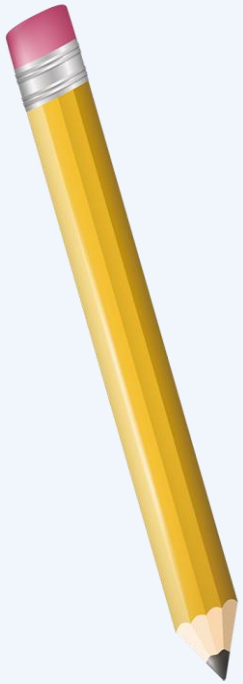
اللهم صل وسلم وبارك على سيدنا محمد وعلى
آله وصحبة وسلم تسليماً كثيراًطيباً مباركاً فيه

File Organization



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File Structures & Organization

Secondary Storage and System Software

Lecture No. 3

Contents

Introduction

Secondary Storage Devices

- Since secondary storage is different from main memory we have to understand how it works in order to do good file designs.

- The Secondary storage is different from main memory (RAM).
  - RAM is fast but temporary data is lost when power goes off.
  - But secondary storage keeps data permanently. So to design good file systems and understand how data is stored and retrieved, we must understand how secondary storage works.

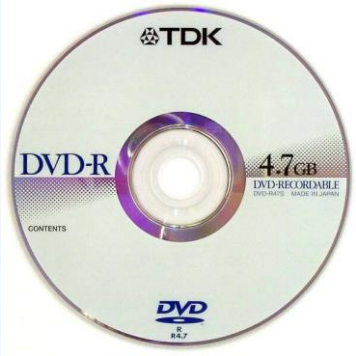
Secondary Storage Devices

- Two major types of storage devices according to Access type:
  - Direct Access Storage Devices (DASDs)
    - Hard Disk Drives (HDD), Solid-State Drives (SSD)
      - Magnetic Disks (Access Type: Direct/random access)
        Hard Disks Drives (HDD) (high capacity, low cost per bit)
      - Solid State Storage (Direct/random access)
        Solid-State Drives (SSD) (Much faster read/write times than HDDs, Very low latency, Uses less energy, Higher cost per GB compared to HDDs)
      - Optical Disks (Access Type: Direct access)
        CD-ROM,DVD-ROM, Blu-ray
        (Read-only/write-once, holds a lot of data, cheap)
  - Serial Devices
    - Magnetic Tapes (Access Type: Sequential access)

Storage Basics

- A data storage system has two main components: a storage medium and a storage device.

- A **storage medium** the physical material where data is stored (disk, tape, CD, DVD, paper, or other substance that contains data).

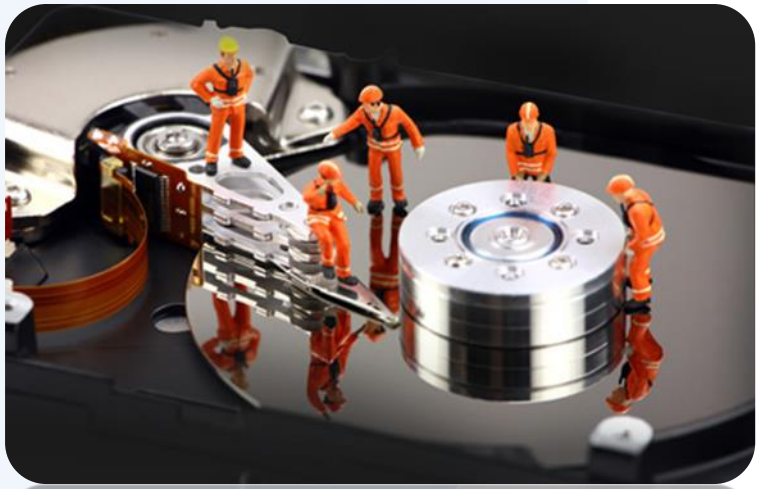


- A **storage device** the hardware that reads/writes data to the medium (mechanical device that records and retrieves data from a storage medium).

Storage Basics

- Three types of **storage technologies** are commonly used for personal computers: magnetic, optical, and solid state

- Each storage technology has its advantages and disadvantages.



Magnetic Storage Technology

Magnetic Storage Technology

- **Magnetic storage** stores data by magnetizing microscopic particles on a disk or tape surface.

- The particles retain their magnetic orientation until that orientation is changed, thereby making disks fairly permanent but modifiable storage media.

Hard disk

Floppy disk

Tape

Magnetic Storage Technology

Three Storage Technologies

Storage Type	Examples	How it works
Magnetic Storage	Hard disks (Main storage in computers, large capacity, cheap), floppy disks (Old storage device, now obsolete), magnetic tape (Very cheap, used for backups, but slow)	Stores data by magnetizing particles
Optical Storage	CD, DVD, Blu-ray	Uses laser light to read/write
Solid State Storage	USB flash drive, SSD, memory card	Uses electronic circuits, no moving parts

Hard Disks

- A **hard disk drive** contains one or more platters and their associated read-write heads.
- A hard disk platter is a flat, rigid disk made of aluminum or glass and coated with magnetic iron oxide particles.
- More platters mean more data storage capacity. The platters rotate as a unit on a spindle, making thousands of rotations per minute (RPM).
- Hard disk platters are typically 3.5" in diameter, with storage capacities ranging from 40 GB to 2 TB.

Hard Disks

- **Hard Disk Overview**

  A **hard disk drive (HDD)** contains:

  - One or more **platters** (circular disks)
  - **Read/Write heads** that hover above the surface
  - **Actuator arm** to move heads
  - **Spindle** that spins the platters
  - The more platters → **more storage**.
  - Spin speed: **5400–7200 RPM**
  - Capacity: **40GB – 2TB or more**
  - Excellent for **large storage and fast access**

Hard Disks

Hard Disks

Hard Disk Components

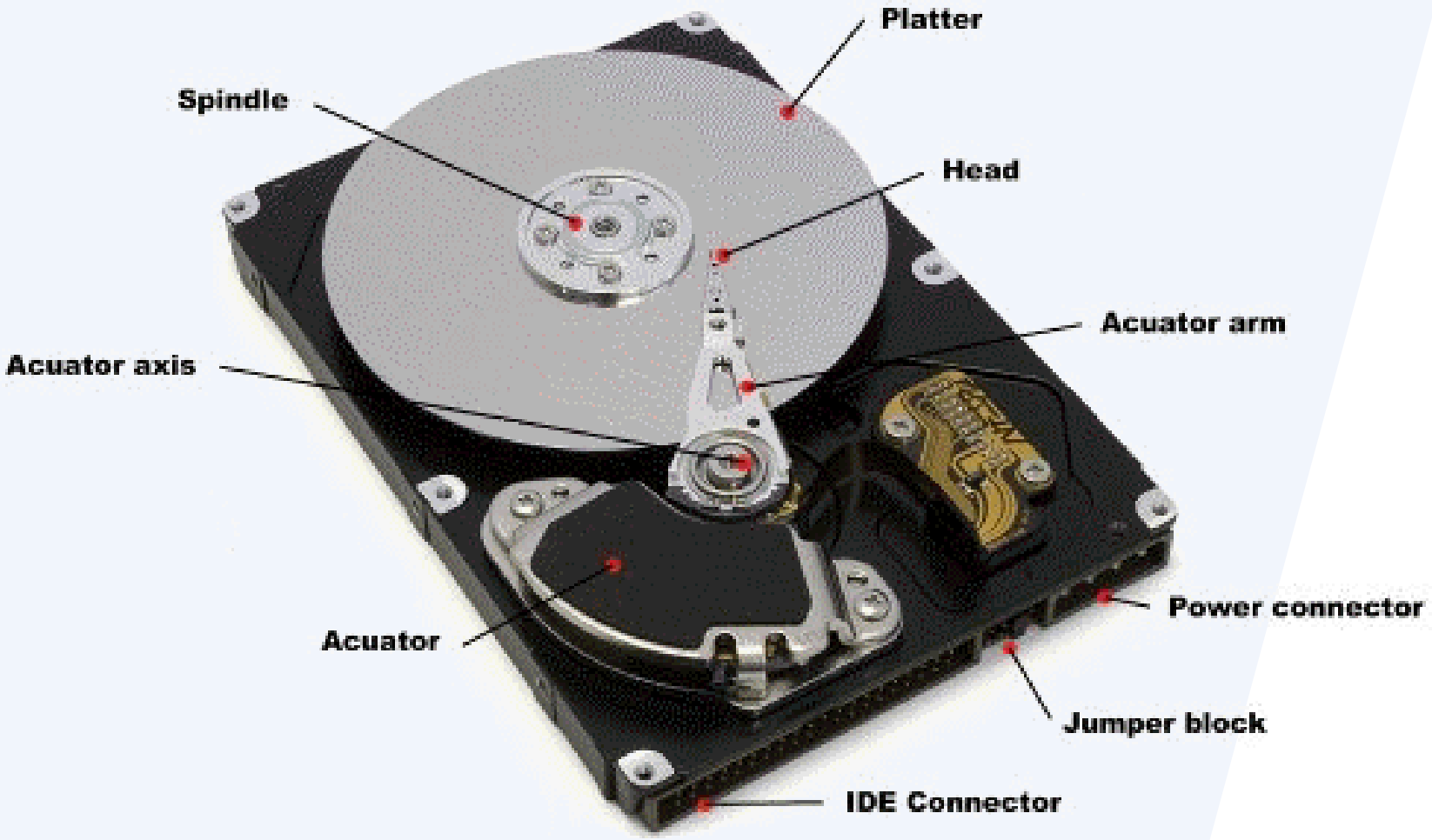
Term	Explanation
Platter	The circular magnetic disk inside the hard drive where data is actually stored. A hard drive can have multiple platters stacked together.
Spindle	The rotating shaft that holds the platters in place and spins them at high speeds (e.g., 5400 or 7200 RPM).
Read/Write Head	A tiny magnetic sensor that reads data from the platter and writes new data onto it without touching the surface.
Actuator Arm	The mechanical arm that moves the read/write head across the platter to access data tracks.
Actuator Axis	The pivot point that allows the actuator arm to move back and forth accurately.
Actuator	The motor that controls the movement of the actuator arm using a voice coil mechanism for fast precision.

Hard Disks

Cont. Hard Disk Components

Term	Explanation
Power Connector	The port where the hard drive receives electrical power from the computer's power supply.
Jumper Block	Small pins used in old IDE hard drives to configure settings such as Master, Slave, or Cable Select.
IDE Connector	A data interface port used to connect older hard drives to the motherboard using an IDE ribbon cable.
Controller Board (PCB)	The Printed Circuit Board on the bottom of the drive that manages all operations like data transfer, reading, and writing.

Hard Disks


Platter
Spindle
Head
Acuator arm
Acuator axis
Acuator
Power connector
Jumper block
IDE Connector

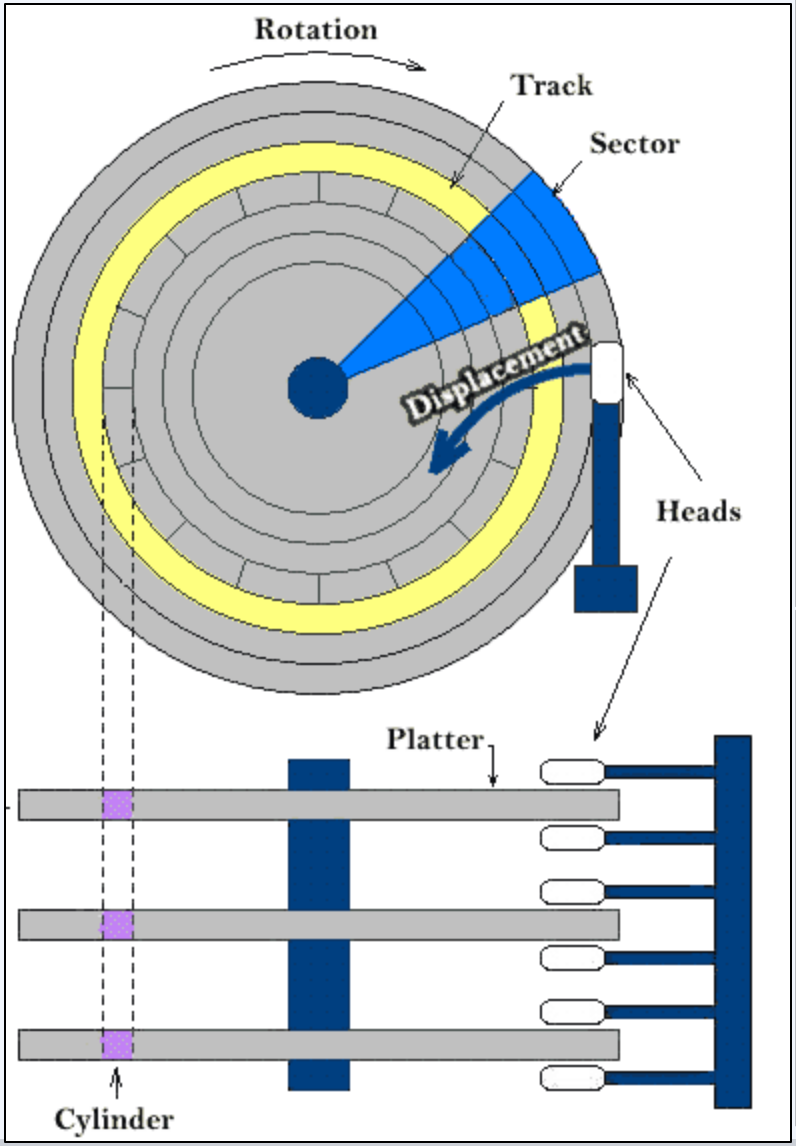
Hard Disks

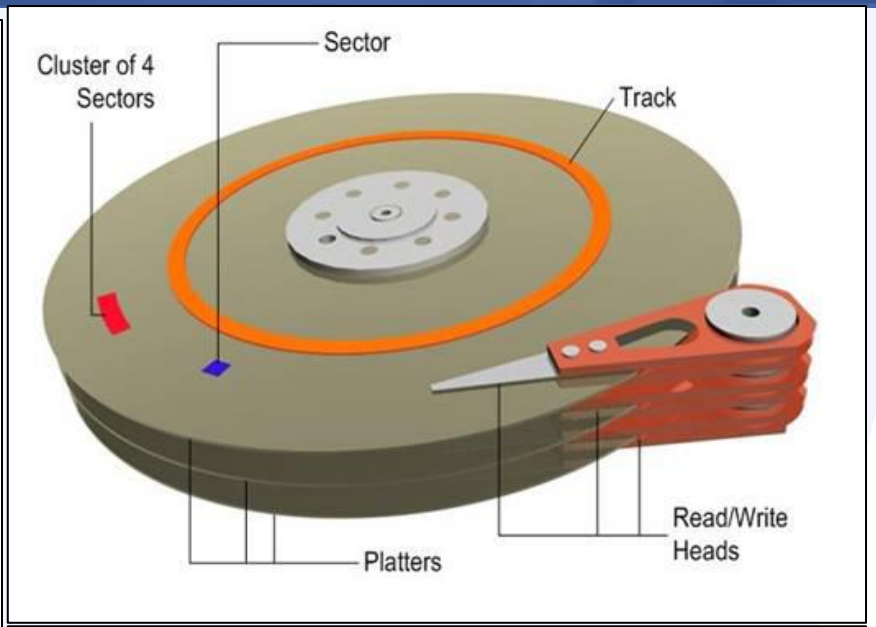
How Data is Stored in Hard Disks

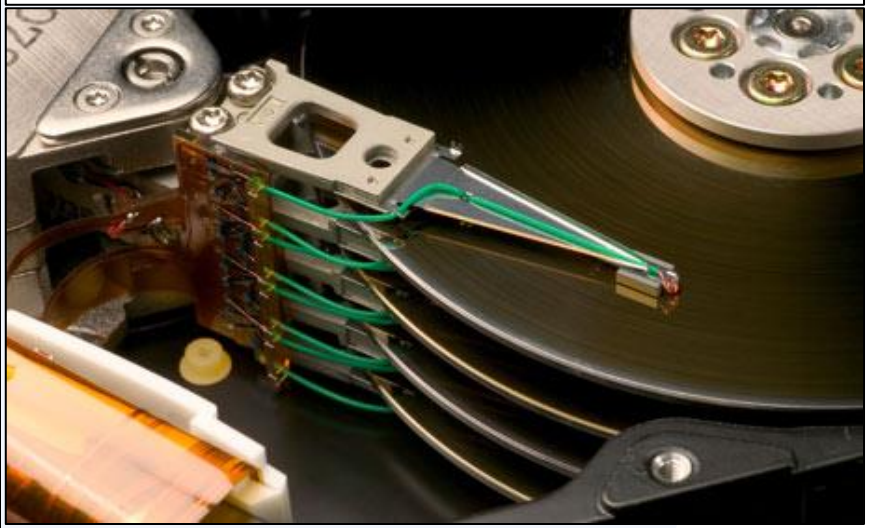
Here's how a hard disk organizes data:

Term	Meaning
Track	A circular path on a platter
Sector	Smallest storage unit on disk (usually 512 bytes or 4KB)
Cylinder	Tracks aligned on top of each other across platters
Disk Head	Reads or writes data
Disk Controller	Manages data transfer

Hard Disks


Rotation
Track
Sector
Displacement
Heads
Platter
Cylinder


Cluster of 4
Sectors
Sector
Track
Read/Write
Heads
Platters



Hard Disks

How to Calculate Disk Capacity

Here are the common terms used:

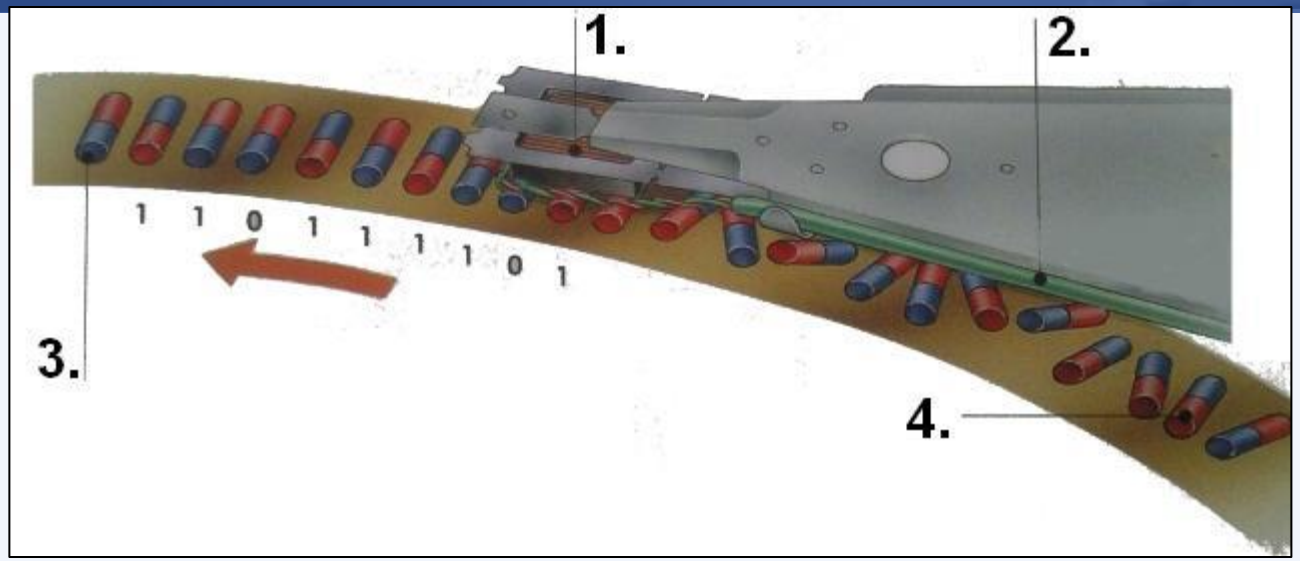
Term	Meaning
Bytes per sector	Size of one sector
Sectors per track	Number of sectors in one track
Tracks per cylinder	Each platter surface has tracks
Number of cylinders	Total number of track groups
Drive capacity	Total disk size

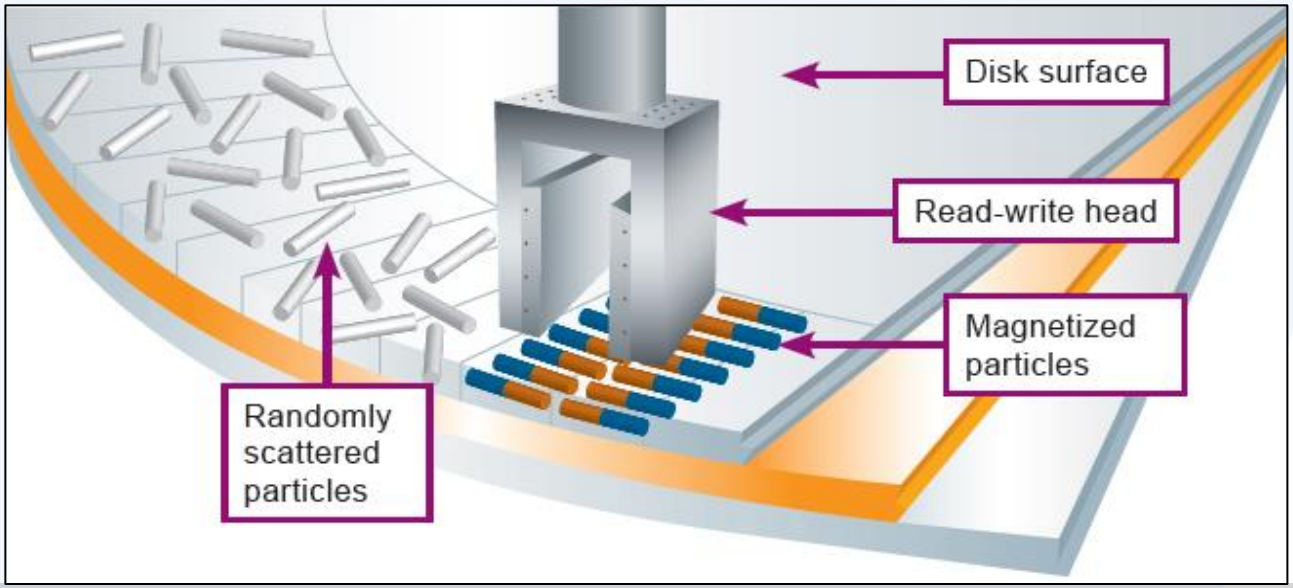
Hard Disks

Hard Disks

- Each platter has a read-write head that hovers just a few microinches above the surface.
- A read-write head mechanism in the disk drive magnetizes particles to write data, and senses the particles' polarities to read data.
- Hard disk technology is the preferred type of main storage for most personal computers because:
  - It provides lots of storage capacity.
  - It provides fast access to files.
  - A hard disk is economical.

Hard Disks

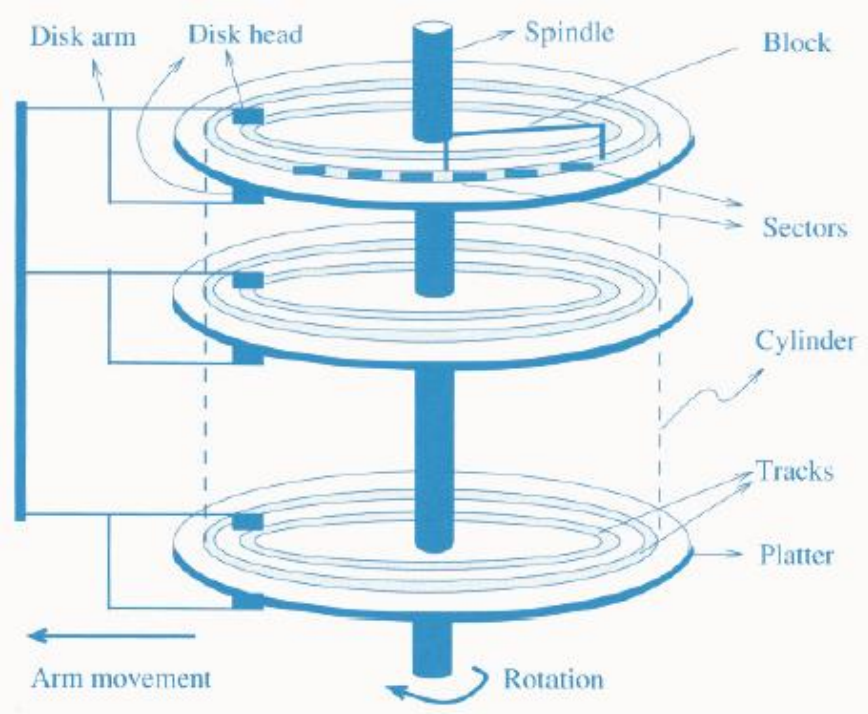

1.
2.
3.
4.
1 1 0 1 1 1 1 0 1


Disk surface
Read-write head
Magnetized particles
Randomly scattered particles

Hard Disks

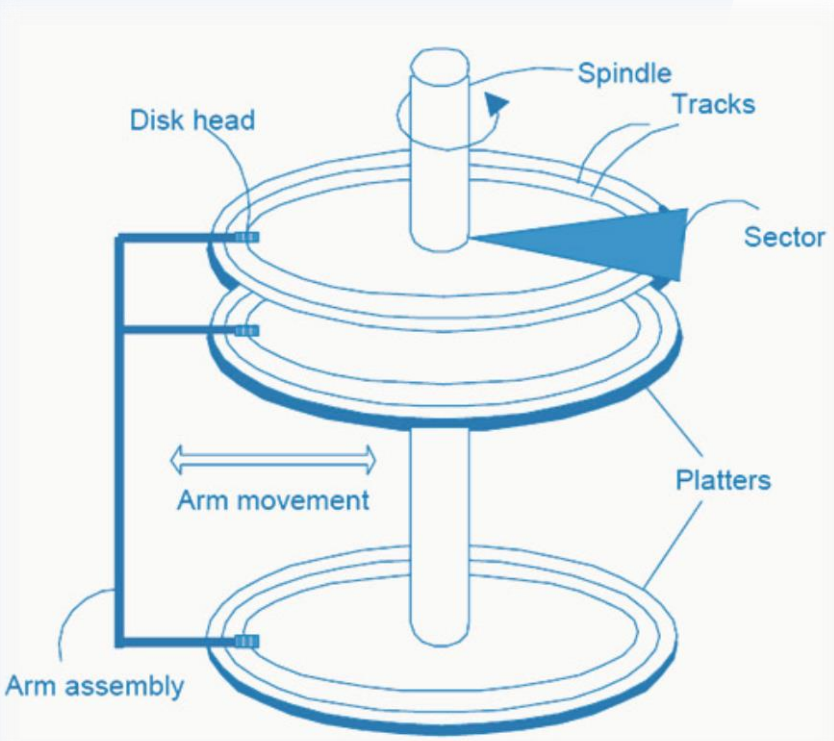
- Magnetic disks support direct access to a desired location

- Simplified structure of a disk:
  - Disk blocks
  - Tracks
  - Platters
  - Cylinder
  - Sectors
  - Disk heads
  - Disk Controller
  - Seek Time
  - Rotational delay



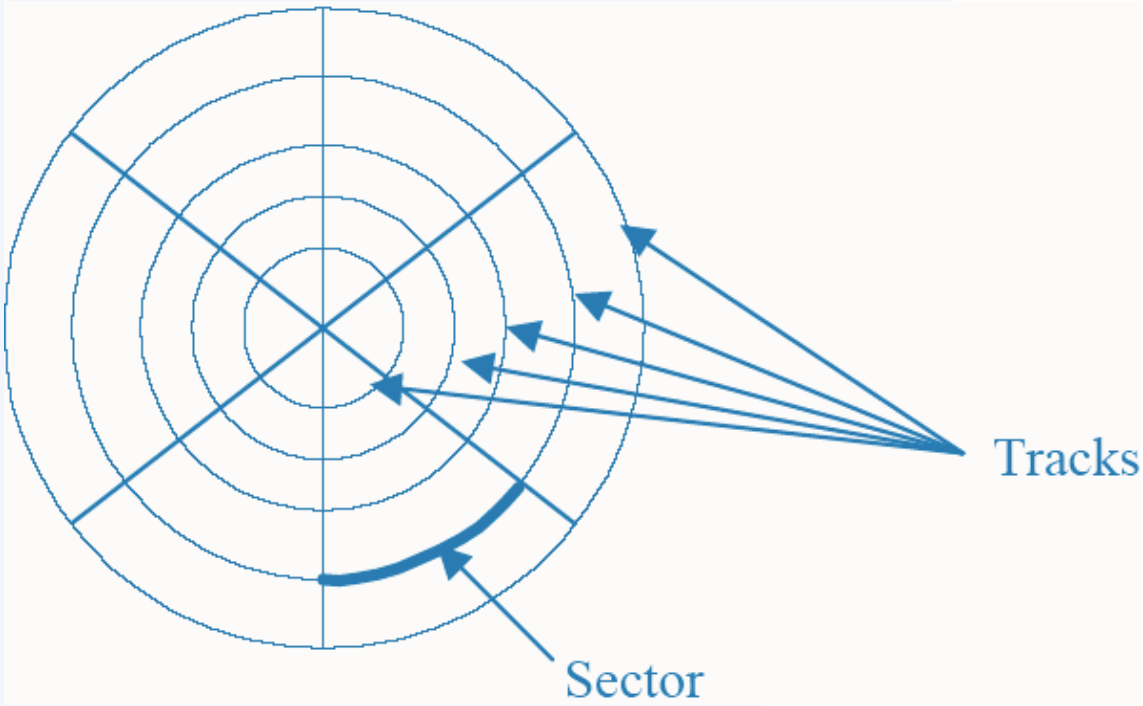
Hard Disks

- The platters spin (7200 rpm or 5400 rpm)
- The arm assembly is moved in or out to position a head on a desired track.
- Tracks under heads make a cylinder.
- Only one head reads/writes at any one time

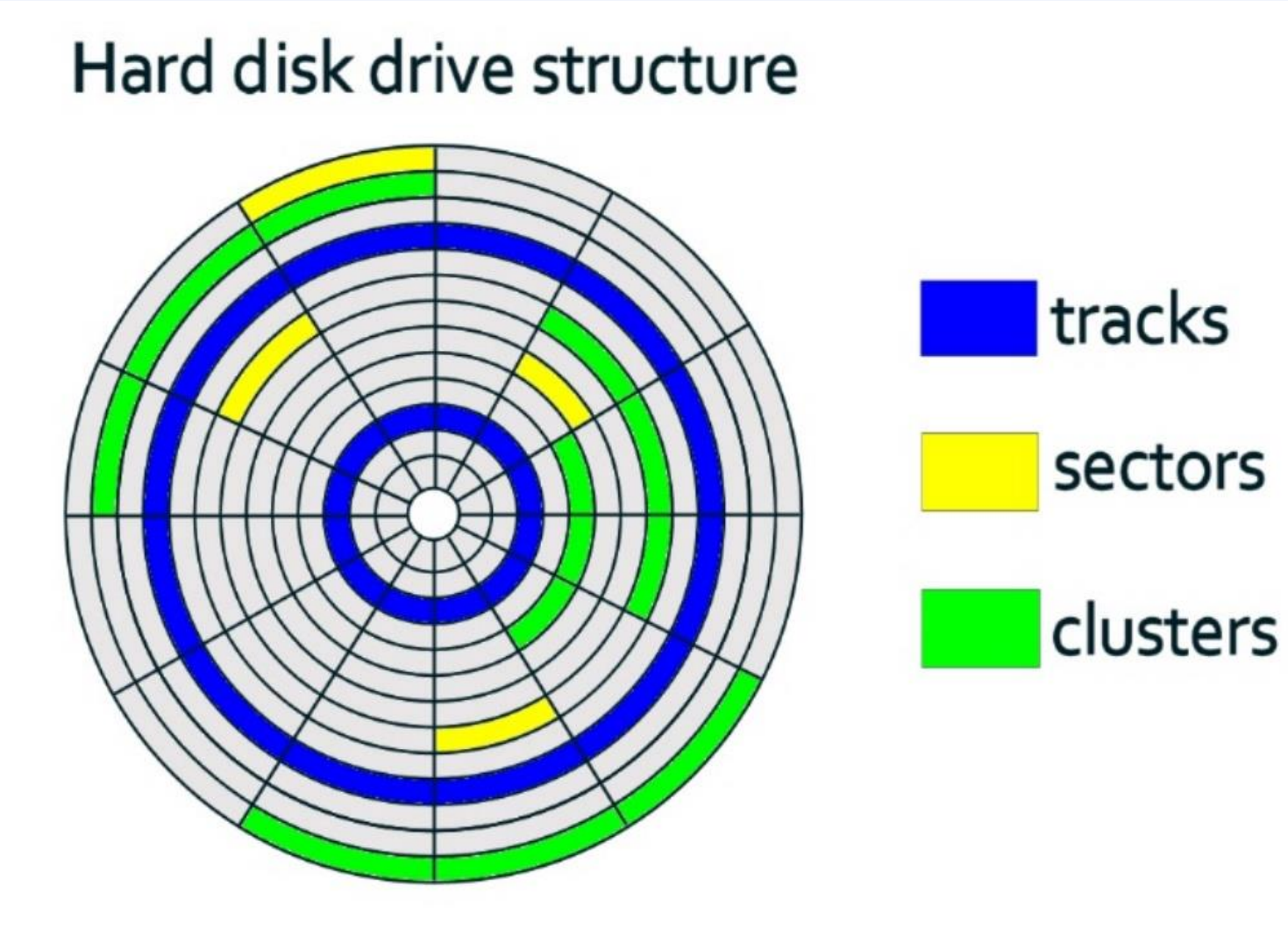


Hard Disks

- Disk contains concentric tracks
- Tracks are divided into sectors
- A sector is the smallest addressable unit in disk



Hard Disks



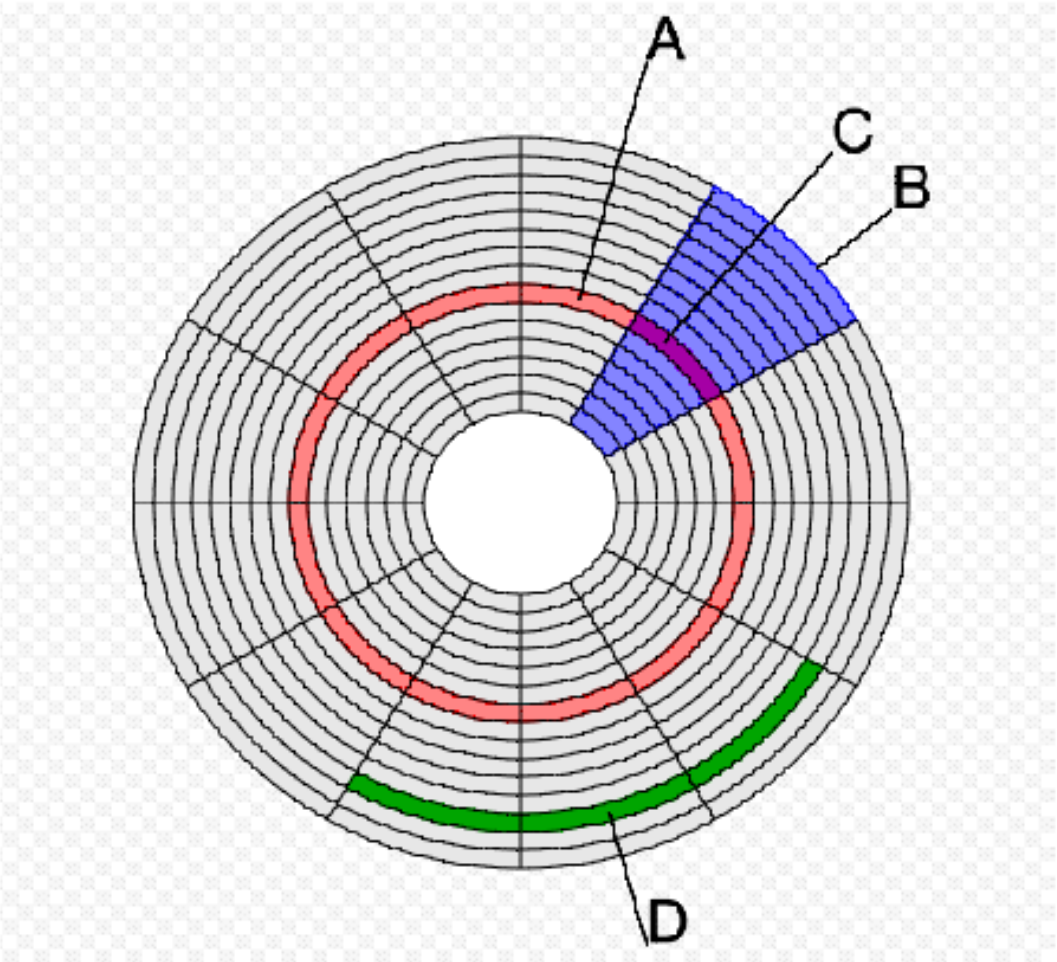
Hard Disks

A : Track

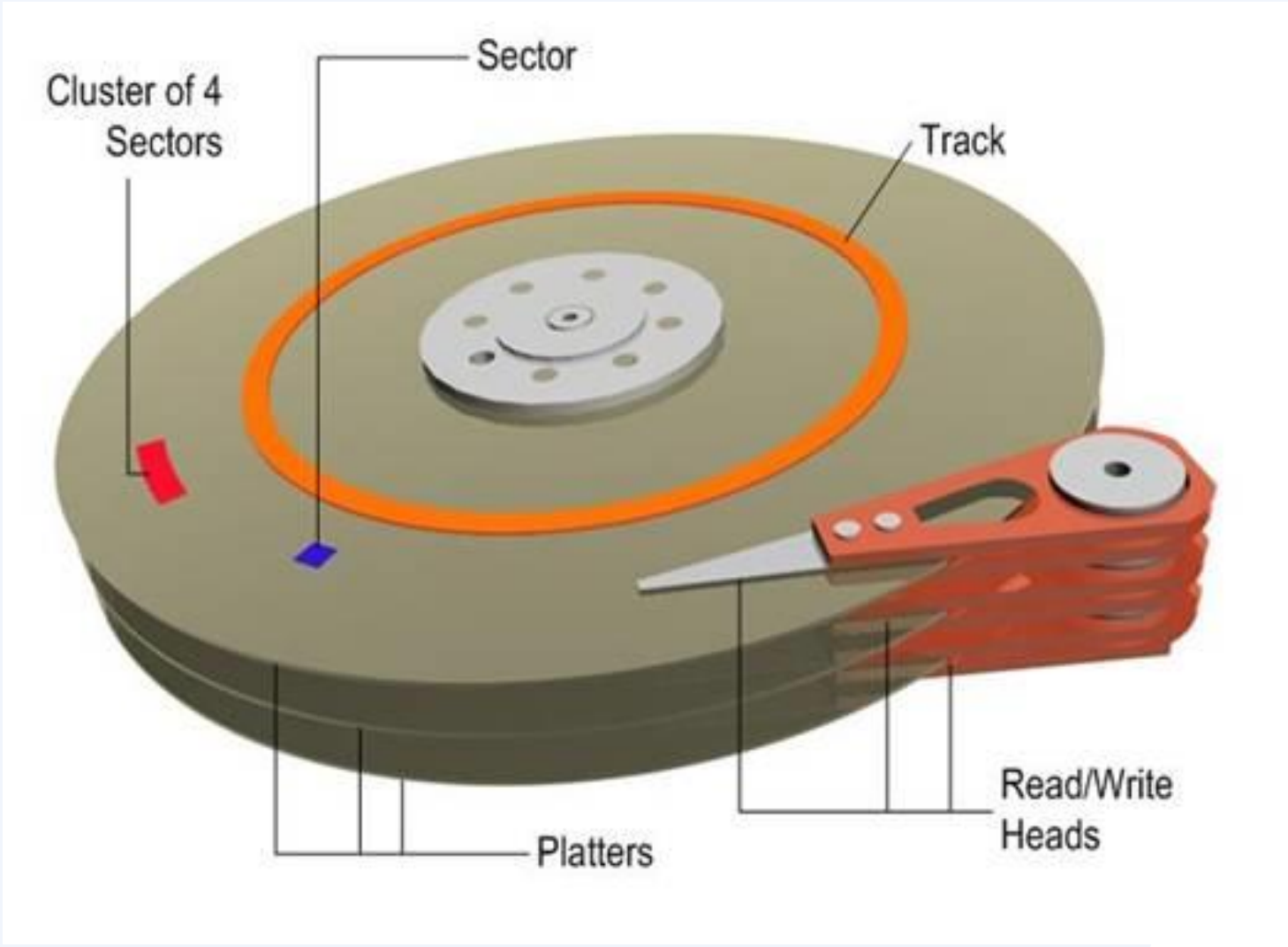
B : Geometrical Sector

C: Track Sector

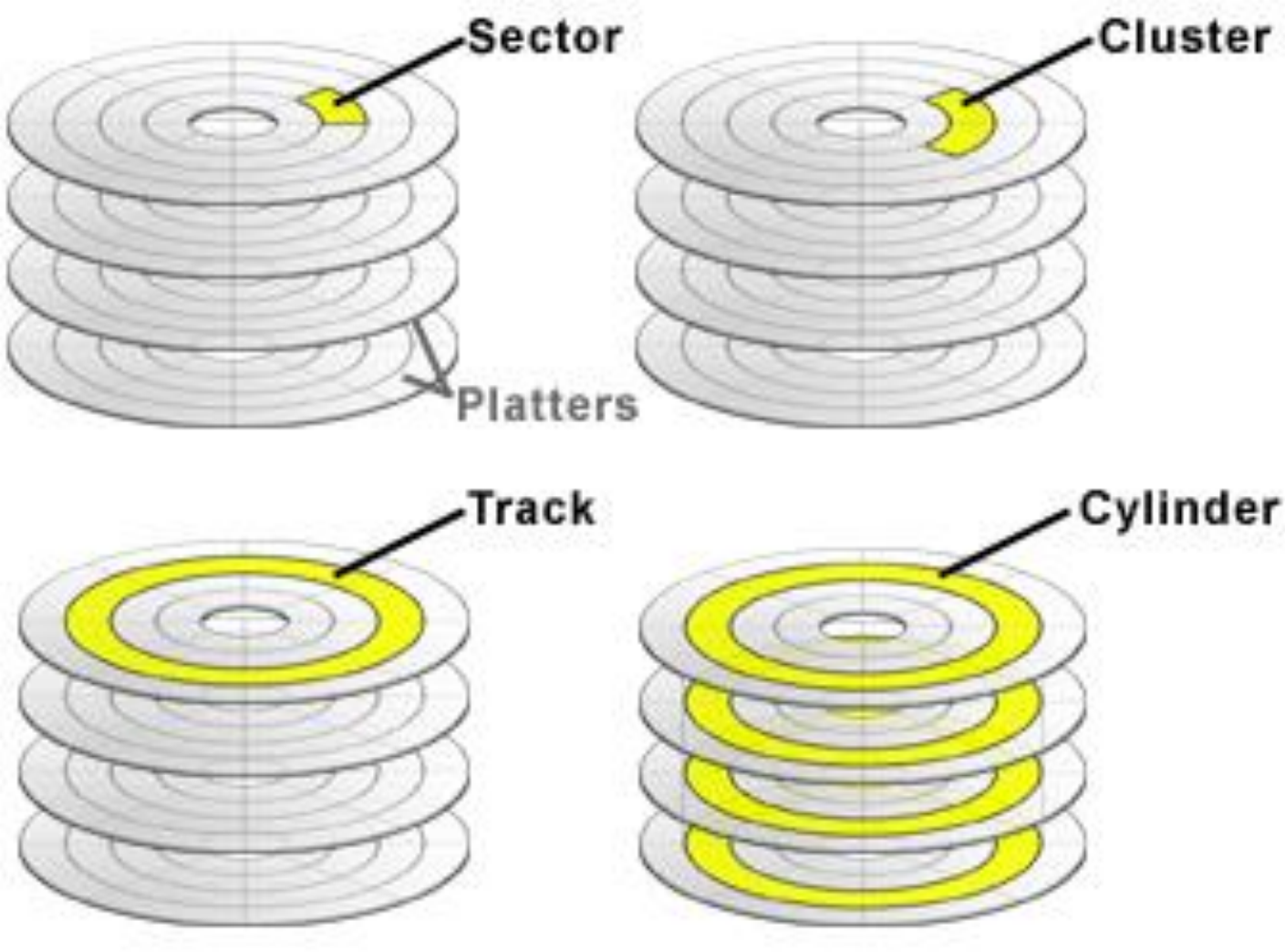
D: Cluster



Hard Disks


Cluster of 4
Sectors
Sector
Track
Read/Write
Heads
Platters

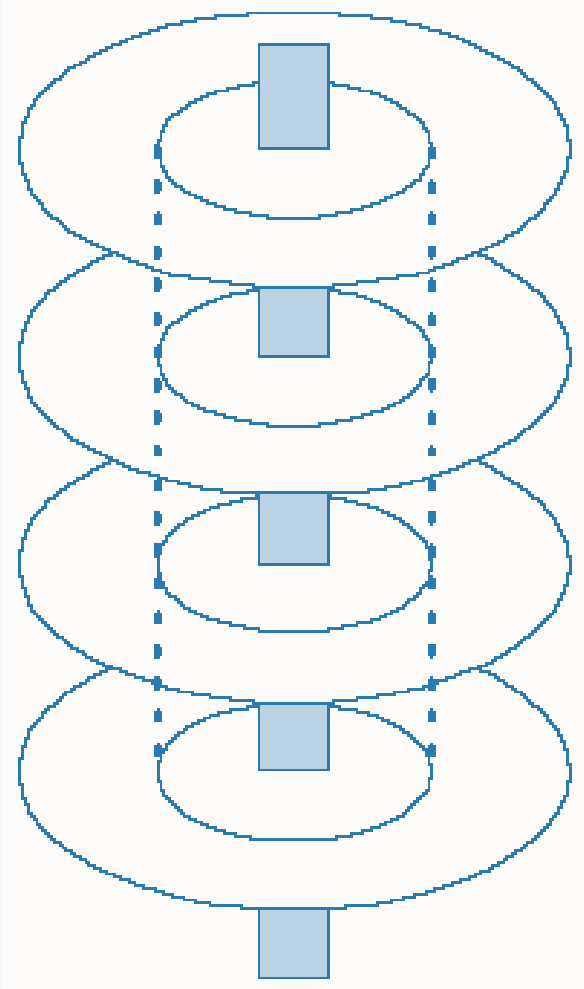
Hard Disks



Hard Disks

- **Cylinder**: the set of tracks on a disk that are directly above/below each other

- All the information on a cylinder can be accessed without moving the read/write arm (**seeking**)



Disk Access Bottleneck

- When a program reads a byte from the disk, the operating system locates the surface, track and sector containing that byte, and reads the entire sector into a special area in main memory called buffer.
- The bottleneck of a disk access is moving the read/write arm.
- So, it makes sense to store a file in tracks that are below/above each other in different surfaces, rather than in several tracks in the same surface.

How to calculate Disk Capacity?

- Number of cylinders = number of tracks in a surface
- Track capacity = number of sector per track × bytes per sector
- Cylinder capacity = number of surfaces × track capacity
- Drive capacity = number of cylinders × cylinder capacity

How to calculate Disk Capacity?

- Disk characteristics
  - Number of bytes per sector = 512
  - Number of sectors per track = 63
  - Number of tracks per cylinder = 16
  - Number of cylinders = 4092
- Drive capacity

Track capacity = 63 × 512 = **32,256 bytes**
Cylinder capacity = 16 × 32,256 = **516,096 bytes**
Drive capacity = 4092 × 516,096 ≈ **2.11 GB**

How to calculate Disk Capacity?

- If we know the number of bytes in a file, we can use it to compute the amount of disk space the file is likely to require.
- Suppose we have a file containing fixed-length records
  - Number of records = 50.000 records
  - Size of a record = 256 bytes
- Disk characteristics
  - Number of bytes per sector = 512
  - Number of sectors per track = 63
  - Number of tracks per cylinder = 16
  - Number of cylinders = 4092

1. **What is the total file size?**
2. **How many tracks are required?**
3. **How many cylinders are needed?**

1. What is the total file size?

Total bytes = number of records × size per record
= 50,000 × 256 =12,800,000 bytes

- **Number of sectors required**

  Sectors needed = ceil(total bytes / bytes per sector)
  = ceil(12,800,000 / 512) = 25,000 sectors

- then ceil(number of records / Number of sectors)

  = (50,000 / 25,000) = 2

2. How many tracks are required?

- **Number of tracks required**
- Tracks needed = ceil(sectors / sectors per track)
  = ceil(25,000 / 63)

  Compute multiples of 63:

  63 × 396 = 63×(400−4) = 25,200 − 252 = **24,948**

  63 × 397 = 24,948 + 63 = **25,011**

  25,000 lies between these, so we need **397 tracks** (because 396 tracks give only 24,948 sectors < 25,000).

3. How to calculate Disk Capacity?

- Since each sector can hold two records, the file requires:

$$\frac{50\,000}{2} = 25\,000 \text{ sectors}$$

- One cylinder can hold:

$$63 \times 16 = 1008 \text{ sectors}$$

- so the number of cylinders required is approximately

$$\frac{25\,000}{1008} = 24.8 \text{ cylinders}$$

The Cost of Disk Access

- **Seek time**: the time required to move the access arm to position disk head on the correct track.
- **Rotational delay**: the time it takes for the disk to rotate so the desired sector is under the read/write head.
- **Transfer time**: the amount of time required to move data to/from disk surface.
- **Average Total time** = **Average Seek time** + **Average Rotational delay** + **Transfer time**

External Hard Disks (Portable)

- The storage capacity of your desktop or laptop computer can be increased by adding a second hard disk drive.
- Internal drives are inexpensive and can be easily installed in a desktop computer's system unit.
- External drives are slightly more expensive and connect to a desktop or laptop computer using a cable.

Floppy Disk

- **Floppy disks** (also called floppies or diskettes) is a type of disk storage composed of a disk of thin and flexible magnetic storage medium, sealed in a rectangular plastic carrier lined with fabric that removes dust particles.

- This storage technology is no longer used because a floppy disk's 1.44 MB capacity is not sufficient for today's media-intensive applications.

Tapes

- A **tape** is a magnetically coated strip of plastic on which data can be encoded.
- Tapes are similar to tapes used to store music.
- Storing data on tapes is considerably cheaper than storing data on disks.

Tapes

- Accessing data on tapes, however, is much slower than accessing data on disks.

- Tapes are sequential-access media, which means that to get to a particular point on the tape, the tape must go through all the preceding points

Where is Magnetic Tape Used?

Magnetic Tape is mainly used for **backup storage** and **long-term archiving** in large organizations and data centers.

Area of Use	Explanation
Backup Storage	Used to store backup copies of important data in companies and banks to prevent data loss.
Long-Term Archiving	Stores data that is rarely accessed but must be kept for legal or historical reasons (e.g. hospital records, university archives, government data).
Data Centers	Tape is still widely used to store massive amounts of data because it is very cost-effective.
Disaster Recovery	Tape cartridges are stored in off-site locations and used to restore data after disasters like fire, ransomware, or system failure.
Scientific and Research Organizations	Organizations like NASA use magnetic tape to store large volumes of scientific data because it is reliable over time.

Why is Tape Still Used Today?

Even though it is older technology, **magnetic tape is still used** because:

- ✔ **Low cost per terabyte** (cheaper than HDD and SSD)
- ✔ **Very high storage capacity** (modern tapes like LTO-9 can store up to 18TB per tape)
- ✔ **Long lifespan** (up to 30 years of reliable storage)
- ✔ **High security** – offline and immune to cyberattacks like ransomware
- ✔ **Energy efficient** – consumes power only when in use

Examples of Tape Storage Systems

- ➢ **LTO (Linear Tape-Open)** – the most widely used tape technology today
- ➢ **IBM Tape Systems** – used in enterprise and government data centers
- ➢ **Oracle StorageTek Tape Libraries**

Thank You !