A9

COURSE OUTLINES

TECHNICAL UNIVERSITY OF CRETE
School of Mineral Resources Engineering

Course Outlines

MSc Title: Sustainable Technologies of Energy Resources and Raw Materials

Contents

Course Outlines

1st Semester of Studies

Porous materials in environmental protection

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST213	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Select* Appropriate porous materials to solve specific environmental problems. • *Analyse* the surface properties of certain minerals. • *Assess* porous materials for environmental applications. • *Compare (Evaluate)* different porous materials • *Propose* suitable surface modifications of porous materials for environmental applications. • *Develop* critical thinking • *Collect* bibliographical data and use bibliography • *Evaluate* issues and challenges related with environmental problems and select/modify suitable raw materials in solving these problems. • *Combines* data with the use of appropriate approaches/methodologies and contribute in designing processes to tackle environmental issues.
Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Adapting to new situations
- Autonomous work
- Teamwork
- Project design and Management
- Respect for the natural environment
- Promoting free, creative and inductive thinking
- Written communication
- Oral communication
- Leadership
- Self Assurance
- Problem Solving

(3) COURSE CONTENT

1. Introduction to nano/micro porous minerals. Structure of clay minerals and zeolites.
2. Porous minerals (clays zeolites and Fe-Mn oxides) in geological environments.
3. Layer charge of clay minerals and methods of determination.
4. Characterization of porous materials for environmental applications.
5. Electrochemical properties of clay surfaces-Diffuse double layer.
6. Adsorption of inorganic pollutants on clays and zeolites-ion exchange.
7. Interaction of clays with water. Swelling-rheological properties.
8. Organophilic porous minerals. Clay polymer nanocomposites (CPNs).
9. Interaction of porous minerals with organic pollutants.
10. Porous minerals in the pharmaceutical industry.
11. Application of porous minerals in agriculture
12. Porous minerals in containment of waste materials
13. Projects presentation.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Slides via computer - via e-class
In Communication with Students:	- μέσω e-class

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	58 hours
Research/ Study	93 hours
Seminars	20 hours
Literature Review	40 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	50%	(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)
Individual Project	50%	(Public Presentation)
		(Oral Exam)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

• Advances in the characterization of industrial minerals (2011), G.E Christidis (ed). EMU Notes in Mineralogy, vol. 9..
• Clay Surfaces. Fundamentals and Applications (2004). F.Wypych & K. Gundappa Satyanarayana (Eds.) Elsevier, Amsterdam.
• Introduction to colloid and surface chemistry (1992)- D.J. Show
• Natural zeolites: Occurrence, properties, applications. (2001) D.L. Bish & D.W. Ming (Eds). MSA Reviews in Mineralogy and Geochemistry, Vol. 45.
• Various papers suggested by the course instructor during the course.

Trace Element Analysis

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST012	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Compare (Evaluate)* various analytical methods • *Recognise* the advantages and disadvantages of various analytical techniques • *Explain* the difficulties arising during instrumental chemical analysis • *Select* to choose the most appropriate technique, depending on the problem he has to solve • *Interpret* the basic mode of operation of specific analytical techniques

Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Decision-making • Autonomous work • Production of new research ideas • Exercise of criticism and self-criticism • Promoting free, creative and inductive thinking • Initiative • Time Management

(3) COURSE CONTENT

1) Measurement Statistic and Computation, Accuracy and Precision,
2) Probability and Distribution of Error, Samples, estimation and hypothesis testing,
3) The elementary statistics of calibration,
4) Background and detection limits, Standard reference materials
5) Sample preparation, Standard reference materials,
6) Energy dispersive X-ray Fluorescence
7) Modern extraction techniques,
8) Chemical sensors and selective electrodes,
9) Emerging contaminants
10-12) Special applications of selected analytical methods
13) Presentations

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Viewing slides using a PC

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	71 hours
Self Studies	140 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Individual Project	100%	(Public Presentation)

(6) RECOMMENDED-BIBLIOGRAPHY

Books:
Analytical Chemistry by Robert Kellner (Editor), Matthias Otto (Editor), H. Michael Widmer (Editor), Jean-Michel Mermet (Editor) Wiley-VCH
Measurement Statistic and Computation (John Wiley and Sons)
Handbook of Practical X-Ray Fluorescence Analysis (Springer)
Handbook of X-Ray Spectrometry (Marcel Dekker,Inc.)

Journals:
Chemical Review (American Chemical Society)
Analytical Chemistry (American Chemical Society) Special issues
Analyst (The Royal Society of Chemistry) Tutorial reviews
X-Ray Spectrometry (Wiley)

Industrial Safety and Risk Management

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST011	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	Specialization background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to: • *Select* appropriate techniques for analyzing industrial accidents • *Use* methods for qualitative and quantitative estimation of risk • *Develop* plans for the effective management of the occupational risk
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Adapting to new situations • Decision-making • Autonomous work • Teamwork • Production of new research ideas • Project design and Management • Exercise of criticism and self-criticism • Promoting free, creative and inductive thinking • Written communication • Oral communication • Alternative/ Innovative Thinking • Problem Solving

(3) COURSE CONTENT

Definitions and terms (hazard, risk, accident, incident etc), accidents' theory, risk analysis process, hazard identification techniques (Job safety analysis JSA, workplace risk assessment and control WRAC, event tree ETA, fault tree analysis FTA, hazard and operability HAZOP, failure modes error and criticality analysis FMEA, FMECA), risk evaluation methods (qualitative, semi-quantitative, quantitative-stochastic and fuzzy methods), human factor and international standards for the occupational health and safety risk assessment and management.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Power point presentations - e-class support
In Communication with Students:	- face to face - e-class support

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	108 hours
Self Studies	103 hours
Total	250 hours

Other comments about the Teaching Organisation :

Lectures /week

1. Introduction to industrial safety
2. Accidents' theory
3. Accidents cost

4. Hazard identification techniques (JSA, WRAC,)
5. Hazard identification techniques (ETA, FTA)
6. Hazard identification techniques (BOWTIE, HAZOP)
7. Hazard identification techniques (FMEA, FMECA)
8. Qualitative risk assessment methods
9. Quantitative risk assessment methods
10. Stochastic and fuzzy methods in risk assessment
11. Human factor
12. OHSA International standards – safety audits
13. Projects presentation

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	60%	(Comparative evaluation of theoretical issues)
		(Problem solving questions)
Individual Project	40%	(Public Presentation)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

• Integrated Occupational Safety and Health Management - Solutions and Industrial Cases, Seppo Väyrynen · Kari Häkkinen Toivo Niskanen (Editors), Springer (ebook), 2015.
• On the Practice of Safety, Fred A. Manuele, Wiley 4th edition, 2013.
• Occupational and Environmental Safety and Health, Pedro M. Arezes, João S. Baptista, Mónica P. Barroso, Paula Carneiro, Patrício Cordeiro. Nélson Costa, Rui B. Melo, A. Sérgio Miguel, Gonçalo Perestrelo (Editors), Springer (ebook), 2019.
• Basic Guide to System Safety, Jeffrey W. Vincoli, Wiley 3rd edition, 2014.
• Concise encyclopedia of system safety : definition of terms and concepts, Clifton A Ericson, Wiley, 2011.
• Safety and Health for Engineers, Brauer R. L., 2nd edition, J. Wiley, 2006.

Design of sustainable energy and mobility systems

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST016	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	Specialization		

PREREQUISITE COURSES	
LANGUAGE OF TEACHING AND EXAMINATIONS	English
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to:

- *Assess* environmental impact analysis, measurement and monitoring systems, noise control
- *Revise* the design of green energy applications for buildings and cities
- *Calculate* the use of alternative fuels in transport (biofuels, electricity, etc.)
- *Report* the design of transport/mobility solutions for cities and rural areas

Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Project design and Management
- Respect for the natural environment
- Promoting free, creative and inductive thinking
- Problem Solving

(3) COURSE CONTENT

Design principles. Demonstration of the use of the course's virtual Lab. Special renewable energy applications. Electrical systems. Wind - photovoltaic - hybrid. Desalination, autonomous energy systems. Solar air conditioning. Integration into the built environment. Biofuels. Energy, environmental and economic assessment. Multi-criteria analysis for the optimal choice of energy systems. Use of Life Cycle Analysis to study environmental impacts. Critical issues of large transport systems. Sustainable design of large-scale net-zero system (islands, cities). Applications, system dimensioning and examples.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES

TEACHING ORGANIZATION	
Lectures	39 hours
Laboratories	100 hours
Self Studies	120 hours
Total	259 hours

Course Material per Week (13 weeks) :

1. Introduction in design principles
2. Presentation and demonstration of the use of the course's virtual Lab
3. Special renewable energy applications
4. Electrical systems. Wind - photovoltaic - hybrid
5. Desalination, autonomous energy systems
6. Solar air conditioning. Integration into the built environment
7. Biofuels. Energy, environmental and economic assessment
8. Multi-criteria analysis for the optimal choice of energy systems
9. Use of Life Cycle Analysis to study environmental impacts
10. Critical issues of large transport systems
11. Sustainable design of large-scale net-zero system (islands, cities)
12. Applications, system dimensioning and examples.
13. Final Project presentation

(5) STUDENTS ASSESSMENT

Επιμορφωτική/Διαμορφωτική	
Written Final Examination	30%
Individual Project	70%

(6) RECOMMENDED-BIBLIOGRAPHY

Publications using the ReSEL library¨

http://www.resel.tuc.gr/index.php?option=com_content&view=article&id=8&Itemid=26&lang=en

Sustainable processing of ores, by-products and critical raw materials

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST212	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		

THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Relate (Apply)* and understand the linkage between macro-, micro-, and nano-scale (scale effect), as well as to comprehend the significance of (nano)-mineralogy of ores, by-products & critical raw materials (CRMs). • *Describe* and know the properties that allow a material to be classified as a mineral and understand the importance of minerals to mining industry and to society. • *Evaluate* and investigate the mineral-chemistry of base-/noble-metals and CRM hosting phases in ores & by-products. • *Design (Synthesise)* explore & understand the fundamental principles of mineral processing. • *Explain* the unit operations used to separate and recover economic minerals and metals from their ores & by-products. • *Propose* the unit operations to be used in order to separate and to recover economic minerals and metals from their ores & by-products. • *Develop* and instill an attitude of life-long learning, critical thinking and becoming a responsible citizen scientist in the Era of energy transition. • *Operate* and work proficiently and effectively in small teams.
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Autonomous work • Teamwork • Promoting free, creative and inductive thinking • Written communication • Oral communication • Determination • Work in interdisciplinary environment

(3) COURSE CONTENT

The course aims to introduce postgraduate students to basic concepts, definitions and design principles related to the sustainable mineral processing in the Era of the energy transition and the significance of (nano)-mineralogy and mineral processing technologies of selected ores, by-products and critical raw materials (CRM). After successfully completing the course, the student will be able to identify physical-chemical properties of a mineral and, thus, be able to correctly identify several minerals and to design a suitable mineral process technology. Besides, the student know the basic principles and methodology and how to process and evaluate data regarding XRD and optical & electron microscopes. Moreover, the student will be able to apply state-of-the-art combination of sustainable mineral processing methods to harvest the metals and materials we all depend on. Finally, the course promotes free, creative and causative thinking.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Power point presentations - Videos & animations - Workshops & Projects

In Communication with Students:	- Power point presentations - Interactive Instructions - e-class

TEACHING ORGANIZATION	
Lectures	39 hours
Team Project	15 hours
Individual Project	150 hours
Research/ Study	23 hours
Literature Review	23 hours
Total	250 hours

Other comments about the Teaching Organisation :

1. Introduction to (nano)-mineralogy & the scale effect
2. Introduction to critical raw materials, the supply risk & stages of mining
3. Mineral-chemistry of selected base & noble metals ores
4. Mineral-chemistry of selected critical raw materials
5. Mineral-chemistry of selected mining-metallurgical by-products
6. Introduction to instrumental methods in ore mineralogy
7. Principles of mineral processing
8. Particle size & particle size distribution models
9. Comminution – separation – concentration and energy consumption
10. Lab-/industrial-scale sieving & sieving efficiency, mass balance
11. Application of sustainable mineral processing technologies in ores & by-products
12. Application of sustainable mineral processing technologies in critical raw materials
13. Projects presentation

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Team Project	10%	(Public Presentation)
		(Oral Exam)
Individual Project	90%	(Public Presentation)
		(Oral Exam)

(6) RECOMMENDED-BIBLIOGRAPHY

- Putnis A. (1992): Introduction to Mineral Sciences, Cambridge Univ. Press.
- Klein C. & Hurlbut C.S.Jr. (1999): Manual of Mineralogy (after J.D. Dana), J. Wiley & Sons, revised 21st Edition.
- Nesse W.D. (2000): Introduction to Mineralogy, Oxford Univ. Press.
- Lufkin J.L. (2012): Ore Mineralogy & Microscopy, Golden Publishers.
- Wills B.A. & Finch J.A. (2016): Wills Mineral Processing Technology: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery, Butterworth-Heinemann Publishers, Oxford, UK.
- Fuerstenau M.C. & Han K.N. (2003): Principles of Mineral Processing, Society for Mining, Metallurgy, and Exploration, USA.

Raw materials exploitation methods with low environmental footprint

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST211	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	Specialization background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Evaluate* Operations and equipment requirements • *Apply* Modern tools to design critical mining operations • *Design (Analyse)* Underground and surface mining operations with low environmental impact
Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Decision-making
- Project design and Management
- Promoting free, creative and inductive thinking

(3) COURSE CONTENT

1. General principles for mine design.
2. Methods of underground mining.
3. Mechanical equipment for mining.
4. Use of software packages in mine design
5. Critical minerals mining.
6. Exploitation-restoration of abandoned mines.
7. Green Energy Sources in Surface Mining.
8. Long-term carbon storage.
9. Re-exploitation of old mines deposits.
10. Coal substitution in mining energy systems.
11. Use stochastic estimations into optimization of mining operations.
12. Case studies
13. Projects presentation

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Powerpoint - eclass - Whiteboard
In Communication with Students:	- email - eclass - zoom meetings

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	108 hours
Self Studies	103 hours
Total	250 hours

Other comments about the Teaching Organisation :

Lectures/week

1. General principles for mine design.
2. Methods of underground mining.
3. Mechanical equipment for mining.
4. Use of software packages in mine design
5. Critical minerals mining.
6. Exploitation-restoration of abandoned mines.
7. Green Energy Sources in Surface Mining.
8. Long-term carbon storage.
9. Re-exploitation of old mines deposits.
10. Coal substitution in mining energy systems.

11. Use stochastic estimations into optimization of mining operations.
12. Case studies
13. Projects presentation

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	60%	(Multiple Choice Questions / Matching)
		(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)
Individual Project	40%	(Public Presentation)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

Books
[1] Hustrulid, W. A., Kuchta, M., & Martin, R. K. (2013). Open pit mine planning and design, two volume set & CD-ROM pack. CRC Press.
[2] Hoek, E. & Bray, J.W. (1981). Rock Slope Engineering. Institute of Mining and Metallurgy, London.
[3] Fouquet, Y., & Lacroix, D. (Eds.). (2014). Deep Marine Mineral Resources. Springer Netherlands. https://doi.org/10.1007/978-94-017-8563-1
Articles
[4] Strazzabosco, A., Gruenhagen, J. H., & Cox, S. (2022). A review of renewable energy practices in the Australian mining industry. Renewable Energy, 187. https://doi.org/10.1016/j.renene.2022.01.021
[5] Kalantari, H., Sasmito, A. P., & Ghoreishi-Madiseh, S. A. (2021). An overview of directions for decarbonization of energy systems in cold climate remote mines. Renewable and Sustainable Energy Reviews, 152. https://doi.org/10.1016/j.rser.2021.111711
[6] Batterham, R. J. (2017). The mine of the future – Even more sustainable. Minerals Engineering, 107. https://doi.org/10.1016/j.mineng.2016.11.001
[7] Manuel Bustillo Revuelta (2018). Mineral Resources: From Exploration to Sustainability Assessment, Springer (ebook).

Application of geoinformatics, Satellite and Uncrewed Systems on the Energy sector

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST112	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10

COURSE TYPE	General background
PREREQUISITE COURSES	
LANGUAGE OF TEACHING AND EXAMINATIONS	English
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Analyse* satellite data for energy applications • *Design (Analyse)* a GIS sytem • *Evaluate* wind and wave energy potential in offshore areas • *Identify* suitable areas for renewable energy platforms • *Measure* morphology for areas with energy potential • *Review* coresponding literature • *Collect* data through unmanned aerial systems - drones • *Assess* how an underwater, sea surface and terrestrial unmanned systems collect data
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Decision-making • Autonomous work • Production of new research ideas • Project design and Management • Respect for the natural environment • Promoting free, creative and inductive thinking • Written communication • Oral communication • Initiative • Alternative/ Innovative Thinking • Time Management • Determination • Computer Skill • Problem Solving • Work in interdisciplinary environment

(3) COURSE CONTENT

1. Introduction to Geoinformatics 2. Term project structure 3. Geographic Information Science 4. GIS for energy applications 5. Remote Sensing 6. Term project meeting 7. Earth observation for energy applications 8. Entrepreneurship of Geoinformatics and Energy 9. Surveying and laser scanning for energy applications 10. Introduction to machine and deep learning 11. Energy mapping, energy efficiency, mapping energy infrastructure 12. Term project presentation 13. Synopsis of the class

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- PC - eclass
In Laboratory Education:	- PC - eclass
In Communication with Students:	- PC - eclass

TEACHING ORGANIZATION	
Lectures	36 hours
Laboratories	10 hours
Team Project	10 hours
Individual Project	72 hours
Field Work	2 hours
Research/ Study	20 hours
Self Studies	70 hours
Literature Review	30 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	40%	(Multiple Choice Questions / Matching)
		(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)

Team Project	5%	(Project Score)
Individual Project	25%	(Public Presentation)
		(Oral Exam)
		(Project Score)
Intermediate Exams	10%	
Exercises	20%	

(6) RECOMMENDED-BIBLIOGRAPHY

Journal of Applied Remote Sensing
International Journal of Geo-information
Remote Sensing

Environmental control technologies in energy production

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST111	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to: • *Compare (Analyse)* Control technologies before and during the energy exploitation of raw materials (beneficiation, modern clean energy systems, in situ control techniques, use of renewable energy sources) • *Analyse* Particulate matter cleaning technologies from flue gases • *Measure* Sulfur oxide and nitrogen oxide cleaning technologies from flue gases • *Relate (Apply)* Other pollutant compounds cleaning technologies from flue gases • *Relate (Know)* Water pollution control techniques. Solid waste control techniques • *Evaluate* Issues and challenges related with environmental control of thermochemical processes for energy production
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Autonomous work • Teamwork • Production of new research ideas • Respect for the natural environment • Promoting free, creative and inductive thinking • Written communication • Alternative/ Innovative Thinking • Determination • Computer Skill

(3) COURSE CONTENT

1. Energy and the environment
2. Emission of air pollutants from thermal power plants (particulates, sulfur compounds, nitrogen compounds, CO2, CO, HCs, trace elements etc.)
3. Environmental impacts of air pollution (human health, fauna, flora, climate)
4. Techniques of measurement of pollutant emissions
5. Control technologies before and during the energy exploitation of raw materials (beneficiation, modern clean energy systems, in situ control techniques, use of renewable energy sources)- Part I
6. Control technologies before and during the energy exploitation of raw materials (beneficiation, modern clean energy systems, in situ control techniques, use of renewable energy sources)- Part II
7. Particulate matter cleaning technologies from flue gases
8. Sulfur oxide and nitrogen oxide cleaning technologies from flue gases, other pollutant compounds cleaning technologies from flue gases - Part I
9. Sulfur oxide and nitrogen oxide cleaning technologies from flue gases, other pollutant compounds cleaning technologies from flue gases - Part II
10. Techniques for reduction of carbon dioxide emissions. Contamination of water and soil from energy plants and environmental impacts
11. Water pollution control techniques
12. Solid waste control techniques
13. Projects presentation

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Power point presentations, videos and e-class support

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	100 hours
Self Studies	120 hours
Total	259 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	60%	(Comparative evaluation of theoretical issues)
Individual Project	40%	(Public Presentation)
		(Oral Exam)

(6) RECOMMENDED-BIBLIOGRAPHY

D. Vamvuka, “Biomass, Bioenergy and the Environment”, Tziolas publications, 2009 ·
D Vamvuka, “Clean Use of Coals. Low-Rank Coal Technologies”, ION Publishing Co., 2001. ·
International Journals such as “Fuel”, “Energy and Fuels”, “Bioresource Technology” etc.

Political economy of environment and natural resources

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST014	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General knowledge		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to: • *Analyse* processes of development • *Appraise* various theoretical explanations • *Assess* the impact of various technologies • *Combines* social and technical aspects of development • *Compare (Evaluate)* different technical proposals • *Compose* a comprehensive presentation of a project • *Contrast* different energy sources • *Criticise* various theories and models of development • *Debate* the impact of different environmental policies • *Describe* a process of technical and social development • *Discuss* the implications of alternative policies • *Evaluate* the impact of alternative technologies • *Explain* theoretical models and ecological policies • *Review* the relevant literature in a certain area • *Relate (Know)* energy sources and climate crisis
Generic Skills
• Adapting to new situations • Decision-making • Autonomous work • Production of new research ideas • Respect for diversity and multiculturalism • Respect for the natural environment • Exercise of criticism and self-criticism • Promoting free, creative and inductive thinking • Written communication • Oral communication • Alternative/ Innovative Thinking • Time Management • Self Assurance • Determination • Work in interdisciplinary environment

(3) COURSE CONTENT

This graduate course includes: 1. Brief introduction/overview of basic economic concepts and a comparative evaluation of alternative methodological approaches, 2. Socio-philosophical approach to the relationship between people and nature, and to technology, 3. A critical analysis of methods of evaluating investments and of the cost – benefit approach, 4. A comparative presentation of the utilization of natural resources and environmental management under different socio-organizational conditions, 5. A consideration of the economic and ecological implications from the extraction and utilization of natural resources in some characteristic cases, 6. Analysis of the conditions of substitution of alternative energy sources, and of the socioeconomic and environmental implications from the use of these alternative sources, and 7. A critical consideration of the energy question in relation to the problem of climate change.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	100 hours

Research/ Study	36 hours
Literature Review	75 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Individual Project	60%	(Public Presentation)
		(Oral Exam)
Intermediate Exams	40%	

Comments about the Students Assessment :
Apart from the final project (60% of student evaluation), there will be three assignments to students to study, present and discuss in class some articles from the reading list. The performance in this and the active participation in the relevant discussions in class will count for the rest (40%) of the student evaluation.

(6) RECOMMENDED-BIBLIOGRAPHY

Books:

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Exploring data analytics

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST013	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Arrange* Collection, organization, visualization, and analysis of data in a context associated with the primary field of geosciences • *Collect* Intermediate proficiency in the acquisition and organization of data. • *Employ* Intermediate proficiency in the visualization of data to communicate information and patterns that exist in the data • *Create* Proficiency the tools of statistics to ask questions of and explore patterns in data. • *Demonstrate* Display, interpret, and explore data using descriptive statistics and graphs. • *Manage* Use random variables and probability distributions. • *Develop* Determine whether and how to perform statistical inference. • *Prepare* Write programs to perform data analytics on large, complex datasets. • *Examine* Write a clear, focused, concise, complex, and arguable research question. • *Combines* Import, manipulate, clean, visualize, and export data in R, python, Matlab • *Estimate* Aadvanced understanding of the underlying concepts in the time series and frequency domains. • *Practise* Acquire a fundamental understanding of the analytical techniques and software tools necessary to effectively generate useful information from structured and unstructured datasets of any size
Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Decision-making
- Production of new research ideas
- Project design and Management
- Exercise of criticism and self-criticism
- Computer Skill
- Problem Solving

(3) COURSE CONTENT

How to use programming software (R, python, Matlab) as a tool for research and technical computing, including 2-D and 3-D visualization features, numerical capabilities, and toolboxes. Practical skills in areas such as data analysis, time series analysis, computational statistics, regressions, optimization, spectral analysis, differential equations, image analysis, Monte Carlo simulations, uncertainty quantification and propagation.

Week 1 - How to use programming software (R, python, Matlab) as a tool for research and technical computing: Introduction to the programming software environment

Week 2 - Descriptive statistics

Week 3 - 2-D and 3-D visualization features, numerical capabilities, and toolboxes.

Week 4-5 - Probability distributions

Week 6-7 - Data analysis, time series analysis (autoregressive models-AR, moving average models-MA, ARMA, ARIMA, SARIMA)

Week 8-9 - Computational statistics (regressions, simulations,optimization)

Week 10-11 - Clustering and Heatmaps

Week 12-13 - Uncertainty quantification and propagation.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Distance Learning

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Eclass platform - web apps - Moodle
In Communication with Students:	- Eclass platform

TEACHING ORGANIZATION	
Lectures	30 hours
Tutorials	30 hours
Laboratories/Tutorials	30 hours
Individual Project	60 hours
Research/ Study	30 hours
Self Studies	50 hours
Seminars	20 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	40%	(Short answer questions)
		(Problem solving questions)
Individual Project	60%	(Oral Exam)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

Hristopulos, Dionissios T. Random fields for spatial data modeling. Springer Netherlands, 2020.
Hengl, T., 2007. A practical guide to geostatistical mapping of environmental variables, Office for Official Publications of the European Communities, Luxembourg.

Applied geochemistry in raw materials exploration and mining

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST015	**SEMESTER OF STUDIES**	1st
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to: • *Identify* the role of geochemical survey in discovering and exploiting ore deposits • *Describe* fundamentals of primary and secondary dispersion processes • *Propose* geochemical analysis schemes to answer specific geochemical questions
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Autonomous work • Teamwork • Respect for the natural environment • Exercise of criticism and self-criticism • Promoting free, creative and inductive thinking • Written communication • Oral communication • Time Management • Self Assurance • Work in interdisciplinary environment

(3) COURSE CONTENT

The course provides an overview of the critical role of applied geochemistry throughout the mineral recourses value chain, from early stage exploration to mine closure. Subjects covered: Primary and Secondary environment with emphasis in water-rock interaction. Metal and mineral deposits as geochemical anomalies. Fundamentals of elements mobility (transport-fixation) in the near -surface environment. Elemental associations, indicator and vector elements. Speciation Purposes served by geochemical analysis. Types of geochemical exploration surveys. Geochemical datasets. Case Studies of geochemical exploration

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- power point
In Communication with Students:	- e-class

TEACHING ORGANIZATION	
Lectures	39 hours
Team Project	35 hours
Individual Project	46 hours
Research/ Study	50 hours
Self Studies	80 hours
Total	250 hours

Course Material per Week (13 weeks) :

1-Introduction to applied geochemistry. Purposes served by geochemical analysis.
2-3 week
Primary and Secondary environment with emphasis in water-rock interaction.
4-7 week
Metal and mineral deposits as geochemical anomalies. Fundamentals of element mobility (transport-fixation) in the near -surface environment.
8-9 week
Elemental associations, indicator and vector elements. Speciation.
10 week
Purposes served by geochemical analysis. Types of geochemical exploration surveys. Geochemical datasets.
11-13 week
Case Studies of geochemical exploration. Projects presentation. Course review.

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	100%	(Comparative evaluation of theoretical issues)
		(Short answer questions)

(6) RECOMMENDED-BIBLIOGRAPHY

"Introduction to Geochemistry: Principles and Applications" KULA C. MISRA, John Wiley & Sons
"Principles of Environmental Geochemistry" NELSON EBY, Brookscole

https://www.sciencedirect.com/journal/applied-geochemistry

www.appliedgeochemists.org
https://www.eag.eu.com/

Reservoir Engineering for hydrocarbon production, storage and CCS

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST113	SEMESTER OF STUDIES	1st
TEACHING ACTIVITIES	WEEKLY TEACHING HOURS		CREDITS
Lectures	3		
Total	0		10
COURSE TYPE	Specialization background		
PREREQUISITE COURSES			

LANGUAGE OF TEACHING AND EXAMINATIONS	English
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Compare (Analyse)* The different development options of a hydrocarbon reservoir • *Calculate* The possible environmental and financial potential of each reservoir utilization option • *Review* Different operational schemes for hydrocarbon production, gas (Natural, H2) storage and CCS. • *Report* The pros and cons of each operational scheme: Efficiency, capacity, produciton limitations. • *Construct* Simulation geo-models to assess each option • *Choose* Sites suitable for storage based on geological and geophysical prospecting tools
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Decision-making • Teamwork • Promoting free, creative and inductive thinking • Written communication • Computer Skill • Problem Solving

(3) COURSE CONTENT

Module 1: Introduction
- Introduction to hydrocarbon reservoir management
- Introduction to hydrocarbon production
- Introduction to CCS
- Introduction to subsurfase storage

Module 2 (Week 2 and Week 3): Reservoir concepts and storage requirements
- Reservoir trap and seal systems for pore space storage
- Characteristics of reservoir porous media: Porosity, permeability (relative), capillary pressures in drainage - imbibition.
- Shallow reservoirs and saline aquifer storage
- Storage capacity, transition zone
- Production mechanisms

Module 3 (Week 4 and Week 5): Flow mechanics
- Single phase flow in porous media - Darcy
- Single phase flow in porous media - Mass conservation
- Two-phase transport - Pore scale processes
- Two phase transport: Non-linear processes
- Link to dynamic reservoir modelling/simulation

Module 4: Fluids phase behavior
- Hydrocarbon phases PVT
- Characterization of components / liquids
- Types of Reservoirs according to PVT behavior of the fluids
- CO2 / water PVT
- Formation of solids

Module 5: Reservoir simulation
- Mass Balance: Volumetric determination of reserves initially-in-place and remaining reserves
- Well production (VFP, IPR)
- Geomodelling
- PVT modeling (black oil, compositional)
- History matching
- Concepts of reservoir simulation

Module 6: Storage risks: Seals, assessment, geomechanics and geochemistry
- Geochemical requirements to safely store natural gas and hydrogen
- Geomechanical requirements to safely store CO2
- Seal integrity

Module 7: Reservoir monitoring and risk assessment
- Well integrity and subsurface monitoring
- Seabed/shallow subsurface monitoring
- (Near) Surface and Marine monitoring

Module 8: Public perception, policy and emerging/niche of hydrocarbon/hydrogen/CO2 storage options
- CO2 for enhanced oil production
- Emerging/niche options to subsurface storage
- Public perception and policy

Module 9: Economics / project characteristics
- Economics of hydrocarbon production and storage
- CO2 for enhanced oil production and disposal
- Hydrogen storage
- Reservoir recommissioning
- Project stages and milestones

Course timeline:
Week 1, Module 1:
- Introduction to hydrocarbon reservoir management
- Introduction to hydrocarbon production
- Introduction to CCS
- Introduction to subsurfase storage

Week 2, Module 2:
- Reservoir trap and seal systems for pore space storage
- Characteristics of reservoir porous media: Porosity, permeability (relative), capillary pressures in drainage - imbibition.

Week 3, Module 2 (cont.):
- Shallow reservoirs and saline aquifer storage
- Storage capacity, transition zone
- Production mechanisms

Week 4, Module 3:
- Single phase flow in porous media - Darcy
- Single phase flow in porous media - Mass conservation

Week 5, Module 3 (cont.):
- Two-phase transport - Pore scale processes
- Two phase transport: Non-linear processes
- Link to dynamic reservoir modelling/simulation

Week 6, Module 4:
- Hydrocarbon phases PVT
- Characterization of components / liquids
- Types of Reservoirs according to PVT behavior of the fluids

Week 7, Module 4 (cont.):
- CO_2 / water PVT
- Formation of solids

Week 8, Module 5:
- Mass Balance: Volumetric determination of reserves initially-in-place and remaining reserves
- Well production (VFP, IPR)
- Geomodelling

Week 9, Module 5 (cont.):
- PVT modeling (black oil, compositional)
- History matching
- Concepts of reservoir simulation

Week 10, Module 6:
- Geochemical requirements to safely store natural gas and hydrogen
- Geomechanical requirements to safely store CO_2
- Seal integrity

Week 11, Module 7:
- Well integrity and subsurface monitoring
- Seabed/shallow subsurface monitoring
- (Near) Surface and Marine monitoring

Week 12, Module 8:
- CO_2 for enhanced oil production
- Emerging/niche options to subsurface storage
- Public perception and policy

Week 13, Module 9:
- Economics of hydrocarbon production and storage
- CO_2 for enhanced oil production and disposal
- Hydrogen storage
- Reservoir recommissioning
- Project stages and milestones

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Distance Learning

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- zoom meetings - Powerpoint slides - Eclass

In Laboratory Education:	- Reservoir simulation software
In Communication with Students:	- Text editor - Excel examples

TEACHING ORGANIZATION	
Lectures	40 hours
Laboratories	12 hours
Tutorials	12 hours
Team Project	20 hours
Individual Project	20 hours
Laboratory Exercises	10 hours
Self Studies	120 hours
Literature Review	30 hours
Total	264 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	50%	(Multiple Choice Questions / Matching)
		(Short answer questions)
		(Problem solving questions)
Team Project	30%	(Public Presentation)
		(Oral Exam)
		(Project Score)
Individual Project	20%	(Oral Exam)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

Tarek Ahmed, D. Nathan Meehan, 'Advanced Reservoir Management and Engineering (2nd Ed.)', Gulf Professional Publishing, 2012, ISBN 9780123855480, https://doi.org/10.1016/B978-0-12-385548-0.00013-0.
Ronald E. Terry, J. Brandon Rogers, 'Applied Petroleum Reservoir Engineering (3rd Ed.)', Prentice Hall,2015, ISBN-13: 978-0-13-315558-7
Reza Azin, Amin Izadpanahi, 'Fundamentals and Practical Aspects of Gas Injection', SpringerLink, 2022, ISBN: 978-3-030-77200-0
Ringrose Philip, 'How to Store CO2 Underground: Insights from early-mover CCS Projects', SpringerLink, 2020, ISBN: 978-3-030-33113-9

2o Semester of Studies

Emerging technologies for the exploration of raw materials

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST221	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Analyse* images • *Apply* image based analysis • *Solve* exploration challenges using geophysical methods • *Value* the capabilities and limitations of geophysical data types • *Compose* geostatistical data analysis • *Demonstrate* Simulation methods • *Evaluate* Uncertainties
Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Adapting to new situations
- Decision-making
- Autonomous work
- Production of new research ideas
- Exercise of criticism and self-criticism
- Promoting free, creative and inductive thinking
- Written communication
- Oral communication
- Alternative/ Innovative Thinking
- Time Management
- Determination
- Computer Skill
- Problem Solving
- Work in interdisciplinary environment

(3) COURSE CONTENT

Week 1. Introduction to image analysis
Week 2. Image enhancement
Week 3-4. Image analysis
Week 5. Convolutional Neural Networks
Week 6. Introduction to geophysical methods
Week 7. Gravity and magnetic methods
Week 8. Electrical and electromagnetic methods
Week 9. Data acquitision, enhancement and interpretation
Week 10-11. Spatial/spatiotemporal geostatistical analysis principles
Week 12. Conditional Simulation methods
Week 13. Uncertainty propagation

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- PC - eclass - web Apps
In Laboratory Education:	- PC - eclass
In Communication with Students:	- PC - eclass

TEACHING ORGANIZATION	
Lectures	38 hours
Laboratories	12 hours
Tutorials	15 hours
Laboratories/Tutorials	15 hours
Individual Project	60 hours
Research/ Study	40 hours

Self Studies	40 hours
Literature Review	30 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	40%	(Multiple Choice Questions / Matching)
		(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)
Individual Project	30%	(Public Presentation)
		(Oral Exam)
		(Project Score)
Laboratory Exercises	30%	(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

Digital Image Processing by Rafael Gonzalez, Richard Woods

Geophysics for the Mineral Exploration Geoscientist by Michael Dentith, S.T. Mudge

Varouchakis, Emmanouil A. "Geostatistics: mathematical and statistical basis.". Elsevier, 2019. 1-38.

Varouchakis, E.A., 2019. 2 - Background of Spatiotemporal Geostatistical Analysis: In: Corzo, G., Varouchakis, E.A. (Eds.), Spatiotemporal Analysis of Extreme Hydrological Events. Elsevier, pp. 39-57.

Modern technologies for the near-zero-waste processing of low-grade primary ores and secondary raw materials

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST223	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		

Total	0	10
COURSE TYPE	Specialization	
PREREQUISITE COURSES		
LANGUAGE OF TEACHING AND EXAMINATIONS	English	
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes	
COURSE WEBSITE (URL)		

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Select* Processing technologies based on mineralogical analyses • *Compare (Evaluate)* Innovative treatment technologies • *Assess* Economical and environmental impacts • *Apply* Problem (Project) based learning • *Evaluate* The selected toolbox, so that impacts and costs are divided over the entire value chain • *Define* Critical issues pertinent to raw material characterisation, mineral processing, metal extraction. metal recovery, and matrix valorisation
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Decision-making • Teamwork • Written communication • Oral communication • Initiative • Problem Solving • Work in interdisciplinary environment

(3) COURSE CONTENT

1. Introduction to near-zero-waste processing of low-grade primary ores and secondary raw materials
2. Case study 1 - PBL example
3. Case study 2 - PBL example
4. Raw material characterization techniques, examples
5. Mineral processing techniques, Introduction to Project 1
6. Metal recovery, Project 1
7. Matrix valorization, Project 1
8. Project 1 - presentation
9. Introduction to Project 2
10. Project 2
11. Project 2
12. Project 2 – presentation
13. Lessons learnt - Discussions

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Χρήση αρχείων ppt - Υποστήριξη του συστήματος ασύγχρονης ηλεκτρονικής εκπαίδευσης (Open eClass)
In Communication with Students:	- μέσω ιδρυματικού email και eclass

TEACHING ORGANIZATION	
Lectures	39 hours
Team Project	100 hours
Individual Project	56 hours
Research/ Study	35 hours
Literature Review	20 hours
Total	250 hours

Other comments about the Teaching Organisation :
The type of projects (individual / team) will depend on the number of students taking the course.

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Team Project	50%	(Public Presentation)
		(Oral Exam)
		(Project Score)
Individual Project	50%	(Public Presentation)
		(Oral Exam)
		(Project Score)

Comments about the Students Assessment :
Assess / evaluate PBL
Propose project topics for individual work and team work

(6) RECOMMENDED-BIBLIOGRAPHY

• Spooren et al., 2020. Near-zero-waste processing of low-grade, complex primary ores and secondary raw materials in Europe: technology development trends, Resources, Conservation & Recycling 160, 104919, https://doi.org/10.1016/j.resconrec.2020.104919
• Komnitsas et al., 2023. A novel and greener sequential column leaching approach for the treatment of two different Greek laterites, Science of the Total Environment, 854, 158748, https://doi.org/10.1016/j.scitotenv.2022.158748
• Komnitsas et al., 2020. Factors affecting co-valorization of fayalitic and ferronickel slags for the production of alkali activated materials, Science of the Total Environment, 721, 137753, https://doi.org/10.1016/j.scitotenv.2020.137753

Selected Topics in Analytical Chemistry

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST021	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to:

- *Compare (Evaluate)* various analytical methods
- *Recognise* the advantages and disadvantages of various analytical techniques
- *Explain* the difficulties arising during instrumental chemical analysis
- *Select* to choose the most appropriate technique, depending on the problem he has to solve
- *Interpret* the basic mode of operation of specific analytical techniques

Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Decision-making
- Autonomous work
- Production of new research ideas
- Exercise of criticism and self-criticism
- Promoting free, creative and inductive thinking
- Initiative
- Alternative/ Innovative Thinking

(3) COURSE CONTENT

1) Interaction of radiation with matter, spectral line broadering 2) X-Ray Analysis modern applications 3) Analytical applications of synchrotron radiation 4) Gamma ray spectrometry, 5) Activation analysis, 6) Mössbauer spectroscopy, 7) Microbeam and surface analysis, 8) Environmental radioactivity, the table of isotopes, 9) The radon problem, 10) Membranes in analytical chemistry, Speciation analysis, 11-12) Special applications of selected analytical methods 13) Presentations

(4) **TEACHING AND LEARNING METHODS - EVALUATION**

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Viewing slides using a PC

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	71 hours
Self Studies	140 hours
Total	250 hours

(5) **STUDENTS ASSESSMENT**

Επιμορφωτική/Διαμορφωτική	
Individual Project	100%

(6) **RECOMMENDED-BIBLIOGRAPHY**

Books: Analytical Chemistry by Robert Kellner (Editor), Matthias Otto (Editor), H. Michael Widmer (Editor), Jean-Michel Mermet (Editor) Wiley-VCH Measurement Statistic and Computation (John Wiley and Sons) Handbook of Practical X-Ray Fluorescence Analysis (Springer) Handbook of X-Ray Spectrometry (Marcel Dekker,Inc.) Radiation Protection of the Public and the Environment, International Atomic Energy Agency, Vienna 2018 Journals: Chemical Review (American Chemical Society) Analytical Chemistry (American Chemical Society) Special issues Analyst (The Royal Society of Chemistry) Tutorial reviews X-Ray Spectrometry (Wiley)

Biofuels-Thermochemical processes

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST121	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Analyse* Biomass composition as feedstock for conversion to solid, liquid and gaseous biofuels • *Apply* New clean pyrolysis, combustion and gasification technologies as thermochemical processes for conversion to biofuels • *Assess* The environmental impact of pyrolysis, combustion and gasification processes • *Examine* Production of transportation fuels and the biofuels market • *Evaluate* Issues and challenges related with thermal utilization of solid biofuels for energy production, as well as production of transportation fuels
Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Autonomous work
- Teamwork
- Production of new research ideas
- Respect for the natural environment
- Exercise of criticism and self-criticism
- Written communication
- Alternative/ Innovative Thinking
- Computer Skill

(3) COURSE CONTENT

1. Energy consumption, depletion of reserves and environmental issues
2. Biomass and organic wastes as sources of biofuels
3. Resources, abundance and energy potential.
4. Physical, chemical and thermal properties. Storage, handling and transportation
5. Production of solid, liquid and gaseous biofuels by pyrolysis (fundamentals, designs, upgrading of liquids, case studies)- Part I 6. Production of solid, liquid and gaseous biofuels by pyrolysis (fundamentals, designs, upgrading of liquids, case studies)- Part II
7. Conversion of cellulosic materials to liquid biofuels-Liquefaction (fundamentals, processes)
8. Combustion for heat and power production (fundamentals, systems, case studies)
9. Co-combustion of fossil and renewable fuels
10. Gasification processes for syngas and hydrogen production (fundamentals, designs, advanced systems)
11. Combined heat and power applications.
12. Production of transportation fuels (methanol, hydrogen, dieselFT, dimethylether). Biofuels market
13. Projects presentation

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Power point presentations, videos and e-class support

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	100 hours
Self Studies	120 hours
Total	259 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	60%	(Comparative evaluation of theoretical issues)
Individual Project	40%	(Public Presentation)
		(Oral Exam)

(6) **RECOMMENDED-BIBLIOGRAPHY**

D. Vamvuka, "Biomass, Bioenergy and the Environment", Tziolas publications, 2009 · D Vamvuka, "Clean Use of Coals. Low-Rank Coal Technologies", ION Publishing Co., 2001. · International Journals such as "Fuel", "Energy and Fuels", "Bioresource Technology" etc.

Mine Geotechnical Investigation

(1) **GENERAL**

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST023	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	Skills development		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) **LEARNING OUTCOMES**

Learning Outcomes
After completing this course the student will be able to: • *Design (Synthesise)* and manage a geotechnical investigation program for mining projects. • *Evaluate* geological, hydrogeological and geotechnical data and identify potential issues that may arise during mining.
Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Adapting to new situations
- Decision-making
- Autonomous work
- Teamwork
- Production of new research ideas
- Project design and Management
- Respect for the natural environment
- Exercise of criticism and self-criticism
- Written communication
- Determination
- Problem Solving

(3) COURSE CONTENT

General competencies / skills
The course provide students with understanding of the application of geotechnical engineering principles in mining.
They will able to
- determine structural, hydrogeological, and stress-related conditions that could influence the design and stability of mine excavations
- assess environmental impacts
- work in small groups
- explore project based learning

Course syllabus
- Drilling programs to gather data for characterization the site's geotechnical conditions.
- Evaluation of geotechnical parameters to be used for the mine design. Case study I – Project based learning.
- Design of geotechnical models and simulation.
- Analysis of monitoring results and engineering recommendations. Case study II – Project based learning
- Introduction to Project
- Project presentation
- Lessons learnt - Discussion

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Power point presentations
In Communication with Students:	- e-class support

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	166 hours
Self Studies	45 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment

Written Final Examination	30%	(Multiple Choice Questions / Matching)
		(Short answer questions)
		(Problem solving questions)
Individual Project	70%	(Public Presentation)
		(Oral Exam)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

A SHORT COURSE IN GEOTECHNICAL SITE INVESTIGATION. Simons, N., Menzies, B. & Matthews, M. Thomas Telford, 2002.

CORES AND CORE LOGGING FOR GEOSCIENTISTS, 2nd edition. Graham A. Blackbourn Whittles Publishing, 2012.SOIL AND ROCK DESCRIPTION IN ENGINEERING PRACTICE. David Norbury. Whittles Publishing, 2010.

SOIL STRENGTH AND SLOPE STABILITY. J. Michael Duncan, Stephen G. Wright, Thomas L. Brandon. Second edition. Hoboken, New Jersey John Wiley & Sons Inc., 2014.

Monopolis D., Stiakakis E., Agioutantis Z., Kavouridis K. (1999). Geotechnical Investigation at lignite mines. Mineral Resources Engineering, Vol 8, No 4, pp. 405 - 418.

Steiakakis E., Agioutantis Z. (2010). A kinetic behavior model at a surface lignite mine, based on geotechnical investigation. Simulation Modelling Practice and Theory. Volume 18, Issue 5, May 2010, Pages 558-573. http://dx.doi.org/10.1016/j.simpat.2009.12.011.

Steiakakis E., Kavouridis K., Monopolis D. (2009). Large scale failure of the external waste dump at the "South Field" lignite mine, Northern Greece. Engineering Geology 104 (2009) pp. 269-279.

Steiakakis, E., A. Lazaropoulos, A. Vafidis, Z. Agioutantis, G. Kritikakis (2017). Determination of shear wave velocities in sediment deposits. International Journal of Geotechnical Engineering, 2017; http://dx.doi.org/10.1080/19386362.2017.1374494.

Galetakis, M.; Deligiorgis, V.; Steiakakis, E.; Raka, S.; Alheib, M. Risk Assessment Methodology for Pit Lakes Instabilities. Mater. Proc. 2021, 5, 92. https://doi.org/10.3390/

Instrumental analysis for raw materials

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST222	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		

PREREQUISITE COURSES	
LANGUAGE OF TEACHING AND EXAMINATIONS	English
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to:

- *Describe* the analytical techniques employed for raw material chemical characterization
- *Apply* the methodology required to produce accurate and precise results
- *Compare (Evaluate)* analytical techniques employed in geochemical analysis
- *Choose* analytical methodology to provide information to help solving a specific geochemical problem

Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Autonomous work
- Teamwork
- Respect for the natural environment
- Written communication
- Oral communication
- Self Assurance
- Work in interdisciplinary environment

(3) COURSE CONTENT

The course provides an overview of the analytical techniques and methodology employed to chemically characterize raw materials. Topics covered:

Steps of analytical process. Geochemical analysis. Sampling, decomposition/pretreatment techniques.

Bulk analysis, spatial analysis, real - time (field based) analysis.

Quantitative Spectroscopy and Electron microscopy techniques for raw material analysis.
Raw materials: properties and characteristics related to their spectroscopic analysis
Emerging techniques and novel applications

Data quality control. Figures of merit. Data processing.
Method selection
.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- power point

In Communication with Students:	- e-class

TEACHING ORGANIZATION	
Lectures	39 hours
Team Project	31 hours
Individual Project	50 hours
Research/ Study	40 hours
Self Studies	60 hours
Literature Review	40 hours
Total	260 hours

Course Material per Week (13 weeks) :
Week 1
Introduction to geochemical analysis, challenge and purpose
Week 2-3
Steps of analytical process. Geochemical analysis. Sampling, decomposition/pretreatment techniques.
Week 3
Bulk analysis, spatial analysis, real – time (field based) analysis.
Week 4-7
Quantitative Spectroscopy and Electron microscopy techniques for raw material analysis.
Raw materials: properties and characteristics related to their spectroscopic analysis
Emerging techniques and novel applications
Week 8-11
Data quality control. Figures of merit. Data processing.
Method selection
Week 12-13
Case studies. Project presentation. Course review, discussion
.

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	100%	(Comparative evaluation of theoretical issues)
		(Short answer questions)

(6) RECOMMENDED-BIBLIOGRAPHY

"Modern analytical Geochemistry" ed. Robin Gill, Pearson Education "A Handbook of Silicate Rock Analysis" P.J. Potts, Spinger "Principles of Instrumental Analysis" Douglas A. Skoog, F. James Holler, Stanley R. Crouch, Cengage Learning https://www.sciencedirect.com/journal/applied-geochemistry www.appliedgeochemists.org https://www.eag.eu.com/

Advanced topics in Applied Geophysics

(1) **GENERAL**

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST026	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) **LEARNING OUTCOMES**

Learning Outcomes
After completing this course the student will be able to: • *Tell* capabilities and limitations of various geophyical data types • *Combines* geological and geophysical information during mineral resources exploration • *Define* the importance of geophysics in the future of mineral resources exploration • *Explain* the state-of-the-methods for analysing geophysical data • *Examine* exploration challenges using geophysical methods
Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Adapting to new situations
- Decision-making
- Autonomous work
- Production of new research ideas
- Exercise of criticism and self-criticism
- Promoting free, creative and inductive thinking
- Written communication
- Oral communication
- Alternative/ Innovative Thinking
- Time Management
- Determination
- Computer Skill
- Problem Solving
- Work in interdisciplinary environment

(3) COURSE CONTENT

The purpose of this course is to introduce advanced topics in applied geophysics for mineral resources exploration. This course teaches the students how to integrate geological and geophysical data in a mineral exploration context. Emphasis will be given in modern data acquisition techniques and advaced optimal geophysical data processing methods.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- PC - e-class
In Laboratory Education:	- PC - e-class
In Communication with Students:	- PC - e-class

TEACHING ORGANIZATION	
Lectures	30 hours
Laboratories	14 hours
Tutorials	36 hours
Individual Project	80 hours
Research/ Study	80 hours
Literature Review	10 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	40%	(Multiple Choice Questions / Matching)
		(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)
Individual Project	30%	(Public Presentation)
		(Oral Exam)
		(Project Score)
Laboratory Exercises	30%	(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

Geophysics for the Mineral Exploration Geoscientist by Michael Dentith, S.T. Mudge

Economic geology of industrial minerals and rocks

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST024	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Assess* certain types of industrial rocks and minerals • *Combines* data obtained from different approaches/methodologies and design assessment routes for characterization of useful raw materials. • *Discuss* economic aspects of industrial minerals and rocks, related to their superior physical and chemical properties. • *Design (Analyse)* assessment routes for important industrial minerals and rocks. • *Develop* free, creative and causative thinking. • *Analyse* main physical and chemical properties of industrial rocks and minerals that are essential for their characterization. • *Examine* high added value products produced from low added value materials, including synthetic materials.
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Decision-making • Autonomous work • Teamwork • Production of new research ideas • Project design and Management • Respect for the natural environment • Exercise of criticism and self-criticism • Promoting free, creative and inductive thinking • Written communication • Oral communication • Initiative • Alternative/ Innovative Thinking • Time Management • Problem Solving

(3) COURSE CONTENT

1. Introduction to and special features of industrial minerals and rocks. Geological terrains/environments for industrial minerals and rocks.
2. Physical and chemical properties of industrial minerals and rocks. Part I
3. Physical and chemical properties of industrial minerals and rocks. Part II
4. Industrial Clays. Part I Kaolins
5. Industrial Clays. Part II Bentonites-Zeolites
6. Industrial Clays. Part III Common Clays and Shales.
7. Limestone raw materials
8. Aggregates and building materials
9. Industrial Mineral Fillers
10. Raw materials for the cement industry.
11. Raw materials for the refractory industry.
12. Glass and foundry sands.
13. Utilization of industrial minerals waste materials-Circular economy.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Slides via computer - via e-class
In Communication with Students:	- via e-class

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	80 hours
Research/ Study	70 hours
Seminars	20 hours
Literature Review	41 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	50%	(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)
Individual Project	50%	(Public Presentation)
		(Oral Exam)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

- Advances in the characterization of industrial minerals (2011), G.E Christidis (ed). EMU Notes in Mineralogy, vol. 9.
- Industrial Minerals and Rocks 6th Edition (1994) D.D. Carr editor.
- Introduction to Industrial Minerals (1995) D.A.C Manning.
- Industrial Minerals and Rocks commodities, markets and uses. 7th Edition (2006) J. Elzea-Kogel et al. (eds).
- Aggregates. Sand gravel and crushed rock aggregates for construction purposes. 2nd edition (1993). M.R. Smith & L. Collis. The Geological Society, London.
- Various papers suggested by the course instructor during the course.

Fossil Fuels and Energy Transition

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST122	SEMESTER OF STUDIES	2nd
TEACHING ACTIVITIES	WEEKLY TEACHING HOURS		CREDITS

Lectures	3	
Total	0	10
COURSE TYPE	Specialization background	
PREREQUISITE COURSES		
LANGUAGE OF TEACHING AND EXAMINATIONS	English	
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes	
COURSE WEBSITE (URL)		

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Analyse* Analyze energy production systems in terms of efficiency and their environmental impacts (both in the short and longer term) • *Propose* Propose and design efficient and sustainable energy production and transformation process utilizing different power sources in ways that are compatible with recent EU net-zero carbon directives. • *Develop* Develop independent and analytic thinking and effective response to complex design problems with both economic and environmental impact
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Decision-making • Project design and Management • Respect for the natural environment • Demonstrating social, professional and ethical responsibility and sensitivity to gender issues • Promoting free, creative and inductive thinking • Oral communication • Initiative • Problem Solving • Work in interdisciplinary environment

(3) COURSE CONTENT

This course focuses on conventional and renewable energy technologies within the framework of the European net-zero carbon target for 2050. The students will be progressively introduced to the primary energy sources and their basic transformation processes, including Fossil Fuels (Oil, Gas, Coal) and their uses in Internal Combustion Engines and Thermal Power Stations, Solar and Wind Energy Systems, Thermal and Photovoltaic Solar Systems, and Hydroelectric plants. The course will also cover the Environmental and Climate Impact of Energy-related Processes, including global warming from CO2 production, transitional mitigation strategies, such as CCS, and the European Energy Transition Strategies and Policies. The technological bottlenecks related to energy storage from renewables, the transfer of energy in the form of synthetic fuels (methane, hydrogen) and their integration in the power grid will also be discussed. The course will be delivered in 13 weeks according to the following weekly schedule: 1. Introduction to basic forms of energy 2. Basic energy transformation processes 3. Fossil fuels and related energy systems 4. Environmental impacts of carbon-based fuels 5. EU energy policies and directives 6. Carbon capture and storage and transitional technologies 7. Renewable Energy Systems (Solar, Aeolian) 8 Renewable Energy Systems (Biomass, Geothermal) 9. Nuclear and Hydroelectric power plants 10. Contribution of different energy sources in global power production and consumption – Main importers and exporters of energy 11. Transitional energy production, transport, and consumption technologies 12. Technological Bottlenecks for novel energy production systems 13. Costs and Life-cycle assessment of novel technologies

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Powerpoint presentations - Educational videos
In Communication with Students:	- Eclass platform - Online data repositories - Email

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	100 hours
Research/ Study	101 hours
Seminars	10 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	60%	(Multiple Choice Questions / Matching)
		(Short answer questions)
		(Problem solving questions)
Individual Project	40%	(Public Presentation)

(6) RECOMMENDED-BIBLIOGRAPHY

• Energy Technologies and Economics, P.A Narbel, J. P. Hansen and J.R. Lien, Springer
• Fundamentals of Renewable Energy Processes 3rd Edition, A.V. da Rosa, Academic Press

Circular Economy

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST029	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to:

- *Identify* The environmental problems and issues that led to the need for paradigm shift
- *Recognise* The relation and interconnection between sustainability and circularity
- *Distinguish* The basic principles and approach of circular economy
- *Develop* The adoption of circularity in the business sector and the industry
- *Propose* The change in mindset and way of thinking
- *Illustrate* The benefits of circular economy for the users, the economy, the society and the businesses

Generic Skills

- Adapting to new situations
- Decision-making
- Autonomous work
- Project design and Management
- Respect for the natural environment
- Promoting free, creative and inductive thinking
- Oral communication
- Problem Solving

(3) COURSE CONTENT

The course aims to present and analyze the basic principles and concept of Circular Economy. As a relatively new paradigm of economic development, Circular Economy is rapidly growing. The course will show how Circular Economy can be applied in practice, in which disciplines and areas, and the opportunities that provides for multi- and interdisciplinary collaboration. The course also aims at supporting the participant to carry out or reflect upon her/his research and study with a transdisciplinary approach.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Videos
In Communication with Students:	- Eclass & emails - Zoom calls

TEACHING ORGANIZATION	
Lectures	39 hours
Individual Project	100 hours
Research/ Study	120 hours
Total	259 hours

Course Material per Week (13 weeks) :
Week 1: Introduction to the Circular Economy – Class Overview
Week 2: Sustainable growth and Circular Economy
Week 3: Circular Economy Principles
Week 4: Waste and Systems-Level Thinking
Week 5: Enterprise Environmental Performance - Environmental Management Systems (Part I)
Week 6. Green Entrepreneurship & Financing
Week 7: Environmental Management & Policy
Week 8: Enterprise Environmental Performance - Environmental Management Systems (Part II)
Week 9: Enterprise Environmental Performance & Environmental Practices
Week 10: Material and Product Design
Week 11: Environmental Quality Assurance Techniques
Week 12: Circular Economy at the Urban and Regional Level - Case Studies
Week 13: Project presentations by students

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Individual Project	100%	(Public Presentation)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

- Ellen MacArthur Foundation, “Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition,” 2013. Executive Summary.
- Stefanakis, A.I. and Nikolaou, I., 2021. Circular Economy and Sustainability - Management and Policy, Volumes I & II. Elsevier Publishing, Amsterdam, The Netherlands, September.
- A. Wijkman and K. Skanberg, “The Circular Economy and Benefits for Society,” Sections 2 and 4, 2015
- Ellen MacArthur Foundation, “Completing the picture - How the Circular Economy tackles climate change”, September 2019.
- Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. Journal of Cleaner Production, 115, 36-51. https://doi.org/10.1016/j.jclepro.2015.12.042

Data science for Exploration and Exploitation

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST025	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to: • *Analyse* Describe and identify basic practical uses of geostatistical principles • *Develop* Basic modeling informatic needs and objectives to computer specialists • *Apply* Data analytics objectives for model building to data scientists (treatment of missing values, sparse data, univariate and bivariate statistics). • *Assess* Identify the important univariate and bivariate statistical metrics from input data for use in preparing and building static and dynamic models • *Arrange* Describe the basic requirements for building geostatistical models. • *Create* Modify and write scripts to construct omnidirectional and directional experimental semivariograms and fit them with authorized variogram models • *Compose* Space-time variogram analysis • *Demonstrate* Construct space-time kriging and conditionally simulated maps • *Prepare* Machine Learning and other data science methods
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Adapting to new situations • Decision-making • Autonomous work • Teamwork • Project design and Management • Exercise of criticism and self-criticism • Alternative/ Innovative Thinking • Computer Skill • Problem Solving

(3) COURSE CONTENT

This course provides an overview of the most relevant areas of data science (applied statistics, machine learning) to address geoscience challenges, questions and problems. Using actual geoscientific research questions as background, principles and methods of data scientific analysis, modeling, and prediction are covered. Data science areas covered are: Week1 -2 multi-variate analysis, factor analysis, compositional data analysis, Week 3-4 spatial information aggregation models, spatial estimation, Week 5-6 geostatistical simulation (Bayesian method), Week 7 data fusion, treating data of different scales of observation, Week 8-9 spatio-temporal modeling (geostatistics), Week 10-11 self organizing maps, k-means (clustering methods) Week 12-13 gaussian processes.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Moodle - web apps
In Communication with Students:	- Eclass platform

TEACHING ORGANIZATION	
Lectures	39 hours
Tutorials	26 hours

Team Project	50 hours
Individual Project	50 hours
Research/ Study	25 hours
Self Studies	50 hours
Seminars	10 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	50%	(Comparative evaluation of theoretical issues)
		(Problem solving questions)
Team Project	20%	(Project Score)
Individual Project	30%	(Public Presentation)
		(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

Corzo, Gerald, and Emmanouil Varouchakis, eds. Spatiotemporal analysis of extreme hydrological events. Elsevier, 2018.
Hristopulos, Dionissios T. Random fields for spatial data modeling. Springer Netherlands, 2020.
Goovaerts, Pierre. Geostatistics for natural resources evaluation. Oxford University Press on Demand, 1997.

Environmental economics and policy

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST028	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		

PREREQUISITE COURSES	
LANGUAGE OF TEACHING AND EXAMINATIONS	English
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to:

- *Relate (Know)* background concepts of economic thought and rationality
- *Analyse* issues and challenges in terms of social welfare
- *Compare (Analyse)* environmental policy impacts in presence of conflicting criteria
- *Formulate* best satisficing alternatives taking into consideration social, economic and environmental dimensions
- *Use* critical, creative and causative evidence-based thinking

Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Decision-making
- Teamwork
- Respect for the natural environment
- Exercise of criticism and self-criticism
- Promoting free, creative and inductive thinking
- Oral communication
- Alternative/ Innovative Thinking
- Computer Skill
- Problem Solving
- Work in interdisciplinary environment

(3) COURSE CONTENT

This course studies the economics of public policy toward the environment. Concepts discussed comprise demand and supply basics, the economic agents' surplus and welfare, the problem of market failure in the presence of externalities and public goods. Then, public policy responses to these market failures are discussed, including command-and-control regulations, tax and subsidy incentives, marketable pollution permits, voluntary programs, and information as regulation. Decision theory completes the course making reference to cost-benefit analysis method for project evaluation complemented by an extensive overview of state-of-the-art multi-criteria methods thereby implemented in relevant problems.

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Power point presentations, videos and e-class support
In Laboratory Education:	- appropriate software applications
In Communication with Students:	- eclass, email

TEACHING ORGANIZATION	
Lectures	39 hours
Laboratories/Tutorials	30 hours
Team Project	100 hours
Self Studies	71 hours
Literature Review	10 hours
Total	250 hours

Course Material per Week (13 weeks) :

1st week Economics in environmental management; Building a green economy
2nd week Benefit/Cost analysis – investment appraisal - hands on
3rd week Multi-criteria decision analysis in environmental problems
4th week Outranking methods - Analytical Hierarchy Process
5th week Multi-criteria methods - hands on experience
6th week Case studies – published relevant paper presentations
7th week Basic concepts of economic analysis: demand and supply
8th week Market clearing and economic welfare
9th week Market failures, externalities
10th week Command & control policy measures
11th week Policy through incentives
12th week CBA versus Multi-criteria analysis : critical state-of-the-art policy practice
13th week Case studies – presentations

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	50%	(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)
Team Project	20%	(Public Presentation)
Individual Project	30%	(Public Presentation)

Comments about the Students Assessment :

Student evaluation is meant to provide feedback to better organize and enrich the course.

(6) RECOMMENDED-BIBLIOGRAPHY

Environmental Economics and Management: Theory, Policy, and Applications, fifth edition, by Scott J. Callan and Janet M. Thomas (Fort Worth, TX: The Dryden Press, 2010).
Multiple Criteria Decision Analysis: State of the Art Surveys, second edition, by S. Greco, M. Ehrgott, JR Figueira, eds. (Springer, 2016)
T. A. Easton and T.D. Goldfarb, Taking Sides -Environmental Issues, 2003. εκδ. McGraw-Hill/Dushkin

Seismic signal processing

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST027	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to:

- *Define* the assumptions involved in processing approaches
- *Analyse* seismic reflection images
- *Apply* seismic data processing methods
- *Choose* the most appropriate technique during certain seismic signal processing steps

Generic Skills

- Research, analysis and synthesis of data and information, using the necessary technologies
- Adapting to new situations
- Decision-making
- Autonomous work
- Production of new research ideas
- Exercise of criticism and self-criticism
- Promoting free, creative and inductive thinking
- Written communication
- Oral communication
- Alternative/ Innovative Thinking
- Time Management
- Determination
- Computer Skill
- Problem Solving
- Work in interdisciplinary environment

(3) COURSE CONTENT

1.Introduction to the seismic reflection method
2.Introduction to data acquisition techniques
3.Static corrections
4.Velocity analysis
5.Introduction to Fourier analysis
6.Deconvolution
7.Signal to noise ratio enhancement techniques
8.Multiple elimination
9. Stacking
10. Migration
11. Velocity model building
12. Introduction to AVO, 4D seismics and seismic inversion
13. Review of seismic signal processing techniques using real data examples

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- PC - e-class
In Laboratory Education:	- PC - e-class
In Communication with Students:	- PC - e-class

TEACHING ORGANIZATION	
Lectures	30 hours
Laboratories	14 hours
Tutorials	36 hours
Individual Project	80 hours
Research/ Study	80 hours
Literature Review	10 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	40%	(Multiple Choice Questions / Matching)
		(Comparative evaluation of theoretical issues)
		(Short answer questions)
		(Problem solving questions)

Individual Project	30%	(Public Presentation)
		(Oral Exam)
		(Project Score)
Laboratory Exercises	30%	(Project Score)

(6) RECOMMENDED-BIBLIOGRAPHY

Seismic data processing by Oz Yilmaz
Geophysical signal analysis by Enders Robinson, Sven Treitel
Exploration Seismology by Robert Sheriff, L.P. Geldart

Energy-efficient mineral processing plant design

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST123	**SEMESTER OF STUDIES**	2nd
TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**		**CREDITS**
Lectures	3		
Total	0		10
COURSE TYPE	General background		
PREREQUISITE COURSES			
LANGUAGE OF TEACHING AND EXAMINATIONS	English		
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes		
COURSE WEBSITE (URL)			

(2) LEARNING OUTCOMES

Learning Outcomes

After completing this course the student will be able to: • *Define* and understand the fundamental principles of mineral processing. • *Calculate* the mass balances for a mineral processing plant. • *Apply* basic engineering principles to the mineral processes. • *Assess* the investment efficiency of a mineral processing plant. • *Describe* typical unit processes and flow-sheets for metal production.
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Decision-making • Autonomous work • Teamwork • Promoting free, creative and inductive thinking • Written communication • Oral communication • Determination • Problem Solving • Work in interdisciplinary environment

(3) **COURSE CONTENT**

The course deals with the introduction of the general principles of mineral processing, as well as with the simulation of mineral processing plants aiming to improve their energy efficiency. After successfully completing the course, the student will be able to design mineral processing plants toward the optimization of mineral processing operations. In particular, the students will gain insights into the unit operations used to separate and recover economic minerals and metals from their ores. Finally, the course promotes free, creative, and causative thinking, aiming to adapt students into responsible citizen scientists in the Era of the energy transition.

(4) **TEACHING AND LEARNING METHODS - EVALUATION**

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Power Point presentations - Videos and animations - Work-shops and projects
In Communication with Students:	- Power Point presentations - Interactive instructions - e-class

TEACHING ORGANIZATION	
Lectures	39 hours
Team Project	15 hours
Individual Project	150 hours
Research/ Study	23 hours
Literature Review	23 hours
Total	250 hours

Other comments about the Teaching Organisation :

1. Principles of simulation of mineral processing plants.
2. Introduction to MODSIM simulator, flow-sheet construction, system data and model parameters.
3. Particle size distribution models, screening, open/close circuit crushing operation.
4. Crushing plant simulation, data entry, unit model parameters.
5. Closed-circuit grinding plant, data entry, unit model parameters, optimization.
6. Energy-particle size reduction relationships.
7. Grinding kinetic modeling, optimization of energy consumption.
8. Distribution of particles over grade classes and S-classes.
9. Simulation of integrated mineral processing plants.
10. Economic analysis methodology.
11. Criteria for investment efficiency assessment.
12. Methodology of techno-economic analysis in the design of mineral processing plants.
13. Projects presentation.

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Team Project	10%	(Public Presentation)
		(Oral Exam)
Individual Project	90%	(Public Presentation)
		(Oral Exam)

(6) RECOMMENDED-BIBLIOGRAPHY

- Wills B.A. & Finch J.A. (2016): Wills Mineral Processing Technology: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery, Butterworth-Heinemann Publishers, Oxford, UK.
- Fuerstenau M.C. & Han K.N. (2003): Principles of Mineral Processing, Society for Mining, Metallurgy, and Exploration, USA.

Advanced Geomechanics

(1) GENERAL

SCHOOL	Mineral Resources Engineering		
LEVEL OF EDUCATION	Postgraduate		
COURSE CODE	ST022	SEMESTER OF STUDIES	2nd
TEACHING ACTIVITIES	WEEKLY TEACHING HOURS		CREDITS
Lectures	3		
Total	0		10
COURSE TYPE	General background		

PREREQUISITE COURSES	
LANGUAGE OF TEACHING AND EXAMINATIONS	English
THE COURSE IS OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes
After completing this course the student will be able to: • *Analyse* Safe design of surface/underground mining • *Calculate* Estimates support measures required • *Illustrate* Use modern tools to design critical mining operations.
Generic Skills
• Research, analysis and synthesis of data and information, using the necessary technologies • Adapting to new situations • Decision-making • Autonomous work • Project design and Management • Problem Solving

(3) COURSE CONTENT

1. Stresses and deformations, linear elasticity, of continuum mechanics.
2. Mechanical behavior of rock and rock mass, experimental tests.
3. Intact rock failure criteria.
4. Mechanical behavior of discontinuities.
5. In situ stresses measurements.
6. Plasticity equations.
7. Numerical analysis with finite element method.
8. Non-linear finite element method.
9. Safe surface mining slope design.
10. Finite difference method.
11. Fracture mechanics theory.
12. Case studies.
13. Projects presentation

(4) TEACHING AND LEARNING METHODS - EVALUATION

LECTURE METHOD	Face to Face

USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES	
In Teaching:	- Powerpoint - eclass - Whiteboard

In Laboratory Education:	- eclass - Laboratory notes
In Communication with Students:	- email - eclass - zoom meetings

TEACHING ORGANIZATION	
Lectures	39 hours
Laboratories/Tutorials	39 hours
Individual Project	108 hours
Laboratory Exercises	39 hours
Research/ Study	25 hours
Total	250 hours

(5) STUDENTS ASSESSMENT

Collective / Concluding (for student degree) assessment		
Written Final Examination	40%	(Multiple Choice Questions / Matching)
		(Short answer questions)
		(Problem solving questions)
Individual Project	40%	(Public Presentation)
		(Project Score)
Laboratory Project	10%	(Project Score)
Exercises	10%	

(6) RECOMMENDED-BIBLIOGRAPHY

[1] Brady B.H.G. and Brown E.T. (2004). Rock Mechanics for Underground Mining. Kluwer Academic Publishers, Dordrecht, 3rd ed. https://link.springer.com/book/10.1007/978-1-4020-2116-9
[2] Wyllie D. C. (2018). Rock Slope Engineering. Civil Applications. CRC Press, Boca Raton, 5th ed.
[3] Jaeger J.C., Cook N.G.W. and Zimmerman R.W (2007). Fundamentals of Rock Mechanics. Blackwell Publishing, Singapore, 4th ed.
[4] Anderson, T. (1995). Fracture Mechanics: Fundamentals and Applications. (second ed.). CRC Press.
[5] Broek, D. (1982). Elementary engineering fracture mechanics. Netherlands: Martinus-Nijhoff.
[6] Reddy, J.N. (2006). An Introduction to the Finite Element Method (Third ed.). McGraw-Hill.
[7] Crouch, S.L. and Starfield, A. M., 1983. Boundary Element Methods in Solid Mechanics_ With Applications in Rock Mechanics and Geological Engineering-George Allen & Unwin.