



Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination 2023

Computer Science

Sections A & B

Higher Level

Wednesday 24 May Morning 9:30 - 11:00

130 marks

Examination Number

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Day and Month of Birth

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For example, 3rd February
is entered as 0302

For Examiner use only								
Section	Question	Mark	Section	Question	Mark	Section	Question	Mark
A	1		A	7		B	13	
	2			8			14	
	3			9			15	
	4			10		Section B Total:		
	5			11		C	16	
	6			12		Section C Total:		
	Section A Total:						Total:	

The 2023 examination papers were adjusted to compensate for disruptions to learning due to COVID-19. This examination paper does not necessarily reflect the same structure and format as the examination papers of past or subsequent years.

Instructions

There are **three** sections in this examination. Section A and B appear in this booklet. Section C is in a separate booklet that will be provided for the computer-based element.

Section A	Short Answer Questions	Attempt any nine questions All questions carry equal marks	54 marks
Section B	Long Questions	Attempt any two questions All questions carry equal marks	76 marks
Section C	Programming	Answer all question parts	80 marks

Calculators may **not** be used during this section of the examination.

The superintendent will give you a copy of page 78 (Logic gates) of the *Formulae and Tables* booklet on request. You are not allowed to bring your own copy into the examination.

Write your answers for Section A and Section B in the spaces provided in this booklet. There is space for extra work at the end of the booklet. Label any such extra work clearly with the question number and part.

Answer any **nine** questions.

Question 1

Enter the appropriate data type in Column B to match the values in Column A.

Column A Value	Column B Data Type
Ciara	
255	
083-1234567	
1.5, 1.7, 1.2, 0.9, 1.3	
False	
−99.99	

Question 2

Information systems can represent numbers in decimal, binary and hexadecimal format. Many software developers use hexadecimal numbers.

(a) Explain **one** advantage of using hexadecimal numbers.

(b) Convert the hexadecimal number C9 into a decimal number.

--

Question 3

The diagram in **Figure 1** below, shows the Cartesian plane divided into four quadrants by an x-y axis, centred on the point $(0, 0)$.

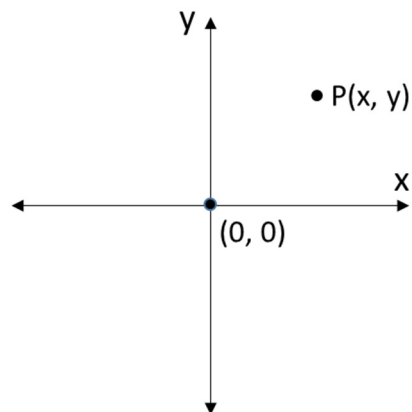


Figure 1

- (a) A point $P(x, y)$ is plotted inside the top right quadrant, as shown. Complete the truth table below to verify that P is inside the top right quadrant.

$x > 0$	$y > 0$	$x > 0 \text{ and } y > 0$
False	False	False
False	True	
True	False	
True	True	

- (b) Construct a Boolean expression in the space below that will evaluate to `True` for all points (x, y) inside the shaded area shown in **Figure 2**.

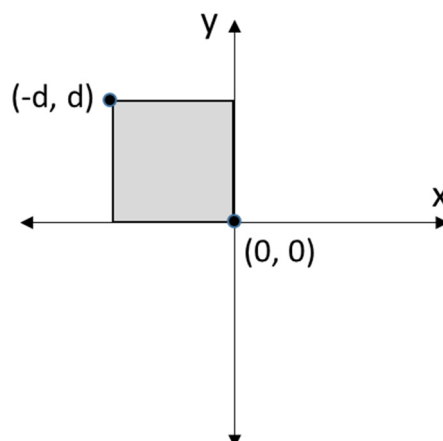


Figure 2

Question 4

User interfaces have evolved constantly over the past 40 years to become more user-friendly and accessible.

(a) What is meant by the term 'user interface'?

(b) Name and describe **one** type of user interface that a computer system might use.

Name:
Description:

Question 5

Transmission Control Protocol / Internet Protocol (TCP/IP) refers to a suite of protocols used to send and receive messages over the internet. The TCP/IP protocol suite contains a number of different layers. Name **one** of these layers and describe what happens within this layer.



Layer Name:
Layer Description:

Question 6

Smart homes make use of embedded systems to make living spaces more enjoyable and convenient for home owners.

(a) State **two** examples of embedded systems you might find in a smart home.

1.
2.

(b) Describe **two** characteristics of embedded systems that distinguish them from general computer systems.

1.
2.

Question 7

Complete the trace table for the Python code shown below.

1	x = 10
2	y = 5
3	
4	while x >= y:
5	x = x - 1
6	y = y + 1

x	y
10	5

Question 8

A farmer needs to ferry a wolf, a goat and a cabbage from one side of a river to the other in a boat, as shown in **Figure 3**. However, the boat only has room for the farmer and one other item, either the wolf, the goat or the cabbage. If left alone without the farmer present, the wolf would eat the goat, and the goat would eat the cabbage.



Figure 3

The state of the system at any given point in time can be represented using an ordered list of four values as follows:

(`<side for farmer>`, `<side for wolf>`, `<side for goat>`, `<side for cabbage>`)

By using the letter **E** to represent the east side of the river, and the letter **W** to represent the west side of the river, the state (**E**, **E**, **E**, **E**) means that all four are on the east side of the river.

(**E**, **E**, **E**, **E**) is the initial state of the system.

(a) Using this notation, what is the desired final state of the system?

--

(b) The state (**W**, **E**, **E**, **W**) is considered a loss state because the wolf will eat the goat (as the farmer and the cabbage are both on the west side).

(i) Using this notation, name any other **two** loss states.

1.
2.

(ii) Using this notation, name any **one** non-loss state, other than the initial and final states.

--

Question 9

Chop Cup is a magic routine which involves three cups face down and one ball underneath one of the cups. In any single move the position of two cups can be swapped using one of three possible moves, A, B or C as shown in **Figure 4** below.

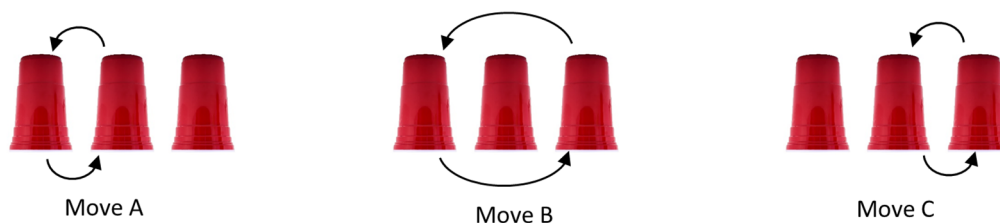


Figure 4

Each cup is identified by its position. Initially the leftmost cup is at position 1, the middle cup is at position 2 and the right cup is at position 3.

- (a) Given that the ball starts under the leftmost cup (position 1) and always remains under the same cup, state the ball position after the sequence of moves, ABCBCA.

- (b) Without knowing which cup the ball is under, construct a sequence involving at least three moves which results in the ball ending in the same position as it started from.

Question 10

Quicksort is widely recognised as one of the most efficient sorting algorithms. It works by recursively partitioning a list about one of the elements known as the pivot. Consider the unsorted list of integers shown in **Figure 5** below and answer the questions that follow.

60	30	80	40	10	50	20	70	90
----	----	----	----	----	----	----	----	----

Figure 5

- (a) Using the leftmost element as the pivot, show the contents of the list after the initial partition by the quicksort algorithm. You should assume that the elements in the left and right sub-lists are not re-ordered.

--	--	--	--	--	--	--	--	--

- (b) Explain why 90 would have been a poor choice of pivot to partition the list shown in **Figure 5**.

Question 11

Figure 6 depicts a flowchart of a Python algorithm which can be used to generate new usernames for students. You can assume that the date is in the format: ddmmyyyy.

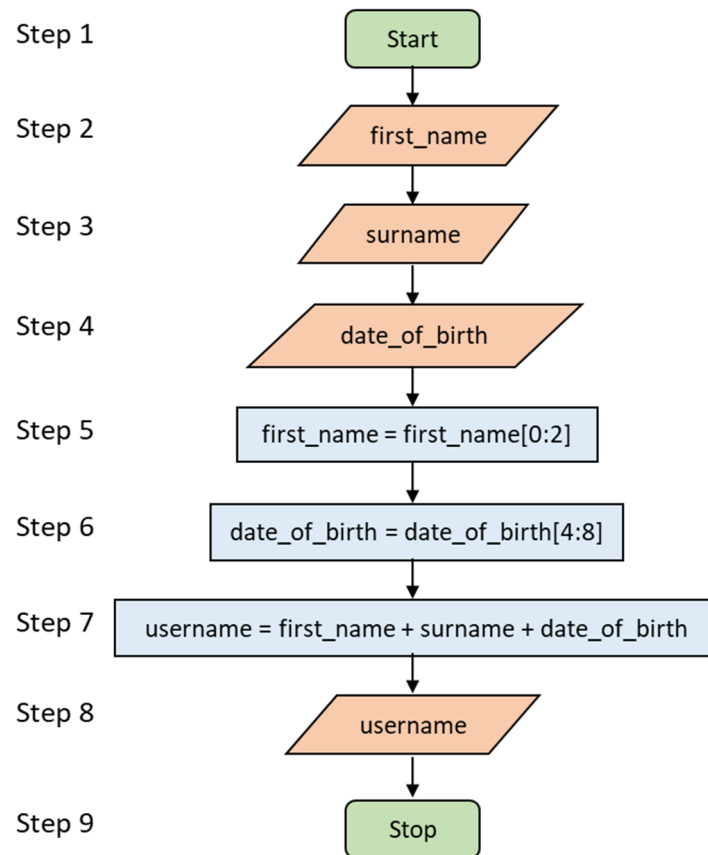


Figure 6

(a) Name **one** input and **one** output of the algorithm.

Input:
Output:

(b) Referring to the relevant step(s) in the flowchart explain how the algorithm uses string slicing and string concatenation.

String slicing:
String concatenation:

Question 12

A Software Development Lifecycle (SDLC) such as the one shown in **Figure 7** below, is usually followed when creating information systems.



Figure 7

(a) Outline briefly **two** reasons why the SDLC is important.

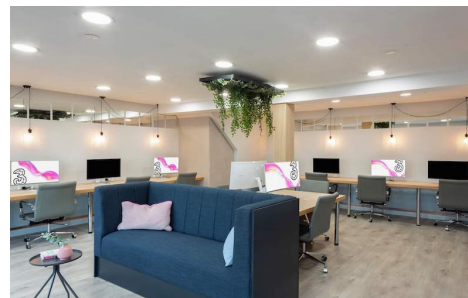
Reason 1:
Reason 2:

(b) Distinguish between functional and non-functional testing.

Answer any **two** questions.

Question 13

The National Hub Network is an initiative set up by the Irish Government to allow people across Ireland to work closer to home through providing digital working hubs with modern facilities and high-speed internet connections. There are over 260 working hub locations spread across Ireland with over 4000 desks available. Many of these hubs have been set up in rural and remote areas.



(a)

- (i) Consider the impact that a digital working hub might have to a rural community's culture and society. Provide **one** argument in support of this initiative and **one** argument against.

Support:
Against:

- (ii) As the demand for desk space in digital hubs increases, the Government plan on using computer modelling to plan ahead and make sure they have enough resources in place and also that they are targeting the correct areas when it comes to opening new hubs. Suggest **one** data item that could be collected in order to model the situation. Justify your answer.

Item:
Justify:

This question continues on the next page.

- (iii) To ensure that the digital hubs are accessible for anyone who wishes to use them, adaptive and assistive technologies are in place for anyone who should need them. Name **two** types of such technologies and describe how each could support someone with additional needs when using a computer system.

Technology 1:
Description:
Technology 2:
Description:

- (b) **Figure 8** shows the set of hubs and distances in kilometres between each pair of hubs. A technician must travel around each hub to check the equipment and to fix any technical issues that arise. The technician will begin at Hub A and visit all hubs exactly once, before returning to Hub A.

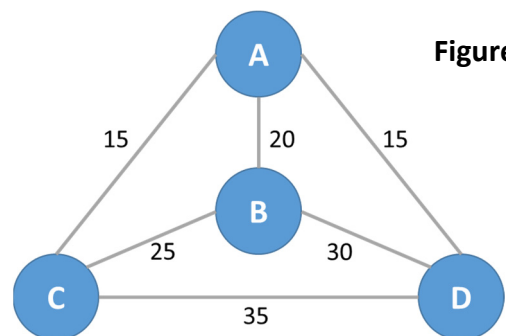


Figure 8

- (i) Calculate and state the shortest possible route the technician should take.

- (ii) Outline briefly **two** features of abstraction contained in **Figure 8**.

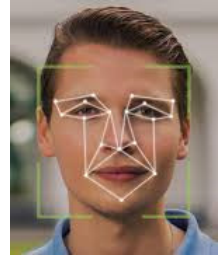
Feature 1:
Feature 2:

This question continues on the next page.

- (iii) At the beginning of each day the technician has a look at all of the locations that she needs to visit. To try and do this in the shortest time possible the technician will use heuristics. Explain what is meant by heuristics.

- (c) In 2022, the Irish Government announced plans to introduce legislation to grant Gardaí new powers to use Facial Recognition Software (FRS). However, the Irish Council for Civil Liberties (ICCL) said it strongly opposes the use of such technology for law enforcement and in public spaces.

Outline **two** arguments for and **two** arguments against the use of FRS for law enforcement.



For 1:
For 2:
Against 1:
Against 2:

Question 14

In the 1940s John von Neumann discovered that computer systems could treat instructions as data and, as such, could be manipulated inside the computer's memory while a program is running. This major breakthrough in computing became known as the stored program concept, and is still used in the majority of computer systems we use today. The von Neumann architecture is shown in **Figure 9**.

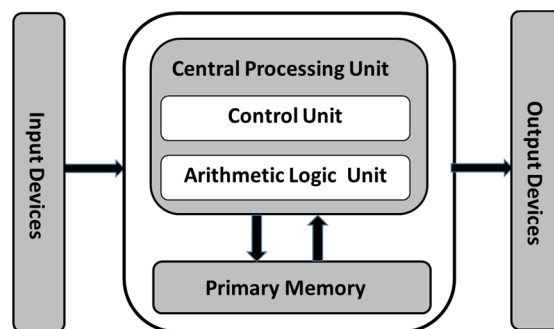


Figure 9

(a)

- (i) Explain the term 'output device'. Provide **two** examples.

Explain:
Example 1:
Example 2:

- (ii) The CPU cycle carried out to process data and instructions has three steps to it. The first step 'Fetch Instruction' has been completed for you in **Figure 10** below. Complete the diagram by filling in the next **two** steps of the process, labelled (a) and (b).

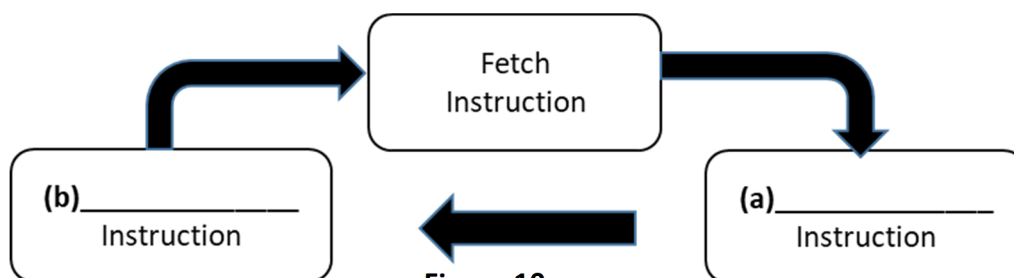


Figure 10

- (iii) The CPU contains a number of registers including the Program Counter and the Accumulator. Explain **one** difference between these two registers.

This question continues on the next page.

- (iv) The CPU is often described as the brains of the computer. It is made up of two main components, namely the Arithmetic Logic Unit (ALU) and the Control Unit (CU). State the purpose of these **two** components.

ALU:
CU:

- (v) The CPU is the most important component of a computer system and determines how fast a computer can run. Describe **two** factors that can impact the performance of the CPU.

1.
2.

- (b) As well as having main memory, computer systems tend to have secondary storage which allows users to save data such as programs and files.

- (i) Sarah is looking to buy a new laptop. So far, all the laptops she has looked at have either magnetic or solid state hard drives. Which type of secondary storage would you recommend? Justify your answer.

Recommendation:
Justify:

This question continues on the next page.

- (ii) When a computer is carrying out lots of tasks it can start to run out of memory. In some cases, a computer may have to rely on virtual memory. What is meant by the term 'virtual memory'?

- (iii) For a school software development project Sarah has to work with classmates to produce a computational artefact for a local business. The group will be working on this both at school and at home. Sarah suggests working in the cloud for the project. Describe **one** advantage and **one** disadvantage of working in the cloud.

Advantage:
Disadvantage:

- (iv) As part of the school project Sarah has been assigned the role of Business Analyst. Describe **two** activities typically undertaken by a Business Analyst in a software development company.

Activity 1:
Activity 2:

Question 15

Computers can use a choice of different search algorithms to find information much quicker than humans. Two common search algorithms are the linear search and the binary search.

(a) Consider the following list of seven names.

Amir	Dean	Eoin	Helen	Natalia	Steve	Terry
------	------	------	-------	---------	-------	-------

- (i) What search algorithm would be best suited to search the list of names shown above? Justify your answer.

Search Algorithm:
Justify:

Search algorithms work by comparing the list elements with a particular search value, known as a key.

- (ii) List, in order, the names that would be compared until *Natalia* is found using the linear search algorithm.

--

- (iii) List, in order, the names that would be compared until *Natalia* is found using the binary search algorithm.

--

- (iv) Complete the table below to show the best and worst case time complexities for the two search algorithms. You can assume that the size of the input is N .

	Best Case	Worst Case
Linear Search	$O(1)$	
Binary Search		

- (v) What is meant by $O(1)$ time complexity?

This question continues on the next page.

(b) The Python code below shows an implementation of a binary search function.

```
1 def binary_search1(v, L):
2
3     lo = 0
4     hi = len(L) - 1
5
6     while (lo <= hi):
7         mid = (lo + hi)//2
8
9         if L[mid] > v:
10             hi = mid - 1
11         elif L[mid] < v:
12             lo = mid + 1
13         else:
14             return mid
15
16     return len(L)
```

(i) In the code there is one example of iteration. State on which lines the iteration starts and ends and explain what it does.

Start line number:
End line number:
Explain:

(ii) The function contains two examples of a `return` statement – line 14 and line 16. What is the purpose of a `return` statement?

(iii) Explain the reason for `len(L)` on line 16.

This question continues on the next page.

(c) An alternative implementation of the binary search can be achieved using recursion as shown.

```
1 def binary_search2(v, L, lo, hi):
2
3     if lo > hi:
4         return len(L)
5
6     mid = (lo + hi)//2
7
8     if L[mid] > v:
9         return binary_search2(v, L, lo, mid-1)
10    elif L[mid] < v:
11        return binary_search2(v, L, mid+1, hi)
12
13    return mid
```

(i) Referring to the code above, describe **two** properties of recursive functions.

Property 1:
Property 2:

(ii) State **one** advantage and **one** disadvantage of using recursion.

Advantage:
Disadvantage:

(iii) Given a list of names, initialised as shown below, write a line of code to call the function `binary_search2` to find the name *Natalia*. You should store the result of the function in a variable called `result`.

```
names = ["Amir", "Dean", "Eoin", "Helen", "Natalia", "Steve", "Terry"]
```

--

Space for extra work.

Indicate clearly the number and part of the question(s) you are answering.

[illegible]

Space for extra work.

Indicate clearly the number and part of the question(s) you are answering.

[illegible]

Space for extra work.

Indicate clearly the number and part of the question(s) you are answering.

[illegible]

Acknowledgements

Images

Image on page 5: <https://www.ccnahub.com/ip-fundamentals/understanding-tcp-ip-and-osi-models/>

Image on page 7: https://www.researchgate.net/figure/On-the-left-is-the-Wolf-Goat-and-Cabbage-puzzle-environment-Right-screenshot-from-a_fig2_305084487

Image on page 11: <https://devoxsoftware.com/blog/software-development-lifecycle/>

Image on page 12: <https://www.donegaldaily.com/2021/05/12/making-remote-work-an-office-with-a-view-on-arranmore/>

Image on page 14: <https://skybiometry.com/the-best-face-recognition-software-for-your-business/>

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Leaving Certificate – Higher Level

Computer Science – Sections A & B

Wednesday 24 May

Morning 9:30 – 11:00



Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination 2023

Computer Science

Section C

Higher Level

Wednesday 24 May Morning 11:30 – 12:30

80 marks

Do not hand this up.
This document will not be returned to the
State Examinations Commission.

Instructions

There is one section in this paper.

Section C	Programming	One question	80 marks
		Answer all question parts	

Answer all parts of the question on your digital device.

Calculators may be used during this section of the examination.

The *Formulae and Tables* booklet cannot be used for this section of the examination.

The superintendent will give you a copy of the *Python Reference Guide*.

Ensure that you save your work regularly.

Save your files using the naming structure described at the beginning of each question part.

If you are unable to get some code to work correctly, you can comment out the code so that you can proceed. The code that has been commented out will be reviewed by the examiner.

Rough work pages are provided at the end of this booklet. Please note that this booklet is not to be handed up and will **not** be reviewed by an examiner.

At the end of the examination it is your responsibility to ensure that you have saved your files onto your external media.

You will be provided with a brown envelope for your external media. Write your examination number on this envelope and place your external media into it before sealing. Place this envelope in the pouch at the front of the red envelope that contains your examination booklet from Section A and B.

There is no examination material on this page

Answer all question parts.

Question 16

- (a) Open the program called **Question16_A.py** from your device. The source code is shown below.

Before making any changes, you should save your working copy of the file using the format **ExaminationNumberQuestion16_A.py**. For example, you would save the file as **123456Question16_A.py** if your Examination Number was 123456.

Enter your Examination Number in the space provided on **line 2** in your Python file.

The program defines a function called `guess_game` which simulates a guessing game.

When the function is called, the program generates a secret number between 1 and 5 inclusive. This is stored in a variable called `secret_number`.

The program then enters a loop in which the user is prompted to guess the number. The user's guess is stored in the variable `user_guess`. Every time the user enters a guess the program increases the variable `guess_count` by one. If the user's guess matches the computer's secret number, the message 'Congratulations! You win!' is displayed. The loop continues until the user guesses the secret number.



```
1  # Question 16(a)
2  # Examination Number:
3  from random import randint
4
5  def guess_game(max_guesses_allowed):
6
7      secret_number = randint(1, 5)
8      guess_count = 0
9      user_guess = 0
10
11     while (user_guess != secret_number):
12
13         user_guess = int(input("Enter your guess: "))
14         guess_count += 1 #Increase guess_count by 1
15         if user_guess == secret_number:
16             print("Congratulations! You win!")
17
18 print("Welcome to the guessing game!")
19 guess_game(3)
```

This question continues on the next page.

When the program is run, the output may look as follows.

Your output may be different as the secret number is generated randomly.

```
Welcome to the guessing game!
Enter your guess: 2
Enter your guess: 3
Enter your guess: 1
Congratulations! You win!
```

Make the following changes to the program:

- (i) Change the program to display an extra line of output when the user wins, showing the number of guesses taken.

When the program is run the output may now look as follows:

```
Welcome to the guessing game!
Enter your guess: 2
Enter your guess: 3
Enter your guess: 1
Congratulations! You win!
You took 3 guesses.
```

- (ii) The program does not display a message unless the user guesses the secret number.

Change the program so that it displays one of the following messages as a hint to the user:

'Sorry! Your guess was too low' or 'Sorry! Your guess was too high'

When the program is run the output may now look as follows:

```
Welcome to the guessing game!
Enter your guess: 1
Sorry! Your guess was too low
Enter your guess: 5
Sorry! Your guess was too high
Enter your guess: 3
Sorry! Your guess was too low
Enter your guess: 4
Congratulations! You win!
You took 4 guesses.
```

This question continues on the next page.

- (iii) Currently the program has no way of ending unless the user guesses the secret number.
Change the program so that it does not allow the user more than three guesses. This is the value currently being passed into the function.

Hint: You will need to change the loop so that it continues as long as the user's guess is not equal to the secret number and the number of guesses is less than `max_guesses_allowed`.

When the program is run the output may now look as follows:

```
Welcome to the guessing game!
Enter your guess: 1
Sorry! Your guess was too low
Enter your guess: 5
Sorry! Your guess was too high
Enter your guess: 2
Sorry! Your guess was too low
```

- (iv) Currently the number of guesses that the user is allowed is hard coded to three.
Modify the program so that the user is presented with the prompt:

Enter the maximum number of guesses allowed.

Store the value entered as an integer and pass this value into the function `guess_game`.

When the program is run the output may now look as follows:

```
Welcome to the guessing game!
Enter the maximum number of guesses allowed: 2
Enter your guess: 1
Sorry! Your guess was too low
Enter your guess: 5
Sorry! Your guess was too high
```

- (v) Currently the secret number is always between 1 and 5 inclusive.

Modify the program so that it prompts the user to enter a difficulty level – 'E' for easy and 'H' for hard. If the user chooses 'H' the secret number should be between 1 and 100 inclusive. A value of anything other than 'H' can be interpreted as easy.

When the program is run the output may now look as follows:

```
Welcome to the guessing game!
Enter the maximum number of guesses allowed: 3
Enter difficulty E(as) or H(ard): H
Enter your guess: 50
Sorry! Your guess was too low
Enter your guess: 75
Sorry! Your guess was too low
Enter your guess: 95
Sorry! Your guess was too low
```

This question continues on the next page.

- (vi) Modify the code so that if the user guesses a number that was already guessed the following message is displayed: *'You already guessed this number.'*

When the program is run the output may now look as follows:

```
Welcome to the guessing game!
Enter the maximum number of guesses allowed: 3
Enter difficulty E(asy) or H(ard): E
Enter your guess: 1
Sorry! Your guess was too low
Enter your guess: 1
You already guessed this number.
Sorry! Your guess was too low
Enter your guess: 3
Congratulations! You win!
You took 3 guesses.
```

Save your file using the format **ExaminationNumberQuestion16_A.py**. For example, you would save the file as **123456Question16_A.py** if your Examination Number was 123456.

This question continues on the next page.

- (b) Open the program called **Question16_B.py** from your device. This file contains only two comments, on lines 1 and 2.

Before adding any code, you should save your working copy of the file using the format **ExaminationNumberQuestion16_B.py**. For example, you would save the file as **123456Question16_B.py** if your Examination Number was 123456.

Enter your Examination Number in the space provided on **line 2** in your Python file.

Implement a number guessing game in Python. The game requires the user to guess a random number between 1 and 100 and they are awarded points based on how close they get to the number.

You should use comments throughout your program to explain your code. You may wish to reuse some of the code you used in part (a) as part of your solution.

The game should proceed according to the following sequence:

- The user's score is set to zero.
- At the start of every new round the computer generates a random number between 1 and 100. This is the secret number that the user is trying to guess.
- The user is then prompted to enter a guess as shown below.

```
Enter your guess:
```

- Calculate the difference between the secret number and the user guess.
- The numbers are then displayed in a meaningful message on a single line as shown below.

```
Secret number is 55. You guessed 50. Difference is 5.
```

- The numbers are compared and the score is updated according the following rules:
 - If the user's guess and the secret number are the same then the score is increased by 100 and the message *"JACKPOT!!! You score 100 points"* is displayed.
 - If the user's guess is within 20 (either side) of the secret number the user's score is increased by 20 and the message *"You score 20 points"* is displayed.
 - If the user's guess is more than 30 away from the secret number the user's score is decreased by 30 and the message *"You lose 30 points"* is displayed.
- At the end of each round the score is displayed and user is prompted with the message *"Play again? (Y/N):"*
- The game ends when the user enters anything other than the single letter 'Y'.

An example output is shown on the next page.

This question continues on the next page.

Example:

```
Enter your guess: 35
Secret number is 31. You guessed 35. Difference is 4.
You score 20 points
Your total score is: 20
Play again? (Y/N): Y
Enter your guess: 91
Secret number is 6. You guessed 91. Difference is 85.
You lose 30 points
Your total score is: -10
Play again? (Y/N): Y
Enter your guess: 54
Secret number is 54. You guessed 54. Difference is 0.
JACKPOT!!! You score 100 points
Your total score is: 90
Play again? (Y/N): Y
Enter your guess: 50
Secret number is 28. You guessed 50. Difference is 22.
Your total score is: 90
Play again? (Y/N): N
```

Use the format **CandidateNumberQuestion16_B.py** to save your file. For example, you would save the file as **123456Question16_B.py** if your candidate number was 123456.

Space for rough work.

This page will not be reviewed by an examiner.

Space for rough work.

This page will not be reviewed by an examiner.

Acknowledgements

Images

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Leaving Certificate – Higher Level

Computer Science – Section C

Wednesday 24 May

Morning 11:30 – 12:30