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UPDATED TO 2023-2025 SYLLABUS

CAIE IGCSE

COMPUTER SCIENCE

SUMMARIZED NOTES ON THE THEORY SYLLABUS

Prepared for Nyasha for personal use only.

1. Data Representation

1.1. Number Systems

Binary System

- Base 2 number system
- It has two possible values only (0 and 1)
- 0 represents OFF, and 1 represents ON
- A point to be noted is that the most left bit is called the MSB (Most Significant Bit)

Denary System

- Base 10 number system
- Has values from 0 to 9

Hexadecimal (aka Hex)

- Base 16 number system
- Have values from 0 to 9 followed by A to F
- A represents 10, B represents 11 and so on until 15, which is F

Binary Value	Hexadecimal Value	Denary Value
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	A	10
1011	B	11
1100	C	12
1101	D	13
1110	E	14
1111	F	15

1.2. Number Conversions

Converting Binary to Denary

- Place the binary value in columns of 2 raised to the power of the number of values from the right starting from 0. e.g. For binary value 11101110, place it in a table like this:

128	64	32	16	8	4	2	1
1	1	1	0	1	1	1	0

- As can be seen it starts from 1 and then goes to 128 from left to right
- Now values with 1 are to be added together, giving the final answer, as for the example, it is 128 + 64 + 32 + 8 + 4 + 2 = 238

Converting Denary to Binary

- Take the value and successively divide it by 2, creating a table like follows:

2	142		
2	71	Remainder:	0
2	35	Remainder:	1
2	17	Remainder:	1
2	8	Remainder:	1
2	4	Remainder:	0
2	2	Remainder:	0
2	1	Remainder:	0
	0	Remainder:	1

- Note that when the value itself is not divisible by 2, it is divided by the previous value of the current number and 1 is added to the remainder column for that specific number
- When you reach 0, the remainder has to be read from bottom to top giving us the binary value (as in this case, it is 1 0 0 0 1 1 1 0)

Converting Hexadecimal to Binary

- Separate each value from each other and convert them to denary
- Each separate denary value to be converted to binary
- All the binary values to be merged together
  e.g.

```
Hexadecimal : 2    1    F    D
Denary      : 2    1    15   13
Binary      : 0010 0001 1111 1101

Final Answer: 0010000111111101
```

Converting Binary to Hexadecimal

- Divide the binary value into groups of 4 starting from the right. If at the end, the last division is less than 4, add 0s until it reaches 4
- For each group, find the denary value as shown above, and then convert each denary value to its corresponding hexadecimal value (if less than 10, then itself, else, 10 is A, 11 is B, 12 is C, 13 is D, 14 is E and 15 is F).
- After conversion, just put all the hexadecimal values in order to get the final answer

```
Given Value : 1 0 0 0 0 1 1 1 1 1 1 1 0 1
When grouped: 10 0001 1111 1101

After 2 values added to left: 0010 0001 1111 1101

After Conversion to Denary: 2 1 15 13

Denary to Hexadecimal: 21FD
```

Converting Hexadecimal to Denary

- Convert the value to binary as shown above, and then convert the final answer to denary

Converting Denary to Hexadecimal

- Convert the value to binary, and then convert it to hexadecimal as explained above

1.3. Binary Calculations

- Binary values are not added the way denary values are added, as when adding 1 and 1, we cannot write two because it doesn't exist in binary.

Points to Note:

- 0 + 0 = 0
- 1 + 0 / 0 + 1 = 1
- 1 + 1 = 0 (1 carry)
- 1 + 1 + 1 = 1 (1 carry)

Overflow

- When adding two values, if the solution exceeds the limit of given values, e.g., the solution has 9 bits, but the question had 8 bits per value, the 9th bit (most left bit) is called overflow.
- This indicates that the memory doesn't have enough space to store the answer to the addition done in the previous part.

Steps to add Two Values (With Example)

- The values we will add are 1 1 0 1 1 1 0 and 1 1 0 1 1 1 1 0
    1. Convert both the bytes into 8 bits (add zero to the left-hand side to match them).
       e.g., 1 1 0 1 1 1 0 would become 0 1 1 0 1 1 1 0
    2. Add the values as follows with the points given above

Carry	1	1	1	1	1	1	1		
Byte 1		0	1	1	0	1	1	1	0
Byte 2		1	1	0	1	1	1	1	0
	OVERFLOW								
Solution	1	0	1	0	0	1	1	0	0

Note: We move from RHS to LHS, and when adding values, we use the rules given above. If the bit crosses the limit (overflows), we put the value in brackets, denoting it is overflow.

```
iii. The solution would now be  (1) 0 1 0 0 1 1 0 0
```

Logical Shifts

- The logical shift means moving a binary value to the left or the right
- When doing a logical shift, keep in mind that the bit being emptied is going to become 0

Explanation with Example

- **Shifting 10101010 - 1 place left:**
    1. The furthest bit in the direction to be logically shifted is removed (in this case, one at the LHS is removed) - ==(if it were two places, 2 bits would have been removed)==
    2. Every bit is moved in given places to the given direction (every bit is moved one place to the left in this case, and the leftover bit in the right is marked 0, so **10101010** would become **01010100**)

Two's Complement (Binary Numbers)

- Two's complement is a method used to represent negative values in binary. Here, the MSB (Most Significant Bit) is replaced from 128 to -128; thus, the range of values in a two's complement byte is -128 to 127

Converting Binary Values to Two's Complement

- Firstly, write the binary value and locate the first one from the right; e.g., 1101100 would have the first one at the third position from the right.
- Now, switch every value to the left of the first one located above (not switching the one), e.g., the value in our example becomes 0010100, which is the two's complement of itself.

Converting negative values to two complement

- Find the binary equivalent of the value ignoring the - sign
- Convert the binary value to two's complement
- Make the MSB 1, if not already

Converting Two's Complement Value to Denary:

- We do it the same way as a normal value is converted from binary to denary; we only replace 128 with -12,8 e.g., for 1011101,0 we do the:

-128	64	32	16	8	4	2	1
1	0	1	1	1	0	1	0

-128 + 32 + 16 + 8 + 2 = -70

1.4. Use of the Hexadecimal System

Examples:

- Defining colours in Hypertext Markup Language (HTML)
- Media Access Control (MAC) addresses (a number that uniquely identifies a device on a network)
- Assembly languages and machine code
- Memory Dumps
- Debugging (method to find errors in a program)
- Display error codes (numbers refer to the memory location of the error)
- IP (Internet Protocol) addresses

Memory Dumps

- Hexadecimal is used when developing new software or when trying to trace errors.
- Memory dump is when the memory contents are output to a printer or monitor.

Assembly code and machine code (low-level languages)

- Computer memory is machine code/ assembly code
- Using hexadecimal makes writing code easier, faster, and less error-prone than binary.
- Using machine code (binary) takes a long time to key in values and is prone to errors.

1.5. Text, Sound and Images

ASCII

- The standard ASCII code character set consists of 7-bit code that represents the letters, numbers and characters found on a standard keyboard, together with 32 control codes
- Uppercase and lowercase characters have different ASCII values
- Every subsequent value in ASCII is the previous value + 1. e.g. “a” is 97 in ASCII, “b” will be 98 (which is 97 + 1)
- Important ASCII values (in denary) to remember are as follows:

- ☐ 0 is at 48
- ☐ A is at 65
- ☐ a is at 97

- ASCII uses one byte to store the value
- When the ASCII value of a character is converted to binary, it can be seen that the sixth-bit changes from 1 to 0 when going from lowercase to uppercase of a character, and the rest remains the same. e.g.

'a'	1	1	0	0	0	0	1	hex 61 (lower case)
'A'	1	0	0	0	0	0	1	hex 41 (upper case)

Unicode

- ASCII does not contain all of the international languages thus, Unicode is used to solve this problem
- The first 128 values are the same as ASCII.
- Unicode supports up to four bytes per character, storing multiple languages and more data.
- **To represent text in binary, a computer uses a character set, a collection of characters and the corresponding binary codes that represent them.**

Sound

- Sound is analogue, and for it to be converted to digital form, it is sampled
- The sound waves are sampled at regular time intervals where the amplitude is measured. However, it cannot be measured precisely, so approximate values are stored

How is Sound Recorded

- The amplitude of the sound wave is first determined at set time intervals
- The value is converted to digital form
- Each sample of the sound wave is then encoded as a series of binary digits
- A series of readings gives an approximate representation of the sound wave

Sampling Resolution:

- The number of bits per sample is known as the sampling resolution (aka bit depth)
- Increasing the sampling resolution increases the accuracy of the sampled sound as more detail is stored about the amplitude of the sound.
- Increasing the sampling resolution also increases the memory usage of the file as more bits are being used to store the data.

Sampling Rate

- The sampling rate is the number of sound samples taken per second, which is measured in Hertz (Hz)
- A higher sampling rate would allow more accurate sound as fewer estimations will be done between samples.

Images

Bitmap Images

- Bitmap images are made up of pixels
- A bitmap image is stored in a computer as a series of binary numbers

Colour Depth

- The number of bits representing each colour is called the colour depth.
- An 8-bit colour depth means that each pixel can be one of 256 colours (because 2 to the power of 8 = 256)
- A 1-bit colour depth means each pixel can store one colour (because 2 to the power of 1 is 2) - (This is done as the bit can either be 0 or 1, with 0 being white and 1 being black)
- Increasing colour depth increases the size of the file when storing an image.

Image Resolution

- Image resolution refers to the number of pixels that make up an image; for example, an image could contain 4096 × 3072 pixels.
- Photographs with a lower resolution have less detail than those with a higher resolution.
- When a bitmap image is ' blurry ' or ' fizzy ' due to having a low amount of pixels in it or when zoomed, it is known as being **pixelated.**
- High-resolution images use high amounts of memory as compared to low-resolution ones.

1.6. Measurement of the Size of Computer Memories

- A binary digit is referred to as a **BIT**
- 8 bits is a **byte**
- 4 bits is a **nibble**
- Byte is used to measure memory size

IECB System (Most Common)

Name of memory size	No. of Bytes	Equivalent Denary Value
1 kibibyte (1KiB)	2^{10}	1 024 bytes
1 mebibyte (1MiB)	2^{20}	1 048 576 bytes
1 gibibyte (1GiB)	2^{30}	1 073 741 824 bytes
1 tebibyte (1TiB)	2^{40}	1 099 511 627 776 bytes
1 pebibyte (1PiB)	2^{50}	1 125 899 906 842 624 bytes

Conventional System

Name of memory size	No. of Bytes	Equivalent Denary Value
1 kilobyte (1KB)	10^3	1 000 bytes
1 megabyte (1MB)	10^6	1 000 000 bytes
1 gigabyte (1GB)	10^9	1 000 000 000 bytes
1 terabyte (1TB)	10^{12}	1 000 000 000 000 bytes
1 petabyte (1PB)	10^{15}	1 000 000 000 000 000 bytes

Calculation of File Size

- The file size of an image is calculated as image resolution (in pixels) × colour depth (in bits)
- The size of a mono sound file is calculated as sample rate (in Hz) × sample resolution (in bits) × length of sample (in seconds). `(For a stereo sound file, you would then multiply the result by two.)`

Sample Question:

find the size of bitmap image with the width 500 and height 500. The color depth of this image is 24.

working:

(500 x 500 x 24)
= 6,000,000 bits (bit to bytes) /8 = 750,000 bytes
(bytes to KiB) /1024 = 732 KiB

or:

24 bits = 3 bytes
(500 x 500 x 3)
= 750,000 bytes
(bytes to KiB) /1024 = 732 KiB

1.7. File Types

Musical Instrument Digital Format (MIDI)

- Storage of music files
- A communications protocol that allows electronic musical instruments to interact with each other
- Stored as a series of demands but no actual music notes
- Uses 8-bit serial transmission (asynchronous)
- Each MIDI command has a sequence of bytes:
  - The first byte is the status byte – which informs the MIDI device what function to perform
  - Encoded in the status byte is the MIDI channel (operates on 16 different channels)
- Examples of MIDI commands:
  - Note on/off: indicates that a key has been pressed
  - Key pressure: indicates how hard it has been pressed (loudness of music)
- It needs a lot of memory storage

MP3

- It uses technology known as Audio Compression to convert music and other sounds into an MP3 file format
- This compression reduces the normal file size by 90%
  - Done using file compression algorithms, which use Perceptual Music Shaping
  - Removes sounds that the human ear cannot hear properly
  - Certain sounds are removed without affecting the quality, too much
- CD files are converted using File Compression Software
- Use lossy format as the original file is lost following the compression algorithm

MP4

- This format allows the storage of multimedia files rather than just sound
- Music, videos, photos and animations can be stored
- Videos could be streamed without losing any real discernible quality

Joint Photographic Experts Group (JPEG)

- JPEG is a file format used to reduce photographic file sizes
- Reducing picture resolution is changing the number of pixels per centimetre
- When a photographic file undergoes compression, file size is reduced
- JPEG will reduce the raw bitmap image by a factor between 5 and 15

1.8. Lossless and Lossy File Compression

Lossless File Compression

- All the data bits from the original file are reconstructed again when the file is uncompressed.
- Important for files where the loss of data would be disastrous (spreadsheet)
- An algorithm is used to compress data
- No data is lost
- Repeated patterns/text are grouped together in indexes

Run-Length Encoding

- It reduces the size of a string of adjacent, identical data (e.g. repeated colours in an image)
- A repeating string is encoded into two values: the first value represents the number of identical data items (e.g. characters), and the second value represents the code of the data item (such as ASCII code if it is a keyboard character), e.g. 'aaaaabbbbccddddd' becomes "05 97 04 98 02 99 05 100."
- RLE is only effective where there is a long run of repeated units/bits
- One difficulty is that RLE compression isn't perfect for strings like "cdcdcdcdcd". We use a flag to solve this; e.g., 255 can be made as the flag. Now 255 will be put before every repeating value, e.g. our previous example becomes `255 05 97 255 04 98 255 02 99 255 05 100` where 255 now indicates that the next character/set of characters is approaching

Lossy File Compression

- The file compression algorithm eliminates unnecessary data bits like in MP3 and JPEG formats.
- It is impossible to get the original file back once it is compressed
- Reduces file quality
- In this, the image's resolution and colour depth are reduced.

2. Data Transmission

2.1. Types and Methods of Data Transmission

Data Packets

- Packet Structure -
  - Header
    - Contains the IP address of the sender and the receiver
    - The sequence number of the packet
    - Size of the packet
  - Payload
    - Contains the actual data
  - Trailer
    - Includes a method of identifying the end of the packet
    - Error-Checking methods
- Packet Switching - Method of data transmission where the data is broken into multiple packets. Packets are then sent independently from start to end and reassembled at the receiver's computer.

Advantages	Disadvantages
There is no need to create a single line of communication	Packets may be lost
Possible to overcome failed or busy nodes	More prone to errors in real-time streaming
High data transmission speed	Delay at the receiver while the packets are being re-ordered
Easy to expand package usage	

Data Transmission

- *Simplex data transmission* is in one direction only (e.g. computer to printer)
- Half-duplex data transmission is in both directions but not at the same time (e.g., walkie-talkie)
- *Full-duplex data transmission* is in both directions simultaneously (e.g. broadband connection on the phone line)
- *Serial data transmission* is when data is sent one bit at a time over a single wire
- *Parallel data transmission* is when data of several bits (1 byte) are sent down several wires at the same time.

Comparison of Serial and Parallel Data Transmission

Serial	Parallel
Better for longer distances (Telephone Lines)	Better for short distances (Internal circuits)
Cheaper Option	Expensive (More hardware required)
Used when the size of data transmitted is small	Used when speed is necessary
Slower Option	Faster than Serial
Easier to synchronise as there's only one data stream.	Difficult to synchronise due to skew between bits.

2.2. Universal Serial Bus (USB)

- USB is an asynchronous serial data transmission method
- USB consists of:
  - Four-wire shielded cable
  - Two wires are used for power and earth
  - Two wires are used in data transmission

Advantages	Disadvantages
Automatically detected	Transmission rate is less than 120 MB/sec
Only fit one way, prevents incorrect connections	Maximum cable length is about 5 metres
Different data transmission rates	
Backwards compatible	
Industry-standard	

2.3. Methods of Error Detection

Parity Checks

- It uses the number of 1-bits in a byte
- Two Types -
  - Even - Even number of 1-bits
  - Odd - Odd numbers of 1-bits
- Example (Even Parity) -

0	1	0	1	1	0	1	0

- The **LMB (Left-Most Bit)** is the parity bit. As the number of 1s is even, the parity bit would be set to even.

Limitations with Parity Checks

- Two bits may change during transmission; therefore error is not found
- Even though the parity checks would reveal the errors, the bit(s) changed wouldn't be identified

Parity Blocks

- To overcome the limitations of parity bits, Parity blocks would be used.

	1	2	3	4	5	6	7	
A	1	0	1	1	1	1	1	0
B	1	1	0	1	0	0	0	1
C	1	0	1	1	0	1	1	1
D	1	1	0	1	0	0	1	1
E	1	1	1	0	0	1	0	0
	1	1	1	0	0	1	1	1

- Any changes in bits would be identified through the rows and columns

Checksum

- Whenever a block of data needs to be sent, the sender would calculate the checksum value using a specific algorithm.
- Once the data has been sent, The receiver would calculate the checksum again with the same set of data and the same algorithm used before.
- The receiver would then compare the value received and the newly calculated value. If they aren't matched, A request is made to re-send the data.

Echo Check

- Once the data has been sent, The receiver will send the data back to the sender for verification.
- The sender would compare the received and original data for errors.
- The only downside is that we wouldn't know if the error occurred when sending the data or sending the data back for verification.

Check Digits

- Check digits are calculated from all the other digits in the data (ex-codes). The check digit would be the last digit of the code.
- These are used to identify mistyping errors such as -
  - 6372 typed as 6379
  - 8432 typed as 842

Automatic Repeat Requests (ARQs)

- Uses acknowledgements and timeouts to make sure the user received the data
- The receiver would check the data for any errors; if none are found, a positive acknowledgement is sent to the sender. However, if errors are found, a negative acknowledgement will be sent, and the data will be sent again.
- The sender uses timeouts to wait for a pre-determined amount for the acknowledgement.
- If no acknowledgements are received after the timeout, the data will be sent again to the receiver.

2.4. Encryption

- Encryption is a process of turning the data into an unreadable form so it doesn't make sense to hackers and other attackers.

Plaintext and Ciphertext

- Plaintext is the original data that is being sent
- Ciphertext is the text produced after encryption

Symmetric and Asymmetric Encryption

- Symmetric Encryption:
  - It uses an encryption key for the encryption process; the same key is used for encrypting and decrypting the data.
- Asymmetric Encryption:
  - Uses a public key and a private key. The public key is available to everyone, whereas the private key is only available to the user.
  - The receiver would have the private key, and they would send the public key to the sender. The sender can encrypt the message with the public key, and the data can be decrypted using the private key.

3. Hardware

3.1. Computer Architecture & Von Neumann Architecture

- The central processing unit (CPU) (also known as a microprocessor or processor) is central to all modern computer systems

The CPU consists of the following architecture:

- **Processor:** The processor contains the Arithmetic and Logic Unit (ALU)
- **Control Unit:** The control unit controls the operation of the memory, processor and input/output devices
- **Arithmetic Logic Unit:** Carries out the logic system like calculations
- **System Clock:** The system clock is used to produce timing signals on the control bus

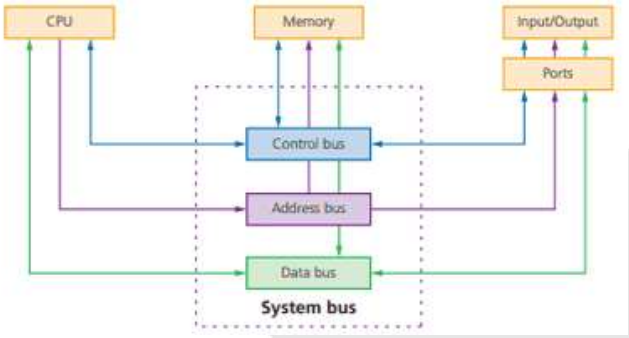
Buses: Carry data through components. The following are its types.

- *Address bus* – unidirectional
- *Data Bus* – bi-directional
- *Control Bus* – bi-directional

Immediate Access Store: Stores the instructions that are to be processed, which are fetched by the CPU

- **The following registers also exist in the architecture:**

REGISTER	ABBREVIATION	FUNCTION
CIR	Current instruction register	Stores the instruction the CPU is currently decoding or executing
MAR	Memory address register	Stores the Address of the instruction, copy it, and sends it to MDR
MDR	Memory data register	Stores the Data from the address received from the MAR and sends data to CIR
PC	Program counter	Stores the address of the next instruction to be fetched from memory
ACC	Accumulator	During calculations, data is temporarily held in it



The Fetch-Execute Cycle

1. PC contains the address of the next instruction to be fetched
2. This address is copied to the MAR via the address bus
3. The instruction is fetched from the main memory (RAM) via the data bus.
4. The instruction of the address is copied into the MDR temporarily
5. The instruction in the MDR is then placed in the CIR
6. The value in the PC is incremented by 1, pointing to the next instruction to be fetched
7. The instruction is finally decoded and then executed

Stored Program Concept

- Instructions are stored in the main memory
- Instructions are fetched, decoded, and executed by the processor
- Programs can be moved to and from the main memory

Memory Concept

- A computer's memory is divided into partitions: Each partition consists of an address and its contents, e.g.

MEMORY LOCATION	CONTENT
10101010	01010110

Instruction Set:
An instruction set is a list of all the commands that a CPU can process, and the commands are machine code

3.2. Cores, Cache and Internal Clock

System's Clock

The clock defines the clock cycle that synchronises all computer operations. **By increasing the clock speed, the computer's processing speed also increases.** This **doesn't** mean that the computer's performance is increased, however.

Overclocking

Using a clock speed higher than the computer was designed for.
It leads to multiple issues.

- Operations become unsynchronised - (the computer would frequently crash and become unstable)
- can lead to serious overheating of the CPU

Length of Data Buses

The wider the data buses, the better the performance of the computer

Cache

Cache memory is located within the CPU itself
-- allows faster access to the CPU
-- stores frequently used instructions and data that need to be accessed faster, which improves CPU performance
The larger the cache memory size, the better the CPU performance

Cores

The more cores in the CPU, the better and faster the performance

- But if any number of cores are used, it could slow down the system performance as the communication between each core increases, and so do the data cables between each. Which in turn reduces the potential system performance.
- You might have heard about quad and dual cores as well as septa and octa cores as they are becoming increasingly common.

3.3. Input Devices

Two-dimensional Scanners:

- Used to input hard-copy documents
- The image is converted into an electronic form, which can be stored in the computer
  - The document is placed on a glass panel
  - A bright light illuminates the document
  - A scan head moves across the document until the whole page is scanned. An image of the document is produced and sent to a lens using a series of mirrors
  - The lens focuses on the document image
  - The focused image now falls onto a *charge-coupled device (CCD),* which consists of several integrated circuits
  - The software produces a digital image in the electronic form
- *Optical Character Recognition (OCR)* is a software which converts scanned documents into a text file format
- If the original document was a photo/image, then the scanned image forms an image file such as JPEG

Three-dimensional Scanners

- 3D scanners can scan solid objects and produce a three-dimensional image
- Scanners take images at several points, x, y and z (lasers, magnetic, white light)
- The scanned images can be used in *Computer-Aided Design (CAD)* or in a 3D printer to produce a working model

Application of 2D Scanners at an Airport:

- Make use of (OCR) to produce digital images which represent the passport pages
- Text can be stored in ASCII format
- The 2D photograph in the passport is also scanned and stored as jpeg image
- The passenger's face is also photographed using a digital camera and compared to using face recognition software
- Key parts of the face are compared (distance between eyes, width of nose)

Barcode readers/scanners

- A barcode is a series of dark and light parallel lines of varying thicknesses
- The numbers 0 -9 are each represented by a unique series of lines
- The left and right-hand sides of the barcode are separate using guard bars
- Allows barcode to be scanned in any direction
  - The barcode is read by a red laser or red LED
  - Light is reflected off the barcode; dark areas reflect little light, which allows the bars to be read
  - Reflected light is read by sensors (photoelectric cells)
  - The pattern is generated, which is converted to digital

Quick Response (QR) Codes

- Another type of barcode is the QR codes
- Made up of a matrix of filled-in dark squares on a light background
- Can hold more storage (7000 digits)
- Advantages of QR codes:
  - No need for the user to write down the website address
  - QR codes can store website addresses
  - QR Codes are easier to use as they can be read by phone cameras

Digital Cameras

- It is controlled by a microprocessor that adjusts the shutter speed, focuses the image, etc.
- Photo is captured when light passes through the lens onto a light sensitive cell
- The cell is made up of pixels
- The number of pixels determines the size of the file

Keyboards

- Connected to a computer with a USB connection or by wireless connection
- Each character has an ASCII value and is converted into a digital signal
- Slow method
- Prone to errors

Pointing devices

- Mouse/trackball
  - Traditional mechanical ball, connected by USB port
- Modern type: red LEDs to detect movement

Microphones

- Used to input sound to a computer
- When a microphone picks up sound, a diaphragm vibrates, producing an electric signal
- The signal goes to a sound card and is converted into digital values and stored in a computer
- *Voice recognition:* voice is detected and converted into digital

Touchscreens

- Capacitive (medium cost tech)
  - Made up of many layers of glass
  - Creating electric fields between glass plates in layers
  - When the top layer of glass is touched, electric current changes
  - Co-ordinates where the screen was touched are determined by an on-board microprocessor
- Infra-red *heat* (expensive)
  - Use glass as the screen material
  - Needs a warm object to carry an input operation
- Infra-red *optical* (expensive)
  - Uses glass as screen material
  - Uses an array of sensors (grid form)
  - Point of contact is based on which grid co-ordinate is touched
- Resistive (inexpensive)
  - The upper layer of polyester, the bottom layer of glass
  - When the top polyester is touched, the top layer and bottom layer complete a circuit
  - Signals are then sent out, which are interpreted by a microprocessor to determine where the screen was touched

Sensors

- Devices that read or measure physical properties
- Data needs to be converted to digital
- *Analogue-to-digital converter (ADC)* converts physical values into digital
- Sensors and their purposes:
  - Acoustic - These sensors act like a microphone that converts sound to electric pulses.
  - Accelerometer - These sensors measure an object's acceleration or deceleration and motion.
  - Flow - This sensor measures the flow of liquid or gas.
  - Gas - These sensors measure the amount/level of any gas in the environment.
  - Humidity - This sensor measures the water vapour in the air or any sample.
  - Infra-red (active) - This IR sensor uses an invisible infrared beam. When the beam is broken/disturbed, it changes the amount of infrared light reaching the detector.
  - Infra-red (passive) - These sensors detect the heat emitted by any object.
  - Level - This sensor detects the solids, liquids, or gas level.
  - Light - These devices use light-sensitive cells that generate electric current based on light brightness.
  - Magnetic field - This sensor detects the change in magnetic field.
  - Moisture - This type of sensor detects the water content wherever this sensor has been installed.
  - pH - This measures the acidity or alkalinity.
  - Pressure - This sensor measures the pressure applied
  - Proximity - This sensor detects the nearby objects around the sensor
  - Temperature - These sensors measure the temperature of the environment.
- (Note: You do not need to know the working principle of the sensor. But have an idea of their purposes.)

Control of Street Lighting

- The light sensor sends data to the ADC
- The data is digitised and sent to the microprocessor
- Microprocessor samples data every minute
- If data from sensor < value stored in memory:
  - Signal sent from microprocessor to street lamp
  - Lamp switched on

3.4. Output Devices

Inkjet Printers

- Used to print one-off pictures and documents
- Data from the document sent to the printer driver
- The printer driver ensures data is in the correct format
- Check made by printer driver that the chosen printer is available
- Data is sent to the printer and stored in a temporary memory (printer buffer)
- A sheet of paper is fed; the sensor detects if the paper is available in the paper tray
- The print head moves across paper printing text/image, four ink colours sprayed in the exact amount
- Paper is advanced, so the next line is printed
- Repeated until the buffer is empty
- Once it is done, the printer sends an interrupt to the processor (request for more data to be sent)

Laser Printers

- Used to print flyers, high quality
- Use dry powder ink (toner) and static electricity to produce text and images
- Prints the whole page in one go

1. (steps 1-4 same as inkjet)
2. The printing drum is given a positive charge; as the drum rotates, a laser beam is scanned across it; removing the positive charge leaves negatively charged areas which match the text/image
3. The drum is then coated with positively charged *toner; it* only sticks to negatively charged parts of the drum
4. A negatively charged sheet is rolled over the drum
5. The toner on the drum now sticks to the paper to produce a copy of the page
6. Paper finally goes through a fuser (set of heated rollers); heat melts the ink so it is permanent
7. The discharge lamp removes all electric charge from the drum, ready to print on the next page

3D Printers

- Used for models of cars
- Produce solid objects that work
- Built up layer by layer, using powdered resin, ceramic powder
- A design is made using Computer-aided Design (CAD)

2D and 3D Cutters

- 3D cutters can recognise objects in x, y, z direction
- 3D laser cutters can cut glass, crystal, metal, wood

Actuators

- The actuators convert electrical signals to mechanical processes.
- Used in many control applications involving sensors and devices (ADC and DAC)

Loudspeakers/Headphones

- Sound is produced by passing the digital data through a DAC, then through an amplifier, and then emerges from the loudspeaker
- Produced by voltage differences vibrating a cone in the speaker at different frequencies

LCD and LED Monitors

- The front layer of the monitor is made up of *Liquid Crystal Display* (LCD); these tiny diodes are grouped in threes as pixels (LCD doesn't emit any light)
- LCD monitors are backlit using *Light Emitting Diode (LED)* because:
  - LEDs reach their maximum brightness immediately
  - LEDs sharpen image (higher resolution), and CCFL has a yellow tint
  - LEDs improve the colour image
  - Monitors using LED are much thinner than CCFL
  - LEDs consume very little power
- Before LEDs, LCD monitors were backlit using CCFL
- CCFL uses two fluorescent tubes behind the LCD screen, which supplies the light source

Light Projectors:

- Two common types of light projectors:
  - Digital Light Projector (DLP)
  - LCD Projector
- Projectors are used to project computer output onto larger screens/interactive whiteboards

Digital Light Projectors (DLP)

- Uses millions of micromirrors
- the number of micromirrors and the way they are arranged on the DLP chip determines the resolution of the image
- When the micromirrors tilt towards the light source they are *on*
- When the micromirrors tilt away from the light source, they are *off*
- This creates a light or dark pixel on the projection screen
- A bright white light source passes through a colour filter on its way to the DLP chip
- White light splits into primary colours

LCD Projectors

- Older technology than DLP
- A powerful beam of white light is generated from a bulb
- This beam of light is then sent to a group of chromatic-coated mirrors; these reflect the light at different wavelengths
- When the white light hits the mirrors, the reflected light has wavelengths corresponding to red, green, and blue
- These three different lights pass through three LCD screens; these screens show the image to be projected as millions of pixels in grayscale
- When the coloured light passes through the LCD screens, a red, green and blue version of the grey image emerges
- Finally, the image passes through the projector lens onto the screen

	Advantages	Disadvantages
Digital light projector (DLP)	higher contrast ratios	image tends to suffer from 'shadows' when showing a moving image
	higher reliability/longevity	
	quieter running than LCD projector	DLP do not have grey components in the image
	uses a single DMD chip, which mean no issues lining up the images	the colour definition is frequently not as good as LCD projectors because the colour saturation is not as good (colour saturation is the intensity of colour)
	smaller and lighter than LCD projector	
	they are better suited to dusty or smoky atmospheres than LCD projectors	
LCD projector	give a sharper image than DLP projectors	although improving, the contrast ratios are not as good as DLPs
	have better colour saturation than DLP projectors	LCD projectors have a limited life (that is, the longevity is not as good as DLPs)
	more efficient in their use of energy than DLP technology – consequently they generate less heat	since LCD panels are organic in nature, they ten to degrade with time (screens turn yellow and th colours are subsequently degraded over time)

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

3.5. Memory, Storage Devices & Media

Primary vs. Secondary Storage

- The CPU directly accesses primary storage
- RAM, ROM, and cache memory are some examples of primary storage
- The CPU does not directly access secondary storage
- HDD, SSD, DVD, memory stick, and Blu-ray disc are some examples of secondary storage

Primary Memory:
Random Access Memory (RAM)

- RAM is used by a system when it needs to store and access data that is actively being used or processed by the user immediately.
- Features of RAM
  - Volatile/temporary memory (contents lost if RAM is turned off)
  - Used to store; data, files
  - It can be written to or read from, and the contents of the memory can be changed
- The larger the size of the RAM, the faster the computer will operate
- RAM never runs out of memory and continues to run slow
- As RAM becomes full, the processor has to access the continually hard drive to overwrite old data on RAM with new data
- RAM is of two types:

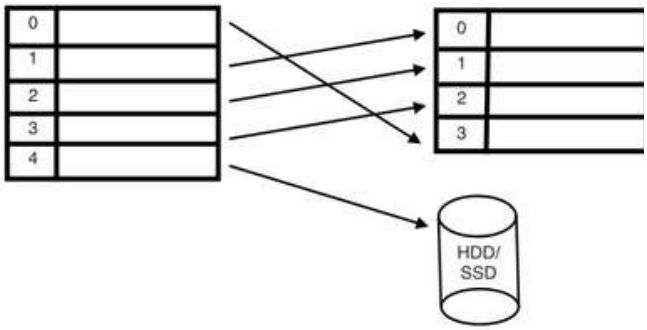
DRAM (Dynamic RAM) and SRAM (Static RAM)

DRAM	SRAM
consists of a number of transistors and capacitors	uses flip flops to hold each bit of memory
needs to be constantly refreshed	doesn't need to be constantly refreshed
less expensive to manufacture than SRAM	has a faster data access time than DRAM
has a higher memory capacity than SRAM	CPU memory cache makes use of SRAM
main memory is constructed from DRAM	
consumes less power than SRAM	

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

Virtual memory

- When RAM runs out of memory, there is a problem with memory management; thus, the system has a high chance of crashing. This is why virtual memory comes into the picture.
- The virtual memory can be either HDD or SSD (these storages are discussed below)



- You may be expected to draw a diagram like the above.
- The main advantages of virtual memory are
  - They can be larger than the physical memory provided in the RAM.
  - Avoids the need to install/upgrade RAM, as it could be expensive
  - The system wastes no storage on unwanted/unused data.

Read Only Memory (ROM)

- Features of ROM
  - Non-volatile/permanent memories (contents remain even when ROM is turned off)
  - Used to store start-up instructions (basic input/output systems)
  - Data/contents of a ROM chip can only be read and cannot be changed

Secondary Storage:
Hard Disk Drives (HDD)

- Data is stored in a digital format on the magnetic surface of the disks (platter)
- A number of read/write heads can access all of the surfaces of the disk
- Each platter will have two surfaces which can be used to store the data
- Data is stored on the surfaces in sectors and tracks
- HDD has very slow data access compared to RAM

Solid-State Drive (SSD)

- There are no moving parts, and all data is received at the same time (not like HDD)
- Store data by controlling the movement of electrons within NAND chips, as 1s and 0s
- Non-volatile rewritable memory
- Benefits of using SSD rather than HDD:
  - More reliable (no moving parts)
  - Considerably lighter (suitable for laptops)
  - Lower power consumption
  - Run much cooler than HDDs
  - Very thin
  - Data access is faster than HDD
- Drawback – questionable longevity (20GB per day)

Off-Line Storage:
CD/DVD Disks

- Laser (red) light is used to read and write data on the surface of the disk.
- A thin layer of metal alloy is used to store data.
- Both systems use a single spiral track that runs from the centre of the disk to the edge
- DVD uses *Dual-Layering,* which increases the storage capacity (two individual recording layers)

Blu-ray Disks

- Uses a blue laser to carry out read-and-write operations
- The wavelength of laser light is less than CD and DVD (stores up to five times more data than DVD)
- Automatically come with secure encryption (prevent piracy and copyright infringement)
- Used as backup systems

USB Flash Memories

- Very small, lightweight, and suitable for transferring files
- Small back-up devices for photo, music
- Solid state, so needs to be treated with care

Cloud Storage:

- Cloud storage is a method of data storage where data is stored on remote servers
- The same data is stored on more than one server in case of maintenance or repair, allowing clients to access data at any time. This is known as **data redundancy.**

The following are its types:

- **Public cloud** – this is a storage environment where the customer/client and cloud storage provider are different companies
- **Private cloud** – this is storage provided by a dedicated environment behind a company firewall; customer/client and cloud storage provider are integrated and operate as a single entity
- **Hybrid cloud** – this is a combination of the two above environments; some data resides in the private cloud, and less sensitive/less commercial data can be accessed from a public cloud storage provider

Benefits of using cloud storage	Drawbacks of using cloud storage
customer/client files stored on the cloud can be accessed at any time from any device anywhere in the world provided internet access is available	if the customer/client has a slow or unstable internet connection, they would have many problems accessing or downloading their data/files
there is no need for a customer/client to carry an external storage device with them, or even use the same computer to store and retrieve information	costs can be high if large storage capacity is required; it can also be expensive to pay for high download/upload data transfer limits with the customer/client internet service provider (ISP)
the cloud provides the user with remote back-up of data with obvious benefits to alleviate data loss/disaster recovery	the potential failure of the cloud storage company is always possible – this poses a risk of loss of all back-up data
if a customer/client has a failure of their hard disk or back-up device, cloud storage will allow recovery of their data	
the cloud system offers almost unlimited storage capacity	

3.6. Embedded System

- A combination of hardware and software is designed to carry out a specific set of tasks.
- Embedded systems may contain -
  - Microcontrollers - CPU, RAM, ROM and other peripherals on one single chip
  - Microprocessor - Integrated circuit with CPU only
  - System on Chips (SoC) - microprocessor with I/O ports, storage and memory
- Process of Embedded Devices -
  - Input from the user is sent to the microprocessor (ADC needed if the data is analogue)
  - Data from the user interface is also sent to the microprocessor
  - The microprocessor then sends signals to actuators which are the output
- Non-programmable devices need to be replaced if they need a software update.
- Programmable devices have two methods of updating
  - Connecting the device to a computer and downloading the update
  - Updating automatically via a satellite, cellular or Wi-Fi link

Advantages and Disadvantages of using embedded systems

Advantages	Disadvantages
Small in size, therefore can easily fit into devices	Can be difficult to upgrade
Low cost to make	The interface can be confusing sometimes
Requires very little power	Troubleshooting is a specialist's job
Very fast reaction to changing input	Often thrown away as difficult to upgrade and faults are harder to find
Dedicated to one task only	Increased garbage as they are thrown away
Can be controlled remotely	Any computerised system is prone to attacks

- **Applications of Embedded devices**
  - GPS systems
  - Security Systems
  - Vending Machines
  - Washing Machines
  - Oven
  - Microwave

3.7. Network Hardware

Network Interface Card (NIC)

A network interface card (NIC) is needed to allow a device to connect to a network (such as the Internet).

Media Access Control (MAC)

A MAC address comprises 48 bits which are shown as six groups of hexadecimal digits. The first six display the manufacturer's code, and the second half shows the device serial number.

- These do not change and are primarily constant for every device
- there are two types of MAC addresses: the Universally Administered MAC Address (UAA) and the Locally Administered MAC Address (LAA)

The only difference between the two types is that UAA is made Universally and cannot be changed, but it is the opposite for LAA.

IP Addresses

- IP address allocation:
  - The network allocates IP addresses.
  - Two types of IP addresses: static and dynamic.
- Static IP addresses:
  - Assigned manually to a device.
  - Does not change over time.
- Dynamic IP addresses:
  - Assigned automatically by a DHCP (Dynamic Host Configuration Protocol) server.
  - Changes periodically or when the device connects to a different network.
- IPv4 (Internet Protocol version 4):
  - Widely used protocol.
  - Consists of four groups of decimal numbers separated by dots (e.g., 192.168.0.1).
  - Provides approximately 4.3 billion unique addresses.
- IPv6 (Internet Protocol version 6):
  - Developed to address the limitations of IPv4.
  - Uses eight groups of hexadecimal numbers separated by colons (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334).
  - Provides an extremely large number of unique addresses (approximately 340 undecillion).
- Differences between IPv4 and IPv6:
  - Address format: IPv4 uses a 32-bit address, while IPv6 uses a 128-bit address.
  - Address space: IPv4 provides approximately 4.3 billion addresses, whereas IPv6 offers around 340 undecillion addresses.
  - Address allocation: IPv4 addresses are allocated manually using DHCP, while IPv6 addresses are primarily assigned using stateless autoconfiguration.

Routers

- Router functionality:
  - A router is a networking device that directs data packets between different networks.
  - It determines the most efficient path for data transmission.
- Sending data to a specific destination on a network:
  - A router examines the destination IP address of incoming data packets.
  - It uses routing tables to determine the next hop or the next router on the path to the destination.
  - The router forwards the data packet to the appropriate next hop.
- Router's role in IP address assignment:
  - A router can act as a DHCP server (Dynamic Host Configuration Protocol) and assign IP addresses to devices on a local network.
  - It dynamically allocates IP addresses from a predefined range to connected devices.
  - DHCP allows for automatic IP address configuration and simplifies network management.
- Connecting a local network to the Internet:
  - A router serves as the gateway between a local network and the internet.
  - It connects the local network to an internet service provider (ISP) network.
  - The router receives data packets from devices on the local network and forwards them to the internet.
  - It also receives incoming data packets from the internet and routes them to the appropriate devices on the local network.

4. Software

4.1. Types of Software and Interrupts

Types of Software

1. **System Software** e.g. Operating System, Utility programs and device drivers
2. **Application Software** e.g. spreadsheet, word processor, etc.

System Software:

- these are a set of programs which control and manage the operations of hardware
- gives a platform for other software to run
- it is required to allow hardware and software to run without problems
- provides a human-computer interface (HCI) to the user
- controls the allocation and usage of hardware resources

Application Software:

- allows a user to perform specific tasks using the computer's resources
- maybe a single program (for example, NotePad) or a suite of programs (for example, Microsoft Office)
- user can execute the software when they require, and it is mostly not automatic

Examples

System Software:

- Compiler: Translates high-level language into machine code, allowing for direct use by a computer to perform tasks without re-compilation.
- Linker: Combines object files produced by a compiler into a single program, allowing the use of separately written code modules in the final program.
- Device driver: Software that enables hardware devices to communicate with a computer's operating system, without which a device like a printer would be unable to work.
- Operating system: Software that manages basic computer functions such as input/output operations, program loading and running, and security management, making computers more user-friendly.
- Utility programs: Software that manages, maintains, and controls computer resources by carrying out specific tasks, such as virus checking, disk repair and analysis, file management, and security.

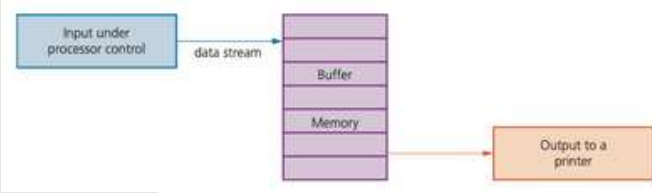
Application Software:

- Word Processor: Software used for manipulating text documents, including creating, editing, and formatting text with tools for copying, deleting, spell-checking, and importing images.
- Spreadsheet: Organizes and manipulates numerical data using a grid of lettered columns and numbered rows, with each cell identified using a unique combination of columns and rows. It can calculate using formulas, produce graphs, and do modelling and "what if" calculations.
- Database: Software used to organize, analyze, and manipulate data consisting of one or more tables that hold records and fields. It provides the ability to query and report on data and add, delete, and modify records in a table.
- Control and Measuring Software: A program designed to interface with sensors and allow a computer or microprocessor to measure physical quantities and control applications by comparing sensor data with stored data and altering process parameters accordingly.
- Apps: Software designed to run on mobile phones or tablets, downloaded from an "App Store" and ranging from games to sophisticated software such as phone banking. Common examples include video and music streaming, GPS, and camera facilities.
- Photo and Video Editing Software: Software that allows users to manipulate digital photographs or videos, including changing colour, brightness, and contrast, applying filters and other enhancements, and creating transitions between clips.
- Graphics Manipulation Software: Software that allows the manipulation of bitmap and vector images, with bitmap graphics editors changing pixels to produce a different image, while vector graphics editors manipulate lines, curves, and text to alter the stored image as required.

Interrupts

An interrupt is a signal sent to the microprocessor, either from a device or software, prompting the microprocessor to pause its ongoing tasks and handle the interrupt temporarily. Various factors can trigger interrupts, including:

- **Timing signals:** Scheduled signals prompt the microprocessor to pause and handle tasks at specific intervals.
- **Input/Output processes:** Events such as a disk drive or printer requiring additional data cause an interruption in the microprocessor's activities.
- **Hardware faults:** Issues like a paper jam in a printer, signalling the microprocessor to halt its operations and address the hardware problem.
- **User interaction:** Instances like a user pressing specific keys on a keyboard (e.g.,), leading to an interrupt in the system's operation.
- **Software errors:** Problems such as missing .exe files needed to initiate a program, conflicts like two processes accessing the exact memory location, or attempts to divide by zero. These errors trigger interrupts, prompting the microprocessor to handle the issues.



Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

4.2. Utility Software

- Computer users have access to utility programs as part of system software
- Utility programs can be initiated by the user or run in the background without user input
- Common utility programs include virus checkers, defragmentation software, disk analysis and repair tools, file compression and management software, backup software, security tools, and screensavers.

Virus Checkers & Anti-Virus Software

- Virus checkers or anti-virus software are important for protecting computers from malware.
- They should be kept up to date and run in the background to maintain their effectiveness.
- Anti-virus software checks files before they are run or loaded and compares possible viruses against a database of known viruses.
- Heuristic checking is used to identify possible viruses that are not yet on the database.
- Infected files are put into quarantine for automatic deletion or for the user to decide.
- Anti-virus software must be updated as new viruses are constantly discovered.
- Full system scans should be carried out regularly to detect dormant viruses.

Disk Defragmentation Software

- Defragmentation software rearranges the data blocks on a hard disk drive (HDD) to store files in contiguous sectors, reducing head movements and improving data access time.
- As an HDD becomes full, blocks used for files become scattered all over the disk surface, making it slower to retrieve data as the HDD read-write head needs several movements to find the data.
- When a file is deleted or extended, new data does not fill the vacant sectors immediately, causing the files to become more scattered throughout the disk surfaces.
- A disk defragmenter rearranges the data blocks to store files in contiguous sectors wherever possible, allowing for faster data access and retrieval.
- The defragmentation process can free up previously occupied sectors and empty some tracks.

Backup Software

- Backup software is a utility software that helps create and manage backup copies of data files and programs.
- Manual backups using memory sticks or portable hard drives are good practices, but operating system backup utilities are also recommended.
- Backup utilities allow scheduling backups and only backup files if changes have been made to them.
- There could be three file versions for total security: the current version stored on the internal HDD/SSD, a locally backed-up copy on a portable SSD, and a remote backup on cloud storage.

Security Software

- Security software is a utility software that manages access control, user accounts, and links to other utilities such as virus and spyware checkers.
- It also protects network interfaces using firewalls to prevent unauthorized access.
- Security software uses encryption and decryption to ensure intercepted data is unreadable without a decryption key.
- It oversees software updates to verify legitimate sources and prevent malicious software from being installed.
- Access control and user accounts use IDs and passwords to secure user data and prevent unauthorized access.

Screensavers

- Screensavers display moving and still images on the monitor screen after computer inactivity.
- They were originally developed to protect CRT monitors from 'phosphor burn'.
- Screensavers are now mostly used for customizing a device and as a part of computer security systems.
- They automatically log out of the user after a certain period of inactivity.
- Some screensavers activate useful background tasks like virus scans and distributed computing applications.

Device Drivers

- Device drivers translate data into a format that can be understood by the hardware device they are associated with.
- Without the appropriate device driver, a hardware device cannot work with a computer and may not be recognised by the operating system.
- USB device drivers contain descriptors, which include a vendor ID (VID), product ID (PID) and unique serial number that allow the operating system to identify the device.
- Serial numbers must be unique to avoid confusion if two devices with the same serial number are plugged into a computer simultaneously.

4.3. Operating Systems

- Operating Systems are designed to establish communication between the user and the computer
- Functions of a typical operating system -
  -managing files
  – handling interrupts
  – providing an interface
  – managing peripherals and drivers
  – managing memory
  – managing multitasking
  – providing a platform for running applications
  – providing system security
  – managing user accounts
- WIMP - Windows, Icons, Menu, and Pointing Devices

Advantages and Disadvantages of CLI and GUI

Interface	Advantages	Disadvantages
command line interface (CLI)	the user is in direct communication with the computer the user is not restricted to a number of pre-determined options it is possible to alter computer configuration settings uses a small amount of computer memory	the user needs to learn a number of commands to carry out basic operations all commands need to be typed in which takes time and can be error-prone each command must be typed in using the correct format, spelling, and so on
graphical user interface (GUI)	the user doesn't need to learn any commands it is more user-friendly; icons are used to represent applications a pointing device (such as a mouse) is used to click on an icon to launch the application – this is simpler than typing in commands or a touch screen can be used where applications are chosen by simply touching the icon on the screen	this type of interface uses up considerably more computer memory than a CLI interface the user is limited to the icons provided on the screen needs an operating system, such as Windows, to operate, which uses up considerable memory

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

- Memory Management - Manages the RAM and the HDD/SSD during the execution of programs
- Security Management - Providing security features such as Anti-Virus, System updates and so on
- Hardware Peripheral Management - Managing the device drives, Inputs, Outputs, Queues and buffers
- File Management - Opening, Creating, Deleting, Renaming, and many more functions
- Multitasking - OS would share the hardware resources with each of the processes
- Management of User Accounts - OS would allow multiple users to customise their accounts individually.

Running of Applications

- The computer starts its OS (booting up the computer) through the bootstrap loader.
- The BIOS (Basic Input/Output System) tells the computer the location of the OS in the storage.
- BIOS is often referred to as the firmware

Interrupts

- Signal that causes the microprocessor to stop what it's doing and service the task
- Ensures important tasks are dealt with on a priority basis
- It can be a software or a hardware interrupt
- Peripherals like a keyboard & mouse can generate it
- Different interrupts have different levels of priority
- After interruption is dealt with, the previous process continues

4.4. Programming Languages, Translators and IDEs

- Computers can only understand **machine code;** therefore, translators are needed

High-Level Languages

- It is easier to read and understand as the language is closer to human language.
- Easier to write in a shorter time
- Easier to debug at the development stage
- Easier to maintain once in use

Low-Level Languages

- Refer to machine code
- Binary instructions that the computer understands

Language	Advantages	Disadvantages
High-level	independent of the type of computer being used	programs can be larger
	easier to read, write and understand programs	programs can take longe to execute
	quicker to write programs	programs may not be able make use of special hardware
	programs are easier and quicker to debug	
	easier to maintain programs in use	
Low-level	can make use of special hardware	it takes a longer time to write and debug program
	includes special machine-dependent instructions	programs are more difficult to understand
	can write code that doesn't take up much space in primary memory	
	can write code that performs a task very quickly	

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

Assembly Language

- Few programmers use assembly language to -
  - Make use of special hardware
  - Write code that doesn't take up much space
  - Write code that runs very quickly
  - Assembly language must be translated into machine code using an assembler to run.

4.5. Translators

Compiler

- Translates a program written in a high-level language into machine code
- Used without compiler
- Executable file of machine code produced
- One high-level language translated into several machine code instructions
- Used for general use

Interpreter

- Executes a high-language program a statement at a time
- No executable file of machine code produced
- One high-level language program statement may require several machine code instructions to be executed.
- Interpreted programs cannot be used without an interpreter
- Used when the program is being developed

Assembler

- Translates a low-level language program into machine code
- Executable file of machine code produced
- One low-level language translated into one machine code instructions
- It can be used without an assembler
- Used for general use

Compiler	Interpreter	Assembler
Translates a high-level language program into machine code.	Executes a high-level language program one statement at a time.	Translates a low-level assembly language program into machine code.
An executable file of machine code is produced.	No executable file of machine code is produced.	An executable file of machine code is produced.
One high-level language statement can be translated into several machine code instructions.	One high-level language program statement may require several machine code instructions to be executed.	One low-level language statement is usually translated into one machine code instruction.
Compiled programs are run without the compiler.	Interpreted programs cannot be run without the interpreter.	Assembled programs are used without the assembler.
A compiled program is usually distributed for general use.	An interpreter is often used when a program is being developed.	An assembled program is usually distributed for general use.

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

Integrated Development Environments (IDEs)

- An IDE would usually have these features -
  - Code Editor
  - Translator
  - Debugger
  - Error Reports
  - Auto-Completion and Auto-Correction
  - Auto-Documenter
  - Pretty Printing

5. The Internet and Its Uses

5.1. The Internet and the World Wide Web

Internet	World Wide Web (WWW)
Uses transmission protocols such as TCP and IP (Internet Protocols)	Collection of webpages and other information on websites
Allows the user to communicate with other users via chat, email, calling and more	Uses HTTP(S) protocols that are written using Hypertext Mark-up Language (HTML)
Worldwide Collection of Interconnected Networks and Devices	URLs (Uniform Resource Locator) are used for the location of the web pages
	Web browsers can access web pages.

Uniform Resource Locator (URLs)

- URLs are used to locate and access web pages. The typical format of URLs is -

  protocol://website address/path/file name

- The protocol would usually be **HTTP** or **HTTPS**
- The website address would contain -
  - domain host (www)
  - domain name (website name)
  - domain type (.com, .org, .net, .gov) or sometimes country codes (.uk, .in, .cy)
- The path would usually become the file directory roots. for example, https://www.znotes.com/computer-science
  - The /computer-science is the file name

HTTP and HTTPS

- HTTP stands for Hypertext Transfer Protocol, and HTTPS stands for Hypertext Transfer Protocol secure
- They are safety protocols maintained while transmitting data.

Web Browsers

- It is software used to connect to the internet
- It translates the HTML code
- ensures SSL & TLS security can be established
- Offers additional features like search history & ad blockers

Retrieval and Location of web pages

- The browser sends the URL to the domain name server (DNS)
- DNS stores the index and matches it with the IP
- IP is sent to the browser if it exists
- The browser sends a request to the IP of the webserver
- Browser interprets the HTML

Cookies

- Cookies are small files stored on the user's computer
- They are used to track data about the users and autofill forms or give suggestions accordingly
- Types of Cookies -

Session Cookie	Persistent Cookie
Temporary cookies are stored in the RAM till the browser is closed.	Remembers the user's login details so the user doesn't have to log in every time they visit a website
Doesn't collect any information on the user	Stored on the hard disk on the computer until their expiry date or the user deletes them
A good example is the virtual shopping basket on e-commerce websites.	

5.2. Digital Currency

- Form of payment to pay for goods and services
- A few examples are Debit/Credit Cards, Apps (Paypal, Apple Pay, Bank Transfers and many more)
- Cryptocurrency was later introduced due to the problem in centralised banking systems.
- Cryptocurrency uses cryptography to maintain track of transactions.
- Cryptocurrency is also more secure because it uses **Blockchain Network**

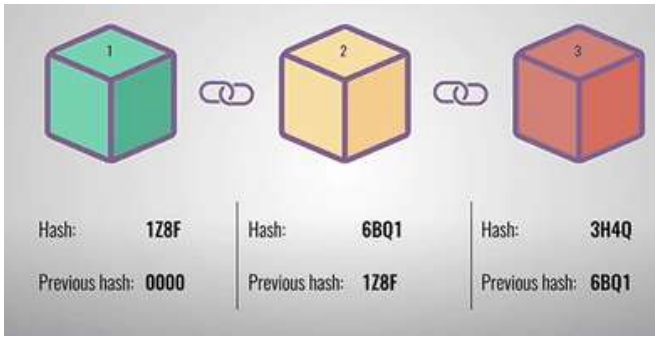
Blockchain Network

- Blockchain Network involves several interconnected computers where the transaction data is stored
- Hacking isn't possible here as transaction details would be sent to all the computers, and the data can't be changed without the consent of all the network members

How do blockchains work

Every time a transaction takes place, A block is created. The block would contain -

- Data - Name of the sender and the receiver, amount of money and more
- Hash Value - Unique value generated by an algorithm
- Previous Hash Value - Hash Value of the previous block in the chain



The first block is called the genesis block as it doesn't point to any previous block (Previous Hash Value - 0000)

5.3. Cyber Security

Brute Force Attack:

- Hackers try to guess your password by trying all the different combinations of letters, numbers and symbols.
- Effect:
  - Hacker gets access to user's personal data (credit cards, passwords and more)
- To remove risk:
  - Use stronger passwords with more characters and symbols

Data Interception:

- This involves stealing data by tapping into a wired or a wireless transmission line
  - Wardriving - The act of locating and using wireless internet connections illegally
  - Packet Sniffing - Uses Packet sniffers to examine packets sent over a line; all the data collected is sent back to the attacker
- Effect:
  - It can cause a computer to crash
  - Can delete or corrupt files/data
- To remove risk:
  - Install anti-virus software
  - Don't use software from unknown sources
  - Be careful when opening emails from unknown

Distributed Denial of Service Attacks (DDoS)

- An attempt at preventing users from accessing part of a network
- Usually temporary but may be damaging
- An attacker may be able to prevent the user from:
  - Accessing their emails
  - Accessing websites
  - Accessing online services

Hacking

- The act of gaining illegal access to a computer system
- Effect:
  - This leads to identity theft, gaining personal information
  - Data can be deleted, changed or corrupted
- To remove risk:
  - Firewalls
  - Strong passwords/ user IDs
  - Use of anti-hacking software
- Difference between hacking and cracking
  - Hacking breaks into computer systems to steal data
  - Cracking is when someone edits a program code, malicious

Malware

- Stands for Malicious Software. A few examples are -
  - Virus - A program that can replicate itself with the intention of deleting or corrupting files, causing a computer malfunction
  - Ransomware - Attackers encrypt the user's data until a certain amount of money is paid
  - Adware - Displays unwanted ads on the user's screen
  - Trojan Horse - Programs that are disguised as legitimate software
  - Spyware - Sends data about all the activities of the user to the attacker
  - Worms - Programs that can replicate themselves with the intention of corrupting the entire network instead of the computer alone

Phishing

- Attackers send legitimate-looking emails to bait the user into giving out their information.
- To remove risk:
  - Don't open links from unknown receivers
  - Use anti-phishing tools
  - Block pop-up ads
  - Have an up-to-date browser

Pharming

- The attacker installs a malicious code on the computer, which redirects the user to fake websites
- Effect:
  - The user gives out login details and other personal details
- To remove risk:
  - Using anti-virus software
  - Checking the spelling and the weblink carefully
  - Make sure that the green padlock is present in the URL bar

Social Engineering

- Attackers create a social situation which leads to victims giving out their details (For example - Spam calls informing them that their account has been hacked)

Keeping data safe from threats

- Access Levels - Having Different levels of access for different people (for example - Only doctors can have access to patient's data)
- Antivirus - Protects user's computer from malware attacks
- Authentication - User proving who they are. The most common methods are passwords, PINs, Mobiles (OTPs), biometrics and more)

Benefits and Drawbacks of Biometric Method

Biometric Methods	Benefits	Drawbacks
Fingerprint Scans	Most development methods are very easy to use and require very low storage space to store the biometric data.	Intrusive as used to identify criminals, Can't be used if the finger gets dirty or damaged (e.g. cuts)
Retina Scan	With very high accuracy, it Impossible to replicate a person's retina	It is very intrusive, Takes longer to verify, Expensive to install and set up
Face Recognition	Non-intrusive method, Relatively cheaper	Can't identify if there are any changes in the lighting or a person's age or if the person is wearing glasses
Voice Recognition	Non-Intrusive method, verification is done quickly and relatively cheaper	Voices can be recorded and used for verification, but low accuracy and illnesses such as colds or coughs can affect a person's voice, making identification impossible.

- Two-Step Verification - Requires two methods of authentication to prove who the user is
- Automatic Software Updates - Latest updates contain patches which improve device security
- Spelling and Tone - Fake emails tend to have wrong spelling and grammar (amazonn instead of amazon), and the tone would also seem urgent
- Firewalls - Hardware or Software which monitors the traffic between a network and the user's computer
- Proxy Servers - Acts as an intermediate between the user's computer and the web server. They are used for -
  - Filtering Internet traffic
  - Keeping the user's IP Address Confidential
  - Blocking access to certain websites
  - Attacks like DDoS and Hacking attack the proxy server, keeping the web server safe.
  - Acts as a firewall as well.
- Privacy Settings - Used to limit who can access and see a user's profile
- SSL (Secure Socket Layer) - Set of rules used while communicating with other users on the internet.

6. Automated and Emerging Technologies

6.1. Automated Systems

- Automated Systems are a combination of software and hardware designed to function without human intervention.
- **Process of Automated Systems**
  - Sensors take inputs, and they are sent to the microprocessor. The data is usually analogue, so it has to go through Analogue-to-Digital Converter (ADC)
  - The microprocessor processes the data and makes the necessary decisions based on its program
  - The actions are then executed by the actuators (Motors, wheels and so on)

Advantages and Disadvantages of Automated Systems

Advantages	Disadvantages
Faster and Safer	Expensive to set up and maintain
Any changes can be identified quickly	Any computerised systems are prone to attacks
Less Expensive in the long run	Over-reliance on automated systems may cause humans to lose skills
Higher Productivity and Efficiency	

You should be able to describe the advantages and disadvantages of an automated system used for a given scenario.
Including scenarios from:

- industry
- transport
- agriculture
- weather
- gaming
- lighting
- science

6.2. Robotics

- Robotics is the branch of computer science that combines robot design, construction and operation.
- Isaac Asimov's Laws of Robotics -
  - A robot may not injure a human through action or inaction
  - A robot must obey orders given by humans unless it comes into conflict with Law 1
  - a robot must protect itself unless this conflicts with either law 1 or 2.
- Characteristics of a robot -
  - Ability to sense their surroundings
  - Have a degree of movement
  - Programmable

NOTE - ROBOTS DO NOT POSSESS AI; THEY TEND TO DO REPETITIVE TASKS RATHER THAN REQUIRING HUMAN CHARACTERISTICS

- Types of Robots -
  - Independent - Have no human intervention; they can completely replace humans
  - Dependent - Needs human intervention through an interface, can supplement but can't completely replace humans

Advantages and Disadvantages of Robots

Advantages	Disadvantages
Robots can work 24/7	Robots can find it difficult to do non-standard tasks
Robots can work in hazardous conditions	Robots can lead to higher unemployment
They are less expensive in the long run	Risk of deskilling as robots replace humans in some task
They have high productivity and are more consistent	Expensive to install and maintain in the short run
	Robots have the risk of getting hacked.

6.3. Artificial Intelligence

- AI is the branch of computer science that simulates intelligent human behaviour.
- Types of AI -
  - Narrow AI - A machine has superior performance to a human when doing one specific task
  - General AI - A machine is similar to a human when doing one specific task
  - Strong AI - Machine has superior performance to a human in many tasks
- Characteristics of AI -
  - Collection of Data and Rules
  - Ability to Reason
- Ability to learn and adapt

Types of AI

- **Expert System** - AI that is developed to mimic human knowledge and experiences. They are usually used for answering questions using knowledge and inference.
- They have many applications, including chatbots, diagnosis in the medical industry, financial calculations and so on

Advantages and Disadvantages of Expert Systems

Advantages	Disadvantages
High level of Expertise	Setup and Maintenance costs are very high
High Accuracy and Consistent	Can only rely on the information in the system
High response times	Tend to give cold responses sometimes

- **Machine Learning is a subset of AI in which machines are trained to learn from** past experiences.

Difference Between AI and Machine Learning

AI	Machine Learning
Representation of human intelligence in machines	Machines are trained to make decisions without being programmed to
The aim is to build machines that think like humans	The aim is to make machines learn through data acquisitions

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