ITT Technical Institute

ET3280T

Electrical Machines and Energy Conversion

Onsite Course

SYLLABUS

Credit hours: 4.5

Contact/Instructional hours: 54 (54 Theory Hours)

Prerequisite(s) and/or Corequisite(s):

Prerequisites: ET1210T DC-AC Electronics or equivalent, PH2530T Physics or equivalent

Course Description:

In this course, students study concepts of basic energy conversion and physical phenomena in electrical machine operation. Topics include magnetic materials and circuits, motors, generators, transformers and induction machines, synchronous machines and alternators.

Where Does This Course Belong?

In general, this is a fourth quarter course that is required for the Electrical Engineering and Communications Technology Bachelor program in the School of Electronics Technology. This program covers the following core areas:

- Process control
- Embedded systems
- Electronic circuit analysis and design
- Data and network communications
- Telecommunications and wireless technology
- Fiber optic communications
- Electrical machines and energy conversion
- Power electronics and power systems
- Green energy technology
- Computer programming

NOTE: *Refer to the catalog for the state-specific course and program information, if applicable.*

Course Summary

Major Instructional Areas

1. Safety considerations (NEMA, NEC, IEEE, company best practices)
2. Magnetism – Faraday's law
3. DC motors
4. Single-phase transformers
5. Single-phase motors
6. Three-phase transformers
7. Three-phase AC motors
8. Synchronous motors
9. Synchronous generators (alternators)
10. Considerations for Integration with control systems – PLCs, microcontrollers, thyristors, and/or networks

Course Objectives

1. Describe the characteristics and properties of magnetic materials.
2. Demonstrate an understanding of the fundamental principles and concepts of electromagnetic circuits.
3. Demonstrate an understanding of energy conversion in electrical power systems.
4. Describe electromechanical energy conversion components associated with power system generation, utilization, transmission, and distribution.
5. Describe the fundamental operating principles and characteristics of AC and DC motors.
6. Describe the fundamental operating principles and characteristics of AC and DC generators.
7. Describe the fundamental operating principles and characteristics of transformers.
8. Describe the fundamental operating principles and characteristics of alternators.
9. Describe the fundamental operating principles and characteristics of induction machines.
10. Describe the fundamental operating principles and characteristics of synchronous machines.

Learning Materials and References

Required Resources

Complete Textbook Package	New to this Course	Carried over from Previous Course(s)	Required for Subsequent Course(s)
Hubert, C. I. (2002). *Electric Machines: Theory, Operations, Applications, Adjustment, and Control* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.	■		■
MultiSim Simulation Software for Circuits		■	

Recommended Resources

ITT Tech Virtual Library
http://library.itt-tech.edu/Pages/default.aspx

Books> Ebrary

- Vishnu, Murthy, K. M. (2008) *Computer-Aided Design of Electrical Machines* Global Media
- Upadhyay, K. C. (2008) *Design of Electrical Machine*, New Age International
- Emerald Insight Staff (2004) *Selected Papers from the 16th International Conference on Electrical Machines*, Emerald Group Publishing
- Sorrell, C. (2005) *Materials for Energy Conversion Devices* Woodhead Publishing
- Malick, M. A. (2009) *Basic Electrical Engineering,* Global Media

Books, Professional Journals

- Kaiser, J. L. (1997). *Electrical power: Motors, controls, generators, transformers*. (3rd Ed.). Tinley Park, IL: Goodheart-Wilcox Publisher.
- Wildi, T. (2006) *Electrical Machines, Drives and Power Systems, 6/E*. Upper Saddle River, NJ: Pearson Prentice Hall.
- IEEE Power & Energy Society Magazine (bimonthly): www.ieee-pes.org/publications/ieee-power-energy-magazine
- IEEE Industry Applications Magazine (bimonthly): http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?reload=true&punumber=2943
- IEEE Spectrum Magazine (monthly): spectrum.ieee.org/

Professional Associations

- IEEE: http://www.ieee.org/index.html
- IEEE Power and Energy Society: http://www.ieee-pes.org
- ISCET: http://www.iscet.org/
- ETA: http://www.eta-i.org/

Other References

- Siemens Learning Modules http://www3.sea.siemens.com/step/default.html
  - This website provides short interactive online courses on motors and power distribution.
- Electric motors and generators http://www.animations.physics.unsw.edu.au/jw/electricmotors.html
  - Electric motors, generators, alternators and loudspeakers are explained using animations and schematics. This is a resource page from Physclips, a multi-level multimedia introduction to physics.
- How 3 Phase Induction Motors Work http://www.knoware-online.com/motors.html

    - This site provides an animated tutorial explaining 3-Phase motors.
- North American Electric Reliability Corporation http://www.nerc.com/
    - This is the home page of the electric reliability organization certified by the Federal Energy Regulatory Commission to establish and enforce reliability standards for the bulk-power system.
- Arkansas Tech University Instructional Laboratory Safety Procedures http://www.atu.edu/engineering/electrical/lab_safety_plan.shtml
    - This is a review of general safety procedures that apply to any laboratory.
- Lab Safety Facts : Electrical Safety http://www.labsafety.com/refinfo/ezfacts/ezf266.htm
    - This site reviews safety procedures for electricity and electrical equipment.
- Electric Motors: Think Change http://www.climatechange.gov.au/what-you-need-to-know/appliances-and-equipment/electric-motors.aspx
    - This site created by the Australian government contains detailed information about applications and efficiencies of electric motors.
- The Financial Impact of Motors http://www.interstates.com/Resources/Energy_Savings/thefinancialimpactofmotorselection.html
    - This site contains useful information about costs, efficiencies, and budgeting.
- Electric Motor Controls Tutorial http://www.scribd.com/doc/72759925/Electric-Motor-Controls-Tutorial
    - This teaches the methods used to control electric motors.

NOTE: All links are subject to change without prior notice.

Information Search

Use the following keywords to search for additional online resources that may be used for supporting your work on the course assignments:

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- Safety considerations (NEMA, NEC, IEEE)
- Magnetism – Faraday's law
- DC motors
- DC motor characteristics
- Single-phase transformers
- Single-phase motors
- Three-phase transformers
- Three-phase AC motors
- Synchronous motors
- Synchronous generators (alternators)

Suggested Learning Approach

In this course, you will be studying individually and within a group of your peers. As you work on the course deliverables, you are encouraged to share ideas with your peers and instructor, work collaboratively on projects and team assignments, raise critical questions, and provide constructive feedback.

Use the following advice to receive maximum learning benefits from your participation in this course:

DO	DON'T
▪ Do take a proactive learning approach. ▪ Do share your thoughts on critical issues and potential problem solutions. ▪ Do plan your course work in advance. ▪ Do explore a variety of learning resources in addition to the textbook. ▪ Do offer relevant examples from your experience. ▪ Do make an effort to understand different points of view. ▪ Do connect concepts explored in this course to real-life professional situations and your own experiences.	▪ Don't assume there is only one correct answer to a question. ▪ Don't be afraid to share your perspective on the issues analyzed in the course. ▪ Don't be negative about the points of view that are different from yours. ▪ Don't underestimate the impact of collaboration on your learning. ▪ Don't limit your course experience to reading the textbook. ▪ Don't postpone your work on the course deliverables – work on small assignment components every day.

Course Outline

Unit 1: MAGNETICS, ELECTROMAGNETIC FORCES, GENERATED VOLTAGE, AND ENERGY CONVERSION

Out-of-class work: *5.25 hours*

Upon completion of this unit, students are expected to:

- Explain magnetism, electromagnetic forces, generated voltage, and energy conversion.
- Analyze and solve basic magnetic circuits.
- Explain magnetic nomenclature and the practical meanings of magnetic concepts.
- Identify the purpose of various parts of DC machines.
- Summarize efficient and effective measures to deal responsibly with safety issues and environmental hazards, etc.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
• Hubert, Chapter 1	Exercise	Unit 1 Exercise 1: Magnetic Circuit Calculations	2%
	Assignment	Unit 1 Assignment 1: Unit 1 Homework	3%

Unit 2: PRINCIPLES OF DIRECT-CURRENT MACHINES

Out-of-class work: *6.5 hours*

Upon completion of this unit, students are expected to:

- Summarize efficient and effective measures to deal responsibly with safety issues and environmental hazards.
- Describe the configuration of direct-current generators and motors.
- Describe torque principles and motor starting principles.
- Perform calculations and solve equations for direct-current machines.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
• Hubert, Chapter 10	Exercise	Unit 2 Exercise 1: Types of DC Motors	2%
	Assignment	Unit 2 Assignment 1: Unit 2 Homework	3%

Unit 3: DIRECT-CURRENT MOTOR CHARACTERISTICS AND APPLICATIONS

Out-of-class work:
7 hours

Upon completion of this unit, students are expected to:

- Describe direct-current motor characteristics and applications.
- Measure and calculate motor speed.
- Solve equations for torque including both no load calculations and loading calculations.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
• Hubert, Chapter 11	Exercise	Unit 3 Exercise 1: Braking, Plugging, and Jogging	2%
	Assignment	Unit 3 Assignment 1: Unit 3 Homework	3%

Unit 4: TRANSFORMER PRINCIPLES

Out-of-class work:
11.5 hours

Upon completion of this unit, students are expected to:

- Explain mutual induction and mutual flux.
- Describe power and distribution transformers.
- Perform calculations and solve equations for line losses with and without transformers.
- Describe single-phase transformer concepts and their eventual application to three-phase transformer analysis.
- Identify nameplate ratings.
- Draw circuit diagrams.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
• Hubert, Chapter 2	Exam	Unit 4 Exam 1	10%
	Exercise	Unit 4 Exercise 1: Basic Concepts for Transformers	2%
	Assignment	Unit 4 Assignment 1: Unit 4 Homework	3%

Unit 5: TRANSFORMER CONNECTIONS, OPERATION, AND SPECIALTY TRANSFORMERS

Out-of-class work:
9.4 hours

Upon completion of this unit, students are expected to:

- Explain mutual induction and mutual flux.
- Describe power and distribution transformers.
- Perform calculations and solve equations for basic three-phase circuits.
- Explain Wye and Delta configurations.
- Explain autotransformer identification and basic principles.

- Identify nameplate ratings.
- Introduce and explain causes and consequences of harmonics,

and explain the design and consequences of harmonic suppression.

- Explain instrument transformers and their applications.
- Draw circuit diagrams.
- Perform calculations and solve equations for three-phase transformers.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	Activity/Deliverable Title	Grade Allocation (% of all graded work)
• Hubert, Chapter 3	Project	Project 1: DC Motor Design (*PORTFOLIO)*	5%
	Exercise	Unit 5 Exercise 1: Transformer Predictions	2%
	Assignment	Unit 5 Assignment 1: Unit 5 Homework	3%

Unit 6: SINGLE-PHASE INDUCTION MOTORS AND SPECIALTY MACHINES

Out-of-class work: *7 hours*

Upon completion of this unit, students are expected to:

- Describe single-phase AC motors.
- Explain induction motor action and split phase, shaded pole, reluctance, and hysteresis motors.
- Explain NEMA standards.
- Describe locked rotor torque, reversing motors, and fault conditions.
- Perform calculations and solve equations for equivalent circuits and power and torque.
- Explain specialty machines such as stepper motors, universal motors, reluctance motors, and hysteresis motors.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	Activity/Deliverable Title	Grade Allocation (% of all graded work)
• Hubert, Chapter 6 • Hubert, Chapter 7 (pp. 279-286 and pp. 299-301)	Exercise	Unit 6 Exercise 1: Single Phase Motor Facts	2%
	Assignment	Unit 6 Assignment 1: Unit 6 Homework	3%

Unit 7: PRINCIPLES OF THREE-PHASE INDUCTION MOTORS

Out-of-class work: *9.25 hours*

Upon completion of this unit, students are expected to:

- Perform calculations and solve equations for equivalent circuits and power

and torque.
- Describe the principles of three-phase induction motors.
- Explain specialty machines.
- Explain the classification, performance, applications, and operation of three-phase induction machines.
- Analyze and identify squirrel cage and wound rotor motors.
- Describe performance as a function of slip and stator voltage.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	Activity/Deliverable Title	Grade Allocation (% of all graded work)
• Hubert, Chapter 4 • Hubert, Chapter 7 (pp. 279-303)	Exercise	Unit 7 Exercise 1: Three Phase Motor Calculations	2%
	Assignment	Unit 7 Assignment 1: Unit 7 Homework	3%

Unit 8: CLASSIFICATION, PERFORMANCE, APPLICATIONS, AND OPERATION OF THREE-PHASE INDUCTION MACHINES

Out-of-class work: *7.6 hours*

Upon completion of this unit, students are expected to:
- Explain National Electrical Manufacturers Association (NEMA) standards.
- Describe locked rotor torque, reversing motors, and fault conditions.
- Describe the principles of three-phase induction motors.
- Perform calculations and solve equations for equivalent circuits and power and torque.
- Explain specialty machines.
- Explain the classification, performance, applications, and operation of three-phase induction machines.
- Analyze and identify squirrel cage and wound rotor motors.
- Describe performance as a function of slip and stator voltage.
- Perform calculations and solve equations for three-phase induction machines.
- Describe the construction of synchronous motors.
- Explain counter electromagnetic fields (EMF) and armature voltage.
- Describe the equivalent circuit model

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	Activity/Deliverable Title	Grade Allocation (% of all graded work)
• Hubert, Chapter 5	Exercise	Unit 8 Exercise 1: Facts about Three-Phase Induction Machines	2%
	Assignment	Unit 8 Assignment 1: Unit 8 Homework	3%

	Project	Project 2: Transformer Design (*PORTFOLIO)*	5%

Unit 9: SYNCHRONOUS MOTORS

Out-of-class work: *9 hours*

Upon completion of this unit, students are expected to

- Describe the construction of synchronous motors.
- Explain counter electromagnetic fields (EMF) and armature voltage.
- Describe the equivalent circuit model.
- Explain speed control, pull in torque, rotor excitation, and braking in synchronous motors.
- Perform calculations and solve equations for synchronous motors.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
• Hubert, Chapter 8	Exam	Unit 9 Exam 2	10%
	Exercise	Unit 9 Exercise 1: Synchronous Motor Facts	2%
	Assignment	Unit 9 Assignment 1: Unit 9 Homework	3%

Unit 10: SYNCHRONOUS GENERATORS (ALTERNATORS)

Out-of-class work: *9.4 hours*

Upon completion of this unit, students are expected to:

- Describe motor-to-generator transition.
- Explain the construction of synchronous generators.
- Perform calculations and solve equations for synchronous generators.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
• Hubert, Chapter 9	Exercise	Unit 10 Exercise 1: Understanding Synchronous Generators	2%
	Assignment	Unit 10 Assignment 1: Unit 10 Homework	3%

Unit 11: COURSE REVIEW AND FINAL EXAMINATION

Out-of-class work: *8 hours*

Upon completion of this unit, students are expected to:

- Review key concepts, principles, and applications for Units 1-10.
- Create a formula sheet to be approved by the instructor.
- Take final exam.

READING ASSIGNMENT	GRADED ACTIVITIES / DELIVERABLES		
	Grading Category	Activity/Deliverable Title	Grade Allocation (% of all graded work)
• Review Text	Exam	Final Exam	15%
	Project	Project 3: Induction Motor Selection (*PORTFOLIO)*	5%

Evaluation and Grading

Evaluation Criteria
The graded assignments will be evaluated using the following weighted categories:

Category	Weight
Assignment	30%
Project	15%
Exercise	20%
Exam	35%
TOTAL	**100%**

Grade Conversion
The final grades will be calculated from the percentages earned in the course, as follows:

Grade	Percentage	Credit
A	90–100%	4.0
B+	85–89%	3.5
B	80–84%	3.0
C+	75–79%	2.5
C	70–74%	2.0
D+	65–69%	1.5
D	60–64%	1.0
F	<60%	0.0

Academic Integrity

All students must comply with the policies that regulate all forms of academic dishonesty or academic misconduct, including plagiarism, self-plagiarism, fabrication, deception, cheating, and sabotage. For more information on the academic honesty policies, refer to the Student Handbook and the Course Catalog.

(End of Syllabus)

Outside Work Addendum

Unit Number	Explore Practice Apply	Title of Activity (for work completed OUTSIDE of class)	Type of Activity	Estimated Time of Activity (minutes)
1	Explore	Chapter 1 (34 pages)	Reading	136
	Practice	Magnetic Circuit Calculations	Assignment	60
	Apply	Homework problems	Assignment	120
2	Explore	Chapter 10 (53 pages)	Reading	212
	Practice	Types of DC Motors	Assignment	60
	Apply	Unit 2 Homework	Assignment	120
3	Explore	Chapter 11 (31 pages)	Reading	124
	Practice	Braking, Plugging, and Jogging	Assignment	60
	Apply	Unit 3 Homework	Assignment	120
	Apply	Project 1: Select Industrial Application	Project	120
4	Explore	Chapter 2 (52 pages)	Reading	208
	Practice	Transformer Worksheets	Assignment	60
	Apply	Unit 4 Homework	Assignment	120
	Apply	Project 1: DC Motor Calculations	Project	180
	Apply	Unit 4 Exam 1	Exam Prep	120
5	Explore	Chapter 3 (41 pages)	Reading	204
	Practice	Transformer Predictions	Assignment	60
	Apply	Unit 5 Homework	Assignment	120
	Apply	Project 1: DC Motor Writeup	Project	180
6	Explore	Chapter 6 (22 pages)	Reading	88
	Explore	Chapter 7 pp. 279-286, 299-301 (9 pages)	Reading	36
	Practice	Single Phase Motor Facts	Assignment	60
	Apply	Unit 6 Homework	Assignment	120
	Apply	Project 2: Transformer Research	Project	120
7	Explore	Chapter 4 (32 pages)	Reading	128
	Explore	Chapter 7 287-304 (17 pages)	Reading	68
	Practice	Three Phase Motor Calcualtions	Assignment	60
	Apply	Unit 7 Homework	Assignment	120
	Apply	Project 2: Transformer Calculations	Project	180
8	Explore	Chapter 5 (24 pages)	Reading	96
	Practice	Facts about Three-Phase Induction Machines	Assignment	60
	Apply	Unit 6 Homework	Assignment	120
	Apply	Project 2: Transformer Writeup	Project	180
9	Explore	Chapter 8 (31 pages)	Reading	124
	Practice	Synchronous Motor Facts	Assignment	60
	Apply	Unit 6 Homework	Assignment	120
	Apply	Project 3: AC Motor Research	Project	120

Unit Number	Explore Practice Apply	Title of Activity (for work completed OUTSIDE of class)	Type of Activity	Estimated Time of Activity (minutes)
	Apply	Unit 9 Exam 2	Exam prep	120
10	Explore	Chapter 9 (51 pages)	Reading	204
	Practice	Facts about Three-Phase Induction Machines	Assignment	60
	Apply	Unit 6 Homework	Assignment	120
	Apply	Project 3: AC Motor Calculations	Project	180
11	Apply	Project 3: AC Motor Writeup	Project	180
	Final Exam	Final Exam	Final Exam Prep	300