A LEVEL 9618

COMPUTER SCIENCE

Paper 3 Topical

WITH **MARK SCHEME**

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Topic 1

Data Representation

In this Unit

You will practice the following topics:

1.1 User-defined Data Types

1.2 File Organisation & Access

1.3 Floating-point Numbers, Representation & Manipulation

9618 Computer SCIENCE Topical Paper 3

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STUDENTS RESOURCE

Topic 1: Data Representation

1 9608/32/M/J/15/Q3

(a) A particular programming language allows the programmer to define their own data types.

`ThisDate` is an example of a user-defined structured data type.

```
TYPE ThisDate
   DECLARE ThisDay    :  (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,
                         13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23,
                         24, 25, 26, 27, 28, 29, 30, 31)
   DECLARE ThisMonth  :  (Jan, Feb, Mar, Apr, May, Jun, Jul, Aug,
                         Sep, Oct, Nov, Dec)
   DECLARE ThisYear   :  INTEGER
ENDTYPE
```

A variable of this new type is declared as follows:

```
DECLARE DateOfBirth : ThisDate
```

(i) Name the non-composite data type used in the `ThisDay` and `ThisMonth` declarations.

.....[1]

(ii) Name the data type of `ThisDate`.

.....[1]

(iii) The month value of `DateOfBirth` needs to be assigned to the variable `MyMonthOfBirth`.

Write the required statement.

.....[1]

(b) Annual rainfall data from a number of locations are to be processed in a program.

The following data are to be stored:

- location name
- height above sea level (to the nearest metre)
- total rainfall for each month of the year (centimetres to 1 decimal place)

A user-defined, composite data type is needed. The programmer chooses `LocationRainfall` as the name of this data type.

A variable of this type can be used to store all the data for one particular location.

(i) Write the definition for the data type `LocationRainfall`.

.....

.....

.....

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.....

.....[5]

(ii) The programmer decides to store all the data in a file. Initially, data from 27 locations will be stored. More rainfall locations will be added over time and will never exceed 100.

The programmer has to choose between two types of file organisation. The two types are serial and sequential.

Give **two** reasons for choosing serial file organisation.

.....

.....

.....

.....[2]

2 9608/33/M/J/15/Q4

(a) A particular programming language allows the programmer to define their own data types.

An example of a user-defined data type for an address is:

```
TYPE ThisAddress
   DECLARE ThisHouseNo : INTEGER
   DECLARE ThisStreet  : STRING
   DECLARE ThisTown    : STRING
ENDTYPE
```

A variable of this new type is declared as follows:

```
DECLARE HomeAddress : ThisAddress
```

(i) Write the statement that assigns the house number 34 to `HomeAddress`.

.....[1]

(ii) The type definition for `ThisAddress` is to be changed.

Rewrite one line from the definition for each of the following changes.

House numbers are in the range from 1 to 10.

`DECLARE` .....

The possible towns are limited to: Brightown, Arunde and Shoram.

`DECLARE` .....[2]

(b) Temperature data from a number of weather stations are to be processed by a program.

The following data are to be stored:

- weather station ID (a unique four-letter code)
- latitude (to 2 decimal places)
- average temperature (to the nearest whole number) for each year from 2001 to 2015 inclusive

A programmer designs a composite data type `WeatherStation`. A variable of this type can be used to store all the data for one particular station.

(i) Write the definition for the user-defined data type `WeatherStation`.

.....

.....

.....

.....

.....

.....[5]

(ii) The programmer decides to store all the data in a file. The number of weather stations could grow to reach 20000, but not all stations will be present at first.

The programmer decides on random organisation for the file.

Describe **three** steps which show how a new weather station record is added to the file.

1 .....

.....

2 .....

.....

3 .....

.....[3]

3 9608/31/O/N/15/Q1

In a particular computer system, real numbers are stored using floating-point representation with:

- 8 bits for the mantissa, followed by
- 8 bits for the exponent

Two's complement form is used for both mantissa and exponent.

(a) (i) A real number is stored as the following two bytes:

Mantissa

0	0	1	0	1	0	0	0

Exponent

0	0	0	0	0	0	1	1

Calculate the denary value of this number. Show your working.

.....

.....

.....

.....

.....

.....[3]

(ii) Explain why the floating-point number in **part (a)(i)** is not normalised.

.....

.....[2]

(iii) Normalise the floating-point number in **part (a)(i)**.

Mantissa

Exponent

[2]

(b) (i) Write the largest positive number that can be written as a normalised floating-point number in this format.

Mantissa

Exponent

[2]

(ii) Write the smallest positive number that can be written as a normalised floating-point number in this format.

Mantissa

Exponent

[2]

(iii) If a positive number is added to the number in **part (b)(i)** explain what will happen.

.....

.....

.....

.....[2]

(c) A student writes a program to output numbers using the following code:

```
X ← 0.0
FOR i ← 0 TO 1000
   X ← X + 0.1
   OUTPUT X
ENDFOR
```

The student is surprised to see that the program outputs the following sequence:

0.0 0.1 0.2 0.2999999 0.3999999 ……

Explain why this output has occurred.

.....

.....

.....

.....

.....

.....[3]

4 9608/32/O/N/15/Q1

In a particular computer system, real numbers are stored using floating-point representation with:

- 8 bits for the mantissa, followed by
- 4 bits for the exponent

Two's complement form is used for both mantissa and exponent.

Two's complement form is used for both mantissa and exponent.

(a) (i) A real number is stored as the following 12-bit binary pattern:

0	1	1	0	1	0	0	0	0	0	1	1

Calculate the denary value of this number. Show your working.

.....

.....

.....

.....

.....

.....[3]

(ii) Give the normalised binary pattern for +3.5. Show your working.

.....

.....

.....

.....

.....

.....[3]

(iii) Give the normalised binary pattern for –3.5. Show your working.

.....

.....

.....

.....

.....

.....[3]

The number of bits available to represent a real number is increased to 16.

(b) (i) If the system were to use the extra 4 bits for the mantissa, state what the effect would be on the numbers that can be represented.

.....

.....[1]

(ii) If the system were to use the extra 4 bits for the exponent instead, state what the effect would be on the numbers that can be represented.

.....

.....[1]

(c) A student enters the following expression into an interpreter:

```
OUTPUT (0.1 + 0.2)
```

The student is surprised to see the following output:

0.3000000000000001

Explain why this output has occurred.

.....

.....

.....

.....

.....

.....[3]

5 9608/32/M/J/16/Q4

(a) Three file organisation methods and two file access methods are shown below.

Draw lines to link each file organisation method to its appropriate file access method or methods.

File organisation method	File access method
serial	direct
sequential	sequential
random	

[4]

(b) A bank has a very large number of customers. The bank stores data for each customer. This includes:

- unique customer number
- personal data (name, address, telephone number)
- transactions

The bank computer system makes use of three files:

- A – a file that stores customer personal data. This file is used at the end of each month for the production of the monthly statement.
- B – a file that stores encrypted personal identification numbers (PINs) for customer bank cards. This file is accessed when the customer attempts to withdraw cash at a cash machine (ATM).
- C – a file that stores all customer transaction records for the current month. Every time the customer makes a transaction, a new record is created.

For each of the files A, B and C, state an appropriate method of organisation. Justify your choice.

(i) File A organisation .....

Justification .....

.....

.....

.....[3]

(ii) File B organisation .....

Justification .....

.....

.....

.....[3]

(iii) File C organisation .....

Justification .....

.....

.....

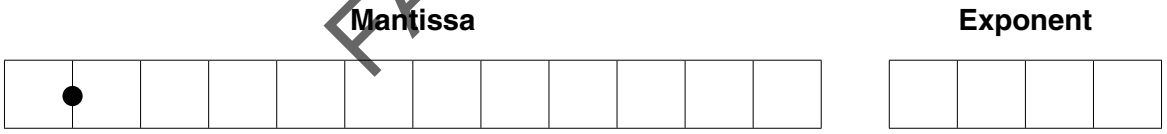
.....[3]

6 9608/31/O/N/16/Q1

In a particular computer system, real numbers are stored using floating-point representation with:

- 12 bits for the mantissa
- 4 bits for the exponent
- two's complement form for both mantissa and exponent

(a) Calculate the floating-point representation of +2.5 in this system. Show your working.



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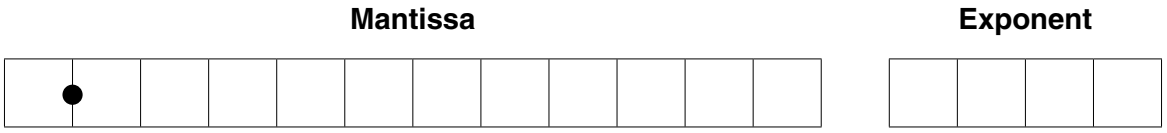
.....[3]

(b) Calculate the floating-point representation of –2.5 in this system. Show your working.



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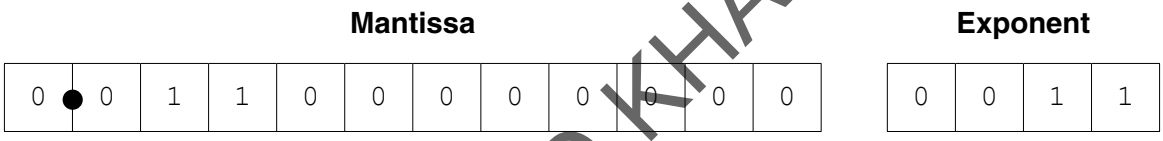
..... [3]

(c) Find the denary value for the following binary floating-point number. Show your working.



.....

.....

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.....

.....

..... [3]

(d) (i) State whether the floating-point number given in **part (c)** is normalised or not normalised.

..... [1]

(ii) Justify your answer given in **part (d)(i)**.

.....

..... [1]

(e) The system changes so that it now allocates 8 bits to both the mantissa and the exponent.

State **two** effects this has on the numbers that can be represented.

1 .....

.....

2 .....

..... [2]

7 9608/32/O/N/16/Q1

In a particular computer system, real numbers are stored using floating-point representation with:

- 8 bits for the mantissa
- 8 bits for the exponent
- two's complement form for both mantissa and exponent

(a) Calculate the floating point representation of +3.5 in this system. Show your working.

.....

.....

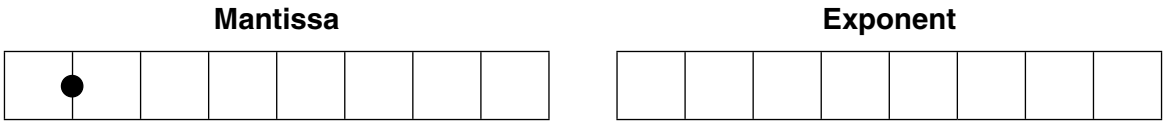
.....

.....

.....

..... [3]

(b) Calculate the floating-point representation of –3.5 in this system. Show your working.



.....

.....

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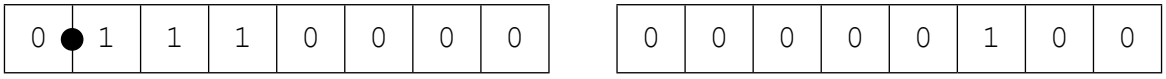
.....

..... [3]

(c) Find the denary value for the following binary floating-point number. Show your working.

Mantissa **Exponent**



.....

.....

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.....

.....

..... [3]

(d) **(i)** State whether the floating-point number given in **part (c)** is normalised or not normalised.

..... [1]

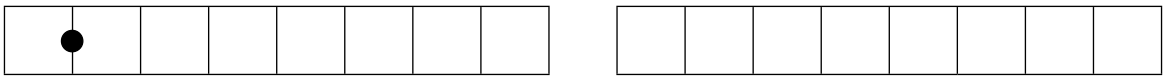
(ii) Justify your answer given in **part (d)(i)**.

.....

..... [1]

(e) Give the binary two's complement pattern for the negative number with the largest magnitude.

Mantissa **Exponent**



8 **9608/31/M/J/17/Q1**

(a) Consider the following user-defined data type:

```
TYPE LibraryBookRecord
   DECLARE ISBN      : INTEGER
   DECLARE Title     : STRING
ENDTYPE
```

(i) Write a pseudocode statement to declare a variable, `Book`, of type `LibraryBookRecord`.

.....[1]

(ii) Write a pseudocode statement that assigns 'Dune' to the `Title` of `Book`.

.....[1]

(b) The user-defined data type `LibraryBookRecord` needs to be modified by adding the following fields:

- a field called `Genre` which can take two values, fiction or non-fiction
- a field called `NumberOfLoans` which can be an integer value in the range 1 to 99

Write the updated version of `LibraryBookRecord`.

.....

.....

.....

.....

.....

.....

.....[3]

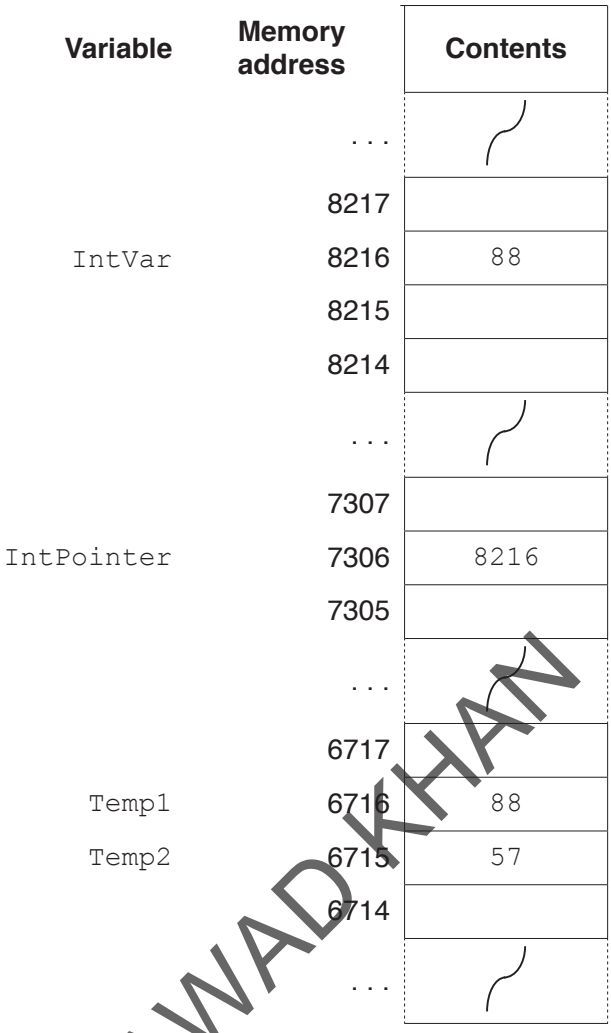
(c) A pointer is a variable that stores the address of a variable of a particular type.

Consider the code on page 3, which uses the following identifiers:

Identifier	Data type	Description
IntPointer	^INTEGER	pointer to an integer
IntVar	INTEGER	an integer variable
Temp1	INTEGER	an integer variable
Temp2	INTEGER	an integer variable

```
IntVar ← 57            // assigns the value 57 to the integer
                       // variable IntVar
IntPointer ← @IntVar   // assigns to IntPointer the address of the
                       // integer variable IntVar
Temp2 ← IntPointer^    // assigns to variable Temp2 the value at an
                       // address pointed at by IntPointer
IntPointer^ ← Temp1    // assigns the value in the variable Temp1 to
                       // the memory location pointed at by IntPointer
```

The four assignment statements are executed. The diagram shows the memory contents after execution.



Use the diagram to state the current values of the following expressions:

(i) `@Temp2` .....[1]

(ii) `IntPointer` .....[1]

(iii) `IntPointer^` .....[1]

(iv) `IntPointer^ = Temp2 + 6` .....[1]

(d) Write pseudocode statements that will achieve the following:

(i) Assign the value `22` to the variable `Temp2`.

.....[1]

(ii) Place the address of `Temp1` in `IntPointer`.

.....[1]

(iii) Copy the value in `Temp2` into the memory location currently pointed at by `IntPointer`.

.....[1]

9 9608/32/M/J/17/Q1

(a) Consider the following pseudocode user-defined data type:

```
TYPE MyContactDetail
   DECLARE Name        : STRING
   DECLARE HouseNumber : INTEGER
ENDTYPE
```

(i) Write a pseudocode statement to declare a variable, `NewFriend`, of type `MyContactDetail`.

.....[1]

(ii) Write a pseudocode statement that assigns 129 to the `HouseNumber` of `NewFriend`.

.....[1]

(b) The user-defined data type `MyContactDetail` needs to be modified by:

- adding a field called `Area` which can take three values, uptown, downtown or midtown
- amending the field `HouseNumber` so that house numbers can only be in the range 1 to 499.

Write the updated version of `MyContactDetail`.

.....

.....

.....

.....

.....

.....

.....[3]

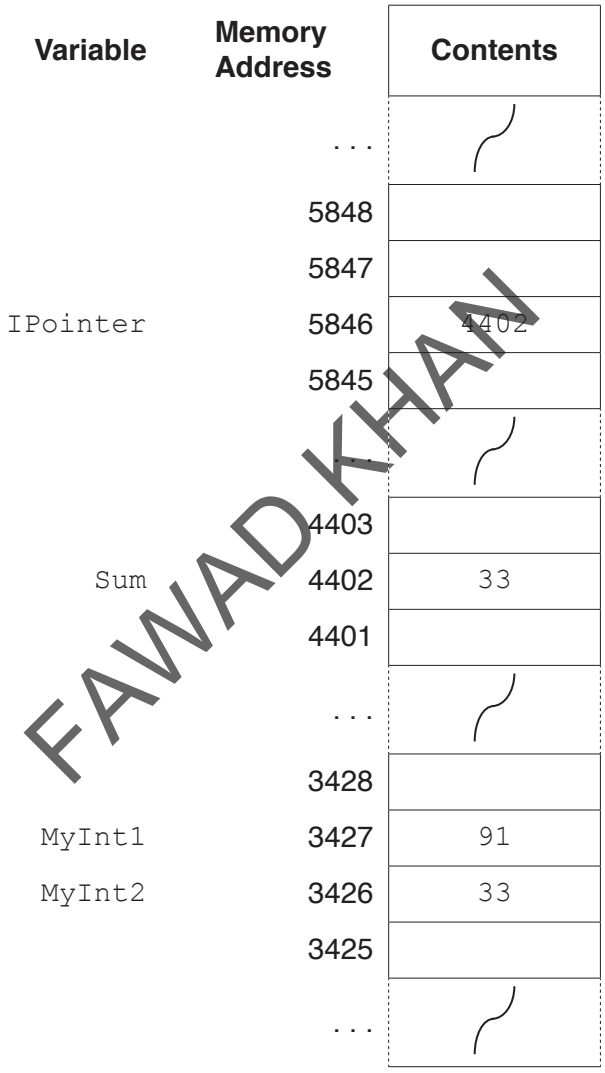
(c) A pointer is a variable that stores the address of a variable of a particular type.

Consider the pseudocode on page 3, which uses the following identifiers:

Identifier	Data type	Description
`IPointer`	`^INTEGER`	pointer to an integer
`Sum`	`INTEGER`	an integer variable
`MyInt1`	`INTEGER`	an integer variable
`MyInt2`	`INTEGER`	an integer variable

```
Sum ← 91              // assigns the value 91 to the integer variable Sum
IPointer ← @Sum       // assigns to IPointer the address of the
                      // integer variable Sum
MyInt1 ← IPointer^    // assigns to variable MyInt1 the value at an
                      // address pointed at by IPointer
IPointer^ ← MyInt2    // assigns the value in the variable MyInt2 to
                      // the memory location pointed at by IPointer
```

The four assignment statements are executed. The diagram shows the memory contents after execution.



Use the diagram to state the current values of the following expressions:

(i) `IPointer` .....[1]

(ii) `IPointer^` .....[1]

(iii) `@MyInt1` .....[1]

(iv) `IPointer^ = MyInt2` .....[1]

(d) Write pseudocode statements that will achieve the following:

(i) Place the address of `MyInt2` in `IPointer`.

.....[1]

(ii) Assign the value `33` to the variable `MyInt1`.

.....[1]

(iii) Copy the value in `MyInt2` into the memory location currently pointed at by `IPointer`.

.....[1]

10 9608/32/M/J/17/Q4

(a) Three file organisation methods and two file access methods are shown below.

Draw lines to link each file organisation method to its appropriate file access method(s).

File organisation method	File access method
random	sequential
serial	direct
sequential	

[4]

(b) An energy company supplies electricity to a large number of customers. Each customer has a meter that records the amount of electricity used. Customers submit meter readings using their online account.

The company's computer system stores data about its customers.

This data includes:

- account number
- personal data (name, address, telephone number)
- meter readings
- username and encrypted password.

The computer system uses three files:

File	Content	Use
A	Account number and meter readings for the current month.	Each time a customer submits their reading, a new record is added to the file.
B	Customer's personal data.	At the end of the month to create a statement that shows the electricity supplied and the total cost.
C	Usernames and encrypted passwords.	When customers log in to their accounts to submit meter readings.

For each of the files A, B and C, state an appropriate file organisation method for the use given in the table.

All three file organisation methods must be different.

Justify your choice.

(i) File A organisation .....

Justification .....

.....

.....

.....[3]

(ii) File B organisation .....

Justification .....

.....

.....

.....[3]

(iii) File C organisation .....

Justification .....

.....

.....

.....[3]

11 **9608/31/M/J/18/Q1**

In a computer system, real numbers are stored using normalised floating-point representation with:

- 12 bits for the mantissa
- 4 bits for the exponent
- Two's complement form for both mantissa and exponent.

(a) Find the denary value for the following binary floating-point number.

Mantissa

1	0	1	1	1	0	0	1	1	0	1	0

Exponent

0	1	0	1

Show your working.

Working .....

.....

.....

.....

.....

Answer .....

[3]

(b) Calculate the normalised floating-point representation of 5.25 in this system. Show your working.

Working .....

.....

.....

.....

.....

.....

Mantissa

Exponent

[3]

(c) The size of the mantissa is decreased and the size of the exponent is increased.

State how this affects the range and precision of the numbers that the computer system can represent.

.....

.....

.....

.....[2]

12 9608/31/M/J/18/Q2

A programmer uses non-composite and composite data types to create a program.

(a) Define the term **non-composite data type**.

.....

.....[1]

(b) Describe **two** different non-composite data types.

Data type 1 .....

Description .....

.....

.....

Data type 2 .....

Description .....

.....

.....

[4]

(c) Define the term **composite data type**.

.....

.....[1]

(d) Describe **two** different composite data types.

Data type 1 .....

Description .....

.....

.....

Data type 2 .....

Description .....

.....

.....

[4]

13 9608/32/M/J/18/Q1

Data types can be defined in a programming language.

The data type, `StudentRecord`, is defined by the code:

```
TYPE StudentRecord
   DECLARE StudentID        : INTEGER
   DECLARE StudentFirstName : STRING
   DECLARE StudentSurname   : STRING
   DECLARE StudentDOB       : DATE
   DECLARE StudentCourse    : ARRAY[1:10] OF STRING
ENDTYPE
```

A variable, `CollegeStudent`, is declared with the code:

```
DECLARE CollegeStudent : StudentRecord
```

(a) Write a pseudocode statement to assign 6539 to the `StudentID` of `CollegeStudent`.

.....[1]

(b) The type definition for `StudentRecord` is changed.

(i) Students can take six courses from: Computer Science, Engineering, Science, Maths, Physics, Chemistry, Music, Drama and English Language.

Rewrite **one** line from the type definition of `StudentRecord` to implement the change.

`DECLARE` .....

.....

.....

[2]

(ii) The values for the field `StudentID` must be between `1` and `8000` inclusive.

Rewrite **one** line from the type definition of `StudentRecord` to implement the change.

`DECLARE` .....[1]

(c) A programmer is asked to write a program to process the assessment data for each student. Students sit one exam in every course they take.

A composite data type, `StudentAssessment`, needs to be defined with the following three fields.

- a student assessment code (a unique code of three letters and two digits)
- the marks for the six exams
- the average mark of the six exams

(i) Write **pseudocode** to define the data type `StudentAssessment`.

.....

.....

.....

.....

.....

.....[4]

(ii) Data about all students and their assessments are stored in a file that uses random organisation. The `StudentID` is used as the key field.

The program allows a user to enter data for a new student.

Explain how the program adds the new data to the file.

.....

.....

.....

.....

.....

.....[3]

14 9608/32/M/J/18/Q3

In a computer system, real numbers are stored using normalised-floating point representation with:

- 8 bits for the mantissa
- 4 bits for the exponent
- two's complement form for both mantissa and exponent.

(a) Calculate the normalised floating-point representation of + 21.75 in this system. Show your working.

Working .....

.....

.....

.....

.....

.....

Mantissa								Exponent			

[3]

(b) Find the denary value for the following binary floating-point number.

Mantissa								Exponent			
1	0	1	1	0	0	0	0	1	1	1	0

Show your working.

Working .....

.....

.....

.....

.....

Answer .....

[3]

15 9608/31/O/N/18/Q1

Consider the following user-defined data type.

```
TYPE Book
     DECLARE ISBN     : INTEGER
     DECLARE Author   : STRING
     DECLARE Title    : STRING
     DECLARE Supplier : (Amazone, Stones, Smiths, Blackwalls, Greens,
                         Coals, Boarders)
ENDTYPE
```

(a) Name the data type of `Book`.

.....[1]

(b) Name the non-composite data type used in the `Supplier` declaration.

.....[1]

(c) (i) Write a pseudocode statement to declare a variable, `BestSeller`, of type `Book`.

.....[1]

(ii) Write a pseudocode statement to assign "`John Williams`" to the author of `BestSeller`.

.....[1]

16 9608/31/O/N/18/Q2

(a) A computer system stores real numbers using floating-point representation. The floating-point numbers have:

- eight bits for the mantissa
- four bits for the exponent.

The mantissa and exponent are both in two's complement form.

(i) Calculate the denary value of the following floating-point number.

Mantissa

0	0	1	1	1	0	0	0

Exponent

0	1	1	1

Show your working.

Working .....

.....

.....

.....

.....

Answer .....

[3]

(ii) State how you know the floating-point number in **part (a)(i)** is not normalised.

.....

.....[1]

(iii) Normalise the floating-point number in **part (a)(i)**.

Mantissa								Exponent			

[2]

(b) (i) Write the largest positive number that this system can represent as a normalised floating-point number in this format.

Mantissa								Exponent			

[2]

(ii) Write the smallest positive number that can be stored as a normalised floating-point number in this format.

Mantissa								Exponent			

[2]

(c) The number of bits available to represent a real number is increased to 16.

State the effect this has on the numbers that can be represented, if the additional four bits are used in the:

(i) mantissa .....

.....[1]

(ii) exponent .....

.....[1]

(d) A student enters the following code into an interpreter.

```
X = 0.1
Y = 0.2
Z = 0.3
OUTPUT (X + Y + Z)
```

The student is surprised to see the output:

```
0.6000000000000001
```

Explain why this is output.

.....

.....

.....

.....

.....

.....[3]

17 9608/32/O/N/18/Q1

(a) A computer system uses floating-point representation to store real numbers. The floating-point numbers have:

- 8 bits for the mantissa
- 8 bits for the exponent

The mantissa and exponent are both in two's complement form.

(i) Calculate the denary value of the following floating-point number. It is **not** in normalised form.

Mantissa								Exponent							
0	0	1	0	1	0	1	0	0	0	0	0	0	1	0	1

Show your working.

Working .....

.....

.....

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Answer .....

[3]

(ii) Convert the denary number +7.5 into a normalised floating-point number.

Show your working.

Mantissa								Exponent							

Working .....

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[3]

(iii) Convert the denary number –7.5 into a normalised floating-point number.

Show your working.

Mantissa **Exponent**

Working .....

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[3]

(b) A normalised floating-point number is shown.

Mantissa **Exponent**

0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1

(i) State the significance of this binary number.

.....

.....[1]

(ii) State what will happen if a positive number is added to this number.

.....

.....[1]

18 **9608/31/M/J/19/Q1**

In a computer system, real numbers are stored using normalised floating-point representation with:

- twelve bits for the mantissa
- four bits for the exponent.

The mantissa and exponent are both in two's complement form.

(a) Calculate the denary value for the following binary floating-point number.

Show your working.

Mantissa

1	0	0	1	0	1	1	1	0	0	1	1

Exponent

0	1	1	1

Working .....

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Answer .....

[3]

(b) Calculate the normalised floating-point representation of +1.5625 in this system.

Show your working.

Working .....

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Mantissa

Exponent

[3]

(c) **(i)** Write the largest positive number that can be stored as a normalised floating-point number using this format.

Mantissa **Exponent**

[2]

(ii) Write the smallest non-zero positive number that can be stored as a normalised floating-point number using this format.

Mantissa **Exponent**

[2]

(d) The developer of a new programming language decides that all real numbers will now be stored using 20-bit normalised floating-point representation. She must decide how many bits to use for the mantissa and how many bits for the exponent.

Explain the trade-off between using either a large number of bits for the mantissa, or a large number of bits for the exponent.

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..... [3]

19 **9608/32/M/J/19/Q1**

(a) A computer stores real numbers using floating-point representation. The floating-point numbers have:

- eight bits for the mantissa
- four bits for the exponent.

The mantissa and exponent are both stored in two's complement format.

(i) Calculate the denary value of the following floating-point number.

Show your working.

Mantissa **Exponent**

0	0	1	1	0	1	1	1	0	1	0	1				

Working .....

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Answer .....

[3]

(ii) State why the floating-point number in **part (a)(i)** is **not** normalised.

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..... [1]

(iii) Give the floating-point number in **part (a)(i)** in normalised two's complement format.

Mantissa **Exponent**

[2]

(b) (i) Convert the denary number +11.625 into a normalised floating-point number.

Show your working.

Working .....

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Mantissa **Exponent**

[3]