Unit information

Program	Mechanical Science (53001010053P0)
Course unit	Magnetohydrodynamics
Unit code	PCMEC
Unit number	0086
Credit points	4
Period	01/01/2004 - Current
Professor	Francisco Ricardo da Cunha
Prerequisites	No, but familiarity with both Fluid Mechanics and Electrodynamics will be an advantage.

Unit outline

Objective:	The aim of the magnetohydrodynamics (MHD) course is to contribute to the training of students of the Mechanical Sciences program in advanced interdisciplinary topics, in addition to increasing the process of disseminating new knowledge associated with cutting-edge and wide-ranging technologies in the current context of engineering and mechanical sciences . In addition, the course also seeks to provide complementary bases in advanced topics of fluid mechanics, mainly aimed at those students who may decide to develop a dissertation or thesis on the subject at hand. The course deals with the study of the interaction between a magnetic field and an electrically conductive (non-polar) fluid in motion. There is a wide spectrum of MHD applications in engineering and mechanical sciences. Namely: shaft-bearing system lubrication of moving parts, heating processes and pumping electrically conductive fluids, mixing processes and levitation of liquid metals. MHD flows involve fluids such as liquid metals, saline solutions, and heated ionized gases. With this goal in mind, it becomes necessary to establish the fundamental principles involved in the coupling between Maxwell's equations of electromagnetism and the hydrodynamic equations that govern the motion of eletrically conducting fluids (modified Navier-Stokes equation).
Purpose:	The offer of the Magnetohydrodynamics course in the context in which will be treated can be considered an essential increment for the formation of graduate students in Mechanical Sciences since it deals with the fundamentals involved in the formulation of coupled equations of hydrodynamics (Cauchy/Navier Stokes equation) and electromagnetism (Maxwell equations). With this added ingredient, the student is expected to be able to solve problems of laminar flows of electrically conductive Newtonian fluids with emphasis on lubrication regimes, boundary layer, diffusion and magnetic advection, natural convection of electrically conductive fluids. Additionally a study of electromagnetic waves in incompressible and compressible media (Alfvén waves and magneto-acoustic waves) will be explored in this course. The theoretical lectures will be expositive and composed of the following general topics: brief history of magnetohydrodynamics and applications: qualitative view of the matter; Hydrodynamic and electromagnetic forces and fields; Electromagnetism theorems; Balance laws of electromagnetism; Hydrodynamic equations; Maxwell and Navier-Stokes governing equations for the context of Magnetohydrodynamics (MHD); Approximation of MHD flows for low magnetic Reynolds numbers.

Contents:	**Module 1**: Brief history of magnetohydrodynamics and its applications: qualitative view of the matter; **Module 2**: Hydrodynamic and electromagnetic forces and fields; **Module 3:** Theorems of electromagnetism; **Module 4:** Laws of conservation of electromagnetism: Equation of continuity, Ampere's law, Ohm's law and Biot-Savart's law, Poynting's theorem, Maxwell's equations, boundary conditions, electromagnetic force (Lorentz force), Maxwell's stress tensor, Faraday's law and potential vector, current displacement, electromagnetic waves and Alfvén waves; **Module 5:** Hydrodynamic Equations, Cauchy equation and Navier-Stokes equation, vorticity, hydrodynamic helicity, angular momentum, Biot-Savart law and vorticity-velocity inversion, general equation of vorticity dynamics and deformation rate of vortex lines (stretching); **Module 6**: Maxwell and Navier-Stokes governing equations for Magnetohydrodynamics (MHD), dimensionless parameters in MHD, incompressible MHD - an analogy between vorticity and magnetic induction, diffusion and advection of a magnetic field, Alfvén's Theorem for ideal conductors, Invariance of magnetic helicity in ideal MHD; **Module 7:** Approximation of MHD flows for low magnetic Reynolds numbers, compressible MHD formulation, sunspot model, unidirectional flows of conductive fluids in lubrication regime, MHD boundary layer (Hartmann), flows in ducts and natural convection of electrically conductive fluid in magnetic fields.
Assessment	Self-student exercices (40% of the final grade); Exercise lists (30% of the final grade), a Student seminar (30% of the final grade) based on a scientific paper related to the covered topics on magnetohydrodynamics and its applications. Exercise lists will be delivered during the course. The course's didactic/pedagogical material will be made available to students throughout the semester in digital form via the link: http://www.vortex.unb.br/.
Obs:	All necessary information will be provided in lectures. For reference consult:
Reference:	**1)** Introduction to Magnetohydrodynamics, P.A. Davidson, CUP-Cambridge, UK, 2017; **2)** Introduction to Eletrodynamics, D.J. Griffiths, CUP-Cambridge, UK., 2017; **3)** Electrodynamics of continuous media, L.D. Landau and E.M. Lifshitz, Pergamon Press – Oxford, UK, 1987; **4)** Introduction to Fluid Dynamics, G.K. Batchelor, CUP-Cambridge, UK, 1967; **5)** Fluid Dynamics, R.H.F. Pao, (1966), C. E. Merrill, Inc, Columbus, Ohio, 1966; **6)** Moffat, H.K. Magnetic field generation in electrically conducting fluids, CUP, Cambridge, 1978.