Engineering 11
Fall 2003
James Hunt

Name KEY

Quiz No. 1
(October 10, 2003)

1 (25 pts) ____

2 (25 pts) ____

3 (25 pts) ____

4 (25 pts) ____

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.

Partial credit is given for partially correct work.

1. Answer the following questions in the space provided.

5 (a) List one air quality contaminant, indicate its source, and state why it is a contaminant. (you may not use lead)

SO_x
NO_x
PM_{10} / $PM_{2.5}$
O_3
CO

5 (b) List one water quality contaminant, indicate its source, and state why it is a contaminant. (you may not use perchlorate)

many

5 (c) List one contaminant of the land surface, indicates its source, and state why it is a contaminant.

many

1 (cont.)

5 (d) Why was lead removed from gasoline?

So that catalytic converters would work.

5 (e) List three ways of increasing the fuel efficiency of gasoline-powered automobiles.

Reduce weight
Reduce coef. of friction for tires
Reduce coef. of drag
Reduce projected area
Reduce velocity

2. Radioactive materials undergo first order decay (the decay rate is proportional to the atoms present). Consider a decay chain series of three radioisotopes: A, B, and C:

$A \rightarrow B \rightarrow C \rightarrow \ldots$

5 (a) If there exists A_o atoms initially, derive the expression for the number of atoms of A as a function of time. Assume the first order decay rate constant is k_A.

IN = OUT + ACCUMUL.

$0 = k_A A \Delta t + \Delta A$

-3 deriv.

$\frac{dA}{dt} = -k_A A$

Integrate

$A = A_o e^{-k_A t}$

5 (b) What is the expression for the half life of A?

at $t = t_{1/2}$ $A = \frac{1}{2} A_o$

$\frac{1}{2} \cancel{A_o} = \cancel{A_o} e^{-k_A t_{1/2}}$

$\ln 2 = k_A t_{1/2}$

$t_{1/2} = \frac{\ln 2}{k_A}$

5 (c) Derive a differential equation whose solution would predict the number of atoms of B. Let k_B represent the first order decay rate constant for B.

IN = out + accumul.

$k_A A \Delta t = k_B B \Delta t + \Delta B$

$$\boxed{\frac{dB}{dt} = k_A A - k_B B}$$

-3

2 (cont.)

(5) (d) A hazardous waste facility received a container having an unknown amount of isotope A within it. After the container sat around for 10 days, the container was measured to have a radioactive decay rate of 10^3 atoms of A per second. The container was counted again after being at the facility for 20 days and found to have a decay rate of 10^2 atoms of A per second. What is the first order decay rate constant for isotope A?

decay rate at time $t = \left.\frac{dA}{dt}\right|_t = \frac{d}{dt}\left(A_o e^{-k_A t}\right) = -A_o k_A e^{-k_A t}$

$t = 10d \qquad 10^3 = A_o k_A e^{-k_A(10d)}$

$t = 20d. \qquad 10^2 = A_o k_A e^{-k_A(20d)}$

divide 2 eqn's: $\qquad 10 = e^{-k_A(10-20)}$

Solve $\qquad k_A = \frac{\ln 10}{10\,d} = 0.23\,d^{-1} = 2.7 \times 10^{-6}\,s^{-1}$

(5) (e) For the conditions in (d), how many atoms of A were initially delivered to the hazardous waste facility?

use k_A from (d), plug into one of the equations.

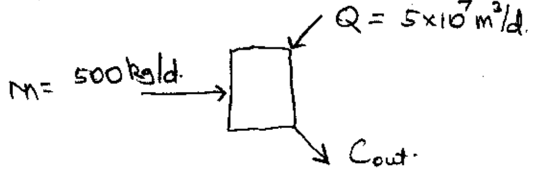
$10^3/s = A_o k_A e^{-k_A(10d)}$

$A_o = \frac{10^3 (\#/s)}{k_A e^{-k_A(10d)}} \quad (3600 \cdot 24\,s/d)$

$A_o = 3.7 \times 10^9$ atoms.

3. Perchlorate has been introduced into the Colorado River system from the manufacturing system in Henderson, Nevada. The manufacturing facility has been discharging perchlorate at a rate of 500 kg/day for 30 years. As you recall, perchlorate dissolved in water is inert and can be modeled as a conservative, nonreactive compound. The flow rate in the Colorado River leaving Nevada is $5x10^7$ m^3/day.

9 (a) What is the concentration of perchlorate in the Colorado River leaving Nevada?



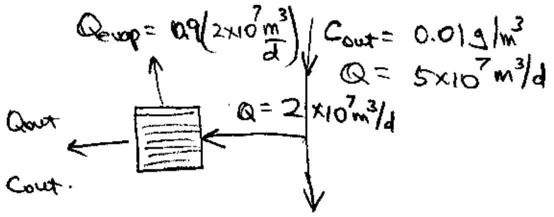
mass in = mass out. (Steady State)

$$500\ kg/d = C_{out}\left(5\times10^7\ m^3/d\right)$$

$$C_{out} = \frac{(500\ kg/d)(1000\ g/kg)}{5\times10^7\ m^3/d}$$

$$C_{out} = 0.010\ g/m^3$$

8 (b) After the Colorado River flows into California, $2x10^7$ m^3/day of water is diverted for irrigation where 90% of that water undergoes evaporation and transpiration. What is the perchlorate concentration in the irrigation return flow?



Water Balance for farm. $Q_{irr.\ ret.} = 0.20\times10^7\ m^3/d$

Perchlorate balance $(0.01\ g/m^3)(2\times10^7\ m^3/d) = C_{irr\ ret}\cdot(0.20\times10^7\ m^3/d)$

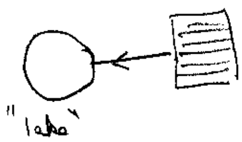
Solving $C_{irr\ ret.} = (0.01\ g/m^3)\dfrac{2\times10^7\ m^3/d}{0.2\times10^7\ m^3/d}$

$$= 0.10\ g/m^3$$

5 (c) The irrigation return flow is dumped into a terminal lake with no outlet. The lake has a steady state water volume of 10^9 m^3. What is the perchlorate concentration in the lake?

mass perchlorate added to lake (-4)

$$= (0.10\ g/m^3)(0.2\times10^7\ m^3/d)\left(365\ \frac{d}{yr}\right)(30\ yr)$$



$$= 2.2\times10^9\ g$$

$$\text{Perchlorate Conc.} = \frac{\text{mass}}{\text{Volume}} = \frac{2.2\times10^9}{10^9\ m^3}$$

$$= 2.2\ g/m^3$$

4. Under some circumstances, population growth is modeled as constant and independent of the current population:

dP/dt = R

where P is the population and R is the growth rate.

(8) (a) If the initial population is P_o, what is the expression for the population as a function of time?

$$\frac{dP}{dt} = R$$

integrate.

$$\int_{P_0}^{P} dP = R\int_0^t dt \Rightarrow P - P_o = Rt \Rightarrow \boxed{P = P_o + Rt}$$

(8) (b) One extension for this growth model is to include population decay (death) that is Proportional. ~~proposal~~ to the population. Let k_D represent the first order decay rate constant. What is the differential equation that describes population under these conditions?

IN = out + accumul.

$$R\Delta t = k_D P \Delta t + \Delta P$$

$$\frac{dP}{dt} = R - k_D P$$

(-4)

(8) (c) What is the expression for the maximum population under the conditions in (b)?

P_{max} occurs when growth balanced by decay

$$\frac{dP}{dt} = 0 \Rightarrow R = k_D P_{max} \Rightarrow P_{max} = \frac{R}{k_D}$$

(1) (d) Speculate on what might cause constant growth rates.

immigration limitation (US had limit)

transportation limitation (gold rush.)