A-level
Computer Science

Data storage

Lesson Objectives

Students will learn about:

- RAM and ROM
- Different types of storage devices
- How data is stored and retrieved in these storage devices
- Usage of each type of storage device
- Choosing a storage device

1.

Content

Memory

- Memory is the space where data and programs are stored. Data in memory is accessed through instructions from the CPU.
- Memory in a computer system is classified into primary and secondary memory.

Types of memory

Primary memory

Primary memory is a type of memory that is accessed directly by the CPU. For example: RAM, ROM and cache.

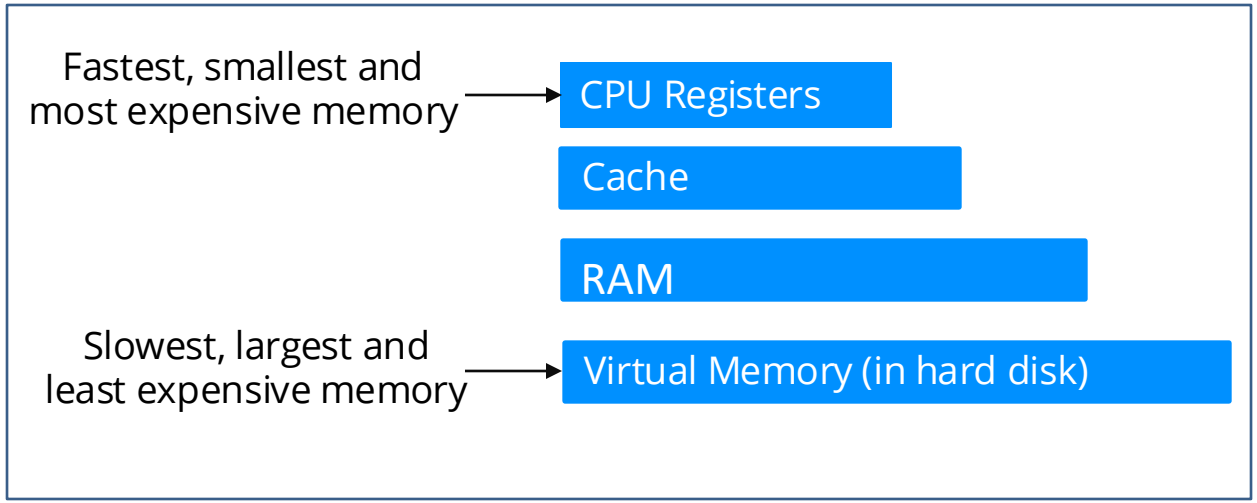
Secondary memory

Secondary memory refers to external storage devices such as hard drives, CDs, flash drives, etc.

Primary memory

- The various primary memories available in a CPU are listed below in order of its closeness to the CPU:
  i. Registers
  ii. Cache
  iii. RAM
  iv. Virtual Memory
- But, the closer the memory type, the more expensive it is.
- The closer the memory type, the faster the access is.

Primary memory



Latency

- Latency is the time taken by components to respond to a request.
- To avoid short delays between the CPU’s request for data and finding the data in the memory, some instructions and data are copied to the cache.

Random access memory (RAM)

- RAM is a temporary memory which stores data, files and parts of the operating system that is currently in use.
- When a program is loaded from the hard drive, all its contents, such as its instructions and data, are loaded to the RAM and the CPU accesses this information. It is also called the main memory.
- Used by the operating system, applications and any data that are currently used.
- The access time for a CPU to access any data from the RAM is less when compared to accessing data from a hard drive.
- The larger the size of RAM, the faster the computer operates.

Random access memory (RAM)

- Buffers also use RAM.
- When the power is lost, the contents of RAM are lost.
- The contents of RAM can be read from, written to, and changed.
- Each memory location in RAM has a unique address.

Types of RAM

Dynamic RAM (DRAM)

DRAM consists of transistors that act as switches and capacitors that hold binary data.

DRAM has to be constantly refreshed (every 15 microseconds) to maintain the charge in the capacitor.

DRAM is used for main RAM memory.

Static RAM (SRAM)

SRAM uses ‘flip-flops’ which hold each bit of memory.

SRAM need not be refreshed constantly. SRAM is faster than DRAM.

SRAM is used in cache memory.

SRAM is more complex to build than DRAM and is therefore more expensive.

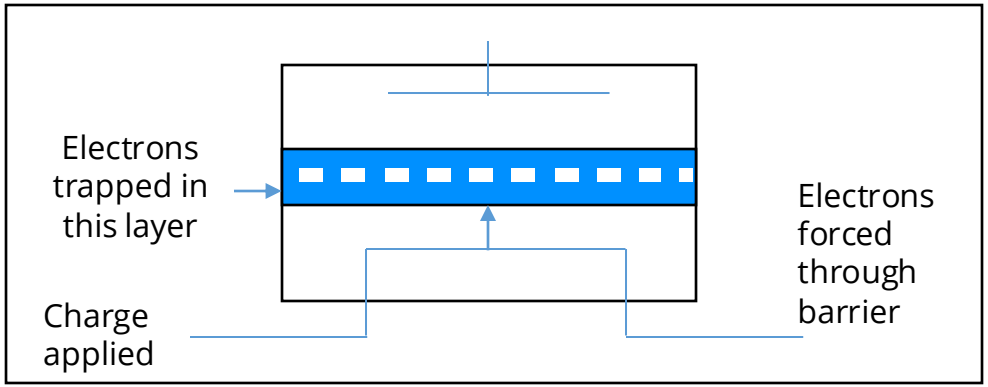
Due to the complex design and more transistors and additional wiring required in SRAM, it offers smaller capacity compared to DRAM.

Read only memory (ROM)

- Read Only Memory (ROM) is a permanent memory that is used to store the instructions that are executed once the computer is switched ON. This set of instructions is called a boot process.
- This is responsible for initialising the hardware and operating system soon after the power is switched ON.
- The contents of ROM are not erased, even when the power is switched OFF.
- The contents of ROM can only be read and cannot be changed.
- ROM is made by interconnecting several transistors. It is an example for non-volatile memory.
- firmware

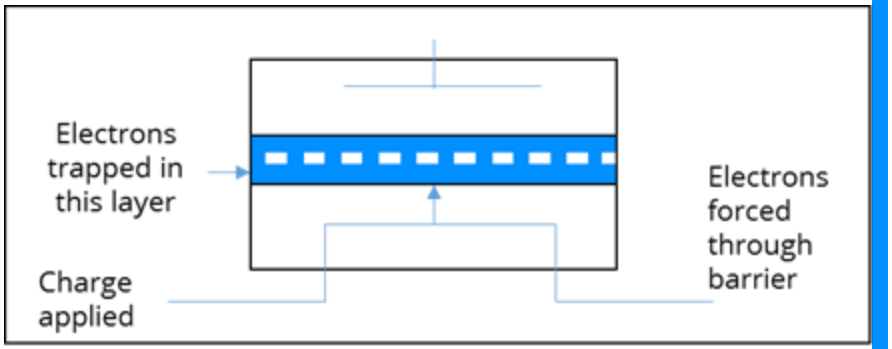
Flash memory

- Flash memory is a type of ROM. It is programmed by applying a slightly larger electric current that forces an electron through a barrier.



Flash memory

- Once the electrons cross this barrier, they get stored in a layer.
- The electrons can then be detected without affecting its position.
- As a flash of current is used to store data, it is called flash memory.
- Flash memory is also rewritable.



Storage devices

Need for storage devices

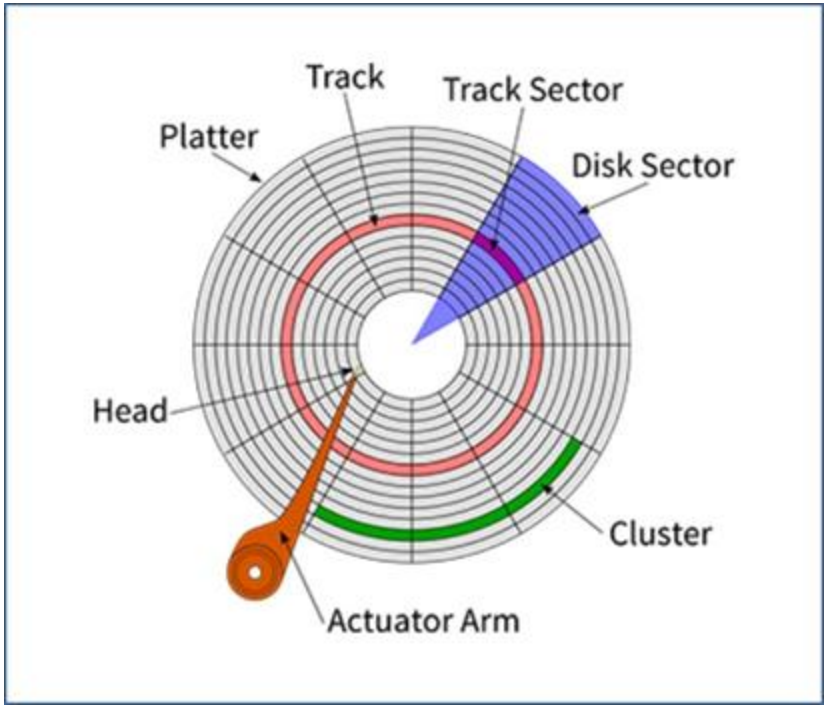
- Users need storage devices to store media and other files that require large amounts of space.
- This problem is solved by storage devices that work based on magnetic, optical and solid-state principles.

Hard disk drives (HDD)

- Hard disk drives, also called magnetic disk drives, are used in computers and laptops.
- It provides high storage capacity and is cost-effective.
- Large storage facilities also use this technology.
- In a computer, it stores the operating system, installed programs and user’s data.
- External hard disks are available to store data that are not frequently used or to back-up important information.

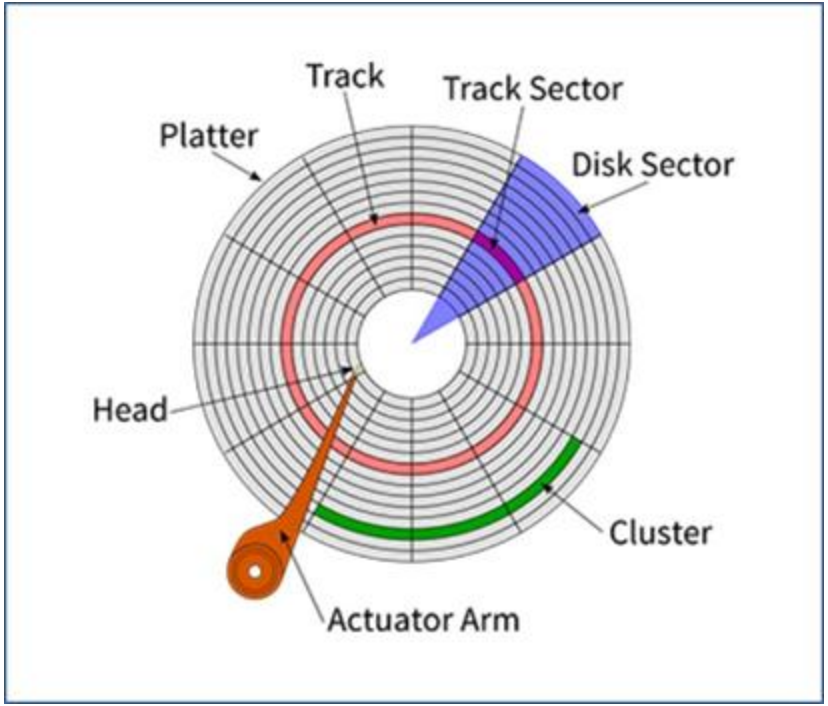
Hard disk drives

- The disk is made of a magnetic surface, which is known as a platter.
- Digital data is stored in these magnetic platters.
- This disk can spin at about 7000 revolutions a second.
- Data can be accessed by a number of read-write heads on the surface.



Hard disk drives

- The read-write heads move from the centre of the disk to the edge of the disk (and back again) 50 times a second.
- The data is read/written using magnetic properties.
- The disk is divided into various sectors and tracks.
- Each sector in a track can store a specific number of bytes.



Latency of HDD

- The access time of a hard disk drive is high compared to RAM. This is due to a large number of head movements.
- Latency is defined as the time taken for a specific block of data to rotate around to the read-write head.
- The effect of latency becomes significant when a user receives messages such as ‘not responding’ and ‘please wait’.

Solid-state drives (SSD)

- The latency is reduced in SSD compared to HDD as there is no read/write head that needs to be moved.
- Data is stored and retrieved using the electronic properties in NAND chips.
- This type of memory is used in USB devices to transfer information from one device to another. This is a type of solid-state device. Solid-state drives are a larger version of flash memory.

Solid-state drives

- Digital data is stored in millions of transistors within the chip.
- An SSD is a non-volatile rewritable memory.
- These are used in portable devices such as tablets and mobile phones.

Hard disk drives	Solid state drives
Use magnetic properties to read/write data	Use electronic properties of NAND/NOR chips
Heat is produced due to movement of read-write heads moving to fetch data	No moving parts so it runs cooler
Heavy	Lighter and used in tablets
More power consumption compared to SSD	Lower power consumption
Noise due to a spinning disc	Silent as no moving parts
Less reliable, as the moving parts could break	Highly reliable, as no moving parts
HDD can be used for a long time. Widely used in servers where huge numbers of operations take place every day.	SSD has limited read-write operations for a limited period of time. For example: 20 GB write operations in 3 years for early SSDs. Hence, cannot be used in servers.
HDD can store up to 5TB	SDD can store up to 512 GB

HDD or SSD?

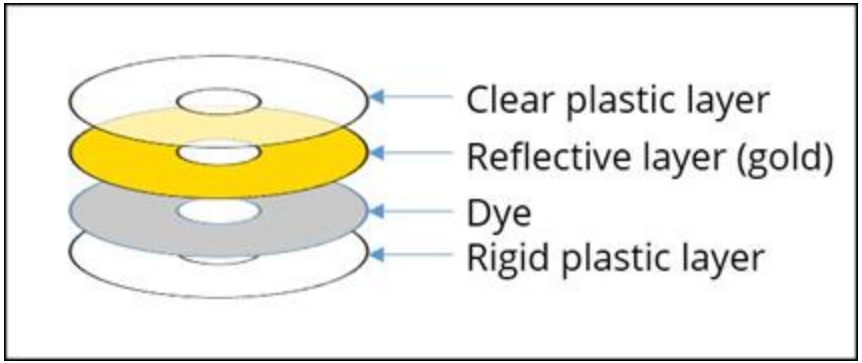
- A computer system has various applications with different requirements. Some applications need faster access time.
- A SSD can improve the access time but it is expensive compared to HDD.
- Therefore, a combination of both is provided in a system.
- Applications that require high performance are loaded into an SSD and those that are not frequently used are stored in an HDD.

Optical Storage Systems

- CD, DVD and Blu-ray discs use optics to store data.
- The surface of CDs and DVDs are made of light-sensitive organic dyes or metal alloys.
- Data is read and written using laser light.
- DVDs (4.7GB) can store large amounts of data compared to CDs (800 MB).
- Blu-ray discs use blue laser light and can hold up to 50 GB. These optical storage systems are used to store music, movies and games.

Optical Storage systems

- The clear plastic layer on the surface allows the laser light to pass through it.
- The colour changes in the dye layer when light falls on it.
- This change in colour is reflected and is detected by the computer while the data is read.



Types of optical devices

Read-only:

The data can be written only once at the manufacturing stage.

For example: programs, movies, and songs distributed by its producers.

Read/write:

Read/write optical devices are used as external storage devices to transfer data from one device to another.

Optical Storage systems

- The time taken to transfer data in these devices is comparatively higher than flash memory.
- These devices are still widely used for transferring large files such as back-ups and programs, due to its robust nature and cost-effectiveness.

Calculating the required capacity

- A user has to consider the size, number and types of files while deciding on the storage device.
- A text file occupies only a few kilobytes of space but a video occupies up to several gigabytes.

File type	Approximate size
A page of processed word document without images	100 KB
Photograph (postcard-size)	6 MB
MP3 music track (3 minutes)	6 MB
MPEG video (1 minute)	50 MB
DVD film	4 GB
Blu-ray film	20–25 GB

Calculating the required capacity: Example

Estimate the total size of the following files and choose a suitable storage device.

a) 10 minutes of music at 10 MB/min

b) 7 minutes of video at 50 MB/min

c) 8 photographs at 6 MB/photo

File type	Approximate size
A page of processed word document without images	100 KB
Photograph (postcard-size)	6 MB
MP3 music track (3 minutes)	6 MB
MPEG video (1 minute)	50 MB
DVD film	4 GB
Blu-ray film	20–25 GB

Calculating the required capacity: Solution

Estimate the total size of the following files and choose a suitable storage device.

a) 10 minutes of music at 10 MB/min

b) 7 minutes of video at 50 MB/min

c) 8 photographs at 6 MB/photo

The total space required is 547.8 MB and this would fit into a CD. This could also be transferred from one device to another using a flash drive.

File	File size
10 minutes of music	100 MB
7 minutes of video	350 MB
8 photographs	48 MB
Total file size	498 MB
extra 10 % space for overheads	49.8 MB
Total space required	547.8 MB

Choosing a storage device

The various parameters considered for choosing a storage device are:

a) Capacity

b) Speed

c) Portability

d) Durability

e) Reliability

Choosing a storage device

The various parameters are:

a) Capacity
b) Speed
c) Portability
d) Durability
e) Reliability

The total space required for all the files and overheads needs to be calculated and, according to this required capacity, a storage device has to be selected.

Choosing a storage device

The various parameters are:

a) Capacity
b) Speed
c) Portability
d) Durability
e) Reliability

According to user's requirements regarding speed, device can be selected.

Storage device	Transfer rate
RAM	12-20 GB/s
SSD	200-550 MB/s
Magnetic hard disk	50-120 MB/s
Blu-ray disc	72 MB/s
USB flash drive	45-90 MB/s
DVD	1.32 MB/s
CD	0.146 MB/s

Choosing a storage device

The various parameters are:

a) Capacity
b) Speed
c) Portability
d) Durability
e) Reliability

For data that needs to be portable, it is important to choose a device with less weight and size. In cases where the data is to be distributed, the cost of the device must be considered too. For example: film, music and software.

Choosing a storage device

The various parameters are:

a) Capacity
b) Speed
c) Portability
d) Durability
e) Reliability

It is also important to look at the robustness of the storage device to make sure that the data is protected from external damage. Some applications require devices to operate under extreme conditions.

Choosing a storage device

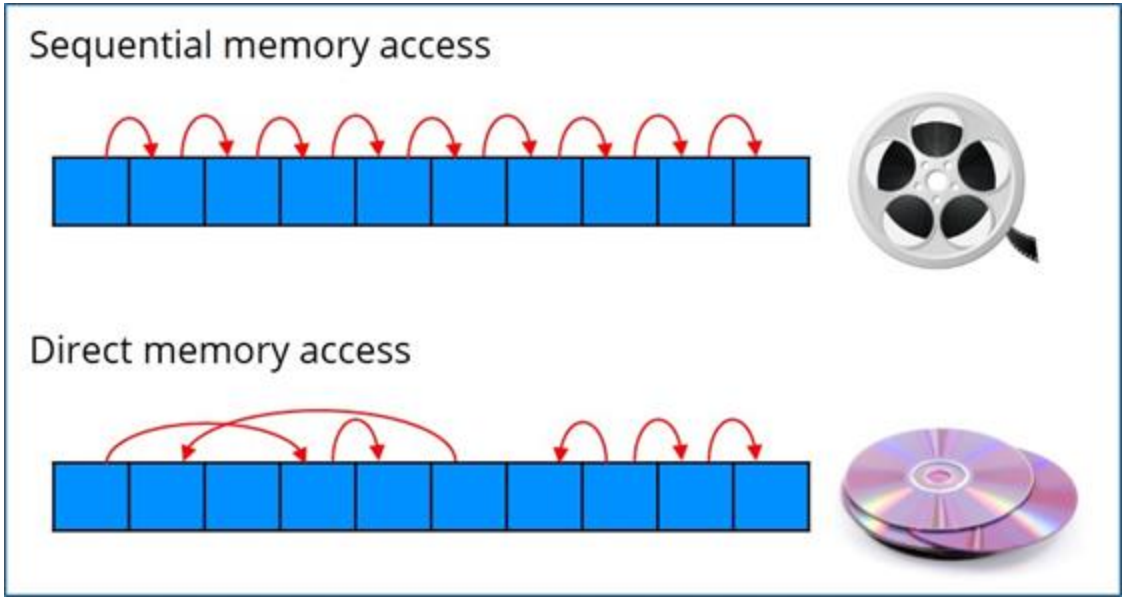
The various parameters are:

a) Capacity
b) Speed
c) Portability
d) Durability
e) Reliability

Storage devices must enable us to operate it many times without causing errors or failure.

Types of memory access

Memory can be accessed directly or sequentially.



Types of memory access

Direct memory access:

Any storage location can be accessed at any moment – such as a DVD.

Sequential memory access:

Allows the user to access data one by one in a sequence.

Sequential memory access is slower than direct memory access.

For example: film reel or video tape.

Let’s review some concepts

Memory

Memory is the space where data and programs are stored. Data in memory is accessed through instructions from the CPU.

Primary memory

Primary memory is a type of memory that is accessed directly by CPU.

DRAM

Dynamic Random Access Memory. A type of RAM, made of transistors and capacitors, and has to be constantly refreshed.

RAM (Random Access Memory)

RAM is a temporary memory which stores data, files and parts of the operating system that is currently in use.

ROM (Read Only Memory)

Read Only Memory (ROM) is a permanent memory that is used to store the instructions that are executed once the computer is switched ON.

SRAM

Static Random Access Memory. A type of RAM, made of ‘flip-flops’ and need not be constantly refreshed.

Let’s review some concepts

Hard disk drives

Data is stored and retrieved using magnetic properties.

It stores the operating system, installed programs and user’s data.

Solid-state drives

Reduced latency compared to HDDs.

Data is stored and retrieved using the electronic properties in NAND chips.

Optical Storage Systems

The surface of these devices are made of light-sensitive organic dyes or metal alloys. Data is stored and retrieved using optics.

Parameters to choose storage device

Capacity
Speed
Portability
Durability
Reliability

Direct memory access

Any storage location can be accessed at any moment.

Sequential memory access

Allows the user to access data one by one in a sequence.

2.

Activities

Activity-1

Duration: 10 minutes

1. Complete the table below with the keywords given in the box.

Non-volatile	Volatile	Boot process	Programs and data currently in use

	Is?	Stores?
RAM		
ROM		

Activity-1

Duration: 10 minutes

2. Arrange the following primary memories in the order of increasing access time.

Hard disk	CPU registers	RAM	Cache

Activity-2

Duration: 10 minutes

1. Estimate the total size of the following files and choose a suitable storage device.
   a) 5 minutes of music at 10 MB/min
   b) 8 minutes of video at 50 MB/min
   c) 12 photographs at 6 MB/photo

Activity-3

Duration: 15 minutes

1. Complete the table with the application of each storage device.

Storage device	Application
Hard dish drive	
Solid state drive	
Flash drive	
CD-ROM	
DVD-ROM	
CD-RW	
Blu-ray disc	

3.

End of topic questions

End of topic questions

1. Why is some data copied to the cache memory?
2. What is the difference between the basic operation of RAM and ROM?
3. What does RAM contain?
4. What does ROM contain?

End of topic questions

5. Why do computers need storage devices apart from primary memory and ROM?
6. What is the principle behind the functioning of hard disk drives?
7. What are solid state drives? What are its advantages over hard disk drives?
8. What are the different discs available to a user in optical storage systems? What is the memory available within each type?

End of topic questions

9. How is data read from a CD-RW?
10. Why do people use flash drives for basic file transfers rather than a CD?
11. What are the various parameters considered when choosing a storage device?
12. How is accessing memory in DVDs different from video tapes?