NPRE 475
Wind Power Systems
Spring 2018

Number	Date Assigned	Due Date	Description
1	1/17	1/24	1. List the components of the envisioned Internet of Things (IoT) for a future energy system. 2. 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. 3. 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 1,700 Gigawatts (1 Gigawatt, GW = 1,000 Megawatts, MW) of wind power installed rated capacity per year. One 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 a conversion efficiency of 70 percent.
2	1/19	1/26	Wind power, being an industrial process, poses challenges and concerns to be surmounted for its sustainable implementation. List the environmental concerns encountered in its development.
3	1/22	1/29	List the perceived advantages of wind power generation. List the components of a modern Horizontal Axis Wind Turbine (HAWT).
4	1/24	1/31	Briefly explain: a) Coriolis force, b) Beaufort wind speed scale, c) Correlation between solar activity and wind activity hypothesis. 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.
5	1/26	2/2	For the random variable representing the points obtained in throwing a single die: $\xi_{die\ \ throw} : \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \end{pmatrix}$ Calculate: 1. The mean value, first moment, mathematical expectation, or average value, 2. The second moment or mean of squares, 3. The variance as the "mean of squares minus the square of the mean". The probability density function (pdf) of the two parameter Weibull distribution used in modelling wind duration curves is:

			$$W(v)=\frac{k}{C}\left(\frac{v}{C}\right)^{k-1}e^{-\left(\frac{v}{C}\right)^{k}}$$ $$\text{where: } k = \text{shape parameter or slope}$$ $$C = \text{scale parameter or charactreristic wind speed}$$ 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). 4. Use a plotting routine to plot the pdf, cdf, and ccdf for a value of C = 2.
6	1/29	2/5	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?
7	1/31	2/7	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, 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.
8	2/2	2/9	a) Consider the average wind speed at the Champaign Willard airport location from the graph in the lectures as about 5 m/s. b) Determine its wind class classification. c) Plot the corresponding Rayleigh probability density function. d) Using the power curve for the Gamesa G52-850 kW wind turbine, generate the graph of the potential energy production as a function of wind speed. e) Estimate the yearly total energy production.

			f) Compare the total potential energy production for this wind class site to that obtainable from a wind class 7 location as shown in the example in the lecture notes.
9	2/5	2/12	Compare the wind speed at a height of 50 m on the surface of water to that in rough city terrain using: 1. The power law, 2. The logarithmic law. Use: Average wind speed is 5 m/s at a measurement height of 10 m. Adopt average values of the equations parameters n and z_0.
10	2/7	2/14	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	2/9	2/16	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 speed in m/s, km/hr and miles/hr. Discuss the implication regarding the possible ice formation on the blades. Use: v= ω.r, ω=2 π f, f=frequency in Hz. 1 Hz= 1 revolution/sec.
12	2/12	2/12	Class Quizz: 1. 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. 2. If the diameter is doubled, what is the effect on the power content? 3. If the wind speed is doubled, what is the effect on the power content?
13	2/12	2/19	List the basic principles of energy conversion and extraction from the environment and their corollaries.
14	2/14	2/21	Write a one paragraph description of the "Desertec" project. By differentiation of the expression of the 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.
15	2/16	2/23	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.
16	2/19	2/26	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. 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:

<table>
<tr><td></td><td></td><td></td><td>1. Rotor blade radius R = 30 m.
2. Coefficient of performance C_p = 40 percent.
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.</td></tr>
<tr><td>17</td><td>2/21</td><td>2/26</td><td>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>
</table></td></tr>
<tr><td>18</td><td>2/23</td><td>2/26</td><td>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 wind turbine with a gearing ratio of unity and an rpm of 18?</td></tr>
<tr><td>19</td><td>2/28</td><td>3/7</td><td>1. 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.
2. 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</td></tr>
</table>

			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 speed at this point.
20	3/2	3/12	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, 3. The bending moment in the air stream on a *three* bladed turbine nacelle with a tower height of 50 meters. Hint: $C_L = \frac{(L/A_L)}{\frac{1}{2}\rho V^2}$, $C_D = \frac{(D/A_D)}{\frac{1}{2}\rho V^2}$. Use: Lift to drag ratio C_L/C_D = 18, Drag coefficient C_D = 0.06.
21	3/5	3/12	List the major components of gear-driven wind machines.
22	3/7	3/14	Construct a table comparing the characteristics, advantages and disadvantages of: 1. Horizontal Axis Wind Turbines, HAWTs, 2. Vertical Axis Wind Turbines, VAWTs.
23	3/12	3/26	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.
24	3/14	3/26	Compare small wind turbines to utility level wind turbines as to: 1. Their applicable power range, 2. Their fields of applications, 3. Their rotational speeds, 4. The use of transmissions.
25	3/16	3/26	1. Assuming the same pressure drop and density, compare the resulting wind velocities ratio due to the tunnel effect for a decrease of the constriction or contraction ratio from β = 0.9 to β = 0.5. 2. Consider a zero porosity building, 20 meters in height and 60 meters in width positioned 300 meters from a 50 meter-height at the hub wind turbine. At the hub height, the wind speed would be decreased by 3 percent to 97 percent of the wind speed without the obstacle. Estimate the relative loss in power production caused by the decrease in wind speed.
26	3/26	4/2	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.
27	3/28	4/4	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: $P_t =$ __________________ $Watts$

<table>
<tr><td></td><td></td><td></td><td>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:
$r_{0,t} = \sqrt[3]{\frac{2T_t}{\pi \sigma_{s,\max}(r_0)}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{cm}$
$r_{0,m} = \sqrt[3]{\frac{2T_m}{\pi \sigma_{s,\max}(r_0)}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{cm}$
What is the implication regarding the low speed shaft design?_________________________________</td></tr>
<tr><td>28</td><td>3/30</td><td>4/6</td><td>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 ρ = 1 kg/m^3
The kite area A= 40 m^2
Product of generator efficiency and gearbox efficiency $\eta_{gear\ box}\eta_{generator}$ = 0.70
The mean cos α = 0.45
Lift to drag ratio C_L / C_D = 18
Drag coefficient C_D = 0.06
Thrust to axial speed coefficient $C_{thrust\ to\ axial\ speed}$ = 2</td></tr>
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<tr>
<td>29</td>
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<td>4/9</td>
<td>
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: 1,200 kW
Turbine price: $900,000
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.
<table>
<tr><th>Year
n</th><th>Expenditures
$</th><th>Gross Income Stream
$</th><th>Net Income Stream
$</th><th>Present value factor
$1/(1+r)^n$
r = 0.05</th><th>Net present value of income stream
$</th></tr>
<tr><td>0</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>16</td><td></td><td></td><td></td><td></td><td></td></tr>
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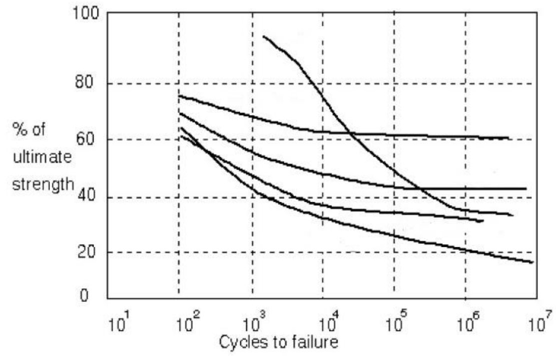
<tr><td>18</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>19</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>20</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Net present value of income stream at r = 5 percent/yr real rate of interest:
$______________________

$$\text{Yearly net real rate of return.} = \frac{\text{Net present value of income stream}}{\text{Total turbine cost}} \cdot \frac{1}{\text{Project lifetime}}$$
= ______________________________ percent/year.

$$\text{Present value of electricity cost per kWhr} = \frac{\text{Net present value of income stream}}{\text{Yearly energy production . Project lifetime}}$$
= ______________________________ cents / kWhr.
Please fill up all the entries in the table.</td></tr>
<tr><td>30</td><td>4/4</td><td>4/9</td><td>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.</td></tr>
<tr><td>31</td><td>4/6</td><td>4/9</td><td>List nine operational problems encountered in Wind Power generation.
Briefly describe the two forms of flicker resulting from rotor blades rotation.
Derive an expression for the probability of a bird collision with a rotating rotor blade.</td></tr>
<tr><td>32</td><td>4/11</td><td>4/18</td><td>Identify 10 sources of risk in wind turbines operation. Rank them according to what you conceive as their level of risk.
Define the total technological accident Risk (R) in terms of the number of occurrences N, the probability of each occurrence P_i, and the consequence of each occurrence C_i.
Blade ejection is a risk in small wind turbines power generation. Calculate the tip speed in miles per hour and meters per second of a 2-meters-diameter such turbine rotating at 200 rpm.</td></tr>
<tr><td>33</td><td>4/13</td><td>4/20</td><td>List the types of loads a wind turbine is subject to during service.
Write one paragraph about the effects of positioning of wind turbines above other engineering structures.</td></tr>
<tr><td>34</td><td>4/16</td><td>4/23</td><td>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.</td></tr>
</table>

			
35	4/18	4/25	Briefly describe the use of a controller in wind power generation: 1. For excess load dumping, 2. As back electromotive force for turbine braking.
38	4/20	4/27	To overcome the intermittence in renewable sources of energy, list the energy storage options under development.
39	4/23	4/30	List the equations governing the field of Computational Fluid Dynamics (CFD). List the variables usually used in one phase flow CFD. 1. Discretize the equation of motion or conservation of momentum for a fluid into its finite difference form and derive the corresponding updated speeds: $\frac{du}{dt} = -V\nabla p = -V\frac{\partial p}{\partial x} = -V\frac{\Delta p}{\Delta x}$ 2. 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: $dE = -pdV$ $\Delta E \simeq -p\Delta V$ 3. Derive the finite difference form of the updated interface positions using the approximation to the speeds: $u \simeq \frac{\Delta x}{\Delta t}$
40	4/25	5/2	List the wind energy storage available options for the following power ranges: 1. 1 kW to 100 kW, 2. 100 kW t0 10 MW, 3. 10 MW to 1,000 MW.
41	4/27	5/10	1. 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. 2. List the advantages of High Voltage Direct Current (HVDC) over High Voltage Alternating Current (HVAC) for electrical power transmission over long distances.
42	4/30	5/10	Briefly describe the two electronic devices used in HVDC power conversion: a) Thyristor, b) IGBT. On the basis of: i) the installation costs, ii) the line losses, use two diagrams to explain why HVDC is the favored option to HVAC for the long distance conveyance of wind power from the production sites to the consumption centers. What are the breakeven distances above which one option becomes more favorable than the other?

<table>
<tr>
<td>43</td>
<td>5/2</td>
<td>5/10</td>
<td>
Using a linear heat conduction model, the heat flux in region I of the lower atmosphere is:

$$q_I = +kA\frac{(t_s - t_m)}{r}, \text{ since } t_s > t_m$$

In region II of the upper atmosphere, the heat flux is:

$$q_{II} = -kA\frac{(t_u - t_m)}{s}, \text{ since } t_u > t_m$$

The net heat flux becomes a constant at any given height as:

$$q_{net} = q_I - q_{II} = +kA\left[\frac{(t_s - t_m)}{r} - \frac{(t_u - t_m)}{s}\right]$$

Adopt the following values for the parameters:

$$r = 13 \ km$$

$$s = 40 - 13 = 27 \ km$$

$$t_m = 210 \ K$$

Calculate the percent relative increase in the net heat fluxes to the troposphere as:

$$PRI = \left|\frac{q_{net} - q_{ref}}{q_{ref}}\right| \times 100$$

for a tripling of the CO_2 concentration by volume, estimate the percent net heat flux to the troposphere in the following table implying increased energy input to the region of the atmosphere where the weather phenomena are initiated.

<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) (× kA)</th><th>Temperature gradient, upper atmosphere (K/km) (× kA)</th><th>Net heat flux (× kA)</th><th>Relative increase (percent)</th></tr>
<tr><td>150 (Reference Case)</td><td>282</td><td>269</td><td>?</td><td>?</td><td>?</td><td>---</td></tr>
<tr><td>450</td><td>285</td><td>247.5</td><td>?</td><td>?</td><td>?</td><td>?</td></tr>
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<tr>
<td>Term project</td>
<td>4/16</td>
<td>Th. May 10, Day of final exam</td>
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Goal: “Explore the use of energy storage options in conjunction with wind power generation to increase the capacity factor and overcome its intermittence nature.”
Participants are expected to make a contribution to the project and present an individualized final report in printed and electronic forms on a CD, DVD or memory-stick about the full project.
Available wind turbines will be used by two groups, each with a project manager.
Please stay within the project’s budget of $500 for each group.
The report would be a blue-print for an interested individual or a group of people for replicating the project for some beneficial use.
Project highlights:
1. Electrical generation from the turbine will be demonstrated at a suitable location with minimum traffic. Plot the measured generated voltage as a function of the measured wind speed.
2. Choose a method of energy storage, discussing the merits of the choice: e. g. Battery storage, hydrogen storage using an electrolyzer, flywheel, capacitor, etc.
3. Investigate the use of a controller for the energy storage process.
4. Discuss potential alternatives and your own suggestions for an improved design.
5. Identify possible uses of such a design including needed specific extra components that you would suggest.
Include diagrams, photographs and videos to document the group’s work.
Participation in the project is voluntary.
Up to 5 extra points of credit will be awarded to the final grade for the contributors.

Please contact the following Project Managers by email to join the groups:

Group I: “Hydrogen as an energy carrier in Wind Power Generation”
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			Stephen Westman, swestma2@illinois.edu, project manager. Project members: Monet Worsham Jason Piermen Jessica Rabczak Pratik Ainapure Tyler Kennely Christopher Willenborg Jacob Wynveen Alex Bergereon Tom Crawshaw Akeem Kennedy Krislin Sharp Group II: “Battery storage in conjunction with Wind Energy.” Ryan Osborn, rtosbor2@illinois.edu, project manager. Project members: Daphne Shen jundais2@illinois.edu Alex Zickar azickar2@illinois.edu

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.