

Course guide

230858 - MSM - Molecular and Soft Condensed Matter

Last modified: 14/12/2023

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2018). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN BIO & PHARMACEUTICAL MATERIALS SCIENCE (Syllabus 2021). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 4.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here:
<https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura>

Others: Consultar aquí / See here:
<https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assigant-idioma>

PRIOR SKILLS

Basic knowledge of algebra and calculus (also with complex numbers), and of elementary thermodynamics

REQUIREMENTS

None

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Basic:

CB6. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context

CB7. Students should know how to apply the knowledge acquired and their problem-solving ability in new or little-known environments within broader (or multidisciplinary) contexts related to their area of study.

CB9. Students should know how to communicate their conclusions and the knowledge and ultimate reasons that support them to specialized and non-specialized audiences in a clear and unambiguous way.

CB10. Students should possess the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

TEACHING METHODOLOGY

Theory classes

Excercise classes

Description of some practical applications

LEARNING OBJECTIVES OF THE SUBJECT

After taking this course, the students should be able to:

- based on the shape and size of its microscopic constituents, describe the types of condensed phases that can be displayed by a single-component systems, and ascertain which of them are observed at lower or higher temperature;
- describe the main experimental techniques available to identify phases and study molecular dynamics and phase transitions, and explain linear response theory and its main implications;
- discuss the degree of disorder inherent to a condensed phase, and its main characteristic microscopic dynamic processes; discuss the role of disorder and dynamics for rheological and mechanical properties
- express the degree of orientational order of liquid crystals through the nematic order parameter, and be able to relate it with the anisotropy of rheological, dielectric and optical properties of nematic phases;
- use random walk models, self-similarity, affine deformation and entropic elasticity theory to describe the properties of linear polymers and of polymer networks such as rubbers;
- classify phase transitions, and describe the phenomenology of the glass transition in a number of systems ranging from atomic and molecular structural glasses to plastic crystals, to polymers and colloids;
- describe the basic phenomenology of binary mixtures such as molecular and polymer solutions, hydrogels, polymer blends and water-surfactant systems
- enumerate the main technological applications of molecular and soft condensed matter systems, and discuss the relevance of soft condensed matter to explain biological structure formation and biophysical processes.

STUDY LOAD

Type	Hours	Percentage
Self study	64,0	64.00
Hours large group	36,0	36.00

Total learning time: 100 h

CONTENTS

(1) BASICS ASPECTS OF ORGANIC CONDENSED MATTER

Description:

(1a) Introduction to condensed phases: liquids, crystals, glasses, mesophases; classification and description of phase transitions (first order, continuous, glassy); Eyring theory and van der Waals theory of fluids, cell models in condensed matter physics; microscopic constituents: degrees of freedom and mutual interactions.

(1b) Statistical physics formalism for condensed phases; disorder, molecular dynamics, and relaxation processes; mechanical, electric and dielectric properties; linear response theory in the time domain and in the frequency domain.

Specific objectives:

- based on the shape and size of its microscopic constituents, describe the types of condensed phases that can be displayed by a single-component systems, and ascertain which of them are observed at lower or higher temperature;
- describe the main experimental techniques available to identify phases and study molecular dynamics and phase transitions, and explain linear response theory and its main implications

Related activities:

Students will have to solve on their own and hand in a series of problems on the content of this topic.
Part of the final exam will cover this topic of the syllabus.

Full-or-part-time: 33h

Theory classes: 12h

Self study : 21h



(2) SINGLE-COMPONENT SYSTEMS

Description:

(2a) Small-molecule condensed phases; structural glasses, ageing, Adam-Gibbs theory; orientationally disordered solids & plastic crystals; thermotropic liquid crystals: order parameter and Maier-Saupe theory of the isotropic-nematic transition, optical properties. Primary & secondary relaxations; residual entropy.

(2b) Amorphous & semicrystalline linear homopolymers, Miller's theory; the Ising chain model; ideal chain statistics, entropic elastic forces, Rouse theory, entanglement effects and reptation; segmental and normal relaxations, polymer glass transition and viscoelasticity; polymers networks: gelation, affine network model of rubber elasticity; conjugated and conductive polymers; liquid crystal polymers and fibers

Specific objectives:

- discuss the degree of disorder inherent to a condensed phase, and its main characteristic microscopic dynamic processes; discuss the role of disorder and molecular and macromolecular dynamics for rheological and mechanical properties
- describe orientational order in liquid crystals, and the resulting anisotropy of mechanical, dielectric and optical properties
- use random walk models, self-similarity, entropic elasticity models and affine deformation theory to explain the properties of linear polymers, entangled polymer melts, and of polymer networks such as rubbers
- describe the phenomenology of the glass transition in a number of systems ranging from atomic and molecular structural glasses to plastic crystals, to polymers and colloids

Related activities:

Students will have to solve on their own and hand in a series of problems on the content of this topic.
Part of the final exam will cover this topic of the syllabus.

Full-or-part-time: 40h

Theory classes: 14h

Self study : 26h

(3) MULTICOMPONENT AND AQUEOUS SYSTEMS

Description:

(3a) Binary systems: miscibility versus phase separation, entropy and enthalpy of mixing

(3b) Binary polymer systems: polymer solutions, non-ideal chains, theta-solutions; swelling phenomena; hydrogels & solvatogels; polymer blends; Flory-Huggins theory; superhydrophobic/hydrophilic, superoleophobic, superamphiphilic, and self-healing polymer coatings; biopolymers, helix-coil & coil-globule transitions

(3c) Self-assembly in condensed matter: specific and non-specific interactions; block copolymers; surfactant-water systems, chemical potential theory of self-assembly and law of mass action; biomembranes, lyotropic liquid crystals, emulsions; semiflexible polymers and cytoskeleton; applications in drug release and delivery.

Specific objectives:

- discuss the thermodynamic theory of the free energy of solutions and binary mixtures
- use the concept of chemical potential to describe self-assembly in water-surfactant systems
- enumerate the main technological applications of molecular and soft condensed matter systems, and discuss the relevance of soft condensed matter to explain biological structure formation and biophysical processes.

Related activities:

Students will have to solve on their own and hand in a series of problems on the content of this topic.
Part of the final exam will cover this topic of the syllabus.

Full-or-part-time: 27h

Theory classes: 10h

Self study : 17h

GRADING SYSTEM

The students' grading system will consist of an evaluation during the course, based on two elements: a series of homework problems to be solved by the student on his/her own and handed in (TE), and a final written exam on the course content (EF).

The final mark will be given by:

$$\text{Max}\{EF ; 0.8*EF + 0.2*TE\}$$

Students who do not pass the course with the final exam will be able to take another written exam (ER). The student mark after this second evaluation exam will be:

$$\text{Max}\{ER ; 0.8*ER + 0.2*TE\}$$

If the student mark does not improve after this second assessment exam, the student will retain his/her course mark obtained after the final exam.

EXAMINATION RULES.

Only students who do not pass the course after the final exam are allowed to take the second assessment exam.

BIBLIOGRAPHY

Basic:

- Strobl, Gert. The physics of polymers: concepts for understanding their structures and behavior [on line]. 3rd ed. Berlin: Springer, 2010 [Consultation: 23/09/2022]. Available on: <https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3062750>. ISBN 9783642064494.
- Doi, Masao. Soft matter physics [on line]. Oxford: Oxford University Press, 2013 [Consultation: 23/09/2022]. Available on: <https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=1219993>.
- Jones, R.A.L. Soft condensed matter. Oxford: Oxford University Press, 2002. ISBN 0198505892 (paperback).

Complementary:

- Strobl, Gert. Condensed matter physics: crystals, liquids, liquid crystals, and polymers. Berlin: Springer, 2003. ISBN 3540003533.
- Mattsson, J. "The glass transition". Mattsson, Johan. Fluids, colloids and soft materials: an introduction to soft matter physics [on line]. Hoboken, New Jersey: John Wiley & Sons, 2016. 13, pp.249-278 [Consultation: 03/10/2018]. Available on: <https://onlinelibrary.wiley.com/doi/book/10.1002/9781119220510>.
- Papon, P.; Leblond, J.; Meijer, P.H.E.. The physics of phase transitions, concepts and applications. 2nd ed. Berlin: Springer, 2006. ISBN 3540333894.
- Hamley, Ian W.. Introduction to soft matter: synthetic and biological self-assembling materials [on line]. Chichester: Wiley, 2007 [Consultation: 23/09/2022]. Available on: <https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/9780470517338>. ISBN 9780470516096.
- Rubinstein, M.; Colby, R.H. Polymer physics. Oxford: Oxford University Press, 2003. ISBN 9780198520597.

RESOURCES

Other resources:

- Theory slides in Atenea
- One of the textbooks, and one of the complementary books, are available online (bibliotècnica UPC) at: <https://bibliotecnica.upc.edu/en/> />- Non-technical books:
M. Mitov, "Sensitive Matter". Harvard University Press (2012)
M. Miodownik , "Liquid Rules: The Delightful and Dangerous Substances That Flow Through Our Lives". Houghton Mifflin Harcourt (2019)