UCLouvain

lphys1221

2021

Electromagnetism 1

10.00 credits	52.5 h + 52.5 h	Q1

Teacher(s)	Govaerts Jan ;
Language :	French
Place of the course	Louvain-la-Neuve
Prerequisites	LPHYS1111 or equivalent teaching unit from another programme. Having followed and passed LMAT1121 and LPHYS1112 is an asset. *The prerequisite(s) for this Teaching Unit (Unité d'enseignement – UE) for the programmes/courses that offer this Teaching Unit are specified at the end of this sheet.*
Main themes	The concepts of electric charges (charge density) and of electric fields, Coulomb's law, the electric potential. Introduction to a number of mathematical tools (gradient, divergence). The concepts of conductors and electrical capacity, electric currents (current density), and Ohm's law (with its physical modeling). The fields produced by moving charges, the transformation of the electric field and Ampère's law. Definition of the magnetic field through the Lorentz force, the concepts of the curl of a vector field and of the magnetic vector potential, and the Biot-Savart law. Faraday's law, the concepts of electromotive force, of self-inductance, of the displacement current, and the expression of Maxwell's equations in the form of differential equations. Notions of electrical circuits with alternating currents, RL, LC, RC and RLC circuits. Electromagnetic waves and light propagation. Concepts of wave packets, phase and group velocities for electromagnetic waves. Waves in two and three dimensions, polarization. Wave guides and transmission lines. Interference and diffraction, and the justification of the geometrical optics description. Electric and magnetic fields in matter : polarization phenomena, the concepts of microscopic and macroscopic fields, the D field, diamagnetism and paramagnetism, magnetization, the H field, ferromagnetic materials.
Learning outcomes	**At the end of this learning unit, the student is able to :** 1 **a. Contribution of the teaching unit to the learning outcomes of the programme** **AA1 :** 1.1, 1.3, 1.4, 1.5 **AA2 :** 2.1, 2.2, 2.4 **AA3 :** 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 **AA4 :**4.3 **AA6 :**6.3, 6.4 **b. Specific learning outcomes of the teaching unit** At the end of this teaching unit, the student will be able to : 1. express in mathematical form the laws of electromagnetism based on experimental observations ; 2. distinguish the complementarity and the relations linking the ensembles charge-current, E- and B-fields, V- and A-potentials ; 3. appreciate the relative character of some fundamental concepts such as the E and B fields ; 4. appreciate the relevance of a reductionist approach towards a fundamental understanding of the electromagnetic phenomena ; 5. solve concrete electromagnetic problems by putting into action the laws, methods and theorems having been discussed in the teaching unit ; 6. provide a mathematical description of oscillatory and wave phenomena in classical physics ; 7. distinguish the basic concepts related to electromagnetic waves and the relations these concepts possess ; 8. identify and account for the important interference and diffraction phenomena ; 9. handle experimental instrumentation, perform measurements and provide a physical analysis of their results.
Evaluation methods	• Written final exam : resolution of problems, demonstration of theoretical reasoning. • Examples of writing of laboratory reports. • Modest graded entry test for each laboratory, practical conditions permitting.

Teaching methods	Blackboard lectures and demonstrations, slide projections and animations, experimental demonstrations during lectures. Tutored laboratory and exercise practicals. It is deemed crucial to emphasize the physical concepts through their mathematical formulation based on experimental facts such as the laws of Coulomb, Ampère and Faraday. Likewise the concepts of the invariance and the conservation of a series of physical quantities and observables are emphasized. The unification of these physical laws through the concept of the electric charge and of the electromagnetic interaction which results from these, is thoroughly highlighted. Consequently, and in contradistinction to general physics courses as usually taught in scientific curriculae, an important emphasis is given to the relativity of the E and B fields through Lorentz transformations (the latter having already been discussed in the teaching unit LPHYS1111, and being reconsidered in the present one). Maxwell's laws are thereby represented through differential equations rather than integral equations. A more inductive approach is followed within the laboratory practicals which remain modest in number to allow for a better integration of the experimental method (and to avoid reducing these solely to acquiring experience in instrumentation) in direct relation with the theoretical and abstract concepts being developed in the lectures in class. Discussions during lectures in class and in tutored exercise practicals of solutions to « pedagogical » exercises and to problems typical of final examination questions. In particular two categories of problems are suggested : those for which the physical system displays maximal symmetry thereby allowing for integral theorems to readily construct a solution, and those for which the physical system possesses less symmetries but only a single or a few non trivial degrees of freedom, in which case students are led into setting up parametrised equations in order to construct a solution to the problem. The necessary methodological tools are developed during lectures and practicals alike. A list of exercises with their solutions is provided.
Content	The teaching unit is structured in sections organised along the different general themes being addressed : 1. Electrostatics : concepts of electric charges (charge density) and fields, Coulomb's law ; 2. Electric potential : introduction to a number of mathematical tools and methods (gradient, divergence) ; 3. Fields around conductors : the concepts of conductors and electrical capacity ; 4. Electrical currents : the concept of current density, Ohm's law (physical model) ; 5. The field of moving charges, transformation of the electric field, Ampère's law ; 6. The magnetic field : definition, based on the Lorentz force, the concepts of curl, of vector potential, the Biot-Savart law ; 7. Electromagnetic induction and Maxwell's equation. Faraday's law, the concept of electromotive force, self-inductance, displacement current. Maxwell's equations. 8. Notions of electrical circuits with alternating currents, RLC circuits. 9. Electric fields in matter : polarisation, microscopic and macroscopic fields, the D field ; 10. Magnetic fields in matter : physical origin of diamagnetism and paramagnetism, magnetisation, the H field, ferromagnetic materials. --------- 11. Electromagnetic waves ; 12. Reflection ; 13. Modulation, electromagnetic impulses and wave packets ; 14. Electromagnetic waves in two and three dimensions ; 15. Light polarisation ; 16. Interference and diffraction ; 17. Elements of geometrical optics.
Bibliography	Cours de physique de Berkeley. Volume 2 : Electricité et magnétisme. Cours de physique de Berkeley, Volume 3 : Ondes (sections et paragraphes relatifs aux ondes électromagnétiques) En plus des exercices proposés en séances (et au cours), une liste additionnelle d'exercices corrigés est par ailleurs mise à disposition des étudiants via une plateforme Moodle en ligne dédicacée à cet enseignement.
Faculty or entity in charge	PHYS

Programmes containing this learning unit (UE)

Program title	Acronym	Credits	Prerequisite	Learning outcomes
Bachelor in Physics	PHYS1BA	10	LPHYS1111	🔍
Minor in Physics	MINPHYS	10		🔍