Student ID: .....

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI

VICTORIA
UNIVERSITY OF WELLINGTON

EXAMINATIONS – 2014

TRIMESTER 2

ENGR 110

ENGINEERING MODELLING AND DESIGN

Time Allowed: THREE HOURS

Instructions: Closed Book
Attempt ALL Questions.

The exam will be marked out of 180 marks.

Only silent non-programmable calculators or silent programmable calculators with their memories cleared are permitted in this examination.

Printed foreign language to English dictionaries are permitted.

No other material is permitted.

Answer in the appropriate boxes if possible — if you write your answer elsewhere, make it clear where your answer can be found.

There are spare pages for your working and your answers in this exam, but you may ask for additional paper if you need it.

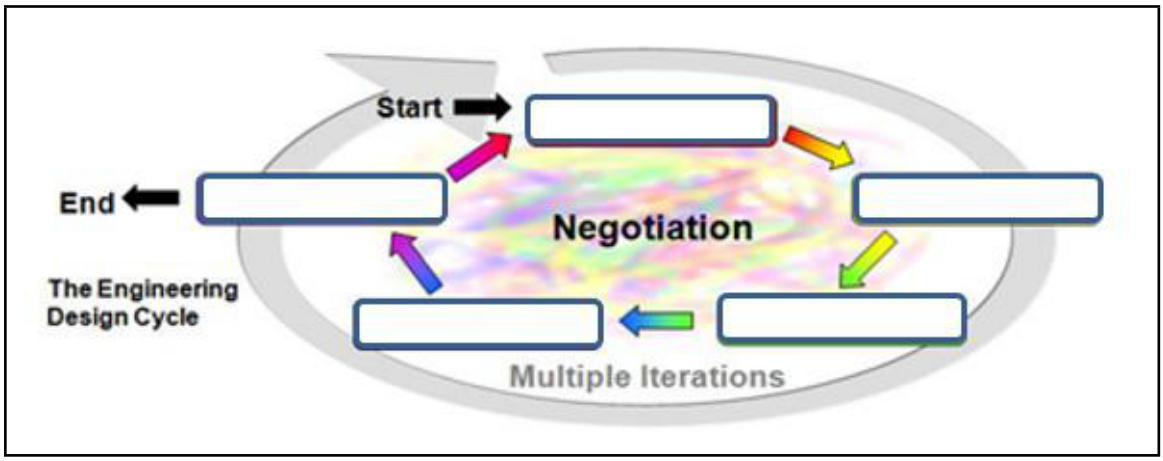
Questions

	Marks
1. Engineering Design Cycle	[20]
2. Finite State Machines	[30]
3. Class Diagrams	[30]
4. Use Cases	[20]
5. User Interfaces	[20]
6. Modelling	[20]
7. Control Systems	[20]
8. Circuit Modelling	[20]

Question 1. Engineering Design Cycle [20 marks]

A student wishes to design a novel slot car racing system. In Engineering modelling and design, the design cycle is essential in the systematic development of any new system.

(a) [5 marks] Complete the diagram below, by stating the five major steps of the engineering design cycle in the boxes.



(b) [9 marks] The student models the system as single input–single output, Linear Time Invarient (LTI) system. Explain each of these terms, illustrating each term with an example from the design of the slot car racing system.

Single input–single output:

Linear:

Time-invariant:

(Question 1 continued on next page)

(Question 1 continued)

During the initial design cycle, testing showed that the optimum strategy was to simply hold down the throttle (generating a constant acceleration signal). User testing showed that this resulted in a boring game. The student redesigns the system so that at high speed, the car becomes unstable and crashes off the track.

(c) [3 marks] Explain why this system is no longer an LTI system

(d) [3 marks] Given that part of the response of the system is no longer LTI, discuss whether it is still worth modelling it through the engineering design cycle?

Example of a slot car (from RealFX on Kickstarter.com)

Question 2. Finite State Machines [30 marks]

(a) [10 marks] Consider the following FSM controller for a revolving entrance door that minimises heat loss by controlling the angle where it stops.

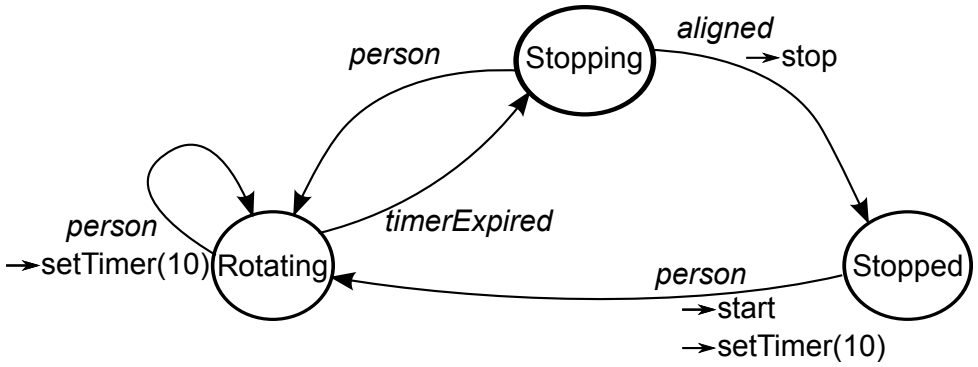
The door has motion sensors that detect if a person is approaching the door, a timer, and a sensor to record when the door is aligned with the edeges of the walls of the door.

The sensors provide three signals to the controller:

- `"person"`,
- `"timerExpired"`, and
- `"aligned"`.

The possible actions the controller can perform on the door are:

- start(),
- stop(),
- setTimer(int).



On the facing page, show how this controller could be implemented in a Java program by completing the signal method.

Assume that the signal method is called every time a sensor event occurs, and that for each action above, there is a corresponding method that can be called on the value of the door field.

(Question 2 continued on next page)

(Question 2 continued)

```
public class DoorController {
    private String state = "Stopped";
    private EntranceDoor door;
    public DoorController(EntranceDoor dr){door = dr;}

  public void signal(String sensor){
        if (state.equals(
}
```

(Question 2 continued on next page)

(Question 2 continued)

(b) [8 marks] Draw the design of an event-based FSM controller for the following hotel room air-conditioning system. Your design must have three states.

The air-conditioning system has a temperature sensor and a two level cooling unit which can be on high speed, low speed, or off. The system tries to keep the room at a specified goal temperature

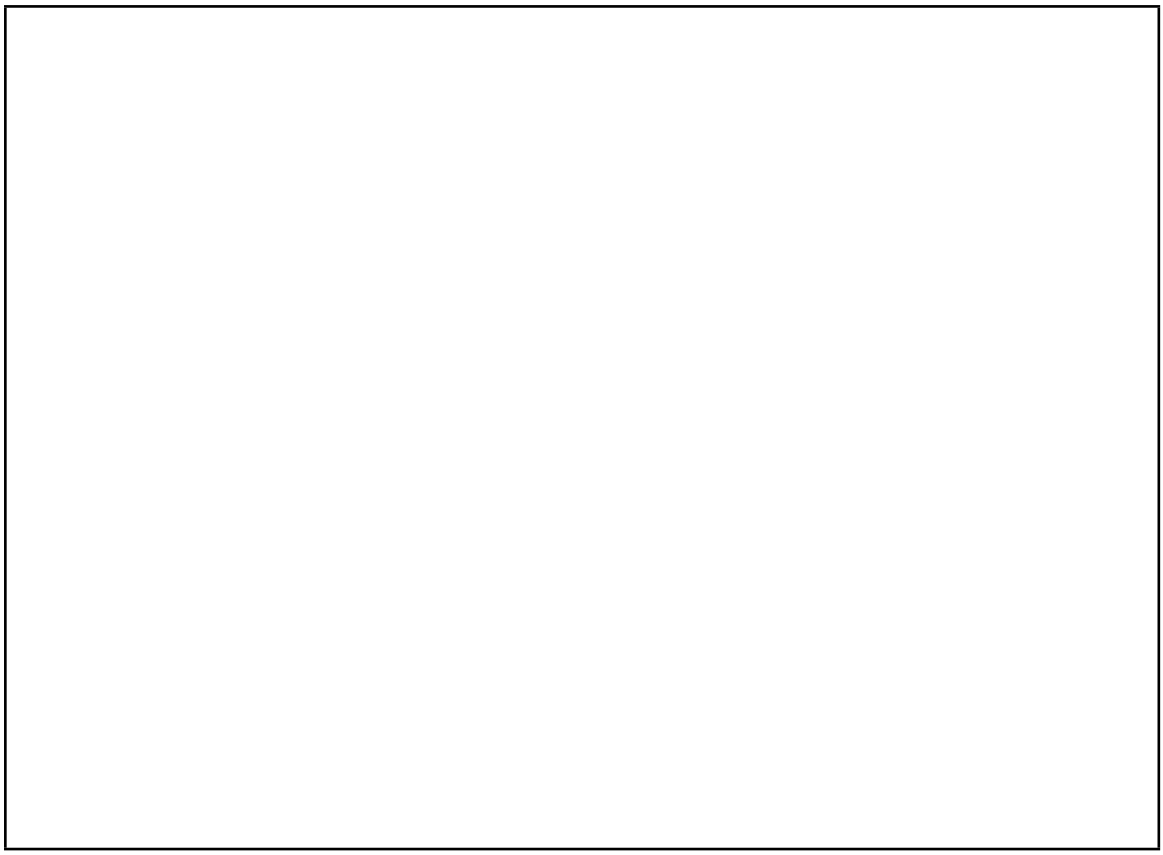
The desired operation of the air-conditioning system is that the cooling unit should be off when the room temperature is below the goal temperature, on low speed if the room temperature is between the goal temperature and a limit temperature 2° above the goal, and on high speed ff the room temperature is above the limit temperature.

The system sends the following signals to the controller:

- AboveGoal, when the room temperature rises from below to above the goal temperature
- AboveLimit, when the room temperature rises from below to above the limit temperature
- BelowLimit, when the room temperature falls from above to below the limit temperature
- BelowGoal, when the room temperature falls from above to below the goal temperature

There are three actions that the controller can perform on the system:

- **lowSpeed** to turn the cooler on to low
- **highSpeed** to turn the cooler on to high
- **off** to turn the cooler off.



(Question 2 continued on next page)

(Question 2 continued)

(c) [7 marks] Extend the design of your event-based FSM controller to handle an additional input switch.

Suppose the user can turn a "quiet mode" switch to on or off. The operation should be the same as the previous case, except that when quiet mode is on, the air-conditioning system should never go to high speed.

The system sends two additional signals to the controller:

- QuietOn, when the user turns the quiet mode switch on
- QuietOff, when the user turns the quiet mode switch off

Your design should **NOT** be factored; *i.e.*, you may **NOT** use additional variables to record state information.

Hint: It is sensible to have six states in your extended design.

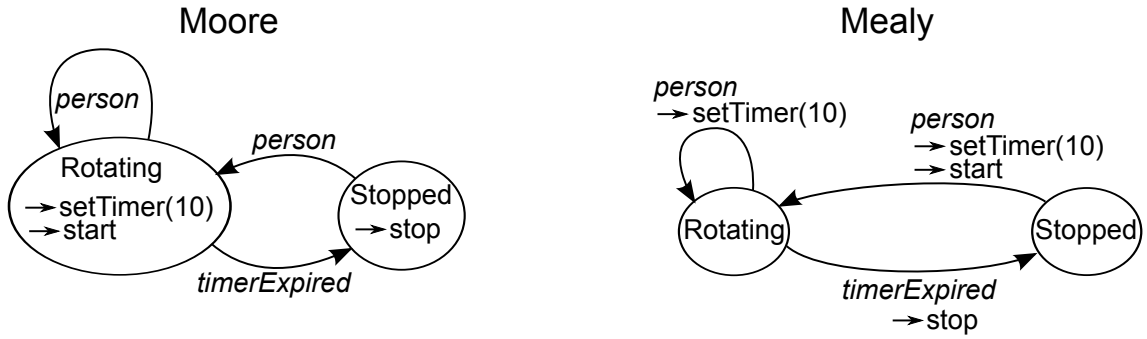
(Question 2 continued on next page)

(Question 2 continued)

(d) [5 marks] The lectures discussed two ways of designing Finite State Machines:

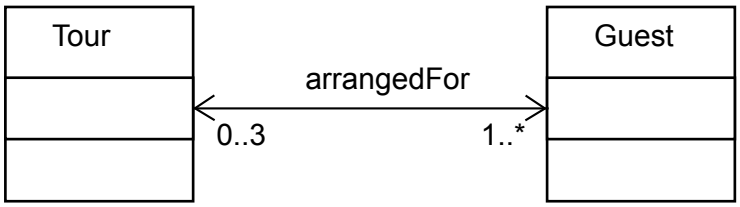
- Moore Diagrams, in which the actions are attached to the states (the action happens when the system enters a state), and
- Mealy Diagrams, in which the actions are attached to the transitions (the action happens when the system transitions from one state to another).

Briefly discuss the advantages and disadvantages of the two approaches. You may refer to the following two examples if you wish.



Question 3. Class Diagrams [30 marks]

(a) [5 marks] Consider the following fragment of a class diagram with two classes and an association:



Explain what the *multiplicities* (0..3 and 1..*) of the "arrangedFor" association mean in terms of individual Guest objects and individual Tour objects.

(b) [13 marks]

Complete the class diagram on the facing page for a Hotel Check-in system:

- Include associations and attributes to represent all the information specified below.
- Include any operations on the Room class that would be needed (other than "getters" and "setters" that simply return the value in a field or assign a value to a field).

Information about the system:

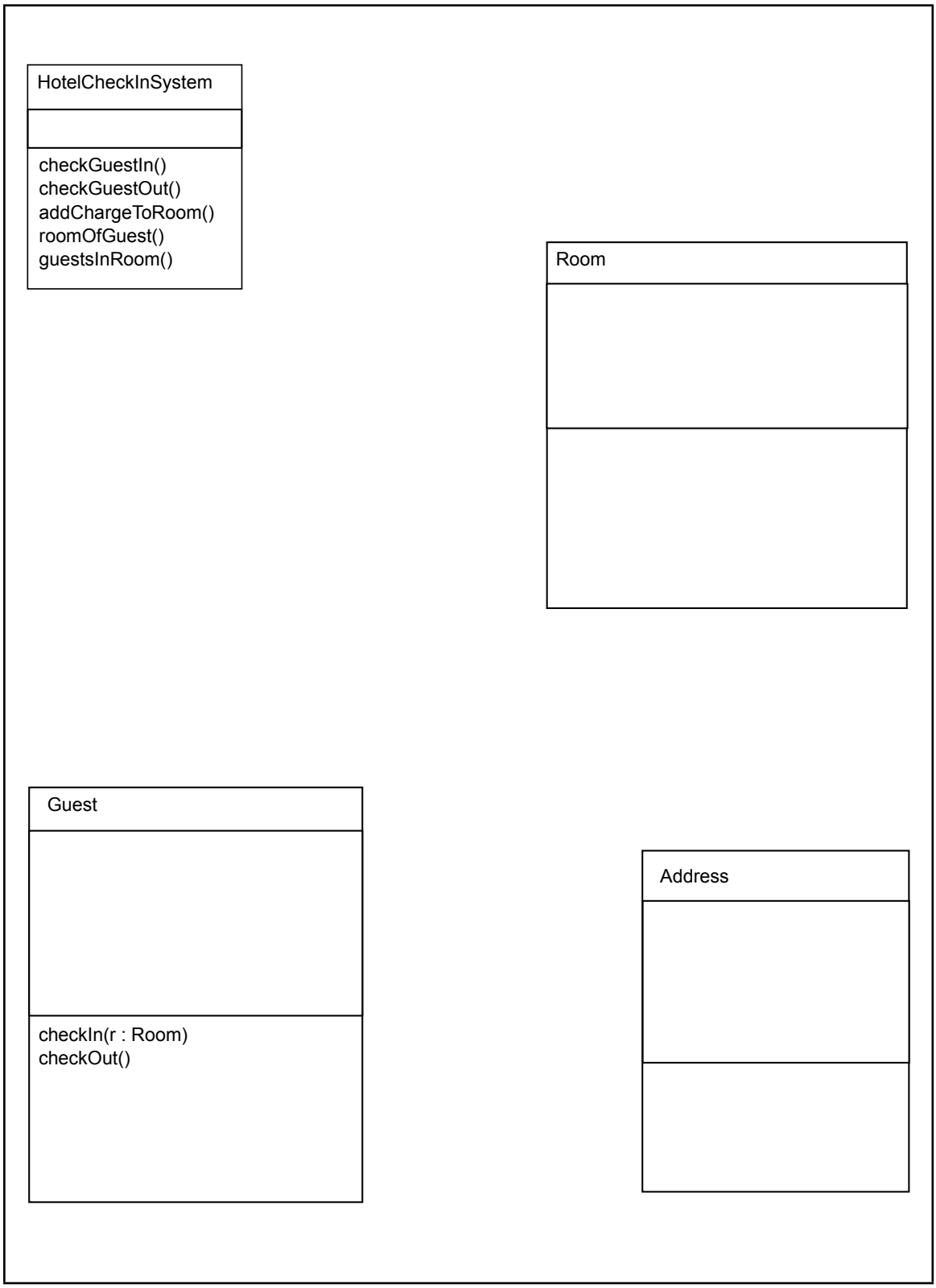
- Each individual guest is recorded in the system, including their name and address.
- Addresses have a street, a city and a post code.
- The rooms are identified by their floor and a room number, *e.g.* floor 6, room 5. The system also records the number of king beds and the number of single beds in each room.
- Each guest must be checked in to a room. The system should be able to easily find the room that a guest is in, and all the guests in a given room.
- If there are several guests in the same room, one of the guests must be identified as responsible for the room.
- When the guest responsible for a room checks out, all the other guests in the room are checked out also.
- Some rooms are connected to one or both of the adjacent rooms; the system should record which rooms are connected to each other.

Hints:

- Include names, directionality, and multiplicities on all associations. Roles are optional.
- Include any parameters of any operations.
- The top-level actions on the check in system are shown; they ask the user to choose a guest and/or room as appropriate.

(Question 3 continued on next page)

(Question 3 continued)

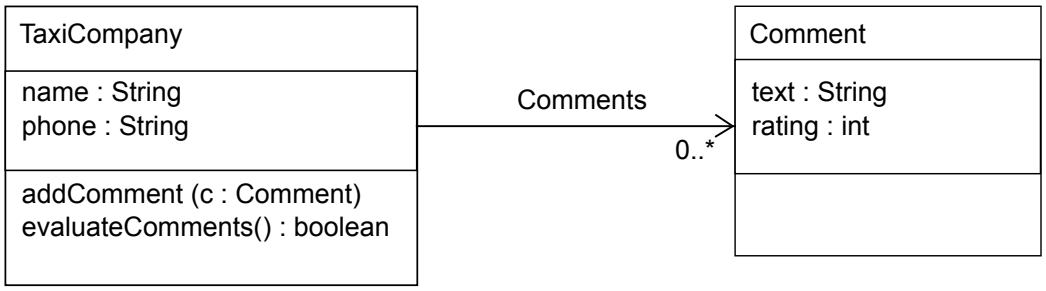


(Question 3 continued on next page)

(Question 3 continued)

(c) [12 marks]

The following class diagram is part of the design for a Hotel Reception system that helps the receptionist book taxis for hotel guests. On the facing page, complete the Java code for the TaxiCompany class. Include all code that could be constructed directly from the given design, including constructors and appropriate "getters" and "setters". You do not need to modify the Comment class.



(Question 3 continued on next page)

(Question 3 continued)

```
public class TaxiCompany {

    public TaxiCompany(String nm, String ph){

}
public class Comment {
    private String text;
    private int rating;
    public Comment(String t, int r){
        text = t;
        rating = r;
    }
    public String getText(){ return text; }
    public int getRating(){ return rating; }
}
```

Question 4. Use Cases [20 marks]

You have been asked to design a web-based booking system for a new hotel. The system should allow customers to browse the site (so that they can view descriptions of the hotel and the rooms), check availability, and make a booking.

To check availability, customers have to enter information relevant to their stay (e.g. dates, number of nights, number of people/rooms). The system then shows them the rooms available during their stay and the associated costs.

To make a booking customers first check availability, and having found an appropriate option they select to make booking. This takes them through a secure payment channel, where they are asked for their credit card details. If the payment is successful the booking is made, and the customer is sent a confirmation email with booking reference details.

Having made a booking, guests are able to log into the hotel website where they can amend their booking (e.g. changing dates or number of nights). If their new preferences are available their booking is changed, though there may be a change in price associated with this (e.g. due to seasonal rate changes or changes in the number of nights stayed) which must be processed securely.

Once they are logged in, guests are also able to cancel their booking completely. Again, the refund must be processed securely.

(Question 4 continued on next page)

(Question 4 continued)

(a) [6 marks]

Draw a use case diagram for the hotel booking system.

Hint: the description suggests 6 use cases and 3 actors.

(Question 4 continued on next page)

(Question 4 continued)

(b) [8 marks] Convert the following use case body into an activity diagram, making sure to clearly label the error and alternate sequences.

Use case: Make booking Actors: Customer (primary), Payment Authorisation System (secondary)	
Actions of actors	Actions of system
1. Do: Check availability	
2. Customer selects preferred room	3. System requests payment details
4. Customer enters payment details	5. System requests payment authorisation
6. Payment AS confirms	7. Reservation made, confirmation email sent to customer

Alternative scenarios
A1: Payment details entered incorrectly 1 or 2 times
The A1 scenario starts at point 5 of the main success scenario

Actions of actors	Actions of system
6. Payment AS denies	7. System checks if incorrect details entered fewer than 3 times.
	8. Go to M.3

Error scenarios E1: Payment details entered incorrectly 3 times
The E1 scenario starts at point 5 of the main success scenario

Actions of actors	Actions of system
6. Payment AS denies	7. System checks if incorrect details entered 3 times.
	8. System notifies AS system, transaction denied, Use Case fails.

(Question 4 continued on next page)

(Question 4 continued)

(Question 4 continued on next page)

SPARE PAGE FOR EXTRA ANSWERS

Cross out rough working that you do not want marked.
Specify the question number for work that you do want marked.

(Question 4 continued)

(c) [6 marks] Consider the use case Check Availability. Provide the use case body for the main success scenario, and for one possible error scenario.

Question 5. User Interfaces [20 marks]

Usage-centred design and user-centred design are two different approaches for modelling users of a system. In usage-centred design we consider users in terms of the roles they play in the system, and we utilise user models, task models, and content models. In user-centred design we consider the needs, wants, and limitations of users, and utilise personas and scenarios.

(a) [4 marks] Give two benefits to developing and using personas in user-interface design.

(b) [6 marks] Describe three characteristics of an effective persona.

(Question 5 continued on next page)

(Question 5 continued)

(c) [4 marks] Provide one example of a situation in which you may want to use expert evaluation to test your user interface and explain why.

(d) [6 marks] Describe two metrics that you might use to evaluate a user interface, and explain the benefits and limitations of this assessment.

SPARE PAGE FOR EXTRA ANSWERS

Cross out rough working that you do not want marked.
Specify the question number for work that you do want marked.

Question 6. Modelling [20 marks]

When modelling a physical system, we form the dynamic equations describing how the system behaves in an instant. We are interested in how the input (effort variable or signal) *drives* the output (flow variable or signal), e.g. how force drives the distance a spring moves when compressed.

(a) [2 marks] In a direct current (DC) electronic circuit consisting of capacitors, resistors and inductors powered by a battery, state the *effort* variable and *flow* variable:

Effort:

Flow:

Modelling is useful in understanding how a system will respond to a given input signal.

(b) [3 marks] Explain why it is useful to make analogies between different types of systems in terms of the models created?

(Question 6 continued on next page)

(Question 6 continued)

A new virus has been detected that attacks New Zealand apple trees. It has been found that the number of apple trees (A) infected depends on the number of bees detected on the trees (B).

(c) [2 marks] State the *effort* variable and the *flow* variable.

Effort:

Flow:

(d) [2 marks] Experiments show that one component is the beehive population. For every 100 bees detected, 1 apple tree is infected. Write an equation linking A to B for this component.

(e) [2 marks] Another component is governed by pesticide use which affects the rate that the bee population changes. If the number of infected trees is 1.3 times the **rate of change of the bee population**, write an equation linking A to B for this component.

(f) [2 marks] The final component of the infection is due to how long the bees have been around the trees. If the number of infected trees is 0.004 times the **the summation of the number of bees over time**, write an equation linking A to B for this component.

(Question 6 continued on next page)

(Question 6 continued)

A bee expert has determined that all the components of the problem have now been identified. These components can be combined into a single function linking bees to infected apple trees.

(g) [1 mark] What is the name of the function that links the input to the output of the complete system?

(h) [2 marks] Assuming that the three components can be combined by a simple summation, write the function linking infected apple trees and bees.

(i) [1 mark] A Farmer wants a prediction of how many apple trees will become infected over the next 2 months so that she can order an appropriate amount of vaccine for the apple trees. What is the name of the graph that displays this information?

(j) [3 marks] In general, provided that we know how a system is changing in an instant, state three methods by which we can determine how it will respond in time?

Question 7. Control Systems [20 marks]

Engineers and computer scientists have to design a wide range of systems from weather balloons to spacecraft that must land on comets.

(a) [2 marks] Define what is meant by an 'open loop' system, using a weather balloon as an example.

(b) [2 marks] Define what is meant by a 'closed loop'system using the comet landing spacecraft as an example.

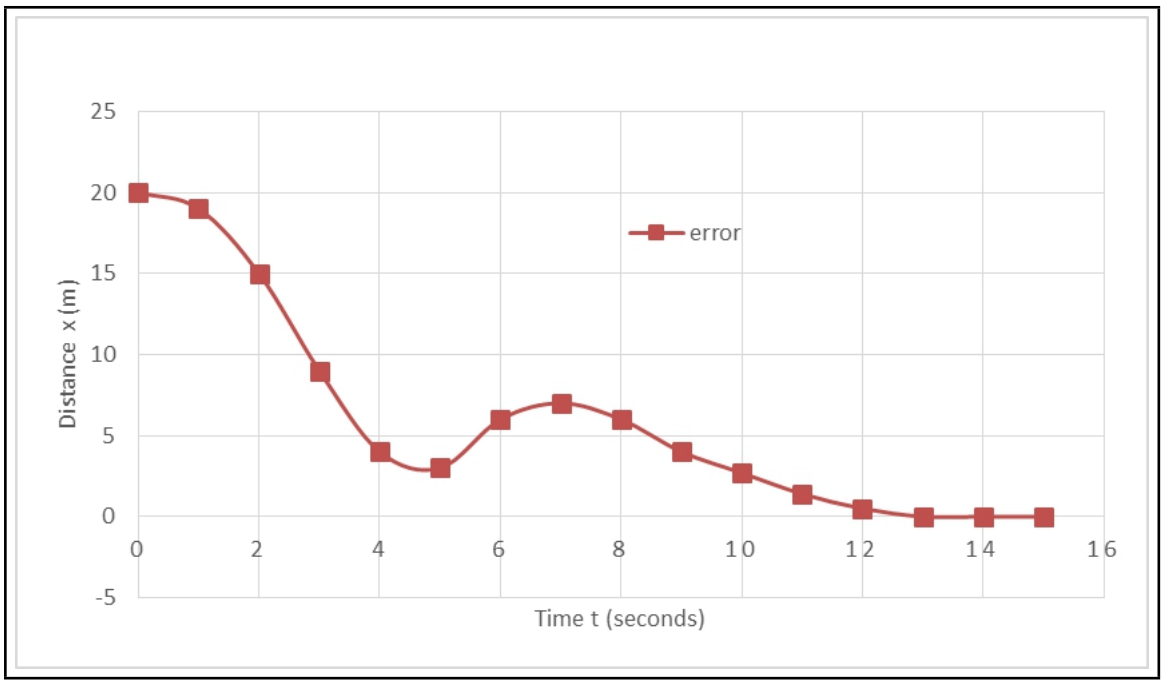
(c) [3 marks] State three benefits of utilising an open loop system compared with a closed-loop system, considering systems in general.

(Question 7 continued on next page)

(Question 7 continued)

The engineers on earth received the following telemetry from the spacecraft after it successfully touched down on the comet. The telemetry shows the error in height (dependent variable) plotted against time (independent variable). This error is fed into a PID controller that controls the thrusters of the comet lander.

(d) [2 marks] On the following plot of the error, sketch the proportional signal component of the PID controller when the proportional constant k_p is set to 0.5:



(e) [3 marks] Given that the differential constant was set to 0.2, i.e. $k_d = 0.2$, calculate the Differential (D) signal at times $t = 2s$, $t = 3s$, and $t = 4s$.

Hint: A precision Δ of one second is acceptable in this calculation.

At $t = 2s$:

At $t = 3s$:

At $t = 4s$:

(f) [3 marks] Given that the Integral constant was set to 0.4, i.e. $k_i = 0.4$, calculate the Integral (I) from time $t = 0$ seconds until $t = 2$ seconds, showing your working.

Hints:

- A precision (Δ) of one second is acceptable in this calculation.
- Remember to show your calculations rather than simply state the answers!

At $t = 0s$:

At $t = 1s$:

At $t = 2s$:

(Question 7 continued on next page)

(Question 7 continued)

(g) [3 marks] Discuss the role of the Proportional, Integral and Derivative components of the PID controller.

Proportional:

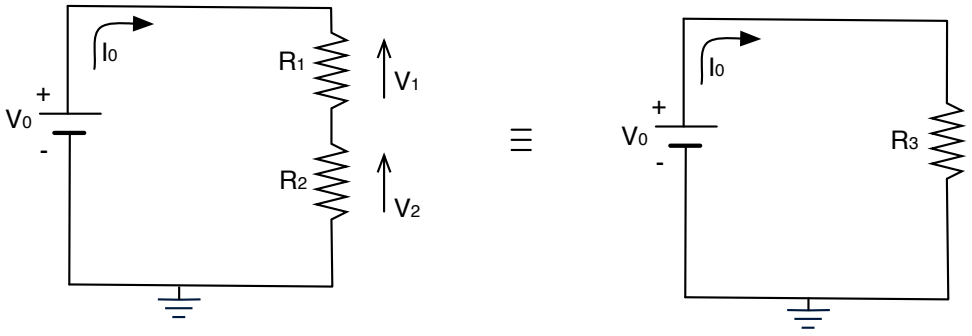
Integral:

Derivative:

(h) [2 marks] A new engineer to the team notices that the craft took a long time to land and suggests increasing the proportional control term. Comment on any advantages and disadvantages of this approach.

Question 8. Circuit Modelling [20 marks]

(a) [4 marks] The diagram below shows a circuit with two resistors connected in series, and an equivalent circuit with just one resistor. Assuming that $V_0 = 12V$, $R_1 = 4\Omega$, and $R_2 = 2\Omega$, determine the value of R_3 and the magnitude of the current I_0.



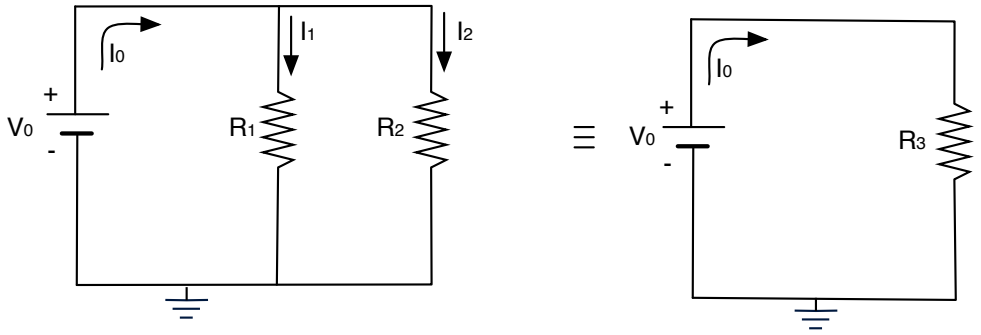
$R_3 =$

$I_0 =$

(Question 8 continued on next page)

(Question 8 continued)

(b) [6 marks] The diagram below shows a circuit with two resistors connected in parallel, and an equivalent circuit with just one resistor. Assuming that $V_0 = 9V$, $R_1 = 9\Omega$, and $R_2 = 4.5\Omega$, determine the magnitudes of the currents I_1, I_2, and I_0, and calculate the value of R_3.



$I_1 =$

$I_2 =$

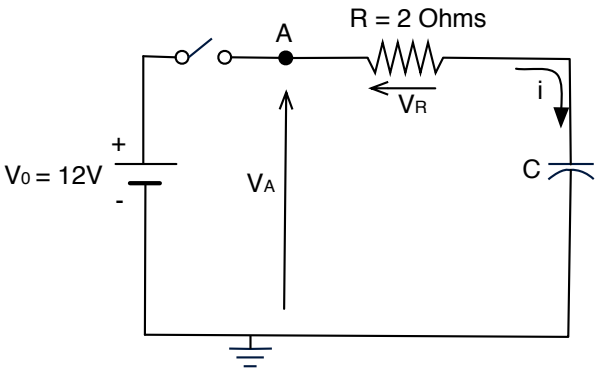
$I_0 =$

$R_3 =$

(Question 8 continued on next page)

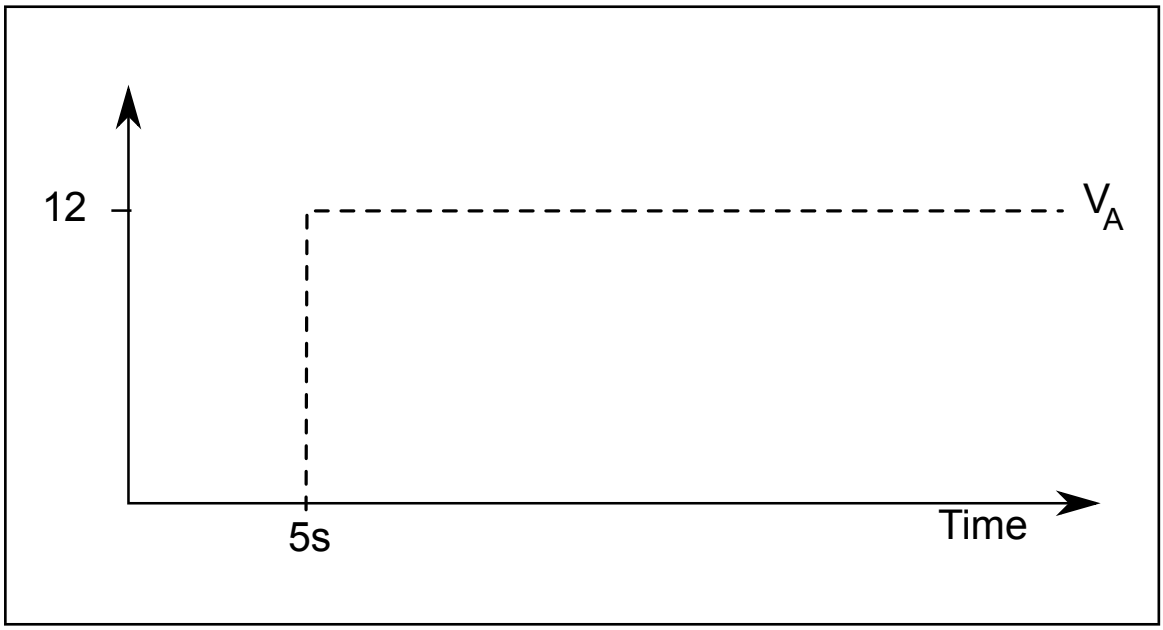
(Question 8 continued)

(c) [4 marks] The voltage across the capacitor in the following circuit can be calculated according to the equation $V_C = (1/C) \times Q$, where C is the value of the capacitance and Q is the amount of charge built up on the plates.



At time $t = 0$, the switch is open and there is no charge stored in the capacitor. At time $t = 5s$, the switch is closed. The graph below shows how V_A changes with time. Add labeled lines to the graph to also show

1. how the voltage across the capacitor V_C changes over time, and
2. how the current through the circuit i changes over time.



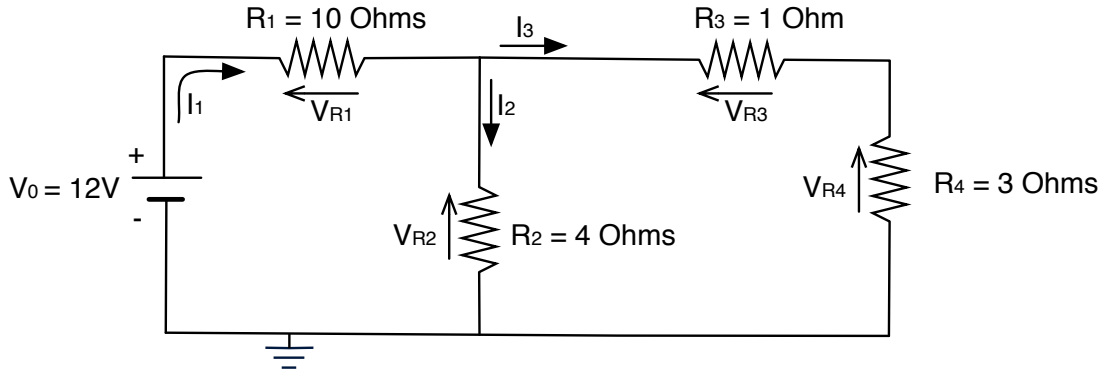
(Question 8 continued on next page)

(Question 8 continued)

(d) [6 marks] Work out the currents flowing through each of the resistors in the following circuit. Make sure to show your working.

You may wish to use Kirchoff's laws.

- Kirchoff's current law states that the sum of all the currents flowing into a particular node in a circuit must be equal to the sum of all the currents leaving that node.
- Kirchoff's voltage law states that the sum of the voltage drops around a circuit is equal to the sums of the voltage sources around that circuit.



$I_1 =$

$I_2 =$

$I_3 =$

* * * * * * * * * * * * * * *