JOHN MONASH SCIENCE SCHOOL

VICTORIAN CERTIFICATE OF EDUCATION

2017

STUDENT NAME:

ALGORITHMICS (HESS)

Practice Exam 1

2017

Reading Time: 15 minutes
Writing time: 120 minutes

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	12	12	80
		Total	100

- Students are permitted to bring into the test room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination: blank sheets of paper and/or correction fluid/tape.

Materials supplied

- Question and answer book of 28 pages.
- Answer sheet for multiple-choice questions.

Instructions

- Write your name in the space provided above on this page.
- All written responses must be in English.

At the end of the examination

- Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

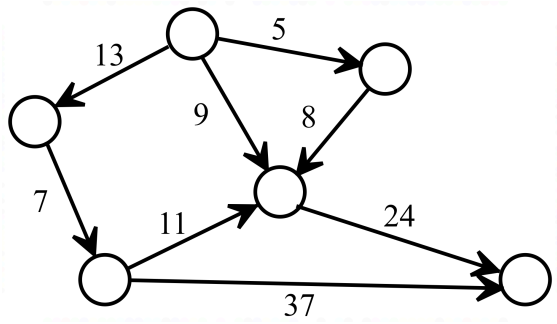
SECTION A – Multiple-choice Questions

Instructions for Section A

Answer **all** questions in pencil on the answer provided for multiple-choice questions.
Choose the response that is **correct** or that **best answers** the question.
A correct answer scores 1, an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.

Question 1

Which of the following features are **NOT** present in the graph shown below:



A. Cyclicity

B. Directedness

C. Weightedness

D. None of the above

Question 2

The term 'Abstraction' in relation to Abstract Data Types is best described as:

A. The representation of all information related to a problem as an ADT.

B. The process of converting information from a problem into an ADT that can then be modeled.

C. The removal of all unnecessary information required to model or find a solution to a problem.

D. The breaking up of a problem into smaller sections to be solved separately.

Question 3

A tree is best defined as:

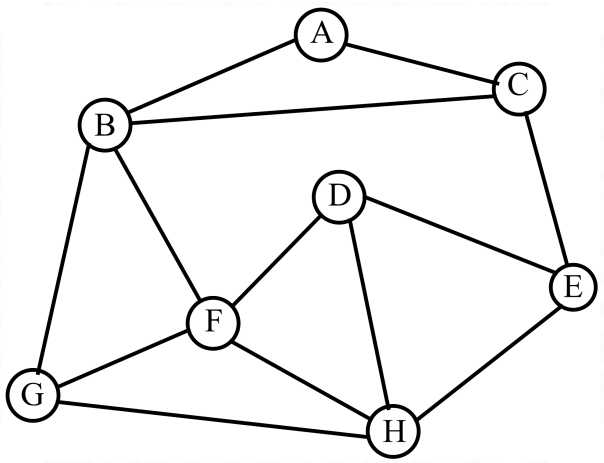
A. A graph where each node is only connected by a single edge to another node.

B. A graph where every node is directly connected to every other node.

C. A graph that contains no cycles.

D. A graph that is fully connected and contains no cycles.

Use the following information to answer Questions 4 and 5



Question 4

A depth-first search traversal of the graph shown above will visit the nodes in which one of the following orders? (Alphabetical order is used when there is more than one option.)

A. ABCFGEDH

B. ABCEDFGH

C. ABFDECHG

D. ACEDFBGH

Question 5

A breadth-first search traversal of the graph shown above will visit the nodes in which one of the following orders? (Alphabetical order is used when there is more than one option.)

A. ABCFGEDH

B. ABCGFDHE

C. ACEDFBGH

D. ACBEFGHD

Question 6

When considering different types of algorithms, which one of the following statements is **true**?

A. Greedy algorithms always produce a better solution than brute-force algorithms for the same problem.

B. Brute-force algorithms are always faster than greedy algorithms for the same problem.

C. Divide and conquer algorithms are always faster than greedy algorithms for the same problem.

D. Greedy algorithms generally give fast and good approximate solutions to a problem which, in some cases, might end up being the best possible answer.

Question 7

An unspecified ADT, *X*, is initialized with the values {1, 2, 3}. The following operations are then carried out on *X* in the order indicated:

X . Push(2)

X . Pop ( )

X . Peek ( )

X . Pop ( )

X . Push (1)

The resultant state of *X* after these operations are:

A. {1, 2, 3, 2, 1}

B. {1, 1, 2, 3}

C. {1, 2, 1, 2, 3}

D. {1, 2, 3}

Question 8

Which one of the following algorithms is best suited to finding the all-pair shortest path between nodes in a graph?

A. Prim's Algorithm

B. Dijkstra's Algorithm

C. The Bellman-Ford Algorithm

D. The Floyd-Warshall Algorithm

Question 9

A child is building a giant tower out of coloured lego blocks. Each block is put directly on top of the block below it.

Which abstract data type (ADT) would be most appropriate to use to record the order of blocks the child uses?

A. Stack

B. Queue

C. Array

D. Dictionary

Question 10

Which of the following statements about the PageRank Algorithm is **false**?

A. the ranking of a web page is based on the probability of a random direct landing on a web page.

B. the ranking of a web page is based on the number of outbound links from the web page.

C. the ranking of a web page is based on the number of inbound links from the web page.

D. the damping factor is associated with the probability of a person following an outbound link from a web page.

Question 11

Consider the following pseudocode.

```
a = 1
total = 0
for i = 0 to i = 5
     total = total + a
     a = a + 1
endfor
```

Which one of the following statements correctly describes the values of `a` and `total` after the algorithm is executed.

A. `a = 5, total = 15`

B. `a = 6, total = 15`

C. `a = 6, total = 21`

D. `a = 7, total = 21`

Question 12

Consider a graph, G, with V number of vertices and E number of edges. The time complexity of Prim's Algorithm on G is:

A. $O(E)$

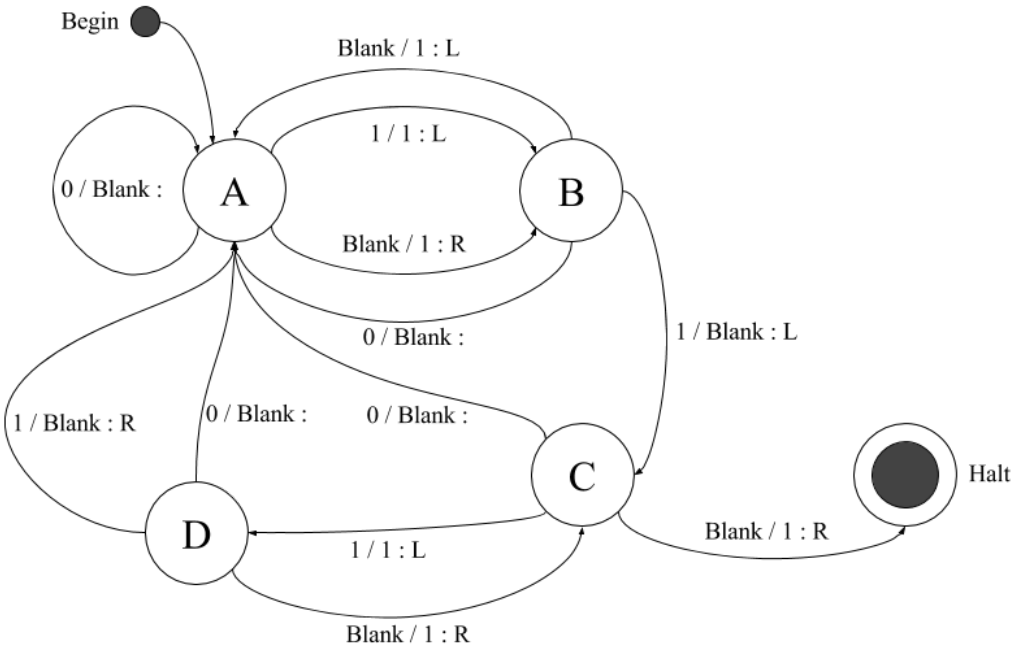
B. $O(V)$

C. $O(V \times E)$

D. $O\left(V^2\right)$

Use the following information to answer Questions 13 and 14

A Turing Machine is configured with the instructions represented in the state diagram below.



Each edge is labelled *i* / *j* : *k*, where:

- *i* is the input
- *j* is the output
- *k* is the direction the head moves (L = left, R = right) after the output.

The machine starts in state A.

The machine is given the following tape. For this machine, the tape remains stationary while the head moves. The arrow shows the starting point of the head.

				0	0				

↑

Question 13

The Turing Machine is run for 4 steps. In what state will the Turing Machine be in at this time?

A. State B

B. State C

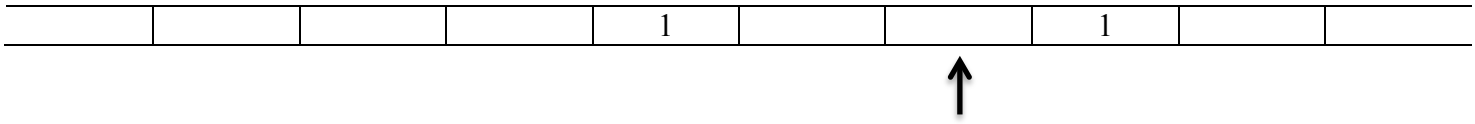
C. State D

D. It will be in its Halt State.

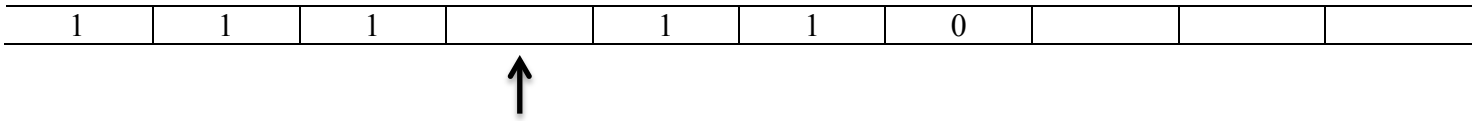
Question 14

Which one of the following best represents the tapes appearance and the position of the head when the Turing Machine halts?

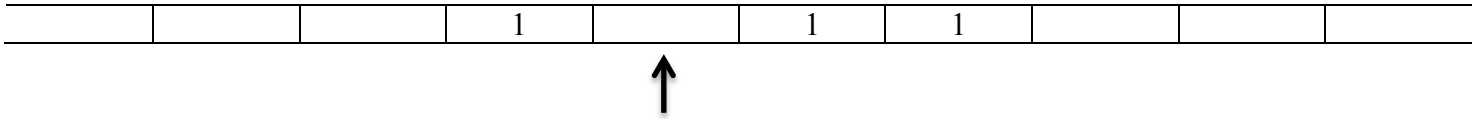
A.



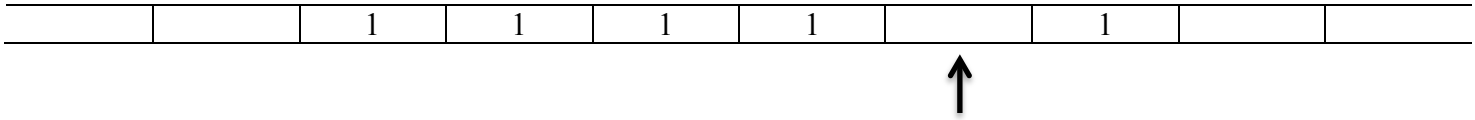
B.



C.



D.



Question 15

Which of the following statements about NP-complete problems is **false**?

A. NP-complete problems are at least as hard as NP-hard problems

B. NP-complete problems are decision problems

C. All NP-hard problems can be reduced to NP-complete problems in polynomial time

D. All NP problems can be reduced to NP-complete problems in polynomial time

Question 16

Dijkstra's algorithm for finding the shortest path between two nodes:

A. will always find the shortest distance between two nodes

B. will sometimes find the shortest distance between two nodes if a negative edge weight is present

C. will never find the shortest distance between two nodes if a negative edge weight is present

D. will not work at all if a negative edge weight is present

Question 17

A recursive algorithm has a recurrence relation $T(n) = 2n^3 + 4T\left(\frac{n}{2}\right)$.

The time complexity of this algorithm is:

A. $O\left(n^3\right)$

B. $O\left(n^3 \log(n)\right)$

C. $O\left(\log_2(4)\right)$

D. $O\left(n^2\right)$

Question 18

Mergesort is an example of which of the following algorithm design patterns?

A. Decrease and conquer

B. Divide and conquer

C. Dynamic Programming

D. Backtracking

Question 19

Which of the following statements best describes the meaning of the Church-Turing Thesis?

A. A Turing Machine can do anything that any other computing device can do.

B. All functions are computable on a Turing Machine.

C. A function can be described as being computable if, and only if, it is computable by a Turing Machine.

D. A function that cannot be computed by a Turing Machine is considered NP-hard.

Question 20

Which one of the following problems is best suited to being solved using Neural Networks?

A. The Graph Colouring Problem

B. Calculating the n^{th} Fibonacci Number

C. Sorting a list of names into alphabetical order

D. Playing a game of Chess

END OF SECTION A
TURN OVER

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided

Question 1 (3 marks)

George has started up a company producing chocolate chip cookies (mainly to profit off Curtis' recent obsession). Unfortunately, he has recently been receiving a large number of complaints that some of his chocolate chip cookies do not contain any chocolate chips.

Upon investigation of his cookie-making machine, George discovers that there is always exactly one cookie from each batch that does not contain any chocolate chips. This cookie always weighs significantly less than the cookies that do have chocolate chips.

George wishes to develop an algorithm that will check the chocolate chip cookies and identify ones that don't have chocolate chips in them. He does not want to check each chocolate chip cookie individually though.

Describe an algorithmic design pattern that George could use to successfully identify the chocolate chip cookies that do not contain any chocolate chips and explain how this algorithm will solve the problem efficiently.

Question 2 (2 marks)

As a way of practising mindfulness (and avoiding eating too many of George's cookies), Angus decides to spend 5 minutes every day writing signature specifications for various ADTs. Today, he begins writing the signature specification for a graph.

```
name:        graph
import:      list, element, boolean
operations:  empty : → Graph
             addNode : graph x element → graph
             addEdge :
             adjacent : graph x element x element → Boolean
             neighbours : graph x element → list
```

Angus can't quite remember what the specification is for the addEdge operation.

In the space below, write the specification for the addEdge operation of the graph ADT.

Question 3 (17 marks)

Marcus has been following George's cookie making company with an enthusiasm that borders on being obsessive. He is intrigued by the fact that the density of the chocolate chip cookies seems to be abnormally large. Through his hacking of George's email, he learns that the chocolate chips come from a remote island in Greece. Marcus decides to investigate.

Marcus begins to pack a bag for his trip. He has a wide variety of items that each have a weight and value associated with them.

Marcus wants to find out what the best combination of items he should put in his bag to maximise the total value of his bag, whilst keeping it under a certain weight limit.

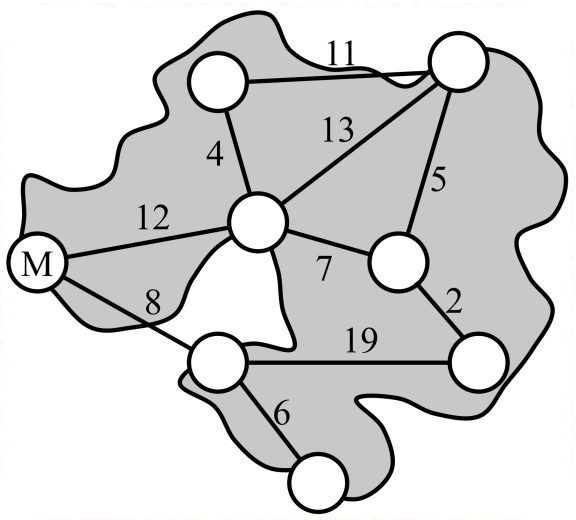
At first Marcus uses a greedy approach towards selecting items to put in the bag.

a. Describe what a greedy approach towards solving this problem might look like and explain why it won't necessarily lead to an optimal solution. 3 marks

b. How might a dynamic programming approach be used to find a solution to Marcus' bag packing problem in reasonable time? 3 marks

c. Explain why Marcus' bag packing problem is a NP-hard problem and not an Non-deterministic Polynomial-time (NP) problem. 3 marks

Marcus uses a travel algorithm created by Alex to determine the most effective way of getting to the remote island where the chocolate chips originate. When he arrives at the island he finds the following map of the island.



Each vertex on this map represents a different community living on the island. Marcus is initially located at the vertex labelled M. The weightings on each edge connecting the vertices represent the time, in hours, it will take Marcus to walk from one community to another.

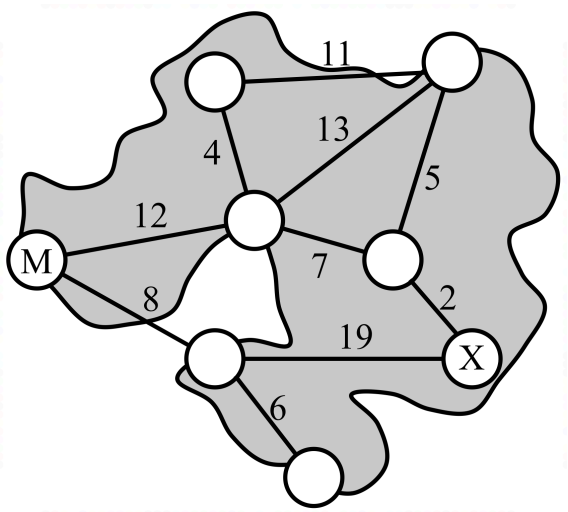
At this moment, Marcus doesn't know the location of the community where the chocolate chips are made. He remembers back to an Algorithmics class where he learnt about Prim's Algorithm, Dijkstra's Algorithm, the Bellman-Ford Algorithm and the Floyd-Warshall Algorithm.

d. **i.** Which of these four algorithms would be most suitable for Marcus to use to find the shortest path from node M to all other nodes in the map? Give reasons for your answer. 3 marks

Marcus hears a church bell ringing in the distance and so decides to use the Bellman-Ford algorithm.

ii. How many iterations of the Bellman-Ford Algorithm will this graph require to find the shortest distance from M to all other nodes? 1 mark

Marcus talks to some locals and learns that the community he is looking for is located at Node X in the diagram below.



iii. After two iterations of the Bellman-Ford Algorithm what distance, from M, will the algorithm have stored for node X? 1 mark

iv. Which algorithm would be most suitable for Marcus to use to find the shortest path from node M to node X? Give reasons justifying your choice. 3 marks

Upon arriving at the community, Marcus discovers Tom leading the chocolate chip making process. Tom explains that the reason the chocolate chips are so dense is because they have been made out of a combination of chocolate and dark matter to make a 'dark chocolate matter chip'.

How Tom and George came by the dark matter was not made clear but Marcus knew better than to ask too many questions.

Question 4 (9 marks)

Kyle was caught on facebook by Mr Chisholm during Chemistry the other day and, as punishment, was forced to do some Geography work. Mr Chisholm got the coloured pencils and asked Kyle to colour in a map of the distribution of different types of tourism and tourist destinations in Eastern Europe. Mr Chisholm insisted that Kyle colour it in so that no two adjacent regions were the same colour and using as few colours as possible (remember Mr Chisholm is colour blind).

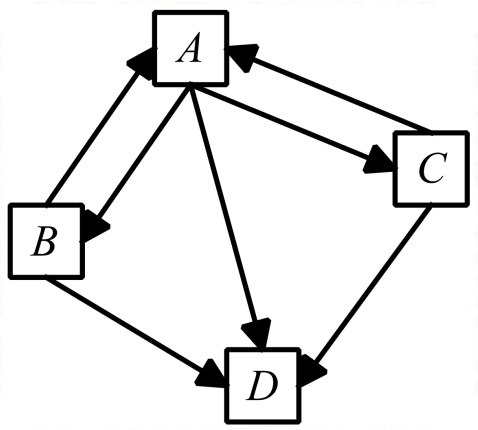
a. Describe the decision version of the graph colouring problem and explain why it is a Non-deterministic Polynomial-Time (NP) problem. 3 marks

b. How could Kyle make use of Randomised Heuristics to aid him in finding a solution to Mr Chisholm's problem. 3 marks

c. Would the use of Randomised Heuristics lead to Kyle finding the optimal solution to the problem? 3 marks

Question 5 (6 marks)

The following graph represents links between a series of web pages.



The PageRank of Page *A* is given by

$$\mathrm{PR}(A) = \frac{(1-d)}{N} + d\left(\frac{\mathrm{PR}(B)}{\mathrm{L}(B)} + \frac{\mathrm{PR}(C)}{\mathrm{L}(C)} + \frac{\mathrm{PR}(D)}{\mathrm{L}(D)}\right)$$

where $\mathrm{PR}(x)$ is the PageRank of Page *x*, *N* is the number of pages in this network and $\mathrm{L}(x)$ is the number of outgoing links from Page *x*.

a. Explain the purpose of *d* in the PageRank. 2 marks

b. What does $\frac{(1-d)}{N}$ represent in the PageRank? 1 mark

c. What does $d\left(\frac{\mathrm{PR}(B)}{\mathrm{L}(B)} + \frac{\mathrm{PR}(C)}{\mathrm{L}(C)} + \frac{\mathrm{PR}(D)}{\mathrm{L}(D)}\right)$ represent in the PageRank? 1 mark

d. Explain how PageRank would handle the values attributed to node *E* given that there are no outbound links from Page *E*? 2 marks

Question 6 (9 marks)

Marc and Faris are having an argument about Neural Networks and how they can be used to overcome soft limits of computability.

Marc states

"Neural Networks emulate the way in which information is processed in the human brain. As such, they do not contain algorithms that can be written down in the traditional sense and are therefore no longer Turing Complete."

Faris retorts with

"You're wrong Marc. Neural Networks, while able to handle a variety of problem types that traditional algorithms would find challenging, are no threat to the Church-Turing Thesis."

a. What is the Church-Turing Thesis and what does it mean to say that something is Turing Complete? 3 marks

b. Explain what Marc means when he states that Neural Networks "do not contain algorithms that can be written down in the traditional sense". 2 marks

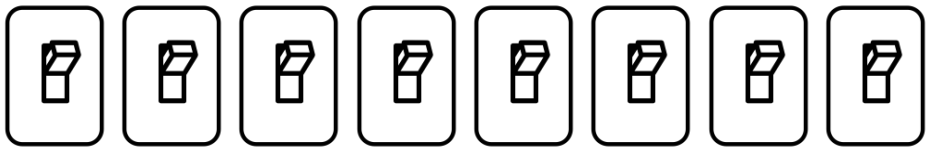
c. Give an example of a problem type that Neural Networks are better suited at solving than traditional algorithms? 1 mark

d. Explain how Neural Networks operate and how they relate to the concept of machine learning. 3 marks

Question 7 (3 marks)

Tim was on his way home one night when he spotted a new escape room. Being an escape room enthusiast, he quickly handed over some money to get locked in the room.

Once in the room, he discovered that he could only escape by turning off a series of *n* switches. The switches are all arranged in a line as shown below.



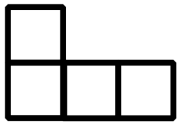
After some experimentation he learns that the switches follow the following set of rules:

1. The rightmost switch may be turned on and off at will
2. Any other switch can only be turned on or off if the switch to its immediate right is on **and** all other switches to its right are turned off.
3. Only one switch may be toggled at a time.

Write the pseudocode for an algorithm that would turn off all of the switches for Tim whilst obeying the set of rules outlined above.

Question 8 (4 marks)

Dylan, after many competitions and trips overseas, has decided to settle down and become a tradie. In particular, after seeing some of the amazing mosaics in Spain, he is looking at becoming a tiler. As part of his apprenticeship with George (the Scottish maintenance worker at JMSS) Dylan is asked to tile a 16x16 sized grid with the unique L-shaped tile made up of four 1x1 squares as shown below.



Describe two different approaches that Dylan could use to find a possible arrangement of the L-shaped tiles on the 16x16 sized grid.

1.

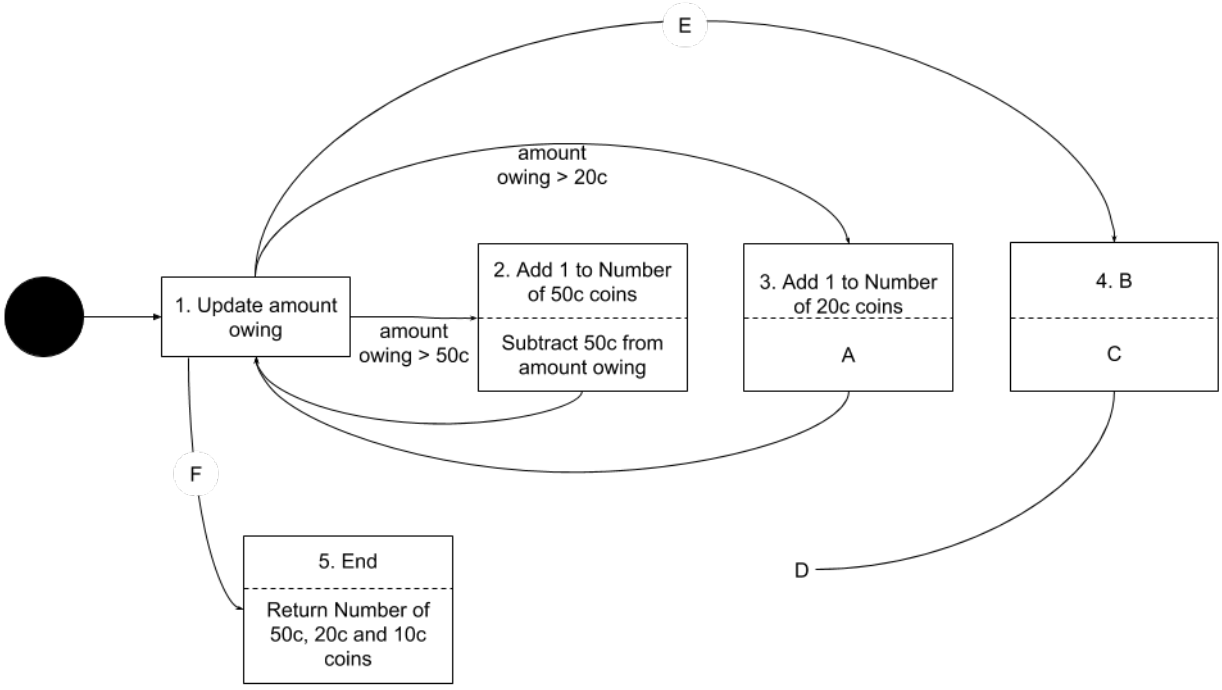
2.

Question 9 (6 marks)

Noelani has been practising designing algorithms in the lead up to the exams. She has created an algorithm that will determine the amount of change a vending machine should give a customer using only 50c, 20c, and 10c coins.

In order to understand her algorithm better she draws a state diagram to represent the process her algorithm.

The diagram that Noelani has drawn so far is shown below. The upper case letters A through to F represent components that Noelani has not completed yet.



a. If state 3 is reached, Noelani expects an action to take place. What action should take place at A? 1 mark

_____

b. **i.** Noelani has identified a 4th state at B. What should the label of B be?. 1 mark

_____

_____

ii. If state 4 is reached, Noelani expects an action to take place. What action should take place at C? 1 mark

_____

_____

c. Noelani has started another transition labelled D. To which state should this transition go? 1 mark

d. For the transition from state 1 to 4, what should Noelani write at E? 1 mark

e. For the transition from state 1 to 5, what should Noelani write at F? 1 mark

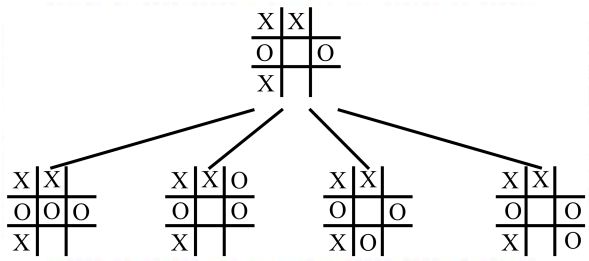
Question 10 (5 marks)

Percival and Riley are procrastinating and decide to play a game of tic-tac-toe. Because they have been studying tic-tac-toe in algorithmics and both know how to reach a draw with ease, they decide to play with different rules. The game is still played by Player 1 writing a cross in an unoccupied square of their choosing followed by Player 2 writing a naught in an unoccupied square of their choosing. This process is then repeated until one of the players either gets three naughts or three crosses in a row. In the new version of the game, however, the player who has three naughts or crosses in a row, loses.

After playing a few turns, Percy is struggling to figure out what to do next. He decides to distract Riley with a laser pointer whilst he uses the minimax algorithm to determine what move he should make next.

The current state of the board is shown below and it is Percy's turn to write a naught somewhere on the grid.

Using the minimax algorithm, complete the game tree until you can determine what move Percy should make next.



Question 11 (7 marks)

Jess has been growing rather concerned watching Curtis eating the cookies he has been purchasing from George every day. She is worried that Curtis will overdose on cookies if he is not careful. She comes up with a cunning plan to reduce the number of cookies that Curtis eats.

Every time Curtis takes a cookie from his box of cookies he becomes so distracted by the enjoyment of eating the cookies that Jess is able to steal the jar of cookies and remove some of the cookies before putting it back without him realising. She doesn't want to make the removal of the cookies obvious though so every time Curtis eats a cookie, she removes one third of the remaining cookies from the cookie jar and returns the rest.

a. Write the pseudocode for an algorithm, `operationCookie(jar)`, that describes Jess' recursive theft of cookies from Curtis' cookie jar. 3 marks

b. Write a recurrence relation for the time complexity of `operationCookie(jar)` and use the Master Theorem to solve the time complexity. 4 marks

Question 12 (9 marks)

William has been pondering the meaning of intelligence. Unfortunately, he is finding it difficult to ponder this during class when people keep talking about Chinese speakers. He finds himself a quiet room with a large book in it where he can ponder intelligence in peace. Just as he has made himself comfortable, people start sliding notes written in chinese under the door. Frustrated, he puts his headphones in and listens to some 'Rage Against the Machine'.

If William had been paying more attention, he might have realised that the class was actually discussing John Searle's argument regarding artificial intelligence.

a. In the space below, describe John Searle's Chinese Room Argument and John Searle's position regarding the possibility of artificial intelligence. 3 marks

b. Discuss two possible counter arguments to John Searle's Chinese Room Argument. 6 marks

END OF QUESTION AND ANSWER BOOK