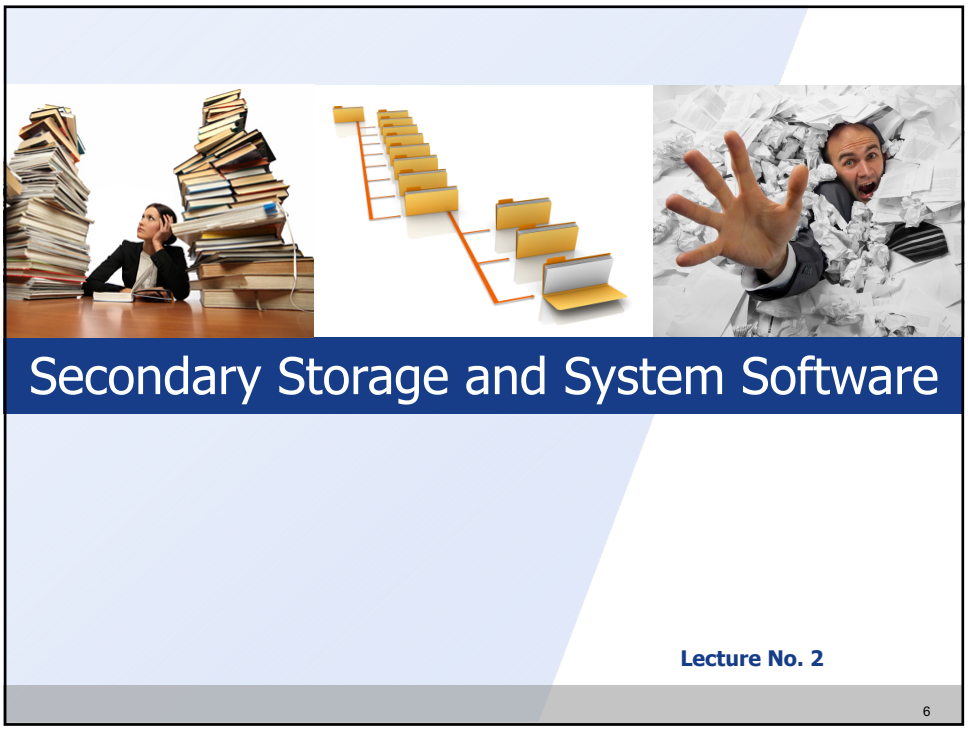
Secondary Storage and System Software
Lecture No. 2
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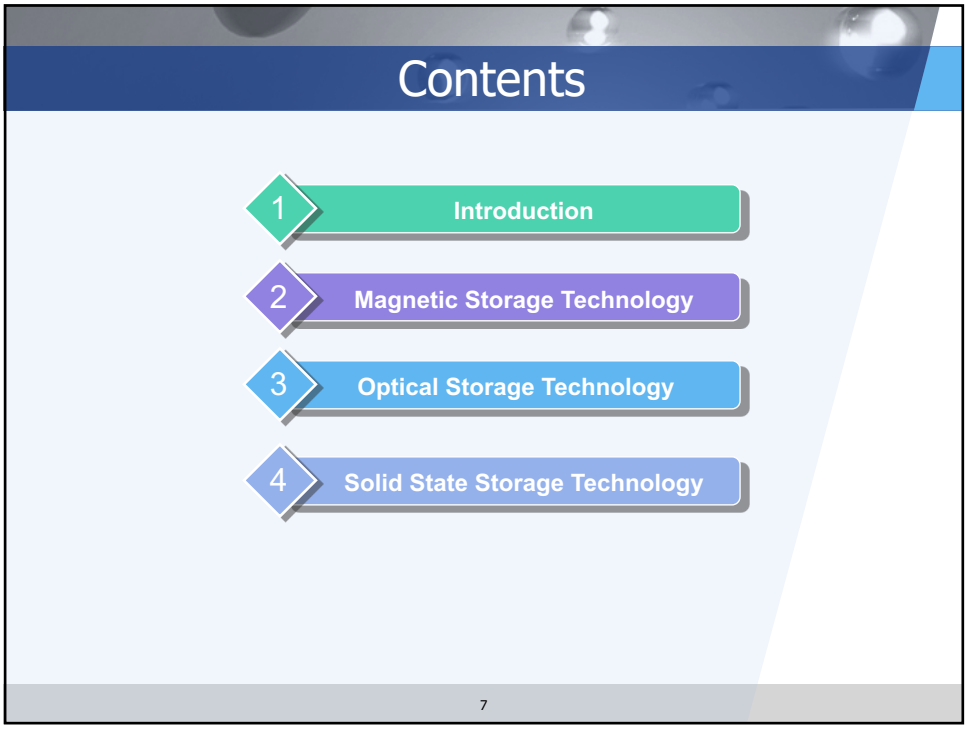
Contents
1 Introduction
2 Magnetic Storage Technology
3 Optical Storage Technology
4 Solid State Storage Technology
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Introduction

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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.
- Two major types of storage devices according to Access type:
  - Direct Access Storage Devices (DASDs)
    - Magnetic Disks
      Hard Disks (high capacity, low cost per bit)
    - Optical Disks
      CD-ROM,DVD-ROM
      (Read-only/write-once, holds a lot of data, cheap)
  - Serial Devices
    - Magnetic Tapes

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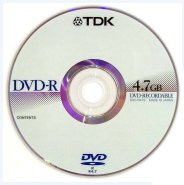
Storage Basics

- A data storage system has two main components: a storage medium and a storage device.
- A **storage medium** is the disk, tape, CD, DVD, paper, or other substance that contains data.



- A **storage device** is the mechanical device that records and retrieves data from a storage medium.

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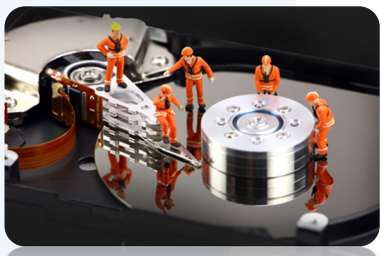
Storage Basics

- Three types of **storage technologies** are commonly used for personal computers: magnetic, optical, and solid state
- Each storage technology has its advantages and disadvantages.



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Magnetic Storage Technology

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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

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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.

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Hard Disks

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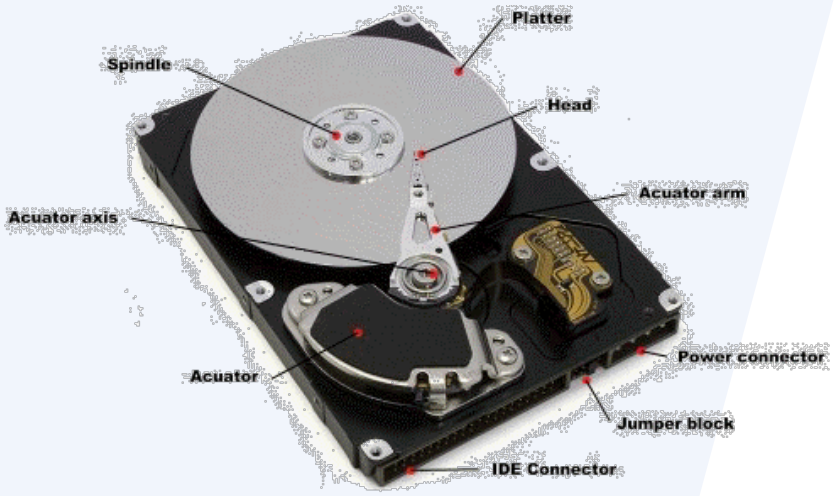
Hard Disks



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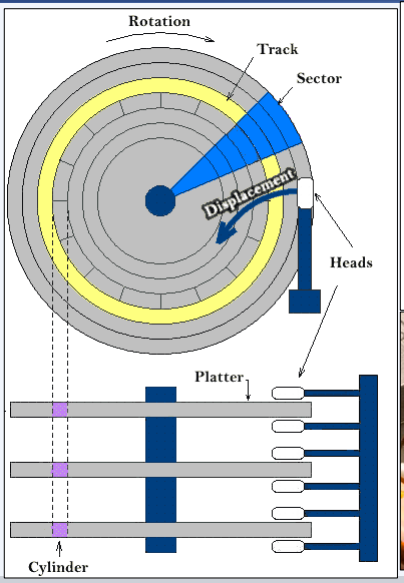
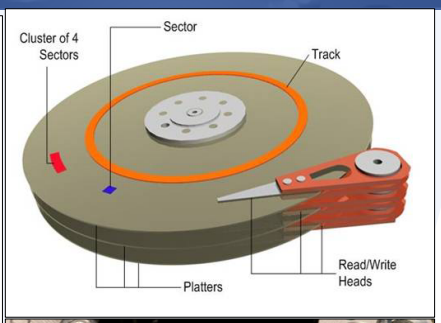
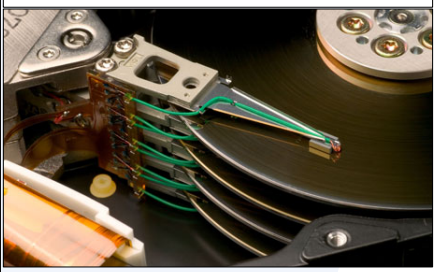
Hard Disks







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Hard Disks

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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.

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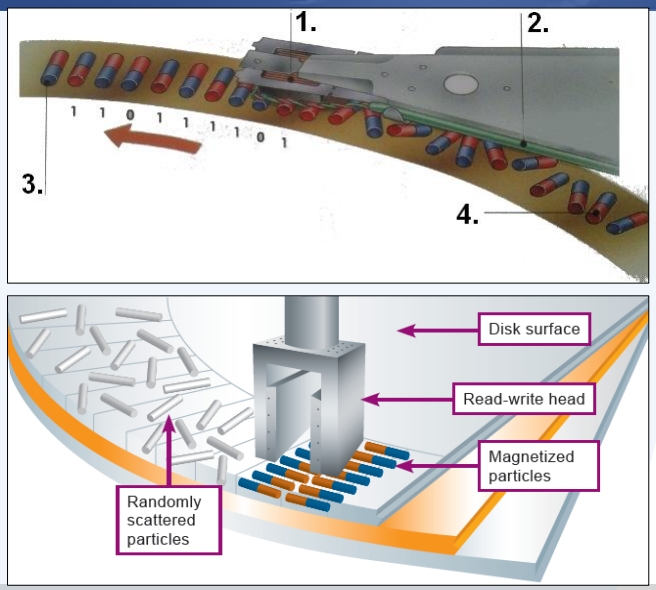
Hard Disks



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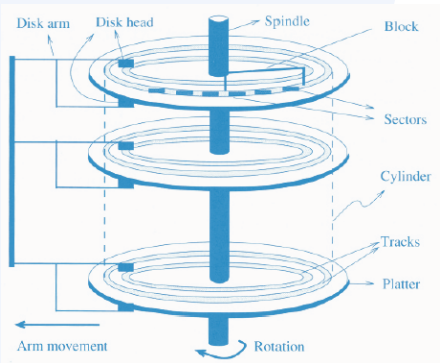
Hard Disks

- 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



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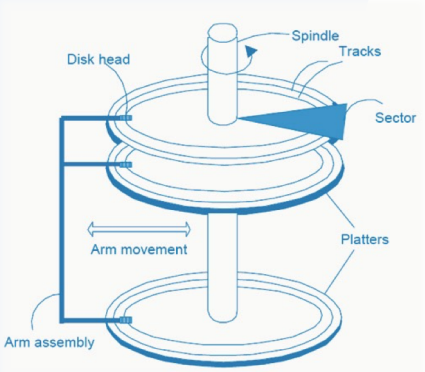
Hard Disks

- 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



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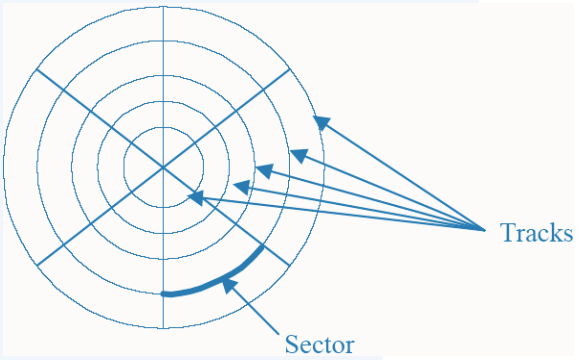
Hard Disks

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



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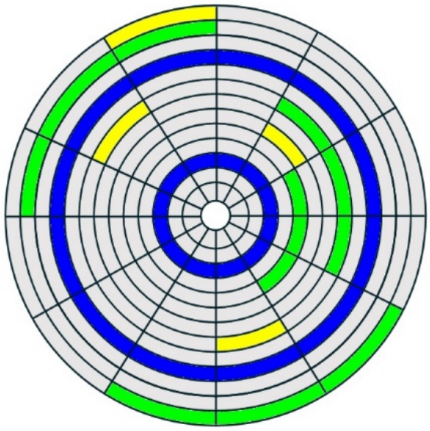
Hard Disks

Hard disk drive structure



tracks

sectors

clusters

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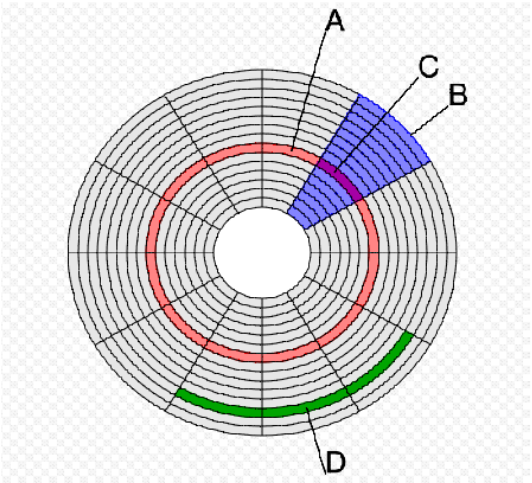
Hard Disks

A : Track

B : Geometrical Sector

C: Track Sector

D: Cluster



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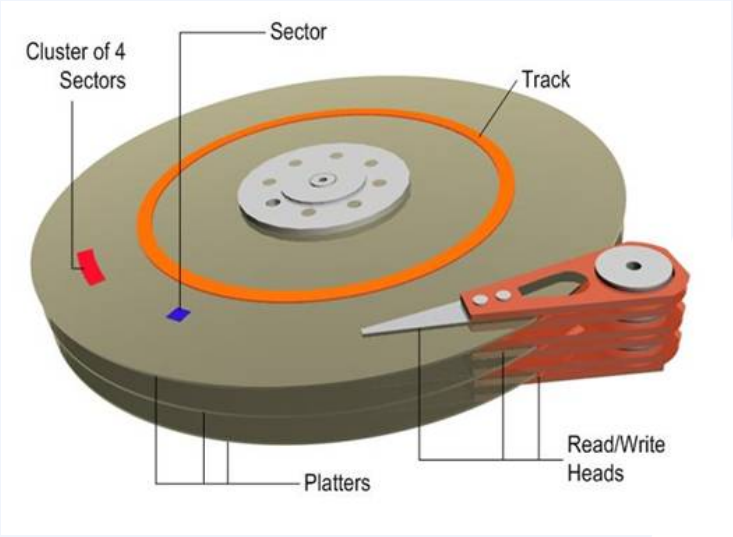
Hard Disks



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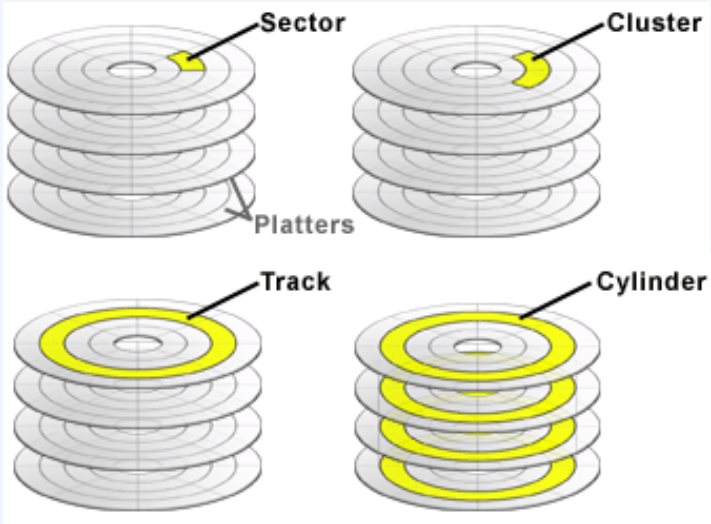
Hard Disks



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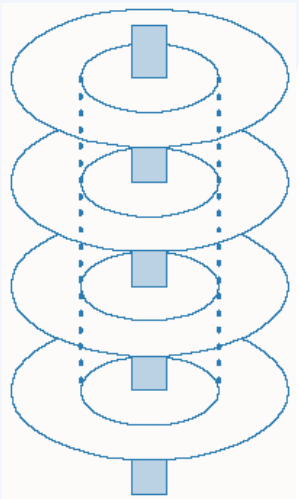
Hard Disks

- **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**)



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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.

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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

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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
- How many cylinders are needed?

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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

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

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Clusters, Extents, and Fragmentation

- The **file manager** is the part of the operating system responsible for managing files
- The file manager maps the logical parts of the file into their physical location
- A **cluster** is a fixed number of contiguous sectors
- The file manager allocates an integer number of clusters to a file.

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Clusters, Extents, and Fragmentation

- **An example:** Sector size: 512 bytes, Cluster size: 2 sectors
- If a file contains 10 bytes, a cluster is allocated (1024 bytes).
- There may be unused space in the last cluster of a file.
- This unused space contributes to internal fragmentation

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Clusters, Extents, and Fragmentation

- Clusters are good since they improve sequential access: reading bytes sequentially from a cluster can be done in one revolution, seeking only once.
- The file manager maintains a file allocation table (FAT) containing for each cluster in the file and its location in disk
- An **extent** is a group of contiguous clusters. If file is stored in a single extent then seeking is done only once.
- If there is not enough contiguous clusters to hold a file, the file is divided into 2 or more extents.

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Fragmentation

- Due to records not fitting exactly in a sector
  - Example: Record size = 200 bytes, sector size = 512 bytes
  - To avoid that a record span 2 sectors we can only store 2 records in this sector (112 bytes go unused per sector)
  - The alternative is to let a record span two sectors, but in this case, two sectors must be read when we need to access this record)
- Due to the use of clusters
  - If the file size is not multiple of the cluster size, then the last cluster will be partially used.

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How to Choose Cluster Size

- Some OS allow the system administrator to choose the cluster size.
- When to use large cluster size?
  - When disks contain large files likely to be processed sequentially.
  - Example: Updates in a master file of bank accounts (in batch mode)
- What about small cluster size?
  - When disks contain small files and/or files likely to be accessed randomly
  - Example : online updates for airline reservation

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Organizing Tracks by Blocks

- Disk tracks may be divided into user-defined blocks rather than into sectors.
- The amount transferred in a single I/O operation can vary depending on the needs of the software designer
- A block is usually organized to contain an integral number of logical records.

Blocking Factor = number of records stored in each block in a file

- No internal fragmentation, no record spanning two blocks

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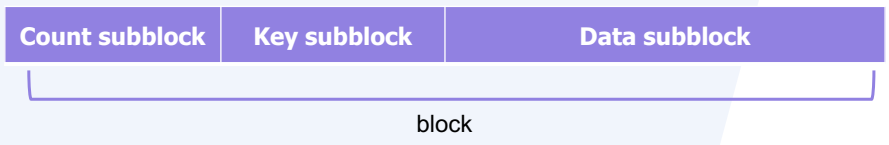
Organizing Tracks by Blocks

- A block typically contains subblocks:
  - Count subblock: contains the number of bytes in a block
  - Key subblock (optional): contains the key for the last record in the data subblock (disk controller can search for key without loading it in main memory)
  - Data subblock: contains the records in this block.



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Nondata Overhead

- Amount of space used for extra stuff other than data
- Sector-Addressable Disks
  - At the beginning of each sector some info is stored, such as sector address, track address, condition (if sector is defective);
  - There is some gap between sectors
- Block-Organized Disks
  - subblocks and interblock gaps is part of the extra stuff; more nondata overhead than with sector-addressing

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Solved Example

- Disk characteristics
  - Block-addressable Disk Drive
  - Size of track = 20.000 bytes
  - Nondata overhead per block = 300 bytes
- File Characteristics
  - Record size = 100 bytes
- How many records can be stored per track for the following blocking factors?
  1. Block factor = 10
  2. Block factor = 60

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Solved Example

- Blocking factor is 10
- Size of data subblocks = 1000
- Number of blocks that can fit in a track =

$$\left\lfloor \frac{20000}{1300} \right\rfloor = \lfloor 15.38 \rfloor = 15$$

- Number of records per track = 150 records

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Solved Example

- Blocking factor is 60
- Size of data subblocks = 6000
- Number of blocks that can fit in a track =

$$\left\lfloor \frac{20000}{6300} \right\rfloor = \lfloor 3.17 \rfloor = 3$$

- Number of records per track = 180 records

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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**

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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.

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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.

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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.

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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

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Optical Storage Technology

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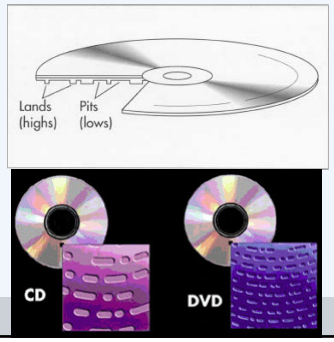
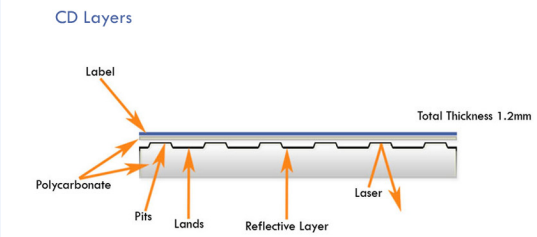
Optical Storage Technology

- CD, DVD, and Blu-ray technologies are classified as **optical storage**, which stores data as microscopic light and dark spots on the disc surface.
- The dark spots are called pits. The lighter, non-pitted surface areas of the disc are called lands.





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Optical Storage Technology

- Optical drives contain a spindle that rotates the disc over a laser lens.
- The laser directs a beam of light toward the underside of the disc.
- The dark pits and light lands on the disc surface reflect the light differently.
- As the lens reads the disc, these differences are translated into the 0s and 1s that represent Data

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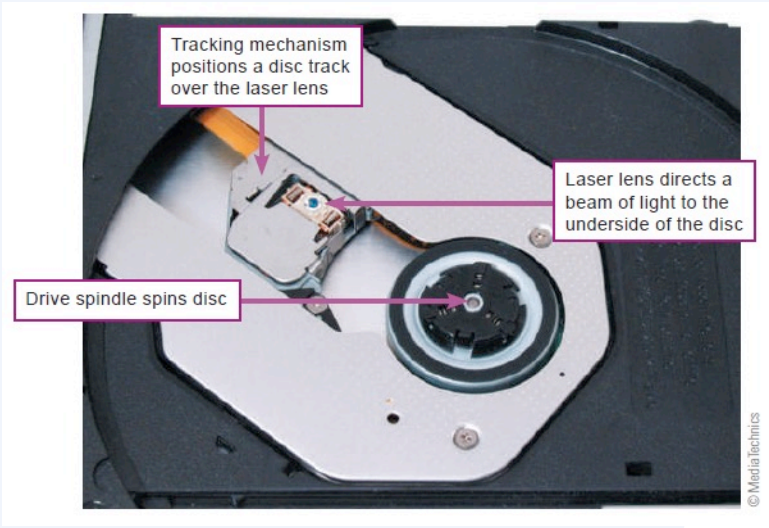
Optical Storage Technology



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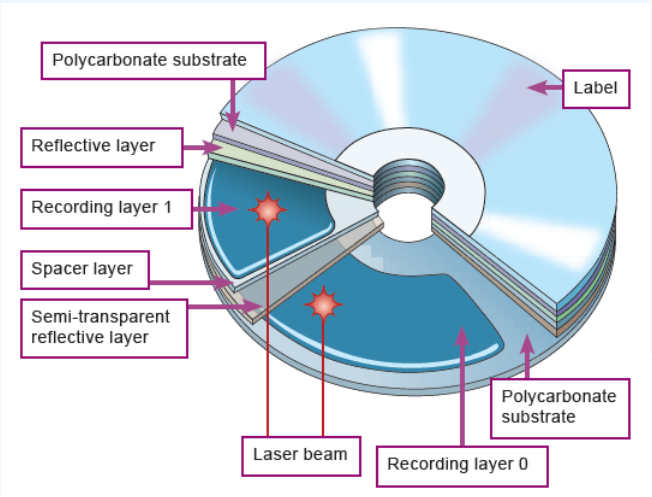
Optical Storage Technology



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Optical Storage Technology

- Optical technologies are grouped into three categories: read-only, recordable, and rewritable.

Read-only

Read-only Technology (ROM)

You cannot write to a -ROM disc, which left the factory with data already on it. A -ROM drive can read discs but not write to them, and has no use at all for a blank disc.

Recordable

Recordable Technology (R)

You can write to one of these discs once (provided you have an -R drive). But when you're done, it's effectively a -ROM disc

Rewritable

Rewritable Technology (RW)

You can write to these discs, erase them, and write to them again. The term re-recordable (RE) is sometimes used instead of rewritable

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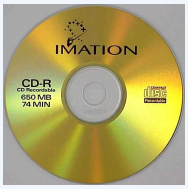
CD (Compact Disc)

- **CD (Compact Disc)** technology was originally designed to hold 74 minutes of recorded music.
- The original CD standard was adapted for computer storage with capacity for 650 MB of data.
- Later improvements in CD standards increased the capacity to 80 minutes of music or 700 MB of data.



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DVD (Digital Video Disc)

- **DVD (Digital Video Disc or Digital Versatile Disc)** is a variation of CD technology that was originally designed as an alternative to VCRs, but was quickly adopted by the computer industry to store data.
- The initial DVD standard offered 4.7 GB (4,700 MB) of data storage.
- A double layer DVD has two recordable layers on the same side and can store 8.5 GB of data.

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Blu-ray

- **Blu-ray** is a high-capacity storage technology with a 25 GB capacity per layer.
- The name Blu-ray is derived from the blue-violet colored laser used to read data stored on Blu-ray discs.
- DVD technology uses a red laser; CD technology uses a near infrared laser

Blu-ray Disc

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Solid State Storage Technology

- **Solid State Storage** (sometimes called flash memory) is a technology that stores data in erasable, rewritable circuitry, rather than on spinning disks or streaming tape.
- It is widely used in portable consumer devices, such as digital cameras, portable media players, iPads, and cell phones.
- It is also used as an alternative for hard disk storage in some laptop computers.

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Solid State Storage Technology

- Solid state storage contains a grid work of circuitry.
- Each cell in the grid contains two transistors that act as gates to hold the 1s and 0s that represent data
- Very little power is required to open or close the gates, which makes solid state storage ideal for battery-operated devices, such as digital cameras and media players.

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Solid State Storage Technology

- Solid state storage has the following advantages:
  - Fast access to data because it includes no moving parts.
  - Very durable; it is virtually impervious to vibration, magnetic fields, or extreme temperature fluctuations.
- However, the capacity of solid state storage does not currently match that of hard disks.
- The cost per megabyte of solid state storage is slightly higher than for magnetic or optical storage.

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Solid State Storage Technology

- Several types of solid state storage are available to today's consumers: memory cards, solid state drives, and USB flash drives.

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Memory Cards

- A **memory card** is a flat, solid state storage medium commonly used to transfer files from digital cameras and media players to computers.
- A **card reader** is a device that reads and writes data on solid state storage.

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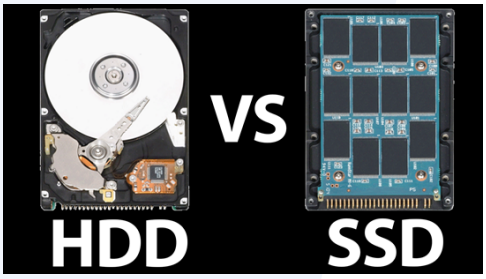
Solid State Drive (SSD)

- A **solid state drive (SSD)** is a package of flash memory that can be used as a substitute for a hard disk drive.
- Some solid state drives are about the same size as a microprocessor chip, whereas others are about the size of a small hard disk drive.



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USB Flash Drives

- A **USB flash drive** is a portable storage device that plugs directly into a computer's system unit using a built-in connector.
- USB flash drives have capacities ranging from 16 MB to 256 GB.
- Flash drives are slower than hard disk drives.

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Advantages & Disadvantages of Different Storage Technology

Storage Type	Cost of Device	Capacity	Data Transfer Rate	Technology	Removable
USB Flash Drive	$$	2–256 GB	Medium	Solid state	Yes
CD-RW	$	700 MB	Slow	Optical	Yes
DVD+RW	$	8.5 GB	Slow	Optical	Yes
Blu-ray	$$$$	50 GB	Slow	Optical	Yes
Floppy Disk	$	1.44 MB	Glacial	Magnetic	Yes
Hard Drive (Internal)	$$$	80 GB–2 TB	Fast	Magnetic	No
Hard Drive (External)	$$$	80 GB–2 TB	Fast	Magnetic	Yes
Solid State Drive (Internal)	$$$	32 GB–256 GB	Fast	Solid state	No

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