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MONASH University

Semester Two 2016
Examination Period

Faculty of Information Technology

EXAM CODES: **FIT1008**

TITLE OF PAPER: **INTRODUCTION TO COMPUTER SCIENCE - PAPER 1**

EXAM DURATION: 3 hours writing time

READING TIME: 10 minutes

THIS PAPER IS FOR STUDENTS STUDYING AT: (tick where applicable)

☐ Berwick	**X** Clayton	**X** Malaysia	☐ Off Campus Learning	☐ Open Learning
☐ Caulfield	☐ Gippsland	☐ Peninsula	☐ Monash Extension	☐ Sth Africa
☐ Parkville	☐ Other (specify)			

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AUTHORISED MATERIALS

OPEN BOOK	☐ **YES**	**X NO**
CALCULATORS	☐ **YES**	**X NO**
SPECIFICALLY PERMITTED ITEMS	☐ **YES**	**X NO**
if yes, items permitted are:		

Page	Marks	Page	Marks
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13		33	
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19		39	
21		**Total**	

Candidates must complete this section if required to write answers within this paper

STUDENT ID: __ __ __ __ __ __ __ __ __ DESK NUMBER: __ __ __ __ __

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Question 1 [10 marks]

In this part you are required to answer the following short questions. Your answer should be concise. As a guideline, it should require no more space than the space that is provided.

(1) In MIPS, how many bits are required to store a word?

---

(2) In MIPS, how many bytes are required to store an array of 6 integers?

---

(3) Recursion is usually memory intensive because... (**Hint:** Use your MIPS knowledge)

---

(4) In the worst-case time complexity scenario, Merge-sort outperforms Quick-sort. However, quick-sort is often a better choice because...

---

(5) The two main operations of a Stack ADT are?

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(6) How does a Circular Queue differ from a standard array-based Queue?

(7) List 3 container ADT's covered in the lectures

(8) A class variable is...

(9) The instance variables of a simple Node to support a Linked Structure are....

(10) By convention, a parameter `self` in a method definition refers to...

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Question 2 [5 marks = 3 + 2]

This question is about sorting. Consider the following implementation of `selection_sort`.

```
def selection_sort(a_list):
    n = len(a_list)
    for k in range(n-1, -1, -1):
        max_position = find_max(a_list, k)
        a_list[k], a_list[max_position] = a_list[max_position], a_list[k]
```

(a) Using Python, define the function `find_max(a_list, limit_index)` that completes the implementation.

(b) Is Selection sort as implemented above stable? Explain your answer.

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Question 3 [8 marks = 2 + 2 + 2 + 2]

This question is about time complexity. For algorithms (a) to (d) express their Big-O notation time-complexity in the best and worst case. Provide a short explanation in each case. No explanation means no marks.

(a)

```
def algorithm_a(a_list):
    n = len(a_list)
    for k in range(n-1):
        a = k
        for i in range(k+1, n):
            if a_list[i] < a_list[a]:
                a = i
        a_list[k], a_list[a] = a_list[a], a_list[k]
```

Best time complexity: _____. Worst time complexity: _____
Explanation:

(b)

```
def algorithm_b(a_list):
    n = len(a_list)
    for k in range(0, n-1):
        position = 0
        for i in range(k, -1, -1):
            if a_list[i] == a_list[position]:
                break
            else:
                position += 1
        a_list[k], a_list[position] = a_list[position], a_list[k]
```

Best time complexity: _____. Worst time complexity: _____

Explanation:

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(c)
```
def algorithm_c(a_list):
    return a_list[-1]
```

Best time complexity: _____. Worst time complexity: _____

Explanation:

(d)
```
def algorithm_d(a_list, item):
    a = 0
    b = len(a_list) -1
    while a <= b:
        c = (a+b)//2
        if a_list[c] == item:
            return c
        elif a_list[c] > item:
            b = c - 1
        else:
            a = c + 1
    return -1
```

Best time complexity: _____. Worst time complexity: _____

Explanation:

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Question 4 [7 marks = 2 + 2 + 3]

This question is about Stacks. Consider the partial implementation of a Stack ADT below:

```
class Stack:
    def __init__(self, size):
        assert size > 0, "size should be positive"
        self.array =  size * [None]
        self.count =  0
        self.top = -1

    def is_full(self):
        return self.count > = len(self.array)

    def is_empty(self):
        return self.count == 0
```

(a) Implement the method `push(self, item)` using an assertion to check for the precondition.

(b) Implement the method `pop(self)` using an assertion to check for the precondition.

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(c) Consider the method `factorial` below, which relies on recursion.

```
def factorial(n):
    if n == 0:
        return 1
    else:
        return n*factorial(n-1)
```

Provide a version of `factorial` which uses the Stack implementation to replace recursion.

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Question 5 [6 marks = 2 + 2 + 2]

This question is about linked structures. Consider the following partial implementation of a linked SortedList.

```
class Node:
    def __init__(self, item=None, link=None):
        self.item = item
        self.next = link

class SortedList:
    def __init__(self):
        self.head = None
        self.count = 0

    def _getnode(self, index):
        assert 0 <= index <= self.count, "index out of bounds"
        node = self.head
        for _ in range(index):
            node = node.next
        return node
```

(a) Define the method `add(self, item)`, which adds one item to the list keeping the list sorted.

(b) What is the best and worst-case time complexity of a correct and efficient implementation of `add(self, item)` for this data type. Explain your answer.

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(c) Define the method `__next__(self)`, of the Iterator below, which is intended to go through all elements of the Sorted List defined above.

```
class SortedListIterator:
    def __init__(self, head):
        self.current = head
    def __iter__(self):
        return self
```


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Question 6 [6 marks = 3 + 3]

This question is about recursion.

(a) The greatest common divisor (GCD) of two integer numbers is the largest positive integer that divides the numbers without a remainder. Convert the following iterative version of the GCD algorithm into a recursive algorithm.

```
def gcd(a, b):
    while(b != 0):
        r = a%b
        a = b
        b = r
    return a
```

(b) Provide a tail-recursive version of the following algorithm::

```
def fib(n):
    if n == 0 or n == 1:
        return n
    else:
        return fib(n-2) + fib(n-1)
```


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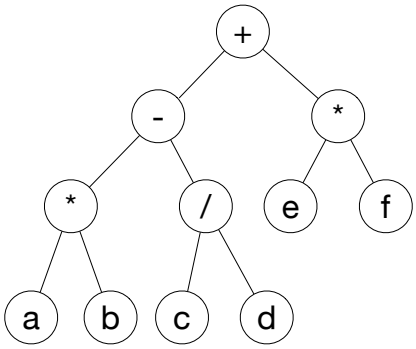
Question 7 [10 = 1 + 2 + 2 + 5 marks]

This question is about Binary Trees and Binary Search Trees. Consider the graph below, which represents an expression tree:



(a) What is the infix arithmetic expression given by this Binary Tree?

(b) List the sequence of characters as they occur when you traverse the tree above in pre-order?

(c) List the sequence of characters as they occur when you traverse the tree above in post-order?

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(d) For the BinarySearchTree data type defined below, write down the recursive method `_insert_aux(self, current, key, item)`:

```
class BinarySearchTreeNode:
    def __init__(self, key, item=None, left=None, right=None):
        self.key = key
        self.item = item
        self.left = left
        self.right = right


class BinarySearchTree:
    def __init__(self):
        self.root = None

    def insert(self, key, item):
        self._insert_aux(self.root, key, item)
```


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Question 8 [10 marks = 3 + 3 + 4]

This question is about Heaps. Consider the partial implementation of a Max Heap.

```
class Heap:
    def __init__(self):
        self.count = 0
        self.array = [None]

    def __len__(self):
        return self.count

    def add(self, item):
        if self.count + 1 < len(self.array):
            self.array[self.count + 1] = item
        else:
            self.array.append(item)
        self.count += 1
        self.rise(self.count)

    def swap(self, i, j):
        self.array[i], self.array[j] = self.array[j], self.array[i]

    def get_max(self):
        item = self.array[1]
        self.swap(1, self.count)
        self.count -= 1
        self.sink(1)
        return item

    def sink(self, k):
        while 2*k <= self.count:
            child = self.largest_child(k)
            if self.array[k] >= self.array[child]:
                break
            self.swap(child, k)
            k = child
```

(a) Implement the method `rise(self, k)` which complements the `add` function.

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(b) Implement the method `largest_child(self, k)` which complements the `sink` function

(c) Using only the methods defined above define a function `get_minimum(a_max_heap)` that returns the minimum element of the Heap in $O(N)$. The parameter of the function is assumed to be a Max-Heap. Your method **can** modify the Heap if necessary, but only through the operations of the Data Type (i.e., you should not access instance variables directly).

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Question 9 [9 marks = 3 + 3 + 3]

This question is about Hash Tables. Keep answers short using the space provided only.

(a) Explain how quadratic probing is used to resolve collisions in a HashTable.

(b) Explain how separate chaining is used to resolve collisions in a HashTable.

(c) If you were given a perfect hash function, would collision handling be necessary? Explain why/why not.

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Question 10 [11 marks]

Translate to MIPS faithfully using only the instructions available in the reference sheet and following the function calling convention discussed in the lectures.

Python Code	MIPS Code

`a = 5`
 	
`a_abs = 0`	

`def my_function(x):`
 	
`  if x > 0:`
`  return x`
 	
`  else:`
 	
`  return -x`	

`a_abs = my_function(a)`
 	
`print(a_abs)`	

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Question 11 [12 marks = 4 + 4 + 4]

For each situation described in the rows of the table below, choose one of the following structures: Linked List (1), Array-based List (2), SortedList Array-based (3), or Sorted Linked-List (4). Explain briefly the reason behind your choice in the space provided.

Situation	**Choice of Data Type**	**Explanation**
A post office needs to store in a list a record for each packet being processed. Postal demand is volatile so the number of packages arriving each day is unpredictable. It is not necessary to keep track of the order.		
A University needs to keep a list of students. Demand is predictable so the approximate size of the list is known and after enrolments not a lot of changes are needed in terms of additions or deletions. The students do not need to be sorted.		
A University needs to keep a list of employees. The approximate size of the list is known and new items or removals happen infrequently. The critical functionality to be provided is search by name.		

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Question 12 [6 marks = 1 × 6]

In MIPS, the function calling convention has the following steps. For each step, explain in the space provided **why** this action is required by the convention.

(1) Caller saves temporary registers on the stack.

(2) Caller passes arguments on to the stack.

(3) Caller calls function using `jal`.

3

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(4) Callee saves `ra` and `fp` on the stack.

(5) Callee copies `sp` to `fp`.

(6) Callee allocates local variables on the stack.

END OF EXAM.

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