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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:	2019
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 compex 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.

Generical:

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
Excercise 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 fot the resolution of electrostatics problems involving applied voltages,

electric charge and dipole distributions, near or within metals and dielectric materials
- describe the properties of dielectric and magnetic materials from the microscopic and macroscopic point of view, both in general and in applications such as resistors, capacitors, magnets, and magnetic circuits
- calculate the energy of an electromagnetic system, and from it, determine the forces which may be present, both for static and slowly varying fields
- analyze the working principle of the elements of the electric grid
- describe the relation between time-carying electric an magnetic field, light, and basic optical phenomena starting from Maxwell's equations
- make use of the complex notation to describe electromagnetic waves and their interference, as well as to solve differential equations
- describe the propagation of electromagnetic waves through media like dielectrics, metals or plasmas, and at the interface between different media

Study load

Total learning time: 150h	Hours large group:	65h	43.33%
	Self study:	85h	56.67%

Content

Electrostatics and magnetostatics without currents: dielectric and magnetic materials and applications	Learning time: 80h Theory classes: 21h Practical classes: 13h Guided activities: 2h Self study : 44h

Description:

0) Introduction: microscopic fields produced by charges and spins vs classical field theory
1) Summary and extension of electrostatics
1.1) Electrostatic field (E), charge density (¿), electrostatic potential (V): Coulomb, Gauss, and Poisson ' s laws
1.2) Electric dipole (p): potential and field of the point dipole; induced and permanent dipoles, torque and energy of a permanent electric dipole under an applied field
1.3) Special dipole distributions: the line dipole and the sphere dipole; multipole expansion for V (and E)
1.4) Electrostatic properties of metals, surface charge density (s), boundary conditions for E at a metal surface
1.5) Uniqueness theorem: capacitance (C) and electrostatic energy; image charge method
2) Dielectric materials
2.1) Polarization field (P), bound charge density; E-field of polarized dielectrics (depolarizing field)
2.2) Linear dielectrics vs ferroelectric materials (electrets); electric susceptibility & macroscopic electric field in linear dielectrics
2.3) Electric displacement field (D); dielectric constant and capacitance of capacitors with dielectrics
2.4) Boundary conditions for E and D; relationships between free, bound and total charge densities
2.5) Electrostatic energy with linear dielectrics and calculation of electric forces in capacitors
2.6) Microscopic description of linear media (Clausius-Mossotti relation) and of ferroelectrics
3) Magnetic materials and magnetic field
3.1) Spin and magnetic moment (m); dipolar magnetic field, Coulomb ' s law for magnetism; torque and energy of a permanent magnetic dipole under an applied field
3.2) Magnetization field (M), magnetic poles and pole densities; auxiliary field (H) for magnetized media
3.3) Linear materials: magnetic susceptibility and permeability, paramagnetism and diamagnetism; demagnetizing H-field, macroscopic H and B fields; saturation magnetization
3.4) Maxwell ' s equations for magnetostatics without free currents, boundary conditions for H and B
3.5) Microscopic description of permanent magnets: exchange interactions, magnetic domains; soft and hard ferromagnetic materials

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, and in capacitors
- describe the porperties of dielectric and magnetic materials from the macroscopic and microscopic standpoints
- calculate the effect generated on charges, dipoles and linear materials, by electrostatic and magnetostatic fields

Magnetostatics with currents, magnetic circuits, time-varying fields: Maxwell's equations and electromagnetic waves	Learning time: 70h Theory classes: 18h Practical classes: 11h Guided activities: 1h Self study : 40h

Description:

4) Summary and extension of electric currents and magnetism
4.1) Electric current (I) & current densities (J, K); charge conservation; free and bound currents
4.2) Ohm ' s local law: dc conductivity (g), classification of materials; generation of steady currents
4.3) Calculations of resistance (R); Joule ' s law; R-C relation in homogeneous media; charge densities at boundaries between media
4.4) Magnetic field due to free currents: Biot-Savart ' s and Ampère ' s laws for B
4.5) Free currents near and inside linear magnetic media: Ampère law for H; magnetic circuits, reluctance, Hopkinson ' s law
4.6) Ampère ' s equivalence theorem, equivalent currents; multipole expansion; magnetic dipole of a current loop
4.7) Superconductivity and superconducting currents
5) Magnetic energy & forces, Maxwell ' s equations, electromagnetic waves
5.1) Lorentz force and electromotive force; Faraday ' s law of induction
5.2) Energy stored in the B-field, self-inductance (L), magnetic energy in linear materials
5.3) Magnetic forces within solenoids and magnetic circuits
5.4) Overview of electric technology: electromagnets, generators, transformers, electric motors
5.5) Displacement current and macroscopic Maxwell's equations; quasi-static approximations
5.6) Poynting ' s vector (S) and Poynting ' s theorem; electromagnetic wave equations and speed of light in vacuum; monochromatic waves, irradiance, vacuum wavelength & electromagnetic spectrum
5.7) Speed of light in perfect dielectrics, refractive index; boundary conditions: constancy of the frequency, Snell ' s law of refraction; reflectivity for normal incidence
6) Description and propagation of electromagnetic (e.m.) waves in vacuum, metals and dielectrics
6.1) Complex notation for planar, spherical, and cylindrical e.m. waves; application to spatial & temporal interference: standing waves, phase velocity vs group velocity
6.2) Attenuation of e.m. waves in lossy media: complex conductivity (s ~), complex dielectric function (e ~), and complex refractive index (ñ); skin depth; macroscopic model for e ~ and ñ
6.3) Drude theory for metals, collisionless plasma model; current relaxation and frequency-dependent resistance
6.4) Electromagnetic properties of dielectrics: Lorentz-Rayleigh model of the complex permittivity & refractive index of insulators; Rayleigh scattering; Debye model of the dipolar relaxation.

Related activities:

Handed-in homework
Final exam

Specific objectives:

At the end of the second half of the course, the students will be able to:
- calculate the magnetic field produced by current distributions in the presence of magnetic materials
- describe magnetic fields and forces in magnetic circuits with constant or time-varying currents, and the applications of magnetic circuits
- calculate electromagnetic energies and verify the fundamental energy theorem of electromagnetism
- describe the interplay of time-varying electric and magentic fields, and 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

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:
max{EF, 0.55*EF + 0.35*EP + 0.10*TE, 0.9*EF + 0.1*TE}

Bibliography

Basic:

Pollack, G.L.; Stump, D.R. Electromagnetism. San Francisco: Addison Wesley, 2002. ISBN 0805385673.

Reitz, J.R.; Milford, F.J.; Christy, R.W. Foundations of electromagnetic theory. 4th revised ed. Reading, Mass.: Addison Wesley, 2008. ISBN 9780321581747.

Complementary:

Zangwill, A. Modern electrodynamics. Cambridge: Cambridge University Press, 2013. ISBN 9780521896979.

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

Lorrain, P.; Corson, D.R. Campos y ondas electromagnéticos. 5a ed. Madrid: Selecciones Científicas, 1990. ISBN 8485021290.

Feynman R.P; Leighton, R.B.; Sands, M. The Feynman lectures on physics: vol.1 i vol.2. New millennium ed. New York: Basic Books, 2010. ISBN 9780465024148 (V. 1) ; 9780465024162 (V. 2).

Grant, I.S.; Phillips, W.R. Electromagnetism [on line]. 2nd ed. Chichester [England]: John Wiley and Sons, 2013 [Consultation: 26/09/2018]. Available on: <https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=1211896>. ISBN 9781118723371.

Hayt, W.H.; Buck, J.A. Teoría electromagnética. 8a ed. México, DF: Mc Graw Hill, 2012. ISBN 9786071507839.

Peatross, J. y Ware, M.. Physics of Light and Optics [on line]. ed. 2015. 2017 [Consultation: 26/09/2018]. Available on: <http://optics.byu.edu/textbook.aspx>. ISBN 9781312929272.

Others resources:

Videoclips of the lectures of the course Electromagnetism of the Massachussets Institute of Technology (MIT) taught in 2002 by profesor Walter Lewin.
Available at: https://www.youtube.com/playlist?list=PLUdYlQf0_sSsfcNOPSNPQKHDhSjTJATPu /