Midterm Exam, Spring Semester 2016
CEE 546: Air Quality Control

This is an open book, note, and library exam. The exam is to be taken without the exchange of information that is relevant to this exam between you and anyone else. If you have questions about the exam (e.g., difficulty understanding the questions or the calculations appear to be inappropriate), then please call me, send me an e-mail message, or stop by my office. My office phone number is 217-333-6963, my cell number is 217-390-2237, my e-mail address is mrood@illinois.edu, and my office address is 3230E NCEL.

Your solutions to this exam shall be submitted electronically to mrood@illinois.edu within 48.00 hr of receiving the exam. Show all of your calculations. Include an interpretation of your results for problem 4. A paragraph of 10-15 sentences for the interpretation is sufficient. If all the information is not given in the problem statements, then make the necessary assumptions to solve the problems and indicate what assumptions you made with justifications. Good luck!

1) (10 pt) Provide a critical review (critical yet constructive) of Table 2.3 “Property of Selected Solid Fuels” that was discussed during lecture in the underlined area provided below.
   Critical Review:
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2) (10 pt) Discuss Figure 2.6 “Equilibrium Composition and Temperature for Adiabatic Combustion of Kerosene, CH1.8, as a Function of Equivalence Ratio” for fuel lean conditions in the underlined area provided below.
   Discussion:
   __________________________________________________________
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(16 pt) Describe in the area below the following terms when trying to reduce the emissions of an air pollutant. Then provide two examples of each term when trying to reduce the emissions of sulfur dioxide (SO₂) into the atmosphere in the underlined areas provided below.

3a) Modify feed stream:
(4 pt) Description: ______________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

(4 pt) Two examples: ____________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

3b) Demand Side management:
(4 pt) Description: ______________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

(4 pt) Two examples: ___________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
3) (75 pt) An electrical-power production facility burns coal to produce 500 MW.e. The combustion air enters at 400 K and 101 kPa and coal enters at 320 K and 101 kPa. The thermal to electrical energy conversion efficiency is 32% when using the higher heating value (HHV) of the coal to determine the thermal to electrical conversion efficiency. Assume: (1) complete (no CO formation) and adiabatic combustion, (2) all nitrogen in the fuel and air forms N\textsubscript{2} (no NO\textsubscript{x} formation), (3) Cl forms HCl and Cl\textsubscript{2}, (4) S forms SO\textsubscript{2} and SO\textsubscript{3} formation), and (5) all ash becomes flyash. Standard temperature and pressure are 0°C and 1 atm, respectively. The coal is high-volatile bituminous coal from Kentucky as described in Table 2.3 “Property of Selected Solid Fuels”. The ash melts at 1,363 K and its enthalpy of fusion is 0.2 J/g. The specific heats for the coal and ash are 1.5 J/g-K and 1.8 J/g-K, respectively.

4a) (15 pt) Calculate and provide a plot (using linear scales) of adiabatic flame temperature (in unit of K) on the ordinate (vertical axis) vs. equivalence ratio ranging from 0.5 to 0.9 on the abscissa (horizontal axis).

4b) (15 pt) Calculate the concentrations of gaseous end-products and provide a plot of concentrations (in unit of % by volume) on the ordinate (vertical axis) using log scale vs. equivalence ratio ranging from 0.5 to 0.9 on the abscissa (horizontal axis) using a linear scale.

4c) (15 pt) Provide a plot (using log scale) for the chlorine (Cl) and sulfur (S) containing species (in unit of ppmv) on the ordinate (vertical axis) vs. equivalence ratio (using linear scale) for equivalence ratios ranging from 0.5 to 0.9 on the abscissa (horizontal axis).

4c) (15 pt) Compare the moles of CO\textsubscript{2} generated per MJ of fuel burned for the coal case described above and for No. 4 natural gas case at an equivalence ratio of 0.9. Assume a thermal to electrical conversion efficiency value for the natural gas of 38%.