1. A chemical reaction is of order 2.5
   a. What are the units of the rate constant?
   b. What is the solution to the rate equations [i.e., what is C(t)]?
   c. Write an expression for the half-life and e-folding time.

2. In the atmosphere, \( \text{N}_2\text{O}_5 \) will transform to \( \text{NO}_2 \) due to the chemical reaction:
   \[
   2\text{N}_2\text{O}_5 \rightarrow 4\text{NO}_2 + \text{O}_2
   \]
   Experimental data show the concentration of \( \text{N}_2\text{O}_5 \) varies as a function of time. Giving the measured data in the following table, determine
   a. The order of the reaction.
   b. The reaction constant.

<table>
<thead>
<tr>
<th>Time (minute)</th>
<th>( \text{N}_2\text{O}_5 ) Concentration (mg/liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.883</td>
</tr>
<tr>
<td>10</td>
<td>0.625</td>
</tr>
<tr>
<td>20</td>
<td>0.471</td>
</tr>
<tr>
<td>30</td>
<td>0.362</td>
</tr>
<tr>
<td>40</td>
<td>0.255</td>
</tr>
<tr>
<td>50</td>
<td>0.186</td>
</tr>
<tr>
<td>60</td>
<td>0.142</td>
</tr>
<tr>
<td>70</td>
<td>0.115</td>
</tr>
</tbody>
</table>

3. A river has the following characteristics: water depth \( h = 2.0 \) m, width \( B = 200 \) m, bottom slope \( S = 1 \times 10^{-3} \), Manning coefficient \( n = 0.01 \), and turbulent intensity 20%.
   a. Use the Lewis-Whitman model to estimate the transfer velocity \( k_l \). A typical layer thickness \( \sigma \) is of order \( O(0.1 \) mm) to \( O(1 \) mm).
   b. Use the small-eddy film renewal model to estimate \( k_l \).
   c. Use the large-eddy film renewal model to estimate \( k_l \).
   d. Compare and discuss the three \( k_l \)'s you obtained.
   e. Calculate the flux of dissolved oxygen (DO) into the river using the most reasonable \( k_l \) (use your own judgment with justification) among the three
above. The saturated concentration \([\text{DO}_{\text{sat}}]\) is 8.0 mg/L while the measured \([\text{DO}]\) near the bottom of the river is 4.0 mg/L.

f. What is the total mass transfer of DO into the river for every km length?

4. Apply the two-layer interfacial wave solution to the case of a deep layer above a shallow layer. Obtain the expressions for the interfacial waves for
   a. Dispersion relationship (i.e., function \(\omega\))
   b. Phase speed
   c. Discuss your solutions and comparing them with that of the surface waves.

5. A lake has a length of 6 km and a depth of 100 m. During a certain day in the summer, the temperature at the upper layer of the lake is 22 °C while at the bottom layer is 10 °C. The wind speed \(U_{10}\) is 5.0 m/s that day. Estimate
   a. The modified Richardson number
   b. The mixing regime of the lake
   c. The surface wave amplitude of the seiches
   d. The interfacial wave amplitude of the seiches
   e. If another day the lake temperature varies approximately linearly from 22 °C to 10 °C over an elevation of 5 m at a certain depth, calculate the eigenfrequency.