Course guide
295504 - FETRA - Transport Phenomena

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: 2022  ECTS Credits: 6.0  Languages: Catalan

LECTURER
Coordinating lecturer: EULALIA PLANAS CUCHI
Others: Primer quadrimestre:
ALBA ÂGUEDA COSTAFREDA - Grup: M1
EULALIA PLANAS CUCHI - Grup: M1

PRIOR SKILLS
Fundamentals of Chemistry, thermodynamics, differential equations, numerical computation

REQUIREMENTS
TERMODINÀMICA - Precorequisite

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study</td>
<td>90,0</td>
<td>60.00</td>
</tr>
<tr>
<td>Hours large group</td>
<td>60,0</td>
<td>40.00</td>
</tr>
</tbody>
</table>

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:

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:**

**Specific objectives:**
OE1

**Related activities:**

**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:**

**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:**

**Specific objectives:**
OE1, OE2

**Related activities:**

**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:**

**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:

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:

Specific objectives:
OE1,OE2

Related activities:

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 COEFFICIENTS**

**Description:**

**Specific objectives:**
OE1, OE2, OE3

**Related activities:**

**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:**

**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:

\[ NF = 0.45 \cdot \text{NEF} + 0.25 \cdot \text{NEP} + 0.15 \cdot \text{NAC} + 0.15 \cdot \text{NT} \]

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-academicques/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:

Complementary:

RESOURCES

Other resources:
Book of Problems and Tables