National Qualifications 2024

X816/77/11 Computing Science

MONDAY, 20 MAY
1:00 PM – 3:00 PM

Total marks — 55

SECTION 1 — Software design and development — 35 marks

Attempt ALL questions.

Attempt EITHER Section 2 or Section 3

SECTION 2 — Database design and development — 20 marks

SECTION 3 — Web design and development — 20 marks

You may use a calculator.

Write your answers clearly in the answer booklet provided. In the answer booklet you must clearly identify the question number you are attempting.

Use **blue** or **black** ink.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

MARKS

SECTION 1 — SOFTWARE DESIGN AND DEVELOPMENT — 35 marks

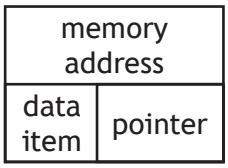
Attempt ALL questions

1. State the comparisons needed to locate **Sycamore** using a binary search on the following alphabetically sorted list:

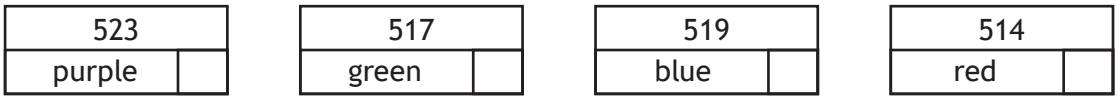
Beech, Birch, Cedar, Oak, Sycamore, Willow, Yew **1**

2. A single linked list is used to store colour names.

The contents of each node of the list are in the form:



The diagram below shows the contents of the linked list.



The contents of the linked list are sorted into alphabetical order of colour name.

(a) State the value that would be stored in the head pointer of the sorted linked list. **1**

(b) Copy and complete the table below to indicate the value of the pointer of each node in the sorted linked list. **2**

Node	Contents	Pointer
523	purple	
517	green	
519	blue	
514	red	

MARKS

3. The Sudoku puzzle is played on a grid as shown below. Each row, column and cell in the grid must be filled using the numbers 1 to 9, without repeating any numbers within the row, column or mini-grid.

A completed Sudoku puzzle is shown below.

2	4	9	8	1	5	6	3	7
6	8	3	2	7	9	5	1	4
7	5	1	3	4	6	2	8	9
8	2	5	7	**9**	3	4	6	1
3	7	6	1	2	4	9	5	8
1	9	4	5	6	8	7	2	3
9	6	2	4	8	1	3	7	5
4	3	8	6	5	7	1	9	2
5	1	7	9	3	2	8	4	6

(a) Using a programming language of your choice, define a 2-D array structure that can be used to store the puzzle data in a program. **1**

(b) The highlighted mini-grid in the middle of the puzzle contains the value 9.

Using a programming language of your choice, write the code that would assign this value to the appropriate element of the array that you defined part (a). **1**

[Turn over

MARKS

4. (a) A system is being developed to allow staff in a veterinary practice to book appointments.

Prior to testing the system, the developers produce the following description:

> Greig is one of the admin staff at the veterinary practice. He is 58 years old and has over 20-years' experience of using the existing paper-based appointments system. However, he is a reluctant user of technology and has little experience of more modern systems. He has been asked to make an appointment for Marketa Jabeur's dog to be treated at 10 am on 23 June 2024.

Explain how this description would be used to test the new appointments system and gain feedback on its ease of use. **2**

(b) After the appointments system has been in use for a month, staff suggest that an integrated text messaging facility could be used to send reminders about upcoming appointments.

Name the type of maintenance that would be required and justify your answer. **1**

[Turn over for next question

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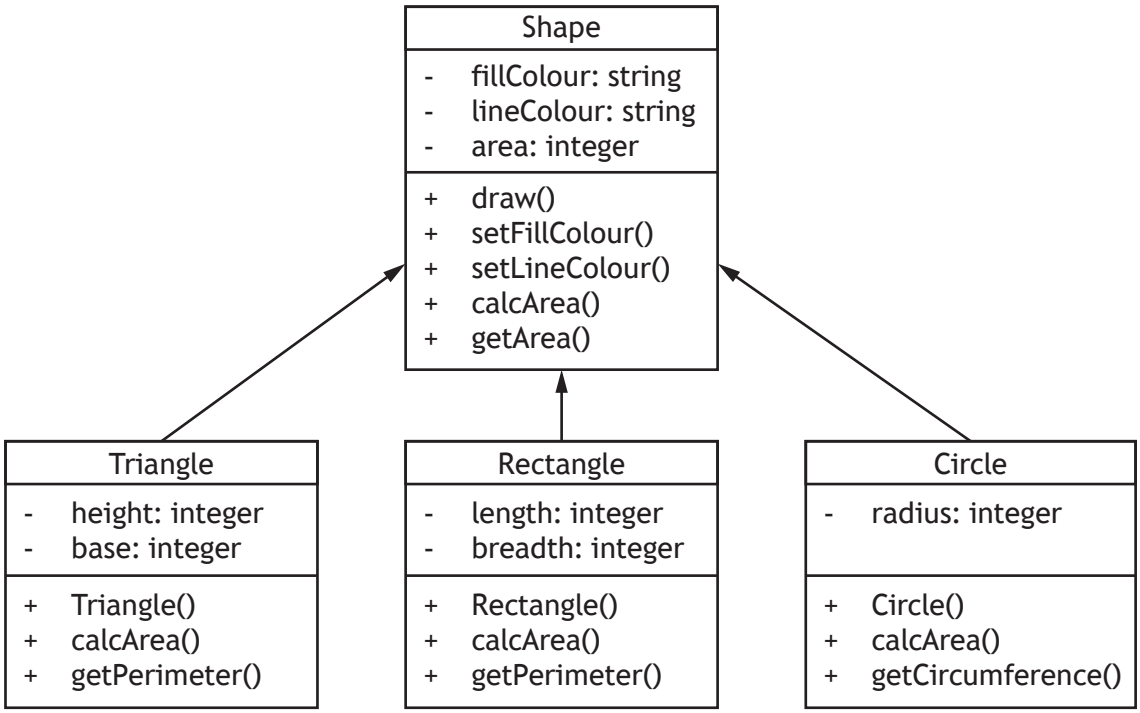
5. Object-oriented code is used to create a drawing app for children.

The simplified UML class diagram below represents the classes used in the app.



Some of the code used to implement the drawing app is provided below.

```
CLASS Shape { STRING fillColour, STRING lineColour, INTEGER area}

METHODS

    CONSTRUCTOR ( STRING fill, STRING line )
      DECLARE THIS.fillColour TO fill
      DECLARE THIS.lineColour TO line
      DECLARE THIS.area TO 0
    END CONSTRUCTOR
    …
    PROCEDURE setFillColour ( STRING colour )
      SET THIS.fillColour TO colour
    END PROCEDURE

    PROCEDURE calcArea()
      SEND "The area is the space enclosed within the boundary of
      the shape" TO DISPLAY
    END PROCEDURE

    FUNCTION getArea() RETURNS INTEGER
      RETURN THIS.area
    END FUNCTION
END CLASS
```

5. (continued)

```
CLASS Triangle INHERITS Shape WITH { INTEGER height, INTEGER
base }

    METHODS
    …
    OVERRIDE PROCEDURE calcArea()
      SET THIS.area TO THIS.height * THIS.base / 2
    END PROCEDURE
…
END CLASS


CLASS Rectangle INHERITS Shape WITH { INTEGER length, INTEGER
breadth }

    METHODS

    CONSTRUCTOR Rectangle ( STRING fill, STRING line, INTEGER
    length, INTEGER breadth )
      DECLARE THIS.fillColour TO fill
      DECLARE THIS.lineColour TO line
      DECLARE THIS.length TO length
      DECLARE THIS.breadth TO breadth
      DECLARE THIS.area TO 0
    END CONSTRUCTOR

    OVERRIDE PROCEDURE calcArea()
      SET THIS.area TO THIS.length * THIS.breadth
    END PROCEDURE
    …
END CLASS

CLASS Circle INHERITS Shape WITH { INTEGER radius }

    METHODS

    CONSTRUCTOR Circle ( STRING fill, STRING line, INTEGER
    radius )
      DECLARE THIS.fillColour TO fill
      DECLARE THIS.lineColour TO line
      DECLARE THIS.radius TO radius
      DECLARE THIS.area TO 0
    END CONSTRUCTOR

    OVERRIDE PROCEDURE calcArea()
      SET THIS.area TO 3.14 * THIS.radius^2
    END PROCEDURE
    …
END CLASS
```

MARKS

5. (continued)

(a) With reference to the UML class diagram and code, explain the use made of overriding. **2**

(b) The following code appears within the main program that controls the app.

```
DECLARE r1 AS Rectangle ("white", "black", 20, 16)
```

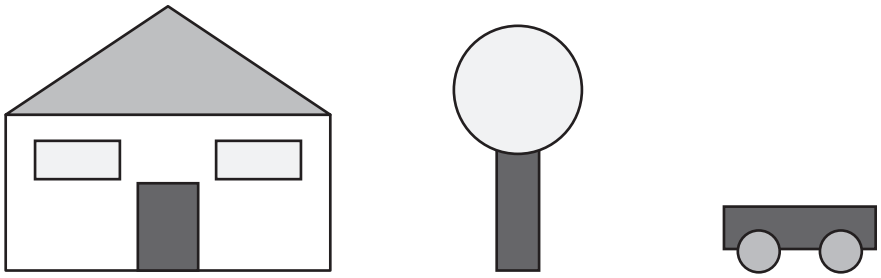
(i) Using appropriate object-oriented terminology, explain the effect of this statement. **2**

(ii) State the output that would be produced by the following code: **2**

```
SEND "The area is " & r1.getArea() TO DISPLAY
r1.calcArea()
SEND "The area is " & r1.getArea() TO DISPLAY
```

5. (continued)

(c) A young child uses the app to create a simple image consisting of a house, a tree and a wagon. The final image is shown below.



Within the app, an array of `Shape` objects called `list` is used to keep track of the individual shapes used in the image:

Index	*Object referenced*	*Where used in the image*
0	r1	House building
1	r2	Window left
2	r3	Window right
3	r4	Door
4	t1	Roof
5	r5	Tree trunk
6	c1	Tree top
7	r6	Wagon
8	c2	Wheel left
9	c3	Wheel right

(i) Describe the effect of the following statement: **1**

```
list[4].setFillColour("red")
```

(ii) Explain why the following statement generates an error: **2**

```
list[8].getCircumference()
```

[Turn over

5. (continued)

(d) The statement `sort(list)` in the main program invokes the procedure `sort()` and passes the actual parameter `list`. This procedure makes use of the bubble sort algorithm to arrange the contents of the variable `list` into descending order of area.

The design and data flow for this procedure is shown below.

```
1.  procedure sort(array)                                    IN: array
2.      set n = number of shapes in the array
3.      set swapped = true
4.      start while loop
5.          set swapped = false
6.          start fixed loop for i from 0 to n−2
7.              if area of array(i) and array(i+1) are in the wrong order
8.                  swap contents of array(i) and array(i+1)
9.                  set swapped = true
10.             end if
11.         end fixed loop
12.         set n = n−1
13.     end conditional loop
14. end procedure
```

Using a programming language of your choice, write code to implement the following steps of the design:

(i) Step 4 **1**

(ii) Step 7 **2**

(iii) Step 8 **1**

[Turn over for next question

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MARKS

6. A wildlife society stores data on mammals around the world.

This mammal data is held in a database. Whenever new readings become available they are stored in a text file. The text file is read into a program to update the mammal data. The data is then analysed to identify any mammals at risk of extinction.

A sample of the data in the database is shown below.

Table name: MammalData			
mammal	**numberRemaining**	**readingNumber**	**readingDate**
Tiger	3890	2	12/05/2024
Blue Whale	5000	2	12/05/2024
Polar Bear	31000	1	12/05/2024
Rhinoceros	5600	1	12/05/2024
Orangutan	105000	1	12/05/2024
Blue Whale	7632	1	05/05/2024
Tiger	4432	1	05/05/2024
African Wild Dog	3000	1	05/05/2024

Part of the top-level design of the program is shown.

1. declare data structures used in the program
2. read mammal data from database and store in array of records
3. update array of records using data from the readings file
4. add new readings to database
5. analyse the data
6. …

Some of the code used to implement step 1 of the design is shown below.

```
RECORD Animal IS { STRING mammal, INTEGER numberRemaining,
INTEGER readingNumber, STRING readingDate }

DECLARE animalList AS ARRAY OF Animal INITIALLY [NULL] * 1000
```

(a) Using pseudocode, refine step 2 of the design to show the steps needed to read the data from the database server and store it in the array of records called `animalList`. **3**

(b) The number of each mammal is recorded regularly. Whenever new data about a mammal becomes available, the name of the mammal, number remaining and reading number are stored in a text file `readings.txt`.

The contents of the latest `readings.txt` are shown below:

24/05/2024
Polar Bear,29140,2
Giant Panda,1864,1
Tiger,3745,3
African Wild Dog,3012,2

Step 3 of the top-level design processes the readings file.

The refinement for this step is shown below.

3.1 declare temporary array `temp` as array of `Animal`
3.2 read data from `readings.txt` file into `temp`
3.3 sort temp into descending order of `readingNumber`
3.4 move existing records in `animalList` array to create empty rows required
3.5 copy contents of `temp` into empty rows of `animalList` array

Once step 3.2 has been completed, the contents of the array `temp` will be:

mammal	numberRemaining	readingNumber	readingDate
Polar Bear	29140	2	24/05/2024
Giant Panda	1864	1	24/05/2024
Tiger	3745	3	24/05/2024
African Wild Dog	3012	2	24/05/2024

(i) The incomplete design of the insertion sort used to arrange the contents of the `temp` array into descending order of `readingNumber` at step 3.3 is shown below.

```
3.3.1   procedure insertionSort(list)                IN/OUT: list
3.3.2       set value = 0
3.3.3       set index = 0
3.3.4       loop from n = 1 to length(list)–1
...         ...
...         ...
...         ...
...         ...
...         end loop
...     end procedure
```

Write the pseudocode needed to complete the insertion sort algorithm. **3**

(ii) At step 3.4, the data stored in the array `temp` is copied into the `animalList` array.

The table below shows the contents of the `animalList` array **before** step 3.4 is executed.

mammal	numberRemaining	readingNumber	readingDate
Tiger	3890	2	12/05/2024
Blue Whale	5000	2	12/05/2024
Polar Bear	31000	1	12/05/2024
Rhinoceros	5600	1	12/05/2024
Orangutan	105000	1	12/05/2024
Blue Whale	7632	1	05/05/2024
Tiger	4432	1	05/05/2024
African Wild Dog	3000	1	05/05/2024

Step 3.4 requires the contents of the `animalList` array from index 0 to be moved to accommodate the data currently stored in the `temp` array.

The table below shows the contents of the `animalList` array **after** step 3.4 is executed.

mammal	numberRemaining	readingNumber	readingDate
Tiger	3890	2	12/05/2024
Blue Whale	5000	2	12/05/2024
Polar Bear	31000	1	12/05/2024
Rhinoceros	5600	1	12/05/2024
Orangutan	105000	1	12/05/2024
Blue Whale	7632	1	05/05/2024
Tiger	4432	1	05/05/2024
African Wild Dog	3000	1	05/05/2024

Using pseudocode, refine step 3.4 of the top-level design to show the steps needed to move the rows of data within the `animalList` array. **4**

Once the update has taken place, the contents of the `animalList` array are:

mammal	numberRemaining	readingNumber	readingDate
Tiger	3745	3	24/05/2024
Polar Bear	29140	2	24/05/2024
African Wild Dog	3012	2	24/05/2024
Giant Panda	1864	1	24/05/2024
Tiger	3890	2	12/05/2024
Blue Whale	5000	2	12/05/2024
Polar Bear	31000	1	12/05/2024
Rhinoceros	5600	1	12/05/2024
Orangutan	105000	1	12/05/2024
Blue Whale	7632	1	05/05/2024
Tiger	4432	1	05/05/2024
African Wild Dog	3000	1	05/05/2024

(iii) At step 5 of the top-level design, the program will analyse the contents of the updated `animalList` array to identify any mammals at risk of extinction.

A mammal at risk of extinction is one where the number remaining in the most recent update represents a reduction of 5% or more when compared with the previous reading.

Using pseudocode, write an algorithm to display the name and percentage reduction of any mammal at risk of extinction. **3**

[END OF SECTION 1]

[Turn over

MARKS

SECTION 2 — DATABASE DESIGN AND DEVELOPMENT — 20 marks

Attempt ALL questions

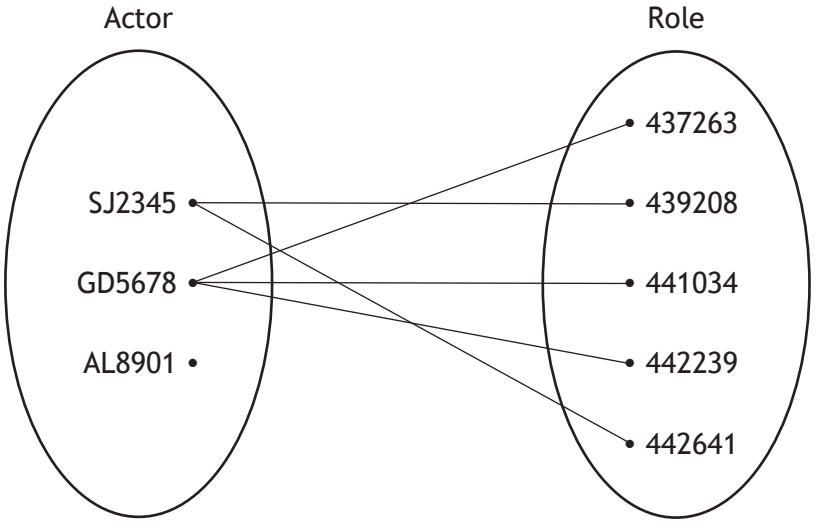
7. Details of actors, roles and movies are stored in three database tables as shown below.

Actor
actorID
surname
firstName
dateOfBirth
nationality

Role
roleNumber
actorID*
movieID*

Movie
movieID
title
genre
director
rating

The entity-occurrence diagram below shows the Actor and Role entities.



(a) State whether the Actor and Role entities are strong or weak. **1**

(b) Describe the relationship participation between the Actor and Role entities. **2**

(c) The `genre` field of the `Movie` table can have the values Horror, Comedy or Action.

Using these data values, write the SQL clause that would be part of the `CREATE` statement required to correctly implement the `genre` field of the `Movie` table. **2**

MARKS

8. A new database-driven appointments system is being introduced in a medical centre.

(a) The developers begin by investigating the hardware and software required for running this system.

State the type of feasibility being investigated. **1**

(b) The appointments system will allow admin staff to make appointments, edit appointments or cancel appointments. In addition, medical staff will also be able to view patient notes and, if required, they can add details to a patient's notes.

Draw a UML use case diagram for the appointments system. **3**

[Turn over

8. (continued) **MARKS**

The database will store details of patients, appointments, doctors and notes in the four entities shown below.

Patient
patientID
patientFirst
patientLast
contactNumber
patientType
notesID*

Appointment
patientID*
staffID*
dateApp
timeApp
appointmentType

Staff
staffID
staffFirst
staffLast
staffType

Notes
notesID
comments

(c) The data dictionary for the Appointment entity is shown.

Entity: Appointment					
Attribute name	**Key**	**Type**	**Size**	**Required**	**Validation**
patientID	PK/FK	varchar	6	Yes	Existing patientID from Patient table
staffID	PK/FK	integer		Yes	Existing staffID from Staff table
dateApp	PK	varchar	10	Yes	
timeApp	PK	varchar	5	Yes	
appointmentType		varchar	30	Yes	

The developers decide to replace the primary key of the Appointment entity with a surrogate key called appointmentID.

Describe two benefits of using a surrogate key for the Appointment entity of the database. **2**

(d) The `patientType` field for patient GS0901 contains the value Child.

This patient has now reached the age of 18 and the contents of the `patientType` field must be updated from Child to Adult.

The following query is used to update the relevant record by first checking that the specified record is already in the database.

```
UPDATE Patient
SET patientType = "Adult"
WHERE patientID = "GS0901"
AND _____________ ;
```

Write the SQL clauses needed to complete this query. **2**

8. (continued)

The updated `Appointment` table is shown below, together with the other tables of the database.

Patient
patientID
patientFirst
patientLast
contact
patientType
notesID*

Appointment
appointmentID
patientID*
staffID*
dateApp
timeApp
appointmentType

Staff
staffID
staffFirst
staffLast
staffType

Notes
notesID
comments

(e) The medical centre runs group physiotherapy classes for adult and senior patient types.

Appointments for these classes are recorded in the `Appointment` table with the value of the `appointmentType` field set to 'Physiotherapy class'.

A query is required to display dates when more than 10 patients, who are not children, are attending a group physiotherapy class from 27 May to 31 May 2024.

The design of this query is shown below.

Field(s)/calculations	Date
Tables(s) query(-ies)	Appointment, Patient
Search criteria	Count(*) greater than 10, appointment type is Physiotherapy class age >= 18 dates from 27 May to 31 May 2024
Grouping	Date
Having	
Sort order	

This design is not fit for purpose.

(i) Identify problems with the design and describe how those problems could be resolved. **2**

(ii) Using a suitable Advanced Higher logical operator, write the SQL clause that would be needed to specify the date range in the implemented query. **1**

MARKS

8. (continued)

(f) Sample data from the `Appointment` table is shown below.

appointmentID	patientID	staffID	dateApp	timeApp	appointmentType
3461271	AL0121	1	09/06/2024	09:00	Physiotherapy class
3461272	PC0123	2	09/06/2024	10:30	Doctor appointment
3461273	DS0099	3	12/06/2024	13:30	Vaccination
3461274	BN0021	1	12/06/2024	14:00	Physiotherapy class
3461275	PC0123	2	12/06/2024	09:45	Nurse appointment
3461260	AL0121	1	12/06/2024	10:00	Doctor appointment
3461277	GS0249	2	13/03/2024	14:30	Nurse appointment
3461278	SW0671	3	14/06/2024	11:15	Physiotherapy class
3461279	BN0021	1	14/06/2024	12:00	Vaccination

One of the SQL queries used in the appointments system is shown below.

```
SELECT dateApp
FROM Appointment
WHERE staffID = 2
AND dateApp = ANY (
    SELECT dateApp
    FROM Appointment
    WHERE staffID = 1 )
```

Using the sample data provided:

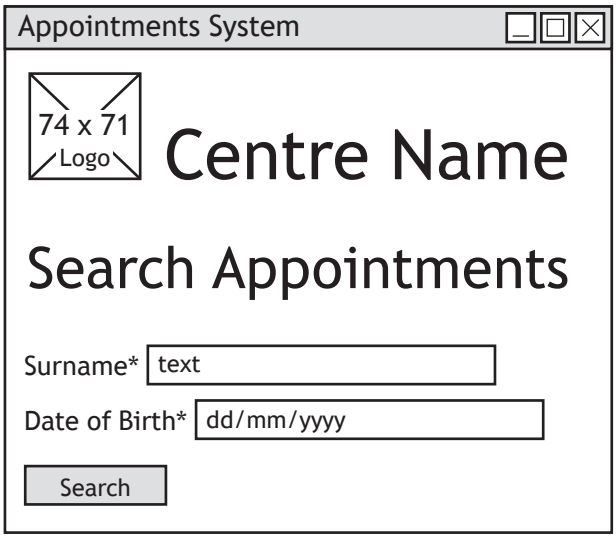
(i) state the output returned from the subquery **1**

(ii) state the output returned from the query. **1**

8. (continued)

(g) The database system will integrate with a webserver to allow users to access the data through a web interface.

A wireframe of the appointments system's search facility is shown below.



During the implementation stage of the development process, the form code below is produced.

```
Line 1  < form _____________________ >
Line 2  Surname *
Line 3  < input type="text" value="text" name="surname" required >
Line 4  < br >
Line 5  Date of Birth *
Line 6  < input type="date" value="dd/mm/yyyy" name="dob" required >
Line 7  < br >
Line 8  < input type="submit" value="Search" >
Line 9  < /form >
```

Complete the code needed at line 1 to send data gathered using this form securely to a page called `search.php`. **2**

[END OF SECTION 2]

[Turn over

MARKS

SECTION 3 — WEB DESIGN AND DEVELOPMENT — 20 marks

Attempt ALL questions

9. The GrowPlants website provides information for gardeners about plant care and the identification of plants.

The CSS used to display the site content includes the following media query.

```
@media only screen and (max-width: 600px) {}
```

Explain the purpose of this media query. **1**

10. The pricing details shown below are displayed on the WeHost website.

row 1	Price per month	Basic	Standard	Premium
row 2	Gb storage	10	20	30
row 3	SQL databases	5	10	20
row 4	Websites	50	100	Unlimited
row 5	Email addresses	2	4	8
row 6	Online support	No	No	Yes
row 7	Backup	Monthly	Weekly	Daily

These details are displayed on the page `hostingPlans.php` using the HTML `table` element.

```
<?php
…
echo "<table>";
…
…
…
echo "</table>";
…
?>
```

Using appropriate HTML `table` tags, write the HTML statement used to display:

(a) row 1 of this table **1**

(b) row 2 of this table. **1**

MARKS

11. A Munro is a mountain in Scotland that is over 3,000 feet high. A database-driven website is being created to share information about these mountains and to allow climbers to record which Munros they have climbed.

The details of each Munro will be stored, along with a difficulty level from 1 (easy) to 5 (difficult).

(a) The developers begin by investigating the hardware and software required for running this system.

State the type of feasibility being investigated. **1**

(b) The website will allow all users to search for details of a Munro and register for an account. In addition, registered users can add details of any climb they have completed, and if required, they can add a comment about the climb. Registered users can then view details of all climbs that have completed.

Draw a UML use case diagram for this website. **3**

[Turn over

11. (continued)

Information processed by the website is stored in a database in three related tables: Munro, Climber and Climb.

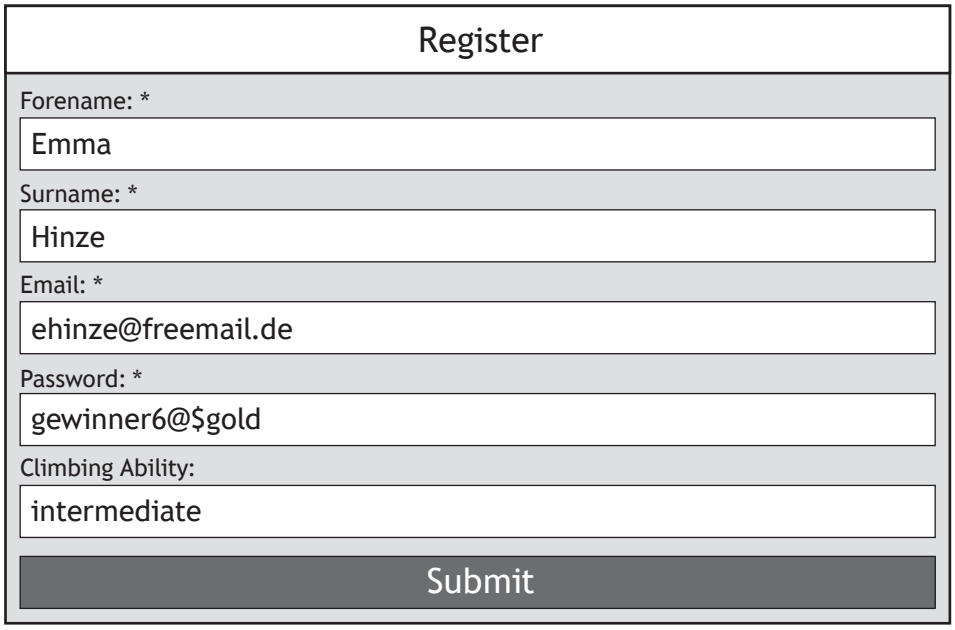
Munro
munroID
munroName
height
latitude
longitude
difficulty level

Climber
climberID
forename
surname
email
password
climbingAbility

Climb
climbID
climberID*
munroID*
date
timeTaken
notes

When a new user registers with the website, they complete a registration form.

(c) A wireframe for this form is shown below. When submitted, this data is sent to a page called `checkUser.php`.



11. (c) (continued)

When this form data is submitted, the following design is used to check whether the submitted email address has already been registered.

```
...
22.  create query to select climbers with email address = submitted email
23.  execute SQL query
24.  set $matches to _____________________________________
25.  if $matches > 0 then
26.      _____________________________________
27.  else
28.      add new user details to Climber table
29.  end if
```

(i) Write the pseudocode needed to complete line 24 and line 26 of the design. **2**

(ii) The HTML form elements used on the registration form are shown below.

```
< input type = "text" name = "first" required >
< input type = "text" name = "last" required >
< input type = "text" name = "email" required >
< input type = "text" name = "pass" required >
< input type = "text" name = "level" >
```

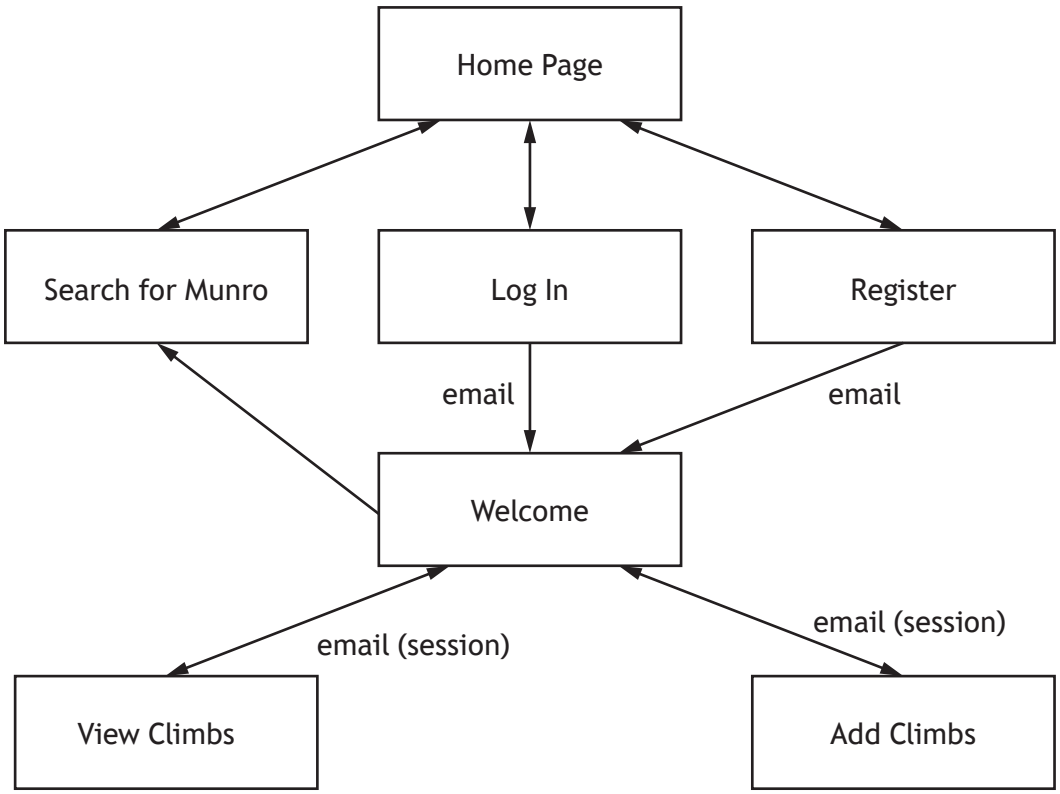
Write the PHP code that will be used on the `checkUser.php` page to assign the data submitted from the registration form to PHP variables. **2**

(iii) Write the SQL query to add details of the new user shown on the wireframe to the database. **2**

[Turn over

11. (continued)

(d) The navigational structure of the website is shown below.



When a registered user logs in using their email address and password, the 'Welcome' page is displayed.

This page contains the following code:

```
session_start();
$email = $_SESSION['email'];
```

The same code is also used on the 'View Climbs' and the 'Add Climb' pages.

(i) Explain why a session variable is necessary on these pages. **1**

(ii) Describe the use made of this session variable on the 'View Climbs' page used to display details of all climbs completed by a logged in user. **1**

[Turn over for next question

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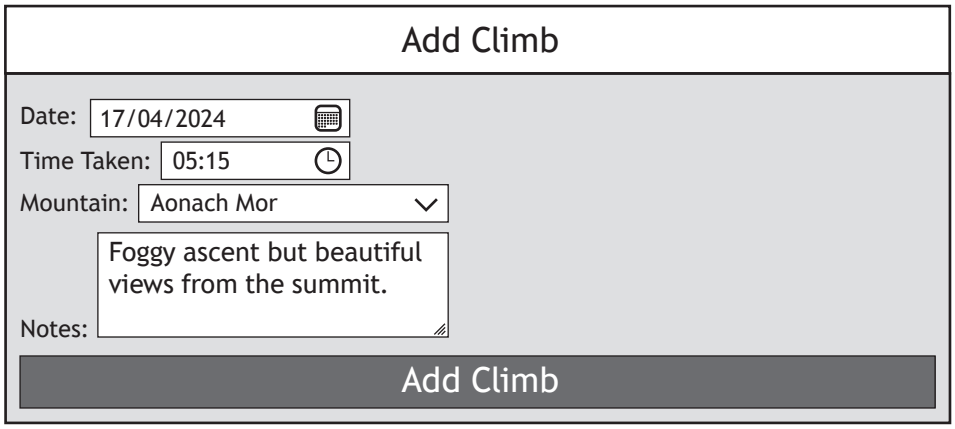
11. (continued)

(e) The 'Add Climb' page uses the form below to allow registered users to record details of any Munros they have climbed.



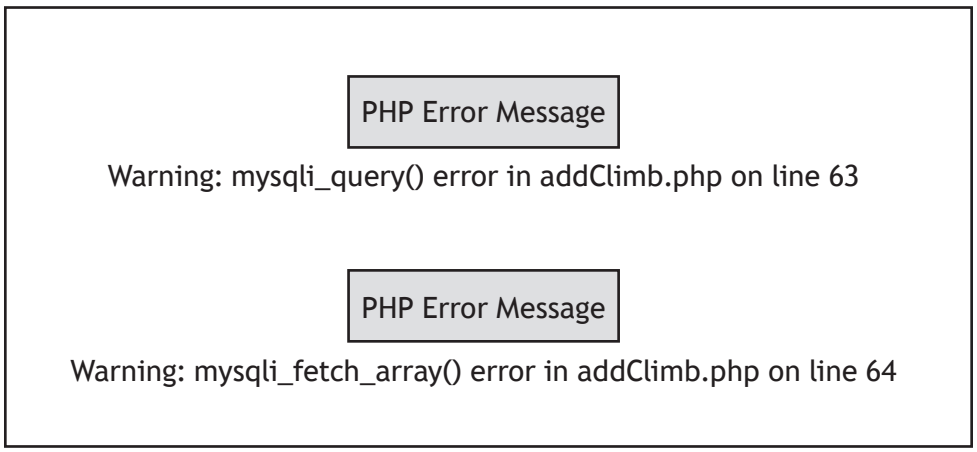
The first attempt to create the drop-down list for selection of the mountain resulted in the PHP and HTML code shown below.

```
...
Line 59   < select name="mountain" >
Line 60   < ?php
Line 61   $connection = mysqli_connect("scottishClimbs",
          "nevis", "lomond", "climbing");
Line 62   $sql = "SELECT munroName, munroID FROM Munro ORDER
          BY munroName ASC";
Line 63   $result = mysqli_query($sql);
Line 64   while($row = mysqli_fetch_array()) {
Line 65       echo "< option value = " .$row['munroID']." >
          ".$row['munroName']."< /option >";
Line 66   }
Line 67   mysqli_close($connection);
Line 69   ? >
Line 70   < /select >
...
```

(i) Identify the username for this database connection. **1**

11. (e) (continued)

(ii) When this code is executed, the following error messages are produced:



Explain these errors and describe how they could be resolved. **2**

(f) The 'View Climbs' page is used to display details of climbs completed by registered users of the website.

PHP code is to be added to this page.

The design of one process performed by the code is shown below.

```
1.  set $numClimbers to number of climbers in Climber table
2.  set $most = 0
3.  start loop from 1 to $numClimbers
4.      set $climberID = loop
5.      set $howMany = number of climbs completed by $climberID
6.      if $howMany > $most then
7.          set $most = $howMany
8.      end if
9.  end loop
10. create query to select full name of climber(s) with number of climbs
    completed = $most
11. execute query and assign results to $result
12. assign $result to array $target
13. display forename(s) and surname(s) stored in $target
```

(i) Describe the intended purpose of this design. **1**

(ii) Identify a potential problem at line 5 of the design. **1**

[END OF SECTION 3]

[END OF QUESTION PAPER]

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