Summer 2023, Session I - Course Syllabus : Fundamentals of Wind Power

Course: ECE & ME 4570 / 6570 - Fundamentals of Wind Power, 3(3,0)

Class Time: Monday - Friday (on line course)

Instructor: Dr. John Wagner, Professor of Mechanical Engineering, jwagner@clemson.edu
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Clemson University, Clemson, SC 29634-0921, 864-656-7376
Skype Name: john.wagner.clemson

Teaching Assistant (TA): tbd

Office Hours: *Virtual Sessions: Questions can be directed to Dr. Wagner and the TA during their (a) scheduled availability as identified in periodic course e-mails, or (b) specific appointments per student's request as communicated and confirmed through e-mail.

*E-mails: Generally limited to administrative questions and the arrangement of virtual appointments for Dr. Wagner and the TA

Appointments: You can arrange for a meeting by sending an e-mail to Dr. Wagner or the TA.

Textbooks: J. F. Maxwell, J. G. McGowan, and A. L. Rogers, Wind Energy Explained – Theory, Design, and Applications, Chicago: John Wiley & Sons, 2010, ISBN: 978-0-470-01500-1. (*Recommend hardcopy to accommodate Respondus LockDown*)

Dr. John Wagner, Fundamentals of Wind Power, Lecture Notes and Homework Problems, May 2023. (*Canvas: Suggest printing a copy to accommodate Respondus)*

References: M. Hansen, Aerodynamics of Wind Turbines, London, UK: Earthscan Jan 2013.

S. Heier, Grid Integration of Wind Energy Conversion Systems, Hoboken, NJ: John Wiley & Sons, 2014.

F. M. Vanek, L. D. Albright, and L. Angenent, Energy Systems Engineering – Evaluation & Implementation, Chicago: McGraw Hill Education, 2016.

Catalog Description:

Introduces wind turbine systems, including wind energy potention and application to power generation. Topics include wind energy principles, wind site assessment, wind turbine components, power generation machinery, control systems, connection to the electric grid, and maintenance. May also be offered as ECE & ME 6570. Preq: ECE 2070 or ECE 3200 with a C or better.

Course Objectives:

1. To develop historical and societal perspectives regarding the demand for mechanical and electrical power generation from the renewable wind using land and offshore turbines.
2. To identify and mathematically model the wind turbine components, calculate the available wind power, predict mechanical loads based on design, and discuss power generation.

3. To numerically simulate the wind turbine dynamic system behavior with integration of components, sensors, and control for given application.
4. To evaluate the environmental, political, and economic issues associated with wind energy.

Attendance Policy:

This is an on-line course, so physical attendance is not applicable. However, it is expected that you will view each of the on-line section slides and videos posted on Canvas. You will be responsible for all material covered in class, both from the slides and the required textbook.

Class E-mail:

We will use the Canvas Announcement and E-Mail utilities to communicate with the class members. You should check your announcements and e-mail regularly, since we will send out important information and reminders this way. You can also contact the instructor and teaching assistant using the e-mail address(es) listed as well as occasional telephone calls.

On Line Procedures:

ECE & ME 4570 / 6570 is an on-line course during the Summer One session. All materials, except for the textbook, will be provided on Canvas. The suggested study pace for the course will also be posted. Procedures for taking the two on-line exams will be provided to the class via Canvas postings and/or e-mail messages.

We will only answer e-mails related to administrative issues. It is too difficult and time consuming to answer technical questions with an e-mail. If you really believe you need to ask a quick technical question using e-mail, then please send it to the teaching assistant. Technical questions to us can be asked by making an appointment to call the TA or instructor.

Course Grading:

Final grades will be determined by statistically weighting the homework, midterm exam, and the final exam based on the scale listed below which is composed of three components.

ECE & ME 4570	Homework (assignments throughout summer session)	= 20 %
	Midterm Examination (2.5 hours)	= 40 %
	Final Examination (2.5 hours)	= 40 %
	Total	= 100%

ECE & ME 6570	Homework (assignments throughout summer session)	= 15 %
	Midterm Examination (2.5 hours)	= 30 %
	Final Examination (2.5 hours)	= 30 %
	Design Project	= 25 %
	Total	= 100%

Grading Policy:

All questions and problems regarding examination grades must be presented in writing within two (2) school days after the particular test score has been posted. Course grades will be assigned based on all the work you have completed during the session following traditional

practices. In ECE & ME 4570, A=90-100, B=80-89, C=70-79, D=60-69, and F<60, while for ECE & ME 6570, A=90-100, B=80-89, C=70-79, and F<70.

Midterm & Final Exam (Test Attendance Policy)

There will be an open book, open notes, and open homework midterm exam and final exam. You will be allowed to have one 8.5"*11" sheet of paper for each exam on which you may write anything you wish; you may bring along the original sheet to the final. Exams will be on-line multiple choice, fill-in-the-blank, true/false, and/or essay questions. The midterm and final exam will be held on Days 15-of-27 and 27-of-27 (refer to the Suggested Study Pace for Course) and will be 2½ hours in duration. You will be required to use Respondus LockDown Browser with Web Camera on your computer when completing the Canvas-based tests which will not allow use of on-line accessed learning materials during the exams.

An absence from a test will only be excused for a medical reason or a serious immediate family problem. A student who anticipates missing a test should speak with the instructor at least one week prior to the exam date. No make up tests will be given. However, the respective course grading weights listed above might be adjusted (at the discretion of the instructor) to accommodate a missed examination if a compelling basis can be established by the student.

Exam Administration:

You will be required to have an internet connected computer (laptop, desktop) with functional web camera that can access Clemson University's Canvas utility for the two exams. In addition, you are required to use the Respondus LockDown Browser and Respondus Monitor (Web Camera) on your computer when completing the two exams for virtual proctoring.

It is important to verify the operational functionality of your hardware/software by Day 05-of-27 (Validate Respondus Lockdown Browser + Web camera). To ensure the timely completion of this task, a 1% penalty in the final course score will be assessed for each day that the student has not verified that their computer hardware/software is functional for exams by Day 05-of-27. Please take the opportunity in the beginning days of the course to complete the Canvas-based two question non-graded practice test to evaluate and demonstrate your system.

Homework:

Homework assignments along with the solutions will be posted on-line. Students are required to work out the problems in their own handwriting / self-generated computer responses, scan them into a PDF file, and submit their assignments. The homework solutions are due on days 13-of 27 (Sets 1-6) and 25-of-27 (Sets 7-11) as single PDF files to Canvas (note: requested file size <12MB). Working these problems is essential to the learning of the course materials. In fact, most of your learning will come from doing the homework. It is expected that your solutions will represent your own work, although working in groups is allowed, and even encouraged. To reduce the submitted homework for grading, you can select to work 6-of-9 problems for the section assignments. Please complete the "Grading Sheet for Homework Problem Sets of Sections 01-11" form and attach as a cover sheet for each submission. *No late homework will be accepted for grading*.

Design Project (Applies to ECE & ME 6570 Students):

A multiple week comprehensive design project will be assigned on day 1-of-27 for ECE & ME 6570 students to fulfill the graduate requirements of this technical elective. This multi-disciplinary project, due on day 25-of-27, requires the student to prepare a thorough, yet concise, engineering report that fully covers the important issues associated with a small-scale wind turbine installation. The assignment features wind turbine operation and system design, tower selection, electric power connect, control system, economic analysis, and acoustic/ environmental analysis. Complete information regarding the project, including the scoring rubric, are available in separate documents.

Integrity Disclaimer on Design Project Title Page: All submitted reports must include a signed integrity disclaimer at the top of the front page to be accepted. The disclaimer must be signed by the student. The disclaimer must state, "*I certify that all the writing is my own and not acquired from external sources. I have cited sources appropriately and paraphrased correctly. I have not shared my writing with other students, nor have I acquired any written portion of this document from past or present students*."

All design reports must be submitted to Canvas at which time they will be immediately scanned for plagiarism. In the event of plagiarism, a zero will be immediately assigned to the report. Further, the plagiarism will be documented and may be submitted to the appropriate Clemson University academic office.

Academic Honesty (Clemson University Undergraduate and Graduate Announcements):

"*As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning." Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or stealing in any form.*"

For ECE & ME 4570 students, "When, in the opinion of a faculty member, there is evidence that a student has committed an act of academic dishonesty, the faculty member shall make a formal written charge of academic dishonesty, including a description of the misconduct, to the Associate Dean for Undergraduate Studies. The reporting person may, at his/her discretion, inform each involved student privately of the nature of the alleged charge. In cases of plagiarism (I.B.2.) instructors may use, as an option, the Plagiarism Resolution Form available from the Office of Undergraduate Studies."

Those students enrolled in ECE & ME 6570 should refer to the Clemson University Graduate School Policies & Procedures Handbook for the graduate level academic honesty materials.

Academic Integrity:

Anyone caught in an act of academic dishonesty (cheating) will be penalized to the extent allowed by Clemson University Academic Regulations. It is the responsibility of the student to become familiar with the official definitions of plagiarism and penalties for violating the

academic integrity policies. For details, see the most recent undergraduate and graduate announcements on academic integrity.

Canvas:

The Canvas utility (www.clemson.edu/canvas) will be used for this course. For students not familiar with this utility, please visit the Clemson Computer & Information Technology site at *https://ccit.clemson.edu*. Inside Canvas itself, the Course Syllabus, Course Schedule, and Examination Virtual Proctor materials are located in the "Modules" area if not displayed upon log in. Similarly, the Homework Assignments, Homework Solutions, Learning Material Sections (Slides), Learning Material Lectures (MP4 Files), Homework Submission, and Laplace Transform Tables will also be placed in the "Modules" area too. Some supplemental materials will also be available on Canvas for the student to review.

You are encouraged to have updated hardware/software on the designated testing computer to properly view the illustrations that will appear on the Canvas hosted midterm and final exams.

Calculator and Computer Usage:

You will need a scientific calculator for this class for both the homework and the two examinations. The software package MATLAB (The Mathworks) or equivalent (e.g., OCTAVE) may be used for the homework assignments (optional and not required) but not the two examinations. Students completing the design project should plan on submitting a professional appearing comprehensive report featuring text, equations, numerical calculations, graphical results, etc. These individuals may wish to draw upon a variety of computer tools.

Accessibility Statement:

Any student with an official Clemson University recognized learning disability should kindly inform the instructor within the 1st week of the course (by day 06-of-27) so that appropriate arrangements can be made to meet the individual's needs.

"Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to a class should let the professor know and make an appointment to meet with a staff member in Student Accessibility Services as soon as possible. You can make an appointment by calling 864-656-6848 or by emailing studentaccess@lists.clemson.edu. Students who receive Academic Access Letters are strongly encouraged to request, obtain and present these to their professors as early in the semester as possible so that accommodations can be made in a timely manner. It is the student's responsibility to follow this process each semester. You can access further information here: http://www.clemson.edu/campus-life/campus-services/sds/."

Clemson UniversityTitle IX (Sexual Harassment) Statement:

"This policy is located at http://www.clemson.edu/campus-life/campus-services/access/title-ix/. Ms. Alesia Smith is the Clemson University Title IX Coordinator and the Executive Director of Equity Compliance. Her office is located at 110 Holtzendorff Hall, 864.656.3181

(voice) or 864.656.0899 (TDD). The statement is as follows: 'Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity in employment, educational programs and activities, admissions and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972.'"

Course Topical Outline:

1. Introduction
2. Historical Perspectives on Wind Turbines
    a. Windmills and Wind Turbines
    b. Global Installations
    c. Case Study – Aermotor Windmill
3. Wind Energy System Components
    a. Blades, hub, nacelle
    b. Gearbox, generator, brakes
    c. Tower, foundation, control system
4. Turbine Design
    a. Review of Fluid Flow Concepts
    b. Aerodynamics and Wind Machines
    c. Blade Design
5. Mechanics and Dynamics
    a. Drivetrain Components
    b. General Principles Primer (stress, strain, vibrations)
    c. Rotor Dynamics
6. Electrical Aspects of Wind Turbines
    a. Electrical Fundamentals
    b. Electrical Machines
    c. Power Converters and Ancillary Equipment
7. Fatigue and Wind Turbine Design
    a. Primer on Fatigue
    b. Fatigue in Wind Systems
    c. Wind Turbine Design Process
8. Wind Turbine Control
    a. Control Primer
    b. Wind Turbine Model
    c. System Monitoring
9. Wind Energy System Economics
    a. Engineering Economics Basics
    b. Wind Turbine Cost Analysis
10. Wind Farm Feasibility Studies
    a. Wind Turbine Siting
    b. Environmental and Wildlife Impact
    c. Noise Issues
11. Conclusion

ECE & ME 4570 / 6570 (On Line): Fundamentals of Wind Power – Summer 2023
Reading, Homework, Section Slides, and Section Video Assignments

Dr. John Wagner, Department of Mechanical Engineering, Clemson University, Clemson, SC

The following is a list of materials that will be covered in this on-line multi-disciplinary technical elective course. You are expected to read the various chapters and topics in the required class textbook, review the section slides, and listen to the section videos. The homework assignments are listed and their solutions will be provided to facilitate your learning on the first day of the class. The material covered in the lectures and homework assignments are the key to what you will actually be tested on in the course. The slides and videos are meant to be read and listened too several times for maximum benefit which is an advantage over traditional instruction methods All of these materials are available on Canvas.

Section 1: Introduction – Wind Energy
Homework Assignment & Solution: 01
Slides: ECE_ME4570_Section01_Slides (pp. 1 – 24)
Video: ECE_ME4570_Section01_Video
Assigned Reading: †Chapter 1.1

Section 2: Historical Perspective on Wind Energy – Windmills, Wind Turbines, and Global Installations
Homework Assignment & Solution: 02
Slides: ECE_ME4570_Section02_Slides (pp. 25 - 47)
Video: ECE_ME4570_Section02_Video
Assigned Reading: †Chapters 1.2, 2.1-2.2

Section 3: Wind Energy System Components – Wind Turbine Operation
Homework Assignment & Solution: 03
Slides: ECE_ME4570_Section03_Slides (pp. 48 - 67)
Video: ECE_ME4570_Section03_Video
Assigned Reading: †Chapter 6.5

Section 4: Turbine Design – Aerodynamics, Blade Design, and Wind Machines
Homework Assignment & Solution: 04
Slides: ECE_ME4570_Section04_Slides (pp. 68 - 112)
Videos: ECE_ME4570_Section04_PartA_Video, ECE_ME4570_Section04_PartB_Video, and ECE_ME4570_Section04_PartC_Video
Assigned Reading: †Chapters 2.8, 3

Section 5: Mechanics and Dynamics – Wind Loads, Basic Principles, and Rotor Dynamics
Homework Assignment & Solution: 05
Slides: ECE_ME4570_Section05_Slides (pp. 113 – 166)
Videos: ECE_ME4570_Section05_PartA_Video, ECE_ME4570_Section05_PartB_Video, and ECE_ME4570_Section05_PartC_Video
Assigned Reading: †Chapter 4

Section 6: Electrical Aspects of ;Turbines – Fundamentals, Electrical Machines, Power Converters
Homework Assignment & Solution: 06
Slides: ECE_ME457_Section06_Slides (pp. 167 – 198)
Videos: ECE_ME457_Section06_PartA_Video, ECE_ME457_Section06_PartB_Video
Assigned Reading: †Chapter 5

Section 7: Fatigue and Wind Turbine Design – Fundamentals, Fatigue, and System Design
Homework Assignment & Solution: 07
Slides: ECE_ME4570_Section07_Slides (pp. 199-224)
Videos: ECE_ME4570_Section07_PartA_Video, ECE_ME4570_Section07_PartB_Video
Assigned Reading: †Chapters 6, 7

Section 8: Wind Turbine Control – Control Primer, Implementation, Modeling, and Diagnostics
Homework Assignment & Solution: 08
Slides: ECE_ME4570_Section08_Slides (pp. 225 – 268)
Videos: ECE_ME4570_Section08_PartA_Video, ECE_ME4570_Section08_PartB_Video
Assigned Reading: †Chapter 8

Section 9: Wind Energy System Economics – Engineering Economics and Wind Energy Economic Assessment
Homework Assignment & Solution: 09
Slides: ECE_ME4570_Section09_Slides (pp. 269 – 296)
Videos: ECE_ME4570_Section09_PartA_Video, ECE_ME4570_Section09_PartB_Video
Assigned Reading: †Chapter 11

Section 10: Wind Farm Feasibility Studies – Onshore and Offshore Farm Siting with Environmental Aspects
Homework Assignment & Solution: 10
Slides: ECE_ME4570_Section10_Slides (pp. 297 – 327)
Videos: ECE_ME4570_Section10_PartA_Video, ECE_ME4570_Section10_PartB_Video
Assigned Reading: †Chapters 2.3-2.9, 9, 12

Section 11: Conclusion – Renewable Wind Energy
Homework Assignment & Solution: 11
Slides: ECE_ME4570_Section11_Slides (pp. 328 – 342)
Video: ECE_ME4570_Section11_Video
Assigned Reading: †Chapter 10

Reading Assignment: †J. F. Maxwell, J. G. McGowan, A. L. Rogers, Wind Energy Explained, 2010.

Course Calendar and Suggested Study Pace

No.	Section	Activities	Date
1	1	Section #01 Video, HW 1	05.16.2023 (First Day of Class)
2	2	Section #02 Video, HW 2	05.17.2023
3	3	Section #03 Video, HW 3	05.18.2023
4	4	Section #04 - Part A Video, HW 4	05.19.2023
5	4	Section #04 – Part B Video; **Validate Respondus Lockdown Browser + Webcam Functionality on Practice Test (Last Day)**	**05.22.2023**

6	4	Section #04 – Part C Video; **Learning Disability Notification**	**05.23.2023**
7		Self-Review of Sections 1-4	05.24.2023
8	5	Section #05 – Part A Video, HW 5	05.25.2023
9	5	Section #05 – Part B Video	05.26.2023
		Memorial Day Holiday	*05.29.2023*
10	5	Section #05 – Part C Video	05.30.2023
11	6	Section #06 – Part A Video, HW 6	05.31.2023
12	6	Section #06 – Part B Video	06.01.2023
13		Self-Review of Sections 1-6; **Submit Homework (Sets 1-6)**	**06.02.2023**
14	7	Section #07 – Part A Video, HW 7	06.05.2023
15		**Midterm Exam over Sections 1-6**	**06.06.2023**
16	7	Section #07 – Part B Video	06.07.2023
17	8	Section #08 – Part A Video, HW 8	06.08.2023
18	8	Section #08 – Part B Video	06.09.2023
19		Self-Review of Sections 7-8	06.12.2023
20	9	Section #09 – Part A Video, HW 9	06.13.2023
21	9	Section #09 – Part B Video	06.14.2023
22	10	Section #10 - Part A Video, HW 10	06.15.2023
23	10	Section #10 – Part B Video	06.16.2023
24	11	Section #11 Video, HW 11	06.19.2023
25		Self-Review of Sections 9-11; **Submit Homework (Sets 7-11)**; **Design Project**	**06.20.2023 (Last Day of Class)**
26		Self Review of Sections 1-11	06.21.2023 (Study Day)
27		**Final Exam over Sections 1-11**	**06.22.2023**