TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Student ID: ....

EXAMINATIONS — 2011

MID-TERM

SWEN 224
Formal Foundations of Programming

Time Allowed: 100 Minutes

Instructions: There are 100 possible marks on the exam.
Answer all questions in the boxes provided.
Every box requires an answer.
If additional space is required you may use a separate answer booklet.
Non-electronic foreign language dictionaries are allowed.
Calculators ARE NOT ALLOWED (and not required).
No other reference material is allowed.

Question	Topic	Marks	Achieved
1.	Writing Assertions	16	
2.	Writing Specifications 1	24	
3.	Verifying Loops	30	
4.	Dynamic Modelling in Alloy	30	
	Total	100	

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Specify the question number for work that you do want marked.

Question 1. Writing Assertions [16 marks]

Write an assertion (using either JML or ordinary mathematical notation) to express each of the following conditions. If the condition is unclear, explain why it is unclear and how you have chosen to interpret it.

(a) A is a non-empty array of distinct elements.

(b) The first n elements of array A are in strictly descending order.

(c) Every element of array A occurs at least twice.

(d) Arrays A and B contain the same elements.

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Question 2. Writing Specifications [24 marks]

You are to write a JML specification for a method which takes as its argument a string, assumed to contain only words (sequences of letters) and spaces, and returns the number of words in the string.

(a) Firstly, give a version assuming that the string has no leading or trailing spaces, and that words are separated by a single space.

(b) Secondly, give a version where the string may include leading and/or trailing spaces, and where words may be separated by multiple spaces.

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Question 3. Verifying Loops

[30 marks]

Consider the following method, which takes two arrays of integers of the same size and finds the number of indexes at which they differ:

```
//@ requires a != null && a.length = b.length;
/*@ ensures \result ==
        (\num_of int j; 0 <= j && j < a.length; a[j] == b[j]); @*/
public int hits(int[] a, int[] b) {
    int i = 0;
    int c = 0;
    while ( i < a.length ) {
        if ( a[i] == b[i] )
            c = c+1;
        i = i+1;
    }
    return c;
}
```

(a) Give a loop invariant that can be used to verify the loop in this method.

(b) State the three verification conditions that must be proved in order to show that the loop is correct, and give a brief explanation of why each of these verification conditions is valid.

Verification condition 1

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Verification condition 2

Verification condition 3

Question 4. Dynamic Modelling in Alloy [30 marks]

A *maze* is a square grid consisting of walls and corridors, so each cell on the grid is either wall or corridor. The aim is to get from a given *start cell* to a given *goal cell*, only passing through corridor cells.

A *solution* to a maze can be described as a sequence of *moves*, directing a robot how to get from the start cell to the goal cell, where a move is either: *turn left* by 90°, *turn right* by 90°, or *move forward* a given number of cells.

For example, writing L for *turn left*, R for *turn right*, and Fn for *move forward n cells*, the following maze (where X's denote walls) has the solution: $F1, R, F1, L, F2, L, F2, R, F1$.

	1	2	3	4	5
1	X	X	X	X	X
2	X		X		
3			X		X
4	X				X
5	X	X	X	X	X

(a) Write Alloy definitions to describe a maze and the position and direction of the robot.

(b) Write Alloy definitions to describe the three kinds of moves the robot may make.

(c) Write an Alloy definition to describe a valid solution to a maze.

(d) Extend your answer to part **(c)** to also require that the solution be non-redundant, i.e. that there are never two consecutive turns or two consecutive forward moves.

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