UNIVERSIDAD POLITÉCNICA DE MADRID /
TECHNICAL UNIVERSITY OF MADRID

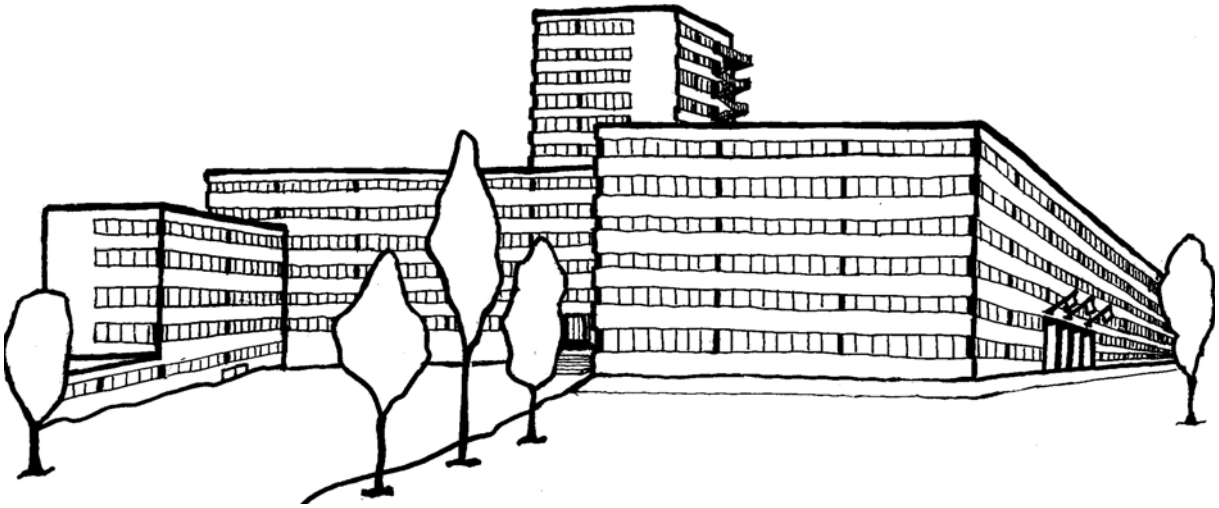
***ESCUELA DE INGENIEROS DE CAMINOS, CANALES Y PUERTOS* / CIVIL ENGINEERING**

TEACHING OBJECTIVES & SUBJECTS' PROGRAMS

OF THE SYLLABUS TO OBTAIN THE DEGREE

DIPLOMA IN CIVIL ENGINEERING

(*INGENIERO DE CAMINOS, CANALES Y PUERTOS*, SIX-YEAR DEGREE RESULTING IN THE PROFESSIONAL QUALIFICATION FOR CIVIL ENGINEER IN SPAIN)



ESCUELA DE INGENIEROS DE
CAMINOS, CANALES Y PUERTOS

UNIVERSIDAD POLITÉCNICA DE MADRID

TECHNICAL UNIVERSITY OF MADRID

Teaching objectives & Subjects' Programs

of the Syllabus to obtain the Degree

DIPLOMA IN CIVIL ENGINEERING

INGENIERO DE CAMINOS, CANALES Y PUERTOS

(six-year Degree resulting in the professional qualification for Civil Engineer in Spain)

Official Syllabus approved by

Order of June 27th, 1983 of the General Direction for Higher Education, Spanish Ministry of Education, published in the Spanish Official State Gazette (*Boletín Oficial del Estado*) of September 9th, 1983

This document contains the latest review of the official Teaching Objectives and Programs of all subjects that comprise the official Syllabus to obtain the Diploma in Civil Engineering (*Ingeniero de Caminos, Canales y Puertos*) from the Technical University of Madrid.

These Teaching Objectives and Subjects' Programs have been approved following the official processes of the School (*Escuela de Ingenieros de Caminos, Canales y Puertos*) and the Technical University of Madrid. Each program has been approved by the relevant Department Committee, which is also in charge of the teaching duties according with the regulations and criteria established by the Board of the School. The last review was approved by the Board meeting on July 5th, 2006.

Teaching objectives & Subjects' programs

of the syllabus to obtain the Diploma in Civil Engineering (*Ingeniero de Caminos, Canales y Puertos*) from the Technical University of Madrid

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Teaching objectives & Subjects' programs

of the syllabus to obtain the Diploma in Civil Engineering (*Ingeniero de Caminos, Canales y Puertos*) from the Technical University of Madrid

Introduction

Syllabus regulations

The current syllabus of the Diploma in Civil Engineering of the Technical University of Madrid was established by the Order of June 27th, 1983, of the General Direction for Higher Education of the Spanish Ministry of Education (Official State Gazette of September 9th, 1983). The Syllabus was last revised by the Order of November 4th, 1983 (Official State Gazette of January 13th, 1984).

The Syllabus is essentially the same as, except for minor modifications, the one established by the Order of September 16th, 1976 (Official State Gazette of October 30th, 1976) which defines the six academic years and the four specializations of the Degree. Such modifications were only intended to move two of the subjects (Urban Planning and General Procedures of Construction) to a different academic year, as well as to introduce the subject Transportation in the fifth year and to review some of the specialization subjects.

Syllabus contents

In compliance with the above regulation, the Syllabus comprises a total of 79 subjects of different character in addition to a Diploma Final Project (DFP). Below there is a summary of all subjects included in each academic year:

TOTAL SUBJECTS OF THE SYLLABUS					
	Common subjects		Specialization subj.		**Total**
	Annual	Semester	Annual	Semester	
Year One	5				
Year Two	5				
Year Three	7				
Year Four	7				
Year Five	5	1	1	17	
Year Six	4 and DFP	2	2	23	
Total	**33 and DFP**	**3**	**3**	**40**	**79 and DFP**

Below there is a more detailed version of the above table indicating also the amount of teaching hours for each subject, academic year and the totals for the complete Diploma:

SYLLABUS				
Subject name	**Type**	Hours of lecture	Hours of practical classes	Total annual hours
YEAR ONE				
Linear Algebra	Annual	4	2	180
Infinitesimal Calculus	Annual	4	2	180
Physics and Materials Physics	Annual	4	2	180
Chemistry	Annual	3	1	120
Technical Drawing	Annual	2	1	90
	Total	25		**750**
YEAR TWO				
Mathematical Analysis	Annual	4	2	180
Mathematical Methods for Engineers	Annual	4	2	180
Mechanics	Annual	3	2	150
Construction Materials	Annual	3	2	150
Representation Systems	Annual	2	2	120
	Total	26		**780**
YEAR THREE				
Differential Equations and Numerical Analysis	Annual	3	2	150
Statistics	Annual	3	1	120
Electricity and Electrotechnics	Annual	3	1	120
Strength of Materials, Elasticity and Plasticity	Annual	3	2	150
Applied Geology	Annual	3	2	150
Topography, Geodetics and Astronomy	Annual	2	1	90
English I	Annual	2	1	90
	Total	29		**870**
YEAR FOUR				
Structural Analysis	Annual	3	2	150
Hydraulics and Hydrology	Annual	3	2	150
Reinforced and Prestressed Concrete I	Annual	3	1	120
Geotechnics and Foundations	Annual	3	2	150
Economics	Annual	3	0	90
Urban Planning	Annual	2	1	90
English II	Annual	2	1	90
	Total	28		**840**
YEAR FIVE				
Common subjects				
Art and Aesthetics in Civil Engineering	Annual	2	0	60
Steel Structures	Annual	3	1	120
Hydraulic Works	Annual	3	1	120
Roads and Airports	Annual	3	1	120
Ports and Coasts	Annual	3	1	120
Transportation	Semester	2	0	30
	Required common subjects			**570**

SYLLABUS

Subject name	Type	Hours of lecture	Hours of practical classes	Total annual hours
1. Specialization in Structures and Foundations				
Compulsory				
Reinforced and Presstressed Concrete II	Semester	3	0	45
Advanced Structural Analysis	Semester	3	0	45
Materials Physics	Semester	3	0	45
Optional (select one)				
Experimental Structural Analysis	Semester	3	0	45
Rock Mechanics	Semester	3	0	45
	Required specialization subjects			**180**
2. Specialization in Transports				
Compulsory				
Transportation Economics	Semester	3	0	45
Traffic Engineering	Semester	3	0	45
Pipeline Transportation	Semester	3	0	45
	Required specialization subjects			**135**
3. Specialization in Urban Planning and Environment				
Compulsory				
Urban Planning	Semester	3	0	45
Optional (Select three)				
Surface and Subsurface Hydrology	Semester	3	0	45
Socio-Economic Structures	Semester	3	0	45
Civil Engineering and Ecology	Semester	3	0	45
Urban Services	Semester	3	0	45
Oceanography and Coastal Engineering	Semester	3	0	45
	Required specialization subjects			**180**
4. Specialization in Hydraulics and Energy				
Compulsory				
Thermodynamics. Energy System. Power Plants	Annual	3	0	90
Power Electric Systems	Semester	3	0	45
Optional (Select one)				
Underground Excavations	Semester	3	0	45
River Hydraulics and Engineering	Semester	3	0	45
	Required specialization subjects			**180**
YEAR SIX				
Common subjects				
Business Organization and Management	Semester	3	1	60
Administrative and Labor Law	Semester	3	0	45
Sanitary and Environmental Engineering	Annual	3	1	120
Railways	Annual	3	1	120
Engineering Projects	Annual	2	1	90
General Procedures of Construction and Organization	Annual	3	1	120
	Required Common subjects			**555**
Diploma Final Project			4	120

SYLLABUS

Subject name	Type	Hours of lecture	Hours of practical classes	Total annual hours
1. Specialization in Structures and Foundations				
Compulsory				
Bridges I	Semester	3	0	45
Special Foundations Methods	Semester	3	0	45
Special Steel Procedures	Semester	3	0	45
Optional (select one)				
Bridges II	Semester	3	0	45
Structural Typology	Semester	3	0	45
Building Construction and Prefabrication	Semester	3	0	45
	Required specialization subjects			**180**
2. Specialization in Transports				
Compulsory				
Port Management and Planning	Semester	3	0	45
Transportation Planning	Semester	3	0	45
Optional (select two)				
Road and Airport Infrastructure	Annual	3	0	90
Port Engineering	Semester	3	0	45
Railway Technology	Semester	3	0	45
Port Traffic and Operation	Semester	3	0	45
	Required specialization subjects			**225***
3. Specialization in Urban Planning and Environment				
Compulsory				
Land Planning	Annual	3	0	90
Optional (select two)				
Environmental Engineering	Semester	3	0	45
Water Resources Planning	Semester	3	0	45
Landscape in Engineering	Semester	3	0	45
Methods and Techniques for Land Planning	Semester	3	0	45
Urban Transportation and Techniques	Semester	3	0	45
	Required specialization subjects			**180**
4. Specialization in Hydraulics and Energy				
Compulsory				
Dams I	Semester	3	0	45
Optional (select three)				
Dams II	Semester	3	0	45
Power Plant Civil Engineering	Semester	3	0	45
Electrical Installations	Semester	3	0	45
Groundwater Prospection, Exploitation and Management	Semester	3	0	45
Hydropower Development	Semester	3	0	45
Nuclear Engineering	Semester	3	0	45
	Required specialization subjects			**180**
	TOTAL HOURS OF SYLLABUS:			**4.845**

Below there is a summary of the above table stating the syllabus equivalence in credits and the difference between common (core) credits and specialization credits (that can be considered as compulsory, optional and free configurable credits):

SYLLABUS SUMMARY

Course and specialization	Annual teaching hours	Credits			
		Totals	Common subjects	Specialization subjects	
				Required	Offered
Year One	750	75	75		
Year Two	780	78	78		
Year Three	870	87	87		
Year Four	840	84	84		
Year Five					
1. Structures and Foundations				18	22,5
2. Transports	750	75	57	13,5	13,5
3. Urban Planning and Environment				18	27
4. Hydraulics and Energy				18	22,5
Year Six					
1. Structures and Foundations				18	27
2. Transports	735	73,5	55,5	22,5	31,5
3. Urban Planning and Environment				18	31,5
4. Hydraulics and Energy				18	31,5
Diploma Final Project	120	12	12		
TOTAL SYLLABUS	**4.845**	**484,5**	**448,5**	**36** for spec.	**207** in totals

Note
Each credit is equivalent to 10 hours of teaching (Art. 2.7, RD 1497/1987)

Teaching objectives and subjects' programs

The following pages will describe the teaching objectives and the program of each subject included in the syllabus to obtain the Degree *Ingeniero de Caminos, Canales y Puertos* (Diploma in Civil Engineering) from the Technical University of Madrid. The teaching objectives indicate the skills that students achieve after completing the subject. The program indicates the units included in each subject. Finally, there is a mention of the basic bibliography used follow the content of each subject, which is limited to the five most relevant references.

Year One

- Lecture hours of the Year One: 750 hours
- Common subjects compulsory: 5 annual

Linear Algebra [1101]

Year One, common, annual, 6 h/week (4 h lectures and 2 h practical classes), 180 h/year, 18 credits.

Teaching objectives

First, it is intended the student to become familiar with Mathematics and in particular with Algebra as a language to make symbolic representations of the realities we perceive, to help students become used to employing those symbols. At the end of the course, students should not only have a wide understanding of the structural features of groups, rings, fields, vectors, and matrices but also comprehend the application of this structural view when interpreting the geometrical spaces around us and be able to identify the elements that comply with pre-fixed conditions within a structure.

Program

Unit 1. Relations, functions and applications
Unit 2. Groups
Unit 3. Rings and fields
Unit 4. Vector spaces
Unit 5. Vector space homomorphism. Duality
Unit 6. Matrices and determinants
Unit 7. Systems of linear equations
Unit 8. Affine spaces
Unit 9. The Euclidean vector space
Unit 10. The ordinary Euclidean vector space
Unit 11. The Euclidean plane
Unit 12. The ordinary Euclidean affine space
Unit 13. Bilinear and quadratic forms
Unit 14. Matrix similarity
Unit 15. Conics
Unit 16. Quadrics

REFERENCES

BURGOS, J. de (1993); *Curso de Álgebra Geometría;* Alambra Longman; Madrid.

BURGOS, J.: Álgebra Lineal: 80 problemas útiles. 2007

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GARCIA, M., BRONTE, R., RODRÍGUEZ, M., CASTIÑEIRA, C. (1984); *Problemas de Álgebra y Analítica;* los Autores; Madrid.

AVELLANAS, P. (1961); *Geometría Básica;* Romo; Madrid.

DONEDDU, A. (1980); *Curso de matemáticas. Complementos de Geometría Algebraica;* Aguilar; Madrid.

Infinitesimal Calculus [1124]

Year One, common, annual, 6 h/week (4 h lectures and 2 h practical classes), 180 h/year, 18 credits.

Teaching objectives

It is expected that students will become familiar with using single and multiple variable functions, being able to differentiate terms and to integrate them as well as their applications into the techniques.

Special focus will be given to learning representation of geometric and physic problems through mathematical functions and the interpretation of the results obtained once solved.

Program

Unit 1. Real numbers

Unit 2. Real functions of one variable. Continuity

Unit 3. Derivation

Unit 4. Integration

Unit 5. Numerical Sequences and power series

Unit 6. Functions of several variables

Unit 7. Multi-dimensional integrals

Unit 8. Line and surface integrals

REFERENCES

BURGOS ROMÁN, Juan de: Cálculo: definiciones, teoremas y resultados. 2009

SOLER DORDA, M.: Cálculo infinitesimale integral. 1992

Physics and Physics of Materials [1110]

Year One, common, annual, 6 h/week (4 h lectures and 2 h practical classes), 180 h/year, 18 credits.

Teaching objectives

It is expected that students will achieve: (1) instrumental capacity to assimilate the course's technological disciplines taught through this subject, (2) ability to apply the subject's theoretical models in real life situations and to critically evaluate the application's results, as well as (3) to demonstrate rigor, mental alertness and familiarity when using subject related technical and scientific methodology for the rest of their academic training and their professional career ahead.

Program

PRELIMINARY PART

Preliminary Unit. Sliding Vectors

PART I. CLASSICAL MECHANICS

Unit 1. Kinematics of point particle
Unit 2. Laws of Mechanics
Unit 3. Dynamics of point particle
Unit 4. Compound movements
Unit 5. Mass Geometry
Unit 6. Kinematics of rigid bodies
Unit 7. Dynamic of rigid bodies
Unit 8. Percussions and vibrations
Unit 9. Statics

PART II. SOLIDS AND FLUIDS MECHANICS

Unit 10. Introduction to Hookean solids
Unit 11. Fluid Statics
Unit 12. Fluid Dynamics

PART III. THERMODYNAMICS

Unit 13. Thermodynamic balance
Unit 14. First Law of Thermodynamics
Unit 15. Second Law of Thermodynamics
Unit 16. Multiphase systems
Unit 17. Air thermodynamics
Unit 18. Thermal conduction

PART IV. WAVES

Unit 19. Wave motion
Unit 20. Wave propagation
Unit 21. Wave Interference
Unit 22. Diffraction of Waves

PART V. ELECTRICITY AND MAGNETISM

Unit 23. Electrostatics
Unit 24. Conductive materials
Unit 25. Dielectric materials
Unit 26. Magnetostatics
Unit 27. Magnetic materials
Unit 28. Electromagnetic Induction
Unit 29. Electric currents
Unit 30. Electromagnetic radiation

REFERENCES

TIPLER, P. A. (1992); Física; Reverté.

BEER, F. JOHNSTON, J. R. Y EISENBERG, E. R. (2005); Mecánica Vectorial para Ingenieros: Estática; McGraw-Hill.

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MORAN, M. J. Y SHAPIRO, H. N. (1993); Fundamentos de Termodinámica Técnica; Reverté.

ALONSO, M. Y FINN, E. J. (1987); Física, Volumen II: Campos y Ondas; Addison-Wesley Iberoamericana.

ALONSO, M & FINN, E.J.: Campos y ondas. Vol. II. 1987

Chemistry [1109]

Year One, common, annual, 4 h/week (3 h lectures and 1 h practical classes), 120 h/week, 12 credits.

Teaching objectives

The teaching objectives are aimed at reflecting the duality of this subject, which involves multiple disciplines but also a practical and experimental content. The first aspect is aimed at providing the student with a solid general knowledge of chemistry to serve as a basis in the study and comprehension of other subjects. The second aspect's main goal is to show the student the technical applications of this discipline in several situations that will lie ahead during their professional career. It is expected to provide the student with the main notions that they must possess in order to be able to deal with the contents of future subjects studied in this diploma such as: (1) Macroscopic behavior of continuous media, (2) Bituminous materials, plastic, cement and concrete (3) Petrology, erosion chemistry, clayey and metal materials, Properties of materials and physics and chemistry of corrosion, (4) Physical and chemical properties of water and desalination, (5) Corrosion of metals and plastics within structures, and (6) Composition of matter, radioactivity and nuclear reactions.

Program

Unit 1. Introduction
Unit 2. Radioactivity
Unit 3. Chemical bonding
Unit 4. Aggregation states of matter
Unit 5. Dissolutions
Unit 6. Chemical balance
Unit 7. Electrolyte solution
Unit 8. Aqueous solution: solubility
Unit 9. Colloids
Unit 10. Oxidation - reduction reactions
Unit 11. Batteries
Unit 12. Metals
Unit 13. Silicon Chemistry
Unit 14. Introduction to organic chemistry
Unit 15. Plastic polymers

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PETRUCCI, RALPH H.: *Química general* 8ª ed., Prentice Hall, 2003

MASTERTON, WILLIAM L.: *Química: principios y reacciones* 4ª ed., Thomson-Paraninfo, 2003

MORAN, MICHAEL J.: *Fundamentos de termodinámica técnica*, Reverté, 2004

LEVINE, IRA N.: *Fisicoquímica*, McGraw-Hill, 2004

CALLISTER, WILLIAM D.: *Introducción a la ciencia e ingeniería de los materiales*, Limusa, 2009

ASKELAND, DONALD R.: *Ciencia e ingeniería de los materiales,* Paraninfo, 2001

RAMOS CARPIO, M. A.: *Ingeniería de los materiales plásticos*, Díaz de Santos, 1988

PAINTER P.C.: *Fundamentos de Ciencia de Polímeros*, Editorial Technomic, 1996

TAYLOR, H. F. W.: *Cement Chemistry*, 2nd edit., Thomas Telford Publishing, 2003

Technical Drafting [1107]

Year One, common, annual, 3 h/week (2 h lectures and 1 h practical classes), 90 h/year, 9 credits.

Teaching objectives

This subject covers two different areas: Projection and Metric Geometry and Technical Drawing itself. The objectives pursued by this subject, apart from providing general knowledge, can be split into two groups, each devoted to one of the above mentioned areas, including: (1) Notions and application of a series of basic Metric Plane Geometry concepts and constructions, (2) familiarization with Metric Geometry of Space, (3) calculation of areas and volume of all kind of geometric shapes (4) introduction to Project Geometry procedures as a fundamental basis for further study of conical shapes and surfaces. As regards to the Technical Drawing teaching, it can be summarized as follows: (1) Application of previously acquired geometric notions to the preparation of drawings, (2) introduction to various representation systems, (3) development of the student's "spatial vision" in order to acquire the necessary skill and ability to be able to produce and interpret maps, and (4) notions of current legislation regarding graphic representations.

Program

PART I. METRIC PLANE GEOMETRY

Unit 1. Introduction

Unit 2. Polygons

Unit 3. Plane curves

Unit 4. Constructions

PART II. METRIC GEOMETRY OF THE SPACE

Unit 5. Introduction

Unit 6. Constructions

Unit 7. Polyhedrons

Unit 8. Cone, cylinder and sphere

PART III. PROJECTIVE GEOMETRY

Unit 9. Introduction

Unit 10. First order elementary forms

Unit 11. Second order elementary forms

Unit 12. Graphic and projective determination of conics

PART IV. TECHNICAL DRAWING IN CIVIL ENGINEERING

Unit 13. Orthographic projection

Unit 14. Technical normalization

Unit 15. Isometric projection

Unit 16. Oblique projection

Unit 17. Conical projections

REFERENCES

MARTÍNEZ SIMÓN, J.M. et al. (1995); *Geometría métrica. Conceptos básicos*; Servicio de Publicaciones del Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

UNIDAD DE DOCENCIA DE DIBUJO TÉCNICO Y SISTEMAS DE REPRESENTACIÓN (1997); *Apuntes de geometría métrica*; Servicio de Publicaciones Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

MÉNDEZ, L. et al. (1995); *Geometría proyectiva. Tomo I*; Servicio de Publicaciones del Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

PALENCIA, J. et al. (1981); *Dibujo técnico. Introducción a los sistemas de representación*; Servicio de Publicaciones del Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

UNIDAD DE DOCENCIA DE DIBUJO TÉCNICO Y SISTEMAS DE REPRESENTACIÓN (1998-2005); *Dibujo técnico. Problemas de examen. Cursos 1990/1991 a 2004/2005*; Servicio de Publicaciones del Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

Year Two

- Lecture hours for the Year Two: 780 hours
- Common subjects compulsory: 5 annual

Mathematical Analysis [2003]

Year Two, common, annual, 6 h/week (4 h lectures and 2 h practical classes), 180 h/year, 18 credits.
Pre-requirements: *Infinitesimal Calculus [1124] and Linear Algebra [1101]*

Teaching objectives

It is expected that students will acquire the capacity to achieve accurate and approximate solutions of ordinary differential equations and boundary value problems, employing various techniques such as Laplace transforms, Fourier Analysis and Green's theorem, as well as linear one-step and multistep methods (Runge-Kutta and Adams methods). Special focus is made in the learning of representation of geometric, physical and technical problems through differential equations. The general aim is that the student will become conscious of the value of Mathematics as a work tool by promoting the use of mathematical techniques that will enable them to produce and process models with the purpose of solving problems in relation to specific situations. It is also expected that students will become familiar with the use of advanced complex variable functions and to solve problems involving the Residue Theory and complex power series with ease.

Program

PART I. FUNCTIONS OF A COMPLEX VARIABLE

Unit 1. Complex numbers

Unit 2. Advanced functions of a complex variable

Unit 3. Analytic Functions

Unit 4. Contour integrals

Unit 5. Singularities and residues

Unit 6. Conformal mappings

PART II. ORDINARY DIFFERENTIAL EQUATIONS

Unit 7. First order differential equations

Unit 8. Existence and uniqueness theorems for solutions

Unit 9. Linear differential equations systems

Unit 10. Higher order linear differential equations

Unit 11. Laplace Transform

Unit 12. Numerical methods for one-step differential equations

Unit 13. Multistep linear methods

Unit 14. Boundary value problems

REFERENCES

CHURCHILL, R.V.; BROWN, J.W. (1987); *Variable compleja y sus aplicaciones*; Mc Graw-Hill.

GONZALEZ-VELASCO, E. A. (1995); *Fourier Analysis and Boundary Value Problems*; Academic Press.

MENDIZABAL, A. (1985); *Análisis Matemático*; Servicio de publicaciones de la E.T.S. Ingenieros de Caminos; Madrid.

SIMMONS, F. (1992); *Ecuaciones diferenciales con aplicaciones y notas históricas*; McGraw-Hill.

ZILL, D.G. (1997); *Ecuaciones diferenciales con aplicaciones de modelado*; Thomson Editorial.

MOLERO, M et al.: Anñalisis Matemático para Ingeniería. 2007

Mathematical Methods for Engineering [2012]

Year Two, common, annual, 6 h/week (4 h lectures and 2 h practical classes), 180 h/year, 18 credits.
Pre-requirements: *Infinitesimal Calculus [1124] and Linear Algebra [1101]*

Teaching objectives

The first part of the subject is aimed at providing the student with the required vectorial and tensor tools to further study the mechanics of continuous media and electrical engineering, which are an important area in the skills of a civil engineer. More precisely: (1) instrumental use of vectors and tensors in Cartesian and general curvilinear coordinates of space and Euclidean space. (2) study of vectors and tensors in differential geometry of curves and differential geometry of space (3) instrumental use of differentiation and integration of scalar and vectorial fields in space including differential operators and classical theorems in the Field theory. The second part of the subjects is intended to provide students with a practical knowledge of the most widely used technical and scientific computing tools: C and MATLAB programming languages. It will also include the teaching of algorithmic techniques that will be further used in the design of numerical calculus programs to SOLVE SPECIFIC PROBLEMS within Civil Engineering. Learning development of computer graphics.

Program

PART I. VECTOR AND TENSOR TECHNIQUE METHODS

Unit 1. Tensor algebra on 2D or 3D Euclidean vector space

Unit 2. Representation of curvilinear coordinates in space

Unit 3. Fields (1): derivation and differentiation. Differential operators

Unit 4. Differential geometry of curves and surfaces

5. Fields (2): integration

Unit 6. Potential theory

PART II. COMPUTER MATHEMATICAL METHODS FOR ENGINEERS

Unit 7. Basic notions of computer science

Unit 8. The first C language application. Data types

Unit 9. Structured types of data

Unit 10. Flow control commands

Unit 11. Intrinsic functions in C

Unit 12. Pointers

Unit 13. Functions

Unit 14. Files

Unit 15. Basic MATLAB notions

Unit 16. MATLAB matrices

Unit 17. MATLAB programming

Unit 18. MATLAB graphics

REFERENCES

DANIELSON, D.A. (1992); *Vectors and tensors in engineering and Physics*; Addison-Wesley.

STRUIK, D.J. (1966); *Geometría diferencial clásica*; Aguilar. (en inglés, Editorial Dover, 1988)

SPIEGEL, M. R., *Análisis Vectorial*, SCHAUM McGraw-Hill

NAKAMURA, S. (1996); *Numerical Analisis and Graphic Visualization with MATLAB*; Prentice Hall

LANTARÓN, S. Y LLANAS, B. (2004); *Introducción a la Informática: Programación práctica en C y MATLAB*; Bellisco

Mechanics [2015]

Year Two, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.
Pre-requirements: *Physics and Materials Physics [1110]*

Teaching objectives

It is expected that students will : (1) learn and apply kinetic methods to describe the kinetic energy of particle and rigid bodies, as well as to calculate kinematic magnitudes.; (2) become aware of the general Dynamic Mechanical Systems theorems and methods (quantity of motion, kinetic energy , Principal of Virtual Work and D'Alembert's, Centre of Mass frame, ...) and be able to apply them to particle systems and rigid bodies, (3) have an understanding of and apply dynamic and small oscillation analysis methods in systems of one or several degrees of freedom; (4) have an understanding of and apply the dynamic analytical techniques to develop analytical skills through the application of Lagrange and Hamilton. (5) have an understanding of and apply mechanic mathematical methods to static methods in general systems, solve practical problems, assemblies of rigid parts and threads ; and (6) develop analytical skills by applying mechanic mathematical models to solve practical problems

Program

PART I. NEWTONIAN DYNAMICS

Unit 1. Axioms and principles

Unit 2. Dynamics of particles

Unit 3. Kinematics of rigid bodies

Unit 4. Central forces and orbits

Unit 5. Dynamics general theorems

Unit 6. Variable mass systems

PART II. DYNAMICS OF RIGID BODIES

Unit 7. General rigid bodies dynamic equations

Unit 8. Rigid bodies dynamic applications

Unit 9. Impulsive dynamics

PART III. ANALYTICAL DYNAMICS

Unit 10. Lagrange's equation

Unit 11. Hamilton's equations

PART IV. LINEAR OSCILLATIONS

Unit 12. Systems with one degree of freedom

Unit 13. Systems with several-degrees of freedom

PART V. STATICS AND CABLES

Unit 14. Statics

Unit 15. Cables

REFERENCES

GOICOLEA, J.M., (2001); *Apuntes de Mecánica,* Servicio de Publicaciones del Colegio de Ingenieros de Caminos, C. y P.; Madrid., o disponibles para descarga en http://w3.mecanica.upm.es/mecanica.html.

FERNÁNDEZ PALACIOS, J.A. (1989); *Mecánica teórica de los sistemas de sólidos rígidos*.

CÁTEDRA DE MECÁNICA, *Problemas resueltos de mecánica (problemas de examen y de prácticas puntuables);* http://w3.mecanica.upm.es/mecanica.html

PRIETO ALBERCA, M. (1992); *Curso de Mecánica Racional. I Cinemática y Estática; II Dinámica;* ADI, Madrid.

MARION, J.B. (1984); Dinámica clásica de las partículas y sistemas, Reverté.

Construction Materials [2008]

Year Two, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.
Pre-requirements: *Chemistry [1109]*

Teaching objectives

The subject's aim is that students will: (1) have an understanding of the properties, application, working method, use and relations of the structural shape of construction materials.; (2) learn to choose the most adequate materials for each application, identifying all requirements and evaluating the properties of each material through the use of calculus, laws and general principles; (3) have an understanding of the regulatory notions that enable us to control and guarantee the quality of materials; (4) have an understanding of the main physical and chemical processes to modify the performance and their effect on the materials throughout their life cycle. (5) learn to evaluate the influence of the material's life cycle on the environment: manufacturing, use and disposal or recycling

Program

PART I. INTRODUCTION

Unit 1. Materials throughout History

Unit 2. Materials in Civil Engineering and Construction

PART II. MATERIALS SCIENCE AND TECHNOLOGY: FUNDAMENTALS

Unit 3. Constitution of matter

Unit 4. Solid state

Unit 5. Development of microstructure

PART III. PROPERTIES OF MATERIALS

Unit 6. Physical properties

Unit 7. Behavior of materials under stress (I)

Unit 8. Behavior of materials under stress (II)

Unit 9. Behavior of materials under stress (III)

Unit 10. Behavior of materials under stress (IV)

PART IV. KNOWLEDGE OF MATERIALS

Unit 11. Natural stones (I)

Unit 12. Natural stones (II)

Unit 13. Plasters

Unit 14. Limes

Unit 15. Composition and manufacture of Portland cement

Unit 16. Portland cement features and hydration

Unit 17. Cements

Unit 18. Water and aggregates in concrete

Unit 19. Particle size of aggregates

Unit 20. Fresh concrete

Unit 21. Additives

Unit 22. Concrete dosage (I)

Unit 23. Concrete dosage (II)

Unit 24. Production, transportation and use of concrete

Unit 25. Concrete curing and protection

Unit 26. Physical properties of hardened concrete (I)

Unit 27. Physical properties of hardened concrete (II)

Unit 28. Durability of concrete (I)

Unit 29. Durability of concrete (II)

Unit 30. Special concretes (I)

Unit 31. Special concretes (II)

Unit 32. Concrete quality control

Unit 33. Introduction to metallic materials

Unit 34. Properties of metallic materials

Unit 35. Structural steel

Unit 36. Steel processing

Unit 37. Steel production

Unit 38. Classification of steel products

Unit 39. Metallic products in construction

Unit 40. Steel products in construction

Unit 41. Ceramic materials (I)

Unit 42. Ceramic materials (II)

Unit 43. Glass

Unit 44. Wood and cork (I)

Unit 45. Wood and cork (II)

Unit 46. Introduction to bituminous materials in construction

Unit 47. Properties of bituminous materials

Unit 48. Use of bituminous materials

Unit 49. Epoxy resins

Unit 50. Polymers and plastic (I)
Unit 51. Polymers and plastic (II)
Unit 52. Introduction to composite materials
Unit 53. Properties of composite materials
Unit 54. Further auxiliary materials
Unit 55. Materials selection and the environment

REFERENCES:

ARREDONDO: Generalidades sobre Materiales de Construcción. 1990
ALAMÁN: Materiales metálicos. 2000
ARREDONDO: Piedras, Cerámica y Vidrio. 1991
ARREDONDO: Madera y Corcho, 1992
ARREDONDO: Yesos y Cales. 1991
FERNÁNDEZ CÁNOVAS, M.: Hormigón. 2007
FERNÁNDEZ CÁNOVAS, M.: Materiales bituminosos. 1991
GALVEZ Y LUCEA: Problemas de Materiales de Construcción, 2012
LLORCA Y GALVEZ: Problemas de Materiales Compuestos. 2000

Representation Systems [2006]

Year Two, common, annual, 4 h/week (2 h lectures and 2 h practical classes), 120 h/year, 12 credits.
Pre-requirements: *Technical Drawing [1107]*

Teaching Objectives

It is expected that students will complete their learning of graphic representation of their ideas, the capacity to express them through drawings, whilst enabling them to interpret those produced by others unmistakably and with great accuracy. The unit is completed with a CAD (computer- aided design) practical course in new technologies that is both suited for representation as well as for team work.

Program

PART I. ORTHOGRAPHIC PROJECTION

Unit 1. Introduction
Unit 2. Parallelism, inclination and perpendicularity
Unit 3. Folds, distances and angles
Unit 4. Representation of plane figures
Unit 5. Trihedron
Unit 6. Change of projection planes. Rotation

PART II. TOPOGRAPHICAL MAPS

Unit 7. Introduction
Unit 8. Intersections, parallelism and perpendicularity
Unit 9. Folds, distances, angles
Unit 10. Representation of flat lines, surfaces and shapes
Unit 11. Building roofs
Unit 12. Topographical surfaces
Unit 13. Introduction to cartography

PART III. AXONOMETRIC PROJECTION

Unit 14. Introduction
Unit 15. Intersections, parallelism and perpendicularity
Unit 16. Folds, distances and angles
Unit 17. Representation of plane figures

PART IV. OBLIQUE PROJECTION

Unit 18. Introduction
Unit 19. Intersections, parallelism and perpendicularity
Unit 20. Folds, distances and angles
Unit 21. Representation of plane figures

PART V. ADVANCED METRIC GEOMETRY

Unit 22. Polyhedrons
Unit 23. Plane and 3D curves
Unit 24. Surfaces

REFERENCES:

GONZALEZ GAMEZ, F.: Problemasresueltos de sistemas de repreentación. 1992
GORDO MURILLO, C.: Sistemas de representación: probleas de representación …

Year Three

- Lecture hours for the Year Three: 870 hours
- Common subjects compulsory: 7 annual

Differential Equations and Numerical Analysis [3005]

Year Three, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.
Pre-requirements: *Mathematical Analysis [2003]*

Teaching objectives

This subject aims at providing students with the required basis to solve complex problems briefly introduced by subjects in the former years using mathematical and numeric models. Engineering problems introduced in these subjects are expressed through mathematical models that are not always open to an analytical solution, so it is imperative to either simplify the problem or to solve it using a numeric model. The subject covers the solution of equations governing problems like structural analysis by finite element methods, deformability analysis and geostructures and foundations break, marine and open channel flow hydrodynamics, issues of the transportation of polluting substances in environmental engineering, etc.

Program

PART I. PARTIAL DIFFERENTIAL EQUATIONS

Unit 1. Introduction to partial differential equations

Unit 2. Evolution equations

Unit 3. Mixed problems for evolution equations 1D. Fourier Analysis

Unit 4. Cauchy's problem of 1D equation

Unit 5. Finite difference method

Unit 6. Theory for stationary processes special functions

Unit 7. Spectral theory Special functions

Unit 8. Variational methods

Unit 9. Finite energy. Variational equations

Unit 10. Finite element methods

Unit 11. Variational formulation for diffusion problems

Unit 12. Variational formulation for wave problems

PART II. NUMERICAL CALCULUS

Unit 13. Interpolation and numerical approximation of functions

Unit 14. Uniform approximations

Unit 15. The Root Mean Square error of Approximation

Unit 16. Numerical differentiation and integration

Unit 17. First order hyperbolic equations

Unit 18. Numerical solution of non linear systems

REFERENCES

DE LA ROSA, E. (1999); *Modelos diferenciales y numéricos en la Ingeniería*; Editorial Bellisco; Madrid

DUCHATEAU, P; ZACHMAN, D.W. (1986); *Ecuaciones diferenciales parciales;* McGRAW-HILL; México

PUY, J. (1985); *Algoritmos numéricos en Pascal*; Servicio de Publicaciones de la Revista de Obras Públicas; Madrid

KINCAID, D. ; CHENEY, W. (1994); *Análisis numérico*; Addison Wesley Iberoamericana.

DE LA FUENTE, J.L; (1993); *Tecnologías computacionales para sistemas lineales de ecuaciones. Optimización lineal y entera*; Editorial Reverté

Statistics [3004]

Year Three, common, annual, 4 h/week (3 h lectures and 1 h practical classes), 120 h/year, 12 credits.

Teaching objectives

This subject is intended to instil into students the notion of statistical analysis thought as a means of approximation to reality, in order to fully understand it and to exercise the best possible control over the natural environment that they will be interacting with, in order to maximize the efficiency of their actions. And for that purpose the modules included are related to both the concept of probability and the random variable theory, as well as the theory of sampling and statistical inference.

Program

PART I: PROBABILITY AND RANDOM VARIABLE THEORY

Unit 1. Introduction to probability and statistics

Unit 2. Events and probability

Unit 3. One dimensional random variable

Unit 4. Two dimension random variable

Unit 5. N-dimensional random variables

Unit 6. Regression and correlation

Unit 7. Discrete probability models

Unit 8. Continuous probability models

Unit 9. Sequences and random variable series

Unit 10. Sequences and processes for dependent random variable

PART II. SAMPLING THEORY AND SATISTICAL INFERENCE

Unit 11. Sampling theory

Unit 12. Estimation theory

Unit 13. Creation of estimators I. Point estimation

Unit 14. Creation of estimators II. Interval estimation

Unit 15. Hypothesis contrast. Basic principles

Unit 16. Most common contrasts I. Adherence test, contingency tables and others

Unit 17. Most common contrasts II. Analysis of variance

Unit 18. Most common contrasts III. Sample regression

Unit 19. Most common contrasts IV. Non-parametric statistics

Unit 20. Creation of critical areas through simulation

Unit 21. Sampling scope

Unit 22. Random variables extremal regime

Unit 23. Random regional variables

REFERENCES

MURUZÁBAL, J.J. (2003); *Elementos de estadística aplicada. Cálculo de probabilidades y teoría de variable aleatoria*; Servicio de Publicaciones, Colegio de Ingenieros de Caminos, Canales y Puertos; Madrid.

MURUZÁBAL, J.J. (2004); *Elementos de estadística aplicada. Teoría de muestras e inferencia estadística*; Servicio de Publicaciones, Colegio de Ingenieros de Caminos, Canales y Puertos; Madrid.

SAN MIGUEL, J.M. (1990); *Estadística radical*; Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos; Madrid.

Electricity and Electrotechnics [3020]

Year Three, common, annual, 4 h/week (3 h lectures and 1 h practical classes), 120 h/year, 12 credits.

Teaching objectives

The aim of this subject is to enable the student to: (1) learn the physical laws that rule the behavior of electromagnetic fields as a fundamental basis to grasp the operation of equipment, machines and electrical installations; (2) master the theory of electric circuits in direct and alternating current and multi phase systems before analyzing any type of electric current; (3) identify any type of electrical machine through the knowledge of its basic constructional aspects. Understand the physical laws of EMF generation and the operation of magnetic circuits (4) have an understanding of the operation of power transformers and their applications in building site installations, developments, etc.; (5) have an understanding of the operation and applications of induction motors; (6) understand the qualitative working principles of synchronous machines and direct current motors;(7) describe the basic types of power plants: hydraulic, thermal and nuclear; (8) have the required skills to design a power distribution grid for building sites and developments; (9) have an understanding of the different types of electric lamps and their main applications; and (10) be capable of executing an interior lighting project and to design a public lighting project.

Program

PART I. ELECTROMAGNETISM

Unit 1. General laws of electromagnetic fields

Unit 2. Divisions of electromagnetism

PART II. Electric Circuits

Unit 3. Introduction to electric machines theory

Unit 4. Sinusoidal alternating current circuits

Unit 5. Three-phase circuits

PART III. ELECTRIC MACHINES

Unit 6. Magnetic to electric machines theory

Unit 7. Basic electric machine principles

Unit 8. Transformers

Unit 9. Induction or asynchronous motor

PART IV. ELECTRICAL INSTALLATIONS

Unit 10. Electric power stations

REFERENCES

FRAILE MORA, J. (2005); *Electromagnetismo y circuitos eléctricos*; McGraw-Hill Interamericana de España.

FRAILE MORA, J. (2003); *Máquinas eléctricas*; McGraw-Hill Interamericana de España.

FRAILE MORA, J., FRAILE ARDANUY, J., HERRERO, N., GARCÍA, P. (2004); *Ejercicios resueltos de electromagnetismo y circuitos eléctricos*; Servicio de publicaciones de la E.T.S.I. de Caminos, Canales y Puertos de Madrid

FRAILE MORA, J., FRAILE ARDANUY, J. (2005); *Problemas de máquinas eléctricas*; McGraw-Hill Interamericana de España.

FRAILE MORA, J.: Introducción a las instalaciones eléctricas. 2002

Strength of Materials, Elasticity and Plasticity [3125]

Year Three, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.

Teaching objectives

After the study of section Strength of Materials, students should: (1) determine, in arbitrary sections (homogeneous or compsite) subjected to sectional forces, the resulting distribution of normal and tangential stresses; (2) calculate the elastic and linear responses of simple plane structures comprising columns and straight or curved beams under arbitrary actions (thermal actions, imposed motions, permanent and live loads), and (3) apply energetic methods to the analysis of simple structures. After the study of the section Elasticity, students should: (1) understand the tensorial nature of strains and stresses in 2-D and 3-D elastic bodies, and their representation in different coordinate axes, (particularly according to the principal directions); (2) formulate an elastic problem and verify its resolution in different coordinate axes and (3) have an understanding of elastic solutions to classic elastic problems and compare them with the approximate solutions studied in Strength of Materials. Finally, after the completion of the section Plasticity, students should: (1) have a basic understanding of the behaviour of plastic materials (rigid-plastic and elastic-plastic), the concept of ductility and the redistribution of stresses and forces that is produced in sections and structures as a consequence of it, and (2) obtain the plastic loads of beams and frames.

Program

PART I. STRENGTH OF MATERIALS

Unit 1. Fundamental concepts
Unit 2. Static relations
Unit 3. Compatibility relations
Unit 4. Constitutive equations
Unit 5. Study of the different elements (I)
Unit 6. Study of the different elements (II)
Unit 7. Energy theorems
Unit 8. Portal frames
Unit 9. Influence lines
Unit 10. Arches
Unit 11. Non linear structural problems

PART II. PLASTICITY

Unit 12. Introduction
Unit 13. Behaviour of cross-sections under pure bending
Unit 14. Behaviour of cross-sections under simple bending
Unit 15. Plastic calculation of beams
Unit 16. Calculation of torsion and deflection type in statically indeterminate beams
Unit 15. Plasticizing of simple portal frames

PART III. ELASTICITY

Unit16. Fundamental concepts
Unit 17. Motions and deformations
Unit 18. Constitutive equations of materials
Unit 19. Local formulation of the elastic problem
Unit 20. General statement of the elastic problem
Unit 21. Torsion
Unit 22. Plane elasticity
Unit 23. Plane elasticity in polar coordinates
Unit 24. Special cases

REFERENCES

SAMARTÍN, A. (1995); *Resistencia de Materiales*, Colegio de Ingenieros de Caminos, Canales y Puertos.

SAMARTÍN, A. (1990); *Curso de Elasticidad*, Editorial Bellisco

BENITO, C. (1975); *Curso de Plasticidad*, Editorial Dossat

FERNÁNDEZ MUNIO, R: Tutorial de resistencia/ Problemas

ARGÜELLES AMADO, A.: Formulario técnico de elasticidad y resistencia de mat..

FERNÁNDEZ DÍAZ-MUNIO, R.: Plasticidad abreviada 95. 1995

Applied Geology [3126]

Year Three, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.

Teaching Objectives

It is expected that the student will acquire: (1) Sufficiently profound knowledge of Geologic sciences, particularly in the areas of External and Internal Geodynamics, Petrology and Mineralogy, Paleontology and Geology History, (2) use of geological concepts with ease and skill to understand the importance of the interactions between public works and their geological environment during planning, design, construction and performance phases. (3) predict and explain behaviors and responses from the interactions between land and the public works, (4) develop the required familiarity with all concepts learned during the course to ensure that they are used to all purely technical subjects remaining to be studied in further years, having an understanding of the technical constraints that may only be grasped through the knowledge of the geological features of the environment. (5) a realistic and experimental comprehension of the geological problems that can affect public works, particularly in Spain.

Program

PART I. INTERNAL AND EXTERNAL GEODYNAMICS

Unit 1. Constitution of the Earth, structural geology and tectonics

Unit 2. Geomorphology

Unit 3. Rivers

Unit 4. Lakes. Action of the sea. Action of the wind. Biological action

PART II. PETROLOGY

Unit 5. Crystallography and mineralogy

Unit 6. Rock formations. Endogenous rocks

Unit 7. Volcanics

Unit 8. Metamorphic rocks

Unit 9. Sedimentary rocks

Unit 10. Carbonate rocks. Plasters

PART III. GEOLOGY HISTORY

Unit 11. The science of Palaeontology

Unit 12. Geology history

Unit 13. Mesozoic

Unit 14. Tertiary, Paleocene and Neogene

Unit 15. Quaternary

PART IV. Applications

Unit 16. Geological survey

Unit 17. Geophysical prospection

Unit 18. Geological cartography for public works. Remote sensing

Unit 19. Quarries

Unit 20. Hydrogeology

Unit 21. Dams

Unit 22. Linear works

Unit 23. Tunnels and underground excavations

Unit 24. Geological report

PART V. GEOLOGY AND ENVIRONMENT

Unit 25. Geology and environment

REFERENCES

IGME (Instituto Geológico y Minero de España) (2004); *Geología de España*. Ministerio de Educación y Ciencia.

LÓPEZ MARINAS, J.M. (2000); *Geología Aplicada a la Ingeniería Civil*. Ed. Dossat.

MELÉNDEZ, B. Y FUSTER, J.M. (2003); *Geología*. Ed. Paraninfo.

POZO, M.; GONZÁLEZ, J. Y GINER, J. (2003); *Geología Práctica*. Pearson

SÁENZ, C. Y TALABÁN, J.L. (1972); *Ejercicios de Geología Aplicada*; Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos.

TARBUCK LUTGENS, E: Ciencias de la tierra: una introducción a la geografía física

GONZÁLEZ VALLEJO, L.I.: Ingeniería Geológica. 2002

Topography, Geodesics and Astronomy [3121]

Year Three, common, annual, 3 h/week (3 h lectures and 1 h practical classes), 90 h/year, 9 credits.

Teaching objectives

This subject is aimed at providing students with the necessary training to plan, appoint, collaborate and supervise topography works both from the office and on the site. For that reason, and practical lessons shall be held in order to form and inform students until they are capable of developing all activities in relation to topography, geodetics, astronomy, cartography, digital terrain models and satellite navigation systems (GPS) that are currently used in the profession. It is also intended that students will be able to understand, develop and review any bid data sheet in relation to the above mentioned subjects. The structure designed for the purpose above is divided into two areas: that include exercises and practical lessons. The latter including field work surveying and placement of total station and GPS, as well as laboratory practice, photogrammetry and digital terrain models.

Program

Unit 1. Basic concepts

Unit 2. Errors. Types and processing

Unit 3. Astronomy

Unit 4. Geodetics and Cartography

Unit 5. Types of Instruments

Unit 6. Angle-measuring instruments

Unit 7. Distance measuring instruments

Unit 8. Level measuring instruments

Unit 9. Satellite navigation systems (GPS)

Unit 10. Planimetric surveying

Unit 11. Altimetrical surveying

Unit 12. Topographic networks

Unit 13. Photogrammetry and digital terrain models

Unit 14. Setting and construction

Unit 15. Connection with the project

REFERENCES

CHUECA PAZOS M. et al. (1996); *Topografía Tomos I, II y III*; Paraninfo; Madrid.

DOMINGUEZ GARCÍA-TEJERO F. (2002); *Topografía General y Aplicada*; Mundi-prensa; Madrid.

MARTINEZ MARIN R. (2003); *Introducción a los Modelos Digitales del Terreno y al GIS vectorial*; Colegio de Ingenieros de Caminos, Canales y Puertos; Madrid.

MARTINEZ MARIN R. et al. (2004); *Formulario Técnico y Científico de Geodesia y Topografía*; Bellisco; Madrid.

WOLF PAUL R. (1997); *Topografía*; Alfaomega; Madrid.

English I [3073]

Year Three, common, annual, 3 h/week (3 h lectures and 1 h practical classes), 90 h/year, 9 credits.

Teaching objectives

Throughout this subject, students shall develop, as general objectives, the four basic language skills (reading comprehension, writing, listening comprehension and speaking), as well as the ability to translate technical engineering texts to and from English. In a more specific way, students must also carry out the following activities: (1) reading comprehension of civil engineering texts using different reading techniques; (2) understand the organization of technical discourse; (3) correctly express the most frequent rhetoric functions in technical texts; (4) prepare summaries, reports and technical articles, letters...; (5) carry out oral presentations in English (6) learn specific civil engineering terminology, both technical and semi-technical; (7) improve pronunciation through the practice of phonetics; (8) maintain a conversation in English correctly using the required conventions both in every day informal language as well as academic and professional situations.

Program

Unit 1. Engineering materials
Unit 2. Facts about matter
Unit 3. Instruments and tools
Unit 4. Environmental concerns
Unit 5. Electricity
Unit 6. Mathematical expressions and formulae
Unit 7. Graphic information
Unit 8. The engineering profession
Unit 9. Civil engineering companies
Unit 10. Professional careers in civil engineering

REFERENCES

BEIGBEDER, F. (1997); *Nuevo Diccionario Politécnico de las Lenguas Española e Inglesa*. Díaz de Santos; Madrid.

BRIEGER, N & A. Pohl, **(2004)**;*Technical English. Vocabulary and Grammar*; Summertown Publishing; Oxford.

GLENDINNING, E. & N. GLENDINNING,(1995); *Electrical and Mechanical Engineering*; Oxford University Press; Oxford.

ROBB, L., (2005); *Diccionario para Ingenieros. Español/Inglés – Inglés/Español*; México.

Year Four

- Lecture hours for the Year Four: 840 hours
- Common subjects compulsory: 7 annual

Structural Analysis [4021]

Year Four, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.

Teaching objectives

The aim of this subject is to further the training received by students in the previous subjects, such as Mechanics and Strength of Materials, in areas related with analysis and structural modelling, providing them with the required ability to: (1) assimilate future concepts to be learned in specific technological subjects due to both the type of material (concrete, steel) and its use (buildings, bridges, dams, etc.), (2) correctly apply theoretical structural examples to the analysis of real life problems and (3) attain rigor, mental alertness and familiarity with the use of different structural analysis models and methods in view of their professional career ahead.

Program

PART I. ANALYSIS OF PLANE TRUSSES

Unit 1. Introduction

Unit 2. Calculation of internal forces

Unit 3. Determination of displacements

Unit 4. Statically indeterminate structures

Unit 5. Influence lines

PART II. ANALYSIS OF PLANE GRIDS

Unit 6. Introduction

Unit 7. Formulation of non translational analysis

Unit 8. Non-sway frames

Unit 9. Sway frames

Unit 10. Influence lines

PART III. ELASTIC ANALYSIS OF PLATES

Unit 11. Introduction

Unit 12. General formulation

Unit 13. Solution methods

PART IV. INTRODUCTION TO SHELL STRUCTURES

Unit 14. Introduction

PART V. MATRIX METHOD FOR ANALYSIS OF PRISMATIC ELEMENT STRUCTURES

Unit 15. Introduction

Unit 16. Basic equation for a bar

Unit 17. Structure stiffness matrix

Unit 18. Other aspects

PART VI. FINITE ELEMENT METHOD FOR STRUCTURAL ANALYSIS

Unit 19. Introduction

Unit 20. Energy methods

Unit 21. General formulation. Element analysis

Unit 22. General formulation. Structure

Unit 23. Plane element development

Unit 24. Final considerations

PART VII. INTRODUCTION TO DYNAMIC CALCULUS

Unit 25. Introduction to dynamic calculus

REFERENCES

TIMOSHENKO, S.P. y YOUNG, D.H. (1981); *Teoría de las estructuras*; URMO; Bilbao

VÁZQUEZ FERNÁNDEZ, MANUEL (1999); *Resistencia de Materiales*; Noela; Madrid

TIMOSHENKO Y KRIEGER. (1975); *Teoría de placas y láminas*; URMO; Bilbao

LIVESLEY, R.K. (1964); *Matrix methods of structural analysis*; Pergamon Press Ltd.; Londrés

ZIENKIEWICZ, O.C. (1994); *El Método de los Elementos Finitos*; Reverté; Barcelona

Hydraulics and Hydrology [4023]

Year Four, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.

Teaching objectives

This subject must provide students with an understanding of the main fundamentals of fluid mechanics and technical hydraulics, and introduce the principles that rule the flow of water in the natural medium. After the completion of this subject, students must: (1) be capable of describing and explaining the physical laws behind the behavior of fluids as a fundamental base for the understanding of hydraulic works operation, (2) grasp the hydraulic operation of steady flow pressurized pipes. (3) grasp the hydraulic operation of steady flow open channel pipes. (4) have an understanding of the hydraulic operation of transients in steady flow pressurized and open channel. (5) be able to describe and explain the principles that rule the water flow in the natural medium and (6) be capable of carrying out hydrological resources and flooding surveys

Program

PART I. FLUID PROPERTIES

Unit 1. Water and other fluids properties
Unit 2. Dimensional analysis
Unit 3. Hydraulic similitude
Unit 4. Hydraulic models

PART II. Hydrostatics

Unit 5. Law of pressure and thrust on surfaces
Unit 6. Flotation and stability

PART III. Hydrodynamics

Unit 7. Equations of motion of perfect fluids
Unit 8. Equations of motion of real fluids
Unit 9. Laminar and turbulent flows
Unit 10. Hydrodynamic boundary layer, boundary layer separation and friction
Unit 11. Turbulent transport in the cloud topped boundary layer
Unit 12. Wave and flow motions

PART IV. Pressurized Pipes Hydraulics: General Principles

Unit 13. Continuity and movement quantity assessment equations
Unit 14. Bernoulli equation
Unit 15. Friction hydraulic load loss
Unit 16. Localized load loss
Unit 17. Cavitation

PART V. Pressurized Pipes Hydraulics: Steady Flow Analysis

Unit 18. Pipeline network calculation
Unit 19. Hydraulic machines
Unit 20. Measurement and control devices

PART VI. Pressurized Pipes Transients

Unit 21. Mass oscillation and surge shafts
Unit 22. Water hammer

PART VII. Main Open Channel Hydraulic Principles

Unit 23. Open cannel flow
Unit 24. Energy principles and movement quantity
Unit 25. Specific energy

PART VIII. LOCAL PHENOMENA IN OPEN CHANNEL HYDRAULICS

Unit 26. Local transitions
Unit 27. Hydraulic jump
Unit 28. Energy dissipation
Unit 29. Control structures

PART IX. UNIFORM AND VARIED FLOW REGIME

Unit 30. Resistance formulae
Unit 31. Backwater curves
Unit 32. Closed cannel flow

PART X. VARIABLE REGIME IN OPEN CHANNELS

Unit 33. Variable regime equations
Unit 34. Solution methods
Unit 35. Channel regulation and control
Unit 36. Erodible channels

PART XI. HYDROLOGY: WATER IN THE ATMOSPHERE

Unit 37. Rainfall generation mechanisms
Unit 38. Precipitation
Unit 39. Evapotranspiration

PART XII. HYDROLOGY: SURFACE WATER

Unit 40. Runoff generation
Unit 41. Unit hydrograph
Unit 42. Flood wave propagation

PART XIII. HYDROLOGY: UNDERGROUND WATER

Unit 43. Hydraulics of groundwater
Unit 44. Groundwater motion
Unit 45. Well hydraulics

PART XIV. HYDROLOGIC DESIGN

Unit 46. Hydrological frequency analysis

Unit 47. Resources estimation

Unit 48. Flood volume calculation

Unit 49. Computer assisted models

REFERENCES

OSUNA, A.: Hidráulica: Hidráulica Técnica y Mecánica de fluidos
MARTÍNEZ MARÍN; E.: Hidráulica
MARTÍNEZ MARÍN, Ed: Hidrología
LAGUNA, F.& DOMINGUEZ, J.R.: Problemas de Hidráulica

Reinforced and Prestressed Concrete I [4028]

Year Four, common, annual, 4 h/week (3 h lectures and 1 h practical classes), 120 h/year, 12 credits.

Teaching objectives

The teaching objectives for this subject are to provide students with: (1) qualitative knowledge of the resistance response mechanisms in reinforced concrete elements (2) ability to design and execute reinforced concrete structure projects in accordance with Spanish regulations (3) basic notions of the behavior of prestressed concrete structures, and (4) general notions of the existence of special types of concrete and their applications.

Program

PART I. INTRODUCTION TO REINFORCED CONCRETE

Unit 1. Brief reinforced concrete history

Unit 2. General properties of concrete and steel

Unit 3. Concrete behavior under severe loading

PART II. MATERIALS. STRENGTH. RHEOLOGICAL PROPERTIES

Unit 4. Mechanical features of concrete

Unit 5. Rheological features of concrete

Unit 6.Mechanical features of steel

PART III. DESIGN OF REINFORCED CONCRETE STRUCTURES

PART III.1. SAFETY THEORY AND BASICS OF DESIGN

Unit 7. Concept of safety

PART III.2. Ultimate Limit States

Unit 8. Axial forces (1)

Unit 9. Axial forces (2)

Unit 10. Axial forces (3).

Unit 11. Axial forces (4).

Unit 12. Axial forces (5).

Unit 13. Instability ultimate limit state

Unit 14. Anchorage

Unit 15. Shear

Unit 16. Torsion

Unit 17. Bending

PART III.3. SERVICEABILITY LIMIT STATES

Unit 18. Cracking

Unit 19. Deflections

PART III.4. STRUT-AND-TIE MODELS

Unit 20. Strut-and-Tie models

PART IV. PRESTRESSED CONCRETE

Unit 21. Introduction. Concept of prestressing

Unit 22. Materials

Unit 23. Prestressing design

Unit 24. Losses

Unit 25. Structural effects of prestressing

Unit 26. Project bases

Unit 27. Serviceability limit states

Unit 28. Normal stress ultimate limit state

PART V. APPLICATIONS TO PUBLIC WORKS, BUILDINGS AND PREFABRICATION

Unit 29. Practical application to public works, buildings and prefabrication

REFERENCES

CALAVERA, J.: "*Proyecto y cálculo de estructuras de hormigón para edificios*". Editado por INTEMAC. Madrid, 1984.

CORRES, H.; MARTÍNEZ, J.L.; PÉREZ A.; LÓPEZ J.C.: "*Prontuario Informático del Hormigón Armado*" v 3.0. IECA. Madrid, 2001.

Gª. MESEGUER, A.; MORÁN, F.; ARROYO, J.C.: "*Hormigón Armado. Jiménez Montoya*". Ed. Gustavo Gili. Barcelona, 2009.

LEONHARDT, F.; MÖNNIG, E.: "*Estructuras de Hormigón Armado*". Ed. El Ateneo. Buenos Aires, 1985.

PARK, R.; PAULAY, T.: "*Estructuras de Concreto Reforzado*" Ed. Limusa. México, 1979

MILLANES, F.: "La flexión en Estructuras Metálicas". Apuntes de 5ºcurso. E.T.S. Ingenieros de Caminos, Canales y Puertos. Madrid.
MILLANES, F.: "Introducción a las Estructuras Mixtas". Apuntes de 5º curso E.T.S. Ingenieros de Caminos, Canales y Puertos. Madrid.

VIÑUELA RUEDA, L; MARTÍNEZ SALCEDO, J.: "Proyecto y Construcción de Puentes Metálicos y Mixtos". Editado por APTA. Madrid, 2009.

HURTADO MINGO, C. Y OTROS.: "Estructuras de Acero en Edificación". Editado por APTA. Madrid, 2008.
HIRT, M.A.; BEZ, R. : "Construction Métallique". Traité de Génie Civil (vol. 10). École Polytechnique Fédérale de Lausanne. Editado por Presses Polytechniques Universitaires Romandes. Lausanne, 2001.
SIMÕES DA SILVA, L Y OTROS.: "Design of Steel Structures: Eurocode 3. Part 1-1". ECCS Eurocode Design Manuals. Editado por Ernst&Sohn. Berlin 2010.

GARDNER, L.; NETHERCOT, D.A.: "Designers guide to EN 1993-1-1". Eurocodes Expert & The Steel Construction Institute. Editado por Thomas Telford. Londres, 2005.

Geotechnics and Foundations [4122]

Year Four, common, annual, 5 h/week (3 h lectures and 2 h practical classes), 150 h/year, 15 credits.

Teaching objectives

This subject is aimed at teaching the basic principles or soil mechanics and its main applications. Students must become familiarized with elemental soil properties, characterization methods of such properties through laboratory and field tests as well as to have an understanding of geotechnical land surveying techniques. It is also expected that they will learn the basic laws that rule the problems of water flow in soils, deformation and stress issues and the procedures to evaluate geotechnical ultimate limit states and their application on basic problems: shallow and deep foundations, walls and slopes.

Program

PART I. SOILS AND ROCKS MECHANICS

Unit 1. Introduction to Geotechnics
Unit 2. Particle size and soil classification
Unit 3. Elemental features
Unit 4. Plasticity of clayey soil
Unit 5. Surface water flow
Unit 6. Effective stress concept
Unit 7. Effects of surface tension of water
Unit 8. Soil Swelling and Compressibility
Unit 9. Theory of consolidation and applications
Unit 10. Soil compaction
Unit 11. Soil and rock resistance
Unit 12. Laboratory resistance tests
Unit 13. Soil and rock deflections. Interstitial pressure
Unit 14. Soil and rocks dynamics

PART II. GEOTECHNICAL APPLICATIONS

Unit 15. Filtration networks
Unit 16. Filtration networks (continuation)
Unit 17. Elastic materials
Unit 18. Elastic materials (continuation)
Unit 19. Plastic materials
Unit 20. Rankine's theory
Unit 21. Surveying techniques. In-situ tests
Unit 22. Shallow foundations
Unit 23. Deep foundations
Unit 24. Retaining walls
Unit 25. Slope stability
Unit 26. Geotechnical auscultation
Unit 27. Safety factors

REFERENCES

JIMÉNEZ SALAS ,J.A. y JUSTO ALPAÑÉS, J.L., *Geotecnia y Cimientos I*, Editorial Rueda, Madrid.

JIMÉNEZ SALAS, J.A., JUSTO ALPAÑÉS, J.L. y SERRANO GONZÁLEZ, A., *Geotecnia y Cimientos II*, Editorial Rueda, Madrid.

PUERTOS DEL ESTADO ROM 05.94, *Recomendaciones geotécnicas para el proyecto de obras marítimas y portuarias*, Ministerio de Fomento, Madrid.

MINISTERIO DE FOMENTO, *Guía de cimentaciones en obras de carretera*, Madrid.

Economy [4060]

Year Four, common, annual, 3 h/week, 90 h/year, 9 credits.

Teaching objectives

The main objectives are to provide students with a strong background in economics that will serve them as a basis to study and understand other subjects in the curriculum and demonstrate the use and application of their knowledge regarding this discipline in several aspects of their professional career. This approach, in conjunction with the study of fundamental Economic Analysis and Private Company economic concepts, shall be used in particular for the introduction of these economic notions and their application to real life civil engineering and construction industry situations.

Program

PART I. GENERAL ECONOMY. MICROECONOMICS. MACROECONOMICS

Unit 1. Basic economic notions
Unit 2. Demand, supply and price
Unit 3. Use of demand and supply
Unit 4. Consumption
Unit 5. Labor supply and savings
Unit 6. Production costs
Unit 7. Production
Unit 8. Monopolies and imperfect competition
Unit 9. Macroeconomic point of view: objectives and indicators
Unit 10. Full employment model
Unit 11. Macroeconomic analysis of unemployment
Unit 12.Aggregate demand
Unit 13. Money, banks and credit
Unit 14. Inflation
Unit 15. Tax and monetary policy
Unit 16. Growth and productivity
17. Economic development
Unit 18. Introduction to public economics
Unit 19. Economic effect of infrastructures
Unit 20. Infrastructures and economic development
Unit 21. Public works funding
Unit 22. Economics and environment
Unit 23. Economic integration in Europe

PART II. PRIVATE COMPANY ECONOMICS. ACCOUNTS. FINANCES

Unit 24. Accounting theory
Unit 25. Balance sheet
Unit 26. Trading books
Unit 27. Accounts receivable
Unit 28. Current accounts
Unit 29. Industrial company accounting cycle
Unit 30. Building a company accounting cycle
Unit 31. Fixed assets
Unit 32. Profit and loss accounts
Unit 33. Liabilities
Unit 34. Year end process
Unit 35.General Accounting Plan
Unit 36. Corporations
Unit 37. Civil Engineering corporations
Unit 38. Financial entities
Unit 39. Credit entities Balance Sheet structure
Unit 40.Public Works corporations Balance Sheet structure
Unit 41. Cash management in the engineering field
Unit 42. Public Works corporations funding structure
Unit 43. Fixed and current assets funding
Unit 44. Stock market
Unit 45. Introduction to investment projects evaluation

REFERENCES

STIGLITZ, J.: Microeconomía. Ed. Ariel, 1998
STIGLITZ, J.: Macroeconomía. Ed. Ariel, 1998
LÓPEZ CORRAL, A. & SÁNCHEZ SOLIÑO, A.: Economía Pública e infraestructuras.

Urbanism [4053]

Year Four, common, annual, 3 h/week (2h lectures and 2 h practical classes), 90 h/year, 9 credits.

Teaching objectives

The aim is that students will attain a complete comprehension of the complex urban phenomenon through the presentation of different approaches: urban planning history, urban economics, urban morphology, urban activities and transportation. With the above understanding, students are expected to develop the ability to draw up urban development projects.

Program

PART I. INTRODUCTION

Unit 1. Introduction to urban planning

PART II. HISTORIC EVOLUTION OF CITIES

Unit 2.Urban planning in ancient times

Unit 3. Urban planning in medieval times

Unit 4. Renaissance urban planning

Unit 5. Baroque urban planning

Unit 6.Urban planning in the 19th century

Unit 7. Urban planning in the 20th century

PART III. URBAN ECONOMICS

Unit 8. Economic fundamentals of the urban phenomenon

Unit 9. Urban land market

Unit 10. Urban land use

Unit 11. Urban growth

PART IV. TRANSPORTATION

Unit 12. Transport and urban structure

Unit 13. Transportation demand

Unit 14. Transportation supply

Unit 15. Urban transport organization and management issues

Unit 16.Public urban transport economics

PART V. ELEMENTS, PARAMETERS AND BASIC NOTIONS

Unit 17. Public roads

Unit 18. City blocks and buildings. Brief contemporary architecture history

Unit 19. Parks

Unit 20. Basic transport infrastructures

Unit 21. Morphology and urban design

PART VI. URBAN ACTIVITIES

Unit 22. Activities and residential areas. Additional uses: non residential areas

Unit 23. Urban economic activities: industry and commerce

Unit 24. Transport policy and issues, traffic management and parking

Unit 25. Town center and centralism

PART VII. INTRODUCTION TO URBAN PLANNING REGULATIONS

Unit 26. Creation of legal techniques for urban intervention in Spain

Unit 27. Planning system. Urban planning

Unit 28. Execution of planning, property rights and urban planning

Unit 29. Urban legality control. Land market intervention tools

PART VIII. REAL ESTATE MARKET

Unit 30.Introduction to the real estate market

Unit 31.Production process and real estate operators

PART IX. URBAN ISSUES

Unit 32. Urban society

Unit 33. Current society. Characteristics and trends. Review

Unit 34. Environmental crisis and society

PART X. URBAN PLANNING AND LAND USE

Unit 35. Execution projects

Unit 36. Partial Plans

Unit 37. Urban renewal plans

Unit 38. Supra-local urban plans

REFERENCES

VALERO, J. (2005); *Apuntes de urbanismo 1. Historia*, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, , Madrid

VALERO, J. (2005); *Apuntes de urbanismo 2. Economía, movilidad*, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, Madrid

SANTAMERA, J.A. (1998); *Introducción al planeamiento urbano*, Colegio Ingenieros de Caminos, Canales y Puertos, Madrid.

SANTOS DÍEZ, R.: Derecho urbanístico: manual para juristas y técnicos. 2008

English II [4074]

Year Four, common, annual, 4 h/week (2 h lectures and 1 h practical classes), 90 h/year, 9 credits.
Pre- requirements: *English I [3073]*

Teaching objectives

The aim of this subject is, firstly, that students acquire the adequate language to enable them to efficiently and correctly interact and communicate throughout their academic and professional life. From the basis of a themed approach applied to meet their needs, they are familiarized with the practice of the most frequent techniques and topics in the civil engineering field. A selection of the most appropriate and useful topics has been compiled to help them in their future career. The study areas include a wide range of up to date practice in the main functions and conventions used by today's scientific and technical professionals, in consideration of the following specific goals: (1) Reading skills: practice of intensive and extensive reading differentiating various parts of the text. Writing skills: Summarizing, report writing, case studies, and written instructions practice (2) Listening skills: Practice of spoken engineering examples (3) speaking skills: Practice of everyday engineering situations (4) Technical translation skills: Translation of civil engineering texts to and from English.

Program

Unit 1. Construction materials
Unit 2. Foundations and soil mechanics
Unit 3. Road construction
Unit 4. Hydraulic structures
Unit 5. Steel beams and trusses
Unit 6. Building bridges
Unit 7. Tunneling techniques
Unit 8. Environmental and sanitary engineering
Unit 9. Metal fracture and fatigue
Unit 10. The engineering professional market

REFERENCES

BEIGBEDER ATIENZA, F. (2002); *Polytechnic Dictionary of Spanish and English Languages, (2 tomos)*, Díaz de Santos: Madrid.

BENESH, S. (2001);*Critical English for Academic Purposes, Theory, Politics, and Practice*. New Jersey Laurence Erlbaum Associates, Inc.

EMDEN, J. van (1996); *Technical Writing and Speaking*, The McGraw-Hill Companies: London.

KOCH, P. (1984);*Engineering. Civil and Mechanical Engineering*, Macmillan Publishing Company: New York.

WEISSBERG, R. (1990); *Writing Up Research*, Prentice Hall, New Jersey.

Year Five

- Total Lecture hours of Year Five: 750 hours
- Lecture hours of common subjects: 570 hours
- Lecture hours of specialization: 180 hours

Common Subjects

- Lecture hours of common subjects: 570 hours
- Common subjects: 5 annual and 1 semestral

Art and Aesthetics in Engineering [5027]

Year Five, common, annual, 2 h/week, 60 h/year, 6credits.

Teaching objectives

The aim of this subject is to familiarize students with the different types of construction and their main authors. From the point of view of aesthetics as a philosophical branch, we rely on history to demonstrate our ancestors' building skills, which form the basis of all disciplines in the current engineering profession. We will use images to discuss the most important constructions ever built, and analyze how they developed the stages of construction from a blueprint design, with a view to connecting all previously acquired practical knowledge in other disciplines into a common hub that defines the spirit of this profession.

Program

PART I. HISTORY AND AESTHETICS IN CIVIL ENGINEERING

Unit 1. Introduction
Unit 2. Basic notions: structural types and terminology
Unit 3. Classical space organization: Egypt, Greece, Rome
Unit 4. Roman architecture
Unit 5. Roman hydraulic engineering
Unit 6. Roman bridges and cities
Unit 7. Pre-Romanesque, byzantine, Romanesque
Unit 8. Medieval bridges and cities
Unit 9.Spanish-Arabic construction: Castles. Cordoba and Granada
Unit 10. Gothic Ribbed structure
Unit 11. Renaissance, ideas, engineers
Unit 12. Public works in the 15th and 16th century: Bridges and dams
Unit 13. Cities and villages: Domenico Fontana's Saint Peter's
Unit 14. Engineering in the 18th century. Perronet
Unit 15. Industrialization. Steel and bridges
Unit 16. Hydraulic engineering in the 19th century. Waterways and dams
Unit 17.Steel and glass roofs. Paxton. Railway stations. Eiffel
Unit 18. Cities at the end of the 19th century. City expansion. Cerdá. Soria
Unit 19. Great suspension bridges, Roebling, Ammann, Strauss
Unit 20. Huge steel bridges. Arches and lattices
Unit 21. Reinforced concrete Maillart, Torroja
Unit 22. Big dams before 1945

Unit 23. Prestressed concrete and prefabrication. Freyssinet, Nervi

Unit 24. Arch and cable-stayed bridges

PART II. CIVIL ENGINEERING AND TERRITORY

Unit 25. Current hydraulic works and planning

Unit 26. Ports and coastal uses

Unit 27. Transport infrastructures: motorways, railways, airports

Unit 28.End of the century bridges

Unit 29. Towers and tall buildings

Unit 30. Road engineers and great constructors

REFERENCES

AGUILÓ, M.: Forma y tipo en el arte de construir puentes. Abada. Madrid. 2008

FERNÁNDEZ ORDOÑEZ, J.A.: Eugène Freyssinet. 2C Editios. Barcelona. 1979.

FERNÁNDEZ TROYANO: Tierra sobre el agua. CSIC. Madrid. 1999

LÓPEZ GARCÍA, M & BERNABEU, J.: 50 años construyendo el futuro, ingenieria …

MEEKS, C.L.V.: The railroad stationAn Architectural History.

SIMONNET, C.: Le béton.

TORROJA, E.: Razón y ser de los tipos estructurales. CSIC

Steel Structures [5030]

Year Five, common, annual, 4 h/week (3 h lectures and 1 h practical classes), 120 h/year, 12 credits.

Teaching objectives

The purpose of this subject is to transfer theoretical and practical knowledge to students in regards to the analysis of steel structures, including the design according to Spanish and European. Students will learn about the materials used, the advantages and disadvantages of their use and the structural types. Amongst the objectives of this subject, it is included the ability to calculate a building structures, defining the correct classification, the requierements for the materials to be used, the execution, and the protection processes for an adequate maintenance and preservation. It is also included the discussion of particular case studies like tall buildings and the influence of seismic and wind effects.

Program

Unit 1. Standards for metallic structures
Unit 2. Types of steel used in construction
Unit 3. Yielding criteria
Unit 4. Calculation methods
Unit 5. Elastic, plastic and elastoplastic analysis
Unit 6. Analysis of structures subjected to bending
Unit 7.Study of shear effects
Unit 8. Torsion: causes
Unit 9.Instability phenomena
Unit 10. Second order effects
Unit 11. Elements under compressive forces
Unit 12. Buckling behavior in structural members. National codes
Unit 13. Buckling in real structural members. European codes
Unit 14.Instability of steel panels
Unit 15. Local instability
Unit 16. Bolted connections
Unit 17. Ordinary bolts
Unit 18. Welded connections
Unit 19. Welded connection calculations
Unit 20. Composite structures
Unit 21. Shear connections in composite structures
Unit 22. Execution of steel structures
Unit 23. Execution safety and quality control
Unit 23. Protection against corrosion. Maintenance and conservation
Unit 24. Building structures
Unit 25. Study of buildings under horizontal loads
Unit 26. Industrial building structures
Unit 27. Types of metallic structures

REFERENCES
Eurocódigo III

Hydraulic Works [5034]

Year Five, common, annual, 4 h/week (3h lectures and 1h practical classes), 120 h/year, 12 credits.

Teaching objectives

This subject is introduced as the end of the civil engineer's generic training in regards to hydraulic works. The purpose of this subject is to provide students with the required capacity to fully develop competence with respect to: 1) envisage and study the feasibility and create and prepare preliminary hydraulic works projects (2) draw up hydraulic works projects. (3) supervise the construction of hydraulic engineering works (4) manage, preserve, operate and repair hydraulic systems and (5) plan, promote and manage hydraulic system projects.

Program

PART I. WATER RESOURCES STUDY

Unit 1. Water and hydraulic works

Unit 2. Hydrologic surveys

Unit 3. Regulation surveys

PART II. WATER REGULATION HYDRAULIC WORKS: DAMS

Unit 4. General dam issues

Unit 5. Concrete dams

Unit 6. Embankment dams

Unit 7. Dam elements

Unit 8. Dam operation

PART III. WATER TRANSPORTATION HYDRAULIC WORKS: PIPES

Unit 9. Pressurized pipes

Unit 10. Open channel flow pipes

PART IV. PUMPING AND ENERGETIC USES

Unit 11. Pumping stations

Unit 12. Hydroelectric uses

PART V. IRRIGATION, FLUVIAL WORKS, AQUIFERS AND ENVIRONMENTAL RESTORATION

Unit 13. Irrigation

Unit 14. Fluvial works

Unit 15. Aquifers

Unit 16. Environmental restoration

PART VI. HYDRAULIC RESOURCES OPTIMIZATION AND PLANNING

Unit 17. Hydrographic management

Unit 18. Economic project evaluation

Unit 19. Hydrologic planning methods

REFERENCES

VALLARINO, E., (2004); *Tratado Básico de Presas, Volumenes I y II;* Colegio de Ingenieros de Caminos, Canales y Puertos; Madrid.

GRANADOS, A. et al., (2000); *Problemas de Obras Hidráulicas;* Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

MARTIN CARRASCO, F.J. y GARROTE, L., (2005): *Diseño y Optimización de Obras Hidráulicas;* Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

GRANADOS, A. y PIMENTEL, H. (1997); *In fraestructuras de Regadío;* Colegio de Ingenieros de Caminos, Canales y Puertos; Madrid.

CUESTA, L., VALLARINO, E. (2000); *Aprovechamientos Hidroeléctricos, 2 volúmenes;* Colegio de Ingenieros de Caminos, Canales y Puertos; Madrid.

Roads and Airports [5037]

Year Five, common, annual, 4 h/week (3h lectures and 1h practical classes), 120 h/year, 12 credits.

Teaching Objectives

The main purpose of this subject is to prepare students for future participation in any stage of development of the required actions for the services provided by road and airport infrastructures within three main points of reference: safety, quality and maintenance of a balance with the environment. The specific goals sought are as follows : (1) analyze and quantify vehicle traffic variables, as well as roads' capacity and service levels (2) analyze the required parameters to geometrically design the road's layout. (3) have an understanding and evaluate the road operation management, (4) analyze the parameters that may affect road traffic safety. (5) have an understanding of the layout and dimensions of aerodromes, their organization in terminal and auxiliary buildings, as well as their points of access. (6) classify soils depending on their use within the transport infrastructures. (7) organize the safe and technically correct construction of cut and fill areas, (8) calculate and design the flow volume expected for outlets and drainage elements (9) Understand and manage the project units used in the construction of road and airport pavements and be able to calculate their size according to the current Spanish regulations, (10) have an understanding of the main road elements features and the criteria for its usage. (11) understand the techniques used to preserve roads within acceptable usage level and the organization and management of this activity.

Program

PART I. BASIC ROAD SYSTEM FEATURES

Unit 1. Road systems

Unit 2. Road engineering activities. Road management

Unit 3. Vehicles, drivers and pedestrians

PART II. ROAD PLANNING AND TRAFFIC SURVEYS

Unit 4. Variable traffic features. Traffic surveys. Traffic capacity and service levels

Unit 5. Road planning

PART III. Geometric Design

Unit 6. Speed and visibility. Vehicle path. Tyre pavement interaction. Speed.

Unit 7. Alignment and profile design elements. Alignment and profile design coordination

Unit 8. Solution generation and optimization. Environment integration

Unit 9. Cross section

Unit 10. Geometric link design

PART IV. Road Survey

Unit 11. Inventories

Unit 12. Road surveys and scope

Unit 13. Levelling, measurement and compensation

Unit 14. Land occupation and stake

PART V. Traffic Control, Regulations and Management

Unit 15. Road operation. Road signs. Usage criteria

Unit 16. Road assistance management. Winter road assistance. Incident management

Unit 17. Traffic management

PART VI. ROAD SAFETY

Unit 18. Road safety issues

Unit 19. In service road safety improvements

Unit 20 Road safety in road design

PART VII. INFRAESTRUCTURES

Unit 21. Geotechnical road issues. Geological and geotechnical surveys

Unit 22. Soil and rock types

Unit 23. Compaction

Unit 24. Soil bearing capacity

Unit 25. Esplanade construction

Unit 26. Esplanade formation .Soil stabilization

Unit 27. Surface drainage. Underground drainage. Geotextiles usage

Unit 28. Slope erosion

Unit 29. Cross works, structures and tunnels

PART VIII. Pavements

Unit 30. Pavement constitution

Unit 31. Basic materials

Unit 32. Base and subbase layers

Unit 33. Surface finishes and bituminous mixes

Unit 34. Concrete pavements

Unit 35. Pavement structural design

Unit 36. Surface pavement characteristics

Unit 37. Ordinary and special pavements

PART IX. Road Elements

Unit 38. Road signs, markings and warning bollards

Unit 39. Vehicle restraint devices

Unit 40. Other road elements

PART X. PRESERVATION

Unit 41. Maintenance principles and organization

Unit 42. Maintenance management

Unit 43. Maintenance and refurbishment techniques

PART XI. AIRPORTS

Unit 44. Airports

REFERENCES

KRAEMER, C. et al. (2003); *Ingeniería de Carreteras, volumenes I y II*, McGraw-Hill, Madrid.

TRANSPORTATION RESEARCH BOARD (2000); *Highway Capacity Manual*, TRB, Washington D.C.

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RICO, A. Y DEL CASTILLO, H. (1977); *La ingeniería de suelos en las vías terrestres, 2 volúmenes*, Limusa, México, D.F.

YODER, E.J. & WITCZAK, M.W. (1975); *Principles of Pavement Design*, 2ª edicion, John Wiley & Sons, New York y Toronto.

Ports and Coasts [5045]

Year Five, common, annual, 4 h/week (3h lectures and 1h practical classes), 120 h/year, 12 credits.

Teaching objectives

The aim of the subject is that students to acquire the skills needed to (1) determine the maritime climate affecting actions on coasts and ports, from the wind to waves and the level of calculus. It is the required to study the structure of the wind and waves, their propagation and transformation, and the nature and frequency storms occur, as well as other climate and oceanic magnitudes. (2) Understand the interaction between coastal dynamics and the morphodynamics of coastal forms, and their genetic classification and generation. This will enable students to make deductions about the coastal resources consequences of the various ways of coastal occupation and ports actions, (3) understand the nature and evolution of ports, the factors affecting ships and land transportation, and the basic criteria for arranging their layout and planning. There is also an introduction to operating, managing and planning ports and the engineering works and actions in ports and off-shore. (4) Be able to carry out functional and structural design of docks, works on berths in ports and works and actions to protect and develop the coast and conceive construction procedures. All the above knowledge will be taught according to multivariate analysis and design specifications

Program

Unit 1. The port, the harbor and the coast

Unit 2. Wind actions (ROM 0.4/95)

Unit 3. Mechanics of waves

Unit 4. Wave generation

Unit 5. Waves theories

Unit 6. Waves statistics (ROM 0.3/91)

Unit 7. Maritime Works, risk and failure modes (ROM 0.2/90 & ROM 0.0/2001)

Unit 8. The ocean and the coast

Unit 9. Coastal forms and littoral processes. Environmental factors

Unit 10. The Port and the lay-out

Unit 11. The vessel (ROM 3.1/99 & ROM 2.0/2012). Port and vessel interaction

Unit 12. Breakwaters: Rubble mound, vertical and composite breakwaters. Structural and Hydraulic design and construction

Unit 13. Berthing and mooring maritime Works. The dock, wharf, jetty and dolphin. Structural and Hydraulic design and construction

Unit 14. Vulnerability of maritime works. Probability of failure. Level I, II and III

Unit 15. Construction of maritime works

Unit 16. Port management. Environmental effects

Unit 17. Coastal planning. Shore act. Environmental impacts

Unit 18. Scale model

REFERENCES

DÍEZ GONZÁLEZ, J. (1996); *Guía Física de España. Las Costas*, Alianza Editorial.

SUÁREZ BORES, P., *Apuntes de Diques. Oleaje y Formas costeras*, Servicio de Publicaciones de la Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, Madrid.

U.S. CORPS OF ENGINEERS (1984); *Shore protection manual,* American Society of Civil Engineers.

NEGRO, V. et al. (2001); *Diseño de Diques verticales*, Colegio de Ingenieros de Caminos, canales y Puertos. Colección Seinor, Número 26.

NEGRO, V. et al. (2002); *Diseño de Diques rompeolas*, Colegio de Ingenieros de Caminos, canales y Puertos. Colección Seinor, Número 28.

Transportation [5028]

Year Five, common, semester, 2 h/week, 30 h/year, 3 credits.

Teaching objectives

The main aim of this subject is to provide an overview of the transportation sector to all students studying the subject. They should be familiar with the main elements comprising the sector, their development throughout history and their relationship with other sectors, as well as the most important instruments for analysis.

Having a view of transports as a science with a deep sociological content is another of the course's objectives. Furthermore, included among the teaching objectives is that students should be able to set the orders of magnitude of the main transport parameters in Spain, Europe and the world.

Program

Unit 1. Introduction

Unit 2. History Evolution

Unit 3. The Transportation sector: current situation

Unit 4. Transport Infrastructure

Unit 5. Transport and Territory

Unit 6. Transport and Economy, Energy, Security and Environment

REFERENCES

GONZÁLEZ TASCÓN, I., *Historia del Transporte en España*. Ineco-Tifsa, 2005.

IZQUIERDO DE BARTOLOMÉ, R., *Transportes: un enfoque integral*. Servicios de Publicaciones C.I.C.C.P. Colección Escuelas. Madrid, 1994

OTERO PASTOR, I (Coord.), *Impacto ambiental de Carreteras: evaluación y restauración.* Asociación Española de la Carretera, Madrid, 1999.

RUS DE MENDOZA, G., *Economía y política de transportes: España y Europa.* IETC., Madrid, 1992.

VUCHIC, V. R. *Urban Public Transportation: Systems and Technology*. Prewntice-Hall, New Jersey, 1981.

Specialization in Structures and Foundations

- Lecture hours for the specialization: 180 hours out of a total of 225 hours
- Subjects: 3 compulsory and 1 optional to be chosen out of 2 (both semester)

Reinforced and Prestressed Concrete II [5129]

Year Five, compulsory for the specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objectives of the subject Reinforced and Prestressed Concrete II deal with advanced structural concrete, including in-depth study of prestressed concrete. The most general models such as the "Strut-and-Tie" model are developed and the basic methodology is extended to the project with most recent concretes such as the high strength ones. The knowledge of external prestressed concrete is completed reaching a significant command of this technique with very specific aspects such as the external prestressing process. It also includes the issues of durability, maintenance and repair of elements of structural concrete, the incidence of the shrinkage and relaxation of evaluating structures and typical aspects.

Program

Unit 1. Introduction

Unit 2. Materials

Unit 3. Durability

Unit 4. Basis of design

Unit 5. Ultimate limits states

Unit 6. Strut and tie models

Unit 7. Serviceability limit states in prestressed structures

Unit 8. Construction

REFERENCES

CALAVERA, J.: "*Proyecto y cálculo de estructuras de hormigón para edificios*". Editado por INTEMAC. Madrid, 1984.

CORRES, H.; MARTÍNEZ, J.L.; PÉREZ A.; LÓPEZ J.C.: "*Prontuario Informático del Hormigón Armado*" v 3.0. IECA. Madrid, 2001.

Gª. MESEGUER, A.; MORÁN, F.; ARROYO, J.C.: "*Hormigón Armado. Jiménez Montoya*". Ed. Gustavo Gili. Barcelona, 2009.

LEONHARDT, F.; MÖNNIG, E.: "*Estructuras de Hormigón Armado*". Ed. El Ateneo. Buenos Aires, 1985.

PARK, R.; PAULAY, T.: "*Estructuras de Concreto Reforzado*" Ed. Limusa. México, 1979

MILLANES, F.: "La flexión en Estructuras Metálicas". Apuntes de 5ºcurso. E.T.S. Ingenieros de Caminos, Canales y Puertos. Madrid.

MILLANES, F.: "Introducción a las Estructuras Mixtas". Apuntes de 5º curso E.T.S. Ingenieros de Caminos, Canales y Puertos. Madrid.

VIÑUELA RUEDA, L; MARTÍNEZ SALCEDO, J.: "Proyecto y Construcción de Puentes Metálicos y Mixtos". Editado por APTA. Madrid, 2009.

HURTADO MINGO, C. Y OTROS.: "Estructuras de Acero en Edificación". Editado por APTA. Madrid, 2008.

HIRT, M.A.; BEZ, R. : "Construction Métallique". Traité de Génie Civil (vol. 10). École Polytechnique Fédérale de Lausanne. Editado por Presses Polytechniques Universitaires Romandes. Lausanne, 2001.

SIMÕES DA SILVA, L Y OTROS.: "Design of Steel Structures: Eurocode 3. Part 1-1". ECCS Eurocode Design Manuals. Editado por Ernst&Sohn. Berlin 2010.

GARDNER, L.; NETHERCOT, D.A.: "Designers guide to EN 1993-1-1". Eurocodes Expert & The Steel Construction Institute. Editado por Thomas Telford. Londres, 2005.

Advanced Structural Analysis [5122]

Year Five, compulsory for the specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The subject is divided into two areas of study: Dynamic analysis and advanced Finite Element Method. The main objective of the first part, Dynamic Analysis, is to provide students with the concepts appearing as basic differences between static analysis, with which they are already familiar, and dynamic analysis, in addition to highlighting the similarities between both types. They are presented with methods of calculus that are sufficiently simple to develop the structural insight required to analyze the validity of solutions from computer calculations. Furthermore, students will be introduced to discretization techniques required for modelling real structures for dynamic analysis.

After the second part, students will be familiar with advanced formulae of finite elements, in the linear field, as an extension to the previous years' studies. Given the unavoidable use of the computer in this method, the stages to go through to obtain a practical solution to a structural problem are analyzed. However, students should acquire deeper knowledge than learning how a program works as a "black box". The aim is to have knowledge of the underlying theory, so that they have the criteria to assess and choose the best program to solve the problem matter among the many available commercial programs.

Program

PART I: DYNAMICS OF STRUCTURES

Unit 1. Introduction

Unit 2. Actions

Unit 3. General approach to the problem of dynamics

Unit 4. One-degree-of-freedom discrete model

Unit 5. Analytical solution of one-degree-of-freedom model in the time domain

Unit 6.Examples of a one-degree-of-freedom model

Unit 7. Discrete resolution of a one-degree-of-freedom model

Unit 8. Multiple-degree-of freedom models

Unit 9. Equilibrium equations for the structure

Unit 10. Resolution of the multiple-degree-of-freedom model

Unit 11. Deterministic Seismic Hazard Analysis

Unit 12. Seismic regulations in Spain

PART II: FINITE ELEMENT METHOD. AMPLIATION

Unit 13.Introduction

Unit 14. Approach to the FEM

Unit 15. Method of shape functions

Unit 16. Elastic shape functions

Unit 17. Numerical integration

Unit 18. Convergence

Unit 19. Detailed study of elements: trusses, beams, plates and shells

Unit 20. Other techniques for FEM

REFERENCES

CLOUGH, R.W.: Dynamics or Structures. 2010.

VÁZQUEZ, M. & LÓPEZ, E: El método de los elementos finitos aplicado al Análisis.

Physics of Materials [5111]

Year Five, compulsory for the specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

Students should learn how the materials used in structures behave, why they do it in a particular way and, therefore, the possibilities of modifying such behavior. To fulfil this aim, the knowledge and skills to be acquired by students are the following: (1) understanding of the most interesting theoretical models of mechanical behavior applied to structural materials. (2) understanding the physical bases of macroscopic behavior. (3) know how to apply the previous points to the design, construction and maintenance of structures and (4) be familiarized with the scientific methodology of the disciplines contained in the subject

Program

PART I. FRACTURE MECHANICS

Unit 1. Global approach to Fracture: Energy release rate G

Unit 2. Local approach to Fracture: Stress-Intensity Factor K

Unit 3 Subcritical crack growth: Fatigue

Unit 4. Subcritical crack growth: Stress corrosion cracking, Corrosion-fatigue, Creep fracture

PART II. PHYSICS OF PLASTICITY

Unit 5. Physics of Plasticity

Unit 6. Plasticity equations

Unit 7. Viscoplasticity equations

Unit 8. Composite materials: introduction

REFERENCES

ELICES, M.(2008): Mecánica de la Fractura. Publicaciones de la Escuela (6º Edición)

ANDERSON, T.L (1995): Fracture Mechanics. Fundamentals and Applications, CRC Press, Boca Raton (Florida)

BROEK,D. (1989): The Practical Use of Fracture Mechanics, Kluwer Academic Publisher, Dordrecht (Holanda)

Experimental Structural Analysis [5114]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

After the first part of the subject, students should be ready to (1) understand which situations require a model to be made and the instrumentation needed for each case: (2) design a scale model in accordance with laws of similarity: (3) be aware of the limitations of the model: (4) design a load test: (5) reflect on the current possibilities for supervising and maintaining the built structures. After having completed the second part of the subject, students should be able to (1) understand the problem arising from defining the seismic actions and the various possibilities of its definition for calculus; (2) understand the influence of soil in seismic actions; (3) assess the effects of dynamic interaction between ground and structure, including problems; (4) know Spanish and European regulations on actions and methods of seismic calculation of structures.

Program

PART I. EXPERIMENTAL STRUCTURAL ANALYSIS

Unit 1. Introduction

Unit 2. Experiments in real structures

Unit 3. Study of the structural response: Types of tests

Unit 4. Study of the structural response: Systems of Measurement

Unit 5. Data analysis and interpretation

Unit 6 Experiments with scale models

PART II. Seismic Engineering

Unit 7. Dynamic actions

Unit 8. Concept of the elastic response spectrum

Unit 9. Multi-degree-of-freedom systems

Unit 10. Orthogonal damping matrices

Unit 11. Response in the frequency-domain analysis

Unit 12. Soil-structure interaction

Unit 13. Fluid-structure interaction

Unit 14. National and International Seismic Standards

REFERENCES

DOYLE, J.F. (2004); *Modern Experimental Stress Análisis*, John Wiley

SAMARTÍN, A. y ORTEGA, L. (1975); *Ensayos geomecánicos de presas en modelos reducidos*, Publicación 204, Laboratorio Central, CEDEX

NORMA ECSE-94

NORMA EC-8

CLOUGH, R. W. and PENZIEN, J. (1993); *Dynamics of Structures*, Mac-Graw Hill

NEWMARK, N.M. and ROSENBLUETH (1971); *Fundamentals of Earthquake Engineering*, Prentice Hall International.

Rock Mechanics [5127]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

After completing the course, when facing a rock massif, students should be able to (1) program a geotechnical campaign of recognition; (2) draft, or interpret, a geotechnical report; (3) apply the results of the geotechnical report to the design of a simple foundation; analyze the stability of an embankment and propose any corrective measures required; foresee any difficulties that may arise during underground works.

Program

PART I. DESCRIPTION OF ROCKS

Unit 1. Rock classification

Unit 2. Faults in rock masses

Unit 3. Description of the rock matrix

Unit 4. Description of faults in the rock mass

Unit 5. Geomechanical classifications

Unit 6. Natural stresses

PART II. ROCK PROPERTIES

Unit 7. In-situ mechanical tests

Unit 8. Isotropic resistance of the rock matrix

Unit 9. Criterion of isotropic resistance

Unit 10. Discontinuities resistance

Unit 11. Anisotropic resistance of rocks

Unit 12. Rock massifs characterization through geophysical seismic in-situ tests

Unit 13. Deformability of rocks

Unit 14. Deformability of faults

PART III. APPLICATIONS

Unit 15. Shallow foundations

Unit 16. Deep foundations

Unit 17. Embankments

Unit 18. Underground excavations (tunnels)

REFERENCES

GOODMAN, R. (1980); *Introduction to Rock Mechanics*, John Wiley & Sons.

HOEK, E & BROWN, E.T. (1980); *Underground Excavations in rock*, Ins. Min. Metall.

HOEK, E & BRAY, J.U. (1981); *Rock Slope Engineering*, Ins. Min. Metall.

SERRANO, A. (2002); *Mecánica de las Rocas I. Descripción de las Rocas*, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos

SERRANO, A. (2002); *Mecánica de las Rocas II. Propiedades de las Rocas*, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos

Specialization in Transports

- Lecture hours of the specialization: 135 hours
  - Subjects: 3 compulsory (semestral)

Transportation Economics [5229]

Year Five, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The overall objective of this subject is to introduce the students to the transportation market, its characteristics, and the needed criteria to properly manage it, considering its social, environmental and economic effects. Once this subject has been studied, students should be able to understand the economic, legal and social fundamentals that determine the transportation market in order to understand the policies and planning tools that will be developed during the course of Transportation Planning.

Program

Unit 1. Transportation Market

Unit 2. Transportation services management and competition

Unit 3. Transportation demand analysis and models

Unit 4. Logistics

Unit 5. Costs and financing

Unit 6. Urban transportation

REFERENCES

BUTTON, K.J. (1993); *Transport Economics*, Edwar Elgar, UK.

IZQUIERDO R. ET AL. (1994); *Transportes: un enfoque integral*, Servicio de Publicaciones Colegio de Ingenieros de Caminos, Canales y Puerots, Colección Escuelas, Madrid.

IZQUIERDO, R. y VASSALLO J.M. (2005); *Nuevos Sistemas de Gestión y Financiación de Infraestructuras de Transporte*, Colección SEINOR Nº 35, Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

MONZÓN, A. ET AL. (2005); *Observatorio de Movilidad Metropolitana*, Ministerio de Medio Ambiente, Madrid.

ORTÚZAR, J.D. (2000); *Modelos de Demanda de Transporte*, Alfaomega.

Traffic Engineering [5238]

Year Five, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This subject aims to provide the necessary traffic engineering knowledge for the professional development of its activity. The aim of the course is to provide students with the capacity to fully develop the competencies in relation to (1) analyze the characteristics of road traffic and relations among variables that characterize it; (2) Develop and interpret traffic studies and apply the concepts of capacity and level of service; (3) Know the basic principles of the models used to forecast road traffic; (4) Apply the methods of traffic control in urban zones and interurban traffic management (5) Apply intelligent transportation systems (ITS) to traffic management; (6) Plan and design measures to improve road safety.

Program

PART I. TRAFFIC STUDIES

Unit 1. Fundamental quantities and techniques of data collection

Unit 2. Traffic performance simulation models

Unit 3. Traffic simulation models

Unit 4. Capacity and level of service analyzing methods

Unit 5.Traffic assignment and prognosis

PART II. TRAFFIC MANAGEMENT

Unit 6. Inter-urban traffic management IT Systems

Unit 7. Traffic management centers

Unit 8. Traffic management of urban networks

Unit 9. Traffic light regulation

Unit 10. Road safety

REFERENCES

PARDILLO, J.M. Y SÁNCHEZ BLANCO V. (2003); *Apuntes de Ingeniería de Tráfico*

TRANSPORTATION RESEARCH BOARD (2000); *Highway Capacity Manual,* Washington DC

PLINE, J. (ed.) (1999); *Traffic Engineering Handbook (5ª edición*), ITE, Washington DC

EDWARDS, J.D. (ed.) (1999); *Transportation Planning Handbook*, Institute of Transportation Engineers, Prentice Hall

PARDILLO, J.M. (2004); *Procedimientos de estudio, diseño y gestión de medidas de seguridad vial en las infraestructuras* , Fundación Agustín de Betancourt

Pipeline Transportation [5271]

Year Five, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This course aims at providing students with the sufficient capacity to fully develop the competencies in relation to fluid transport (oil pipelines, natural gas pipelines, aqueducts, etc.): (1) design, study the feasibility and draft pipeline infrastructure systems, for the transportation of fluids (liquids, gases, fluidized solids), (2) write and describe the pipeline infrastructure construction project, (3) direct the construction of pipeline infrastructures, (4) manage, preserve, preform and repair pipeline transportation systems and (5) plan, promote and manage projects about pipeline transportation systems.

Program

PART I. GENERAL CONCEPTS ABOUT PIPELINE TRANSPORTATION

Unit 1. Introduction to pipeline technology

Unit 2. The pipeline: way of transportation

Unit 3. Energy and pipeline transportation

PART II. PIPELINE SYSTEMS

Unit 4. Pipeline infrastructure: pipelines, pumping and compression stations, oil and gas storage

Unit 5. Pipeline material

Unit 6. Pipeline corrosion

Unit 7. Hydraulic machinery

Unit 8. Hydraulic machines

PART III. PIPELINE DESIGN. HYDRAULIC AND STRUCTURAL DESIGN

Unit 9. Transported fluid

Unit 10. Pipeline structural analysis

Unit 11. Pipeline routing and layout

PART IV. CONSTRUCTION AND SUBMARINE PIPELINES

Unit 12. Construction of terrestrial pipelines

Unit 13. Submarine pipelines (construction)

Unit 14. Submarine pipelines (project)

PART V. PIPELINE MANAGEMENT

Unit 15. Facilities attached to the pipeline

Unit 16. Performance

Unit 17. Costs

REFERENCES

CEGARRA PLANÉ, M. (1996); Proyecto de tuberías de transporte, Colegio de Ingenieros de Caminos, Canales y Puerotos, Servicio Publicaciones, Colección Escuelas, Madrid.

CEGARRA PLANÉ, M. (1999); *Las tuberías (Acueductos, oleoductos, gasoductos);* Colegio de Ingenieros de Caminos, Canales y Puerotos, Servicio Publicaciones, Colección Escuelas, Madrid.

SZILAS, A.P. (1985); *Production and Transport of oil and gas,* Elsevier, Amsterdam.

HERNING, F. (1975); *Transporte de fluidos por tuberías*, Editorial Labor, Barcelona.

ASCE, (1975); Pipeline Design for Hydrocaarbon Gases and Liquids, New York.

Specialization in Urban Planning and Environment

- Lecture hours of the specialization: 180 hours out of 270 hours
- Subjects: 1 compulsory and 3 optional to be chosen out of 5 (all semestral)

Urban Planning [5330]

Year Five, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The teaching objectives of this course are to provide students with the knowledge and methodology necessary to elaborate the General Plan as the most important figure in Spanish legislation. It is also aimed at familiarizing the student with the urban legislation in its planning branch.

It is also intended to continue and finish the Partial Order Planning carried out during the 4th year, designing the necessary infrastructure networks and elaborating drafts of land use and edification regulatory ordinances. For this purpose, the theoretical knowledge required for the design of urban services and ordinances drafting are taught.

Program

PART I. PRELIMINARY CONCEPTS

Unit 1. Introduction. Terminology and concepts

PART II. URBAN TECHNIQUES

Unit 2. Legislation and urban techniques

Unit 3. General planning

Unit 4. Development planning

Unit 5. Sectoral planning legislation

Unit 6. Regional planning legislation

PART III. URBAN PLANS

Unit 7. Partial plans

Unit 8. Road and pavement

Unit 9. Urban networks layout and characteristics

REFERENCES

ARIZMENDI BARNES, L. J. (1992); *Instalaciones urbanas: Infraestructura y planeamiento*.

FERNÁNDEZ RODRÍGUEZ, T. R. (1998); *Manual de Derecho Urbanístico*, 13ª edición, Publicaciones Abella, Editorial El Consultor de los Ayuntamientos.

MOYA GONZÁLEZ, L. (1994); *La práctica del planeamiento urbanístico*, Editorial Síntesis.

SANTAMERA SÁNCHEZ, J. (1998); *Introducción al Planeamiento Urbano*, 2ª edición, Colegio de Ingenieros de Caminos, Canales y Puertos.

SANTOS DIEZ, R. y CASTELAO RODRÍGUEZ, J. (2002); *Derecho Urbanístico Manual para Juristas y Técnicos*, 5ª edición, Editorial El Consultor de los Ayuntamientos.

Surface and Subsurface Hydrology [5321]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The course aims at providing students with the sufficient knowledge to deal realistically with the drafting and solving of actual problems in engineering in relation to flowing streams. This subject deepens to a level from which the student must: (1) be able to describe and explain the physical laws that quantify each of the components of the hydrological cycle, being perfectly aware of the problems associated with the measurement of the variables and their interpretation and possible correction or estimation, (2) master the methodologies to calculate the flows generated by rainfalls including their transit through the channels and the interaction with the river geometry, (3) acquire a detailed knowledge of the operation of the underground cycle, the specific studying techniques and their relationship with the surface hydrological cycle, (4) master the statistical procedures used to assess the risk of the designs, extrapolate the results and generate hydrologic time series, (5) know the architecture of the modeling methodologies, the calibration techniques and the models' limitations, coming into contact and experience with the most established business models (6) attain sufficient knowledge to develop real studies of surface and underground water resources, floods, natural channel hydraulics and water quality with current methods.

Program

Unit 1. Water in the atmosphere.

Unit 2. Hydrological processes, measurement and instrumentation networks.

Unit 3. Runoff generation.

Unit 4. Movement of surface water.

Unit 5. Movement of subsurface water.

Unit 6. Hydrological statistics.

Unit 7. Hydrologic design.

Unit 8. Hydrologic models.

REFERENCES

BEAR, J. (1979): Hydraulics of Groundwater. Mc. Graw-Hill, Inc 569 págs

CUSTODIO,E. Y LLAMAS,M.R.(1976): Hidrología Subterránea.Barcelona.Ed Omega, 2 vols. (reedición 1983) 2350 pp.

SANZ,E.; MENÉNDEZ-PIDAL, I. (2013): Hidráulica Subterránea Aplicada. Colección Escuela.Ed Colegio Ing Caminos.

DAVIS,S. Y DE WIEST, R. (1971): Hidrogeología. Ed Ariel. Barcelona

DOMENICO,P.A. AND SCHWARTZ,F.W. (1990): Physical and Chemical Hydrogeology. John Wiley & Sons, New York. 824 pp.

Socio-Economic Structures [5361]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

It is intended that students acquire basic training about the structural relations of economic activity and the tools and goals of growth, stability, employment and sustainability.

Additionally it is intended that students acquire skills to analyze the sectors of economy, to write reports and present and defend, in public, their reports.

Program

Unit 1. The natural environment

Unit 2. Natural resources

Unit 3. Demography and population

Unit 4. Political organization

Unit 5. Education, healthcare and public safety

Unit 6. The agricultural sector: rainfed and irrigated crops, industrial crops

Unit 7. Forestry and livestock sector

Unit 8. Fishing

Unit 9. Basic industrial sector: energy, mining, Steel industry and processed metals

Unit 10. Chemicals and construction industries

Unit 11. Infrastructure and housing

Unit 12. Transportation, trade and tourism

Unit 13. Knowledge industry and communications

Unit 14. The social context of the economy

REFERENCES

TAMAMES,RAMON Y G. HUERTA, BEGOÑA (2010): "Estructura Económica Internacional".21ªedición.Alianza editorial.Madrid

SANCHEZ SOLIÑO,A.; CARPINTERO LÓPEZ,S.; LARA GALERA,A.; ALCARAZ CARRILLO DE ALBORNOZ,V.; PÉREZ LOZANO,J.M.; MOLINA MILLÁN, J. (2013): Economía y Financiación de la Empresa, ETSI Caminos, C. y P. Madrid

Civil Engineering and Ecology [5331]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This course aims at equipping students with the basic knowledge necessary to adequately assess the relationship among civil engineering interventions, territory and environment, with special attention to our immediate environment (Spain, Mediterranean catchment area, Europe). It is therefore necessary to acquire those basic concepts that allow students to understand the characteristics, operation and evolution of landscapes and environments in order to, subsequently, analyze separately the environmental, landscape and territorial impact of public works and other actions typical of Civil Engineering.

Program

PART I. ENVIRONMENTAL AND LANDSCAPE FACTORS

Unit 1. Engineering, environment, landscape and territory

Unit 2. Biogeography and landscape

Unit 3. The human action on nature

PART II. ENVIRONMENTAL EFFECTS OF PUBLIC WORKS

Unit 4. Hydraulic Works. Underground water

Unit 5. Land routes. Underground works

Unit 6. Coastal works

Unit 7. Power plants and industrial facilities. Earth movement and aggregates exploitation

PART III. PROTECTION MEASURES AGAINST NATURAL ACTIONS

Unit 8. Natural hazards linked to internal geodynamics

Unit 9. Geological hazard linked to internal geodynamics

Unit 10. Building conservation

PART IV. Spanish environmental regulations

Unit 11: Regional, national and European environmental legislation

REFERENCES

DELGADO, F.; MERINO, J.A. Y BARRIDO, N. (1995); *Legislación del Medio Ambiente*, Tecnos, Madrid.

GÓMEZ OREA, D. (1998); ***Evaluación de impacto ambiental*****,** Editorial Agrícola Española, Madrid.

I.T.G.E. (1990); *Evaluación y corrección de impactos ambientales*.

KELLER, E.A. (2000); Environmental Geology. Prentice Hall.

MINISTERIO DE MEDIO AMBIENTE (2004); *Libro Blanco del Agua*.

Urban Services [5340]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The initial goal of this subject is to acquaint students with the dynamics of urban services, their content and organization. Secondly, to educate students, making them able to design the basic municipal services. The third objective is aimed at training students in the management of these services. In conclusion, to train students in the design, service organization, management, financing and control of urban services.

Program

Unit 1. Urban public utilities and system analysis.
Unit 2. Urban public utilities and system analysis.
Unit 3. Management of urban services (I).
Unit 4. Management of urban services (II).
Unit 5. Management of urban services (III).
Unit 6. Housing and urban development.
Unit 7. The street.
Unit 8. Urban water cycle (I).
Unit 9. Urban water cycle (II).
Unit 10. Water distribution (I).
Unit 11. Water distribution (II).
Unit 12. Water distribution (III).
Unit 13. Urban sanitation network (I)
Unit 14. Urban sanitation network (II)
Unit 15. Urban sanitation network (III)
Unit 16. Urban waste (I)
Unit 17. Urban waste (II)
Unit 18. Street cleaning and maintenance of parks and gardens.
Unit 19. Urban waste (III)
Unit 20. Roads.
Unit 21. Lighting.
Unit 22. Irrigation (I)
Unit 23. Irrigation (II)
Unit 24. Urban traffic.
Unit 25. Snow and ice control.
Unit 26. Other municipal services in relation to urban engineering.
Unit 27. Public electricity distribution.
Unit 28. Fuel supply.
Unit 29. Urban communication system.

REFERENCES

ARIZMENDI, L.J.: Cálculo y normativa básica de las instalaciones en los edificios
HERNÁNDEZ MUÑOZ, A.: Abastecimiento y distribución de agua. 2008

Oceanography and Coastal Engineering [5332]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objective of this course is to seek the expertise of students in engineering activities related to the coast. To achieve this aim, this subject deepens into the knowledge of the marine environment and its dynamic interaction with the atmosphere and lithosphere. Bases for human actions effects on the coasts are also provided, functionally and environmentally.

Program

Unit 1. The Port, the harbor and the coast.

Unit 2. Physical oceanography.

Unit 3. Chemical and biological oceanography.

Unit 4. Coastal Engineering. Littoral processes. Beach profile and sediment transport.

Unit 5. Coastal engineering techniques. Rigid and soft solutions.

Unit 6. Marine resources. Fish farming.

Unit 7. Marine pollution. The ocean and the coast.

REFERENCES

PEÑA OLIVAS, J.M.: Guía técnica de estudios litorales. (manual de costas). 2007

NEGRO VALDECANTOS, V.: Metodología para el estudio de costas: teoría y práctica

Specialization in Hydraulics and Energy

- Lecture hours of the specialization: 180 hours out of 225 hours
- Subjects: 1 compulsory (annual), 1 compulsory and 1 optional to be chosen out of 2 (all semestral)

Thermodynamics. Energy Systems. Power Plants [5333]

Year Five, compulsory for specialization, annual, 3 h/week, 90 h/year, 9 credits.

Teaching objectives

The objective of this course is to provide students with (1) the theoretical basis for treating thermodynamic phenomena of great technological application, (2) the practical application to energy production systems, cooling and heating systems, thermal converters, and (3) the theoretical and practical knowledge of renewable energy.

Program

PART I. GENERAL THERMODYNAMICS. LAWS AND PRINCIPLES

Unit 1. Concepts y definitions

Unit 2. First Law of Thermodynamics

Unit 3. Phase changes

Unit 4. Second Law of Thermodynamics

Unit 5. Third Law of Thermodynamics. First and Second Laws of Thermodynamics mathematical equations

Unit 6. Exergy and irreversibility.

PART II. AIR STANDARD CYCLES. RANKINE CYCLES

Unit 7. Introduction to thermodynamic cycles

Unit 8. Gas power cycles

Unit 9. Vapor power cycles

Unit 10. Cooling systems

PART III. Refrigeration

Unit 11. Psichrometry

PART IV. HEAT TRANSFER

Unit 12. Heat transfer by conduction

Unit 13. Convective heat transfer

Unit 14. Heat transfer through radiation

PART V. FUELS AND COMBUSTION

Unit 15. Fuels

Unit 16. Combustion

PART VI. RENEWABLE ENERGY

Unit 17. Wind power

Unit 18. Solar thermal power

Unit 19. Photovoltaic power

Unit 20. Bioclimatism

Unit 21. Thermal converters

PART VII. NUCLEAR ENERGY

Unit 22. Basics of radioactivity

REFERENCES

GALLUDO, M.: Apuntes d ela asignatura de sistemas energéticos.

Power Electric Systems [5457]

Year Five, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This subject is intended to provide students with the sufficient capacity to: (1) Understand general aspects concerning the structure and operation of a power system. (2) Describe the key features of development and management of the Spanish electricity sector. (3) Understand the key aspects of the operation of a hydroelectric plant. (4) Pose and solve the problem of optimal operation of a hydroelectric plant. (5) Pose and solve the problem of optimal operation of a system with mixed hydrothermal generation. (6) Understand the methodology applicable to the problem of scheduling a hydroelectric system in the short, medium and long term. (7) Understand the operation of the frequency control system of a hydroelectric plant. (8) Determine the dynamic response of a hydroelectric plant through computer simulation. (9) Determine the influence of the design parameters of the plant during its transient regime behavior. (10) Understand the essential concepts of generation and transformation of electrical energy. (11) Understand the essential aspects of operation of electricity transmission lines and networks.

Program

Unit 1. Introduction. Electric Energy Systems. Electric power generation. Electric power transmission.

Unit 2. Hydroelectric power plants; hydraulic system.

Unit 3. Optimal scheduling of hydroelectric systems

Unit 4. Control of hydro power plants.

Unit 5. Hydroelectric power plants; electrical system.

Unit 6. Transportation of energy. Electricity networks.

REFERENCES

WILHELMI, J.R. (2000); *Análisis de sistemas hidroeléctricos*, Colegio de Ingenieros de Caminos, Canales y Puertos, Servicio de Publicaciones.

GÓMEZ EXPÓSITO, A. et al. (2002); *Análisis y operación de sistemas de energía eléctrica*, McGraw-Hill.

CUESTA, L., VALLARINO, E. (2000); *Aprovechamientos Hidroeléctricos, 2 volúmenes*, Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

CASTILLO, E. et al (2002); *Building and solving mathematical programming models in engineering and science*, Wiley.

CHAUDRY, M.H. (1987); *Applied Hydraulic Transients*, Van Nostrand.

Underground Excavations [5417]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

It is intended that students achieve a sufficient understanding of the fundamental concepts used in Underground Excavations, both from the point of view of the Soil and Rock Mechanics and Geology subjects and the construction aspects related to these.

Program

Unit 1. Overall approach

Unit 2. Ground behavior models

Unit 3. Other aspects of behavior, influence of the construction method

Unit 4. Siding, roof supports and cut and cover tunnels. Calculation

Unit 5. Grubbing-up scheme and excavation techniques

Unit 6. Types and execution of retaining Structures and special Treatments

Unit 7. Process of Construction

Unit 8. Geomechanical classifications and behavior of different geological formations

Unit 9. Geological and geotechnical characterization

Unit 10. Case studies

REFERENCES

SERRANO,A.: Elementos de Estática de los Túneles.Servicio de Publicaciones de la Escuela.

HOEK, E. Y BROWN, E.T.: Underground excavations in rock. Institution of Mining and Metallurgy, London, 1980.

JIMÉNEZ SALAS, J.A.: Geotecnia y Cimientos III.2ª parte.Ed. Rueda,Madrid,1980.

KÁROLY SZÉCHY. The Art of Tunnelling. Akadémiai Kiadó.Budapest 1973.

JONH O. BICKEL & T.R. KUESEL: Tunnel Engineering Handbook. Ed. Van Nostrand Reinhold Company. New York. 1982

CORNEJO, L.: Excavación Mecánica de Túneles. Ed. Rueda. Madrid, 1988

HOEK,E.; KAISER,P.K.; BAWDEN,W.F.: Support of Underground Excavations in Hard Rock.Ed A.A. Balkema. Rotterdam,1995.

BIENIAWSKI,Z.T. ;JOHN WILEY & SONS: Engineering Rock Mass Classifications. United States, 1989

BIENIAWSKI,Z.T.: Rock Mechanics Desing in Mining and Tunnelling.Ed A.A. Balkema. Rotterdam, 1984

VARIOS AUTORES EDITADO POR LOPEZ GIMENO, C.: Manual de Túneles y Obras Subterráneas. Distribuido por Entorno Gráfico, S.L. Madrid, 1996.

River Hydraulics and Engineering [5424]

Year Five, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This course aims at presenting the basics of river engineering. Once this course has been passed, the student must (1) be able to describe the basic features of the ecosystem, the river morphology and dynamics, (2) know the basic principles and laws governing the sediment transport in the river, (3) be able to perform calculations of beginning of erosion, load losses and bottom and suspended sediment transport, (4) design riverbank protection works and channeling, and (5) be aware of the conditions of the river dynamics on engineering works.

Program

Unit 1. Introduction.
Unit 2. River ecosystem.
Unit 3. River morphology.
Unit 4. Qualitative response of river systems.
Unit 5. Sediment properties.
Unit 6. Beginning of erosion.
Unit 7. Hydraulic roughness and bed forms.
Unit 8. Resistance formulae.
Unit 9. Sediment production. Soil loss.
Unit 10. Trawling.
Unit 11. Transport of suspended material.
Unit 12. Models for river hydraulics.
Unit 13. Waterway protection and stabilization.
Unit 14. Channeling.
Unit 15. Bridge hydraulics. Local erosions.
Unit 16. Reservoir sedimentation.

REFERENCES

MARTINEZ MARÍN, E.: Hidráulica fluvial: principios y prácticas. 2001
OSUNA, A.: Hidráulica técnica y mecánica de fluidos. 1987
DOMINGUEZ DE MIGUEL, J.R.: Problemas de hidráulica. 2000

Year Six

- Lecture hours of the Year Six: 735 hours, and 120 hours in Diploma Final Project
  - Lecture hours of common subjects: 555 hours
    - Lecture hours of specialization: 180 hours

Common subjects

- Lecture hours: 555 hours, and 120 hours in Diploma Final Project.
- Common subjects: 45 annual, 2 semestral and Diploma Final Project.

Business Administration and Management [6066]

Year Six, common, semester, 4 h/week (3h lectures and 1h practical classes), 60 h/year, 6 credits.

Teaching objectives

The objective is to complete the training in the field of the management and administration of production units and in general terms. The purpose of the subject is to provide students with the fundamental and minimum required knowledge needed to organize and administer a company, and especially those in the construction field and their peripheral economic sectors. This includes the acquisition of the dominion of the main functions of a company and the basic tools for the management and administration of them, the understanding of the fundamental relationships between these functions and reciprocal influences among these functions, enabling the analysis of the social reality outside the company, especially of the markets in which it acts, the forecasting of situations and plans for reacting to them and the preparation of overall strategies.

Program

PART I. ELEMENTAL CONCEPTS OF THE COMPANY

Unit 1. General concepts of the company

PART II. MAIN FUNCTIONS OF THE COMPANY

Unit 2. Human resources in the company
Unit 3. The financial function
Unit 4. The production function
Unit 5. The sales function
Unit 6. The logistics function
Unit 7. The purchasing function
Unit 8. The control function
Unit 9. Corporate governance
Unit 10. Auditing

PART III. STRATEGY AND MANAGEMENT

Unit 11. Strategic management

PART IV. THE CONSTRUCTION COMPANY AND ITS PERIPHERAL SECTORS

Unit 12. The construction company
Unit 13. Companies and sectors related to construction and civil engineering
Unit 14. Public investments

REFERENCES

GARDETA, J. G. et al., *Temas Básicos de la Empresa*, Colegio de Ingenieros de Caminos, Canales y Puertos.
GARDETA, J.G.: Adminsitración de empresas y sectores económicos de la in. Civil
GARDETA, J.G.: Principios de la Administración de empresas para ingenieros.

KOTLER, P. (2000); *Dirección de Marketing,* Prentice May.

DOMÍNGUEZ, J.A., *Dirección de Operaciones*, McGraw Hill.

BUENO, E., *Dirección estratégica de la Empresa*, Pirámide, S.A.

TONY, J.R., *Introduction to Materials Management*, Prentice Hall.

Administrative and Labor Law [6072]

Year Six, common, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objective is, basically, that students end the course with the following skills and competences: (1) Bases of law, its sources, the fundamentals of the juridical ordering of the state and the branches or specialties in law (private and public); (2) Organization of the administration, its relationship with the rest of the organization of the state, most important acts for the public administration in general and, especially, for the civil engineering profession; (3) The basis for the relationship of Spain with the European Union in the legal field and with the civil engineering profession; (4) Bases of the basic employment and social security legislation; (6) Knowledge of the legislation applied to the civil engineering sector, mostly issued by the Ministries of Development and Environment.

Program

Unit 1. Basis of law and its relationship with the economy

Unit 2. The community juridical order

Unit 3. National Administrative Law

Unit 4. Public administration contractual regulation

Unit 5. Applicable basic laws of the Ministries of Development and Environment

Unit 6. Labor law and employment relationships

REFERENCES

LASARTE, C. (2004); *Curso de derecho Civil Patrimonial: Introducción al Derecho*, Técnos, Madrid.

GARDETA, C., y ARRRIZABALAGA, F., *Derecho Aplicado a la Ingeniería Civil*.

GARDETA, J.G. Bases del derecho para la formación de ingenieros. 2011

ALONSO OLEA, M. (2005); *Manual de Derecho Laboral*

PARADA, I (2004); *Derecho Administrativo*

Sanitation and Environmental Engineering [6041]

Year Six, common, annual, 4 h/week (3h lectures and 1h practical classes), 120 h/year, 12 credits.

Teaching objectives

The first objective is to ensure that students have knowledge of quantitative and qualitative needs of water resources as well as the quantitative and qualitative aspects of used water, the generation of wastes and air and noise pollution. Secondly, students will acquire knowledge of the assessment of the environmental impact as a fundamental tool in the fight against pollution. Thirdly, to provide students with the knowledge about various systems and installations for supply, sewerage and the fight against pollution and the resources recovery. The teaching level is aimed at reaching sufficient qualification for the design and calculation of these installations. Finally, students will be provided with sufficient knowledge to manage, plan and control the above installations with regard to the environment.

Program

PART I. WATER QUALITY. RATE OF CONSUMPTION. SOURCE OF WATER SUPPLY

Unit 1. Water as a phyto-zoological habitat and sanitary engineering
Unit 2. Qualitative legal dispositions regarding water
Unit 3. Surface water catchment
Unit 4.Underground water catchment
Unit 5. Design and building of conduits
Unit 6. Regulation and distribution tanks
Unit 7. Distribution systems
Unit 8. Calculation of distribution systems
Unit 9. Operation of a water service
Unit 10. Management of a water service

PART II. WATER TREATMENT PROCESS TECHNOLOGIES. WATER SUPPLY. COLLECTION AND DISTRIBUTION

Unit 11. Preliminary and physical and chemical treatments
Unit 12. Disinfection and other treatment methods

PART III. DESIGN AND CONSTRUCTION OF SEWERS

Unit 13. Water pollution
Unit 14. Sewerage systems
Unit 15. Design of sewers and collectors
Unit 16. Sewage pumping
Unit 17. New sanitation systems
Unit 18. Dumping into rivers, lakes and the sea
Unit 19. Operation of sewerage services
Unit 20. Management of sewerage services

PART IV. WASTEWATER TREATMENT AND SLUDGE MANAGEMENT

Unit 21. Sewage treatment policy and regulations
Unit 22. Self-purification of rivers
Unit 23.Treatment of sewage
Unit 24. Pretreatment in a treatment plant
Unit 25. Physical treatment: clarifying
Unit 26. Biological treatment mechanism
Unit 27. Bacterial beds
Unit 28. Activated sludge
Unit 29. Sludge treatment, use and disposal
Unit 30. Industrial and urban wastes compatibility
Unit 31. Small sanitary sewer systems
Unit 32. Operation of waste water treatment plants
Unit 33. Management of waste water treatment plants

PART V. URBAN SOLID WASTE MANAGEMENT

Unit 34 .Production and combination of waste
Unit 35. Solid waste regulations
Unit 36. Impact of waste. Environmental considerations
Unit 37. Street sweeping
Unit 38. Urban solid waste collection systems
Unit 39. Waste transport and transfer stations
Unit 40.Sorting and use of waste
Unit 41. Composting
Unit 42. Incineration
Unit 43. Dumps
Unit 44. Urban solid waste management

PART VI. ENVIRONMENTAL IMPACT ASSESSMENT. AIR, NOISE AND SOIL POLLUTION

Unit 45. Environmental impacts and their assessment
Unit 46. Analysis of the project or cause
Unit 47. Elements of ecology and environmental inventory
Unit 48. Natural resources and sustainability

Unit 49. Pollution and models of cause and effect

Unit 50. Methods and models used

Unit 51. A.H.M method

Unit 52. Environmental monitoring

REFERENCES

HERNÁNDEZ MUÑOZ, A. (2000), *Abastecimiento y distribución de agua,* Colección Seinor, nº6, Paraninfo, 4ª edición, Madrid.

HERNÁNDEZ MUÑOZ, A. (1998), *Saneamiento y alcantarillado. Vertidos de aguas residuales,* Colección Seinor, nº7, Paraninfo, 3ª edición, Madrid.

HERNÁNDEZ MUÑOZ, A. (2001), *Depuración de aguas residuales,* Colección Seinor, nº9, Paraninfo, 4ª edición, Madrid.

HERNÁNDEZ MUÑOZ, A., HERNÁNDEZ LEHMANN, A. y DEL CASTILLO, I. (2004), *Residuos,* Aula BP Medio Ambiente UPM, Madrid.

HERNANDEZ LEHMANN: Manual de diseño de estaciones depuradoras. 1999

HERNÁNDEZ MUÑOZ, A., GORDILLO MARTÍNEZ, J.A. y HERNÁNDEZ LEHMANN, A. (2004), *Manual para la evaluación de impactos ambientales,* (pendiente de publicación y actualmente en apuntes en la Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos), Madrid.

TCHOBANOGLOUS et al.: Gestión integral de residuos sólidos. 1994

Railways [6043]

Year Six, common, annual, 4 h/week (3h lectures and 1h practical classes), 120 h/year, 12 credits.

Teaching objectives

This subject is focused as the culmination of the students' generalist training in railway engineering. Its objective is to give students sufficient capacity to fully develop the skills referring to (1) conception, viability study and draft project of railway systems; (2) preparation of railway line construction projects; (3) management of railway works construction; (4) management, conservation, operation and repair of railway systems; and (5) planning, promotion and management of railway system projects.

Program

Unit 1. Track structure

Unit 2. The alignment

Unit 3. Mechanics of railway tracks

Unit 4. Track maintenance

Unit 5. Rolling stock

Unit 6. Rail transport operations

Unit 7. The railway project

Unit 8. Urban railways

REFERENCES

ALIAS, J.; VALDÉS, A.: *"La vía del ferrocarril"*. Editorial Bellisco. Madrid 1990.

ESVELD, C.: *"Modern railway track"*. MRT Productions. Duisburg, 1989.

GARCÍA DÍAZ DE VILLEGAS, J.M.; Rodríguez Bugarín, M.: *"Desvíos ferroviarios"*. Presentado y prologado por RENFE. Ingeniería cántabra, S.A. 1995

GARCÍA LOMAS Y COSSÍO, J.M.: *"Tratado de explotación de ferrocarriles. Tomo I. La vía"*. Edix, S.A. 1965

GARCÍA LOMAS Y COSSÍO, J.M.: *"Tratado de explotación de ferrocarriles. Tomo II. El material móvil"*. 1956

LÓPEZ PITA,A.: *"Alta velocidad en el ferrocarril"*

LÓPEZ PITA,A.: *"Explotación de líneas de ferrocarril"*

LÓPEZ PITA, A.: *"Infraestructuras ferroviarias"*

LOSADA M.: *Curso de Ferrocarriles, Cuadernos I, II, III, IV y V*. Servicio de Publicaciones

WAIS, F.: *"Compendio de explotación técnica de ferrocarriles"*. Editorial Labor, S.A. 1949

WAIS, F.: *"Historia de los ferrocarriles ESPAÑOLES"*. EDITORA NACIONAL. 1974

MELIS MAYNAR, M.: *"Apuntes de introducción a la dinámica vertical de la vía y a las señales digitales en ferrocarriles"*, con 151 programas en Matlab, Simulink, Visual C++, Visual Basic y Excel. 2008

MELIS MAYNAR, M.; GONZÁLEZ FERNÁNDEZ, F.J.: *"Ferrocarriles metropolitanos. Tranvías, metros ligeros y metros convencionales"*. Colegio de Ingenieros de Caminos, Canales y Puertos. Colección seinor 29. 2002

OLIVEROS RIVES, F.; LÓPEZ PITA, A.; MEGÍA PUENTE, M.: *"Tratado de ferrocarriles I. Vía"*. 1977

OLIVEROS RIVES, F.; RODRÍGUEZ MÉNDEZ, M.; MEGÍA PUENTE, M.: *"Tratado de ferrocarriles II. Ingeniería civil e instalaciones"*. 1980

OLIVEROS RIVES, F.; RODRÍGUEZ MÉNDEZ, M.; MEGÍA PUENTE, M.: *"Tratado de explotación de ferrocarriles I. Planificación"*. 1983

PROFILLIDIS, V.: *"La voie ferree et sa fondation modelisation mathematique"*. Tesis Doctoral. 1983

Engineering Projects [6059]

Year Six, common, annual, 3 h/week (2h lectures and 1h practical classes), 90 h/year, 9 credits.

Teaching objectives

The purpose of this subject is to teach the students how to prepare a project in the most suitable way possible. Therefore the objective of the theoretical part of the subject is to explain the most important concepts, methods and materials used generally to undertake projects in professional life both from the construction and the operating points of view. The objective of the applied exercises is also to help to fix the ideas received during the explanation of the specific cases in the most important sections of the . The purpose is to provide a basis for a correct focus on engineering projects and to initiate a system that leads to the undertaking of increasingly complex projects with greater rigor and with greater technical quality in professional life for which this subject has been freed of administrative or legal matters, which are taught in seminars and special conferences.

Program

PART I. INTRODUCTION

Unit 1. Design engineering training
Unit 2. The process of undertaking projects
Unit 3. Additional materials for project preparation
Unit 4. Features of the various types of projects (scope, scales)
Unit 5. Project organization
Unit 6. Objectives, legal framework and national and foreign standards to be used
Unit 7. Methodology for memorandum preparation
Unit 8. Climate, physical and social data appendices
Unit 9. Cartography appendix
Unit 10. Functional studies and justification of solutions for the entire project and its parts

PART II. PRIOR STUDIES

Unit 11. Preparation and presentation of drawings. Examples
Unit 12. Geological appendix
Unit 13. Structural calculations
Unit 14. Geotechnical appendix, based on existing bibliography
Unit 15. Environmental and landscaping management
Unit 16. Hydrology and drainage
Unit 17. Comparison table of studied solutions
Unit 18. Prices and valuing of studied solutions

PART III. UNDERTAKING A CONSTRUCTION PROJECT

Unit 19. Structural calculations appendix
Unit 20. Industrial installations appendices for various types of project
Unit 21. Geology appendix
Unit 22. Geotechnical appendix
Unit 23. Surface and underground drainage
Unit 24. Choice and calculation of roadbeds
Unit 25. Quality control appendix
Unit 26. Project planning appendix
Unit 27. Environmental correction measures
Unit 28. Health and safety appendix
Unit 29. Choice and calculation of foundations
Unit 30. Maintenance appendix
Unit 31. Prices justification appendix. Examples
Unit 32. Table of prices, measurements and budgets. Examples
Unit 33. Technical specifications document

REFERENCES

BARBER LLORET, P.: Organización, medición y valoración de obras ECU
CARTAGENA RUIZ,E.; Y CARBONELL LADO,MªMANUELA: Organización práctica de obras. Universidad de Alicante
CASTRO FRESNO,D. Y AJA SETIÉN,J.L.: Organización y Control de Obras. Universidad de Cantabria.
MARTÍNEZ MONTES,G. Y PELLICER ALMIÑANA,E.: Organización y Gestión de Proyectos y Obras. McGran
LARA GALERA,A.: Planificación y Organización de Obras, Servicio Publicaciones Escuela
GOMEZ HERMOSO,J.: Técnicas aplicadas de construcción.Servicio Publicaciones Escuela
AREVALO SARRATE,C.: Seguridad y Salud en el proceso constructivo.Servicio publicaciones Escuela

Construction Methods and Construction Site Management

[6033]

Year Six, common, annual, 4 h/week (3h lectures and 1h practical classes), 120 h/year, 12 credits.

Teaching objectives

To provide the future civil engineer with the training needed to undertake the management and technical management of a project under construction.

Program

PART I. GENERAL PROCEDURES OF CONSTRUCTION

Unit 1. Machinery monitoring and maintenance
Unit 2. Lubrication
Unit 3. Electric installations and motors
Unit 4. Internal combustion engines
Unit 5. Tyres and crawler track systems
Unit 6. Clutches, gearboxes and brakes
Unit 7. Explosives
Unit 8. Blasting
Unit 9. Compressed air
Unit 10. Drills. Geotechnical investigations, soil samples and diaphragm walls
Unit 11. Mechanized excavation procedures in tunnels
Unit 12. Lifting machines
Unit 13. Earth moving machine
Unit 14. The tractor
Unit 15. Transport elements
Unit 16. Aggregates treatment machinery
Unit 17. Concrete preparation and transport equipment
Unit 18. Cables
Unit 19. Pumps
Unit 20. Specific road and airports building machines
Unit 21. Rail track machinery
Unit 22. Specific port machinery

PART II. APPLIED CONSTRUCTION TECHNIQUES

Unit 23. Roads
Unit 24. Railways
Unit 25. Marine works
Unit 26. Hydraulic works
Unit 27. Bridges, viaducts and aqueducts
Unit 28. Tunnels
Unit 29. Buildings

PART III. CONSTRUCTION ORGANIZATION AND MANAGEMENT

Unit 30. Background to a project
Unit 31. Construction installation and assembly
Unit 32. Resource management and optimization
Unit 33. Safety in the construction process
Unit 34. Quality in the construction process

REFERENCES

DÍAZ DEL RÍO, M.; Manual de maquinaria de construcción. 2007
MARTÍNEZ MONTES, G.: Organización y gestión de proyectos y obras. 2006
TOLOSA TRIBIÑO, C.: Prontuario seguridad en la edificación. 2006

Graduation Project

Year Six, common, annual, equivalent to 4 h/week, 120 h/year, 12 credits.

Teaching objectives

The Diploma Final Project is an original and individual work carried out by students that consists in developing a complete civil engineering project. The purpose of the Diploma Final Project is to provide students, in the final phase of their studies, with a practical case similar to the tasks to be carried out in the professional world, integrating the knowledge required in all the subjects in the Diploma courses. Admitting that all the parts of a project are important in this engineers training phase, it is considered that the prior study of the project with its planning of alternatives, study of solutions, definition of the chosen solution and its evaluation approaching the level of a project draft is the facet that must be given the greatest weight.

Specialization in Structures and Foundations

- Specialization Lecture hours: 180 hours out of 270 hours
- Subjects: 3 compulsory and 1 optional to be chosen out of 3 (all semestral)

Bridges I [6148]

Year Six, obligatory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The main objective of Bridges I is to provide students with the basic elements for conceiving and designing short- and medium-span bridges (up to 45 m). To achieve this aim, the teaching is structured into three interrelated parts: current morphology of bridges, resistant response, and construction. In morphology, the current state of the forms and types of bridges is described, especially for short and medium spans. The resistant response is analyzed then in terms of the structural function. The possibilities for the construction process for each type of bridge are finally studied. This sets the general procedures for training students to undertake calculations and practical exercises.

Program

PART I. INTRODUCTION

Unit 1. History and morphology of bridges

Unit 2. Loads on bridges

PART II. SUPERSTRUCTURE

Unit 3. General analysis procedures

Unit 4. Behavior of decks

Unit 5. Construction of decks

PART III. SUBSTRUCTURE

Unit 6. Supports and connections

Unit 7. Piers

Unit 8. Abutments

REFERENCES

MANTEROLA, F.: Puentes. 2000

MANTEROLA, F.: Puentes: apuntespara su diseño, cálcuo y construcción. 2006

Special Foundation Methods [6126]

Year Six, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The purpose of this course is for students to know the techniques to build special foundations, used to solve geotechnical problems of various categories that may arise in the great variety of existing ground types and the possible kinds of structures for which the foundations are required. Within the wide variety of possible situations, those of most interest have been chosen to be descripted during the course. Students will also learn various procedures applicable to other uncommon situations.

Program

Unit 1. Basis of the geotechnical project

Unit 2. Foundations of buildings

Unit 3. Pre-loading

Unit 4. Stone and soil-cement columns

Unit 5. Vibroflotation and dynamic compaction

Unit 6. Jet grouting. Injections

Unit 7. Diaphragm walls for containing excavations. Bailing

Unit 8. Anchoring and micropiles. Underpinning

Unit 9. Bridge foundations. Scour

Unit 10. Foundations for walls. Hillside foundations

Unit 11. Foundations for port works

Unit 12. Dynamic and seismic effects

REFERENCES

JIMÉNEZ SALAS, J.A. et al., *Geotecnia y Cimientos III*, Editorial Rueda, Madrid.

AENOR, *Eurocódigo 7. Bases del proyecto geotécnico.*

MINISTERIO DE FOMENTO, ROM 05.94, *Recomendaciones geotécnicas para el proyecto de obras marítimas y portuarias*, Puertos del Estado, Madrid.

MINISTERIO DE FOMENTO, *Guía de cimentaciones en obras de carreteras*, Madrid.

Special Steel Structures [6131]

Year Six, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The main objectives of the course are (1) to know the functioning and methods for analyzing composite structures in both buildings and bridges; (2) to know the theoretical fundamentals of modern regulations and standards for steel and composite structures for buildings and bridges (Spanish and European standards); (3) to know the most usual types, the applicable construction processes and an introduction to the problem of monitoring, manufacturing and undertaking in workshops and on site as well as the basis for the maintenance and conservation of steel and composite structures; (4) to undertake a full practical exercise for an evolutionary designed composite structure, monitoring the serviceability and ultimate limit states, for a real building or bridge case; and (5) to introduce students to the professional point of view of the designing and building of composite systems.

Program

PART I. THEORETICAL BASIS FOR ANALYZING COMPOSITE SYSTEMS

Unit 1. Composite structures

Unit 2. Materials in composite construction

Unit 3. Treatment of deferred deformation of concrete

Unit 4. Elastic analysis of composite cross sections

Unit 5. Deferred elastic analysis of composite cross sections

Unit 6. Prestressing composite structures

Unit 7. Elastic analysis under crosswise stresses

Unit 8. Elastic-plastic calculation of composite cross sections

Unit 9. Shear force depletion analysis

Unit 10. Stiffness of connection systems—types and field of application

Unit 11. Non-elastic calculation of connections

Unit 12. Mixed supports

PART II. ANALYSIS OF COMPOSITE SYSTEMS IN SERVICEABILITY AND ULTIMATE LIMIT STATES

Unit 13. Serviceability limit states in composite structures

Unit 14. Ultimate limit states in composite structures

PART III. DESIGN AND CONSTRUCTION OF COMPOSITE SYSTEMS

Unit 15. Developments and trends in types of composite building systems

Unit 16. Developments and trends in types of composite road bridges

Unit 17. Developments and trends in types of composite conventional and high-speed railway bridges

Unit 18. Construction processes for composite structures for buildings

Unit 19. Construction processes for composite structures for bridges

PART IV. ADVANCED STEEL STRUCTURES

Unit 20. Twisting and distortion of Steel structures

Unit 21. Systems for transverse stay and support diaphragms for steel bridge decks

Unit 22. Global stability of steel lattices

Unit 23. Stability of special structural elements

Unit 24. Stability analysis of slender core structures

Unit 25. Design criteria for stiffened reinforced beams

Unit 26. Design criteria for stiffened compressed flanges

Unit 27. Stability analysis of compressed flanges

Unit 28. Fatigue monitoring in steel and composite structures

Unit 29. Corrosion protection for steel and composite structures

Unit 30. Quality control in manufacturing in workshops and in situ installations of steel and composite structures

Bridges II [6149]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The main objective of the course is to provide students with the basic elements for conceiving and designing long-span bridges (in general, longer than 40 m). To achieve this aim, the teaching is structured into three interrelated parts: current morphology of bridges, resistant response and construction. Through the morphology part, the current state of the forms and types of long-span bridges are described. For the resistant response, the general calculation procedures are set and practical exercises are carried out. The general procedures for the construction of bridges are taught in class. With this training, students will be able to undertake a design or construction of a bridge with a span longer than 40 m.

Program

Unit 1. Morphology of long-span bridges
Unit 2. Box-section decks
Unit 3. Bridges with special forms
Unit 4. Analysis of creep and shrinkage
Unit 5. Incrementally launched bridges
Unit 6. Cable stayed and extradosed bridges

REFERENCES

MANTEROLA, F.: Puentes. 2000
MANTEROLA, F.: Puentes: apuntespara su diseño, cálcuo y construcción. 2006
KAWADA, Tadaki: Hstory of the Modern Suspension Bridge. 2010

Structural Typology [6132]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The teaching objectives of this course are (1) to provide students with a synthesis of the acquired structural behavior knowledge, with a new perspective; (2) to initiate students in conceptual design matters; and (3) to awake sensitivity in students for creative work, helping them to recognize their creative capabilities and awaking their interest in and fondness for creative inception.

Program

Unit 1. Conceptual design
Unit 2. Basic structural concepts
Unit 3. Materials
Unit 4. Structural elements
Unit 5. Structural functions

Edification and Prefabrication [6102]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The teaching objectives of this course are (1) to train students to design and manage building projects, considering all the limitations that they may have professionally, fundamentally being able to act in the structural field, to work in multi-disciplinary teams or as the designer of this part; (2) to allow students to act as Site Manager or as technician in construction companies dedicated to the construction of buildings; (3) to provide them with the knowledge needed to act as quality control engineer, in construction laboratories, consultancies and other organizations related to construction.

Program

Unit 1. Building construction. Introduction

Unit 2. Building with concrete structures

Unit 3. Construction of concrete structures for buildings

Unit 4. Monitoring of concrete structures

Unit 5. Quality assurance

Unit 6. Building with steel structures

Unit 7. Building with masonry and brick structures

Unit 8. Façades, partitions and windows

Unit 9. Building systems

Unit 10. Prefabrication

REFERENCES

CALAVERA, J: Edificación. 2010

Specialization in Transports

- Lecture hours of the specialization: 180 hours out of 270 hours
- Subjects: 2 compulsory and 2 optional to be chosen out of 4 (all semestral)

Port Management and Planning [6262]

Year Six, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This course aims at (1) providing students with a general understanding of the elements of maritime transport, vessels, means of transfer and link with ground transportation, as well as the Spanish port organization, (2) classifying and analyze freight traffic according to their nature and forms of presentation and manipulation as well as criteria and forecasting methods appropriate for that traffic, (3) the dimensioning and design of port facilities, canals, docks, piers, etc., these being empirical, statistical or simulation ones, and (4) physically planning port facilities, particularly docks and terminals, according to data from the previous point, the nature of the goods, the transport organization criteria, environmental protection…

Program

PART I. MARITIME TRANSPORT

Unit 1. Evolution of maritime and port transport

Unit 2. The vessel. Physical and economic aspects

Unit 3. Traffic. Physical and economic aspects

PART II. THE PORT

Unit 4. The port. General and physical aspects

Unit 5. Port administration and users

Unit 6. Port competitiveness

Unit 7. Exploitation systems

Unit 8. Maritime entry points

PART III. PORT PLANNING

Unit 9. Traffic fundamentals and forecasts

Unit 10. Dimensioning

PART IV. TERMINAL MANAGEMENT

Unit 11. Introduction to terminals

Unit 12. Study of bulk terminals

REFERENCES

DEL MORAL, R. Y BERENGUER, J.M. (1980): *Planificación y Explotación de Puertos*. Dirección General de Puertos y Costas y CEEOP.

RODRÍGUEZ PÉREZ., F. (1985): *Dirección y explotación de puertos*, Puerto Autónomo de Bilbao.

CAMARERO, A.; PERY, P. Y POLO, G. (2002): *II Curso de Transporte Marítimo y Gestión Portuaria*. Universidad Politécnica de Madrid

CAMARERO, A. Y PERY, P. (2002): *Determinación de la línea de atraque en los puertos españoles*. Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos de Madrid.

PERY, P. (2003): *Conceptos de Explotación y Planificación de Puertos*. Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos de Madrid.

Transportation Planning [6234]

Year Six, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

Students who complete this course should know, on the one hand, the bases of transport policy and its relationship with other sectoral policies, and, on the other hand, the assessment techniques (economic, financial, social, territorial and environmental) required at all levels of activity of a Civil Engineer (transport networks, projects, plans, etc.). When having successfully completed this course, the student will be provided with the enough baggage to address the drafting of plans, the functional design of services, the evaluation of investment alternatives, selection of environmentally friendly alternatives, multi-criteria analysis techniques, etc.

Program

Unit 1. Transportation planning: definition and concepts

Unit 2. Transportation Planning Tools

Unit 3. Transport Planning

Unit 4. Transport Policy

REFERENCES

ARCE, R. (2002); *La evaluación de impacto ambiental en la encrucijada*, Ecoiuris, Madrid.

BOARDMAN, A.E. et al. (2001); *Cost-Benefit Analysis: Concepts and Practice*, Prentice-Hall, Toronto.

FONTAINE, E.R. (1999); *Evaluación social de proyectos*. Alfaomega-Ediciones, Universidad Católica de Chile.

IZQUIERDO, R. et al. (2001); *Transportes: un enfoque integral*, Colegio de Ingenieros de Caminos, Canales y Puertos. Madrid.

MINISTERIO DE FOMENTO (2004); *Plan Estratégico de Infraestructuras y Transportes*, Madrid.

Road and Airport Infrastructure [6239]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The student, after having completed this subject, will have improved the ability to (1) write a study about pavements from a road project; (2) dimension a pavement using both empirical and analytical methods; (3) understand the unique aspects of road tunnels and be able to assess their functional characteristics; (4) know the main features of the pavement technologies; (5) know the principles of conservation and rehabilitation of pavements; and (6) to distinguish the impairments that may appear in the pavements, being able to analyze possible causes, ways of assessment and repair techniques; dimension the structural rehabilitation of a pavement.

Program

PART I. STUDIES, PROJECT AND DIMENSIONING OF PAVEMENTS

Unit 1. Pavement studies in road projects

Unit 2. Dimensioning methods

Unit 3. Pavement design in special areas

Unit 4. Airport pavements

PART II. ROAD TUNNELS

Unit 5. The Project of a road tunnel and its content

Unit 6. Installations. Exploitation and security

PART III. INFRASTRUCTURE CONSTRUCTION

Unit 7. Flat plain construction

Unit 8. Pavement lower layers

Unit 9. Wearing courses

PART IV. MANAGEMENT, CONSERVATION AND REHABILITATION

Unit 10. Management and conservation principles

Unit 11. Assessment of pavement condition

Unit 12. Conservation actions

REFERENCES

AASHTO (1993): *AASHTO Guide for Design of Pavement Structures*, AASHTO, Washington, D.C.

ATKINSON, K. et al. (1997): *Highway Maintenance Handbook*, 2ª edición, 562 pág., Thomas Telford, London.

CRONEY, D., CRONEY, P. (1998): *Design and Performance of Road Pavements*, 3ª edición, 508 pág., McGraw-Hill, New York.

KRAEMER, C. et al. (2004): *Ingeniería de Carreteras, Volumen II*, 555 pág., McGraw-Hill, Madrid.

SETRA-LCPC (1994): *Conception et dimensionnement des structures de chaussée*, Laboratoire Central des Ponts et Chaussées, Paris.

Port Engineering [6247]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objectives of this subject are (1) to continue, support and clarify the concepts presented during the subject Ports and Coasts, emphasizing on their practical application and assisting, when possible, with the realization of projects in its technical aspects and documentation sources and data, and (2) to deepen into both the constructive processes of port works of all kinds, and in the case aspects of special significance and timeliness.

Program

Unit 1. Types of marine works.
Unit 2. Risk assessment and wave buoy data.
Unit 3. Design of rubble mound breakwaters.
Unit 4. Caisson and mixed breakwaters.
Unit 5. Layout plant of ports.
Unit 6. Wharf works.
Unit 7. Pier hydraulics.
Unit 8. Wave reflection and transmission.
Unit 9. Additional works.

REFERENCES

NEGRO, V.: Puertos obras: conceptos básicos y casos reales de estudio. 2001

Railway Technology [6244]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This course is intended to provide a contact and a practical learning of the most innovative aspects of the recent railway evolution, not only for inter-city rail, but also urban transport modes guided by rails: subway and tram.

Program

Unit 1. The railway project
Unit 2. New lines and variants
Unit 3. Track quality
Unit 4. Track maintenance
Unit 5. Track and facilities on high-speed lines
Unit 6. High-speed rail technology worldwide
Unit 7. Urban railways

REFERENCES

MELIS MAYNAR, M.: Apuntes de introducción a la dinámica vertical de la vía..

VILLARONTE FDEZ-VILLA, J.A.: Tecnología e ingeniería ferroviaria. 2008

Port Traffic and Operation [6263]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objectives are: (1) Analyze the major global traffic, its evolution and forecasting, (2) Know and be able to manage the most frequent and characteristic port operations: towage, pilotage, berthing, handling containers, solid and liquid bulks, combined and multimodal operations, etc., (3) analyze the needs of labor and its specialization, as well as the composition of the production units and automation processes, (4) Establish criteria for achieving security in operations. Analyze accidents, thefts, damages, etc., as well as their prevention and corrective measures, (5) Analyze the costs of operations and the impact on the overall economy of maritime and port traffic, freight, delays, bonuses and penalties, etc. ., and (6) Develop the composition of port operations costs. Services, exploitation installations, fees, funding criteria and amortization of facilities, investment optimization, etc.

Program

PART I. MARITIME TRANSPORT

Unit 1. European maritime transport policy

Unit 2. International trade and maritime transport

Unit 3. Maritime transport services

PART II. PORT OPERATIONS

Unit 4. Port operations

PART III. PORT LOGISTICS

Unit 5. Port logistics

PART IV. TERMINALS

Unit 6. Dry bulk terminals

Unit 7. Liquid bulk terminals

Unit 8. Container terminals

Unit 9. General cargo terminals

Unit 10. Ro-ro terminals

Unit 11. Passenger terminals

Unit 12. Fishing terminals

REFERENCES

DEL MORAL, R. Y BERENGUER, J.M. (1980): *Planificación y Explotación de Puertos*. Dirección General de Puertos y Costas y CEEOP.

RODRÍGUEZ PÉREZ., F. (1985): *Dirección y explotación de puertos*, Puerto Autónomo de Bilbao.

CAMARERO, A.; PERY, P. Y POLO, G. (2002): *II Curso de Transporte Marítimo y Gestión Portuaria*. Universidad Politécnica de Madrid

CAMARERO, A. Y PERY, P. (2002): *Determinación de la línea de atraque en los puertos españoles*. Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos de Madrid.

CAMARERO, A. & CAMARERO, Alfonso: Tráfico marítimo de pasajeros. 2013

PERY, P. (2003): *Conceptos de Explotación y Planificación de Puertos*. Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos de Madrid**.**

Specialization in Urban Planning and Environment

- Lecture hours for the specialization: 180 hours out of total of 315 hours
- Subjects: 1 compulsory annual and 2 optional to be chosen out of 5 (all semester)

Land Planning [6369]

Year Six, compulsory for specialization, annual, 3 h/week, 90 h/year, 9 credits.

Teaching objectives

The aims of the subject are (1) to present an integrated view of space that overcomes partial approaches (sectoral), (2) incorporate consideration of the consequences that the activity of civil engineers causes on the environment, and (3) provide an integrated view of economic, social and environmental consequences of projects and regional plans, based on the proposals of the European Union in sustainability.

Program

PART I. SUPRA-MUNICIPAL, NATIONAL AND EUROPEAN LEGAL FRAMEWORK OF REGIONAL PLANNING IN SPAIN

Unit 1. Land Planning.

Unit 2. Land Planning as a discipline.

Unit 3. Constitutional division of powers and laws in Land Planning.

Unit 4. Land Planning instruments.

Unit 5. The impact of land planning instruments on urban planning. Urban planning as development and implementation of land planning.

Unit 6. Sectoral legislation with an effect on Land Planning. Inter-administrative conflicts.

Unit 7. European territorial issue.

Unit 8. The Regional Policy in the European Union.

Unit 9. Sectoral policies in the European Union: Their influence on Land Planning.

PART II. ANALYSIS OF LAND PLANNING BASIC STAGES

Unit 10. General outline of the planning process.

Unit 11. Systems in territorial analysis.

Unit 12. Regional economy.

Unit 13. Location of activities.

Unit 14. Systems of cities.

Unit 15.Aims and objectives.

Unit 16. Land Planning Techniques.

Unit 17. Land systems description.

Unit 18. Data sources in land planning. Analysis of the information basic offer in Spain.

Unit 19. Demography. Population projection methods.

Unit 20. Territorial models.

Unit 21. The example of transport models.

Unit 22. Interaction models.

Unit 23. Alternatives generation.

Unit 24. Evaluation and selection of the alternatives.

Unit 25. Economic evaluation.

PART III. ENVIRONMENTAL ASSESSMENT IN PLANNING.

Unit 26. The natural environment in Planning.

Unit 27. Rating and characterization of environmental impacts.

Unit 28. Environmental assessment of alternatives procedures (I).

Unit 29. Environmental assessment of alternatives procedures (II).

Unit 30. Multi-criteria methods.

PART IV. APPLICATION TO THE PLANNING OF SPACES OF SPECIFIC USES AND BASIC RESOURCES.

Unit 31. Planning of Rural Areas.

Unit 32. Water resources planning.

Unit 33. Analysis and review of major sectoral plans at regional or national level.

REFERENCES

CALDERÓN BALANZATEGUI, E.; *Lecciones de Ordenación del Territorio: Política Territorial de la Unión Europea*; Servicio de Publicaciones de la Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos; Madrid

SANTOS DIEZ, R. y CASTELAO RODRIGUEZ, J. (2005); *Derecho Urbanístico. Manual para Juristas y Técnicos*; Editorial: "El Consultor de los Ayuntamientos"; 6ª edición.

SANTOS DÍEZ, R.: 6º curso: Ordenación del Territorio. Marco jurídico de la planificación territorial en España. 2012

PÉREZ DE ANDRÉS, A. A. (1998); *La Ordenación del Territorio en el Estado de las Autonomías*; Instituto Universitario de Derecho Público "García Oviedo", Editorial Marcial Pons; Madrid-Barcelona

ARCE RUIZ, R. M. (2002); *La Evaluación de Impacto Ambiental en la Ecrucijada;* Ecoiuris.

GOMEZ OREA, D. (2002); *La Evaluación de Impacto Ambiental*; Mundi Prensa (2ª edición.

Environmental Engineering [6342]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The aim of the course is that students are aware of the causes that generate significant impacts on the environment and correction factors, being able to sufficiently analyze the cause and effect vectors, in order to set the parameters of environmental control.

Program

Unit 1. Introduction to environmental engineering

Unit 2. Air pollution

Unit 3. Water pollution effects

Unit 4. Urban and industrial waste treatment and management

Unit 5. Noise pollution

Unit 6. Soil contamination

Unit 7. The urban environment

Unit 8. Environmental sociology

REFERENCES

HERNÁNDEZ MUÑOZ, A.: Manual para la evaluación de impactos ambientales. 2006

KIELY, G.: Ingeniería Ambiental. 1999

Water Resources Planning [6336]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This subject aims at specializing in the field of Water Resources Systems Planning. It has a twofold aim. On the one hand it is intended that students acquire theoretical and practical knowledge of the most common methods to develop professional surveys of water resources systems. On the other hand, they are intended to know and manage the legal, regulatory and administrative bases framing water planning in Spain, including the Water Framework Directive.

Program

PART I. TECHNICAL ASPECTS OF PLANNING

Unit 1. Water resources systems

Unit 2. Water demands

Unit 3. Acquisition and processing of water resources data

Unit 4. Water infrastructure design and operation

Unit 5. Water infrastructure operation

Unit 6. Water resources allocation mathematical problem

Unit 7. Simulation methods

Unit 8. The management model as a planning tool

Unit 9. The management model as an operating tool

Unit 10. Reservoir operation

Unit 11. Specific problems: maintenance flows, drought declaration, flood control defenses

PART II. LEGAL ASPECTS OF PLANNING

Unit 12. European water directives

Unit 13. Water supply regulations

Unit 14. Water Resource Plans

Unit 15. Hydraulic Public Domain Administration

REFERENCES

BALAIRON PÉREZ, Luis: Gestión de recursos hidrícos.

Landscape in Engineering [6368]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The goal is that students understand the environment from a twofold perspective: as a support in which engineering works are inserted along with the transformations that it entails, and as a cultural territory to be ordered through planning. To fulfill this aim, working instruments are developed to analyze, classify and evaluate the landscape, its processes and history are analyzed and the special features of each type of work are reviewed in their interaction with the landscape.

Program

PART I. LANDSCAPE CONCEPTS AND TREATMENT

Unit 1. Subject presentation

Unit 2. Engineering and Nature. Attitudes and evolution

Unit 3. The Landscape Concept

Unit 4. Visibility. Limits, modifiers, viewshed

Unit 5. Visual quality and fragility. Models

Unit 6. Global analysis of the landscape. Object lesson

Unit 7. Landscape ecology

PART II. THE IDEA OF SITE

Unit 8. Site. Overview

Unit 9. The place as territorial experience

Unit 10. The fit between the work and the environment

Unit 11. The assignment of meanings to the site

Unit 12. Properties and evolution of sites

PART III. HISTORY IN THE LANDSCAPE

Unit 13. The history in the landscape

Unit 14. Habitat theory

Unit 15. Archaic vision of the landscape

Unit 16. Introduction to the garden and its history

PART IV. LANDSCAPE AESTHETICS AND PERCEPTION

Unit 17. Arts in the landscape

Unit 18. Perception, aesthetics and interpretation of the environment

PART V. LANDSCAPE OF ENGINEERING WORKS

Unit 19. The landscape of roads and highways

Unit 20. The landscape of bridges

Unit 21. The landscape of railways

Unit 22. The landscape of Hydraulic Works

Unit 23. The landscape of ports

Unit 24. The landscape of the coast

PART VI. LANDSCAPE MANAGEMENT FRAMEWORK

Unit 25. Landscape management and protection systems

REFERENCES

AGUILÓ, M.: El paisaje construido. Colegio de Ingenieros de Caminos. Madrid. 1999

ESPAÑOL ECHANIZ, Ignacio: Las obras públicas en el paisaje.

Methods and Techniques for Land Planning [6135]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

It is intended that students acquire skills to (1) define and assess the sustainability of territorial actions, (2) identify and obtain the needed territorial information for planning, (3) make population projections, (4) establish criteria for location of activities in the territory, taking into account economic, social and environmental aspects, (5) identify and assess the environmental impacts of development activities, (6) select alternative locations using multi-criteria methods and (7) learn and use GIS tools to locate activities in the territory.

Program

Unit 1. Sustainability in Planning.

Unit 2. Demographic projections in Land Planning.

Unit 3. Alternative evaluation approach in planning.

Unit 4. The environmental Assessment in planning.

Unit 5. Content of the Environmental Impact Studies.

Unit 6. Environmental impact assessment.

Unit 7. Methods of environmental evaluation of activities.

Unit 8. GIS in Land Planning.

Unit 9. ARCVIEW solution

Unit 10. Locating a shopping center in a selected area of the territory using GIS (1)

Unit 11. Locating a shopping center in a selected area of the territory using GIS (2)

Unit 12. Socioeconomic location criteria.

Unit 13. Location criteria.

Unit 14. Selecting location alternatives.

Unit 15. Environmental impacts of activity.

Unit 16. Justification of the chosen alternative.

Unit 17. Elaboration and presentation of maps in GIS

REFERENCES

CALDERON, E.: Lecciones de Ordenación del Territorio. 2011

FERNÁNDEZ GARCÍA, J.F.: La evaluación ambiental de los planes urbanísticos …

Urban Transportation and Techniques [6136]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objective of this subject is to provide students with the necessary skills for professional practice in planning, implementation and management of either the overall urban activity or urban transportation. The particular objective is to update the students' knowledge in the following areas: (1) Current status of urban legislation, (2) aspects of planning execution and main techniques applicable to urban management, (3) practical and rational aspects of the urbanization project, and (4) aspects of non-motorized transportation and environment.

Program

PART I. URBAN MANAGEMENT AND PLANNING IMPLEMENTATION TECHNIQUES

Unit 1. Current legal framework of urban planning.

Unit 2. The urban transformation and its process.

Unit 3. Systematic and unsystematic use management.

Unit 4. Requirements for the unsystematic planning execution.

Unit 5. Requirements for implementation of planning in systematic actions.

Unit 6. Land reparcelling.

PART II. PLANNING IMPLEMENTATION: URBAN INTERVENTION

Unit 7. Planning implementation: urbanization Projects.

Unit 8. Practical analysis of the Urbanization Project: contents, processing and approval.

Unit 9. The road, public or residual space of planning.

Unit 10. Project without a plan: the environmental impact assessment.

REFERENCES

FERNÁNDEZ RODRÍGUEZ, T. R. (2005); *Manual de Derecho Urbanístico,* El Consultor de los Ayuntamientos y de los Juzgados, Abella, Madrid.

SANTOS DIEZ, R. y CASTELAO RODRÍGUEZ, J. (2005); *Derecho Urbanístico. Manual para Juristas y Técnicos*, Abella, El Consultor de los Ayuntamientos, Madrid.

SANTOS DIEZ, R: Técnicas de gestión urbanística y ejecución del planeamiento.

GARCÍA-BELLIDO, J., JALVO MÍNGUEZ, J. y SANTOS DIEZ, R. (1987); *Práctica de la Reparcelación. Ejemplos y modelos*, Instituto de Estudios de Administración Local, Madrid.

SANTAMERA SÁNCHEZ, J. A. y MANCHÓN CONTRERAS, L. F (1995); *Recomendaciones para el proyecto y diseño del viario urbano*, Ministerio de Obras Públicas, Transportes y Medio Ambiente, Madrid.

COMISIÓN EUROPEA (1992); *Libro Verde sobre el impacto del transporte en el medio ambiente. Una estrategia comunitaria para un desarrollo de los transportes respetuoso con el medio ambiente*, Propuesta legislativa COM (92) 46, febrero de 1992.

Specialization in Hydraulics and Energy

- Lecture hours of the specialization: 180 hours out of 315 hours
- Subjects: 1 compulsory and 3 optional to be chosen out of 6 (all semestral)

Dams I [6464]

Year Six, compulsory for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objective of this subject is to provide students with a specialization concerning the design, feasibility study, draft, construction project, management, maintenance, operation and repair of dams.

Program

PART I. TYPES OF DAMS

Unit 1. History of dams

PART II. GRAVITY DAMS

Unit 2. Stability and dimensioning

Unit 3. Mass concrete dams

Unit 4. Roller compacted dams

Unit 5. Buttress dams

PART III. ARCH DAMS

Unit 6. Typology, geometry and structural behavior of arch dams

Unit 7. Calculation situations for arch dams

PART IV. EMBANKMENT DAMS

Unit 8. Rockfill dams with clay core

Unit 9. Asphaltic faced rockfill dams

Unit 10. Stability calculations

REFERENCES

ÁLVAREZ, A. (1981); *Apuntes de proyecto y construcción de presas*, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, Madrid.

VALLARINO, E. (2006); *Tratado básico de presas,* Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

CNEG (2003); *Guías técnicas de seguridad de presas,* Comité Español de Grandes Presas y Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

USBR (1987); *Design of Small Dams,* U.S. Bureau of Reclamation, Denver.

Dams II [6465]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objective of this subject is to ensure a high specialization of students in relation to certain aspects of dam engineering and to emphasize the issues of operation, safety and environmental suitability of these works.

Program

Unit 1. Spillways
Unit 2. Outlet works
Unit 3. River diversion
Unit 4. FEM modelling of dams
Unit 5. Dam foundation
Unit 7. Dam heightening and rehabilitation
Unit 8. Dam safety. Monitoring
Unit 9. Dams and environment

REFERENCES

ÁLVAREZ, A. (1981); *Apuntes de proyecto y construcción de presas*, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, Madrid.

VALLARINO, E. (2006); *Tratado básico de presas,* Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

CNEG (2003); *Guías técnicas de seguridad de presas,* Comité Español de Grandes Presas y Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

USBR (1987); *Design of Small Dams,* U.S. Bureau of Reclamation, Denver.

Power Plant Civil Engineering [6456]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

This subject is focused as the culmination of the specialized training of students in Energy Engineering. The educational objective is to provide students with the basic knowledge necessary to the drafting and construction process of the elements of civil engineering at a Thermal power Plant, in the cases of using fossil or nuclear fuels. It aims particularly at providing students with the capacity to fully develop competencies concerning the following activities: (1) be aware of the energy resources, characteristics, distribution, operation and market, (2) know the geometry of the two main plant systems: fuel system and cooling water system, (3) acquire criteria for distributing the Plant elements in the area, (4) be aware of the construction requirements that must be respected in the project, for both the whole and the various elements, (5) be familiar with the morphology and typology of the civil work: foundations, structures, enclosure, interior construction and finishes, (6) dimension and check the turbo generator pedestal to medium powers, (7) get information about the procedures and construction techniques of peculiar elements (8) know other general considerations for the project: political, economical and environmental, (9) know the criteria for placing nuclear and conventional thermal power plants (10) be aware of the safety criteria that determine the design of nuclear power plants and (11) know the techniques for the dismantling of nuclear power plants.

Program

PART I. ENERGY RESOURCES STUDY

Unit 1. The energy.

Unit 2. Spanish thermoelectric equipment.

PART II. DESIGN OF THERMAL POWER PLANTS

Unit 3. Design basis of a thermal power plant.

Unit 4. Plant location.

Unit 5. Fundamental systems: cooling water, fuel and combustion products.

Unit 6. Plant layout.

Unit 7. Plant layout: nuclear power Plants

Unit 8. Foundations.

Unit 9. Turbo generator pedestal.

Unit 10. Superstructures.

Unit 11. Nuclear safety criteria.

Unit 12. Containment building.

Unit 13. Disposal of radioactive waste.

Unit 14. Dismantling of Nuclear power Plants.

REFERENCES

GAFFER, Centrales de vapor, 1954

Electrical Installations [6437]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

It is intended to deepen into the students' ability to: (1) describe the configuration and main components of power lines; (2) understand how steady state lines work, the key procedures of voltage regulation and the effects of lines' electromagnetic fields; (3) carry out the dimensioning and testing of the lines in an electrical distribution network; (4) perform the electrical and mechanical calculation of the conductors of a line, applying the appropriate regulation; (5) calculate short circuit currents in an electrical distribution network; (6) know the auxiliary systems of power supply and variable speed drives; (7) define an adequate system of protection for a distribution network, with the corresponding adjustments; (8) understand the essential aspects of overvoltage protection in distribution networks; (9) understand the operation of grounding systems and carry out their dimensioning; (10) understand the protection procedures against contact in a distribution network; (11) understand the operation of the logical systems and know the essential features of PLCs; (12) know the general configuration and essential elements of a transformer.

Program

Unit 1. Power lines

Unit 2. Steady state analysis

Unit 3. Electrical design

Unit 4. Mechanical design of overhead power lines

Unit 5. Calculation of fault currents

Unit 6. Overcurrent and overvoltage protections

Unit 7. Grounding systems in distribution networks

Unit 8. Electrical contact protection

Unit 9. PLCs

Unit 10. Transformers

REFERENCES

FRAILE, J.J., HERRERO, N., SÁNCHEZ, J.A., WILHELMI, J.R. (2004); *Líneas e Instalaciones Eléctricas*, Servicio de Publicaciones de la Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos.

SEIP,G.G. (1989); *Instalaciones eléctricas*, 3 volúmenes, Siemens.

RAS, E. (1975); *Teoría de líneas eléctricas*, Marcombo.

MAYOL I BADIA, A. (1987); *Autómatas programables*, Marcombo.

ASSOCIATION GENÉRALE DES HYGIÉNISTES ET TECHNICIENS MUNICIPAUX (1991); *Les stations de pompage d'eau*, Lavoisier-Tec&Doc.

Groundwater Prospection, Exploitation and Management

[6419]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The subject deepens into the knowledge of groundwater resources. It aims at providing an overview of the theoretical issues and practical considerations related to this type of resource, emphasizing the study of flow, as the aspect that most frequently appears throughout the engineering practice. The student must achieve sufficient theoretical and practical knowledge to address any issues that, directly or indirectly, relate to groundwater; in a broader sense: evaluation of resources and supplies, drainage problems, pollution problems, etc.

Program

Unit 1. Groundwater and aquifers. Water cycle and groundwater

Unit 2. Flow in porous media. Flow networks and piezometric surfaces

Unit 3. Catchments hydraulics

Unit 4. Geology and groundwater

Unit 5. Surface water / groundwater relations

Unit 6. Hydrogeochemistry. Quality and pollution of groundwater

Unit 7. Simulation of aquifers by mathematical models

Unit 8. Methods for studying, evaluating and exploiting groundwater

Unit 9. Groundwater in Spain

REFERENCES

CUSTODIO, E. Y LLAMAS, M.R. (1976); *Hidrogeología Subterránea*, Omega (reedición 1983), Barcelona.

DOMÉNICO, P.A. AND SCHWARTZ, F.W. (1990); *Physical and Chemical Hydrogeology*, John Wiley and Sons, New York.

FREEZE, A.R. AND CHERRY, J.A. (1979); *Graundwater*, Prentice-Hall, Int. Inglowood Cliffs. New York.

MARTÍNEZ ALFARO, P.; MARTÍNEZ, P. Y CASTAÑO, S. (2006); *Fundamentos de Hidrogeología*, Mundi Prensa.

SANZ, E. (2004); *Hidráulica subterránea aplicada*, Colegio de Ingenieros de Caminos, Canales y Puerots.

Hydropower [6435]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The objective of this subject is to specialize the students in planning, designing, construction, exploitation and maintenance of hydropower plants, developing their skills in relation to: (1) design, study the feasibility and draft hydropower installations, (2) plan, promote and manage the corresponding projects, (3) draft construction project of hydropower installations, (4) lead their construction, and (5) manage, maintenance, exploit and repair hydroelectric plants.

Program

PART I. GENERAL APPROACHES

Unit 1. Basics.

Unit 2. Dimensioning of hydropower installations.

PART II. INTAKE AND CONDUCTION WORKS

Unit 3. Intakes.

Unit 4. Canals and high pressure tunnels.

Unit 5. Piezometric towers and water hammer.

Unit 6. Pressure conduits.

PART III. HYDROPOWER INSTALLATIONS

Unit 7. Dimensioning and selection of turbines.

Unit 8. Alternators, equipment and auxiliary systems.

Unit 9. Power plants.

REFERENCES

GRANADOS, A. et al., (2000); *Problemas de Obras Hidráulicas;* Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

MARTIN CARRASCO, F.J. y GARROTE, L., (2005): *Diseño y Optimización de Obras Hidráulicas;* Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

CUESTA, L., VALLARINO, E. (2000); *Aprovechamientos Hidroeléctricos, 2 volúmenes;* Colegio de Ingenieros de Caminos, Canales y Puertos; Madrid.

Nuclear Engineering [6455]

Year Six, optional for specialization, semester, 3 h/week, 45 h/year, 4,5 credits.

Teaching objectives

The aim of the subject is students to get specialized in the use of nuclear energy in solving the previous and subsequent problems arising from its operation. It deepens into the knowledge of the characteristics of nuclear power plants, in both its design and construction and engineering works related to the nuclear fuel cycle: manufacture of nuclear fuel, transportation, radioactive waste and decommissioning, etc.

Program

PART I. NUCLEAR PHYSICS

Unit 1. Basics
Unit 2. Structure of matter
Unit 3. Ionizing radiations
Unit 4. Interaction of radiation with matter
Unit 5. Dose and Exposure

PART II. POWER REACTORS THEORY

Unit 6. Fundamentals of Nuclear Power Plants
Unit 7. Physics of the nucleus
Unit 8. Dynamics of power reactors
Unit 9. Thermohydraulics

PART III. NUCLEAR POWER PLANTS

Unit 10. Power reactor cooling system
Unit 11. Power reactor internal structure
Unit 12. Nuclear power reactor types
Unit 13. Nuclear fuel cycle

PART IV. RADIOACTIVE WASTE ORIGIN AND MANAGEMENT

Unit 14. Radioactive waste
Unit 15. Radioactive waste management
Unit 16. Low and intermediate level waste storage
Unit 17. High level radioactive waste storage

PART V. INSTALLATIONS DECOMMISSION

Unit 18. Decommission and closing
Unit 19. Installations decommission and closing in Spain

PART VI. NUCLEAR FUSION

Unit 20. Nuclear fusion. ITER project

REFERENCES

KENNETH WARK, DONALD E RICHARDS (2001): Reactores nucleares Ed. Mc Graw Hill
S. GLASSTONE, A. SESONSKE: Nuclear Reactor Engineering, Ed. ITP, 1994
W. M. STACEY: Nuclear Reactor Physics, Ed. John Wiley & Sons, 2001
ORTEGA X., JORBA J.: Radiaciones Ionizantes,Editorial Ediciones UPC, 1996
KOK, KENNETH D.: Nuclear engineering handbook, Bsoca Raton, Fla. :CRC, 2009
MARTÍNEZ-VA,JOSÉ M.; : Reactores Nucleares, ETSI Industriales, 1997