Hardware

(Chapter 3)

Syllabus Content:

3.1 Computer architecture

Candidates should be able to:	Notes and guidance
1 (a) Understand the role of the central processing unit (CPU) in a computer	• The CPU processes instructions and data that are input into the computer so that the result can be output
(b) Understand what is meant by a microprocessor	• A microprocessor is a type of integrated circuit on a single chip
2 (a) Understand the purpose of the components in a CPU, in a computer that has a Von Neumann architecture	• Including: – units: arithmetic logic unit (ALU) and control unit (CU) – registers: program counter (PC), memory address register (MAR), memory data register (MDR), current instruction register (CIR) and accumulator (ACC) – buses: address bus, data bus and control bus
(b) Describe the process of the fetch–decode–execute cycle including the role of each component in the process	• How instructions and data are fetched from random access memory (RAM) into the CPU, how they are processed using each component and how they are then executed • Storing data and addresses into specific registers • Using buses to transmit data, addresses and signals • Using units to fetch, decode and execute data and instructions
3 Understand what is meant by a core, cache and clock in a CPU and explain how they can affect the performance of a CPU	• The number of cores, size of the cache and speed of the clock can affect the performance of a CPU
4 Understand the purpose and use of an instruction set for a CPU	• An instruction set is a list of all the commands that can be processed by a CPU and the commands are machine code
5 Describe the purpose and characteristics of an embedded system and identify devices in which they are commonly used	• An embedded system is used to perform a dedicated function, e.g. domestic appliances, cars, security systems, lighting systems or vending machines. This is different to a general purpose computer that is used to perform many different functions, e.g. a personal computer (PC) or a laptop

Syllabus Content:

3.2 Input and output devices

Candidates should be able to:	Notes and guidance
1 Understand what is meant by an input device and why it is required	• Including: – barcode scanner – digital camera – keyboard – microphone – optical mouse – QR code scanner – touch screen (resistive, capacitive and infra-red) – two-dimensional (2D) and three-dimensional (3D) scanners
2 Understand what is meant by an output device and why it is required	• Including: – actuator – digital light processing (DLP) projector – inkjet printer – laser printer – light emitting diode (LED) screen – liquid crystal display (LCD) projector – liquid crystal display (LCD) screen – speaker – 3D printer
3 (a) Understand what is meant by a sensor and the purposes of sensors	• Limited to: – acoustic – accelerometer – flow – gas – humidity – infra-red – level – light – magnetic field – moisture – pH – pressure – proximity – temperature

Syllabus Content:

(b) Identify the type of data captured by each sensor and understand when each sensor would be used, including selecting the most suitable sensor for a given context	
3.3 Data storage	
Candidates should be able to:	Notes and guidance
1 Understand what is meant by primary storage	• Primary storage is directly accessed by the CPU • Including the role of: – random access memory (RAM) – read only memory (ROM) • Including why a computer needs both RAM and ROM, and the difference between them
2 Understand what is meant by secondary storage	• Secondary storage is not directly accessed by the CPU and is necessary for more permanent storage of data
3 Describe the operation of magnetic, optical and solid-state (flash memory) storage and give examples of each	• Magnetic storage uses platters which are divided into tracks and sectors. Data is read and written using electromagnets • Optical storage uses lasers to create and read pits and lands • Solid-state (flash memory) uses NAND or NOR technology. Transistors are used as control gates and floating gates
4 Describe what is meant by virtual memory, how it is created and used and why it is necessary	• Pages of data are transferred between RAM and virtual memory when needed
5 Understand what is meant by cloud storage	• Cloud storage can be accessed remotely in comparison to storing data locally • Physical servers and storage are needed to store data in cloud storage
6 Explain the advantages and disadvantages of storing data on the cloud in comparison to storing it locally	

Syllabus Content:

3.4 Network hardware

Candidates should be able to:	Notes and guidance
1 Understand that a computer needs a network interface card (NIC) to access a network	
2 Understand what is meant by and the purpose of a media access control (MAC) address, including its structure	• A network interface card is given a MAC address at the point of manufacture • MAC addresses are usually written as hexadecimal • MAC addresses are created using the manufacturer code and the serial code
3 (a) Understand what is meant by and the purpose of an internet protocol (IP) address (b) Understand that there are different types of IP address	• An IP address is allocated by the network and they can be static or dynamic • Including the characteristics of and differences between IPv4 and IPv6
4 Describe the role of a router in a network	• A router sends data to a specific destination on a network • A router can assign IP addresses • A router can connect a local network to the internet

3 Hardware

3.1 | Computer Architecture

3.1.1 Central Processing Unit (CPU):

- The central processing unit (CPU) processes instructions and data that are input into the computer so that the result can be output.
- The CPU (also known as microprocessor or processor) is central to all modern computer systems including tablets & smartphones.

Microprocessor:

- A microprocessor is a type of integrated circuit on a single chip.

The CPU (processor) consists of the following components:

- Control Unit (CU)
- Arithmetic & Logic Unit (ALU)
- Registers & Buses

3.1.2 Von Neumann Architecture:

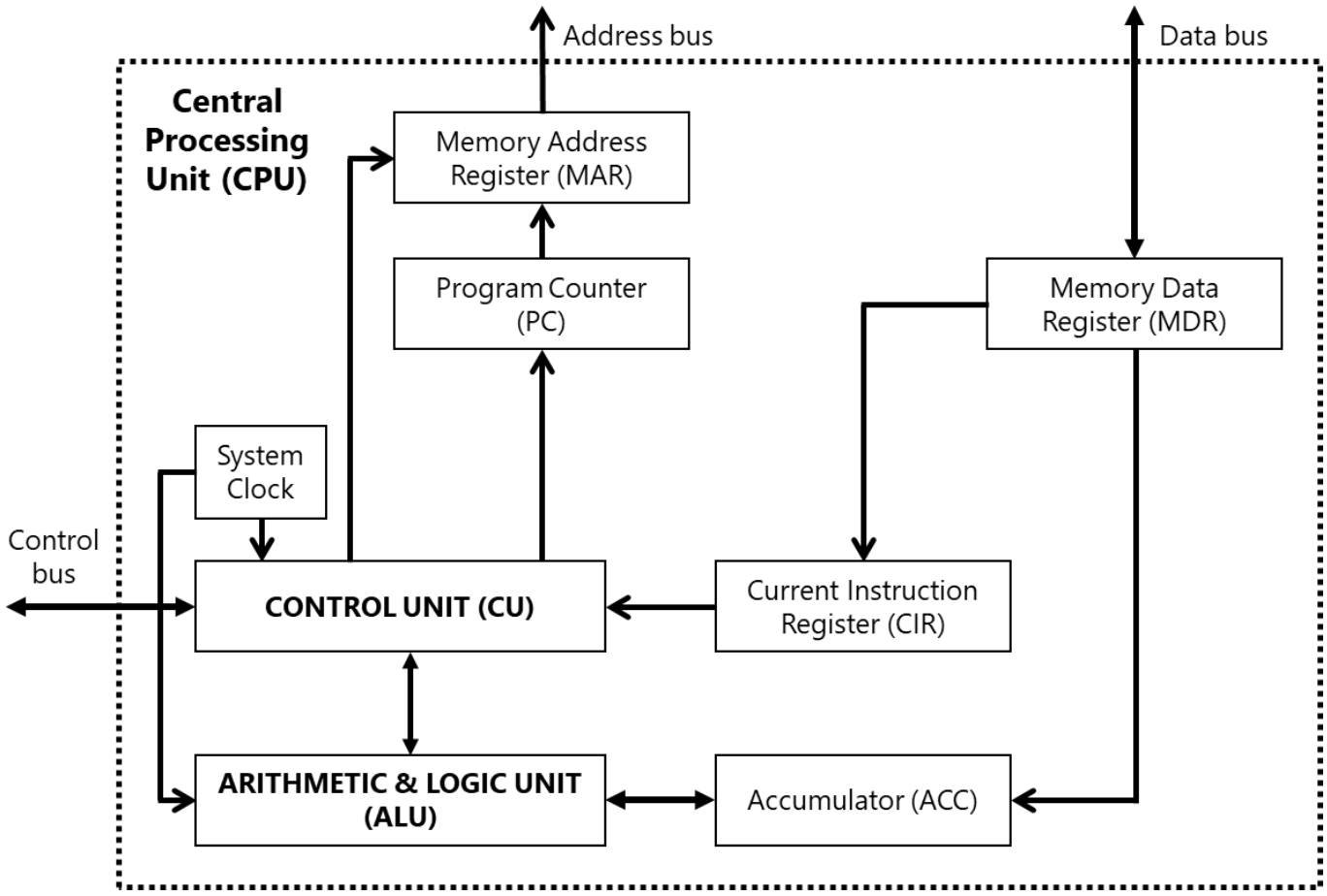
In early years, computers were not able to store programs until 1945; John von Neumann developed the concept of the stored program computer, referred to as Von Neumann Architecture concept.

He designed architecture for an electronic digital computer with subdivisions of a central arithmetic part, a central control part, a memory to store both data and instructions, external storage, and input and output mechanisms.

The von Neumann architecture had the following main features:

- The concept of a central processing unit (CPU or processor)
- The CPU was able to access the memory directly
- The computer memories could store programs as well as data
- The stored programs were made up of instructions which could be executed in sequential order.

The following diagram is a simple representation of von Neumann CPU architecture:



Components of the Central Processing Unit (CPU):

There are different purposes of components in a CPU, in a computer that has a Von Neumann architecture. Those components include:

1) **Units:**
   - arithmetic logic unit (ALU)
   - control unit (CU) including system clock
2) **Registers:**
   - program counter (PC)
   - memory address register (MAR)
   - memory data register (MDR) // memory buffer register (MBR)
   - current instruction register (CIR)
   - accumulator (ACC)
3) **Buses:**
   - address bus
   - data bus
   - control bus

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The Von Neumann model for a computer system has several components other than the CPU and those within the CPU.

These components include:

1. Immediate Access Store (IAS)
2. Main Memory (RAM)
3. Input Device
4. Output Device
5. Secondary Storage Device

Immediate Access Store (IAS):

- It temporarily holds data and instructions waiting to be processed after they are loaded from the main memory.
- It is used because read/write operations carried out using the IAS are considerably faster and so any key data needed by an application will be stored temporarily in IAS to speed up operations.
- The Immediate Access Store (IAS) is another name for primary main memory (RAM).

Main Memory (RAM):

What is main memory and how it is used in the Von Neumann model for a computer system:

- The main memory means the primary memory or RAM.
- It is a volatile memory.
- It is used to hold data/instructions that are currently in use.
- It is directly accessed by the central processing unit (CPU).

Stored Program Concept when applied to the Von Neumann Model:

- The program is stored on a secondary storage device.
- The data and instructions are moved to main memory/RAM.
- The data and instructions are stored in the same memory/RAM.
- The data and instructions are moved to registers to be executed.
- The instructions are fetched and executed in a sequence, one after another..

Input & Output Devices:

- It is used to allow interaction with the computer.
- Input device allows data to be entered into a computer system (e.g. keyboard, touch screen & microphone etc.).
- Output device allows the user to view/hear the data that has been entered into a computer system (e.g. printer, monitor & loudspeaker etc.).

The main components of the CPU (processor) are the arithmetic logic unit (ALU), the control unit (CU) and the system clock.

Units:

Arithmetic & Logic Unit (ALU):

- It is the component within the CPU that carries out calculations.
- It performs arithmetic operations such as addition, subtraction, multiplication, division and logical operations/comparisons such as AND, OR, NOT etc.
- It holds temporary values during calculations in a register called the accumulator (ACC).

Control Unit (CU):

- It is the component within the CPU that controls the flow of data and manages operations between the components of the CPU (processor).
- It sends/receives control signals that manage the transfer of data and execution of instructions within the CPU.
- It decodes an instruction using an instruction set.
- It fetches instructions from memory, decodes them and synchronizes the operations before sending signals to other components of the computer telling them "what to do".
- A system clock is used to generate the timing signals on the control bus to synchronize all the components on the motherboard.
- It controls the operations of memory, processor, and input/output.

Registers:

- A register is a small piece of fast memory.
- It is a temporary storage of data and instructions which is about to be or has been processed.
- It is part of the processor.
- A register can be general or special purpose.

Special Purpose Registers:

Memory Address Register (MAR):

- It holds the address of the next/current instruction to be fetched/processed.
- It holds the memory address of where the data needs to be stored.
- It uses the address bus to send an address to another component.

Memory Data/Buffer Register (MDR):

- It holds data or an instruction that are in use and has been fetched from the memory/the address stored in MAR.
- It is temporary storage of data between the CPU and primary memory.

Program Counter (PC):

- It holds the address of the next/current instruction to be fetched/processed/executed.
- It uses the address bus to send an address to another component.
- It increments to point to the address of the next instruction to be fetched and so stores the number of processes that have been completed.

Current Instruction Register (CIR):

- It holds the data received from the MDR.
- It holds the current instruction that is to be executed/being processed.

Accumulator (ACC):

- It is built into the arithmetic logic unit (ALU).
- It temporarily holds the result of a calculation OR temporarily holds the data that is currently being used in a calculation.

Memory:

- The computer memory is made up of a number of partitions; each consisting of an address and its contents.
- The address uniquely identifies each location in the memory and the content is the binary value stored in each location.

The following is a section of computer memory:

Address	Contents
1111 0000	0111 0010
1111 0001	0101 1011
1111 0010	1101 1101
1111 0011	0111 1011
↓	↓
1111 1100	1110 1010
1111 1101	1001 0101
1111 1110	1000 0010
1111 1111	0101 0100

Let us now consider two examples of how the MAR & MDR registers can be used when carrying out a read and write operation to and from memory:

READ & WRITE Operations:

READ operation:

- We will use the memory section shown below. Suppose we want to **READ** the contents of memory location **1111 0001**. We will use this address and its content:

Address	Contents
1111 0000	0111 0010
1111 0001	**0101 1011**
1111 0010	1101 1101
1111 0011	0111 1011
↓	↓
1111 1100	1110 1010
1111 1101	1001 0101
1111 1110	1000 0010
1111 1111	0101 0100

- The address of location **1111 0001** to be **READ** from is first **WRITTEN** into the **MAR** (memory address register):

MAR	1	1	1	1	0	0	0	1

- A **read signal** is sent to the computer memory using the control bus.
- Then the contents of the memory location **1111 0001** are put into the **MDR** (memory data register):

MDR	0	1	0	1	1	0	1	1

WRITE operation:

- We will again use the memory section shown below. Suppose we want to show how the value **1001 0101** was **WRITTEN** into the memory location **1111 1101**.

Address	Contents
1111 0000	0111 0010
1111 0001	0101 1011
1111 0010	1101 1101
1111 0011	0111 1011
↓	↓
1111 1100	1110 1010
1111 1101	**1001 0101**
1111 1110	1000 0010
1111 1111	0101 0100

- The data to be stored is first **WRITTEN** into **MDR** (memory data register):

MDR	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**

- This data has to be **WRITTEN** into memory location with the address **1111 1101**; so, this address is now written into **MAR** (memory address register):

MAR	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**

- Finally, a **write signal** is sent to the computer memory using the control bus and the value **1001 0101** will then be written into the correct memory location.

Examination Question Tips:

- The examiner will give you a table of memory section like the ones above.
- You will be asked to perform either **READ** or **WRITE** or maybe **both operations**.

In the part of READ operation:

- The examiner will tell you that the content of a memory location e.g. **1111 0000** is to be READ and then ask you to show contents of MAR and MDR during this READ operation.
- There will be two registers given to you, one for MAR and one for MDR.
- Now you simply have to write the address which is to be read e.g. **1111 0000** in the MAR register.
- The content value given in the table at this address will be simply copied and written into the MDR register.

In the part of WRITE operation:

- The examiner will tell you that the value e.g. **1100 1100** is to be written into memory location e.g. **0011 1111** and then again ask you to show contents of MAR and MDR during this WRITE operation.
- There will be two registers given to you, one for MAR and one for MDR.
- Now you simply have to write the value (content) which is to be written e.g. **1100 1100** in the MDR register.
- The memory location in which this value is to be written e.g. **0011 1111** will be simply written in MAR register.

In the end:

- The examiner may ask you to state or show any changes to the memory following the read and write operations.
- In this case, just look at the table of memory sections. Look at the two addresses used in both parts of the questions.
- If you find that any address has the value of its content missing, just state that value over there which was given to you in any of the both parts depending upon which parts content value is missing.

Exam Style Questions:

Question 1:

A section of computer memory is shown below:

Address	Contents
1000 0000	0110 1110
1000 0001	0101 0001
1000 0010	1000 1101
1000 0011	1000 1100
≀	≀
1000 1100	
1000 1101	
1000 1110	
1000 1111	

(a) (i) The contents of memory location 1000 0001 are to be read.

Show the contents of the Memory Address Register (MAR) and the Memory Data Register (MDR) during this read operation:

MAR

MDR

[2]

(ii) The value 0111 1001 is to be written into memory location 1000 1110.

Show the contents of the MAR and MDR during this write operation:

MAR

MDR

[2]

(iii) Show any changes to the computer memory following the read and write operations in **part (a)(i)** and **part (a)(ii)**.

Address	Contents
1000 0000	0110 1110
1000 0001	0101 0001
1000 0010	1000 1101
1000 0011	1000 1100
1000 1100	
1000 1101	
1000 1110	
1000 1111	

[1]

Answer:

(a) (i)

MAR	1	0	0	0	0	0	0	1
MDR	0	1	0	1	0	0	0	1

[2]

(ii)

MAR	1	0	0	0	1	1	1	0
MDR	0	1	1	1	1	0	0	1

[2]

(iii)

Address	Contents
1000 0000	0110 1110
1000 0001	0101 0001
1000 0010	1000 1101
1000 0011	1000 1100
1000 1100	
1000 1101	
1000 1110	**0111 1001**
1000 1111	

[1]

Question 2:

The table shows a segment of primary memory from a Von Neumann model computer.

Address	Contents
10001	11001101
10010	11110001
10011	10101111
10100	10000110
10101	00011001
10110	10101100

The program counter contains the data 10010.

(a) (i) State the data that will be placed in the memory address register (MAR).

.....[1]

(ii) State the data that will be placed in the memory data register (MDR).

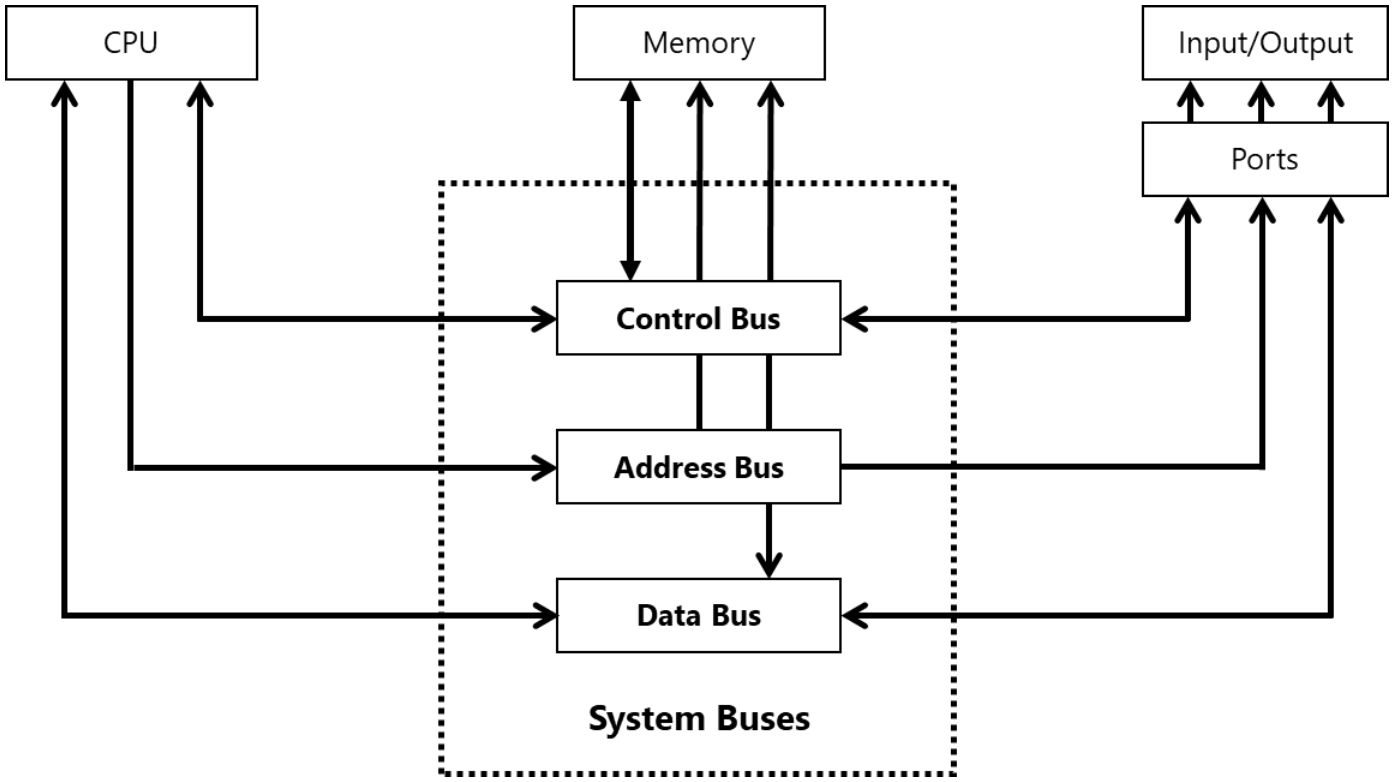
.....[1]

Answer:

(a)(i) 10010

(a)(ii) 11110001

The following diagram shows how buses are used to connect the CPU to the memory and to input/output devices:



Buses:

- They are used to connect together the internal components of the CPU and provide a pathway for transmitting data and instructions.
- The data, address and control buses connect the processor, memory, and I/O controllers.
- They essentially move data around the computer and send out control signals to ensure everything is properly synchronized.

There are three common buses used in the Von Neumann architecture given below:

Address Bus:

- It is a unidirectional bus (signals travel in one direction only).
- It carries signals relating to addresses between the CPU/processor and the memory of the next item to be fetched.

Width of Address Bus:

- The width of the address bus determines the number of directly accessible memory locations.
- Increasing the width of address bus significantly increases the number of directly accessible/addressable memory locations.

Benefit of increasing the address bus width from 16 bits to 32 bits:

- A bus width of 16 bits can address 2^{16} memory locations whereas a bus width of 32 bits allows 2^{32} memory locations to be simultaneously accessed.

Data Bus:

- It is a bi-directional bus (data can travel in both directions).
- It sends data between the processor, the memory unit and the input/output devices that is currently being processed.
- The data can be an address, an instruction, or a numerical value.

Width of Data Bus:

- The width of the data bus determines the number of bits that can be simultaneously transferred.
- Increasing the width of data bus increases the number of bits/amount of data that can be moved at one time.
- It improves processing speed and computer performance as fewer transfers are needed.
- For example, double the width of the data bus moves 2x data per clock pulse.

Control Bus:

- It is a bi-directional bus (signals can travel in both directions).
- It carries control signals around the CPU and transmits timing signals to control all the components.
- It carries signals to synchronize the fetch-execute cycle.

It is usually 8-bits wide as there is no need for it to be any wider since it only carries control signals.

Fetch–Decode–Execute Cycle:

- The processor firstly fetches some data and instructions from memory and stores them in suitable registers.
- Both the address bus and data bus are used in this process.
- Each instruction is then decoded before finally being executed.
- This is known as the Fetch–Decode–Execute cycle.

To process an instruction, a central processing unit (CPU) goes through a cycle that has three main stages:

Stage 1 → Fetch

Stage 2 → Decode

Stage 3 → Execute

How an instruction is fetched in a computer based on the Von Neumann model:

- The program counter (PC) holds the address of the instruction.
- The address held in the program counter (PC) is sent to memory address register (MAR).
- The address is sent using the address bus.
- The program counter (PC) is incremented.
- The instruction is sent from the address in memory to memory data register (MDR).
- The instruction is transferred using the data bus.
- The instruction is sent to the current instruction register (CIR).

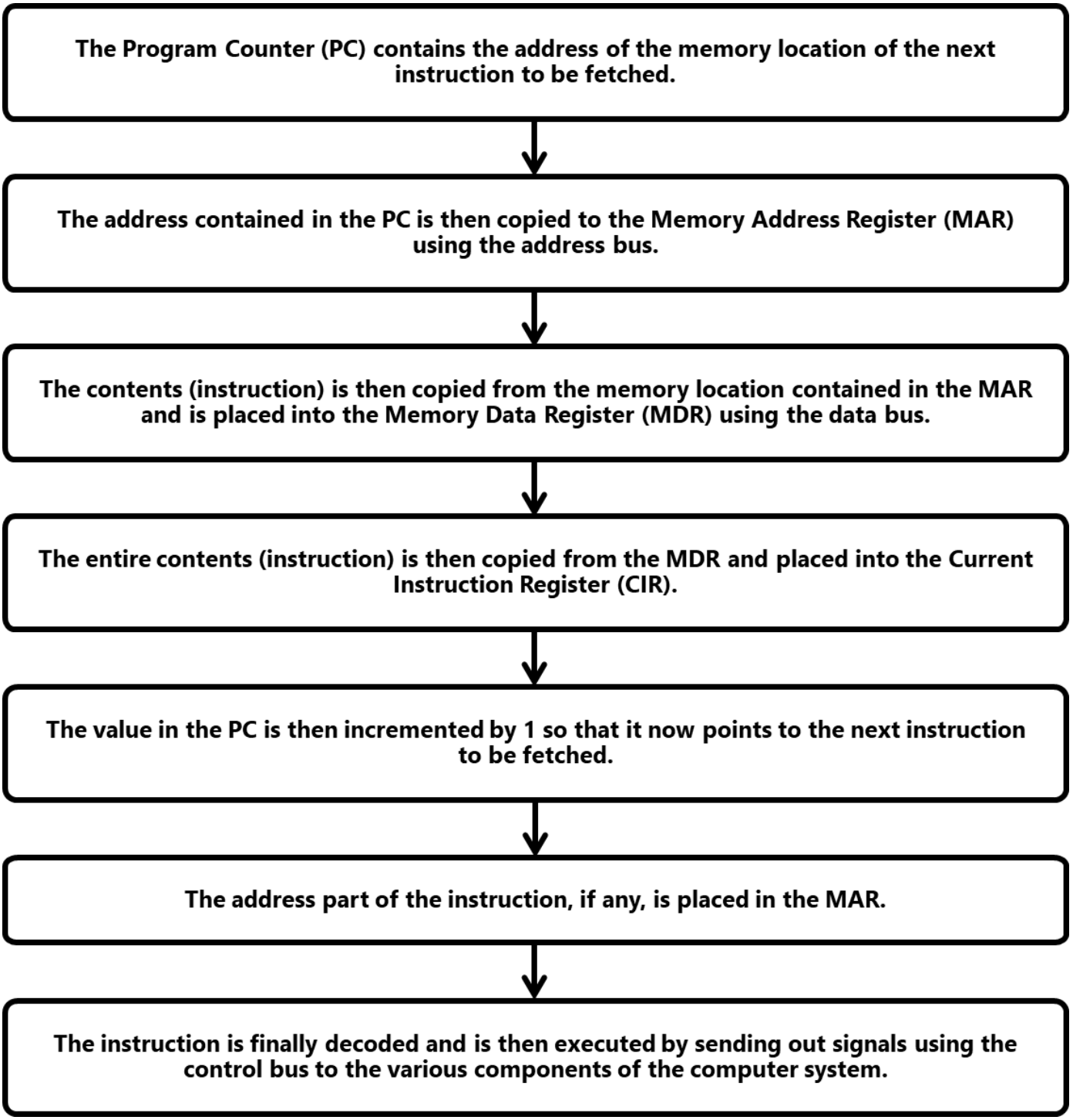
The component of the CPU that is responsible for decoding instructions:

Control Unit (CU)

How an instruction is executed in a computer based on the Von Neumann model:

- The CPU passes the decoded instruction as a set of control signals using the control bus to the appropriate components within the computer system.
- This allows each instruction to be carried out in its logical sequence.

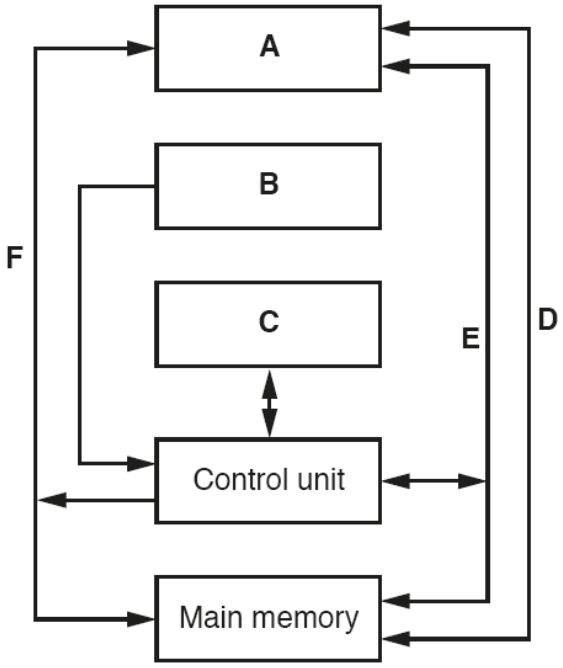
The following diagram shows how the Fetch–Decode–Execute cycle is carried out in the Von Neumann computer model:



Exam Style Questions:

Question 1:

The following diagram shows the components and buses found inside a typical personal computer (PC).



(a) Some components and buses only have labels **A** to **F** to identify them.

For each label, choose the appropriate title from the following list. The title for label **D** is already given.

- Control bus
- Address bus
- Arithmetic Logic Unit (ALU)
- General purpose registers
- Secondary storage
- System clock

A .....

B .....

C .....

D Data bus

E .....

F .....

[5]

Answer:

Question	Answer	Marks
4(a)	**1 Mark** for each correct answer A – General purpose registers B – System clock C – ALU E – Control bus F – Address bus	**5**

Question 2:

(b) The seven stages in a von Neumann fetch-execute cycle are shown in the table below.

Put each stage in the correct sequence by writing the numbers 1 to 7 in the right hand column. The first one has been done for you.

Stage	Sequence number
the instruction is then copied from the memory location contained in the MAR (memory address register) and is placed in the MDR (memory data register)	
the instruction is finally decoded and is then executed	
the PC (program counter) contains the address of the next instruction to be fetched	**1**
the entire instruction is then copied from the MDR (memory data register) and placed in the CIR (current instruction register)	
the address contained in the PC (program counter) is copied to the MAR (memory address register) via the address bus	
the address part of the instruction, if any, is placed in the MAR (memory address register)	
the value in the PC (program counter) is then incremented so that it points to the next instruction to be fetched	

[6]

Answer:

(b)

description of stage	sequence number
the instruction is then copied from the memory location contained in the MAR (memory address register) and is placed in the MDR (memory data register)	**3**
the instruction is finally decoded and is then executed	**7**
the PC (program counter) contains the address of the next instruction to be fetched	*(1)*
the entire instruction is then copied from the MDR (memory data register) and placed in the CIR (current instruction register)	**4**
the address contained in the PC (program counter) is copied to the MAR (memory address register) via the address bus	**2**
the address part of the instruction is placed in the MAR (memory address register)	**6**
the value in the PC (program counter) is then incremented so that it points to the next instruction to be fetched	**5***

The incrementation of the program counter can appear at any stage after 2. All other stages must be in the correct given order. [6]

Question 3:

(ii) Identify **four** components that are part of the CPU.

Component 1 .....

Component 2 .....

Component 3 .....

Component 4 .....

[4]

Answer:

5(c)	Any **four** from: – MAR – MDR – PC – ALU – CU – ACC – CIR – Buses – Registers	4

Question 4:

Explain how an instruction is fetched in a computer based on the Von Neumann model.

.....

.....

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.....

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.....

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.....

.....

.....

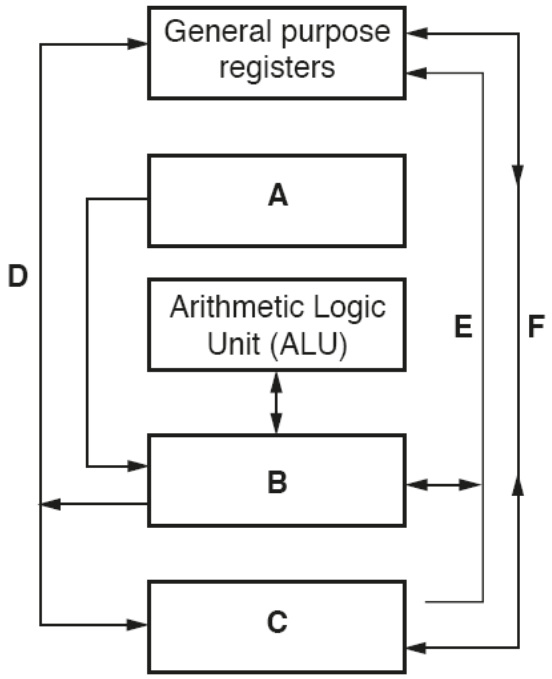
..... [6]

Answer:

Question	Answer	Marks
10	Any **six** from: – Program counter (PC) holds address / location of the instruction – The address held in PC is sent to MAR – Address is sent using address bus – PC is incremented – The instruction is sent from address in memory to MDR – Instruction is transferred using the data bus – Instruction sent to CIR	6

Question 5:

(a) The diagram shows the components and buses found inside a typical Personal Computer (PC).



Some components and buses only have labels **A** to **F** to identify them.

For each label, choose the appropriate title from the following list. The title for label **D** is already given.

- Control bus
- System clock
- Data bus
- Control unit
- Main memory
- Secondary storage

A .....

B .....

C .....

D Address bus

E .....

F .....

[5]

Answer:

Question	Answer	Marks
4(a)	A – System clock B – Control unit C – Main memory E – Control bus F – Data bus	**5**

Question 6:

Signals are sent to and from the components of a processor using buses.

Identify and describe the purpose of **two** different buses.

Bus 1 .....

Purpose .....

.....

.....

.....

.....

.....

Bus 2 .....

Purpose .....

.....

.....

.....

.....

.....

[6]

Answer:

Question	Answer	Marks
6	1 mark for correct bus name and up to 2 further marks for appropriate purpose. **Address (bus)** **Two** from: □ Carries / transports an address / location … □ … of the next item to be fetched □ Data travels one way (unidirectional) **Data (bus)** **Two** from: □ Carries / transports data / example of data ... □ … that is currently being processed // that will be / has been processed □ Data can travel in both directions (bidirectional) **Control (bus)** **Two** from: □ Carries / transports signals □ Control / directs the actions of the CPU / processor □ Can be either Unidirectional or Bidirectional	**6**

Question 7:

(a) Tick (✓) to show whether each statement applies to the Memory Address Register (MAR), Memory Data Register (MDR) or Program Counter (PC).

Some statements may apply to more than one component.

Statement	MAR (✓)	MDR (✓)	PC (✓)
it is a register in the CPU			
it holds the address of the next instruction to be processed			
it holds the address of the data that is about to be fetched from memory			
it holds the data that has been fetched from memory			
it receives signals from the control unit			
it uses the address bus to send an address to another component			

[6]

Answer:

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>6(a)</td><td>One mark per each correct row.

<table>
<tr><th>Statement</th><th>MAR (✓)</th><th>MDR (✓)</th><th>PC (✓)</th></tr>
<tr><td>it is a register in the CPU</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>it holds the address of the next instruction to be processed</td><td>(✓)</td><td></td><td>✓</td></tr>
<tr><td>it holds the address of the data that is about to be fetched from memory</td><td>✓</td><td></td><td>(✓)</td></tr>
<tr><td>it holds the data that has been fetched from memory</td><td></td><td>✓</td><td></td></tr>
<tr><td>it receives signals from the control unit</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>it uses the address bus to send an address to another component</td><td>✓</td><td></td><td>✓</td></tr>
</table></td><td>6</td></tr>
</table>

Question 8:

(a) Identify the component within the CPU that controls the flow of data.

..... [1]

(b) Identify the component within the CPU where calculations are carried out.

..... [1]

(c) Identify the component within the CPU that stores the address of the next instruction to be processed.

..... [1]

(d) Identify the register within the CPU that holds an instruction that has been fetched from memory.

..... [1]

(e) Identify the register within the CPU that holds data that has been fetched from memory.

..... [1]

Answer:

Question	Answer	Marks
2(a)	– Control unit // CU	1
2(b)	– Arithmetic logic unit // ALU	1
2(c)	– Program counter // memory address register // PC // MAR	1
2(d)	– Memory data register // current instruction register // MDR // CIR	1
2(e)	– Memory data register // MDR	1

Question 9:

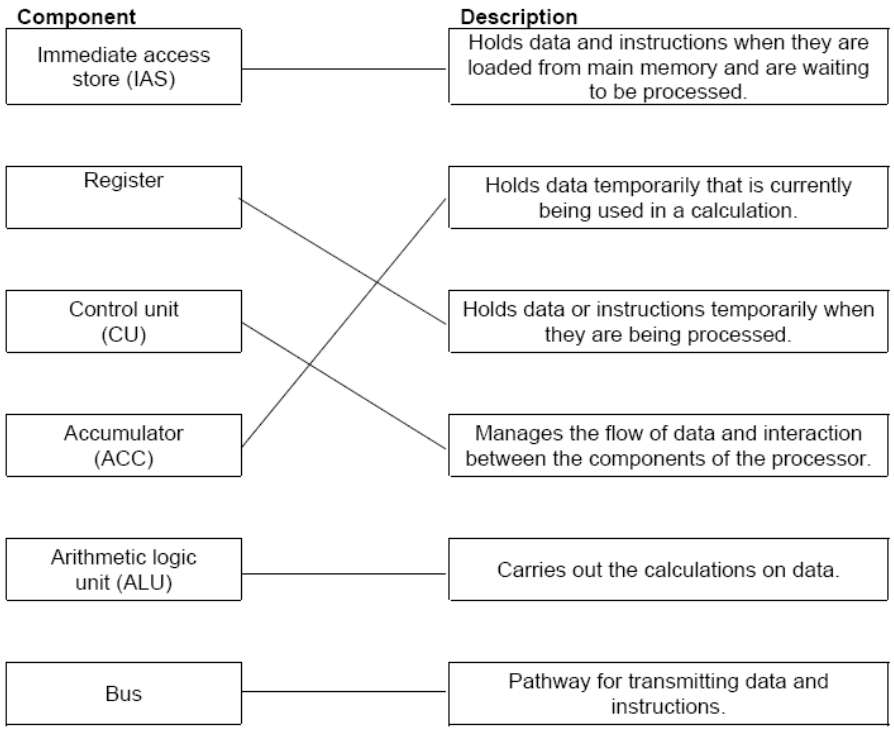
Six components of the Von Neumann model for a computer system and **six** descriptions are given.

Draw a line to match each component to the most suitable description.

Component	Description
Immediate access store (IAS)	Holds data and instructions when they are loaded from main memory and are waiting to be processed.
Register	Holds data temporarily that is currently being used in a calculation.
Control unit (CU)	Holds data or instructions temporarily when they are being processed.
Accumulator (ACC)	Manages the flow of data and interaction between the components of the processor.
Arithmetic logic unit (ALU)	Carries out the calculations on data.
Bus	Pathway for transmitting data and instructions.

[5]

Answer:

Question	Answer	Marks
5	1 mark for each correct line, up to a maximum of 5 marks:  	5

Question 10:

In a Von Neumann model for a computer system, a Central Processing Unit (CPU) contains a number of different components.

The table contains the name of a component or a description of their role in the fetch-execute cycle.

Complete the table with the missing component names and descriptions.

Component name	Description
Memory Address Register (MAR)	....
Program Counter (PC)	....
.....	This is a register that is built into the arithmetic logic unit. It temporarily holds the result of a calculation.
.....	This is a register that holds data or an instruction that has been fetched from memory.
Control Unit (CU)	....
.....	This carries addresses around the CPU.

[6]

Answer:

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>5</td><td>One mark per correct term or description.

<table>
<tr><th>Component name</th><th>Description</th></tr>
<tr><td>Memory Address Register (MAR)</td><td>(A register that) holds the address of the data/instruction that needs to be fetched/processed // holds the address of where the data needs to be stored.</td></tr>
<tr><td>Program Counter (PC)</td><td>(A register that) holds the address of the next / current instruction to be processed.</td></tr>
<tr><td>accumulator // ACC</td><td>This is a register that is built into the arithmetic logic unit. It temporary holds the result of a calculation.</td></tr>
<tr><td>memory data register // MDR</td><td>This is a register that holds data or an instruction that has been fetched from memory.</td></tr>
<tr><td>Control Unit (CU)</td><td>Sends control signals to control the flow of data through the CPU // manages the execution of instructions in the CPU</td></tr>
<tr><td>address bus</td><td>This carries addresses around the CPU.</td></tr>
</table></td><td>6</td></tr>
</table>

3.1.3 Core, Cache & Clock:

NOTE: Core, Cache, & Clock are newly added topics in the Computer Science (2210) syllabus for the session 2023–2025.

We need to understand the meaning of the core, cache, and clock in a CPU. The number of cores, size of the cache and speed of the clock can affect the performance of a CPU.

System Clock:

- The control unit sends the signals on the control bus to coordinate events based on the pulses of the system clock.
- The system clock generates the timing signals and clock pulses are used to synchronize all components on the motherboard.
- It determines the number of cycles the CPU can execute per second as the clock sends out a number of pulses in a given time interval (clock speed).

Clock Speed:

- It is a factor that affects the performance of a PC.
- Each instruction is executed on a clock pulse e.g., one F-E cycle is run on each clock pulse.
- So, the clock speed dictates the number of instructions that can be run per second.
- Increasing the clock speed increases the number of instructions/number of fetch-execute cycles that can be run per second.
- The higher the clock frequency, the shorter the execution time for the instruction so increasing the clock frequency improves performance.

However, there is a limit on clock speed because the heat generated by higher clock speeds cannot be removed fast enough.

Overclocking: The clock speed can be changed by accessing the BIOS (Basic Input/Output System) and altering the settings.

Using clock speed higher than the computer was designed for can lead to problems, such as:

1. The execution of instructions outside design limits, which can lead to seriously unsynchronized operations (in other words, an instruction is unable to complete in time before the next one is due to be executed) and the computer would frequently crash and become unstable.
2. It can cause serious overheating of the CPU leading to unreliable performance.

Computer Performance:

As discussed earlier, by increasing the clock speed the processing speed of the computer is also increased. However, it is not possible to say that a computer's overall performance is necessarily increased by using a higher clock speed.

Four other factors need to be considered:

1. **The width of the address bus and data bus can affect computer performance.**

   Increasing the width of buses allows more memory locations to be directly accessed and allows the transfer of more data per clock pulse. It improves processing speed and computer performance.

2. **Overclocking: using a clock speed higher than the computer was designed for can lead to problems, such as:**

   1) The execution of instructions outside design limits, which can lead to seriously unsynchronized operations (in other words, an instruction is unable to complete in time before the next one is due to be executed) and the computer would frequently crash and become unstable
   2) It can cause serious overheating of the CPU leading to unreliable performance.

3. **The use of cache memory can also improve CPU performance.**

   Cache memory is located within the CPU, and it uses SRAM so cache memories will have faster access times, since there is no need to keep refreshing, which slows down access time. Cache memory stores frequently used instructions and data that need to be accessed faster. The larger the cache memory size, the more frequency used instructions it can store for fast access and better the CPU performance.

4. **The use of a different number of cores can improve computer performance (one core is made up of an ALU, a CU and the registers).**

   Many computers are dual core (the CPU is made up of two cores) or quad core (the CPU is made up of four cores).
   Each core processes one instruction per clock pulse. More/multiple cores mean that sequence of instructions can be split between them and so more than one instruction is executed per clock pulse and more sequence of instructions can be run at the same time.
   Therefore, more cores decrease the time taken to complete task and improves CPU performance.

Potential Problem:

However, doubling the number of cores does not necessarily double the computer's performance since CPU needs to communicate with each core and this will reduce overall performance.

For example:

- The dual core has one channel and needs the CPU to communicate with both cores using one channel, reducing some of the potential increase in its performance.
- The quad core has six channels and needs the CPU to communicate with all four cores using six channels, considerably reducing potential performance.

Summary of factors affecting computer performance:

1. **Clock Speed:** higher clock speed means more Fetch—Decode—Execute cycles per second.
2. **Number of Cores:** more cores mean more instructions can be carried out simultaneously.
3. **Bus Width:** increasing width allows transfer of more data each time and allows more memory location to be directly accessed.
4. **Cache:** the higher the capacity of cache memory, the more frequently used instructions it can store for fast access.

Exam Style Questions:

Question 1:

(c) The computer has a single core CPU.

(i) State **one** purpose of a core in a CPU.

.....

..... [1]

(ii) The computer is upgraded to a dual core CPU.

Explain how the upgrade can affect the performance of the computer.

.....

.....

.....

..... [2]

Answer:

4(c)(i)	Any **one** from: • to process an instruction • to carry out a fetch-execute cycle.	**1**
4(c)(ii)	• It can now process two instructions simultaneously (where suitable) • … increasing the performance.	**2**

Question 2:

(a) Explain how the width of the data bus and system clock speed affect the performance of a computer system.

Width of the data bus .....

.....

.....

.....

Clock speed .....

.....

.....

.....[3]

Answer:

(a) **maximum** of **2 marks** for data bus width and **maximum** of **2 marks** for clock speed

data bus width

- the width of the data bus determines the number of bits that can be simultaneously transferred
- increasing the width of the data bus increases the number of bits/amount of data that can be moved at one time (or equivalent)
- …hence improving processing speed as fewer transfers are needed
- By example: e.g. double the width of the data bus moves 2x data per clock pulse

clock speed

- determines the number of cycles the CPU can execute per second
- increasing clock speed increases the number of operations/number of fetch-execute cycles that can be carried out per unit of time
- ...however, there is a limit on clock speed because the heat generated by higher clock speeds cannot be removed fast enough **[3]**

Question 3:

(b) Describe the ways in which the following factors can affect the performance of his laptop computer.

Number of cores

.....

.....

.....

.....

Clock speed

.....

.....

.....

.....

[4]

Answer:

5(b)	**1 mark** per bullet point to **max 3** per factor. **max 4** overall. Number of cores: • Each core processes one instruction per clock pulse • More/multiple cores mean that **sequences of instructions** can be split between them • … and so more than one instruction is executed per clock pulse // more **sequences of instructions** can be run at the same time • **More** cores decreases the time taken to complete task Clock speed: • Each instruction is executed on a clock pulse // one F-E cycle is run on each clock pulse • ... so the clock speed dictates the number of instructions that can be run per second • The **faster** the clock speed the more instructions can be run per second	**4**

Question 4:

(b) Identify **one** factor that can affect the performance of the computer system **and** state how it impacts the performance.

Factor .....

Impact .....

.....

.....

[2]

Answer:

6(b)	**1 mark** for factor **1 mark** for impact e.g. • Clock speed… • …higher clock speed means more FE cycles per second • Number of cores… • …means more instructions can be carried out simultaneously • Bus width … • …allows the transfer of more data each time // allows more memory locations to be directly accessed • Cache … • … the higher capacity the more frequently used instructions it can store for fast access	**2**

Question 5:

(b) Clock speed is a factor that affects the performance of a PC. Explain this statement.

.....

.....

.....[2]

Answer:

4(b)	**1 Mark** per bullet, max 2 - The clock sends out a number of pulses in a given time interval (clock speed) - Each processor instruction takes a certain number of clock cycles to execute - The higher the clock frequency, the shorter the execution time for the instruction // Increasing the clock frequency improves performance	**2**

3.1.4 Instruction Set:

NOTE: Instruction Set is a newly added topic in the Computer Science (2210) syllabus for the session 2023–2025.

An instruction set is a list of all the commands that can be processed by a CPU and the commands are machine code.

The instructions are a set of operations which are decoded in a sequence by CPU using the sequence of steps of Fetch–Decode–Execute cycle to process each instruction in sequence.

The Current Instruction Register (CIR) holds the op code and operand of an instruction ready for it to be decoded.

Operations:

- Each operation will instruct the Arithmetic Logic Unit (ALU) & Control Unit (CU) which are part of the Central Processing Unit (CPU).
- An operation is made up of an opcode & operand.
- Some examples of instruction set operations include ADD, JMP, LDA, and so on.

Opcode & Operand:

- The opcode informs the CPU what operation needs to be done.
- The operand is the data which needs to be acted on or it can refer to a register in the memory.

Example of Instruction Set:

- An example of an instruction set is the X86, a common CPU standard used in many modern computers.
- If the computer is based on the X86 CPU then all designs will share almost identical instruction sets despite different electronic designs.

Differences between Program Code & Instruction Set:

- The instruction set is machine code instructions that instruct the CPU about how to carry out an operation.
- The program code needs interpreters or compilers to convert the code into the instruction set understood by the computer.
- Therefore, instruction sets must not be confused with program code.

3.1.5 Embedded System:

NOTE: Embedded System is a newly added topic in the Computer Science (2210) syllabus for the session 2023–2025.

- An embedded system is used to perform a dedicated function.
- It has a microprocessor/microcontroller within a larger system that performs one specific task.
- These functions include domestic appliances, cars, security systems, lighting system or vending machines.
- An embedded system is different to a general purpose computer that is used to perform many different functions, e.g. a personal computer (PC) or a laptop.
- The embedded system is built into/integrated into the device and this enables operations to be controlled in a more efficient way.
- The devices such as cookers, refrigerators and central heating systems can now all be activated by a web-enabled device (such as a mobile phone, computer or tablet).

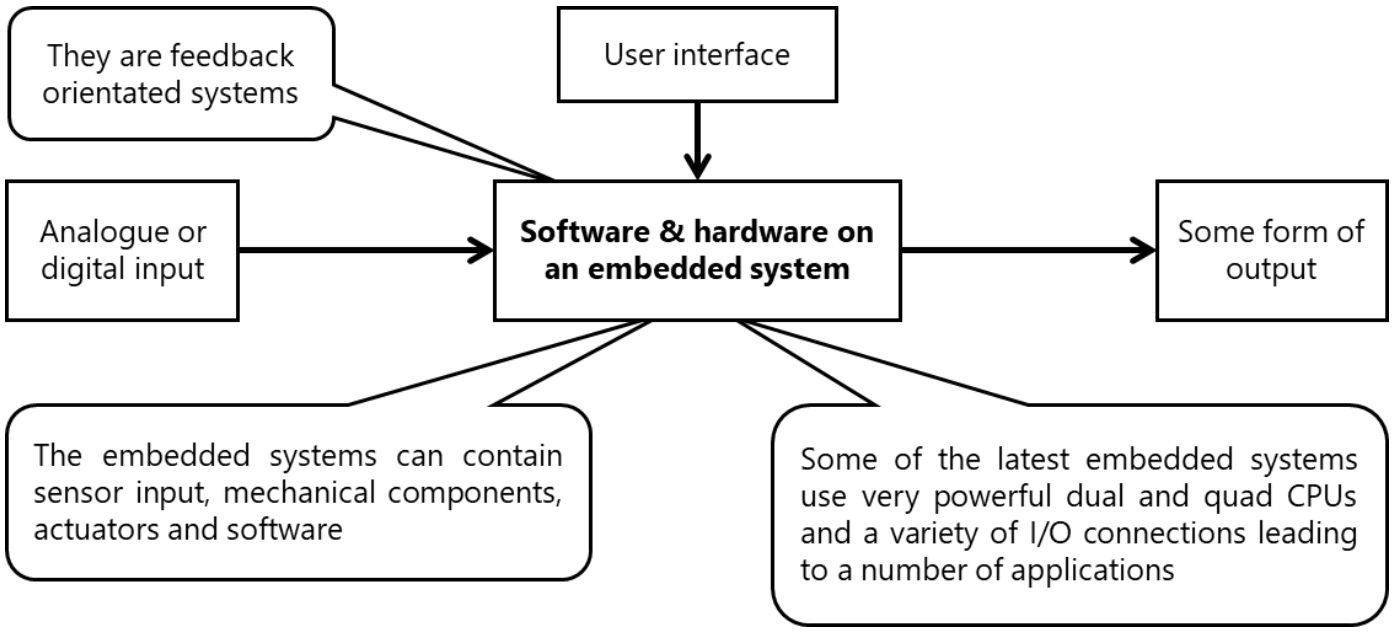
Microcontroller:

- This has a CPU in addition to some RAM and ROM and other peripherals all embedded onto one single chip and together they can carry out a specific task.

Microprocessor:

- It is an integrated/embedded circuit which only has a CPU on a one single chip.
- It does not have RAM, ROM or other peripherals – these need to be added.

The following diagram summarizes how Embedded Systems work in general:



Working of Embedded Systems:

- When an embedded system is installed in a device, either an operator can input data manually (e.g., select a temperature from a keypad or turn a dial on an oven control panel) or the data will come from an automatic source, such as a sensor.
- This sensor input will be analogue or digital in nature (e.g. inputs such as oxygen levels or fuel pressure in a car's engine management system).
- The output will then carry out the function of the embedded system by sending signals to the components that are being controlled (e.g. increase the power to the heating elements in an oven or reduce fuel levels in the engine).

The embedded system is dedicated to a specific set of tasks therefore engineers can optimize their designs to reduce the physical size and cost of the devices.

Programming of Embedded Systems:

The embedded systems are either programmable or non-programmable depending on the device in which they are used.

- The non-programmable devices need to be replaced if they require a software upgrade.
- The programmable devices allow upgrading by two methods:
  1. Connecting the device to a computer and allowing the download of updates to the software (e.g. this is used to update the maps on a GPS system used in a vehicle).
  2. Automatic updates via a Wi-Fi, satellite or cellular (mobile phone network) link (e.g. many modern cars allow updates to engine management systems and other components via satellite link).

Controlling of Embedded Systems:

- The embedded systems can be controlled remotely using a smartphone or computer due to their internet connectivity.
- The central heating system can be set to switch on or off while the user is away from home and the set top box can be instructed remotely to record a television programme.

General Purpose Computers & Embedded Systems:

- The personal computer (PC) and laptop is not an example of an embedded system.
- An embedded system is used to perform a dedicated function/one specific task.
- The computers/laptops are multi-functional that is they can carry out many different tasks which can be varied by using different software and so they cannot be classified as embedded systems.

Benefits & Drawbacks of Embedded Systems:

Benefits of Embedded Systems:

1. They are small in size and therefore easy to fit into devices.
2. They are relatively low cost to make.
3. They are usually dedicated to one task allowing simple interfaces and often no requirement for an operating system.
4. They consume very little power.
5. They can be controlled remotely using a mobile phone.
6. They have a very fast reaction to changing input as they operate in real time and are feedback orientated.
7. The mass production of embedded systems bring reliability.

Drawbacks of Embedded Systems:

1. It can be difficult to upgrade some devices to the latest technology.
2. The troubleshooting faults in the device becomes a specialist task.
3. The interface can appear to be more simple (e.g. a single knob) but in reality it can be more confusing (e.g. changing the time on a cooker clock can require several steps).
4. They are always susceptible to cyber hacking & viruses as they are accessed over the internet.
5. The devices are often just thrown away rather than being repaired which is very wasteful due to difficulty in upgrading and finding faults.
6. It can lead to an increase in the 'throw away' society if devices are discarded after they have become out-of-date.

Applications of Embedded Systems:

The range of applications are vast, ranging from a single microcontroller (e.g. in an MP3 player) to a complex array of multiple units (e.g. in a medical imaging system).

1) Cars:

The modern cars have many parts that rely on embedded systems to function correctly. The following components are some of the many that are controlled in this way:

1. GPS system
2. Lane detection system
3. Airbags
4. In-car entertainment system
5. Fuel injection system
6. ABS braking
7. Vehicle security
8. Traction control
9. Exhaust emission

Lane Detection System:

- This system monitors the lines on either side of the lane. If the car gets too close to one line, the system automatically moves the car away from the line.

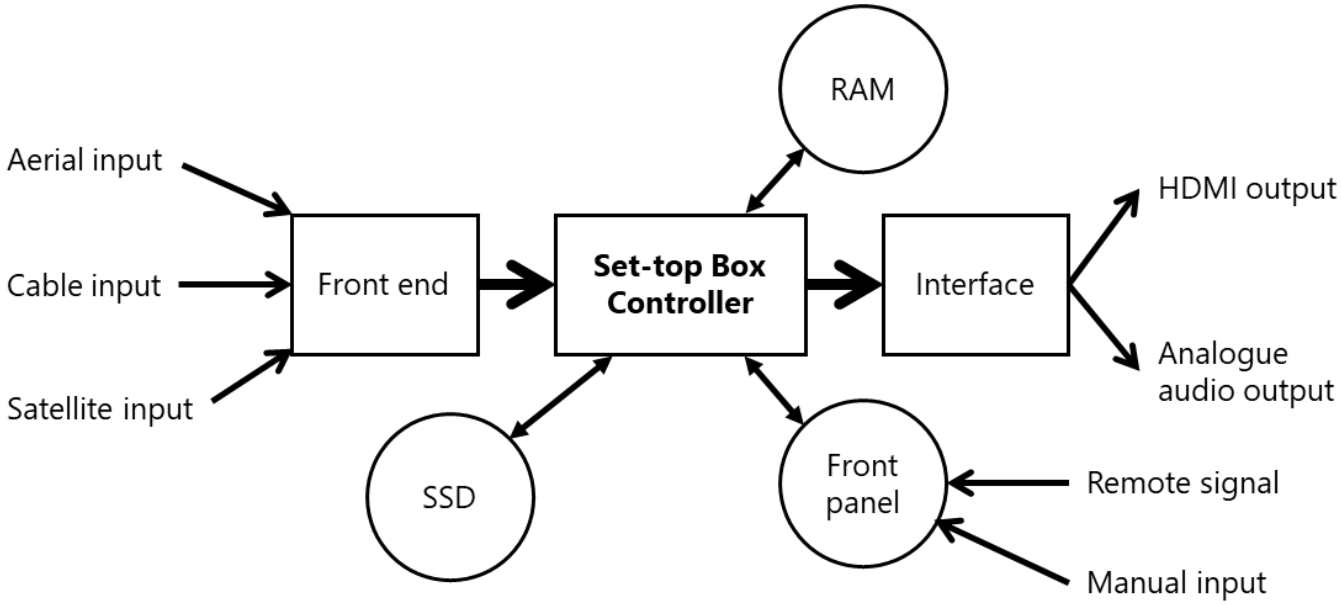
Why the lane detection system is an example of an Embedded System:

- The lane detection system is built into/integrated into the car.
- The lane detection system only performs one task.
- The lane detection system is not easily changed/updated by the car owner.

2) Set-top Box:

- It uses an embedded system to allow recording and playback of television programmes.
- This can be operated remotely by the user when not at home using an internet-enabled device or by using the interface panel when at home.
- The embedded system will look after many of the functions involving inputs from a number of sources such as a Solid State Device (SSD) or a satellite signal.
- The SSD stores or retrieves television programmes.
- The satellite signal will decode the incoming signal.

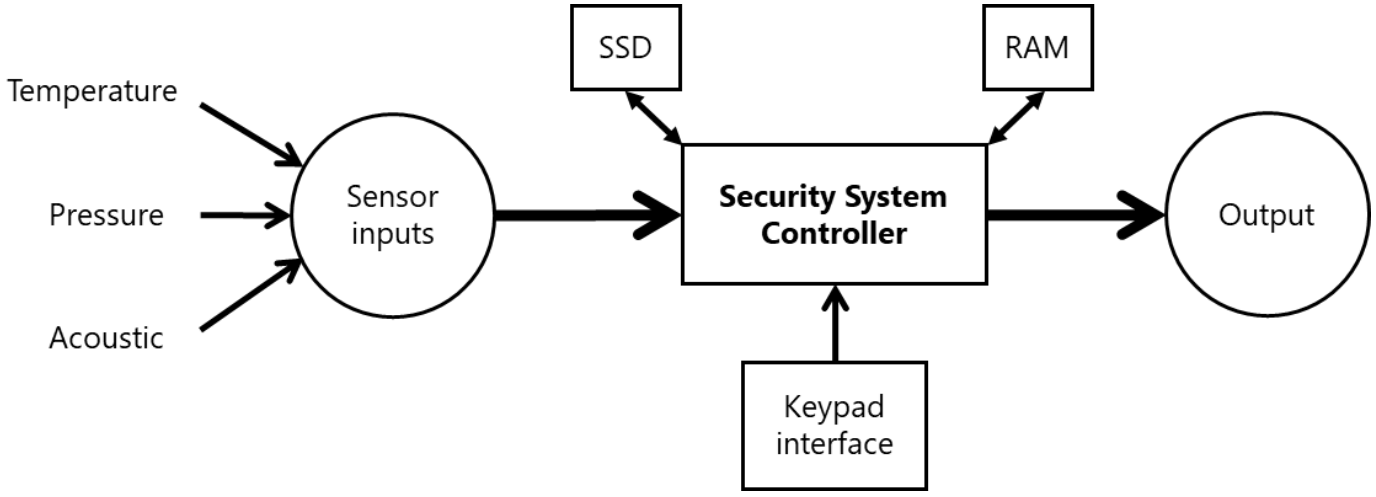
The following diagram shows the Embedded System found in a set-top box:



3) Security Systems:

- The security code is set in RAM and the alarm is activated or deactivated using the keypad.
- The data from the sensors is sent to the controller which checks against values stored on the SSD (these settings are on SSD rather than RAM in case the sensitivity needs to be adjusted).
- An output can be a signal to flash lights, sound an alarm or send a message to the user via their mobile phone.
- The user can also interface with the system remotely if necessary.

The following diagram shows the Embedded Systems used in many security devices:



4) Lighting Systems:

The embedded systems are used in modern sophisticated lighting systems. We will consider the lighting system used in a large office.

The system needs to control the lighting according to:

1. The time of the day or day of the week:
   The time of the day or day of the week is important data in an office environment since energy is saved if the system switches to low lighting levels when unoccupied.
2. Whether the room is occupied or empty:
   If there is movement in the office then correct lighting levels be automatically restored.
3. The brightness of the natural light:
   On a very bright sunny day, the system could automatically dim the lights, only increasing the light output if natural light levels fall below a set value.

An embedded system can automatically control the lighting using a number of inputs (such as light sensors) and key data stored in memory.

- There are many internal and external lighting systems that could be controlled by embedded system such as fountain light display or a light show on a building to celebrate a special occasion.
- They are also used to trigger emergency lighting.

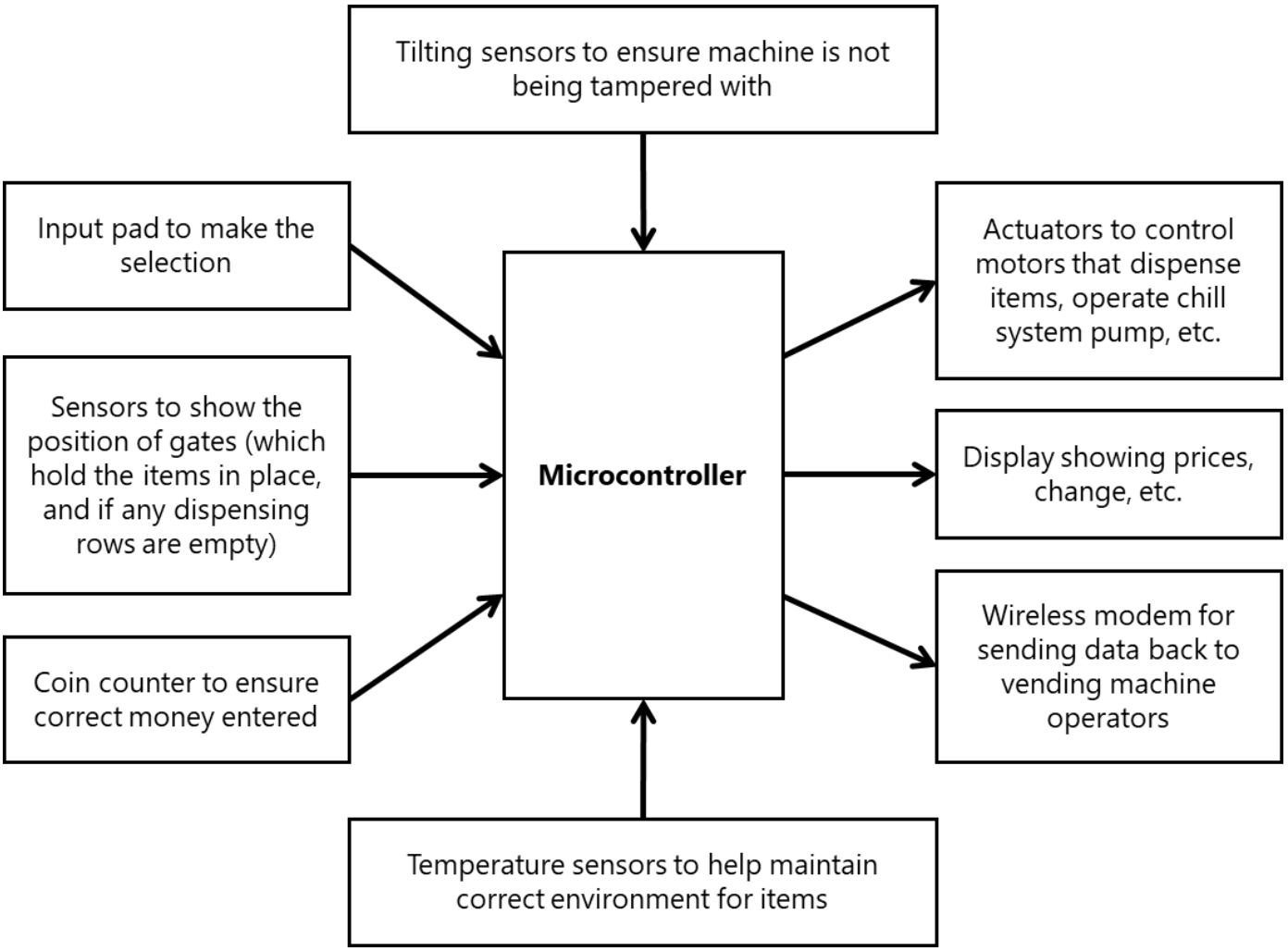
Lighting Bulbs:

- Some lighting systems use Bluetooth light bulbs.
- This allows the embedded system to control each bulb independently.
- Many of the bulbs available today use LEDs and many come in a number of colors to change the mood.

5) Vending Systems:

- The vending machines usually use microcontrollers to control a number of functions that are associated with them.

The following diagram shows the Embedded Systems used in a vending machine:



- The embedded system is in the form of a microcontroller.
- The inputs to this system come from the keypad (item selection) and from sensors (used to count the coins inserted by the customer, the temperature inside the machine and a 'tilt sensor' for security purposes).
- The outputs are:

1) The actuators to operate the motors, which control the helixes (coil) to give the customers their selected items.
2) The signals to operate the cooling system if the temperature is too high.
3) The item description and any change due is shown on an LCD display panel.
4) The data sent back to the vending machine company so that they can remotely check sales activity including the instructions to refill the machine without having to visit each machine.

All of this is controlled by an embedded system which makes the whole operation automatic but also gives immediate sales analysis which would otherwise be very time consuming.

6) Washing Machines:

- Many large electrical goods used domestically such as refrigerators, washing machines, microwave ovens, and so on (called white goods) are controlled by embedded systems.
- They all come with a keypad or dials that are used to select the temperature, wash cycle or cooking duration.
- This data forms the input to the embedded system, which then carries out the required task without any further human intervention.
- These devices can also be operated remotely using an internet-enabled smartphone or computer.

Meaning of an Embedded System using the washing machine as an example:

- An embedded system in washing machine only controls the programs for the washing cycle.
- It is part of the washing machine but does not perform any other function within it.

The washing machine's embedded system makes use of both Random Access Memory (RAM) and Read Only Memory (ROM).

Purpose of RAM within the washing machine's Embedded System:

1. It stores the choices/wash program the user has entered.
2. It stores the data read from the sensors.
3. It stores the time left in the program

Purpose of ROM within the washing machine's Embedded System:

1. It stores the start-up instructions for the washing cycles.

Exam Style Questions:

Question 1:

A car has several features.

(a) One feature is a lane detection system. This system monitors the lines on either side of the lane. If the car gets too close to one line, the system automatically moves the car away from the line.

Explain why the lane detection system is an example of an embedded system.

.....

.....

.....

..... [2]

(b) Two other features:

- record the number of miles travelled in the current journey, from when the engine is turned on to when it is turned off
- record the total number of miles the car has travelled since it was built.

Identify the data that will be stored in the primary **and** secondary storage of the car for these **two** features.

Primary .....

.....

Secondary .....

.....

[2]

Answer:

Question	Answer	Marks
2(a)	**1 mark** per point to **max 2** • The lane detection system is **built into / integrated into the car** • The lane detection system only performs one task • The lane detection system is not easily changed/updated **by the car owner**	**2**
2(b)	**1 mark** for primary • e.g. Miles travelled in the current journey, before the engine is turned off **1 mark** for secondary • e.g. Total miles travelled since the car was built // miles for most recent journey **after engine switched off**	**2**

Question 2:

Kiara has a washing machine and a refrigerator.

(a) She has an embedded system in her washing machine.

Describe what is meant by an **embedded system**, using the washing machine as an example.

.....

.....

.....

..... [2]

(b) The washing machine's embedded system makes use of both Random Access Memory (RAM) and Read Only Memory (ROM).

State the purpose of RAM and ROM within the washing machine's embedded system.

RAM .....

.....

ROM .....

.....

[2]

Answer:

Question	Answer	Marks
5(a)	**1 mark** per bullet point to **max 2** • Definition: Microprocessor/microcontroller within a **larger system** // microprocessor/microcontroller that performs **one specific task** • Example: e.g. Embedded system in washing machine only controls the programs for the washing cycle // it is part of the washing machine but does not perform any other function within it	**2**
5(b)	**1 mark** for RAM, **1 mark** for ROM RAM: • **Store** the choices/wash program the user has entered // **stores** the data read from the sensors // **stores** the time left in the program // by example ROM: • **Store** the start-up instructions (for the washing cycles)	**2**

3.2 | Input & Output Devices

3.2.1 Input Devices:

- A device that allows the data to be entered into a computer system.

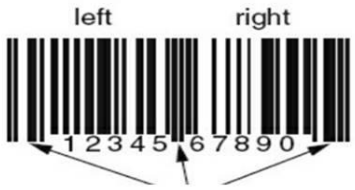
The input devices included in our syllabus are:

1. barcode scanner
2. digital camera
3. keyboard
4. microphone
5. optical mouse
6. QR code scanner
7. touch screen (resistive, capacitive & infra-red)
8. two-dimensional (2D) scanner
9. three-dimensional (3D) scanner

Barcode Scanners (Readers):

They are automatic data capture devices which means that they can save and collect data with no actual need for human interaction. They can often be built into an Electronic Point of Sale (EPOS) terminal, for example, a supermarket checkout.

Barcode Scanners



Barcodes

- The barcodes are a series of vertical black and white parallel lines with varying thicknesses.
- The barcode is one-dimensional (1D).
- The digits from 0 to 9 are each represented by a unique series of lines.
- The normal barcodes can hold up to 30 digits.
- The actual left-hand and right-hand sides of the barcode are separated using guard bars.

Remember:

- The width of lines representing each digit is the same, thus speed of scanning is also same.
- The arrangement of bars on left and right side allows a barcode to be scanned in any direction.

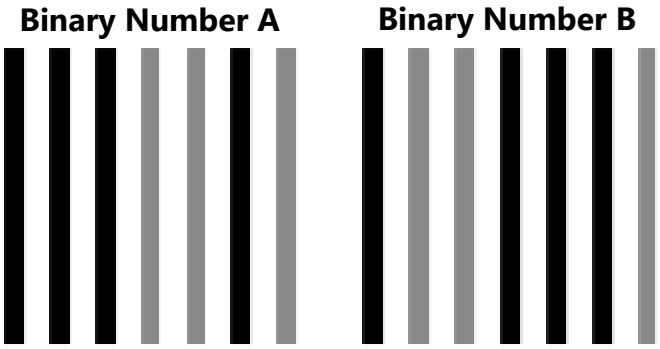
How Barcode is read:

- A barcode reader/scanner is used.
- The reader shines a red laser or red LED at barcode.
- The light is reflected back off the barcode (black lines reflect little or no light at all and hence, the black and white areas are determined).
- The reflected light is read by sensors (photoelectric cells).
- As the laser or red LED light is scanned across the barcode, it generates a black-and-white pattern due to different reflections.
- The different reflections pattern is then converted to different binary values.
- A microprocessor then interprets the data, and it uses check digit error checking method.

Binary values of:

- Binary value of light area = 0
- Binary value of dark area = 1

Binary numbers that would be produced from this Barcode:



Binary Number A = 1 1 1 0 0 1 0 **Binary Number B =** 1 0 0 1 1 1 0

How the Barcode system could help the supermarket manage its stock:

- The barcode can be used to look up product in a stock database.
- The data about stock levels can be stored on a system.
- The stock levels for the product can be automatically deducted from the system.
- The stock can be automatically re-ordered if at or below a certain level.
- A flag is put to stop re-ordering every time until the stock has arrived and when the stock is re-ordered, the flag is reset.
- It automatically updates the new stock level in the database once the new stock items arrive.

How the price of the product is found using Barcode at a supermarket checkout:

- The database stores data about barcodes, products & prices.
- The barcode value is transmitted to the database system and searched in the database.
- The price is found and then displayed.

How the stock control system automatically keeps the stock levels above a minimum level:

- The stock control system has a database of stock items.
- Each product has a unique barcode.
- The barcode is scanned, and the product is looked up in a database.
- The stock levels for the product are reduced by 1.
- The stock is checked against the minimum level.
- If the stock is at or below the minimum level, an order is placed.
- A flag is put to stop re-ordering every time until the stock has arrived.
- When the stock is re-ordered, the flag is reset.

Advantages of Barcodes to the management:

1. It is easier and faster to change the price on stock items.
2. It provides more updated sales information.
3. There is no need to price every stock item on the shelves (which saves time and cost).
4. It allows for automatic stock control.
5. It is possible to analyze customer buying habits more easily by linking barcodes to loyalty cards.

Advantages of Barcodes to the customers:

1. The queues are faster as the staff doesn't need to remember prices.
2. The errors in charging customers are reduced.
3. The customer is given an itemized bill.
4. The cost savings can be passed on to the customer.
5. It allows a better track of 'sales-by-dates'; so, food should be fresher.

Input and output devices found at the checkout in supermarkets along with Barcode Scanners:

Input/output device	How it is used
Keypad	To key in the number of same items bought; to key in a weight.
Screen/monitor	To show the cost of an item and other information.
Speaker	To make a beeping sound every time a barcode is read correctly; or another sound if there is an error when reading the barcode.
Printer	To print out a receipt/bill.
Magnetic stripe reader	To read the customer's credit/debit card.
Touchscreen	To select items by touching an icon; or to select payment method.

Applications of Barcode Scanners:

1) Barcode scanners are used in supermarket checkouts:

- They are used to find the prices and descriptions.
- They allow for automatic stock control.

2) Barcode scanners are used in library systems:

- They can track books on loan.
- They allow for linking books to borrowers using barcoded cards.

3) Barcode scanners are used at airport check-ins:

- They are placed on luggage to track its whereabouts.

Benefits of using Barcodes:

1. It is quicker to scan rather than type into a system.
2. There are fewer errors as no human input is required.

Quick Response (QR) Codes:

QR Codes

- It is another type of barcode.
- It is two-dimensional (2D) and contain squares.
- It is made up of a matrix of filled-in dark squares on a light background.
- These codes can hold up to 7000 digits.
- The QR code can be read from any angle and are faster to scan.
- These codes are more error tolerant.

Working of QR codes:

- The Quick Response (QR) code is scanned using a camera on a mobile device.
- It is then processed by an appropriate QR code reading application on the phone.
- The three large squares are used for alignment & the corners of code are used for orientation.
- It uses position and alignment markers for orientation when scanning.
- The squares reflect light differently; black squares reflect less light than white squares which enables the squares to be read.
- Each small square is converted to a binary value.
- The data is then decoded.
- The user is redirected to a specific web page or opens a document.
- The QR code can be saved for future reference.

Uses of QR codes:

1. These are used for redirecting devices to specific web pages after these codes are scanned.
2. They are used in shopping malls and on public transport for advertising products.
3. They are used in giving automatic access to a website or contact telephone number.
4. They are used for storing boarding passes electronically at airports and train stations.

Benefits of QR codes:

1. There is no need for the user to manually write down or key in a website address; scanning the QR code does this automatically.
2. QR codes can store website addresses/URLs that appear in magazines, trains, buses or even on business cards, giving a very effective method of advertising.

Advantages of QR codes compared to traditional Barcodes:

1. They can hold much more data/information.
2. The QR codes are more error tolerant as the higher capacity of the QR code allows the use of built-in error-checking systems.
3. The QR code can be read from any angle whereas some barcode readers have to be lined up with the barcode.
4. The QR codes are faster to scan than barcodes.
5. The QR codes are easier to read as they don't need expensive laser or LED scanners like barcodes because they can be read by the cameras on smartphones or tablets.
6. It is easy to transmit QR codes either as text messages or images.
7. It is also possible to encrypt QR codes which gives them greater protection than traditional barcodes.

Disadvantages of QR codes compared to traditional Barcodes:

1. There is more than one QR format available.
2. QR codes can be used to transmit malicious code known as attagging.
   It is relatively easy to write malicious code and embed this within the QR code as there are a large number of free apps available to any user for generating QR code.
   When the code is scanned, it is possible the creator of the malicious code could gain access to everything on user's phones such as photographs, stored passwords, address book and so on.
   The user could also be sent to a fake website or even a virus could be downloaded.

The QR code is scanned at the entrance to the venue. A person can only enter the venue with a valid QR code that allows entry. When a person enters, a count is incremented to show how many people have entered the venue.

How the system scans the QR code, checks if a person can enter and counts how many people have entered:

- The Quick Response (QR) code is scanned using a camera on a mobile device.
- The three large squares are used for alignment & the corners of code are used for orientation.
- The squares reflect light differently; black squares reflect less light than white squares which enables the squares to be read.
- Each small square is converted to a binary value and digital data is sent to microprocessor.
- There is a database of valid QR codes and data is compared to stored values of valid QR codes.
- If the data matches, entry is granted is raised and count is incremented.
- If data does not match, entry is denied.

Differences between a Barcode and a Quick Response (QR) code:

1. The barcode is one-dimensional (1D) and QR code is two-dimensional (2D).
2. The barcodes contain vertical lines and QR codes contain squares.
3. The QR code can hold more data than a barcode.
4. The QR code can be read from any angle whereas some barcode readers have to be lined up with the barcode.
5. The QR codes are more error tolerant and faster to scan than barcodes.
6. The barcodes are frequently used at checkouts/libraries whereas QR codes are used for advertising or frequently used by mobile phones to obtain certain information.

Frame QR Codes:

- The newer codes called frame QR codes are now being used because of the increased ability to add advertising logo.
- The frame QR codes come with a canvas area where it is possible to include graphics or images inside the code itself.
- Unlike normal QR codes, software to do this is not usually free.

Frame QR Codes

Digital Cameras:

Digital Cameras

- A digital camera is similar to a traditional film-based camera, but it captures images digitally.
- When you take a picture with a digital camera, the image is recorded by a sensor, called a charged coupled device (CCD).
- Some digital cameras have built-in memory, but most use an SD or Compact Flash card.

Linkage of Digital Cameras:

- Modern digital cameras simply link to a computer system via a USB port or by using Bluetooth.

Working of Digital Cameras:

- A button is pushed to take a photograph.
- An aperture opens at the front of the camera to allow light to stream in through the lens.
- This is captured by a sensor called a charge-coupled device.
- The analogue-to-digital converter then converts each pixel into a digital binary value.
- The number of pixels determines the size of the file used to store the photograph.

How the images captured by the camera are converted to digital photo files.

- The image is converted from analogue to digital using ADC (analogue-to-digital converter).
- It is then turned into pixels.
- Each pixel is given a binary value and has a color.
- The pixels form a grid to create the image.
- The pixels are then stored in sequence in a file.
- It is stored in a suitable photo file format e.g. JPEG.

Uses of Digital Cameras:

1. The digital cameras are used for digital photographic art.
2. They are used to record a meeting or an event.
3. They are used to capture objects for presentation.
4. They are used for virtual reality tours of houses, shopping malls etc.:
   Photos are taken from a single point and the camera is rotated around the room. The images are "stitched" together using software, resized and configured for Internet use.

Advantages of Digital Cameras:

1. It requires no film processing.
2. It doesn't run out of film and saves the cost of buying film as well.
3. It allows seeing photographs instantaneously.
4. Digital camera won't need manual emptying.

Functions of Digital Cameras:

- These cameras are controlled by an embedded system which can automatically carry out the following tasks:
  1. Adjust the shutter speed.
  2. Focus the image automatically.
  3. Operate the flash automatically.
  4. Adjust the aperture size.
  5. Adjust the size of the image.
  6. Remove 'red eye' when the flash has been used.

The quality of the photograph depends on factors such as:

1. The type of lens used (how good the camera lens is and how good the sensor array is).
2. The number of pixels (the more pixels used, the better the image).
3. The lighting/levels of light.
4. The storage format of image (JPEG, raw file and so on).

Pixels (picture element):

- It is the smallest controllable element of a picture represented on the screen.

Advantages of buying a camera with a higher resolution:

1. It results in higher quality photos.
2. When the image is enlarged/magnified, it is less likely for photo to pixelate.

Disadvantages of buying a camera with a higher resolution:

1. It uses up more memory on the card.
2. It takes longer to upload or download a photo.
3. The file size will be greater.

Keyboards:

	
Keyboard	**Ergonomic Keyboard**

- Keyboards are by far the most common method used for data entry.
- They are used as input devices on computers, tablets, mobile phones etc.

Connection of Keyboards:

- The keyboard is connected to the computer by using USB connection or a wireless connection.
- The keyboard is virtual or type of touch screen technology in tablets and mobile phones.

Working of Keyboards:

- A keyboard has a key matrix underneath the keys.
- When a key is pressed, it presses a switch that completes a circuit.
- This allows the current to flow.
- The location of the key pressed is calculated.
- The location of the key pressed is compared to a character map to find the binary value for the key that has been pressed.

How key presses on a Keyboard are processed by the computer.

- A matrix/membrane or a circuit board is present at the base of keys.
- A key is pressed that presses a switch.
- When a key is pressed it completes the circuit changing the current in it.
- The location of the key pressed is calculated.
- An index of characters is searched to find the corresponding key presses.
- Each character has an ASCII value (which in turn has a binary value).
- The binary value can then be processed by the CPU to action the key press.

Quite simply, each character on a keyboard has an ASCII value. Each character pressed on a keyboard is converted into a digital signal, which the computer interprets.

Advantages of Keyboards:

1. It is the easiest way to enter text into a computer.

Disadvantages of Keyboards:

1. It is a relatively slow method of data entry hence takes a lot of time.
2. It is also prone to errors hence easier to make mistakes.

Possible injury & solution:

- Frequent use of these devices can lead to injuries such as repetitive strain injury (RSI) in the hands and wrist.
- Ergonomic keyboard can help to overcome this problem as they have keys arranged differently.
- They are designed to provide more support to hands and wrist when doing a lot of typing.

Applications of Keyboards:

1. It is used for typing messages for communication (e.g. typing a mail).
2. It is used for using shortcuts in a computer system (e.g. pressing ALT and F4 together).
3. It is used for writing data manually in word processor, spreadsheet, database etc. for purposes such as report writing.
4. It is used for keying in data manually in a control room interface for purposes such as flow speed of liquid.

Concept Keyboard:

Concept Keyboard

- A concept keyboard is a specialized keyboard with no preset keys.
- It is a flat board that contains a grid of buttons.
- Each button can be programmed with a wide range of different functions for the users to do whatever they want.
- An overlay sheet with pictures or symbols is placed on the grid so that the user can tell what pressing on different areas will do.

A restaurant has a concept keyboard that is overlaid with images of food items available from their menu. Staff can click on an image to add the food item to a customer order.

Benefits of using a concept keyboard:

1. It has fewer typing errors because only one button is pressed to order an item.
2. It speeds up the time to enter an order because fewer buttons are pressed to complete the order.
3. It requires less training of staff because it is easier to identify an order item from its image rather than typing it.

Microphones:

- A microphone, colloquially named mic is a device that converts sound into an electrical signal.
- These are used to input sound into a computer for purposes such as:
  1. Doing a 'voice over' in a presentation.
  2. Part of a speech recognition system.
  3. Part of a voice recognition system.
  4. Enabling a disabled person to communicate with computer.

Connection of Microphones:

- They are either built into the computer or external devices connected through USB port/wireless connectivity.

Working of Microphones:

- The microphone has a diaphragm.
- The incoming sound waves cause vibrations of the diaphragm causing a coil to move past a magnet.
- The coil cuts through the magnetic field around the permanent magnet, producing an electrical signal.
- The electrical signal is then either amplified or sent to a recording device.
- The electrical signal output from the microphone can also be sent to a computer where a sound card converts the analogue current into a digital value using analogue-to-digital converter (ADC) which can then be stored in the computer.

Advantages of Microphones:

1. It is faster to provide voice as input using microphone than to type text using keyboard.
2. Sound waves can be manipulated in real time.
3. It can help in improving safety and security of drivers and riders when used with voice activation systems e.g. switching on radio, keeping phone in speaker mode etc.
4. They are inexpensive in general.
5. Most of the microphones tolerate extreme high sound pressure levels.
6. It does not require power supply except few.

Disadvantages of Microphones:

1. Sound files require large memory for storage for further processing and use.
2. Voice recognition software is not as accurate as manual typing. For example, it cannot distinguish between "there" and "their".
3. Sound signals are required to be amplified for proper reconstruction. Hence amplifiers are needed.
4. It has reduced performance at high frequencies**.**

Uses of Microphones:

1. It is used in multimedia presentations and allows voice-overs on presentations.
2. It is used in voice recognition system that allows a computer to recognize spoken words and use them as input to, e.g., a word processor.
3. It is used in video conferencing/VoIP and allows the users to speak to each other.
4. It is used in sound and music recording.
5. It is used in radio and television broadcasting.
6. It is used in computers for recording voice.
7. It is used in speech recognition.

Voice Recognition:

- If the microphone is being used in a voice recognition system, the user's voice is detected and then converted into digital.
- A few words spoken produce a digital wave pattern.
- A software compares this wave pattern to wave patterns stored in memory to see if they match.

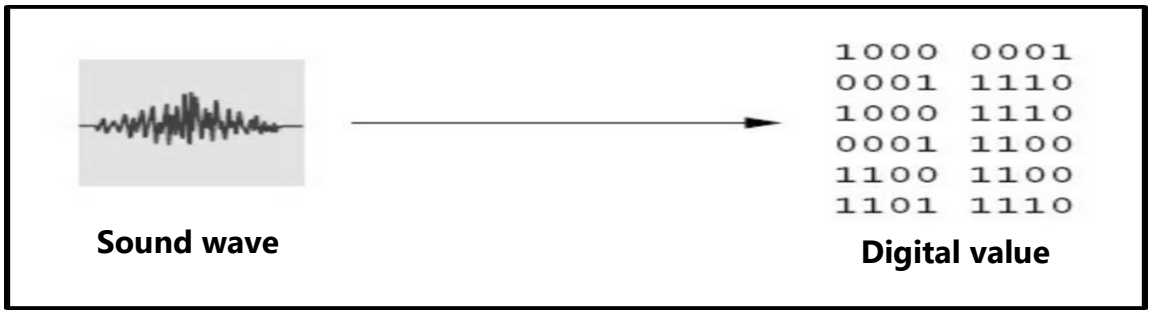
Use of Voice Recognition:

1. This technology can be used in security systems (e.g. a user may be asked to say their name and if the user's voice is identified then he/she is given access).

Speech Recognition:

- It is a different and more complex technology.
- It uses a microphone to input words spoken by a user.
- The spoken words are recognized and shown on a screen, input into a word processor or used in other application.

Example of Speech Recognition:



1. Suppose a person says any word; the sound card in the computer will convert the sound wave into a digital form.
2. The software takes the digital image and breaks it up into phonemes (these are the smallest elements that make up a language).
3. These phonemes are compared with words found in the built-in dictionary.
4. That word would then be suggested by the software in whatever application is being run.

Why is this technology complex?

- It is a complex technology since computer is unable to differentiate between similar sounding words (e.g., their and there) due to different dialects and accents of human beings.

Uses of Speech Recognition:

1. This technology can be used in phones for giving commands such as "open camera".
2. This technology can be used in cars for giving commands such as "switch on GPS".

Difference between Speech Recognition and Speech Synthesis:

Speech recognition:

- The speech recognition is a form of input.
- It requires a microphone.
- It is an example of an expert system (artificial intelligence).

Speech synthesis:

- The speech synthesis is a form of output.
- It requires speakers.
- In speech synthesis, words are chosen from a database.

Optical Mouse:

Optical Mouse

- An optical mouse is an example of a pointing device.
- It uses rolling ball, optical sensor, and red laser to detect motion in the x—y direction.
- The movement is echoed on screen and curser/pointer is moved on screen.
- It has scroll wheel and buttons to allow data input.
- They can use either a USB wired connection or a wireless Bluetooth connectivity to the computer.

Advantages of wired Mouse:

1. There is no signal loss since there is a constant signal pathway (wire).
2. It is cheaper to operate as no need to buy new batteries or charge batteries.
3. There are fewer environmental issues as no need to dispose of old batteries.

Working of Optical Mouse:

- An optical mouse shines a red light from a Light-Emitting Diode (LED) from the bottom of the mouse onto a surface.
- The light reflects back from the surface into a photoelectric cell (CMOS sensor) through a lens.
- The lens magnifies the reflected light to allow detection of smaller movements.
- When a button on the mouse is clicked, a microswitch is pressed.
- The reflection of light is converted to a binary value that is transmitted to the computer.
- The computer then determines the direction and speed of the movement.
- The coordinates are calculated, and the computer moves the cursor on the screen based on the coordinates received from the mouse.

Advantages of Optical Mouse:

1. It has no moving parts which mean less wear and a lower chance of failure, so it is more reliable.
2. There's no way for dirt to get trapped in the mouse and interfere with the tracking sensors/mechanical components.
3. It allows for an increased tracking resolution meaning smoother response.
4. It does not require a special surface, such as a mouse pad.

2D & 3D Scanners:

	
2D Scanner	**3D Scanner**

Scanners are either two-dimensional (2D) or three-dimensional (3D):

Two-Dimensional (2D) Scanners:

- The 2D scanners are the most common form of scanners.
- They are generally used to input hard-copy (paper) documents.
- The scanned image is converted into an electronic form which can be stored on computer.

Working of a 2D Scanner:

- The scanner shines light onto the surface of a document.
- The light source is automatically moved across the document.
- An image of document is produced as reflected light is captured using a series of mirrors and sent to the lens.
- The lens focuses the image which falls onto a charge couple device (CCD).
- Each light-sensitive pixel of CCD creates an electric charge when light falls on it.
- An electronic form is produced which is finally converted to a 2D digital image.

Charge Couple device (CCD):

- It consists of integrated circuits etched into silicon.
- It is made up of thousands of light-sensitive pixels.

After scanning:

- Computers equipped with optical character recognition (OCR) software can convert the scanned text into a text file format.
- Otherwise, if the scanned document was a photograph, then it forms an image file such as JPEG.

Application of 2D Scanners at an airport:

1) They are used at airports to scan and then read passports:

- OCR technology is used to produce digital images of passport pages.
- Due to OCR, these images can be manipulated.
- **Example:** OCR software is able to review these images, select the text part and then automatically put the text into correct fields of an existing database.

2) They are used at airports to scan 2D photograph in passport:

- It is stored as jpeg image.
- The passengers face is then photographed using a digital camera.
- The two digital images are compared using face recognition/detection software.
- Key parts of the face are compared such as:

    1. Distance between eyes
    2. Width of the nose
    3. Shape of the cheekbones
    4. Length of the jaw line
    5. Shape of the eyebrows

- It is done to ensure that the two images represent the same face and for security clearance purposes.

Meaning of Terms:

Optical Character Recognition (OCR):

- Optical character recognition (OCR) is a technology that enables you to convert different types of documents, such as scanned paper documents, PDF files or images captured by a digital camera into editable and searchable data.
- It simply allows scanned text from a document to be converted into text file format for manipulation and editing.

Optical Mark Recognition (OMR):

- Optical mark recognition (OMR) is the process of capturing human-marked data from document forms such as surveys and tests.
- They are used to read questionnaires, multiple choice examination papers in the form of lines or shaded areas.
- It is simply a system that reads pencil or pen marks on a piece of paper in pre-determined positions.

Facial Recognition Software:

- A facial recognition system uses biometrics to map facial features from a photograph or video.
- It compares the information with a database of known faces to find a match.
- Key parts of the face such as distance between eyes, width of nose etc. are compared.
- It can help verify personal identity.

Three-Dimensional (3D) Scanners:

- The 3D scanners scan solid objects and produce a three-dimensional image.
- They scan the x, y and z coordinates taking images at several points which produces a digital image that represents the solid object formed.
- The scanned images can be used in computer aided design (CAD) or sent to a 3D printer to produce a working model of the scanned image.
- Technologies used are lasers, magnetic resonance, and white light etc.

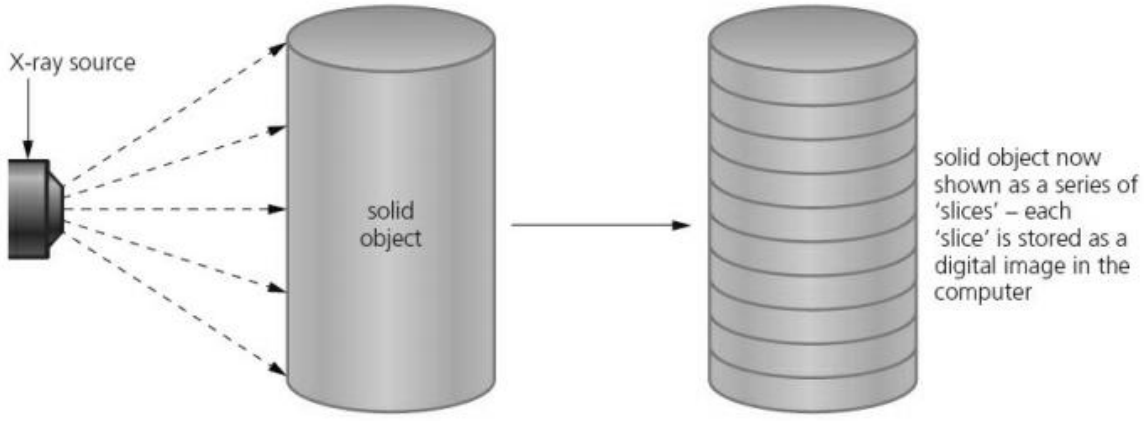
Working of a 3D Scanner:

- The scanner shines a laser or light source over the surface of a 3D object.
- It scans the shape and appearance of an objecting recording the measurements of the dimensions of the object such as the width, height, and depth.
- Then the measurements are converted into digital file.
- Hence, it produces a 3D digital model.

Application of 3D Scanners:

1) Computed tomographic (CT) scanners are used to create a 3D image of a solid object.

- This is based on tomography technology (shown below) which basically builds up an image of the solid object through a series of very thin slices.
- These 2D slices together make up a representation of the 3D solid object.
- Each slice is built up by use of X-rays, radio frequencies or gamma imaging.
- Each slice is then stored as a digital image in computer memory. The whole of solid object is represented digitally in the computer memory.



Tomographic scanners can have different names depending on technology used:

1. X rays technology	2. Radio frequencies technology	3. Gamma rays technology
CT scanners (computerized tomography)	**MRI** (magnetic resonance imaging)	**SPECT** (single photon emission computed tomography)

An airport has a security system that uses:

- **Computers**
- **Scanners**
- **Digital cameras**

Each passenger must have a passport or ID card which contains a recent photograph and other personal data.

- **The passenger places their passport or ID card on a scanner that reads machine-readable characters and scans the photograph.**
- **Look toward the camera that takes an image of the passengers face.**

How a computer checks whether the image just taken by the camera matches the scanned photograph:

- A facial recognition software is used to scan the face.
- The captured image of face is converted to digital data by the camera.
- The scanned photo stored in a passport is converted into digital data.
- The key features of the face are compared in both images such as distance between the eyes, width of the nose etc.

Touch Screens:

- It is now a very common form of input.
- It allows users to interact with devices just by touching the screen.

There are 3 types of touch screens technologies:

1. Capacitive
2. Infra-red
3. Resistive

Uses of Touch Screens:

1. The touch screens are used in mobile phones, tablets etc. because it is an easy method to input data and icons are used for application selection.
2. They are used in laptop displays.
3. They are used in control room interface because it is a faster/easier method to input data into system and fewer chances of error since number of choices are limited.
4. They are used in ticket kiosks and information kiosks because it is an easy method for the public to enter data as it limits the number of options available for ease of use.

Benefits of using a Touch Screen:

1. It does not require peripherals (mouse or keyboard).
2. It has a menu driven interface as the number of possible inputs is limited.
3. There is a less chance of input error.
4. It is resistant to weather in indoor places.

Capacitive:

Working of Capacitive Touch Screen:

- An electrostatic field is created across the screen as current flows out from all 4 corners of the screen.
- The sensors are located around the screen which is used to read the electrostatic field.
- When finger touches screen, the conductive/capacitive properties of a user cause current changes in the field as the electrostatic charge is transferred to the user's finger.
- The coordinates of touch are calculated by an onboard microprocessor.

Advantages of Capacitive Touch Screen:

1. It is a medium cost technology.
2. The screen visibility is good even in strong sunlight.
3. The screen is very durable with high scratch resistance; it takes a major impact to break the glass.
4. It allows multi-touch capability.

Disadvantages of Capacitive Touch Screen:

1. It cannot be used when wearing gloves as it allows only the use of bare fingers for input.

Why gloves cannot be used in capacitive technology?

- The gloves are not conductive.
- They block current from finger and hence stop electrostatic field being changed.

How to use capacitive technology with gloves:

- Use a conductive stylus as they allow charge to be disturbed/changed.
- Use capacitive gloves as they allow charge to disturbed/changed.

Types of Capacitive Touch Screens:

There are presently two main types of capacitive touch screens:

1. Surface
2. Projective

Surface Capacitive Screens:

- An electrostatic field is created across the screen as current flows out from all 4 corners of the screen.
- The sensors are located around the screen which are used to read the electrostatic field.
- When finger touches screen, the conductive/capacitive properties of a user cause current changes in the field as the electrostatic charge is transferred to the user's finger.
- The coordinates of touch are calculated by an onboard microprocessor.
- This system only works with a bare finger or stylus.

Projective Capacitive Screens:

- The transparent conductive layer is in the form of an X—Y matrix pattern.
- A three-dimensional (3D) electrostatic field is created across the screen as current flows out from all 4 corners of the screen.
- The sensors are located around the screen which are used to read the electrostatic field.
- When finger touches screen, the conductive/capacitive properties of a user cause current changes in the 3D electrostatic field as the electrostatic charge is transferred to the user's finger.
- The coordinates of touch are calculated by an onboard microprocessor.
- This system works with bare fingers, stylus and thin surgical or cotton gloves.

Infra-Red:

Working of Infra-Red Touch Screen:

- Infrared rays are sent across screen from the edges.
- It has sensors around edges.
- Infrared rays form an invisible grid across the screen.
- Infrared ray is broken by a finger blocking a beam.
- Calculation is made on where beam is broken to locate the 'touch'.

Heat-Sensitive Infra-Red system:

- It uses glass as the screen material and needs a warm object (e.g. fingers) to carry out an input operation.

Optical Infra-Red system:

- It uses glass as the screen material and uses an array (group) of sensors in the form of a gird; the point of contact is based on which grid coordinate is touched.

Advantages of Infra-Red Touch Screen:

1. The screen is very durable; it takes a major impact to break the glass.
2. It allows multi-touch capability.
3. Optical system allows use of bare fingers, gloved fingers or stylus for input.

Disadvantages of Infra-Red Touch Screen:

1. It is an expensive technology.
2. It is sensitive to water, moisture, and dust/dirt.
3. It is possible for accidental activation to take place if infrared beams are disturbed in any way.
4. Heat-sensitive system only allows use of bare fingers for input.

Resistive:

Working of Resistive Touch Screen:

- It uses an upper layer of polyester (type of plastic) and a bottom layer of glass that transmit electric currents.
- When the top polyester layer is touched, the top and bottom layer complete a circuit.
- As a result, the electric current changes and signals are sent out.
- They are interpreted by a microprocessor and calculation is carried out on where layers are connected to determine the coordinates of the touch.

Advantages of Resistive Touch Screen:

1. It is cheaper to manufacture/inexpensive technology.
2. It allows use of bare fingers, gloved fingers, or stylus for input.
3. It has good resistance to dust and water.

Disadvantages of Resistive Touch Screen:

1. The screen visibility is poor in strong sunlight.
2. It does not allow multi-touch capability.
3. It has low touch sensitivity.
4. The screen is vulnerable to scratches and wears out through time.

The following tables compare capacitive and resistive technologies:

(i) Table 1:

Statement	Resistive (✓)	Capacitive (✓)
This touch screen has multi-touch capabilities		✓
This touch screen cannot be used whilst wearing gloves		✓
This touch screen is made up of two layers with a small space in between	✓	
This touch screen uses the electrical properties of the human body		✓
This touch screen is normally cheaper to manufacture	✓	
This touch screen has a quicker response time		✓

(ii) Table 2:

Statement	Capacitive (✓)	Resistive (✓)
Needs pressure to be applied to create a circuit		✓
May not register a touch if the user is wearing gloves	✓	
More commonly used in smartphones	✓	
More responsive to a touch	✓	
Needs an electrical field to be changed to register a touch	✓	
Cheaper to manufacture		✓

Exam Style Questions:

Question 1:

Give an application which makes use of each device and state a reason why the device is appropriate for that application.

Your application must be different in each case.

Input device	Application and reason
Light sensor	Application ..... Reason ....
Keyboard	Application ..... Reason ....
Barcode reader	Application ..... Reason ....
Touch screen	Application ..... Reason ....

[8]

Answer:

1 mark for each named application + 1 mark for each matching reason for choice

Input device	Application and reason
Light sensor	Automatic doors – detects a person when light beam broken and opens doors Street lighting – detects change in light and switches on / off the street lights Greenhouse – ensures correct lighting conditions for growth of plants
Keyboard	Word processor / spreadsheet / database – need to key in data manually (e.g. report writing) Control room interface – need to manually key in data (e.g. flow speed of liquid)
Barcode reader	Supermarket checkout – read barcodes to find prices, description – allows automatic stock control Library system – can track books on loan – can link books to borrowers using barcoded cards Airport check-ins – barcodes on luggage to track whereabouts
Touch screen	Ticket / information kiosk – easy method for public to enter data – limited number of options Mobile phone / tablet – easy method to input data – use of icons for application selection Control room interface – faster / easier method to input data into system – fewer chances of error since number of choices limited

[8]

Question 2:

Airline boarding passes can be read from a smartphone instead of a printout.

Identify what type of barcode **A** is an example of. Explain how the data stored in this type of barcode is read.

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.....[4]

Answer:

Question	Answer	Marks
6	1 mark for correct name of code, up to a further 3 marks for appropriate explanation • Quick response (QR) Code **Three** from: • Barcode is captured / scanned / imaged, by a camera / scanner / barcode reader / QR code reader • Read using a laser • Processed by an app • Light is reflected back • Black squares reflect less light than white squares • Modules are used for orientation / alignment • Squares / data are decoded	**4**

Question 3:

Describe the operation of a 2D scanner and a 3D scanner.

2D .....

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3D .....

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[6]

Answer:

Question	Answer	Marks
6	Any **six** from: 2D – (Scanner) shines a light onto the surface of a document // Light moves across document – Reflected light is captured – Uses mirrors and lenses – Captured image is converted into a digital file – Produces a 2D digital image 3D – Scanners shines a laser (or light) over the surface of a 3D object – Records measurements of the geometry/dimensions of the object – Measurements are converted to digital file – Produces a 3D digital model	**6**

Question 4:

A supermarket has a system that allows customers to check out their own shopping.

Identify and describe the purpose of **two** input devices and **one** output device used in this system.

Input device 1 .....

Purpose .....

.....

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Input device 2 .....

Purpose .....

.....

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Output device 1 .....

Purpose .....

.....

.....

[6]

Answer:

Question	Answer	Marks
9	1 mark for appropriate device name and 1 further mark for appropriate purpose. **Input devices** **Two** from: • **Keypad / Keyboard** … • … e.g. to allow customer to input the quantity of an item • **Touchscreen** … • … e.g. to allow a customer to select a payment method • **Barcode scanner / Barcode reader** … • … e.g. to allow a customer to scan in their shopping • **Card reader // Cash deposit / intake** … • … e.g. to allow a customer to pay for their shopping • **Weighing scales** … • … e.g. to allow a customer to weigh fresh produce **Output devices** **One** from: • **Display / Touchscreen** … • … e.g. to allow a customer to see the running total of their shopping • **Speaker** … • … e.g. to give audio instructions to a customer about how to use the self-checkout • **Printer** … • … e.g. to print a receipt for the customer	**6**

Question 5:

Describe the differences between a barcode and a Quick Response (QR) code.

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.....[3]

Answer:

Question	Answer	Marks
10	Any **three** from: • barcode 1D **and** QR code 2D • barcodes contain vertical lines **and** QR codes contain 'squares' • QR code can hold more data than a barcode • QR code can be read from any angle, some barcode readers have to be lined up with the barcode // QR codes are more error tolerant / faster to scan than barcodes • barcodes are frequently used at checkouts / libraries // QR codes are used for advertising // QR codes are frequently used by mobile phones to obtain information	**3**

Question 6:

A keyboard is a type of input device that can be used to enter data into a computer.

Complete the paragraph that describes one method of operation for a keyboard, using the most appropriate terms from the given list. **Not** all terms in the list need to be used.

- Binary
- Breaks
- Calculated
- Character
- Circuit
- Current
- Information
- Network
- Press
- Processor
- Signal
- Switch

A keyboard has a key matrix underneath the keys. When a key is pressed, it presses a

..... that completes a ..... . This allows

..... to flow. The location of the key pressed is

..... . The location of the key pressed is compared to a

..... map to find the ..... value for the key that

has been pressed.

[6]

Answer:

8	One mark for each correct term in the correct order – Switch – Circuit – Current – Calculated – Character – Binary	**6**

Question 7:

The paragraph explains the operation of different touch screen technologies.

Complete the paragraph using the list of terms. **Not** all terms in the list need to be used.

- capacitive
- change
- circuit
- conductive
- coordinates
- grid
- heat
- infra-red
- insulating
- light
- manufacture
- pressure
- resistive

In ..... touch screen technology, an electrostatic field is present on the surface of the touch screen. The ..... properties of a user cause a ..... in the field. The ..... of the user's touch can be calculated.

In ..... touch screen technology, a user pushes the top layer of the screen and makes it connect with the bottom layer to complete a ..... .

This type of touch screen is cheaper to ..... .

[7]

Answer:

Question	Answer	Marks
4	**One** mark per each correct term in the correct order. – Capacitive – Conductive // Capacitive – Change – Coordinates – Resistive – Circuit – Manufacture	7

Question 8:

A train station uses large touch screens to allow passengers to search for train information and buy tickets.

(a) State **three** benefits of using a touch screen in the train station.

Benefit 1 .....

.....

Benefit 2 .....

.....

Benefit 3 .....

.....

[3]

(b) The touch screens at the station use resistive touch technology.

Describe how resistive touch technology works.

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..... [4]

Answer:

Question	Answer	Marks
7(a)	Any **three** from: – Does not require peripherals (mouse or keyboard) – Number of possible inputs limited / menu driven interface – Less chance of input error – Resistant to weather	3
7(b)	– Uses two/multiple layers – When top layer touched / pushed two layers make contact – Circuit is completed when layers touch – Point of contact is determined/calculated	4

Question 9:

A supermarket uses a barcode scanner to read the barcodes on its products.

(a) Describe how the barcode scanner reads the barcode.

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(b) Explain how the barcode system could help the supermarket manage its stock.

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[3]

(c) An infrared touch screen is used to view and navigate the supermarket stock system.

Explain how the infrared touch screen detects a user's touch.

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[4]

Answer:

Question	Answer	Marks
8(a)	Any **four** from: – Shines light / (red) laser at barcode – Light is called an illuminator – Light is reflected back // White lines reflect light // Black lines reflect less light/absorbs light – Sensors / photoelectric cells detect the light – Different reflections / bars will give different binary values / digital values // pattern converted to digital values – A microprocessor interprets the data	**4**
8(b)	Any **three** from: – barcode identifies a (unique) product – barcode can be used to look up product (in a database) – data about stock levels can be stored on a system – stock can be automatically deducted from the system – can check stock is below a certain level // check stock level – automatic re-order // Alerts when stock is low – automatically update new stock level – to locate if an item of stock is available in another location	**3**
8(c)	Any **four** from: – (Infrared) rays are sent across screen (from the edges) – Has sensors around edge // Sensors capture beams – (Infrared) rays form a grid across the screen – (Infrared) ray is broken (by a finger blocking a beam) – **Calculation** is made (on where beam is broken) to locate the 'touch' // Co-ordinates are used to locate the touch	**4**

Question 10:

Pradeep uses his personal computer to complete work at home.

(a) Pradeep uses a mouse and a keyboard to control the computer.

(i) Complete the descriptions of the principles of operation of a mouse and a keyboard using the most appropriate terms from the list. **Not** all terms in the list need to be used.

- absorbs
- ball
- biometric
- circuit
- colour
- digital
- direction
- Light-Emitting Diode (LED)
- Liquid Crystal Display (LCD)
- reflects
- speed
- switch
- transparency

An optical mouse shines a red light from a ..... underneath the mouse. The light ..... back from a surface through a lens in the mouse and is converted to a value. This value is transmitted to the computer. The computer then determines the ..... and ..... of the movement.

When the user presses a key on a keyboard, the key pushes the ..... on the circuit board. This completes a ..... . Signals are sent to the computer. The computer uses the data to calculate which key was pressed.

[6]

(ii) Identify **two** other input devices Pradeep could use with his personal computer.

Input device 1 .....

Input device 2 .....

[2]

Answer:

Question	Answer	Marks
4(a)(i)	1 mark for each completed statement An optical mouse shines a red light from a **Light-Emitting Diode//LED** underneath the mouse. The light **reflects** back from a surface through a lens in the mouse and is converted to a value. This value is transmitted to the computer. The computer then determines the **direction** and **speed** of the movement. When the user presses a key on a keyboard, the key pushes the **switch** on the circuit board. This completes a **circuit**. Signals are sent to the computer that uses the data to calculate which key was pressed.	**6**
4(a)(ii)	1 mark each e.g. • touchscreen • touchpad • scanner • microphone	**2**

Question 11:

An optical mouse is a type of input device that can be used to input data into a computer system.

(a) Complete the paragraph about the operation of an optical mouse, using the most appropriate terms from the given list. **Not** all terms need to be used.

- Ball
- Battery
- LCD
- LED
- Lens
- Magnifies
- Matrix
- Microswitch
- Photoelectric
- Photographic
- Reduces
- USB

An optical mouse shines an ..... from the bottom of the mouse onto a surface. Light bounces straight back from the surface into a ..... cell. This has a ..... that ..... the reflected light to allow detection of smaller movements. When a button on the mouse is clicked, a ..... is pressed. A ..... connection is used to carry the data to the computer.

[6]

Answer:

Question	Answer	Marks
3(a)	**One** mark per each correct term, in the correct place. – LED – Photoelectric – Lens – Magnifies – Microswitch – USB	**6**

Question 12:

(c) Georgia uses a digital camera. The digital camera takes a photograph that is then converted into a digital image.

Complete the paragraph about the operation of a digital camera, using the most appropriate terms from the list. **Not** all terms in the list need to be used.

- analogue-to-digital
- binary
- charge-coupled
- digital-to-analogue
- lens
- light
- mirror
- pixel
- reflection
- sensor
- storage

When Georgia pushes the button to take a photograph, an aperture opens at the front of the camera to allow ..... to stream in through the ..... . This is captured by a sensor called a ..... device. The ..... converter then converts each ..... into a digital value.

[5]

Answer:

4(c)	– Light – Lens – Charge-coupled – Analogue-to-digital – Pixel	**5**

Question 13:

Alexandra has a new mobile device.

It has a touch screen that uses capacitive technology.

(a) Describe how a capacitive touch screen registers Alexandra's touch.

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..... [4]

(b) Alexandra is wearing gloves because it is cold.

She presses an icon on her touch screen but her action is not registered.

(i) Explain why the touch screen will not register her touch.

.....

.....

.....

..... [2]

(ii) Alexandra does not want to remove her gloves.

Explain how Alexandra could use her mobile device whilst still wearing gloves.

.....

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..... [2]

Answer:

Question	Answer	Marks
10(a)	Any **four** from: – Conductive layer – An electrostatic/electric field is created – **Sensor(s)** (around the screen) monitor the electrostatic field – When touched (electrostatic) charge is transferred to finger – Location of touch is **calculated** // Co-ordinates used to **calculate** touch	**4**
10(b)(i)	Any **two** from: – Gloves are not conductive // Gloves are an insulator – Block current/charge from finger / body / person – Stop the electrostatic field being disturbed/changed	**2**
10(b)(ii)	Any **two** from e.g. (1 mark for method, 1 for expansion): – She could use a (conductive) stylus… – … this will allow the charge to be charged/disturbed – She could use capacitive gloves… – … this will allow the charge to be charged/disturbed – She could use a natural language interface/voice operated interface … – … she could give vocal commands to the device	**2**

Question 14:

(b) Genevieve writes a paragraph about a barcode reader.

Using the list given, complete the paragraph. Not all terms in the list need to be used.

- actuators
- binary
- black
- input
- microprocessors
- output
- sensors
- storage
- white

A barcode reader is an ..... device. It shines a light at the barcode and the light is reflected back. The ..... bars in the barcode reflect less light than the ..... bars.

..... are used to capture the amount of reflected light and the different reflections are converted to ..... values.

[5]

Answer:

Question	Answer	Marks
2(b)	– Input – Black – White – Sensors – Binary **One** mark for each correct term in the correct place	5

Question 15:

A zoo has an information point.

- Visitors use a menu to select information about animals.
- The menu includes 500 different animals.
- The information is provided only using high definition video with an audio track.

(a) State **one** input device that could be used for the information point.

..... [1]

(b) The output is shown on a monitor.

State **one** other output device that could be used for the information point.

..... [1]

(c) The video files are stored at the information point.

State **one** secondary storage device that could be used.

..... [1]

(d) The zoo decides to introduce Quick Response codes in different places in the zoo. These provide further information about the animals.

Describe how customers obtain the information from the Quick Response codes.

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..... [4]

Answer:

Question	Answer	Marks
4(a)	**One** from: Touch screen Keyboard Microphone Mouse	1
4(b)	**One** from: Headphones Speakers Printer Light / LED	1
4(c)	**One** from: HDD SSD USB drive	1
4(d)	**Four** from: QR code is scanned using a camera on a mobile device … … and read / decoded using an application / software Illuminator shone on code Squares reflect light differently Corners of code are used for orientation Opens document with information // Directs to website with information QR code can be saved for future reference	4

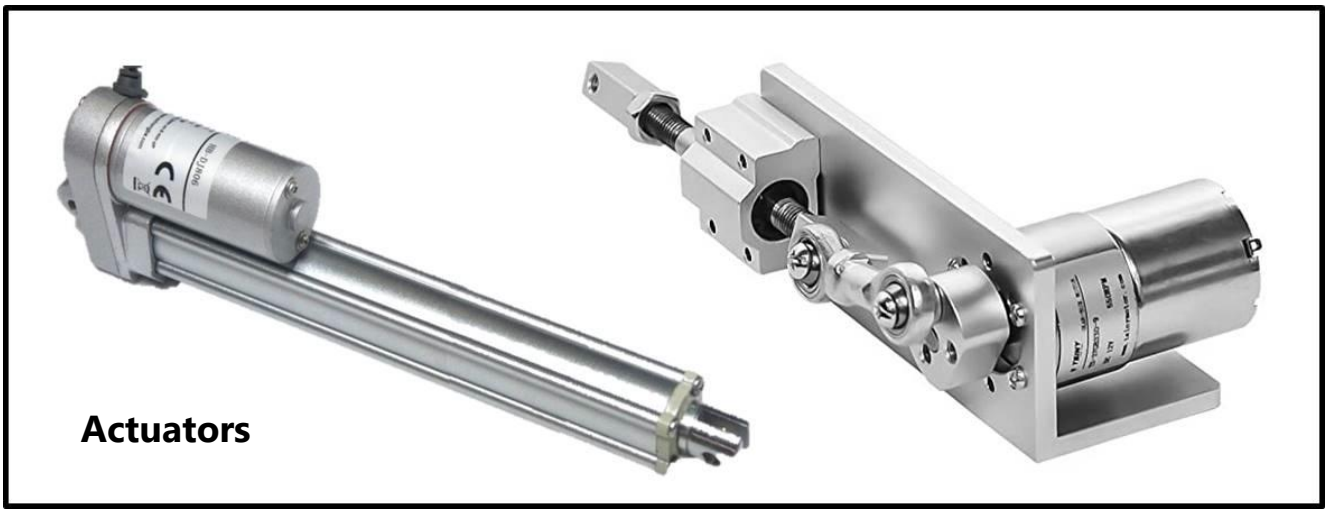
3.2.2 Output Devices:

- A device that allows the user to view/hear the data that has been entered into a computer system.

The output devices included in our syllabus are:

1. actuator
2. digital light processing (DLP) projector
3. inkjet printer
4. laser printer
5. light emitting diode (LED) screen
6. liquid crystal display (LCD) projector
7. liquid crystal display (LCD) screen
8. speaker
9. 3D printer

Actuators:



Actuators

- It is an electromechanical device such as a relay, solenoid, or motor.
- It is operated by signals to cause physical movement.
- It controls the movement of a machine, e.g., electric door locks in automobiles.
- It is a component of a machine that is responsible for powering and moving a motor in machinery, such as a robot arm in a factory.
- An actuator requires a control signal and a source of power/energy to convert the signal into mechanical motion.

Uses of Actuators:

1. It is mainly used in many control applications involving sensors and devices such as ADC and DAC.
2. It is used in control devices such as a conveyer belt to start and stop the conveyer belt.
3. It is used in control devices such as a valve to open and close the valve.

Examples of Actuators:

1. Electric motor.
2. Comb drive.
3. Digital micro mirror device.
4. Hydraulic cylinder.
5. Screw jack.

Light Projectors:

Projectors

There are two common types of light projector:

1. Digital light projector (DLP)
2. Liquid crystal display (LCD) projector

Projectors are used to project computer output onto larger screens, walls or even onto interactive whiteboards. They are often used in presentations and in multimedia applications.

Digital Light Projectors (DLP):

- It uses thousands of tiny mirrors that can move very quickly to create an image.

Working of DLP:

- It uses a large number of tiny mirrors.
- The mirrors are laid out in a grid/matrix.
- Each mirror creates a pixel in the image.
- The mirror can tilt toward or away from the light source which creates a light or dark pixel of projection screen.
- The mirrors reflect light toward a projection lens.
- The color is produced using a color wheel.
- The light passes through color wheel, and it is filtered into red, green, and blue.
- It can be used to display an image on a wall/screen.

Features of DLP:

- The DLP projector can create over 16 million different colors.
  The tilting of each tiny mirror towards or away from the light source is linked with colors from the color wheel to produce the different colored images.

Advantages of DLP:

1. It has a higher contrast ratio.
2. It has higher reliability/longevity.
3. It is smaller and lighter than an LCD projector and easily portable.
4. It is better suited to dusty or smoky atmospheres than an LCD projector.

Disadvantages of DLP:

1. The image tends to suffer from shadows when showing a moving image.
2. It has more moving parts and therefore produces more heat.
3. It does not have grey components in the image.
4. It produces poorer reds and yellows color when running at full power.
5. The color definition is poorer than LCD projectors because the color saturation is not as good.

Liquid Crystal Display (LCD) Projectors:

- It is an older technology than DLP.
- It uses a high intensity beam of light shone through three layers of changing pixels.

Working of LCD Projectors:

- A powerful beam of white light is generated from a bulb or LED inside the projector body.
- This beam of light is then sent to a group of chromatic-coated mirrors which reflect the light back at different wavelengths corresponding to red, green, and blue light components.
- These three different colored light components pass through three LCD screens and a red, green, and blue version of the grey image emerges.
- These images are then combined using a special prism to produce a full color image which consists of millions of colors.
- Finally, the image passes through the projector lens onto a screen.

Advantages of LCD Projectors:

1. It has a higher resolution and more visible pixels.
2. It has higher color contrast in ambient lightning and more vivid colors.
3. It uses less power and produces less heat, so it is more efficient in their use of energy than DLP projector.
4. It runs quieter than a DLP projector.
5. It has better color saturation than DLP projector and it does not give the rainbow effect the DLP projector often gives.

Disadvantages of LCD Projectors:

1. It has a poorer contrast ratio than DLP projector.
2. It has a limited life and longevity is not as good as DLP projector.
3. It is bulkier and not very convenient for portability.

A projector is needed to watch high-definition (HD) films. The projector will be attached to the ceiling at home. Why an LCD projector would be more appropriate for this purpose as compared to DLP projector?

1. It has a higher resolution and more visible pixels.
2. It has higher color contrast in ambient lightning and more vivid colors.
3. The colors are often more accurate.
4. The image usually appears brighter with same wattage.
5. The projector will be stationary, so it does not need the portability and compactness of the DLP projector.
6. The cost of purchase is usually less.
7. It runs quieter than a DLP projector and any surface can be used as a display.
8. It uses less power and produces less heat.
9. It does not give the rainbow effect the DLP projector often gives.

Inkjet Printers:

Inkjet Printers

They consist of:

- A print head which consists of nozzles that spray droplets of ink on to the paper to form characters.
- An ink cartridge or cartridges/liquid ink.
- A stepper motor and belt which moves the print head assembly across the page from side to side.
- A paper feed which automatically feeds the printer with pages as they are required.

It has a small ink cartridge and small paper tray.

Working of Inkjet Printers:

- It uses rollers which move the paper through the printer.
- It makes use of thermal bubble or piezoelectric technology.
- The nozzles spray droplets of ink onto the paper.
- A print head moves across the paper to distribute the ink.
- The different color inks are mixed to create required colors.

It is suitable for low volume and high-quality output e.g., a photograph.

The droplets of ink are propelled onto paper using either thermal bubble or piezoelectric technology:

Thermal Bubble:

- The tiny resistors create localized heat which makes the ink vaporize.
- The ink forms a tiny bubble and as it expands some of the ink is ejected from print head onto the paper.
- Then the bubble collapses and a small vacuum is created which allows fresh ink to be drawn into the print head.

Piezoelectric:

- A crystal is located at the back of the ink reservoir for each nozzle.
- The crystal is given a tiny electrical charge which makes it vibrate.
- This vibration forces droplets of ink to be ejected onto paper through the nozzle.

Advantages of Inkjet Printers:

1. The printing may be of higher quality.
2. It can be used in larger paper sizes.
3. It can print onto different media.
4. It is more reliable.
5. It does not need warm-up time.

Disadvantages of Inkjet Printers:

1. The ink is more expensive so printing cost per page is high.
2. The printing will be slower.
3. The ink can be smeared if ink is not smudging proof.

Applications of Inkjet Printers:

1. It is used for the production of one-off photographs of very good quality.
2. It is used when only a few pages of good quality, color printing is needed.
3. It is used when small quantities of documents are to be printed.

Sequence of events during printing of Inkjet Printers:

Stage in process	Description of what happens
1	The data from the document is sent to a printer driver.
2	The printer driver ensures that the data is in a format that the chosen printer can understand.
3	A check is made by the printer driver to ensure that the chosen printer is available to print (e.g. is it busy, is it off line, is it out of ink, and so on).
4	The data is then sent to the printer and it is stored in a temporary memory known as a printer buffer.
5	A sheet of paper is then fed into the main body of the printer; a sensor detects whether paper is available in the paper feed tray – if it is out of paper (or the paper is jammed) then an error message is sent back to the computer.
6	As the sheet of paper is fed through the printer, the print head moves from side to side across the paper printing the text or image; the four ink colors are sprayed in their exact amounts to produce the desired final color.
7	At the end of each full pass of the print head, the paper is advanced very slightly to allow the next line to be printed; this continues until the whole page has been printed.
8	If there is more data in the printer buffer, then the whole process from stage 5 is repeated until the buffer is finally empty.
9	Once the printer buffer is empty, the printer sends an interrupt to the processor in the computer; this is a request for more data to be sent to the printer; the whole process continues until the whole of the document has been printed.

Laser Printers:

Laser Printers

It has a large toner cartridge and large paper tray. It uses powdered toner and rotating drum to transfer the image to the paper.

Working of Laser Printers:

- It makes use of the properties of static electricity.
- It uses dry powdered ink/toner cartridges.
- A laser beam removes positive charges in certain areas.
- It then uses positive and negative charged rotating drums.
- The paper then goes through a fuser which melts the ink onto the paper making it permanent.
- Then a discharge lamp removes all electric charges from drum making it ready to print further pages, if any.
- It does not have any moving head.

It is suitable for high volume and high-quality output e.g., leaflets.

Advantages of Laser Printers:

1. It has faster speed of printing.
2. It can print on both sides/duplex.
3. It prints text at a high quality.
4. It has a cheaper printing cost per page as many pages can be printed from one toner cartridge.
5. It can print in high volumes.

Disadvantages of Laser Printers:

1. It is expensive to purchase.
2. The toner cartridge is expensive.
3. It prints images at a lower quality.
4. It needs more time to warm-up
5. It can be quite large in size.

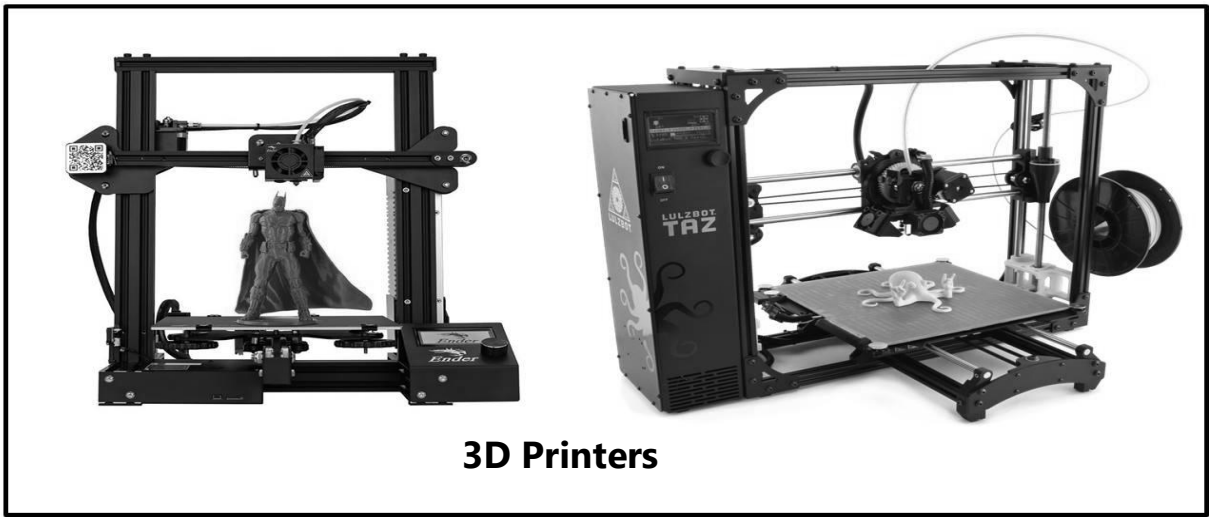
Application of Laser Printers:

1. It is used for producing a large number (e.g., 2000) of high quality flyers, leaflets, magazines and posters for advertising.
2. It is used when large quantities of documents are to be printed.

Sequence of events during printing of Laser Printers:

Stage in process	Description of what happens
1	The data from the document is sent to a printer driver.
2	The printer driver ensures that the data is in a format that the chosen printer can understand.
3	A check is made by the printer driver to ensure that the chosen printer is available to print (e.g., is it busy, is it offline, is it out of ink, and so on).
4	The data is then sent to the printer, and it is stored in a temporary memory known as a printer buffer.
5	The start of the printing process involves a printing drum being given a positive charge; as this drum rotates, a laser beam is scanned across it removing the positive charge in certain areas; this leaves negatively charged areas which exactly match the text/images of the page to be printed.
6	The drum is then coated with positively charged TONER (powdered ink); since the toner is positively charged, it only sticks to the negatively charged parts of the drum.
7	A negatively charged sheet of paper is then rolled over the drum.
8	The toner on the drum now sticks to the paper to produce an exact copy of the page sent to the printer.
9	To prevent the paper sticking to the drum, the electric charge on the paper is removed after one rotation of the drum.
10	The paper finally goes through a fuser which is a set of heated rollers; the heat melts the ink so that it fixes permanently to the paper.
11	At the very end, a discharge lamp removes all the electric charge from the drum making it ready to print the next page.

3D Printers:



3D Printers

- It produces/outputs a solid, physical, three-dimensional (3D) product/object/prototype.
- They are primarily used in computer aided design (CAD) applications.

The software used to create the computerized designs for 3D printing:

- Computer Aided Design (CAD)

Working of 3D Printer:

- It makes use of tomography/slices of an object.
- The solid object is built up layer by layer using materials such as powdered resin, powdered metal, plastic, paper or ceramic powder.
- They use additive manufacturing.
- Additive manufacturing is a process that adds successive layers of material to create an object (e.g. building up the object layer by layer).

The more traditional method is: Subtractive Manufacturing

- It involves removing sections or portions of a material by machining or cutting it away to make it into any shape we want, for making the object.
- Similarly, CNC machining removes metal to form an object; hence it uses subtractive manufacturing method.

An example to show the difference between Additive and Subtractive manufacturing:

- If we have to make a statue using 3D printing, additive method will involve building it up layer by layer using powdered stone until the final object is formed.
- The subtractive method would involve carving the statue out of solid stone (e.g., removing the stone not required) until the final item is produced.

Be very clear that additive manufacturing (building up layer by layer) is called 3D printing. Subtractive manufacturing s not 3D printing or any method of 3D printing

There are two technologies of 3D Printing:

Direct 3D Printing:

- It uses inkjet technology.
- A print head can move from left to right as in a normal printer.
- A print head can also move up and down to build up the layers of an object.

Binder 3D Printing:

- It is similar to direct 3D printing.
- However, this method uses two passes for each of the layers.
- The first pass sprays dry powder.
- The second pass sprays a binder (type of glue) to form a solid layer.

However, the newer technologies are using lasers and UV light.

The following are the steps involved in 3D Printing:

A design is made using computer-aided design (CAD) software.

↓

The finalized drawing is imported into some special software that prepares it in a format which is understood by the 3D printer.

↓

The 3D printer is set up to allow the solid object to be made.

↓

The solid object is built up layer by layer (often only 0.1 mm thick); this can take several hours, depending on the thickness of the layers, the material used and the size of the final object.

↓

The object is removed from the printer and is then prepared; for example, some use a jelly-like support which needs to be washed away by immersion in water, some require the removal of excess plastic powder and others require the cutting away of unused material; in many cases, the object has to be left to 'cure' for a few hours.

Uses of 3D Printing:

1. A physical model can be made from a blueprint.
2. It is used to make prosthetic limbs that exactly fit the recipient.
3. It is used to make items that allow precision reconstructive surgery.
4. It is used in aerospace; wings and other parts are made due to precision and lightweight.
5. It is used for making suspension parts for a vintage car that are no longer in production.

The following tables compare inkjet, laser, and 3D printers:

(i) Table 1:

Statement	3D (✓)	Inkjet (✓)	Laser (✓)
Uses a moving print head	✓	✓	
Uses liquid ink		✓	
Produces output using materials such as plastic and resin	✓		
Uses piezoelectric or thermal technology	(✓)	✓	
Uses a rotating drum to transfer the image to the paper			✓
Uses layer upon layer of material to create the output	✓		

(ii) Table 2:

Statement	Inkjet (✓)	Laser (✓)
Uses a rotating drum to transfer the image to the paper		✓
Uses powdered toner		✓
Uses nozzles to spray droplets on to the paper	✓	
Uses a print head mechanism that moves side to side	✓	

(iii) Table 3:

Statement	Inkjet (✓)	Laser (✓)
Can print in color	✓	✓
Uses a charged drum to create the printed item		✓
Uses powdered toner		✓
Creates output line by line using a print head	✓	

Light Emitting Diode (LED):

LCD/LED

Working/Operation of LED:

- It is a flat panel display that uses an array of light-emitting diodes as pixels.
- The display is made of up pixels that are arranged together as a matrix.
- Each pixel is formed of three light emitting diodes (LEDs)/filters.
- The shades of color are achieved by mixing red, green, and blue diodes.
- The screen can be back-lit/edge-lit.
- It is used in mobile devices such as smartphones and tablets.

Benefits of LED technology:

1. It has low power consumption/energy efficient.
2. It has greater longevity (long lasting).
3. It has a focused beam and less light strays from the beam.
4. It has brighter/vivid colors.
5. It has high resolution image and there is fewer pixel failure.
6. It does not suffer flicker issues.
7. The display is thinner.
8. It is mercury free technology so environmentally friendly.
9. It has increased viewing in sunlight.

Liquid Crystal Display (LCD):

Working/Operation of LCD:

- It is a flat panel display that uses the light modulating properties of liquid crystals.
- The display of an LCD screen is made up of pixels that are arranged together as a matrix.
- The screen is backlit using some form of technology such as CCFL or LED.
- Each pixel has three filters red, blue, and green.
- The different shades of color are achieved by mixing red, blue, and green.
- The light is shone through the liquid crystals, and the crystals can be turned between opaque and transparent to allow light to pass.

Backlighting of LCD:

- LCD doesn't emit any light; some form of backlit technology needs to be used.
- Modern LCD monitors are backlit using light emitting diode (LED) technology which gives the image better contrast and brightness.
- When LEDs are used, a matrix of tiny LEDs is used behind the LCD screen.
- Before the use of LEDs, LCD monitors used a cold cathode fluorescent lamp (CCFL) as the backlighting method.
- Essentially, CCFL uses two fluorescent tubes behind the LCD screen which supplies the light source.

Benefits of LCD technology:

1. It has low power consumption.
2. It runs at cool temperature.
3. It does not suffer image burn.
4. It does not suffer flicker issues.
5. It has bright image/colors.
6. It has high resolution image.
7. It is cheaper to purchase than e.g., an LED screen.

Advantages of using LED back-lit technology compared to the older cold cathode fluorescent lamp (CCFL) in LCD monitors & televisions:

1. LED's do not need to warm up and reach maximum brightness immediately.
2. LED gives a whiter tint which makes colors appear more vivid and brighter.
3. LED provides a higher resolution display/good color definition.
4. LED allows for much thinner screens with lighter weights.
5. LED is a more reliable technology and longer lasting.
6. LED uses much less power, and it is more efficient.

Organic Light Emitting Diode (OLED):

Future LED technology is making use of organic light emitting diodes (OLEDS).

- These use organic materials (made up of carbon compounds) to create semi-conductors which are very flexible.
- The organic films are sandwiched between charged metallic cathode and a glass anode.
- When an electric field is supplied to the electrodes, they give off light.
- This means that no form of backlighting is required.
- It also removes the need to use LCD technology, since OLED is a self-contained system.

Advantages of using OLED compared with existing LEDs and LCDs:

1. The plastic, organic layers of an OLED are thinner, lighter and more flexible than the crystal structures used in LEDs or LCDs.
2. The light-emitting layers of an OLED are lighter and these layers can be made from plastic rather than the glass used in LED and LCD screens.
3. OLEDs give a brighter light than LEDs.
4. OLEDs do not require backlighting like LCD screens as they generate their own light.
5. They use much less power than LCD screens as no backlighting is required (this is very useful in battery-operated devices such as mobile phones).
6. OLEDs are essentially plastics and so they can be made into large, thin sheets (this means they could be used on large advertising boards in airports, subways, and so on).
7. OLEDs have a very large field of view, about 170 degrees, which makes them ideal for use in television sets and for advertising screens.

Uses of these technologies:

They are used in:

1. television screens
2. computer monitors
3. portable systems with touchscreens
4. smartphones
5. tablets
6. handheld game consoles

Speakers:

Speakers

Components of Speakers:

1. Diaphragm/cone
2. Coil of wire
3. Spider/suspension
4. Permanent magnet
5. Basket
6. Dust cap
7. Outer frame

Working of Speakers:

- It takes an electrical signal and translates it into physical vibrations to create sound waves by passing the digital data (binary values) through a digital-to-analogue converter (DAC).
- An electric current in the coil creates an electro-magnetic field.
- The changes in the audio signal causes the direction of the electric current to change.
- The direction of the current determines the polarity of the electro-magnet.
- The electro-magnet is repelled by or attracted to the permanent magnet.
- This causes the coil to vibrate.
- The movement of the coil causes the diaphragm/cone to vibrate.
- The vibration is transmitted to the air in front of the diaphragm/cone as sound waves.
- The amount of movement will determine the frequency and amplitude of the sound wave produced.

Exam Style Questions:

Question 1:

The steps to print a document using a laser printer are shown in the table below.

Put each step in the correct order. The first step has been done for you.

Step	Order
As the printing drum rotates, a laser scans across it; this removes the positive charge in certain areas	
The printing drum is coated in positively-charged toner; this then sticks to the negatively-charged parts of the printing drum	
The paper goes through a fuser which melts the toner so it fixes permanently to the paper	
The printer driver ensures that the data is in a format that the laser printer can understand	**1**
A negatively-charged sheet of paper is then rolled over the printing drum	
Data is then sent to the laser printer and stored temporarily in the printer buffer	
The toner on the printing drum is now transferred to the paper to reproduce the required text and images	
The printing drum is given a positive charge	
Negatively-charged areas are then produced on the printing drum; these match exactly with the text and images to be printed	

[8]

Answer:

Steps in the printing process	Step order
As the printing drum rotates, a laser scans across it; this removes the positive charge in certain areas	**4**
The printing drum is coated in positively-charged toner; this then sticks to the negatively-charged parts of the printing drum	**6**
The paper goes through a fuser which melts the toner so it fixes permanently to the paper	**9**
The printer driver ensures that the data is in a format that the laser printer can understand	***(1)***
A negatively-charged sheet of paper is then rolled over the printing drum	**7**
Data is then sent to the laser printer and stored temporarily in the printer buffer	**2**
The toner on the printing drum is now transferred to the paper to reproduce the required text and images	**8**
The printing drum is given a positive charge	**3**
Negatively-charged areas are then produced on the printing drum; these match exactly with the text and images to be printed	**5**

[8]

Question 2:

(b) Pradeep uses a projector attached to the ceiling at his home to watch high-definition (HD) films.

The projector has broken. He wants to buy a replacement. He needs to choose between an LCD projector and a Digital Light Projector (DLP).

Explain why an LCD projector would be more appropriate for Pradeep.

.....

.....

.....

.....

.....

..... [3]

Answer:

4(b)	Any three from: • More visible pixels // higher resolution • Higher colour **contrast** (in ambient lighting) // more vivid colours • Colours are (often) more accurate • Image (usually) appears brighter (with same wattage) • Will be stationary so does not need the portability of DLP • Does not need the compactness of DLP • Cost of purchase (usually) less • Run quieter • Any surface can be used as a display • Uses less power • Produces less heat • Does not give the rainbow effect DLP often gives • Longer lasting lamps	3

Question 3:

(d) The library often holds events that introduce new authors.

At the events, the library has a Liquid Crystal Display (LCD) screen that displays data, including an image and information about the author.

Describe how an LCD screen operates to display this data.

.....

.....

.....

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.....

.....

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.....

.....

..... [5]

Answer:

1(d)	**Five** from: □ The display is made up of pixels … □ … that are arranged together as a matrix □ Each pixel has three filters, red, blue and green □ Shades of colour are achieved by mixing red, blue and green □ The screen is backlit □ Light is shone through the liquid crystals □ The liquid crystals can be made to turn solid or transparent/on or off … □ … by changing the shape of the crystal	5

Question 4:

(a) Inkjet printers and laser printers are two common types of printer.

Describe the features and principles of operation of each type of printer.

(i) Inkjet printer

.....

.....

.....

.....

.....

.....

.....

..... [4]

(ii) Laser printer

.....

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.....

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.....

..... [4]

(b) Another type of printer is the 3D printer.

Describe 3D printing.

.....

.....

.....

.....

.....

..... [3]

Answer:

(a) (i) Inkjet printer

Any **four** from:
- uses cartridges/liquid ink
- makes use of thermal bubble/piezoelectric technology
- sprays ink in droplets on the paper
- uses a moving print head
- suitable for low volume (high quality) output, e.g. a photo

[4]

(ii) Laser printer

Any **four** from:
- uses powdered ink/toner cartridges
- uses a (charged) printing drum
- makes use of static electricity charges
- uses a fuser to fix/melt ink onto the paper
- uses a discharge lamp to remove static charge from the drum
- useful for high volume (high quality) output, e.g. leaflets

[4]

(b) Any **three** from:
- produces solid, 3D objects/prototypes
- used in CAD/CAM
- makes use of tomography/slices of an object
- solid built up in thin layers
- uses resin, powdered metal, paper, plastic…

[3]

Question 5:

Modern Liquid Crystal Display (LCD) monitors use Light-Emitting Diode (LED) backlit technology.

Give **four** benefits of using LED technology.

1 .....

.....

.....

2 .....

.....

.....

3 .....

.....

.....

4 .....

.....

.....

[4]

Answer:

Any **four** from:

– reaches maximum brightness quickly
– colours are vivid
– good colour definition/contrast can be achieved
– screens can be thinner/thin
– more reliable as LED's are long lasting
– consume very little/less energy [4]

Question 6:

Matthew is buying a new television with a display that uses LED technology.

(a) Explain what is meant by LED technology.

.....

.....

.....

.....

.....

..... [3]

(b) State **three** benefits of LED technology.

Benefit 1 .....

.....

Benefit 2 .....

.....

Benefit 3 .....

.....

[3]

(c) Identify **one other** technology that could have been used for the display.

..... [1]

Answer:

Question	Answer	Marks
8(a)	Any **three** from: – Light emitting diodes (technology) – The **display** is made up of pixels – … that are arranged together as a matrix – … each is formed of three LEDs/filters – Shades of colour are achieved by mixing red, blue and green – The screen can be back-lit/edge-lit NOTE: Use of liquid crystals with LED technology can also be awarded	3
8(b)	Any **three** from: – Energy efficient // low power consumption – Long lasting // longevity – Focussed beam // less light strays from beam – Brighter/vivid colours – High resolution – No flicker – Display is thinner – Mercury free technology // environmentally friendly – Fewer pixel failure – Increased viewing in sunlight	3
8(c)	– LCD	1

Question 7:

Benny is a photographer and prints his photos using an inkjet printer.

(a) Benny is printing some photos and the paper gets jammed in the printer.

A signal is sent to alert the computer about the paper jam.

State the name of this type of signal.

..... [1]

(b) Identify **one** benefit and **two** drawbacks of Benny using an inkjet printer, instead of a laser printer, to print his photos.

Benefit .....

.....

Drawback 1 .....

.....

Drawback 2 .....

.....

[3]

Answer:

Question	Answer	Marks
8(a)	– Interrupt	1
8(b)	**One** mark for benefit, **two** marks for drawbacks Benefit: – Printing may be higher quality – Can use larger paper sizes – Can print onto different media – No warm-up time Drawbacks: – Printing will be slower – Ink is more expensive per page – Ink can be smeared // ink is not smudge proof	3

Question 8:

Leonard has a new laser printer to print letters for his business.

Leonard connects his printer to his computer using the USB port.

(b) State **two** benefits and **one** drawback of Leonard using a laser printer, instead of an inkjet printer, to print the letters.

Benefit 1 .....

.....

Benefit 2 .....

.....

Drawback .....

.....

[3]

Answer:

8(b)	**Two** marks for benefits, **one** mark for drawback Benefits: – Faster speed of printing – Can print duplex / on both sides – Many letters can be printed from one toner cartridge – Can print in high volumes Drawback – Toner cartridge more expensive to buy – More time to warm-up – Larger footprint	3

Question 9:

Edith is buying a new computer monitor that displays images using LCD technology.

(a) Explain what is meant by LCD technology.

.....

.....

.....

.....

.....

..... [3]

(b) State **three** benefits of LCD technology.

Benefit 1 .....

.....

Benefit 2 .....

.....

Benefit 3 .....

.....

[3]

Answer:

Question	Answer	Marks
8(a)	Any **three** from: – Liquid crystal display – The **display** is made of pixels – … arranged in a matrix – Uses a flat panel display – Backlit display – … with CCFLs/LEDs – Uses light-modulating properties of liquid crystals – Crystals can be turned between opaque and transparent (to allow light to pass) – Colours created using RGB	3
8(b)	Any **three** from: – Low power consumption – Runs at cool temperature – Do not suffer image burn – Do not suffer flicker issues – Bright image/colours – High resolution image – Cheaper to purchase than e.g. LED screen	3

Question 10:

(b) Identify the software used to create the computerised designs for 3D printing.

..... [1]

(c) A Digital Light Projector (DLP) is another example of an output device.

Describe how a DLP displays an image.

.....

.....

.....

.....

.....

..... [3]

Answer:

6(b)	Computer Aided Design/CAD	**1**
6(c)	**Three** from: • Uses a large number of tiny mirrors • Mirrors are laid out in a grid/matrix • Each mirror creates a pixel in the image • Mirrors can tilt toward or away from light source • The mirrors reflect light toward a (projection) lens • Colour is produced using a colour wheel // Light passes through colour wheel // filters light into red/green/blue • Can be used to display an image on a wall/screen	**3**

Question 11:

(b) Nadia's printer uses powdered toner rather than liquid ink.

(i) State the type of printer Nadia has purchased.

..... [1]

(ii) Give **two** benefits of using this type of printer.

Benefit 1 .....

.....

Benefit 2 .....

.....
[2]

(iii) Give **one** drawback of using this type of printer.

Drawback 1 .....

..... [1]

Answer:

6(b)(i)	– Laser printer	1
6(b)(ii)	**Two** from: – Cheaper **printing** cost per page – It **prints** at a faster **speed** – It prints **text** at a high quality – Colour fast	2
6(b)(iii)	**One** from: – Expensive to **purchase printer** – **Toner** is expensive – Print **images** at a lower quality – Can be quite large in size	1

Question 12:

The given table shows the name or description of four devices. The table is incomplete.

Complete the missing device names and descriptions.

Device name	Description
.....	Uses either thermal bubble or piezoelectric technology
Actuator	....
.....	Uses thousands of tiny mirrors that can move very quickly to create an image
Mouse	....

[4]

Answer:

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>3</td><td>One mark for each device/description
<table>
<tr><th>Name of device</th><th>Description</th></tr>
<tr><td><u>Inkjet</u> Printer</td><td>Uses either thermal bubble or piezoelectric technology</td></tr>
<tr><td>Actuator</td><td>– Operated by signals to cause a physical movement Controls the movement of a machine // by example</td></tr>
<tr><td>DLP//Projector</td><td>Uses thousands of tiny mirrors that can move very quickly to create an image</td></tr>
<tr><td>Mouse</td><td>– Uses rolling ball / optical sensor / laser to detect motion // by example
– Movement echoed on screen // moves curser/pointer (on screen)
– Has scroll wheel / Buttons to allow data input // by example</td></tr>
</table></td><td>4</td></tr>
</table>

3.2.3 Sensors:

- It is an input device.
- It measures/takes physical readings of the surrounding environment (e.g. temperature) and records, indicates, or otherwise responds to it.
- A system can be developed using sensors, converters, a feedback cycle, and a control system.

Analogue Data:

- It is a continuous data.
- It is non-discrete.
- **Example:** data such as a sound wave.

Digital Data:

- It is discrete data that has only two values.
- **Example:** binary data 1's and 0's.

ADC & DAC:

- ADC is analogue-to-digital converter and DAC is digital-to-analogue converter.

Why is there a need for ADC & DAC?

- Computers cannot make any sense of physical quantities.
- The data needs to be converted into a digital format (binary values) so that the computer can understand.
- This is usually achieved by an analogue-to-digital converter.
- This device converts physical values into discrete binary/digital values.
- When the computer is used to control devices such as a motor or a valve, it is necessary to use a digital-to-analogue converter since these devices need analogue data to operate in many cases.
- Actuators are used in such control applications.

Examples of Sensors:

1) acoustic (sound) sensor
2) accelerometer sensor
3) flow (rate) sensor
4) gas sensor
5) humidity sensor
6) infra-red sensor
7) level sensor
8) light sensor
9) magnetic field sensor
10) moisture sensor
11) pH sensor
12) pressure sensor
13) proximity sensor
14) temperature sensor

Sensors, Description & Example Applications:

Sensor	Description	Example Applications
Temperature	It measures temperature of the surrounding by sending signals; these signals will change as the temperature changes	1) control a central heating system 2) control/monitor a chemical process 3) control/monitor temperature in a greenhouse
Moisture	It measures water levels in, for example, soil (it is based on the electrical resistance of the sample being monitored)	1) control/monitor moisture levels in soil in a greenhouse 2) monitor the moisture levels in a food processing factory
Humidity	It is slightly different to moisture; it measures amount of water vapor in, for example, a sample of air (based on the fact that the conductivity of air will change depending on the amount of water present)	1) monitor humidity levels in a building 2) monitor humidity levels in a factory manufacturing microchips 3) monitor/control humidity levels in the air in a green house
Light	It uses photoelectric cells that produce an output (in the form of electric current) depending on the brightness of the light	1) switching streetlights on or off depending on light levels 2) switch on car headlights automatically when it gets dark
Infra-red	**Active Infrared:** It uses an invisible beam of infrared radiation picked up by a detector; if the beam is broken, then there will be a change in the amount of radiation reaching the detector (sensor)	1) turn on car windscreen wipers automatically when it detects rain on the windscreen 2) security alarm system (intruder breaks the infra-red beam)
	Passive Infrared: It measures the heat radiation given off by an object, for example, the temperature of an intruder or the temperature in a fridge	1) security alarm system (detects body heat of intruder) 2) monitor the temperature inside an industrial freezer or chiller unit

Sensor	Description	Example Applications
Pressure	It is a transducer and generates different electric currents depending on the pressure applied	1) weighing of lorries at a weighting station 2) measure the gas pressure in a nuclear reactor
Acoustic (sound)	It is basically a microphone that converts detected sound into electric signals/pulses	1) pick up the noise of footsteps in a security system 2) detect the sound of liquids dripping at a faulty pipe joint
Gas	It uses various methods to detect the gas being monitored and produce outputs that vary with gas levels such as oxygen & carbon dioxide gas sensors; they monitor oxygen or carbon dioxide levels present	1) monitor pollution levels in the air at an airport 2) monitor oxygen and carbon dioxide levels in a greenhouse 3) monitor oxygen levels in a car exhaust
pH	It measures acidity through changes in voltages in, for example, soil	1) monitor/control acidity levels in the soil in a greenhouse 2) control acidity levels in a chemical process
Magnetic field	It measures changes in magnetic field – the signal output will depend on how the magnetic field changes	1) detect magnetic field changes (e.g., in mobile phones & CD players) 2) used in anti-lock braking systems (ABS) in cars
Accelerometer	It measures acceleration and motion of an application i.e., the change in velocity (a piezoelectric cell is used whose output varies according to the change in velocity)	1) used in cars to measure rapid deceleration and apply air bags in a crash 2) used by mobile phones to change between portrait and landscape mode
Proximity	It detects the presence of a nearby object	1) detect when a face is close to a mobile phone screen and switches off screen when held to the ear

Sensor	Description	Example Applications
Flow (rate)	It measures the flow rate of a moving liquid or gas and produce an output based on the amount of liquid or gas passing over the sensor	1) used in respiratory devices and inhalers in hospitals 2) measure gas flows in pipes (for example, natural gas)
Level	It uses ultrasonics (to detect changing liquid levels in, for example, a tank) or capacitance/conductivity (to measure static levels, for example, height of water in a river) – level sensors can also be optical or mechanical in nature	1) monitor levels in a petrol tank in a car 2) in a pharmaceutical process where powder levels in tablet production need to be monitored 3) leak detection in refrigerant (air conditioning)

Benefits of using Sensors to monitor the manufacture of plastic pipes by measuring pressure, temperature, and speed of production:

1. They can work continuously.
2. They avoid human error.
3. It could be a dangerous environment and they will avoid human risk.
4. They detect errors instantly.
5. They maintain consistent and correct conditions.

NOTE: 11 different examples have been given on the following pages for you to understand the questions asked regarding sensors in terms of:

- sensors and their applications
- sensors to be used for certain scenarios
- sensors to be used for certain tasks
- and how each sensor could be used in a given system

Example 1:

Identify two sensors that the security system could use to detect intruders. Describe how each sensor could be used in the security system.

1) Infrared sensor:

- It receives infrared rays/heat.
- It sends data to a microprocessor.

1. It can be placed in the corner of a room.
2. It is used to detect the heat of an intruder.

2) Pressure sensor:

- It receives current if the circuit is created and stops receiving current if circuit is broken.
- It sends data to a microprocessor.

1. It can be placed on a window or a door.
2. It is used to detect a change in pressure.

Example 2:

Identify four sensors that could be used in the washing machine. State what each sensor could be used for.

Sensor	Example of use
Temperature	It could be used to monitor the temperature of the water.
Pressure	It could be used to monitor the level of the water in the washing machine.
Motion	It could be used to monitor whether the drum is still in motion.
pH	It could be used to monitor the level of detergent present in the water.

Example 3:

Identify four sensors that could be used on a farm that grows fruit. State what each sensor could be used for.

Sensor	Example of use
Temperature	It could be used to measure the temperature of the environment. It can alert when it is too hot/too cold for the fruit to grow.
Light	It could be used to measure the brightness of the environment. It can alert when the fruit has too little/too much light.
Moisture	It could be used to measure the water content of the soil. It can alert when the soil is too dry or too wet.
pH	It could be used to measure how acidic/alkaline the soil is. It can alert when there is something polluting the soil.

Example 4:

The processes in a chemical factory are monitored by sensors connected to a microprocessor. Identify two different sensors used in this application. Give an example of how each sensor could be used in the chemical factory.

Sensor	Example of use
Gas	To measure the levels of oxygen/carbon dioxide/nitrogen in the factory to make sure they are not too high or low.
Temperature	To measure the temperature of the chemicals to make sure it is not too high or low.
Motion/Infra-red	To detect any persons in an unauthorized area of the factory.
Pressure	To measure the pressure of chemicals flowing through pipes to check that levels are not too high or low.
pH	To measure the pH to make sure the acidity/alkalinity of the chemicals is correct.

Sensor	Example of use
Light	To measure the level of light to make sure it remains at a constant level for the chemical process.

Example 5:

Sensors are used at the finish line of long-distance running to identify the number of competitors who finish the race. Identify two different sensors that could be used to identify the number of competitors.

1) Pressure sensor
2) Light sensor
3) Motion sensor
4) Magnetic field sensor (can be used if competitors are wearing a compatible chip)

Example 6:

Sensor	Application
Light	Control the switching off and on of street lighting
Moisture	Monitor the amount of water left in clothes in a drier
Gas	Monitoring the pollution levels in a river
pH	Monitor acidity levels in the soil in a greenhouse
Pressure	Detection of intruders breaking into a building

Example 7:

Sensor	Application
Light	controlling streetlights
Gas, pH, temperature, light	monitoring a river for pollution
Pressure, magnetic field	controlling traffic lights

Example 8:

Sensor	Application
Pressure	Weighing a baby in a hospital
Temperature	Turning off a kettle when it boils
Infrared/Light/Pressure	Controlling an automatic door
Oxygen/Gas/Humidity	Monitoring the air quality in an aero plane
Pressure/Infrared/Magnetic Field	Counting cars crossing a bridge

Example 9:

Sensor	Scenario
Pressure/Motion/Infrared	Detecting when a person is approaching an automatic door system
pH/Light	Monitoring the pollution level in a river
Temperature	Checking if a tropical aquarium is 25 degrees Celsius
Magnetic Field/Pressure/Motion /Infrared	Counting the number of cars that cross a bridge

Example 10: Car Parking System

Sensor	Task
Infrared/Light	Check if a vehicle is too high
Magnetic Field/Pressure	Count the vehicles entering the car park
Pressure/Magnetic Field/Infrared/Light	Check if a vehicle is parked in a parking space

Example 11: Washing Machine

Sensor	Task
Temperature	Checking the water is 30°C
pH	Checking the water acidity level after detergent is added
Pressure	Checking the weight of the clothes to make sure that the washing machine is not overloaded

Uses of Sensors:

Sensors are used in both monitoring and control applications:

Examples of monitoring include:

1. monitoring a patient in a hospital for vital signs such as heart rate, temperature, etc.
2. monitoring of intruders in a burglar alarm system.
3. checking the temperature levels in a car engine.
4. monitoring pollution levels in a river.

Examples of control include:

1. turning streetlights on at night and turning them off again during daylight.
2. controlling the temperature in a central heating/air conditioning system.
3. chemical process control (for example, maintaining temperature and pH of process)
4. operating anti-lock brakes on a car when necessary.
5. controlling the environment in a greenhouse.

Standard working procedure of Sensors in monitoring application:

1. The sensor sends data/signals to the microprocessor.
2. The analogue data/signals are converted from analogue to digital using ADC (analogue-to-digital converter).
3. The microprocessor compares the data received to a stored/pre-set/pre-determined value.
4. If the value is outside the acceptable range, a signal is sent by the microprocessor to display a warning message on a monitor or activate an alarm.
5. If the value is within an acceptable range, no action is taken.
6. The whole process is a continuous loop.

Standard working procedure of Sensors in controlling application:

1. The sensor sends data/signal to the microprocessor.
2. The analogue data/signals are converted from analogue to digital using ADC (analogue-to-digital converter).
3. The microprocessor compares the data received to a stored/pre-set/pre-determined value.
4. If the value is outside the acceptable range, a signal is sent by the microprocessor to actuator, control valves, motors etc. to cause an action to occur.
5. If the value is within an acceptable range, no action is taken.
6. The whole process is a continuous loop.

NOTE: The topic 'sensors' from input and output devices is the most frequently asked topic in computer science exams since the highest number of questions ever asked are from sensors.

- A question from sensor is asked in almost every paper, every year.
- It is asked for 4 to 8 marks.
- The answer to each question related to sensor is very similar and consists of statements and same keywords in a sequence.
- Just memorizing the standard procedures stated on previous page and writing them in exams will help you earn complete marks.

However, the situation would change, and the examiner can give you any scenario and question about the functioning of any sensor accordingly.

- The procedures stated on previous page will always be the same; you only need to make slight changes in answer according to question statement and the scenario asked.

18 complete questions of sensors (worth 5-8 marks) that have been asked in recent years are given below with their answers so that you can realize the pattern of answering and understand how to make changes in your answer according to question statement and the scenario asked.

Sensors Working Related Questions:

Q1. A security light is controlled by sensors and a microprocessor.

Describe how the sensors and microprocessor interact to switch on the security light when an intruder is detected. [6]

- An infrared/motion/pressure sensor is used.
- When the sensor detects movement, it continuously sends signal to the microprocessor.
- The analogue signals are converted from analogue to digital using ADC.
- The microprocessor compares the data received to a pre-set/pre-determined/stored value.
- If the value is outside the acceptable range, a signal is sent by the microprocessor to switch on the light and keep it on for a period of 30 seconds.
- If the value is within an acceptable range, no action is taken.
- The process is a continuous loop.

Q2. A cold store is kept at a constant low temperature using a sensor, a microprocessor, and a cooling unit.

Explain how the sensor and the microprocessor will maintain a constant low temperature. [6]

- A temperature sensor is used.
- The sensor sends a signal to the microprocessor.
- The analogue signals are converted from analogue to digital using ADC.
- The microprocessor compares the data received to a pre-set/pre-determined/stored value.
- If the temperature value is too high or low, a signal is sent by the microprocessor to turn on or off the cooling unit.
- An actuator is used to turn the cooling unit on or off.
- If the temperature matches the stored value, no action is taken.
- The process is a continuous loop.

Q3. A factory uses a security system to control a security light. The system uses a sensor and a microprocessor.

Explain how the security system makes use of the sensor and the microprocessor to control the security light. [6]

- An infrared/motion sensor is used.
- The sensor sends a signal to the microprocessor.
- The analogue signals are converted from analogue to digital using ADC.
- The microprocessor compares the data received to a pre-set/pre-determined/stored value.
- If the value is outside the acceptable range, a signal is sent by the microprocessor to turn the security light on and wait for a suitable period.
- If no motion is detected, lights are turned off.
- If the value is within an acceptable range, no action is taken.
- The process is a continuous loop.

Q4. A sports stadium uses a pressure sensor and a microprocessor to monitor the number of people entering the sports stadium. For the counter to increment the weight on the pressure sensor must exceed 5 kg.

Explain how the system uses the pressure sensor and the microprocessor to monitor the number of people entering. [5]

- The sensor sends data to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares the data received to a stored value of 5 kg.
- If the value is greater than 5 kg, a counter is incremented.
- The whole process is a continuous loop.

Q5. An underground car park has a system. Each parking space has a red and a green light above it. If a car is parked in the parking space only the red light is on, otherwise only the green light is on. Sensors and a microprocessor are used to control the system.

Describe how the sensor and the microprocessor are used to display the red or green light above the parking space. [6]

- The sensor sends data to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares the data received to stored value.
- If the data is greater than the stored value, a signal is sent by the microprocessor to actuator to turn red light on and the green light off.
- If the data is less than the stored value, a signal is sent by the microprocessor to actuator to turn the green light on and the red light off.
- If the data is within an acceptable range, no action is taken.
- The actuator is used to turn on and off the lights.
- The whole process is a continuous loop.

Q6. A system uses pH sensors and a microprocessor to help monitor pollution in a river. The pH of the water should be between 6 and 8. The system outputs and alert if the pH of the water is not in this range.

Explain how the system uses the pH sensors and the microprocessor to help monitor the pollution. [5]

- The sensor sends a signal to the microprocessor.
- The analogue signals are converted from analogue to digital using ADC.
- The microprocessor compares the data received to a pre-set/pre-determined/stored value.
- If the reading is > 8 or < 6, a signal is sent by the microprocessor to display a warning message on a monitor or activate an alarm.
- If the value is within an acceptable range, no action is taken.
- The process is a continuous loop.

Q7. An elevator (lift) has a maximum weight limit of 2400 kg. The weight carried is monitored by a sensor and a microprocessor.

Describe how the sensor and the microprocessor are used to make sure the maximum weight limit is not exceeded. [6]

- A pressure sensor is used.
- The sensor sends a signal to the microprocessor.
- The analogue signals are converted from analogue to digital using ADC.
- The microprocessor compares the data received to a pre-set/pre-determined/stored value.
- If the value is > 2400 kg, a signal is sent by the microprocessor to display a warning message to passengers and signal sent to actuator for stopping the lift from operating.
- If the value is <= 2400 kg, no action is taken.
- The process is a continuous loop.

Q8. An office has an automated lighting system. When movement is detected in the office the lights are switched on. If movement is not detected for a period of 2 minutes the lights are switched off. The system uses a sensor and a microprocessor.

Describe how the automated lighting system uses a sensor and a microprocessor. [6]

- A motion sensor is used.
- The sensor sends a signal to the microprocessor.
- The analogue signals are converted from analogue to digital using ADC.
- The microprocessor compares the data received to a pre-set/pre-determined/stored value.
- If the value is outside the acceptable range, a signal is sent by the microprocessor to actuator for switching lights on.
- A timer is set for 2 minutes and every time a movement is detected, the timer is reset.
- If the value is within an acceptable range, no action is taken.
- The process is a continuous loop.

Q9. A sensor and a microprocessor are used to monitor the pH of the cleaning products. The system records each reading that is taken. If the reading is greater than 7 a waning message is displayed on a monitor.

Explain how the sensor and microprocessor are used in the system. [6]

- The sensor sends a signal to the microprocessor.
- The analogue signals are converted from analogue to digital using ADC.
- The microprocessor compares the data received to a pre-set/stored value of 7.
- If the value is > 7, a signal is sent by the microprocessor to display a warning message on a monitor or activate an alarm.
- If the value is within an acceptable range, no action is taken.
- The process is a continuous loop.

Q10. A business wants to use a biometric security system to control entry to the office. The system will use a biometric device and a microprocessor.

Explain how the biometric security system will make use of the biometric device and the microprocessor to control entry to the office. [6]

- A fingerprint scanner can be used. User will place their finger on touchscreen device so their finger gets scanned.
- The sensor in the fingerprint scanner will take readings of user.
- The readings are converted from analogue to digital using ADC.
- The readings are sent to the microprocessor.
- The readings are compared to stored values.
- If readings match, the user can enter.
- If readings do not match, then user is declined entry and alarm may sound to alert the security.

Q11. A theme park has a game where a player tries to run from the start to the finish without getting wet. The system for the game uses sensors and a microprocessor to spray water at a player as they run past each sensor.

Describe how the sensors and the microprocessor are used in this system. [6]

- A motion sensor/pressure sensor is used.
- The sensor sends data to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares the data received to stored data.
- If the value is outside the acceptable range, a signal is sent by the microprocessor to actuator to spray water.
- If the value is within an acceptable range, no action is taken.
- The whole process is a continuous loop.

Q12. A long-distance running race uses an electronic counter that counts each competitor who finished the race. The sensors are used with a microprocessor to count how many competitors finish the race.

Explain how the sensor and the microprocessor are used. [6]

- The sensor sends signal to the microprocessor.
- The analogue signal is converted from analogue to digital using ADC.
- The microprocessor compares the data received to stored value.
- If the data is out of range, the counter is incremented by 1.
- The whole process is a continuous loop.

Q13. Jamelia has a greenhouse that she uses to grow fruit and vegetables. She needs to make sure the temperature in the greenhouse stays between 25°C and 30°C (inclusive).

A system that has a temperature sensor and a microprocessor is used to maintain the temperature in the greenhouse. The system will:

- **open a window and turn a heater off if it gets too hot**
- **close a window and turn a heater on if it gets too cold**

Describe how the system uses the temperature sensor and the microprocessor to maintain the temperature in the greenhouse. [8]

- The sensor sends data/readings/signals to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares the data received to stored values/range of values.
- If the data is greater than 30, a signal is sent by the microprocessor to actuator to open window and to turn heater off.
- If the data is below 25, a signal is sent by the microprocessor to actuator to close window and to turn on heater.
- If the data is between 25 and 30, no action is taken.
- The actuator is used to operate heater and windows.
- The whole process is a continuous loop.

Q14. A security light system is used by a factory. The light only comes on when it is dark and when movement is detected. The light will stay on for 1 minute before switching off. Sensors and a microprocessor are used to control the security light system.

Describe how the sensors and the microprocessor control the security light system. [8]

- A light sensor and infra-red/motion sensor are used.
- The sensor sends data to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares the data received to stored values.
- If one value or both values are within range, no action is taken.
- If both values are out of range, a signal is sent by the microprocessor to actuator to switch the light on.
- The 1-minute timer is started.
- When the timer reaches 1 minute, a signal is sent by the microprocessor to actuator to switch the light off.
- The actuator is used to switch on and off the light.
- The whole process is a continuous loop.

Q15. An electronic game has three square mats that are colored red, green and blue.

The player will see a color displayed on a screen and has 1 second to hit the mat that matches the color. If the player hits the correct mat, within 1 second, a counter is incremented. When a player hits an incorrect mat, the game ends.

The game uses sensors and a microprocessor to determine if the player hits the correct mat within 1 second.

Explain how the game uses sensors and a microprocessor to count the number of times a player hits a correct mat within 1 second. [7]

- A pressure sensor is used within each mat and a timer is started.
- The sensor sends data to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares the data received to stored values.
- If the data is out of range, the microprocessor stops the timer and checks if the data has come from the correct color mat sensor.
- If the data is out of range, the microprocessor checks to see if timer is stopped at less than 1 second and increments the counter if timer is less than 1 second and the color mat is correct.
- If the correct color mat is hit, the timer is reset and the whole process is repeated.
- If the data has not come from the correct color mat sensor, the game ends.

Q16. A washing machine uses sensors and a microprocessor to control the washing cycle of clothes.

Describe how the sensor and the microprocessor are used to make sure the water remains at 30°C. [6]

- The sensor sends data to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares the data received to stored value of 30.
- If the data is below 30 then a signal is sent by the microprocessor to actuator to turn the heater on to heat the water up or add hot water.
- If the data is above 30 then a signal is sent by the microprocessor to actuator to turn the heater off to allow the water to cool down or add cool water.
- The actuator is used to turn headset on/off or to add water.
- If the data is 30, no action is taken.
- The whole process is a continuous loop.

Q17. A room has an automatic lighting system. Electric lights are automatically turned on when a person enters the room and the natural light in the room is 10 or less.

Explain how sensors and a microprocessor are used to control electric lights in the room. [7]

- A light sensor and infra-red/motion/pressure sensor are used.
- The sensor sends data to the microprocessor.
- The analogue data is converted from analogue to digital using ADC.
- The microprocessor compares both values received to stored values.
- If the motion value is out of range, the light value is checked.
- If the light value is <= 10, a signal is sent by the microprocessor to actuator to turn the lights on.
- If the motion value is within an acceptable range, the light value is checked.
- If the light value is > 10, a signal is sent by the microprocessor to actuator to turn the lights off.
- The actuator is used to turn on and off the light.
- The whole process is a continuous loop.

Q18. A business uses a closed-circuit television (CCTV) system that starts recording when motion is detected. It stops recording after two minutes if no further motion is detected. The system uses a motion sensor and a microprocessor.

Describe how the motion sensor and microprocessor work together to control the CCTV system. [7]

- The motion sensor sends signals to the microprocessor.
- The analogue signal is converted from analogue to digital using ADC.
- The microprocessor compares signal values received to stored value.
- If the motion value is out of range (and if camera is not recording), a signal is sent by the microprocessor to camera to start recording.
- If the motion value is within acceptable range, the microprocessor starts/resets the timer.
- When the timer reaches 2 minutes, a signal is sent by the microprocessor to camera to stop recording.
- The whole process is a continuous loop.

3.3 | Data Storage

The memory and storage devices can be split up into two distinct groups:

1. Primary Storage
2. Secondary Storage (External & Internal)

3.3.1 Primary Storage:

- The primary storage is the main memory that is directly accessed by the CPU.
- It is internal to the computer (inside a computer).
- It has faster access speed.
- It stores boot-up instructions and can hold data whilst being processed.
- It has both volatile and non-volatile.

Examples: Random Access Memory (RAM) and Read Only Memory (ROM).

- The RAM stores programs and data that are currently in use and ROM stores boot-up instructions.
- The RAM is volatile, and ROM is non-volatile.

The primary memory consists of random access memory (RAM) and read only memory (ROM):

Random Access Memory (RAM):

Features of RAM:

- It is volatile/temporary memory (the contents of the memory are lost when the power to the RAM is turned off).
- It is used to store instructions, programs, data, and parts of the operating system that are currently in use.
- The data can be written to or read from RAM & the contents of the memory can be changed.
- The RAM is much faster to write to or read from than other types of memory.
- The RAM normally has a larger capacity than ROM.

The buffers use RAM since they need to be a fast memory and the data only needs to be held temporarily.

Why does RAM get slower and its solution?

Note: RAM never runs out of memory

- As the RAM becomes full, it becomes slower since the processor has to continually access the hard disk drive to overwrite old data on RAM with new data.
- By increasing the RAM size, the number of times this access operation is carried out is reduced, resolving this issue, and making the computer run faster.

There are currently two types of RAM technology:

1. Dynamic RAM (DRAM)
2. Static RAM (SRAM).

1) Dynamic RAM (DRAM):

- It has to be refreshed periodically.
- It uses a single transistor and capacitor.
- It stores each bit as a charge.
- It has less complex circuitry.
- It requires higher power consumption under low levels of access, which is significant when used in battery-powered devices because it requires more circuitry for refreshing.
- It is less expensive to purchase as it requires fewer transistors.
- It has slower access time/speed because it needs to be refreshed.
- It can have higher storage/data density.
- It is used in main memory

Advantages of DRAM:

1. DRAMs are much less expensive to manufacture than SRAM.
2. They have a higher storage capacity than SRAM.

Use of DRAM:

1. DRAM is the most common type of RAM used in computers except for high-speed areas.

2) Static RAM (SRAM):

- It does not require a refresh.
- It uses more than one transistor.
- It stores each bit using a flip-flop/latch.
- It has more complex circuitry.
- It uses less power as there is no need to refresh.
- It is more expensive to purchase as it requires more transistors.
- It has faster access time/speed.
- It has lower storage/data density.
- It is used in cache memory.

Advantages of SRAM:

1. It is much faster than DRAM when it comes to data access as typical access time for SRAM is 25 nanoseconds and for DRAM is 60 nanoseconds.
2. It has lower power consumption.

Uses of SRAM:

1. SRAM is the most used technology in areas where absolute speed is essential.
   For example, the processor's memory cache is the high-speed portion of the memory.

By keeping most of the data and instructions in SRAM, the computer avoids having to access the slower DRAM.

The following tables compare DRAM & SRAM technologies:

(i) Table 1:

Statement	DRAM (✓)	SRAM (✓)
Does not need to be refreshed as the circuit holds the data while the power supply is on		✓
Mainly used in cache memory of processors where speed is important		✓
Has less complex circuitry	✓	
Requires higher power consumption under low levels of access, which is significant when used in battery-powered devices	✓	
Required data to be refreshed occasionally so it retains the data	✓	

(ii) Table 2:

Statement	SRAM (✓)	DRAM (✓)
More expensive to make	✓	
Requires refreshing (recharging)		✓
Made from flip-flops	✓	

(iii) Table 3:

Statement	DRAM (✓)	SRAM (✓)
Is less expensive to manufacture	✓	
Needs to be refreshed	✓	
Has more complex circuitry		✓
Is often used as cache		✓
Has faster access time		✓

Read Only Memory (ROM):

Features of ROM:

- It is non-volatile/permanent memory (the contents of the memory remain even when the power to the ROM is turned off).
- It is used to store the start-up instructions when the computer is first switched on (e.g., BIOS (basic input/output system).
- The data of a ROM chip can only be read and not written to; the contents of the memory cannot be changed.
- The ROM normally has a smaller capacity than RAM.

Main Differences between RAM & ROM:

- The RAM is volatile whereas ROM is non-volatile.
- The RAM is temporary whereas ROM is permanent.
- The RAM normally has a larger capacity than ROM.
- The RAM can be edited while ROM cannot be edited.
- The ROM is read only memory while RAM can have read and write operations.
- The ROM holds instructions for boot up whereas RAM holds files, data, and instructions currently in use.

Applications of RAM & ROM:

Example 1:

A remote-controlled toy car has a circuitry which contains both RAM and ROM chips. The remote control is a hand-held device.

The functions of:

- **ROM:** It stores factory settings such as remote-control frequencies.
  It stores the 'start-up' routines when the toy car is first switched on.
  It stores the set routines (e.g., how the buttons on the hand-held device control turning left, acceleration, stopping, and so on).
- **RAM:** It stores routines that the user may wish to program.
  It stores new instructions given by the user.
  It stores the data/instructions received from the remote-control unit.

Example 2:

A mobile device uses RAM, ROM and an SSD.

What the RAM, ROM and SSD are used for:

- **RAM:** To store the data/instructions/parts of OS that are currently in use.
- **ROM:** To store the firmware/bootup instructions/BIOS.
- **SSD:** To store the files/software.

Example 3:

A smartphone needs both RAM and ROM.

Why a smartphone needs RAM and ROM:

- It needs RAM to store the data and programs currently in use.
- It needs ROM to permanently store the boot up instructions.

Example 4:

The software for the stock control system is stored on a central computer. The computer is a Von Neumann model computer system with a central processing unit (CPU) that uses random access memory (RAM), read only memory (ROM) and a hard disk drive (HDD).

Purpose of the RAM, ROM, and HDD in the central computer:

- It has RAM to store the data/programs currently in use.
- It has ROM to permanently store the boot up instructions.
- It has HDD to store the stock database/software/OS.

3.3.2 Secondary Storage:

- The secondary storage is persistent memory that is not directly accessed by the CPU.
- It is necessary for more permanent storage of data.
- It can be internal or external to the computer.
- It has a slower access speed.
- It stores files, data, operating system, and softwares etc. that can be accessed at a later stage.
- It is non-volatile only.

Examples: Hard Disk Drive (HDD) and Solid State Drive (SSD).

NOTE: The Secondary storage can be divided into two categories:

- internal to the computer
- external to the computer (removable)

The Secondary storage that is internal to the computer include Hard Disk Drive (HDD) & Solid State Drive (SSD).

The Secondary storage that is external to the computer (removeable) is known as Off-line storage.

The Off-line storage include CD, DVD, Blu-ray discs, USB flash memory/memory sticks, external/removeable Hard Disk Drives (HDD).

Off-line Storage:

- The off-line storage is not directly accessed by the CPU.
- It is necessary for more permanent storage of data.
- It is external to the computer (removeable from a computer) // not internal to the computer.
- It is used to store files as a backup.
- It is non-volatile memory that can be removed from a computer system.

Examples: CD, DVD, Blu-ray, USB flash memory/memory sticks, external HDD

Exam Style Questions:

Question 1:

(a) Explain what is meant by primary, secondary and off-line storage. Give an example of each.

Primary storage .....

.....

.....

Example .....

Secondary storage .....

.....

.....

Example .....

Off-line storage .....

.....

.....

Example .....

[6]

Answer:

Question	Answer	Marks
13(a)	Primary storage – main memory inside a computer /directly accessed by CPU Example – ROM / RAM Secondary storage – non-volatile/persistant memory that is accessed by a device that is part of a computer system / not directly accessed by the CPU Example – HDD / SSD Off-line storage – non-volatile memory that can be removed from a computer system Example – DVD/ Blu-ray / CD / USB flash memory / removable or external HDD or SSD	6

Question 2:

Complete the paragraph by choosing **six** correct terms from the list.

- Optical
- On-line
- RAM
- HDD
- Primary
- SSD
- Secondary
- ROM
- Off-line

A computer has two different types of memory. ..... memory is not directly accessed by the CPU, but it allows a user to store data that can easily be accessed by applications. Two examples of this type of memory are ..... and ..... . The second type of memory is ..... memory. This memory is directly accessed by the CPU. It allows the processor to access data and instructions that are stored in this memory. Two examples of this memory are ..... and ..... .

[6]

Answer:

Question	Answer	Marks
8	Secondary HDD/SSD SSD/HDD Primary ROM/RAM RAM/ROM	**6**

Question 3:

Storage devices and storage media can be categorised as primary, secondary or off-line.

Write **primary**, **secondary** or **off-line** next to each storage device or medium to indicate its most suitable category.

HDD .....

RAM .....

ROM .....

CD-ROM .....

SSD .....

DVD-RAM .....

[6]

Answer:

Question	Answer	Marks
2	1 mark for each correct category: *HDD* – Secondary *RAM* – Primary *ROM* – Primary *CD-ROM* – Off-line *SSD* – Secondary *DVD-RAM* – Off-line	**6**

Question 4:

(c) Describe the differences between primary and secondary storage.

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.....[4]

Answer:

9(c)	**Four** from: (Max 2 for either primary or secondary) – Primary RAM and ROM – Secondary HDD and SSD – Primary is directly accessible by CPU – Secondary is not directly accessible by CPU – Primary is internal to computer – Secondary can be internal **or** external to the computer – Primary stores boot up instructions **and** can hold data whilst being processed – Secondary stores files/software – Primary has faster access speed – Secondary has a slower access speed – Primary has both volatile **and** non-volatile – Secondary is non-volatile	**4**

Question 5:

(b) Describe **one** item that is stored in RAM.

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.....

.....[2]

(c) Explain **three** ways that RAM is different to ROM.

1 .....

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2 .....

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3 .....

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[3]

Answer:

8(b)	Instructions/programs/data … currently in use	2
8(c)	Any **three** from: RAM is volatile, ROM is non-volatile RAM is temporary, ROM is (semi) permanent RAM normally has a larger capacity than ROM RAM can be edited ROM cannot be edited // Data can be read from and written to RAM, ROM can only be read from.	3

Question 6:

(b) A microprocessor uses ROM.

Explain what is meant by ROM.

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..... [3]

Answer:

7(b)	**Three** from: – Read only memory – Non-volatile memory // Contents of memory are retained when power is turned off//permanent storage – Primary storage // directly accessed by the CPU – Holds firmware/boot-up instructions/start-up instructions/BIOS – Cannot be written to	3

Question 7:

(c) Shazia's computer has Dynamic RAM (DRAM) and Static RAM (SRAM).

Explain the differences between Dynamic RAM and Static RAM.

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..... [4]

Answer:

Question	Answer	Marks

4(c)	**1 mark** per bullet to **max 4**
	
	• DRAM has to be refreshed / charged and SRAM does not require a refresh
	• DRAM uses a single transistor and capacitor and SRAM uses more than one transistor
	• DRAM stores each bit as a charge and in SRAM each bit is stored using a flip-flop/latch
	• DRAM requires higher power consumption under low levels of access, (which is significant when used in battery-powered devices because it requires more circuitry for refreshing) // SRAM uses less power (no need to refresh)
	• DRAM less expensive to purchase (requires fewer transistors) // SRAM is more expensive to buy (as it requires more transistors)
	• DRAM has slower access time/speed (because it needs to be refreshed) // SRAM has faster access times
	• DRAM can have higher storage/bit/data density // SRAM has lower storage/bit/data density
	• DRAM used in main memory and SRAM used in cache memory
		4

Question 8:

(a) The hardware includes different types of memory.

(i) Complete the description of computer memory.

Random Access Memory (RAM) and Read Only Memory (ROM) are both examples of

..... memory.

One item that is stored in RAM is ..... .

One item that is stored in ROM is ..... .

RAM can be either Static RAM (SRAM) or Dynamic RAM (DRAM).

SRAM uses transistors arranged as ..... .

DRAM uses transistors and ..... .

[5]

Answer:

Question	Answer	Marks
2(a)(i)	**1 mark** for each correct term. Random Access Memory (RAM) and Read Only Memory (ROM) are both examples of **primary** memory. One item that is stored in RAM is **currently running software/data/part of OS**. One item that is stored in ROM is **the start-up/boot-up instructions/BIOS**. RAM can be either Static RAM (SRAM) or Dynamic RAM (DRAM). SRAM uses transistors arranged as **flip-flops/latches.** DRAM uses transistors and **capacitors**.	**5**

Question 9:

(a) There are two types of RAM: dynamic RAM (DRAM) and static RAM (SRAM).

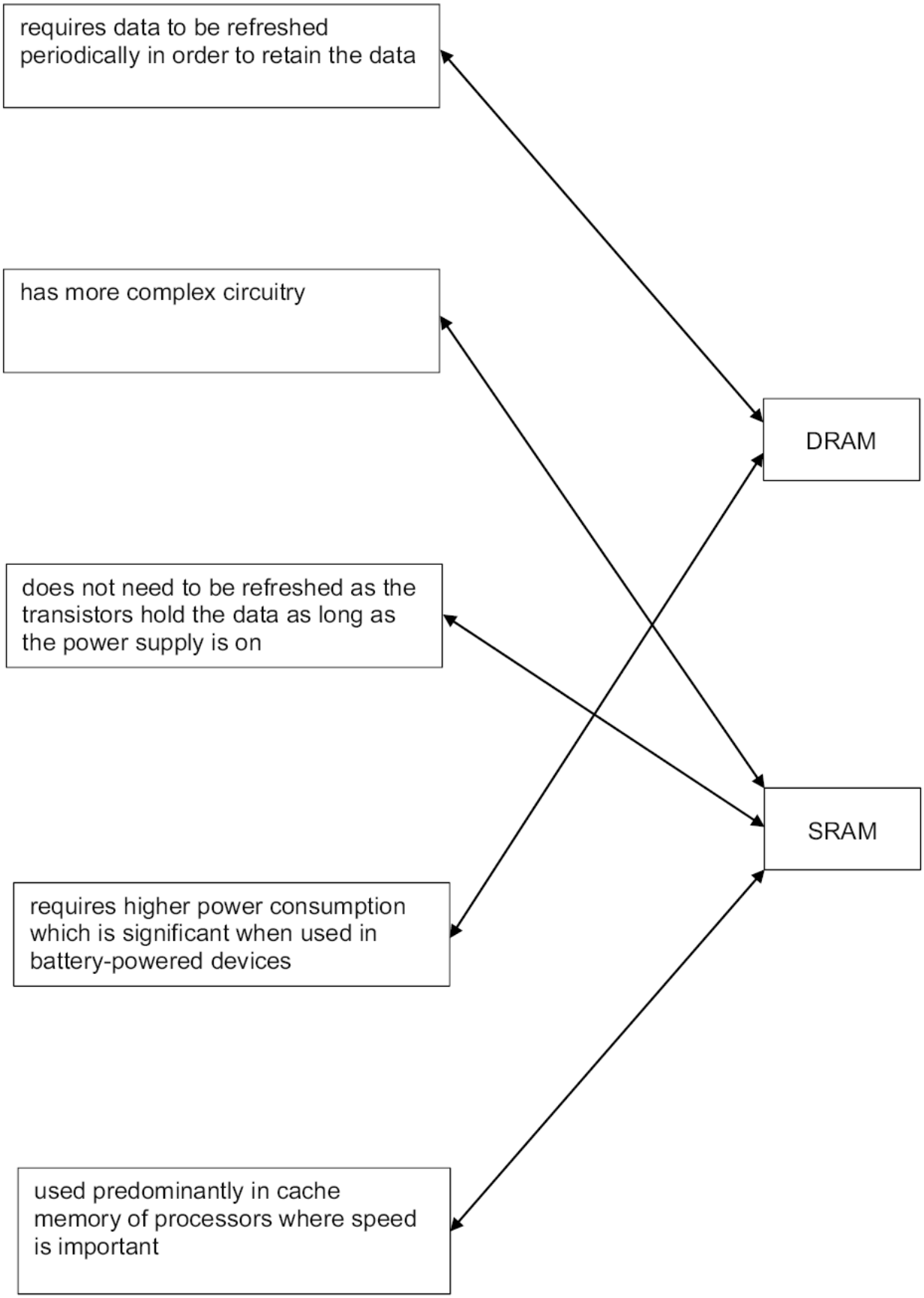
Five statements about DRAM and SRAM are shown below.

Draw a line to link each statement to the appropriate type of RAM.

Statement	Type of RAM
requires data to be refreshed periodically in order to retain the data	
has more complex circuitry	DRAM
does not need to be refreshed as the circuit holds the data as long as the power supply is on	
requires higher power consumption which is significant when used in battery-powered devices	SRAM
used predominantly in cache memory of processors where speed is important	

[5]

Answer:



[5]

3.3.3 Magnetic, Optical & Solid-State Storage:

The secondary (and off-line) storage can be divided into three categories according to the technology used. The technologies are:

1. Magnetic
2. Solid-State
3. Optical

<table>
<tr><th colspan="5">Secondary Storage</th></tr>
<tr><th colspan="2">Internal Secondary Storage</th><th colspan="3">Off-line (External) Secondary Storage</th></tr>
<tr><th>Magnetic Storage</th><th>Solid-State Storage</th><th>Magnetic Storage</th><th>Optical Storage</th><th>Solid-State Storage</th></tr>
<tr><td rowspan="3">Hard Disk Drive (HDD)</td><td rowspan="3">Solid State Drive (SSD)</td><td rowspan="3">External HDD (Hard Disk Drive)</td><td>CD Disk</td><td rowspan="3">USB Flash Memory/Memory Stick</td></tr>
<tr><td>DVD Disk</td></tr>
<tr><td>Blu-ray Disc</td></tr>
</table>

Is an internal Solid State Drive (SSD) an example of primary, secondary or off-line storage? Justify your choice.

- It is an example of secondary storage because it is non-volatile storage.
- It is not directly accessed by the CPU.

Basic Operation		
Magnetic Storage	**Optical Storage**	**Solid-State Storage**
It uses platters which are divided into tracks & sectors. The data is read and written using electromagnets.	It uses lasers to create and read pits and lands.	It uses NAND technology or NOR technology. The transistors are used as control gates & floating gates

Magnetic Storage:

How a Magnetic Storage Device stores data:

- The storage device has platters and data is stored on platters.
- The platters are divided into tracks and sectors.
- The storage platter is spun.
- It has a read and write arm that moves across storage media.
- It reads data from and writes the data to the platters using electromagnets.
- It uses magnetic fields to control magnetic dots of data.
- The magnetic field determines the binary value.

Advantages of Magnetic Storage Devices compared to Solid State Storage devices:

1. The magnetic storage is cheaper per unit of data.
2. The magnetic storage has more longevity, and it can perform more read/write cycles.

NOTE: The operation and characteristics of a magnetic storage device is applicable to both Hard Disk Drive (HDD) and external Hard Disk Drive (external HDD) because they are both magnetic storage devices.

The operation of HDD and external HDD and how they store the data along with advantages and disadvantages of each are exactly same as they are both magnetic storage devices.

The magnetic storage devices are following:

1. Hard Disk Drive (HDD)
2. External Hard Disk Drive (external HDD)

1) Hard Disk Drive (HDD):

- It is a magnetic storage device.
- It has moving parts.
- It is non-volatile storage.
- It uses magnetic properties to store data.
- The data is read and written using electromagnets.
- It has the slowest read and write speed compared to solid-state storage.
- It can be used as an external storage device to backup data.

Operation of an HDD & how it stores data:

- It has platters and data is stored on platters.
- The platters are divided into tracks and sectors.
- The storage platter is spun.
- It has read and write arms that move across storage media.
- It reads data from and writes the data to the platters using electromagnets.
- It uses magnetic fields to control magnetic dots of data.
- The magnetic field determines the binary value.

Advantages of an HDD compared to SSD:

1. The HDD is cheaper per unit of data (cheaper for larger amounts of storage space) OR it is normally cheaper for the same capacity of storage as SSD.
2. It has greater longevity, and it can perform more read/write cycles than SSD.
3. It is available in a larger storage capacity than SSD.
4. The HDD is a more trusted technology, and it is expensive to change the technology.

Disadvantages of an HDD compared to SSD:

1. It has moving parts, so it is less durable than SSD.
2. It has slower data access speed (slower read/write operation) due to greater latency compared to SSD.
3. It has higher power consumption than SSD.
4. It will create noise and heat.
5. It is larger in physical size and heavier than SSD.
6. It has greater latency and takes more time to warm up (start-up) than SSD.
   Latency is defined as the time it takes for a specific block of data on a data track to rotate around to the read–write head. It can be noticed by messages such as 'not responding'.

2) External Hard Disk Drive (external HDD)/(removeable HDD):

- It is an external magnetic storage device mostly used to back up the data.
- It has moving parts.
- It is non-volatile storage, and it uses magnetic properties to store data.
- The data is read and written using electromagnets.
- It has the slowest read and write speed compared to solid-state storage.

NOTE: The external hard disk drive are essentially HDDs external to the computer. They are similar to HDD, but the only difference is that they are not inside the computer.

- The external HDD is connected to the computer using one of the USB ports.
- It is removeable and portable magnetic storage device.
- It is essentially used as a back up device or simply another way of transferring files between computers.

Solid State Storage:

How a Solid State Storage Device stores data:

- It uses flash memory.
- It stores the data by flashing it onto the silicon chips.
- It uses NAND or NOR technology.
- The data is stored by controlling the flow of electrons using transistors which are used as control gates and floating gates.
- The electric current reaches the control gate and flows through to the floating gate to be stored.
- It is a type of EEPROM technology.
- When the data is stored, the transistor is converted from 1 to 0 or 0 to 1.
- It writes and reads sequentially.

NOTE: The operation and characteristics of a solid-state storage device is applicable to both Solid State Drive (SSD) and USB Flash Memory/Memory Stick (pen drive) because they are both solid-state storage devices.

The operation of SSD and USB Flash Memory and how they store data along with advantages and disadvantages of each are exactly same as they are both solid-state storage devices.

The solid-state storage devices are following:

1. Solid State Drive (SSD)
2. USB Flash Memory/Memory Stick (pen drive)

1) Solid State Drive (SSD):

- It is a solid-state storage device.
- It has no moving parts.
- It is non-volatile storage.
- It uses flash memory to store data which uses NAND or NOR technology.
- It uses transistors and cells that are laid out in a grid which are used as control gates and floating gates.
- It can be NAND or NOR technology.
- It uses EEPROM technology.
- It has a limited number of read/write cycles.
- It has fast read and write speed compared to magnetic storage.
- It can be used as an external storage device to backup data.

Operation of an SSD & how it stores data:

- It uses flash memory.
- It stores the data by flashing it onto the silicon chips.
- It uses NAND or NOR technology.
- The data is stored by controlling the flow of electrons using transistors which are used as control gates and floating gates.
- The electric current reaches the control gate and flows through to the floating gate to be stored.
- It is a type of EEPROM technology.
- When the data is stored, the transistor is converted from 1 to 0 or 0 to 1.
- It writes and reads sequentially.

Advantages of an SSD compared to HDD:

1. It has no moving parts, so it is more durable than HDD.
2. It has faster data access speed (faster read/write operation) due to less latency compared to HDD.
3. It has less latency and takes less time to warm up (start-up) than HDD.
4. It has lower power consumption and so produces less heat and runs cooler than HDD.
5. It runs quieter than HDD.
6. It is less susceptible to interference as it is not affected by magnetic forces.
7. It is more compact, lighter, and smaller in physical size than HDD.
8. It is portable.

Disadvantages of an SSD compared to HDD:

1. It has lower longevity, and a limited number of read-write cycles can be performed than HDD.
2. It is normally expensive for the same capacity of storage as HDD.

The two types of technologies mostly used in solid-state drives are:

1) Electronically Erasable Programmable Read-Only Memory (EEPROM) technology:

- It uses NOR chips rather than NAND.

Advantages:

1. This makes them faster in operation.
2. The EEPROM allows data to be read or erased in single bytes at a time.
   This makes EEPROM technology more useful in certain applications where data needs to be accessed or erased in byte-sized chunks

Disadvantages:

1. The devices using EEPROM are considerably more expensive than those that use NAND technology.

2) Flash/NAND technology:

- It uses NAND chips.

Advantages:

1. The devices using NAND are cheaper than those that use EEPROM technology.

Disadvantages:

1. The use of NAND only allows blocks of data to be read or erased.

2) USB Flash Memory/Memory Stick (pen drive):

- It is an external solid-state storage device mostly used to back up the data.
- It has no moving parts.
- It is non-volatile storage.
- It uses flash memory to store data which uses NAND or NOR technology.
- It uses transistors and cells that are laid out in a grid which are used as control gates and floating gates.
- It can be NAND or NOR technology.
- It uses EEPROM technology.
- It has a limited number of read/write cycles.
- It has fast read and write speed compared to magnetic storage.

NOTE: The USB flash memory/memory stick are essentially SSDs external to the computer. They are similar to SSD, but the only difference is that they are not inside the computer.

- The USB flash memory is connected to the computer using one of the USB ports.
- It is removeable and portable solid-state storage device.
- It is very small and lightweight, which makes it suitable as a method of transferring files between computers.
- It can also be used as a small back up device for music or photo files etc.

Operation of USB Flash Memory & how it stores data:

- It stores the data by flashing it onto the silicon chips.
- It uses NAND or NOR technology.
- The data is stored by controlling the flow of electrons using transistors which are used as control gates and floating gates.
- The electric current reaches the control gate and flows through to the floating gate to be stored.
- It is a type of EEPROM technology.
- When the data is stored, the transistor is converted from 1 to 0 or 0 to 1.
- It writes and reads sequentially.

Main Advantage of USB Flash Memory:

1. Their main advantage is that they are very small in size which makes them easily portable.

Magnetic Storage & Solid-State Storage:

NOTE: The operation and characteristics of all magnetic storage devices are same as well as operation and characteristics of all solid-state storage devices are same.

You must not be confused by the magnetic storage term as it refers and applies to both HDD and external HDD whereas the solid-state storage term refers and applies to both SSD and USB flash memory.

The only difference is that magnetic storage is the technology while HDD and external HDD are simply devices which are implementing that technology. Similarly, the solid-state storage is the technology while SSD and USB flash memory are simply devices which are implementing that technology.

If a question asks anything related to the technology e.g., magnetic, you must write about that technology whereas if a question asks anything about the particular device using the technology e.g., HDD you must refer to that throughout the answer.

However, the answer for both magnetic or HDD will be the same, but you must understand the difference that one is a technology and other is simply a device implementing that technology.

Main Similarities between an HDD & an SSD:

1. They are both non-volatile.
2. They are both secondary storage and not directly accessed by the CPU.
3. They both have a high capacity of storage.
4. They both have read and write abilities.

Main Differences between an HDD & an SSD:

1. The HDD has moving parts, but SSD does not.
2. The HDD uses magnetic storage whereas SSD uses flash memory.
3. The HDD is slower to access data than SSD as it has greater latency than SSD.
4. The HDD will create noise & heat whereas SSD runs quieter and cooler.
5. The HDD has higher power consumption than SSD.
6. The HDD has greater longevity and more read-write cycles whereas SSD has lower longevity and limited number of read-write cycles.
7. The HDD is larger in physical size and heavier than SSD.
8. The HDD is normally cheaper for the same capacity of storage as SSD.
9. The HDD is available in a larger storage capacity than SSD.

A few examples are given below which will help you better understand the choice of each device according to the required use (scenario) and the justification needed for choosing that particular device according to the examination question.

Example 1:

Why a model car uses a solid state drive rather than another type of secondary storage.

- A solid state drive has no moving parts.
- A solid state drive has faster random access.
- A solid state drive has a quick start up/shut down time (reduced latency).
- A solid state drive is very small.
- A solid state drive is very light.
- A solid state drive consumes very little power.
- A solid state drive does not generate a lot of heat (therefore safer in this application).

Example 2:

A law company wants to purchase a new file server. The company can purchase a server with either solid state storage or magnetic storage. After discussion, it decides to purchase a file server with magnetic storage.

Why the company chose magnetic storage rather than solid state storage:

- It has greater longevity as there is likely to be a lot of read/write functions each day.
- The read/write speed is sufficient enough even though it is slower than solid-state storage.
- It is cheaper per unit of data stored, which is a better value for the company to purchase so the law company can afford to buy a server with greater storage capacity.
- It is a trusted technology as it has been traditionally used for many years.

Example 3:

A sports event company uses a digital camera attached to a drone, to video their events from the sky. The video is stored as it is captured, on a device that is attached to the drone.

Which type of storage would be the most suitable to store the video and justify your choice.

- The solid-state storage would be most suitable to store the video.
- It has no moving parts so it will be more durable.
- It is small/compact so it can be easily fit onto the device.
- It is light so it will not be difficult to lift for the drone.
- It can hold the large amount of data needed for video.
- It uses less power so drone battery will last longer.

Example 4:

Which type of storage would be the most suitable for use in a web server and justify your choice.

In case of Magnetic storage:

- The webserver is likely to receive many requests a day.
- The webserver will likely need to store a lot of data and magnetic storage is high capacity.
- The magnetic storage is cheaper to buy for storage per unit than solid-state storage.
- The magnetic storage is capable of more of read/write requests over time as it has greater longevity.
- There is no requirement for the storage to be portable, so moving parts does not matter.

In case of Solid-State storage:

- The webserver is likely to receive many requests a day.
- The webserver will likely need to store a lot of data and solid-state storage is high capacity.
- The solid-state storage is more energy efficient.
- The solid-state storage runs cooler so it will not overheat.
- The solid-state storage has faster read/write speeds to handle the volume of traffic.

Example 5:

A mobile device uses an SSD. Why an SSD, rather than an HDD, is used in the mobile device:

- It has no moving parts, so it is more durable.
- It has a faster read/write speed (access speed).
- It is more compact, lightweight, smaller, and portable.
- It uses less energy, and the battery will last longer.
- It is quieter.
- It is not affected by magnetic forces.
- It runs at a cooler temperature.
- It has less latency and takes less time to warm up.

Example 6:

Pradeep stores his collection of films and his work files on his personal computer. Pradeep wants to save a copy of all his films and files onto a single storage device.

Which type of storage device would be the most suitable to store the copies and justify your choice.

In case of HDD:

- The HDD is a large capacity storage for videos/films that require large storage space.
- It has greater longevity so the copies will be accessible for a long time and may require large number of read/write operations to access fields.
- It is relatively cheaper than SSD per GB of data and there is a large storage capacity required therefore overall cost will be less than other storage devices.
- The device will not be moved regularly so there is no need for portability or durability.

In case of SSD:

- The SSD is a large capacity storage for videos/films that require large storage space.
- It has no moving parts so it can be carried/moved to other locations with limited risk of damage.
- It has fast access speed and so large video files will be stored and accessed in less time.
- The cost per GB of data is not significant in comparison as there is a large storage capacity required therefore overall cost will not be significantly more than other storage devices.
- The longevity of SSD is insignificant because the copy of files may not be accessed regularly so limited number of read/write operations are insignificant.
- It uses less power and runs cooler.
- It has no latency and so does not take time to start-up.

The following tables compare Magnetic Storage devices & Solid-State Storage devices:

(i) Table 1:

Statement	HDD (✓)	SSD (✓)
It has a limited number of read/write cycles		✓
It uses magnetic properties to store data	✓	
It has moving parts	✓	
It is non-volatile storage	✓	✓
It can be used as an external storage device to back-up data	✓	✓
It uses flash memory to store data		✓

(ii) Table 2:

Statement	HDD (✓)	SSD (✓)	USB flash memory drive (✓)
It has no moving parts		✓	✓
It is non-volatile	✓	✓	✓
It can use NAND gates to store data		✓	✓
It uses magnetic properties to store data	✓		
It has the smallest physical size			✓
It has the slowest read/write speeds	✓		

Optical Storage:

How data is written to Optical Storage Device/Media:

- The disk is rotated/spun.
- A laser beam is used to write the data.
- The laser beam makes indentations on the surface of the disk.
- The data is written in a spiral track.
- The pits and lands are used to store data.
- The pits and lands represent binary values 1s and 0s.
- It is called burning data to the disk.

How data is read from an Optical Storage Device/Media:

- The disk is rotated/spun at a constant speed to be read.
- A laser beam is used to read the data.
- The laser beam shines onto the surface of the disk.
- The surface is covered in a track that spirals from the center.
- The data is represented on the surface using pits and lands.
- The pits and lands represent binary values 1s and 0s.
- The pits reflect light back differently to the area in land.
- The optical device can determine the binary value from the light reflection.

The optical storage devices are following:

1. Compact Disc (CD)
2. Digital Versatile Disc (DVD)
3. Blu-Ray Disc

1) Compact Disc (CD):

- It is an optical storage device.
- It is non-volatile and off-line storage.
- It is only a single polycarbonate layer.
- The data is read/written using a red laser.
- It is spun/rotated to be read.
- It uses a spiral track for storing data.
- It uses pits and lands to store data on the spiral track.
- It has the smallest storage capacity.
- It has the longest wavelength laser.
- It can be read only (R) or read write (RW).

How the data is written to a CD:

- The disk is rotated/spun.
- A red laser beam is used to write the data.
- The red laser beam makes indentations on the surface of the disk.
- The data is written in a spiral track.
- The pits and lands are used to store data.
- The pits and lands represent binary values 1s and 0s.
- It is called burning data to the disk.

How the data is read from a CD:

- The disk is rotated/spun at a constant speed to be read.
- A red laser beam is used to read the data.
- The red laser beam shines onto the surface of the disk.
- The surface is covered in a track that spirals from the center.
- The data is represented on the surface using pits and lands.
- The pits and lands represent binary values 1s and 0s.
- The pits reflect light back differently to the area in land.
- The CD can determine the binary value from the light reflection.

Laser Color & Storage Capacity of CD:

- It uses red lasers with a wavelength of 780 nanometers.
- It has a storage capacity of 700-800 MB only.

Uses of CD:

1. It is commonly used to store music albums.
2. It is used as a back-up system for photos, music, and multimedia files.
3. It is used to transfer files between computers.
4. It is used for supplying software e.g., printer drivers.

2) Digital Versatile Disc (DVD):

- It is an optical storage device.
- It is non-volatile and off-line storage.
- It is a dual polycarbonate layer.
- The data is read/written using a red laser.
- It is spun/rotated to be read.
- It uses a spiral track for storing data.
- It uses pits and lands to store data on the spiral track.
- It has a higher storage capacity than CD.
- It has a shorter wavelength laser than CD.
- It is spun/rotated faster than CD.
- It has a higher data transfer rate than CD of approximately 10 mbps.
- It can be read only (R) or read write (RW).

How the data is written to a DVD (dual-layer):

- The disk is rotated/spun.
- A red laser beam is used to write the data.
- The red laser beam makes indentations on the surface of the disk.
- The data is written in a spiral track.
- The second polycarbonate layer is written by the red laser focusing on the fraction of a millimeter difference compared to the first layer.
- The pits and lands are used to store data.
- The pits and lands represent binary values 1s and 0s.
- It is called burning data to the disk.

How the data is read from a DVD (dual-layer):

- The disk is rotated/spun at a constant speed to be read.
- A red laser beam is used to read the data.
- The red laser beam shines onto the surface of the disk.
- The surface is covered in a track that spirals from the center.
- The data is represented on the surface using pits and lands.
- The pits and lands represent binary values 1s and 0s.
- The second polycarbonate layer is read by the red laser focusing on the fraction of a millimeter difference compared to the first layer.
- The pits reflect light back differently to the area in land.
- The DVD can determine the binary value from the light reflection.

Structure of DVD:

- It uses dual layering which considerably increases the storage capacity.
- There are two individual recording layers.
- The two layers of a standard DVD are joined together with a transparent (polycarbonate) spacer, and a very thin reflector is also sandwiched between the two layers.

Laser Color & Storage Capacity of DVD:

- It uses red lasers with a wavelength of 650 nanometers.
- It has a storage capacity of 8.5 GB.

Uses of DVD:

1. It is used to store movies and games.
2. It is used as a back-up system for photos, music, and multimedia files.
3. It is used to transfer files between computers.
4. It is used for supplying software e.g., printer drivers.

Compact Disc (CD) & Digital Versatile Disc (DVD):

Main Similarities between a CD & DVD:

1. They both need a red laser to read/write data.
2. They both are spun/rotated to be read.
3. They both use spiral tracks for data.
4. They both are optical storage.
5. They both are non-volatile/off-line storage.
6. They both use pits and lands to store data.
7. They both can be read only (R) or read write (RW).

Main Differences between a CD & DVD:

1. The DVD can be dual layer, but CD can only be a single layer.
2. The DVD has a higher storage capacity.
3. The DVD has a shorter wavelength laser.
4. The DVD are spun/rotated faster.
5. The DVDs have a higher data transfer rate (of approximately 10 mbps).

3) Blu-Ray Disc:

- It is an optical storage device.
- It is non-volatile and off-line storage.
- It can be a single layer or dual layer.
- The data is read/written using a blue laser.
- It is spun/rotated to be read.
- It uses a spiral track for storing data.
- It uses pits and lands to store data on the spiral track.
- It has the largest storage capacity.
- It has the shortest wavelength.
- It is spun/rotated the fastest.
- It has the highest data transfer rate of approximately 36 mbps.
- It has a built-in secure encryption system.

How the data is written to a Blu-Ray:

- The disk is rotated/spun.
- A blue laser beam is used to write the data.
- The blue laser beam makes indentations on the surface of the disk.
- The data is written in a spiral track.
- The pits and lands are used to store data.
- The pits and lands represent binary values 1s and 0s.
- It is called burning data to the disk.

How the data is read from a Blu-Ray:

- The disk is rotated/spun at a constant speed to be read.
- A blue laser beam is used to read the data.
- The blue laser beam shines onto the surface of the disk.
- The surface is covered in a track that spirals from the center.
- The data is represented on the surface using pits and lands.
- The pits and lands represent binary values 1s and 0s.
- The pits reflect light back differently to the area in land.
- The Blu-ray can determine the binary value from the light reflection.

Structure of Blu-Ray:

- It can be a single layer or dual layer.
- The pits and lands are much smaller due to the use of blue laser light (with shorter wavelength).
- The single layer Blu-ray disc uses a 1.2 mm thick polycarbonate layer.
- The dual layer Blu-ray disc uses a sandwich of two 0.6 mm thick polycarbonate layers.

Laser Color & Storage Capacity of Blu-Ray:

- It uses blue lasers with a wavelength of 405 nanometers.
- The single layer Blu-ray disc has a storage capacity of 27 GB.
- The dual layer Blu-ray disc has a storage capacity of 50 GB.

Interactivity of Blu-Ray:

1. It can record high-definition television programmes.
2. It can skip quickly to any part of the disc.
3. It can create playlists of recorded movies and television programmes.
4. It can edit or re-order programmes recorded on the disc.
5. It can automatically search for empty space on the disc to avoid over-recording.
6. It can access websites and download subtitles and other interesting features.

Uses of Blu-Ray:

1. It is used to store high-definition movies.
2. It is used to store video games for the PlayStation.
3. It can store large quantities of high-quality photos, high-definition videos, audios and other digital content.
4. It is used as a back-up system for photos, music, and multimedia files.

Digital Versatile Disc (DVD) & Blu-Ray Disc:

Main Differences between DVD & Blu-Ray Disc:

1. The Blu-ray disc uses blue lasers and DVD uses red lasers.
2. The Blu-ray disc has a much higher storage capacity than standard DVD.
3. The Blu-ray disc can be single polycarbonate layer or dual polycarbonate layer, but DVD can only be dual polycarbonate layer.
4. The Blu-ray has a faster transfer rate (of approximately 36 mbps) whereas DVD has a slower transfer rate (of approximately 10 mbps).
5. The Blu-ray discs have a built-in secure encryption system.

Factors affecting storage capacity of Optical Media:

1. The smaller the pit size and track width, the greater the storage capacity of the medium.
2. The shorter the wavelength of laser light, the greater the storage capacity of the medium.

The main differences between CDs, DVDs and Blu-ray are summarized in the following table:

Disk Type	Laser Color	Wavelength of Laser Light	Disk Construction	Track Pitch (distance between tracks)	Storage Capacity
CD	Red	780 nm	single 1.2 mm polycarbonate layer	1.60 µm	800 MB
DVD (dual-layer)	Red	650 nm	two 0.6 mm polycarbonate layers	0.74 µm	8.5 GB
Blu-ray (single-layer)	Blue	405 nm	single 1.2 mm polycarbonate layer	0.30 µm	27 GB
Blu-ray (dual-layer)	Blue	405 nm	two 0.6 mm polycarbonate layers	0.30 µm	50 GB

The following table compares CD, DVD & Blu-Ray Disks:

(i) Table 1:

Statement	Blu-ray (✓)	CD (✓)	DVD (✓)
A type of optical storage	✓	✓	✓
Has the largest storage capacity	✓		
Can be dual layer	✓		✓
Read using a red laser		✓	✓
Has the smallest storage capacity		✓	
Stores data in a spiral track	✓	✓	✓

The following table compare Magnetic Storage, Solid-State Storage & Optical Storage:

(ii) Table 2:

Statement	Magnetic (✓)	Solid-State (✓)	Optical (✓)
No moving parts are used to store data		✓	
Pits and lands are used to store data			✓
Data is stored on platters	✓		
Flash memory is used to store data		✓	
Parts are rotated to store data	✓		✓
Data can be stored permanently	✓	✓	✓

Exam Style Questions:

Question 1:

Five storage devices are described in the table below.

In column 2, name the storage device being described.

In columns 3, 4, or 5, tick (✓) to show the appropriate category of storage.

1	2	3	4	5
Description of storage device	**Name of storage device**	**Category of storage**		
		Primary	**Secondary**	**Off-line**
optical media which use one spiral track; red lasers are used to read and write data on the media surface; makes use of dual-layering technology to increase the storage capacity				
non-volatile memory chip; contents of the chip cannot be altered; it is often used to store the start up routines in a computer (e.g. the BIOS)				
optical media which use concentric tracks to store the data; this allows read and write operations to be carried out at the same time				
non-volatile memory device which uses NAND flash memories (which consist of millions of transistors wired in series on single circuit boards)				
optical media which use blue laser technology to read and write data on the media surface; it uses a single 1.1 mm polycarbonate disc				

[10]

Answer:

1 mark per device, **1** mark per category

Description of storage device	Name of storage device	Category of storage		
		Primary	Secondary	Off-line
optical media which uses one spiral track; red lasers are used to read and write data on the media surface; makes use of dual-layering technology to increase the storage capacity	**DVD**			✓
non-volatile memory chip; contents of the chip cannot be altered; it is often used to store the start-up routines in a computer (e.g. the BIOS)	**ROM**	✓		
optical media which uses concentric tracks to store the data; this allows read and write operations to be carried out at the same time	**DVD-RAM**	✓		(✓)
non-volatile memory device that uses NAND flash memories (which consist of millions of transistors wired in series on single circuit boards)	**Solid State Drive/memory (SSD)**		✓	
	(SD/XD card) (USB storage device)			(✓)
optical media that uses blue laser technology to read and write data on the media surface; it uses a single 1.1 mm polycarbonate disc	**Blue-ray**			✓

[10]

Question 2:

State which types of storage device or media would be most suitable for these scenarios.

For each device or media, justify your choice.

(a) Creating a backup of 150 GB of data.

.....

Justification .....

.....

[2]

(b) Storing applications on a tablet device.

.....

Justification .....

.....

[2]

(c) Storing a 1200 MB high-definition promotional movie about a new car. The movie is to be given to people who are interested in buying a new car.

.....

Justification .....

.....

[2]

Answer:

Question	Answer	Marks
13(a)	1 mark for storage, 1 mark for justification • External/Removable HDD // External/Removable SSD // Large capacity USB Flash Drive • Backups must be stored separately • Will hold sufficient data • Faster write abilities (SSD/USB drive only)	2
13(b)	1 mark for storage, 1 mark for justification • SSD // SD card // Flash memory • Small physical size • Lightweight • Low heat production • Low power consumption • It's quiet • Fast read/write times	2
13(c)	1 mark for storage, 1 mark for justification • DVD // Blu-ray // USB Flash Drive // SD card • Easy to distribute • Small in size • Cheap to buy • Universal storage therefore compatible with many devices	2

Question 3:

(a) Optical storage media can be used to store data.

Describe how the data is read from a Compact Disc (CD).

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.....[4]

Answer:

Question	Answer	Marks
9(a)	Any **four** from: – (Red) laser is used – (Laser beams) shines onto surface of the disk – It is rotated (at a constant speed) to be read – Surface is covered in a track (that spirals from the centre) – Data is represented on the surface using pits and lands – Pits and lands represent binary values – Pits reflect light back differently (to the area in between/land) – Optical device can determine the binary value from the light reflection	4

Question 4:

(b) The law company wants to purchase a new file server.

The company can purchase a server with either solid state storage or magnetic storage. After discussion, it decides to purchase a file server with magnetic storage.

Explain why the company chose magnetic storage rather than solid state storage.

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..... [4]

Answer:

Question	Answer	Marks
6(b)	**Four** from (max 3 marks for benefits only, without an explanation): • More read/write cycles (over its lifetime) // greater longevity … • … likely to be a lot of read/write functions each day • Read/write speed is sufficient … • … even though it is slower than solid-state • Cheaper **per unit of data** stored … • … better value for the company to purchase • … so the law company can afford to buy a server with greater storage capacity • No requirement for portability … • … as a server, it does not need to be moved • Trusted technology … • … it has been traditionally used for many years	4

Question 5:

(a) Marley wants to store a video he has created for his school project.

He considers using a DVD or a Blu-ray to store the video.

Explain **two** differences between a DVD and a Blu-ray.

1 .....

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2 .....

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[2]

Answer:

Question	Answer	Marks
4(a)	**Two** from e.g.: – DVD uses red **laser**/light whereas blu-ray uses **blue**/violet laser/light – DVD has a **smaller** (storage) capacity // Blu-ray has a **larger** (storage) capacity – DVD has **two layers** (of polycarbonate) whereas Blu-ray disks have a **single layer** (of polycarbonate) – DVD has a **slower transfer** rate (of approximately 10 mbps) // Blu-ray has a **faster transfer** rate (of approximately 36 mbps)	**2**

Question 6:

Elle uses both CDs and DVDs to store her school projects.

(a) Give **three** similarities between a CD and a DVD.

1 .....

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2 .....

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3 .....

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[3]

(b) State **one** difference between a CD and a DVD.

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..... [1]

Answer:

Question	Answer	Marks
9(a)	Any **three** from: – Both need a **red** laser to read/write data – Both are spun to be read – Both use spiral tracks for data – Both are optical storage – Both are off-line storage // both non-volatile – Both use pits and lands to store data	3
9(b)	Any **one** from: – DVD can be dual layer, but CD can only be single – DVD has higher storage capacity – DVD has a shorter wavelength laser – DVD are spun faster – DVDs have a higher data transfer rate	1

Question 7:

(a) Tick (✓) **one** box to identify if an internal Solid State Drive (SSD) is an example of primary, secondary or off-line storage. Justify your choice.

Tick (✓)

- ☐ Primary
- ☐ Secondary
- ☐ Off-line

Justification .....

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[3]

(b) Describe the operation of an SSD and how it stores data.

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..... [4]

Answer:

Question	Answer	Marks
7(a)	**One** mark per correct storage, **two** marks for justification. – Secondary – It is non-volatile storage – It is not directly accessed by the CPU	**3**
7(b)	Any **four** from: – Uses flash memory – Data is flashed onto (silicon) chips – Uses NAND/NOR technology // Can use flip-flops – Uses transistors/control gates/floating gates … – … to control the flow of electrons – It is a type of EEPROM technology – When data is stored the transistor is converted from 1 to 0 / 0 to 1 – Writes (and reads) sequentially	**4**

Question 8:

(c) Pradeep stores his collection of films and his work files on his personal computer.

Pradeep wants to save a copy of all his films and files onto a single storage device.

Identify and justify an appropriate storage device to store the copies.

Storage device .....

Justification .....

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[4]

Answer:

Question	Answer	Marks
4(c)	1 mark for naming appropriate device • hard disk / HDD / magnetic • solid state drive / SSD / USB memory stick / flash drive 1 mark each for matching justification to max 3. e.g. HDD • Large capacity storage • …for videos/films that have large file sizes / require large storage space • Longevity // Can be read from/written to large number of times • … the copies will be accessible for a long time // device will not break if accessed regularly • …may require large number of read/write to access fields • Relatively cheap per GB // cheaper than SSD per GB … • … there is a large capacity required therefore overall may cost less than other devices • Device will not be moved regularly so no need for portability/durability SSD • Large capacity storage • …for videos/films that have large file sizes / require large storage space • No moving parts • …can be carried/moved to other locations with limited risk of damage • Fast access speed • … videos are large files that will be stored/accessed in less time • Cost per GB is not significant (in comparison) • …there is a large capacity required therefore overall cost will not be significantly more than others • Used as a copy of files to may not be accessed regularly • … the limited number of read/write times/longevity is inconsequential • Uses less power // runs cooler • No latency // does not take time to start-up	4

Question 9:

(b) Users can store their data on optical storage media.

Explain how data is written to optical storage media.

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..... [4]

Answer:

5(b)	**Four** from: • The disc is rotated/spun • Laser beam is used • The laser beam makes indentations on the surface of the disc/pits and lands • The data is written in a spiral/concentric tracks • The pits and lands represent binary values/1s and 0s • It is called burning data to the disc	**4**

Question 10:

(iii) Identify which type of storage would be the most suitable for use in a web server and justify your choice.

Type of storage .....

Justification .....

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[3]

(c) Describe the operation of USB flash memory and how it stores data.

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..... [3]

Answer:

2(b)(iii)	**One** for type of storage, **two** for matching justification from: – Magnetic // HDD – (Web server) is likely to receive many requests a day – (Web server) will likely need to store a lot of data and magnetic is high capacity – Magnetic is **cheaper** to buy for **storage per unit** than solid state – Magnetic is capable of more of read/write requests **over time** // has more **longevity** // SSD has more limited number of read/write requests (before it is no longer usable) – No requirement for it to be portable, so moving parts does not matter – Solid-state // SSD – (Web server) is likely to receive many requests a day – (Web server) will likely need to store a lot of data and solid-state is high capacity – Solid-state is more energy efficient – Solid-state runs cooler so will not overheat – Solid state has faster read/write speeds to handle volume of traffic	**3**
2(c)	Any **three** from: – Data is flashed onto (silicon) chips – Uses NAND/NOR technology // can use flip-flops – Uses transistors/control gates/floating gates … – … to control the flow of electrons – It is a type of EEPROM technology – When data is stored the transistor is converted from 1 to 0 / 0 to 1 – Writes (and reads) sequentially	**3**

Question 11:

(b) Greta stores data on several off-line storage devices, including an external hard disk drive (HDD), a USB flash memory drive and a compact disc (CD).

(i) Identify the type of storage for each device.

External HDD .....

USB flash memory drive .....

CD .....

[3]

(ii) Describe the operation of a HDD and how it stores data.

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..... [4]

Answer:

1(b)(i)	– Magnetic – Solid state – Optical	**3**
1(b)(ii)	Any **four** from: – It has platters – Platters/disk divided into tracks – Platter/disk is spun – Has a read/write arm that moves across storage media – Read/writes data using **electromagnets** – Uses magnetic fields to control magnetic dots of data – Magnetic field determines binary value	**4**

Question 12:

(ii) Nadia is considering purchasing a magnetic storage device.

Describe how a magnetic storage device stores data.

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..... [6]

(iii) Give **two** advantages of using a magnetic storage device rather than a solid state storage device.

Advantage 1 .....

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Advantage 2 .....

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[2]

Answer:

Question	Answer	Marks
6(c)(ii)	**Six** from: – Storage device has platters – Platters/disk divided into tracks – Storage platter / disk is spun – Has a read/write arm that moves across storage media – Read/writes data using electromagnets – Uses magnetic fields to control magnetic dots of data – Magnetic field determines binary value NOTE: Marks can be awarded for an alternative description e.g. magnetic tape	6
6(c)(iii)	– Magnetic is cheaper **per unit of data** – Magnetic has more longevity // Magnetic can perform more read/write cycles	2

Question 13:

Priya studies music at school. She is buying a new computer to complete her school work at home.

(a) Priya has a choice between an internal Hard Disk Drive (HDD) and an internal Solid State Drive (SSD) to store data.

(i) Give **one** similarity between an HDD and an SSD.

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..... [1]

(ii) Explain **three** differences between an HDD and an SSD.

1 .....

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2 .....

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3 .....

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[3]

(b) Priya needs to transfer files between the school and her home computer.

Identify **one** off-line storage device she could use to transport the files.

Answer:

Question	Answer	Mark
3(a)(i)	Any **one** from: • They are both non-volatile • They are both secondary storage // Both not directly accessed by the CPU • They both have a high capacity of storage • Both have read **and** write abilities	1
3(a)(ii)	Any **three** from: • HDD has moving parts but SSD does not • HDD uses magnetic storage whereas SSD uses flash memory • HDD is slower to **access data** than SSD // HDD has greater latency than SSD • HDD will create noise/heat, whereas SSD runs quieter/cooler • HDD has higher power consumption than SSD • HDD have greater longevity/more read-write cycles whereas SDD has lower longevity/limited number of read-write cycles • HDD larger in physical size/heavier than SSD • HDD is normally cheaper for the same capacity of storage as SSD • HDD is available in a larger storage capacity than SSD	3
3(b)	Any **one** from: • USB flash memory drive • **External** HDD/SSD • SD Card • CD / DVD / Blu-ray	1

3.3.4 Virtual Memory:

NOTE: Virtual Memory is a newly added topic in the Computer Science (2210) syllabus for the session 2023–2025.

We need to understand the meaning of virtual memory, how it is created and used, and why is the use of virtual memory necessary.

Virtual Memory:

It is basically using secondary storage to stimulate additional main memory (RAM). The physical memory (RAM) is managed using virtual memory and paging.

- The secondary storage is used to extend the RAM (main memory) available so the CPU can access more memory space than already available RAM space.
- The only part of program/data which is in use needs to be in the RAM.
- The pages of data are transferred between the RAM and the virtual memory when needed.

Paging:

- The main memory (RAM) is divided into equal-size blocks, called page frames.
- Each process that is executed is divided into blocks of the same size, called pages.
- Each process has a page table that is used to manage the pages of this process.

It is used by memory management in operating system to store and retrieve data from HDD/SSD and copy it into the RAM.

Page:

- It is a fixed size consecutive block of data utilized in virtual memory systems.
- The pages (data blocks) are moved in and out of an HDD/SSD (secondary storage) which allows virtual memory system to work.

Page Frame:

- The main memory (RAM) is divided into page frames of the same/equal size blocks as a page (data block).

Page Table:

- The page map table shows the mapping of pages to page frames.

Page Replacement:

- It occurs when a requested page is not in memory.
- When a new page is requested but is not in memory, a page fault occurs, and the operating system (OS) replaces one of the existing pages with the new page(s).
- There are several methods for page replacement and their purpose is to minimize the number of page faults.

Page Fault:

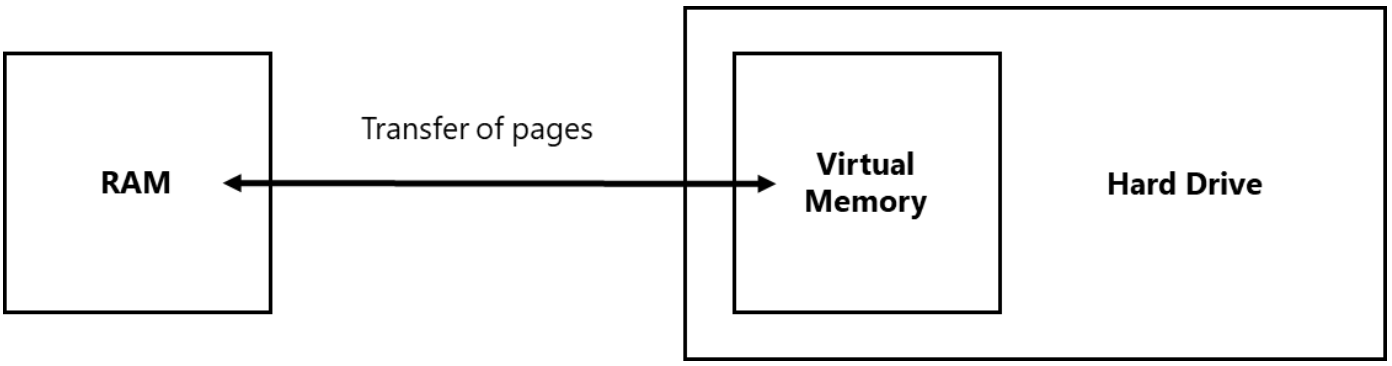
- It occurs when there is an attempt to load an instruction for a page not in memory.
- This generates an interrupt, and the interrupt service routine (ISR) code is executed.
- This causes the operating system (OS) to load the page into the memory.

How Paging is used to manage Virtual Memory:

- It divides the RAM (main memory) into frames.
- It divides the virtual memory into blocks of the same size called pages.
- The frames and pages are of fixed size.
- It sets up a page table to translate logical to physical addresses.
- It keeps a track of all free frames.
- It transfers/swaps the pages in RAM (main memory) with new pages from the secondary memory (HDD/SSD) whenever needed.

The following diagram represents how Virtual Memory is created and used:

- The diagram has a hard drive (HDD)(secondary storage) and a RAM (main memory).
- The hard drive is portioned/divided in some way to create a virtual memory.
- The pages are transferred between the RAM and the virtual memory.

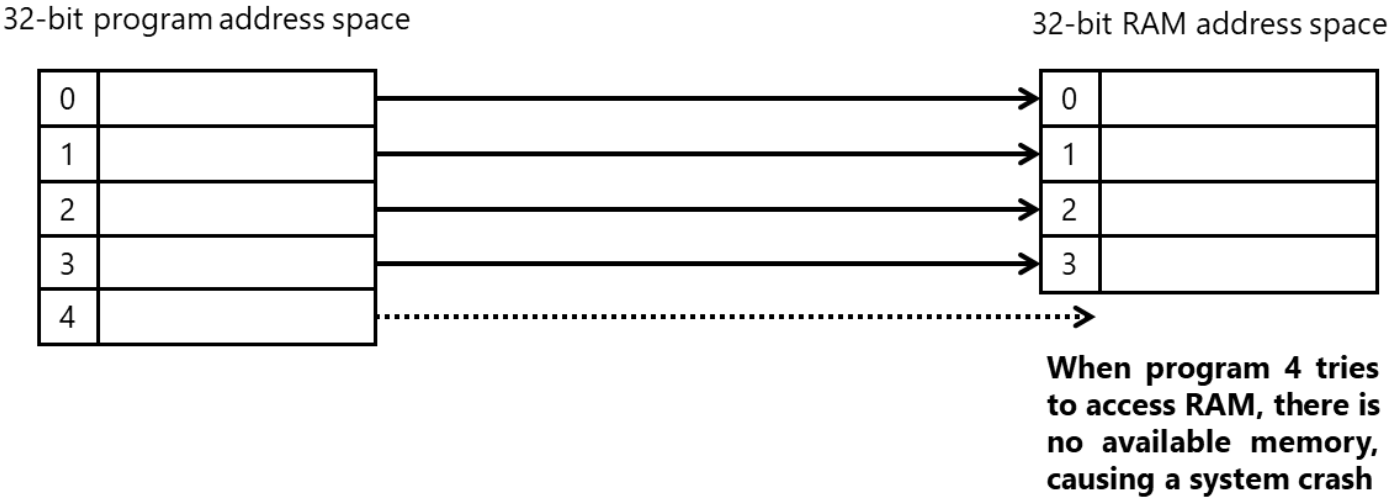


The following diagrams show differences between paging without virtual memory and paging using virtual memory:

(i) Without virtual memory (normal memory management):

Suppose there are five programs (numbered 0 to 4) that are in memory, all requiring access to RAM.

The diagram shows what would happen without virtual memory being used (when the computers run out of RAM memory space)

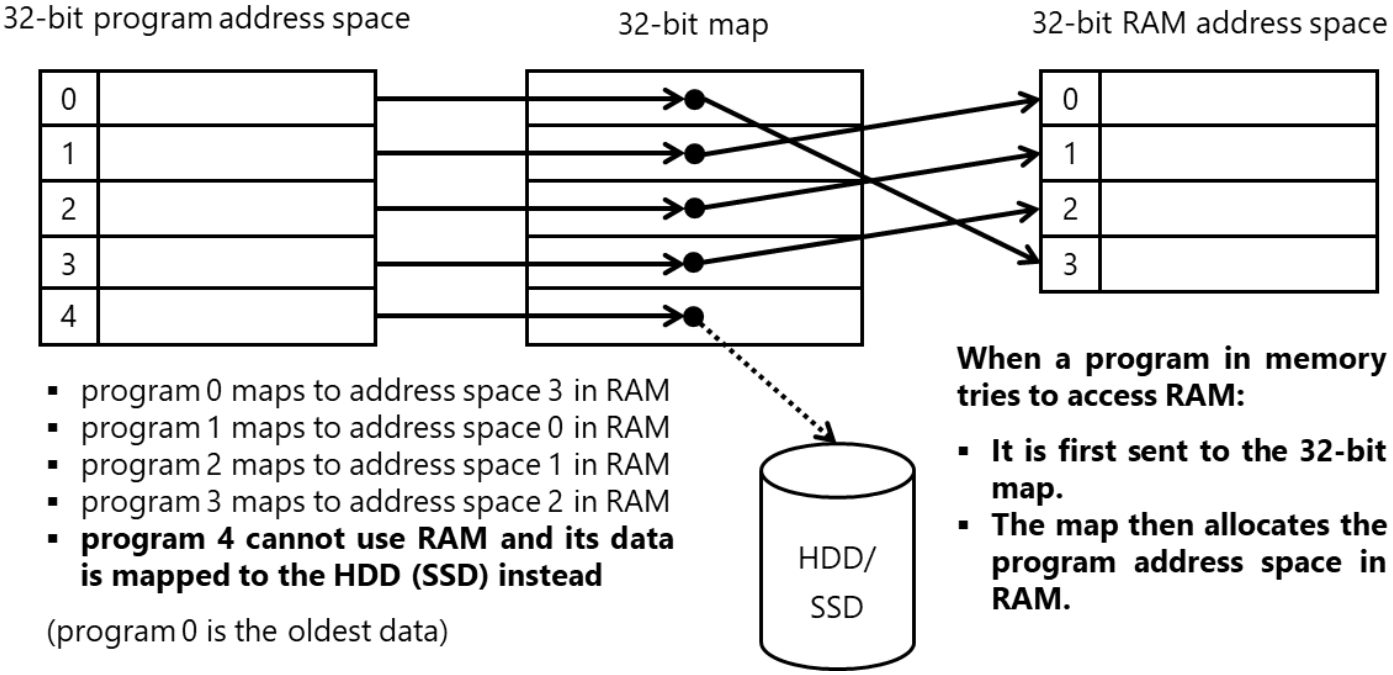


When program 4 tries to access RAM, there is no available memory, causing a system crash

(ii) With virtual memory (before program 4 is given RAM space):

We will now consider what happens if the CPU uses virtual memory to allow all five programs to access the RAM as required. This will require moving data out of RAM into the HDD/SSD (secondary storage) and then allowing other data to be moved out of HDD/SSD (secondary storage) into RAM.

The diagram shows what would happen with virtual memory being used and the status just before program 4 is given RAM space:



- program 0 maps to address space 3 in RAM
- program 1 maps to address space 0 in RAM
- program 2 maps to address space 1 in RAM
- program 3 maps to address space 2 in RAM
- **program 4 cannot use RAM and its data is mapped to the HDD (SSD) instead**

(program 0 is the oldest data)

When a program in memory tries to access RAM:

- **It is first sent to the 32-bit map.**
- **The map then allocates the program address space in RAM.**

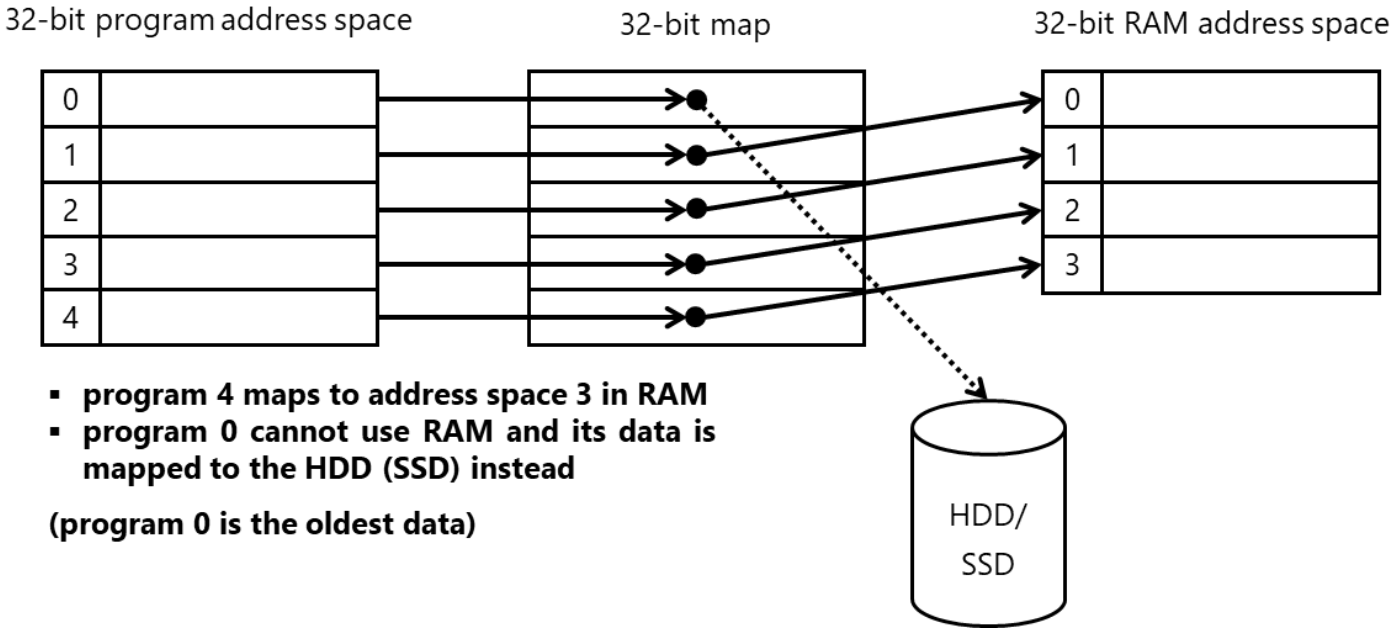
(iii) With virtual memory (after program 4 is given RAM space):

The virtual memory now moves the oldest data (in this case, program 0) out of RAM into the HDD/SSD (secondary storage) to allow the new data (in this case, program 4) to gain access to RAM.

The 32-bit map is now updated to reflect the new situation which is:

- The data from program 0 (oldest data which was using RAM address space 3) is now mapped to the HDD/SSD (secondary storage) instead, leaving the address space 3 free for use by program 4 (new data).
- The data from program 4 now maps to RAM address space 3, which means program 4 now has access to the RAM.

The diagram shows what would happen with virtual memory being used and the status after the program 0 (oldest data) is mapped to HDD/SSD (secondary storage) which empties the RAM address space 3 and then the program 4 (new data) has access to that RAM space:



- **program 4 maps to address space 3 in RAM**
- **program 0 cannot use RAM and its data is mapped to the HDD (SSD) instead**

(program 0 is the oldest data)

This whole process will continue to occur until RAM is no longer being over-utilized by the competing programs running in the memory.

The virtual memory gives the illusion of unlimited memory being available as even though RAM is full, the data can be moved in and out of the secondary storage (HDD/SSD) which provides the illusion that there is still memory available.

A software is being used to create 3D models which often requires the use of virtual memory.

Why virtual memory is needed for this process?

- It is needed to extend the RAM capacity to stop the 3D modelling software from freezing/crashing when the physical RAM is full.
- It is needed to allow the computer to process the large amount of data required for 3D modelling.

Benefits & Drawbacks of Virtual Memory:

Benefits of using Virtual Memory:

1. It extends the RAM capacity as the programs can be larger than RAM (physical memory) and still be executed.
2. It prevents the system/softwares from freezing/crashing when multiple programs are running, and the physical RAM is full.
3. It allows the computer to process the large amount of data required for a software/program.
4. It prevents wastage of memory with data that is not being used (e.g., during error handling).
5. It reduces the need to buy and install more expensive RAM memory.
6. It leads to more efficient multi-programming with less input/output loading and swapping programs into and out of memory.
7. It eliminates external fragmentation/reduces internal fragmentation.

Drawbacks of using Virtual Memory:

1. It is slower to access data in virtual memory.
2. It can cause disk thrashing.

Disk Thrashing:

- The pages are required to be back in RAM as soon as they are moved to hard drive (secondary storage).
- There is a continuous swapping of the same pages.
- This results in no useful processing (deadlock) because the pages that are in RAM and on hard drive are inter-dependent.
- This results in nearly all processing time to be used for swapping pages.
- The processing speed of the computer is considerably reduced.
- The system may reach a thrash point where the execution of a process comes to a halt since the system is continuously swapping pages rather than doing any actual execution.

Ways to reduce Disk Thrashing:

1. It can be reduced by installing more RAM.
2. It can be reduced by reducing the number of programs running at one time.
3. It can be reduced by reducing the size of the swap file.
4. It can be reduced by making use of a solid state drive (SSD) rather than using HDD.

Exam Style Questions:

Question 1:

(a) Describe what is meant by **virtual memory**.

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..... [2]

(b) **(i)** Explain how paging is used to manage virtual memory.

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..... [4]

(ii) Give a suitable page replacement algorithm for this process.

..... [1]

(iii) One drawback of using virtual memory is disk thrashing.

Describe what is meant by the term **disk thrashing**.

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..... [2]

Answer:

Question	Answer	Marks
4(a)	1 mark per bullet point to **max 2** • Disk / secondary storage is used to extend the RAM / memory available • … so CPU can access more memory space than available RAM • Only part of program / data in use needs to be in RAM • Data is swapped between RAM and disk	**2**
4(b)(i)	1 mark per bullet point to **max 4** • Divide memory / RAM into frames • Divide virtual memory into blocks of same size called pages • Frames / pages are a fixed size • Set up a page table to translate logical to physical addresses • Keep track of all free frames • Swap pages in memory with new pages from disk when needed	**4**
4(b)(ii)	First-in-first-out // least-recently-used page // least-used-page	**1**
4(b)(iii)	1 mark per bullet point to **max 2** • Pages are required back in RAM as soon as they are moved to disk • There is **continuous** swapping (of the same pages) • No useful processing happens // deadlock • … (because) pages that are in RAM and on disk are inter-dependent • … (nearly) all processing time is used for swapping pages	**2**

Question 2:

(a) Draw a diagram to represent how virtual memory is created and used.

[4]

(b) A student is using software to create 3D models. This process often requires the use of virtual memory.

Explain why virtual memory is needed for this process.

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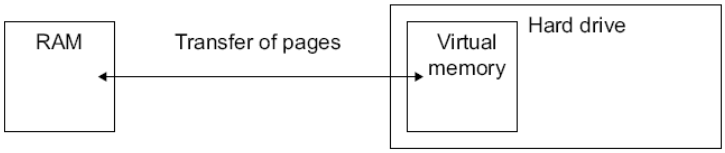
..... [3]

Answer:

8(a)	**One** mark for each part of the diagram: The diagram shows: • a hard drive • the hard drive portioned in some way to create virtual memory • RAM • an indication of pages transferred between the RAM and the virtual memory. For example:  	**4**
8(b)	• to extend the RAM capacity • … to stop the 3D modelling software from freezing/crashing when the physical RAM is full • to allow the computer to process the large amount of data required for 3D modelling.	**3**

3.3.5 Cloud Storage:

NOTE: Cloud Storage is a newly added topic in the Computer Science (2210) syllabus for the session 2023–2025.

- The cloud is an online data storage where the data is stored on offsite/remote servers.
- It can be accessed remotely, and physical servers & storage are needed to store data in cloud storage.
- The same data is stored on more than one server in many locations.
- The servers are owned and managed by a hosting company and may include hundreds of servers in many locations.
- It uses data redundancy.

Data Redundancy: When the same piece of data is stored in more than one place.

Cloud Computing:

- It allows the user to access/run and manage data, files, service, or software/application etc. on a remote server over the Internet.

NOTE: The term 'cloud storage' means storing the data on remote servers to make it accessible over the Internet whereas the term 'cloud computing' means accessing data, files, software etc. over the Internet.

Examples of cloud storage: Dropbox, iCloud, Google Drive, Microsoft One Drive etc.

Examples of cloud computing: Google Docs, Microsoft 365 etc.

Public & Private Cloud Computing:

There are three common systems:

1) Public Cloud:

- It is the computing services offered by a 3rd party provider over the public Internet.
- It is open/available to anyone with the appropriate equipment/software/credentials.

2) Private Cloud:

- It is the computing services offered either over the Internet or a private internal network.
- It is only available to selected users and not the general public.
- It is a dedicated/bespoke system which is only accessible for/from the organization.

3) Hybrid Cloud:

- It is a combination of both public and private clouds.
- It stores some data in the private cloud and the less sensitive/less commercial data is accessed from a public cloud storage provider.

The user can save their data in the cloud instead of saving data on a local hard disk or other storage device so it can be accessed remotely.

3.3.6 Advantages & Disadvantages of Cloud Storage:

Advantages of Cloud Storage compared with Physical Storage Devices (Storing Locally):

1. The cloud has greater storage capacity than other methods.
2. The data could be sent directly to the cloud from any device.
3. The data can be accessed from any device and anywhere in the world.
4. The backups are automatic.
5. It is easier to add storage capacity (extra storage).
6. It has a lower capital outlay.
7. There is no need for user to carry an external storage device with them and cloud storage cannot be misplaced or damaged.
8. The owner would only pay for the storage they used.
9. The cloud is more robust.
10. The cloud is more secure as it is password protected.

Disadvantages of Cloud Storage compared with Physical Storage Devices (Storing Locally):

1. The data cannot be saved, accessed, or downloaded if there is no Internet access.
2. It may have security issues as personal data might be stored.
3. The owner of the data loses control over it.
4. It requires a high bandwidth to download/upload data from/to the cloud and so it can be expensive to pay the user internet service provider (ISP).
5. The cost of storage in the cloud may be restrictive in the long term as it may require costs for extra storage/large storage capacity.
6. It is easier to hack the cloud as the data is stored for a long period of time on many servers.
7. The potential failure of the cloud storage company poses a risk of loss of all back-up data.

Benefits of using an SSD rather than the Cloud to store data:

1. The SSD is stored within the computer therefore the user has control over the data.
2. The SSD is a physical storage device in the computer therefore is present at all times.
3. Once the SSD is purchased there are no more costs for storage.
4. The SSD does not necessarily need internet access when saving data.
5. It may take less time to transfer data to the SSD than cloud.
6. It may be more difficult to find the data on the cloud than with SSD.
7. It is easier to hack the cloud as the data is stored for a long period of time on many servers.

Drawbacks of using an SSD rather than the Cloud to store data:

1. The data can be accessed from any device and anywhere in the world on cloud.
2. The extra storage can be set automatically on the cloud whereas SSD is a fixed size storage.
3. The SSD device can easily be misplaced or damaged.
4. The backups are automatic on the cloud whereas SSD may require the user to set up the back-up.

Advantages & Disadvantages of Cloud Computing:

Advantages of using Cloud Computing:

1. It can be accessed from anywhere with Internet access.
2. The user does not need to install security and it provides better security.
3. The user does not need to perform backups.
4. The user does not need to buy specific software or hardware.
5. It allows documents to be easily shared.
6. It allows multiple people to work on the same document.

Disadvantages of using Cloud Computing:

1. It cannot be accessed if there is no Internet access.
2. It cannot be accessed if the server goes down.
3. It is reliant on someone else to backup.
4. It is reliant on someone else for security and might have poorer security.

Exam Style Questions:

Question 1:

(a) Define cloud computing.

.....

..... [1]

(b) State what is meant by a public cloud and a private cloud.

Public cloud .....

.....

Private cloud .....

.....

[2]

(c) Give **two** benefits and **one** drawback of using cloud computing.

Benefit 1 .....

.....

Benefit 2 .....

.....

Drawback .....

.....

[3]

Answer:

Question	Answer	Marks
8(a)	Accessing a service/files/software on a remote **server**	1
8(b)	**1 mark** each from: Public e.g. • Computing services offered by 3rd party provider over the public Internet • Public is open/available to anyone with the appropriate equipment/software/credentials Private e.g. • Computing services offered either over the Internet or a private internal network • Only available to select users not the general public • Private is a dedicated/bespoke system only accessible for/from the organisation	2
8(c)	**1 mark** for each benefit to **max 2** e.g. • Can be accessed anywhere **with Internet access** • Do not need to install security // security might be better • Do not need to perform backups • Do not need to buy specific software/hardware • Can easily share documents • Can have multiple people working on the same document **1 mark** for drawback e.g. • You cannot access it if no internet access • Reliant on someone else to backup • Reliant on someone else for security // **can have** poorer security • Cannot access if server goes down	3

Question 2:

A music festival is attended by very large crowds each year. Large amounts of data are collected by the organisers, who are planning to store it in the cloud.

(a) Give **four** advantages of storing the data in the cloud rather than using other storage methods.

1 .....

.....

2 .....

.....

3 .....

.....

4 .....

.....

[4]

(b) The organisers are worried that there are drawbacks in storing data in the cloud.

Describe **three** disadvantages of using the cloud to store data rather than other storage methods.

.....

.....

.....

.....

.....

..... [3]

Answer:

Question	Answer	Marks
5(a)	**Four** from: The cloud has greater storage capacity than other methods The data could be sent directly to the cloud from any device on the festival ground Access the data from any device Easier to add storage capacity Lower capital outlay The organisers would only pay for the storage they used Data can be analysed more quickly	**4**
5(b)	**Three** from: More security issues as personal data is used The owner of the data loses control over it The cost of storing in the cloud may be restrictive in the long term The devices must be connected to the cloud at all times for ticket sales	**3**

Question 3:

Computer data can be stored on physical storage devices. Data can also be stored in the 'cloud'.

(a) Explain what is meant by the cloud, giving **two** advantages of storing data in the cloud compared with physical storage devices.

Explanation.....

.....

.....

.....

Advantage 1.....

.....

Advantage 2.....

.....

[4]

Answer:

Question	Answer	Marks
10(a)	**Two** from: Data is stored on offsite servers Many servers in many locations Data is stored on more than one server Uses data redundancy Cloud is an online service/data storage **Two** from: The cloud has greater storage capacity than other methods The data could be sent directly to the cloud from any device Access the data from any device/anywhere Easier to add storage capacity Lower capital outlay The owner would only pay for the storage they used Backup up tends to be automatic Cloud is more robust Cloud is more secure as it is password protected	**4**

3.4 | Network Hardware

3.4.1 Network Interface Card (NIC):

NOTE: Network Interface Card (NIC) is a newly added topic in the Computer Science (2210) syllabus for the session 2023–2025.

- A computer needs a network interface card (NIC) to access a network.
- It is a hardware component that allows each individual device to connect to the network.
- It provides a MAC address to the device to uniquely identify it on the network.
- It provides a hardware interface/physical connection between the computer and network.

Wireless Network Interface Card (WNIC):

- It is a hardware component that allows each individual device to connect to a wireless network.
- It provides a MAC address to the device to uniquely identify it on the wireless network.

Functions of a Wireless Network Interface Card (WNIC):

- It provides an interface to the wireless network as an antenna.
- It receives analogue radio waves and converts them to binary.
- It checks incoming transmissions for correct MAC/IP address and ignores transmission not intended for it.
- It encrypts/encodes the data and decrypts/decodes the data.
- It takes binary input and converts it to analogue waves and sends those radio waves via the antenna.

Exam Style Questions:

Question 1:

(c) Explain how the following devices are used to support the university LAN.

(i) Router .....

.....

.....

..... [2]

(ii) Network Interface Card (NIC) .....

.....

.....

..... [2]

Answer:

2(c)(i)	**1 mark** per bullet point (**max 2**) • Allows (internal) connections between the university LANs • Allows external connection from the main LAN	**2**
2(c)(ii)	**1 mark** per bullet point (**max 2**) • Provides device with a MAC address • …to uniquely identify it on the network • Allows each individual device to connect to the network	**2**

Question 2:

A school is setting up a network within one of its buildings.

(c) The school has several laptops. Each laptop has a Wireless Network Interface Card (WNIC).

Describe the functions of a Wireless Network Interface Card.

.....

.....

.....

.....

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.....

.....

..... [4]

Answer:

8(c)	**1 mark** per bullet point to **max 4** • Provide interface to wireless network • … as an antenna • Receives analogue radio waves • … convert them to digital / binary • Checks incoming transmissions for correct MAC / IP address • … ignore transmissions not intended for it • Encrypts / encodes the data • Decrypts / decodes the data • Takes digital/binary input and converts to analogue waves • … sends the radio waves via the antenna	**4**

Question 3:

(a) The following incomplete table contains four network devices and their descriptions.

Complete the table by writing the missing devices and missing descriptions.

Device	Description
.....	Receives and sends data between two networks operating on the same protocol
Wireless Network Interface Card (WNIC)	....

Answer:

Question	Answer	Marks
9(a)	**1 mark** for each completed name or description	**4**

Device	Description
Router	Receives and sends data between two networks operating on the same protocol
Wireless Network Interface Card (WNIC)	Hardware component that allows a device to connect to a wireless network // Provides a MAC address to the device to identify it on the wireless network

3.4.2 Media Access Control (MAC) Address:

It is made up of 48 bits and represented using six groups of hexadecimal digits:

NN–NN–NN–DD–DD–DD **OR** NN:NN:NN:DD:DD:DD
(manufacturer ID) **(device serial number)**

Example of MAC address:

00:15:E9:2B:99:3C

What is meant by MAC address?

- It is media access control (address).
- A network interface card (NIC) is given a MAC address at the point of manufacture.
- It is a unique address that identifies a device connected to the internet.
- It is a static address which means it does not change.
- The first part of the address is manufacturer ID, and second part is the serial number of device.
- It is set/assigned by the manufacturer.

Structure of a MAC address:

- It uses hexadecimal values.
- It is normally 48 bits in length.
- The first part of the address is the manufacturer ID.
- The second part is the serial number.

Purpose of MAC address OR why MAC addresses are used:

- It allows all devices to be uniquely identified.

NOTE: The hexadecimal code in a MAC address is the NN's and DD's.

What the hexadecimal code in a MAC address represents:

- It is a unique physical address/number associated with network interface card in a device.
- It is usually made up of 48 bits which are shown as six groups of hexadecimal digits.
- The first part or 6 digits (NN-NN-NN) is the manufacturer ID of device.
- The second part or last 6 digits (DD-DD-DD) is the serial number of device.

Features of MAC address:

- The first part is the manufacturer ID.
- The second part is the serial number.
- Each part has 3 pairs of number OR each part has 6 numbers between 00 and FF separated by ":" (colons)
- It is 48 bits long.
- It is represented using hexadecimal.

Exam Style Questions:

Question 1:

A school network has several computers.

Each computer in the network has a media access control (MAC) address.

Hexadecimal is used for MAC addresses.

Part of a MAC address is given.

97–5C–E1

(b) Describe what is meant by a MAC address.

.....

.....

.....

.....

.....

.....

.....

..... [4]

Answer:

1(b)	Any **four** from: • used to identify a device • it is a unique (address) • it is a static address // it does not change • it is set by the manufacturer • the first part is the manufacturer ID / number / identifies the manufacturer • the second part is the serial number / ID.	**4**

Question 2:

Greta has a computer that she uses for schoolwork and leisure.

(a) The computer has the Media Access Control (MAC) address:

00:A0:C9:14:C8:29

(i) Tick (✓) to show whether the MAC address is initially assigned to the computer by the network, the manufacturer or the user.

	Tick (✓)
Network	☐
Manufacturer	☐
User	☐

[1]

Answer:

Question	Answer	Marks
1(a)(i)	– manufacturer	1

Question 3:

(c) All smartphones have a MAC address.

(i) State what is meant by the term MAC address.

.....

..... [1]

(ii) Describe the structure of a MAC address.

.....

.....

.....

.....

.....

..... [3]

Answer:

1(c)(i)	Any **one** from: – Media access control – Unique address given to each device	**1**
1(c)(ii)	Any **three** from: – Uses hexadecimal values – Normally 48/64 bits in length (accept any other reasonable value) – First half is manufacturer number/code/ID – Second half is serial number	**3**

3.4.3 Internet Protocol (IP) Address:

- It is a unique address allocated to each device on the internet by the network/ISP (internet service providers).
- It is used to identify the location of a device on the Internet/network.
- IP addresses can be IPv4 (32 bit) or IPv6 (128 bit).
- It can be static meaning it doesn't change each time a device is connected to the Internet.
- It can be dynamic meaning that it can change each time a device is connected to the Internet.
- It can be used in place of URL.

Example: 198.167.214.1
192.168.0.255

Purpose of IP address:

- It is an address given to each device that is unique within the network.
- It is used to locate a device on a network.
- It allows a device/gateway to send data to the correct destination i.e., specific device/gateway.

Characteristics of an IP address:

- It consists of values between 0–255 / 0–FFFF.
- The values are separated by full stops/colons.
- It is a unique address.
- It can be static or dynamic.
- It can be public or private.
- It can be IPv4 having four groups of digits.
- It can be IPv6 having eight groups of digits.
- The consecutive groups of 0000 can be replaced with double colons (::) in IPv6.

NOTE: Public & Private IP address, Static & Dynamic IP address, IPv4 & IPv6 address are newly added topics in the Computer Science (2210) syllabus for the session 2023–2025.

Public & Private IP Address:

Public IP Address:

- It can be reached over the Internet.
- It is less secure than a private address.
- It is provided by the ISP (Internet Service Provider).
- It is unique to the Internet and cannot be duplicated in different networks.

Private IP Address:

- It can only be reached internally/through the LAN.
- The NAT (Network Address Translation) is necessary for a private IP address to access the Internet directly.
- It is more secure than a public address.
- It is assigned by the router of the network.
- It is unique within its network but can be duplicated in other/different discrete networks.

Static & Dynamic IP Address:

Static IP Address:

- In this type of address, when a computer/device disconnects and rejoins a network, the address does not change.
- This address is permanently assigned to a device by the internet service provider (ISP).

It is usually assigned to:

- remote servers which are hosting a website
- an online database
- a File Transfer Protocol (FTP) server.
  FTP servers are used when files need to be transferred to various computers throughout the network.

Dynamic IP Address:

- In this type of address, each time the computer/device rejoins a network, the address changes.
- This address is temporarily assigned by the network OS.
- It is automatically temporarily assigned using a Dynamic Host Configuration Protocol (DHCP) server.

Comparison of Dynamic & Static IP addressing:

A device using Dynamic IP addressing:

- When the device wants to download a webpage from a website, the DNS translates the required website URL into an IP address and sends it back to the device.
- A message is sent by the device to the IP address of the website server (given by the DNS) requesting a webpage. The website server sends the required webpage back to the device.

A device using Static IP addressing:

- The device can access the website resources directly.
- This gives the device a consistent location and also means less bandwidth is used reducing the network traffic (and takes less time to retrieve data).

Reasons for a web server using a Static instead of a Dynamic IP address:

- The static IP does not change whereas a dynamic IP address does change.
- In the static IP, the DNS does not need updating which might be delayed causing 'address not found' errors.
- The web server may be accessed directly using just the IP address as it is still held in cache memory.
- This gives a device consistent location and also means less bandwidth is used reducing the network traffic (and takes less time to retrieve data).

The following table compares Dynamic & Static IP addresses:

Dynamic IP addresses	Static IP addresses
It provides greater privacy since it changes each time a user logs on.	It allows each device to be fully traceable since it does not change.
It can be an issue when using, for example, VoIP since this type of addressing is less reliable as it can disconnect and change the IP address causing the VoIP connection to fail.	It allows for faster upload & download speeds.
	It is more expensive to maintain since the device must be constantly running so that information is always available.

VoIP: Voice over Internet Protocol (VoIP), is a technology that allows you to make voice calls using a broadband Internet connection instead of a regular (or analog) phone line.

IPv4 address:

Features of IPv4 address:

- It has 4 groups of numbers separated by full stops (.)
- Each group has values between 0–255
- It is 32 bits long (4 bytes).
- It is represented in denary.

Format of IPv4 address:

- It has 4 groups of denary or hexadecimal integers separated by full stops (.)
- Each group has numbers between 0–255 in Denary and 0–FF in Hexadecimal.
- Each group is stored in 8 bits (1 byte) and the whole is stored in 32 bits (4 bytes).

Examples of valid IPv4 addresses:

1. 192.168.0.1
2. 128.12.2.30
3. 254.25.28.77

IPv6 address:

Features of IPv6 address:

- It has 8 groups of numbers separated by colons (:)
- Each group has values between 0–FFFF.
- It is 128 bits long (16 bytes).
- The consecutive groups of 0000 can be replaced with double colons (::)
- It is represented in hexadecimal.

Format of IPv6 address:

- It has 8 groups of hexadecimal digits separated by colons (:)
- Each group has numbers between 0–FFFF.
- Each number is 4 hexadecimal digits.
- Each group is stored in 16 bits (2 bytes) and the whole is stored in 128 bits (16 bytes).
- The first instance of multiple groups of zero can be replaced by a double colon (::)

NOTE: The range of numbers of 0–FFFF in Hexadecimal is equivalent to 0–65535 in Denary.

Examples of valid IPv6 addresses:

1. 12F3:2356:AB12:2015:0000:0000:1234:5123
2. A8FB:7A88:F FF0:0FFF:3D21:2085:66FB:F0FA
3. 12F3:2356:AB12:2015:0000:0000:1234:5123

Problems with IPv4 addressing:

- The use of IPv4 is only 32-bit addresses which considerably reduces potential number of devices and routers used on the internet at any one time.
- A newer version called IPv6 is now used which is 128-bit addresses and so considerably increases number of devices and routers used on the internet at any one time.

Why is there a need for IPv6 addressing:

- The number of IP addresses needed will exceed the number available using IPv4.

Advantages of IPv6 compared to IPv4:

1. It removes the risk of IP address collisions.
2. It has built-in authentication checks.
3. It allows for more efficient packet routes.

Main Differences between formats of IPv4 address & IPv6 address:

1. The IPv4 has 4 groups of digits whereas IPv6 has 8 groups of digits.
2. In IPv4, each group is from 0–255 whereas in IPv6, each group is from 0–65535.
3. The IPv4 uses a full-stop between each group whereas IPv6 uses a colon between each group.
4. The IPv4 is 32-bit (4 bytes) whereas IPv6 is 128-bit (16 bytes).

The following table compares IPv4 & IPv6 addresses:

Statement	IPv4 (✓)	IPv6 (✓)
Can use hexadecimal notation	✓	✓
Each group of digits is a number between 0 and 65535		✓
Consists of four groups of digits	✓	
Uses double colons (::)		✓
The total length of the address is 32 bits	✓	

The following True & False statements are regarding IP addresses:

Statement	True (✓)	False (✓)
The IP address consists of any number of digits separated by single dots (.)		✓
Each number in an IP address can range from 0 to 255	✓	
IP addresses are used to ensure that messages and data reach their correct destinations	✓	
Public IP addresses are considered to be more secure than private IP addresses		✓

A few examples are given below which will help you better understand the formats of IPv4 & IPv6 addresses. The examples will show whether the given IP addresses are valid or invalid and the justification needed for proving that according to the examination question.

Example 1:

The following table shows four IPv6 addresses. State if each address is valid or invalid.

IP Address	Valid or invalid
21E5:69AA:FFFF:E100:B691:1285:F56E	Valid
::255.255.255.255	Valid
59FB::1005:CC57:6571	Valid
56FE::2159:5BBC::6594	Invalid

Example 2:

The following table shows four IPv4 addresses. Indicate for each IP address whether it is valid or invalid and give a reason.

IP Address	Valid or invalid	Reason
3A.21.2H.1	Invalid	H is not a valid hexadecimal digit
299.53.2.2	Invalid	299 is out of range as largest individual number is 255
192.2.1.0	Valid	It consists of four numbers in the range 0–255 separated by full stops
12.258.3	Invalid	258 is out of range as largest individual number is 255 4 numbers are needed and so one group of numbers is missing

Example 3:

The following table shows four possible IP addresses. Indicate for each IP address whether it is valid or invalid and give a reason.

IP Address	Denary/ Hexadecimal	Valid or Invalid	Reason
3.2A.6AA.BBBB	Hexadecimal	Invalid	This is more than 32 bits 6AA/BBBB in Hex is bigger than FF/255 in denary 6AA/BBBB uses more than 8 bits (1 byte)
2.0.255.1	Denary	Valid	There are 4 bytes, each 255 or below All the values are in the range 0–255
6.0.257.6	Denary	Invalid	257 is above 255 // third group is above 255
0A.78.F4.J8	Hexadecimal	Invalid	J is not a valid hexadecimal digit

Example 4:

The following is an IPv6 address:

15EF:5L63::2014:BB::60AA

Why is this IP address invalid?

- L is not a valid hexadecimal number.
- There are two double colons whereas in IPv6 only one double colon is allowed.

Example 5:

The following is an IPv6 address:

C100:2235::1000:25AA:AA50

Why this IPv6 address would be an invalid IPv4 address.

- There are too many digits per group.
- There are too many groups of digits.
- The address is more than 32 bits (4 bytes).
- The colons are used as separators.

Exam Style Questions:

Question 1:

(a) A web server has an internet protocol (IP) address.

(i) Give **three** characteristics of an IP address.

1 .....

2 .....

3 ..... [3]

(ii) Identify the network component that uses the IP address to send data only to its correct destination.

..... [1]

Answer:

Question	Answer	Marks
3(a)(i)	Any **three** from: • consists of values between 0–255 / 0–FFF • values are separated by full stops / colons • it is a unique address • can be static or dynamic • can be public or private • can be IPv4 / have four groups of digits • can be IPv6 / have eight groups of digits • in IPv6 :: can replace groups of zeros.	3
3(a)(ii)	router	1

Question 2:

(b) Describe what is meant by an Internet Protocol (IP) address.

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.....[4]

Answer:

3(b)	**Four** from: – IP address is used to identify a device (on the Internet / network) – IP address is allocated by the network/ ISP – Can be used in place of URL – IP addresses can be IPv4 or IPv6 – IP address can be static … – … meaning it doesn't change each time it is connected to the Internet – IP address can be dynamic …. – … meaning that it can change each time a device is connected to the Internet – Any valid example (e.g. xxx.xxx.xxx.xxx or xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx)	**4**

Question 3:

(b) IP addresses can be static or dynamic.

Explain the reasons for the web server using a static instead of a dynamic IP address.

.....

.....

.....

.....

.....

..... [3]

Answer:

Question	Answer	Marks
7(b)	**1 mark** per bullet point to **max 3** • Static IP does not change whereas a dynamic IP address does change • … the DNS does not need updating • … which might be delayed causing 'address not found' errors • The webserver may be accessed directly using just the IP address // the IP address is still held in cache memory	**3**

Question 4:

Yvette runs a company that books walking holidays for groups of people. She has a website that customers use to book the holidays.

(a) The website has a URL and an IPv6 address.

Describe, using an example, the format of an IPv6 address.

.....

.....

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.....

.....

..... [4]

(b) An IP address can be static or dynamic. Describe static and dynamic IP addresses.

Static .....

.....

.....

.....

Dynamic .....

.....

.....

.....

[4]

Answer:

Question	Answer	Marks	Guidance
2(a)	1 mark per bullet • A set of 8 numbers • Each number is 4 hexadecimal digits • Separated by colons: • Valid example e.g. 12F3:2356:AB12:2015:0000:0000:1234:5123	4	**Allow valid examples such as** 12F3:2356:AB12:2015:: where :: designates 0 for remaining spaces
2(b)	1 mark per bullet to max 2 for static, max for dynamic Static: • When a computer disconnects and rejoins a network • ... the address does not change • Address is assigned by the server/ISP Dynamic: • Each time the computer rejoins a network • ... the address changes • address is assigned by the network OS	4	**Accept valid alternatives with the same meaning**

Question 5:

(d) A device needs an IP address to connect to the Internet. IPv4 is the more common type of IP address.

Describe, using an example, the format of an IPv4 address.

.....

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.....

.....[3]

Answer:

(d) **Two marks** for description, **one mark** for correct example. **[3]**

- Four numbers separated with '.'
- Each number is between 0 and 255 / 00 and FF in Hex / stored in one byte.
- 32 bits long
- Correct example

Question 6:

A laptop on a home network connects to the Internet through a router.

(a) The laptop has an IP address.

(i) Give the reasons why the laptop has an IP address.

.....

.....

.....

..... [2]

(iii) The router has an IPv4 address.

Give **three** differences between the format of an IPv4 address and an IPv6 address.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

Answer:

Question	Answer	Marks
4(a)(i)	**1 mark** per bullet point • To identify the laptop on the home network • To allow the router to send data to the laptop from the Internet / another device on the home network	**2**
4(a)(iii)	**1 mark** per bullet point to **max 3** • IPv4 has 4 groups of digits, IPv6 has 8 groups of digits • In IPv4 each group is from 0-255, in IPv6 each group is from 0-65535 • IPv4 uses a full-stop between each group, IPv6 uses a colon between each group • IPv4 is 32-bit, IPv6 is 128-bit // IPv4 uses 4 bytes, IPv6 uses 16 bytes	**3**

Question 7:

(b) The web page `9608.html` is accessed from the URL:

`https://www.cambridgeinternational.org/9608.html`

An employee of the company states, "A Domain Name and an IP address are exactly the same thing".

State whether this statement is true or false **and** justify your choice.

.....

.....

.....

.....

.....

.....

..... [3]

Answer:

6(b)	**1 mark** per bullet point for justification to **max 3** • IP address is (physical) address of the server • A domain name is a memorable form for an IP address • `cambridgeinternational.org` is the domain name • An example of an IP address is 198.162.2.1 • Each domain name is linked to an IP address • A Domain Name Server/Service (DNS) is used to translate a domain name into its corresponding IP address • Domain name does not change but IP address could change (dynamic) • IP address can be used to address server directly, • The domain name needs translation before server can be assessed	**3**

IP address & MAC address:

The IP address gives the location of a device on the internet. It is an address given to each device on the internet by the network/ISP.

The MAC address identifies the device connected to the internet. It is a unique address given to a device on a network by the manufacturer.

Main Similarities between IP Address & MAC Address:

1. Both addresses can be used to identify a computer/device.
2. Both addresses are unique.
3. Both addressed can be represented as hexadecimal.
4. Both addresses do not change if the IP address is static.

Main Differences between IP Address & MAC Address:

1. An IP address is assigned by the network/ISP whereas a MAC address is assigned by the manufacturer.
2. An IP address can be changed if dynamic, whereas a MAC address cannot be changed.
3. The IP address has 4/8 groups of values whereas MAC address has 6 groups/pairs of values.
4. The IP address is 32-bit/128-bit whereas MAC address is 48-bit.
5. The IP address does not contain serial number or manufacturer ID whereas MAC address does.
6. The IPv4 address is denary and MAC address is hexadecimal.

The following True & False statements compare IP addresses & MAC addresses:

Statement	True (✓)	False (✓)
A MAC address is unique to a computer on a network	✓	
Once an IP address has been set it cannot be changed		✓
A MAC address is made up of the computer's serial number and the IP address		✓
If a computer does not have an IP address, it cannot communicate with another device using the Internet	✓	

Exam Style Questions:

Question 1:

(b) Tammy connects the computer to her home network. The computer has a MAC address and an IP address.

A paragraph is given about MAC addresses and IP addresses.

Complete the paragraph using the list of terms given. Not all terms need to be used.

- compiled
- computer
- control
- dynamic
- identify
- packet
- principal
- protocol
- similar
- unique

A MAC address is a media access ..... address.

A network device has a ..... MAC address that can help ..... the device in the network. An IP address is an Internet ..... address. An IP address can be static or ..... .

[5]

Answer:

5(b)	**One** mark for each correct term in the correct place: – Control – Unique – Identify – Protocol – Dynamic	5

Question 2:

Benedict has a computer that is assigned an Internet Protocol (IP) address. The IP address is:

198.167.214.0

The IP address is represented as denary values.

(b) Benedict's computer is also assigned a Media Access Control (MAC) address.

(i) Identify **one** similarity between an IP address and a MAC address.

.....

..... [1]

(ii) Identify **two** differences between an IP address and a MAC address.

Difference 1 .....

.....

.....

Difference 2 .....

.....

.....

[2]

Answer:

1(b)(i)	Any **one** from: – Both addresses can be used to identify a computer/device – Both are unique – Both can be represented as hexadecimal – Both addresses do not change if IP address is static	**1**
1(b)(ii)	Any **two** from: – An IP address is assigned by the network/router/ISP, A MAC address is assigned by the manufacturer – An IP address can be changed (if dynamic), MAC address cannot be changed – IP address has 4/8 groups of values, MAC address has 6 groups/pairs of values – IP address is 32-bit/128-bit, MAC address is 48-bit – IP address does not contain serial number/manufacturer number, MAC address does – IP(v4) address is denary and MAC address is hexadecimal	**2**

Question 3:

(b) Gurdeep sets up a web server to host her website. She reads about an Internet Protocol (IP) address, a Media Access Control (MAC) address and a Uniform Resource Locator (URL).

Draw a line to connect each term to the correct example.

Term	Example
IP address	192.168.0.255
MAC address	https://www.cambridgeinternational.org
URL	00:15:E9:2B:99:3C

[2]

Answer:

Question	Answer	Marks
2(b)	1 mark for 1 line, 2 marks for 3 lines **Term** — **Details** IP address — 192.168.0.255 MAC address — https://www.cambridgeinternational.org URL — 00:15:E9:2B:99:3C	**2**

3.4.4 Router:

NOTE: Router is a newly added topic in the Computer Science (2210) syllabus for the session 2023–2025.

- It sends data to a specific destination on a network.
- It can assign IP addresses.
- It can connect a local area network (LAN) to the internet.
- It receives and sends data between two networks operating on the same protocol.
- It receives packets from a network and forwards packets onto a network.
- It stores the IP and/or MAC address of all devices attached to it.
- It may contain a firewall/proxy server.
- It can be a wired or wireless device.

Role of Router in sending data to a specific destination on a network:

- It sends and forwards data packets to their correct destination IP/MAC address.
- It contains a routing table which holds the private IP/MAC addresses of the devices.
- It uses the routing table to determine the most efficient path for sending data packet to its correct destination.
- If the correct IP/MAC address is not found, it keeps passing on the packets on the same network until the correct address and device is found.

Hardware components of Router:

- A router would typically have an internet cable plugged into it and several cables connecting to computers and other devices on the LAN.

How a Router can support a universities LAN:

- It allows internal connections between the university LANs.
- It allows external connection from the main LAN.

Benefits of Wired Router:

1. It provides a faster connection (higher bandwidth) that is suitable for downloading large files and it has less waiting time/less latency.
2. It provides a more reliable/stable connection, and it is less susceptible to issues with distance/walls/interference.
3. It is more secure.

Benefits of Wireless Router:

1. It allows freedom of movement, and the user can move between different rooms with a device and still receive/transmit data.
2. It is easily expanded if other users want to access the same network.
3. It requires less cabling and expertise, making the initial setup less expensive.

The following table shows whether the given tasks are performed by the router or not:

Statement	Performed by router	Not performed by router
Receives packets from a device	✓	
Finds the IP address of a Uniform Resource Locator (URL)		✓
Directs each packet to all devices attached to it		✓
Stores the IP and/or MAC address of all devices attached to it	✓	

Exam Style Questions:

Question 1:

(c) Melinda connects her laptop to the internet through her router.

(i) Tick (✓) **one** box in each row to identify whether the task is performed by the router or not.

Task	Performed by router	Not performed by router
Receives packets from devices		
Finds the IP address of a Uniform Resource Locator (URL)		
Directs each packet to all devices attached to it		
Stores the IP and/or MAC address of all devices attached to it		

[2]

(ii) Melinda mainly uses the internet to watch films and play computer games.

Tick (✓) **one** box to identify whether Melinda should connect to the router using a wired or wireless network **and** justify your choice.

Wired	
Wireless	

Justification .....

.....

.....

.....

.....

..... [3]

Answer:

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>4(c)(i)</td><td>1 mark for first 2 ticks, 1 mark for last 2 (shaded)

<table>
<tr><th>Task</th><th>Performed by router</th><th>Not performed by router</th></tr>
<tr><td>Receives packets from devices</td><td>✓</td><td></td></tr>
<tr><td>Finds the IP address of a Uniform Resource Locator (URL)</td><td></td><td>✓</td></tr>
<tr><td>Directs each packet to all devices attached to it</td><td></td><td>✓</td></tr>
<tr><td>Stores the IP and/or MAC address of all devices attached to it</td><td>✓</td><td></td></tr>
</table></td><td>2</td></tr>
<tr><td>4(c)(ii)</td><td>1 mark per bullet point for justification up to max 3

No mark for identification of wired/wireless

Wired
• Faster connection // higher bandwidth
• …. needed as she is downloading/streaming large files
• … less time waiting / less latency / fewer delays
• More reliable / stable connection
• … is less susceptible to issues with distance/walls/interference
• More secure

Wireless
• Freedom of movement
• … can move between different rooms with a mobile device and still receive/transmit data
• … no need of a physical connection
• Easily expanded if friends want to access the same network
• Less cabling / expertise is needed
• ... making the initial setup less expensive</td><td>3</td></tr>
</table>