Engineering 11
Fall 2003
James Hunt

Name KEY

Quiz No. 2
(November 14, 2003)

1 (25 pts) ____

2 (25 pts) ____

3 (25 pts) ____

4 (25 pts) ____

mean 62
SD 16
range 94 – 27

94 – 75	A	14
74 – 63	B	15
62 – 45	C	21
< 45 –	D	8

The exam is closed books and notes.

Do not ask for clarification of the problem statements, part of the exam is understanding the questions.

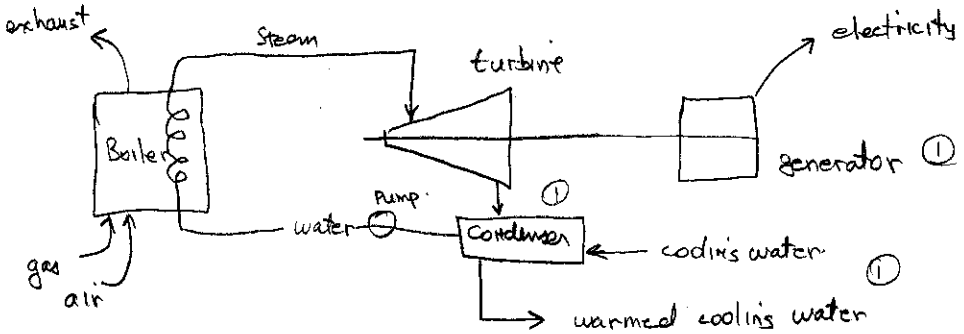
If you think there is an error in the problem, state any necessary assumptions and proceed.

Heat content: $q = mc_pT$ where m is mass [kg], c_p is heat capacity [kJ/kg-K], and T is temperature [K].

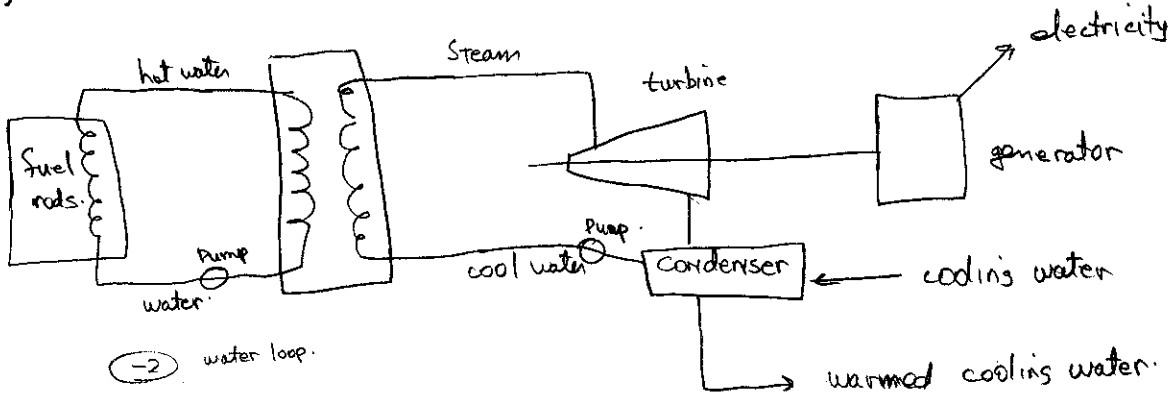
Partial credit is given for partially correct work.

1. Answer the following questions in the space provided.

(4) (a) Sketch the layout of a natural gas fired electrical generating plant that utilizes steam turbines.



(4) (b) Sketch the layout of a conventional nuclear power plant used to generate electricity.



(4) (c) List **two** reasons why nuclear power plants require more cooling water than fossil-fueled power plants.

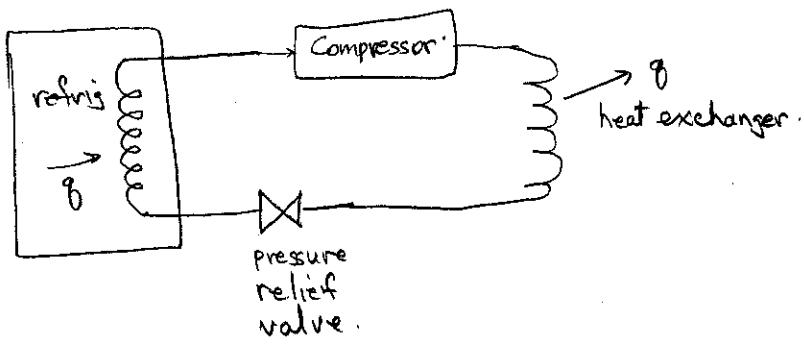
1) No heat loss out exhaust.

2) Operate at lower temperatures, thus less efficient.

3) Has two heat transfer steps rather than one for fossil plant.

1. (cont.)

(4) (d) Sketch the layout of a refrigerator and describe how heat is removed.



Refrigerant absorbs heat when changes to gas from liquid.

Compressor drives circulation.

External heat exchanger releases heat to environment.

(4) (e) How does London smog differ from Los Angeles smog?

London : Smoke + fog. (soot particles + H_2SO_4 + water drops) (2)

Los Angeles : photochemical smog from NO_x + O_3 + hydrocarbons. (2)

(4) (f) Why is ozone a particularly difficult pollutant to control in urban air basins?

There is no direct source of ozone, it is a secondary pollutant formed from the interaction of NO, hydrocarbons and sunlight.

Thus need control of NO_x and hydrocarbons that could have separate sources.

O_3 is difficult to model, thus difficult to set regulations.

2. Urban air quality is impacted by SO_2 in many locations.

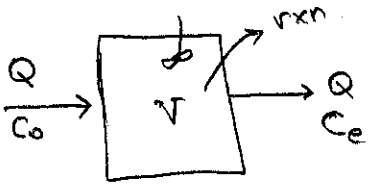
(5) (a) What is the predominant source of SO_2 found in air?

combustion of coal.

(5) (b) SO_2 undergoes first order oxidation to sulfuric acid:

$$SO_2 + \tfrac{1}{2} O_2 + H_2O \rightarrow H_2SO_4$$

with a first order rate constant, k_S [s^{-1}]. Air flows into a well-mixed valley with a flow rate of Q [m^3/s] and the air volume in the valley is V [m^3]. The SO_2 concentration entering the valley is C_o [mol/m^3] and there is no other source of SO_2 within the valley. Derive an expression for the SO_2 concentration leaving the valley under steady state conditions.



SO_2 balance:

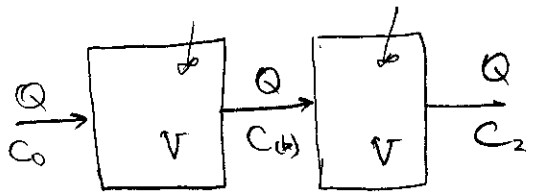
moles in by flow = moles out by flow + moles removed by rxn. (2)

$Q C_o \Delta t = Q C_e \Delta t + k_s C_e V \Delta t$. $C_e \neq C_{inside}$ (-2)

$$C_e = \frac{Q C_o}{Q + k_s V}$$

$$= \frac{C_o}{1 + k_s \frac{V}{Q}} = \frac{C_o}{1 + k_s \tau}$$

(5) (c) Downwind of the valley described in part (b), there is another identical valley of volume V. What is the expression for the SO_2 concentration leaving the second valley under steady state conditions?



repeat process in (b)

$$C_2 = \frac{C_{(b)}}{1 + k_s \tau}$$

$$= \frac{C_o}{(1 + k_s \tau)^2}$$

2. (cont.)

(5) (d) What is the concentration of H_2SO_4 leaving the second valley described in part (c)? There is no deposition of H_2SO_4 to the land surface in either valley.

moles (H_2SO_4) + moles SO_2 = moles SO_2 entering system. (2)

$$C_{H_2SO_4} = C_0 - C_2$$

$$= C_0 \left(1 - \frac{1}{(1+k_s\tau)^2}\right) \quad (3)$$

(5) (e) How would an increase in air flow rate through the valleys change your answers in (b) and (c)?

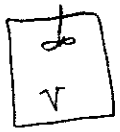
IF Q INCREASE, τ decreases AND C INCREASES, less CONVERSION because less time to react.

3. Nuclear power plants generate radioactive wastes that are fission products that undergo decay and release heat. This process is represented as a first order reaction

$A \rightarrow B$

Where radioisotope A decays to a stable isotope B with a first order rate constant k_A. The reaction generates heat, H [kJ/mol]. You have a closed and thermally insulated vessel containing A at an initial concentration of $C_{A,o}$ [mol/m^3] dissolved in water.

(8) (a) Derive an expression for the concentration of A within the vessel.



IN = OUT + ACCUMUL.

$$0 = k_A C_A V \Delta t + \Delta C_A V \quad \} (4)$$

$$\frac{\Delta C_A}{\Delta t} = -k_A C_A$$

↓ ok.

$$\frac{dC_A}{dt} = -k_A C_A \quad , \text{ integrate with I.C. } C_A(t=0) = C_{A,0} \quad \} (4)$$

$$C_A(t) = C_{A,0} e^{-k_A t}$$

(2) only

(8) (b) Derive an expression for the concentration of B within the vessel.

By mole balance.

$$C_B(t) = C_{A,0} - C_A(t)$$

$$C_B(t) = C_{A,0}\left(1 - e^{-k_A t}\right)$$

(8) (c) If the vessel had an initial temperature of T_o, what is the expression for the steady state temperature?

heat balance.

initial heat + heat added by decay = final heat

$$m C_p T_o + H \cdot C_{A,0} \cdot V = m C_p T_f$$

$$\left[\frac{kJ}{mole}\right]\left(\frac{mole}{m^3}\right)(m^3)$$

$$T_f = \frac{m C_p T_o + H C_{A,0} V}{m C_p}$$

$$T_f = T_o + H C_{A,0} V / m C_p$$

$$T_f = T_o + \frac{H C_{A,0}}{\rho C_p} \qquad \rho = \frac{m}{V}$$