NUI Galway
OÉ Gaillimh

Semester 1 Examinations 2020 / 2021
ONLINE EXAMINATION

Exam Code(s)	4BCT1, 4BSE1, 1MSME1,1MEEE1,1MECS1, 1CSD1, 1CSD2, 2SPE1, 1MAI1
Exam(s)	B.Sc. Degree (Computer Science and Information Technology) B.E. Energy Systems Engineering MSc in Mechanical Engineering ME (Electrical and Computer Engineering) ME (Electrical and Electronic Engineering) M.Sc. in Computer Science (Data Analytics) M.Sc. in Computer Science (Artificial Intelligence)
Module Code(s)	CT561
Module(s)	Systems Modelling and Simulation
Paper No.	I
External Examiner(s)	Dr. Jacob Howe
Internal Examiner(s)	Prof. Michael Madden *Prof. Jim Duggan
Instructions:	Answer any 3 questions. All questions carry equal marks. All answers must be hand-written and uploaded as PDF files.
Duration	2 hrs with 30 minutes for uploading at the end of the exam
No. of Pages	5 (Including Cover Page)
Department(s)	School of Computer Science

Disclaimer

This is an "open book" style exam. In submitting this work I confirm that it is entirely my own. I acknowledge that I may be invited to online interview if there is any concern in relation to the integrity of my exam, and I am aware that any breach will be subject to the University's Procedures for dealing with breaches of Exam Regulations: https://www.nuigalway.ie/media/registry/exams/QA230---Procedures-for-Dealing-with-Breaches-of-Examination-Regulations.pdf

By sitting this exam, you agree to the above terms.

1. (a) For the following model:

$$\frac{dS}{dt} = \frac{(S^* - S)}{AT} - g\,S$$

- Represent it in stock and flow notation
- Explain, for g > 0, why the stock will never reach the goal.
- Show that in steady state, the value of S will be

$$S = \frac{S^*}{g.AT + 1}$$

[8]

(b) Construct a stock and flow model (with feedbacks and equations) - based on the stock management structure - for the following Retailer Stock System.

- Customer demand is 100 and increases to 500 at time 10
- The stock goal is 500
- The anchor and the adjustment must be part of the ordering decision
- The stock cannot go negative, and a record of accumulated lost orders must be kept
- Assume that the stock is replenished without any arrival delays.

Also show the feedback loops and calculate their polarity.

[12]

(c) Suggest an extension to the model in part (b) that would ensure that there are no lost orders in the system. Explain the rationale for the new model structure.

[5]

2. (a) Assume that the population of a city grew from 1.6 million to 3.2 million in 20 years. Assuming the growth can be represented with the following equation

$$\frac{dP}{dt} = g\,P$$

And that the solution to this equation is

$$P_t = \; P_o\, e^{gt}$$

- Represent this as a stock and flow system.
- Calculate the growth rate based on the doubling time.

[5]

(b) Draw a stock and flow model, with feedbacks and equations, for the following limits to growth system

$$\frac{dS}{dt} = r\left(1 - \frac{S}{C}\right) S - gS$$

Assume that the growth rate = r, and the decline rate = g.

Explain how this model compares to the Verhulst model, and highlight its difference.

Under what condition would the value of S reach the limiting capacity?

[12]

(c) Show how the above stock and flow model could be used to build a stock and flow model of urban development, where the stock would be the stock of houses in a city area. Add the number of occupants per house as an average value to estimate the total population that could be housed in the area. Show all the equations, and feedbacks.

[8]

3. (a) Formulate an infectious disease model for a novel pathogen with the following elements.

- People are initially *Susceptible*, and become *Exposed* at a rate Lambda (the force of infection). This force of infection is a summation of three different force of infections
  - The force of infection from asymptomatic people.
  - The force of infection from pre-symptomatic people.
  - The force of infection from symptomatic people.

- People spend 3 days in the *Exposed* state, and this is a second order delay.

- People exit the *Exposed* state into either *Pre-Symptomatic* or *Asymptomatic* states, according to a Clinical Fraction (0.6), which determines how many have clinical symptoms.

- *Pre-Symptomatic* (who are infectious) then transition to becoming *Symptomatic*, after a first order delay of 2 days. *Symptomatic* recover after 3 days, *Asymptomatic* recover after 5 days.

- Assume the contact rate in the population is 10/day, and that infectivity is 0.1 for those showing clinical symptoms, and 0.05 for those who are asymptomatic.

- Assume the total population is 100,000 and there are initially 10 people (asymptomatic) infected.

Based on this, develop:

1. A SEIR model, showing all feedbacks
2. A full set of equations, including the dimensions, and using the force of infection formulation.

[15]

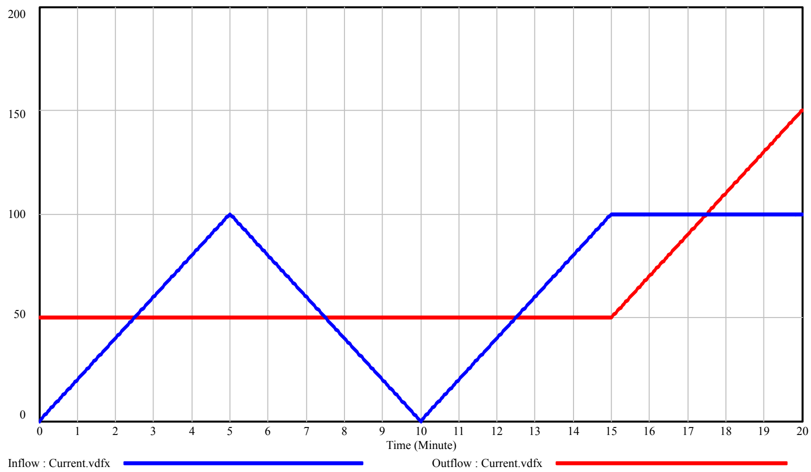
(b) Based on the model above, generate a formulation for the reproduction number R_0, and calculate its value based on the parameters. (Hint: these parameters include: clinical fraction, contact rate, infectivity values, duration of infectious periods).

Identify which compartment has the greatest contribution to R_0.

Also determine the herd immunity threshold for the disease, and discuss two key non-pharmaceutical interventions that could be used slow the spread of the disease.

[10]

4. (a) From the following graph that shows inflows and outflows to a stock, use graphical integration to chart the behaviour of the stock over time. Assume the initial value of the stock is 100 units.



Show the following:

- A stock and flow diagram, and the Vensim equations, including those that would generate the flow behaviours
- The net flow and stocks on aligned graphs (flows on top graph, stock on the bottom graph)
- The different behaviour modes of the stock over time

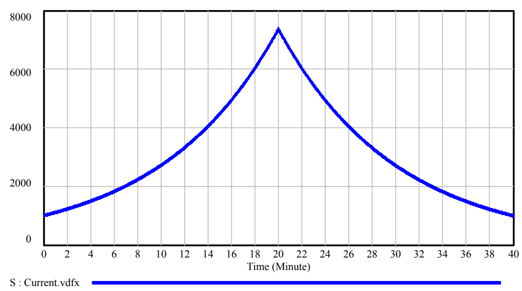
[10]

(b) Describe Euler's algorithm for integrating a net flow, and state its main assumptions.

With DT=5, use Euler's algorithm to integrate the flows from part (a). Clearly show the integration error for each DT interval.

[8]

(c) Using a combination of flows based on fractional increase and fraction decrease, describe a one-stock model that can generate the following stock behaviour. Explain what drives the change in trajectory.



[7]