# Part 1: Course Information

## Course Overview

### Basic Information

College:   
Department:  
Semester:   
Instructor:   
Office:   
Office Hours:   
Office Telephone:   
Email:

### Description

Electrical Systems is a study of the basic electrical components in a complex mechatronics system. This course consists of 15 lessons along with corresponding labs and/or class activities. Topics covered include electrical safety, basic functions and physical properties of electrical components, troubleshooting techniques and strategies to identify, localize, and correct malfunctions, and systematic preventative maintenance.

### Prerequisites

No Mechatronics courses are required as prerequisites.

To succeed in this course, students should be proficient in English and basic Algebra.

## Course Materials

### Recommended Textbook(s)

Kuphaldt, T. R. (2006). *Lessons in Electric Circuits, Volume 1: Direct Current* (5th ed.). Free, online textbook released under the Design Science License. Available: http://www.ibiblio.org/kuphaldt/electricCircuits/ [Accessed: January 2015].

Kuphaldt, T. R. (2007). *Lessons in Electric Circuits, Volume 11: AC* (6th ed.). Free, online textbook released under the Design Science License. Available: http://www.ibiblio.org/kuphaldt/electricCircuits/ [Accessed: January 2015].

### Recommended Workbook

Mazur, G. A. (2011). *Electrical Principles and Practices: Workbook* (3rd ed. *or* 4th ed.). Orland Park, IL: American Technical Publishers. ISBN-13: 978-0826918048 *or* ISBN-13: 978-0826918123.

### Additional Textbook

Mazur, G. & Zurlis, P. (2013). *Electrical Principles and Practices* (4th ed.). Orland Park, IL: American Technical Publishers. ISBN-13: 978-0826918116

## Course Structure

This course is designed to provide a hybrid experience, including both face-to-face and online activities. Activities to be completed online and face-to-face will be updated weekly and provided as a supplement to the course syllabus.

Contact time will be divided in the following way:

80% face-to-face  
20% online

### Face-to-face sessions

Laboratory exercises and in-class work will emphasize skill attainment and content mastery.

### Online Sessions

Online sessions will include content and activities from Platform +, Wisc-Online, Tooling U, simulated lab activities, and other resources. To access online activities, students will need access to the Internet and a supported Web browser. Technical assistance can be obtained from local technical support.

### Technical Requirements

* Internet connection
* Access to college learning management system and Platform+.
* Access to college email account
* Microsoft PowerPoint
* Microsoft Word

# Part 2: Learning Outcomes

Following successful completion of the Electrical Systems course, the student will be able to:

### Safety

* Understand and apply electric safety rules while working on a mechatronic system.
* Use appropriate attire and protective equipment.
* Operate equipment according to safety protocols.
* Demonstrate proper safety techniques.

### Technical Literacy

* Read, interpret, and use electrical and electronics documentation, such as data sheets, circuit diagrams, displacement step diagrams, timing diagrams, function charts, operation manuals, and schematics.

### Applied Mathematics

* Perform calculations using scientific notation and convert between metric units.
* Use basic algebra to solve problems involving current, voltage, resistance, capacitance, torque, work, power, efficiency, Ohm’s Law, and Newton’s Laws.
* Use basic trigonometry (sine, cosine, and tangent) to describe the important parts of a sine wave and a multi-phase signal.

### Foundational Principles

* Define the quantities used in electronics and describe the basic elements of an electric circuit, explaining the various quantities’ function in the circuit.
* Explain, trace, and describe the flow of electrical energy in a mechatronic system.
* Explain the principles and physical operation of electromagnetic and electrostatic components, including coils, solenoids, relays, and various sensors used in a mechatronic system.
* Use Ohm’s Law to determine voltage, current, and resistance, and calculate power in an electric circuit, including both series and parallel circuits.
* Differentiate between single-phase and three-phase AC power.
* Explain the basic physical properties of electrical components, including resistors, capacitors, diodes, transformers, switches, relays, power supplies, and batteries.
* Explain and differentiate between DC and AC power and motor controls.

### Equipment

* Correctly use electrical measuring devices, such as the digital multimeter, oscilloscope, voltmeter, and clamp ammeter, to make AC and DC measurements.
* Explain how to install, calibrate, modify, and replace electrical devices, such as sensors.

### Critical Thinking/Problem Solving

* Interpret and analyze data measurements of electrical components gathered through the use of testing equipment.

### Troubleshooting

* Correct malfunctions in electrical components or correctly identify the expertise required to correct a malfunction.

# Part 3: Course Calendar

This course calendar provides a schedule of lessons and an outline of topics covered. Activities, assignments, and assessments will be explained in detail throughout the course. Please contact the instructor with questions.

## Lesson 1: Introduction and Safety Date

1. Lecture: Course Syllabus, Policies, and Procedures (60 minutes)
2. Lecture: Personal Protective Equipment (PPE) (45 minutes)
3. Eye Protection
4. Ear Protection
5. Gloves
6. Hard Hats
7. Shoes
8. Clothing
9. Lecture: Lock Out Tag Out (LOTO) (45 minutes)
10. Locks
11. Tags
12. Using Keys
13. Gang Lock Devices
14. Lab Activity: Perform LOTO (15 minutes)
15. Lecture: Electrical Safety (60 minutes)
16. Electrical Hazards
17. Causes of Electric Shock
18. Current Paths through Human Body
19. Effects of Current on Human Body
20. Safety Precautions

## Lesson 2: Electrical Quantities and Units Date

1. Lecture: Review of Electrical Safety (30 minutes)
2. Lock Out Tag Out (LOTO)
3. Personal Protective Equipment (PPE)
4. Electrical Hazards
5. Lecture: Scientific and Engineering Notation (45 minutes)
6. Representing Quantities
7. Expressing Numbers Using a Power of Ten
8. Performing Calculations Using a Power of Ten
9. Lecture: Units and Metric Prefixes (30 minutes)
10. Working with Electrical Units and Metric Prefixes
11. Units for Twelve Electrical Quantities
12. Symbols for Electrical Units
13. Metric Prefixes
14. Changing a Power of Ten in Engineering Notation to a Metric Prefix
15. Using Metric Prefixes to Express Electrical Quantities
16. Understanding Significant Digits
17. Quiz: Twelve Electrical Quantities
18. Lab Activity: Identifying and Explaining Units on Trainers (45 minutes)
19. Lecture: Quantities Used in Electronics (60 minutes)
20. Definitions

## Lesson 3: Voltage, Current, and Resistance Date

1. Lecture: Voltage (30 minutes)
2. Definition and Characteristics
3. Formula
4. Unit
5. Basic Sources
6. Lecture: Current (30 minutes)
7. Definition and Characteristics
8. Movement of Electrons
9. Formula
10. Unit
11. Lecture: Resistance (30 minutes)
12. Definition and Characteristics
13. Unit

c. Basic Types of Resistors

d. Resistance Value by Color Coding or Labeling

e. Properties

1. Lecture: Electric Circuit (45 minutes)
2. Definition and Characteristics

b. Open and Closed Circuits

c. Protective Devices

d. Switches

e. Wire Sizes

f. Ground/Common

1. Lecture: Basic Circuit Measurement (45 minutes)

a. Measuring Voltage

b. Measuring Current

c. Measuring Resistance

d. Using a Multimeter

1. Lab Activity: Basic Circuit Measurements with Multimeter (60 minutes)

## Lesson 4: Ohm’s Law, Energy, and Power Date

1. Lecture: Ohm’s Law (60 minutes)
2. Definition and Formula
3. Ohm’s Law Triangle
4. Lab Activity: Ohm’s Law (60 minutes)
5. Application of Ohm’s Law (15 minutes)
6. Calculating Voltage, Current, and Resistance
7. Using Quantities with Metric Prefixes
8. Energy and Power (30 minutes)
9. Definitions of Energy, Power, Watts, Horsepower
10. Formula for Power in Terms of Energy and Time
11. Calculating Energy and Power
12. Converting between Power Units
13. Lecture: Power in an Electric Circuit (15 minutes)
14. Calculating Power in a Circuit
15. Lecture: Power Rating of a Resistor (15 minutes)
16. Lecture: Energy Conversion and Voltage Drop in a Resistance (15 minutes)
17. Lecture: Power Supplies and Batteries (15 minutes)
18. Characteristics and Controls
19. Calculating Power Supply Efficiency
20. Ampere-Hour Rating of Batteries
21. Lecture: Introduction to Troubleshooting (15 minutes)
22. Half-Splitting
23. Measuring Voltage, Current, Resistance
24. Quiz: Energy and Power Formulas and Calculations

## Lesson 5: Components of an Electrical Circuit Date

1. Lecture: Principles of Resistance (45 minutes)
2. Definition
3. Function
4. Measurement
5. Lecture: Principles of Capacitance (45 minutes)
6. Definition
7. Function
8. Measurement
9. Lecture: Diodes (15 minutes)
10. Definition
11. Function
12. OPTIONAL Lecture: Other Components (15 minutes)
13. Definition, Function, Operation of Inductors
14. Definition of Reactance
15. Lab Activities (60 minutes)
16. Measuring Resistors, Capacitors, Diodes
17. Resistor Color Codes
18. Using a Potentiometer

## Lesson 6: Electrical Measuring Devices Date

1. Lecture: Digital Multimeter for DC Measurement (15 minutes)
2. Functions
3. Measuring Voltage (DC), Resistance, Capacitance, Current (DC)
4. Checking Continuity and Diodes
5. Lab Activity: Electrical Measurements (Series DC only) (30 minutes)
6. Lecture: Loading Effect of Voltmeter on Circuit (15 minutes)
7. Lecture: Review Trigonometry for AC (45 minutes)
8. Lecture: Digital Multimeter for AC Measurement (15 minutes)
9. Functions
10. Measuring Voltage (AC), Resistance, Capacitance, Current (ADC), Frequency
11. Checking Continuity and Diodes
12. Lab Activity: Electrical Measurements (DC and AC) (45 minutes)
13. Lecture: Loading Effect of Voltmeter on Circuit (15 minutes)
14. Lecture: Clamp Ammeter (30 minutes)
15. Lecture: Oscilloscope (30 minutes)
16. OPTIONAL Lecture: “Wiggy” Solenoid Voltmeter (1-5 minutes)
17. OPTIONAL Lecture: Megohmmeter (1-5 minutes)

## Lesson 7: Series Circuits Date

1. Lecture: Characteristics of Series Circuits and Resistors in Series (10 minutes)
2. Identifying a Series Circuit
3. Translating a Physical Arrangement of Parallel Resistors into Schematic
4. Lecture: Total Series Resistance RT (10 minutes)
5. Determining RT
6. Adding Series Resistors to Obtain RT
7. Applying Series Resistance Formula
8. Lecture: Current in a Series Circuit (10 minutes)
9. Determining Current throughout a Series Circuit
10. Proving that Current Remains Constant in a Circuit
11. Lecture: Applying Ohm’s Law in a Series Circuit (15 minutes)
12. Determining Current in a Series Circuit
13. Calculating Voltage Drop across Resistances
14. Lab Activity: Basic Series DC Circuits (20 minutes)
15. Lecture: Voltage Sources in a Series Circuit (15 minutes)
16. Determining Total Effect of Voltage Sources Connected in Series
17. Determining Total Voltage of Series Sources with Same and Opposite Polarities
18. Lab Activity: Connecting Batteries to Obtain Voltage (20 minutes)
19. Lecture: Power in a Series Circuit (10 minutes)
20. Determining Power in a Series Circuit
21. Calculating Power Used by Any Component within a Series Circuit
22. Quiz: Power in a Series Circuit
23. Lecture: Troubleshooting (10 minutes)
24. Quiz: Troubleshooting a Series Circuit

## Lesson 8: Parallel Circuits Date

1. Lecture: Resistors in Parallel (15 minutes)
2. Identifying a Parallel Resistive Circuit
3. Translating a Physical Arrangement of Parallel Resistors into a Schematic
4. Lecture: Total Parallel Resistance (15 minutes)
5. Determining Total Parallel Resistance
6. Applying Parallel-Resistance Formula
7. Lecture: Voltage in a Parallel Circuit (15 minutes)
8. Determining Voltage Across Each Branch in a Parallel Circuit
9. Voltage Across All Parallel Resistors
10. Lecture: Application of Ohm’s Law (15 minutes)
11. Applying Ohm’s Law in a Parallel CircuitCalculating Total Current in a Parallel Circuit
12. Identifying Branch Currents, Voltage, and Resistance in a Parallel Circuit
13. Lab Activities (20 minutes)
14. Parallel DC Circuits
15. Parallel Batteries
16. Lecture: Power in Parallel Circuits (15 minutes)
17. Determining the Power in a Parallel Circuit
18. Lecture: Troubleshooting a Parallel Circuit (15 minutes)
19. Checking for an Open Circuit
20. Identifying a Shorted Circuit
21. Lab Activity: Troubleshooting a Short Circuit (10 minutes)
22. OPTIONAL Lecture: Identifying Series-Parallel Relationships (15 minutes)
23. Identifying and Determining Series-Parallel Relationships
24. Analyzing Series-Parallel Circuits
25. Determining Total Resistance, Currents, Voltage Drops
26. Loading Effect of Voltmeter as Application of Series-Parallel Analysis
27. Quiz: Parallel Circuits
28. Module Exam #1

## Lesson 9: AC Date

1. Lecture: Power Supplies (60 minutes)
2. Definition and Characteristics of Power Supplies
3. Definition of Power Supply Efficiency
4. Efficiency and its Impact on Cooling
5. Conversion of AC to DC
6. Lecture: AC Voltage and Concept of Root Mean Square (RMS) (60 minutes)
7. Definition and Characteristics of AC Waveform, including:
8. Frequency
9. Period
10. Amplitude
11. Discussion of Root Mean Square and Average in the Context of AC Waveform
12. Other Waveforms and Their RMS Values
13. Lecture: Three-Phase Power (60 minutes)
14. Identifying Three-Phase AC Signal
15. Relationship Between Phases
16. One-Phase vs. Three-Phase Power
17. Lecture: Advantages of AC over DC (30 minutes)
18. U.S. Usage
19. Role of Transformer
20. Quiz: AC power (30 minutes)

## Lesson 10: Transformers Date

1. Lecture: Transformer Theory and Construction (60 minutes)
2. Mutual Inductance and its Relation to Transformers
3. Transformer construction and operation
4. Step-up and Step-down Transformers
5. Inductance Formula
6. Variable Transformers, Autotransformers, Variable Autotransformers
7. Lab Activities (45 minutes)
8. Transformer Circuits
9. Control Transformers
10. Lecture: Practical Transformers: Troubleshooting and Three-Phase (60 minutes)
11. Troubleshooting Transformers
12. Identifying Three-Phase Transformers
13. Where Three-Phase Transformers are Required
14. Delta- and Y-Connected Transformers
15. Lab Activity: Troubleshooting (45 minutes)
16. Lecture: Transformer Safety (30 minutes)
17. Understanding Dangers of Transformers
18. Safely Connecting a Transformer
19. Safely Testing a Transformer
20. Quiz: Transformers

## Lesson 11: Magnetism Date

1. Lecture: Basic Physics of Magnetism (60 minutes)
2. Magnetic and Electromagnetic Terms, Units, and Properties
3. Permanent Magnets
4. Ferromagnetic Materials
5. Electromagnetism
6. Introduction of Mutual Inductance
7. Cable as Part of a Circuit
8. Lecture: Magnetic Devices (60 minutes)
9. Physics of Coils When Carrying Current
10. Electromagnets in Relays
11. Electromagnets in Solenoids
12. First Introduction to Electric Motors
13. Introduction to Transformers
14. Inductors in Context of Coils
15. OPTIONAL: Further Discussion of Inductors and Inductance
16. Lab Activity: Inductance and Capacitance (60 minutes)
17. Quiz: Magnetism and Electromagnets

## Lesson 12: Routing Electricity Date

1. Lecture: Switches (60 minutes)
2. Function of Switches
3. Types of Switches
4. Differences between Momentary and Maintained Switches
5. Lab Activity: Working with Switches (30 minutes)
6. Lecture: Relays (60 minutes)

a. Function of an Electromagnet in a Relay

b. Relay Schematics

c. Operation of Relays

1. Lab Activity: Working with Relays (30 minutes)
2. Lecture: Fuses and Circuit Breakers/Protectors (30 minutes)
3. Operation of Fuse
4. Operation of Circuit Breaker
5. Fuses and Circuit Breakers Compared
6. Function of Ground Fault Circuit Interrupter (GFCI)
7. Lab Activity: Working with Fuses and Circuit Breakers (30 minutes)
8. Quiz: Routing Electricity
9. Module Exam #2

## Lesson 13: Introduction to Motors Date

1. Lecture: Introduction to Motor Safety and Basic Concept of a Motor (60 minutes)
2. Motor Safety Concepts
3. Review of Single-Phase and Three-Phase Power
4. Basic Concept of an Electric Motor
5. Theory of Operation
6. Group of Motors
7. DC
8. AC Single-Phase and Three-Phase
9. Troubleshooting
10. Lab Activity: Motor Safety
11. Lecture: DC Motors (90 minutes)
12. DC Motor Components
13. Series DC Motors
14. Shunt DC Motors
15. Compound DC Motors
16. Motor Reversing
17. “Runaway” DC Series-Wound Motor
18. Lab Activity: DC Motors (90 minutes)
19. Lecture: AC Motors (90 minutes)
20. AC Motor Components
21. Single-Phase and Three-Phase AC Motors
22. Different Types of AC Motors
23. Single-Phase AC Motor Configurations
24. Split-Phase
25. Capacitor Start
26. Permanent Capacitor
27. Two-Capacitor
28. Three-Phase AC Motors
29. Lab Activity: AC Motors (90 minutes)
30. Lecture: Troubleshooting and Starting (30 minutes)
31. Basic Troubleshooting for Motors
32. Methods for Starting Motors
33. Steppers
34. Single-Phase AC
35. Wound-Rotor
36. Two-Phase AC
37. Split-Phase AC
38. Capacitor-Start AC
39. Lab Activity: Troubleshooting (30 minutes)
40. Quiz: Motors

## Lesson 14: Motor Controls Date

1. Lecture: DC Motor Control (90 minutes)
2. Review of DC Motors
3. Review of Torque, Power, Speed Formulas
4. Gear and Pulley Formulas
5. Definition of Efficiency
6. “Runaway” DC Series-Wound Motor
7. Lab Activity: DC Motor Control (60 minutes)
8. Lecture: AC Motor Control (90 minutes)
9. Review of AC Motors
10. Review of Torque, Power, Speed Formulas
11. Gear and Pulley Formulas
12. Definition of Efficiency
13. Impossibility of AC Motor “Runaway”
14. Lab Activity: AC Motor Control (90 minutes)
15. Quiz: Motor Controls

## Lesson 15: Sensors Date

1. Lecture: Sensor Safety (30 minutes)
2. Review of Power Circuit for System with PLC
3. Sensor Safety Rules
4. Review of Lock Out Tag Out (LOTO)
5. Lab Activity: LOTO Review (15 minutes)
6. Lecture: Sensor Basics (90 minutes)
7. Sensor Terms
8. Sensor Types:
9. Thermocouples
10. Proximity
11. pH
12. Strain
13. LVDT
14. Hall Effect
15. Reed Switch
16. Tachometer
17. Optical Encoders
18. Photoelectric

c. Review of Relays and Contactors

d. Sensor Calibration and Adjustment

e. Sensor Troubleshooting

f. Sensor Installation and Modification

1. Lab Activities (90 minutes):
2. Automatic Input Devices
3. Timer Control
4. Lecture: Sensor Signals (60 minutes)
5. Analog and Digital Signals
6. Voltage or Current as Signal
7. Sensor Signals
8. Step
9. Ramp
10. Trapezoid
11. Square
12. Saw Tooth
13. Random
14. With Time Delay
15. With Noise
16. With Filter
17. With Saturation

d. Sensor Signal Problems

1. Spike
2. Noise
3. Surge
4. Variance
5. Dip

e. Nyquist Frequency

1. Lab Activity: Timers (15 minutes)
2. Quiz: Sensors
3. Module Exam #3
4. Laboratory Final

# Part 4: Grading Information

## Graded Activities

### Module Exams

There will be three module exams, each worth 10% of the final grade.

### Final Exam

There will be a comprehensive final exam worth 25% of the final grade.

### Laboratory Exercises

Laboratory exercises measure skills and abilities relating to knowledge learned in class and will be worth 20% of the final grade.

### Quizzes

Quizzes on assigned material will be designed for review and evaluation of learning and will be worth 10% of the final grade.

### Homework

Doing work outside of class is critical to success. Homework is graded and will be worth 10% of the final grade.

### Class Participation

Class participation is important and will be worth 5% of the final grade.

## Grading Breakdown

Module Exams = 30%  
Final Exam = 25%  
Laboratory Exercises = 20%  
Quizzes = 10%  
Homework = 10%  
Class Participation = 5%

## Grading Scale

A = 90-100   
B = 80-89   
C = 70-79   
D = 60-69   
F = 59 and below

## Late Work

Late work will not be accepted unless it is pre-approved by the instructor. All graded work will be posted in the college learning management system with 48 hours of due date.

# Part 5: College Policies and Resources

## Policies

### Attendance

### Academic Integrity

### Campus Civilitybb

## Resources

### ****Counseling****

### ****Veterans****

### ****Students with Disabilities****

# About These Materials

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## Accessibility

The NSC has made every effort to create accessible materials, following best practices and American with Disabilities Act (ADA) guidelines. For example, to ensure screen reader systems can work with these materials, we write using plain English, heading styles in outline structure, simple layout, minimal tables and charts, bulleted and numbered lists, high-contrast colors, standard fonts, white space for ease of reading, and so on. For more information about ADA compliance, see the 2010 Design Standards on the ADA website: <http://www.ada.gov/2010ADAstandards_index.htm>.

## Disclaimer

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