ENGR 570: Coupled Electromechanical Systems

Syllabus
Fall Semester, 2022

Professor:	Dr. James Cale	Email:	James.Cale@colostate.edu
TA:	Pooja Gangawane	Email:	Pooja.Gangawane@colostate.edu
Office Hours:	By appointment and Tuesdays 4:00–5:00 PM, Spruce Hall, room 16		

Course Description

This course introduces the analysis, modeling and simulation of coupled electrical and mechanical systems. Analysis of energy transfer between these systems using field energy concepts and the Euler-Lagrange method are covered. Computer-aided simulation for the analysis and design of AC and DC motors, linear motors, servo-motors, inductively coupled charging circuits and (time permitting) vibrational modes between coupled electrical and mechanical systems are also covered.

Meeting Location and Time

Engineering Building classroom B4, CSU Fort Collins campus, Tuesday evenings 5:15–8:00 PM (MST).

Prerequisites

- Working knowledge of undergraduate physics of magnetics, basic DC and AC circuit analysis. Can be fulfilled by: ECE 202 or 204 (circuit analysis, with undergraduate physics as a prerequisite).
- Working knowledge of mathematics covered in an undergraduate engineering curriculum (calculus, differential equations, matrices).
- This class includes computer simulations. Students must have working knowledge of at least one programming language for simulations, such as MATLAB or Python.

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 (Not Required): *Analysis of Electric Machinery*, P.C. Krause, O. Wasynczuk, S. Sudhoff, Wiley/IEEE Press, 1995, ISBN No. 978-0-780-31101-5 and *Introduction to Electrodynamics, 4th Edition*, D.J. Griffiths, Pearson Education Limited, 2014, ISBN No. 978-1-292-02142-3.

Communication Policy

Questions on the course material can usually be answered most quickly via Canvas messaging or email; this is the preferred method when possible. The instructor and/or TA will respond to your inquiry within 36 hours (but typically sooner). More in-depth questions should be reserved for office hours. Important: this is *graduate-level course*; questions/office hours will not be used to "walk you through" any assignments.

Homework

Homework will be posted within Canvas and will consist of shorter analytical problems and/or short simulations. Homework will generally be due two weeks from the release date. No late homework solutions will be accepted.

Mid-term Exam

There will be a mid-term exam in this course, which will be released on Canvas on **October 11, 2022**. The exam will be "open-book, open notes" and you will have 48 hours to submit your solution. The mid-term exam problems will be based on the material discussed in lecture, the textbook, and homeworks. No make-up exams will be given, except possibly under severe extenuating circumstances. If unable to make a deadline or comply with the time constraint for any reason, contact the instructor at least five days beforehand.

Computer Simulation Projects

This course will include two group projects (of 2-3 team members) consisting of computer simulations and a short summary report describing your results. The simulations may be performed using MATLAB or other programming language of your choice; however, all solutions will be given in MATLAB only. The purpose of these simulations is to give you more experience applying the analysis techniques introduced in class. The project release dates are shown below. Note well: all team members on a project will receive the *same* grade. Project solutions (code + report) will generally be due 2-1/2 weeks after the release date.

Tentative Project Release Dates

Project 1	November 1, 2022
Project 2	November 29, 2022

Recommended Software

MATLAB installation `https://www.engr.colostate.edu/ets/matlab/`

Grading Weights*

Homework:	25%
Mid-term:	25%
Project 1:	25%
Project 2:	25%

*Your grade will be calculated according to the weights above and your earned points on the assignments, *not* what may be shown within Canvas.

Regrades

Regrading will be accommodated under only two circumstances: (1) incorrect calculation of scores or (2) incorrect assignment of scores. **All requests for regrading must be turned in within 5 days of the return of the graded project/exam**. When requesting a regrade, contact the course instructor. Note that your solution to the entire problem as well as the regrade request form will be scrutinized and the allocation of partial credit is at the discretion of the grader. In some cases, regrade requests may result in a reduced score.

Lecture Topics by Session:[2]

Session	Topic
1	Course introduction, quasi-static sources and fields, magnetic material properties, brief review of energy and three-phase power analysis
2	Inductance and inductive coupling, equivalent magnetic circuit representations, analysis of stationary magnetic systems (transformers)
3	Numerical solution of linear and non-linear state-space systems, introduction to analytical mechanics
4	Analytical mechanics (cont.) and Euler-Lagrange method (with examples)
5	Field energy, electromagnetic energy conversion, derivation of linear and rotary force expressions, application to simple devices
6	Analysis of linear motors and variable reluctance stepper motors
7	Brushed and brushless (permanent magnetic) DC machines: theory and power electronic drives
	Midterm
8	Winding functions and rotating magneto-motive forces
9	Reference-frame theory
10	Analysis of symmetrical induction machines (IM)
11	Analysis of IMs (continued), analysis of synchronous machine (SM)
12	Analysis of SMs (continued), analysis of permanent magnet synchronous machine (PMSM)
	Fall Recess
13	Analysis of PMSM (continued), overview of ac machine drives
14	Special topics: hybrid electric vehicles, magnetically levitated trains, vibratory modes and their mitigation
	Finals Week

*Exam date.

[2]Session topics and dates may change based on added/deleted material and observed progress of students. In the event that the instructor is on business-related travel or personal (sick or emergency) leave the respective class may be canceled or taught by a teaching assistant.

Lecture Material and Text

Knowledge in this course is cumulative, so it's important to attend the lectures and complete all homeworks and project assignments. If you do not attend a lecture, or need to review prerequisite technical concepts or knowledge (e.g., using MATLAB), you are responsible for reviewing the material on your own time.

Working Together

Studying together in this class is encouraged and simulation projects are team-based. However, all individual assignment submissions (homeworks and mid-term solutions) *must be solely your own work*. Solutions will be checked to ensure academic honestly. Academic misconduct has serious consequences (see below).

Final Grade Assignments

Grade	Score
A+	96.67–100.00
A	93.33–96.66
A−	90.00–93.32
B+	86.67–89.99
B	83.33–86.66
B−	80.00–83.32
C+	76.67–79.99
C	70.00–76.66
D	60.00–69.99
F	0.00–59.99

Academic Integrity

The faculty expects every member of the CSU community to practice honorable and ethical behavior. Any actions that might unfairly improve a student's score on homework or examinations will be considered academic misconduct and will not be tolerated. Examples of academic misconduct include (but are not limited to):

- Sharing results or other information during quizzes, projects or examination.
- Working on an assignment before or after the official time allowed.
- Requesting a regrade of answers or work that has been altered.
- Submitting work that is not your own.
- Representing as your own work anything that is the result of the work of someone else. This includes solutions obtained via solution manuals, the Internet and/or other services.

At the professor's discretion, academic misconduct on an assignment or examination/report will result in a reduced score, a zero score, or a failing grade for the course. All occurrences of academic misconduct will be reported to the Vice President for Student Affairs. If there is any question as to whether a given action might be construed as academic misconduct, please see the professor before you engage in any such action. For more information, please see CSU's page on Practicing Academic Integrity.[1] For information on the Honor Pledge, see the Honor Pledge.[2]

[1] http://learning.colostate.edu/integrity/

[2] http://tilt.colostate.edu/integrity/honorpledge/

Sexual Harassment-Free Environment

Colorado State University strives to create and maintain a work and study environment that is fair, humane, and responsible so that each member of the University community is treated with dignity and rewarded for such relevant considerations as ability and performance. Abusive treatment of individuals on a personal or stereotyped basis is contrary to the concepts of academic freedom and equal opportunity. Sexual harassment is one form of such abuse and cannot be tolerated.

For more information, please see the CSU Office of Equal Opportunity's Sexual Harassment Policy[3] and Principles of Community[4].

COVID-19 University Policy

Important information for students: All students are expected and required to report any COVID-19 symptoms to the university immediately, as well as exposures or positive tests from a non-CSU testing location.

If you suspect you have symptoms, or if you know you have been exposed to a positive person or have tested positive for COVID, you are required to fill out the COVID Reporter (https://covid.colostate.edu/reporter/). If you know or believe you have been exposed, including living with someone known to be COVID positive, or are symptomatic, it is important for the health of yourself and others that you complete the online COVID Reporter. Do not ask your instructor to report for you. If you do not have internet access to fill out the online COVID-19 Reporter, please call (970) 491-4600. You may also report concerns in your academic or living spaces regarding COVID exposures through the COVID Reporter. You will not be penalized in any way for reporting. When you complete the COVID Reporter for any reason, the CSU Public Health office is notified. Once notified, that office will contact you and, depending upon each situation, will conduct contact tracing, initiate any necessary public health requirements and notify you if you need to take any steps.

For the latest information about the University's COVID resources and information, please visit the CSU COVID-19 site: https://covid.colostate.edu/.

Additional Resources and Policies

For additional information on university resources and policies, see the "Resources and Policies" document posted under Canvas > Modules > Organizational.

[3] http://oeo.colostate.edu/sexual-harassment-policy

[4] http://oeo.colostate.edu/colorado-state-university-principles-of-community/