NAME DATE STARTED TARGET END DATE

GCE A LEVEL — COMPUTER SCIENCE UNIT 4 QUESTION PACK

1500U40-1 · 2015 spec Unit 4 Topic 3 · A2 unit, first sat 2017, 100 marks, 2h paper

REVISE.wales

COMPUTER SCIENCE — UNIT 4 · Parallel & Distributed Processing

Topic 4.3 — Parallel processing speed-up (Amdahl), limiting factors, distributed systems and distributed databases

Applying the parallel processing speed-up formula, identifying limiting factors (serial bottleneck, communication overhead, code structure), explaining what is meant by parallel vs distributed processing, and weighing the advantages of distributed databases over a single centralised database for multi-site organisations.

2015 specification · current

Estimated time for entire question pack: ~1 h 42 min

Derived from the Unit 4 pace of ~1.5 min/mark, padded for written-prose answers (68 marks over 10 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 4.3 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 Q2	5	
2	S17 Q4	7	
3	S18 Q9	8	
4	S19 Q12	6	
5	S19 Q13	8	

Q	Source	Max	Mark
6	S22 Q11	7	
7	S22 Q12	4	
8	S23 Q2	9	
9	S23 Q12	4	
10	S24 Q4	10	
Total		**68**	

Parallel & Distributed Processing — what the spec asks

WJEC GCE A Level Computer Science (from 2015) · Unit 4: Computer Architecture, Data, Communication & Applications · Topic 4.3.

Parallel processing definition

- Splitting a single task across multiple processors that work simultaneously.
- Each processor works on a different sub-problem, results combined at the end.
- Different from multi-tasking (running unrelated programs on one CPU).
- Used for scientific simulation, image processing, training large models.

Speed-up formula (Amdahl)

- `speed-up = 1 / ((1-p) + p/n)`, where *p* is the parallel fraction and *n* the processor count.
- As *n* → ∞, speed-up → 1 / (1-p).
- If 80% can be parallelised, max speed-up = 5×.
- Used in past papers to compute realistic run times.

Limiting factors

- Serial fraction: parts that *must* run sequentially put a hard ceiling on speed-up.
- Communication / synchronisation overhead between processors.
- Dependencies: a task that needs the output of another can't start early.
- Memory bandwidth and shared-resource contention.

Tasks not suitable for parallelism

- Sequential / dependent calculations (Task 2 needs Task 1's output).
- Short tasks where setup cost dwarfs gain.
- Heavily synchronised work (lots of locking).
- Algorithms with inherent serial bottlenecks (e.g. cumulative state).

Distributed processing

- Multiple connected computers co-operate on one workload.
- Each node has its own CPU and memory; communication via network.
- Provides fault tolerance, scalability and geographic distribution.
- Example: mainframe + clients, cloud compute fleets, content delivery networks.

Distributed databases

- Data is split (partitioned) and/or replicated across multiple sites.
- Local queries are faster — data is close to users.
- Resilience: failure of one site doesn't take down the whole system.
- Trade-offs: complex consistency, replication overhead, harder admin.

Crib sheet »

Parallel & Distributed Processing in one page

Quick-reference notes — revisit before each question.

Amdahl in one line

S = 1 / ((1 − p) + p/n)
p = parallel fraction, n = processors.
Max S as n→∞ is 1/(1−p).

Limit factors

Serial bottleneck (Amdahl).
Communication overhead.
Data dependencies.
Memory / shared-resource contention.

Worked Amdahl example

16h on 1 CPU, 80% parallel, 8 CPUs.
Parallel part = 0.8 × 16h = 12.8h on 1 CPU
→ 12.8/8 = 1.6h.
Serial part = 0.2 × 16h = 3.2h.
Total = 4.8h.

Distributed processing

Multiple nodes co-operate over a network.
Each has own CPU + memory.
Fault tolerance, scalability, locality.

Distributed database

Partitioned and/or replicated.
Pros: locality, resilience, scalable.
Cons: consistency complexity, network dependence.

Parallel vs distributed

Parallel = tight coupling, shared memory, low-latency.
Distributed = loose coupling, message-passing, fault-tolerant.

Answer **all** *questions.*

1. Two tables have been created in a database using SQL commands. They are:

CUSTOMER

CustNum	CustName	DateOfFlight	FlightNum
12455	McClintock	02-Dec-17	370
13670	Storey	03-Jun-17	378
14777	Rice	23-Aug-17	345
14756	Radford	28-Feb-17	370
21328	George	18-Jan-17	378

FLIGHT

FlightNum	Destination	Terminal
370	Rome	1
345	Florida	5
378	Bahrain	1

(a) Write an SQL command to output the names and flight numbers of all the customers. [1]

(b) Write an SQL command to output all details of customers who are on flight number 370. [1]

(c) Write an SQL command to output the names of all the customers flying from Terminal 1. [2]

(d) Write an SQL command to create a new table FREQUENTFLYER to contain the Customer Number and Frequent Flyer points of each customer. [2]

(e) Write an SQL command to enter the following data into the new table.

- Customer 21328 should have 210 points
- Customer 14777 should have 300 points [2]

2. Describe the advantages of using a distributed database. [5]

3. A certain computer has an 8 bit accumulator with the following data stored in memory.

- Memory location 1A holds the number 0_{10}
- Memory location 1B holds the number 1_{10}
- Memory location 1C holds the number 9_{10}

The computer's assembly language instruction set contains the following commands.

Assembly Language Command	Description
LDA X	Load the accumulator with the contents of memory location X
JGT LABEL	Jump to LABEL if the contents of the accumulator are greater than zero
ADD X	Add the contents of memory location X to the accumulator
STA X	Copy the contents of the accumulator to memory location X
CLR	Clear the contents of the accumulator
OUT	Output the contents of the accumulator
DEC X	Decrement the accumulator by the contents of memory location X

(a) Write a simple program using only the assembly language commands above to output the integers 0_{10} to 9_{10}. [4]

(b) Two extra commands are defined as follows:

ASR R	Performs an arithmetic shift right one place on register R
LDR P, Q	Load register P with the contents of memory location Q

Demonstrate what the following fragment of code does, by showing the contents of registers and memory locations at each step. [5]

- Memory location 1D holds the number 0111 1000_2
- Memory location 1E holds the number 0100 0110_2

```
LDR R, 1D
LDR S, 1E
ASR R
LDA R
ADD S
STA R
```

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]

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]

10. *(a)* Explain what is meant by the term biometric data. [2]

(b) Describe **two** examples of biometric data. [2]

(c) Explain using an example how biometric data can permit access to a secure area or system. [4]

(d) Explain why there may be objections to the use of biometric data. [4]

11. Large organisations use database management systems.

Explain what is meant by a database management system and discuss the tasks carried out by the Information Technology staff who operate the database management system. [10]

END OF PAPER

8. Define the term **data mining** and describe how three different organisations might use data mining. [8]

9. Describe four data validation techniques. [4]

10. *(a)* Describe the types of malicious software which might be transferred to computers and the delivery mechanisms, and the steps that can be taken to protect against these. [6]

(b) Computer data may be at its highest security risk during transfer from one location to another. Outline the risks that exist at this time, and how they can be minimised. [4]

11. A city is developing a new light railway system to connect the city centre to the surrounding suburbs. The system will use driverless trains, and several computer centres will control different areas of the network.

(a) Give examples of input and output which might be required by control systems on board the trains. [3]

(b) The system will be safety critical. Explain what is meant by a safety critical system, describing measures that are involved in ensuring safety. [5]

12. Describe the operation of a mainframe computer using a multi-programming, multi-user operating system. [7]

13. Explain what is meant by distributed processing, and describe how this will operate using an example that you have studied. [6]

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10. (a) Describe what is meant by the term relational database. [2]

(b) Describe the advantages of database normalisation. [4]

A health care company is creating a relational database to manage its dental surgeries located in different towns across Wales.

Each dental surgery employs **dentists** who will only work in that **surgery**. **Patients** will be registered with one of the dentists and will only be treated by that dentist. Patients will book **appointments** to see their dentist.

(c) Produce an entity relationship diagram for the system described. [3]

(d) Design a database structure in third normal form for the system. [3]

11. The increase in speed due to parallel processing can be calculated as:

$$\frac{1}{S + \frac{P}{N}}$$

where P = parallel fraction, N = number of processors and S = serial fraction. (S = 1 – P)

(a) Calculate the increase in speed due to parallel processing using 10 processors and the increase in speed of doing the same task using 1000 processors, where the parallel fraction P is equal to:

- 0.5 for 10 and 1000 processors
- 0.9 for 10 and 1000 processors [4]

(b) Discuss the effect that increasing the parallel fraction of the task will have on the speed due to parallel processing. [3]

12. Describe the advantages of using a distributed database. [4]

13. Cryptography may be based on symmetric or asymmetric algorithms. Describe the advantages of using asymmetric encryption. [6]

14. A local hospital needs to ensure that access to its medical laboratories is restricted to authorised personnel. It is considering using biometric technologies to identify and restrict access to authorised personnel only.

Describe the biometric options available to the hospital and explain the main benefits and drawbacks of biometric security technologies. [9]

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END OF PAPER

Answer **all** questions.

1. Giving an example for each, describe why the following applications might be preferred over keyboard entry:

(a) creating a text document by voice recognition. [2]

(b) controlling an electronic device by voice input. [2]

(c) managing a security system by voice print recognition. [2]

2. (a) A series of calculations must be carried out to complete a process:

Task 1: $a = bx + cy$

Task 2: $d = ex + f^2$

Task 3: $g = hy - d$

Explain why these tasks are **not** suitable for parallel processing. [2]

(b) A computer model is to be used to predict economic forecasts for an industrialised country. The model involves many complex calculations. It is estimated that it will take 16 hours to run on a single processor computer.

80% of the algorithm can be carried out in parallel. The remaining parts of the algorithm must be carried out serially.

Determine the time taken to run the parallel processing elements of the economic forecast model on a parallel processing system using 8 processors. [2]

3. In a food factory, packages are filled as they travel along a conveyor belt. The packages are weighed and any underweight packages are rejected.

A control program for the weighing system is to be written in assembly language. The minimum acceptable weight is stored in memory location **R**. The required algorithm is:

```
LOOP continuously
    input package weight
    subtract the value stored in location R from the input weight
    IF the remainder is zero or greater THEN
        output value 1
    ELSE
        output value 2
    ENDIF
END LOOP
```

12. (a) Explain what is meant by a distributed system and describe what will be distributed in the system. [2]

(b) A car manufacturer has a number of dealerships across the UK. Car owners take their cars for servicing each year to a convenient dealership. Records are kept of servicing, any faults found, and replacement parts fitted.

Explain the advantages to the company of implementing a distributed database system across its dealerships compared with using a single centralised database. [4]

13. (a) Explain the advantages and disadvantages of single key (symmetric) encryption compared with double key (asymmetric) encryption, giving an example, for each method, of a situation where that method would be the most suitable. [6]

(b) Text is stored in 8-bit binary ASCII format, with numeric codes representing each character:

A = 65_{10} $0100\ 0001_2$

B = 66_{10} $0100\ 0010_2$

C = 67_{10} $0100\ 0011_2$

The text is encrypted using a sequential XOR method:

- The first character is encrypted by XOR with the key value $0110\ 1010_2$
- The second character is encrypted by XOR with the encrypted value of the first character
- The third character is encrypted by XOR with the encrypted value of the second character

Using this algorithm, encrypt the word CAB. [3]

14. (a) Identify **two** hardware devices required to make a wireless connection to a network. [2]

(b) State **two** protocols used for wireless digital communication. [2]

(c) Describe **one** disadvantage of using a public wireless network. [2]

15. Information and advice on medical and health issues are readily available to the public through the internet, including online expert systems. Discuss the possible effects of using the internet for this purpose on health professionals and the wider community. [9]

END OF PAPER

4. (a) The maximum increase in speed due to parallel processing can be calculated as:

$$\frac{1}{S + \frac{P}{N}}$$

where P = parallel fraction, N = number of processors and
S = serial fraction. (S = 1 – P)

(i) Calculate the maximum increase in speed due to parallel processing using 2 processors and the increase in speed of doing the same task using 20 processors, where the parallel fraction P is equal to:

- 0.5 for 2 and 20 processors
- 0.9 for 2 and 20 processors [2]

(ii) Explain the limiting factor of parallel processing indicated by your calculations. [4]

(b) Explain **two** other limiting factors to parallelisation in parallel processing. [4]

5. An interrupt is a signal that is sent to the processor to request immediate attention. The operating system will have interrupt service routines designed to process each interrupt.

(a) Identify **two** events which could generate an interrupt. [2]

(b) Priorities are used when more than one device raises an interrupt. Describe how priorities are used when handling interrupts. [4]

(c) Describe the process carried out when an interrupt affects the execution of the fetch-decode-execute cycle of a running program. [6]

END OF QUESTION PACK

10 questions · 68 marks · ~1 h 42 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 3 (4.3)