

ET 332a
Dc Motors, Generators and Energy Conversion Devices

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Office Hours: 10:00 am - 10:50 am M-W-F
2:00 pm - 3:00 pm M-W-F
or by appointment

Textbook: Electrical Machines, Theory, Operation, Applications, Adjustment, and Control, 2nd Edition, Charles I. Hubert

References: Electric Machinery and Transformers, Irving L. Kosow
"IEEE Guide: Test Procedures for Direct-Current Machines", IEEE Standard 113-1985
Energy Science Principles, Technologies, and Impacts, John Andrews and Nick Jelley

Grading Scale:	100-90%	A
	89-80%	B
	79-70%	C
	69-60%	D
	59-below	F

Hour Exams (3 at 100 points each)	50%
Final Exam (200 points)	20%
Homework	10%
Laboratory Experiments/Activities	20%

Total	100%

Note: the final exam is optional for all students that have a 90% or higher average on the hour exams, homework, and experiment/activities

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Course Policies

1. **Late Work and Makeup Exams**
No make-up exams. All homework handed in at the beginning of the period it is due. No late homework accepted. Late lab grades reduced by 5% per working day starting from due date.
2. **Attendance Policies**
Class attendance is required and attendance will be taken at the beginning of every period. Students are allowed **four** unexcused absences. Any further absences will reduce the TOTAL grade by 5% per day absent.
3. **Cell Phone/Electronic Device Usage**
Cell phone usage during meeting periods is prohibited. Devices should be TURNED OFF prior to entering class. Other electronics devices (Tablets, iPads, Readers etc) are only allowed for academic/research purposes. No electronic devices other than calculators are allowed during exams. Those violating this policy are subject to disciplinary action under the Student Conduct Code. Follow this link to review this code: (<http://policies.siuc.edu/policies/conduct.html>)
4. **Nicotine Consumption**
No use of electronic cigarettes during class.

Final Exam Scheduling Policy

The course final exam is comprehensive. The course instructor will give the exam during finals week at the time and place prescribed by the University in its final exam schedule. The University final exam schedule, which you can find on Salukinet, gives the date and time for this course final exam. The course instructor will also announce this time and date of the exam in the class several times before semester end. The final will take place in the normal lecture room.

Course Description and Prerequisites

This course introduces the theory and operation of DC machines with an emphasis on the testing and measurement of machine characteristics and parameters. The course introduces the science, application, and economics of renewable DC power using photocells. Laboratory exercises will demonstrate the theoretical concepts and give experience using various types of measurement devices and software.

Prerequisite: Engineering Technology 304a or concurrent enrollment

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Course Content Overview

This course will examine the theory and operation of DC machines. DC machines are energy conversion devices that can operate as either motors or generators. This course will cover the theory and operation of these machines. Circuit models and mathematical formulas will describe their operation. The course develops torque-speed and voltage-load characteristics of common types of DC machines. The course introduces simple protection and control schemes. The course content will emphasize machine efficiency and proper motor application. Photocell arrays are a source of dc power. This course introduces the science and application of photovoltaic devices. Simple economic comparisons highlight the cost of solar energy when compared to grid-supplied electricity. The measurement and test of machine characteristics will be carried out in laboratory experiments. Software packages will be used to eliminate tedious calculations and speed data acquisition.

Course Objectives

At the end of this course, you will be able to:

- 1.) Explain how electromagnetism can transfer electric energy to mechanical energy.
- 2.) Use the basic principles of physics to describe simple linear and rotational motion.
- 3.) Determine the torque-speed relationships for typical mechanical loads.
- 4.) Explain the key parts of magnetic circuits and perform basic magnetic circuit calculations.
- 5.) List the sources of power loss in magnetic circuits.
- 6.) Explain how electromagnetic forces produce motor action.
- 7.) Explain how electromagnetic induction produces generator voltage.
- 8.) Explain how elementary dc machines generate voltage.
- 9.) Define commutation in dc machines and list factors that affect it.
- 10.) List the parts of a practical dc machine.
- 11.) Use the model of separately excited dc generator to perform electrical calculations.
- 12.) Determine the voltage regulation of a dc generator.
- 13.) Explain how torque a separately excited dc motor develops torque.
- 14.) Use the equivalent circuit model of the separately excited dc motor to perform calculations.
- 15.) Explain the operation of a shunt connected dc motor and use an equivalent circuit model to perform calculations.
- 16.) Determine the losses and efficiency of a dc motor.
- 17.) Interpret NEMA ratings.
- 18.) Read basic motor control ladder diagrams.

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- 19.) Interpret standard motor/generator terminal markings.
- 20.) List dc motor starting methods.
- 21.) Compare and contrast the torque speed characteristics of separately excited, shunt, series, and compound connected dc motors.
- 22.) Calculate speed regulation of a dc motor.
- 23.) Calculate motor performance when magnetic circuits saturate.
- 24.) Explain how photocells convert light into electric current.
- 25.) Compute photocell voltage, current, and efficiency.
- 26.) Draw and perform calculations with a solar cell circuit model.
- 27.) Find the maximum power transfer of a solar cell.
- 28.) Analyze the economics of owning a solar panel.

Others Helpful Information

All members of the faculty and staff of SIUC are here to help you as you begin this course and all others on your schedule this semester. Attached to this syllabus is a summary sheet that includes all the important dates and other valuable information to help you succeed during your academic career at SIUC. Please feel free to communicate with the course instructor and any other staff of the Department of Technology if you have any problems and concerns. Good luck this semester.

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Course Outline

Fundamentals of Electricity

Concept of energy conversion Class Notes
Conventional currents.
Source and load power conventions.

Review of Basic Mechanics

Class Notes

Physics of mechanical motion, force, torque,
transformation of energy.
Torque-speed relationships for mechanical
loads

Magnetic Circuits

Chapter 1

Magnetic fields Sections 1-1 to 1-15
Magnetic circuits
Magnetic circuit equations
B-H curves of non-magnetic materials
B-H curves of magnetic materials
Electric and magnetic circuit analogies
Solving Magnetic circuits
Magnetic losses
Electromagnetic forces on conductors
 Motor action
Electromagnetic induction
 Generator action

Elementary Dc Machines

Chapter 10

Generated voltage in elementary dc
machines Sections 10-1 to 10-27
Commutation process Class notes
 resistive commutation
 inductive effects
 armature reaction
 brush shifting

TEST 1

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Dc Motors, Generators and Energy Conversion Devices
Course Outline

Construction of dc machines
Separately excited dc generator
Equivalent circuit
Voltage regulation
Motor-generator operation
Developed torque
Separately excited dc motors
Equivalent Circuit
Basic shunt motor operation
 Equivalent circuit
 dynamic operation
 speed regulation
Speed equations
Torque and power
Losses and efficiency
NEMA ratings
Ladder diagrams
DC motor starting
Step Resistor Starting

Class notes

DC Motor Characteristics

Chapter 11

Shunt motors

Compound motors

Sections 11-1, 11-12

Differential Compound motors

Series motors

Saturation effects

Linear approximations

Characteristics compared

Control

 Variable voltage drive systems

 Dynamic braking

 Plugging/Jogging

Standard terminal markings and connections

TEST 2

Control of Dc Machines

Chapter 13

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Course Outline

Control Components	Sections 13-1 to 13-5, 13-9 to 13-15
Control diagram conventions	
Overload protection	
Short circuit protection	
Auto shutdown for power failure	Class notes
Reversing starters with braking	
<u>Renewable dc Power Sources</u>	Class notes
Solar energy	Handouts
Solar intensity	
Conductors, insulators, and semiconductors	
PN junction	
Photo-electric effect	
Solar cell electrical characteristics	
Circuit model of solar cells	
Cell efficiency	
Solar panels	
Economics of solar power	TEST 3
Final Review	Final Exam

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Homework Listing

Assignment #	Problems	Location
1	1-1/4, 1-2/4	Chapter 1
2	1-4/5, 1-5/5	Chapter 1
3	1-7/5	Chapter 1
4	hw1.wp5	handout
5	hw2.wp5, hw3.wp5	handout
6	1-10/6	Chapter 1
7	1-11/7, 1-12/7	Chapter 1
8	hw4.wp5, hw4a.wp5	handout
9	10-1/2, 10-2/2	Chapter 10
10	10-3/7, 10-4/7	Chapter 10
11	10-5/7, 10-6/7	Chapter 10
12	sepmtr.wp5	handout
13	hw5.wp5, hw6.wp5	handout
14	10-9/12	Chapter 10
15	10-8/12	Chapter 10
16	10-19/22 ¹	Chapter 10
17	hw7.wp5	handout
18	hw8.wp5, 10-25/26 ²	handout/Chapter 10
19	hw9.wp5	handout
20	10-27/27, 10-21/25	Chapter 10
21	hw10.wp5	handout
22	11-1/7	Chapter 11
23	11-11/7	Chapter 11
24	11-10/7	Chapter 11
25	Short Answer Questions 12, 13	Chapter 11
26	6.1, 6.2	PV handout
27	6.6, 6.8	PV handout
28	6.9 6.11	PV handout

¹The value of the resistor in part a is incorrect. Use a value of 0.052 ohms.

²The answers in the back of the book are incorrect. Use a.) 1705.2 W b.) 3270.8 W c.) 93.8%

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Laboratory Activities and Experiments

- 1.) **Using Spreadsheets in Laboratory Calculations**
(Handouts)
The Excel spreadsheet is introduced and used to produce graphs that are commonly found in technical reports. Linear graphs are produced. Semi-log plots are created by using a log function to reduce the range of the data and by using the scaling abilities of the spreadsheet. Embedding the results into reports is also demonstrated. The Microsoft Equation Editor is demonstrated. A student activity uses the developed skills to make plots and produce professional solutions to technical problems.

- 2.) **Power Laboratory Safety and Work Procedures/Resistance of DC machines**
(Hampden Experiment 1)
Students are instructed in high voltage laboratory safety rules. Avoiding electric shock and other safety hazards encountered in the power lab are covered. The basic operation of the fractional-horsepower motor lab equipment will be covered. The class will perform a simple experiment to determine the dc resistance of the field and armature coils of a typical dc motor.

- 3.) **Saturation Curve of a Generator**
(Hampden Experiment 2)
The main object of this lab is to obtain the necessary data to plot a saturation curve of a separately excited dc generator. The shape of this curve is a scaled representation of a machine's B-H curve. The effects of saturation on the output of a generator are observed.

- 4.) **Counter EMF Force**
(Hampden Experiment 16)
The counter EMF force of a dc machine will be observed. The laws of induction and force on a conductor will be verified using a dc machine.

- 5.) **Load Characteristics of a Separately-Excited Shunt Generator**
(Hampden Experiment 6)
The load level Vs terminal voltage characteristic of a separately-excited shunt generator is developed. The voltage output capabilities of the machine are examined at the rated speed and field current of the device.

- 6.) **Shunt Motor Characteristics**
(Hampden Experiment 18)
The speed-torque characteristic of the shunt dc motor is determined experimentally. The speed regulation of the machine will be found. The relationship between the load torque and the armature current is examined.
- 7.) **Efficiency and Losses in a Dc Shunt Motor**
(Hampden Experiment 21)
The operating efficiency of a shunt dc machine will be determined by lab tests. The sources of losses in dc machines are identified and measured. These losses can be divided into fixed and load-variable components.
- 8.) **Series Motor Characteristics**
(Hampden Experiment 19)
The speed-torque characteristic of the series dc motor is determined experimentally. The speed regulation of the machine will be found. The relationship between the load torque and the armature current is examined.
- 9.) **Compound Motor Characteristics**
(Hampden Experiment 20)
The speed-torque characteristic of the compound dc motor is determined experimentally. The speed regulation of the machine will be found. The relationship between the load torque and the armature current is examined.
- 10.) **Shunt Generator Output Polarity and Voltage Build-up**
(Hampden Experiment 3)
This experiment covers the correct procedures for preparing a shunt generator to for operation. The voltage build-up process is examined. The proper connections for voltage build-up are given.
- 11.) **Field Resistance Vs Generator Voltage Build-up/Motor Control Simulator**
(Hampden Experiment 4)
This lab examines the affects of field resistance on generator voltage build-up. The lab demonstrates the effect of excessive field resistance on terminal voltage. The second section introduces ladder diagrams and motor control with an animated, computer-based simulator.
- 12.) **PV Array Economics Report**

Students survey the Web and other technical resources to determine the cost and feasibility of utilizing solar power in a grid-tied residential application. A short report summarizes the findings.

Lab Reporting Format

The laboratory procedure will be handed out approximately a week before it will be performed. Reading the lab prior to lab makes the performance of the experiment more efficient. All data collected in lab must be initialed and dated by the lab instructor. All reports submitted without instructor verification will receive a zero.

The experiments for this course will be reported in an abbreviated format. The laboratory handout has an experiment objective and procedure included. There is no need to restate these sections in another report. To fully document the results of the experiment, all questions, problems and graphs required by the laboratory handout must be completed. Also, a discussion of the topics covered in the experiment and how they relate to the lecture material should be completed. This discussion should be at least one page type written and double-spaced.

The report should have the following sections:

- 1.) Cover page that is like the one attached to this document
- 2.) All the pages from the laboratory handout that have questions, problems, tables, graphs.
- 3.) Discussion

It is permissible to answer the questions/problems on a separate sheet, but the questions and problems must be numbered and all the answers typed. Some of the lab handouts have places to make graph in them. It is also permissible make graphs using software packages such as Excel instead of using this page. If a graph is made on a separate sheet it must have:

- 1.) A title
- 2.) Labels on each axis
- 3.) Units on each axis
- 4.) A legend if more than on curve is on the same axis. This identifies each curve on the graph.

The graphs should be scaled to show the data in the most meaningful way. Change the graph limits so the curve covers most of the axis.

Hints for Good Reports

- 1.) Follow the format. If you are not sure about how something should be done, ask the lab or lecture instructor.
- 2.) Use computer tools whenever possible. (Word processors, drawing tools spreadsheets) If you have never had any experience with some of these tools or have a question about how to perform a function using the common software tools ask the lab or lecture instructor.
- 3.) Spell-check the document.
- 4.) Proof-read the document at least once.

Southern Illinois University at Carbondale

Department of Technology

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Electromagnetic Principles and Devices

Experiment #

Experiment Title

Reported by: your name here

Performed By: student name 1
student name 2
student name 3

Date Performed:

Fall 2003

lab332a3.wp5

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Lab Report Grading and Attendance Policies

Grading

The following table shows the point distribution and items that will be graded in the ET 332 lab report. If all listed items are included and correct, then the maximum grade is received.

Only include the pages from the lab handout that show data and have answers to questions. This includes both the De-Briefing and Quick Quiz sections. All graphs should be generated using a computer program such as Excel. Include the graphs required by the lab procedures and any additional ones specified by the lab instructor.

Late labs will have point totals reduced by 5 points per working day. After one week, late labs will not be accepted

Attendance

Students are expected to be seated in the lab at the scheduled starting time. An attendance sheet will be circulated at the beginning of the lab period. Everyone is responsible for signing this sheet. Anyone entering the lab after the scheduled starting time will be considered late and the work that they are intending to hand in will be considered late by one day. The lab instructor will be available before the lab period begins to answer questions and assist in experimental setups.

Pre-lab Online Presentations

Each lab has an online audio/video presentation describing major technical points and details of the procedure. Students should view these lab presentations before attempting to perform the experiments. The lab instructor may give pop quizzes based on these presentations to test basic knowledge. Students can reference these presentations while writing their experimental discussions

Item	Points	Comments
Title Page	5 pts	The title page must follow the given format exactly to receive credit. See the examples in the syllabus and from the lab T.A.
De-Briefing Questions	20 pts	Complete all short answer questions correctly and completely. Print question responses clearly. Unreadable responses will be considered wrong. Use complete sentences and good grammar. Graphs are sometimes included in this section. Always use a computer program to generate these plots. Additional tables of the collected data can be included with the graphs, but are not required.
Experimental Results	10 pts	All data tables must be filled and contain reasonably accurate values. The values should be written clearly. The data tables must be signed by the T.A. before leaving lab. Unsigned data will receive no credit.
Quick Quiz	20 pts	Correctly answer all multiple choice questions listed in the lab handout. Include these pages in the report.
Discussion	45 pts	To receive maximum credit for the discussion section, each topic on the discussion point handout must be included and thoroughly explained. The discussion can be up to three pages in length. It must be typed with no greater than a 12 point font and double spaced.

"We emphasize student achievement and success because achievement and success are essential if we are to shape future leaders and transform lives." ¹

<http://pvcaa.siu.edu/>

IMPORTANT DATES *

<u>Semester Class Begins</u>	08/18/2014
<u>Last day to add a class</u> (without instructor permission):	08/24/2014
<u>Last day to withdraw completely and receive a 100% refund:</u>	08/31/2014
<u>Last day to drop a course using SalukiNet:</u>	10/26/2014
<u>Last day to file diploma application</u> (for name to appear in Commencement program):	10/31/2014
<u>Final examinations:</u>	12/8–12/12/2014

Note: For outreach, internet, and short course drop/add dates, visit

Registrar's Academic webpage <http://registrar.siu.edu/>

FALL SEMESTER HOLIDAYS

Labor Day 09/01/2014

Fall Break 10/11—10/14/2014

Veterans Day 11/11/2014

Thanksgiving Vacation 11/26—11/30/2014

WITHDRAWAL POLICY ~ Undergraduate only

Students who officially register for a session may not withdraw merely by the stopping of attendance. An official withdrawal form needs to be initiated by the student and processed by the University. For the proper procedures to follow when dropping courses and when withdrawing from the University, please visit <http://registrar.siu.edu/pdf/ugradcatalog1314.pdf>

INCOMPLETE POLICY~ Undergraduate only

An INC is assigned when, for reasons beyond their control, students engaged in passing work are unable to complete all class assignments. An INC must be changed to a completed grade within one semester following the term in which the course was taken, or graduation, whichever occurs first. Should the student fail to complete the course within the time period designated, that is, by no later than the end of the semester following the term in which the course was taken, or graduation, whichever occurs first, the incomplete will be converted to a grade of F and the grade will be computed in the student's grade point average. For more information please visit:

<http://registrar.siu.edu/grades/incomplete.html>

REPEAT POLICY

An undergraduate student may, for the purpose of raising a grade, enroll in a course for credit no more than two times (two total enrollments) unless otherwise noted in the course description. For students receiving a letter grade of A,B,C,D, or F, the course repetition must occur at Southern Illinois University Carbondale. Only the most recent (last) grade will be calculated in the overall GPA and count toward hours earned. See full policy at <http://registrar.siu.edu/pdf/ugradcatalog1314.pdf>

GRADUATE POLICIES

Graduate policies often vary from Undergraduate policies. To view the applicable policies for graduate students, please visit <http://gradschool.siu.edu/about-us/grad-catalog/index.html>

DISABILITY POLICY

Disability Support Services provides the required academic and programmatic support services to students with permanent and temporary disabilities. DSS provides centralized coordination and referral services. To utilize DSS services, students must come to the DSS to open cases. The process involves interviews, reviews of student-supplied documentation, and completion of Disability Accommodation Agreements.

<http://disabilityservices.siu.edu/>

PLAGIARISM CODE

<http://pvcaa.siu.edu/common/documents/Plagiarism/Guide%20to%20Preventing%20Plagiarism.pdf>

SALUKI CARES

The purpose of Saluki Cares is to develop, facilitate and coordinate a university-wide program of care and support for students in any type of distress—physical, emotional, financial, or personal. By working closely with faculty, staff, students and their families, SIU will continue to display a culture of care and demonstrate to our students and their families that they are an important part of the community. For Information on Saluki Cares: (618) 453-5714, or siucares@siu.edu, <http://salukicare.siu.edu/index.html>

EMERGENCY PROCEDURES

Southern Illinois University Carbondale is committed to providing a safe and healthy environment for study and work. We ask that you become familiar with the **SIU Emergency Response Plan** and **Building Emergency Response Team (BERT)** programs. Emergency response information is available on posters in buildings on campus, available on BERT's website at www.bert.siu.edu, Department of Safety's website at www.dps.siu.edu (disaster drop down) and the Emergency Response Guideline pamphlet. Instructors will provide guidance and direction to students in the classroom in the event of an emergency affecting your location. **It is important that you follow these instructions and stay with your instructor during an evacuation or sheltering emergency.**

INCLUSIVE EXCELLENCE

SIU contains people from all walks of life, from many different cultures and sub-cultures, and representing all strata of society, nationalities, ethnicities, lifestyles, and affiliations. Learning from and working with people who differ is an important part of education as well as an essential preparation for any career. For more information please visit: <http://www.inclusiveexcellence.siu.edu/>

MORRIS LIBRARY HOURS

<http://www.lib.siu.edu/about>

LEARNING AND SUPPORT SERVICES

Help is within reach. Learning support services offers free tutoring on campus and math labs. To find more information please visit the Center for Learning and Support Services website:

Tutoring : <http://tutoring.siu.edu/>

Math Labs http://tutoring.siu.edu/math_tutoring/index.html

WRITING CENTER

The Writing Center offers free tutoring services to all SIU students and faculty. To find a Center or Schedule an appointment please visit <http://write.siu.edu/>

AFFIRMATIVE ACTION & EQUAL OPPORTUNITY

Our office's main focus is to ensure that the university complies with federal and state equity policies and handles reporting and investigating of discrimination cases. For more information visit:

<http://diversity.siu.edu/#>

Additional Resources Available:

SALUKINET: <https://salukinet.siu.edu/cp/home/displaylogin>

ADVISEMENT: <http://advisement.siu.edu/>