CIVE 3331 - ENVIRONMENTAL ENGINEERING
Spring 2003

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Purpose: Exercises related to Lecture # 3. These exercises develop skills in materials balance analysis. Critical thinking is exercised in determination of where to draw system boundaries for analysis of various mass and energy flow problems. Direct relationships to various accreditation objectives are highlighted in **Bold** type in the following sections. The exercises start on the next page.

Relevant ABET EC 2000 Criteria: Criterion 3 Program Outcomes and Assessment

(3-a) an ability to **apply knowledge of mathematics, science, and engineering**.
(3-e) an ability to identify, **formulate, and solve engineering problems**.
(3-b) an ability to design and conduct experiments, as well as **to analyze and interpret** data.
(3-k) **an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.**

Relevant CEE Educational Objectives:

(3) Emphasize **problem-identification**, **problem-formulation** and communication skills, **problem-solving techniques** and the many facets of engineering design throughout the curriculum.

(5) **Prepare every student to develop the skills for critical thinking and lifelong learning.**

Relevant CEE Program Outcomes:

ii. **Students should acquire the ability to solve practical civil engineering problems by applying the knowledge of mathematics, science**, **engineering**, **modern techniques**, **skills and practical tools** they **gained in their courses.**

Exercise_003-1

A river with 400 ppm of salts (a conservative substance) and an upstream flow of 25.0 m3/s receives agricultural drainage from a return flow canal of 5.0 m^3/s carrying 2000 mg/L of salts. The salts are quickly mixed in the river. A municipality just downstream of the mixing zone withdraws river water and mixes it with imported (from a pipeline) salt-free water to produce a product water for delivery to customers with salt concentration of 500 ppm.

Determine the mixing ratio *F* of imported water to river water to meet the water producer's criteria. What is the cost of the water if the river water costs $1/volume unit and the imported water is $5/volume unit? Assuming the demand is constant, how much additional revenue could be derived if the water quality standard (of the product water) was relaxed to 600 ppm.

Notes:
The concentration is increased – the standard is relaxed.
The solution is an algebraic expression; the municipal demand is not supplied in the problem statement.

Sketch of system:

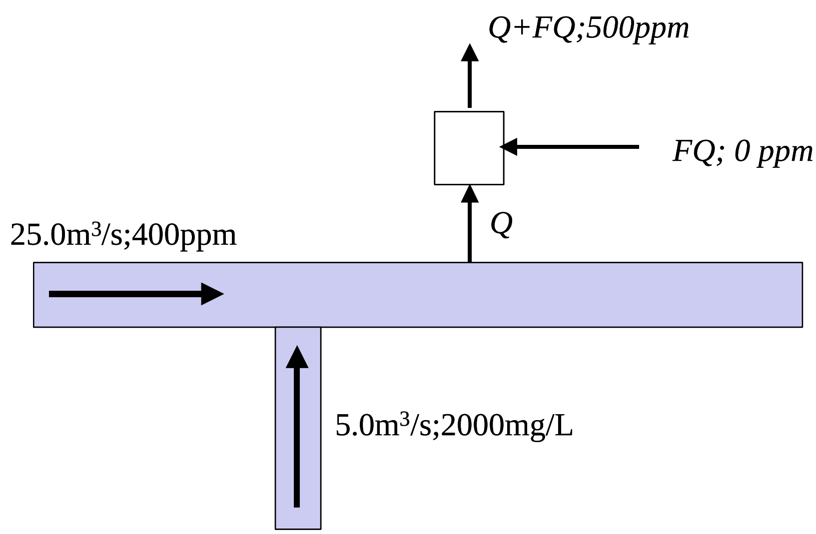

Figure 1. Water supply scenario

Exercise_003-2

A two-lake system is supplied by a stream with a flow rate of 1.0 MGD (million gallons per day) and BOD (a nonconservative pollutant indicator) concentration of 20.0 mg/L. The first-order decay rate of the BOD is 0.30/day. The volume of the first lake is 5.0 million gallons. The volume of the second lake is 3.0 million gallons. Assume complete mixing within each lake. Determine the concentration of BOD exiting each lake. If the decay rate of the first lake is reduced to 0.15/day, what is the concentration of BOD leaving the second lake?

Sketch of system:

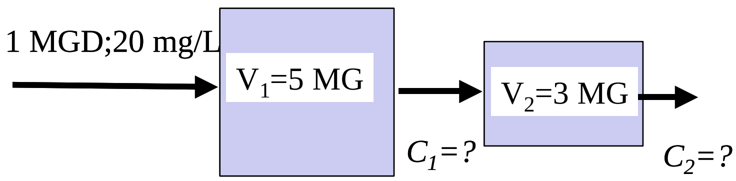

Figure 2. Two-lake system

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Exercise_003-3

You are to ***design*** a storm water lagoon (big pond to let solids settle before flow is allowed to leave the lagoon). The lagoon must accept an inflow of 0.10 m^3/s of non-conservative pollutant with concentration 30.0 mg/L and a first-order decay rate of 0.20/day. The effluent from the lagoon must have pollutant concentration less than 10.0 mg/L.

Assume complete mixing and determine the required volume of the lagoon.

The ratio of the lagoon volume to flow rate is called the hydraulic retention time. A rule-of-thumb for settling of storm water borne pollutants is that the retention time should be at least one hour. Determine the lagoon volume required to achieve a HRT of one hour. Determine the effluent concentration of the pollutant under these conditions, does this lagoon meet the effluent requirement?

If the sidewall height of the lagoon is 3 meters, how much land is needed for a circular lagoon that meets the effluent requirement?

If the sidewall height of the lagoon is 3 meters, how much land is needed for a square lagoon that meets the effluent requirement?

Exercise_003-4

Consider the use of a tracer gas to determine the air exchange rate in a room. Assume the room is modeled as a box model as depicted in the figure. Use the principles of mass balance modeling to derive the governing equation of tracer concentration in the room as a function of time. Use the variable names in the figure.

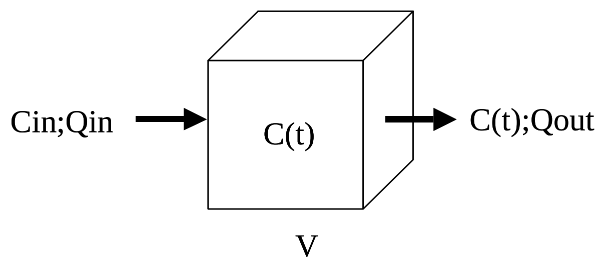


Figure 3. Tracer loss from a room

Using the variable names supplied in table 1, write the differential equation that relates change in mass stored in the room to mass fluxes into and out of the room.

Table 1. Tracer Loss Notation

Description	Symbol	Quantity	Dimensions
Tracer Inlet Concentration	C_{in}	(mass/volume)	M/L^3
Tracer Concentration in Room	$C(t)$	(mass/volume)	M/L^3
Air Flow Rate into Room	Q_{in}	(volume/time)	L^3/t
Air Flow Rate out of Room	Q_{out}	(volume/time)	L^3/t
Room Volume	V	(volume)	L^3

Mass Flow In =

Mass Flow Out =

Change in Mass/Time (in the room) =

Balance Equation (Change in Mass/Time = Mass Flow - In Mass Flow Out):

Exercise_003-5

From the previous exercise (Exercise_003-4) you have a differential equation of tracer concentration in the room.

Assume the initial tracer concentration (time = 0) is C_o.

Assume the inlet concentration $C_{in} = 0$.

Show (do the calculus and algebra) that the analytical solution to the differential balance equation is:

$$C(t) = C_o \exp(-\frac{Q}{V} t)$$

Exercise_003-6

From Exercise_003-5 you have the analytical solution for a time history of concentration in the room after initial tracer release. Assume that the airflow rate is 20 cubic meters per hour and the room volume is 40 cubic meters. Assume that the initial tracer concentration is 100mg/m^3.

Calculate the tracer concentration history (complete the table) below and make a plot of concentration (vertical axis) versus time (horizontal axis). Be sure to include the minimum plotting elements discussed in Lecture_000.

Table 2. Concentration History of Tracer - I

Time (hours)	Concentration (mg/m^3)
0	100
0.5	
1.0	
1.5	
2.0	
2.5	
3.0	
5.0	
10.0	

Exercise_003-7

Suppose you release the same tracer gas as in Exercise_003-6, and collect the following tracer concentration history. Find the airflow rate for a room with a volume $40m^3$.

Table 3. Tracer History in 40 cu.m. room

Time (hours)	Concentration (mg/m^3)
0	100
0.5	80.0
1.0	60.0
1.5	50.0
2.0	33.0

Exercise_003-8

A simple way to model air pollution over a city is with a box model that assumes complete mixing and limited ability for the pollution to disperse horizontally or vertically except in the direction of the prevailing winds. Consider a town with an inversion at 250 m, and 20 km horizontal distance perpendicular to the wind, a wind speed of 2 m/s, and a carbon monoxide (CO) emissions rate of 60 kg/s. Assume CO is conservative and completely mixed in the box, what is the concentration of the CO leaving the box model?

Sketch of system:

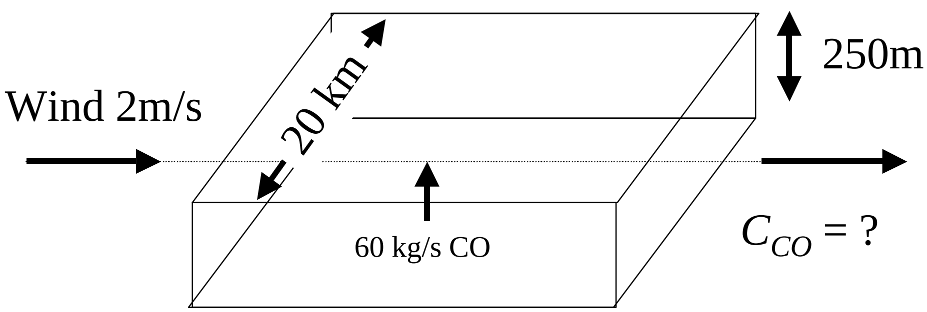


Figure 4. Box model over city

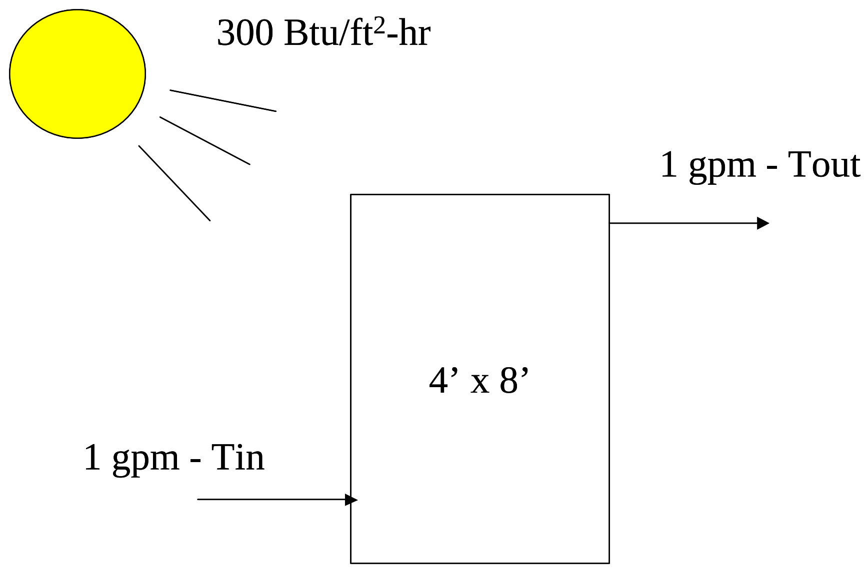
Exercise_003-9

Consider a box model for an air shed over a city 1 x 10 ^{5} m on a side and a mixing depth of 1200 m. Winds with SO_2 = 0 kg/m^3 blow on the west side of the box at 4 m/s. SO_2 is generated within the box (assume complete mixing) at a rate of 20 kg/s. Assume SO_2 is conservative.

a) Sketch the box model and write the mass balance equation for SO_2 in the airshed.
b) Estimate the steady state SO_2 concentration in the air shed.
c) Assume the air shed is initially free of SO_2, estimate the SO_2 concentration after 5 days of emissions.

Exercise_003-10

A 4 x 8 foot solar collector has water circulating through it at a rate of 1.0 gallons per minute wile exposed to sunlight at an intensity of 300 Btu/ft^2-hr. Fifty percent of the sunlight is captured by the collector and heats the water flowing through it. What would be the temperature rise of the water as it leaves the collector?



Exercise_003-11

Two-thirds of the energy content of fuel entering a 1000-MW_e nuclear power plant is removed by condenser cooling water that is withdrawn from a local river (there are no stack losses). The river has an upstream flow rate of 100 m^3/s and a temperature of 20 ^oC.

a) If the cooling water is only permitted to rise in temperature by 10 ^oC, what flow rate from the river would be required?
b) What would be the river temperature rise after the cooling water is released back to the river?

Exercise_003-12

Compare the energy required to evaporate one kilogram of water at 15 ^{o}C to that required raising it 3 km into the air.

Document History:

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