



Université d'Ottawa · University of Ottawa  
SCHOOL OF INFORMATION TECHNOLOGY AND ENGINEERING

**COURSE:** CSI4124/SYS5110  
Foundations on Modeling  
and Simulation

**PROFESSOR:** Gilbert Arbez

**SEMESTER:** FALL 2008

**DATE:** December 17, 2008

**TIME:** 9:30 to 12:30 (3 hours)

**Room:** CBY B202

**FINAL EXAMINATION**

**NAME and STUDENT NUMBER:** \_\_\_\_\_ / \_\_\_\_\_

1. There are four (4) parts in this examination.

Question 1	Short answer questions	20 marks	
Question 2	Conceptual Model	35 marks	
Question 3	Simulation Model	25 marks	
Question 4	CTDS Modelling and Simulation	10 marks	
Total		90 marks	

All questions are answered in the examination paper. If you require more space, use the back of the pages.

You may detach the last page.

Calculators are permitted.

Total number of pages: 16

## Question 1 – Short Answer Questions (20 points – 2 points each)

Complete the following questions using a few words or a simple phrase.

- a) Circle the terms that are directly associated to an Event Scheduling Simulation Program?

Activity	Process Oriented	Event Notice
Activity Scanning	FEL	Transaction
Time Advance Algorithm	Canonical Form	Future Event

- b) How is time advanced in the Discrete Event Simulation Program?
- c) Input entity streams are specified with which ABCmod construct or constructs?
- d) Matlab provides an “*events*” function to specify when an ODE solver should stop solving differential equations. Name two possible uses for such events.
- e) Is it possible to draw a piece wise continuous (PWC) function for trajectory sets, sample sets or both?
- f) Welch’s procedure is used to define what?
- g) The ABCmod conceptual modeling framework is based on which DEDS World View?
- h) In the ABCmod framework, interventions can divide Activity duration into disjoint time periods. What are the two types of interventions available in the ABCmod framework?
- i) An Entity structure is used to specify entities that have a temporary life in an ABCMod conceptual model. What is its basis?
- j) What does the Central Limit Theorem say about point estimates that are generated by many independent simulation runs?

## **Question 2 – Conceptual Modelling (35 marks)**

For the Refrigeration Unit Testing Project (see the SUI Features provided on page 16), complete the ABCmod conceptual model below. It is NOT necessary to provide in the detailed conceptual model, the description for the data models, the constants nor parameters.

### **1 ABCmod Conceptual Model**

#### 1.1 High Level Conceptual Model

##### 1.1.1 Structural Diagram

##### 1.1.2 Data Model List

##### 1.1.3 Behavioural Diagram

1.2 Detailed Conceptual Model

**Structural Components**

<b>Attributes</b>	<b>Description</b>

<b>Attributes</b>	<b>Description</b>

<b>Attributes</b>	<b>Description</b>

<b>Attributes</b>	<b>Description</b>

<b>Attributes</b>	<b>Description</b>

**Data Modelling Components**

<b>Data Modules</b>		
<b>Name</b>	<b>Description</b>	<b>Data Model</b>

<b>Inputs</b>				
<b>Input Variable</b>	<b>Description</b>	<b>Data Models</b>		<b>Action Sequence</b>
		<b>Domain Sequence</b>	<b>Range Sequence</b>	

**Output Components**

<b>Trajectory Sets</b>	
<b>Name</b>	<b>Description</b>

<b>Sample Sets</b>	
<b>Name</b>	<b>Description</b>

<b>Derived Scalar Output Variables (DSOV's)</b>			
<b>Name</b>	<b>Description</b>	<b>Output Set Name</b>	<b>Operator</b>

<b>Simple Scalar Output Variables (SSOV's)</b>	
<b>Name</b>	<b>Description</b>

## Behavioural Components

*Time units:* Hours

*Observation interval:* Steady State Study

<b>Summary of Activities</b>	
<b>Action Sequences</b>	
<b>Activities</b>	
<b>Triggered Activities</b>	

<b>Initialize</b>

<b>Action Sequence:</b>	
Precondition	
Event	

<b>Activity:</b>	
PreCondition	
Event	
Duration	
Event	

<b>Activity:</b>	
PreCondition	
Event	
Duration	
Event	

<b>Triggered Activity:</b>	
Event	
Duration	
Event	

<b>Triggered Activity:</b>	
Event	
Duration	
Event	

### Question 3 – Simulation Modelling (25 marks total)

As part of creating an Event Scheduling Simulation program for the Refrigeration Unit Inspection and Testing Project, define a set of Future Events, Future Event Routines and other required routines to implement the behaviour constructs (Activities, Triggered Activities, etc.) you specified in Question 2.

- ❖ First provide the definition of the future events and the *processEvent( )* routine, including any logic for output to trajectory sets.
- ❖ Then provide the FER's.
- ❖ Finally provide a precondition routine.
- ❖ Please limit yourself to implementing the contents of the behaviour and output (trajectory set, sample set, and SSOVs) constructs, that is, it is not necessary to implement the initialization, data module, user-defined modules, etc. You may use either pseudo-code or Java code to complete this question.



#### Question 4 – CTDS Modelling and Simulation (10 marks total)

This problem is concerned with a simulation study of the vertical motion of a rocket fired from an underwater submarine. While in the water, the rocket experiences significant drag force which is proportional to the square of its velocity, but once it emerges through the surface, the drag is considered to be negligible. The engines of the rocket are active for 10 seconds; then they are automatically turned off. While they are on, the engines provide a constant thrust of 135 Newton. The system model can be written as:

$$M \ddot{y}(t) = f_T(t) - d \dot{y}^2(t) - MG$$

$$d = \begin{cases} 0.5 & \text{for } y < 0 \\ 0 & \text{otherwise} \end{cases}$$

$$f_T(t) = \begin{cases} 135 & \text{for } 0 < t < 10 \\ 0 & \text{otherwise} \end{cases}$$

Where

$y(t)$  is the vertical displacement of the rocket ( $y=0$  corresponds to the surface of the water)

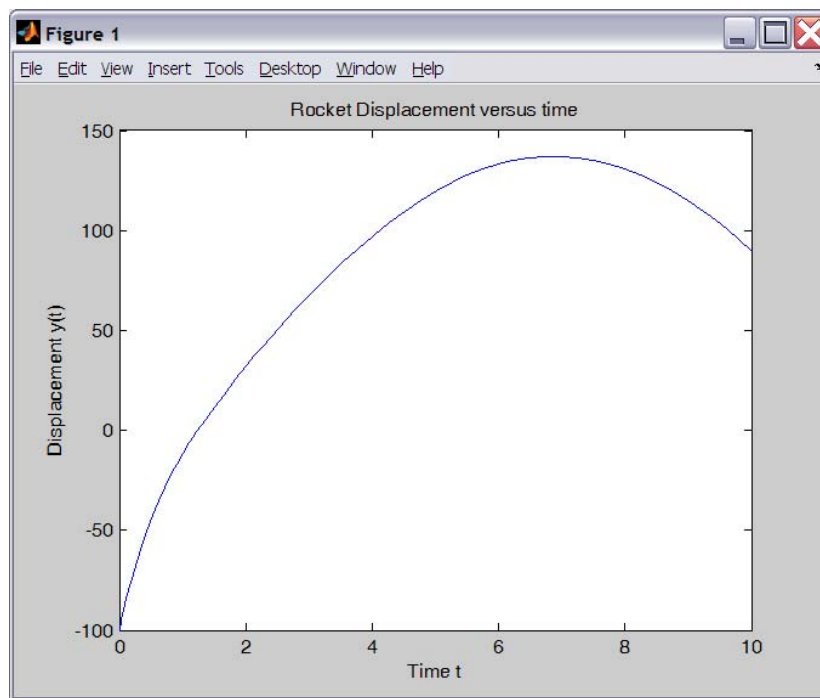
$M$  is the mass of the rocket (45 kg)

$G$  is the acceleration due to gravity ( $9.8 \text{ m/s}^2$ )

$d$  is the drag coefficient ( $\text{Newton}/(\text{m/s})^2$ )

$f_T(t)$  is the thrust (Newton)

Note also that the mechanism which discharges the rocket from the submarine (at time  $t = 0$ ) gives it an initial vertical velocity of 155 m/sec. The vertical trajectory of the rocket relative to time has the following form:



A) Provide the canonical form of the CTDS model (i.e. the set of equations that represents the system's behaviour).

B) The following Matlab program provides the experiment code to determine the initial depth  $y_0 = y(0)$  that results in the rocket reaching a maximum altitude of 100 meters. Complete the program (you will need to complete the two functions *rocketDyn* and *events* to implement the dynamics of the model (i.e. the simulation model). Note that when the rocket reaches its highest altitude, the vertical speed of the rocket reaches zero.

```
function rocket
%-----
% Rocket from submarine
% File rocket.m
%-----
% Define constants; make the global
global G M
G = 9.8; % acceleration due to gravity (meters/sec^2)
M = 45; % mass of the rocket
V0 = 155; % initial release velocity (meters/secs)
%-----
% EXPERIMENT
%-----
refine = 4;
options = odeset('Events',@events, 'Refine', refine);
for Y0 = -200:0.5:-10 % vary the depth from -200 to -10 m
    sv0 = [Y0 ; V0]; % initilize state variables
    tspan=[0;12];
    [t, sv, te, sve, iel] = ode45(@rocketDyn, tspan, sv0, options);
    if sve(1) > 100 % have reached the altitude of 100 m
        break;
    end
end
end
%-----OUTPUT-----
s = sprintf('The initial depth %f meters gives maximum altitude of %f at time %f\n',...
           Y0, sve(1), te);
disp(s);
```

```
%-----  
% DYNAMICS  
%-----  
function dsvdt = rocketDyn(t, sv)  
global M G
```

```
%---Events  
function [value, isterminal, direction] = events(t, sv)
```

# Discrete Event Modelling and Simulation Project

## Refrigeration Unit Inspection and Testing

### 2 SUI Key Features

#### 2.1 Introduction

A new assembly line to assemble refrigeration units is being designed. The end of the assembly line consists of two stations, an inspection and testing station, and a repair station. Given that the units are large, it is necessary to determine the amount of space required for queuing refrigeration units at both the inspection and testing station and the repair station to help estimate the amount of space required by these two stations.

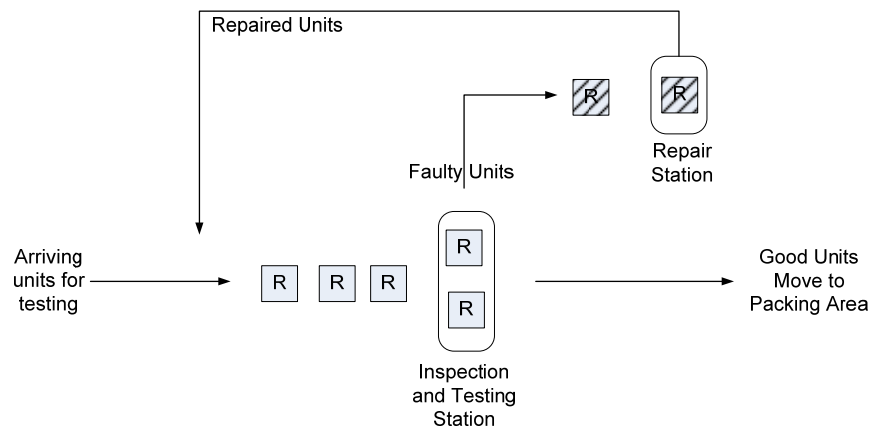
#### 2.2 Goal of project

Determine information about the size of the queues at the testing and the repair stations.

Output: Measure the average and maximum sizes of the two queues using a steady state study.

#### 2.3 SUI Details

The inspection and testing station in the assembly line inspects refrigeration units and runs a series of tests to verify their operation. If a defect is found in a unit, it is routed to the repair station to take care of the defect. After repair the unit is returned back to the inspection and testing station. If a unit passes all tests, it is sent to a packing area. The following diagram illustrates how the refrigeration units move through the two stations.



Note that three technicians work at these two stations: two technicians work at the inspection and testing station and one technician works at the repair station.