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

BOOK OF COURSES

STUDY PROGRAM:

METALLURGICAL ENGINEERING

MASTER ACADEMIC STUDIES

(2^{ND} LEVEL OF THE ACADEMIC STUDIES)

Bor, 2023.

Study program: Metallurgical Engineering
Course: PHYSICAL METALLURGY 3
Lecturer/s: Ivana Markovic, Associated Professor
Status of the course: Compulsory for Metallurgical Engineering
ECTS: 6
Prerequisite: Required knowledge of Physical Metallurgy 1 and Physical Metallurgy 2
Course goals: Providing basic knowledge in the field of real structure of crystals, defects in the lattice and their influence on properties of metals, crystallization of metals, phase transformations in the solid state, strengthening mechanisms of metals and changes in deformed metals upon heating.
Learning outcomes: Acquiring knowledge for successfully following classes in other subjects at master's studies and later at doctoral studies.
Course description: Lectures: Electronic theory of metals. Theory of energy zones. Electrical properties of metals. Magnetism of metals. Thermal properties of metals. Structure of alloys. Solid solutions, intermediate phases, ordered solid solutions. Lattice defects. Diffusion. Crystallization of metals. Phase transformations in the solid state. Dislocations and slipping. Movement of dislocations. Elastic properties of dislocations. Multiplication of dislocations. Cutting reactions of dislocations. Mechanisms of strengthening of metals and alloys. Deformation strengthening. Strengthening by grain refining. Strengthening of solid solutions. Precipitation and dispersion strengthening. Fiber reinforcement. Reinforcement by spot lattice defects. Recovery and recrystallization. Grain growth. Texture. Describing texture, texture deformations, annealing texture. Effect of texture on metal properties. Practice: Theoretical lectures are followed by exercises in the field of strengthening metals and alloys, recrystallization and texture testing using SEM/EDS, DTA, DSC, TG analysis.
Literature: Recommended: 1. Д. Марковић, Физичка металургија 3, Ауторизована скрипта, Универзитет у Београду, Технички факултет у Бору, Бор, 2016. 2. Бошко Перовић, Физичка металургија, Металуршко-технолошки факултет, Подгорица, 1997. 3. W. D. Callister Jr, D. G. Rethwisch, Materials Science and Engineering – An Introduction (9th Edition), John Wiley & Sons, Hoboken, 2014. 4. R. Abbaschian, L. Abbaschian, R.E. Read-Hill, Physical Metallurgy Principles (fourth edition), Cengage Learning, 2009. 5. Ђорђе Дробњак, Физичка металургија. Физика чврстоће и пластичности 1, Технолошко-металуршки факултет у Београду, Београд, 1990. 6. D. Hull, D. J. Bacon, Introduction to Dislocations (fifth edition), Elsevier Butterworth-Heinemann, 2011. Ancillary: 1. Manijeh Razeghi, Fundamentals of Solid State Engineering, Kluwer Academic Publishers, New York, 2002. 2. R. E. Hummel, Understanding Materials Science (Second Edition), Springer-Verlag, New York, 2004. 3. B. Verlinden, J. Driver, I. Samajdar, R. D. Doherty, Thermo-Mechanical Processing of Metallic Materials, ElsevierPergamon, Oxford, 2007.

4. Л. Г. Журавлев, В. И. Филатов, Физические методы исследования металлов и сплавов, ЮУрГУ, Челябинск, 2004. 5. М. И. Михайлович, Лекции по курсу “Материаловедение”, Нижегородский государственный технический университет, 1995.				
Number of classes per week	**Lectures: 3**	**Practical classes: 3**	**Study research work:**	**Other forms of teaching:**
Teaching methods Lectures, exercises-practical teaching, preparation of a seminar with a consulting approach to independent work students.				
Knowledge evaluation (maximum 100 points)				

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance		Written part of the final exam	
Exercise attendance	20	Oral part of the final exam	50
Coloquium exam/s		....	
Term paper	30		

Study program: Metallurgical Engineering
Course: MATERIALS CHARACTERIZATION
Lecturer/s: **Dr. Nada Štrbac, full professor, Dr. Vesna Grekulović full professor and Dr. Ljubiša Balanović associate professor**
Status of the course: Compulsory
ECTS: 8
Prerequisite: Required knowledge in physical chemistry, physical metallurgy and metal testing
Course goals: The aim of this course is to introduce students to methods of characterization of solid materials, primarily metals and fluids, which is of fundamental importance for the field of metallurgical engineering and engineering of metal materials.
Learning outcomes: Students gain knowledge of the most important methods of characterization, theoretically prepared for the adoption of modern methods and being trained in exercises for their use.
Course description: Lectures: *Characterization of solid materials.* Sampling and sampling errors. Chemical and rational analysis. Destructive and non-destructive methods. Microscopic analysis. Study of the structure by using X – ray diffraction. Physical methods for determination of properties. Mechanical materials testing by static and mechanical action of force. Thermochemical characterization. Characterization of powders and sintered materials. Electrochemical methods of characterization. *Characterization of liquids.* Vapor tension. Viscosity. Ideal and non-ideal liquid mixtures and solutions. Activities of the solution components. Practice: Exercises; other forms of lectures; study research work. Laboratory exercises in the field of application of the listed methods of characterization.
Literature: Recommended: 1. B. D. Fahlman, Materials Chemistry, Springer, Dordrecht, 2008. 2. J. Mišović, Instrumentalne metode hemijske analize, TMF, Beograd, 1978. (*in Serbian*) 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. V. K. Pecharsky, P. Y. Zavalij, Fundamentals of powder diffraction and structural characterization of materials, Springer science and Business media, 2003. 6. D. B. Murphy, Fundamentals of Light Microscopy and Electronic Imaging, Willey – Liss, 2001. 7. G.M. Crankovic, ASM Handbook, Volume 10: Materials Characterization, 1986. 8. M. Sardela, Practical Materials Characterization, Springer, 2014. Ancillary: 1. Yu. Lyalikov et al., Problems in physicochemical methods of analysis, Mir Publishers, Moscow, 1974. 2. S. Đorđević, V. Dražić, Fizička hemija, četvrto izdanje, TMF, Beograd, 2000. (*in Serbian*) 3. M. Rajčić Vujasinović, Z. Stanković, Fizička hemija, Praktikum za vežbe, TF Bor, 2001. (*in Serbian*) 4. M. Rajčić Vujasinović, V. Grekulović, Teorija hidro i elektrometalurških procesa, TF Bor, 2017. (*in Serbian*) 5. H.R. Verma, Atomic and Nuclear Analytical Methods, Springer, 2007.

6. P.J. Haines, Principles of Thermal Analysis and Calorimetry, The Royal Society of Chemistry, 2002.
7. P. Brouwer, Theory of XRF: Getting acquainted with the principles, Malvern Panalytical, 2018.
8. M. Ermrich, D. Opper, XRD for the analyst: Getting acquainted with the principles, PANalytical, 2013.
9. C.M.A. Brett, A.M.O. Brett, Electrochemistry, Principles, Methods, and Applications, Oxford University Press Inc., New York, 1993.

Number of classes per week	**Lectures: 3**	**Practical classes: 1**	**Study research work:**	**Other forms of teaching: 3**

Teaching methods

Lectures with interactive discussions, laboratory exercises, seminar work, consultations.

Knowledge evaluation (maximum 100 points)

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	10	Written part of the final exam	
Exercise attendance	10	Oral part of the final exam	50
Coloquium exam/s		....	
Term paper	30		

Study program: Metallurgical Engineering

Course: THERMODYNAMICS OF MATERIALS

Lecturer/s: Dr. Ljubiša Balanović, associate professor

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

ECTS: 7

Prerequisite: Knowledge in Thermodynamics and Physical chemistry is required

Course goals: Acquisition of necessary theoretical and experimental knowledge in the field of thermodynamics of materials, as well as consideration of connections between thermodynamic and other physical and chemical characteristics of materials.

Learning outcomes: Training for independent work on calculations in the field of thermodynamics of materials and when using basic apparatus for thermal analysis and calorimetry, as well as mastering the application of some of the modern thermodynamic software.

Course description:

Lectures:

Thermodynamics of solutions. Models of solutions. Analytical thermodynamic research. Calculations based on the known phase diagram. Thermodynamic properties prediction of multicomponent metal systems. Thermodynamic modeling. Multicomponent solutions. The relationship between thermodynamic and other physical and chemical characteristics of the alloys - viscosity, surface tension, density, etc. Solid state thermodynamics. Diffusion. Surfaces and phases. Experimental methods in the thermodynamics of materials.

Practice:

Exercises, Other forms of teaching, Study research work

Calculation exercises. Laboratory thermodynamic investigations: calorimetric methods, methods based on EMS measurement, gas phase equilibrium. Laboratory work on basic thermal analysis apparatus. Application of thermodynamic computer software (HSC, Thermocalc, FACT, etc.).

Literature:

Recommended:

1. Д. Живковић, Термодинамика материјала, Ауторизована предавања, Технички факултет Бор, 2007. (*in Serbian*)
2. S. Stolen, T. Grande, N. Allan, Chemical Thermodynamics of Materials, John Willey&Sons, New York, 2004.
3. C.H.P. Lupis, Chemical Thermodynamics of Materials, Metallurgia, Moscow, 1989. (*in Russian*)
4. R.A.Swallin, Thermodynamics of Solids, John Willey&Sons, New York, 1962.
5. O. Kubaschewski, C.B. Alcock, Metallurgical Thermochemistry, Pergamon Press, Oxford, 1983.

Ancillary:

1. V. Gontarev, Termodinamika materialov, Univerza u Ljubljani, NTF, Ljubljana, 2000.
2. Thermal analysis of materials, R.F.Speyer, Marcell Dekker, New York, 1994.
3. Ж. Живковић, Б. Добовишек, ДТА – теорија и примена, ТФ, Бор, 1984. (*in Serbian*)
4. N. Saunders, A.P. Miodownik, CALPHAD, calculation of phase diagrams, a comprehensive guide, Pergamon Materials Series - Elsevier, Oxford, 1998.
5. P. Gabbott, Principles and Applications of Thermal Analysis, Blackwell Publishing, 2007.
6. G. Kostorz, Phase Transformations in Materials, Wiley-VCH Verlag GmbH, 2001.

Number of classes per week	**Lectures: 2**	**Practical classes: 1**	**Study research work:**	**Other forms of teaching: 1**

Teaching methods

Lectures, calculations and laboratory exercises, organized on an interactive basis, with the elaboration of practical

examples through a group, individual and combined method of work.			
Knowledge evaluation (maximum 100 points)			
Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	10	Written part of the final exam	20
Exercise attendance	20	Oral part of the final exam	20
Coloquium exam/s		....	
Term paper	30		

Study program: Metallurgical Engineering

Course: THEORY OF SINTERING

Lecturer/s: Dr. Ivana Markovic, Associated Professor

Status of the course: Election course for Metallurgical Engineering

ECTS: 6

Prerequisite: Required knowledge of Physical Metallurgy 1 and Physical Metallurgy 2, and Powder Metallurgy

Course goals: Study of the mechanisms of matter transport in the sintering process of metal materials and composites

Learning outcomes: Acquisition of theoretical knowledge about the process and mechanisms of sintering in the solid phase, in the presence of the liquid phase and during sintering under pressure.

Course description:
Lectures:

Sintering in the solid phase: Mechanisms of mass transport: viscous flow, evaporation-condensation, surface diffusion, bulk diffusion, grain boundary diffusion, plastic flow; Stadiums of sintering: adhesion, rearrangement and initial stage of neck growth, intermediate stage, final stage; Calculation of sintering speed; Sintering diagrams; Microstructure and processes during sintering in solid state (particle packing, pore structure, grain structure, formation of microstructure, speed heating); *Sintering in the presence of a liquid phase*: Key thermodynamic and kinetic factors (interfacial energy, wettability, contact angle, solubility, capillarity, viscous flow in the system solid-liquid, formation of contacts); Microstructure characteristics; Heating and melting stage; Stage of dissolution - deposition: densification, contact formation, neck growth, coalescence, pore filling; Final stage of densification; Consolidation of the microstructure; *Sintering under the pressure*: Deformation mechanisms (plastic flow, viscous flow, creep); Sintering processes under pressure.

Practice:

The exercises accompany the theoretical lectures through the elaboration of practical examples of sintering and the preparation and defense of term paper.

Literature:

Recommended:

1. R.M. German, Sintering Theory and Practice, John Wiley & Cons, 1996.
2. S.J.L. Kang, Sintering - Densification, Grain Growth and Microstructure, Elsevier, 2005.
3. С. Несторовић, Синтерметалургија - практикум, Технички факултет у Бору, 2001.

Ancillary:

1. Z.Z. Fang, Sintering of Advanced Materials Fundamentals and Processes, Woodhead Publishing Limited, 2010.
2. R.H.R. Castro, K. van Benthem, Sintering-Mechanisms of Convention Nanodensification and Field Assisted Processes, Springer, 2013.
3. М. Митков, Д. Божић, З. Вујовић, Металургија праха, БМГ, Завод за уџбенике и наставна средства, Винча,1998.

Number of classes per week	Lectures: 2	Practical classes: 2	Study research work:	Other forms of teaching:

Teaching methods

Lectures, exercises-practical teaching, preparation of a term paper with a consulting approach to independent work students.

Knowledge evaluation (maximum 100 points)

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance		Written part of the final exam	

Exercise attendance		Oral part of the final exam	50
Coloquium exam/s		....	
Term paper	50		

Study program: Metallurgical Engineering
Course: KINETICS OF PHASE TRANSFORMATIONS
Lecturer/s: Dr. Uroš Stamenković, assistant professor
Status of the course: Elective for the students in the first semester
ECTS: 7
Prerequisite: Requires knowledge in Physical chemistry and Physical metallurgy
Course goals: Acquiring fundamental knowledge about kinetics of phase transformations during deformation, heat treatment and welding
Learning outcomes: Controlling the conditions of phase transformation processes in order to obtain desired structure of different metals and alloys

Course description:

Lectures:

Introduction *(basis of kinetic theory, methods for determining the kinetic of reactions, equations for homogenous and heterogeneous reactions, Arrhenius equation).* ***Diffusion in metals and alloys.*** *Diffusion process by atoms moving in solid state. Interstitial and substitutional diffusion. Diffusion in alloys. Darkens' equation. Negative diffusion or "uphill" diffusion. Paths of increased diffusion. Diffusion along the dislocations, intermediate boundary surfaces, grain boundary and free surfaces.* ***Phase transformations liquid-solid.*** *Nucleation and kinetic processes on boundary surfaces liquid-solid. Crystal growth. Fast solidification. Crystallization of amorphous materials.* ***Phase transformations in solid state****. Diffusional and non-diffusional (shear) transformations. Nucleation in solid phase – homogenous and heterogeneous nucleation sites. Intermediate boundaries and nucleation site shape. Kinetics of phase transformations. Transformation rate. CCT and TTT diagrams. Johnson-Mehl-Avrami-Kolmogorov equation. The influence of defects on kinetics of phase transformations. Impact of cooling rates on morphology of the new phase. Diffusional dependent phase transformations: spinodal decomposition, precipitation from super saturated solid solution, coarsening of precipitates, eutectoid transformation and discontinuous precipitation, massive transformation. Non-diffusional phase transformation. Martensitic transformation. Characteristics and kinetics of martensite formation. Thermoelastic martensite and shape memory effect. Shear and diffusional transformation combination. Bainite transformation.*

Practical studies: *Theoretical studies are followed by laboratory exercises in the field of phase transformations during deformation, heat treatment and welding.*

Literature:

Recommended:

1. D.A.Porter, K.E. Easterling, Phase Transformations in Metals and Alloys, Chapman and Hall, Third edition, 1992.
2. R.W. Balluffi, S.M. Allen and W.C. Carter, Kinetics of Materials, Wiley-Interscience, 1st edition, 2005.

Ancillary:

6. M.C. Flemings, Solidification Processing, McGraw-Hill Book Company, New York, 1974.
7. D.W. Readey, Kinetics in Materials Science and Engineering, Taylor and Francis, 1st edition, 2016.

Number of classes per week	**Lectures: 2**	**Practical classes: 2**	**Study research work: /**	**Other forms of teaching: /**

Teaching methods: Lectures and lab exercises.

Knowledge evaluation (maximum 100 points)

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance		Written part of the final exam	
Exercise attendance	**20**	Oral part of the final exam	**50**
Coloquium exam/s		....	
Term paper	**30**		

Study program: Metallurgical Engineering				
Course: TRANSPORT PHENOMENA 1				
Lecturer/s: Dr. Vesna Grekulović, full professor, Dr. Milan Gorgievski, associate professor				
Status of the course: Elective for the study program Metallurgical Engineering				
ECTS: 7				
Prerequisite: Knowledge in mathematics and in mass, heat and momentum transfer is required				
Course goals: Introducing candidates with transport phenomena that occur in extractive metallurgy and metallurgical engineering, and an upgrading of the level of knowledge gained during undergraduate studies.				
Learning outcomes: Students acquire advanced knowledge in the field of transport phenomena, with a special emphasis on training how to control and manage of these phenomena in chemical and metallurgical processes.				
Course description: Lectures: Transport characteristics. Momentum transfer: transport mechanisms, boundary layer transport equations, some partial solutions of these equations; fluid flow regimes. Theory of similarity and dimensional analysis, similarity criteria. Heat transfer: transfer mechanisms; basic heat transfer equations. Heat transfer with the change of phases. Mass transfer: transport mechanisms, basic equations of molecular and convective mass transfer. Models of mass transfer. Interface mass transfer. Simultaneous transfer phenomena. Transfer analogies. Practice: Exercises, Other forms of teaching, Study research work. Computational exercises follow the lectures.				
Literature: Recommended: 1. V. Stanković, Transport phenomena and operations in metallurgy 1, University of Belgrade, Technical Faculty in Bor ,1998. *(in Serbian)* 2. V. Stanković, Transport phenomena and operations in metallurgy 2, University of Belgrade, Technical Faculty in Bor ,1998. *(in Serbian)* 3. F. Zdanski, Mechanics of fluid, Faculty of Technology and Metallurgy, University of Belgrade; 1995. *(in Serbian)* 4. S. Cvijović, N. Bošković-Vragolović, R. Pjanović, F. Zdanski, Fenomeni prenosa i tehnološke operacije-zbirka zadataka sa izvodima iz teorije, Akademska misao, Beograd, 2006. *(in Serbian)* 5. A. Tasić, R. Radosavljević, D. Vulićević, R. Cvijović, F. Zdanski, Zbirka zadataka iz tehnoloških operacija – toplotne operacije, TMF, Beograd, 1980. *(in Serbian)* 6. S. Šerbula i V. Stanković; Praktikum za vežbe iz metalurških operacija, Univerzitet u Beogradu, Tehnički fakultet Bor 2006. *(in Serbian)* Optionally: 1. R.R.Bird, W.E.Stewart, N.Lightfoot, Transport phenomena, Willey&Sons, New York, 1960. 2. J.Szekely, N.J.Themelis, Rate Phenomena in Process Metallurgy, Willey Int., 1971. 3. G.H.Geiger, D.R. Poirier, Transport Phenomena in Metallurgy, Addison-Wesley Publ. Co., Reading Massachusetts, 1973.				
Number of classes per week	**Lectures: 3**	**Practical classes: 3**	**Study research work:**	**Other forms of teaching:**
Teaching methods				

Knowledge evaluation (maximum 100 points)			
Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	10	Written part of the final exam	20
Exercise attendance	10	Oral part of the final exam	40
Coloquium exam/s	2x10	....	
Term paper			

Study program: Metallurgical Engineering
Course: STRUCTURE AND PROPERTIES OF PRECIOUS METALS
Lecturer/s: dr Uroš Stamenković, assistant professor
Status of the course: Elective for the students in the first semester
ECTS: 7
Prerequisite: Required knowledge in physical chemistry, metal testing and physical metallurgy
Course goals: The subject should enable the student to learn the structure and properties of precious metals, their interrelations, as well as interaction with other elements of the periodic table
Learning outcomes: The student should learn the most important elements of the structure and properties of precious metals in order to obtain the necessary basis for combining them with the design and getting of new alloys with required properties and a wide range of applications
Course description: Lectures: *Crystal structure. Electronic structure. Atomic properties. Thermal properties. Electrical properties. Optical properties. Mechanical properties. Chemical properties. Corrosion resistance. Physicochemical properties of gold, silver, platinum, palladium, radium, osmium, ruthenium and radium in liquid state. Binary phase diagrams of gold. Binary phase diagrams of silver. Binary phase diagrams of platinum metals. Ternary and multi-component phase diagrams of gold and silver. Alloy for dentistry. Application of precious metals and their alloys for electrical contacts, conductors, resistors, thermometers, tensiometers, thermocouples, temperature-resistant structural materials, corrosion-resistant materials, catalysts, solders.* Practical studies: *Laboratory practices follow lectures. Application of the phase diagram in the function of determining the properties of the alloys of the given composition.*
Literature: Recommended: 1. C. Corti, R. Holliday, Gold, Science and Applications, CRC Press and W.G. Council, London, 2010. Ancillary: 2. P. Gertik, Plemeniti metali, P.G., Beograd, 1997. (in Serbian)

Number of classes per week	**Lectures: 3**	**Practical classes: 3**	**Study research work: /**	**Other forms of teaching: /**

Teaching methods: Lectures, exercises and practical work, organized on an interactive principle, which besides classical lectures and presentations, includes discussions and active participation of students
Knowledge evaluation (maximum 100 points)

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	**5**	Written part of the final exam	
Exercise attendance	**40**	Oral part of the final exam	**55**
Coloquium exam/s		....	
Term paper			

Study program: Metallurgical Engineering
Course: PHASE EQUILIBRIA
Lecturer/s: Dr. Dragan Manasijević, full professor, Dr. Ljubiša Balanović, associate professor
Status of the course: Elective
ECTS: 7
Prerequisite: Required knowledge in the field of thermodynamics, theory of pyrometallurgical processes and physical metallurgy
Course goals: The aim of the course is to familiarize students with the basic principles of phase equlibria analysis in multicomponent systems as the necessary basics for study and research in the field of metallurgical processes and new materials.
Learning outcomes: Student training for the use and application of phase diagrams in practice and in scientific research.
Course description: Lectures: Introduction. Single-component systems. Phase diagrams of two-component systems. Relationship between phase diagrams and thermodynamic properties. Eutectic, monotectic, peritectic reaction. Solid solutions. Discontinuity in solubility, Intermediate phases. Phase diagrams of three-component systems. Metastable phases and phase diagrams. Thermodynamic models of solutions. Calculation of phase diagrams. CALPHAD method. Experimental techniques for determining phase diagrams. Practice: Experimental methods of testing phase diagrams. Calculation of phase diagrams of metal systems using the PANDAT program.
Literature: Recommended: 1. Dragan Manasijević, Fazne ravnoteže, Autorizovana predavanja, Tehnički fakultet u Boru, 2016. (*in Serbian)* 2. R. W. Cahn, P. Haasen, Physical Metallurgy, Elsevier Science B. V., 1996. (*selected chapters*) 3. H. L. Lukas, S. G. Fries, B. Sundman, Computational Thermodynamics: CALPHAD method, Cambridge University Press, Cambridge, UK 2007. Ancillary: 1. D. Minić, D. Manasijević, D. Živković, Ž. Živković, Fazne ravnoteže i termodinamika sistema Pb-Sb (In, Ga), TF Bor, 2007. (*in Serbian)* 2. N. Saunders, A.P. Miodownik, CALPHAD, Calculation of Phase Diagrams, A comprehensive guide, Pergamon Materials Series - Elsevier, Oxford, 1998.

Number of classes per week	**Lectures: 2**	**Practical classes: 1**	**Study research work:**	**Other forms of teaching: 1**

Teaching methods Lectures, laboratory and computational exercises. Training for the use and application of PANDAT software package.
Knowledge evaluation (maximum 100 points)

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	10	Written part of the final exam	
Exercise attendance	10	Oral part of the final exam	50

Coloquium exam/s		....	
Term paper	30		

Study program: Metallurgical Engineering
Course: CONTINUOUS PROCEDURES FOR OBTAINING WIRE AND PROFILES
Lecturer/s: dr Saša R. Marjanović, Associate Professor
Status of the course: Elective for Module: Processing metallurgy
ECTS: 8
Prerequisite: **Necessary knowledge of physical metallurgy and processing of metals in a plastic state**
Course goals: **The course should enable the student to acquire knowledge and understanding of the basic principles of various procedures for the production of wire and profiles, where the greatest attention is paid to the combination of continuous casting and hot rolling at the same temperature.**
Learning outcomes: The student should learn the processes of continuous casting and rolling and master the specific technologies of wire and profile production of small cross-sections in order to be trained for efficient independent and team work in this field.
Course description: Lectures: Division of production technologies. Semi-continuous and continuous casting. Types of crystallizers. Traditional methods of obtaining wire and profile. Contirod process, casting and hot rolling. Spin casting and hot rolling. Deep Forming procedure, immersion forming technique and hot rolling. Properties of hot rolled wires. Upcast and Upward procedure. Properties of cast wires. Comparison of procedures and comparison of properties of the obtained products. Continuous casting processes with extremely fast cooling of the melt. Continuous pressing procedures. Practice: Computational and laboratory exercises follow the lectures. Determination of melt recrystallization rate and TM mode of metal processing.
Literature: Recommended: 1. Д. Гусковић, Б. Станојевић, С. Стевић, Савремени поступци добијања бакарних жица, ТФ, Бор, 1997. 2. М. Пешић, Б. Мишковић, В. Миленковић, Прерада метала у пластичном стању, ТМФ, Београд, 1989. 3. W. Schwarrzmaier, Непреривнаја разливка, превод са немачког, Москва, Металлургија, 1962. 4. W. F. Hosford, R. M. Caddell, Metalforming: Mecechanics and Metallurgy, Prentice Hall, 3 ed., London, 2007. 5. Д. Гусковић, Добијање аморфних металних материјала из растопа брзим хлађенјем, ТФ Бор, 2010. Ancillary: 1. М. Арсеновић, А. Костов, Ливење профила малих попречних пресека, Наука, Београд, 2001. 2. С. Стојадиновић, Ш. Бешић, Е. Десница, Основи производних технологија, ТФ, Зрењанин, 2006. 3. G. K. Bhat, Special Melting and Processing, Noyes Publications, 1989. 4. Copper wire bonding, Preeti S. Chauhan, 2013. 5. S. H. Herman, Ultrarapid Quenching of liquid Alloys, Academic press, N.Y., 1981.

Number of classes per week	Lectures: 3	Practical classes: 3	Study research work: ?	Other forms of teaching: ?

Teaching methods Theoretical and practical teaching in combination with interactive teaching will be carried out in all areas to a different extent..			
Knowledge evaluation (maximum 100 points)			
Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	**5**	Written part of the final exam	**25**
Exercise attendance	**30**	Oral part of the final exam	*40*
Coloquium exam/s		....	
Term paper			

Study program: Metallurgical Engineering,				
Course: Metallurgy of non-ferrous metal alloys				
Lecturer/s: : Dr. Srba A. Mladenović, full prof.				
Status of the course: Elective for Metallurgical Engineering				
ECTS: 8				
Prerequisite: Knowledge of physical metallurgy and technologies for obtaining and processing non-ferrous metals.				
Course goals: Training of students for independent work within the metallurgy of non-ferrous metal alloys.				
Learning outcomes: Students should learn the basic principles of calculation in the metallurgy of non-ferrous metal alloys and to become familiar with them with technologies for obtaining non-ferrous metal alloys.				
Course Description: Copper and copper alloys - chemical composition, structure, and structural features. Nickel and nickel alloys - chemical composition, structure, and structural properties. Zinc and zinc alloys - chemical composition, structure, and structural properties. Lead, tin, and antimony – chemical composition, structure, and construction properties. Refractory metals and their alloys - chemical composition, structure, properties, and application. Precious metals and their alloys - chemical composition, structure, properties, and use. Aluminum and aluminum alloys - chemical composition, properties, and application. Magnesium and magnesium alloys - chemical composition, structure, properties, and application. Rare metals-properties and applications. Radioactive metals - properties, chemical composition, application and storage. Lectures: Practice: *Exercises. Other forms of teaching. Study research work*				
Literature: Recommended: 3. Murphy, Alfred John, Non-Ferrous Foundry Metallurgy: The Science of Melting and Casting Non-Ferrous Metals and Alloys, Literary Licensing, LLC, 2013 Ancillary: 8. William Gowland, The Metallurgy of the Non-Ferrous Metals, ISBN 978-1-332-23882-8				
Number of classes per week	**Lectures: 3**	**Practical classes: 1**	**Study research work: ?**	**Other forms of teaching: 2**
Teaching methods Lectures, exercises, and practical work, organized on an interactive principle, which in addition to classical lectures and presentations includes discussions and active participation of students.				
Knowledge evaluation (maximum 100 points)				

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	**5**	Written part of the final exam	**20**
Exercise attendance	**15**	Oral part of the final exam	**30**
Coloquium exam/s	**15**	....	
Term paper	**15**		

Study program: Metallurgical Engineering,				
Course: Metallurgy of cast iron and steel				
Lecturer/s: : Dr. Srba A. Mladenović, full prof.				
Status of the course: Elective for Metallurgical Engineering				
ECTS: 8				
Prerequisite: Knowledge of physical metallurgy and technologies for obtaining and processing of ferrous metals.				
Course goals: Training of students for independent work within the metallurgy of ferrous metal alloys.				
Learning outcomes: Students should learn the basic principles of calculation in the metallurgy of ferrous metal alloys and become familiar with technologies for obtaining ferrous metal alloys.				
Course Description: An introduction to cast iron. Cast iron structure Phase composition of cast iron. Classification of cast iron. Graphitization of cast iron. Metallurgy of gray cast iron. Gray iron casting technology. Flaws defects on gray iron castings. Thermal treatment of castings. Characteristics and application of gray cast iron. Cupola furnace. Batch materials of a cupola furnace. The technology of melting inside a cupola furnace. Problems during melting in a cupola furnace. The basics of physicochemical processes in a cupola furnace. Production of cast iron in electric furnaces. Cupola furnaces of special constructions. Theoretical overview of the formation process of nodular graphite. Metal batch materials for the production of ductile iron. Control of the composition of nodular cast iron. Materials for graphite spheroidization and modification of nodular cast iron. Modification procedure. Ductile iron casting technology. Nodular cast iron production control. Classification of nodular cast iron. Factors affecting the properties of nodular cast iron. Thermal treatment of nodular cast iron. Mechanical and physical properties of ductile iron. Non-destructive characterization of ductile iron. Joining and machining of ductile iron castings. Application of ductile iron castings. Production of high-quality gray cast iron with lamellar graphite. Modified gray cast iron. Low alloyed gray cast iron. Tempered iron. High-alloyed graphite iron. Vermicular iron. High alloyed white cast iron. Classification of cast steel. Carbon steel cast, chemical composition, structure, and structural features. Steels alloyed with silicon - chemical composition, properties, application. Steels alloyed with manganese - chemical composition, properties, application. Steels alloyed with nickel - chemical composition, properties, application. Steels alloyed with chrome - chemical composition, properties, application. Steels alloyed with molybdenum - chemical composition, properties, application. Steels alloyed with vanadium - chemical composition, properties, application. Steels alloyed with tungsten - chemical composition, properties, application. Steels alloyed with titanium - chemical composition, properties, application. Steels alloyed with copper - chemical composition, properties, application. Technological bases of steel casting production Lectures: Practice: *Exercises. Other forms of teaching. Study research work*				
Literature: Recommended: 1. Thomas D. West, Metallurgy Of Cast Iron, Woods Press, October 6, 2008 2. Jan Głownia, Metallurgy and Technology of Steel Castings, ISBN: 978-1-68108-571-5 (Print), 2017 Ancillary:				
Number of classes per week	**Lectures: 3**	**Practical classes: 1**	**Study research work: ?**	**Other forms of teaching: 2**
Teaching methods Lectures, exercises, and practical work, organized on an interactive principle, which in addition to classical lectures and presentations includes discussions and active participation of students.				
Knowledge evaluation (maximum 100 points)				
Pre-examination obligations	Points	**Final exam**	Points	
Lecture attendance	**5**	Written part of the final exam	**20**	

Exercise attendance	**15**	Oral part of the final exam	**35**
Coloquium exam/s	**10**	....	
Term paper	**15**		

Study program: Metallurgical Engineering
Course: PROCESSING OF RARE AND PRECIOUS METALS
Lecturer/s: Dr. Saša R. Marjanović, Associate Professor
Status of the course: Elective for Module: Processing metallurgy
ECTS: 8
Prerequisite: Required knowledge of physical metallurgy and technologies of obtaining and processing of rare metals
Course goals: The course should enable the student to learn the evaluations that take place in the liquid and solid state of precious and rare metals in order to shape them more easily into the required form.
Learning outcomes: The student should learn the processes of forming metals in liquid and solid state and master the concrete technologies of melting, casting and plastic processing in order to be able to work effectively independently and in a team in this area.
Course description: Lectures: Melting of metals and alloys. Mold making. Casting in molds, sand, rubber and wax models. Cleaning and processing of castings. Crystal structure and defects. Crystal plasticity. Strengthening curves. Plasticity of precious metals (gold, silver, platinum, palladium, iridium, osmium, ruthenium and rhodium). Plasticity of rare metals. Rolling. Pulling out. Pressing. Forging. Deep draw. Rotary forging of precious metals. Metal joining. Finishing of precious and rare metals. Practice: Computational and laboratory exercises follow the lectures. Determination of the share of components in the batch, determination of TMR processing for a specific alloy, calibrations.
Literature: Recommended: 1. П. Гертик, Племенити метали, својства, прерада, примена, Београд, 1997. 2. Љ. Иванић, Ливарство, ТФ Бор, 2000. 3. М. Пешић, Б. Мишковић, В. Миленковић, Прерада метала у пластичном стању, ТМФ, Београд, 1992. 4. E. M. Savickij, G. S. Burhanov, Redkie metally i splavy, Nauka, Moskva, 1980. 5. E. Bkephol, Teorie und praxis das goldschmiedes, Veb Verlag, Leipzig, 1968. Ancillary: 1. J. C. Wright, Technical Manual for Gold Jewellery, World bdl Council, London 1997. 2. S.Карастојковић, Р. Перић, Материјали и поступци обраде у јувелирству, ЦИК, Београд, 2017. 3. C. Corti, R. Holliday, Gold, Science and Applications, CRC Press and W.G. Council, London, 2010. 4. D. Ott, Handbook on Casting and Other Defects in Gold Jewellery Manufacture, WGC, London, 1998. 5. П. Гертик, Уметничка обрада метала, МПМ, Београд, 2004.

Number of classes per week	**Lectures: 3**	**Practical classes: 3**	**Study research work: ?**	**Other forms of teaching: ?**

Teaching methods			
Lectures, exercises and practical work, organized on an interactive principle, which in addition to classic lectures and presentations, includes discussions and active participation of students in all types of teaching.			
Knowledge evaluation (maximum 100 points)			
Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	**5**	Written part of the final exam	
Exercise attendance	**40**	Oral part of the final exam	*55*
Coloquium exam/s		....	
Term paper			

Study program: Metallurgical Engineering				
Course: THEORETICAL BASICS FOR CREATING A MASTER'S THESIS				
Lecturer/s: Dr. Dragan Manasijević, full professor				
Status of the course: Compulsory				
ECTS: 8				
Prerequisite: Knowledge gained through obligatory and optional curriculum subjects				
Course goals: Acquiring knowledge to define a research problem, its elaboration, writing and public presentation.				
Learning outcomes: Allow students to independently apply the previously acquired knowledge to look at the structure of the problem and its systematic analysis in order to make conclusions about the possible directions of its solution. Through the use of literature alone, students expand their knowledge in studying different methods and papers that relate to similar issues, so the student develops the ability to conduct analysis and identifies issues within the subject matter.				
Course description: Lectures: Creating a master's thesis. Stages in the creation of a master's thesis. Defining the structure of the Master thesis. Searching scientific literature. COBSON. Index databases: Web of Science, SCOPUS. Publishers of scientific literature. ScienceDirect, Springer. Searching domestic scientific literature. Serbian citation index. Establishing research hypotheses and testing them. Statistical analysis and processing of results using different software. Rules and methods of citing literature. Preparation of the public presentation of the master's thesis.				
Literature: Recommended: 1. D. Manasijević, Teorijske osnove za izradu master rada, Tehnički fakultet u Boru, Bor 2016. (*in Serbian*) Ancillary: 1. R. Carver, J. Nash, Doing data analysis with SPSS, Brooks / Cole Cengage Learning, 2009. 2. Articles in international journals from relevant fields.				
Number of classes per week	**Lectures: 2**	**Practical classes: 2**	**Study research work:**	**Other forms of teaching: 1**
Teaching methods Lectures, group work, case studies, workshops.				
Knowledge evaluation (maximum 100 points)				

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	10	Written part of the final exam	
Exercise attendance		Oral part of the final exam	40
Coloquium exam/s	40	....	
Term paper	10		

Study program: Metallurgical Engineering				
Course: PROFESSIONAL PRACTICE				
Lecturer/s: Dr. Vesna Grekulović, full professor, Dr. Ljubiša Balanović, assistant professor and Dr. Uroš Stamenković, assistant professor				
Status of the course: Compulsory				
ECTS: 6				
Prerequisite: Certified 1st semester				
Course goals: Practical application of theoretically acquired knowledge in production conditions or specialized laboratories. In the course of professional practice, the student should adapt to the working conditions in metallurgical practice, in order to be able to make better use of the acquired theoretical knowledge in concrete conditions. Preparation for the future employment after graduation.				
Learning outcomes: Training students for the practical application of previously acquired theoretical and professional knowledge in solving specific practical engineering-technical problems in obtaining and processing metals, as well as related areas.				
Course description: The teachers in charge of organizing the professional practice, in agreement with colleagues from the appropriate company where the professional practice is carried out, determine the content and dynamics of the professional practice and define a specific engineering task that will be discussed in the seminar paper. The content of professional practice is formed for each student separately, in agreement with the management of the company where the professional practice is carried out, and in accordance with the needs of the profession for which the student is trained. The vocational training program for each student is drawn up by the responsible teacher-coordinator of vocational training.				
Number of classes per week	**Lectures:**	**Practical classes:**	**Study research work:**	**Other forms of teaching: 6**
Teaching methods Professional practice in a company or institution is carried out according to a pre-defined program with a task consisting of data collection, measurement and analysis in consultation with experts from the company where the professional practice is carried out and the teacher-coordinator of professional practice. After completing the professional practice, the student submits to the professional practice coordinator a written professional practice diary and a seminar paper with a solution to a specific engineering problem. After the professional internship teacher-coordinator positively evaluates the professional internship diary and the seminar work, the student acquires the right to take the oral part of the exam. Professional practice is carried out within the framework of the following subjects: Characterization of materials, Thermodynamics of materials, Structure and properties of precious metals, Conti procedures for obtaining wire and profiles, Processing of rare and precious metals, Metallurgy of non-ferrous metal alloys.				
Knowledge evaluation (maximum 100 points)				

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	20	Written part of the final exam	
Exercise attendance		Oral part of the final exam	50
Coloquium exam/s		....	
Term paper	30		

Study program: Metallurgical Engineering				
Course: MASTER WORK - RESEARCH				
Lecturer/s: All teachers in the study program are potential mentors				
Status of the course: Compulsory				
ECTS: 4				
Prerequisite: Passed all exams and professional practice carried out.				
Course goals: The goal of the course refers to logical actions that, with the help of abstract concepts, verified theoretical knowledge and empirical research, enable new knowledge from the narrower scientific field of the researched issue. Training students for completely independent work after the completion of master's academic studies, expanding already acquired theoretical and practical knowledge as a good basis for further training in doctoral academic studies.				
Learning outcomes: The student has mastered the theoretical and practical phases of scientific research methods. Independently searches available literature databases (KOBSON, SCOPUS, SCIENCE DIRECT, etc.). The student has a greater degree of independence when working on appropriate devices and equipment. Independently uses software for processing experimental data.				
Course description: The course content is based on the basic stages of the methodical procedure of scientific research: (1) formulation of the problem, (2) establishment of the hypothesis, and (3) verification of the hypothesis. Master thesis - research is a research paper that is formulated for each student separately, in which he gets acquainted with new research methods in the field of metallurgical engineering. The mentor guides the candidate and provides assistance in all phases of the research, through: choosing the topic of the master's thesis, formulating the title of the thesis, setting the goal of the subject of the thesis, engineering methods and ways of solving it, approaching the problem, choosing the way to process the problem, experimental work and data collection.				
Literature: Relevant literature in the field of metallurgical engineering in paper and electronic form.				
Number of classes per week	**Lectures:**	**Practical classes:**	**Study research work: 8**	**Other forms of teaching:**
Teaching methods All necessary general scientific research methods with an emphasis on hypothetical deductive and experimental methods. Sensory-empirical practical activity. The performance methods consist of a theoretical introduction to the problem and independent laboratory work under the supervision of the teacher. During the research, all necessary general scientific research methods are applied in order to obtain valid experimental data.				
Knowledge evaluation (maximum 100 points)				

Pre-examination obligations	Points	**Final exam**	Points
Lecture attendance	50	Written part of the final exam	50
Exercise attendance		Oral part of the final exam	
Coloquium exam/s		....	
Term paper			

Study program: Metallurgical Engineering				
Course: MASTER WORK – PREPARATION AND PRESENTATION				
Lecturer/s: All teachers in the study program are potential mentors				
Status of the course: Compulsory				
ECTS: 4				
Prerequisite: Passed all exams provided for the master's academic studies program of the Metallurgical Engineering study program.				
Course goals: The goal of preparing and presenting the master's thesis is for the student to demonstrate that, by processing a practical task and presenting it, he has a satisfactory ability to apply theoretical knowledge and practical skills in future engineering practice. Also, through the preparation and presentation of the master's thesis, the student is trained for a fast and adequate, economically, ecologically, and ethically based application of acquired knowledge and skills on concrete, practical engineering examples in the company where he will start his professional career.				
Learning outcomes: The student uses more advanced software for processing experimental data. He has great independence in analyzing the obtained results and drawing conclusions. He creates more complex logical connections between the cause and effect of the observed phenomenon. Competencies acquired in this way include the ability to think critically, analyze, synthesize, and make real-time decisions. Specific abilities - knowledge and skills are reflected in the practical application of theoretical knowledge to real problems in practice. This allows master metallurgical engineers to get involved more quickly in solving real production problems at the beginning of their professional career.				
Course description: After conducting experimental research and obtaining valid results, the student prepares a master's thesis in the form containing the following chapters: introduction (defining the goal of the task and expected results); theoretical part (presentation of the most important theoretical foundations, which represent the basis for certain researches); experimental part, practical part (concrete processing of the given engineering problem), results and discussion (presentation of the obtained results in an appropriate technical form, with necessary comments and conclusions in order to solve the current problem), and literature review. The master's thesis - preparation and presentation is formulated for each student separately, in which the student, with a significant degree of independence, with a mentor, processes data and analyzes the obtained results using different methodological procedures, checks the set hypothesis and gives a solution to a set engineering problem. The mentor guides the candidate in all stages of preparation and provides assistance in the entire process of creating and presenting the master's thesis. The student submits the final, mentored version of the work, followed by a public presentation before the committee. At the presentation of the master's thesis, the student must demonstrate that he has mastered the subject in the area of the work, explain the conclusions and findings he has reached and defend them. After a positive assessment by the commission, the student acquires the title of Master of Metallurgical Engineer.				
Literature: Relevant literature in the field of metallurgical engineering in paper and electronic form.				
Number of classes per week	**Lectures:**	**Practical classes:**	**Study research work: 4**	**Other forms of teaching:**
Teaching methods Analytical-deductive method and integration of theoretical and empirical aspects of the research subject. Proposal for a solution to the engineering problem. Theoretical interpretation of sensory-practical activity and comparison with already existing results available in the literature.				
Knowledge evaluation (maximum 100 points)				
Pre-examination obligations	Points	**Final exam**	Points	

Lecture attendance		Written part of the final exam	50
Exercise attendance		Oral part of the final exam	50
Coloquium exam/s		....	
Term paper			