1. The enzyme chain reaction scheme of a system follows $\xrightarrow{V_o} S_1 \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} S_2 \xrightarrow{k_2}$

   Where species S_1 enters the system with a constant rate Vo. S1 is then converted
   to S_2 via a first-order mass action kinetics with forward and backward reaction
   constants, k_1 and k_{-1}, respectively. S_2 then leaves the system with a rate
   proportional to its concentration, and k_2 is the rate constant.

   (1) Given that Vo, k_1, k_{-1}, and k_2 are 1, 100, 100, 1, respectively. Please calculate
   the time constants of the system. (Assume that the parameters are all in
   dimensionless form) (10%)

   (2) Under what time scale can one assume quasi-steady state? (10%)

   (3) If the initial conditions of both S_1 and S_2 are 1 (again, dimensionless), please
   estimate their values at time = 100. (10%)

2. The fastest doubling time for E. coli is about 20 minutes. What is the maximum
   feed rate (liter/hr) for a continuous fermentation tank with a working volume of
   0.5 liter ? (10%)

3. We are trying to grow E. coli cell in a shake flask (batch fermentation).　The
   initial glucose concentration is 10 g/L, and the initial cell concentration is 0.1 g
   dcw/L. Please estimate (1) the glucose concentration when the cell concentration
   reaches 2 g/L, and (2) the time needed for the cell mass to reach 2g/L. Assume
   that the following kinetic parameters are valid: (20%)
   $\mu = S/(0.02 + 4S)$　S: glucose concentration (g/L), μ: spedific growth rate (1/hr)
   $Yx/s = 0.5$

4. What are the roles of CO_2 provided in air to animal cell cultures ? (10%)

5. Please describe the following terminology.(a) k_La (b) collagen (c) steriod
   transformation (d) sialic acid (e) tissue plasminogen activator (f) Good
   Manufacturing Practices (30%)