ECE/ENGR 570: Coupled Electromechanical Systems

Offered every Fall semester

Course Description: Energy transfer between magnetic and electric fields produce linear and rotational forces which underlie numerous engineering applications. Through the examination of magnetic material properties and coupling fields and derivation of physics-based equivalent circuit representations, students will gain the ability to understand, model, simulate and design a large class of electromechanical devices. Devices investigated include: linear motors, switched reluctance stepper and servo motors, DC and AC rotational machines. This course also provides foundational knowledge for other topics such as robotics and hybrid electric vehicles.

Example Applications:

- Inductors, transformers and chokes
- Linear motors and actuators
- DC machines and stepper-motors
- AC induction, permanent magnetic synchronous, and synchronous machines
- Inductive charging for electric vehicles (EVs)

Electromechanical Devices

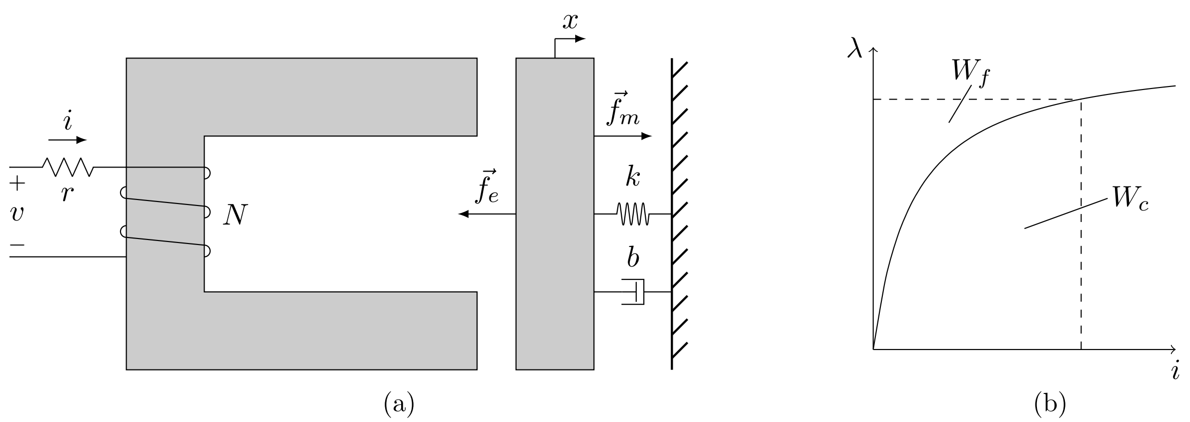

Figure 1: (a) simple electromagnetic device, (b) field energy, W_f, and co-energy, W_c.

Rotational Machine Dynamics

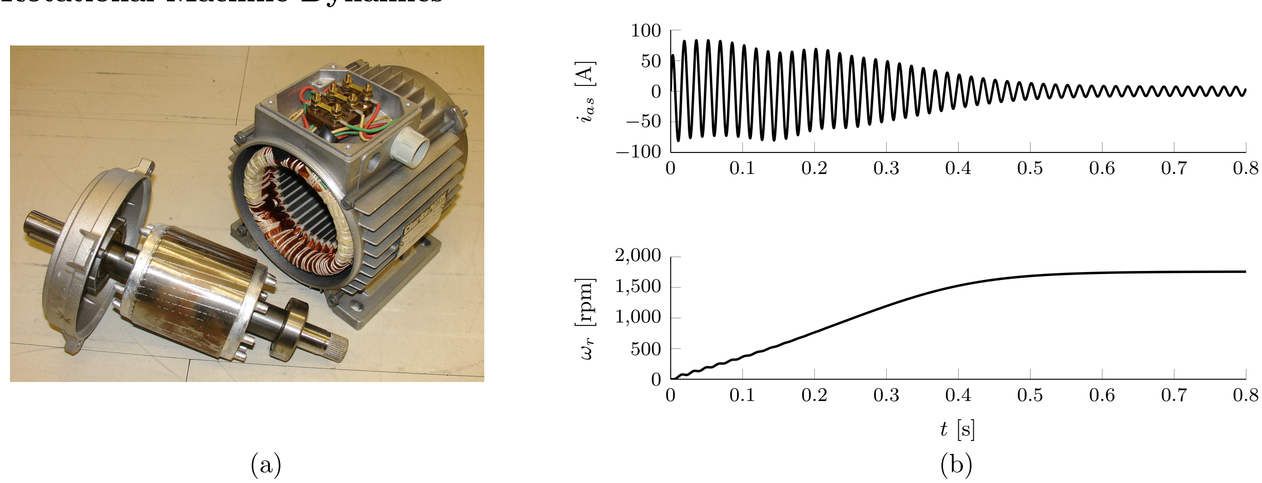

Figure 2: (a) induction machine†, (b) a-phase stator current, i_{as}, and rotor speed, ω_r.

Course Learning Objectives: Students successfully completing this course will be able to:

- Describe energy transfer between electromechanical systems through field coupling
- Create equivalent circuit represenations for various electromagnetic devices
- Calculate the operating characteristics of linear motors, servo-motors, DC motors, and AC motors (induction machines, permanent magnetic synchronous, and synchronous machines)
- Interpret the basic principles of drive systems for DC and AC machines
- Illustrate the basic principles of inductively coupled charging
- Explain the basic principles of vibrational modes that can arise between rotating electrical machines coupled to mechanical loads

Prerequisites[1]

- Working knowledge of undergraduate physics of magnetics, basic DC and AC circuit analysis including phasors. Can be fulfilled by: ECE 202 or 204 (circuit analysis, with undergraduate physics as a prerequisite)
- Assumes working knowledge of mathematics covered in an undergraduate engineering curriculum (calculus, differential equations, matrices)

Course Grading Weights

Class participation:	5%
Homework:	15%
Mid-term exam:	30%
Project presentation:	10%
Final (project report):	40%

Textbooks

Required: *Electromechanical Motion Devices, 2nd Edition*, P. C. Krause, Oleg Wasynczuk, Steven Pekarek, Wiley/IEEE Press, 2012, ISBN No. 978-1-118-29612-7.

Supplementary: *Power Magnetic Devices: A Multi-objective Design Approach*, S.D. Sudhoff, Wiley/IEEE Press, 2014, ISBN No. 978-1-118-48999-4.

Supplementary: *Introduction to Electrodynamics, 4th Edition*, D.J. Griffiths, Pearson Education Limited, 2014, ISBN No. 978-1-292-02142-3.

Professor: Dr. James Cale

Prof. Cale has extensive experience in modeling, simulation and optimal design of electromagnetic systems and devices such as electrical machines and transformers. His background and research focuses on energy conversion, power electronics, computational and applied electromagnetics, biologically-inspired optimization methods, microgrids, power hardware-in-the-loop, and machine learning algorithms. Prior to joining CSU he led the Distributed Energy Systems Integration Group at the National Renewable Energy Laboratory and worked in senior engineering roles at Advanced Energy and Orbital ATK. He earned a doctorate in electrical engineering from Purdue University and bachelors degree in electrical engineering (*summa cum laude*) from Missouri University of Science & Technology.

† Image source: `https://en.wikipedia.org/wiki/Induction_motor`

[1] Contact the instructor (jcale@colostate.edu) with questions and/or requests for waivers for the prerequisites.