ESC 315 | **Electrical Engineering Concepts** | Spring 2021

3 Credits | Cleveland State University

- **Instructor:** Amin Ghorbanpour a.ghorbanpour@vikes.csuohio.edu
- **Textbook:** *Introduction to Electric Circuits*, by Svoboda and Dorf, 9th edition.
- **Lecture hours (remote):** Mon, Wed 6:00 PM – 7:15 PM (ET). Course content will be posted progressively on the Blackboard course site. The students are required to listen to the posted lectures at their convenient time. During the lecture hours, examples will be solved.
- **Office hours:** The instructor will be available on Zoom on Thursday, 1-3 PM, with other times arranged on an individual basis.
- **Goals:** Understand the behavior of electric circuits with resistors, capacitors, inductors, op-amps, transformers and diodes, operated with AC and DC currents. Use analytical and computer simulation tools to calculate the response and power transfer characteristics of circuits. Understand the operation of DC motors and perform basic selection calculations.
- **Learning Objectives:** Upon completion of this course, students should be able to:

1. Use Kirchhoff's laws and mesh or node methods to obtain mathematical descriptions of RLC circuits. Obtain solutions by analytical means (Laplace transforms) or computer simulation tools. SimScape will be used.

2. Understand how power flows across a circuit and calculate stored and dissipated energies.

3. Use phasors, impedances and complex arithmetic to calculate voltages and currents in steady-state AC circuits.

4. Obtain the Thévenin and Norton equivalents of circuits with impedances.

5. Calculate the components of complex power in AC circuits and perform power factor correction calculations. Apply the Maximum Power Theorem for impedances.

6. Analyze and solve circuits containing transformers, diodes and operational amplifiers.

7. Understand the principles of operation of DC, BLDC and stepper motors and perform basic selection calculations on the basis of machine torque-velocity requirements.

Note: Students need to have knowledge of Differential Equations and Physics. Also, they must know how to use Matlab.

- **Evaluation:**
    - Problem sets will be assigned, but not all problems will be graded. Multiple-choice quizzes may be assigned on some weeks, with advance notice. Computer simulation homeworks will be given.
    - A final project will be assigned.
    - One midterm exam and one final exam will be administered, with an open-books and notes format.

- **grade computation:**

Assignments (problem sets, computer simulations)	300
Quizzes	100
Midterm exam	200
Final exam	300
Course project	100
Total	1000

Note:

- Make-up examinations will be arranged ONLY if the student contact the instructor and has a legitimate reason.
- Late assignment, homworks, etc. will be given a zero.

- Conversion to a letter grade will be made as follows:

Range	Letter
890-1000	A
750-889	B
600-749	C
500-599	D
0-499	F

- **Academic honesty:** You are expected to behave ethically concerning all aspects of the course, particularly during exams and home assignments. The CSU code of student conduct will be observed:

  https://www.csuohio.edu/compliance/student-code-conduct

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Lecture synopses: (These topics may be changed/reorganized at the instructor discretion)

Unit 1 : Introduction

- Lecture 1: Reading: S&D Chapters 1 and 2
    - Electric variables, passive convention, power, and units.
    - Passive sign convention.
    - Electrical systems and the role of the ME: past, present and future – supplemental reading / discussion.

- Lecture 2: S&D Chapter 2
  - Electric circuits
  - Active and passive elements and the i,v characteristic
  - Resistors and switches. Resistivity. Power dissipation.
  - Voltmeters and ammeters
  - Solving simple circuits
  - Voltage divider and potentiometer.

Unit 2 : Resistive Circuits

- Lecture 1: Reading: S&D Chapter 3
  - Kirchhoff's laws.
  - Simple circuits: series / parallel equivalent resistances. Voltage dividers, Wheatstone bridges. Resistor color coding, power ratings, thermal stability.
  - Introduction to Simulink and SimScape – (Pre-recorded video)
  - Computer solution of resistive circuits
  - Supplemental reading: Power resistors, rheostats. Joule heating. AWG conductor resistances and current-carrying capacities.

- Lecture 2: Reading: S&D Chapter 3
  - Node and mesh methods – independent sources
  - Node and mesh methods – dependent sources
  - Verification with SimScape
  - Application: The Wheatstone bridge and strain gauges.

Unit 3 : Energy Storage Elements

- Lecture 1: Reading: S&D Chapter 7
  - Capacitance and Capacitors. Stored energy.
  - Inductance and Inductors. Stored energy. Formulas based on core properties, AWG, geometry and number of turns.
  - Simple circuits with capacitors and inductors. Series and parallel equivalents.
  - Some inductive and capacitive components and their applications.
  - Additional reading: solenoids, fluorescent bulb reactors, supercapacitors. Energy density vs. power density and Ragone plots.

Unit 4 - Laplace and computer methods for linear circuits

- Lecture 1: Reading: S&D Chapter 14.
  - Review of Laplace methods for differential equations
  - Circuit application examples: formulation
- Lecture 2:
  - Computer-generated partial fraction expansion and table usage

    - Circuit application example: comparison between analytical and computer solutions (SimScape).

Unit 5 - Sinusoidal Response and Phasors

- Lecture 1: Reading: S&D Chapter 10.
    - Reading: The war between Edison and Westinghouse for the US electric distribution system.
    - Sinewaves, amplitude and phase
    - Review: complex arithmetic
    - Complex representation of sinewaves and phasors.
- Lecture 2: Reading S&D, various sections
    - Complex impedance
    - Impedance of capacitors and inductors
    - Series and parallel impedances
    - Admittance and transfer functions

Unit 6 - Steady-State AC Analysis

- Lecture 1: Reading: S&D various sections.
    - Steady AC response of individual R,L and C elements. Phase lag / lead.
    - Steady AC response of simple RLC circuits with phasors and impedance.
    - Experimental verification: Resonant RLC circuit response in SimScape and lab data.

Unit 7 - Thévenin and Norton Equivalent Circuits

- Lecture 1: Reading: S&D Sec. 10.7

Unit 8 - Power in Steady AC Circuits

- Lecture 1: Reading: S&D Chapter 11.
    - Instantaneous and average power. Effective power and rms value.
    - Complex power and impedance.
    - Apparent and reactive power.
    - Units: VA, VAR and W.
- Lecture 2: Reading: S&D Chapter 11.
    - Power factor
    - Power factor correction
    - Maximum Power Theorem for impedances
    - Verification in SimScape/Simulink.

Unit 9 - Introduction to Op-Amps

- Lecture 1: Reading: Histand and Alciatore, Ch. 5
    - Description. Open-loop and feedback operation. Comparator. Basic Op-Amp laws.
    - Buffering and isolation: the follower.
    - Inverting and non-inverting configurations.

    - Adder and difference amplifier.
    - Integrator and differentiator.
    - Instrumentation applications: filtering+amplification+isolation.
    - Analog computing. Verification with SimScape.

Unit 10 – Coupled Inductors and the Ideal Transformer. Diodes.

- Lecture 1: Reading: S&D Sec. 11.10
    - Electromagnetic Induction. Lenz's and Faraday's laws.
    - Self- and mutual inductance. Coupled inductors. Dot convention.
    - Differential equations of coupled inductors.
    - Power conservation and coupling factor
    - The ideal transformer. Equivalent circuit.
    - Impedance reflection and impedance matching.
- Lecture 2: Reading: Histand and Alciatore Ch. 3
    - The semiconductor diode
    - Quarter, half and full-wave rectifier
    - Application: SimScape model of AC adapter.

Unit 11 - Introduction to Electric Motors

- Lecture 1: Reading: Course notes.
- Electromechanical energy conversion with magnetic coupling. Motor and generator effects.
- DC motors. Commutation.
- Brushless DC motors.
- DC motor differential equation and steady-state characteristics.
- Performance specifications of motors at steady-state. Torque-speed curves.
- Basic selection criteria and calculations.

Unit 12 - Electric Mobility and Smart Grid

- Independent reading topics:
    - Battery technologies and trends. Emerging energy storage systems: supercapacitors.
    - Hybrid and all-electric land vehicles: cars, e-bikes.
    - Hybrid and all-electric aircraft.
    - Economic and technical challenges of electrification in transportation systems.
    - Smart grids and microgrids.