справочник по порошковој металлургии (Handbook of Powder Metallurgy), Минск, Беларус, 1988. (*in Russian*)
8. Svetlana Nestorović, Sintermetalurgija – Praktikum, Bor, 2001. (*in Serbian*)
9. Standard Test Methods for Metal Powders and Powder Metallurgy Products, Metal Powder Industries Federation, Princeton, New Jersey, U.S.A. 1999.
10. L. N. A. Smith Knowledge Based Sistem for Powder Metallurgy Technology, EPMA, 2003.
11. W.G. West, Fundamentals of Powder Metallurgy, 2005.
12. F. Lenel, Powder Metallurgy Principles and Aplications, Princeton, USA, 1980.

Number of classes per week				Other classes:
Lectures: 6	Practical classes:	Other forms of teaching:	Study research work: 4	

Methods of teaching
Traditional lectures with a consultative approach to student independent work, study research work, and the elaboration of the term paper.

Grading system (max. number 100 %)

Exam 50% + term paper 40% + student research work 10%.

Study program: Mining Engineering or Metallurgical Engineering or Technological Engineering or Engineering Management		
Level of study: Doctoral Academic Studies		
Course: DOCTORAL DISSERTATION – DEFINING THEME		
Lecturer: All professors from the study program, eligible to be a mentor		
Status of the course: Obligatory course		
ECTS: 15		
Prerequisites: All exams at the PhD level successfully passed		
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 within the frame of the PhD level courses.		
Learning outcome: The student will be trained to become capable of carrying on analysis and synthesis of the doctoral level course level, on his/her own, and to be capable of applying gained knowledge in the structuring of the research problem, and defining the potential directions of its solution. The independent application of the literature resources from the available data bases with the purpose of complete overview of the predefined research problem.		
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 a written report – the term paper that will be defended in front of the three-member commission, appointed through the Scientific-educational Council of the Technical faculty in Bor. The members of the commission will be initially proposed at the departments' level.		
Literature Available scientific journal publications from the „Kobson" list.		
Number of classes per week	Lectures: 0	Study research work: 20
Methods of teaching The mentor assigns the research task, in consultations with the student, in order to define 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 the available literature resources will be completed by the student. During student's work on the final elaborate, the mentor can be involved with adequate suggestions and instructions that will result in the high quality of explanation of the scientific contribution and the adequacy of the selected theme of the dissertation. During his/her work on the elaborate, the student shall conduct all the necessary experiments, measurements, analysis and other research work, with the aim to define and explain the research problem as well as possible. After defending the elaborate, the mentor will start the procedure for the official acceptance of the doctoral dissertation theme.		
Grading system (max. number of points 100)		

Study program: Mining Engineering or Metallurgical Engineering or Technological Engineering or Engineering Management		
Level of study: Doctoral Academic Studies		
Course: DOCTORAL DISSERTATION – RESEARCH WORK 1		
Lecturer: All professors from the study program, eligible to be a mentor		
Status of the course: Obligatory course		
ECTS: 30		
Prerequisites: 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 course 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 outcome: The student will be trained to become capable of practically applying the knowledge generated through the courses of this study program and using it in solving the defined practical problem. Through independent application of the literature resources from the available data bases, the student will expand his/her knowledge and will become capable of 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 the requirements of his/her future work. Student will review scientific literature and conduct the necessary research work connected with the course of the doctoral thesis theme (laboratory research, field work research, etc.). The 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	Study research work: 20
Methods of teaching The mentor assigns the research task, with the 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 in high quality of the final content of the doctoral dissertation.		
Grading system (max. number of points 100)		

Study program: Mining Engineering or Metallurgical Engineering or Technological Engineering or Engineering Management		
Level of study: Doctoral Academic Studies		
Course: DOCTORAL DISSERTATION – RESEARCH WORK 2		
Lecturer: All professors from the study program, eligible to be a mentor		
Status of the course: Obligatory course		
ECTS: 30		
Prerequisites: 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 within the framework of the course of the doctoral dissertation. Through the defined theme of the doctoral dissertation, the student studies the problem, its structure and complexity, conducts analysis and synthesis, and defines the potential directions for its solution. The goal of student's activities at this study level is in acquiring necessary experience for the independent structuring of the research problem, and finding the solutions for solving it.		
Learning outcome: The student will be trained to become capable of practically applying the knowledge generated through the courses of this study program and using it in solving the defined practical problem. Through independent application of the literature resources from the available data bases, the student will expand his/her knowledge and will become capable of 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 the requirements of his/her future work. Student will review scientific literature and conduct the necessary research work connected with the course of the doctoral thesis theme (laboratory research, field work research, etc.). The 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	Study research work: 20
Methods of teaching The mentor assigns the research task, with the 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 in high quality of the final content of the doctoral dissertation		
Grading system (max. number of points 100)		

Study program: Mining Engineering or Metallurgical Engineering or Technological Engineering or Engineering Management		
Level of study: Doctoral Academic Studies		
Course: DOCTORAL DISSERTATION – RESEARCH WORK 3		
Lecturer: All professors from the study program, eligible to be a mentor		
Status of the course: Obligatory course		
ECTS: 10		
Prerequisites: 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 course 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 outcome: The student will be trained to become capable of practically applying the knowledge generated through the courses of this study program and using it in solving the defined practical problem. Through independent application of the literature resources from the available data bases, the student will expand his/her knowledge and will become capable of 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 the requirements of his/her future work. Student will review scientific literature and conduct the necessary research work connected with the course of the doctoral thesis theme (laboratory research, field work research, etc.). The 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	Study research work: 20
Methods of teaching The mentor assigns the research task, with the 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 in high quality of the final content of the doctoral dissertation		
Grading system (max. number of points 100)		

Study program: Mining Engineering or Metallurgical Engineering or Technological Engineering or Engineering Management		
Level of study: Doctoral Academic Studies		
Course: DOCTORAL DISSERTATION – REALIZATION AND DEFENSE OF THESIS		
Lecturer: All professors from the study program, eligible to be a mentor		
Status of the course: Obligatory course		
ECTS: 20		
Prerequisites: All exams at the PhD level successfully passed		
Course goals: Successful defending the doctoral thesis of the student.		
Learning outcome: After successful and independent work on the doctoral dissertation and its preparation in the written form, from the scientific field of technical sciences selected by the student after enrollment, the student is obligated to: - submit the final text of the written doctoral dissertation, - defend the doctoral dissertation in front of the commission, if previously succeeded in publishing at least one manuscript in a journal from the SCI list.		
Course description: While writing the doctoral dissertation, the student should present the text in the form that should include the following chapters: title, introduction, literature review, research hypothesis and the aim of the research, material and methods, results, discussion, conclusions, list of references.		
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:	Study research work:
Methods of teaching Analysis of the experimental data obtained by using predefined methods, and results processing, followed by writing the dissertation, accompanied by the continuous consultations with the mentor and the commission members.		
Grading system (max. number of points 100)		