Diploma Programme
Programme du diplôme
Programa del Diploma

Computer science
Standard level
Paper 2

30 October 2023

Zone A morning | **Zone B** morning | **Zone C** morning

1 hour

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all of the questions from one of the options.
- The maximum mark for this examination paper is **[45 marks]**.

Option	Questions
Option A — Databases	1 – 3
Option B — Modelling and simulation	4 – 6
Option C — Web science	7 – 9
Option D — Object-oriented programming	10 – 12

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17 pages

Option A — Databases

1. A restaurant stores information about its customers, their orders and the meals available in a database.

(a) Outline **two** reasons why the restaurant would use a database to store this information rather than a spreadsheet. [4]

An extract of some data to be stored is displayed in the table.

Customer	DateOfVisit	Item	Item	Item
Duncan Mark	2021/08/18	Fish and Chips	Pavlova	Wine
Duncan Mark	2021/08/18	Steak and Salad	Sorbet	None
Akemi Watene	2021/08/18	Chicken Biriyani	Wine	None

The DateOfVisit field is stored as year, month, day (yyyy/mm/dd).

(b) Outline **one** benefit of storing the data in the DateOfVisit field in the order of yyyy/mm/dd. [2]

The table structure for the restaurant database is:

CUSTOMER(CustomerID, FirstName, Surname, Phone, Email)
ORDER(OrderID, OrderDate, OrderTime, CustomerID)
ORDERLINE(OrderID, ItemID, Quantity, UnitPrice, LinePrice)
ITEM(ItemID, Name, QtyInStock, UnitPrice)

In the ORDERLINE table, OrderID and ItemID have been selected as a composite primary key. An alternative solution would be to use an OrderlineID primary key.

(c) Outline the reason for using OrderID and ItemID instead of OrderlineID as the primary key. [3]

The UnitPrice field is included in both the ORDERLINE table and the ITEM table.

(d) Outline **one** potential issue that this may create when writing a query for data interrogation. [2]

The restaurant owner wants to introduce a loyalty scheme for customers. After 10 visits, they will receive a voucher for $20.

(e) Identify the steps to create a query to list the visits of a customer with the first name of "Akemi" and the surname of "Watene". The query should display FirstName, Surname and OrderDate. [4]

(Option A continues on the following page)

(Option A continued)

2. The restaurant owner has hired a database administrator to extend the database.

The database administrator has decided to delete the LinePrice field from the ORDERLINE table.

ORDERLINE

OrderID	**ItemID**	**Quantity**	**UnitPrice**	**LinePrice**
DM1007	F1234	1	16.99	16.99
DM1007	W2134	2	6.99	13.98

(a) Explain why the decision to delete the LinePrice field has been made. [3]

The database administrator has created new tables to store employee data and create a work schedule.

When an employee works a shift in the restaurant, their hours and pay rate are recorded by the shift manager as a database transaction.

(b) Define the term *database transaction*. [1]

(c) (i) State **one** way to validate the hours_worked field. [1]

(ii) Outline **one** way to verify the payrate field. [2]

The shift manager sometimes changes the employees' work hours in the database during their shift. Employees can access the work hours and confirm their availability.

(d) Explain how data integrity can be maintained if an employee tries to access their work hours while the shift manager is editing them. [4]

The database administrator has set up a procedure for database recovery.

One method of recovering a database is to use a transaction log.

(e) Describe **one** alternative method that could be used to recover a database after a crash has occurred. [4]

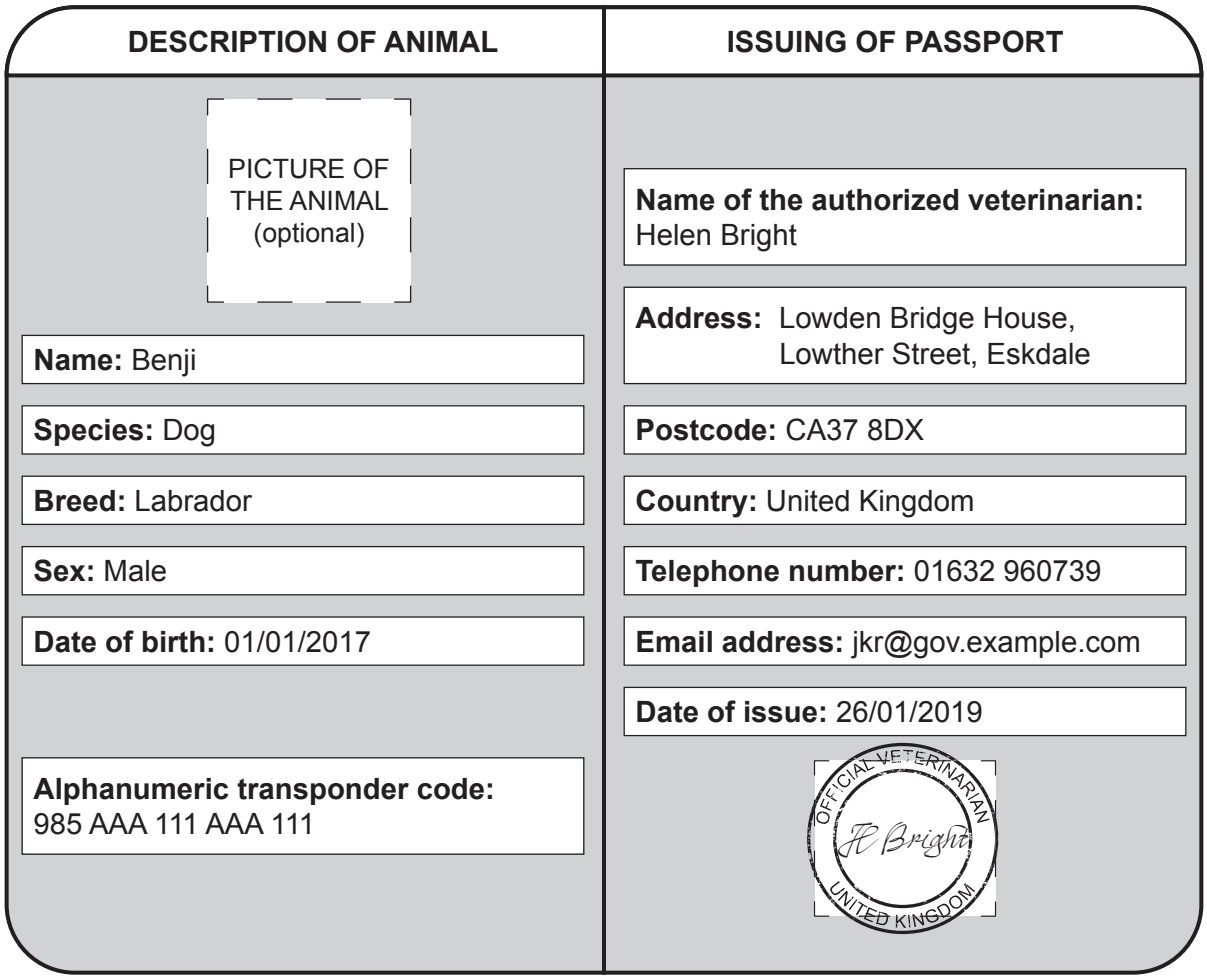
(Option A continues on the following page)

(Option A continued)

3. A European pet passport allows pets to travel between countries in the European Union. All pets have a microchip inserted that gives them a unique alphanumeric transponder code.

The data contained in a pet passport is shown in **Figure 1**. All of the data is stored in a database.

Figure 1: Two pages of a pet passport



A pet owner may have more than one pet, and each pet has their own passport.
Pet passports are issued by registered veterinary surgeons (vets).

(a) Construct the entity-relationship diagram (ERD) that shows the relationship between pet owners, their pets, and the pet passport. [2]

The data stored in the VET table can be represented in the following notation:

VET(VetID, FirstName, Surname, Address, Postcode, City, Country, Phone, Email)

The Phone field will be used as a secondary key.

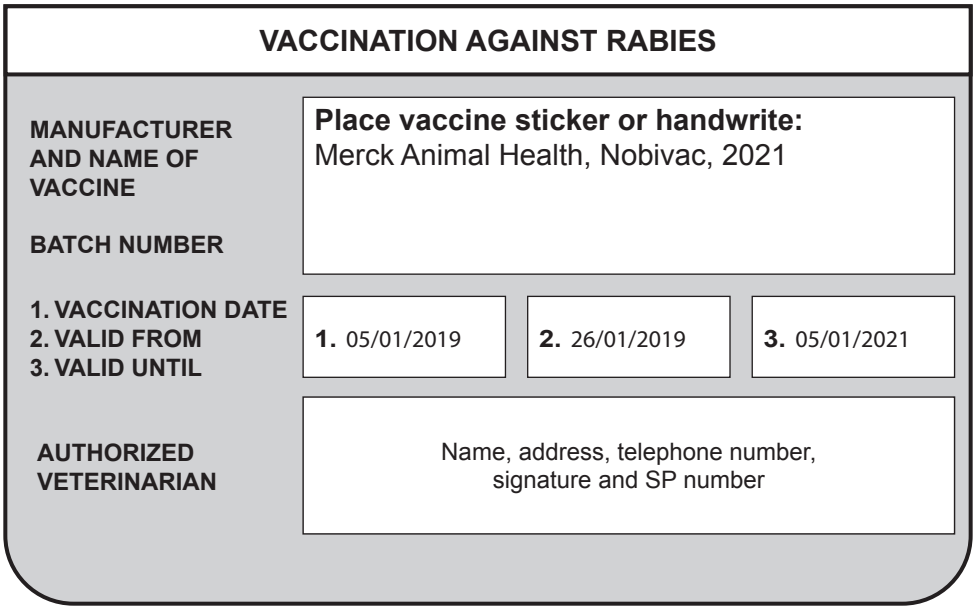
(b) Define the term *secondary key*. [1]

(Option A continues on the following page)

(Option A, question 3 continued)

Each year, pets require vaccinations to prevent them from contracting rabies. Information about each vaccination can be seen in the pet passport (see **Figure 2**).

Figure 2: Vaccination information page in a pet passport



The information in **Figure 1** and **Figure 2** needs to be normalized before being entered into the database.

The VET table is given and will need to be incorporated into the final structure.

(c) Construct the database in 3rd Normal Form (3NF) for all of the entities shown in **Figure 1** and **Figure 2**.

You should use the same notation as that used in the representation of the VET table. [8]

Access to this database must comply with data protection legislation.

(d) Describe the principles of data protection legislation that would apply to a pet owner's data. [4]

End of Option A

Option B — Modelling and simulation

4. Cattery5S is a cat adoption centre where potential cat owners are shown a series of cats one by one.

The rules for choosing a cat are as follows:
- The potential cat owner has five minutes to look at and interact with the cat.
- The potential cat owner must either choose that cat or move to the next cat.
- Once the potential owner has chosen a cat, they must adopt it and must not look at any more cats.
- The potential cat owner can choose one cat only.

If there are only two cats at the adoption centre, the potential cat owner must **either** choose the first cat **or** choose the second cat.

(a) State the probability of choosing the best cat from the two choices. [1]

On one occasion, there are three cats at the adoption centre. The owner of Cattery5S realizes that the number of possible permutations of cat ratings increases significantly as the number of cats increases.

Figure 3 shows the first three rows of a spreadsheet with the permutations of three cats based on a rating system. The permutations shown are the first three of the six that are possible. No two cats can have the same rating.
- The cat rated 3 is the best choice.
- The cat rated 1 is the worst choice.

In row 1, the highest-rated cat is last in the series (column C). In row 2, the highest-rated cat is second (column B). This should continue until all possible permutations have been included.

Figure 3: The first three rows of a spreadsheet with the permutations of three cats based on a rating system

	A	B	C	D
1	1	2	3	
2	1	3	2	
3	2	1	3	
4				

(b) Copy and complete the spreadsheet model in **Figure 3**, showing the remaining permutations for the three cats rated 1 to 3. [1]

(Option B continues on the following page)

(Option B, question 4 continued)

When using the spreadsheet model in **Figure 3**, the following rules apply:
- Never choose the first cat (column A).
- Choose the second cat (column B) if it is rated higher than the first cat.
- Choose the third cat (column C) if the second cat is rated lower than the first cat.

Column D will show the rating of the chosen cat.

For example, the value in cell D3 will be 3 because the rating in cell B3 (1) is lower than the rating in cell A3 (2) and the rating in cell C3 is greater than the rating in cell B3 (1).

(c) Construct a formula in cell D1 to show the rating of the chosen cat. [2]

Cell D1 is copied and pasted into the rest of the rows in column D.

A formula is used to count the number of times each of the three rated cats appear in column D. The formula will need to be used three times because there are three cats.

(d) (i) Construct a formula to count the number of times each cat is chosen. [2]

(ii) Calculate the probability of choosing each of the three cats using this strategy. [3]

The spreadsheet is updated to show the first three rows of permutations for four cats (**Figure 4**).

Figure 4: Updated spreadsheet showing the first three rows of permutations for four cats

	A	B	C	D	E
1	1	2	3	4	
2	1	2	4	3	
3	1	3	2	4	
4					

When using the spreadsheet model in **Figure 4**.The following rules apply:
- Never choose the first cat (column A).
- Choose the second cat (column B) if it is rated higher than the first cat.
- If not, compare the first cat with the third cat (column C) and choose the third cat if it is rated higher than the first cat.
- If not, choose the fourth cat (column D).

For example, if the order of ratings for cats A, B, C and D was 2, 1, 3, 4, you would choose the third cat (C) because $1 < 2$ and $3 > 1$.

(e) Construct a formula in cell E1 to show the rating of the chosen cat. [1]

(f) Discuss the decision to use a spreadsheet mathematical model for choosing the best cat. [6]

(Option B continues on the following page)

(Option B continued)

5. You are going to visit Cattery5S, where you will have the opportunity to see eight cats.

You realize that the number of permutations for eight cats is 8! ($8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1$) or 40 320.

You need to create a function, `FACTORIAL`, that accepts the number of cats, `N`, and returns the factorial of that number.

(a) Construct an algorithm for the function `FACTORIAL(N)`. [2]

The following rules apply when there is an unknown number of cats at Cattery5S:
- Never choose the first three cats.
- Choose the fourth cat if it is rated higher than the best of the first three cats.
- If not, compare the fifth cat with the highest-rated cat from the first three cats.
- Choose the fifth cat if it is rated higher than the best of the first three cats.
- If not, compare the next cat with the highest-rated cat from the first three cats.
- Continue until you have chosen a cat or you have reached the last cat.
- If you reach the last cat, you must choose it.

You need to create a function, `FINDHIGH`, that accepts an array, `ARR`, that contains the ratings of eight cats and returns the highest value from the first three.

For example, if `ARR` contained 1, 3, 2, 5, 4, 7, 8, 6, the value 3 would be returned.

(b) Construct an algorithm for the function `FINDHIGH(ARR)`. [2]

A `NEXTPERMUTATION(ARR)` function has been constructed that passes the last permutation and returns the next permutation.

For example, if the first permutation order of `ARR` is 1, 2, 3, 4, 5, 6, 7, 8, the `NEXTPERMUTATION(ARR)` function would return an array ordered 1, 2, 3, 4, 5, 6, 8, 7. Each call of the `NEXTPERMUTATION(ARR)` function would give the next permutation. So, the second call of the function would return 1, 2, 3, 4, 5, 7, 6, 8.

(c) Construct an algorithm that uses the functions `FACTORIAL(N)`, `FINDHIGH(ARR)` and `NEXTPERMUTATION(ARR)` to output the probability of choosing the best cat. [6]

You are unsure if your strategy will give you the highest probability of finding the best cat.

(d) Outline **one** change you could make to the algorithm to test if it will produce the highest best-match probability. [2]

When you arrive at Cattery5S, you are informed that there are 20 cats to choose from. This is approximately 2.4×10^{18} permutations.

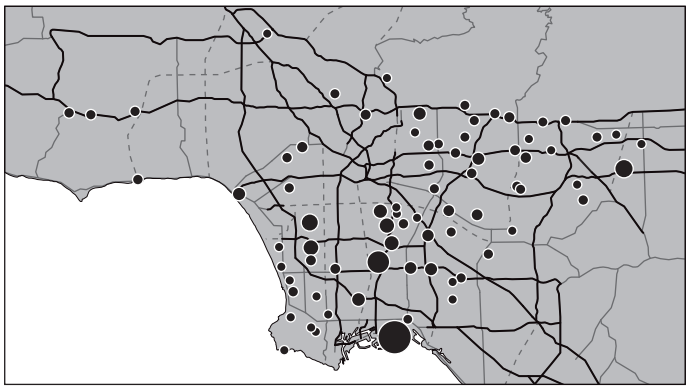
(e) Describe the hardware requirements needed by the algorithm when there are 20 cats. [4]

(Option B continues on the following page)

(Option B continued)

6. The police service, ambulance service, and fire service all use a central emergency management information system (EMIS). The EMIS can be used to create a 2D visualization of reported emergencies superimposed onto a map (see **Figure 5**).

Figure 5: 2D visualization of reported emergencies in Los Angeles, USA, superimposed on a map



(a) Define the term *2D visualization*. [1]

(b) (i) Outline **two** reasons why a 2D visualization is an appropriate visualization method in this scenario. [4]

(ii) Outline the memory requirements for 2D visualization. [2]

The emergency services have been notified of a fire in an office block. Several people are trapped inside and emergency service personnel will enter the building.

A 3D visualization of the building will be rendered from the building's floorplan. This 3D visualization will be electronically transferred to the smartphone/tablet with the emergency rescue team.

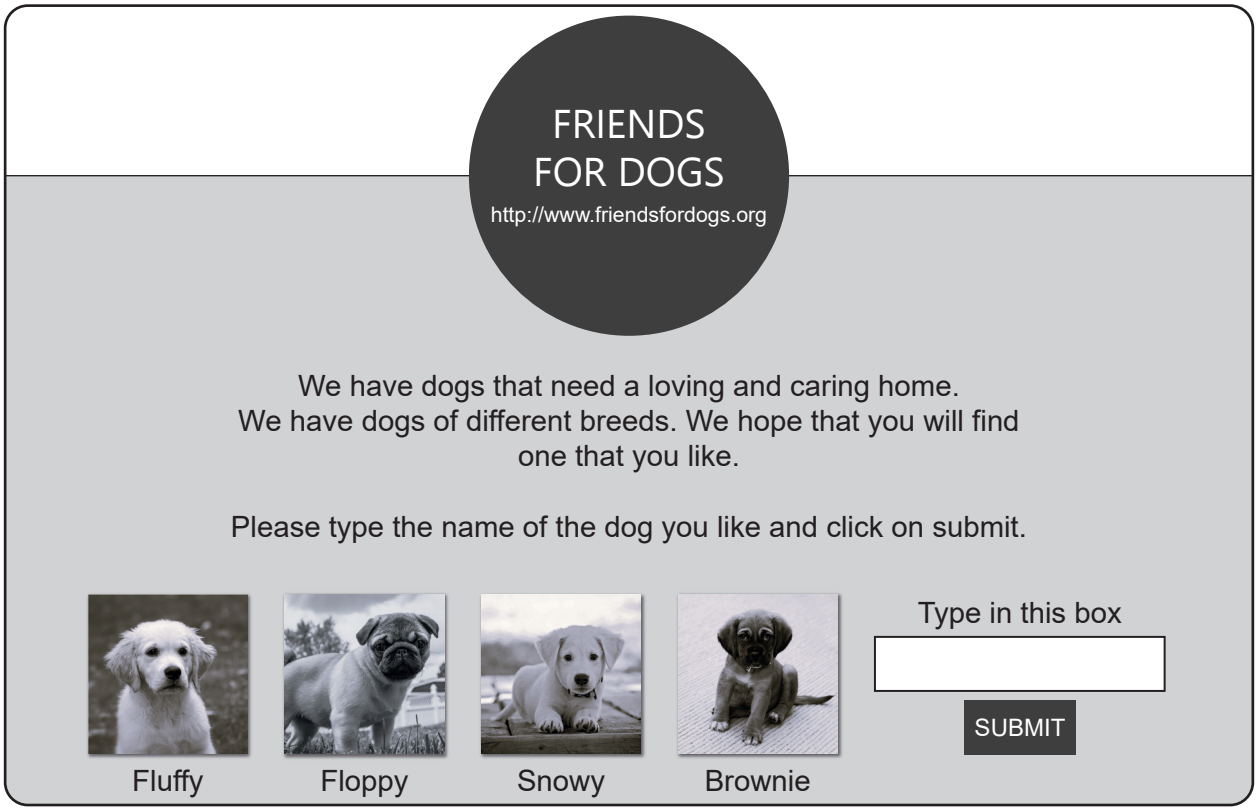
(c) Outline **three** considerations that need to be made before creating a 3D visualization of the building. [6]

End of Option B

Option C — Web science

7. *Friends for Dogs* is a company that finds homes for stray dogs. Potential owners can search the website for a dog to adopt. **Figure 6** shows a webpage from the website.

Figure 6: Webpage from the *Friends for Dogs* website



Each page on the *Friends for Dogs* website has a number of components.

(a) Identify **two** components that may be found on a webpage. [2]

The *Friends for Dogs* website uses the hypertext transfer protocol (HTTP).

(b) Identify **two** characteristics of the hypertext transfer protocol (HTTP). [2]

The following is an excerpt of the code that enables a dog to be chosen for adoption.

```
<p>Please type the name of the dog you like and click on submit</p>
<input type = "text" name = "dogname">
```

(Option C continues on the following page)

(Option C, question 7 continued)

Part of the file dogadoption.php is shown:

```
<?php
$dogname = $_POST["dogname"];
$conn = $mysqli_connect(localhost, $username, $pass,"dogDB");
$sql = "SELECT dname,image, price FROM Dogs WHERE dname=$dogname";
$result = mysqli_query($conn,$sql);
if (mysqli_num_rows($result) > 0){
    while($row= mysqli_fetch_assoc($result)){
        echo "Our ".$row["image"]." ".$row["dogname"]. " is for ".
        $row["price"].<br>;
    }
}
else{
    echo "not found";
}
mysqli_close($conn);
?>
```

The PHP code is executed on the server.

(c) Describe the processing that takes place when this code is executed. [4]

(d) Outline **one** reason why the given code is processed using server-side scripting instead of client-side scripting. [2]

Potential dog owners can download and share images of the dogs they may want to adopt.

(e) Explain why lossy compression has been used to save the image files. [3]

The structure of the *Friends for Dogs* website is based on a template.

(f) Evaluate the use of a template for developing the *Friends for Dogs* website. [5]

(Option C continues on page 13)

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(Option C continued)

8. A travel and tours company has created a website. The website is simple and not interactive.

(a) Identify **two** ways of making this website interactive. [2]

(b) Outline **one** way in which the website developers can avoid breaching copyright laws. [2]

(c) Outline **one** metric that can be used to rank different websites. [1]

(d) Identify **two** white hat search engine optimization techniques to improve the ranking of the website. [2]

(e) Explain why white hat search engine optimization techniques would be used to improve the ranking of the company's website. [4]

(f) Explain **one** way in which the effectiveness of a search engine would change due to the assumptions made during its development. [3]

9. A teacher training company uses a client–server network architecture.

(a) Outline the relationship between the client and the server in a client–server network architecture. [2]

Authentication of an employee is required for them to access the company network.

(b) Distinguish between identification and authentication. [2]

The company is considering changing from a client–server network architecture to one based on cloud storage.

(c) Explain **one** reason why an organization would change from a client–server network architecture to one based on cloud storage. [3]

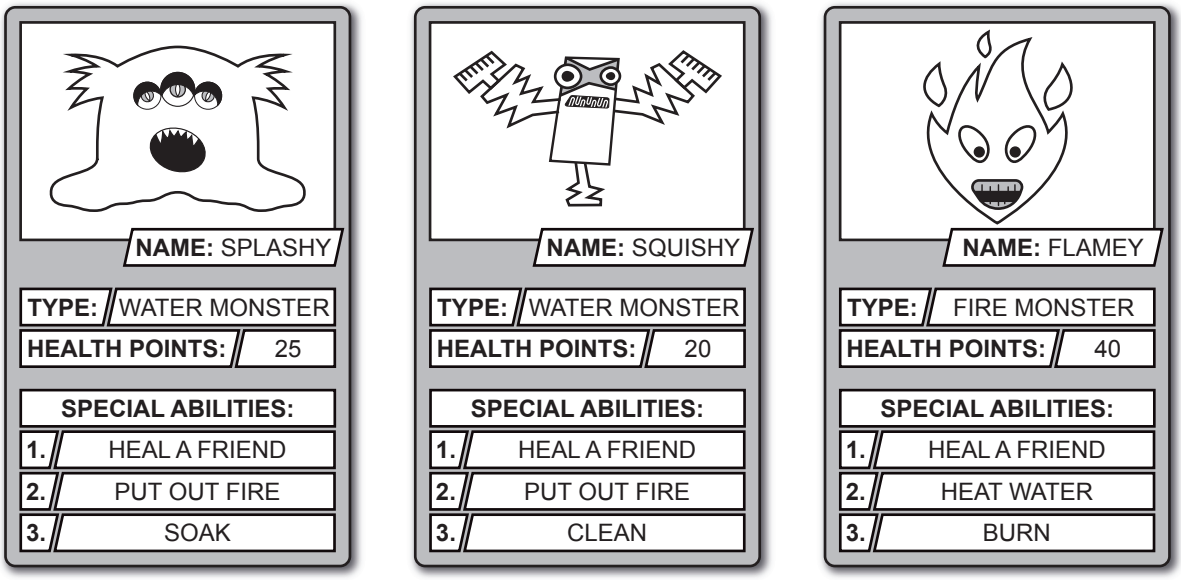
(d) To what extent has cloud-based storage acted as a catalyst for a greater decentralization of the web? [6]

End of Option C

Option D — Object-oriented programming

10. A company that manufactures a children's card game, Monster Battle, wants to create a software version. **Figure 7** shows three sample cards from the game.

Figure 7: Three sample cards from Monster Battle



Each monster begins the game with a number of health points, which are stated on the card, and leaves the game when it has no remaining health points. During a battle between two monsters, players take turns to roll the dice. The results determine how much each monster's attack will reduce the defending monster's health points.

Some initial classes have been created to model this scenario.

```
public class Monster {
    public static final int ICE_MONSTER_TYPE = 1;
    public static final int WATER_MONSTER_TYPE = 2;
    public static final int FIRE_MONSTER_TYPE = 3;
    public String name = "Unknown";
    public int health = 100;
    public int strength = 10;
    public int monsterType = 0;
    public Monster(String name, int health, int monsterType) {
        this.name = name;
        this.health = health;
        this.monsterType = monsterType;
    }
    public void attack(Monster defender) {
        //to be written
    }
```

(Option D continues on the following page)

(Option D, question 10 continued)

```
    private static int rollDice() {
        //returns a random integer between 1 and 12
        return new java.util.Random().nextInt(12)+1;
    }
    public static void output(String message) {
        System.out.println(message);
    }
}
public class WaterMonster extends Monster {
    public WaterMonster(String name, int health) {
        super(name,health, Monster.WATER_MONSTER_TYPE);
    }
}
public class FireMonster extends Monster {
    public FireMonster(String name, int health){
        super(name, health, Monster.FIRE_MONSTER_TYPE);
    }
}
```

(a) Define the term *static* as used in the declaration `ICE_MONSTER_TYPE` in the `Monster` class. [1]

(b) (i) Outline **one** advantage of making all instance variables in the `Monster` class private. [2]

Some instance variables may need to be retrieved **and** changed from outside the class even though they will be declared private.

(ii) State **two** types of method that would allow this to happen. [2]

(c) Outline why the keyword `super` is used in the constructor of the `WaterMonster` class. [2]

The finished game may include some open source software.

(d) Identify **two** aims of the open source movement. [2]

(e) Construct code that creates an instance of a fire-type monster called Flamey with 40 health points. [2]

(Option D continues on the following page)

(Option D continued)

11. The `Monster` class contains the method `attack(Monster defender)`. This is used when a monster attacks another monster (the defender).

This method:
- decreases the health variable of the defending monster by the amount returned by the `rollDice` method
- uses the `output` method to display a defending monster's name, damage and health points if its health variable is greater than zero
- sets the defending monster's health variable to zero if it is less than zero
- outputs the defending monster's name followed by "must leave the game" if its health variable is zero.

(a) Construct the method `attack(Monster defender)`, using any existing static methods in the `Monster` class that might be useful. [4]

(b) Outline **two** differences between the `FireMonster` class and an instance of `FireMonster`. [4]

The programmer has created a class named `Arena` to model the place in which the monsters will battle.

```
public class Arena {
    public Monster[] monsters = new Monster[10];
    int monsterCount = 0; //the number of monsters currently
    in array
    public void addMonster(Monster M) {
        // to be written
    }
    public void removeMonster(Monster M) {
        //to be written
    }
    public void doOneOnOneBattle(Monster A, Monster B) {
        while (A.health > 0 && B.health > 0) {
            gameLog(A.attack(B));
            gameLog(B.attack(A));
        }
        if (A.health > B.health) {
            output(A.name + " WINS!");
            removeMonster(B);
        } else if (B.health > A.health) {
            output(B.name + " WINS!");
            removeMonster(A);
        } else {
            output("IT IS A DRAW!");
        }
    }
    public static void output(String message) {
        System.out.println(message);
    }
}
```

(Option D continues on the following page)

(Option D, question 11 continued)

(c) Construct a simple UML class diagram showing the relationships between `FireMonster`, `Monster` and `Arena`. You do not need to include variables and methods. [2]

The method `addMonster(Monster M)` does the following:
- If the `monster` array is not full and `M` is not in the array, it adds `M` to the array and increases the variable `monsterCount`.
- Otherwise, a message is output stating the reason why.

(d) Construct the method `addMonster(Monster M)`. [5]

(e) Outline **two** disadvantages of using object-oriented programming (OOP) in the development of software. [4]

12. (a) Define the term *polymorphism*. [2]

The method `removeMonster(Monster M)` in the `Arena` class removes `Monster M` from the array without leaving any gaps. It also updates the `monsterCount` variable. You may assume that `Monster M` already exists in the Arena.

(b) Construct the method `removeMonster(Monster M)` [6]

Monsters have three special abilities that may be used on other monsters:
- The ability “Heal”, which can be used on another monster
- An ability specific to the monster type (*eg*, all water-type monsters have the ability “Put out fire”)
- An ability specific to the monster (*eg*, only instances of Squishy have the ability “Clean”).

The methods `ability1(Monster defender)`, `ability2(Monster defender)` and `ability3(Monster defender)` will be created to enable the monsters to perform their abilities. A class for each individual monster card, *eg* “Squishy”, will be created.

(c) (i) Define the term *inheritance*. [2]

(ii) Explain how inheritance and polymorphism could be used to maximize code reuse in these three methods. [5]

End of Option D

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References:

Figure 1. Department of Agriculture, Environment and Rural Affairs. EU Pet Travel Scheme - How to Complete Pet Passports. https://www.daera-ni.gov.uk/publications/eu-pet-travel-scheme-how-complete-pet-passports. Contains public sector information licensed under the Open Government Licence v3.0. Source adapted https://www.daera-ni.gov.uk/crown-copyright.

Figure 2. Department of Agriculture, Environment and Rural Affairs. EU Pet Travel Scheme - How to Complete Pet Passports. https://www.daera-ni.gov.uk/publications/eu-pet-travel-scheme-how-complete-pet-passports. Contains public sector information licensed under the Open Government Licence v3.0. Source adapted https://www.daera-ni.gov.uk/crown-copyright.

Figure 5. Wikipedia, n.d. *California locations by crime rate*. [online] Available at: https://en.wikipedia.org/wiki/California_locations_by_crime_rate [Accessed 11 January 2021] and Wikimedia Commons, 2008. *Locator map of the Harbor Freeway in Los Angeles County, Southern California*. [online] Available at: https://commons.wikimedia.org/wiki/File:Harbor_Freeway.svg [Accessed 11 January 2021]. Source adapted.

Figure 6. minka2507, 2019. *[Fluffy]*. [online] Available at: https://pixabay.com/photos/dog-animal-puppy-pet-mammal-4390884/ [Accessed 11 January 2021]. Source adapted.

SNGPhotography, 2016. *[Floppy]*. [online] Available at: https://pixabay.com/photos/pug-puppy-storm-animal-pet-dog-1502566/. Source adapted.

3914556, 2013. *[Snowy]*. [online] Available at: https://pixabay.com/photos/puppy-dog-pet-animal-cute-white-1903313/ [Accessed 11 January 2021]. Source adapted.

Pexels, 2014. *[Brownie]*. [online] Available at: https://pixabay.com/photos/animal-dog-pet-puppy-pug-1284307/ [Accessed 11 January 2021]. Source adapted.