NATIONAL TECHNICAL UNIVERSITY OF ATHENS

School of Mining and Metallurgical Engineering

Curriculum Guide 2024-2025

Athens 2024

Contents

1 BRIEF HISTORY OF N.T.U.A.

The National Technical University of Athens (N.T.U.A.) is the oldest technical university in Greece.

In its initial form, it was founded as the "School of Arts", in the Spring of 1837, almost simultaneously with the modern Greek State, after the liberation of Greece from the Turkish yoke. At that time, it was a technical school, operating on Sundays and holidays, to offer instruction to those desiring to master in building construction.

The first reformation took place in 1840 and the "School of Arts" switched over to daily operation along with the Sunday's counterpart. Studies reached the three years, were enriched with new disciplines and the administration was taken over by the Committee for the Encouragement of National Industry.

A second major change occurred in 1863 with the introduction of theoretical and applied education for managers and technicians in building construction, metals industry, sculpture, painting, ceramics, tanning, soap manufacturing etc. in 1872 the School was transferred from Pireos Street to the Patission Street Complex.

In 1887, the School was promoted to a higher education establishment for Building Construction Engineers, Architects and Mechanical Engineers and its title became "School of Industrial Arts".

In 1914, the establishment was given the official title of "Ethnicon Metsovion Polytechnion". "Ethnicon" means "National" and "Metsovion" was introduced in the title to honour the establishment's great donors and benefactors Nikolaos Stournaris, Eleni Tositsa, Michail Tositsas and Georgios Averof, all from Metsovo, a small town in the region of Epirus. The same title is still in use in Greece but, abroad, the title "National Technical University of Athens" is used instead in order to avoid possible misconceptions regarding the Institution's academic status. The last radical reformation in the organization and administration of N.T.U.A. took place in 1917, when a special bill gave N.T.U.A. a new structure and established the Schools of Civil, Architecture, Surveying, Mechanical & Electrical and Chemical Engineering.

Today, N.T.U.A.'s Schools educate 13,000 students and are located –except the School of Architecture– on the Zografou Campus, a spacious (910,000m^2) and open green site, 6 km from the centre of Athens. It includes buildings of 260,000m^2 with fully equipped lecture theaters, laboratories, libraries, a Central Library, a Computer Centre and a Medical Centre. Also, on the campus are a Hall of Residence, restaurants, stationery and bookshop, a gymnasium and playing fields.

2 N.T.U.A. STRUCTURE AND ADMINISTRATION

The current legal framework for higher education came into effect in 1982. In accordance with this, N.T.U.A. is divided into nine Schools, as follows:

1. School of Civil Engineering
2. School of Mechanical Engineering
3. School of Electrical and Computer Engineering
4. School of Architecture
5. School of Chemical Engineering

6. School of Rural and Surveying Engineering
7. School of Mining and Metallurgical Engineering
8. School of Naval Architecture and Marine Engineering
9. School of Applied Mathematical and Physical Sciences

As prescribed by law, each School is administrated by a General Assembly consisting of the representatives of Teaching and Research Personnel (TRP: Professors, Associate Professors, Assistant Professors and Lecturers), the representatives of the Scientific and Teaching Personnel (STP: Assistants and Research Associates), the representatives of the Administrative and Technical Personnel (ATP) and representatives of the Students. Certain matters of minor importance are handled by an Executive Board.

A special Electorate elects a professor or an associate professor as Dean of the School and another member of the same rank as Deputy Dean.

Each School is subdivided into Departments covering scientific areas. Departments are also administered by General Assemblies, which are similar to the School's Assembly. The Head of a Department, called Director, is elected amongst the members of the General Assembly.

Finally, there may be further subdivisions, in the shape of laboratories, which deal with specific scientific topics. Each laboratory is headed either by a professor or by an associate professor or even by an assistant professor but administratively it belongs to a Department or directly to the School.

N.T.U.A.'s general administration is effected by the Senate, which consists of the Presidents of the Schools, one TRP member from each School, representatives of STP, representatives of the Special Research Personnel (SRP), representatives of ATP, the administration staff and the representatives of the students. The Senate is headed by the Rector and two Vice-Rectors, who are professors or associate professors elected by a special electorate comprising all N.T.U.A. staff and students.

3 THE SCHOOL OF MINING AND METALLURGICAL ENGINEERING

3.1 HISTORY

The onset of our School was the Department of Mining and Metallurgical Engineering of the National Technical University of Athens (NTUA) that was founded by government decree on February 27th, 1946. According to this decree, the School of Chemical Engineering was subdivided into three Departments: (a) the Department of Chemical Engineering, (b) the Department of Mining Engineering, and (c) the Department of Metallurgical Engineering. The operation of the last two departments was thus started during the academic year 1945-46.

Before the foundation of the Departments of Mining Engineering and Metallurgical Engineering, a number of courses belonging to these disciplines were taught in other departments of NTUA. In particular, since 1878 (when NTUA was called "School of Industrial Arts") the course "Mineralogy and Geology" was taught in the Department of Civil Engineering, while a little later the course "Iron Metallurgy" was first offered in the Department of Mechanical Engineering. These two courses continued to be offered up to the restructuring that took place in 1914, when the current name was given to NTUA (Ethniko Metsovio Polytechneio), while in 1917 the course "Mining

Works" was first offered.

In 1943, the law 935 created the following Chairs: Mining Engineering, Iron Metallurgy, Metallurgy Engineering, and Economic Geology and Applied Geology. However, the actual functioning of the Department starts during the academic year 1945-46, with the 5-year study program in the Department of Mining Engineering and the Department of Metallurgical Engineering. In 1948, three years after the foundation of the two Departments, they are joined together in a single Department under the name "Department of Mining & Metallurgical Engineering", which was still part of the School of Chemical Engineering of NTUA. Thus, during the 1950, 1951 and 1952 years, graduating students from NTUA were designated as having a diploma either in Mining Engineering or in Metallurgical Engineering but not both.

During the academic year 1975-76, the Department was separated from the School of Chemical Engineering and formed an independent school under the name "School of Mining and Metallurgical Engineering". Under the government law 1268/82 "On the Structure and Operation of the Highest Educational Institutions" (Framework Law), the nine existing at the time faculty chairs were split according to the new law into the following three departments:

Department of Mining Engineering

Department of Metallurgy & Materials Technology

Department of Geological Sciences

This structure remain the same today, with the graduates being awarded the Diploma of Mining and Metallurgical Engineer, after their successful completion of a 5 year course.

3.2 STRUCTURE

The educational and research activities of the School have been separated into three (3) departments, each with its corresponding laboratories.

3.2.1 Department of Mining Engineering

Subject of the Mining Engineering department is teaching of all these courses related to exploitation of ores, mining engineering and the construction of geo-engineering works, as well as conducting research pertaining to these topics.

- Laboratory of Laboratory of Excavation Engineering
- Laboratory of Mining Engineering and Environmental Mining
- Laboratory of Hydrocarbon Exploitation and Applied Geophysics
- Laboratory of Tunneling Engineering

3.2.2 Department of Metallurgy and Materials Technology

Subject of the Metallurgical and Materials Technology department is teaching of all these courses related to processing of ores and industrial minerals, to metallurgical

and materials production, to metals and non-metal materials processing, and the environmental protection from all these activities as well as conducting research pertaining to these topics.

- Laboratory of Mineral Processing
- Laboratory of Metallurgy
- Laboratory of Physical Metallurgy
- Laboratory of Environmental Protection Science and Engineering in Metallurgy & Materials Technology
- Laboratory of Computer-Aided Materials Processing – Rheology and Design for Polymers and Composites

3.2.3 Department of Geological Sciences

Subject of the Geological Sciences department is teaching of all these courses related to geological, ore geology, petrological, geochemical, mineralogical, hydrogeological, geotechnical and geoengineering topics, as well as conducting research pertaining to these topics.

- Laboratory of Geology
- Laboratory of Engineering Geology and Hydrogeology
- Laboratory of Mineralogy – Petrology – Economic Geology

3.3 CURRICULUM PRINCIPLES

The curriculum of the School of Mining and Metallurgical Engineering has been formed having in mind: (i) the scientific and professional activities of the Mining and Metallurgical Engineers, (ii) the production and development activities of Greece in the corresponding fields, (iii) the prevailing trends in the above two scientific and the related areas.

The curriculum objectives are to give the graduating engineer the necessary scientific and technological knowledge that will enable him/her to successfully face the needs and requirements of the various scientific and professional activities. That is, to enable the engineer to work efficiently and productively in exploiting the mineral and energy resources of the country, in mines, in quarries, in geotechnical works, in industries which add value to mineral raw materials, in metallurgical plants, in metal-forming enterprises, in business and activities related to the protection and rehabilitation of the environment. This means that the graduated Mining or Metallurgical Engineers must be in a position (i) to keep abreast of the latest scientific advances and to be able to go deeper in the area of their special engineering activities, (ii) to be able to collaborate with other engineers or scientists of related disciplines, (iii) to have the flexibility to adjust to scientific and technological developments, and finally (iv) to have a certain level of knowledge, which will allow them, if they so wish, to pursue graduate studies in their field or even

beyond that.

The curriculum covers 10 semesters (5 years).

In 1999, in an effort of upgrading the undergraduate curriculum, it was decided that the first seven semesters make up the basic curriculum, while from the 8th semester there are introduced five (5) subject streams, which are completed with the fulfilment of a diploma thesis. These five (5) subject streams of the curriculum are:

(a) Environmental Engineering and Geo-Environment.

(b) Mining Engineering.

(c) Geo-Engineering.

(d) Metallurgical Processes.

(e) Materials Science and Engineering.

During the 8th and 9th semesters, students must choose at least six (six to twelve) courses from a subject stream of their choice. In the case of choosing only six courses from their subject stream, the remainder six courses for the completion of the degree requirements may be selected from the courses offered in the other four subject streams or the course pool, with a maximum number of three courses/semester from any one direction or the pool.

Also, during the 8th and 9th semesters, students must register, attend and pass, in each semester, at least three to four courses of the stream they have selected.

Students selecting the streams of (a) Mining Engineering and (b) Geoengineering must include in the six courses they select at least four courses from the common courses of the two subject streams and also another two from the special courses of each subject stream.

The courses are designated as ***Mandatory*** and ***Electives*** (the students must select one or more courses, according to the program of each semester).

As was already mentioned, the completion of the undergraduate studies is achieved by performing work and submitting a diploma thesis (during the 10th semester) in a course of their choice under the supervision of the instructor teaching the course.

3.4 DIPLOMA THESIS

a. *Diploma Thesis and the Assignment Process*.

- The Diploma Thesis has the content and the minimal duration (one complete academic semester, the 10th) of a high level assignment. With the Diploma Thesis the specialization, provided by the courses in the last semesters of the Studies, is completed.

- The Diploma Thesis is prepared by the final semester students in a Department and cognitive object of their choice, under the supervision of a School member of the chosen Department, who teaches the most relevant course, with the potential

restriction of Section iv. The choice of the Department and the Diploma Thesis subject is made after the student applies to the Secretariat of the School, according to the academic calendar of the School. The determination of the Diploma Thesis subject and the Sector is done:

i. By selecting from a list of specific Diploma Thesis subjects that each School member announces at the beginning of each academic semester.

ii. With direct agreement between the student and the School member.

iii. After a proposal by the student, provided that a School member accepts it.

iv. By an application of the student to the School.

- Following the definition of the Diploma Thesis subject, the supervisor informs the Head of the Department, who keeps a record of the Diploma theses in the Department, and the Secretariat of the School, so that the applications are forwarded to the Board of Directors for the final approval and distribution of the Diploma Theses.

- Each School member has the right and obligation of supervising Diploma Thesis, in the field of the courses they teach or in relevant scientific fields.

- In order to ensure the effective supervision and the balanced distribution of educational work among the School members, each School can define, according to the Sectors advice, a low and upper limit of Diploma Theses supervised simultaneously by a School member.

- Since one of the main objectives is the enhancement of student initiative, the Diploma Thesis development is done by each student individually. If required by the nature of the thesis subject, and after the appropriate justification, a team of students can realize the Diploma Thesis provided that each student's individual contribution to the work development and to the thesis presentation is distinct. The extent of the Diploma Thesis should be the appropriate, so that its completion is feasible in one academic semester of full-time work, even though the real completion time depends on the student's ability to fulfill the thesis requirements and his commitment.

b. *Diploma Thesis development, submission and examination*.

- The Diploma Thesis is developed under the student's responsibility, with the continuous monitoring and help of the supervisor. The Sector is responsible for the unhindered development and presentation of the Diploma Thesis, using the means it allocates and, if it is needed, in collaboration with the Institution's printing facility. Before each examination period, the supervisor fills out the relevant printed form certifying the initial acceptance of the Diploma Thesis that he/she supervises. After the initial acceptance of the Diploma Thesis, the additional expenses of the student until the final presentation are covered by the Departments or the Schools that are eligible for credit with the corresponding sums of functional expenses, supplies, etc. The eligible Departments or Schools are credited from the State's Budget, after their application, at the beginning of the academic year with an upper limit determined by the Senate.

- The final version of the Diploma thesis is submitted according to the academic calendar and in time, i.e. at least ten (10) working days before the defined examination day. The Diploma Thesis is submitted to the Department Administration, initially in three copies that are forwarded immediately to the three members of the examination committee. The finally approved copy remains in the possession of the supervisor, while two more copies are obligatorily submitted to the School library and the Central Library and are available for lending.

- The Diploma Thesis presentation text is composed using a text processor and an approved template by the School General Assembly and it should include the following:

  i. Synopsis (1.200 to 2.000 words) and Summary (300 to 500 words) in Greek and a foreign language (preferably English).

  ii. Table of contents.

  iii. References.

- The presentation is given by the student orally and in public, on dates set in the academic calendar of the School and according to the program defined by the School Secretariat. Each presentation should be minimum forty five (45-60) minutes long.

- The examination and marking of the Diploma Thesis is performed by a three-member School Committee, proposed by the Department General Assembly and approved by the School's General Assembly or the Board of the School, in case it is authorized. The committee consists of the supervisor, a possible common member and a member with relevant specialization. In case a Diploma Thesis is assigned to a student from a different School, the third member of the examining committee should be from the most relevant Sector of that School.

- If a student does not pass the Diploma Thesis oral examinations, he/she can repeat the examination in the next period, after submitting an application. If he fails again, he applies for a new subject in the same or different scientific field, in order to be examined in another period.

c. Evaluation criteria of Diploma Theses.

- The main evaluation criteria are the following:

  i. Updating of the existing knowledge level with the corresponding literature research.

  ii. Acquisition of special data (data from lab experiments or field data or theoretical results).

  iii. Logical process (e.g. process of assembled data, definition of mathematic models, trials in computers, applications in concrete problems, evaluation of results).

iv. Structure and the written presentation of the Diploma thesis, e.g. the continuity of text, the right use of terminology and language, the precise formulation of concepts, the adequate documentation of scientific conclusions, etc.

v. Originality.

vi. Student's eagerness and initiatives.

vii. Thesis oral presentation.

- The weighting factors of the above criteria depend on the nature of the thesis subject, and they are in the judgment of the examining committee. For the thesis final degree synthesis it is recommended to use special printed forms. The Thesis final grade is the mean value of the three examiners grades, rounded to the nearest integer or half integer. The lower grade, for successful examination, is 5.5. (Scale is 0-10).

From the five years Course Programme of the School and the Diploma Thesis of the fifth year, it can clearly be concluded that the Diploma offered to the students by N.T.U.A. is substantially at least equivalent to the Master's Degree of acknowledged Anglo –Saxon universities.

3.5 COURSES AND DIPLOMA THESIS MARKING SCHEMES

Marking in all courses is done by the 0-10 scale, without using fractions of an integer, and using as a basis for passing the mark 5. Diploma Thesis marking is an exception, since it is allowed to use half a mark (0.5) and the basis for passing is the mark 5.5. The overall mark for the diploma is calculated by summing the following:

a) the arithmetic average of all course marks taken by the student during his studies, with a weighted coefficient of four fifths (4/5), and

b) the thesis mark, with a weighted average of one fifth (1/5).

Excellent	9 to 10
Very Good	7 to 8,99
Good	5,5 to 6,99
Satisfactory	5 to 5,49
Bad	below 5

3.6 SCHOOL PERSONNEL
Department of Mining Engineering

Professors:	Georgios Apostolopoulos
	Dimitrios Damigos
	Dimitrios Kaliampakos
	Maria Menegaki
	Theodoros Michalakopoulos
	Konstantinos Modis
	Andreas Benardos
	Pavlos Nomikos
Associate Professors:	Vasilios Gaganis
	Ioannis Zevgolis
Lab Teaching Staff:	Georgios Amolohitis
	Paraskevi Giouta-Mitra
	Dimitrios Lamprakis
	Aggeliki Marinou
	Athanassios Mavrikos
	Maria Basanou
	Georgios Papantonopoulos
Special Administrative and Technical Personnel:	
	Irini Dimitrellou
	Evangelia Koffa
	Dimitrios Lefkaditis
	Despina Triantafyllidou
	Emmanouel Tsiavos
	Efstathios Triantis
Temps:	Zaxaro Kerassovitou
	Stavroula Platoni

Department of Metallurgy and Materials Technology

Professors:
Georgios Anastassakis
Anthimos Xenidis
Dimitrios Panias
Spyros Papaefthymiou
Emmanuela Remoundaki
Maria Taxiarchou
Athena Tsetsekou
Georgios Fourlaris
Iliana Halikia

Associate Professors:
Petros Tsakiridis

Assistant Professors:
Efthymios Balomenos
Antonios Peppas
Artin Xatzikiosegian

Lab Teaching Staff:
Panagiotis Aggelopoulos
Maria Gregou
Stavros Deligiannis
Aikaterini Thoma
Lambros Karalis
Apostolos Kourtis
Pavlina Kousi
Irini Kostopoulou
Aikaterini Maliachova
Georgios Bartzas
Paschalis Oustadakis
Ilias Sammas
Adamantia Charokopou
Irini Christodoulou

Special Administrative and Technical Personnel:

Aikaterini Vaxevanidou
Nikolaos Kamarinos
Evangelia Mylona
Ilianna Ntouni
Ioannis Charlambitas

Temps:
Christina Antonakopoulou

Department of Geological Sciences

Professors: Andreas Kallioras
Konstantinos Loupasakis
Maria Perraki
Elias Chatzitheodoridis

Associate Professors: Stavros Triantafyllidis

Assistant Professors: Konstantinos Athanassas
Ioannis Vakalas
Paraskevas Tsangaratos

Lab Teaching Staff: Ioannis Bousoulas
Eudoxia Lykoudi
Konstantinos Markantonis
Ioanna Ilia
Eleni Vasileiou

Special Administrative and Technical Personnel:
Eleni Grigorakou
Stavroula Dragoumani
Evaggelos Rokos

Temps: Ioanna Vavva

SECRETARIAT

Secretary::	Georgia Patakia
Members::	Eleni Eleftheriou
	Ourania Frangou
	Aggeliki Paschalidou
	Kalliroi Papakonstantinopoulou
	Klearchoula Kaminardelli
PC-Laboratory:	Nikolaos Apostolakis
	Emmanouel Papadopoulos
School Network:	Konstantinos Kotsalis
Lavrio:	Dimitrios Skordis

For any information, please use the following address:

Secretariat

School of Mining and Metallurgical Engineering

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Zografou 157 80, Athens

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Please visit the school web page at: **www.metal.ntua.gr**

3.7 COURSE PROGRAMME

	1st SEMESTER				
CODE	**MODULES**	**HOURS PER WEEK**			
	Compulsory				
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7003	Geology	2	2	-	5
7024	Mathematics I	4	2	-	5
7287	Minerology - Petrology	2	-	2	5
7054	Physics I (Mechanics, Oscillations and Waves)	2	-	2	5
7222	Chemistry	2	-	3	5
7166	Historic evolution of mining & metallurgy	2	-	-	3
		14	**4**	7	**28**
	TOTAL HOURS	**25**			
	ELECTIVES (HUMANITIES AND SOCIAL SCIENCES COURSES)				
	Compulsory selection of one module				
7120	Principles of economics (Macro - and micro economics)	2	-	-	3
7224	Applied philosophy of technology	2	-	-	3
7102	Sociology of science and technology	2	-	-	3
	TOTAL HOURS		**27**		**31**

	2nd SEMESTER				
	MODULES	**HOURS PER WEEK**			
	Compulsory				
		Lectures	**Practicals**	**Laboratory**	**ECTS**

7195	Introduction to programming (Programming language Phython)	2	2	-	4
7225	Thermodynamics	3	1	-	5
7072	Mathematics II	3	3	-	5
7286	Engineering economics	2	1	-	5
7253	Physics II - Electromagnetism and optics	2	2	-	5
		12	**9**	-	**24**
	TOTAL HOURS	**21**			
	ELECTIVES (ENGINEERING FUNDAMENTAL COURSES) 2nd & 4th semester				
	Compulsory selection of one module				
7273	Principles of nanotechnology and electron Microscopy	2	-	2	4
7297	Principles of production organization-Project management	2	1	-	4
7196	Introduction to the electric and electronic systems	2	-	2	4
7215	Geographic information systems (GIS)	2	-	2	4
7293	Artificial intelligence and Machine Learning algorithms	2	1	-	4
7082	English Language & terminology	2	-	-	4
	TOTAL HOURS		**23-25**		**28**

	3rd SEMESTER				
	MODULES	**HOURS PER WEEK**			
	Compulsory				
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7230	Basic principles for materials and energy management in the production chains	2	1	-	5
7005	Ore deposit geogoly	2	-	2	5

7229	Mathematics III (ordinary differential equations)	4	-	2	5
7049	Technical mechanics - Statics	1	2	-	5
7294	Hydrogeology	2	2	-	5
		11	**5**	**4**	
	TOTAL HOURS	**20**			**25**
	ELECTIVES (ENGINEERING FUNDAMENTAL COURSES) 3rd & 5th semester				
	Compulsory selection of one module				
7232	Analytical chemistry and physical methods of analysis	2	-	3	4
7227	Numerical analysis	2	2	-	4
7063	Operations research and decision analysis	2	1	-	4
7133	Elements of mechanical design	2	2	-	4
7226	Computer aided design - Mechanical design	2	2	-	4
	TOTAL HOURS	**25-27**			**29**

	4th SEMESTER				
	MODULES	**HOURS PER WEEK**			
	Compulsory				
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7274	Transport phenomena principles	2	1	-	5
7258	Introduction to environmental science & engineering	2	-	2	5
7088	Probability theory and statistics	2	2	-	5
7104	Subsurface exploration methods - Mineral exploration	4	1	-	5
7094	Technical mechanics - Strength of materials	3	2	-	5
		13	**6**	**2**	
	TOTAL HOURS	**21**			

	ELECTIVES (ENGINEERING FUNDAMENTAL COURSES) 2nd & 4th semester				
	Compulsory selection of one module				
7273	Principles of nanotechnology and electron Microscopy	2	-	2	4
7297	Principles of production organization-Project management	2	1	-	4
7196	Introduction to the electric and electronic systems	2	-	2	4
7215	Geographic information systems (GIS)	2	-	2	4
7293	Artificial intelligence and Machine Learning algorithms	2	1	-	4
7082	English Language and terminology	2	-	-	4
	TOTAL HOURS	**23-25**			**29**

	5th SEMESTER				
	MODULES	**HOURS PER WEEK**			
	Compulsory				
		Lectures	**Practicals**	**Laboratory**	
7012	High temperature processing	2	2	-	5
7228	Introduction to physical metallurgy	3	-	2	6
7210	Mechanical preparation and processing of minerals I	4	1	-	5
7233	Surface mine exploitation	2	2	-	5
		11	**5**	**2**	
	TOTAL HOURS	**18**			**21**
	ELECTIVES (ENGINEERING FUNDAMENTAL COURSES) 3rd & 5th semester				
	Compulsory selection of one module				
7232	Analytical chemistry and physical methods of analysis	2	-	3	4

7227	Numerical analysis	2	2	-	4
7063	Operations research and decision analysis	2	1	-	4
7133	Elements of mechanical design	2	2	-	4
7226	Computer aided design - Mechanical design	2	2	-	4

ELECTIVES (ENGINEERING SPECIALIZATION COURSES) 5th & 7th semester

Compulsory selection of one module

7272	Principles and applications of biotechnology	2	-	2	4
7231	Geodynamics and geology of Greece	2	2	-	4
7155	Applied & environmental mineralogy	2	-	2	4
7296	Computational chemical thermodynamics	2	1	-	4
7150	Solid state physicochemistry	2	-	-	4
	TOTAL HOURS	**23-27**			**29**

6th SEMESTER

MODULES		**HOURS PER WEEK**			
Compulsory					
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7151	Physical metallurgy - The alloys	3	-	2	5
7173	Mechanical preparation and processing of minerals II	2	-	2	5
7237	Practical training I	-	-	-	6
7092	Engineering geology - Geohazards	2	-	2	6
7066	Hydrometallurgical unit operations	3	2	-	6
		10	**2**	**6**	**28**
	TOTAL HOURS	**18**			

ELECTIVES (ENGINEERING SPECIALIZATION COURSES)

	Compulsory selection of one module				
7277	Corrosion and Protection of Metallic Materials	2	-	2	4
7145	Elements of reinforced concrete and steel structures	1	2	-	4
	TOTAL HOURS	**21-22**			**32**

	7th SEMESTER				
	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7181	Health & Safety	2	1	-	5
7235	Applied environmental protection	2	2	-	6
7035	Iron and steel metallurgy	3	2	-	5
7034	Rock mechanics	2	1	2	6
7264	Underground mine exploitation	2	2	-	6
		11	**8**	**2**	
	TOTAL HOURS	**21**			**28**
	ELECTIVES (ENGINEERING SPECIALIZATION COURSES) 5th & 7th semester				
	Compulsory selection of one module				
7272	Principles and applications of biotechnology	2	-	2	4
7231	Geodynamics and geology of Greece	2	2	-	4
7155	Applied & environmental mineralogy	2	-	2	4
7296	Computational chemical thermodynamics	2	1	-	4
7150	Solid State Physicochemistry	2	-	-	4
	TOTAL HOURS	**23-25**			**32**

	8th SEMESTER
	MINING ENGINEERING

	MODULES	HOURS PER WEEK			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7031	Geostatistics	2	2	-	4
7017	Rock blasting	3	-	1	4
7176	Marbles and industrial minerals	2	-	1	4
7175	Petroleum engineering	2	1	-	4
7242	Drilling engineering	3	1	-	4
7255	Practical training II / Internship	-	-	-	10
					30

GEO - ENGINEERING

	MODULES	HOURS PER WEEK			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7009	Soil mechanics	2	2	-	4
7268	Methods of geological mapping and tectonic analysis	2	2	-	4
7265	Underground Works	2	1	-	4
7186	Groundwater and construction works	2	2	-	4
7065	Support of underground works	2	2	-	4
7255	Practical training II / Internship				10
					30

ENVIRONMENTAL ENGINEERING AND GEO-ENVIRONMENT

	MODULES	HOURS PER WEEK			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7241	Remediation of contaminated soils	2	-	2	4
7238	Groundwater management and protection	2	2	-	4
7240	Special topics of environmental protection in mining and geotechnical engineering	2	2	-	4
7239	Environmental geochemistry	2	1	-	4
7219	Air pollution control	3	1	-	4
7255	Practical training II / Internship	-	-	-	10

					30

METALLURGICAL PROCESSES

	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7282	Processing and utilisation of industrial minerals	1	-	1	4
7214	Laboratory exercises in pyrometallurgy		-	3	4
7077	Electrometallurgical Processes	2	-	2	4
7189	Metallurgy of non-ferrous metals	3	-	-	4
7192	Technology of cement and concrete production	2	1	-	4
7255	Practical training II / Internship	-	-	-	10
					30

MATERIALS SCIENCE AND ENGINEERING

	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7059	Industrial non-ferrous alloys	2	-	2	4
7153	Ceramic Materials	3	-	1	4
7117	Metallurgy of welding, technology & control of weldments	3	-	3	4
7167	Solid to solid state phase transformations	2	-	2	4
7157	Polymers and composites	2	1	-	4
7255	Practical training II / Internship	-	-	-	10
					30

POOL COURSES

	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7218	Principles of machining	1	2	-	4
7275	Gemology	2	-	1	4
7278	Solid industrial and hazardous waste management	2	1	-	4

7246	Special chapters in ore deposit geology	2	1	-	4
7159	Geothermal fields science and technology	2	1	-	4
7244	Magnetic materials	2	-	2	4
7177	Economics of mineral resources	1	1	-	4
7267	Environment and development	2	1	-	4
7289	Environmental policies and framework for the exploitation of mineral raw materials	2	1	-	4
7260	Environmental chemistry and metals mobility mechanisms	2	2	-	4
7290	Earth and space rocks	2	1	-	4
7190	Design and techno economic analysis of metallurgical industries	1	3	-	4

9th SEMESTER

MINING ENGINEERING

MODULES		**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7174	Mechanical rock excavation	2	1	1	4
7061	Applied geophysics (short presentation)	2	1	1	4
7211	Conventional and robotic mining systems	2	2	-	4
7112	Open pit mine planning and design	2	2	-	4
7111	Underground Mine Planning and Design	3	1	-	4
					20

GEO - ENGINEERING

MODULES		**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7202	Geotechnical ground improvement technics	2	1	-	4
7270	Special topics in geotechnical engineering	2	2	-	4
7291	Principles of foundations and retaining structures	2	2	-	4

7200	Design and construction of tunnels	2	2	-	4
7171	Engineering geology of mining and civil construction	3	-	1	4
					20

ENVIRONMENTAL ENGINEERING AND GEO-ENVIRONMENT

	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7259	Solid waste management - Material recycling	2	1	-	4
7261	Enviromental and natural resources management	2	1	-	4
7281	Energy and environment	2	1	-	4
7283	Geostatistics for environmental applications	2	1	-	4
7110	Wastewater treatment technologies	2	2	-	4
					20

METALLURGICAL PROCESSES

	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7276	Secondary metallurgy	2	-	2	4
7052	Applied hydrometallurgy	2	-	2	4
7256	Design and construction of mineral processing plants	2	2	-	4
7030	Reactor design	2	1	-	4
7143	Chemical Kinetics	3	1	-	4
					20

MATERIALS SCIENCE AND ENGINEERING

	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7284	Casting & forming processes of metals	5	-	-	4
7263	Powder metallurgy & additive manufacturing (emphasis on 3D printing)	3	-	-	4
7179	Advanced physical metallurgy of iron	2		2	4

	and steel				
7048	Refractory materials	2	-	1	4
7204	Surface engineering	2	-	2	4
					20

POOL COURSES

	MODULES	**HOURS PER WEEK**			
		Lectures	**Practicals**	**Laboratory**	**ECTS**
7236	Total quality management principles - Quality control	2	1	-	4
7279	Natural disaster management	1	1	-	4
7280	Alternative energy systems in the industry	2	1	-	4
7285	Fatigue and fracture	2	-	2	4
7220	Polymers and composites processing	2	1	-	4
7288	Hydrocarbon production engineering	2	1	-	4
7183	Mining systems simulation	1	1	-	4
7203	Groundwater modelling	1	2	-	4
7108	Advanced investment analysis	1	1	-	4
7090	Automatic process control	3	-	-	4
7292	Stochastic simulation of geological systems	2	1	-	4
7136	Modern methods in topographic mapping	2	1	-	4
7295	Computational methods on metallurgy and materials technology	1	4	-	4

	10th SEMESTER	
	Diploma Thesis	**40**

3.8 COURSES CONTENTS

1st Semester

Geology 7003

This is an introductory course to geology and the geological processes that form the internal structure of the earth and its surface morphology. The course material aims to introduce the students to basic concepts of geology, helping them to understand topics of applied geology (and applied geoscientific courses in general) in later semesters. Specifically, the course aims to introduce students to:

The internal structure and the physical properties of the earth

The mechanism of plate tectonics

Rock cycle

Basic structures of the earth's crust (faults, folds, joints etc)

Crustal deformation (mountain building, basin formation etc)

Earth surface processes (weathering, erosion, deposition)

Processes of topography and landscape formation

Earthquake geology

Geological Time and geochronology

The geology of Greece

Historic Evolution of Mining & Metallurgy 7166

The course introduces students to the historic evolution of mining and metallurgy in Greece and the world. The course includes as well the developments of the industrial revolutions until today. Some aspects of the School's history are also presented.

The mining and metallurgical historic evolution worldwide from ancient times until today.

Mining & metallurgical history of Greece (prehistory, antiquity, industrial revolution and modern times, present).

The significance of the mining & metallurgical sector for the development of Greece.

Some historic features of the SMME and its contribution to the society relevant issues and the country's development.

Geotechnology and materials as sectors based on the basic technological field of the School

The constant historic evolution of technology and the industrial revolutions (from the 1st to the 4th), their interaction and importance to civil societies and culture.

The role of raw materials, materials technology and circular economy during the upcoming 4th industrial revolution.

Mathematics I 7024

Vector spaces- Vectors in -Inner product and exterior product.

Equations of a line in space-Parallel lines-Skew lines-Equation of a plane-Distance from a plane-Equation of sphere.

Sequences and Series-Differential Calculus (limits, continuity, derivative, Taylor expansion, approximations)-Integral Calculus (definite integral, indefinite integral with applications)-Integration of rational functions-Fourier Series.

Complex numbers-Modulus and argument-De Moivre's formula-roots of unity.

Matrices-Operations of matrices-Determinants-Inverse matrix-Systems of linear equations.

Mineralogy -Petrology 7287

Basic concepts of mineralogy. Chemistry of the elements. Bonding and packing in minerals. Physical properties of minerals. Mineral identification. Systematic mineralogy. Nomenclature and classification, with emphasis on sheetsilicates (clay minerals) and tectosilicates. Basic concepts of crystallography. Crystal structures. Crystal chemistry. Diffraction (X-Ray Diffraction, X-Ray Fluorescence). Optical Microscopy.
Introduction on the formation of the Earth in our Solar System. Origin, evolution, classification of Earth Materials. Plate tectonic setting and mode of occurrence of igneous rocks. Sedimentary rock classification, formation, transport, lithification. Metamorphic rocks and metamorphic grade and facies, geothermometers and geobarometers, plate tectonic significance. Petrography, mineralogy, and geochemistry of rocks. Microscopic and macroscopic textural descriptions and identification of rocks. Petrology for engineers.

Physics I (Mechanics, Oscillations and Waves) 7054

This course covers the basic principles of Mechanics, Oscillations and Waves. The fundamental principles and laws of Physics are taught and their applications to both physical phenomena and technological problems are discussed. In more detail, the main subjects covered by this course are the following:

Introduction, Motion in one dimension, Vectors, Motion in two and three dimensions, Throws, Laws of motion, Friction, Motion under the influence of frictional forces, Circular motion, System energy, Energy conservation, Linear momentum, Conservation of momentum, Plastic and elastic collisions, Rotation of solid bodies, Angular momentum – principle of conservation, Motion in gravitational fields – Satellites, Static equilibrium and elasticity, Simple harmonic oscillation, Damped oscillations, Forced oscillations, Introduction to mechanical waves.

The course also includes laboratory practice.

Chemistry 7222

Atomic Structure (Atomic Standards, Periodic Table of Elements). Chemical Bonds (classical and modern theories on covalent, ionic and metallic bonds, intermolecular forces). Chemical Thermodynamics (definitions of basic thermodynamic variables, driving forces of chemical reactions). Chemical Reactions. Chemistry of Aqueous Solutions (Water Chemistry, Theories of Acids and Bases). Reactions in Aqueous

Solutions (ionization of weak acids-bases, solubility of gases, hydrolysis of ions, ion complexation). Chemical Equilibrium, Electrochemistry.

Eight (8) laboratory exercises take place on the Chemistry of Aqueous Solutions.

Principles of economics – Macro and micro economics 7120

Microeconomics: Introduction to micro-economic theory. Market mechanism: Demand and supply. Behavior of consumer: Theory of absolute utility, Theory of cardinal utility. Theory of production and production cost. Market types: perfect competition, monopoly, monopolistic competition, oligopoly.

Macroeconomics: National Accounts. The Keynesian model. The IS-LM model.

Applied Philosophy of Technology 7224

The course aims to introduce the dynamic concept of technology, through a philosophical perspective. The main objectives are a) to clarify what technology is and to introduce its important milestones, and b) to present the way in which technology gives meaning to the world.

The course syllabus includes concepts such as 'artificial entity' in antiquity, to 'artificial intelligence' today. Challenges posed by technology are examined, as well as case studies of important engineering inventions and professional conduct. In this context, the relationship of technology with the human body, music and mathematics, visual thinking, the social significance of technology, engineering ethics, and an ecocentric approach are discussed and analyzed.

Key Topics:

- Clarification of concepts: Philosophy – Technology – Science
- Ancient Greek technology
- Music as a source of technology
- The special relationship between the craftsman and the craft
- Visual thinking
- Ethical and social manifestations of technology
- Engineering Ethics
- Case studies
- The technology of the mind – A.I.
- Brain – Programs – Perspectives

Sociology of Science and Technology 7102

The course approaches the concept of technology through a critical sociological view. It is a prerequisite that technology is influenced by the structure and function of

social institutions. In pursuing the above goal, the course focuses on the major technological systems and networks that are being developed in the early 20th century as well as on the development of engineering studies in Europe and the United States. Technological systems of the early 20th century are directly related to a way of thinking and organization that will be the main subject of the course, while at the same time the engineers will be to a large extent the focus of this study. During the course an attempt is made to highlight, especially for Greece, what it means to be an engineer, whether this identity is gendered, what are the roles of engineers and their education, how they shaped their professional communities as well as what kind of production, use and ideological intake of technology were promoted in the early 20th century.

2nd Semester

Introduction to Programming (Python programming language) 7195

Advanced knowledge which implies a critical understanding of theories and principles related to the subjects of Computer Science and Programming.

The aim of the course is to present to the students of the School of Mining and Metallurgical Engineering the basic concepts and principles that govern Computer Science as well as Programming. During the course, students come into contact with the concept of computing thinking while developing programming skills and abilities with the help of the programming language Python.

Topics covered in the course "Introduction to Programming (Python Programming Language") involve:

- introduction to Computer Science and the historical development of Computers,
- introduction to Algorithms and Programming, representation of Algorithms with flowcharts, pseudocode, algorithms and data structures, programming languages and design techniques, specifications, design, coding, verification, documentation and maintenance of programs.

In addition, in the context of the laboratory exercises, a detailed presentation is made concerning:

- Python introductory components, installation on different operating systems, sequential, selection, range function, and repetition algorithms (for, while) through examples and exercises, data structures (lists, tuples, sets, dictionaries), strings, with a further description of the operators, functions and methods associated with them, functions, function syntax, parameters and variables,
- Python libraries – modules, object-oriented programming, objects and classes,
- Graphical User Interfaces using Python.

Thermodynamics 7225

Basic Principles and Definitions. Types of Energy. Thermodynamic properties of pure substances. Equations of State. Introduction into the first law of thermodynamics. Heat and work. Specific heats. Introduction into the second law of thermodynamics.

Heating engines, cooling engines and heat pumps. Reversible and irreversible Processes. Reversible operation engines. Entropy. TdS equations.

Mathematics II 7072

Euclidean space Rn, limit and continuity of functions of several variables. Differential Calculus: Differentiability of functions of several variables. Differential of a function. The differential operator's grad, div, rot. Taylor expansion. Implicit functions. Extrema. Integral Calculus: Double, triple, line and surface integrals and applications. Vector Calculus. Practical computational exercises.

Engineering Economics 7286

The course is related to the application of economic principles in decision analysis for engineering problems. Initially, it focuses on the field of microeconomics, as it concerns the behavior of individuals and businesses in decision-making regarding the allocation of limited resources. Also, the course discusses basic accounting and costing issues (e.g. balance sheets and fiscal results, break-even analysis, profit maximization, cost estimation techniques, etc.). By nature, the course combines a simplified application of microeconomic theory with practical engineering applications. It is grounded in the logical framework of economics while also adding the analytical strength of mathematics and statistics. Finally, the course aims to introduce students to the basic concepts and techniques of economic project analysis and economic decision-making (e.g., time value of money, inflation, present and future value of money, cash flow analysis, Net Present Value, Internal Rate of Return, etc.).

Physics II – Electromagnetism and Optics 7253

The course is the first contact of the student with the concepts of electromagnetism (E/M) and optics. The course aims at introducing students to the basic properties of electromagnetic fields in terms of both their static form and their dependence on their respective sources, charges and currents, as well as the E/M interactions when the fields are time dependent and charges or current carrying wires are moving in magnetic fields. At the same time, through the properties of the Electromagnetic Field, the students are familiarized with the use of analytical mathematical tools (integral and differential calculus), through the formulation of laws of the electromagnetic field (Maxwell's laws), and through their applications to elementary Electrostatic- Electro-Induction problems and the introductory description of the E/M waves.

Finally, a small part of the course is devoted to introducing students to geometric and wave optics.

- Electric Charge – Field: Electric Field Properties / Dielectric and Conductors / Induced Charge / Coulomb Law / Electric Field Lines / Motion of charge in Electric Field / Electric Dipole
- Electrostatic Field – Vector Description: Electric Field Flow / Gauss Law / Electric Fields in Conductors
- Electrostatic field – Scalar description: Electrostatic Energy and Potential / Equipotential surface / Poisson and Laplace Laws

- Capacity and Dielectrics: Capacitors and Capacity / Electrostatic Energy Storage / Dielectrics
- Current – Conductivity – Electric Power: Electricity and Current Density / Conductivity and Resistance / Metal Resistance and Ohm law / Power Sources / Energy and Power in Electrical Circuits
- Static Magnetic Field: Magnetism – Natural Magnets – Magnetic Dipole / Magnetic Field and Magnetic Flow / Generation of Magnetic Field by Electric Current / Gauss Law in Magnetism
- Magnetic Forces (Lorenz): Electric charge in magnetic field / Forces on current carrying wires in magnetic field / Strength and Torque in current carrying loop.
- Magnetic Fields: Magnetic field generated by steady currents (Biot / Savart) / magnetic field of current carrying linear conductors and circular loops / Force between Two Parallel current carrying wires
- Ampere Law: Ampere Law and applications (Magnetic field of current carrying conductors: linear, circular coil, solenoid and toroidal coil)
- Magnetic Fields in Matter: Magnetic Materials and Magnetic Susceptibility / Paramagnetism – Ferromagnetism – Diamagnetism / Electromagnets and solenoids
- Electromagnetic Induction: Induced emf / Faraday law, Lenz law – Self-Induction and Storage of Magnetostatic Energy / Induced emf of Moving Conductor in magnetic field / Inductive Electric Fields / Displacement Current and Maxwell's Equations
- Geometric Optics: Reflection / Refraction (Snell's Law) / Total Internal Reflection / Optical Spectrum / Optical Instruments / Spectroscopes

Principles of Nanotechnology and Electron Microscopy 7273

This module represents an essential Introductory module to the principles of nanotechnology and characterization of materials via electron microscopy and microanalysis techniques.

Applications of nanotechnology and nanomaterials

- Introduction to concepts and phenomena that govern nanoscale.
- Categorisation of materials based on their properties and their characterisation with advanced Electron Microscopy
- Techniques.
- Laws that govern nanostructures and nanomaterials and elements of design and production of nanomaterials and nanofibers.
- Processes and Techniques for fabricating nanomaterials.
- Elements of Electron Microscopy: Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy,
- Electron Backscattering Diffraction, Auger Spectroscopy, Energy Dispersive X-Ray Spectroscopy, Wavelength Dispersive

- Spectroscopy, Raman Spectroscopy.
- Properties of Nanomaterials
- Mechanical, Electrical (conductors-semiconductors), Magnetic, Thermal and Optical Properties.

Principles of Production Organization – Project Management 7297

- Productive systems -, Types and Classification of enterprises-Operating Environment –Goals Setting- Organizational Systems of Productive Activities-Job Description, Key Performance Indicators, (KPIs), Sustainable Development Indicators, (SDIs).
- Introduction to Project Management, Project Life Cycle, Critical Parameters, Feasibility Study. Project Evaluation, Project Selection, Planning and Control Cycle, Critical Path Method, Time Planning, Resource Allocation, Project Cash Flow, Project Control, Earned Value, Quality Control, Risk Management, Communication, Team Building, Leadership, Software tools for Project Management.

Introduction to the Electric and Electronic Systems 7196

The course includes the basic elements of electronic systems in production and services, specifically sensors, microcontrollers, and devices. Upon successful completion of the course, the student will be able to:

- Characterize an electronic device using appropriate measuring instruments
- Solve a simple electrical circuit
- Program a microcontroller

Course contents:

- Electronic components
- Laboratory instruments
- Electronic system components: R, L, C, amplifiers etc.
- Solving basic electrical circuits
- Sensors: position, magnetic field, force, temperature
- Microcontrollers. Example: Arduino

Geographic Information Systems – GIS 7215

This course guides student to the understanding of the principles of Geographic Information Systems (GIS) and its integrated application in environmental and mining applications. The acquisition, modelling, analysis and presentation of geodata have been done in such a way as to bring the student in contact with typical geoapplications and is of particular importance for the modern Mining Engineer. The course besides the theoretical lectures runs a semester modular lab project using GIS software tools.

Introduction to GIS, history of GIS, representation of reality, spatial objects and relations, data sources and acquisition methods, spatial models and data structures,

fields and entities, topology, 2.5D and 3D modelling, elements of spatial databases, georeferencing and coordinate transformation, principles of spatial analysis, visualization, GIS applications in geosciences.

Artificial Intelligence and Machine Learning Algorithms 7293

Development and principles of Machine Learning. Machine Learning Techniques, supervised/ unsupervised learning, Baeysian networks, Fuzzy logic, Decision Trees, Support Vector Machine, Artificial neural networks, Deep learning, Dataset selection and development, Normalisation, ML development with the use of Python, R and Matlab, Performance assessment of ML models, Overfitting issues, ML cases studies in mining and metallurgical applications.

English Language & Terminology 7082

This course is designed to combine technical terminology with the development of effective communication skills, particularly in writing. It integrates key topics, such as minerals and rocks, inorganic chemistry, materials engineering and transport phenomena such as fluid mechanics and heat and mass transfer. Alongside this, the course hones academic writing skills, focusing on core skills, such as synthesising information and citing sources, defining and clarifying technical concepts, and constructing critical sections of research papers and Diploma theses, such as abstracts and introductions. Through hands-on activities, collaborative assignments and analysis of research papers, this course ensures that students are well-prepared to communicate complex concepts in their field effectively and confidently in both academic and professional settings.

3rd Semester

Basic principles for Materials and Energy Management in the Production Chains 7230

The basic scope of the course is the studying and the performance of fundamental calculations related to the processing of raw materials, intermediate products and byproducts which will be used for the production of end-products and energy. The chemical and metallurgical processes which are taking place within the framework of mining and metallurgical activities (in the laboratory, in the industry and in the environment) are directly related to the mass and energy consumption. The estimation of the mass and energy required for the realization of a physical or chemical process presents a specific significance as it determines the cost of the raw and final materials. Therefore, the mass and energy consumption are the most important indicator for the evaluation of the environmental impact and it is widely used for the quantification of this impact through the methodology of “life cycle assessment”. At the same time, the scope of the course is the comprehension of the combustion theory and the conversion of the chemical energy and the fuels to thermal energy. Various types of combustion reactors and types of fuels (coal, petroleum, natural gas, biofuels and “green mixtures”) are studied.

- Physicochemical properties and their measurement units
- Fundamental principles of the chemical and metallurgical engineering

- Chemical equations and balance
- Chemical reactions. Degree of chemical reaction progress. Degree of reactants conversation
- Raw materials and final products
- Physical and chemical processes. Processes flows. Flow sheet diagrams
- Fundamental principles of mass balances. Principle of conservation of energy in open systems. Total mass balance (chemical element and chemical compound in a system without or with the realization of a chemical reaction)
- Methodology for the solving of mass balances Fundamental principles of energy balances. Basic terms. Energy balance in a closed system. Specific heat under constant pressure. Enthalpy of chemical reactions. Co-generation of heat and work
- General equation of the energy balance. Energy rate introduced in the system. Energy rate exit by the system. Energy conversion rate into the system.
- Combustion theory, conversion of fuels chemical energy to thermal energy, type of combustion reactors
- Fuels and calorific value (coal, petroleum, natural gas, biofuels and "green mixtures")

Ore Deposit Geology 7005

The basic concepts of ore deposit geology and mineral resources are introduced, including general description and major features (e.g., major commodities, by-products, ore mineralogy and chemistry, ore grades, reserves, the lithologic, geologic and geotectonic setting, and methodologies of exploitation and ore processing). The contemporary classification schemes are discussed, mainly focused on those types present in Greece, as well as the most important ore deposit types around the world. Moreover, case specific samples are studied in both macroscopic and microscopic scale, and ore deposit maps are studied/read/designed. The final goal of the course is the understanding of the importance of ore deposit exploration and the successful communication between mining and processing engineers with geologists.

Mathematics III (ordinary differential equations) 7229

Mathematics III is the course which includes the study of:

- First Order Differential Equations (solve first order differential equations which are exact, separable, homogeneous, linear, Bernoulli or Riccati, understand the existence and uniqueness theorem),
- Higher Order Linear Differential Equations (understand the general theory, solve higher order differential equations with constant coefficients, apply the methods of undetermined coefficients and variation of parameters, solve higher order differential equations with series),

- Laplace transforms (solve higher order differential equations with constant coefficients especially in the case where the inhomogeneous part is expressed as a Heaviside of a Dirac function, understand and apply convolution theorem),
- First Order System of Linear Ordinary Differential Equations (understand the general theory, solve a system using the eigenvalues and the eigenvectors of a matrix, apply the methods of undetermined coefficients and variation of parameters),
- Fourier series.

Technical Mechanics – Statics 7049

Vectors. Forces, Moments, Distributed Loads, Centers of Mass. Kinematic Degrees of Freedom, Supports Types. Free Body diagrams, Equilibrium Equations, 2-D and 3-D Applications. Internal Forces and Moments. Gerber Beam. Trusses, Solution Methods of Joints and Ritter Sections. Beams and Frames, Diagrams of Axial Forces, Shear Forces and Bending Moment, (M, N, Q, M diagrams). Cables. Friction. Virtual Work

Hydrogeology 7294

The content of this course refers to: (i) Principles and process within the hydrologic cycle (surface and unsaturated zone), (ii) hydrogeological systems (aquifer types, hydrogeological basins), (iii) Groundwater hydrology and hydraulics, (iv) fundamental principles of karst hydrology, (v) Groundwater chemistry (interpretation and visualization of hydrochemical results), (vi) Coastal hydrogeology (basic principles of coastal groundwater flow, hydrogeochemistry and seawater intrusion, ion exchange phenomena), (vii) Principles of groundwater modeling (introduction to groundwater modeling, conceptualization, principles of groundwater flow and contaminant transport modeling, computer codes).

Analytical Chemistry and Physical Methods of Analysis 7232

Analytical Chemistry (Classical Chemical Analysis). Acid base equilibria: Acid base titrations. Complex equilibria: Complexiметric titrations. Oxidation Reduction equilibria (Redox equilibria): Redox titrations. Heterogeneous equilibria: Precipitation titrations. Gravimetric Analysis. Qualitative identification chemical tests for characteristic cations and anions in aqueous solutions. Identification chemical tests of characteristic gases.

Physical Methods of Analysis (Instrumental Methods of chemical Analysis). Applied methods and techniques for quantitative analysis in aqueous solutions. Optical Methods: Ultraviolet and Visible Spectrometry UV-VIS. Atomic Absorption Spectrometry AAS. Emission flame photometry FF. X-Ray Diffraction Spectrometry. Thermal methods: Thermobarimetric Analysis TGA- Differential Thermobarimetric Analysis DTG- Differential Scanning Calorimetry DSC. Chromatographic Methods: Gas Chromatography.

Numerical Analysis 7227

The course aims at acquiring the knowledge for: The solution of systems of linear equations, non-linear algebraic equations, ordinary differential equations, interpolation and approximation of data and numerical approximation of integrals.

The aim of the course is to understand the importance of numerical methods for solving scientific and technological problems for which either there is no analytical solution or it is very difficult to calculate it.

On completion of this course, students should be armed with numerical and computational techniques for solving a wide variety of fundamental mathematical problems that arise in various scientific areas.

- Number representation in computers.
- Linear systems: Direct methods (Gauss, factorization methods). Stability of linear systems. Iterative methods (Jacobi, Gauss-Seidel), calculation of eigenvalues.
- Solving non-linear equations: Bisection, fixed point iteration, Newton-Raphson, secant methods. Newton method for nonlinear systems.
- Interpolation: Polynomial interpolation in Lagrange and Newton form and interpolation error.
- Numerical integration: Newton-Cotes formulas, simple and composite trapezoidal and Simpson integration rules.
- Differential equations: Initial value problems for ordinary differential equations. Single step methods (Euler, Taylor, Runge-Kutta). Multi-step methods (Adams, predictor-corrector methods). Boundary value problems, Finite difference method.
- Approximation theory: Discrete least squares, polynomial and exponential approximation.

Operations Research and Decision Analysis 7063

- Subject matter and methodology: background, form and definition of Operations Research (OR), key features, problem categories, related disciplines, application of OR. The concept of mathematical optimization and its extensions in the sciences of Engineering.
- Linear Programming (LP): introduction, formulation of the general model of LP, mathematical modeling of problems, graphical solution of LP problems, solution of LP problems with the help of Microsoft EXCEL™ and Solver. Special LP problems: the Transportation problem, the Assignment problem, the Resource Allocation problem.
- Integer, Separable and Non-Linear Programming: introduction, problem solving with graphical method as well as with the help of EXCEL™ and Solver. Use of Integral Binary Programming to formulate decision problems. The Dual Problem and Sensitivity Analysis. Working with Random Variables and Monte Carlo simulation.

Elements of Mechanical Design 7133

This course introduces students to all key ideas related to the design and construction of mechanical systems encountered in the field of Mining and Metallurgical engineering. It aims at providing knowledge on the principles of kinetics, dynamics and thermodynamics which are utilized to design, develop and optimize complex

mechanical systems at the field and at the plant. The topics presented cover bolts and nuts, gears, clutches, shafts and bearings, hydraulic and pneumatic systems, pumps, internal combustion engines, heating and cooling.

Computer Aided Design – Mechanical Design 7226

This course introduces students to designing parts and structures which are interest to Mining and Metallurgical engineers. The basic design principles are discussed and implemented using LibreCAD. Drawing, adding dimensions, considering auxiliary and hidden lines, viewing of 2D and 3D objects are presented.

Students are evaluated by preparing a drawing and submitting it in an electronic format.

4th Semester

Transport phenomena Principles 7274

The main objective of the course is to familiarize the students with the principles of momentum, mass and heat transport phenomena.

Topics to be covered include:

- Introduction to Transport phenomena. Basic concepts. Equilibrium and rate processes. Simple material and energy balances.
- Molecular transport mechanisms. Examples of molecular transport processes include heat conduction (energy transfer), molecular diffusion (mass transfer), and fluid flow (momentum transfer). The analogy between heat, mass and momentum transfer. Fourier, Fick and Newton Laws. The one-dimensional transport equations. Transport properties (thermal conductivity, diffusivity, viscosity).
- The conservation concept. Input-output balance, generation, accumulation. The general balance equation in differential form. The continuity equation.
- Molecular transport under steady state conditions (one direction transfer problems). Heat and mass transfer without or with a constant generation term. Momentum transfer with generation terms (fluid flow under pressure gradients and gravitational fields). Laminar flow in a tube. Laminar flow between parallel plates. Introduction to tubular flow.
- Transport with Net Convective Flux. Review of convection. Simple heat and mass transfer problems with convection. The Navier-Stokes equations for incompressible fluids. Mass diffusion phenomena (binary mass diffusion in gases and liquids, diffusion in solids).
- Integral methods of analysis. Integral mass balance, mass balance of individual species, momentum balance, energy balance. Bernoulli equation. Fluid statics (manometers).
- Dimensional analysis. Meaning and use of dimensionless numbers. Reynolds, Peclet, Prandtl, Schmidt, Nusselt, Sherwood numbers, etc. Rayleigh Method of Analysis.

Introduction to Environmental Science & Engineering 7258

This is an introductory course with a series of lectures in the area of ecosystems focusing on the water and air as environmental resources amenable to pollution. The course provides essential background knowledge in the mining and metallurgical engineering in the topics of environmental pollution. Specifically, it focuses on the sources of particulate air pollution and CO2 emissions from the energy production sector and the industrial mining activities as well as on the sources of air pollution from the metallurgical industry.

One of the main objectives of the course is the introduction of the students to the principles and functions of the ecosystems by presenting the main elements cycles (e.g. carbon, nitrogen, sulfur and phosphorus) with particular focus on the increased carbon emissions which causes the greenhouse effect and other global level climate change phenomena.

The role and the function of the aquatic ecosystems and the atmospheric environment are presented and analyzed. The students are familiarized with air and water quality parameters in terms of pollution sources, pollution dispersion and pollution effects to the humans and the environment. The course is also focused on the pollution of water bodies with organic discharges and presents the basic monitoring parameters such as the dissolved oxygen, the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD). These monitoring parameters are explained in the lectures as well as with laboratory practices. At the field of air pollution, the students are familiarized with the concept of the point and dispersed pollution sources for gaseous and particulate pollutants. The importance of particulate materials in terms of size and composition in human health and the environment is presented. Pollution dispersion models are taught by tutorials with simulation software.

By completion of this course the students should have acquired the skills to identify/describe:

- The role and the function of the ecosystems on the environment.
- The cycle of the fundamental elements in the environment.
- The pollution sources and the chemical pollutants in the atmospheric and aquatic environment
- Large scale environmental problems such as the greenhouse effect and the global warming.
- The effect of specific pollutants and assess their impact in the environment.
- Identify the industrial activities producing airborne particulate material.
- Identify the significance of the airborne particulate material according to their size and composition.
- Compute with pollution dispersion models the transport of the pollutants in the environment.
- Evaluate data from environmental sampling and monitoring campaigns.
- Acquire basic laboratory skills for measuring water quality parameters such as the dissolved oxygen, the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD).

- Acquire basic laboratory skills for applying air sampling protocols for the measurement of the particulate maters in air samples.

Probability Theory & Statistics 7088

Descriptive statistics. Probability: definitions, laws and properties. Conditional probability. Independent events. Total probability. Bayes' theorem. Random variables and their distributions. Mean and variance and their properties. Important basic distributions. Bivariate random variables. Central limit theorem. Sampling distributions: $\chi 2$, t and F. Point estimation, confidence intervals and tests of hypotheses. The linear model: estimation and tests on parameters, coefficient of determination (R2), prediction. Applications using computers. Laboratory exercises.

Subsurface exploration methods – Mineral exploration 7104

Basic elements, definition and procedure of mineral exploration. Investments and financial risk, expected payoff value, decision analysis, decision trees, value of information, Bayesian statistics. Exploitability of deposits and ore reserve categories, economic feasibility of exploitation, economic indicators, net present value.

Indirect exploration methods: gravitational, magnetic and electromagnetic method, design and execution of geophysical field measurements, elaboration, interpretation and development of subsoil models, correlation of geophysical results, applications in mineral research.

Direct exploration methods: Drill hole sampling, drilling rigs, rotary drilling, mechanical equipment, drilling parameters, sample collectors, soil pickers, standardization. Sampling and statistical population: sampling error, graphical solution of the problem of sample processing. Design of an exploration drilling campaign: calculation of detection probabilities with grids of different dimensions, number of drillings and degree of certainty, calculation and control of statistical parameters and confidence intervals of the results.

Ore reserves estimation: data accumulation and storage, numerical model of the deposit, cut-off grade, estimation by conventional and by geostatistical methods. Evaluation of the investment plan, mine operation life and production capacity, initial amount of investment, operating costs, expected cash flow, environmental impact assessment, feasibility study, cash flow table.

Technical Mechanics II – Strength of materials 7094

Stresses, Normal and Shear Stresses, The Tensor of Stresses. Plane Stress State. Equilibrium equations. Rotated Axes. Principal Axes and Principal Stresses. Mohr's Circle. Strains, Normal and Shear Strains, Deformation Analysis. Plane Strain State. Principal Strains. Bulk Modulus. Generalized Hook's Law.

Axial Loads, Statically Determinate and Indeterminate Frameworks. Moments of Inertia, The Tensor of Moments of Inertia, Principal Axes of Moments of Inertia. Torsion of Cylindrical Beams, Elastic and Elastoplastic Behavior. Pure Bending of elastic beams with symmetric cross section. Eccentric Axial Loading, Neutral Axis, Core of a cross Section. Elastic curve. Castiglianos' Theorem. Shear Stresses in Beams. Shear Stresses in beams of Thin-walled Cross Sections. Shear Centre of Thin-walled Open Sections. Failure Criteria of Materials.

The description of this course is provided in the 2nd-semester section. Students may choose these specific courses in either the 2nd or 4th semester.

Principles of Nanotechnology and Electron Microscopy 7273

Principles of Production Organization – Project Management 7297

Introduction to the Electric and Electronic Systems 7196

Geographic Information Systems – GIS 7215

Artificial Intelligence and Machine Learning Algorithms 7293

English Language and Terminology 7082

5th Semester

High Temperature Processing 7012

The subject of the extractive metallurgy is related to the study of various processes and combination of processes for the extraction of metallurgical products by raw materials and, as well as, to the selection of the required chemicals. The combination of processes that configure the metallurgical methodology depends on the nature of the reactants and the type of the end metallurgical product. The metallurgical processes are classified into: pyro metallurgical, hydrometallurgical and electrolytic. The aim of the High Temperature Processing course is the teaching of the general principles of the extractive metallurgy the pyrometallurgy. A background on chemistry, physics and physiochemistry is necessary for the course comprehension.

Introduction to the extractive metallurgy

– Metallurgical raw materials and end-products

– Ores

– Categories of metallurgical processes

Balancing of chemical equations

Ellingham diagrams

Reduction of metal oxides

Reactions of sulfides

Pyrometallurgical processes-pyrometallurgical reactors

Drying

Calcination

Roasting

Smelting

Solid fuels

Introduction to Physical Metallurgy 7228

This module represents the essential introductory module to the principles of physical metallurgy providing essential knowledge on metallic materials. Principles of Materials Selection. The role of the Engineer in selecting materials for the design of Engineering applications. Main characteristics and properties of metallic materials. Atomic bonding and crystalline structure of metals. Solidification of metals. Metallographic techniques. Light optical, electron microscopy and microanalysis. Investigation Of crystalline structures with Xray diffraction. Defect theory in crystalline solids and Dislocation theory. Work hardening, recovery and recrystallisation, grain boundaries and grain boundary mobility, speroidisation. Mechanism of hardening in metals. Elastic and plastic behavior in metals. Correlation of mechanical properties with Schimdt's Law. Fracture and elements of Fracture mechanics. Crack propagation. Introduction to Griffith's theory. Elements of Fractography. Toughness and ductile to brittle transition. Fatigue. Creep, Corrosion and High Temperature Oxidation. Wear and lubrication.

Mechanical Preparation and Processing of Minerals I 7210

Introduction, Mineral liberation, Separation Flow Sheets, Mathematical Expression of Separation Results – Exercises, Comminution (crushers, tumbling mills): Principles, equipment, laws-calculations, and circuits, Classification: industrial screens, hydroclassifiers, air classifiers, cyclones, size distribution functions, Concentration Methods and Equipment: Attrition and Scrubbing, Sorting, Heavy Media, Jigging, Tabling, Spiral Concentration, Air-Separation.

Surface Mine Exploitation 7233

The course introduces the basic concepts related to surface mining. The main categories and the basic definitions of the surface mining are described, the basic characteristics of surface mining exploitation are analyzed and the basic mining methods (rock blasting and mechanical excavation) are presented.

- Brief presentation of the Greek mineral wealth and the most important surface mines.
- Basic mining terminology. Methods of exploitation: distinction between surface and underground mining. Factors influencing the selection of exploitation method, Selection criteria.
- Determination of pit limits. Surface mining methods. Fields of application of surface mining methods based on the type of ore deposit.
- Continuous and conventional mining methods.
- Rock blasting excavation in surface mining operations
- Mechanical rock excavation in surface mining operations

Principles and Applications of Biotechnology 7272

The principles of biotechnology are presented in the context of the mechanisms of interactions between microorganisms (microbial biomass) and the metals. The mechanisms of biogeochemistry in natural habitats may be used for the development of environmentally friendly technologies. The interactions and roles of microorganisms with carbon, sulfur, nitrogen and phosphorus cycles as well as with those of selected elements such as iron, manganese arsenic and selenium are initially presented and discussed. More specifically, after the presentation of the microbially mediated transformations of metal species such as bioprecipitation, bioreduction and biooxidation, their potential applications in a number of processes follow. The course includes laboratory exercises aiming at the deeper understanding of the processes and the achievement of skills on the experimental study of the interactions between metals and microbial biomass and their applications in environmental technology, metallurgy and materials engineering.

- Environmental biotechnology principles: The lithosphere and the hydrosphere as microbial habitats.
- The microbial metabolism. Biochemical processes.
- Energy production by the microbial cell (Bioenergetics).
- The biochemical reaction/methodology of writing a biochemical reaction.
- The sequence of microbial interactions in relation to the terminal electron acceptor: Oxygen-aerobic metabolism. Nitrogen-Denitrification
- Manganese-Mn reduction. Iron-Fe reduction. Sulfur-SO_4^{2-} reduction
- Geomicrobiology of carbon, nitrogen, sulfur and phosphorus.
- Geomicrobiology of iron, manganese, arsenic and selenium.
- Cell surface reactivity and metal interactions:
- Cell surface structure. The charge of the cell surface. Acid-base reactions in the cell surface. Electrophoretic mobility.
- Biosorption of metals. Modeling. Sorption isotherms (Freundlich, Langmuir), complexation on the cell surface.
- Interactions of metals and microbial biomass by metabolically active cultures. The role of microorganisms in the mobility of metals.
- Bioremediation for metals sequestering from wastes and Biorecovery of metals.
- Biosynthesis (biomineralization – biological induced mineralization). Microbially mediated formation of nuclei and crystal growth (mineral nucleation and growth). Biotransformation of iron species: iron hydroxides/ magnetite. Biotransformations of manganese oxides. Biotransformations of carbonates, phosphates and sulfur species. Characterization and applications of the materials formed by the above mechanisms.
- Microbial weathering.

- Biochemical reactions in the surface of ores. Decomposition of silicates and carbonates in minerals and ores. Biooxidation of sulfide ores. Bioleaching.

Geodynamics – Geology of Greece 7231

The course is an advanced study in geodynamics and geotectonics, with a focus on geodynamic processes specific to the broader Greek region. Students are acquainted with the dynamic processes that affect rocks and shape the architecture (tectonic structure) of the Earth's crust on all scales. Beyond the substantial theoretical interest for students looking to deepen their knowledge in geology, geodynamic processes and the resulting tectonic structure are fundamental regulators of the Earth's crust, making the latter a system of prosperity as well as one of potential destruction. This course aims to deepen students' understanding of the mechanisms driving the dynamic evolution of the lithosphere and its tectonic structure, which create favorable geological conditions for mining exploration. Special emphasis is given to the geodynamic and tectonic geology of Greece, unique on a global scale in terms of its geotectonics and the distinct mining and other conditions that it establishes.

Applied & Environmental Mineralogy 7155

Industrial rocks and minerals of Greece. Clay minerals in cement industry. Minerals in color industry. Minerals in paper industry. Ore mineralogy and its importance on mineral beneficiation processes. Sedimentary mineralogy with emphasis on the mineralogy of marine sediments.

Introduction to Environmental Mineralogy. Minerals and natural ecosystems. Mineralogy of anthropogenic environment. Environmental toxicity of minerals. Acid-generating and acid-consuming minerals. Soil mineralogy in industrial, with emphasis placed on mining, areas. Geogenic-anthropogenic interaction fingerprint on soil mineralogy. Asbestos and asbestiform minerals. CO_2 mineralization.

Computational Chemical Thermodynamics 7296

The course aims to familiarize students with the various computational chemical thermodynamics tools (HSC, FACTSAGE) which are used for the analysis of complex and multiphase metallurgical systems. The way of calculating the basic thermodynamic quantities is analyzed, the chemical potential of each component of a metallurgical system is defined and the way of determining the equilibrium state is analyzed through the principle of minimization of the free energy of the system. Then, with the use of appropriate computational tools, hydro-, pyro- and electro-metallurgical systems are studied and their energetic and exergetic analysis is performed.

The course include: Introduction to computational thermodynamics, Basic concepts and calculation of basic thermodynamic quantities (Enthalpy, Entropy, Heat capacity, Gibbs free energy, Exergy), Determination of chemical equilibrium state (Chemical potential, Principle of free energy minimization), Applications with HSC & FACTSAGE including a) Thermodynamic analysis of aqueous systems – Hydrometallurgy (Extraction, Precipitation & crystallization, Dissolution of gases), b) Thermodynamic analysis of high temperature systems – Pyrometallurgy (Roasting, Smelting systems, Thermal decomposition), c) Thermodynamic analysis of electrochemical systems (Pourbaix diagrams) and d) Energy & Exergy analysis of simple systems.

Solid State Physicochemistry 7150

The aim of the course is to understand the fundamental relationships that exist between structure, properties, processing and final performance of materials. Emphasis will also be placed on the study of the effect (description of phenomena/mechanisms) of the external environment (stress, wear....) on the fundamental characteristics of materials at the micro- and macro-structural level.

The course will focus on fundamental concepts-phenomena-processes that stem from the structure (Atomic structure and interatomic bonding in solids. Structure of crystalline and amorphous solids. Elementary theory of energy band structures in solids. Electrons and holes in semiconductors. Surface properties of solids-surface tension, chemical activity. Diffusion in crystalline solids. Ionic conductivity. Solid electrolytes). The ultimate goal will be to understand the macroscopic properties (mechanical, thermal, electrical, magnetic, optical, rheological, surface) of the solid phase (crystalline, amorphous solids) at microscopic and nanoscopic level and the effect of external conditions on them as well as to investigate the structure-properties relationship.

Understanding this relationship is the basis for all areas of materials (metallurgy, surface treatments, microelectronics, sensors, optoelectronics, biomedical technology).

- Atomic structure and interatomic bonding in solids. Potential energy functions.
- Structure of crystalline and amorphous solids.
- Structure of crystalline and amorphous solids (continued).
- Elementary theory of energy band structures. Electrons and holes in the semiconductors. Types of semiconductors.
- Surface properties of solids – surface tension, chemical activity.
- Diffusion in crystalline solids.
- Ionic conductivity. Solid electrolytes.
- Understanding of the macroscopic properties of the solid phase (in crystalline, amorphous solids) at microscopic and nanoscopic level and of the effect of external conditions on them. Structure-properties- performance correlations.
- Mechanical properties.
- Mechanical properties (continued).
- Thermal properties
- Electrical/ magnetic properties
- Optical properties
- Rheological, surface properties

The description of this course is provided in the 3rd-semester section. Students may choose these specific courses in either the 3rd or 5th semester.

Analytical Chemistry and Physical Methods of Analysis 7232

Numerical Analysis 7227

Operations Research and Decision Analysis 7063

Elements of Mechanical Design 7133

Computer Aided Design – Mechanical Design 7226

6th Semester

Physical Metallurgy – The Alloys 7151

This module represents the essential introductory module to the principles of physical metallurgy providing essential knowledge on alloy systems. Solid Phases in Metallic Systems. Definition of solid solutions/ alloys. Crystalline structure, microstructure and physical properties of ferrous alloys. Metastable Phase Diagram of Iron-Cementite. Steels and Cast Irons. Non-Equilibrium Phase Transformations. TTT and CCT plots. Precipitation Reactions, examples from Aluminium Alloys. Study of various Alloy systems.

Mechanical Preparation and Processing of Minerals II 7173

Magnetic and Electrostatic Concentration, Flotation, Thickening, Filtration, Pelletizing and Briquetting, Feeding and Transportation, Pumping, Sampling, Control, Flow Sheets, Tailing Deposition, Solid Waste Recycling. Laboratory Training: Classification, Sampling, Liberation, Jigging, Tabling, Heavy Liquid analysis, Magnetic Separation, Flotation, Thickening, Filtration.

Practical Training I 7237

Practical Training I, PTI consists a compulsory course of the 6th semester of the Curriculum of the School of Mining and Metallurgical Engineering, NTUA. PT I is conducted in the summer period, following the completion of the 6th semester, and has an average duration of 10 calendar days.

During Practical Training I groups of twenty students visit a number, 6-7, mining and metallurgical sites based on a detailed plan prepared by the Scientific Coordinator. These industrial facilities mainly located at the Greek periphery include activities related to the thematic areas of the School of Mining and Metallurgical Engineering curriculum, e.g. Mines, Quarries, Metallurgical Plants, Metal Recycling Plants etc.

Following the completion of Practical Training I, the students prepare a Technical Report where one of the industrial sites visited is presented. In this report main features of the company are given including location, process facilities, main products, economic data, environmental performance etc. The Report is submitted and evaluated by the Scientific Coordinator of PTI.

Engineering Geology – Geohazards 7092

Geotechnical properties of the geological formations, Engineering Geological – Geotechnical investigation techniques (Drilling, Sampling, Lab & In situ testing) Engineering Geological – Geotechnical properties of the geological formations of Greece, Geohazards: Landslides and Land Subsidence phenomena (mechanisms, classification, triggering effect, investigation methods).

Geotechnical Ground improvement technics 7202

Draining techniques, electrokinetic stabilization techniques, frizzing and heating techniques, Compaction and compression techniques (preloading & gravel piles, dynamic compaction, Deep Dynamic Compaction, Rapid Impact Compaction, Vibro Rod, Vibroflotation, Vibro Replacement) grouting (Jet Grouting, Wet Soil Mixing), chemical stabilization techniques, geotextiles, slope retaining constructions (gravity walls, pile walls), rock fall protection systems.

Hydrometallurgical Unit Operations 7066

The aim of the course is to acquire new knowledge and skills on the basic principles and various sub-processes of Hydrometallurgy which is an alternative, and in many cases the main, method applied for the extraction of metals from ores and secondary raw materials with low environmental footprint and low energy consumption. It includes the following main parts:

- History of Hydrometallurgy – Introductory data (ancient and modern history of hydrometallurgy, basic flow chart of hydrometallurgical processes, applications of hydrometallurgy, introductory elements for extraction, means, types and extraction techniques)
- Preparation/pretreatment of Raw Materials for Hydrometallurgical Processing
- Basic principles of extraction/leaching (aim, basic parameters, solid-liquid heterogeneous reactions, equilibrium-complexation-speciation in aqueous phase and solid-liquid interface, influence of major factors such as pH, redox potential and composition aqueous solution and in extraction, kinetics, models and mechanisms of heterogeneous reactions, stability diagrams, extractants (acids, bases, salts), types of extraction reactions).
- Tank reactors (agents, sizing, equipment, layout and applications).
- Autoclaves (types, environments, modes of operation, equipment, examples).
- In situ, heap and vat leaching (techniques, wells construction, pile construction techniques, types of bases, law permeability layers, equipment, examples).
- Bioleaching (historical background, types of microorganisms, bacteria for bioleaching, growth phases, operation in heaps and stirred reactors, mechanisms).
- Chemical precipitation for solution purification and metal recovery (principle, mechanism (supersaturation, nucleation, crystal growth), sediment aging, precipitation and its mechanisms (sorption, solid solution formation, inclusion), filtration properties, equipment, examples)
- Solvent extraction for separation of metals and purification of solution (organic-aqueous phase, mechanisms of extraction of a metal in the organic phase, distribution of metals, extraction-scrubbing-stripping phases, equipment and extraction calculations in a continuous system, applications)
- Export of metals by ion exchange (general principles, categories of ion exchangers, methods and equipment, examples
- Electrolysis (general principles for electrolysis / refining of metals, elements and principles, equipment and technology, case studies)

Corrosion and Protection of Metallic Materials 7277

The course is an introduction to the basic principles of Electrochemistry, Corrosion and Protection of Metallic Materials.

The student will acquire skills, knowledge and understanding in:

1) The basic principles of electrochemistry

2) The basic principles and the effects of corrosion

3) The effect of various parameters on corrosion

4) The different corrosion types and the ways of avoiding and dealing with them

5) The principles governing the basic corrosion tests

6) The distinct differences between anodic and cathodic protection

The course contains the background knowledge for understanding various corrosion processes, protection methods and materials selection with practical examples. It covers the aspects of:

- Electrochemical basis of corrosion, Thermodynamics, Potential-pH diagrams.
- Kinetics of corrosion reactions: Polarisation curves, mixed potential theory, passivity, effect of mass transfer.
- Types, mechanisms, causes and propagation of corrosion.
- Effect of metallurgical, mechanical, microbiological and environmental factors.
- Quantitative estimation of corrosion rates.
- Description of mechanisms for types of corrosion for different metal and environment combinations, with special focus on important structural materials.
- Corrosion protection: Electrochemical methods, inhibitors, surface treatment, effect of material properties, materials selection, design.
- Corrosion properties of important construction materials.
- Test methods. Measurement and monitoring of corrosion. Corrosion Management including corrosion monitoring.

Elements of Reinforced Concrete and Steel Structures 7145

Introduction to structural design. Modern European structural codes. Basis of Design. Ultimate and serviceability limit states. Loads and load combinations. Partial safety factors. Design checks. Design material properties of concrete, reinforcing steel and structural steel.

Reinforced concrete sections in bending. M-N interaction diagrams. Cross-section reinforcement. Second order phenomena. Reinforced concrete sections in shear. Design of reinforced concrete beams, slabs and columns. Durability.

Design of steel structural elements: cross-section classification, design against tensile, bending, shear, compression and combined loading. Axial buckling. Lateral – torsional buckling. Design at serviceability limit state. Design of steel connections.

7th Semester

Health & Safety 7181

The course aims to introduce the students to the basic principles of Occupational Health & Safety, emphasis placed on the Extractive Industry, Mines and Quarries, and the Metallurgical Industries, i.e. covers the whole Raw Materials Life Cycle. The course is organized in separate thematic sections that allow the student

- to get familiarized with the prevailing Health & Safety Legal framework in Greece and EU,
- to recognize the importance of Occupational Risk Assessment for the identification of prevention and mitigation measures and their incorporation in the design and operation of productive activities
- to define and apply the suitable indicators for monitoring safety at work

A significant part of the course relates to training the students in the analysis and synthesis of literature data for the preparation and presentation of reports on selected topics related to Health and Safety in the Mining and Metallurgical Industry.

- Introduction-Basic Concepts- Terminology-Legal Framework- Εισαγωγή – Safety Indicators Occupational Safety Statistics in Greek and EU Level- Data for the Mining and Quarry Sector- Metallurgical Industry-Construction sector
- Common Industrial Risks- -Chemical Risks-Prevention and Mitigation measures
- Explosion Risks- Fires- Prevention and Mitigation measures
- Occupational Risk Assessment- Legal framework, Case studies
- Regulations of Mining and Quarrying Works, (RMQW) & Specific topics on Explosives
- Extractive Waste Management, Legal framework, Classification- Causes of Failure of Extractive Waste Management Facilities-Prevention and Mitigation measures.
- SEVESO Directive –Safety Report
- Health & Safety Plans, (HSP), Health& Safety Files, (HSF), Legal framework, Case studies
- Case studies – Tests – Presentations of Students Reports.
- Lectures of H&S experts from the Industry and Competent authorities.

During the semester and in parallel with the lectures of the specific thematic sections the students have the option to conduct three reports that are submitted within the course progress. The 1st report refers to Safety Statistics and Accidents Analysis, the 2nd report covers sections of the Regulations of Mining and Quarrying Works, whereas the 3nd report covers issues related to Extractive Waste Management or Major Industrial Accidents-SEVESO facilities. The reports are submitted in Word & Power Point formats and are presented in class, physical or virtual.

Applied Environmental Protection 7235

The course presents theoretical concepts and practical approaches to the effects of the mineral resources industry (mining – metallurgy), the major geotechnical projects and the materials industry. The main categories of impacts are analyzed, the available technologies for the protection of the environment are described as well as the conditions for management, treatment and disposal of the gaseous, liquid and solid waste of this activity.

The understanding of the concepts is realized through the presentation and analysis of specific case studies.

A. Impact of mining activity on the environment

- Introduction – Mining activity and environment: Historical background, The current relationship between mining activity and environment. International trends.
- Description and treatment of environmental problems of quarries (industrial minerals and aggregates). Impact on the landscape – Noise – Dust. Case study.
- Description and treatment of environmental problems of marble exploitation. Waste from mining and quarrying. Case study.
- Description and treatment of environmental problems of other ore exploitation types (mixed sulfides, etc.). The acid mine drainage. Case study.
- Description and treatment of environmental problems of lignite exploitation. The restoration of the mining areas. Case study.
- Mining activity and sustainable development in Greece. Perspectives.

B. The importance of environmental protection in metallurgy and materials technology.

The course provides insight on the theoretical aspects and available technologies related to the protection of the environment from the mining and metallurgical activities as well as on the prevailing legislation and methods for management, treatment and disposal of the gaseous, liquid and solid waste resulting from those activities. It includes:

- Air pollution – Control of gaseous emissions: Introductory concepts, relevant legislation, main gaseous emissions in Metallurgy and Materials Technology (dust, SO2, fluorides and chlorides, etc.), Flue gas control technologies (gravitation chamber, cyclons, bag filters, electrostatic precipitators, venture, etc).
- Wastewater treatment: Introductory concepts, sources of pollution, legislation treatment technologies, prediction – prevention – treatment of Acid Mine Drainage, case studies)
- Solid waste: Categories of solid waste, Legislation for the management of solid industrial waste and in particular mining and metallurgical waste, Environmental classification of solid waste (physicochemical parameters, laboratory tests), Classification of non-toxic Configuration of solid waste landfills (bottom sealing, covers), Landfill failures, Stabilization and environmental remediation techniques.
- Environmental protection applications in metallurgy and materials technology

Iron and Steel Metallurgy 7035

The course provides a detailed analysis of the theoretical and technological aspects of the production of sponge iron and cast iron from the respective raw materials as well as the theory and technologies used for the production of steel and iron alloys.

In the theoretical part of the course, the properties of raw materials and auxiliary materials, the physicochemistry of the iron reduction process, the factors that affect the reduction kinetics of iron oxides as well as the technology of ferrous products production are discussed. Emphasis is placed on the main metallurgical processes, fossil fuels/reducing agents (solids and gases) properties as well as their modifications for the production of reducing gases. The composition and properties of the metallurgical slags of various compositions and origin as well as the chemical equilibrium between slag and metal phases are discussed in detail. The main chemical reactions that take place in the stages of steel purification are also discussed.

The technological part of the course includes the methods of direct reduction of iron ores and their technological development for the production of sponge iron in shaft and rotary kilns. The technology of gasification of solid fuels and production of reducing agents from hydrocarbons by methods of catalytic conversion or partial oxidation in order to be used in reductive roasting plants is presented. The methods of reductive melting for cast iron production in blast furnaces from iron ores and smelting of scrap iron in electric arc furnaces for the production of molten iron are also examined in detail. Refining methods in AOD and VOD furnaces as well as in ladle furnaces and their technological developments are presented. The technology for the production, refining and regulation of steel quality is analyzed. Essential aspects of the whole process such as electrode and refractory consumption and energy consumption are discussed. The operation of the electric arc furnace is analyzed and the formation and operation of the Soderberg electrodes are described. The technology of production of ferro-alloys (FeSi, FeMn, FeNi, FeCr) and stainless steel is also described.

Rock Mechanics 7034

- Introduction. Definitions. The rock as a continuous and discontinuous medium. Rock mass. Rock mechanics and geotechnical engineering. Applications in civil and mining works.
- Basic engineering mechanics. Rock stress. Natural stress field. Rock deformation. Stress – strain relations.
- Physical properties of rock and laboratory determination.
- Uniaxial compression of intact rock: uniaxial compression test. Indirect assessment of uniaxial compressive strength (point load test, Schmidt hammer rebound index, other indirect tests).
- Triaxial compressive strength: Conventional triaxial compression test. True triaxial test. Mechanical behaviour of rock in triaxial compression. Failure criteria.
- Tensile strength of rock. Direct and indirect tests.
- Dynamic rock behavior.

- Shear strength of rock discontinuities: Friction resistance, roughness, persistence effect. Laboratory and in situ shear test. Empirical criteria of discontinuities' shear strength. Shear strength of filled discontinuities. Shear strength of rock plane with non-persistent discontinuities.
- Rock mass mechanical behavior: Rock mass structure. Discontinuities. Rock mass classifications – empirical determination of mechanical rock mass properties. Failure criteria. In situ testing.
- Rock slopes stability analysis: Failure mechanisms. Plane failure: factor of safety (F.S.) computation, effect of groundwater, effect of discontinuities' roughness. Tensile cracks. Effect of seismic loading. Stabilization – reinforcement against plane failure. Wedge failure: kinematic conditions, FS computation. Sliding on a curved surface: Hoek – Bray diagrams, analytical determination of FS – methods of slices (Fellenius, Bishop, Janbu). Rock slope stability according to Eurocode 7. Rock toppling.
- Basic principles of stability analysis of underground excavations.
- The above modules are supplemented by practice exercises, presentation and execution of laboratory tests and use of specialized geotechnical software.

Underground Mine Exploitation 7264

Introduction to underground mining technology, challenges and issues encountered. Selection of optimal mine access (number, location, type and characteristics). Optimal size of deposit section served by the access works. Tunnel excavation methods and shaft sinking development. Special techniques to address aquifers and unstable formations. Drill-and-blast excavation cycle (drilling, charging, blasting, ventilation, haulage, support).

Introduction to underground mining methods. Main characteristics and prerequisites. Application examples. Mine development works. Determination of annual production and life time of the mine.

Ventilation of underground mines. Principles of air flow and resistance. Determination of required air flow volume. Fan characteristics and connection types. Primary and secondary networks. Solving complex networks. Mine resistance and operating point. Energy requirements.

The description of this course is provided in the 5th-semester section. Students may choose these specific courses in either the 5th or 7th semester.

Geodynamics – Geology of Greece 7231

Applied & Environmental Mineralogy 7155

Computational Chemical Thermodynamics 7296

Solid State Physicochemistry 7150

8th Semester

Subject directions

I. Mining Engineering

Geostatistics 7031

Overview of conventional ore reserve estimation methods and accuracy of the results. Data accumulation and storage, descriptions of drill hole samples, geological model and domaining. Exploration data analysis: statistical and graphical analysis of drilling data as a whole and per geological unit, correlation between variables, definition of selective unit of estimation (block), development of block model.

Non-parametric statistics of one, two or more Random Variables (RV). RV sequences, vector representation of RV. The concept of Random Function (RF), simplified RF models. Spatial correlation and variogram function, variogram models. The projection methods with known and unknown mean (simple and ordinary Kriging algorithms).

Structural analysis of the deposit: calculation of experimental variogram function, isotropy and analysis of its characteristics. Reserves estimation: determination of estimation neighborhood, application of kriging algorithm, calculation of content of each block, calculation of errors, cross – validation of the numerical model with graphical overview and statistical comparison, grade- tonnage curves. Classification of ore reserves according to the estimation errors.

Rock Blasting 7017

- Introduction to Excavation Engineering. Rock blasting vs. mechanical excavation. Rock mass properties. Fragmentation.
- Rock Blasting Technique: principles, mechanism and technology. Rock Drilling.
- Explosives: detonation theory, properties, industrial explosives, initiation and firing systems, blasthole charging, transportation, storage, safety.
- Design of Blasting Rounds: bench blasting, tunneling, shaft sinking, controlled blasting, underwater blasting.
- Environmental Effects of Blasting: vibrations, air blast, flyrock.

Marbles and Industrial Minerals 7176

The course includes basic elements for the exploitation of marbles and industrial minerals. In addition, it deals with the processing of marbles, as well as the utilization of the by-products of the exploitation.

- The marble industry in Greece – Historical background
- Types of marble and ornamental stones
- Marble deposits in Greece
- Properties and specifications of marbles
- Exploration of marble deposits
- Exploitation of marble quarries (overburden removal – methods of extraction and rectification of marble)
- Marble processing (splitting, cutting, grinding)
- Production and utilization of by-products

- Industrial Minerals -Categories – Special Characteristics

Petroleum Engineering 7175

This courses introduces students to hydrocarbon reservoir engineering by demonstrating the nature and principles which govern fluids flow in subsurface reservoirs. It provides tools and methods to evaluate the size and value of a reservoir as well as the way it is expected to respond to production. Moreover, tools to identify and optimize primary, secondary and tertiary production are also discussed.

Discussions in the class, solution of demonstrative examples and the presentation of related topics by the students are parts of the learning process.

Drilling Engineering 7242

This course introduces students to the drilling process of deep wells for hydrocarbon production, high enthalpy geothermal projects and underground CO2 storage. It provides knowledge to understand all parameters affecting the subsurface environment, combining various design techniques, selecting equipment and optimizing cost and revenue under the constraint of technically and environmentally safe development.

The topics discussed include geo-pressures, drilling process description, drilling bits, drill and casing string design, casing and cementing methodology, kick control and deviated wells design. Discussions in the class, solution of demonstrative examples and the presentation of related topics by the students are parts of the learning process.

Practical Training II / Internship 7255

Practical Training II, (PTII) / Internship consists a compulsory course of the 8th semester of the Curriculum of the School of Mining and Metallurgical Engineering, NTUA/.

PT II is conducted in the period July – September, following the completion of the 8th semester, and lasts one calendar month. The scope of the Practical Training II is to link the students university education with their future professional environment. This training process encourages the students to apply in practice the theoretical knowledge acquired during their studies. Moreover, the hosting companies have the opportunity to enhance the knowledge and the skills of the graduate students potentially consisting their future associates.

The Subject and Plan of the students' Internship is defined by the Supervising Professor in cooperation with the Supervisor engineer from the hosting company. The Supervising Professors are assigned by the Scientific Coordinator of the Practical Training II according to the specific subject of the PT.

Following the completion of the Practical Training, the students prepare a Technical Report where their activities and the special subject on which they focused during their training are presented. The Report is submitted and evaluated by the Supervising Professor or other Academic of the SMMM with relevant expertise.

II. Geo-engineering

Soil Mechanics 7009

Nature and composition of soil. Physical properties of soils. Grain size distribution. Atterberg limits. Relationships among physical properties. Description and classification of soil. Classification systems. Principe of effective stresses. In situ stress state. Effect of ground water flow in effective stress. Determination of parameters of mechanical behavior of soils. Mohr circle. Shear strength parameters. Unconfined compression test. Direct shear test under drained and undrained conditions. Triaxial test. 1D consolidation test.

Stresses in a soil mass. Stress state due to external loads. Influence depth of external loads. Superposition principle. Saint-Venant principle. Ground water flow through soil. Soil strains. Stress – strain relationships. Constitutive laws: linear isotropic elasticity, nonlinear stress – strain relations. Stress paths. Theory of 1D compression (consolidation). 2D and 3D consolidation. Failure criteria. Shear strength. Mechanical behavior under drained and undrained loading conditions.

Methods of Geological Mapping & Tectonic Analysis 7268

- Cartography and Topographic Maps. Geometric Relations between Topographic Relief and Geological Surfaces. Remote Sensing – Interpretation of Aerial Photographs. Identification of Geological Formations and Geological Contacts: principles and Morphotectonic Characteristics. Chronology of the Geological Events. Complex Structures. Isopach Maps.
- Tectonic Structures, Folds – Faults: Geometric, Kinematic and Dynamic Characteristics. Tectonic Stresses and Deformations. Stereographic Projections.
- Interpretation of Geological maps and construction of Geological Cross Sections.
- Maps of Regions with Economic or Engineering Interest. Geological Maps and GIS.

Underground Works 7265

Modern underground infrastructure development. Types and uses of underground structures – selected case studies Underground projects for hosting special use types. Underground space development and future trends – advantages and disadvantages. Environmental importance of underground development. Modified mining techniques for the development of underground installations. Design of underground structures using the principles of room-and-pillar mining method. Design of large underground rock caverns. Development strategies for mined spaces. Cost analysis of underground projects. Cost-benefit assessment of underground facilities. Environmental valuation of underground space development.

Groundwater and Construction Works 7186

The content of this course refers to: (i) Fundamental principles of hydrogeology, (ii) Groundwater flow (Darcy's Law, hydraulic conductivity, aquifer transmissivity, flow in anisotropic aquifers, (iii) Groundwater hydraulics (steady/unsteady flow in confined/unconfined/leaky aquifers), (iv) Objectives of groundwater control in construction (problems for excavations in soils/rock), (v) Design of groundwater

control systems (methods for surface water and groundwater, site investigation for groundwater lowering, design of groundwater lowering systems), (vi) Groundwater control during construction (sump pumping, wellpoint systems, deep well systems, methods for groundwater exclusion, permanent groundwater control systems), (vii) Environmental impacts and monitoring of groundwater lowering systems, (viii) Groundwater modeling of lowering systems (model conceptualization, available codes, modeling techniques and boundary conditions)

Support of Underground Works 7065

Terminology and definitions. Stabilization measures of underground openings. Technology, mechanical behavior and load-bearing capacity calculation of rock reinforcement, rock support, pre-reinforcement and pre-support measures. Support of rock wedges. Stratified or laminated rock roofs: mechanical behavior, suspension, reinforcement, behavior after cracking. Stress and deformation analysis around underground openings in: massive rocks, blocky rocks, very blocky and fragmented rock masses, weak rock masses and squeezing rocks. Interaction of neighboring openings. Analytical solutions and numerical simulation methods. Rock–support interaction: sequential excavation and support installation, rock mass de-confinement and convergence, support reaction. Convergence-confinement curves and interaction with the support for elastic, elastoplastic, brittle and time dependent rock mass behavior. Analytical solutions and numerical simulation methods for rock-support interaction analysis. Design of support systems in dynamic conditions: explosive rock behavior, response of support measures to dynamic loads, selection of support measures.

III. Environmental Engineering and Geo-Environment.

Remediation of Contaminated Soils 7241

The course deals with the problem of soil contamination, which is a crucial environmental problem worldwide. The topics which are covered include presentation of the main categories of pollutants and analysis of their fate and transport in the environment. A risk assessment methodology, as decision making tool for evaluating the risks associated with contaminated sites and for setting remediation priorities, is also presented. The most important remediation technologies for the case of organic contaminants, based on physical and biological processes, are analyzed in detail.

Groundwater Management and Protection 7238

The content of this course refers to: (i) Analysis of hydrogeological systems (aquifer types, groundwater flow hydrology and hydraulics), (ii) Groundwater chemistry (hydrochemical analyses, water-rock interactions), (iii) Principles of isotope hydrology (applications in the hydrogeological cycle), (iv) Nitrate contamination (nitrification/denitrification processes, agrochemical diffuse sources), (v) aquifer vulnerability (vulnerability index, application in diffuse and point sources), (vi) aquifer ecosystem services, (vii) Managed Aquifer Recharge (methods and technologies, monitoring and management of MAR facilities, Soil-Aquifer-Treatment systems, EU legislation in wastewater reuse), (viii) Introduction to groundwater modeling (emphasis in mass and contaminant transport, variable density flow), (iv) Application of hydroinformatics in groudwater chemistry.

Special Topics of Environmental Protection in Mining and Geotechnical Engineering 7240

The course presents theoretical concepts and practical approaches to the environmental, social and economic impact of the exploitation of mineral and energy resources as well as the best ways to manage them. More specifically, the environmental risks associated with the exploitation of mineral and energy resources and large geotechnical projects are analyzed and the best techniques for dealing with them are presented.

- The effects of mining activity on the environment: Introduction, Impacts on the natural environment, Impacts on humans, Socio-economic effects, Factors affecting the size and intensity of environmental problems.
- Environmental impacts of large geotechnical projects.
- Visual pollution: Introduction, Theoretical background, Landscape quality assessment systems, Design of mining projects aiming at the minimum possible alteration of the landscape.
- Ground vibrations and air pressure (airblast): Introduction, Theoretical background, Monitoring and systems for measuring vibrations from blasting, Measures to reduce ground vibrations and air pressure, Vibrations and human disturbance.
- Noise pollution: Introduction, Theoretical background, Noise sources in mining works, Monitoring and measurement systems, Prediction models, Response measures, Greek and international standards.
- Air pollution: Introduction, Theoretical background, Sources of cuasing gaseous pollutants in quarries and mines, Monitoring and measurement systems, Prediction models, Response measures.
- Exploitation planning with the aim of optimal environmental protection.
- Rehabilitation of mining and quarrying areas: Introduction, Factors affecting the rehabilitation, New land uses, Criteria for evaluation of alternative plans. The problem of abandoned mines and quarries.

Environmental Geochemistry 7239

The course is part of the subject direction Environmental Engineering and Geoenvironment and the basic concepts of environmental geochemistry are discussed. The main objective is to teach students about the interactions between rocks, soil, water, atmosphere and biosphere, the pollution originating from geogenic and anthropogenic sources, as well as the environmental footprint and the potential impact of mining activities. The mobility of trace elements, particularly potentially harmful ones, in the surface and subsurface environment and their effects on the biosphere are discussed, as are the geochemical processes that contribute to the release of contaminants into the environment and the processes that lead to the fixation of contaminants and the physicochemical/geochemical conditions under which they occur. Moreover, the methodologies to address the problem of environmental degradation and also the use modern methods to develop models for solving environmental problems are discussed.

Air Pollution Control 7219

The course provides insight on the theoretical background, the various aspects of air pollution resulting from industrial activities and focuses on the detailed design of air pollution control systems. Emphasis is given on the increasingly strict legal framework related to the anti-pollution technology. The introduction to the course includes topics related to suspended particles (characteristics, behavior of particles in fluids (traction force, Stokes Law), external forces, gravitational precipitation, aerosols). Students are then taught detailed design issues including gravitation chambers for flue gas dedusting, centrifugal collectors (cyclones, polycyclones), electrostatic precipitators, bag filters and wet scrubbers (Spray chamber and cyclonic spray scrubbers, Venturi, etc). The advantages and disadvantages of each specific air pollution control system and its relative energy consumption are discussed in detail.

IV. Metallurgical Processes

Processing and Utilization of Industrial Minerals 7282

The scope of the course is the studying of basic chemical methodologies that used for the processing and the valorization of industrial minerals and, as well as, the examination of various applications of industrial minerals and the description of complex materials with advances physicochemical properties.

1. Classification of industrial minerals

2. Fundamental principles of industrial minerals processing

3. Processing of industrial minerals and respective required installations

– Physical processes

– Chemical processes

– Thermal processes

4. Physicochemical properties and characterization of industrial minerals and end-products

5. Application of industrial minerals and their products in the following sectors of the industry

– Building and structural materials

– Insulation materials

– Drilling materials with applications in the petroleum industry

– Adsorbents and filler materials

– Fire-protection materials

– Materials used for environmental purposes such as the decontamination of soils by solid and liquid residues

– Soil conditioner materials

6. Flow sheet diagrams of industrial minerals processing

– Analysis of basic flow sheet diagrams

– Design of new flow sheet diagrams for the production of end-products with advanced physicochemical properties

7. Processing of industrial minerals of specific interest for the Greek industry

– perlite

– bentonite

– zeolites

– magnesite

– attapulgite

8. Analysis and techno economic design, using flow sheets, of the production of products with improved physicochemical properties

Laboratory Exercises in Pyrometallurgy 7214

It includes the execution of at least eight experimental exercises in the laboratory related to respective processes of extractive metallurgy. The theoretical background for each specific laboratory exercise will be also presented. The main pyrometallurgical processes to be presented/executed are calcination, reductive and oxidative roasting using various reducing/oxidizing media, reductive smelting, etc. for iron, nickel, copper and other metal ores. The individual processes will be evaluated following each experiment in terms of metals recovery, slag composition, reducing agents, fluxes, gases and other reagents consumption as well as their cost.

Electrometallurgical Processes 7077

The course develops the basic principles of electrochemistry and the techniques of analysis of electrochemical systems aiming at their application for the analysis, development and design of electrometallurgical processes. It is accompanied by a series of laboratory exercises aimed at consolidating and understanding the theoretical principles of electrochemistry. The course focuses on both applications in aqueous electrolyte solutions and applications of electrolysis in molten salts which are the method of production of many active metals such as aluminium and magnesium.

The course includes: Introduction to electrometallurgy and fundamental principles of electrochemistry (Electrodes and electrode reactions, Electrochemical cells and potentials, Nernst equation, Faraday Law, Power efficiency, Special energy consumption), Electrochemical Techniques with laboratory exercises (Potentiometry, Voltammetry, Conductivity measurements), Kinetics of electrode reactions (Tafel Law) and Applications in Metallurgy (Electrowinning and Electrorefining of metals).

Metallurgy of Non-Ferrous Metals 7189

Primary Alumina and Aluminum Production: Bayer Process, Hall-Heroult Process, Environmental Consequences, Innovations in Alumina and Aluminum Production, Exergy and Energy Analysis of current industrial practice. Extractive Metallurgy of Cu, Zn, Pb from oxidic and sulphidic ores. Extractive Metallurgy of precious metals.

Technology of Cement and Concrete Production 7192

The Greek Cement Industry. Structure and Mineralogical Composition of Cements. Cement Types, Composition and Uses. Raw Materials and Calculation of Raw Mix Composition. Size Reduction Operations. Pyroprocessing Technology. Hydration of Cements. Metallurgical Processes in Cement Production. Chemical Behavior of Cement in Production and Use of Concrete. Methods of Aggregates production. Test Methods for Aggregates Materials for Proper Concrete (Particle Size Composition, Shape, Mineralogical Characteristics, Strength, etc.). International and Greek Standards for Cement Testing. Environmental Aspects of Production and Use of Cement and Concrete.

V. Materials Science and Engineering

Industrial Non-Ferrous Alloys 7059

This module represents an essential course for the basic principles of Industrial non ferrous Alloys. Student will acquire expertise, knowledge and understanding in:

- Titanium alloys, aluminium and its alloys, nickel based superalloys and specific catergories of bronzes.
- Will correlate processing with microstructure in non ferrous alloys and attendant properties.
- Physical Metallurgy of titanium alloys, aluminium and its alloys, nickel base supealloys, brasses and bronzes.

Ceramic Materials 7153

The subject concerns the basic course in the Technology of Ceramic Materials.

The content of the course initially includes the presentation of ceramic materials, their classification and the presentation of the range of their applications. This is followed by the study of the manufacturing processes of ceramics with emphasis on the effect of process parameters (material quality, raw material preparation, shaping technique, thermal cycle) on the properties of the final product. Then, the methods of producing powders from chemical methods and the techniques for the development of ceramic coatings are analysed followed by the presentation of traditional ceramic products with emphasis on the manufacturing and properties of porcelain. Finally, the properties of especially important ceramic materials (alumina, zirconia, carbides) are presented and discussed.

During the semester, the students attend laboratory exercises and deliver the relevant reports for deepening into the subject and developing skills. The cooperation and the development of critical thinking are also encouraged.

- Introduction, Categories – Ceramics Microstructure-Applications.

- Advanced ceramics- Technological requirements for mechanical, biological, chemical applications. Electronic ceramics.
- Ceramic Production Technologies – Flow Chart
- Preparation and characterization of powders
- Shaping Techniques-Dry Methods
- Shaping Techniques-Wet Methods
- Principles/Mechanisms of sintering
- Sintering techniques
- Methods for the development of protective ceramic coatings-Thermal spraying techniques
- Thin Films-Manufacturing Technologies
- Composition of powders by chemical methods- Development of coatings
- Traditional ceramics – Porcelain
- Advanced Ceramics-Properties and Applications of Main Ceramics-Zirconia-Carbides

Metallurgy of Welding – Technology & Control of Weldments 7117

This course introduces students in Welding Metallurgy, technology and control of weldments.

The taxonomy of different welding methods/techniques is initially introduced to the students. The lectures include arc welding techniques (e.g. TIG, MIG, etc.), beam welding (laser, electron beam) and solid state welding methods/techniques (e.g. friction stir, ultrasonic, diffusion). The importance of the protective atmosphere, the available protection means (gasses, powders, slags etc.) is underlined. Furthermore, the students deepen in the metallurgical phenomena related to the welding thermal cycle, the welding zones, the microstructure evolution, phase transformations and the residual stresses.

In the final stage, non-destructive methods for weldment control are reviewed combined always with the appropriate measures for health and safety of welders and welding staff.

- Basic principles of welding Metallurgy.
- Welding thermal cycle, welding zones, phase transformations, microstructure evolution and residual stresses.
- Arc welding techniques (e.g. TIG, MIG, etc.), beam welding (laser, electron beam) and solid state welding methods/techniques (e.g. friction stir, ultrasonic, diffusion).
- Protective atmosphere, available protection means (gasses, powders, slags etc.)
- Current and voltage, main equipment & techniques
- Main welding defects and non-destructive testing techniques, weldment control
- Health safety

Solid to Solid State Phase Transformations 7167

This module represents an advanced course on the principles of phase transformations in metals and alloys during solid state phase transformations. Basic principles that govern the behavior of metallic materials.

- Equilibrium condition in alloy systems.
- The concept of metastability and transient phases.
- Mechanisms of phase transformations in solid state, homogeneous and heterogeneous nucleation and growth.
- Classic thermodynamic models of homogeneous and heterogeneous nucleation.
- Diffusion and diffusive transformations.
- Diffusionless transformations.
- Development of Interphases.
- Pearlitic, Bainitic and Martensitic Transformations.

Polymers and Composites 7157

Introduction to Polymer Structure. Macromolecular Chemistry. Crystallinity. Mechanical and Thermomechanical Behavior of Polymers. Viscoelasticity. Rheology. Deformation and Fracture. Polymerization, Types of Polymers, Plastics, Elastomers, Fibers, Applications. Composites. Reinforced Composites. Composite Materials with Metallic or Ceramic Matrix. Composites with Carbon Fibers.

Pool courses

Principles of Machining 7218

Introduction. Basic elements of theory (waste development, cutting force/power, surface quality, tool damage, cutting liquids). Cutting tools. Conventional mechanical processing (lathe, milling machine, plane, gear cut, burr drill, corrugation machines, cutting press, polishing machines). Non-conventional mechanical processing (electrowear, ultrasonics, water cut, electric arc, electrochemical process, electron beam use, lasers, other methods). Machine tool control systems. Treatment ability of various materials. Production applications (product design / material selection, method selection / machine tool selection, treatment parameter determination). Mechanical measurements.

Gemology 7275

Basic concepts of Gemology. Gem material, geological formation, and occurrence of gemstones on the earth. Important gemstones. Natural and synthetic gemstones. Gemstone certification. Criteria for defining the economic value of precious stones (rarity, purity, mining costs, processing costs). Economic data. Legislation. Gemstones of Greece: Types, Genesis and Occurrences.

Solid Industrial and Hazardous Waste Management 7278

The aim of the course is to gain knowledge in the field of solid waste management resulting from metallurgical, mining and energy activity.

- Introductory definitions – Categories of solid industrial waste (from metallurgical, mining and energy activity) – Principles of solid industrial and hazardous waste management.
- Environmental characterization of solid industrial waste: European and national institutional framework-European waste list- Tests to determine major physical-geotechnical and geochemical parameters-Evaluation of hazardous properties of waste-Classification.
- Environmental risk assessment from solid industrial waste facilities (definitions, methodology, identification, risk analysis and assessment).
- Industrial and hazardous waste management methods, including underground hazardous waste disposal
- Management of tailings: Characteristics of tailings depending on the type of ore- Tailings dam integrity failure – Improvement of physical and geochemical stability of disposal sites (treatment of tailings, bottom liners and covers) - Methods of waste utilization.
- Management of pyrometallurgical waste (slag, dust, etc.): Recycling / recovery and disposal methods.
- Hydrometallurgical solid waste management: Characteristics-Stabilization methods-Recycling / recovery and disposal methods.
- Economics of industrial and hazardous waste management

Special Chapters in Ore Deposit Geology 7246

The geological structure of mainland Greece (pre-Alpine and Alpine system-structure) is examined, the discrimination between Internal and External Geotectonic zones – units. The major Greek metallogenic provinces are examined, focused on the most important Greek mineral resources and deposits (e.g. chromite, bauxite, Ni-laterites, precious, base and strategic metals, industrial minerals, fossil fuels). The correlation of Greek metallogenic provinces with the geologic, geodynamic and geotectonic evolution of Greece is presented, and how these processes led to the creation of the Greek mineral resources and deposits. Furthermore, insights in future research and exploration for mineral deposits based on the geology and geologic evolution of Greece are also discussed. Finally, the basic concepts of special techniques related to ore deposit research (e.g. stable and radiogenic isotopes) are taught, as well as the contemporary analytical techniques facilitating mineral exploration.

Geothermal Fields Science and Technology 7159

This course introduces students to geothermal fields exploration, engineering and exploitation. It aims at helping students familiarize with the features and properties of the subsurface where sources of geothermal energy can be spotted and produced. High enthalpy, low enthalpy and shallow geothermal energy systems are presented along with their applications. Geological issues, geophysical exploration, hydrogeological aspects, reservoir engineering and applicable law are among the topics discussed. The course further provides the means to develop combined approaches for designing a geothermal project, selecting suitable techniques, appropriate equipment and materials as well as to optimize cost and revenue under the constraint of technically and environmentally safe development.

Students are asked to study a related topic, organize the material, write an extended report and give a detailed presentation so as to enhance their ability to present technical topics to any audience.

Magnetic Materials 7244

This module aims to provide the theoretical background and technological importance of magnetic materials.

- Principles of Magnetism
- Magnerisation
- Magnetic wall movement and rotation of magnetic domains
- Parametric control of magnetisation
- Categories of ferromagnetic materials
- Magnetic Phenomena
- Techniques for Magnetic characterization
- Hysteresis loop
- Magnetostriction
- B-H loop
- Iron and Iron alloys
- Cobalt, nickel and its alloys
- Permanent magnets, Review and basic applications
- Hard/Permanent Magnets
- Rare earth, Theory and properties
- Electrical Steels
- Magnetic Oxides
- Spinels, ferrites, orthoferrites,
- Granets
- Magnetic semiconductors
- 2D magnetic materials
- Magnetic powders

Laboratatory Practicals:

- Magnetisation Loop
- Electocal Steels, measurement of magnetic properties and correlation with microstructure
- Fe-Co-Ni alloys, magnetic behavior and characterization of magnetic domains with electron microscopy
- Magnetic oxides and superconductors

Economics of mineral resources 7177

The course presents theoretical and practical approaches related to the economics of mineral resources (metallic ores, industrial minerals, energy minerals). Emphasis is placed on analyzing the market for mineral raw materials, examining factors that influence their supply and demand, and exploring trade and price formation (exchanges, futures markets, decentralized markets, etc.). The course also looks into the impact of metal substitution and recycling, among other topics. Additionally, it

addresses issues concerning market distortions (monopolies, oligopolies, cartels, etc.), taxation of mining companies, the direct, indirect, and consequential impacts of mining activities on the national economy, optimal use of non-renewable resources, and more. Finally, a significant part of the course involves analyzing and forecasting the demand and prices of metals, energy products, and more, using time series models and cross-sectional data with time series.

Environment and Development 7267

The interdepartmental course "Environment & Development" is an innovative initiative offered as a cross-disciplinary course for all undergraduate students at the National Technical University of Athens (NTUA). Its aim is to explore the connection between the country's developmental prospects and environmental protection. The course is structured around a series of lectures, each addressing a topic through a productive debate on the dichotomy of "Development" versus "Environment.". This initiative involves contributions from NTUA faculty across all schools, along with established researchers, academics, and professionals in the field. Students actively participate in the discussions, bringing diverse perspectives from their respective schools within NTUA. Throughout the semester, students work in small groups to research a relevant topic, developing well-founded arguments for or against it based on the course's theme.

Environmental Policy and Institutional Framework for the Exploitation of Mineral Raw Materials 7289

The goal of the course is to familiarize students with the regulatory framework and core Environmental Policies governing the Sustainable Development of Mineral Raw Materials in Greece, Europe, and internationally. Considering the increasing demand for mineral resources in the EU alongside the constraints imposed by current environmental legislation and the need to improve societal acceptance of the sector, the course is organized into thematic sections aimed at enhancing students' skills in improving the environmental performance of the Mining and Metallurgical Industry and achieving the UN Sustainable Development Goals (SDGs). The course content includes the following sections:

Environmental Chemistry and Metals Mobility Mechanisms 7260

It aims to present the main physical, chemical and biological processes influencing and/or controlling the mobility and the immobilization of metals in aquatic environment and in the air.

Pollution may be transported in very long distances of thousands of kilometers via the atmosphere. The atmosphere participates in the hydrological cycle and plays an important role in the biogeochemical cycles of the elements. Emissions in the atmosphere of both natural and anthropogenic origin are responsible for changes that occur at planetary scale.

Aquatic systems play an important role in the fate of pollutants: 1. A number of organisms are grown and live in aquatic systems and are included in the hierarchy of a food chain. 2. As aquatic systems interact with soils and solid wastes, pollution from soils and solid wastes is transferred in aquatic systems. Metals mobility/immobilization mechanisms are influenced by physical, chemical and biological parameters (pH, redox potential, presence of other chemical species and

microorganisms). The role of each one of these parameters is discussed by introducing them successively in a system under study.

The acquired knowledge is necessary for the understanding of metals mobility mechanisms and the development of environmental technologies. Metals immobilization mechanisms occurring in natural systems are often the basis for the development of environmental technology aiming at metals immobilization and sequestering from waste water and also metals recovery from waste streams.

i. The mobility of pollutants in the air: – Atmospheric particles/aerosols: Mechanisms of generation and transformations. The fate of atmospheric aerosols.

– Gaseous pollutants-tropospheric chemistry.

ii. The mobility of pollutants (metals) in aquatic systems. – The system of carbonates. – Precipitation of metals species. – Complexation of metals species.

– Oxidation-reduction.

iii. The role of microorganisms in the mobility of metals. – Bioleaching of metals (acid mine drainage). – Bioprecipitation of metals (Environmental technology).

iv. Phase interactions: chemical interactions among gases, water and air. – The formation of sediments – Colloids – Adsorption on the surface of solids

Earth and Space Rocks 7290

Mineralogy, petrology and geochemistry of terrestrial rocks and space materials (meteorites, cosmic dust, asteroids, comets). Introduction to thermodynamics of natural systems, phase transformation of minerals, phase diagrams. Alteration of Earth and Space materials. Advanced instrumental analysis and characterization of rocks and minerals. Isotope and trace element analysis. Remote sensing and mineral/rock reconnaissance and mapping with hyper-spectral images. Rock classification for engineers, chemical, physical and textural properties. Sampling methods of rocks. Geometallurgy, textural analysis with image processing, core logging, and other engineering properties with case studies. Planetary and space exploration. Simulant and analogue rocks for space exploration and construction technologies (additive manufacturing / 3D printing).

Design and Techno Economic Analysis of Metallurgical Industries 7190

The current course examines the simulation and the optimization of metallurgical processes using a PC.

The course's content aims to: (a) the introduction of fundamental knowledge on the simulation of metallurgical processes, (b) the practice and use of available computational tools (software) and (c) the solving exercise of energy and mass balances.

The exercises to be solved require knowledge on other courses of the School, including: "Study and design of ore beneficiation industry", "Chemical kinetics", "Reactors design" etc. aiming to:

- The operation of the simulation program

- The preparation of a flow diagram describing the operation of the factory plant
- The transition from the basic design (conseptual) of a plant to the detailed design ενός (rigorous)
- The identification of variables, the required data and the values to be calculated
- The calculation of mass and energy balances using the computational program
- The design optimization concerning the mass and energy flows
- The current course can be considered as the application of the theoretical knowledge obtained by the specialization courses.

Finally, the target of the course is the comprehension by the undergraduates of; (a) the mode of operation of various parts in the plant, (b) the thermodynamic data and the methodology followed in each part of the plant and (c) the detailed evaluation of the results according to the industrial practice.

- Basic Knowledge. Data of simulator. Environment of simulator.
- Selection of measurement units, components and methodology for the calculation of the thermodynamic parameters.
- Processes design. Installation and flows. Introduction of parameters and results display (reports, diagrams). Sensitivity analysis. Restrictions and estimation of optimum parameters. Recycling possibilities
- Economic analysis of the process. Estimation of capital cost. Estimation of total operating cost

9th Semester

Subject Directions

I. Mining Engineering

Mechanical Rock Excavation 7174

Theory and applications of current mechanical rock excavation technologies:

- Rock cutting tools: Drag cutter and disc cutters
- Rock cutting theories: Merchant, Evans, Roxborough, Nishimatsu, Ozdemir
- Specific energy
- Wear of cutting tools
- CERCHAR abrasivity index
- Roadheaders, surface miners
- Tunnel boring machines
- Impact hammers
- Dozing
- Ripping
- Scraping
- Performance estimation
- Cutterhead design
- Laboratory rock cutting tests

Applied Geophysics 7061

Theory and fields of application of Applied Geophysics. Geophysical survey methods: Gravity, Magnetics, Geoelectrical {Electric Resistivity (profiling, soundings, electrical tomography), Induced Polarization, Self Potential). Electromagnetics (Georadar, FEM, TEM). Seismics (Reflection, Refraction). Geophysical recordings within drillings. Measuring instruments. Field data acquisition design. Processing and interpretation of geophysical measurements and display of results with relevant diagrams, sections, 3D cubes and geophysical maps. Computers in geophysical research. Case studies in mining engineering, geotechnical, environmental, hydrogeological, geothermal, hydrocarbon exploration, archaeological studies. Laboratory Exercises, in the field and in the Laboratory, of application of the above geophysical methods.

Conventional and Robotic Mining Systems 7211

Mining systems and material-handling unit operations.

Conventional mining systems:

- Discontinuous mining system: Excavators, loaders, and trucks
- Haul roads
- Continuous mining system: Bucket-wheel excavators, conveyors, and spreaders
- Mechanical, electrical, and hydraulic equipment components
- Operational analysis and performance estimation
- Equipment selection, maintenance, and replacement

Robotic mining systems:

- Advances in mining technology
- Technology drivers in mining
- Technological challenges in underground and surface mining
- Autonomous trucks
- Field mapping, equipment navigation, and collision detection
- Shovel-truck interactions
- Data acquisition, transmission, and management
- Automated truck dispatching and fleet management
- Safety considerations, ISO 17757
- Socio-economic challenges
- Conventional vs. robotic mining systems

Open Pit Mine Planning and Design 7112

The course aims to educate students on rational design of open pit mines in the light of technical, economic, environmental criteria and safety of work. During the course students are trained in design using specialized software.

- Familiarization with basic mining concepts.
- Medium-term exploitation planning

- Assessment of the economic feasibiltiy of the exploitation through the determination of critical parameters (Cut off grade, Strip Ratio)
- Learning specialized mining software for surface mining design
- Configuration of a deposit block model
- Pit limits optimization
- Identification of optimal geometric characteristics and design of exploitation plans
- Special exploitation design features per type of ore deposit category (marbles, industrial minerals, aggregates, metallic ores, etc.).

Underground Mine Planning and Design 7111

Fundamental Principles of Mining. Main categories and types of underground mining methods. Characteristics and principles of Stoping (breast stopping, room-and-pillar, sublevel open stopping, AVOCA, long-hole drilling, VCR), Filling (cut-and-fill, drift-and-fill, bench-and-fill, shrinkage stopping) and Caving methods (sublevel caving, block caving, logwall mining). Design and dimensioning of room and pillar mining schemes, stability graph and dilution design, sublevel mining design. Mining method selection. Cost assessment. Use of SURPAC in the design of mining works.

II. Geo-engineering

Geotechnical Ground Improvement Technics 7202

Draining techniques, electrokinetic stabilization techniques, frizzing and heating techniques, Compaction and compression techniques (preloading & gravel pilles, dynamic compaction, Deep Dynamic Compaction, Rapid Impact Compaction, Vibro Rod, Vibroflotation, Vibro Replacement) grouting (Jet Grouting, Wet Soil Mixing), chemical stabilization techniques, geotextiles, slope retaining constructions (gravity walls, pile walls), rock fall protection systems.

Special Topics in Geotechnical Engineering 7270

Limit equilibrium methods: Basic principles. Typical applications – ultimate limit load of a shallow foundation, ultimate depth of a vertical cut, ultimate inclination of a slope.

Slope stability: Infinite slopes. Plane failure in slopes of finite length. Mechanism of circular failure – methods of slices: Fellenius, Bishop simplified. Mechanism of slip surfaces of arbitrary shape: Janbu method. Slope stability according to Eurocode 7 (EC7). Slope stability under seismic loading. Applications using specialized limit equilibrium software.

Numerical methods: Basic principles of numerical simulations. Simple soil constitutive models. The shear strength reduction technique. Applications using a specialized finite elements software.

Probabilistic methods of analysis: Reliability index, probability of failure, reliability of geotechnical structures. Reliability analysis methods: first order second moment (FOSM) method, point estimate method (PEM), Monte Carlo simulations.

Topics in environmental geotechnics: Geotechnical design of landfills. Geotechnical characterization of extractive industry's wastes (waste dumps, tailing dams).

Principles of Foundations and Retaining Structures 7291

Shallow foundations: Types of shallow foundations. General shear, local shear, and punching failure of soils. Bearing capacity of a strip footing. The general bearing capacity equation. Foundation subjected to load eccentricity. Undrained and drained loading conditions. Bearing capacity of foundations on a slope. Bearing capacity according to Eurocode 7 (EC7). Bearing capacity under seismic loading. Bearing capacity of shallow foundations on rock. Settlements: types of settlements and allowable settlements. Elastic settlements. Settlements of shallow foundations on clays and sands.

Deep foundations: Types of piles. Axial bearing capacity of piles. Settlements of piles.

Retaining structures: Types of retaining structures. Earth pressures at rest. Active and passive earth pressures – Rankine and Coulomb theory. Earth pressures according to EC7. The role of groundwater. The role of external loading. Geotechnical design according to EC7: gravity walls, embedded walls (flexible retaining structures – cantilever sheet-pile walls, singly-anchored sheet-pile walls), propped and braced excavations. Retaining structures under seismic loading.

Design and Construction of Tunnels 7200

Historical development of tunneling. Distinction of tunnelling projects. Geometric design of tunnels. Geotechnical investigation for tunnelling projects. Conventional tunneling methods: sequential excavation and support, empirical guidelines for construction. Norwegian Tunneling Method (NTM). New Austrian Tunneling Method (NATM). ADECO-RS method. Numerical simulation techniques for tunnelling. Urban tunnelling: SCL method, LaserShell method. Tunnel portals. Mechanized tunnelling methods. Tunnelling settlements. Microtunnelling, pipe-jacking, box jacking tunnel construction. Shafts. "Cut & Cover" and "Cover & Cut" techniques. Submerged tunnels. Tunnel final lining. Geotechnical monitoring. Economic and environmental issues.

Engineering Geology of Mining and Civil Construction 7171

Content of the Engineering Geological – Geotechnical investigation studies. Rock mass classification systems, Rock slope stability studies (case study: photomapping, in situ engineering geological mapping, joints sets` recording and statistical evaluation (Schmidt Net), kinematic analysis of plane and wedge failures),Engineering geological design of earth dams, tailing ponds, road and railway networks, urban and sub-urban environment. Aggregates natural & artificial (properties, lab testing, sources).

III. Environmental Engineering and Geo-Environment

Solid waste management – Material Recycling 7259

Introduction, basic definitions, The problem of municipal solid waste, institutional framework, technologies and main research directions, Composition, characterization and sampling of waste, Storage, collection and waste transfer, Solid waste sorting,

Recovery and reuse of materials, Final processing and disposal of non-useful materials, Processing diagrams, Environmental problems from the uncontrolled disposal of waste, Sanitary landfills, Leachate and Biogas Management, Examples, case studies and exercises, Special cases (hazardous waste)

Environmental and Natural Resources Management 7261

The course aims to familiarize students with fundamental concepts and tools for managing the environment and natural resources, drawing from natural and socioeconomic sciences (such as multi-criteria analysis, cost-effectiveness and cost-benefit analysis, risk management, stakeholder analysis, etc.). The primary objective of the course is to provide students with an interdisciplinary approach to addressing environmental and social issues arising from the utilization of mineral resources, thus supporting optimal decision-making regarding the use, management, conservation, and protection of the environment and both exhaustible and renewable natural resources.

Energy and Environment 7181

Presentation of the basic forms of energy as well of as the energy sources, renewable and non-renewable. The main technical characteristics of each technology for the utilization of each energy source are analyzed with special emphasis on their interaction with the environment. Important aspects of energy policy and energy economics are also presented.

- Historical context, Introductory concepts
- Energy mixture. Environmental impacts of energy projects and technologies. Introduction to impact assessment methodologies (environmental footprint, life cycle analysis, economic impact assessment).
- Fossil fuels (solids, liquids, gases), types of energy utilization units, combustion equations and environmental impact
- Wind energy utilization and environmental impacts
- Utilization of solar energy and environmental impacts
- Utilization of energy from Biomass and environmental impacts
- Geothermal utilization and environmental impact
- Energy saving, energy studies and energy efficiency certificates
- Energy Poverty, concept, impacts, treatment.

Geostatistics for Environmental Applications 7283

Spatiotemporal mapping in geosciences. Sources of physical knowledge: natural laws, empirical rules, obvious correlations, etc. The principle of maximum entropy for measuring information. Knowledge assimilation through Bayesian statistics. The Bayesian Maximum Entropy (BME) method.

Pollution mapping based solely on statistical moments of measurements. Certain and uncertain data. Data transformations. Analysis of spatial correlation through the covariance function. Confidence intervals and risk assessment. Error mapping and evaluation of an existing sampling network. BME Lib open-source applications.

Spatiotemporal mapping with incorporation of the occurring natural law. Stochastic differential equations. Solution with numerical analysis via Matlab and Excel. Applications in underground pollutants transportation and public health.

Wastewater Treatment Technologies 7110

The course is optional for the students following the direction of "Environmental Engineering and Geo Environment". It is offered to the students at the 9th semester of their curriculum. The course consists of lectures and tutorials.

The subject of the course is focused on the physical and biological processes applied in the wastewater treatment units and specifically on the design of these processes.

The lectures are structured according to the following schedule:

- Physical and chemical characteristics of the wastewater: Color, Odor, Turbidity, Solids (total, suspended, soluble, settleable, fixed, volatile), Organic loading (xenobiotics), Inorganic loading (metal ions), anions, nutrients (NH_4^+,PO_4^{3-}), nitrogenous compounds (NO_3^-, NO_2^-, organic nitrogen), pathogenic microorganisms.
- Microbial growth kinetics – growth equations – The Monod equation, other growth kinetic equations.
- Wastewater quality: Biochemical Oxygen Demand, (BOD), Chemical Oxygen Demand, (COD), methods of measurements – importance in environmental engineering.
- Removal of solids – Settling processes: Discrete particles settling (Type I) – Primary settling (Type II), Thickening (Type III and IV). Design of settlers – Grit removers – Primary settlers – Thickening – Dewatering.
- Biological reactors engineering – Bioreactors design: Basic principles. Material balances. Design of batch reactors, continuous stirred tank reactors (CSTR) with and without recycling, plug flow reactors, immobilized biofilm reactors.
- The activated sludge process.
- Comparison of biological reactor.
- Sludge treatment – Anaerobic processes – Anaerobic digestion – Biogas production

i. Introductory concepts. The physical and chemical characteristics of the waste water. ii. Microbial growth kinetics – growth equations – The Monod equation, other growth kinetic equations iii. Wastewater quality: Biochemical Oxygen Demand, (BOD), Chemical Oxygen Demand, (COD), methods of measurements – importance in environmental engineering. iv. Removal of solids – Settling processes: Discrete particles settling (Type I) – Design of grit removers. v. Primary settling (Type II) Design of primary settlers – Numerical exercises. vi. Settling Type III and IV. Design of thickeners – Numerical exercises. vii. Principles of batch bioreactors: Material balances for biomass and nutrients – Design – Numerical exercises. viii. Principles of continuous flow bioreactors (Completely Stirred Tank Reactors CSTR): Material balances for biomass and nutrients – The washout principle – Design – Numerical exercises. ix. Continuous flow bioreactors (Completely Stirred Tank Reactors CSTR) with recycling: Material balances for biomass and nutrients – Stability analysis – Design – Numerical exercises. x. Plug flow bioreactors with and without biomass

recycling: Material balances for biomass and nutrients – Stability analysis – Design – Numerical exercises. xi. Biofilm reactors: Material balances for biomass and nutrients – Diffusional processes in biofilm – Design – Numerical exercises. xii. Comparison of the performance of biological reactors. Stability, size differences, toxic effects. xiii. Wastewater treatment plants design and operation.

IV. Metallurgical Processes

Secondary Metallurgy 7276

In the circular economy model which was adopted by the European Union, but also by most countries outside the EU, the key principle is the recycling and recovery of elements, mainly metals, from recycled materials. Undergraduate courses related to Extractive Metallurgy focus mainly on the production of metals and/or their compounds from primary raw materials (ores), with the exception of the production of iron from scrap. This course examines the methods used to produce metals from recycled materials and the various potential secondary product streams after the end of their life cycle. More specifically, the course focuses on the methods for:

- production of secondary aluminium from aluminium scrap
- recovery of lead from car batteries and other lead waste streams
- recycling of copper products
- recovery of basic, precious and critical metals from electric and electronic equipment (WEEEs)
- recovery of precious metals from industrial catalysts and car catalysts
- recovery of metals and graphite from alkaline and other batteries
- recovery of technologically important metals from rechargeable lithium-ion (LiB), nickel-cadmium (Ni-Cd) and Nickel–Metal Hydride (NiMH) batteries from digital devices, cars (hybrid and electric) and power storage units.
- recovery of metals from other streams of recycled products

Applied Hydrometallurgy 7052

The course provides detailed analysis of the existing integrated methods for the hydrometallurgical treatment of ores using the various hydrometallurgical units which are described in the course “Hydrometallurgical unit operations” of the basic curriculum., including a) production of nickel and cobalt from laterites by extraction with sulfuric acid – alternative methods, b) production of gold from sulfide ores by bio-extraction methods, c) production of gold by extraction with cyanide, d) production of copper by extraction methods in piles, e) uranium production.

Furthermore, laboratory experiments/tests will be performed by the students concerning all the individual processes of metals recovery from a nickel-iron lateritic sample and ending with the production of a marketable product (metal or hydroxide, or sulphate salt) and their results will be evaluated. The individual steps to be progressively tested include a) Ore sampling and pretreatment, b) chemical analysis using different techniques (aqua regia – fusion – dilution – analysis by Atomic Absorption Spectrometry), c) mineralogy analysis with X-Ray Diffraction and Electron Microscopy, d) ore leeching in tanks at ambient conditions, e) leaching in columns following agglomeration (heap leaching simulation), f) leaching in autoclaves, g) removal of impurities/precipitation in the form of iron hydroxide and

goethite – comparison of properties of an amorphous and a crystalline precipitate), h) bioprecipitation of metals as Sulfur compounds using thio-reducing bacteria, k) recovery/separation of elements with organic Solvents, l) recovery of metals from aqueous solution by electrolysis

Design and Construction of Mineral Processing Plants 7256

Introduction, Equipment and Circuit Calculation, Flow Sheets, Selection and Purchase of Equipment, Engineering Design, Construction Planning and Startup, Examples.

Reactor Design 7030

The course includes the description of three ideal reactor types: the batch reactor and the two continuous flow reactors involving plug or mixed type flow. The operation and optimum design of reactors for single and multiple reactions systems are examined. A section is dedicated to the study of temperature and pressure effects. The energy balance analysis is carried out for all reactor types. Non-isothermal problems involving adiabatic operation or operation with the use of heat exchangers are also examined. Cases of non-ideal flow reactors are described and the methodology for determining the residence time distribution using non-reactive tracers is presented. Finally, there is an introduction to the heterogeneous reactions between solid particulates and fluids. The shrinking core model is analyzed and characteristic examples of reactors are presented.

Chemical Kinetics 7143

Basic Concepts of Chemical Kinetics. Mathematical Description of Kinetic Systems. Experimental Techniques for Kinetic Studies. Interpretation of Experimental Data. Catalysis. Kinetics of Solid-Fluid Systems. Applications in Metallurgy.

V. Materials Science and Engineering

Casting & Forming Processes of Metals 7228

This course introduces students in casting and forming processes. In the frame of the lectures a short review of the non-destructive testing techniques for ensuring as-cast piece integrity also takes place.

The lectures include the theoretical background for the deformation techniques. The plasticity theory sets the scientific foundation for the theoretical understanding of the forming processes and techniques. The complete process chain from casting to material (metals and alloys) processing is presented, reviewed and discussed in the lecture series. Net shape of the as-cast piece, continuous casting processes, reheating and forming operations (forging, rolling, extrusion, sheet metal forming e.g. deep drawing), both hot & warm (for the case of forging, rolling and extrusion) and cold forming operations (mainly rolling) are shown and discussed.

Physical metallurgy background starting from solidification during casting, micro- & macro- segregation, the casting defects and other related metallurgical phenomena are explicitly brought into students' attention. Case studies for instance related to steel and aluminum production are thoroughly covered.

Taxonomy of casting and forming operations are presented as well. As the correlation of processing conditions and microstructure-properties relationships are of great significance, the students are encouraged to think creatively and critically and they are introduced in project-based learning, critical thinking and develop critical skills including working in teams and presenting abilities. Students dive in the effect of temperature and deformation that define the microstructure (including the phenomena that influence static and dynamic recrystallization, residual stresses etc.) and the material properties accordingly.

They learn how to evaluate process steps, microstructures, properties and to select proper forming operations to fit the given purpose for all modern applications and metals/alloys.

- Basic principles of solidification and main casting techniques/methods.
- Plasticity theory and background to plastic deformation. Introduction to plasticity of metals, hardening, elastic and plastic deformation, the Bauschinger effect etc.
- Introduction to the main methods/techniques of plastic deformation in metals/alloys (rolling, extrusion, forging, wire drawing, sheet metal forming e.g. deep drawing), thermomechanical processes, reduction and rolling schedules (roll pass design, deformation rate etc.)
- Influence of thermomechanical deformation in the microstructure evolution and control, recrystallization, grain size and microstructure-properties relationships.
- Main defects from deformation processes (e.g. during rolling, extrusion, forging etc.)
- Anticipation of the manufacturing footprint and value chain.

Powder Metallurgy & Additive Manufacturing (emphasis on 3D printing) 7263

Introduction, production methods of powders in metallurgy, properties of powders (particle size distribution, specific surface, additives), thermal treatment of powders. Compression and shaping, thermal coagulation (mono- or multi-component). Powder metallurgy products: iron and steel, copper, nickel and super alloys, hard metals, high-melting-temperature metals, metal composites.

Advanced Physical Metallurgy of Iron and Steel 7179

This module is an essential module for the knowledge of Industrial Ferrous Alloys. Special Alloy Steels, stainless steels, special cast irons. Alloy steels, Tool Steels, High Speed Steels. Steels resistant to high temperature oxidation and under creep. Carburisation-Nitriding. Electrical Steels. Surface treatments of steels and surface coatings.

Refractory Materials 7048

The subject concerns the basic course in the Technology of Refractory Materials.

The content of the course initially includes the presentation of the refractory materials and their classification followed by an analysis of the properties of these materials and the relevant tests. Then the most significant categories of refractory materials are presented and discussed.

During the semester, the students attend laboratory exercises and deliver the relevant reports for deepening into the subject and developing skills. The cooperation and the development of critical thinking are also encouraged.

- Definition-Classification-Types of refractories
- Microstructure of refractories
- Properties and test methods of refractories
- Shaped refractories (introduction-individual systems-raw materials-production-properties):
- Magnesia based refractories
  - Magnesia based refractories with carbon additions
  - Magnesia based refractories -additions of nanomaterials-antioxidants
  - Chromia based refractories, Magnesio-chromite refractories, Chromo-magnesia refractories
  - Silica based, Aluminosilicate, Corundum based refractories
- Dolomite refractories – Special and insulating refractories
- Phase diagrams of refractory systems
- Monolithic refractories (introduction-raw materials-production-properties): Cast, Launcher, Fiber reinforced, Applications
- Refractory Cement-Properties
- Adjustment of the rheological properties of monolithic refractories

Surface Technology – Surface Engineering 7204

Modification of the outer-surface layers of a material, through relatively low-cost treatments, thus improving-strengthening its properties in order to utilize in high-demand applications. The purpose of the Science of Surface Technology is to guide engineers and scientists in the selection and application of surface treatments that cover a wide range of requirements. For this reason, research in the field of materials surface properties improvement has been focused in recent years in two areas:

- Development of surface properties (strength, hardness, optical, conductive, semi-conductive, magnetic) different from the substrate
- Materials properties improvement regarding their interaction with the environment (e.g. oxidation, corrosion, friction), i.e. aiming to improve the surface properties of materials, as the surface is the area of contact between the material and its environment

The main categories of Surface Treatments are distinguished in:

A. Modification Treatments: Modification of the surface, thus achieving changes regarding in the crystal structure, the microstructure and/or the chemical

composition of the surface, without depositing additional material. They strengthen the base metal itself with/or without the addition of other elements. The basic surface modification treatments are:

1. Flame Hardening
2. Induction Hardening
3. Laser Hardening
4. Electron Beam Hardening
5. Shot Peening
6. Surface Rolling
7. Carburizing
8. Nitriding
9. Boronizing
10. Nitrocarburising
11. Ion Implantation

B. Coatings: Processes with material deposition, during which a layer of another material (coating or deposition) is deposited on the surface, in order to improve the surface properties. Development of a protective, metallic or ceramic coating. The main methodologies of coatings development are:

1. Plating – Electodeposition
2. Hot Dip Coatings
3. Thermal Spray
4. Overlay
5. Physical Vapor Deposition
6. Chemical Vapor Deposition

Pool Courses

Total Quality Management Principles – Quality Control 7236

Introduction to the Principles of Quality Assurance, Standardization, Certification and Calibration. Introduction to the Series of Standards ISO/EN/ELOT 9000, EN 45000 and ISO 14000. Principles of Development and Use of Testing Laboratories and Corresponding Techniques.

Natural Disaster Management 7279

The course material aims to introduce students to the basic concepts of risk, hazard, vulnerability and resilience, in relation to the subject of natural disaster management. It also refers to the specific characteristics of the individual categories of natural disasters. Emphasis is placed on the fundamental design of disaster management at distinct stages, through a holistic and interdisciplinary approach. The graduate of the School, as the engineer with the greatest familiarity with the forces that shape and influence the earth, presents a comparative advantage in understanding natural disasters. This advantage must be enhanced by knowledge of natural disaster management, which covers the whole of the response, from the stage of prevention of a natural disaster to the restoration of the consequences.

- Basic concepts and types of risk, danger, vulnerability, resilience, ability to deal with natural disaster.
- Categories of natural disasters. Characteristics, causes, effects, socio-economic dimensions, statistics, examples from Greece and the world.
- Time phases of disaster. Stages of disaster management planning. Disaster risk management cycle: before, during and after disaster.
- Risk, vulnerability, risk assessment: qualitative, semi-quantitative and quantitative approach, deterministic and probabilistic models, mapping. Risk assessment and acceptance.
- Forecasting / prevention (land use planning etc).
- Impact preparedness and mitigation (early warning systems, contingency planning, evacuation plans).
- Response and recovery (search and rescue, evacuation, emergency assistance, disaster recovery, etc.).
- Risk perception and communication.
- Institutional framework. Stakeholders involved.
- New challenges (e.g. globalization of risk and climate change).

Alternative Energy Systems in the Industry 7280

The basic scope of the current lesson is the teaching of the fundamental practices in the sector of raw materials processing. The environmental impact of the respective processes is, at the same time, studied. The chemical and metallurgical processes, which are applied for the processing and the valorization of mineral raw materials, are correlated to high energy consumption, high consumption of regents and the extensive generation of solid and liquid residues and hazardous off gases. Aiming to the achievement of the targets of the green and circular economy, it is necessary the design of process according to the lowest energy consumption levels. At the same time, the generation of carbon dioxide should be minimized.

The undergraduates will be taught the methodology of energy flows reporting, analysis and management in a real industrial plant aiming to the achievement of the optimum energy consumption result. The undergraduates will be also taught the design and application of green energy sources, such as solar and wind energy, at industrial processes aiming to the elimination of fossils fuels use. The hydrogen production and storage as a raw material for the production of clean energy or as a reduction agent will be stressed out.

The fundamental principles of "life cycle assessment" methodology, which can describe the environmental impact and the evaluate the techno economic data of a process, will be also taught. Finally, various software tools (such as thermodynamic programs, simulators of metallurgical processes and "life cycle assessment tools" will be described within the framework of the course.

- Introduction. Energy demand of developed and less developed countries. Energy sources: energy production and demand issues
- Energy flows and energy cost. Energy demand for the production of ores, concentrates and metals
- Climate change and geo-environment. Exposure of greenhouse gases and impact. Impact on ecosystem, biodiversity and economy
- Management actions for the accumulation of carbon dioxide in atmosphere. Carbon dioxide taxes. Exposure of greenhouse gases by the mining and metallurgical industries. Impact on the economy by the mining and metallurgical industries.
- General issues on conventional plants for energy production (advantages and disadvantages). Thermoelectric, hydroelectric and nuclear power plants. Fossil fuels, technologies and environmental problems. Co-production of thermal energy. Energy recovery by rejected flows. Heat recuperators- heat generators – heat pipes-heat pumps – pinch technology.Production of metallurgical reduction agents by fossil fuels. Comparative evaluation of conventional energy sources
- Alternative and green energy sources. Solar energy: basic principles of design and installation of photovoltaics. Wind energy: basic principles of design and installation of wind turbines. Biofuels: basic principles of design and installation of biofuel plants. Hydrogen: energy carrier, storage and installations design. Use of alternative and green energies in the mining and metallurgical industry. Comparative evaluation of conventional and alternative sources of energy.
- Environmental impact and "life cycle assessment". Definition of the scope and the target in a life cycle assessment.Data inventory and collection and quantification of energy and materials flows. Evaluation and quantification of the environmental impact using ISO indicators. Methodology for the processing and presentation of the results.

Fatigue and Fracture 7285

This module addresses the way that crack formation under fatigue and creep conditions leads to catastrophic failure of metallic materials. The student will acquire skills, knowledge and conceptual understanding on:

- Crack Behaviour and theoretical modelling
- Fracture mechanics and how failure under static conditions and fatigue conditions can be contained.
- How control of material microstructure could be utilised to check behavious and development of cracks.

- Use of modern techniques of fracture mechanics for engineering materials properties and predicting life cycle of components.
- Understanding and analysis of failures

Polymers and Composites Processing 7220

Introduction to Polymer Structure. Macromolecular Chemistry. Crystallinity. Mechanical and Thermomechanical Behavior of Polymers. Viscoelasticity. Rheology. Deformation and Fracture. Polymerization, Types of Polymers, Plastics, Elastomers, Fibers, Applications. Composites. Reinforced Composites. Composite Materials with Metallic or Ceramic Matrix. Composites with Carbon Fibers.

Hydrocarbon Production Engineering 7288

This course is the third in a series following Drilling engineering and Petroleum Engineering. It aims at providing knowledge about the operation and design of production systems, that is by focusing on the big picture of the system through which hydrocarbons travel from the reservoir to the bottom hole, to the wellhead and eventually to the sales point. It provides the tools and methodology to design a production system, study and simulate flow in the wellbore, enhance and maximize production rates, design surface facilities and transport networks while avoiding flow assurance issues.

Mining Systems Simulation 7183

Modeling and analysis of mining systems using discrete-event simulation:

- Introduction to discrete-event simulation
- Random and pseudo-random numbers
- Sampling and parameter estimation
- Variance reduction techniques
- Input modeling
- Simulation with arena
- Simulation of mining systems

Groundwater Modelling 7203

The content of this course refers to: (i) Introduction to groundwater modeling, (ii) Development of conceptual model (hydrolgeological system analysis, determination of hydraulic and hydrologic boundaries, model domain characteristics, spatial and temporal discretization), (ii) Design and construction of groundwater flow model (numerical methods, software and codes, model domain and boundary conditions), (iii) steady state and transient conditions in groundwater modeling (iii) Calibration and sensitivity analysis (parameter estimation), (iv) Forecasting and uncertainty (uncertainty analysis, forecast uncertainty), (v) Mass and contaminant transport (simulation of contaminant transport under saturated/unsaturated conditions), (vi) variable density flow (simulation of seawater intrusion), (vii) Simulation of thermal transport in shallow geothermal fields, (viii) Groundwater model report.

Advanced Investment Analysis 7108

Investment project evaluation is based on the discounted cash flow method, using criteria such as Net Present Value (NPV) and Internal Rate of Return (IRR). To manage the uncertainty inherent in investment project evaluation, techniques like sensitivity analysis and probabilistic risk analysis are employed. In recent years, however, new techniques have emerged. This course focuses on investment evaluation using these specialized techniques, particularly Real Options, which are especially applicable in the extractive sector due to the high levels of uncertainty that characterize it.

Automatic Process Control 7090

Introduction. Basic Principles. Mathematical Methods for Process Control Systems. Dynamic Systems Behavior. Measurements and Instrumentation. Controllers and their Design. Methods of Assessing System Stability. Automatic Control Applications to the Design of Process Control Systems.

Stochastic Simulation of Geological Systems 7292

Synthesis of geological, technical, economic and other information related to the geological system under study for the creation of a unified numerical model. Basic principles of stochastic simulation.

Correlation and consolidation of heterogeneous data: covariogram and the linear model of coregionalization for several random variables. Use of categorical variables for the description of lithofacies: indicators and categorical variables, kriging and cokriging with indicators. Development of lithofacies models using Plurigaussian simulation, incorporation of geological rules for simulation variables.

Introduction to the inverse problem. Methods for solving linear inverse problems in the geosciences. Nonlinear inverse problems and solving methods (McMC, Iterative Algorithms). The inverse problem as an optimization problem. Likelihood function of the parameters of the geological model, spatiotemporal configuration (history matching).

Case studies: Use of acoustic resistance seismic measurements as additional information to improve the knowledge of porosity from borehole sampling. Reservoir volumetrics using data from boreholes related to the depth of the roof and its thickness, assisted by seismic measurements after velocity processing. Determination of the spatial distribution of lithofacies of a simulated aquifer based on its response to pumping conditions.

Modern Methods in Topographic Mapping 7136

The aim of the course is to introduce mine engineering student to the basic principle, measurements and calculations in Geodesy in addition to modern techniques, instruments and applications. The basic principles about the shape and size of the earth, reference surfaces, Geodetic reference systems and frames, and coordinate systems in geodesy are described. The topographic instruments, measurements of angles, distances, height differences are given. Traversing, calculations in rectangular reference system, measurements in underground environment for azimuths, distances, height differences, mapping methods, topographic plans, sections are provided in addition to Calculation of areas and volumes, Shafts (straight, curved arcs). The general principles of satellite positioning systems (GNSS) as well as state-

of-the-art 3D technology and mapping systems, laser scanning, SLAM are discussed. The course is completed with the basic principles for the control of the excavation guidance such as for the geodetic alignment control of a TBM all-front cutting machine.

Computational Methods on Metallurgy and Materials Technology 7295

This course aims to provide general and detailed information on specific computational methods and advanced computer programs are applied by the students for: a) the determination of the structure of complex systems using basic principles with the Reverse Monte Carlo (RMC) simulation method, b) determination of the properties of molten systems using molecular dynamics methods (Molecular Dynamics, MD), c) solving complex and multiparametric computational fluid dynamics (CFD) problems using ANSIS Fluent tools and/or COMSOL Multiphysics, d) the study and prediction of phase and microstructure transformations and their kinetics in liquid/solid and solid/solid systems in industrial alloys using modern methods and simulation software (CALPHAD, Thermo-Calc®, DICTRA, MICRESS®).

The course briefly describes the relevant theoretical background while providing an initial approach to advanced simulation methods applied in Metallurgy and Materials Technology that can be used in various aspects related to the structure and transformations of materials based on basic principles, principles of fluid dynamics, thermodynamics and chemical kinetics. It includes the following

- Structure calculation with Reverse Monte Carlo. X-ray and neutron diffraction. Calculation of structure coefficient and pair distribution functions. Analysis of the RMC optimization method. Calculation of structure of melts, fluids, glass and crystalline materials.
- Molecular Dynamics simulation (MD). Introduction to molecular dynamics simulation and case studies. Basic principles of statistical engineering. Potential functions, supercells, periodic conditions and calculation of the dynamic energy function. Equilibrium statistical sets (micro-normal, normal and isotherm-equilibrium). Correlation of equilibrium statistical sets with equations for calculating thermodynamic properties. Molecular dynamics simulations. Algorithms for solving dynamic equations and basic principles for solving. Analysis of results (particle orbits) for the calculation of structural, dynamic and thermodynamic properties (density, viscosity, electrical conductivity, dielectric constant, etc.). Simulation of metallurgical materials using computer packages (eg slag, ferro-nickel, etc.)
- Computational fluid dynamics (CFD). Introduction. Equations of conservation of mass, momentum and energy. Analysis of incompressible and compressible fluids. Study of the basic turbulence equations. Finite differences and finite volumes. Navier-Stokes equations and assumptions. Methods for discretizing conservation equations. Simulation of metallurgical systems using finite volume computer codes.
- Introduction to the CALPHAD method for the calculation of thermodynamic equilibrium.

- Computational methods of kinetic phase transformations. Basic concepts regarding diffusion. Introduction to moving interface simulation. Analysis of Sharp Interface, Mixed – mode and Solute Drag models. Analysis of local equilibrium conditions.
- Computational method of phase-field microstructure evolution. Introduction to the phase-field model. Simulation of liquid-solid phase transformations, solid-solid. Investigation of recrystallization and grain growth phenomena.

4 Alphabetical Course Listing