NORTH CAROLINA STATE UNIVERSITY
DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

MAE/ECE 535: DESIGN OF ELECTROMECHANICAL SYSTEMS

DR. GREGORY D. BUCKNER

SPRING 2024

Classroom: 2213 EBIII
Schedule: TTh 10:15-11:30 am
Moodle Site: https://wolfware.ncsu.edu/courses/my-wolfware/

E-mail: gbuckner@ncsu.edu
Office Hours: TTh 4:00-5:30 pm (also by appointment)

COURSE DESCRIPTION

A practical introduction to electromechanical systems with emphasis on modeling, analysis, and design considerations. Provides theory and practical tools for the design of electric machines (standard motors, linear actuators, magnetic bearings, etc). Involves some self-directed experimental work and culminates in an industry-sponsored design project.

COURSE TOPICS

Electric and magnetic field theory, magnetic circuit analysis, electromechanical energy conversion, generalized machine theory, modeling and simulation, design considerations.

COURSE OBJECTIVES

Students completing this course will be able to:

1. Understand the fundamentals of electromagnetism (Maxwell's equations) and apply them to standard problems;
2. Apply magnetic circuit analysis to predict the electromagnetic characteristics of electric machines; utilize finite element analysis to predict magnetic fluxes, forces, and torques in electric machines;
3. Understand the fundamentals of permanent magnetism and select permanent magnet materials for specific applications;
4. Understand the principles of electromechanical energy conversion and apply these principles to predict forces and torques in electric machines;
5. Develop nonlinear dynamic models of electric machines, simulate these systems using MATLAB and Simulink, and analyze their performance and response characteristics;
6. Explain the fundamentals (machine topology, etc.) and basic operating characteristics (torque, speed, efficiency, etc.) of common electrical machines;
7. Design, model, simulate, and analyze the dynamics of common (dc motors, induction motors, etc.) and unique (railguns, active magnetic bearings, etc.) electric machines

COURSE NOTES (REQUIRED)

- **Print**: Buckner, G.D., ***Course Notes: MAE/ECE 535 Design of Electromechanical Systems***, available via the NCSU Bookstores (anthony_sanders@ncsu.edu, 919-515-3868)
- **Digital**: https://ladbookstore.com/products/design-of-electrical-and-electromechanical-systems

WEBASSIGN ACCESS (REQUIRED)

- Access code must be purchased for homework and exams (http://www.webassign.net)

REFERENCE TEXTS (NOT REQUIRED; BOTH PRINT AND DIGITAL ("ALL-IN") VERSIONS AVAILABLE)

- Sadiku. Elements of electromagnetics, (any recent edition). Oxford University Press.
- Fitzgerald, Kingsley, and Umans. Electric machinery, (any recent edition). McGraw-Hill.

GRADING (YOUR CHOICE… FINAL EXAM IS OPTIONAL)

	Option 1	Option 2
Homework	25%	33.33%
Midterm Exam	25%	33.33%
Design Project	25%	33.33%
Final Exam	25%	

GRADING SCALE (REQUIRED %)

A+	A	A-	B+	B	B-	C+	C	C-	D+	D	D-
98	92	90	88	82	80	78	72	70	68	62	60

OTHER

- This course deals extensively with the fundamentals of problem solving… **attention to homework is highly recommended**.
- **Late homework will not be accepted**.
- Academic dishonesty rules, as outlined in the NCSU Code of Student Conduct, will be strictly enforced. **Any suspected act of academic misconduct will be immediately referred to the NCSU Office of Student Conduct.**
- Students are encouraged to work in small groups and use additional reference materials for the solution of homework assignments and design projects. However, **copying and submitting the work of other students as your own is a violation of the NCSU Code of Student Conduct, and will be treated as such.**
- Note: copying figures, equations, or text from other sources without properly referencing these sources is **plagiarism: a violation of the NCSU Code of Student Conduct that will be referred to the NCSU Office of Student Conduct.**
- Any student with a disability who is registered with the University Office of Student Disability Services should schedule an appointment with Dr. Buckner at the beginning of the semester to discuss academic accommodations.
- Video copies of each lecture are accessible via the course Moodle site
- Online class evaluations will be available for students to complete during the last three weeks of the semester

TENTATIVE SCHEDULE

Dates	Topics	Optional Reading
Jan 9	**Introduction**	
	Course objectives, overview, and policies	
Jan 11	**Fundamentals of Electromagnetism: Maxwell's Equations**	
	Static electric fields: Coulomb's law, Gauss's law,	S 4.1-4.10
Jan 16, 18	visualizing fields and potentials, capacitance	S 6.5
	Electric currents: Ohm's law, continuity equation, Static	S 5.1-5.8
Jan 23, 25	magnetic fields: conservation of flux,	S 7.1-7.2
	Biot-Savart's law, Lorentz's force equation,	S 7.3-7.6
Jan 30, Feb 1	Ampere's law	S 8.1-8.2
	Faraday's law, inductance	S 9.1-9.3,8.8
Feb 6, 8	Summary of Maxwell's equations	S 9.5
Feb 15	**Demonstration projects assigned**	
(Feb 13 Wellness Day)	**Magnetic Circuit Theory**	F 1.1-1.3,
	Magnetic circuits: theory and applications	S 8.10
Feb 20, 22	**Finite Element Analysis for EM Circuits**	
	Introduction to FEA	S 15.5
	2D using FEMM	FEMM User's
	3D using ANSYS Maxwell	Manual
Feb 27, 29	**Permanent Magnets**	
	Magnetic hysteresis, coercivity, load lines, flux leakage	S 8.5-8.6
Mar 5, 7	**Electromechanical Energy Conversion**	F 3.1-3.6
(Mar 11-15 Spring Break)	Conservation of energy, energy and coenergy, force and torque in EM machines	
Mar 19, 21	**Design Projects Assigned**	
	Generalized Machine Theory	
	Analysis of standard rotating machines using GMT	F 4.1-4.11
Mar 26	**Midterm Review**	
Mar 28	**Midterm Exam**	
Apr 2, 4	**Common Electric Machines**	
	Induction motors, synchronous motors, reluctance motors	F 5,6,7,8
Apr 9, 11	**Modeling and Simulation**	
	Modeling and simulation of EM systems	F 3.8-3.9
	Nonlinear analysis: linearization and Simulink	
	Transient and steady-state dynamics	
Apr 16, 18	**Design Considerations for Electric Machines**	
	Iron Losses, Copper Losses, Flux Saturation	
	Case study: Design and Control of EM Machines	
	Magnetic levitation and active magnetic bearings	
Apr 23	**Conclusion**	
	Final Exam Review	
	Course evaluation	
	Design Projects Due	
Apr 30	**Final Exam (Optional)**	