Wind Energy, Theory & Application

ME-511WS

2023 Spring Semester

Instructor: Charles Cohn
Course Web Address: https://sit.instructure.com/courses/35203/modules
Course Schedule: Monday-Sunday
Contact Info: Canvas e-mail or charlescohn17@yahoo.com, Tel. 973-696-4611
Virtual Office Hours: Any time during the week, 9:00am – 5:00pm
Prerequisite(s): None
Corequisite(s): None
Cross-listed with: None

COURSE DESCRIPTION

This course provides a description of the fundamentals of converting wind energy to electricity and its effective use for a variety of applications. The topics span a wide range of fields, from meteorology through mechanical, electrical, aerodynamic and structural engineering, to economics and environmental concerns. It is very likely that the students will not have a background in all the disciplines mentioned, but the topics are covered in sufficient detail for everyone's understanding.

The course is intended for students who have an interest in alternate energy sources as a contributor to sustainability. It will provide a comprehensive treatise on the science and technology of converting wind energy to electricity and its applications. Using the knowledge gained from the course, the students are expected to complete a class project designing a small scale wind project.

STUDENT LEARNING OUTCOMES

At the successful completion of this course, the student will be able to:

- Understand the factors that influence the use wind power as an energy source.
- Use of wind speed instruments.

- Identify the various wind energy systems.
- Identify the components in wind turbines.
- Identify the towers and foundations used for onshore and offshore wind turbines.
- Predict wind energy production.
- Have the ability to apply design principles in selecting an appropriate wind energy system to meet requirements.
- Capable of analyzing/designing a wind energy system to either only generate electricity or run water pumps.
- Identify the economic and non-economic benefits of wind turbines.
- Identify the various energy storage capabilities.

COURSE FORMAT AND STRUCTURE

This course is fully online. To access the course, please visit stevens.edu/canvas . For more information about course access or support, contact the Technology Resource and Assistance Center (TRAC) by calling 201-216-5500.

Course Logistics

Every week you should complete the following:

Study the Power-Point slides for that week, shown in Canvas.

Supplement your reading on the subject utilizing the textbooks and recommended references.

The homework is normally assigned on Mondays, unless it falls on a holiday, then it is assigned on a Tuesday and is due a week later, on Monday (not later than 12:00am EST). The homework should be sent to the professor in **WORD** by Canvas e-mail. The weekly assignments will be graded, and grades posted within 48 hours after receiving everyone's homework.

To encourage the student to stay on schedule; 20% of the total points will be deducted for assignments received 1-3 days late; assignments received more than 3 days late will receive 0 points.

Instructor's Online Hours

I will be available via email and will respond as soon as I am available (generally within 24-48) hours.

Online Etiquette Guidelines

Your instructor and fellow students wish to foster a safe online learning environment. All opinions and experiences, no matter how different or controversial they may be perceived, must be respected in the tolerant spirit of academic discourse. You are encouraged to comment, question, or critique an idea but you are not to attack an individual. Our differences, some of which are outlined in the University's inclusion statement below, will add richness to this learning experience. Please consider that sarcasm and humor can be misconstrued in

online interactions and generate unintended disruptions. Working as a community of learners, we can build a polite and respectful course ambience. Please read the Netiquette rules for this course:

- Do not dominate any discussion. Give other students the opportunity to join in the discussion.
- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an "open-mind" and be willing to express even your minority opinion.
- Think and edit before you push the "Send" button.
- Do not hesitate to ask for feedback.

COURSE SCHEDULE

	Week starting on:	
Lecture 1	Wednesday, January 18, 2023	
Lecture 2	Monday, January 23, 2023	
Lecture 3	Monday, January 30, 2023	
Lecture 4	Monday, February 6, 2023	
Lecture 5	Monday, February 13, 2023	
Lecture 6	Monday, February 20, 2023	
Mid-Term Test Posted	Monday, February 27, 2023	
Lecture 7	Monday, March 6, 2023	Mid-Term Test Due
Spring Recess	Monday, March 13, 2023	
Lecture 8	Monday, March 20, 2023	
Lecture 9	Monday, March 27, 2023	
Lecture 10	Monday, April 3, 2023	
Lecture 11	Monday, April 10, 2023	
Lecture 12	Monday, April 17, 2023	
Final Test Posted	Monday, April 24, 2023	
	Monday, May 1, 2023	Final Test Due

Note: The dates shown above start and end on Eastern Standard Time (EST)

COURSE CONTENT

Lecture	Topic	Description
1	Introduction to Wind Energy	• Historical Perspective • Energy Use in the United States • Wind Turbine… A Highly Engineered Product
2	Wind Energy Basics	• Kinetic Energy and Power of Wind • Sensitivity of Power to Rotor Radius and Wind Speed • Conservation of Mass, Energy and Momentum • Derivation and Meaning of Bets Limit • Properties of Wind ➢ How is Wind Generated

		➢ Statistical Distribution of Wind Speed ❖ Rayleigh probability density function (pdf) ❖ Weibull probability density function (pdf) ➢ Power Density ➢ Wind Classes ➢ Wind Shear ➢ Air Density as a Function of Elevation and Humidity • Site Selection ➢ Obstacles and Height • Wind Speed Data ➢ Wind Frequency Charts (Wind Rose Data) ➢ Avg. Wind Speed Data
3	Planning and Execution of a Small-Scale Wind Project	• High-Level Project Plan and Timeline ➢ Prospecting - Site Evaluation **(See Lecture #2)** ➢ Wind Measurement and Detailed Wind Assessment **(See Lecture #4)** ➢ Project Siting and Power Purchase Agreement **(See Lecture #11)** ➢ Selection of Wind Turbine and Related Components **(See Lectures #5 - #9)** ➢ The Economics and Financing of the Wind Project **(See Lecture #10)** • Construction, Installation and Commissioning ➢ Site Preparation ➢ Foundation Construction and Turbine Erection **(See Lecture #4)** ➢ Commissioning • Operations • Start of a Small-Scale Wind Class Project
4	Wind Speed Measurement	• Definition of Wind Speed • Wind Measuring Devices ➢ Anemometers ✓ Cup Anemometer ✓ Propeller Anemometer ✓ Pressure Plate Anemometer ✓ Pressure Tube Anemometer ✓ Sonic Anemometer • Remote Sensing of Wind Speed ➢ Acoustic Doppler Wind Speed Sensor (SODAR) ➢ Laser Doppler Wind Speed Sensor (LIDAR) • Wind Direction Instrumentation • Data Logger and Communication Devices • Analysis of Wind Data • Installation of Met-Towers
5	Aerodynamics of Wind Turbines	• Airfoil • Lift and Drag Forces • Wind Turbine Power and Torque • Aerodynamic Theories ➢ Axial Momentum Theory ➢ Blade Element Theory ➢ Strip Theory • Rotor Design

6	Wind Energy Conversion Systems	• Types of Wind Turbines ➢ Horizontal Axis Wind Turbines (HAWT) ✓ Single, two, three and multi-bladed ➢ Vertical Axis Wind Turbines (VAWT) ✓ Darrieus Rotor ✓ Savonius Rotor ✓ Musgrove Rotor • Characteristics of Wind Rotors • Speed Control of Wind Turbines • Constant Speed Wind Turbines, Stall vs. Pitch Regulated • Variable Speed Wind Turbines
	Mid Term Test	
7	Wind Turbine Components	• In the Air Components ➢ Rotor System ✓ Blades ✓ Rotor Hub ✓ Pitch Drive ➢ Nacelle ✓ Nacelle Housing and Frame ✓ Gear Box ✓ Yaw Drive ✓ Generator ✓ Safety Brakes • On the Ground Components ➢ Tower ➢ Batteries ➢ Inverters ➢ Control Panels
8	On-shore and Off-shore Wind Energy Systems	• On-shore Small Scale Wind Energy Systems ➢ Choosing a Wind Turbine ✓ Range of Size ❖ Cabin Size System ❖ Home Size System ❖ Business Size System ➢ Warranties, Service and Reliability • Off-shore Wind Energy System • Estimating the Power Generated by Wind Turbines ➢ Power Curve of Wind Turbines • Wind Energy System Interconnections
9	Wind Powered Pumps	• Drinking, Irrigation and Livestock Water Pumping Systems ➢ Water Needs ➢ Comparison of Wind and Other Remote Watering Systems ➢ Wind Powered Pumps • Direct Coupled Wind Powered Piston Pumps ➢ Limitations of Wind Driven Piston Pumps ✓ The Hysteresis Effect ✓ Mismatch Between the Rotor and Pump Characteristics

		✓ Dynamic Loading of the Pump's Lift Rod • Direct Coupled, Wind Driven Double Acting Piston Pumps • Direct Coupled, Wind Driven Roto-dynamic Pumps • Wind Driven Electric Pumps ➢ Pump Performance for Livestock and Irrigation Application • Power Requirements for Pumping Water ➢ Calculating H_d in Pipes
10	Economics of Wind Energy	• Introduction • Factors Influencing Wind Energy Economics ➢ Site Specific Factors ➢ Machine Parameters ➢ Energy Market ➢ Incentives and Exemptions • Principles of Discounted Cash Flow Analysis ➢ Annualized Present Worth ➢ Capital Recovery Factor – Series of Payments • Wind Energy System Life Cycle Cost • Annualized Wind Energy Costs – Residential Applications • Pay Back Period
11	Wind Energy and the Environment	• Environmental Benefits of Wind Energy • Life Cycle Analysis ➢ Net Energy Analysis ➢ Life Cycle Emission • Environmental Problems of Wind Energy ➢ Avian Issues ➢ Noise Emission ➢ Visual Impact ➢ Electrical Interference
12	The Future of Wind Power	• Wind Energy Storage ➢ Batteries ➢ Compressed Air ➢ Flywheels ➢ Pumped Hydroelectric • Growth of Wind Turbine Size • A Sampling of Wind Power Installations in the US • Innovative Wind Energy Systems
	Final Test	

COURSE MATERIALS

Required Textbooks:

Textbook #1
"Wind Energy Engineering" by Pramod Jain, McGraw Hill, Inc., 2011.
(Available ONLINE at the Stevens Library)

Textbook #2
"Wind Energy: Fundamentals, Resource Analysis and Economics" by Sathyajith Mathew, Springer, 2006

(Available ONLINE at the Stevens Library)

Textbook #3
"Onshore and Offshore Wind Energy, An Introduction"
By Paul A. Lynn, John Wiley & Sons Ltd., 2012
(Available ONLINE at the Stevens Library)

Additional material on the subjects being discussed, is provided to the students via PowerPoint slides.

References:

"**Wind Energy Explained - Theory, Design and Application"** by J.F. Manwell, J.G. McGowan and A.L. Rogers, John Wiley & Sons Ltd., 2nd ed., 2010, (Available ONLINE at the Stevens Library)

"Principle of Sustainable Energy", Ch. #3, by Frank Kreith & Jan F. Kreider , CRC Press, Taylor & Francis Group, 2011

"Wind Power for the Homeowner"
By Donald Marier, Rodale Press, 1981

COURSE REQUIREMENTS

Homework: The homework is normally assigned on Mondays and is due a week later on Monday (not later than 12:00am EST). The homework should be sent to the professor in **WORD** by Canvas e-mail. The weekly assignments will be graded, and grades posted within 48 hours after receiving everyone's homework.

To encourage the student to stay on schedule; 20% of the total points will be deducted for assignments received 1-3 days late; assignments received more than 3 days late will receive 0 points.

Project: The class is to work on a project that reflects real life consulting tasks in designing a wind turbine for a given application. The business and location mentioned in the project, where the turbine will be located are fictitious, but are tailored as close as possible to an actual application. The class curriculum consisted of first learning the basics of wind energy, then the class project is outlined, followed by numerous topics on wind energy that will help the students complete the project. The students are assigned to work on various parts of the project and their contributions are reflected in a final report. The Class Project will start after Lecture #3.

Exams: There is going to be a Mid Term Exam that will be held after completion of Lecture #6 and will cover Lectures #1- #6. At the end of the semester there will be a Final Exam covering Lectures #1 - #12. The schedules for the above exams are shown above in "Course Schedule". No retakes of exams are allowed.

TECHNOLOGY REQUIREMENTS

Baseline technical skills necessary for online courses

- Basic computer and web-browsing skills
- Navigating Canvas

Required Equipment

- Computer: current Mac (OS X) or PC (Windows 10) with high-speed internet connection

Required Software

- Microsoft Word
- Microsoft Excel
- Microsoft PowerPoint

GRADING PROCEDURES

Grades will be based on:

Homework – 30%
Mid-Term Exam – 30%
Final Exam – 40%

Late Policy

To encourage you to stay on schedule; 20% of the total points will be deducted for assignments received 1-3 days late; assignments received more than 3 days late will receive 0 points.

Academic Integrity

Undergraduate Honor System
Enrollment into the undergraduate class of Stevens Institute of Technology signifies a student's commitment to the Honor System. Accordingly, the provisions of the Stevens Honor System apply to all undergraduate students in coursework and Honor Board proceedings. It is the responsibility of each student to become acquainted with and to uphold the ideals set forth in the Honor System Constitution. More information about the Honor System including the constitution, bylaws, investigative procedures, and the penalty matrix can be found online at http://web.stevens.edu/honor/

The following pledge shall be written in full and signed by every student on all submitted work (including, but not limited to, homework, projects, lab reports, code, quizzes and exams) that is assigned by the course instructor. No work shall be graded unless the pledge is written in full and signed.

"I pledge my honor that I have abided by the Stevens Honor System."

Reporting Honor System Violations
Students who believe a violation of the Honor System has been committed should report it within ten business days of the suspected violation. Students have the option to remain anonymous and can report violations online at www.stevens.edu/honor.

Graduate Student Code of Academic Integrity

All Stevens graduate students promise to be fully truthful and avoid dishonesty, fraud, misrepresentation, and deceit of any type in relation to their academic work. A student's submission of work for academic credit indicates that the work is the student's own. All outside assistance must be acknowledged. Any student who violates this code or who knowingly assists another student in violating this code shall be subject to discipline.

All graduate students are bound to the Graduate Student Code of Academic Integrity by enrollment in graduate coursework at Stevens. It is the responsibility of each graduate student to understand and adhere to the Graduate Student Code of Academic Integrity. More information including types of violations, the process for handling perceived violations, and types of sanctions can be found at www.stevens.edu/provost/graduate-academics.

Special Provisions for Undergraduate Students in 500-level Courses

The general provisions of the Stevens Honor System do not apply fully to graduate courses, 500 level or otherwise. Any student who wishes to report an undergraduate for a violation in a 500-level course shall submit the report to the Honor Board following the protocol for undergraduate courses, and an investigation will be conducted following the same process for an appeal on false accusation described in Section 8.04 of the Bylaws of the Honor System. Any student who wishes to report a graduate student may submit the report to the Dean of Graduate Academics or to the Honor Board, who will refer the report to the Dean. The Honor Board Chairman will give the Dean of Graduate Academics weekly updates on the progress of any casework relating to 500-level courses. For more information about the scope, penalties, and procedures pertaining to undergraduate students in 500-level courses, see Section 9 of the Bylaws of the Honor System document, located on the Honor Board website.

EXAM CONDITIONS

The following procedures apply to exams for this course. As the instructor, I reserve the right to modify any conditions set forth below by printing revised Exam Conditions on the exam.

1. Students may use the following materials during exams. Any materials that are not mentioned in the list below are not permitted.

Material	Permitted?	
	Yes	No
Handwritten Notes Conditions: i.e. size of note sheet	✓	
Typed Notes Conditions: i.e. size of note sheet	✓	
Textbooks Conditions: i.e. specific books	✓	
Readings Conditions: i.e. specific documents	✓	
Laptop	✓	

2. Students are not allowed to work with or talk to other students about exams.

LEARNING ACCOMODATIONS

Stevens Institute of Technology is dedicated to providing appropriate accommodations to students with documented disabilities. The Office of Disability Services (ODS) works with undergraduate and graduate students with learning disabilities, attention deficit-hyperactivity disorders, physical disabilities, sensory impairments, psychiatric disorders, and other such disabilities in order to help students achieve their academic and personal potential. They facilitate equal access to the educational programs and opportunities offered at Stevens and coordinate reasonable accommodations for eligible students. These services are designed to encourage independence and self-advocacy with support from the ODS staff. The ODS staff will facilitate the provision of accommodations on a case-by-case basis.

For more information about Disability Services and the process to receive accommodations, visit https://www.stevens.edu/office-disability-services. If you have any questions please contact: Phillip Gehman, the Director of Disability Services Coordinator at Stevens Institute of Technology at pgehman@stevens.edu or by phone 201-216-3748.

Disability Services Confidentiality Policy

Student Disability Files are kept separate from academic files and are stored in a secure location within the Office of Disability Services. The Family Educational Rights Privacy Act (FERPA, 20 U.S.C. 1232g; 34CFR, Part 99) regulates disclosure of disability documentation and records maintained by Stevens Disability Services. According to this act, prior written consent by the student is required before our Disability Services office may release disability documentation or records to anyone. An exception is made in unusual circumstances, such as the case of health and safety emergencies.

INCLUSIVITY

Name and Pronoun Usage

As this course includes group work and class discussion, it is vitally important for us to create an educational environment of inclusion and mutual respect. This includes the ability for all students to have their chosen gender pronoun(s) and chosen name affirmed. If the class roster does not align with your name and/or pronouns, please inform the instructor of the necessary changes.

Inclusion Statement

Stevens Institute of Technology believes that diversity and inclusiveness are essential to excellence in academic discourse and innovation. In this class, the perspective of people of all races, ethnicities, gender expressions and gender identities, religions, sexual orientations, disabilities, socioeconomic backgrounds, and nationalities will be respected and viewed as a resource and benefit throughout the semester. Suggestions to further diversify class materials and assignments are encouraged. If any course meetings conflict with your religious events, please do not hesitate to reach out to your instructor to make alternative arrangements.

You are expected to treat your instructor and all other participants in the course with courtesy and respect. Disrespectful conduct and harassing statements will not be tolerated and may result in disciplinary actions.

MENTAL HEALTH RESOURCES

Part of being successful in the classroom involves a focus on your whole self, including your mental health. While you are at Stevens, there are many resources to promote and support mental health. The Office of Counseling and Psychological Services (CAPS) offers free and confidential services to all enrolled students who are struggling to cope with personal issues (e.g., difficulty adjusting to college or trouble managing stress) or psychological difficulties (e.g., anxiety and depression) and who can visit the office in person. CAPS is open from 9:00 am – 5:00 pm Mondays, Wednesdays, Thursdays and Fridays and from 9:00 am – 7:00 pm on Tuesdays during the Fall and Spring semesters; appointments are highly encouraged. For those students who cannot visit the Stevens campus for an in-person appointment, you can contact a local mental health care provider for an in-person appointment, or if you are enrolled in the Stevens Student Health Insurance, you may call Care Connect for 24/7 mental health support at 1-888-857-5462.

For further information please visit the CAPS webpage on Seeking Help Off-Campus.

EMERGENCY INFORMATION

In the event of an urgent or emergent concern about the safety of yourself or someone else in the Stevens community, please immediately call the Stevens Campus Police at 201-216-5105 or on their emergency line at 201-216-3911. These phone lines are staffed 24/7, year round. For students who do not reside near the campus and require emergency support, please contact your local emergency response providers at 911 or via your local police precinct. Other 24/7 national resources for students dealing with mental health crises include the National Suicide Prevention Lifeline (1-800-273-8255) and the Crisis Text Line (text "Home" to 741-741). If you are concerned about the wellbeing of another Stevens student, and the matter is *not* urgent or time sensitive, please email the CARE Team at care@stevens.edu. A member of the CARE Team will respond to your concern as soon as possible.