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230007 - EM - Electromagnetism

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2019
Degree: BACHELOR'S DEGREE IN TELECOMMUNICATIONS TECHNOLOGIES AND SERVICES ENGINEERING (Syllabus 2015). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN AUDIOVISUAL SYSTEMS ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN ELECTRONIC SYSTEMS ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN TELECOMMUNICATIONS SCIENCE AND TECHNOLOGY (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN NETWORK ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 6 Teaching languages: Catalan, Spanish, English

Teaching staff

Coordinator: Marta Net Marcé

Others: Net Marcé, Marta
Benadero Garcia-Morato, Luis
Juan Zornoza, José Miguel

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.

Requirements

MATHEMATICS FOR TELECOMMUNICATIONS - Precorequisite
VECTOR CALCULUS - Precorequisite

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.

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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 adquire 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 succesfully 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.
- Adquire 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 schedul the work to achive the final purpose. Identify the required tasks to each component of the team and to assume his own assigned part.

Study load

Total learning time: 150h	Hours large group:	52h	34.67%
	Hours small group:	13h	8.67%
	Self study:	85h	56.67%

Content

Chapter 1. Electrostatic Field	Learning time: 44h Theory classes: 17h Laboratory classes: 2h Self study : 25h

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

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

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 Potencial

Chapter 2: Conductors. Electric current	Learning time: 24h Theory classes: 9h Self study : 15h

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.

Tema 3: Magnetostatics	Learning time: 28h Theory classes: 9h Laboratory classes: 4h Self study : 15h

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

Related activities:

Activities related with theoretical and experimental learning. 2 Laboratory session

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.

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

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

Related activities:

Activities related with Theoretical and experimental learning. 2 Laboratory sessions

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.

Chapter 5. Electromagnetic field in materials	Learning time: 26h Theory classes: 8h Laboratory classes: 3h Self study : 15h

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

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

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

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Qualification 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.

Regulations for carrying out activities

- 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:

Tipler, P.A.; Mosca, G. Física para la ciencia y la tecnología (Vol. 2). 6a ed. Barcelona: Reverté, 2010. ISBN 9788429144307.

Cheng, D.A. Fundamentos de electromagnetismo para ingeniería. Wilmington, Delaware: Addison-Wesley Iberoamericana, 1997. ISBN 9684443277.

Complementary:

Dios, F. [et al.]. Campos electromagnéticos [on line]. Barcelona: Edicions UPC, 1998 [Consultation: 12/01/2015]. Available on: <http://hdl.handle.net/2099.3/36160>. ISBN 8483012499.

Griffiths, D.J. Introduction to electrodynamics. 4th. ed. Boston: Pearson, 2013. ISBN 9781292021423.