NPRE 475
Wind Power Systems
Spring 2023

Online Temporary Alternative Coverage and access during Covid-19 Pandemic and possible resurgence through mutations and variants.

1. Please read the assigned-reading lecture-notes chapters.
2. Then answer the corresponding written assignment,
3. For questions about the assignments, please access the teaching assistants by email:
https://www.mragheb.com/NPRE%20402%20ME%20405%20Nuclear%20Power%20Engineering/talist.htm
4. Submit the corresponding written assignment through email to https://canvas.illinois.edu
5. Please use either the Word or pdf formats
6. In case of internet "rationing" (e. g. to health and government authorities), instability, or collapse through overload, please read the lecture notes and submit the corresponding assignments. Already-taken tests and submitted assignments would be used in assessing the final grade.

Regrettably, some 3,278 colleges and universities across the USA have been impacted by the Covid-19 pandemic, with many temporarily closing their campuses and switching to online classes, affecting more than 22 million students.

To all and everyone we wish good health and well-being.

Threat of Nuclear War:
https://www.youtube.com/watch?v=HSC7Lp1nvx8
https://www.youtube.com/watch?v=M7hOpT0lPGI

Number	Date Assigned	Due Date	Description
1	1/18	1/25	**Reading Assignment** **Preface** **Written Assignment** In Greek mythology, who is Artemis' brother? Who was born first? https://en.wikipedia.org/wiki/Artemis_program Construct a diagram showing the different components of the future smart electrical grid from the perspective of the vision of the Internet of Things (IoT). Construct a table comparing the allocation of electrical energy sources in the French Internet of things, IOT to the electrical energy production mix in the USA.
2	1/20	1/27	**Reading Assignment** **Preface** **Written Assignment** List the components of the envisioned Internet of Things (IoT) for a future energy system. Automobile internal combustion engines are designed to operate for about 5,000 hours over their operational time. Compare this to the required number of design operational hours for a wind turbine operating at an intermittency or capacity factor of 30-50 percent for a design lifetime of 20 years. The USA's goal for wind power production is from presently 2 percent up to 20 percent of electrical energy production by 2030.

			To accomplish this goal, the USA would need to add 1.7 Gigawatts (1 Gigawatt, GW = 1,000 Megawatts, MW) of wind power installed rated capacity per year. One electric megawatt (MWe) of electrical power supplies the electrical use of 240-300 average American homes with a family of four. Estimate the number of people that wind power would serve per year by the year 2030, assuming a wind intermittence factor of 40 percent, and an electrical conversion efficiency of 70 percent. Please remember to differentiate between Rated Power in MWs and Electrical Power in MWe. Hint: MWe = MW x Intermittence factor x electrical conversion efficiencu.
3	1/23	1/30	**Reading Assignment** **1. Introduction** **Written Assignment** Wind power, considered an industrial process, poses challenges and concerns to be surmounted for its sustainable implementation. List the environmental concerns encountered in its development. What do the following acronyms stand for: 1. HAWT 2. VAWT
4	1/25	2/1	**Reading Assignment** **1. Introduction** **Written Assignment** List the components of a modern HAWT. List the perceived advantages of wind power generation. Explain the difference between the "intermittence" and "reliability" concepts as pertains to wind power generation.
5	1/27	2/3	**Reading Assignment** **2. Global Wind Power Status** **3. USA Wind Energy Resources** **Written Assignment** Give the units and explain the difference between: 1. Power flux, 2. Power density. Using a source of your choice (graph or table) of the locational properties of the wind resources to graphically plot the measured average Power flux in Watts/(square meters) against the average wind speed in meters/sec. Can you deduce the functional relationship between the two quantities? Hint: You may try the Excel routine for the plotting process.
6	1/30	2/6	**Reading Assignment** **4. Properties and Statistical Analysis of the Wind** **Written Assignment** One percent of the solar radiation power of 1.7×10^8 GW is converted to wind power. The floral or plant global Net Primary Production (NPP) in all the links of the food and energy chain is: NPP = 4.95×10^6 [cal / (m^2.year)]. The Earth's surface area is: $A_{Earth} = 5.09 \times 10^{14}$ m^2. 1. Estimate the power stored as biomass in Watts.

			2. What is the ratio of wind to biomass power generated from solar radiation? Discuss the implication regarding wind and biomass power generation. Use: 1 calorie = 4.186 Joule, 1 year = 3.1536×10^7 sec, 1 Watt=1 Joule/sec. Briefly explain: a) Coriolis force, b) Beaufort wind speed scale, c) Correlation between solar activity and wind activity hypothesis.
7	2/1	2/8	**Reading Assignment** **4. Properties and Statistical Analysis of the Wind** **Written Assignment** The probability density function (pdf) of the two parameter Weibull distribution used in modelling wind duration curves is: $W(v) = \frac{k}{C}\left(\frac{v}{C}\right)^{k-1} e^{-\left(\frac{v}{C}\right)^k}$ $where:\ k = shape\ parameter\ or\ slope$ $C = scale\ parameter\ or\ charactreristic\ wind\ speed$ As special cases, deduce the forms of: 1. The Rayleigh distribution, 2. The Exponential distribution. Consider the exponential probability density function (pdf): $p(v)dv = \frac{1}{C} e^{-\frac{v}{C}} dv$ 1. Apply the normalization condition to prove that it is indeed a probability density function (pdf). 2. Derive the expression for its cumulative distribution function (cdf). 3. Derive the expression for its complementary cumulative distribution function (ccdf). Use a plotting routine to plot the pdf, cdf, and ccdf for a value of C = 2. Hints: Normalization condition for a function p(v) is: $\int_0^\infty p(v)dv = 1$, $cdf = \int_0^v p(v)dv,\ ccdf = 1 - cdf$
8	2/3	2/10	**Reading Assignment** **5. Wind Generators History** **Written Assignment** Write a one-page summary of the book chapter: Magdi Ragheb (2017), "History of Harnessing Wind Power," Chap. 7, Part III, Wind Turbine Technology, pp. 127 - 142, in: Trevor M. Letcher, Ed., "Wind Energy Engineering, A Handbook for Onshore and Offshore Wind Turbines," Academic Press, Elsevier, 2017. The Suzlon S.66/1250, 1.25 MW rated power at 12 m/s rated wind speed wind turbine design has a rotor diameter of 66 meters and a rotational speed of 13.9-20.8 rpm (revolutions per minute).

			Calculate the range of the tip of its rotor's linear speed v in m/s, km/hr and miles/hr. Discuss the safety implications regarding the possible inclement-weather ice formation on the blades and its possible ejection. Hints: $\mathrm{v} = \omega r,\ \omega = 2\pi f,\ f = \frac{rpm}{60}$ r is radius in meters, f is rotational frequency in rotations/sec (Hz), ω is angular speed in radians per second, v is linear speed in meters/sec.
9	2/6	2/13	**Reading Assignment** **6. Wind Shear, Roughness Classes and Turbine Energy Production** **Written Assignment** To develop maximum power, a wind generator must be mounted as high as possible. Several authors have suggested the following simple power law for the variation of wind speed V with height H: $\frac{V}{V_0} = \left(\frac{H}{H_0}\right)^n$ where V_0 is the observed speed at at a reference height of H_0 meters above ground, and V is the wind speed at altitude H. The value of V_0 is usually given at 10 m height at airports meteorological towers, and the coefficient n takes values over the range 0.1 – 0.4. The wind speed at 20 meters height at the Eiffel Tower, Paris, France is about 2 m/s, and it is about 7-8 m/s at 300 meters above ground. What range of values of the coefficient n best fits the Eiffel Tower situation? A Japan Steel Works (JSW) J82-2.0 / III wind turbine has a rotor blade length of 40 m. Estimate the wind speed at the tips of its rotor blades at the maximum and minimum heights they attain in their rotation, if the hub height is: a. 65 meters. b. 80 meters. Assume the turbine is built within an area with a roughness class of 2.5, for a wind blowing at V_{ref} = 8 m/sec at a height of z_{ref} = 20 m. Use the formula: $V(z) = V_{ref} \frac{\ln \frac{z}{Z_0}}{\ln \frac{z_{ref}}{Z_0}}$, Z_0 = 0.2 m.
10	2/8	2/15	**Reading Assignment** **9. Energy and Power Content of the Wind** **Written Assignment** Derive the equation for the Power content of a wind stream of a constant speed V and swept area S using the conservation of mass and energy principles. The Suzlon S.66/1250, 1.25 MW rated power at 12 m/s rated wind speed wind turbine design has a rotor diameter of 66 meters. For the same rated wind speed, what would the rated power be, if: 1. The rotor diameter is halved to 33 meters. 2. The rotor diameter is doubled to 132 meters. 3. The wind speed is half the rated wind speed at 6 m/s. 4. The wind speed is double the rated wind speed at 24 m/s.

11	2/10	2/17	**Reading Assignment** **30. Historical Wind Generators Machines** **Written Assignment** Construct a table comparing the technical specifications of each of: 1. The Charles Brush and the Smith Putman wind turbines, 2. The MOD-1 and the MOD-2 wind turbines.
12	2/13	2/20	**Reading Assignment** **30. Historical Wind Generators Machines** **10. Wind Energy Conversion Theory, Betz Equation** **Written Assignment** Compare the characteristics of: 1. HAWTs, 2. VAWTs. Describe Paul La Cour wind generation effort concerning the hydrogen energy storage effort and the use of aerodynamic rather than impulse rotor designs. List the basic principles of energy conversion and extraction from the environment and their corollaries.
13	2/15	2/22	**Reading Assignment** **10. Wind Energy Conversion Theory, Betz Equation** **Written Assignment** Write down the expression for the power content of a wind stream of density ρ, constant speed V, and diameter D, expressing the units of each variable. If the diameter D is doubled, what is the effect on the power content? If the wind speed V is doubled, what is the effect on the power content? By differentiation of the expression of the dimensionless wind turbine power coefficient: $C_p = \frac{P}{W} = \frac{1}{2}\left(1-b^2\right)\left(1+b\right)$ with respect to the interference factor b, determine analytically the value of the Betz' limit for wind machines. Explain its physical meaning. Plot the power coefficient as a function of the interference factor and identify on the graph the location and value of the optimal value of b. By differentiating the expression for the power in a wind stream: $P = \frac{1}{4}\rho S\left(V_1+V_2\right)^2\left(V_1-V_2\right)$ with respect to the downstream velocity V_2 for a constant upstream velocity V_1, derive Betz's Equation for the maximum amount of power extractable from a wind stream. Compare your result to the original equation introduced by Betz.
14	2/17	2/24	**Reading Assignment** **10. Wind Energy Conversion Theory, Betz Equation** **13. Components of Wind Machines** **Written Assignment** A wind turbine that operates in an area with a wind power flux resource of 200 Watt/m^2 (measured at 50 m height) has the following operational parameters: 1. Rotor blade radius R = 30 m. 2. Coefficient of performance C_p = 40 percent.

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<td>3. Transmission (gearbox) efficiency: 97 percent.
4. Electrical generator efficiency: 98 percent.
5. Intermittency factor (capacity factor): 30 percent.
Calculate:
1. The rotor swept area.
2. The rated power of the turbine.
3. The transmission power.
4. The electrical generator power.
5. The overall electrical power production in MWe.
Compare the values of the calculated parameters to those in an area with a wind power flux resource of 600 Watts/m^2.

The pioneering Smith-Putman wind turbine had a rotational speed of 29 rpm, and its electrical generator operated at 600 rpm.
1. Estimate the gearing ratio in its gearbox or transmission.
2. Identify the design flaw learned from its operation.</td>
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<tr>
<td>15</td>
<td>2/20</td>
<td>2/24</td>
<td>Reading Assignment
17. Vertical Axis Wind Turbines
18. Small Wind Generators
Written Assignment
List the technical specifications of the Air-X 24 small wind turbine.

Show a diagram of a VAWT Vertical Axis Wind Turbine:
1. Darrius design
2. Savonius design

Calculate the “gearing ratio” of the transmissions or gearboxes from the electrical generator and rotor technical specifications of the following wind turbine designs:
<table>
<tr><th>Rotor</th><th>S.64/1250 (50 Hz)</th><th>S.64/1250 (60 Hz)</th><th>S.66/1250 (50 Hz)</th><th>S.66/1250 (60 Hz)</th></tr>
<tr><td>Blade</td><td colspan="4">3 bladed horizontal axis</td></tr>
<tr><td>Swept area</td><td>3217 m^2</td><td>3217 m^2</td><td>3421 m^2</td><td>3421 m^2</td></tr>
<tr><td>Rotational speed</td><td colspan="4">13.9 / 20.8 rpm</td></tr>
<tr><td>Regulation</td><td colspan="4">Pitch regulation</td></tr>
</table>
<table>
<tr><th>Generator</th><th>S.64/1250 (50 Hz)</th><th>S.64/1250 (60 Hz)</th><th>S.66/1250 (50 Hz)</th><th>S.66/1250 (60 Hz)</th></tr>
<tr><td>Type</td><td colspan="4">Asynchronous 4/6 poles</td></tr>
<tr><td>Rated output</td><td colspan="4">250 / 1250 kW</td></tr>
<tr><td>Rotational speed</td><td>1006/1506 rpm</td><td>1208/1807 rpm</td><td>1006/1506 rpm</td><td>1208/1807 rpm</td></tr>
<tr><td>Frequency</td><td>50 Hz</td><td>60 Hz</td><td>50 Hz</td><td>60 Hz</td></tr>
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<tr>
<td>16</td>
<td>2/22</td>
<td>2/24</td>
<td>Reading Assignment
19. Modern Wind Generators
Written Assignment
Briefly describe the characteristics and the justification regarding the capacity factor of the Haliade-X, 12 MW of rated power GE turbine for offshore applications.</td>
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<td>First Midterm 2/24/2023 During class period</td>
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17	2/27	3/6	**Reading Assignment** [19. Modern Wind Generators] **Written Assignment** List Seven major developments that characterize modern wind machines designs.
18	3/1	3/8	**Reading Assignment** [7. Fluid Mechanics, Euler and Bernoulli Equations] **Written Assignment** Euler's equation applies to a steady incompressible inviscid fluid flow with no body forces. It relates the change in velocity along a streamline dV to the change in pressure dp along the same streamline: $dp = -\rho V dV$ From Euler's equation, derive Bernoulli's equation. Explain its physical meaning in terms of the static and kinetic (dynamic) pressures. A wind rotor airfoil is placed in the air flow at sea level conditions with a free stream speed of 10 m/s. The density at standard sea level conditions is 1.23 kg/m^3 and the pressure is 1.01 x 10^5 $Newtons/m^2$. At a point along the rotor airfoil the pressure is 0.90 x 10^5 $Newtons/m^2$. By applying Bernoulli's equation estimate the stream speed at this point.
19	3/3	3/10	**Reading Assignment** [25. Computational Fluid Dynamics] **Written Assignment** List the conservation equations governing the field of Computational Fluid Dynamics (CFD). List the variables usually used in one phase flow CFD. Discretize the conservation of energy equation for a fluid into its finite difference form and derive the corresponding updated specific energies using the thermodynamic relation: $dE = -pdV$ $\Delta E \simeq -p\Delta V$ Derive the finite difference form of the updated interface positions using the approximation to the speeds: $u \simeq \frac{\Delta x}{\Delta t}$
20	3/6	3/20	**Reading Assignment** [8. Aerodynamics of Rotor Blades] [11. Torque Generation in Wind Turbines] **Written Assignment** Complete the design steps for the high speed and low speed shaft diameters for a wind turbine transmission or gearbox. Consider the design of a wind generator with an electrical output of: $P_e = 1.0\, MWe$ Accounting for the generator efficiency, the power at the transmission output would be: $P_t = \frac{P_e}{\eta_g}$

For a generator efficiency of 90 percent, this would be:

$$P_t = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \ Watts$$

And the power at the transmission input would be:

$$P_m = \frac{P_t}{\eta_t} = \frac{P_e}{\eta_g \eta_t}$$

For a transmission efficiency of 90 percent, this would be:

$$P_m = \_\_\_\_\_\_\_\_\_\_\_\_\_ Watts$$

Taking the rotational speed of the generator at 1,200 rpm, yields:

$$\omega_t = 2\pi \frac{1,200}{60} = 40\pi [\frac{\text{radians}}{\text{sec}}]$$

Taking the rotational speed of the rotor shaft as 24 rpm, corresponding to a gearing ratio of:

$$Gearing\ ratio : GR = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

yields:

$$\omega_m = 2\pi \frac{24}{60} = \frac{4}{5}\pi [\frac{\text{radians}}{\text{sec}}]$$

The torques at the high speed and low speed shafts torques become:

$$T_t = \frac{P_t}{\omega_t} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ [\frac{\text{N.m}}{\text{rad}}]$$

$$T_m = \frac{P_m}{\omega_m} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ [\frac{\text{N.m}}{\text{rad}}]$$

A maximum stress for steel shafts is recommended as 55 Mpa. Accounting for a factor of safety FS of 3 and an ignorance factor IF of 2 yields for the design maximum stress:

$$\sigma_{s,\max}(r_0) = \frac{\sigma_s(r_0)}{FS.IF} = \frac{\sigma_s(r_0)}{3x2} = \frac{\sigma_s(r_0)}{6}$$

$$\sigma_{s,\max}(r_0) = \frac{55}{6} = 9.2 MPa$$

The high speed and low speed shaft radii are:

$$r_{0,t} = \sqrt[3]{\frac{2T_t}{\pi \sigma_{s,\max}(r_0)}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

$$r_{0,m} = \sqrt[3]{\frac{2T_m}{\pi \sigma_{s,\max}(r_0)}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

What is the implication regarding the low speed shaft design?

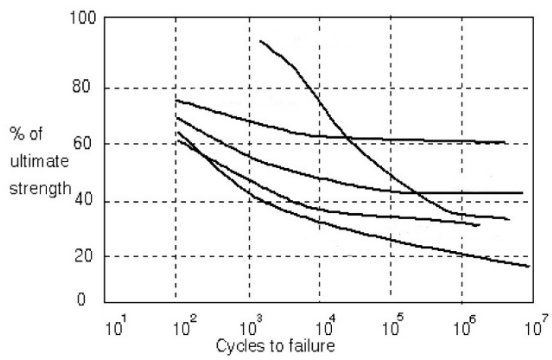
For an air density of 1.23 kg/m^3, a wind speed of 10 m/s, a rotor cross sectional area of 10 m^2, and a rotor effective area in the drag direction of 5 m^2, estimate:

1. The lift force L in Newtons,
2. The drag force D,
3. The thrust force T.

If the angle between the thrust and the incoming undisturbed air flow is 45 degrees, estimate:

1. The perpendicular component of the force leading to translation of the rotor,
2. The force parallel to the undisturbed air flow,

			$C_L = \frac{(L/A_L)}{\frac{1}{2}\rho V^2}$, $C_D = \frac{(D/A_D)}{\frac{1}{2}\rho V^2}$. Lift to drag ratio $C_L / C_D = 18$, Drag coefficient $C_D = 0.06$.
21	3/8	3/20	**Reading Assignment** **52. Wind Turbines Gearbox Technologies** **Written Assignment** Read then write a short summary of the book chapter: Adam M. Ragheb and Magdi Ragheb (2011). "Wind Turbine Gearbox Technologies," Fundamental and Advanced Topics in Wind Power, Rupp Carriveau (Ed.), ISBN: 978-953-307-508-2, InTech, http://www.intechopen.com/articles/show/title/wind-turbine-gearbox-technologies The relationship between the electrical generator rpm, the number of generator poles n, and the current/voltage frequency f is given by Eqn. 6 in the book chapter as: f = (n * rpm) / 120 [Hz] What would be the number of generator poles needed in the USA and in Europe/Asia for: 1. An off-shelf generator with an rpm of 1800 connected to a wind turbine by a gearbox/transmission? 2. A gearless, direct drive wind turbine with a gearing ratio of unity and an rpm of 18?
22	3/10	3/20	**Reading Assignment** **14. Orography and Wind Turbine Siting** **15. Offshore Wind Farms Siting** **Written Assignment** Assuming the same pressure drop and density, compare the resulting wind velocities ratio due to the tunnel speedup effect for a decrease of the constriction ratio from $\alpha = 0.9$ to $\alpha = 0.5$. Construct a table comparing the characteristics of: 1. Offshore wind projects, 2. Onshore wind projects.
23	3/20	3/27	**Reading Assignment** **12. Optimal Rotor Tip Speed Ratio** **16. Airborne Wind Turbine Concepts** For a wind speed of 15 m/s and a 3 bladed rotor radius of 10 meters rotating at 1 rotation / sec, calculate: 1. The angular rotational frequency, 2. The rotor tip speed, 3. The tip speed ratio. Compare this value to the optimal tip speed ratio. Repeat the comparison for a 2-bladed and a 4-bladed turbines. Calculate the obtainable peak electrical power for a cruising kite situation with: The ground wind speed = 9 m/s The altitude wind speed V_w = 15 m/s The kite speed V_k = 80 m/s The mean air density $\rho = 1\ kg/m^3$ The kite area $A = 40\ m^2$

			Product of generator efficiency and gearbox efficiency $\eta_{gear\ box} \times \eta_{generator} = 0.70$ The mean cos $\alpha = 0.45$ Lift to drag ratio $C_L / C_D = 18$ Drag coefficient $C_D = 0.06$ Thrust to axial speed coefficient = 2
24	3/22	3/27	**Reading Assignment** **20. Wind Turbines in the Urban Environment** **21. Dynamic and Structural Loading in Wind Turbines** **22. Fatigue Loading in Wind Turbines** **Written Assignment** On the percent of ultimate strength versus the number of cycles to fatigue failure, identify the curves for the following wind turbines rotors materials: carbon composites, steel, wood laminates, aluminum and fiber glass composites. 
25	3/24	3/27	**Reading Asignment** **23. Wind Energy Converters Concepts** **Written Assignments** Briefly describe the Magnus Effect. List the winter turbines designs that would depend on using the Magnus Effect.
		3/27	**NPRE 475 Spring 2023 Second Midterm.** During class period, Monday, March 27
26	3/29	4/5	**Reading Assignment** **24. Control of Wind Turbines** **29. Structural Towers** **Written Assignment** List the types of structural towers used in wind power installations. Compare the processes of: 1. Pitch control, 2. Stall Control
27	4/3	4/10	**Reading Assignment** **31. Environmental Considerations** **Written Assignment** List the main environmental concerns encountered in Wind Power operation. Derive an expression for the probability of a bird collision with a rotating rotor blade. Calculate the collision probability between a flying object and the rotating blades tips of a wind turbine for the number of rotor blades: 1. n=1,

			2. n=2, 3. n=3. for a rotational frequency f=20 rpm, a thickness of the blades of 0.3 m, and the perpendicular speed of a flying bird of 10 m/sec.
28	4/5	4/12	**Reading Assignment** **34. Economics of Wind Energy** **Written Assignment** Calculate the "present value" of a yearly income stream of $70,000 that is expected 10 and 20 years into the future, considering: 1. A discount rate of i=3 percent. 2. The "real interest rate" r with a discount rate of i=3 percent in addition to an inflation rate of s=2 percent. Hint: The Present Value Factor (PVF) is: $PVF = \frac{1}{(1+r)^t}, r = i + s$
29	4/7	4/14	**Reading Assignment** **34. Economics of Wind Energy** **Written Assignment** Complete the following work sheet for the economic assessment of a single wind turbine project, neglecting the depreciation, subsidies and tax incentives provisions, using present value cost analysis. **Investment** Expected lifetime = 20 years Turbine rated power: 1,500 kW Turbine price: $1.000,000

Year n	Expenditures $	Gross Income Stream $	Net Income Stream $	Present value factor $1/(1+r)^n$ $r = 0.05$	Net present value of income stream $
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Total					

Installation costs: 30 percent of turbine price = $______________________
Total turbine cost = Turbine cost + Installation cost
= $________________________

Payments

The payments, including the initial payment, are used to calculate the net present value and the real rate of return over a 20 years project lifetime since this is the main economic aspect of the analysis.
(Consider that the capital is in the form of available invested funds: if the capital cost is all borrowed funds, then the interest payment on the loan or the bonds must be accounted for.)
Operation and Maintenance: 1.5 percent of turbine price =__________________ $/year.
Total expenditure = Total turbine cost + Operation and maintenance cost (over expected lifetime)
= $____

Current income and expenditures per year

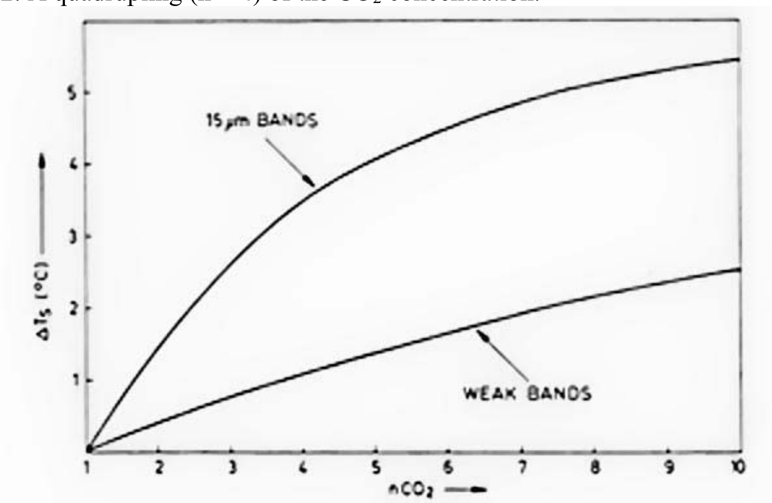
Capacity factor: 28.54 percent = 0.2854.

			Energy produced in a year: ______________________________ kWhr / year. Price of electricity: \$0.05 / kWhr Yearly income from electricity sale= ____________________\$ / yr. Total net income per year: ___________________________\$ /yr. Net present value of income stream at r = 5 percent/yr real rate of interest: \$_________________ Yearly net real rate of return. = $\frac{\text{Net present value of income stream}}{\text{Total turbine cost}} \cdot \frac{1}{\text{Project lifetime}}$ = ______________________ percent/year. Present value of electricity cost per kWhr = $\frac{\text{Net present value of income stream}}{\text{Yearly energy production . Project lifetime}}$ = ______________________ cents / kWhr. Please fill up all the entries in the table. The present generation of wind turbines may need the replacement of their transmissions or gear boxes every 5 years of their operation over the turbines 20 years design lifetime. Assuming that the gearbox cost is 20 percent of the initial turbine cost, recalculate for the previous problem the effect of such replacement on: 1. The yearly rate of return, 2. The present cost or levelized electricity cost. Compare these values to those of a gearless wind turbine design that would not need a gearbox replacement.
30	4/10	4/17	**Reading Assignment** **32. Licensing Policy of Wind Power Systems** **33. Legal Considerations of Wind Power Generation** **Written Assignment** What do the following wind power licensing acronyms stand for? EDP EIA EIS Briefly describe the legal issue of "Eminent Domain" in wind power generation. Briefly describe the legal issue of "Restoration and Decommissioning" in wind power generation.
31	4/12	4/19	**Reading Assignment** **37. Safety of Wind Systems** **Written Assignment** Identify the sources of risk associated with wind turbines operation. Rank them according to what you perceive as their level of risk. Briefly describe the two forms of flicker resulting from rotor blades rotation. Compare the offset distances of wind turbine installations in the USA and Europe.

32	4/14	4/21	**Reading Assignment** [42. High Voltage Direct Current for Wind Power] **Written Assignment** To transmit a given amount of power P = IV, where V = voltage and I = current, show that high voltage V is needed to minimize the magnitude of the ohmic resistive heating losses: I^2R, where R is the resistance of the transmission line wire. List the advantages of High Voltage Direct Current (HVDC) over High Voltage Alternating Current (HVAC) for electrical power transmission over long distances. Include diagrams comparing: 1. The capital or investment costs, 2. The transmission power losses.
33	4/17		**Reading Assignment** 42. High Voltage Direct Current for Wind Power 43. Sustainable Global Energy Desertec Concept **Written Assignment** Briefly describe the two electronic devices used in HVDC power conversion: a) Thyristor, b) IGBT. List the advantages of High Voltage Direct Current (HVDC) over High Voltage Alternating Current (HVAC) for electrical power transmission over long distances. Write a one paragraph description of the “Desertec” project.
34	4/19		**Reading Assignment** 40. Energy Storage with Wind Power 44. Smart Electrical Grid and Metering **Written Assignment** List the methods under consideration for the storage of wind energy as a means of dealing with its intermittent characteristic. Briefly describe the smart metering process in electrical power usage.
35	4/24	5/1	**Reading Assignment** 36. Electrical Generation and Grid System Integration **Written Assignment** In the electrical utilities field, what do these acronyms stand for? FERC, ERCOT, RTO, ISO, PJM, MISO, IRC. What are the main sources of electrical transmission line losses? Does the grid system act as an electrical energy storage medium? Explain why. Briefly describe the sequence of cascading events that occurred in the August 14, 2003 electrical system blackout.
36	4/26	5/3	**Reading Assignment** 35. Wind Project Development and Financing

<table>
<tr><td></td><td></td><td></td><td>Written Assignment
List the possible sources of project financing for wind turbines projects.

Define: Gearing, Leverage

Define: Debt Coverage Service Ratio</td></tr>
<tr><td>37</td><td>4/28</td><td>5/3</td><td>Reading Assignment
47. Global Climatic Variation and Energy Use
Written Assignment
From the diagram, estimate the combined expected temperature increase from both the 15 μm and the weak absorption bands for CO_2, for:
1. A doubling (n = 2) of the CO_2 concentration from 320 ppm to 640 ppm,
2. A quadrupling (n = 4) of the CO_2 concentration.

</td></tr>
<tr><td>38</td><td>5/1</td><td>5/3</td><td>Reading Assignment
47. Global Climatic Variation and Energy Use
Written Assignment
Write a one page summary of the paper:
Magdi Ragheb, "Restoring The Global Equatorial Ocean Current Using Nuclear Excavation,"
i-manager's Journal on Future Engineering & Technology, Vol. 5, No. 1, pp. 74-82, August-October, 2009.

Complete the table showing the effect of carbon dioxide concentration on temperature gradients and atmospheric heat fluxes.
For a doubling of the atmospheric CO_2 concentration, the intensity of weather phenomena would be expected to increase by: ______________________ percent.
For a quadrupling of the atmospheric CO_2 concentration, the intensity of weather phenomena would be expected to increase by: ______________________ percent.
<table>
<tr><th>Carbon dioxide concentration (ppmv)</th><th>Surface temperature (t_s)</th><th>Upper level temperature (t_u)</th><th>Temperature gradient, lower atmosphere (K/km)</th><th>Temperature gradient, upper atmosphere (K/km)</th><th>Net heat flux (x kA)</th><th>Relative increase (percent)</th></tr>
<tr><td>150</td><td>282</td><td>269</td><td>5.54</td><td>2.19</td><td></td><td>-</td></tr>
<tr><td>300</td><td>284</td><td>253</td><td>5.69</td><td>1.59</td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td><table><tr><td>600</td><td>286</td><td>242</td><td>5.85</td><td>1.19</td><td></td><td></td></tr></table></td></tr>
<tr><td>39</td><td>5/3</td><td>5/8</td><td>Reading Assignment
53. Decommissioning Wind Turbines
Magdi Ragheb, Climatic Change, A Historical Perspective, Invited Presentation at the Delta Kappa Gamma Society XI Chapter Meeting, Champaign, Illinois, May 14, 2022.
Youtube Studio link: https://youtu.be/OUEZUun64b0
Written Assignment
Describe the “Fermi Paradox”

List the suggested pessimistic and the optimistic answers to the Fermi Paradox

List the filters or hurdles that are self-inflicted by humanity and need to be avoided.
List the filters or hurdles that require adaptation by humanity.</td></tr>
<tr><td></td><td>Final Exam</td><td>M, May 8 7-10 pm</td><td>Final Exam</td></tr>
</table>

Assignments Policy

Assignments will be turned in at the beginning of the class period, one week from the day they are assigned.
The first five minutes of the class period will be devoted for turning in and returning graded assignments.
Late assignments will be assigned only a partial grade. Please try to submit them on time since once the assignments are graded and returned to the class, late assignments cannot be accepted any more.
If you are having difficulties with an assignment, you are encouraged to seek help from the teaching assistants (TAs) during their office hours. Questions may be emailed to TA's, but face-to-face interaction is more beneficial.
Although you are encouraged to consult with each other if you are having difficulties, you are kindly expected to submit work that shows your individual effort. Please do not submit a copy of another person's work as your own. Copies of other people's assignments are not conducive to learning and are unacceptable.
For further information, please read the detailed assignments guidelines.