DATA REPRESENTATION

- Data can be anything like a number, a name, a special character, or the color in a photograph.
- Data representation can be referred to as the form in which we stored the data, processed it and transmitted it.
- In order to store the data in digital format, we can use any device like computers, smartphones, and iPads.
- Digitization is a type of process in which we convert information like photos, music, number, text into digital data.
- The binary digits or bits are used to show the digital data, which is represented by 0 and 1. The binary digits can be called the smallest unit of information in a computer.

BINARY CODES

- In the coding, when numbers, letters or words are represented by a specific group of symbols, it is said that the number, letter or word is being encoded. The group of symbols is called as a code.
- The digital data is represented, stored and transmitted as group of binary bits. This group is also called as binary code. The binary code is represented by the number as well as alphanumeric letter.
- Advantages of Binary Code:
  - ✞Binary codes are suitable for the computer applications.
  - ✞Binary codes are suitable for the digital communications.
  - ✞Binary codes make the analysis and designing of digital circuits easier.
  - ✞Since only 0 & 1 are being used, implementation becomes easy.

NUMBER SYSTEMS

NAME	BASE	SYMBOL
Binary	Base 2	B
Octal	Base 8	Q or O
Decimal	Base 10	None or D

Hexadecimal	Base 16	H

- While working with any kind of digital electronics in which numbers are being represented, it is important to understand the different ways in which numbers are represented in these systems.
- Modern computer systems do not represent numeric values using the decimal system. Instead, they typically use a binary or two's complement numbering system.
- There are four number bases commonly used in programming.

DECIMAL SYSTEM

- It includes the digits from 0 through 9.
- The decimal number system uses the base 10.

- Each digital appearing in the left of decimal point represents a value between 0 and 9 times power of 10 by its position in the number.
- The weighted values for each position is determined as:

10^4	10^3	10^2	10^1	10^0	10_{-1}	10_{-2}	10_{-3}
10000	1000	100	10	1	0.1	0.01	0.001

BINARY NUMBER SYSTEM

- It includes the digits 0 and 1.
- The binary number system uses the base 2.

- Computers use binary numbers to communicate. Binary numbers represent these two states: 1 for “on/true” and 0 for “off/false”. The **BIT** is the representation of one of these two states.
- The weighted values for each position is determined as:

2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}
32	16	8	4	2	1	0.5	0.25

OCTAL NUMBER SYSTEM

- It includes the digits 0 through 7.
- The octal number system uses the base 8.

- The octal number system is based on the binary system with a 3-bit boundary.
- The weighted values for each position is determined as:

8_5	8_4	8_3	8_2	8_1	8_0
32768	4096	512	64	8	1

HEXADECIMAL NUMBER SYSTEM

- Verbosity is a major problem with binary system which means that to represent the value of 202, eight binary digits are required. Therefore, when dealing with large numbers, binary numbers quickly become too unwieldy.
- Hexadecimal number system is used to solve these problems.

- Hexadecimal uses base 16.
- It includes only the digits 0 through 9 and letters A, B, C, D, E, and F.
- Hex numbers are quite compact and it is easy to convert hex to binary and binary to hex.
- Hex values greater than 9 carry following decimal value:

DECIMAL	**10**	**11**	**12**	**13**	**14**	**15**
HEX	A	B	C	D	E	F

BINARY	OCTAL	DECIMAL	HE16X
0000	00	00	00
0001	01	01	01
0010	02	02	02
0011	03	03	03
0100	04	04	04
0101	05	05	05
0110	06	06	06
0111	07	07	07
1000	10	08	08
1001	11	09	09

1010	12	10	A
1011	13	11	B
1100	14	12	C
1101	15	13	D
1110	16	14	E
1111	17	15	F

NUMBER SYSTEMS

CONVERSIONS

- Conversion is the process of converting one number system to another.

- In this process, conversions of different types can be carried out:

1. Decimal to Binary
2. Decimal to Octal
3. Decimal to Hex

- Usually, numbers from decimal number systems are converted to other systems. When values from other systems are converted to decimal number system, then it is known as Back Conversion.

DECIMAL TO BINARY CONVERSION

- For conversion, divide the given decimal number by 2.

- In this case, if the remainder is 0, write down 0 on the side. If the remainder is 1, write down 1 on the side.
- This process is continued until the quotient divided by 2 becomes 0.
- In the end, the remainders will represent the binary equivalent of the given decimal number.
- It should be noted that the last remainder will serve as the first digit of binary number and the first remainder being the last one.

DECIMAL TO OCTAL CONVERSION

- For conversion, divide the given decimal number by 8 and note down the remainders.

- This process is continued until the quotient divided by 8 becomes 0.
- In the end, the remainders will represent the octal equivalent of the given decimal number.
- It should be noted that the last remainder will serve as the first digit of octal number and the first remainder being the last one.

DECIMAL TO HEX CONVERSION

- For conversion, divide the given decimal number by 16 and note down the remainders.
- This process is continued until the quotient divided by 16 becomes 0.

- In the end, the remainders will represent the hex equivalent of the given decimal number.
- It should be noted that the last remainder will serve as the first digit of octal number and the first remainder being the last one.

BINARY CODING SCHEMES

- The alphabetic data, numeric data, alphanumeric data, symbols, sound data and video data, are represented as combination of bits in the computer.
- The bits are grouped in a fixed size, such as 8 bits, 6 bits or 4 bits. A code is made by combining bits of definite size.
- Binary Coding schemes represent the data such as alphabets, digits 0−9, and symbols in a standard code. A combination of bits represents a unique symbol in the data.

- The standard code enables any programmer to use the same combination of bits to represent a symbol in the data.
- The binary coding schemes that are most commonly used are—

1. Extended Binary Coded Decimal Interchange Code (EBCDIC)
2. American Standard Code for Information Interchange (ASCII) 3. Unicode

EBCDIC

- The Extended Binary Coded Decimal Interchange Code (EBCDIC) uses 8 bits (4 bits for zone, 4 bits for digit) to represent a symbol in the data.
- EBCDIC allows $2^8 = 256$ combinations of bits. 256 unique symbols are represented using EBCDIC code.

- It represents decimal numbers (0−9), lower case letters (a−z), uppercase letters (A−Z), Special characters, and Control characters (printable and non−printable, e.g., for cursor movement, printer vertical spacing, etc.) are also represented.
- EBCDIC codes are mainly used in the mainframe computers.

ASCII

- The American Standard Code for Information Interchange (ASCII) is widely used in computers of all types.
- ASCII codes are of two types:

1. ASCII−7: ASCII-7 is a **7-bit** standard ASCII code. In ASCII-7, the first 3 bits are the zone bits and the next 4 bits are for t9he digits. ASCII-7

allows 2^7 = 128 combinations. 128 unique symbols are represented using ASCII-7. ASCII-7 has been modified by IBM to ASCII-8.

2. ASCII−8: ASCII-8 is an extended version of ASCII-7. ASCII-8 is an **8-bit** code having 4 bits for zone and 4 bits for the digit. ASCII-8 allows 2^8 = 256 combinations. ASCII-8 represents 256 unique symbols.

UNICODE

- Unicode is a universal character encoding standard for the representation of text which includes letters, numbers and symbols in multi−lingual environments.
- The Unicode Consortium based in California developed the Unicode standard.
- Unicode uses 32 bits to represent a symbol in the data.
- Unicode allows 2^{32} = 4164895296 (~ 4 billion) combinations.

- Unicode can uniquely represent any character or symbol present in any language like Chinese, Japanese, etc. In addition to the letters; mathematical and scientific symbols are also represented in Unicode codes.
- An advantage of Unicode is that it is compatible with the ASCII−8 codes. The first 256 codes in Unicode are identical to the ASCII-8 codes.
- Unicode is implemented by different character encodings. UTF-8 is the most commonly used encoding scheme. UTF stands for Unicode Transformation Format. UTF-8 uses 8 bits to 32 bits per code.

BINARY SYSTEM AND BOOLEAN OPERATIONS

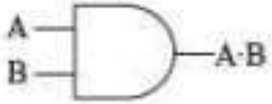
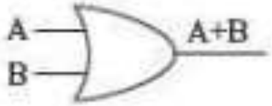
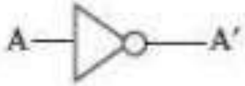
- The information is represented in the computer in binary form. Binary information is represented using signals in two states off or on which correspond to 0 or 1, respectively.
- The manipulation of the binary information is done using logic gates. Logic gates are the hardware electronic circuits which operate on the input signals to produce the output signals.
- Each logic gate has a unique symbol and its operation is described using Boolean algebraic expression.

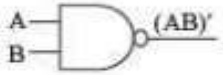
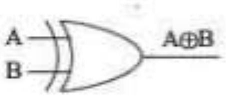
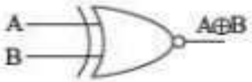
- For each gate, the truth table shows the output that will be outputted for the different possible combinations of the input signal.
- The AND, OR and NOT are the basic logic gates. Some of the basic combination of gates that are widely used are—NAND, NOR, XOR and XNOR.

LOGC GATES & TRUTH TABLE

- A logic gate is a virtual or physical device that performs a Boolean function. These are used to make logic circuits. Logic gates are the main components of any digital system. This electrical circuit can have only one output and 1 or more inputs. The relation between the input and the output is governed by specific logic.
- A truth table represents all the variety of combinations of input values and outputs in a tabular manner. All the possibilities of the input and

output are shown in it and hence the name truth table is kept. In logic problems such as Boolean algebra and electronic circuits, truth tables are commonly used. T or 1 denotes ‘True’ & F or 0 denotes ‘False’ in the truth table.

<table>
<tr><th>Operation</th><th>Symbol</th><th>Algebraic Function</th><th>Comments</th><th>Truth Table</th></tr>
<tr><td>AND</td><td>
</td><td>X = A.B or
X = AB</td><td>• Two or more binary inputs
• The output is 1 if all the inputs are 1, otherwise the output is 0.
• Represented using a multiplication symbol "."</td><td><table><tr><th>A</th><th>B</th><th>A.B</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td></tr>
<tr><td>OR</td><td>
</td><td>X = A + B</td><td>• Two or more binary inputs
• The output is 1 if at least one input is 1, otherwise the output is 0.
• Represented using a "+"</td><td><table><tr><th>A</th><th>B</th><th>A+B</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td></tr>
<tr><td>NOT</td><td>
</td><td>A = A′</td><td>• One binary input
• The output is complement (opposite) of input. If input is 1 output is 0 and if input is 0 output is 1.
• Represented using a " ′ "</td><td><table><tr><th>A</th><th>A′</th></tr><tr><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td></tr></table></td></tr>
</table>

<table>
<tr><th>Operation</th><th>Symbol</th><th>Algebraic Function</th><th>Comments</th><th>Truth Table</th></tr>
<tr><td>NAND</td><td></td><td>X = (AB)′</td><td>• Two or more binary inputs
• NAND is complement of AND</td><td><table><tr><th>A</th><th>B</th><th>(A.B)′</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table></td></tr>
<tr><td>NOR</td><td></td><td>X = (A + B)′</td><td>• Two or more binary inputs
• NOR is complement of OR.</td><td><table><tr><th>A</th><th>B</th><th>(A+B)′</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table></td></tr>
<tr><td>XOR</td><td></td><td>X = (A ⊕ B)</td><td>• Two or more binary inputs
• The output is 1 if the odd number of inputs is 1.
• Represented using a " ⊕ "</td><td><table><tr><th>A</th><th>B</th><th>(A⊕B)</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table></td></tr>
<tr><td>XNOR</td><td></td><td>X = (A ⊕ B)′</td><td>• Two or more binary inputs
• XNOR is complement of XOR.</td><td><table><tr><th>A</th><th>B</th><th>(A⊕B)′</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>[illegible]</td><td>[illegible]</td><td>[illegible]</td></tr></table></td></tr>
</table>

Secondary Storage Media

- A **secondary storage device** refers to any non-volatile storage device that is fixed or removable to the computer. It can be any storage device beyond the primary storage that enables permanent data storage.
- A secondary storage device is also known as an auxiliary storage device, backup storage device, tier 2 storage, or external storage. These devices store virtually all programs and applications on a computer, including the operating system, device drivers, applications and general user data.
- The main advantage of using secondary storage devices is:

1. Secondary memory overcomes the limitation of primary storage by providing permanent storage of data in bulk quantity.
2. In Secondary storage devices, the stored data might not be under the direct control of the operating system.

3. Data stored in secondary storage devices is also more secure as compared to the data stored in primary memory.

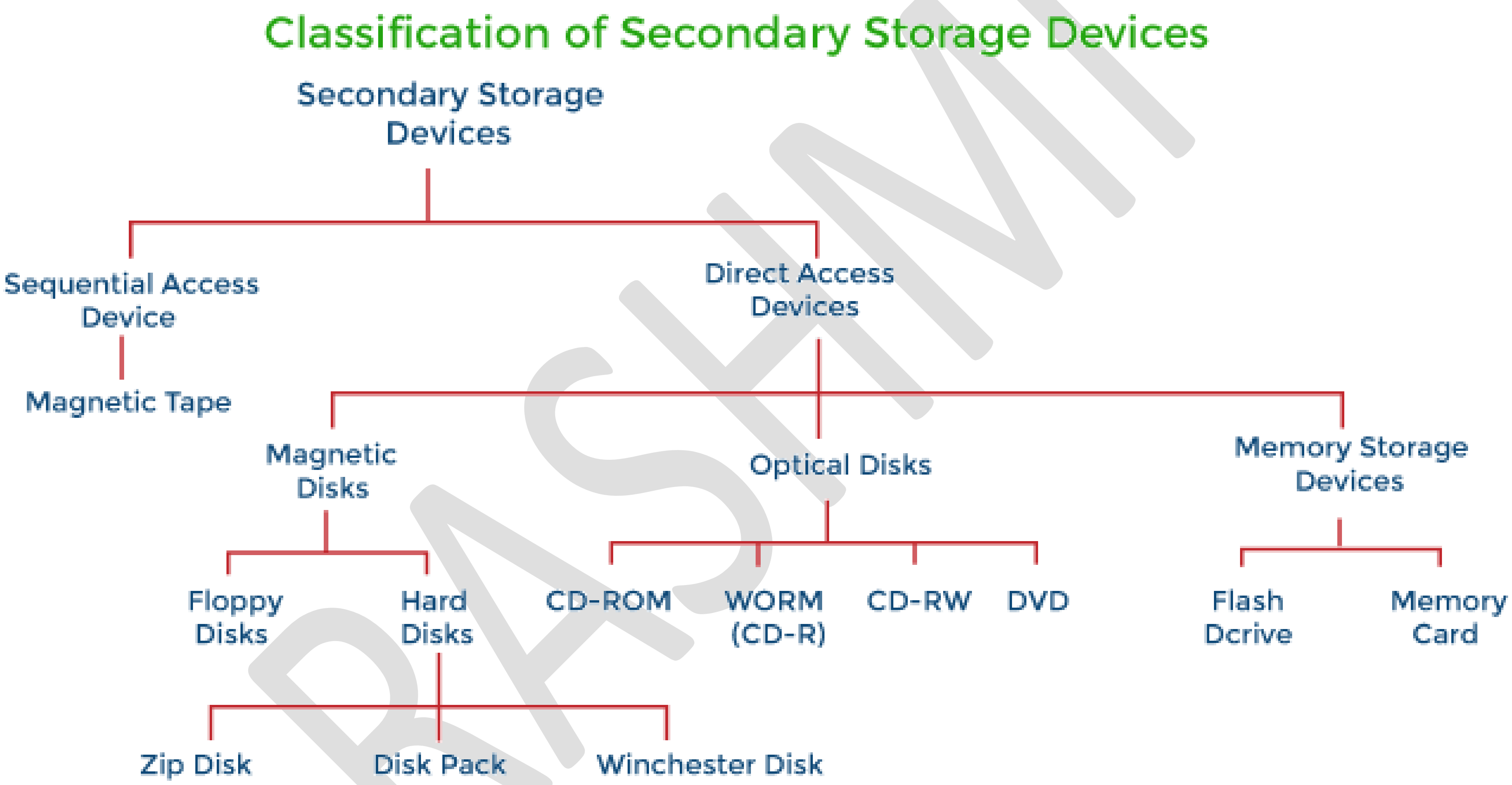
Characteristics of Secondary Storage Media

- It is non-volatile, which means it retains data when power is switched off
- It allows for the storage of data ranging from a few megabytes to petabytes.
- It is cheaper as compared to primary memory.
- Secondary storage devices like CDs and flash drives can transfer the data from one device to another.

Types of Secondary Storage

a) **Sequential access storage device:** It is a class of data storage devices that read stored data in a sequence. This is in contrast to random access memory (RAM), where data can access in any order, and magnetic tape is the common sequential access storage device.

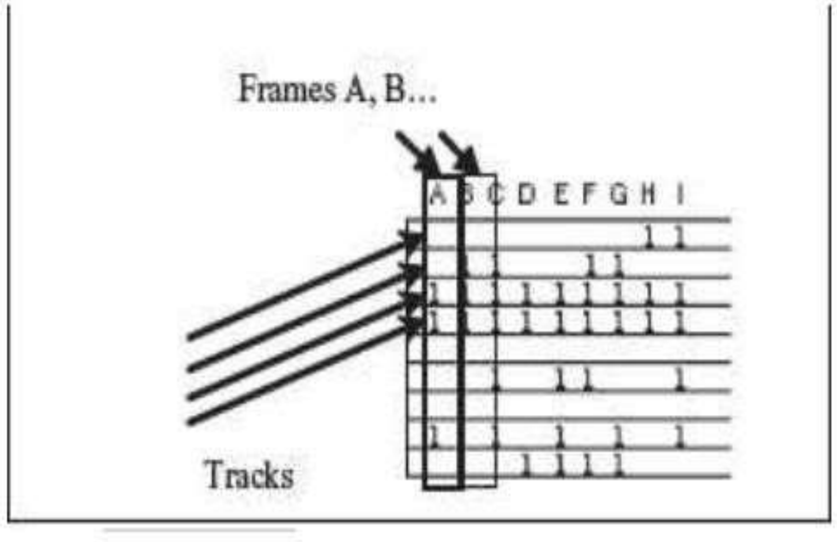
b) **Direct access storage device:** A direct-access storage device (DASD) is another name for secondary storage devices that store data in discrete locations with a unique address, such as hard disk drives, optical drives and most magnetic storage devices. Eg: Magnetic disks, Optical disks etc.



Classification of Secondary Storage Devices
Secondary Storage Devices
Sequential Access Device
Magnetic Tape
Direct Access Devices
Magnetic Disks
Optical Disks
Memory Storage Devices
Floppy Disks
Hard Disks
CD-ROM
WORM (CD-R)
CD-RW
DVD
Flash Dcrive
Memory Card
Zip Disk
Disk Pack
Winchester Disk

Sequential access: Magnetic Tape

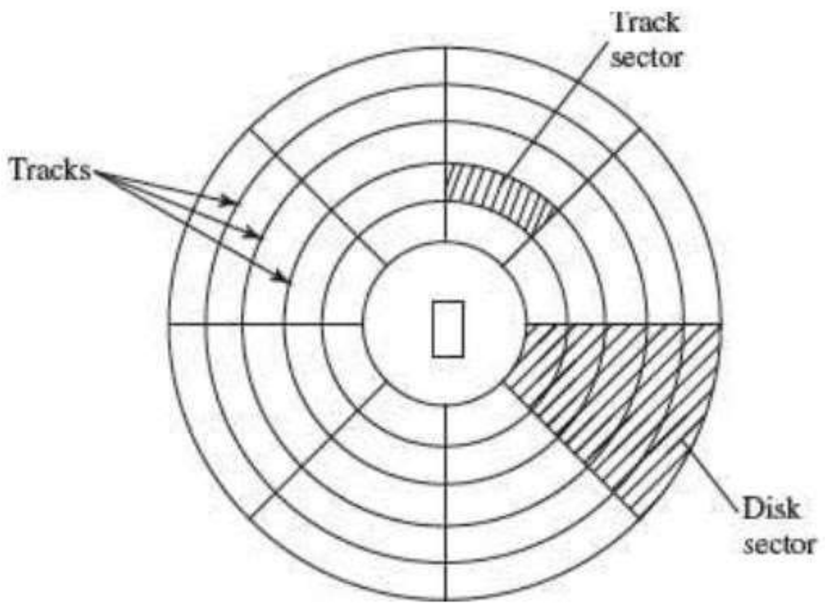
- It is a medium for magnetic recording, made of a thin, magnetizable coating on a long, narrow strip of plastic film.
- Devices that record and play audio and video using magnetic tape are tape recorders and videotape recorders.
- A device that stores computer data on magnetic tape is known as a ***tape drive***.
- It was a key technology in early computer development, allowing unparalleled amounts of data to be mechanically created, stored for long periods, and rapidly accessed.



- Magnetic tape is divided horizontally into tracks (7 or 9) and vertically into frames. A frame stores one byte of data, and a track in a frame stores one bit. Data is stored in successive frames as a string with one data (byte) per frame.

Direct access: Magnetic Disks

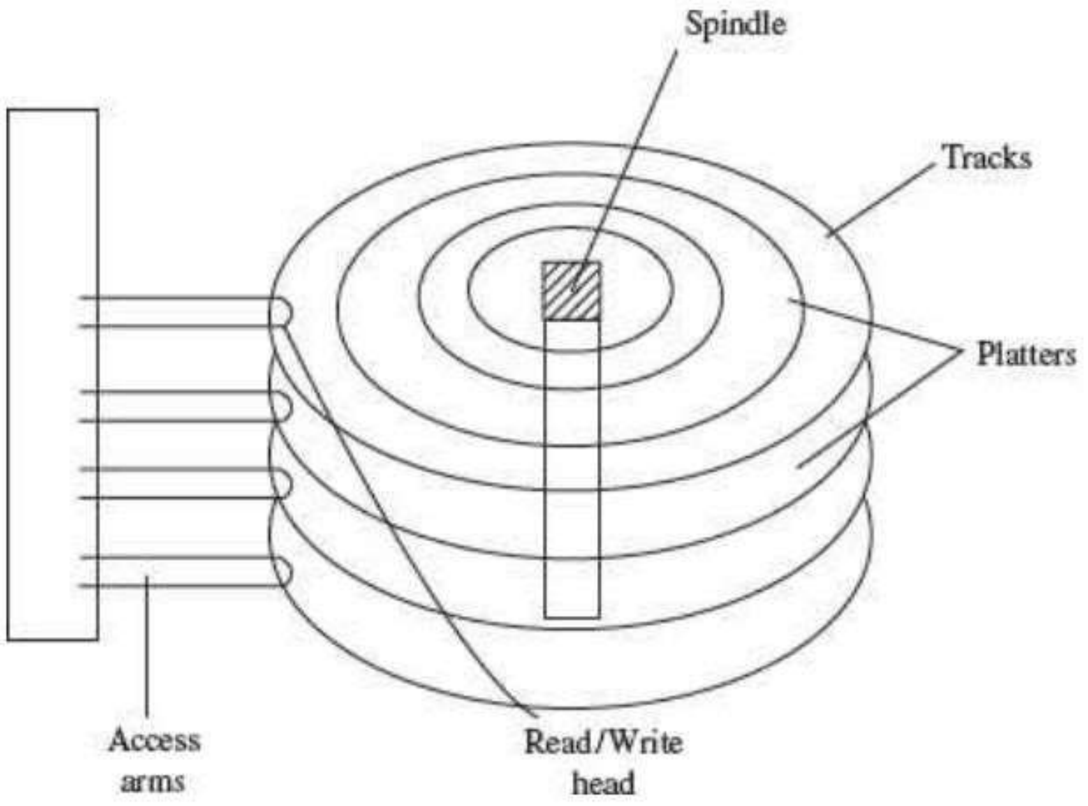
- A magnetic disk is a storage device that uses a magnetization process to write, rewrite and access data. It is covered with a magnetic coating and stores data in the form of tracks, spots and sectors. Hard disks, zip disks and floppy disks are common examples of magnetic disks.



i. **Floppy Disk:** A floppy disk is a flexible disk with a magnetic coating on it, and it is packaged inside a protective plastic envelope. These are among the oldest portable storage devices that could store up to 1.44 MB of data, but now they are not used due to very little memory storage.

Direct access: Magnetic Disks

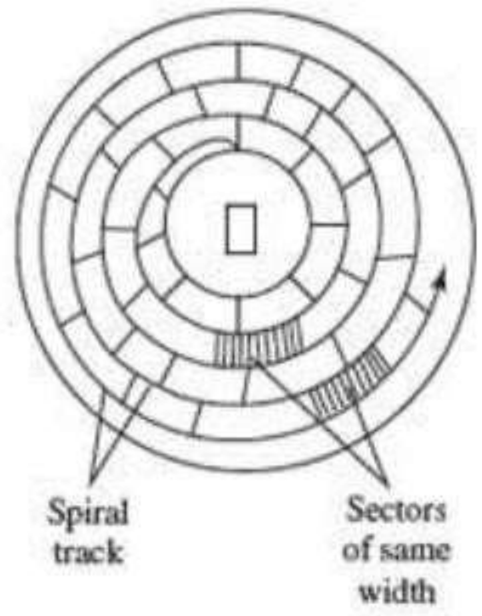
ii. Hard Disk Drive (HDD): Hard disk drive comprises a series of circular disks called **platters** arranged one over the other almost ½ inches apart around a **spindle**. It can be read by a read/write head that pivots across the rotating disks. The data is stored on the platters covered with magnetic coating . A typical modern HDD has a capacity in terabytes (TB). Hard disk is



a fixed disk. The disk is not removable from the drive, unlike floppy disk.

Direct access: Optical Disk

- An optical disk is any computer disk that uses optical storage techniques and technology to read and write data. It is a computer storage disk that stores data digitally and uses laser beams to read and write data.
- It consists of a single spiral track that starts from the edge to the center of disk.
- The tracks on optical disk are further divided into sectors which are of same length. Thus, the sectors near the center of disk wrap around the disk longer than the sectors on the edges of disk.



- Reading the disk thus requires spinning the disk faster when reading near the center and slower when reading near the edge of disk. Optical disks are generally slower than hard disks.
- Optical disks can store large amount of data, up to 6 GB, in a small space. Commonly used optical disks store 600–700 MB of data.
- Eg.: CD-ROM, CD-R, CD-RW, DVD.

Direct access: Memory Storage Devices

- A memory device contains trillions of interconnected memory cells that store data. When switched on or off, these cells hold millions of transistors representing 1s and 0s in binary code, allowing a computer to read and write information. It includes USB drives, flash memory devices, SD and memory cards, etc.

i. Flash Drive: A flash drive is a small, ultra-portable storage device. USB flash drives were essential for easily moving files from one device to another. Flash drives connect to computers and other devices via a builtin USB Type-Aor USB-C plug, making one a USB device and cable combination. Flash drives are often referred to as pen drives, thumb drives, or jump drives. These days, a USB flash drive can hold up to 2 TB of storage. They're more expensive per gigabyte than an external hard drive, but they have prevailed as a simple, convenient solution for storing and transferring smaller files.

Direct access: Memory Storage Devices

ii. Memory card: A memory card or memory cartridge is an electronic data storage device used for storing digital information, typically using flash memory. These are commonly used in portable electronic devices, such as digital cameras, mobile phones, laptop computers, etc. It allows adding memory to such devices without compromising efficiency, as the card is usually contained within the device rather than protruding like USB flash drives.