3. HARDWARE

Central processing unit (CPU)

- Processes instructions & data that are input into computer so that result can be output.

Purpose of CPU

- It processes data
- It processes/executes instructions
- It carries out calculations
- It carries out logical operations

Microprocessor: A type of **integrated circuit** on a single chip.

- Microprocessors are a compact way of processing data.
- Can be used in a wide range of electronic devices (general-purpose computer system + Embedded systems).
- Integrated circuit contains a central processor to perform arithmetic & logic operations.
- Single chip also contains input/output interfaces & memory.

Von Neumann Architecture

Stored program concept:

- The program is stored on a secondary storage device
- Data and instructions are moved to and stored in the main memory / RAM
- Data and instructions are moved to registers to be executed
- Instructions are fetched and executed one after the other

OR

- Data and instructions are stored in the same memory
- and can only be fetched one at a time

Components of CPU

Main memory	- RAM - Primary memory - Volatile memory - Holds data/instructions currently in use - Directly accessed by CPU - Consists of address (to identify memory location) and contents (binary values)
Control unit (CU)	- It sends control signals - … that manage/control transfer of data/ instructions within CPU - It decodes an instruction - … using an instruction set

	- It controls the timings of operations (clock speed)
Arithmetic & logic unit (ALU)	- Carries out arithmetic calculations (+,-) - Carries out logical operations (AND, OR) - Holds temporary / interim values during calculations - « in the accumulator (ACC)
Registers	- To store / hold data / address / instruction - ... temporarily
Buses	- Pathway/wires for transmitting data and instructions - Different buses are collectively called the system bus - Parallel transmission components

Clock speed:

Maximum number of FDE cycles/instructions CPU can perform/process/execute in a second.

Registers

Program counter (PC)	- Holds the address ... - ... of next / current instruction to be processed
Memory address register (MAR)	- To temporarily store/hold address - ... of the next data/instruction that needs to be fetched // where data is to be written to
Memory data register (MDR)	- Holds data/instruction - That has been fetched from memory / to be written to memory
Current instruction register (CIR)	- Holds current data/instruction - that is being decoded & executed
Accumulator (ACC)	- Register that is built into the arithmetic logic unit - To temporarily store/hold... - ... interim values during calculations

Buses

Address bus	Unidirectional	- Transmits / carries addresses ... - ... between components in CPU // from CPU to memory
Data bus	Bidirectional	- Transmits / carries data/instructions ... - ... between components in the CPU
Control bus	Bidirectional	- Transmits control signals ... - ... from the control unit to other components in the CPU - To synchronise the fetch-decode-execute cycle

Fetch-Decode-Execute Cycle

a. Instruction is fetched from RAM into CPU, where it is temporarily stored in MDR.
b. Instruction is sent along data bus to CU to be decoded into an opcode & operand
c. ALU performs any calculations/logic operations required to execute the instruction.

1. CPU fetches data and instructions held in HDD or SSD and stores them in Immediate access store (RAM) to wait to be processed.
2. PC contains the address of the next instruction to be fetched.
3. Address contained in PC is copied to MAR via address bus.
4. Instruction is copied from memory location contained in MAR to MDR, via data bus.
5. Entire instruction is copied from MDR to CIR.
6. Any calculations carried out on the data are done by ALU.
7. During calculations, interim values are temporarily held in ACC.
8. Value in PC is incremented; points to next instruction to be fetched.
9. Instruction is decoded and is then executed.
10. Control unit sends signals to manage the process, using control bus.

Why are data and instructions stored temporarily in the IAS / RAM instead of HDD?
Because read/write operations carried out using RAM are faster than read/write operations carried out using backing stores (HDD or SSD).

How MDR and ALU are used in the fetch–decode–execute cycle

- Data fetched from RAM is stored in the MDR
- Data from MDR is sent to ALU to be executed
- ALU performs calculation and logical operations on data
- ALU has a built-in register …
- … where it stores interim results of calculations
- After calculations, ALU sends data to MDR
- Data is sent from MDR to be written to RAM

Factors affecting performance of CPU

Number of cores: use multi-core CPU	Purpose of core - To perform fetch-decode-execute cycle - To process/execute an instruction - Each core runs separate fetch-decode- execute cycles simultaneously - Using more cores increases performance - More cores = more instructions processed simultaneously - Multiple cores enables multitasking
Clock-speed: increase clock speed	- Clock speed: no. of instructions core can execute each sec - Measured in Hertz

Size of cache	- Cache: small amount of memory situated within/ close to CPU - Stores frequently used instructions/data // recently used instructions/data // instructions to be fetched & executed next - Increasing amount of cache allows more data to be stored - Increasing amount of cache increases read/write speeds
Increase bus width	

Explain the purpose of cache

- It is a type of storage
- ...that stores frequently used data/instructions
- To speed up access
- ... as it is faster to access than RAM
- It has different levels e.g. L1 – L3

Instruction Set

- List of all the instructions/ commands that can be processed by CPU.
- The commands are machine code

- Instruction is decoded into an opcode and an operand
- CPU finds the opcode in the processor's instruction set.
- CPU now knows what operation to perform when executing the instruction

Embedded Systems

- Performs a single/limited/dedicated function/task
- It has a microprocessor
- It has dedicated hardware
- Uses firmware
- It is normally built into a larger device/system
- Works automatically // works without human intervention
- User normally cannot reprogram
- It is a real-time system
- It does not require much power
- It is cheap to manufacture
- It is small (in size)

Examples of embedded system: domestic appliances, cars, security systems, lighting systems, vending machines
Examples of general purpose computer: personal computer (PC), laptop

Embedded system	Possible input devices	Possible Output
Digital clock	- Buttons to set time/mode/alarm	- Screen showing time - Alarm
Traffic Lights	- Pedestrian button - Timer - Movement sensor	- Lights
Lighting system	- Movement sensor	- Lights
Security system	- Keypad to enter alarm code - Camera - Movement sensor	- Alarm
Vending machine	- Keypad to make choice	- Actuator controlling movement of choice
Central heating system	- Keypad to set temperature - Temperature sensor	- Heat

Advantages of embedded systems

- low power consumption
- small physical size
- low cost to manufacturer
- they can be controlled remotely
- can operate in real time and respond to inputs very quickly

INPUT DEVICES

- A device that allows data/commands to be entered into the computer system.
- Converts inputs into digital data
- Which can be processed
- Allows users to interact and add new information to the computer

Examples: barcode scanner, QR code scanner, digital camera, keyboard, microphone, optical mouse, touch screen (resistive, capacitive and infra-red), two-dimensional (2D) and three-dimensional (3D) scanners

Barcode scanner

Barcode: Series of dark & light parallel lines of varying thickness to represent data.

Working of barcode scanner

How barcode is read

- Use barcode reader/scanner to scan barcode
- Barcode reader shines red laser/light at barcode
- Light is reflected back: White lines reflect light // Black lines reflect less light/absorb light
- Sensors/photoelectric cells detect light reflected back
- Different reflections form patterns & patterns converted to binary values
- Microprocessor interprets the data
- Uses check digit error checking

How price of a product is found after scanning barcode

- Database stores data about products + prices
- Barcode/value is transmitted to database // Search for barcode/value in database
- ... price is found/returned

How barcode & stock control system automatically keep stock levels above minimum

- Barcode identifies a (unique) product
- Stock control system has a database of stock
- Barcode can be used to look up product in the database
- Barcode is scanned, and product is looked up in database
- Stock levels for product can be automatically deducted (by 1)
- Check if stock is below the minimum level
- If stock at/below minimum level, an order is placed
- When stock is re-ordered flag is reset
- Automatically update new stock level

Library self-checkout system is linked to stock control system. Explain role of microprocessor in stock control system and how it updates the stock

- Receives data from the self-checkout system
- Compares the book data received to stored book data
- ... that is a database of stock
- If the book is found it decrements the book stock by 1
- If the book is not found an error message is displayed

Applications of barcode scanner

Supermarket checkout

- read barcodes to find prices, description
- faster checkouts
- allows automatic stock control

Library system
- can track books on loan
- can link books to borrowers using barcoded cards

Airport checkouts: barcodes on luggage to track whereabouts

Advantages of using barcodes
- Quicker to scan
- « rather than type into a system
- Fewer errors
- « no human input
- more detailed tracking information

QR code scanner

QR code: Consists of a block of small squares or pixels used to represent data.

Working of QR code
- Visitor scans the QR code with the camera on the mobile device
- Black squares reflect less light // white squares reflect more light
- Corner squares are used for alignment
- The device captures the light reflected back ...
- ... using sensors
- App is used to read/interpret the QR code
- Each small square/pixel is converted to a binary value
- links to a website/opens a document with information
- can store the QR code to refer to again for the information

How QR code on a ticket can be used to check if a person can enter, and count how many people have entered.
- (explain working of QR code)
- There is a database of valid QR codes
- Data compared to stored values/valid QR codes
    - ... If data matches entry is granted is raised
    - ... If data matches count is incremented
    - ... If data does not match, entry is denied

Applications of QR code
- Advertising products
- Sharing contact details
- Providing promotional codes/train tickets/event tickets
- Storing boarding passes electronically at airports and train stations.

Advantages of QR codes compared to barcodes

- Hold much more information
- Internet addresses can be encoded
- Easier to transmit QR as text messages/ images
- Easier to read; Don't need scanners - can use phone camera
- Fewer errors: may include built-in error-checking systems
- Can be encrypted: greater protection

Disadvantages of QR codes compared to barcodes

- More than one QR format available.
- Can be used to transmit malicious codes:
    - Gain access to personal information
    - fake websites
    - Download viruses on user's computer

Digital camera

Working of digital camera

- Light passes through lens and captured by sensor called charge-coupled device.
- Light is converted to electrical signals
- Electrical signals passed through ADC & image is converted from analogue to digital
- Image is turned into pixels, each having a colour
- Each pixel is given a binary value
- Pixels form a grid (to create the image)
- Pixels are stored in sequence (in a file)
- Metadata is stored (to describe the dimensions/resolution/ colour depth)
- Photo file format e.g. JPEG

Applications of digital camera

- used in smartphones to create high quality digital images
- used in security systems
- they show a preview of the image
- can instantly create image, duplicated & transmitted via bluetooth/ WiFi
- software can be used to edit digital photos

Keyboard

Working of keyboard

- Keyboard has key matrix underneath keys.
- When key is pressed, it presses a switch that completes a circuit.
- This allows current to flow.
- Signals sent to computer to calculate which key was pressed

- Location of pressed key calculated.
- Location of key pressed compared to character map to find binary value for pressed key.

When keys are pressed on a keyboard, the text is converted to binary to be processed by the computer. Describe how the text is converted to binary.

- A character set is used
- ... such as Unicode/ASCII
- Each character has a unique binary value

Applications of keyboard

- Word processor/ spreadsheet/ database: need to key in data manually
- Control room interface: need to manually key in data (e.g. flow speed of liquid)
- They are built into laptops.
- Smartphones and tablets have virtual keyboards

Advantages of using a concept keyboard for orders in restaurants (has flat surface overlaid with images of food)

- Fewer typing errors; one button is pressed to order an item
- Speeds up time to enter an order, because fewer buttons are pressed to complete order.
- May require less training because it is easier to identify an order item from its image rather than typing it.
- Can stop dirt/food from getting in, as there are no keys for dirt/food to get into.

Disadvantages of keyboard

- Slow method of data entry.
- Prone to errors
- Dirt/food can get into keys
- Frequent use can lead to repetitive strain injury (RSI)

Microphones

- Sound causes air to vibrate
- Diaphragm picks up air vibrations and begins to vibrate: creates electrical signal.
- Analogue electric signal converted to digital using ADC.

Applications

- Record music
- Voice recognition system/ dictation: allows computer to recognise spoken words and use them as input to, e.g., a word processor
- Multimedia presentations: allows voice-overs on presentations
- Video conferencing/VoIPU/ telephone calls: allows users to speak to each other

Optical mouse

Mouse

- Uses rolling ball / optical sensor / laser to detect motion
- Movement echoed on screen // moves curser/pointer (on screen)
- Has scroll wheel / Buttons to allow data input

Working of optical mouse

- Shines red light from LED from bottom of mouse onto a surface.
- Light reflects back from the surface into photoelectric cell.
- Photoelectric cell has lens that magnifies reflected light to allow detection of smaller movements.
- Reflected light is converted to a value & transmitted to computer, to determine direction & speed of movement.
- When a button on the mouse is clicked, a microswitch is pressed.
- A USB connection is used to carry the data to the computer.

Benefits of optical mouse over mechanical mouse

- Can work on virtually any surface - no need to have any special surfaces.
- No moving parts, therefore more reliable.
- Dirt cant get trapped in any of the mechanical components.

Scanners

Working of 2D scanner

- Light is shone onto surface of document
- The light is moved across/down/under the document
- The reflected light is captured (using mirrors and lenses)
- The reflections are converted to binary

Applications of 2D scanner

- Creating digital versions of documents/ photographs
- Reading passports at airports

<u>Application of 2D scanners at airport - to read passports</u>

- Uses optical character recognition (OCR)
- OCR reviews images and selects text part
- 2D photograph in passport is scanned and stored as JPEG image

<u>How computer checks if image of face taken by camera matches scanned photograph on passport</u>

- facial recognition software/ biometric software used to scan face

- image of face taken by digital camera and converted to digital format
- digital image formed from scanned photo/ biometric data stored in passport
- key features of face checked/ compared

Working of 3D scanner
- Scanners shine a laser across the surface of 3D object, along x, y and z coordinates.
- Dimensions of the object are measured
- Measurements are converted to digital file
- Produces a 3D digital model

Applications of 3D scanner: Used to create 3D models for CAD software

Computed tomographic (CT scanners): Technology that creates 3D image of object by slicing up object into thin layers (tomography).

Touch Screen

Allows users to select / manipulate screen using touch of a finger or stylus.
3 common touch screen technologies:
- Capacitive
- Infrared
- Resistive

Type	Working	Advantages	Drawbacks
Capacitive	- Electrical field is spread across screen - Sensors around screen monitor electric field - When finger touches screen, charge is transferred to finger - « as it is affected by conductivity - Coordinates of touch calculated where charge is transferred	- good visibility in sunlight - high quality image - no need to be calibrated - supports multitouch - requires less pressure - faster response time - if screen shattered, it will still register touch - more longevity	- shatter on impact - cannot use with standard gloves
Infrared	- Infrared rays sent across screen from edge - Sensors around screen to capture beams - Infrared rays form grid	- good visibility in sunlight - high quality image - no need to be calibrated	- shatter on impact - expensive - sensitive to dust/dirt

	across the screen - Infrared ray broken when finger touches - Coordinates of touch calculated where infrared ray is broken	- supports multitouch - requires less pressure - faster response time - if screen shattered, it will still register touch - can use stylus/gloves	
Resistive	- Screen made up of multiple layers - User presses top layer into bottom layer - Layers create a circuit when pushed together - Causing electricity to flow - Coordinates of touch calculated where layers are connected	- cheap - easy to manufacture - can use stylus/gloves - waterproof - less likely to shatter - low power consumption	- Poor visibility in sunlight - Low resolution - don't support multitouch - low response time - Longevity issues - Prone to scratches

Why doesn't a capacitive touch screen work with gloves?

- Gloves are not conductive // Gloves are an insulator
- Block current/charge from finger / body / person
- Stop the electrostatic field being disturbed

How capacitive touch screen can be used while still wearing gloves

- Use a (conductive) stylus
- « this will allow the electrostatic field to be disturbed
- Use capacitive gloves
- « this will allow the electrostatic field to be disturbed
- Use a voice operated interface
- « user can give vocal commands to the device

Applications of touch screen

<u>Mobile telephone/tablet</u>

- allows user to select apps using icons
- easy method to input data

<u>Ticket/information kiosk</u>

- easy method for public to enter data
- limits the options available for ease of use

<u>Control room interface</u>

- faster/ easier method to input data into system
- fewer chances of error since number of choices limited

OUTPUT DEVICES

Allows user to view/hear data that has been entered into a computer system
Examples: actuator, speaker, inkjet printer, laser printer, 3D printer, DLP projector, LCD projector, LED screen, LCD screen

Actuator

- Operated by signals from microprocessor to cause physical movement // Controls movement of a machine.
- Made specifically for a particular function.
- The input of a sensor is checked against stored values. If input is within a certain range, actuator is used to provide movement of a physical object.

Speaker

- take digital sounds and output them as sound waves which can be heard
- digital data is changed into electric current using DAC
- current passed through amplifier to create a large current drive a loudspeaker
- converts current into a sound wave
- Applications: listening to music/video, telephone calls, alarms

Printers

Create hard copies of digital documents.

Inkjet printer	**Laser printer**
<u>Features</u> - moving print head - uses liquid ink - ink sprayed in droplets from nozzles - uses piezoelectric/thermal bubble technology	<u>Features</u> - no moving head - uses toner/powder ink - uses fuser to melt ink onto the paper - uses +ve & -ve charged rotating drums - uses static charge - uses discharge lamp to remove static charge from drum
<u>Applications</u> - slower at printing - suitable for high quality hard copies of digital images/documents - suitable for low volume output	<u>Applications</u> - faster at printing - suitable for high quality, high speed output: e.g. flyers/leaflets/ magazines - suitable for high volume output
<u>Working</u> - Data from document sent to printer driver. - Printer driver ensures data in correct	<u>Working</u> - Data from document sent to printer driver. - Printer driver ensures data in correct

format. - Printer driver ensures printer is online - Data sent to printer & stored temporarily in printer buffer - Sheet of paper is fed - Rollers move paper through printer - Sensors detect if paper is available in paper tray/if paper is jammed - Uses moving print head to print text/image. - Use cartridges / liquid ink - Use of thermal bubble / piezoelectric technology - Nozzles spray ink in droplets onto paper - Paper is advanced so next line is printed, until whole page is printed. - Processes repeated until buffer is empty. - Once buffer is empty, printer sends interrupt to CPU.	format. - Printer driver ensures printer is online - Data sent to printer & stored temporarily in printer buffer - Printing drum given positive charge - Printing drum rotates, laser scans across: remove +ve in some areas. - -ve charge areas produced: match with text & images to be printed. - Printing drum is coated in +ve charge toner which sticks to -ve charge parts of printing drum. - -ve charge sheet of paper rolled over printing drum. - Toner on drum transferred to paper: creates required text and images - Paper goes through fuser which melts toner so it fixes permanently to paper. - Discharge lamp removes all charge from drum; ready to print next page.

Benefits of laser printer

- Faster speed of printing
- Prints whole page in one go
- Can print in high volumes
- Can print duplex / on both sides
- Prints text at high quality
- Cheaper printing cost per page
- Large toner cartridges & large paper trays; many pages printed from one toner cartridge

Drawbacks of laser printer

- Printer is expensive
- Toner cartridge more expensive to buy
- More time to warm-up
- Larger footprint
- Print images at a lower quality
- Can be quite large in size

3D printer

Creates object by building layer upon layer of material.

- produces solid 3D objects/prototypes
- used in CAD

- makes use of tomography/slices of an object
- solid built up in thin layers
- uses resin, powdered metal, paper, plastic

Computer aided design (CAD): software that creates computerised designs for 3D printing.

Applications
- (physical) prototype (from CAD)
- (physical) model (from a blueprint)
- Medical: prosthetic limbs / reconstruction surgery
- Industry: lightweight & precise parts

Projectors

- Used to project computer output onto a large screen.
- Used in presentations and multimedia applications.

Digital light projector (DLP)	**Liquid crystal display (LCD) projector**
<u>Working</u> Uses thousands of tiny mirrors that can move very quickly to create an image. - Uses large number of tiny mirrors - Mirrors laid out in grid/matrix - Each mirror creates a pixel in the image - Mirrors can tilt toward/away from light source - Mirrors reflect light toward a lens - Colour is produced using a colour wheel	<u>Working</u> - Powerful beam of white light generated from LED inside projector. - Beam of light sent to mirror filters to separate image into red, green, blue. - 3 images are recombined using prism - Image passes through projector lens onto the screen.
<u>Benefits</u> - Higher contrast ratios - Compact/ light - Portable - Better suited to dusty/smoky atmosphere - Higher reliability/longevity	<u>Benefits</u> - Higher resolution - Higher colour contrast / more vivid - Colours more accurate - Does not give rainbow effect like DLP - Image appears brighter - Longer lasting lamps - Lesser cost - Runs quieter - Uses less power - Produces less heat - Any surface can be used as display - Used when the projector does not need portability of DLP/ when it is stationary - Used when projector does not need

	compactness of DLP
Drawbacks - Lower resolution/ colour contrast - Gives rainbow effect - More expensive - Uses more power - Produces more heat	Drawbacks - Lower contrast ratios - Not light/compact - Colours degrade over time/ turns yellow - Limited longevity

Screens

Light emitting diode (LED) screen	**LCD screen**
	- Liquid crystal display - Uses light-modulating properties of liquid crystals - Uses a flat panel display
Working - Display made of tiny LEDs - Each covered in red, green or blue filter - Brightness of each LED controlled by varying input voltage - To achieve desired color & brightness - True black can be achieved (unlike LCD)	Working - Display is made up of pixels - Pixels arranged together as a matrix - Each pixel formed of 3 RGB filters - LED at back of screen; back-lit - Light shone through crystals - Diffuser to distribute light evenly - Crystals turned between opaque and transparent (to allow light to pass) - Filters are mixed to create different shades of colours
Benefits - Has bright colours / high resolution - Reaches maximum brightness quickly - Greater longevity/ more reliable - Screens can be small/compact/thin - Consume less power / energy efficient - Runs at a cool temperature - Can operate in cold conditions - Mercury free technology // environmentally friendly	Benefits - Bright image colours/ high resolution - Do not suffer image burn - Do not suffer flicker issues - Low power consumption - Runs at cool temperature - Cheaper than LED screens

DATA STORAGE

Primary memory	**Secondary storage**
Directly accessible by CPU.	Not directly accessible by CPU.
Internal to computer	Can be internal or external to computer
Could be volatile or non-volatile	Non-volatile
Stores boot up instructions and can hold data whilst being processed	Stores files/software
Smaller capacity/ stores lesser data	Larger capacity/ stores more data
Faster access speed // read-write speed	Slower access speed // read-write speed
RAM, ROM	HDD, SSD

Volatile memory: memory that loses its contents when the device is powered off.

PRIMARY MEMORY

- It is directly accessible by the CPU
- It is RAM ...
- ... which is volatile storage
- It is ROM ...
- ... which is non-volatile storage

Random Access Memory (RAM)	**Read Only Memory (ROM)**
Temporary	Permanent
Volatile	Non-volatile
Read/write operations; can be edited	Can only be read from; cannot be edited
Normally has larger capacity	Normally has smaller capacity
<u>Examples of data stored in RAM</u> - Data that is currently in use - Programs that are currently in use - Parts of OS that are currently in use - Currently running application software - Currently running utility software	<u>Examples of data stored in ROM</u> - Start-up instructions - BIOS - Firmware

Why laptop and calculator have ROM

- they both need to store boot-up instructions
- they both need data that should not be deleted

NOTE: cache is a type of primary memory

- It stores frequently/recently used instructions and data
- has faster read/write speeds than RAM

SECONDARY STORAGE

Purpose of secondary storage

- For non-volatile/permanent/long-term storage
- To store the OS/ software/ files/data
- To store data that is not currently required by the CPU
- To store data to transfer it to another computer

Why secondary storage is needed for computer to work

- Data can be permanently stored
- ... meaning that (application) software can be loaded/retrieved
- ... meaning that operating system can be loaded/retrieved
- ... meaning that user data/files can be accessed/retrieve

Types of storage devices / secondary storage

- Magnetic:Hard disk drive/HDD
- Solid state: Solid state drive/SSD
- Optical: Offline storage/CD/DVD

Magnetic Storage - Hard Disk Drive (HDD)

- Storage device has platters
- Platters/disk divided into tracks and sectors
- Uses magnetic fields to control magnetic dots of data
- Magnetic field determines binary value
- Storage platter / disk is spun
- Has a read/write arm that moves across storage media
- Read/writes data using electromagnets

Features of magnetic storage

- Data is stored on platters
- (Platters) are divided into tracks and sectors
- Has components that are spun
- Data is read/written using a read/write arm
- Data is read/written using electromagnets
- Magnetic field determines the binary value
- It is non-volatile

Advantages of HDD / magnetic storage

- HDD is cheaper for larger amounts of storage space
- « affordable and greater value
- HDD has greater longevity for read // can perform more read/write cycles
- « likely to be a lot of read/write functions each day
- Trusted technology
- « it has been traditionally used for many years

Why HDD is used in web servers

- Read/write speed is sufficient
- « even though it is slower than SSD
- HDD has greater longevity for read/write functions
- No requirement for portability
- « as a server, it does not need to be moved
- HDD is cheaper for larger amounts of storage space
- HDD is trusted technology

Solid State Drive (SSD)

- Uses flash memory / flash storage
- Has no mechanical/moving parts
- Stores data by flashing it onto (silicon) chips
- It is a type of EEPROM technology
- Uses NAND/NOR technology
- Uses control gates and floating gates
- Uses transistors that are laid out in grid
- The transistors & control gates/ floating gate are used to control the flow of electrons
- Electric current reaches control gate and flows through to floating gate to be stored
- When data is stored the transistor is converted from 1 to 0 / 0 to 1
- Writes (and reads) sequentially

Features of solid state storage

- Flashes data onto chips
- Uses transistors
- Uses NAND/NOR technology
- Uses control gates
- Uses flow gates
- Controls the flow of electrons
- It can be volatile or non-volatile

Software that can be stored on SSD

- Operating system
- Application software
- Utility software

Advantages of SSD - why it is suitable for mobile devices

- Has no moving parts, so more durable // robust when dropped
- Small in size // compact // lightweight // portable
- Faster read/write operations // faster data access speed
- Less latency // takes less time to warm up // don't need to "get up to speed"
- High capacity // can hold large amounts of data (for videos, etc.)
- Has low power consumption // energy efficient // battery will last longer
- Produces less heat // runs at cool temperature
- Runs quietly
- Less susceptible to interference/magnets // not affected by magnets

Other examples of solid state storage

- SD card
- USB flash memory drive
- Random access memory // RAM

HDD	**SSD**
Has moving parts	Does not have moving parts
Uses magnetic storage	Uses flash memory
Slower data access speed; greater latency	Faster data access speed; no latency
Creates noise/ heat	Runs quieter/cooler
Higher power consumption	Lesser power consumption
Greater longevity/more read-write cycles	Lower longevity/limited number of read-write cycles
Larger & heavier	Smaller & lighter
Normally cheaper for the same capacity of storage as SSD	Normally more expensive

Similarities between HDD and SSD

- 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

Storage devices that can be used to store copy of files (reasons for why they're used)

HDD

- Large capacity storage: For videos 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
- Relatively cheap per GB // cheaper than SSD per GB: A large capacity is required, therefore overall cost is less than other devices.
- Device will not be moved regularly so no need for portability/durability

SSD

- Large capacity storage: For videos 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): A large capacity is required, therefore overall cost will not be significantly more than others.
- Copies of files may not be accessed regularly: Thus the limited number of read/write times/longevity doesn't pose any consequences
- Uses less power // runs cooler
- No latency // does not take time to start-up

Identify which type of storage would be most suitable to use in web server + explain

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

Differences between primary and secondary storage

- Primary storage is directly accessible by the CPU
- ... whereas secondary storage is not directly accessible by the CPU
- Primary storage stores the data that is currently in use/for booting the
- system
- ... whereas secondary storage stores user's files/data/operating system/application software
- Primary storage normally has a small capacity
- ... whereas secondary storage normally has a larger capacity
- Some parts of primary storage are volatile
- ... whereas secondary storage is non volatile
- Some parts of primary storage the data cannot be changed
- ... whereas data in secondary storage can be changed
- Primary storage has faster access speeds to data
- ... whereas secondary storage has slower access speeds to data

Optical Media - Offline Storage

- Non-volatile
- Not directly accessed by the CPU
- Removable from a computer/device // Can be easily disconnected from computer // not internal // portable
- Data is written and read with a laser
- Purpose: To store files / applications as backup

Offline storage devices that could be used to transport files

- USB flash memory drive
- External HDD/SSD
- SD Card
- CD / DVD / Blu-ray

Applications of offline/optical storage

- To store files/ applications as back-up
- To transfer files between computers
- To supply software
- DVD and Blu-ray: supply of movies and games.

CD	**DVD**	**Blu-ray**
Red laser	Red laser	Blue laser

Longest wavelength laser	Shorter wavelength laser	Shortest wavelength laser
Can only be single layer	Can be dual layer	Can be single or dual
Spun slower	Spun faster	
Slower data transfer rate	Higher data transfer rate	Highest data transfer rate
Track pitch (distance between tracks)- greatest.		Track pitch is least.
Larger pit size and track width, thus less storage capacity.	Smaller pit size and track width, thus larger storage capacity than CDs.	Very small pit size and track width, thus largest storage capacity.
no built-in encryption system	no built-in encryption system	built-in secure encryption system

Similarities between CD & DVD

- Both are optical storage
- Both are off-line storage // both are non-volatile
- Both use spiral tracks for data
- Both use pits and lands to store data
- Both need a red laser to read/write data
- Both are spun to be read
- Can be read only (R) or read write (RW)

Differences between DVD-R and DVD-RAM

- DVD-R has one spiral track; DVD-RAM has several concentric tracks
- DVD-RAM can be written to and read from at the same time; DVD-R only allows the read operation to occur
- DVD-R only allows data to be read (can't write to it) whereas DVD-RAM allows reading and writing operation

Explain how data is written to optical storage media

- The disc is rotated/spun
- Laser beam is shone at disc
- An (arm/head) moves the laser across the surface of the disc
- 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

Describe how data is read from optical storage media

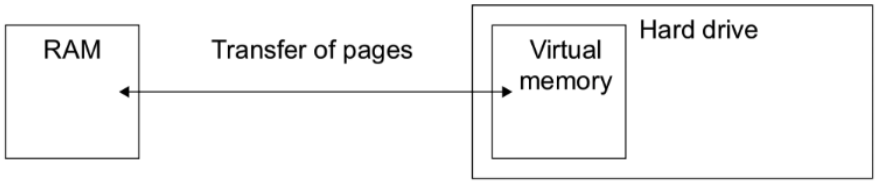
- The disc is rotated/spun
- Laser beam is shown onto surface of the disk
- Surface is covered in a single spiral track / concentric tracks
- Data is represented on the surface using pits and lands
- Pits and lands represent binary values
- The laser is used to read the pits and lands on the surface of the disk
- Pits reflect light back differently from lands
- Reflected light is captured by a sensor and binary value determined

VIRTUAL MEMORY

- The hard drive is partitioned to create virtual memory
- When RAM is full
- … pages of data that are not required …
- … are transferred from RAM to virtual memory
- When the data is required again the pages are transferred back to RAM

Diagram to represent how virtual memory is created and used

- 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.



A computer has pages A, B and C that are stored in RAM. Page D needs to be sent to the RAM but the RAM is full. Page B is not needed immediately. Explain how virtual memory can be used in this scenario.

- The secondary storage / hard drive can be partitioned to create the virtual memory
- … and page B sent to the virtual memory
- … which makes space for page D in RAM
- … Once page A / C / D has been processed/ is not required it is sent to virtual memory
- … page B can be sent from the virtual memory back to RAM when it is required

Why virtual memory is needed when creating 3D models using software

- to extend the RAM capacity
- …to stop 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.

Benefits of virtual memory

- Extends the RAM capacity: Reduces the need to buy and install more expensive RAM memory
- Helps the system process large amounts of data
- Programs can be larger than physical memory, and still be executed: prevents software from crashing, if data exceeds the maximum capacity in RAM
- No need to waste memory on data that isn't being used

Drawback of virtual memory: Accessing data in virtual memory is slower

CLOUD STORAGE

- Storage consisting of physical servers // a collection of servers
- Data is stored in a remote location // can be accessed remotely (rather than locally)
- Data is often maintained/backed up by a third-party company
- Data is accessed using an internet connection/network
- Data is accessible using a web browser / dedicated software

Advantages of cloud storage compared to storing it locally

- Accessibility
  - Data can be accessed from anywhere
  - Data can be accessed by anyone with permission: easy to share files & collaborate
  - Data can be accessed on any device with an internet connection
- Scalability: Allows customers to increase/ decrease storage capacity as needed
- Reliability: Multiple servers to store & backup data - reduces risk of data loss due to hardware failure
- Security
  - Offers advanced security features like data encryption & multi-factor authentication to protect user data from unauthorised access.
  - No need to hire specialist staff as IT services are provided by cloud storage provider

Advantages for company owners of storing data in cloud storage (explain)

- The data can be accessed from any location
- … meaning that employees can work from anywhere with a connection
- The hardware is owned/maintained by a third party
- … meaning that the company are not responsible for maintaining // meaning the company aren't responsible for its security
- Can increase the storage needed easily
- … without needing to buy new hardware
- Do not need to house the hardware needed
- … costs can be saved on the space saved for this

- Cloud system will back up the data
- … meaning the company does not need to do this

Disadvantages of storing photos in cloud storage instead of storing them locally

- May be less secure / data could be intercepted
- May lose access to them if internet connection lost/not available
- Could incur an extra/ongoing fee/cost
- Reliant on a third party maintaining the hardware
- User doesn' have complete control but is legally responsible for ensuring data is secure

Disadvantages for company employees of storing data in cloud storage (explain)

- Internet connection is needed/needs to be stable …
- … and if this is not available/unstable the data cannot be accessed
- Employees could be pressured to work outside of hours …
- … as they can access the data from any location

NETWORK HARDWARE

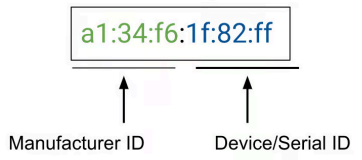
Network Interface Card (NIC)

The component in a computer/device that enables it to connect to/access a network.

- Primary function: send & receive data packets between computer/ device and network.
- Has built in ethernet port: can be connected to the network via Ethernet cable.
- Wireless Network Interface Cards (WNIC) allow device to wirelessly connect to network.
- NIC converts data into signals so it can be sent.
- Through wired network, the signals are voltages through ethernet cable/ pulses of light through fibre
- Through wireless network, the signals are radio waves

MAC address	**Internet Protocol (IP) address**
- Unique address - Used to uniquely identify a device - Assigned to device/ NIC by manufacturer - Doesn't change; static address	- Unique address - Uniquely identify device on a network - Public IP address assigned by ISP; private IP address assigned by router - Can be static or dynamic - Can be public or private - Can be IPv4 or IPv6
- First part is the manufacturer ID - Second part is the serial number	- It contains the network prefix - And the host number

NOTE: public IP addresses are usually static, and private IP addresses are usually dynamic.

MAC	IPv4	IPv6
Represented in hexadecimal	Represented in denary	Represented in hexadecimal
6 bytes long (48 bits)	4 bytes long (32 bits)	16 bytes long (128 bits)
6 groups (pairs) of digits	4 groups of digits	8 groups of digits
Can have numbers between 00 and FF in each group	Can have numbers between 0 and 255 in each group	Can have numbers between 0000 & FFFF in each group
Separated by colon	Separated by dots	Separated by colon
	All 0s displayed	Use double colon (::) to replace repeated groups of 0000
	Has fewer available unique addresses	Has more available unique addresses

Static IP address	Dynamic IP address
Permanently assigned to device by ISP.	Assigned by router each time device logs onto internet.
Don't change each time the device connects to the network.	Changes each time the device connects to the network.
Less privacy: device fully traceable.	Greater privacy since they change each time the user logs on.

Similarities between MAC address & IP address

- They are both unique addresses
- They can both be used to identify a computer/device (on a network)
- They are both assigned to hardware
- They can both be represented as hexadecimal
- Both addresses do not change (if IP address is static)

Differences between MAC address & IP address

- A MAC address is assigned by the manufacturer, whereas an IP address is assigned by the network/router/ISP
- A MAC address is normally static/cannot be changed, whereas an IP address can be dynamic/can be changed

- A MAC address is represented as hexadecimal, whereas an IP address is sometimes represented as denary (IPv4)
- A MAC address has 6 groups of digits, whereas an IP address has 4/8 groups
- A MAC address is 6 bytes (48 bit), whereas IP address is 4/16 bytes (32/128 bit)
- IP address does not contain serial number/manufacturer number, MAC address does

Routers

- A device that sends data to a specific destination on a network // forwards packets to their correct destinations in a network.
- A router can assign IP addresses.
- A router can connect a local network (LAN) to the internet (WAN)
- Router being used to connect LAN to WAN will have public IP address, assigned by ISP.
- This public IP address is identified by other routers & direct packets to the network.