Course guides
295504 - FETRA - Transport Phenomena

Last modified: 12/07/2021

Unit in charge: Barcelona East School of Engineering
Teaching unit: 713 - EQ - Department of Chemical Engineering.

Degree: BACHELOR'S DEGREE IN BIOMEDICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN ELECTRICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN ENERGY ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATIC CONTROL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2021 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: EULALIA PLANAS CUCHI

Others: Primer quadrimestre:
ALBA ÁGUEDA COSTAFREDA - M10
EULALIA PLANAS CUCHI - M10

Segon quadrimestre:
ALBA ÁGUEDA COSTAFREDA - M20
EULALIA PLANAS CUCHI - M20

PRIOR SKILLS

Fundamentals of Chemistry, thermodynamics, differential equations, numerical computation

REQUIREMENTS

TERMODINÀMICA - Precorequisit

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

TEACHING METHODOLOGY

Lectures of theory and problems, participatory problem seminars, work on a case study

LEARNING OBJECTIVES OF THE SUBJECT

The course aims to introduce students in the joint study of the transfer of energy, matter and momentum. Give them to know the basic laws of these three phenomena, closely related, so they can formulate mathematical models that represent the fundamentals of the real problems of chemical processes. At the end of the course the student should be able to:

OE1. Apply the laws governing the transfer of momentum, energy and matter and interrelate the three phenomena.
OE2. Formulate mathematical models that represent complex real systems both steady state and unsteady.
OE3. Propose models for the individual and global transport coefficients necessary for solving real problems.

STUDY LOAD

Type	Hours	Percentage
Self study	90,0	60.00
Hours large group	60,0	40.00

Total learning time: 150 h

CONTENTS

INTRODUCTION TO TRANSPORT PHENOMENA

Description:
What is chemical engineering?. Historical evolution of the chemical engineering discipline. Onset of transport phenomena as a discipline within chemical engineering. Fundamentals of property balances, integral and differential forms.

Specific objectives:
OE1

Related activities:
Theory lessons. Problem solving lessons. Independent learning. Assessment activities A1

Related competencies :
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 5h
Theory classes: 2h
Self study : 3h

VELOCITY EQUATIONS FOR MOLECULAR TRANSPORT

Description:
Introduction: behavior and physical states of matter. Transport of momentum: Newton's Law, viscosity, non-Newtonian fluids. Transport of heat energy: Fourier's Law, thermal conductivity. Transport of mass: Fick's law, diffusivity. General velocity equation.

Specific objectives:
OE1

Related activities:
Theory lessons. Problem solving lessons. Independent learning. Assessment activities A1

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 20h
Theory classes: 6h
Laboratory classes: 2h
Self study : 12h

THE BALANCE EQUATIONS

Description:
The mass balance: the continuity equation, the combination of balance and rate equation. The momentum balance: equation of motion. The energy balance: energy equation. No dimensional conservation equations

Specific objectives:
OE1

Related activities:
Theory lessons. Problem solving lessons. Independent learning. Assessment activities A1

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 19h 10m
Theory classes: 4h
Laboratory classes: 9h 45m
Self study : 5h 25m

STEADY STATE MOLECULAR TRANSPORT

Description:
Momentum transfer: speed profiles. Heat transport: temperature profiles. Mass transport: concentration profiles. Simultaneous transport of properties. Using non-dimensional conservation equations. Study of diffusion with chemical reaction

Specific objectives:
OE1, OE2

Related activities:
Theory lessons. Lessons of resolution of exercises. Independent learning. Assessment activities A1

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 27h 45m
Theory classes: 7h 30m
Laboratory classes: 3h
Self study : 17h 15m

UNSTEADY-STATE MOLECULAR TRANSPORT

Description:
Balance equations. Solving the balance equations: application to finite and semi-infinite media

Specific objectives:
OE1, OE2

Related activities:
Inverse learning of theory lessons. Lessons of resolution of exercises. Independent learning. Assessment activities A1, A2

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 18h 45m
Theory classes: 4h 30m
Laboratory classes: 2h
Self study : 12h 15m

FLOW TURBULENCE

Description:
Description and approaches to the study of turbulence. Mean values technique. Equations of transport under turbulent conditions. Universal velocity distribution

Specific objectives:
OE1, OE2

Related activities:
Theory lessons. Lessons of resolution of exercises. Independent learning. Assessment activities A1

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 11h 28m
Theory classes: 4h 30m
Laboratory classes: 1h
Self study : 5h 58m

BOUNDARY LAYER THEORY

Description:
Introduction. The Prandtl theory: fundamental equations. Boundary layer on flat surfaces: laminar and turbulent regimes.

Specific objectives:
OE1,OE2

Related activities:
Theory lessons. Lessons of resolution of exercises. Independent learning. Assessment activities A1

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 6h 15m
Theory classes: 1h 30m
Laboratory classes: 1h
Self study : 3h 45m

INDIVIDUAL AND GLOBAL TRANSPORT COEFICIENTS

Description:
Individual transport coefficients. Momentum: the friction factor. Individual coefficients of heat and mass transfer. Theories about the transport coefficients: film, penetration, etc.. Global transport coefficients. Transfer units.

Specific objectives:
OE1, OE2, OE3

Related activities:
Theory lessons. Lessons of resolution of exercises. Independent learning. Assessment activities A1

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 18h
Theory classes: 4h
Laboratory classes: 2h
Self study : 12h

ANALOGY BETWEEN THE TRANSPORT PHENOMENA

Description:
Basic relationships. Description of different analogies: Reynolds and Sherwood-Karman, Prandtl-Taylor and Colburn, Karman and Sherwood.

Specific objectives:
OE1, OE2, OE3

Related activities:
Theory lessons. Problem solving lessons. Independent learning. Assessment activities A1

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.

Full-or-part-time: 6h
Theory classes: 1h 30m
Self study : 4h 30m

ACTIVITIES

A1-QUESTIONNAIRES

Description:
Test questionnaires. Continuous evaluation which will be carried out along the semester

Specific objectives:
OE1, OE2, OE3

Material:
Notes from class.Slides. Reading. Exercises solved in class

Delivery:
Answers to the questions of the questionnaire which will be handed in by the end of the activity

Related competencies :
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.

Full-or-part-time: 4h 10m
Theory classes: 2h
Self study: 2h 10m

A2-RESOLUTION WITH MATLAB OF A NON-STEADY STATE CASE

Description:
Inverse learning through videos and validations by means of Atenea quiz. Resolution of a case in a non-steady state by the MATLAB program

Specific objectives:
OE1, OE2

Material:
Videos and quiz in Atenea. The description of the problem to be solved will be uploaded on Atenea. Notes of the class. Slides. MATLAB program

Delivery:
Solution of the quiz. Solution to the exercise, which will have to be introduced into Atenea

Related competencies :
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.

Full-or-part-time: 7h
Laboratory classes: 2h
Self study: 5h

A3-PARTIAL EXAM

Description:
Exam consisting in the resolution of a problem

Specific objectives:
OE1, OE2

Material:
Notes from class. Slides. Exercises solved in class

Delivery:
Answer to the questions of the exam

Related competencies :
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.

Full-or-part-time: 4h 10m
Theory classes: 2h
Self study: 2h 10m

A4-FINAL EXAM

Description:
Final exam of the course based on the resolution of exercises

Specific objectives:
OE1, OE2, OE3

Material:
Notes of the class. Slides. Solved exercises. Bibliographic material of support

Delivery:
Answers to the questions of the exam

Related competencies :
CEQUI-19. Understand mass and energy balances, biotechnology, mass transfer, separation operations, chemical reaction engineering, the design of reactors, and the recovery and processing of raw materials and energy resources.
CEQUI-27. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.

Full-or-part-time: 9h
Theory classes: 3h
Self study: 6h

GRADING SYSTEM

FINAL RATE:

NF = 0.45·NEF + 0.25 NEP + 0,15·NAC + 0,15·NT
Where,

NEF: Rate of the final exam
NEP: Rate of the partial exam
NAC: Average rate of the continuous assessment questionnaires
NT: Rate of the task of solving a problem using Matlab

The course will have a reevaluation exam according to the calendar and rules of the EEBE, this exam will substitute the three scores NEP, NEP and NAC, so will count 90%. The students will be able to access the re-assessment test that meets the requirements set by the EEBE in its Assessment and Permanence Regulations (https://eebe.upc.edu/ca/estudis/normatives-academiques/documents/eebe-normativa-avaluacio-i-permanencia-18-19-aprovat-je-2018-06-13.pdf)

EXAMINATION RULES.

The partial and final exams can be made using all available bibliographic material: lecture notes, reference books, collection of problems, etc. continuous assessment tests (questionnaires) can only be done using class notes, readings and book problems.

BIBLIOGRAPHY

Basic:
- Beek, W. J; Muttzall, Klaus Max Karl; Heuven, J. W. van. Transport phenomena. 2nd ed. Chichester ; New York: Wiley, c1999. ISBN 0471999903.
- Deen, William M. Analysis of transport phenomena. New York [etc.]: Oxford University Press, 2013. ISBN 9780199740253.
- Brodkey, Robert S; Hershey, Harry C. Transport phenomena : a unified approach. Columbus, Ohio: Brodkey Publishing, cop. 1988. ISBN 0972663584.
- Bird, R. Byron; Stewart, Warren E; Lightfoot, Edwin N; Mato Vázquez, Fidel. Fenómenos de transporte : un estudio sistemático de los fundamentos de transporte de materia, energía y cantidad de movimiento. Barcelona: Reverté, 1982. ISBN 8429170502.
- Thomson, William J. Introduction to transport phenomena. Upper Saddle River: Prentice Hall, 2000. ISBN 0134548280.

Complementary:
- Schlichting, Hermann; Gersten, Klaus. Boundary-layer theory [on line]. 9th ed. 2017. Berlin [etc.]: Springer-Verlag, cop. 2017 [Consultation: 26/05/2020]. Available on: http://dx.doi.org/10.1007/978-3-662-52919-5. ISBN 9783662529195.
- Poling, Bruce E.; Praunitz, John M.; O'Connell, John P. The Properties of gases and liquids. 5th ed. New York [etc.]: McGraw-Hill, cop. 2001. ISBN 0070116822.

RESOURCES

Other resources:
Book of Problems and Tables