Computer Systems

[Day] [Month] [Year]

Examination Paper

Answer ALL questions.

Clearly cross out surplus answers.

Time: 3 hours

The maximum mark for this paper is 100.

Any reference material brought into the examination room must be handed to the invigilator before the start of the examination.

Answer ALL questions

Marks

Question 1

a) The correct CPU cycle sequence is (Select ONE (1)) **1**

i) Fetch, decode, write
ii) Fetch, decode, execute
iii) Fetch, uncompress, execute
iv) Decode, fetch, execute

Mark scheme

iii) Fetch, decode, execute

b) ONE (1) nanosecond is (Select ONE (1)) **1**

i) Thousandth of a second
ii) Millionth of a second
iii) Thousand millionth of a second
iv) Million millionth of a second

Mark scheme

iii) Thousand millionth of a second

c) CPU ALU stands for (Select ONE (1)) **1**

i) Advanced logical unit
ii) Allowed access unit
iii) Access limiting utility
iv) Arithmetic and logical unit

Mark scheme

iv) Arithmetic and logical unit

d) Hexadecimal number 3A is binary (Select ONE (1)) **1**

i) 00111010
ii) 10100011
iii) 00110101
iv) 01011100

Mark scheme

i) 00111010

e) Watchdog in a microcontroller is used to (Select ONE (1)) **1**

i) Keep time of the day
ii) Delay CPU instructions
iii) Restart CPU from the beginning
iv) Watch over CPU speed

Mark scheme

iii) 00111010

f) Identify FIVE (5) types of digital computers. **5**

Mark scheme

1 mark for each of the following, maximum 5 marks

- ***Microcontroller***
- ***Server***
- ***Distributed***
- ***Mainframe***
- ***Multi-core***
- ***Any other creditable digital computer***

Total 10 Marks

Question 2

You are designing a new device that has a small but fast memory. The memory is addressed using a 12-bit address bus. A requirement is that the memory contents must not be lost after powering off the device. The data bus is an 8-bit bus. The CPU speed is 50 MHz.

a) Does the device need to use volatile or non-volatile memory? Justify your answer. **2**

Mark scheme

Non-volatile (1 mark), content not lost when no power (1 mark)

b) Is a dynamic or static type of memory best for the device? justify your answer. **2**

Mark scheme

Static (1 mark), it's faster (1 mark)

c) Calculate the maximum size of memory in bytes that can be supported by this device. You must show your working. **2**

Mark scheme

Size = 2^{12} bytes (1 mark) = 4096 bytes (1 mark)

d) The device can transfer 8-bit data every 2 clock cycles. Calculate how long it will take to transfer 10 Mbyte data. You must show your working. **3**

Mark scheme

2 clock times = 2/50 x 103 sec = 40 usec (1 mark), time taken = 40 x 10 x 103 usec (1 mark) = 4 x 105 usec = 4 x 105 /106 sec = 0.4 sec (1 mark)

e) The CPU idle time must not exceed 4 clock cycles while waiting for data from memory. Calculate the minimum speed of memory accesses. You must show your working. **1**

Mark scheme

4 clock times = 4/50 x 103 sec = 80 usec (1 mark)

Total 10 Marks

Question 3

a) An operating system is managing THREE (3) processes P1, P2 and P3. The priorities of the processes are 1, 2 and 3 respectively. Assume the highest priority is 1 and the lowest is 3. Processes start in the order of P2, P3 and P1. The first process, P2, is already running when the other TWO (2) processes, P3 and P1, start. Each process runs once only.

i) Assuming *round-robin scheduling* is used, show in what order the processes will run. **1**

[Insert the marking scheme for part (b) here.] ***[Insert t***

P2, P3, P1 (1 mark for sequence)

ii) Assuming *priority-based scheduling* is used, show in what order the processes will run. **2**

[Insert the marking scheme for part (b) here.] ***[Insert t***

P2, P1, P3 (1 mark for swapping P1 and P3, 1 mark for sequence)

iii) Assuming *priority-based, pre-emptive scheduling* is used, show in what order the processes will run. **2**

[Insert the marking scheme for part (b) here.] ***[Insert t***

P1, P2, P3 (1 mark for swapping P1 and P2, 1 mark for sequence)

iv)

b) An operating system has states, and it moves from one state to another under certain conditions. Moving from one state to another is called a transition.

i) Identify the THREE (3) main states. **3**

[Insert the marking scheme for part (b) here.] ***[Insert t***

1 mark for each of the following, a maximum of 3 marks

- ***Ready***
- ***Running***
- ***Waiting / Suspended***

ii) Identify which state a new process is first put in. Identify which next state this process can possibly transition into. You may use a diagram; use arrows to show directions of the transitions. **2**

[Insert the marking scheme for part (b) here.] ***[Insert t***

Ready (1 mark)

iii) ***Ready → Running (1 mark)***

Total 10 Marks

Question 4

a) Computer systems process binary numbers, and binary numbers can be expressed in different formats.

i) Add binary numbers 10011 and 01011. Give the result as a binary number. **1**

[Insert the marking scheme for part (b) here.]

11110 (1 mark)

ii) Prove your answer by converting the numbers in i) to decimal numbers. **2**

[Insert the marking scheme for part (b) here.]

10011 = 19, 01011 = 11, 11110 = 30 (1 mark for conversions, 1 mark for the proof 19 + 11 = 30)

iii) Convert the hexadecimal number B5C9 to its binary form. **1**

[Insert the marking scheme for part (b) here.]

1011 0101 1100 1001 (1 mark)

iv) Use two's complement method to negate the binary number 01101100. **2**

[Insert the marking scheme for part (b) here.]

10010011 (1 mark for inverting)

v) *10010011 + 1 = 10010100 (1 mark for adding 1)*

b) Computers use logical operators when processing logic values, TRUE or FALSE, in logic circuits. Logic gates in logic circuits function as logic operators.

i) A logic gate has TWO (2) inputs and one output. The only time its output is TRUE is when both inputs are TRUE. Identify the type of this gate. What gate will it be called if both inputs are negated? **2**

[Insert the marking scheme for part (b) here.]

AND gate (1 mark), NAND gate (1 mark)

ii) A water system has TWO (2) valves that control the flow of water. Water stops flowing only when both valves are closed. What logic does this represent? What logic name is given to the system where water stops flowing only when both valves are open? **2**

[Insert the marking scheme for part (b) here.]

OR logic (1 mark), NOR logic (1 mark)

iii)

Total 10 Marks

Question 5

Computer programs are composed of CPU instructions and data, all in binary form. The instructions are executed by the CPU. Some instructions make use of the data when executing. A typical CPU instruction has an opcode and may have ONE (1) or more operands.

a) Explain the function of an Opcode. Give TWO (2) examples of opcodes. **3**

Mark scheme

Opcode defines what operation the instruction is doing (1 mark)
1 mark each for the TWO (2) credible examples, a maximum of 2 marks.

Examples can include:

- ***ADD (values)***
- ***MOVE (data)***
- ***CMP or COMPARE (values)***
- ***JMP or JUMP (to address)***

Allow any other credible examples.

b) Explain what operands are. Give TWO (2) examples of instructions using ONE (1) or TWO (2) operands. **3**

Mark scheme

Operands define what values the Opcode is using (1 mark) or the addresses of the locations where the values can be found. (1 mark)
Example: Opcode value, register / Opcode register, register (1 mark)
Note: Also accept a register name (e.g. R01) for register and an Opcode name (e.g. ADD).

c) I wish to store the same data in memory locations from 100 to 200. Identify the best type of addressing mode I need to use **and** briefly explain how I can use it. **4**

Mark scheme

Indirect addressing is the best mode (1 mark).
Put address value in a register (1 mark); use the register as an indirect address (1 mark); repeat 100 times incrementing register value by 1 each time (1 mark).

Total 10 Marks

Question 6

System software is part of all computer systems. They are needed to support other system software and user applications.

a) Explain how system software differs from application software. **3**

Mark scheme

1 mark for each of the following, a maximum of 3 marks

- ***System software is used to support applications.***
- ***System software has higher privileges than applications.***
- ***Some system software can interface with hardware.***

b) A system software that is essential for producing application software is the language compiler. Explain what its main function is. **2**

Mark scheme

The compiler takes high-level language statements (1 mark) and converts them to executable low-level code, i.e. binary instructions. (1 mark)

c) Some developers use virtual machines. Explain what a virtual machine is and what it is used for. **5**

Mark scheme

A virtual machine emulates (1 mark) a guest computer's instructions on a host computer (1 mark). It is used to evaluate other operating systems on a host operating system (1 mark); it is used to run applications written for one guest operating system on a host operating system (1 mark); it is used to run multiple guest operating systems on host operating system (1 mark).

Total 10 Marks

Question 7

Digital logic is the heart of digital devices such as computers, mobile phones, etc. They take binary inputs and produce binary outputs to fulfil a function.

a) A logic equation is defined as P = ($\overline{A}$. B) + ($\overline{B}$. A) where a dot is an AND operation, a plus is an OR operation and a bar is a NOT operation. Complete the missing values in the truth table below. **4**

A	B	($\overline{A}$. B)	($\overline{B}$. A)	P
FALSE	FALSE			
FALSE	TRUE			
TRUE	FALSE			
TRUE	TRUE			

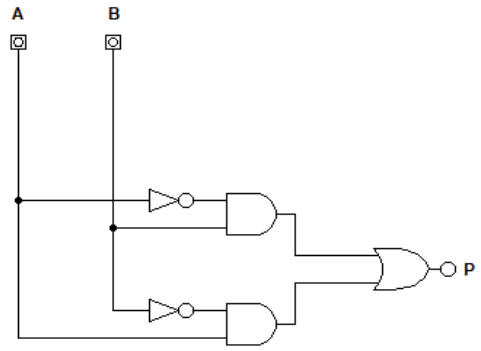
Mark scheme

1 mark for each correct value in the P column, a maximum of 4 marks

A	*B*	*($\overline{A}$. B)*	*($\overline{B}$. A)*	*P*
FALSE	*FALSE*	*FALSE*	*FALSE*	*FALSE*
FALSE	*TRUE*	*TRUE*	*FALSE*	*TRUE*
TRUE	*FALSE*	*FALSE*	*TRUE*	*TRUE*
TRUE	*TRUE*	*FALSE*	*FALSE*	*FALSE*

b) Draw the logic circuit representing the equation in i) where A and B are the inputs and P is the output. **4**

Mark scheme



1 mark for the correct gate types and numbers (2 AND gates + 1 OR gate), maximum 3 marks
1 mark for the correct connections including the NOT functions (ALL connections must be correct)

c) Give the TWO (2) main functions of a hardware design language (HDL). **2**

Mark scheme

HDL is a high-level language used to design digital logic circuits (1 mark). It is also used in the simulation of digital logic circuits (1 mark).

Total 10 Marks

Question 8

A microcontroller is a computer system on a chip (SoC). They are normally embedded in products and tucked away out of sight.

a) Identify THREE (3) products you can find embedded microcontrollers. **3**

Mark scheme

Many products can be named here, the list below is not exhaustive.
1 mark for each of the following products for a maximum of 3 marks:

- ***Domestic appliances***
- ***Handheld devices***
- ***Entertainment equipment***
- ***Cars***
- ***TVs***
- ***Digital receivers***
- ***Toys***

Accept any other credible products

b) A microcontroller has a 100 MHz CPU. We need to program one of its count-down-to-zero timers that uses a CPU clock to count down in order to delay a program code for 10 ms. Calculate the initial count value needed in the timer. **3**

Mark scheme

1 mark for each of the following, a maximum of 3 marks

100 MHz CPU clock period is 1/100 x 1000 sec = 10 usec
The timer value is counted down by one every 10 usec.
Therefore, the timer count should be set to (10 x 1000) / 10 = 1000.

c) Explain what the duty cycle is in a pulse width modulation (PWM) timer. A washing machine's drum speed is controlled by a PWM timer. If the maximum speed of the drum is 1400 rpm, calculate what duty cycle is needed to reduce the speed to 560 rpm. Give the result as a percentage value. **4**

Briefly suggest how a variable voltage potentiometer can be used to adjust the brightness of LED lights.

Mark scheme

The duty cycle defines the ratio between the on and the off periods of the output of the PWM timer (1 mark).
The duty cycle needed is 560 / 1400 = 40% (1 mark).
The potentiometer's analogue output is converted to digital values (1 mark).
The digital values are then used by the PWM timer to change its duty cycle (1 mark).

Total 10 Marks

Question 9

Data communications networking is an integral part of modern computer systems.

a) Explain the differences between half-duplex and full-duplex transmission modes. **4**

Mark scheme

Half-duplex mode communicates in both directions (1 mark) but only in one direction at a time, i.e. not at the same time (1 mark).
Full-duplex mode can communicate in both directions (1 mark) at the same time (1 mark).

b) A data packet header contains some important information. Explain the information needed to make sure packets reach their destinations, they can be acknowledged, and errors can be detected. **3**

Mark scheme

Destination address makes sure the packet reaches its destination (1 mark).
The source address makes sure acknowledgements can be sent to the sender (1 mark).
Error control information can detect corrupt packets (1 mark).

c) Describe TWO (2) conditions for when a data transmission is re-tried. **2**

Mark scheme

Message not received by the destination (1 mark).
Message received by the destination but is corrupt (1 mark).

d) State what the data communication protocol is. **1**

Mark scheme

Data communication protocol defines the rules for successful communication. (1 mark)

Total 10 Marks

Question 10

In an attempt to enhance computer system's performance, advanced technologies have been developed, besides increasing CPU clock speeds.

a) ONE (1) technology to improve computer performance is the CPU pipeline. Explain how it improves performance. **4**

Mark scheme

CPU instructions are divided into multiple stages (1 mark)
CPU pipeline can process different stages (1 mark) of multiple instructions at the same time (1 mark). This way multiple instructions will complete faster than if no pipeline is used (1 mark).

b) Modern compilers produce optimised code that helps enhance computer performance. Name TWO (2) optimisations and explain them. **4**

Mark scheme

For any of the below points, a maximum 4 points

- ***Eliminating redundant instructions (1 mark): This identifies those CPU instructions that if removed will not change the program logic, i.e. they are redundant (1 mark).***
- ***Out-of-order execution (1 mark): The order of the instructions is changed to remove dependencies between close instructions (1 mark).***
- ***Constant folding (1 mark): Any arithmetic expression with constant values is evaluated at compile time removing the need for arithmetic instructions (1 mark).***

c) Explain what feature of a 4-core CPU can improve performance. **2**

Mark scheme

In a 4-core CPU, there are 4 independent CPUs with their separate caches (1 mark). Each CPU can execute different programs' instructions at the same time (1 mark).

Total 10 Marks

End of paper

Learning Outcomes matrix

Question	Learning Outcomes assessed	Marker can differentiate between varying levels of achievement
1	LO 1, LO 3, LO 6	Yes
2	LO 3	Yes
3	LO 2	Yes
4	LO 3	Yes
5	LO 4	Yes
6	LO 5	Yes
7	LO 3	Yes
8	LO 6	Yes
9	LO 7	Yes
10	LO 6	Yes

Grade descriptors

Learning Outcome	Fail	Referral	Pass	Merit	Distinction
Understand and identify the main types and components of computer systems	None or inadequate description of computer systems and components	Some credible but incomplete attempt to demonstrate understanding of computer systems and components	Limited but satisfactory demonstration of understanding of computer systems and components	Good demonstration of understanding of computer systems and components	Excellent demonstration of understanding of computer systems and components
Describe the structure and role of modern operating systems	None or very basic description of components of operating systems	A very limited and basic description of components of operating systems	Limited and above basic description of components of operating systems	Good description of most components of operating systems	Excellent and full description of all components of operating systems
Understand and work with binary numbers and computer logic	No demonstration of working with binary numbers and logic operators	A basic demonstration of restricted range of working with binary numbers and logic operators	An above basic demonstration of of working with restricted range of binary numbers and logic operators	A good demonstration of working with a wide range of binary numbers and logic operators	An excellent demonstration of working with full range of binary numbers and logic operators
Understand the essential structure of computer programs	None or trivial explanation of instruction sets, addressing modes and interrupts	Limited understanding and explanation of instruction sets, addressing modes and interrupts	Basic understanding and explanation of instruction sets, addressing modes and interrupts	Good understanding and explanation of instruction sets, addressing modes and interrupts	Excellent understanding and explanation of instruction sets, addressing modes and interrupts
Explain the hierarchy of computer software	No or wrong explanation of computer software hierarchy	Limited and very basic explanation of computer software hierarchy	Basic but limited explanation of computer software hierarchy	Good and competent explanation of computer software hierarchy	Excellent and complete explanation of computer software hierarchy
Describe alternative computer systems	No or insufficient description of performance enhancing technologies	Limited and very basic description of performance enhancing technologies	Basic and partly satisfactory description of performance enhancing technologies	Good description of performance enhancing technologies	Excellent and complete description of performance enhancing technologies
Discuss the role of Data Communications and Networks in computer systems	No or very trivial discussion of data communications protocols and components	A very basic discussion of data communications protocols and components	Basic but credible discussion of data communications protocols and components	Good and wide-ranging discussion of data communications protocols and components	Excellent and complete discussion of data communications protocols and components