



A-level

COMPUTER SCIENCE

Paper 1

7517/1

Monday 12 June 2023

Afternoon

Time allowed: 2 hours 30 minutes

MATERIALS

For this paper you must have:

- **a computer**
- **a printer**
- **appropriate software**
- **the Electronic Answer Document**
- **an electronic version and a hard copy of the Skeleton Program**
- **an electronic version and a hard copy of the Preliminary Material.**

You must NOT use a calculator.

[Turn over]

INSTRUCTIONS

- **Type the information required on the front of your Electronic Answer Document.**
- **Before the start of the examination make sure your CENTRE NUMBER, CANDIDATE NAME and CANDIDATE NUMBER are shown clearly IN THE FOOTER of every page (also at the top of the front cover) of your Electronic Answer Document.**
- **Enter your answers into the Electronic Answer Document.**
- **Answer ALL questions.**
- **Save your work at regular intervals.**

INFORMATION

- **The marks for questions are shown in brackets.**
- **The maximum mark for this paper is 100.**
- **No extra time is allowed for printing and collating.**
- **The question paper is divided into FOUR sections.**

ADVICE

You are advised to allocate time to each section as follows:

**SECTION A – 40 minutes; SECTION B – 20 minutes;
SECTION C – 20 minutes; SECTION D – 70 minutes.**

AT THE END OF THE EXAMINATION

Tie together all your printed Electronic Answer Document pages and hand them to the Invigilator.

WARNING

It may not be possible to issue a result for this paper if your details are not on every page of your Electronic Answer Document.

DO NOT TURN OVER UNTIL TOLD TO DO SO

SECTION A

You are advised to spend no longer than 40 MINUTES on this section.

Enter your answers for SECTION A in your Electronic Answer Document.

You MUST SAVE this document at regular intervals.

0	1
---	---

Describe the process that should be followed to add an item to a circular queue implemented as a static data structure using an array.

Your method should deal appropriately with any issues which could arise. [5 marks]

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[Turn over]

0	2
---	---

FIGURE 1 shows a logic puzzle.

FIGURE 1

The following five coloured shapes are placed on a table.

Image of coloured shapes not reproduced here due to third party copyright restrictions.

Tabitha secretly chooses one of the coloured shapes and:

- tells **Walter** the colour of the shape she has chosen (pink, yellow or blue)
- tells **Lionel** the type of shape she has chosen (triangle, circle or square).

Lionel and **Walter** both know what coloured shapes are on the table.

Lionel knows that **Walter** has been told the colour chosen by **Tabitha**. **Walter** knows that **Lionel** has been told the type of shape chosen by **Tabitha**. They do not know what the other has been told.

Tabitha first asks **Walter** and **Lionel** if they know which coloured shape she has chosen. They both answer at the same time and say “No”.

Tabitha then asks them again if they know which coloured shape she has chosen. They both answer at the same time and say “No” again.

Tabitha asks them a third time if they know which coloured shape she has chosen and they both answer at the same time and say “Yes”.

0 2 . 1

After they have both replied to Tabitha’s FIRST question, what does Lionel now know about Tabitha’s choice because Walter said “No”? [1 mark]

0 2 . 2

After they have both replied to Tabitha’s FIRST question, what does Walter now know about Tabitha’s choice because Lionel said “No”? [1 mark]

0 2 . 3

Which coloured shape had Tabitha chosen? [1 mark]

[Turn over]

0 3

A binary tree is a type of data structure.

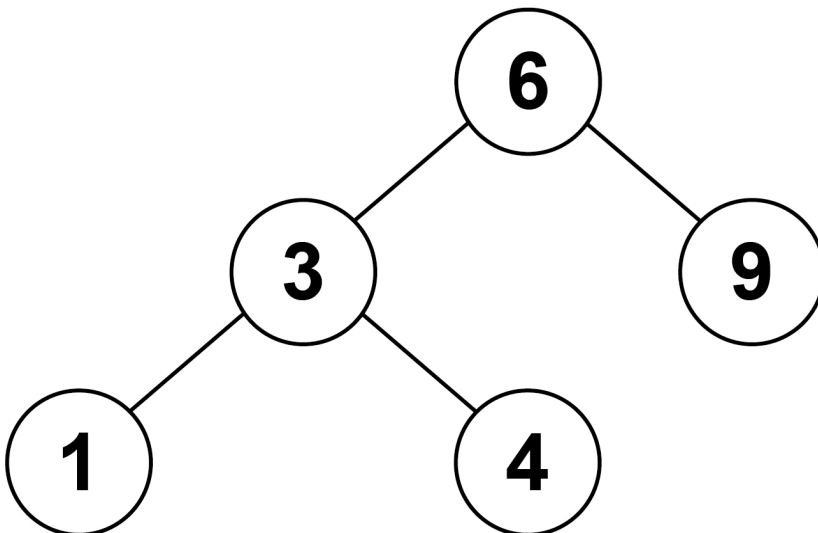
0 3 . 1

State TWO characteristics that make a tree a binary tree. [2 marks]

0 3 . 2

FIGURE 2 shows a binary tree and its representation using an array of records called `Tree`. Each record consists of three fields, `Data`, `Left` and `Right`.

FIGURE 2



	DATA	LEFT	RIGHT
[0]	6	1	4
[1]	3	2	3
[2]	1	-1	-1
[3]	4	-1	-1
[4]	9	-1	-1

Question 03.2 continues on page 10.

[Turn over]

FIGURE 3 shows a subroutine that implements a binary tree search algorithm using the array `Tree`. The subroutine parameter, `k`, is the data item being searched for. The subroutine returns a Boolean value indicating if the data item being searched for is in the binary tree or not.

Parts of the algorithm are missing.

FIGURE 3

```

SUBROUTINE BTS (k)
  Current ←           1          
  WHILE Current >           2          
    IF Tree[Current].Data = k THEN
      RETURN           3          
    ELSEIF Tree[Current].Data < k THEN
                4          
    ELSE
                5          
    ENDIF
  ENDWHILE
  RETURN           6          
ENDSUBROUTINE

```

Complete each row in TABLE 1, to show what the labels indicating missing parts of the algorithm in FIGURE 3 should be replaced by.

TABLE 1

1	
2	
3	
4	
5	
6	

Copy the contents of the unshaded cells in TABLE 1 into the table in your Electronic Answer Document.
[4 marks]

[Turn over]

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03.3

There are similarities in how the binary tree search and the binary search algorithms work.

State the big-O time complexity of the BINARY SEARCH algorithm. [1 mark]

03.4

Explain why the binary search algorithm has the time complexity stated in your answer for 03.3. [1 mark]

03.5

Explain why searching for an item in a list or tree is a tractable problem. [1 mark]

03.6

Heuristics can be used when working with an intractable problem.

Explain what heuristics are. [2 marks]

03.7

Explain what is meant by constant time complexity. [2 marks]

[Turn over]

A regular language is one that can be defined using a regular expression.

FIGURE 4 shows definitions for six different languages.

FIGURE 4

LANGUAGE A

```
<string> ::= <term> <op> <term>
<string> ::= ( <string> )
<op>    ::= ÷ | -
<term>  ::= a | b
```

LANGUAGE B

$(a|b)+ab^*$

LANGUAGE C

`<string> ::= a | b | <num>`
`<string> ::= <string> a | <string> b`
`<digit> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9`
`<num> ::= <digit> <num> | <digit>`

LANGUAGE D

$\{a^n b \mid n \geq 1\}$

LANGUAGE E

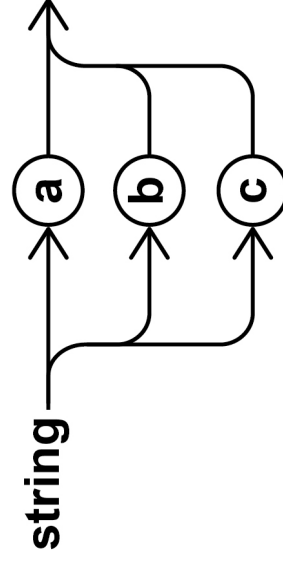
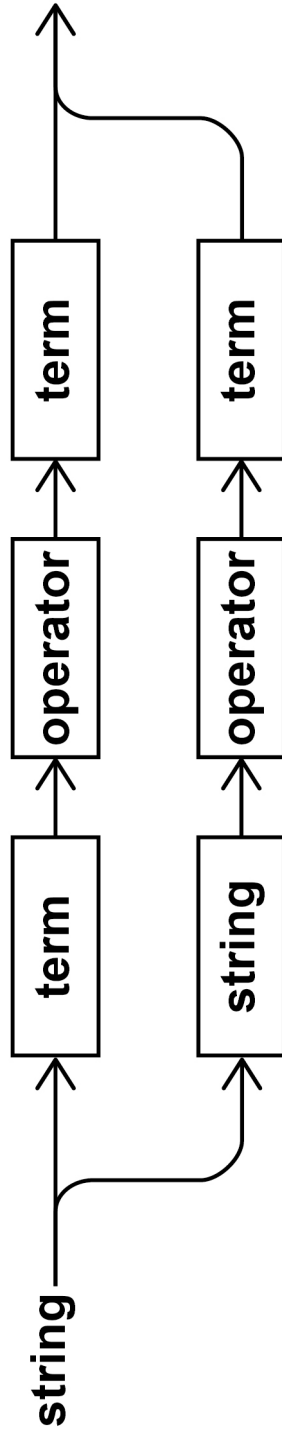
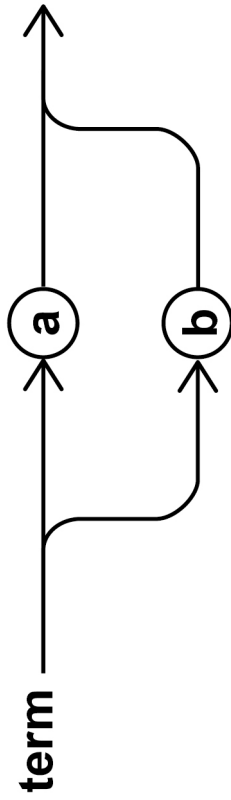
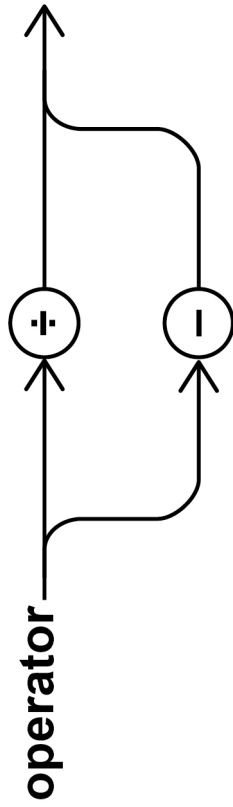


FIGURE 4 continues on page 16

[Turn over]

FIGURE 4 – CONTINUED

LANGUAGE F



04.1

Complete TABLE 2 to show which of the languages in FIGURE 4, on pages 14 to 16, are regular languages.

TABLE 2

LANGUAGE	REGULAR LANGUAGE (Y/N)?
Language A	
Language B	
Language C	
Language D	
Language E	
Language F	

Copy the contents of the unshaded cells in TABLE 2 into the table in your Electronic Answer Document. [3 marks]

[Turn over]

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04.2

Show that the language defined by the union of the sets $\{b^n \mid n > 0\}$ and $\{a, ab\}$ is a regular language by writing a regular expression for the language. [2 marks]

04.3

Explain what is meant by the cardinality of a set. [1 mark]

[Turn over]

0	5
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FIGURE 5, on the opposite page, shows the transition function (represented as a state transition diagram) and part of the tape for a Turing machine designed to count the number of zeros between two # symbols on the tape.

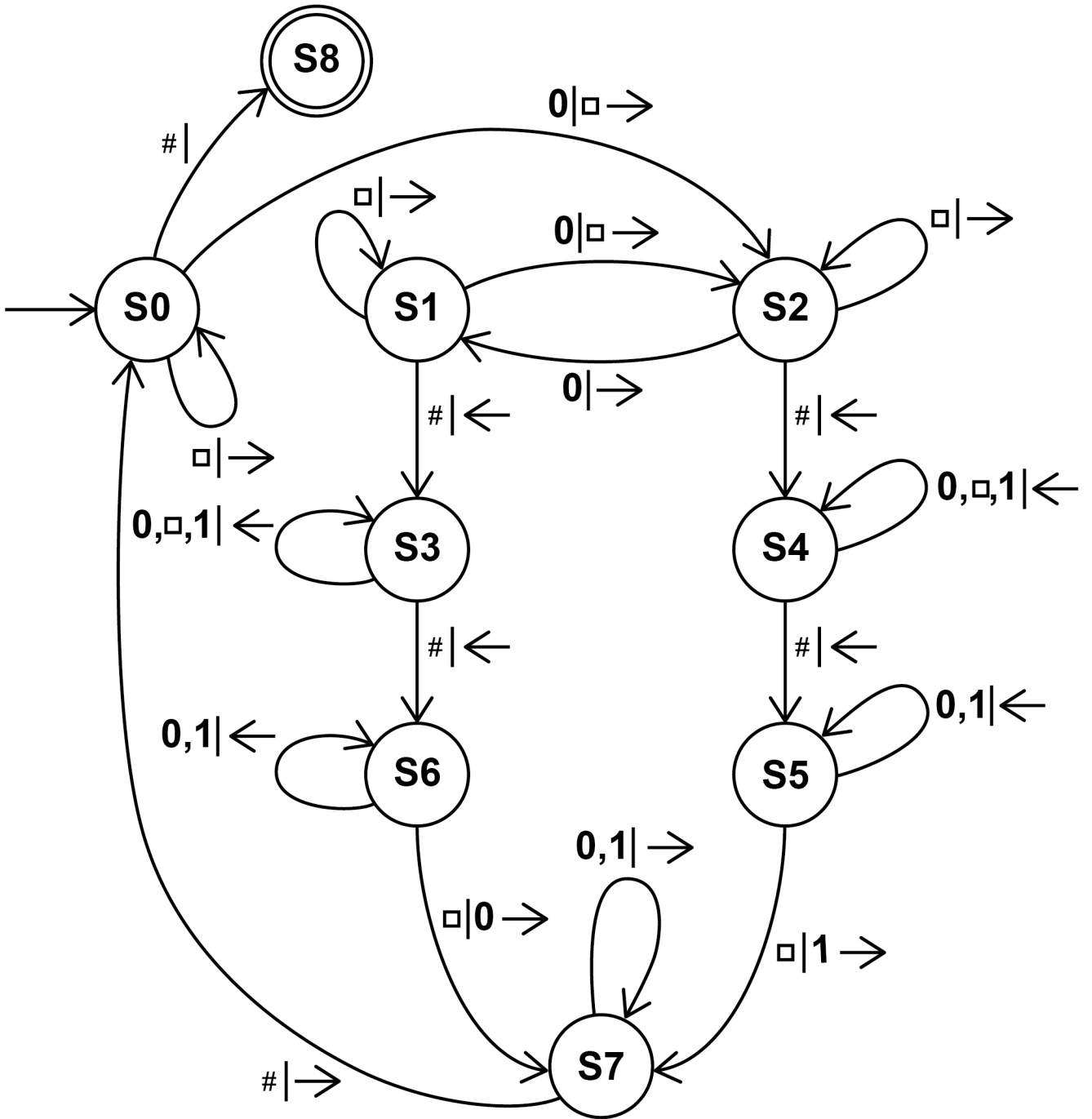
The current position of the read/write head is indicated by the * symbol.

The \square symbol is used to denote an empty cell on the tape.

The label $\square \mid 0 \longrightarrow$ on the transition from S6 to S7 means if the machine is in state S6 and a \square is read from the tape, then a 0 should be written to the tape and then the read/write head is moved one cell to the right.

The label $0, \square, 1 \mid \longleftarrow$ on the transition from S3 to S3 means if the machine is in state S3 and a \square , a 0 or a 1 is read from the tape, then the read/write head is moved one cell to the left; the contents of the tape are not changed.

FIGURE 5



...	#	0*	0	0	#	...
-----	---	----	---	---	---	-----

[Turn over]

0	5	.	1
---	---	---	---

On the opposite page, complete the unshaded cells of TABLE 3 to show the result of tracing the computation of this Turing machine FOR THE FIRST 20 STEPS ONLY.

Show the contents of the tape, the current position of the read/write head and the current state as the input is processed. The top row of the table shows the initial state, the initial position of the read/write head and the starting contents of the tape.

0 5 . 2

Describe TWO circumstances when the transition function for this Turing machine will NOT correctly count the number of zeros between two # symbols on the tape.

You should assume that:

- **the read/write head starts immediately to the right of a cell containing a #**
- **there is a cell containing a # symbol somewhere on the tape to the right of the read/write head's initial position**
- **there are exactly two # symbols on the tape.**

[2 marks]

0 5 . 3

Explain what a Universal Turing machine is. [2 marks]

0 5 . 4

State ONE reason why there are some problems that no real computer can solve that the Universal Turing Machine could solve. [1 mark]

BLANK PAGE

[Turn over]

SECTION B

You are advised to spend no more than 20 MINUTES on this section.

Enter your answers to SECTION B in your Electronic Answer Document.

You **MUST SAVE** this document at regular intervals.

The question in this section asks you to write program code **STARTING FROM A NEW PROGRAM / PROJECT / FILE.**

You are advised to **SAVE** your program at regular intervals.

0	6
---	---

Write a program that gets the user to enter a string. It should keep getting the user to enter a string until they enter a valid string. Each time they enter a string an appropriate message should be displayed telling them whether the string they entered is valid or not.

For a string to be valid:

- it must be between five and seven characters in length (inclusive)
- it must consist only of uppercase letters
- it must contain only unique characters (ie no character appears in the string more than once)

- the sum of the ASCII codes of the characters in the string must be between 420 and 600 (inclusive).

EVIDENCE THAT YOU NEED TO PROVIDE

Include the following evidence in your Electronic Answer Document.

06.1

Your PROGRAM SOURCE CODE [12 marks]

06.2

SCREEN CAPTURE(S) showing the results of testing the program by entering the strings BOIL, BRAiSE, ROAST, BLANCH and PRESSURECOOK. You will need to execute your program more than once to test all of the strings. [1 mark]

[Turn over]

SECTION C

You are advised to spend no more than 20 MINUTES on this section.

Enter your answers to SECTION C in your Electronic Answer Document.

You MUST SAVE this document at regular intervals.

These questions refer to the PRELIMINARY MATERIAL and the SKELETON PROGRAM, but DO NOT require any additional programming.

Refer EITHER to the PRELIMINARY MATERIAL issued with this question paper OR your electronic copy.

0	7
---	---

This question is about the `PlayGame` method in the `Dastan` class.

07.1

Complete the unshaded cells of TABLE 4 to show which statements are true and which statements are false about the `PlayGame` method.

TABLE 4

STATEMENT	TRUE / FALSE
Uses definite iteration	
Uses nested iteration	
Uses nested selection	
Uses one or more global variables	
Uses one or more local variables	
Uses one or more named constants	

Copy the contents of the unshaded cells in TABLE 4 into the table in your Electronic Answer Document.
[2 marks]

[Turn over]

07.2

If the `PlayGame` method was altered to allow the user to select any move option from their queue, what is the maximum amount their score could decrease by after making a move? [1 mark]

08

The SKELETON PROGRAM uses overriding. When a derived class overrides a method from the base class, the base class method could be either a virtual method or an abstract method.

Describe TWO differences between a virtual method and an abstract method. [2 marks]

09

This question is about the `MoveOptionQueue` class.

09.1

**Explain how this class uses information hiding.
[1 mark]**

The data structure `Queue` has NOT been implemented as a first-in first-out (FIFO) queue.

09.2

Explain why the `MoveItemToBack` method in the `MoveOptionQueue` class does NOT use the `Queue` data structure as a FIFO queue. [1 mark]

09.3

State the identifier of a method in the `MoveOptionQueue` class that DOES use the `Queue` data structure as a FIFO queue. [1 mark]

[Turn over]

10

This question is about the `CheckIfGameOver` method in the `Dastan` class.

10.1

Explain why the first selection structure is needed.
[1 mark]

10.2

FIGURE 6 shows a pseudo-code representation of part of the `CheckIfGameOver` method.

FIGURE 6

```
NOT (Player1HasMirza AND Player2HasMirza)
```

Rewrite the code in FIGURE 6 so that it has the same functionality but uses `OR` and `NOT` Boolean operations only, instead of the `AND` and `NOT` Boolean operations.
[1 mark]

1	1
---	---

1	1	.	1
---	---	---	---

State the name of an identifier for a user-defined method that uses string concatenation. [1 mark]

1	1	.	2
---	---	---	---

State the name of an identifier for a class that has a constructor that takes three integer parameters. [1 mark]

1	2
---	---

Explain why a value of `-1` is used in the `CreateMoveOptions` method in the `Dastan` class. [1 mark]

[Turn over]

SECTION D

You are advised to spend no more than 70 MINUTES on this section.

Enter your answers to SECTION D in your Electronic Answer Document.

You **MUST SAVE** this document at regular intervals.

These questions require you to load the **SKELETON PROGRAM** and to make programming changes to it.

1	3
---	---

This question refers to the method `UseMoveOptionOffer` in the `Dastan` class.

The program is to be changed so that it checks the choice made by the player about which move option to replace is valid. A choice is valid if it is between 1 and 5 inclusive.

The program should keep getting the player to enter a value until a valid choice has been made. Each time an invalid value is entered an appropriate error message should be displayed.

WHAT YOU NEED TO DO

TASK 1

Modify the method `UseMoveOptionOffer` so it checks that the value entered by the player is valid. An appropriate error message should be displayed if an invalid value is entered and the user should be made to enter another value.

You may assume that the user will only enter a single numeric digit.

TASK 2

Test that the changes you have made work:

- **run the Skeleton Program**
- **enter 9**
- **enter 6**
- **enter 4**

[Turn over]

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EVIDENCE THAT YOU NEED TO PROVIDE

Include the following evidence in your Electronic Answer Document.

1 **3** . **1**

Your **PROGRAM SOURCE CODE** for the amended method `UseMoveOptionOffer`. **[4 marks]**

1 **3** . **2**

SCREEN CAPTURE(S) showing the results of the requested test. **[1 mark]**

[Turn over]

1	4
---	---

This question extends the Skeleton Program by allowing a player to choose a bhukampa (earthquake).

After choosing a bhukampa the player can then choose a move option, choose to use the move option offer or choose a bhukampa again.

When a bhukampa is chosen the following steps are repeated FIVE times:

- two DIFFERENT squares are randomly selected
- the positions on the board of those two squares are swapped.

The player's score is then reduced by 15 and the new state of the game is displayed.

WHAT YOU NEED TO DO

TASK 1

Create a new method in the `Dastan` class called `ProcessBhukampa` that swaps the squares in the way described.

TASK 2

Modify the `PlayGame` method in the `Dastan` class so that if the player enters 8 when asked for their move option, the new method `ProcessBhukampa` is called, the current player's score is reduced by 15 and the new game state is displayed.

TASK 3

Test that the changes you have made work:

- run the Skeleton Program
- enter 8

The results of your test should show at least one piece or kotla now being in a different location. If your test does not show this (because all the squares randomly selected by your program were empty), then keep doing this test until that is not the case.

EVIDENCE THAT YOU NEED TO PROVIDE

Include the following evidence in your Electronic Answer Document.

1 4 . 1

Your **PROGRAM SOURCE CODE** for the new method `ProcessBhukampa` and the amended method `PlayGame`. [9 marks]

1 4 . 2

SCREEN CAPTURE(S) showing the requested test. [1 mark]

[Turn over]

1	5
---	---

This question extends the Skeleton Program so that there is a new type of square – a gacaka (trap).

When a player makes a move that means a piece moves into a gacaka, the value of `PointsIfCaptured` of the piece is increased by 2 and a message saying "Trap!" is displayed. A player who has a piece in a gacaka has their score decreased by 3 each turn until the piece is moved out of the gacaka.

The location of the gacaka is not shown on the board.

WHAT YOU NEED TO DO

TASK 1

Create a new class called `Gacaka` that is a subclass of the `Square` class.

Create two methods `SetPiece` and `GetPointsForOccupancy` in the `Gacaka` class that allow a gacaka to work in the way described.

The method `SetPiece` in the `Gacaka` class should override the method from the `Square` class.

The method `GetPointsForOccupancy` in the `Gacaka` class should override the method from the `Square` class.

TASK 2

Modify the `CreateBoard` method in the `Dastan` class so that row four, column four is a gacaka instead of a square.

TASK 3

Test that the changes you have made work:

- **run the Skeleton Program**
- **enter 3**
- **enter 24**
- **enter 44**
- **enter 1**
- **enter 54**
- **enter 44**

[Turn over]

BLANK PAGE

EVIDENCE THAT YOU NEED TO PROVIDE

Include the following evidence in your Electronic Answer Document.

1 5 . 1

Your PROGRAM SOURCE CODE for the new class Gacaka, the amended `CreateBoard` method and any other methods you have modified or created when answering this question. [8 marks]

1 5 . 2

SCREEN CAPTURE(S) showing the requested test. [1 mark]

[Turn over]

1	6
---	---

This question extends the program by telling the player how many legal moves they have in the current state of the game.

A legal move is when, using one of the first three move options in their move option queue, a player's piece will move to a square that contains an opponent's piece or to a square that does not contain a piece. There are 45 legal moves at the start of the game for the first player.

When answering this question, you should ignore the option to use the move option offer and the option to use a bhukampa (from Question 14) as these do not count as moves.

WHAT YOU NEED TO DO

TASK 1

Create a new method called `GetNoOfPossibleMoves` in the `Player` class that takes `Board` as a parameter and returns the total number of possible legal moves for that player based on the contents of the squares in the `Board` list.

TASK 2

Modify the `DisplayState` method in the `Dastan` class so that it displays the value returned by a call to `GetNoOfPossibleMoves` for the current player.

TASK 3

Test that the changes you have made work:

- **run the Skeleton Program**
- **enter 1**
- **enter 22**
- **enter 12**

EVIDENCE THAT YOU NEED TO PROVIDE

Include the following evidence in your Electronic Answer Document.

1 6 . 1

Your PROGRAM SOURCE CODE for the new method `GetNoOfPossibleMoves` and the amended method `DisplayState`. [12 marks]

1 6 . 2

SCREEN CAPTURE(S) showing the requested test with the number of legal moves for the second player displayed. [1 mark]

END OF QUESTIONS

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