NAME DATE STARTED TARGET END DATE

GCE A LEVEL — COMPUTER SCIENCE UNIT 4 QUESTION PACK

1500U40-1 · 2015 spec Unit 4 Topic 6 · A2 unit, first sat 2017, 100 marks, 2h paper

REVISE.wales

COMPUTER SCIENCE — UNIT 4 · Number Representation — Binary, Two's Complement & Floating Point

Topic 4.6 — Binary arithmetic, two's complement, hexadecimal, arithmetic shifts, floating-point normalisation and rounding/truncation errors

Converting between denary, binary, hexadecimal and two's complement; performing arithmetic shifts on signed binary; subtraction by complementation; sign-and-magnitude vs two's complement; encoding real numbers in floating-point with separate mantissa and exponent fields, normalising and decoding them; and analysing truncation vs rounding errors.

2015 specification · current

Estimated time for entire question pack: ~1 h 52 min

Derived from the Unit 4 pace of ~1.5 min/mark, padded for written-prose answers (75 marks over 9 questions).

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive topic question pack**, not a single mock paper. It contains every question from the WJEC A2 Unit 4 papers (Summer 2017 – Summer 2024, COVID gap) that maps onto Topic 4.6 of the 2015 specification.

Questions are ordered by source paper date.

INSTRUCTIONS

Use black ink or black ball-point pen. Show all working. A calculator is allowed where useful.

For Examiner's use only

Q	Source	Max	Mark
1	S17 Q5	7	
2	S17 Q6	10	
3	S18 Q6	6	
4	S18 Q7	5	
5	S19 Q4	9	

Q	Source	Max	Mark
6	S22 Q5	10	
7	S23 Q5	8	
8	S23 Q6	6	
9	S24 Q8	14	
Total		**75**	

Number Representation — Binary, Two's Complement & Floating Point — what the spec asks

WJEC GCE A Level Computer Science (from 2015) · Unit 4: Computer Architecture, Data, Communication & Applications · Topic 4.6.

Hex ↔ binary ↔ denary

- 1 hex digit = 4 binary bits (nibble); group from the right.
- Hex digits: 0–9, A=10, B=11, …, F=15.
- Convert via binary as a bridge if either direct conversion is unclear.
- Always state the base on the answer: 123_{10}, $7B_{16}$.

Two's complement

- Most significant bit is the sign bit (1 = negative).
- Negate: invert all bits then add 1.
- Range for n bits: -2^{n-1} to $2^{n-1}-1$.
- Subtraction A − B ≡ A + (−B) using two's complement of B.

Arithmetic shifts

- Left shift by 1 ≡ multiply by 2; right shift by 1 ≡ divide by 2.
- Arithmetic right shift preserves the sign bit (fills with the sign).
- Logical right shift fills with 0 (wrong for negative numbers).
- Can overflow on left shift if a 1 is shifted out of the sign bit.

Floating-point format

- Real numbers stored as mantissa × 2^{exponent}.
- Both mantissa and exponent in two's complement of fixed widths.
- Binary point conventionally just after the leftmost mantissa bit.
- Normalised form: leading bits 01 (positive) or 10 (negative) — maximises precision.

Truncation vs rounding

- Truncation: chop off the extra bits/digits — biased towards smaller magnitude (towards zero).
- Rounding: pick the nearest representable value — smaller average error.
- Absolute error = |actual − stored|.
- Relative error = |actual − stored| / |actual|.

Common pitfalls

- Forgetting to add 1 after inversion in two's complement.
- Sign-extending wrongly on shifts.
- Mis-counting bits in floating-point conversions.
- Confusing logical and arithmetic shifts.

Crib sheet »

Number Representation — Binary, Two's Complement & Floating Point in one page

Quick-reference notes — revisit before each question.

Two's comp negate

1. Invert all bits.
2. Add 1.
e.g. 0000 0111 (+7) → 1111 1000 + 1 = 1111 1001 (−7).

Hex ↔ binary

1 hex digit = 4 bits.
Group bits in 4s from the right.
e.g. 5A = 0101 1010.

Subtraction

A − B ≡ A + (−B).
Negate B with two's comp, then add normally.
Discard carry-out from the sign-bit column.

Floating-point

Mantissa × 2^{exponent}.
Both in two's complement.
Normalise: leading bits 01 (+) or 10 (−).
Bigger exponent → bigger magnitude.

Shift effects

L1 = ×2 · L2 = ×4 · L3 = ×8
R1 = ÷2 · arith R preserves sign.
Overflow if a 1 shifts past the sign bit.

Error types

Absolute error = |true − stored|.
Relative error = absolute / |true|.
Truncation worse (biased to zero); rounding fairer.

4. *(a)* Explain the meaning of the term parallel processing; your answer should make reference to how parallel processing carries out a single task. [3]

(b) Give **four** limiting factors of parallel processing. [4]

5. (a) Explain the difference between truncation and rounding giving a binary example of truncation and a denary example of rounding. [4]

(b) State which method generally produces a more accurate result. [1]

(c) Describe how absolute and relative errors are calculated when truncating and rounding. [2]

6. *(a)* Convert the hexadecimal numbers -7_{16} and A_{16} into two 8 bit binary numbers, using two's complementation. Using binary addition, calculate the binary number that would result from adding them.

You must show all of your working. [4]

(b) In a certain computer system, real numbers are stored in floating point form using 16 bits as shown below.

Mantissa	**Exponent**
12 bits in two's complement form. The binary point in the mantissa is immediately after the left bit.	4 bits in two's complement form

Clearly showing your working, convert 42.875_{10} into this format. [3]

(c) In a different computer system, real numbers are stored in floating point form, an 8 bit signed mantissa and a 4 bit signed exponent.

Clearly showing your working, calculate the decimal value of $0.1111011\ 0101_2$ [3]

4. *(a)* Explain the meaning of the term parallel processing; your answer should make reference to how parallel processing carries out a single task. [3]

(b) Give **four** limiting factors of parallel processing. [4]

5. (a) Explain the difference between truncation and rounding giving a binary example of truncation and a denary example of rounding. [4]

(b) State which method generally produces a more accurate result. [1]

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6. *(a)* Convert the hexadecimal numbers -7_{16} and A_{16} into two 8 bit binary numbers, using two's complementation. Using binary addition, calculate the binary number that would result from adding them.

You must show all of your working. [4]

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Clearly showing your working, calculate the decimal value of $0.1111011\ 0101_2$ [3]

7. *(a)* When scheduling, name and describe the **three** basic states of a process. [6]

(b) Interrupts cause the operating system to respond to system events. Give **two** examples of common interrupts. [2]

(c) Describe a single buffer and a double buffer. Explain the role of a single buffer and a double buffer. Explain why double buffering is usually preferred. [5]

8. Cryptography uses asymmetric or symmetric encryption methods.

Symmetric encryption methods use a single key which encrypts and decrypts data. Asymmetric encryption methods use a public key for encryption and a private key for data decryption.

(a) Describe the advantages of asymmetric encryption and the advantages of symmetric encryption. [4]

(b) The Boolean operation XOR is often used in cryptography.

In the 8 bit ASCII character set, the characters OK! are represented by the following binary numbers.

O = 01001111_2
K = 01001011_2
! = 00100001_2

Use XOR to encrypt the string OK! with the 8 bit binary key 11110011_2 [3]

(c) Describe **two** deficiencies of the key used in question 8*(b)*. [2]

9. A company with a large office building operates a “Bring Your Own Device to Work” (BYOD) scheme allowing employees to use personal devices (e.g. tablet or laptop) on the company’s network.

(a) Describe the hardware necessary to connect a device to the company’s network wirelessly and provide an Internet connection. [3]

(b) Identify and describe **two** network applications that could be used by an employee with a connected device. [4]

6. *(a)* Explain, giving an example, how an integer can be subtracted from another integer using two's complementation. [3]

(b) Identify **three** types of error that could occur when performing logical left shifts on a number in two's complement form. [3]

7. In a certain computer system, real numbers are stored in floating point form using two's complementation, a 10 bit mantissa and a 6 bit exponent.

(a) Calculate the denary number represented by the floating point number:

0110 1101 00	0001 11

[3]

(b) State the effect on the result in question 7*(a)* if 1 is subtracted from the value of the exponent to give:

0110 1101 00	0001 10

Calculate the denary number represented by the new floating point number. [2]

6. *(a)* Explain, giving an example, how an integer can be subtracted from another integer using two's complementation. [3]

(b) Identify **three** types of error that could occur when performing logical left shifts on a number in two's complement form. [3]

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0110 1101 00	0001 10

Calculate the denary number represented by the new floating point number. [2]

8. *(a)* (i) State a security problem that may arise if a single key (symmetric) encryption method is used. [1]

(ii) An asymmetric encryption method makes use of a private and public key pair. Explain how these could be used in the safe transfer of data over the internet. [3]

(b) A method of encrypting text is the Caesar cypher. Each letter is moved forward in the alphabet by a fixed number of places using modulo 26 arithmetic. For example, using a shift of 5 places, W becomes B.

State why messages using the Caesar cypher can be decrypted easily by an unauthorised person. [1]

(c) Two members of staff in a law firm decide to exchange a confidential message over the Internet using a stream cypher method:

- Letters in the original message are shifted forward by a specified number of positions in the alphabet using modulo 26 arithmetic, but each character in the message is moved forward by a different number of letters.
- The shifts for the first two letters in the message have been agreed:

  shift[1] = 4

  shift[2] = 3
- The letter shifts for each following letter in the message are calculated with the formula:

  shift[N+2] = shift[N] + 2 times shift[N+1]

  where N = (position of the letter in the message) –2

  In this way, for the third letter,

  shift[3] = shift[1] + 2 x shift[2] = 4 + (2 x 3) = 10
- Modulo 26 arithmetic is again used. For example, a shift calculated as 30 places would become a shift of (30-26) = 4 places.

(i) Calculate the letter shifts for the characters in the fourth and fifth positions. [2]

(ii) Encrypt the word ZEN using this cypher. [3]

9. A large and complex computing task needs to be carried out. Programmers consider two possible solutions:

- using parallel processing on a large computer
- using distributed processing on smaller computers.

(a) Explain what is meant by parallel processing and distributed processing. [4]

(b) Discuss the factors that the programmers might consider when making a choice between parallel processing and distributed processing. [4]

(a) Write an SQL command to output the CourseTitle and Degree only, for all of the courses. [1]

(b) Write an SQL command to output the ModuleTitle for all modules available on the degree course with CourseID 427. [1]

(c) Write an SQL command to change the year in which the module Freshwater Biology is studied. This module is now to be studied in year 3. [1]

(d) Write an SQL command to output the ModuleTitle and YearStudied for all modules available on the Modern Languages course for the BA Degree. [2]

(e) Write an SQL command to list the ModuleTitle and StudentsEnrolled for all modules which have less than 20 students or more than 40 students enrolled. [2]

4. In a certain computer real numbers are stored in floating point form using 16 bits as shown:

Mantissa (10 bits in two's complement form. The binary point in the mantissa is immediately after the most significant bit)	**Exponent** (6 bits in two's complement form)

(a) Convert the number 5.75_{10} into this floating point form. Your final answer should be normalised. [3]

(b) Two different numbers 5.75_{10} and 25.5_{10} are to be multiplied. Three different methods are considered.

Method 1: Round both numbers to integers, then multiply.
Method 2: Multiply the decimal numbers, then round the final result to an integer.
Method 3: Multiply the decimal numbers, then truncate the final result to an integer.

(i) Calculate the absolute errors which would occur with each of these methods in comparison to the full accuracy of the decimal calculation. [3]

(ii) Discuss the relative accuracies of each of the three methods above. [3]

(c) Integers are stored in a different computer system in 16 bits using two's complementation. Demonstrate, showing your working, how the computer would store the value -152_{10}. [2]

5. In a certain computer the following assembly language commands are available, where R, S, T and U are the processor registers.

Assembly Language Command	**Description**
LOD R, X	Load register R with the numerical value X
ADD R, S	Add the contents of register R to register S, leaving the result in register R
INC R	Add 1 to the contents of register R
DEC R	Subtract 1 from the contents of register R
JMP LABEL	Jump unconditionally to LABEL
JNG R, LABEL	Jump to LABEL if the contents of register R are less than zero
IN R	Input a numerical value and store in register R
OUT R	Output the contents of register R

Write a program to input a number of daily rainfall readings (in mm) for a weather station, ending with a rogue value of –1. The program should then output the total rainfall and the number of readings. [6]

Example: input values 0 16 8 0 2 –1

output 26
5

4. The Internet enables the use of many communication applications. Describe the distinguishing characteristics of these communication applications:

- Podcast
- Blog
- Instant messaging
- Webcast [8]

5. A certain computer uses this 16 bit floating point representation:

Mantissa	**Exponent**
8 bits in two's complement form. The binary point in the mantissa is immediately after the leftmost bit.	8 bits in two's complement form.

(a) Convert the number 7.1875_{10} into this floating point representation. [3]

(b) Determine the most accurate representation possible for 19.3_{10} using this floating point representation. [2]

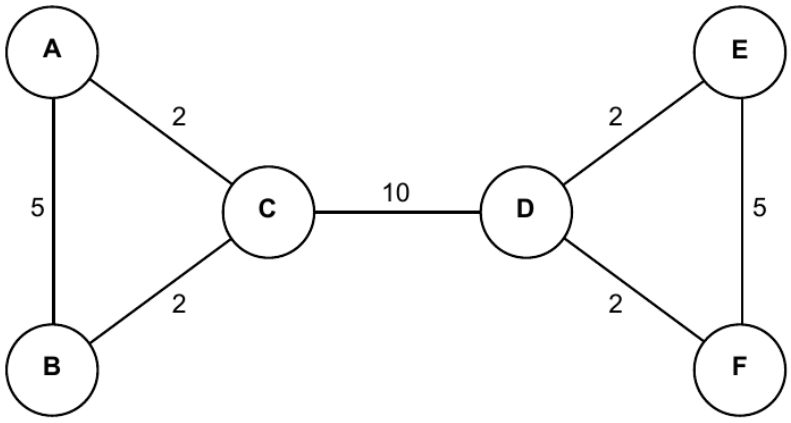
(c) Calculate the absolute and relative errors in denary for this floating point representation of 19.3_{10}. [4]

(d) Describe the relationship between the size of the mantissa and exponent in the representation of a floating point number. [3]

6. In a certain computer network the protocol used to determine lowest cost routes is based on transfer rates and delays. Transfer rates are based on bandwidth of network links. Delays represent the overhead arising from the time taken for a router to process, queue and transmit a data packet.

The total route cost is calculated as the cost of each link multiplied by the total of the delay factors of each intermediate router visited.

This is a diagram of the network. The delay at each intermediate router = 1.2.



(a) Calculate the lowest cost route from router A to router F. [2]

(b) (i) A new link of bandwidth cost = 14 is to be added from B to F. Re-calculate the lowest cost route from router A to router F. [2]

(ii) The link from router C to router D is then upgraded to a network cost of 5. Describe the effect the upgrade will have on overall network costs. [2]

7. Phishing is the most common cyber-attack vector.

(a) Explain what is meant by the term 'cyber-attack vector'. [2]

(b) Describe **two** other cyber-attack vectors. [4]

8. Penetration testing is an important aspect of computer security.

(a) State what is meant by the term penetration testing. [1]

(b) Describe **three** penetration testing strategies. [6]

The assembly language used by the microprocessor has an instruction set, which includes the following commands:

Assembly Language Command	Description
IN	Input a weight to the accumulator
OUT X	Output a numeric value X
ADD Y	Add the numeric value in location Y to the accumulator, leaving the result in the accumulator
SUB Y	Subtract the numeric value in location Y from the accumulator, leaving the result in the accumulator
JNG LABEL	Jump to LABEL if the contents of the accumulator are less than zero
JMP LABEL	Jump unconditionally to LABEL

Using the algorithm and instruction set, write a program in assembly language to control the weighing system. [6]

4. Giving an example for each, explain what is meant by batch processing and real time transaction processing. [8]

5. (a) Giving an example for each, describe the format of sign and magnitude and two's complement when representing negative binary integers. [4]

(b) A certain computer uses this floating point representation:

Mantissa	**Exponent**
10 bits in two's complement form. The binary point in the mantissa is immediately after the leftmost bit.	6 bits in two's complement form.

Find the base-10 (denary) number represented by the floating point value:

0110010101 000110 [2]

6. Describe the process and effects of carrying out arithmetic shifts on a two's complement negative binary number. [4]

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IN	Input a weight to the accumulator
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Find the base-10 (denary) number represented by the floating point value:

0110010101 000110 [2]

6. Describe the process and effects of carrying out arithmetic shifts on a two's complement negative binary number. [4]

7. The owner of a shop requires a program to store stock records. Each stock item has a three-digit identification code in the range 000 to 999. The number of different stock items held by the shop is currently 95.

A programmer considers two different methods of storing the stock records:

- A direct access file with 100 storage locations. The location for each item is calculated using the hash function: identificationCode MOD 100.
- A sequential access file with 1000 storage locations. The stock record is stored at the location corresponding to its identification code, so product 715 will be stored at location 715.

Explain the advantages and disadvantages of these two methods. [6]

8. Describe the three basic states of a process in a multi-tasking computer. [6]

9. Improved worker safety is a benefit of automation.

(a) Describe **two** *other* benefits and **two** drawbacks of automating a manufacturing process. [4]

(b) Explain, giving an example of each type of system, the main purpose of:

- a safety related control system
- a safety critical control system.

[4]

8. (a) Explain, using a suitable example, the difference between truncating and rounding a real number when stored as an integer in a 4-bit register. [4]

(b) Convert the hexadecimal numbers $1A_{16}$ and -14_{16} into two 8-bit binary numbers, using two's complementation. Using binary addition, calculate the binary number that would result from adding the two numbers. [4]

(c) In a certain computer system, real numbers are stored in floating point form using 16-bits as shown.

Mantissa	Exponent
12-bits in two's complement form. The binary point in the mantissa is immediately after the left bit	4-bits in two's complement form

Clearly showing your working, convert 52.875_{10} into this format. [3]

(d) In a different computer system, real numbers are stored in floating point form with an 8-bit signed mantissa and a 4-bit signed exponent.

Calculate the denary value of 00100101 0101. [3]

9. A database administrator will refer to data dictionaries and use a Database Management System (DBMS) in their work.

(a) Describe the contents of a data dictionary. [2]

(b) Explain the purpose of a DBMS. [6]

END OF QUESTION PACK

9 questions · 75 marks · ~1 h 52 min
Source: WJEC A2 Computer Science Unit 4 (1500U40-1), Summer 2017–2024, COVID gap
Curated for WJEC Computer Science 2015 spec A2 Unit 4 — Topic 6 (4.6)