2.650J/10.291/22.81J
INTRODUCTION TO SUSTAINABLE ENERGY

Fall 2010

OPEN BOOK **FINAL EXAM** 3 HOURS

NOTE: The data of Table A may be useful for solving any of the various problems below.

PROBLEM #1

A solar reflector array and "power tower" system produces sodium at a temperature of 400C. The sodium can be stored in an insulated reservoir that will maintain the fluid temperature ≥ 375C over a 24-hour interval. Considering the factors listed in Table A, what are the answers to the following questions?

Table A

Quantity	Value
heat of fusion, water	333.5 kJ/kg
heat of vaporization, water	2257 kJ/kg
specific heat capacity, water	4.184 kJ/kg*K
chemical formula, natural gas	CH4
chemical formula, gasoline	C8H12 (an averagecomposition, with shorter and longer chains present)
chemical formula, coal	C135H96O9NS (average)
chemical formula, methanol	CH3OH
HHV, natural gas	54.0 MJ/kg
HHV, gasoline	47.3 MJ/kg
HHV, coal	27 MJ/kg
HHV, methanol	22.7 MJ/kg
specific heat capacity, sodium	1.23 kJ/kg*K
density, sodium	0.927 g/cm^3
percent of solar array field areacovered with panels	50%
average insolation, problem 4	5 kWh/day
ambient temperature, problem 4	25 C

A. (**10 points**) What is the minimal area of a solar reflector array needed to provide an electricity output ≥ that of a base-loaded "thermal" power plant having a capacity of 1000 MWe?

B. (**10 points**) What minimal mass of sodium must be stored in the insulated reservoir in order to permit the plant's output power to be ≥ 1000 MWe for one day?

C. (**5 points**) What are five important potential environmental effects of building and operating the power plant?

PROBLEM #2

A. (**15 points**) An important hydroelectric plant has a head of 100 m and water volumetric flowrate of 10,000 m^3/s. What is the maximum power that the plant can produce?

B. (**10 points**) The reservoir behind the dam has a surface area of 100 $(km)^2$ and a depth of 10 m. If the water is in thermodynamic equilibrium with its surroundings at a temperature of 20C, what is the fractional rate of evaporative loss from the reservoir? In answering this question, consider only the energetics of the relevant phase changes. (Assume that the mean thermal insolation rate is 100 w/m^2.)

PROBLEM #3

An MIT student lives at 484 Beacon St., Boston (between Hereford St. and Massachusetts Ave.). He wishes to use a 10-speed bicycle to reach a final examination at MIT scheduled for May 2011. Consider the following events that could contribute to his failure to reach the examination site on time:

Table B Events Affecting the Bicycle Journey

- Starting the journey too late
- Closure of the Massachusetts Avenue bridge
- Mechanical failure of the bicycle
- Mechanical failure of the bicycle rider
- Collision between the bicycle and a motorized vehicle
- Unavailability of a lockable bike rack at MIT

A. (**8 points**) Construct an event tree for the event sequence describing success or failure to complete the journey on-time.

B. (**9 points**) Construct a fault tree for the top event, Mechanical failure of the bicycle.

C. (**4 points**) Which of the events of Table B are mutually dependent? Why?

D. (**4 points**) Which of the events of Table B have occurrence probabilities that will vary seasonally? Why?

PROBLEM #4

A. (**10 points**) Natural gas is described as having a carbon intensity less than that of coal. What is the ratio of CO_2 emissions from complete combustion of the two fuels?

B. (**10 points**) By what factor would use of 10% methanol as a constituent of gasohol change the CO_2 emissions for an automobile journey, compared to the case of fueling the journey solely using gasoline?

C. (**5 points**) How is your answer changed when you consider CO_2 emissions that occur in production of the required methanol? What are the activities causing such emissions?

EXTRA CREDIT (7 points)

At the end of 2008 it was broadly expected that federal legislation to establish a tax on CO_2 emissions would be considered by the Congress during the term of the new Congress, starting in 2009. This has not happened. Why?

22.081J / 2.650J / 10.291J / 1.818J / 2.65J / 10.391J / 11.371J / 22.811J / ESD.166J
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