230465 - EMAG - Electromagnetism

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering  
Teaching unit: 748 - FIS - Department of Physics  
739 - TSC - Department of Signal Theory and Communications  

Academic year: 2017  
Degree: BACHELOR’S DEGREE IN ENGINEERING PHYSICS (Syllabus 2011). (Teaching unit Compulsory)  
ECTS credits: 6  
Teaching languages: English

Teaching staff
Coordinator: Macovez, Roberto  
Others: Rius Casals, Juan-Manuel

Prior skills
Knowledge of the fundamental equations of classical electromagnetic theory in the absence of materials. Operative knowledge of their applications to solve elementary problems. Knowledge of the characteristic phenomena displayed by waves of different kinds, and of their mathematical description.  
Operative knowledge of the basic tools in classical field theory and basic knowledge of complex numbers

Requirements
Participants must have passed the exams of the courses "Física 2" and "Càlcul 2"  
They have to have attended the lectures of the course "Mètodes Matemàtics 2" on complex numbers

Degree competences to which the subject contributes

Specific:
1. Knowledge of electromagnetism laws. Ability to solve engineering problems: magnetism, electricity and electrical technology, electromagnetic waves and wave optics.

General:
3. ABILITY TO IDENTIFY, FORMULATE, AND SOLVE PHYSICAL ENGINEERING PROBLEMS. Planning and solving physical engineering problems with initiative, making decisions and with creativity. Developing methods of analysis and problem solving in a systematic and creative way.

Transversal:
4. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
2. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.

Teaching methodology
Theory classes  
Exercise classes  
Description of some practical electromagnetic applications

Learning objectives of the subject
At the end of the course, students will be able to:  
- identify and apply the most adequate method for the resolution of different electrostatics problems involving applied
voltages, electric charges and dipoles, in the presence of metallic and dielectric materials
- describe the properties of dielectric and magnetic materials from the microscopic and macroscopic point of view
- calculate the impact on charges, dipoles and material systems of electric and magnetic fields of different nature: static (homogeneous and inhomogeneous), and slowly or rapidly varying
- describe light and optical phenomena starting from Maxwell's equations
- make use of the complex notation to describe spherical and plane waves, interference, diffraction and scattering, as well as to solve differential equations
- describe light propagation through media like dielectrics, metals or plasmas, and at the interface between different media, and the generation of electromagnetic radiation from the classical point of view

Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group: 65h</th>
<th>43.33%</th>
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<tr>
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<td>Self study: 85h</td>
<td>56.67%</td>
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Content

### Electrostatics and magnetostatics: dielectric and magnetic materials and applications

**Learning time:** 80h
- **Theory classes:** 21h
- **Practical classes:** 13h
- **Guided activities:** 2h
- **Self study:** 44h

**Description:**
INTRODUCTION: electric charge and magnetic dipole (spin) of fundamental particles, electric and magnetic interactions in matter (Gauss’a and Ampère's laws)

1) Summary and extension of electrostatics
   - Curl of the electrostatic field, scalar potential, Poisson's and Laplace's equations
   - Multipolar expansion of the electrostatic potential and field of a general charge distribution, electric dipole field, torque and energy of an electric dipole in an external field
   - Image charge method for conductors

2) Dielectric materials
   - Polarization: permanent and induced dipoles, dipole density and polarization field, bound charge
   - Electret, electric field inside and outside a polarized dielectric
   - Electric displacement field, dielectric constant, capacitors; electrostatic screening
   - Capacitors, energy, boundary conditions with dielectrics, force calculations in capacitors

3) Magnetic materials and magnetostatic field
   - Magnetic dipoles and magnets, magnetic dipole field; torque and energy of a magnetic dipole in an external field
   - Paramagnetism, ferromagnetism and its microscopic origin
   - Magnetization and magnetization field, analogy between electret and magnet, pole density; magnetizing field, magnetic susceptibility and permeability, boundary conditions

4) Summary and extension of electric currents and magnetism
   - Current density and charge conservation; magnetostatics: multipolar expansion, vector potential
   - Charges in constant and variable fields; electric motor
   - Conductivity and classification of materials; superconductivity and diamagnetism
   - Magnetic circuits
   - Maxwell's equations for electrostatics and magnetostatics (microscopic and macroscopic forms)

**Related activities:**
- Handed-in homework
- Midterm exam

**Specific objectives:**
At the end of the first half of the syllabus, students will be able to:
- Identify and apply the most suited method for the resolution of different electrostatic problems with applied voltages, electric charges and dipoles, in the presence of conducting and dielectric media
- Describe the properties of dielectric and magnetic materials from the macroscopic and microscopic standpoints
- Calculate the effect generated on charges, dipoles and materials, by different kinds of electric and magnetic fieldss: static (homogeneous or non-homogeneous) or slowly varying
### Electromagnetic waves and optical phenomena

**Learning time:** 70h  
Theory classes: 18h  
Practical classes: 11h  
Guided activities: 1h  
Self study: 40h

#### Description:

5) Electromagnetic waves  
- Faraday's law; induction and its applications (generators, transformers, the electric grid)  
- Magnetic energy and calculation of magnetic forces in solenoids and magnetic circuits  
- Maxwell's equations and scalar and vector potential, d'Alembert's equation of electromagnetic waves in vacuum and linear ideal dielectrics, speed of light  
- Light polarization (linear polarization), spherical and plane waves in the complex notation, Poynting theorem and irradiance  

TEMA 6) Propagation and generation of e.m. radiation  
- Introduction to optical phenomena; interference and diffraction; boundary conditions with oscillating fields, reflection and refraction  
- Electromagnetic waves in real dielectrics, metals and plasmas; complex refractive index, dielectric function  
- Dispersion, phase and group velocity  
- Maxwell's equations with sources; Radiation of the Hertzian (point-like) oscillating dipole, instability of the atom from the point of view of classical electromagnetism; Rayleigh scattering

**CONCLUSION:** electromagnetism: information vectors and energy sources

#### Related activities:

Handed-in homework

#### Specific objectives:

At the end of the second half of the course, the students will be able to:  
- describe electromagnetic wave phenomena starting from Maxwell's equations  
- use the complex notation to describe waves and their interference, and to solve differential equations  
- Describe mathematically the propagation of light in material media such as dielectrics, metals, plasmas, and at their interfaces  
- describe the emission of electromagnetic radiation from the classical standpoint

### Qualification system

The students' evaluation will consist of a final exam (EF), a midterm exam (EP) in the middle of the 4th topic (towards the end of the first half of the syllabus), as well as on handed-in homeworks (TE).  
The final mark will be given by:

$$
\text{max}\{EF, 0.55*EF + 0.35*EP + 0.10*TE, 0.9*EF + 0.1*TE\}
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Bibliography

Basic:


Complementary:


Others resources: