Course guide
**230007 - EM - Electromagnetism**

**Unit in charge:** Barcelona School of Telecommunications Engineering

**Teaching unit:** 748 - FIS - Department of Physics.

**Degree:** BACHELOR’S DEGREE IN TELECOMMUNICATIONS TECHNOLOGIES AND SERVICES ENGINEERING (Syllabus 2015). (Compulsory subject).

**Academic year:** 2023  **ECTS Credits:** 6.0  **Languages:** Catalan, Spanish, 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-assignat-idioma

**PRIOR SKILLS**

A good level on College Mathematics: Trigonometry, Geometry, Calculus (differential and Integral), Analytic Geometry, Differential equations. Vector Calculus

Basic concepts in Classical Mechanics.

**DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES**

**Generical:**
12 CPE N1. They will be able to identify, formulate and solve engineering problems in the ICC field and will know how to develop a method for analysing and solving problems that is systematic, critical and creative.

**TEACHING METHODOLOGY**

- Lectures
- Tutorials
- Laboratory sessions with final reports
- Self-evaluation with test-questions and/or problems (either in paper or electronically)
- Team and individual assignments (at home)
- Final exam
LEARNING OBJECTIVES OF THE SUBJECT

To learn the main principles and laws of Electromagnetism, and to acquire the ability of solving fundamental problems related to its main topics either in vacuum or in material media. Formulation of the laws in integral and differential form (Maxwell equations). Derivation of the boundary conditions for the electric and the magnetic fields. The main goal is to get the essential knowledge and skills to tackle successfully the high level courses.

After the course the student must:

- Understand the implications of the basic concepts of the fundamental laws of the electromagnetic fields.
- Apply the physical principles to solve engineering and physics problems.
- Acquire experience in getting information on-line.
- Prepare and perform oral presentations, answer the formulated questions, and write reports, correctly.
- Execute the entrusted tasks on time, and be aware of his level of progress according to the initial objectives.
- Identify the aim of a team, be able to schedule the work to achieve the final purpose. Identify the required tasks to each component of the team and to assume his own assigned part.

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours large group</td>
<td>52,0</td>
<td>34.67</td>
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<tr>
<td>Hours small group</td>
<td>13,0</td>
<td>8.67</td>
</tr>
<tr>
<td>Self study</td>
<td>85,0</td>
<td>56.67</td>
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</tbody>
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**Total learning time:** 150 h
Chapter 1. Electrostatic Field

Description:
The chapter is aimed at the study of electric fields created by charges at rest, both point charges and continuous charge distributions. Electric fields are evaluated by superposition and if symmetry permits, by using Gauss' law. Given the fact that electrostatic forces are conservative, it is possible to evaluate the potential energy associated to an electric field and to relate this quantity to the electric potential. The concepts of flux, divergence, the divergence theorem, gradient and circulation are revisited.

1. Electrostatic Field

1.0 Introduction
Scalar and vectorial fields. Representation
Electromagnetic field. Maxwell equations
Lorentz force law

1.1 Electrostatic field. Potential
Electrical charge: conservation and quantization. Continuous charge distributions
Coulomb's Law. Electrostatic field. Electric dipole
Field lines, flux. Gauss's Law (integral and differential form)
Applications of the Gauss's Law
Electrostatic Potential
Electrostatic energy. Energy density of the Electric field

Specific objectives:
Learning the basic concepts of the steady Electric fields needed to understand the development of time-varying electromagnetic field theory.

Calculation of electric fields by applying the superposition principle and the integral Gauss law.
Solving problem related with the electrostatic Potential

Related activities:
Activities related with theoretical and experimental learning.
- 1 Laboratory session
- Solution of problems related to the theory to the lab session experiments

Full-or-part-time: 44h
Theory classes: 17h
Laboratory classes: 2h
Self study: 25h
Chapter 2: Conductors. Electric current

Description:
The chapter begins with the study of the properties of conductors at equilibrium and those of capacitors. The out-of-equilibrium charge transport is undertaken, and concepts as drift velocity, surface and volume current densities, are defined, as well as their relationship with the current intensity. After considering the charge conservation principle, we focus on the ohmic conductors, and resistance and conductivity are defined. Ohm’s law is derived from the classical free electron model.

3. Conductors. Electric current
Conductors. Electrostatic field and potential inside a conductor
Capacitors and capacitance
Laplace equation. Uniqueness Theorem
The method of images
Currents. Surface and volume current densities
Global conservation of charge. The continuity equation
Ohm’s Law. Conductivity

Specific objectives:
Deepening the study of the basic concepts of the properties of conductors in and out of equilibrium. Special attention is devoted to the physical quantities related with charge transport needed to introduce the magnetic field theory in the next chapter.

Full-or-part-time: 24h
Theory classes: 9h
Self study : 15h

Temà 3: Magnetostatics

Description:
In this chapter we study the static magnetic field. We define the magnetic field from the force exerted on a charged particle in motion, the Lorentz force equation, and we describe the magnetic force on a current and on a magnet. We use both the Biot-Savart’s law, which quantifies the magnetic fields produced by a differential element current, and the Ampère's law to evaluate the magnetic field created by static current distributions.

3. Magnetostatics
Magnetic Force
Magnetic forces on moving charges and currents. Magnetic dipole moment
Magnetic field of a steady current. Biot-Savart Law
Ampère's Law (integral and differential form). Applications of the Ampère's Law
Force between parallel currents.
Mutual and self-inductance
Energy density of the Magnetic field

Specific objectives:
Deepening the study of the basic concepts of electromagnetic theory related to steady magnetic fields needed to understand the development of time-varying electromagnetic field theory.

Calculation of magnetic fields by applying the Biot-Savart law and the Ampère law.

Related activities:
Activities related with theoretical and experimental learning. 2 Laboratory session

Full-or-part-time: 28h
Theory classes: 9h
Laboratory classes: 4h
Self study : 15h
Chapter 4. Time dependent fields. Maxwell equations in vacuum

Description:
We start this chapter with the discussion of Maxwell’s equations, no longer restricted to static fields, in integral form and in free space. We show that time dependent magnetic fields are capable of producing electric currents and non conservative electric fields (Faraday’s law), and that a new type of current related with variations of the electric field appears and contributes to create a magnetic field (Ampère-Maxwell law). From Maxwell’s laws we derive Poynting’s theorem and we identify the different terms of the power balance equation.

4. Maxwell’s Laws in the vacuum
Gauss’s Laws for the Electric and Magnetic fields. Integral and differential form
Faraday’s Law. Applications
Displacement current. Ampère-Maxwell Law
Differential formulation of Maxwell’s Laws
Electromagnetic energy density
Poynting’s vector. Electromagnetic power balance. Poynting’s theorem

Specific objectives:
To formulate the fundamental laws of electromagnetism in integral and differential form.

To acquire the ability of handling the Maxwell’s equations in order to have a solid background to start to deal with practical applications like electric power lines, antennas, microwave ovens or broadcast stations at superior level courses.

Related activities:
Activities related with Theoretical and experimental learning. 2 Laboratory sessions

Full-or-part-time: 28h
Theory classes: 9h
Laboratory classes: 4h
Self study: 15h
Chapter 5. Electromagnetic field in materials

**Description:**
This part is an extension of the vacuum electromagnetic theory to linear material media, including the description of the boundary conditions which apply to electromagnetic fields at the boundary surfaces among media.

5.1 Electric fields in matter
- Permanent dipoles and induced dipoles. Polarization
- Bound charges. Physical interpretation
- Gauss's Law in the presence of Dielectrics. Electric Displacement. Energy density
- Linear Dielectrics. Susceptibility, permittivity, dielectric constant

5.2 Magnetic fields in matter
- Atomic magnetic dipoles. Magnetization
- Volume and surface bound currents
- Ampère-Maxwell Law. Magnetic field H. Energy density
- Linear media. Magnetic susceptibility and permeability
- Diamagnetism, Paramagnetism, Ferromagnetism

5.3 Maxwell equations in material regions
- Maxwell equations in materials
- Boundary conditions for electric and magnetic fields
- Electromagnetic power balance. Poynting's Theorem

**Specific objectives:**
The objective of this chapter is the same as the forth

**Related activities:**
Activities related with theoretical and experimental learning. 1 Laboratory session + exam

**Full-or-part-time:** 26h
- Theory classes: 8h
- Laboratory classes: 3h
- Self study: 15h

**GRADING SYSTEM**
- Experimental laboratory evaluation (TE) (15% of the final mark). The lab work is compulsory to pass the subject. The 60% comes from the marks of the experiments performed along the course, and 40% from a final exam of individual work.
- Continuous assessments (C) (It may be 25% of the final mark).
  It comes from the weighted average of the marks of one or two midterm exams (depending on the course development).
- Final exam (F). Theory and problems exam (It may be 60% of the final mark or 85%).

Final evaluation: 15% TE+ max (25% C+60% F, 85% F)

There exists an extra-evaluation exam following the regulation of the School.
Extra-evaluation exam (EA): it may be a test exam. The final evaluation: 15% TE+ 85% EA. The mark TE is what is obtained during the course.
- The experimental laboratory tasks must be completed to attend the re-evaluation exam.
EXAMINATION RULES.

- The use of mobile phones, programmable calculators and other electronic devices is forbidden in any assessment.
- (Final exam) The exam rooms will be published on the web-platform Atenea.

BIBLIOGRAPHY

Basic:

Complementary: