

# CONTROL AND MODELLING OF BIOLOGICAL SYSTEMS

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## Medical Engineering (LM)

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### Exercise 1

Given the following information for a drug following first-order elimination:

- Dose administered: 200 mg
- Elimination rate constant (k):  $0.105 \text{ hr}^{-1}$
- Concentration of the drug at 1 hour post-administration: 90mg/L

Calculate:

- a) The apparent volume  $V_d$ .
  - b) The concentration of the drug at 2 hours post-administration.
  - c) The time required for the drug concentration to decrease to 50 mg/L.
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### Exercise 2

A patient receives a 400 mg dose of a drug intravenously. After injection, the drug is quickly distributed in the body. The drug is eliminated mainly through metabolism in the liver.

The concentrations of the drug in the body are as follows:

- Central compartment (Plasma): 200 mg/L

The drug is known to have an elimination constant of  $0.1 \text{ h}^{-1}$ .

Calculates:

1. The volume of distribution ( $V_d$ ) of the drug and the clearance (CL) of the drug.
2. The concentration of the drug in the central compartment at 2 hours after injection.
3. The half-life of the drug.

Suppose the same dose of the drug is injected every 8 hours. Calculate

4. The concentration of drug immediately after the second and third doses.
  5. The time it takes to reach steady-state.
  6. Steady-state concentration
  7. Steady-state concentration if the drug was taken every 6 hours or every 12 hours.
  8. How should the posology of the drug be changed without modifying the drug doses, if the desired steady-state concentration is 20% higher than the one obtained in the previous point.
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### Exercise 3

A pharmacokinetic system consists of a first-order absorption compartment and a first-order central compartment. A patient receives a dose of 500 mg of an oral medication. After administration, the bioavailable fraction of the drug is 85%. The drug is eliminated mainly through metabolism in the liver with elimination constant  $k_e=0.1 \text{ h}^{-1}$

Two hours after intake, the remaining dose of drug in the absorption compartment is 250mg.

1. Calculate the bioavailable dose
2. Calculate the absorption constant  $k_a$
3. Calculate the peak time and peak concentration value if the apparent volume is 3 L.

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#### Exercise 4

A pharmacokinetic system consists of a first-order absorption compartment and a first-order central compartment. A patient receives a dose of 500 mg of an oral medication. After administration, the bioavailable fraction of the drug is 80%. The drug is eliminated mainly through metabolism in the liver with elimination constant  $k_e = 0.2 \text{ h}^{-1}$

Three hours after intake, the remaining dose of drug in the absorption compartment is 250mg.

1. Calculate the bioavailable dose
2. Calculate the absorption constant  $k_a$
3. Calculate the peak time and peak concentration value if the apparent volume is 2 L.

Suppose the same dose of the drug is administered every 5 hours. Calculate

4. The concentration of drug immediately after the second, third and fourth doses.

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#### Exercise 5

Assume that a patient is started on a 36 mg/hr infusion of aminophylline. After an appropriate amount of time has elapsed (ie, it is estimated that steady state has been achieved), a concentration is drawn and reported as 10 mg/L.

1. What is the patient's clearance (in L/hr)?

The patient has his infusion rate increased to 50 mg/hr.

2. What is the patient's estimated steady state concentration on this new infusion rate?

The patient is to go home on oral therapy. The available tablet strengths are 100 mg, 200 mg, and 300 mg. The tablets are known to be 90% bioavailable ( $F = 0.9$ ).

3. What dose should he receive to produce approximately the same average steady state concentration determined in part 2 if therapy must be given on an every 8-hour interval due to short half-life?
  4. What dose should he receive to produce approximately the same average steady state concentration determined in part 2 if the tablets are known to be 80% bioavailable ( $F = 0.8$ )?
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**Exercise 6**

A patient is started on an infusion of a drug at a rate of 100 mg/hr. The therapeutic range of the drug is considered to be 20 to 40 mg/L. The estimated half-life of the drug in the patient is 15 hr. A concentration measured 24 hr after the start of the infusion is reported as 32 mg/L.

1. What is the estimated steady state concentration of the drug in this patient?

(solve for a multiple dose case and for a constant infusion rate case.)

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**Exercise 7**

In a community of 10,000 people, a flu epidemic occurs. It is known that at the beginning of the epidemic, 100 people were infected (I), while the others are susceptible (S). There are no individuals who are naturally immunized or vaccinated at the beginning of the epidemic. It is assumed that each infected individual can transmit the infection to susceptible people 2 days after contact. The average duration of infection is 7 days, after which infected individuals are removed (R) from the population.

Calculates:

1. The number of susceptible, infected, and removed individuals at Day 0 (at the beginning of the outbreak).
2. The maximum number of infected individuals during the epidemic as a function of susceptible individuals.
3. The total number of individuals removed (recovered or deceased) at the end of the epidemic.