(23)

M. Sc. in Civil Engineering

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ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

TERM: SEMESTER FINAL EXAMINATION — SUMMER SEMESTER: 2021-2022
COURSE NO.: CEE 6305 — TIME: 3.0 Hours
COURSE TITLE: Surface Water Quality Modeling — FULL MARKS: 150

There are **8 (EIGHT)** questions. Answer **ANY SIX** questions. Programmable calculators are not allowed. Do not write on this question paper. The figures in the right margin indicate full marks. Symbols convey their usual meanings. Assume reasonable values for any necessary design data where required.

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1. (a) Distinguish between mass loading rate and mass flux rate. Show a schematic representation of the loading, transport, and transformation of two substances moving through and reacting within a volume of water. (7)

   (b) Lake Ontario in the early 1970s had a total phosphorus loading of approximately 10,500 mta (metric tonnes per annum, where a metric tonne equals 1000 kg) and an in-lake concentration of 21 μg/L. In 1973 the state of New York and the province of Ontario ordered a reduction of detergent phosphate content. This action reduced loadings to 8000 mta. (9)

   (i) Compute the assimilation factor for Lake Ontario.
   (ii) What in-lake concentration would result from the detergent phosphate reduction action?
   (iii) If the water-quality objective is to bring in-lake levels down to 10 μg/L, how much additional load reduction is needed?

   (c) A pond having constant volume and no outlet has a surface area A_s of 10^4 m^2 and a mean depth H of 2 m. It initially has a concentration of 0.8 ppm. Two days later a measurement indicates that the concentration has risen to 1.5 ppm. (i) What was the mass loading rate during this time? (ii) If you hypothesize that the only possible source of this pollutant was from the atmosphere, estimate the flux that occurred. (9)

2. (a) Describe the four periods in the development of water quality modeling. (10)

   (b) Employ the integral method to determine whether the following data is zero-, first-, or second-order: (15)

t (d)	0	1	3	5	10	15	20
c (mg L^{-1})	12	10.7	9	7.1	4.6	2.5	1.8

   If any of these models seem to hold, evaluate k and C_o.

3. (a) With the help of an Illustration show how even small data errors are amplified by numerical differentiation. (5)

(b) Discuss the mass balance of a well-mixed lake. **(5)**

(c) A lake has the following characteristics: **(15)**
Volume = 50,000 m^3
Mean depth = 2 m
Inflow = outflow = 7500 m^3/d
Temperature = 25°C

The lake receives the input of a pollutant from three sources: a factory discharge of 50 kg/d, a flux from the atmosphere of 0.6 $g/m^2/d$, and the inflow stream that has a concentration of 10 mg/L. If the pollutant decays at the rate of 0.25/d at 20°C (θ = 1 .05)

(i) Compute the assimilation factor.
(ii) Determine the steady-state concentration.
(iii) Calculate the mass per time for each term in the mass balance and display your results on a plot.

4 **(a)** For the lake in problem 3 (c), determine the (i) inflow concentration, (ii) transfer function, (iii) water residence time, and (iv) pollutant residence time **(10)**

(b) At time zero, a sewage treatment plant began to discharge 10 MGD of wastewater with a concentration of 200 mg/L to a small detention basin (volume = 20 x 10^4 m^3). If the sewage decays at a rate of 0. 1 d^{-1}, compute the concentration in the system during the first 2 weeks of operation. Also, determine the shape parameters to assess the ultimate effect of the plant. **(10)**

(c) Explain impulse loading and step loading of any pollutant into a water basin. **(5)**

5 **(a)** A well-mixed lake has the following characteristics: **(18)**
Q = 10^5 m^3/yr, z = 5 m, v = 0.25 m/ yr, v = 10^6 m^3, k = 0.2 yr
At t = 0 it receives a step loading of 50 X 10^6 g/yr and has an initial concentration of 15 mg/ L. Use Euler's method to simulate the concentration from t = 0 to 20 yr using a time step of 1 yr. Compare the results with the analytical solution.

$$c = c_0 e^{-\lambda t} + \frac{W}{\lambda V}(1 - e^{-\lambda t})$$

(b) Distinguish between Euler's method and Heun's method of solving ordinary differential equations for solving any completely mixed lake model. **(7)**

6 **(a)** A point source is discharged to a river having the following characteristics: $Q_r = 12 \times 10^6$ m^3/d, C_r = 1 mg/L, $Q_w = 0.5 \times 10^6$ m^3/d, and C_w = 400 mg/L. **(10)**
(i) Determine the initial concentration assuming complete mixing vertically and laterally.
(ii) Calculate the concentration of the pollutant for 8 km below the injection point. Note that the stream has a cross-sectional area of 2000 m^2 and the pollutant reacts with first-order decay (k = 0.8/d).

(b) Five kg of a conservative pollutant is spilled into a stream over a period of about 5 min. The stream has the following characteristics: flow = 2 m^3/s and cross-sectional area = 10 m^2. Determine the concentration and the extent of the spill and how long it takes to reach a water intake located 6.48 km downstream. **(10)**

(c) Explain the diffusion, dispersion and advection process. **(5)**

7 (a) A tracer study is conducted in a stream with a flow of 3×10^5 m^3/d and a width of 45 m. At t = 0, 5 kg of a conservative substance, lithium, is instantaneously injected at x=0. Concentrations are measured at two downstream stations: **(15)**

x = 1 km

t (min)	30	40	50	60	70	80	90	100	110	120
Lithium (μg/L)	0	100	580	840	560	230	70	15	3	0

x= 8 km

t (min)	370	400	430	460	490	520	550	580	610
Lithium (μg/L)	0	10	80	250	280	140	35	5	0

Determine (i) the velocity (m/d) and (ii) the dispersion coefficient (cm^2/s).

(b) Evaluate the estuary number of any stream for a non-conservative tracer with a half-life of 1d, where E= 50,000 cm^2/s and U = 24,000 m/d. **(5)**

(c) How do you estimate low flow for any water reservoir? **(5)**

8. (a) A one-dimensional estuary has constant dimensions and flow: width = 300 m, depth = 3 m, and flow = 15 cms. You measure the following chloride concentrations along its length (note that kilometer points increase toward the ocean): **(10)**

Kilometer point	0	3	6	9	12	15	18	21
Chloride (ppt)	0.3	0.5	0.8	1.4	2.2	3.7	6.0	10.0

Determine the dispersion coefficient for the estuary in cm^2/s.

(b) The following 7-d low flows were compiled for a river:

1971	1.72	1976	4.23	1981	4.48	1986	5.39
1972	3.03	1977	4.11	1982	3.03	1987	3.00
1973	2.76	1978	1.92	1983	2.84	1988	2.50
1974	1.65	1979	2.14	1984	3.66	1989	2.47
1975	2.00	1980	1.48	1985	1.87	1990	3.07

Use this data to determine the 7 Q 10. Use probability paper. **(10)**

(c) Explain the water balance for any well-mixed lake. **(5)**

Formulae

$$vA_s c\frac{H}{H} = \frac{v}{H}(AH)c = k_s V c \qquad a = Q + kV + vA_s$$

$$c = \frac{W}{Q + kV + vA_s} \qquad A_s = \frac{V}{H} \qquad W_{\text{atmosphere}} = JA_s$$

$$\text{Reaction} = kVc$$

$$\frac{c}{c_{\text{in}}} = \beta \qquad W = Qc_{\text{in}} \qquad \beta = \frac{Q}{Q + kV + vA_s}$$

$$\tau_w = \frac{V}{Q} \qquad \tau_c = \frac{V}{Q + kV + vA_s}$$

$$c = \frac{W}{\lambda V}(1 - e^{-\lambda t}) \qquad \bar{c} = \frac{W}{\lambda V} \qquad \lambda = \frac{Q}{V} + k + \frac{v}{H}$$

$$t_{95} = \frac{3}{\lambda} \qquad c_0 = \frac{Q_w c_w + Q_r c_r}{Q_w + Q_r} \qquad c_0 = \frac{W}{Q} \qquad U = \frac{Q}{A_c}$$

$$c = c_0 e^{-\frac{k}{U}x} \qquad c(x,t) = \frac{m_p}{2\sqrt{\pi E t}} e^{-\frac{(x-Ut)^2}{4Et}} \qquad \eta = \frac{kE}{U^2}$$

$$\bar{c} = \frac{\sum_{i=0}^{n-1}(c_i + c_{i+1})(t_{i+1} - t_i)}{2(t_n - t_0)} \qquad U = \frac{x_2 - x_1}{\bar{t}_2 - \bar{t}_1}$$

$$E = \frac{U^2\left(s_{t2}^2 - s_{t1}^2\right)}{2\left(\bar{t}_2 - \bar{t}_1\right)} \qquad p = \frac{m}{N + 1} \qquad T = \frac{1}{p}$$