Course guides
230907 - EMG - Electromagnetism

Last modified: 19/05/2020

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

Degree: BACHELOR'S DEGREE IN ELECTRONIC ENGINEERING AND TELECOMMUNICATION (Syllabus 2018). (Compulsory subject).

Academic year: 2020 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: Oriol Batiste Boleda

Others: José Eduardo García García
Luis Benadero Morsto

PRIOR SKILLS

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

Basic concepts in Classical Mechanics.

REQUIREMENTS

Any

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE1. (ENG) GREELEC: Capacitat per a la resolució dels problemes matemàtics que poguin plantejar-se a l'enginyeria. Aptitut per aplicar els coneixements sobre àlgebra lineal, geometria, geometria diferencial, càlcul diferencial i integral, equacions diferencial i en derivades parcials, mètodes numèrics, algorítmica numèrica, estadística i optimització. (Mòdul de formació bàsica).

Generical:
CG3. (ENG) GREELEC: Coneixmetn de matèries bàsiques i tecnològíes que el capacitin per a l'aprenentatge de nous mètodes i tecnologies, així com que el dotin d'una gran versatilitat per adaptar-se a noves situacions.

Transversal:
CT6. (ENG) GREELEC:APRENENTATGE AUTÒNOM: Detectar deficiències en el propi coneixement i superarles mitjançant la reflexió crítica i l'elecció de la millor actuació per ampliar coneixements.

Basic:
CB5. (ENG) GREELEC: Que els estudiants pugin desenvolupar habillitats d'aprenentatge per empendre estudis superiors amb un alt grau d'autonomia.

TEACHING METHODOLOGY

- Lectures
- Tutorials
- Laboratory sessions with final reports
- Evaluation with fast questions and/or problems during the quatrimester.
- 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.
- 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 be able to assume his own assigned part.

STUDY LOAD

Type	Hours	Percentage
Hours small group	13,0	8.67
Self study	85,0	56.67
Hours large group	52,0	34.67

Total learning time: 150 h

CONTENTS

TEMA 0: Introduction

Description:
The introduction is a remind of some calculus contents needed to follow the subject. In particular, the concepts of flux and circulation of vector fields are revisited. Basic concepts on the evaluation of experimental errors are also studied.

- Scalar and vectorial fields
- Coordinate systems
- Flux of a vector field. Line integrals
- Error theory

Full-or-part-time: 13h
Theory classes: 4h
Laboratory classes: 2h
Self study : 7h

CHAPTER I: Electric and potential fields

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. By the fact that electrostatic forces are conservative, the electric potential is introduced, and related with the potential energy associated to an electric field. This concepts will be applied to the study of the conductors and in particular to the capacitors.

- Electrical charge: conservation and quantization.
- Coulomb's Law.
- Charge distributions. Superposition principle
- Electrostatic field. Electric dipole
- Electric flux. Gauss's Law. Applications of the Gauss Law
- Electrostatic Potential. Potential energy. Electric energy
- Electric field and electric potential in conductors in electrostatic equilibrium. Capacitance
- Systems of conductors. Capacitors

Full-or-part-time: 41h
Theory classes: 15h
Laboratory classes: 2h
Self study : 24h

CHAPTER 2: Conduction theories

Description:
The general concepts of charge transport, current density and intensity of the current are first defined. 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. After explaining the limitations of the classical theory, the atomic structure and the band theory of conduction will be briefly introduced.

- Charge transport, current intensity and current density
- Global conservation of charge. The continuity equation
- Classical conduction theory
- Ohm's Law. Conductivity
- Energy dissipation in conductors
- Atomic structure and band theory

Full-or-part-time: 12h
Theory classes: 5h
Self study : 7h

CHAPTER 3: Time independent magnetic fields

Description:
In this chapter the static magnetic field is studied. We start by defining the magnetic field from the force exerted on a charged particle in motion, i.e. from the Lorentz force. The magnetic forces and torques on currents are next studied. We use both the Biot-Savart's law and the Ampère's law to evaluate the magnetic field created by static current distributions. Finally the magnetic energy is defined.

- The Lorentz Force
- Magnetic force acting on charges. Applications
- Magnetic forces and torques acting on currents. Magnetic dipole
- Force between parallel currents.
- Magnetic field of a steady current. Biot-Savart Law
- Ampère's Law. Applications of the Ampère's Law
- Magnetic energy

Full-or-part-time: 24h
Theory classes: 8h
Laboratory classes: 2h
Self study : 14h

CHAPTER 4: Fundamental laws of Electromagnetism in integral form

Description:
The generation of electric and magnetic due to either the variation of magnetic and electric fluxes or the variations of the own fields in time are studied. The Gauss's law is revisited and the Faraday-Lenz and the Ampère-Maxwell laws are introduced, including some applications of the electromagnetic induction phenomena. Finally, the Poynting vector is defined, and the conservation of the electromagnetic energy is formulated.

- Gauss Laws for the Electric and Magnetic fields.
- Faraday's Law. Mutual and self-inductance. Inductors and transformers
- Displacement current. Ampère-Maxwell Law
- Poynting's Theorem

Full-or-part-time: 27h
Theory classes: 9h
Laboratory classes: 2h
Self study : 16h

CHAPTER 5: Maxwell equations in vacuum

Description:
The differential operators divergence and rotational of a vector field, an Gauss and Stokes theorems are revisited. From them, the fundamental laws of Electromagnetism in differential form are obtained, i.e. the Maxwell equations in the vacuum are finally formualted.

- Divergence and curl of a vector field. Gauss's and Stokes Theorems
- Differential form of the fundamental equations
- Maxwell's equations

Full-or-part-time: 5h
Theory classes: 2h
Self study : 3h

CHAPTER 6: Electric field in dielectric materials

Description:
This chapter studies the electric fields in linear dielectric media. First a microscopic description of the dielectric, in order to understand the behavior of this materials, is undertaken. The polarization vector is defined, and the needed of modifying Gauss's law by introducing the electric displacement vector is explained. The relation polarization vector-electric vector in linear materials, and the definition of electrical susceptibility and permitivity, are explained. Finally, the boundary conditions of the electric fields across two different media are formulated.

- Microscopic model: Permanent dipoles and induced dipoles. Polarization. Bound charges. Physical interpretation
- Gauss's Law in the presence of Dielectrics. Electric Displacement.
- Linear Dielectrics. Electric susceptibility and permittivity
- Poisson and Laplace equations for homogeneous and isotropic linear media
- Boundary conditions between two Dielectric media
- Energy in Dielectric systems

Full-or-part-time: 13h
Theory classes: 4h
Laboratory classes: 2h
Self study : 7h

CHAPTER 7: Magnetic fields in matter

Description:
This chapter studies the electric fields in linear media, including the description of the boundary conditions which apply to electromagnetic fields at the boundary surfaces among two different media. First a microscopic description of the magnetic media, in order to understand the behavior of this materials, is undertaken. The magnetization vector is defined, and the needed of modifying Ampère-Maxwell law by introducing the magnetic vector H is explained. The relation magnetization vector-magnetic vector H in linear materials and the definition of magnetic susceptibility and permeability are explained.

- Atomic magnetic dipoles. Diamagnetism, Paramagnetism, Ferromagnetism. Magnetization
- Volume and surface bound currents
- Ampère-Maxwell Law. Magnetic field H
- Linear and non-linear media. Magnetic susceptibility and permeability. Hysteresis cycle
- Boundary conditions in material media
- Maxwell's Laws in matter
- Magnetic energy. Generalization of Poynting's Theorem

Full-or-part-time: 12h
Theory classes: 4h
Laboratory classes: 1h
Self study : 7h

GRADING SYSTEM

- Experimental laboratory evaluation (TE) (15% of the final mark).
The 60% comes from the marks of the experiments performed along the course, and the 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). It may be 60% of the final mark or 85%. It will be mainly a problem exam, but also of theory if it were considered convenient.

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

- There exists an extra-evaluation exam following the regulation of the School, but maintaining the mark of the experimental part.

- Extra-evaluation exam (EA) : it will be a test exam.

- The final evaluation: 15% TE+ 85% EA. The mark TE is that obtained during the course.

EXAMINATION RULES.

- The use of mobile phones, other electronic devices, and programmable calculators is forbidden in any assessment.

- To leave the exam room and to come back during an assessment is also forbidden.

- (Final exam) The exam room will be published on the web-platform Atenea.

BIBLIOGRAPHY

Basic:
- Lorrain, P.; Corson, D.R. Electromagnetism: principles and applications. 2nd ed. New York: W.H. Freeman, 1990. ISBN 0716720965.
- Purcell, E.M. Electricidad y magnetismo. 2a ed. Barcelona: Reverté, 1988. ISBN 842914319X.
- Griffiths, D.J. Introduction to electrodynamics. 4th ed. Boston: Pearson, 2013. ISBN 9781292021423.
- Cheng, D.K. Fundamentos de electromagnetismo para ingeniería. Wilmington, Delaware: Addison-Wesley Iberoamericana, 1997. ISBN 9684443277.
- Reitz, J.R.; Milford, F.J.; Christy, R.W. Fundamentos de la teoría electromagnética. 4a ed. Wilmington: Pearson, 1996. ISBN 020162592X.
- Tipler, P.A.; Mosca, G. Física para la ciencia y la tecnología. 6a ed. Barcelona [etc.]: Reverté, 2010. ISBN 9788429144284.