SANKALCHAND PATEL UNIVERSITY

FACULTY OF COMPUTER SCIENCE

SHRI C.J. PATEL COLLEGE OF COMPUTER STUDIES

(BCA)

Subject Code: 1CS1010103

Subject Title: FUNDAMENTALS OF COMPUTER ORGANIZATION

UNIT-3

Working Principles of Memory and Storage Devices
Understanding the principles of Main/Cache memory, Primary/Secondary memory, Physical/Virtual memory
Magnetic memory - Magnetic Tape, Hard disk, Floppy disk
Semiconductor memory - RAM, ROM, Flash memory
Optical memory - CD, CD-ROM, CD-RAM, DVD, DVD-ROM, DVD-RAM
Binary classification of codes - 8421 BCD code, Excess-3(XS-3) code

Memory :-

Memory is the brain of the computer which stores data and information for storing and retrieving. Just like a human brain, memory is the storage space of the computer – like a physical device – that is capable of storing data or programs temporarily or permanently.

Memory is a fundamental component of the computer that is categorized into primary and secondary memory.

(1) Primary memory is the main memory of the computer which can be directly accessed by the central processing unit

(2) Secondary memory refers to the external storage device which can be used to store data or information permanently.

Primary Memory :-

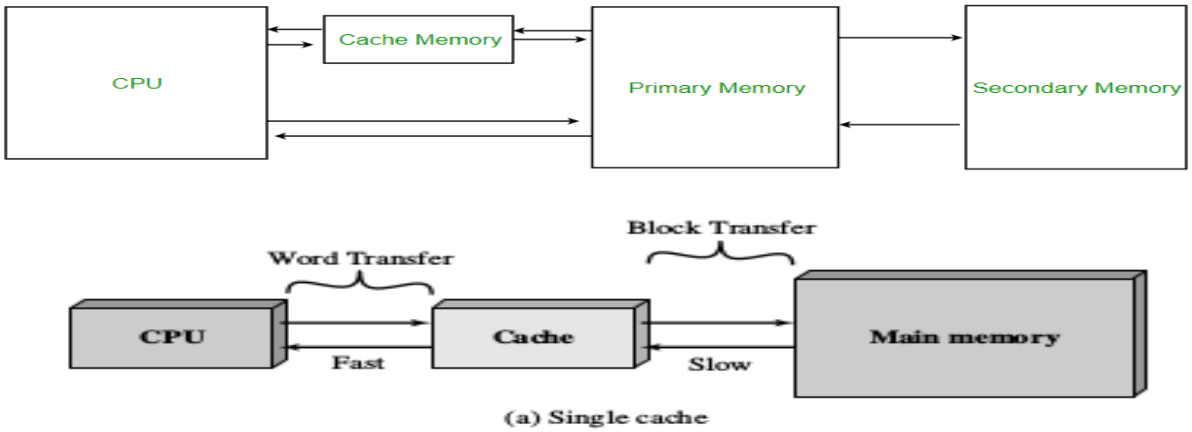
- Primary memory, also known as the main memory, is the area in a computer which stores data and information for fast access.
- Semiconductor chips are the principle technology used for primary memory. It's a memory which is used to store frequently used programs which can be directly accessed by the processing unit for further processing. It's a volatile memory meaning the data is stored temporarily and is liable to change or lose in case of power failure.
- In simple terms, data is intact as long as the computer is running and the moment it's off, data is lost. Every application on the computer first loads into the random access memory (RAM) which makes is faster to access. The term is more ambiguous, since it also refers to internal memory such as internal storage devices.

Secondary Memory :-

- On the contrary, secondary memory is the external memory of the computer which can be used to store data and information on a long-term basis.
- It's a non-volatile memory which means data stays intact even if the computer is turned off. Data cannot be directly processed by the processing unit in secondary memory; in fact, it is first transferred into the main memory and then it's transferred back to the processing unit.
- Secondary memory refers to all external storage devices that are capable of storing high volumes of data such as hard drives, floppy disks, magnetic tapes, USB flash drives, CDs, DVDs, etc. It's generally slower than primary memory but can store substantial amount of data, in the range of gigabytes to terabytes.

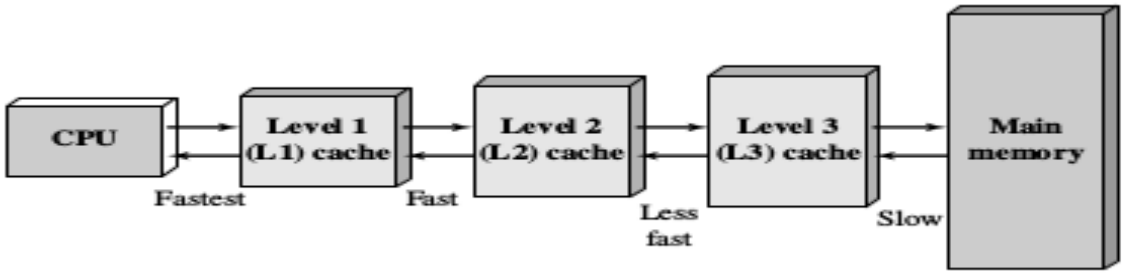
CACHE MEMORY PRINCIPLES : -

Cache memory is intended to give memory speed approaching that of the fastest memories available, and at the same time provide a large memory size at the price of less expensive types of semiconductor memories. The concept is illustrated in figure below.



(a) Single cache

- There is a relatively large and slow main memory together with a smaller, faster cache memory.
- The cache contains a copy of portions of main memory. When the processor attempts to read a word of memory, a check is made to determine if the word is in the cache.
- If so, the word is delivered to the processor. If not, a block of main memory, consisting of some fixed number of words, is read into the cache and then the word is delivered to the processor.
- Because of the phenomenon of locality of reference, when a block of data is fetched into the cache to satisfy a single memory reference, it is likely that there will be future references to that same memory location or to other words in the block.
- Figure below depicts the use of multiple levels of cache.



(b) Three-level cache organization

The L2 cache is slower and typically larger than the L1 cache, and the L3 cache is slower and typically larger than the L2 cache

Difference between Primary and Secondary Memory :-

- **Basics of Primary and Secondary Memory**

  Memory plays a critical part in computers to store and retrieve data. Computer memory is categorized into primary and secondary memory. While primary memory is the main memory of the computer which is used to store data or information temporarily, whereas secondary memory refers to external storage devices that are used to store data or information permanently.

- **Access of Primary and Secondary Memory**

  Primary memory holds only those data or instructions which the computer is currently processing allowing the processor to access running applications and services that are stored temporarily in a specific memory address. Secondary memory, on the other hand, is persistent in nature which means instructions are transferred to the main memory first and then re-routed to the central processing unit.

- **Data in Primary and Secondary Memory**

  In primary memory, data is directly accessed by the processing unit and it resides in the main memory until processing. Information and data are stored in semiconductor chips so they have a limited storage capacity. In secondary memory, information is stored in external storage devices and they cannot be directly accessed by the processing unit.

- **Nature of Primary and Secondary Memory**

  Primary memory is volatile in nature which means data or information stored in the main memory is temporarily which may lead to loss of data in case of power failure and it cannot be retained. On the contrary, secondary memory is non-volatile in nature which means information is stored permanently with no data loss in case of power failure. Data is intact unless the user erases it intentionally.

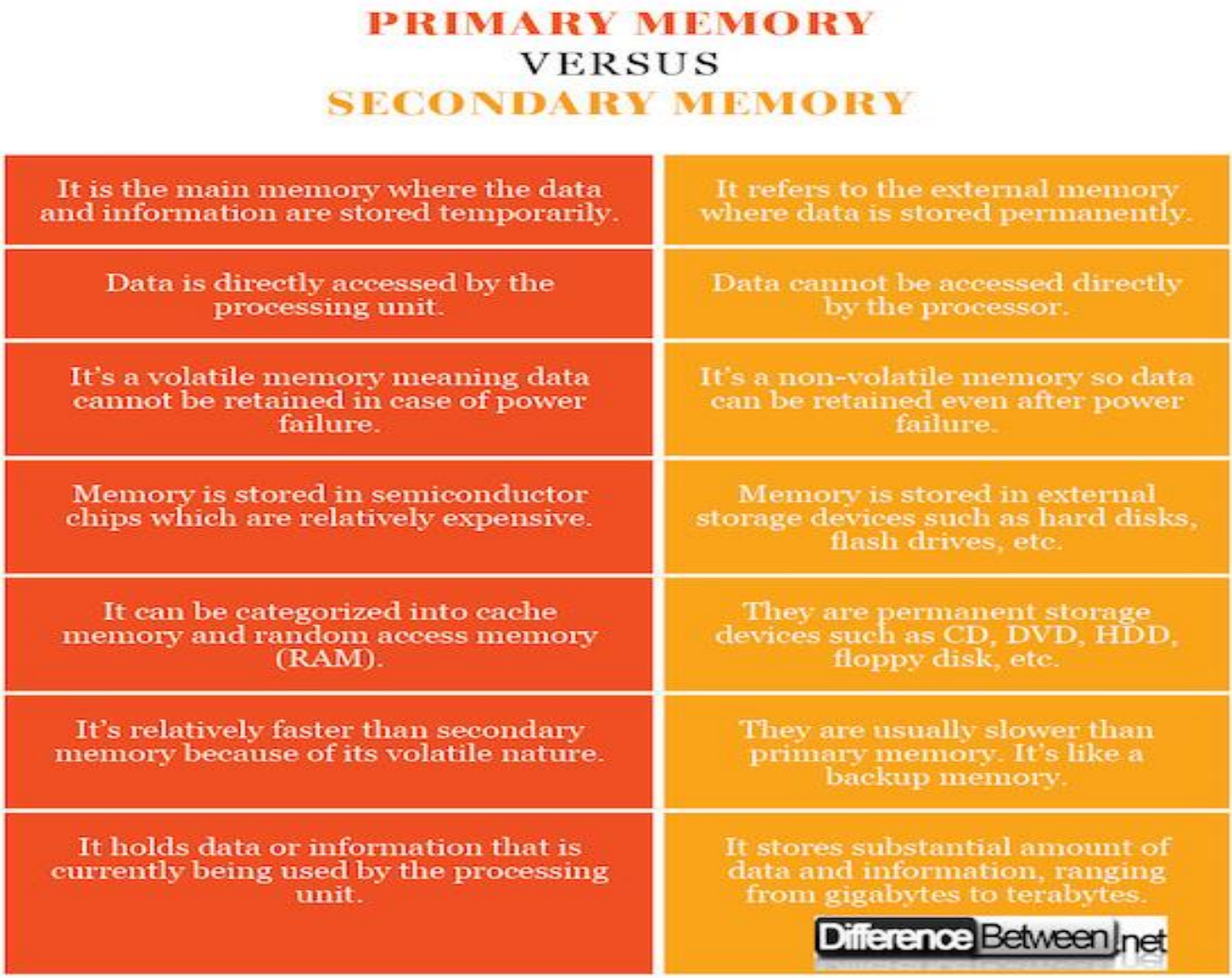
- **Devices for of Primary and Secondary Memory**

  Primary memory can also be referred to as RAM, short for Random Access Memory, because of the random selection of memory addresses.

RAM holds data in a uniform manner and it can be lost when power fails. Secondary memory refers to external storage devices such as hard disk, optical disk, compact disk, flash drives, magnetic tapes, etc. They are high-storage devices with substantial storage capacities, in the range of gigabytes to terabytes.

- **Speed of Primary and Secondary Memory**

  In primary memory, applications and instructions are stored in the main memory which makes them relatively faster to access via data bus. Processor is able to retrieve data faster than it does with secondary memory, which acts more like a backup memory to store data in external storage devices.



Characteristic of Primary Memory : -

- The computer can't run without primary memory
- It is known as the main memory.
- You can lose data in case power is switched off
- It is also known as volatile memory
- It is a working memory of the computer.
- Primary memory is faster compares to secondary memory.

Characteristic Secondary Memory:-

- These are magnetic and optical memories
- Secondary memory is known as a backup memory
- It is a non-volatile type of memory
- Data is stored permanently even when the power of the computer is switched off
- It helps store data in a computer
- The machine can run without secondary memory
- Slower than primary memory

Physical & virtual memory :-

Physical and virtual memory are forms of memory (internal storage of data).

- Physical memory exists on chips (RAM memory) and on storage devices such as hard disks.
- Virtual memory is a process whereby data (e.g., programming code,) can be rapidly exchanged between physical memory storage locations and RAM memory**.**

Virtual memory :-

- Virtual memory is a feature of an operating system that enables a computer to be able to compensate shortages of physical memory by transferring pages of data from random access memory to disk storage.
- This process is done temporarily and is designed to work as a combination of RAM and space on the hard disk.

Physical memory:-

- **Physical memory** (also known as random-access **memory** (**RAM**)) is a form of very fast, but volatile data storage.
- Therefore, when possible, Windows and Windows Server keep the most frequently accessed pages of **memory** in **physical memory** and rely on a disk only if needed.

Magnetic memory:-

- **Magnetic memory is the main way how data is being stored on magnetic medium.**
- **It is how data is stored on devices like hard drive which is the device people use to store documents audios and videos in their computers.**
- **Magnetic storage is one of the most affordable ways to store large amounts of data.**
- **Magnetic storage uses the two types of magnetic polarities to represent the binary information consisting of zeros and ones.**
- **Commonly used devices that use magnetic storage include**
  (1) Magnetic tape
  (2) Floppy disks
  (3) Hard-disk drives.

• Magnetic tape :-

- **A magnetic tape, in computer terminology, is a storage medium that allows for data archiving, collection, and backup.**
- **At first, the tapes were wound in wheel-like reels, but then cassettes and cartridges came along, which offered more protection for the tape inside.**
- **Magnetic tape data storage is a system for storing digital information on magnetic tape using digital recording. ...**
- **The device that performs the writing or reading of data is called a tape drive, and autoloaders and tape libraries are often used to automate cartridge handling.**
- **Large organizations who need to back up their systems daily tend to use magnetic tapes to store their data.**
- **Magnetic tapes can store up to one terabyte of uncompressed data - as much as can be stored on a hard disk.**

- **Magnetic tape uses 'serial access' to find a piece of data. This means that to find a specific piece of the tape and continue fast forwarding until it gets to the piece of data that needed.**

Characteristics of Magnetic Tape :-

- They are formed by creating a plastic base coated with a substance containing iron oxide.
- Magnetic tapes can also degrade over time, which can damage the audio and visual images as well as leave a residue on machine equipment.
- Magnetic tape can degrade over time.

Working of Magnetic tape:-

- **Magnetic tape** recording works by converting electrical audio signals into **magnetic** energy, which imprints a record of the signal onto a moving **tape** covered in **magnetic** particles.
- Playback is achieved by converting the recording on **tape** back into electrical energy to be amplified

Advantages of magnetic tape:-

- Probably the cheapest form of storage per megabyte of storage
- Can store large amounts of data - up to 1 Terabyte per tape cartridge
- Can be set up to do the back up overnight or over the weekend

Disadvantages of magnetic tape:-

- Serial access so can be quite slow to access data
- Need a special piece of equipment to record and read the data on the tape
- The data may be corrupted if the tape is placed near a strong magnetic field e.g. a large speaker or magnet

Properties of magnetic tape

Type of storage	Magnetic
Data access	Serial access (unlike the direct access of a hard disk)
Cost of storage	This is probably the most cost effective method of storing data which is why it is the technology choice for archiving data.
Capacity	Can be a Terabyte or more
Speed	The slowest of all of the storage media from which to access data, which is why it is fine for archiving but not for immediate data retrieval.
Portability	The magnetic tape itself is fairly small and would fit into a pocket or bag. However, in order to be read, an external tape drive is required. Thus, this form of storage is not considered to be very portable.
Durability	Although data can be saved to and erased from the tape many times, each tape does have a limited life span and eventually the quality of the data storage will decline. However if a tape is only used once for archiving, then it will last many years, typically 15 years. But of course you also need to keep the tape reading equipment that can read back the data for that time as well. Needs to be protected from extremes of heat.
Reliability	As long as it is not damaged, a magnetic tape is very reliable method of data storage.

(2) Hard disk :-

Introduction:-

- A hard disk drive (sometimes abbreviated as a hard drive, HD, or HDD) is a non-volatile data storage device.
- It is usually installed internally in a computer, attached directly to the disk controller of the computer's motherboard.
- It contains one or more platters, housed inside of an air-sealed casing.
- Data is written to the platters using a magnetic head, which moves rapidly over them as they spin.
- Internal hard disks reside in a drive bay, connected to the motherboard using an ATA, SCSI, or SATA cable.
- They are powered by a connection to the computer's PSU (power supply unit).
- Examples of data stored on a computer's hard drive include the operating system, installed software, and the user's personal files.

History of the hard drive:-

- The first hard drive was introduced to the market by IBM on September 13, 1956.
- The hard drive was first used in the RAMAC 305 system, with a storage capacity of 5 MB and a cost of about $50,000 ($10,000 per megabyte).
- The hard drive was built-in to the computer and was not removable.
- In 1963, IBM developed the first removable hard drive, having a 2.6 MB storage capacity.
- The first hard drive to have a storage capacity of one gigabyte was also developed by IBM in 1980. It weighed 550-pounds and cost $40,000.
- 1983 marked the introduction of the first 3.5-inch size hard drive, developed by Rodime. It had a storage capacity of 10 MB.
- Seagate was the first company to introduce a 7200 RPM hard drive in 1992.
- Seagate also introduced the first 10,000 RPM hard drive in 1996 and the first 15,000 RPM hard drive in 2000.

Why does a computer need a hard drive?

- A computer requires an operating system to allow users to interact with and use it.
- The operating system interprets keyboard and mouse movements and allows for the use of software, like an Internet browser, word processor, and video games.
- To install a computer operating system, a hard drive (or another storage device) is required.
- The storage device provides the storage medium where the operating system is installed and stored.
- A hard drive is also required for the installation of any programs or other files you want to keep on your computer.
- When downloading files to your computer, they are permanently stored on your hard drive or another storage medium until they are moved or uninstalled.

Can a computer work without a hard drive?

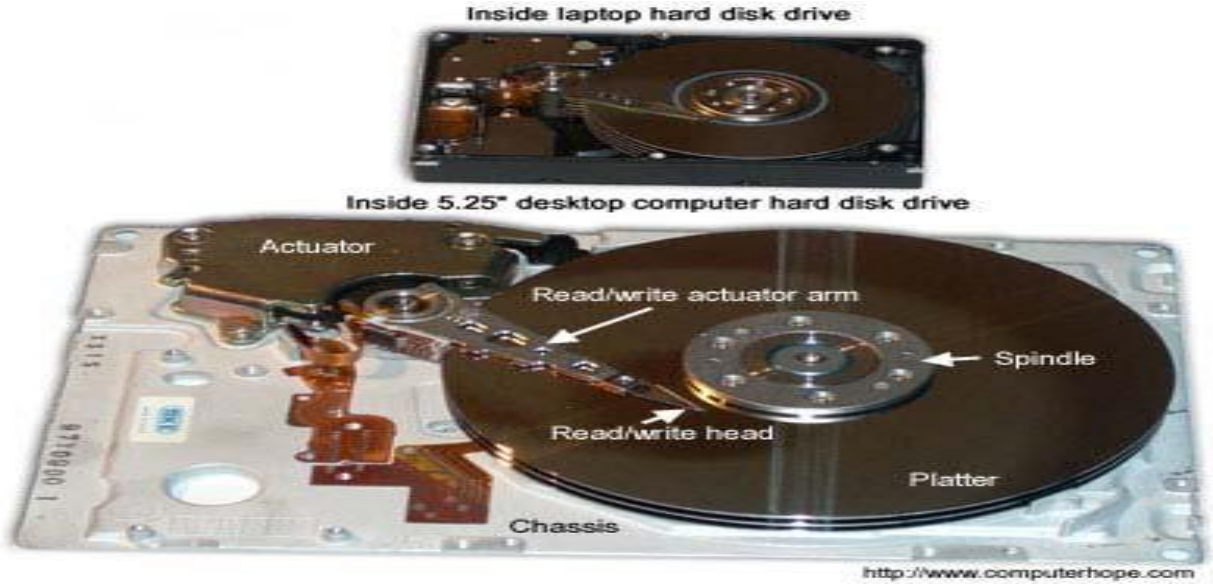
- Without a hard drive, a computer can turn on and POST. Depending on how the BIOS is configured, other bootable devices in the boot sequence are also checked for the necessary boot files.
- For example, if the USB device is listed in your BIOS boot sequence, you can boot from a bootable USB flash drive in a computer without a hard drive.
- Examples of bootable flash drives include a Microsoft Windows installation disk, GParted Live, Ubuntu Live, or UBCD.
- Some computers also support booting over a network with a PXE (preboot execution environment).

Hard drives in modern computers:-

- Modern computers often use an SSD (solid-state drive) as the primary storage device, instead of an HDD.
- HDDs are slower than SSDs when reading and writing data, but offer greater storage capacity for the price.
- Although an HDD may still be used as a computer's primary storage, it's common for it to be installed as a secondary disk drive.

- For example, the primary SSD may contain the operating system and installed software, and a secondary HDD may be used to store documents, downloads, and audio or video files.

Hard drive components



- As shown in the picture above, the desktop hard drive consists of the following components: the head actuator, read/write actuator arm, read/write head, spindle, and platter.
- On the back of a hard drive is a circuit board called the disk controller or interface board. This circuit is what allows the hard drive to communicate with the computer.

How is a hard drive connected to a computer?

- An internal hard drive connects to the computer using two means: a data cable (IDE, SATA, or SCSI) to the motherboard and a power cable to the power supply.

Where is the hard drive found in a computer?

- All primary computer hard drives are found inside a computer case and are attached to the computer motherboard using an ATA, SCSI, or SATA cable.
- Hard drives are powered by a connection to the PSU (power supply unit).

What is stored on a hard drive?

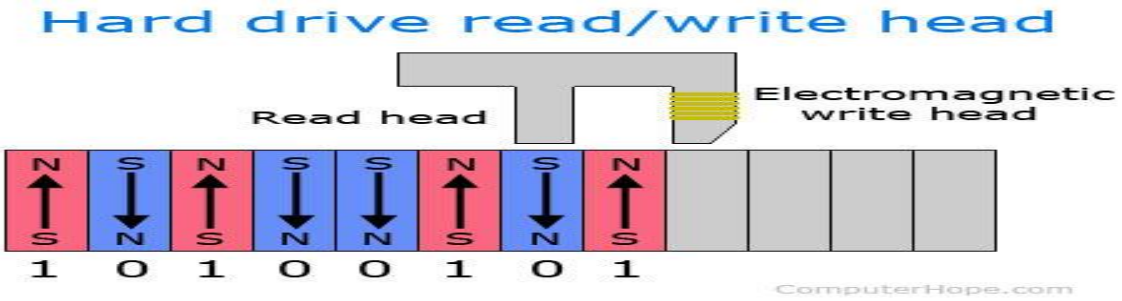
- A hard drive can store any data, including pictures, music, videos, text documents, and any files created or downloaded.
- Also, hard drives store files for the operating system and software programs that run on the computer.

What are the sizes of hard drives?

- The hard drive is often capable of storing more data than any other drive, but its size can vary depending on the type of drive and its age.
- Older hard drives had a storage size of several hundred MB (megabytes) to several GB (gigabytes).
- Newer hard drives have a storage size of several hundred gigabytes to several TB (terabytes). Each year, new and improved technology allows for increasing hard drive storage sizes.

How is data read and stored on a hard drive?

- Data sent to and read from the hard drive is interpreted by the disk controller. This device tells the hard drive what to do and how to move its components.
- When the operating system needs to read or write information, it examines the hard drive's FAT (File Allocation Table) to determine file location and available write areas.
- Once they determined, the disk controller instructs the actuator to move the read/write arm and align the read/write head.
- Because files are often scattered throughout the platter, the head needs to move to different locations to access all information.



- All information stored on a traditional hard drive, like the above example, is done magnetically.
- After completing the above steps, if the computer needs to read information from the hard drive, it would read the magnetic polarities on the platter.
- One side of the magnetic polarity is 0, and the other is 1. Reading this as binary data, the computer can understand what the data is on the platter.
- For the computer to write information to the platter, the read/write head aligns the magnetic polarities, writing 0's and 1's that can be read later.

External and internal hard drives

- Although most hard drives are internal, there are also stand-alone devices called external hard drives or portable hard drives that backup data on computers and expand the available space.
- External drives are often stored in an enclosure that helps protect the drive and allows it to interface with the computer, usually over USB, eSATA, or FireWire.
- An excellent example of an external backup device that supports multiple hard drives is the Drobo.
- External hard drives come in many shapes and sizes. Some are large, about the size of a book, while others are about the size of a large smartphone.
- External hard drives can be very useful since they usually offer more space than a jump drive and are still portable. The picture is an example of a laptop hard disk drive enclosure from Adaptec.
- With this enclosure, the user installs a laptop hard drive of any storage capacity into the enclosure and connects it via USB port to the computer.

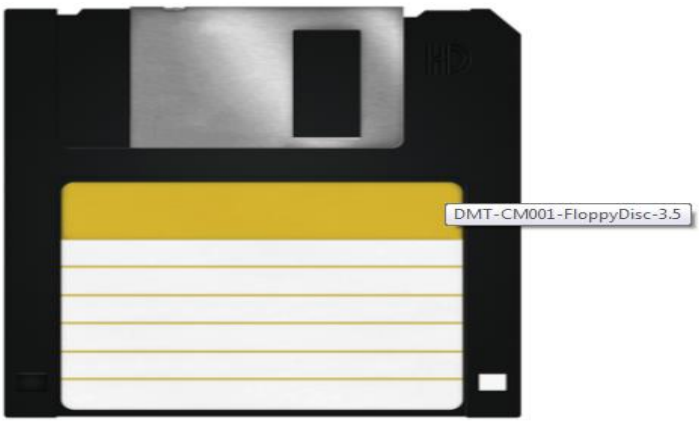
HDD being replaced by SSD

- SSDs (solid-state drives) have started to replace HDDs (hard disk drives) because of the distinct performance advantages they have over HDD, including faster access times and lower latency.
- While SSDs are becoming popular, HDDs continue to be used in many desktop computers largely due to the value per dollar that HDDs offer over SSDs.
- However, more and more laptops are beginning to utilize SSD over HDD, helping to improve the reliability and stability of laptops.

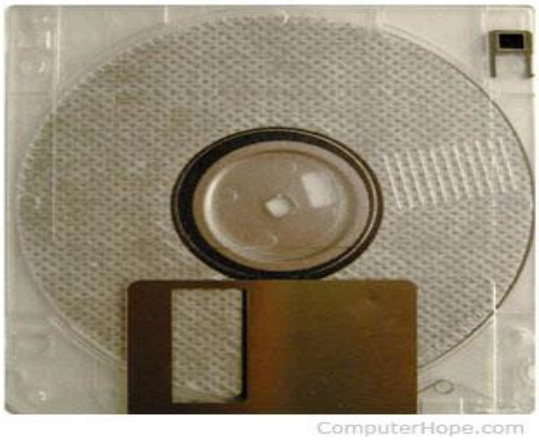
(3) Floppy Disk:-

- Alternatively referred to as a floppy or floppy disk, a floppy diskette is a type of storage media capable of storing electronic data, like a computer file.
- The floppy diskette was first created in 1967 by IBM as an alternative to buying hard drives, which were extremely expensive at the time.

- The picture shown on this page is an example of a 3.5" floppy diskette, one of the most commonly used floppy diskettes, capable of storing 1.44 MB of data.



Floppy Diskette



How were floppy disks used?

- Early computers did not have CD-ROM drives or USB, and floppy disks were the only way to install a new program onto a computer or backup your information.
- If the program was small (less than 1.44 MB for the 3.5" floppy disk), the program could be installed from one floppy disk.
- However, since most programs were larger than 1.44 MB, most programs required multiple floppy diskettes.
- For example, the diskette version of Windows 95 came on 13 DMF diskettes and had to be installed one disk at a time.

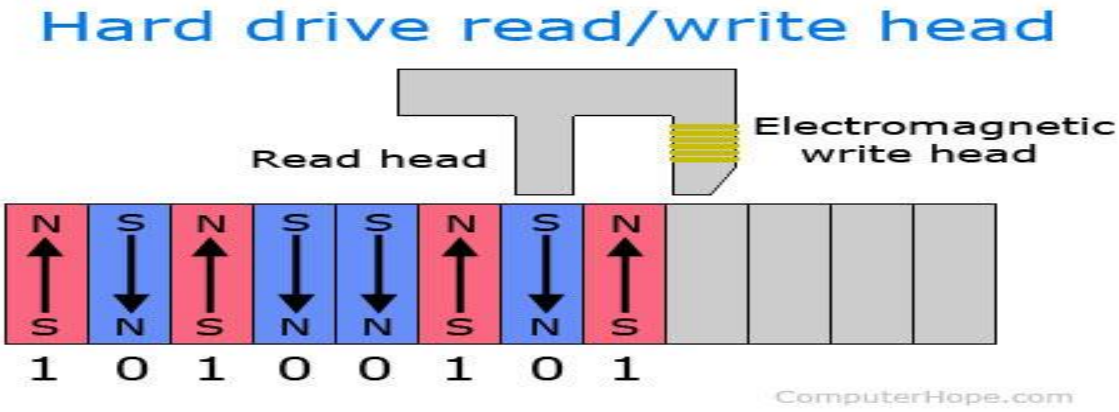
Are floppy diskettes still used today?

- There are still a few diehards who are still using floppy diskettes, some governments still even use 8" floppy diskettes.
- However, since the early 2000s, computers began no longer shipping with floppy disk drives as users moved to CD-R and Zip drives to store their information.
- All the latest versions of Microsoft Windows also no longer have support for internal floppy drives.

How does a floppy disk store data?

- A floppy disk is a magnetic media and stores and reads data on the floppy disk using a read head. When a 3.5" floppy diskette is inserted into the drive, the metal slide door is opened and exposes the magnetic disk in the floppy diskette.

- The read/write head uses a magnetic polarity of 0 or 1. Reading this as binary data, the computer can understand what the data is on the platter.
- For the computer to write information to the platter, the read/write head aligns the magnetic polarities, writing 0's and 1's that can be read later.



The history of the floppy disk and drive

Below is a brief history of each of the three major floppy diskettes.

- **8" floppy disk**

  The first disk was introduced in 1971. The disk was 8" in diameter with a magnetic coating, enclosed in a cardboard case with the capacity of one megabyte. Conversely to hard drives, the heads touched the disk, like in a cassette or video player that wears the media down over time.

- **5.25" floppy disk**

  The 5.25" floppy diskette first started development in 1976 and later became a standard in 1978, these disks were first released with only 160 KB of disk space. These diskettes were commonly used in the 1980s and stopped being used in the early 1990s. See our 5.25" floppy diskette definition for further information, pictures, and related links.

- **3.5" floppy disk**

  The 3.5" floppy was created by IBM in 1984 and were first introduced with a total capacity of 720 KB. The 1.44 MB floppy diskettes were used widely in the 1990s and were seldom found or used by 2000. See our 3.5" floppy diskette definition for further information, pictures, and related links.

Semiconductor memory :-

- **Semiconductor memory** technology is an essential element of today's electronics.
- Normally based around semiconductor technology, memory is used in any equipment that uses a processor of one form or another.
- With the rapid growth in the requirement for semiconductor memories there have been a number of technologies and types of memory that have emerged.
- Names such as ROM, RAM, EPROM, EEPROM, Flash memory, DRAM, SRAM, SDRAM, and the very new MRAM can now be seen in the electronics literature. Each one has its own advantages and area in which it may be used.

Types of semiconductor memory

- Electronic semiconductor memory technology can be split into two main types or categories, according to the way in which the memory operates(1) RAM (2) ROM

(1) RAM - Random Access Memory

- Random Access Memory (RAM)is the best known form of computer memory. The Read and write (R/W) memory of a computer is called RAM.
- The User can write information to it and read information from it.
- The RAM is a volatile memory, it means information written to it can be accessed as long as power is on.
- As soon as the power is off, it can not be accessed. so this mean RAM computer memory essentially empty.
- RAM holds data and processing instructions temporarily until the CPU needs it.
- Scratchpad storage in memory space is used for the temporary storage of data.

(2) ROM - Read Only Memory

- Read only memory (ROM) is an example of nonvolatile memory.
- ROM is a class of storage medium used in computers and other electronic devices.
- Read Only Memory (ROM), also known as firmware, is an integrated circuit programmed with specific data when it is manufactured.
- The instructions for starting the computer are housed on Read only memory chip.

Semiconductor Memory Technologies

- There is a large variety of types of ROM and RAM that are available. These arise from the variety of applications and also the number of technologies available.
- This means that there is a large number of abbreviations or acronyms and categories for memories ranging from Flash to MRAM, PROM to EEPROM, and many more:

PROM:

- This stands for **Programmable Read Only Memory**. It is a semiconductor memory which can only have data written to it once - the data written to it is permanent.
- These memories are bought in a blank format and they are programmed using a special PROM programmer.
- Typically a PROM will consist of an array of fusible links some of which are "blown" during the programming process to provide the required data pattern.
- The PROM stores its data as a charge on a capacitor. There is a charge storage capacitor for each cell and this can be read repeatedly as required.
- However it is found that after many years the charge may leak away and the data may be lost.
- Nevertheless, this type of semiconductor memory used to be widely used in applications where a form of ROM was required, but where the data needed to be changed periodically, as in a development environment, or where quantities were low.

EPROM:

- This is an Erasable Programmable Read Only Memory. This form of semiconductor memory can be programmed and then erased at a later time.
- This is normally achieved by exposing the silicon to ultraviolet light. To enable this to happen there is a circular window in the package of the EPROM to enable the light to reach the silicon of the chip.
- When the PROM is in use, this window is normally covered by a label, especially when the data may need to be preserved for an extended period.
- EEPROM: This is an Electrically Erasable Programmable Read Only Memory. Data can be written to it and it can be erased using an electrical voltage.

- This is typically applied to an erase pin on the chip. Like other types of PROM, EEPROM retains the contents of the memory even when the power is turned off. Also like other types of ROM, EEPROM is not as fast as RAM.
- EEPROM memory cells are made from floating-gate MOSFETS (known as FGMOS)

Flash memory:

- Flash memory may be considered as a development of EEPROM technology. Data can be written to it and it can be erased, although only in blocks, but data can be read on an individual cell basis.
- To erase and re-programme areas of the chip, programming voltages at levels that are available within electronic equipment are used. It is also non-volatile, and this makes it particularly useful.
- As a result Flash memory is widely used in many applications including memory cards for digital cameras, mobile phones, computer memory sticks and many other applications.
- Flash memory stores data in an array of memory cells. The memory cells are made from floating-gate MOSFETS (known as FGMOS).
- These FG MOSFETs (or FGMOS in short) have the ability to store an electrical charge for extended periods of time (2 to 10 years) even without a connecting to a power supply.

DRAM:

- Dynamic RAM is a form of **random access memory**. DRAM uses a capacitor to store each bit of data, and the level of charge on each capacitor determines whether that bit is a logical 1 or 0.
- However these capacitors do not hold their charge indefinitely, and therefore the data needs to be refreshed periodically.
- As a result of this dynamic refreshing it gains its name of being a dynamic RAM.
- DRAM is the form of semiconductor memory that is often used in equipment including personal computers and workstations where it forms the main RAM for the computer.
- **Disadvantage:** Need to refresh the capacitor charge every once in two milliseconds

SRAM:

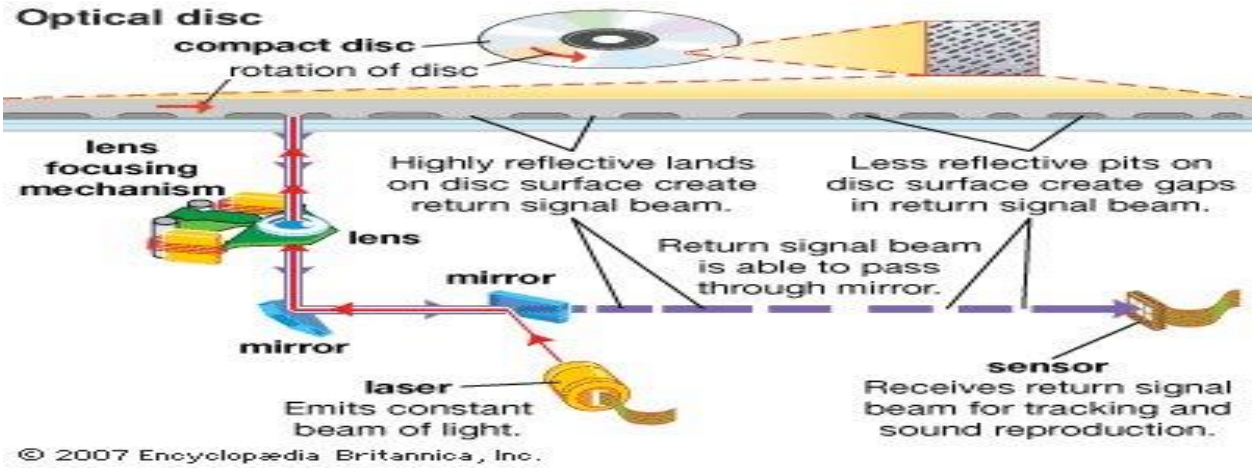
- **Static Random Access Memory**. This form of semiconductor memory gains its name from the fact that, unlike DRAM, the data does not need to be refreshed dynamically.
- It is able to support faster read and write times than DRAM (typically 10 ns against 60 ns for DRAM), and in addition its cycle time is much shorter because it does not need to pause between accesses.
- However it consumes more power, is less dense and more expensive than DRAM. As a result of this it is normally used for caches, while DRAM is used as the main semiconductor memory technology.

Optical storage Devices:-

Optical storage is any storage type in which data is written and read with a laser. Typically, data is written to optical media, such as compact discs (CDs) and DVDs.

Optical disc

- On optical discs such as compact discs (CDs) and digital videodiscs (DVDs), information is stored as a series of lands, or flat areas, and pits.
- A laser assembly reads the spinning disc, converting lands and pits into sequences of electric signals.
- When the beam hits a land, it is reflected onto a photodiode, which produces an electric signal. Laser beams are scattered by pits, so no signal is generated.



1) Compact Disk :

a) CD –ROM

- The disk is formed from polycarbonate.
- The data on a compact disc (CD) is stored on the disc as a series of tiny, almost microscopic **pits** and **lands**
- The pit is an indicator of data, roughly equivalent to a "1" in binary code.
- The lands, or flat surfaces on the CD, are considered to be the "0" in binary code.
- When data is read from a CD, a laser directs an extremely fine stream of light onto the surface of the disc.
- The laser follows the data stream of pits and lands from the inside center of the disc outward in a spiral direction.
- As the laser light shines on the CD's data track, **it reflects one pattern of light off of a pit and a different pattern off of a land area.**
- The resulting reflections equate to a series of ones and zeros by a photo sensor.

b) CD Recordable / CD-R :

- CD-R is a type of write once read many (WORM).
- Allows one-time recording on a disc.
- Composed of a polycarbonate plastic substrate, a thin reflective metal coating, and a protective outer coating.

- A layer of organic polymer dye between the polycarbonate and metal layers serves as the recording medium.
- The dye is permanently transformed by exposure to a specific frequency of light.
- The laser creates marks in the dye layer that mimic the reflective properties of the pits and lands (lower and higher areas) of the traditional CD.
- The distinct differences in the way the areas reflect light register as digital data.

c) CD Rewritable :

- CD-RW is a compact disc (CD) format that allows repeated recording on a disc.
- CD-Rs and CD-RWs are composed of a polycarbonate plastic substrate, a thin reflective metal coating, and a protective outer coating.
- In a CD-RW, the dye is replaced with an alloy that can change back and forth from a crystalline form when exposed to a particular light.
- By controlling the temperature of the laser, crystalline areas and non-crystalline areas are formed.
- The crystalline areas will reflect the laser, while the other areas will absorb it.
- The differences will register as digital data.

d) Digital versatile disk /DVD :

- A DVD is based on CD technology with increased storage density.
- It has a much larger data capacity.
- DVDs can be single- or double-sided.
- A two-layered DVD will hold up to 17 gigabytes of video, audio, or other information.
- The DVD has a number of layers of plastic pieces with a total thickness of 1.2 millimeters.
- Poly-carbonate plastic is basically used for making these layers.