Problem 1.
A river with a uniform cross-section and a velocity of 8 km/day flows between Stations 1 and 2, which are 32 km apart. At Station 1, a waste discharge brings the total ammonia nitrogen concentration in the river up to 9 mg/L. The nitrite and organic nitrogen concentrations at this station are negligible.

At the temperature of the waste-river mixture, the parameters for ammonia oxidation at Station 1 are estimated to be:

- \( k_{N1} = 2.25 \text{ day}^{-1} \)
- \( K_{S1} = 2.10 \text{ mg/L} \)
- \( M_{oN1} = 0.20 \text{ mg/L} \)

It is also found that the nitrite oxidation parameters are such that all nitrite is converted directly and rapidly to nitrate (i.e. \( \frac{dC_{N2}}{dt} = 0 \)).

a) Calculate, by trial and error, the ammonia nitrogen concentration at Station 2.

b) Calculate the rate of dissolved oxygen utilization due to nitrification at Stations 1 and 2.

Partial answer to part b \( \frac{dC_{ox}}{dt} = -10.57 \frac{\text{mg O}_2}{\text{L} \cdot \text{d}} \) @ station 2.

Problem 2.
A completely mixed pond of volume, \( V \), has an influent steady-state flow, \( Q \), entering with a BOD_{L} concentration of \( L_0 \) and a dissolved oxygen (D.O.) concentration of \( C_o \) (see the illustration below). Assume a first-order BOD decay constant, \( k_1 \), and a first-order reaeration coefficient of \( k_2 \) as indicated:

- \( Q = 10^7 \text{ L/day} \)
- \( V = 2 \times 10^8 \text{ liters} \)
- \( k_1 = 0.20 \text{ day}^{-1} \)
- \( k_2 = 0.23 \text{ day}^{-1} \)
- \( C_o = 4 \text{ mg/L D.O.} \)
- \( C^* = 10 \text{ mg/L D.O. (saturation level of D.O.)} \)

a) What would be the allowable maximum influent BOD_{L} concentration (\( L_0 \)) in order to maintain the steady-state dissolved oxygen concentration in the pond (\( C \)) above 2 mg/L D.O.?

b) If the initial BOD_{L} concentration in the pond (at time = 0) is 5 mg/L, what will the BOD_{L} concentration be three days after the waste input is begun (with \( L_0 \) equal to the amount you arrive at in part (a))? Ans. (a) \( L_0 = 48.5 \text{ mg/L} \); (b) \( L = 7.48 \text{ mg/L} \)
Problem 3.

The stream shown below has a flow of 28,000 m$^3$/d and a cross-sectional area of 35 m$^2$. The stream is saturated with dissolved oxygen ($C^* = 10$ mg/L), and its $BOD_L$ concentration is 0.5 mg/L. At point (A), 7 km upstream from the stream’s confluence with another much larger river, a food processing industry is continuously discharging 1,500 m$^3$/day of wastewater with an average organic composition of CH$_2$O (which is 90% degradable). The wastewater has a dissolved oxygen concentration of 2 mg/L. A stream sample taken just before the confluence of stream and river has a $BOD_{5}^{20^0C}$ of 3.0 mg/L ($k_{lab} = 0.24$/day for BOD assimilation in the lab).

a) Calculate the concentration of the wastewater (in units of mg CH$_2$O/L) before it is mixed in the river. Relevant constants are given below.

b) Determine whether the D.O. level in the stream remains above 5 mg/L between point A and the confluence of the stream with the larger river. You may assume the following:
   i) plug flow
   ii) instantaneous mixing of stream and wastewater
   iii) stream and wastewater temperatures are 15°C, and the applicable 15°C rate constants are:
      - $k_1 = 0.18$/day for BOD assimilation in the river
      - $k_3 = 0.01$/day for BOD sedimentation in the river
      - $k_2 = 0.23$/day for reaeration
   iv) $C^*$ for the stream = 10.0 mg/L

c) If the wastewater D.O. is raised to the saturation value of 10 mg/L, what degree of waste treatment (% removal), if any, would be needed to keep the D.O. above 5 mg/L in the stream?

Ans. (a) 416 mg CH$_2$O/L; (b) $D.O_{min.}=3.30$ mg/L; (c) 24.38% removal needed
Problem 4. (Adapted from Introduction to Environmental Engineering by Davis and Cornwell).

a) The Watertown town council has asked that your firm determine whether or not the discharge of the town’s wastewater into the Green River will reduce the dissolved oxygen below the state standard of 5.00 mg/L at Smithville, which is located 5.8 km downstream, or at any other point downstream of Watertown. The pertinent data are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Watertown wastewater</th>
<th>Green River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow, m$^3$/s</td>
<td>0.28</td>
<td>0.90</td>
</tr>
<tr>
<td>BOD$_L$ at 28 °C, mg/L</td>
<td>28</td>
<td>2.0</td>
</tr>
<tr>
<td>DO, mg/L</td>
<td>2.00</td>
<td>7.8</td>
</tr>
<tr>
<td>$k_1$ at 28 °C, d$^{-1}$</td>
<td>Not applicable</td>
<td>0.2</td>
</tr>
<tr>
<td>$k_r$ at 28 °C, d$^{-1}$</td>
<td>Not applicable</td>
<td>0.22</td>
</tr>
<tr>
<td>Speed, m/s</td>
<td>Not applicable</td>
<td>0.08</td>
</tr>
<tr>
<td>Depth, m</td>
<td>Not applicable</td>
<td>3</td>
</tr>
<tr>
<td>Temperature, °C</td>
<td>28 °C</td>
<td>28 °C</td>
</tr>
</tbody>
</table>

Use of a spread sheet is recommended in solving this problem. In addition to answering the questions posed by the town council, prepare a plot of dissolved oxygen in the Green River. The range for the x-axis on your plots should be 0 to 50 kilometers; use 0.5 kilometer distance increments in your spread sheet calculations. Assume there is zero salinity in the river and the wastewater. Values for the saturation level of D.O. can be obtained from Appendix F of your recommended text, Water Quality. Values for $k_2$ can be estimated from the quasi-empirical formula developed by O’Connor & Dobbins and discussed in lecture. You may assume $\theta$ for $k_1$ in the river is 1.056 and that $\theta$ for $k_2$ in the river is 1.024.

b) What combination of BOD reduction and/or wastewater D.O. increase would be required in part a so that the D.O. in the Green River never drops below 5.0 mg/L? Assume the cost (per mg/L) of BOD reduction is 3 times higher than that of increasing the D.O., and give the most cost effective solution.

Problem 5.

Do STELLA Exercise #3. Please remember to turn in the STELLA part of your homework separately and with its own transmittal letter.