Computing Fundamentals and Programming (CE-100)
Batch 2019 (Electronic Engineering)
Chapter 5: Storage Hardware

Prepared by:
Engr. Saeed Azhar (Assistant Professor, EED)   (Electronics Sec A)

Common Elements of Storage Technology

To measure the data capacity of secondary storage devices following terms are used

- ☐ Kilobyte (K or KB): is equivalent to 1024 bytes.
- ☐ Megabyte (M or MB): is equivalent to 1 million bytes.
- ☐ Gigabyte (G or GB): is equivalent to 1 billion bytes.
- ☐ Terabyte (T or TB): is equivalent to 1 trillion bytes.

READING: The process of retrieving information from a storage device is referred to as READING

WRITING: The process of copying information to a storage device is referred to as WRITING.

Storage System Characteristics

- Consist of a storage device and a storage medium
  - Device: DVD drive, flash memory card reader, etc.
  - Media: DVD disk, flash memory card, etc.
  - Media is inserted into device to be used
 - Storage devices are typically identified by letter
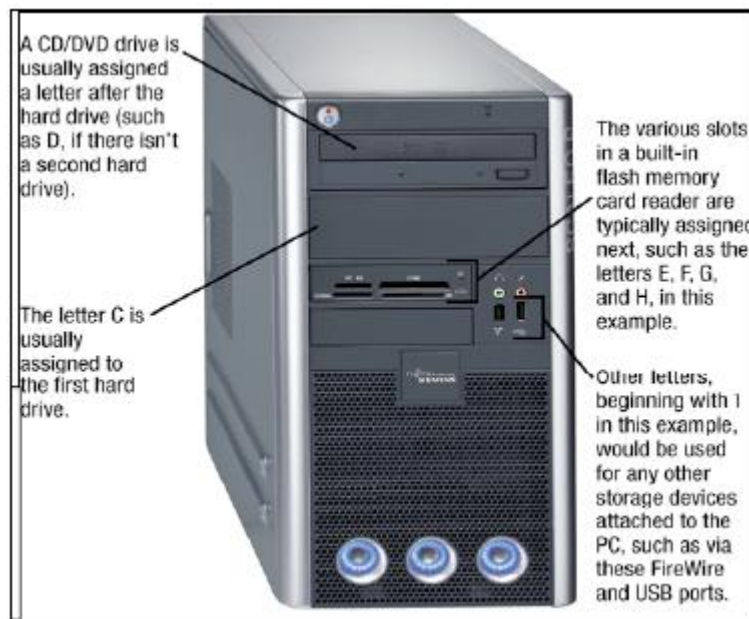
Magnetic Disks vs. Optical Discs

- With magnetic media, such as floppy discs, data is stored magnetically
  - The data (0s and 1s) is represented using different magnetic alignments
- Optical media (such as CDs and DVDs) store data optically using laser beams
  - Data can be permanently burned on the disc
  - Rewritable optical media can be erased and rewritten
- Some storage systems combine magnetic and optical technology
- Others like flash memory represent data using electrons

Magnetic Disk Systems

- Magnetic disks: Record data using magnetic spots on disks made of flexible plastic or rigid metal
  - Most widely used storage medium on today's computers (hard drives)
  - Disks are divided into tracks, sectors, and clusters
  - Data written and read using read/write heads
- **Common types**
  - Floppy disks (common removable storage medium in the past; not widely used today)
  - Hard disks (included on nearly all PCs today)
  - Zip disks (high-capacity magnetic discs that are proprietary)
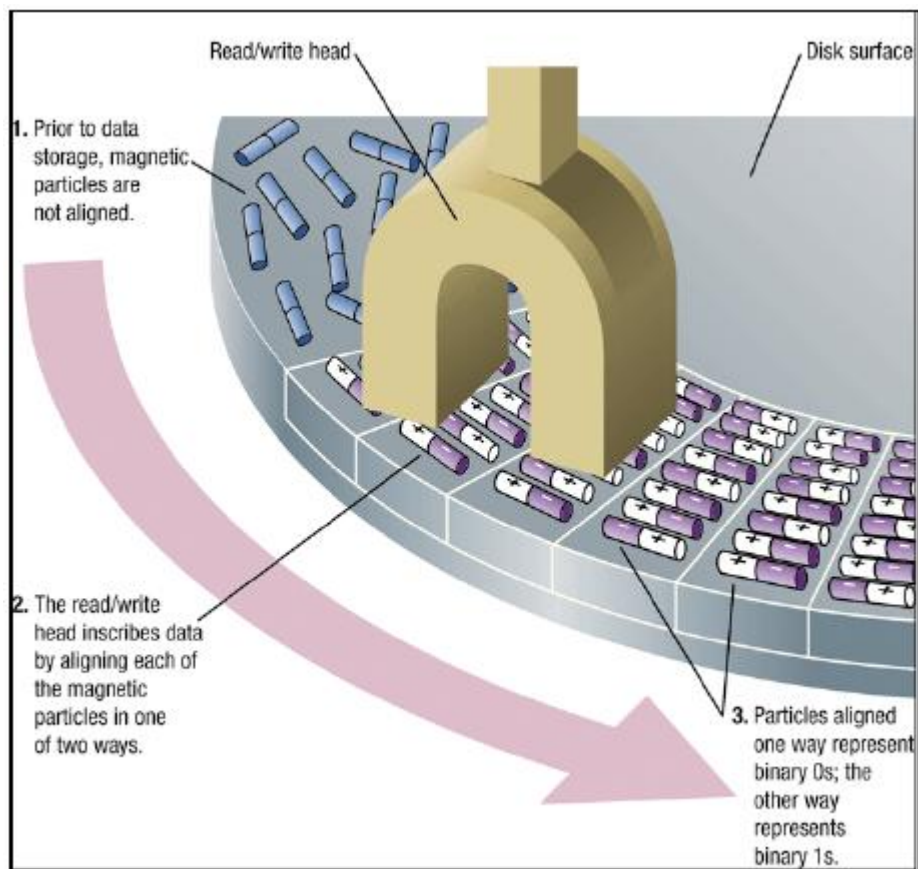
Storing data on Magnetic disks
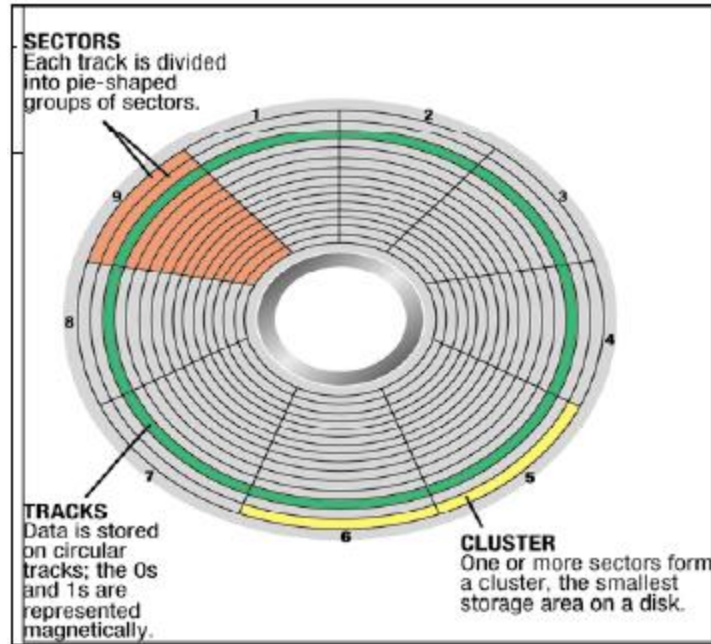
Magnetic disks are organized into tracks, sectors and cluster

Data Access Methods

Information is read from and written to a storage device according to a specific method, called a data access method. The method used affects its speed and its usefulness for certain applications.

1) Sequential Storage
2) Direct Access Storage
3) The Indexed Sequential Access Method

Sequential Storage

☐ It means that data is stored in sequence, such as alphabetically.
☐ Tape Storage falls in this category.
☐ It is ideal for the case when information must be accessed in sequential order.

Direct Access Storage

☐ It is also called Random Access Storage.
☐ The Computer can go directly to the information you want.
☐ Hard disks and other types of disks generally fall in this category.
☐ It is ideal for the case when information must be accessed in random order.

Indexed Sequential Access Method

☐ It has some of the advantages of both the sequential and direct forms of storage.
☐ It stores data in sorted order. However, the file in which the data is stored contains and index that lists the data by key fields and identifies the physical location on the disk.

Diagram on next page illustrates all three methods
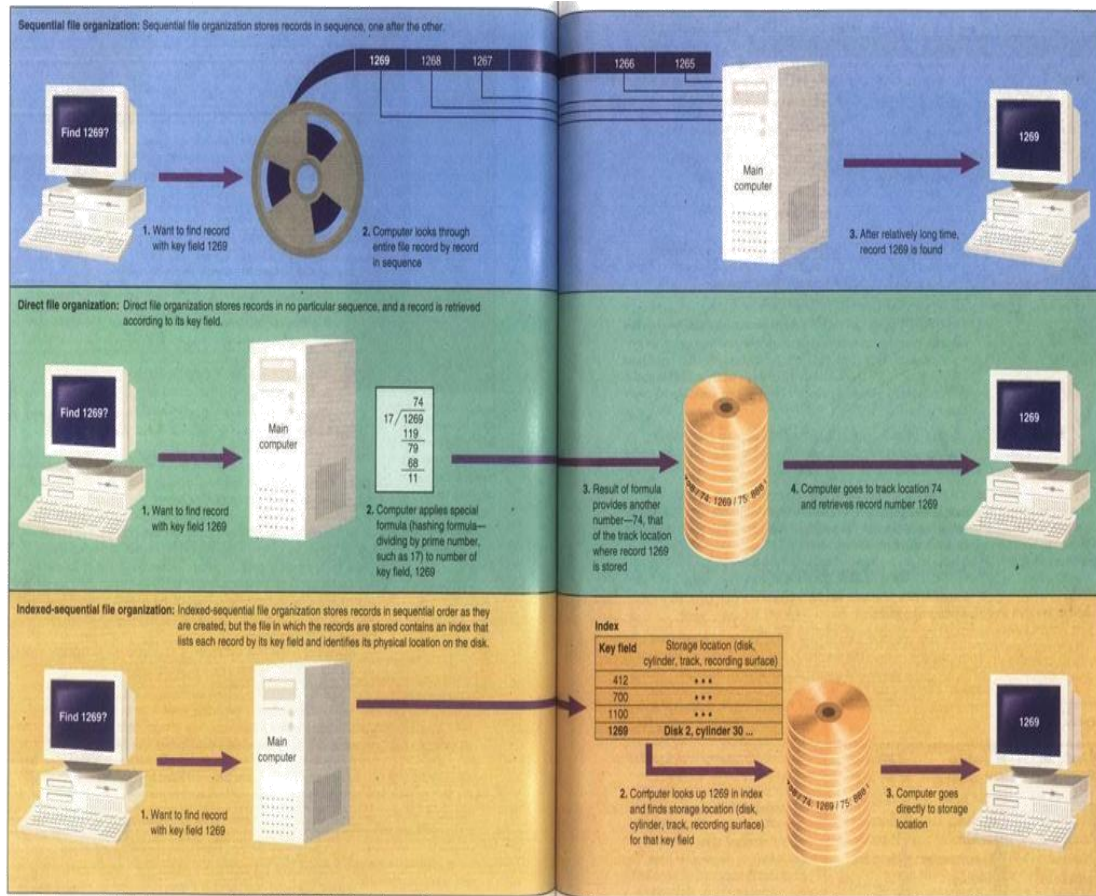
Types of Files

File: A file is a collection of data or information treated as a unit by the computer.

A file name consists of a unique name, which describes its contents, and a three character extension, which describes its type. OS locate these files by means of File Allocation Table (FAT).

FAT: It keeps track where everything is stored on disk by maintaining a sort of indexed table with entries of location for all file names.

Some Common types of files are
- **Program Files**
  - These files contain software instructions
  - Source program files contains high-level computer instructions in their original form, as written by the programmers
- **Data Files**
  - Data files, also called document files, contain data not program
- **ASCII files**
  - ASCII files are text only files that is these files are without formatting, such as bold face, italic and graphics
- **Image files**
  - It contains digitized graphics
- **Audio and Video files**
  - Audio files contains digitized sounds and video files contains video images

Characteristics of Hard disks:
These are rigid metal or glass platters covered with a substance that allows data to be held in the form of magnetized spots.

Nonremovable Internal Hard disk drives of Microcomputers
- In microcomputer, hard disks are platters sealed inside a hard disk drive that is built into the system and can not be removed.
- Inside disks are on a drive spindle; read/write heads mounted on an actuator (access) arm that moves back and forth, and power connections and circuitry. Usually the Tracks per Inch (TPI) is a measurement parameter that tells that how much data a hard disk can hold

Hard Disk Drives (HDDs)
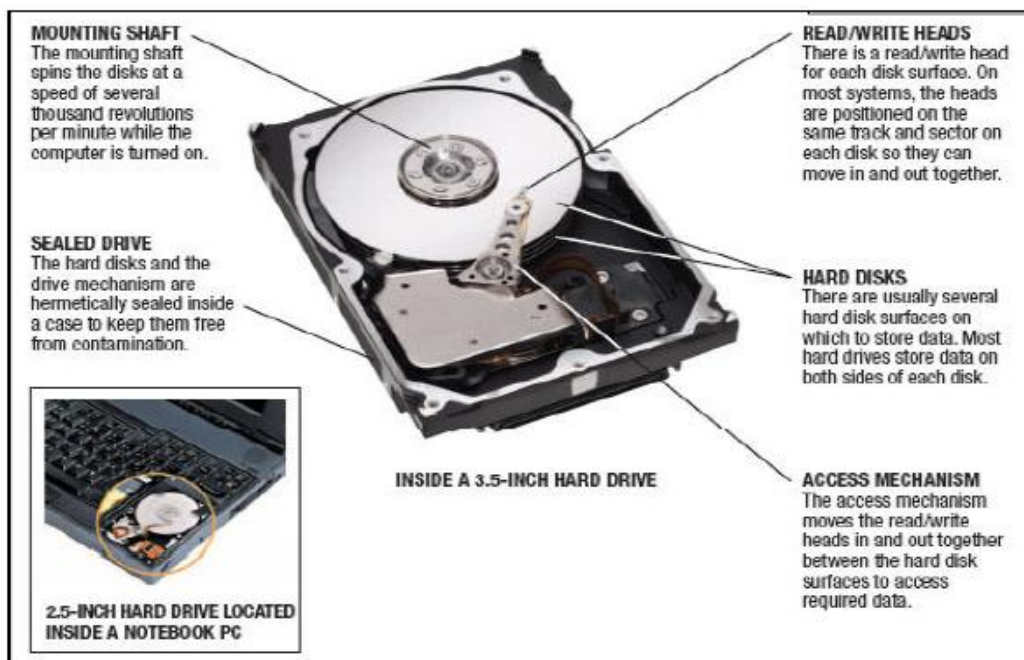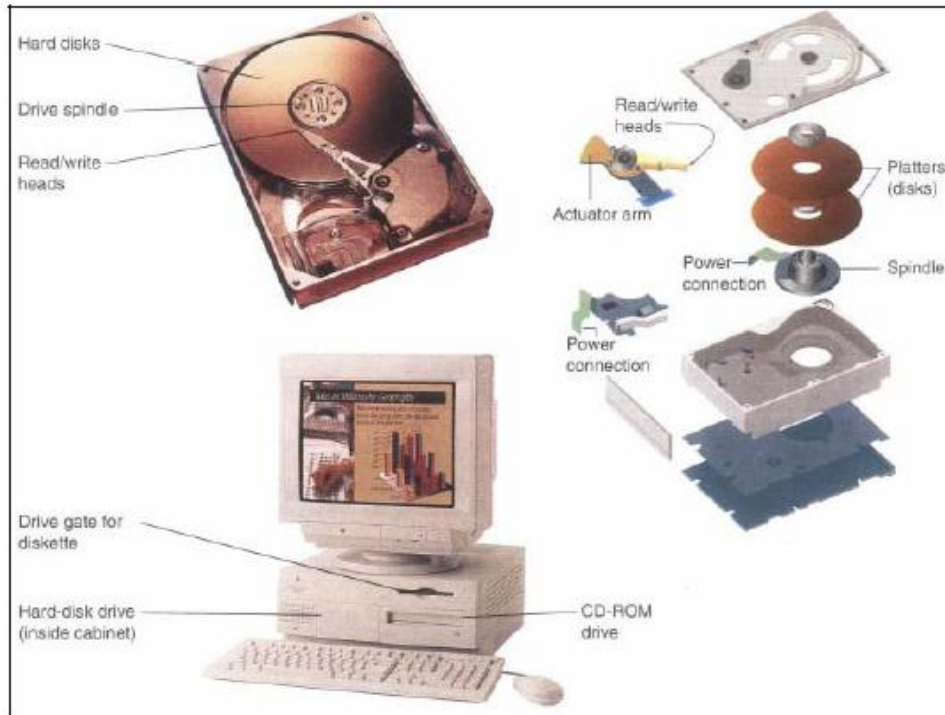
- Organized into tracks, sectors, and clusters like floppy disks
- Also use cylinders (the collection of tracks located in the same location on a set of hard disc surfaces)
- Read/write head doesn't touch the surface of the disc
    - Head crashes can occur
    - Backing up is important
- Most hard disks are sealed inside the drive
    - Some hard drive systems use hard disk cartridges
- HDDs can be:
    - Internal: Permanently located inside the system
    - External: Connected via a USB or FireWire port
    - Portable: Designed to transport large amounts of data from one PC to another
    - Pocket: Very small and portable
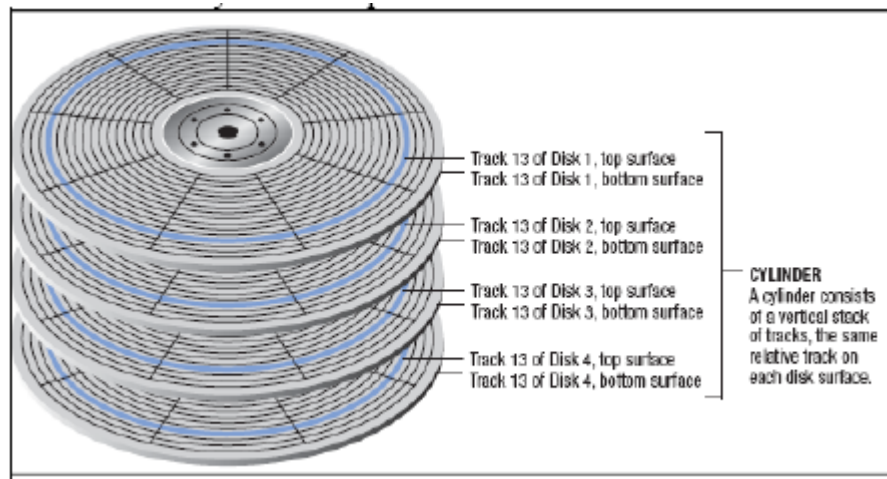
A disk cylinder. Hard drives use cylinders, in addition to tracks, sectors,

and clusters, to keep track of where data is stored

Internal, External, and Portable Hard Drive Systems
- Internal and external hard drives today typically hold between 80 GB and 2 TB
    - Portable and pocket hard drives hold less
- Longitudinal recording: Magnetic particles are aligned horizontally
- Perpendicular recording: Flips bits upright to fit them closer together to increase capacity
- Other technologies may be used to increase capacity in the future
- Security: Some hard drives used fingerprint readers or encryption to protect the data on the drive

Hard Drive Speed and Caching
- Disk access time: Total time that it takes for a hard drive to read or write data
    - Consists of seek time, rotational delay, data movement time
- Hard disk cache:
    Dedicated part of RAM used to store additional data adjacent to data retrieved during a disk fetch to improve system performance
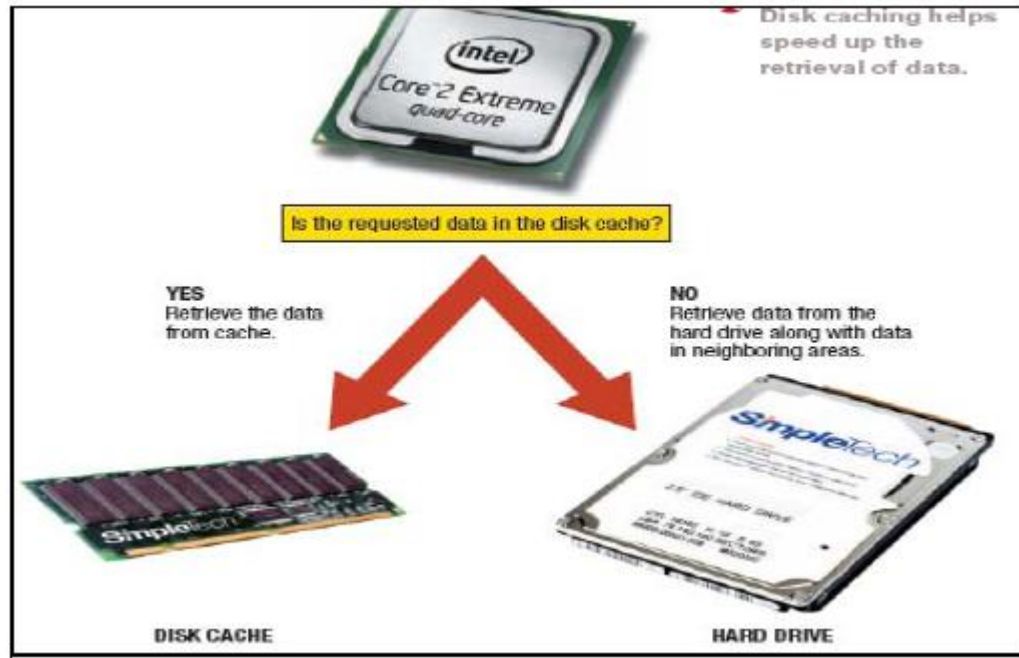
Partitioning and File Systems
- Partitioning: Enables you to logically divide the physical capacity of a single drive into separate areas, called partitions or logical drives
- Used to:
    - Install more than one operating system
    - Create a recovery partition
    - Create a new logical drive for data
    - Increase efficiency (smaller drives can use smaller cluster sizes)
- File system: Determines the cluster size, maximum drive size, and maximum file size
    - FAT, FAT32, and NTFS

Hard Drive Interface Standards
- Determine how a drive connect to the PC and other characteristics
- Common standards:
    - Parallel ATA (PATA)
    - Serial ATA (SATA) and serial ATA II (SATA II)
    - SCSI and the newer serial attached SCSI (SAS)
    - Fibre Channel
    - Fibre Channel over Ethernet (FCoE)
    - eSATA
    - External hard drives can also connect via USB or FireWire, but eSATA is closer in performance to internal hard drives

Hard disk Architectures used in Microcomputers

1) EIDE (Enhanced Integrated Drive Electronics)
- ☐ It refers to a type of hardware interface widely used to connect hard disks and CD-ROM drives to a PC via bus

2) SCSI (Small Cmputer System Interface)
- ☐ It is the drive interface used on Mac computers and high-end PCs, including multimedia workstations and network servers.
- ☐ It allows the connection of 7-15 peripheral devices in a daisy chain lookup to a single expansion board.
- ☐ It provides high data transfer rate

Optical Disks

An optical disk is a removable disk on which data is written and read through the use of laser beams; there is no mechanical arm, as with diskettes and hard disks.

Writing and reading data on optical disk
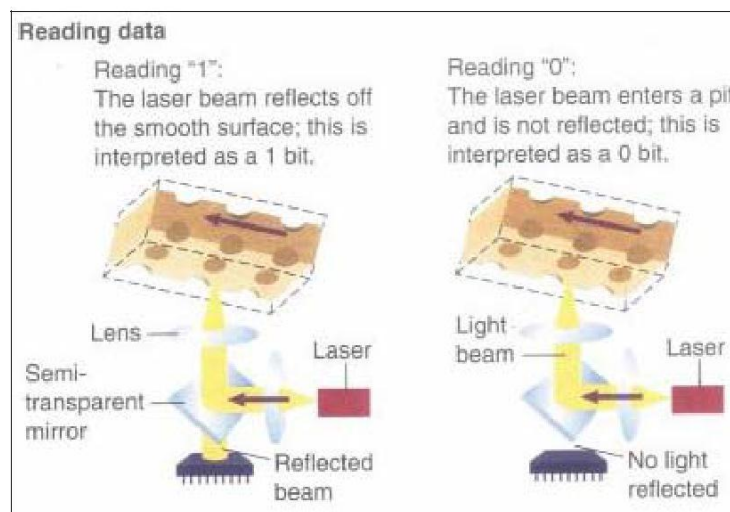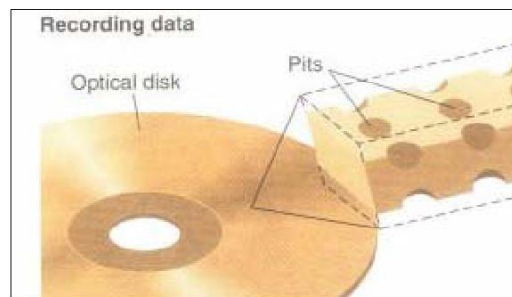
- • Optical discs: store data optically (using laser beams) instead of magnetically
  - – Divided into tracks and sectors like magnetic discs but use a single grooved spiral track
  - – Can be read-only, recordable, or rewritable
  - – Conventional CD discs use infrared lasers
  - – DVDs use red lasers
  - – High-definition DVDs use blue-violet lasers to store data more compactly
- • Burning: Recording data onto an optical disc

- Pits and lands are used to represent 1s and 0s
- Pits can be molded into the disc surface or created by changing the reflectivity of the disc

The transition between a pit and a land represents a 1; no transition represents a 0

TRACK
A single grooved track spirals from the center of the disc outward; recorded data is stored in the groove.

SECTOR
The track is divided into multiple sectors for data organization.

LAND

PIT

WRITING DATA
When data is written to the disc, a laser beam creates pits, represented by dark, nonreflective areas on the disc.

READING DATA
A low intensity laser beam reads the disc. A transition between the pits and lands is interpreted as a 1; a set period of time between transitions is interpreted as a 0.

How recorded optical discs work

Types of Optical disks
Read-Only Discs
- Can be read from, but not written to, by the user
- CD-ROM (compact disc read-only memory)
  - Usually holds about 650 MB
- DVD-ROM (digital versatile disc read-only memory)
  - Holds 4.7 GB (single-sided); 8.5 GB (double-sided)
- BD-ROM and HD DVD-ROM
  - Both hold more content, but are currently in strong competition
- Read-only disc formats also exist for gaming systems (UMD discs)
- Are read by an appropriate drive
- Hybrid drives can read multiple formats

Recordable Discs
- Can be written to, but cannot be erased and reused
  - Used for back up, sending large files to others, creating custom music CDs, storing home movies, etc.
  - Are written to using an appropriate optical drive
- CD-R discs: Recordable CDs
- DVD-R/DVD+R discs: Recordable DVDs
  - DVD+R DL and DVD-R DL discs use two recording layers (8.5 GB capacity)
- BD-R/HD DVD-R discs: high-definition

Rewritable Discs
- Can be recorded on, erased, and overwritten just like magnetic discs
- Most common formats: CD-RW, DVD-RW, BD-RE and DVD+RW discs
  - HD DVD-RW discs are expected to be available soon

- Phase -change technology: Used to record and erase rewritable optical discs
  - Heating and cooling process is used to change the reflectivity of the disc
- Ultra Density Optical (UDO) discs
  - Expected on the market in about 5 years
  - Optimized for data storage rather than home entertainment applications

Figure 4.14 DVD: A new era of data storage. (a) This DVD disk can hold 4.7–17 GB of information. (b) Recording on a DVD disk. (c) Comparative capacities of DVD, CD-ROM, and diskettes.
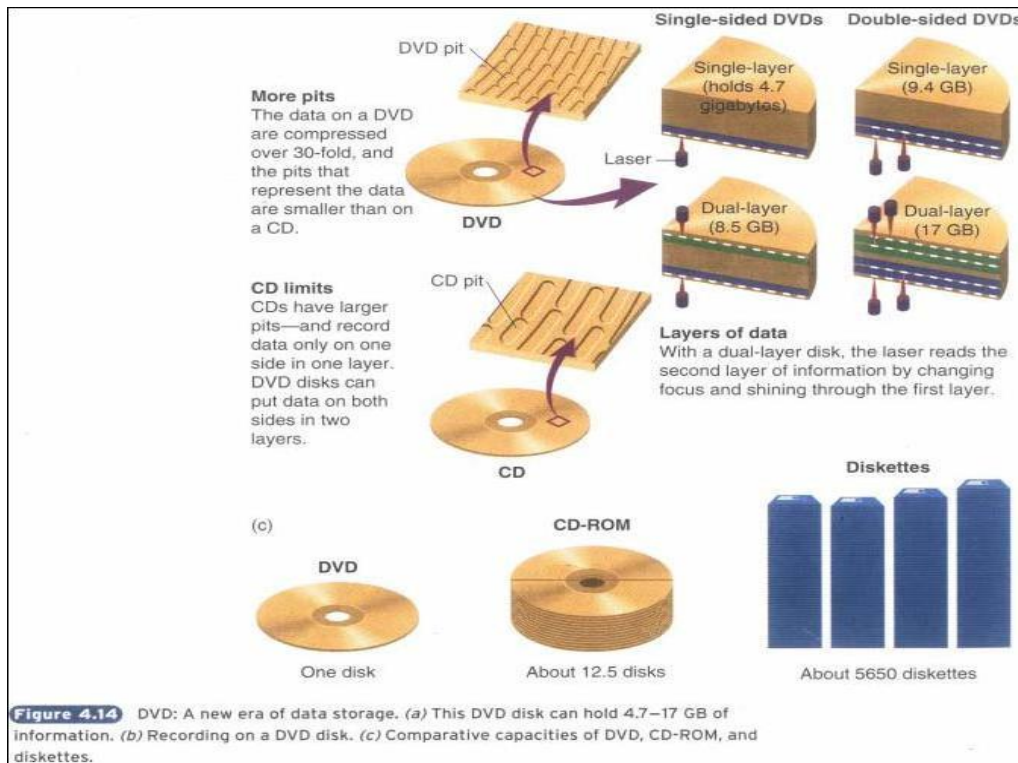
Flash Memory Systems
- Use flash memory media
  - No moving parts so more resistant to shock and vibration, require less power, makes no sound
  - Solid-state storage system

- Most often found in the form of:
  - Flash memory cards
  - USB flash drives
  - Solid-state drives
  - Hybrid hard drives
- Very small and so are very appropriate for use with digital cameras, digital music players, handheld PCs, notebook computers, smart phones, etc.

EMBEDDED FLASH MEMORY
These sunglasses contain a built-in MP3 player with 1 GB of embedded flash memory for storing MP3 files.

FLASH MEMORY CARDS AND READERS
Flash memory cards are often used to store data for a digital camera or other device; that data can be transferred to a PC via a flash memory card reader.

USB FLASH DRIVES
USB flash drives are often used to store data and transfer files from one PC to another.

SOLID-STATE DRIVES
This solid-state drive fits into an ExpressCard slot and holds 32 GB of data.

Flash memory is used in a variety of storage systems today

Flash Memory Cards

- Flash memory card: A small card containing flash memory chips and metal contacts to connect the card to the device or reader that it is being used with
    - CompactFlash
    - Secure Digital (SD)
    - Secure Digital High Capacity (SDHC)
    - MultiMedia Card (MMC)
    - xD Picture Card
    - Memory Stick
    - SmartMedia (SM)
- Read by flash memory card reader

FLASH MEMORY CARD READER
This reader connects to a USB port and can be used with several different types of flash memory media.

COMPACTFLASH (CF) CARD

MEMORY STICK

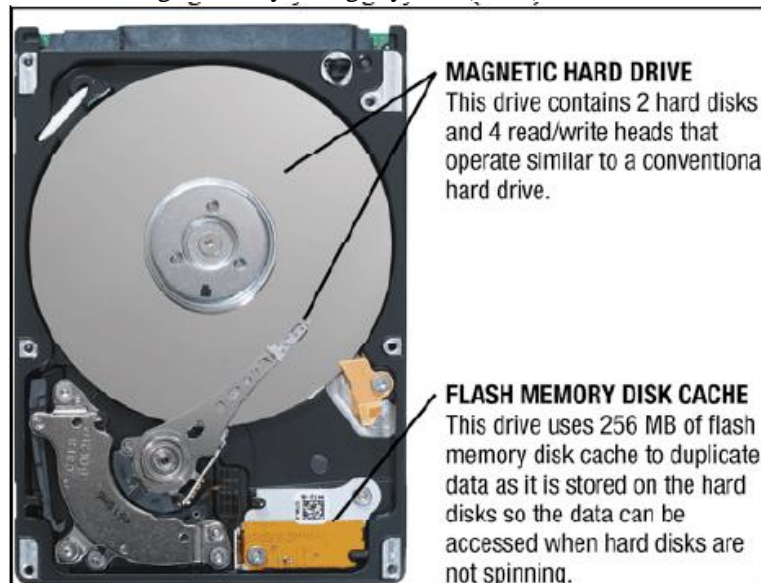**SECURE DIGITAL (SD) CARDS**

XD PICTURE CARD

USB Flash Drives

- Flash memory drives: Consist of flash memory media and a reader in a single self-contained unit
    - Typically portable drives that connect via a USB port
    - Also called USB flash memory drives, thumb drives, jump drives
    - Come in a variety of appearances

USB FLASH DRIVE WITH BACKPACK CLIP   USB FLASH DRIVE BUILT INTO NECKLACE   USB FLASH DRIVE WATCH

## Solid-State Drives (SSDs) and Hybrid Hard Drives (HHDs)

- Solid-state drives (SSDs)
    - Use flash memory instead of spinning platters and magnetic technology
    - Prices have fallen significantly, though SSDs are currently more expensive than conventional drives
- Hybrid hard drives (HHDs)
    - Combine a large flash memory cache with a magnetic hard drive
- Future technologies to replace flash memory storage
    - Magnetoresistive random access memory (MRAM)
    - Phase change memory storage system (PCM)

MAGNETIC HARD DRIVE
This drive contains 2 hard disks and 4 read/write heads that operate similar to a conventional hard drive.

FLASH MEMORY DISK CACHE
This drive uses 256 MB of flash memory disk cache to duplicate data as it is stored on the hard disks so the data can be accessed when hard disks are not spinning.

Hybrid hard drives. It combines a magnetic hard drive with a large

flash memory cache for increased performace

Other Types of Storage Systems

- Remote storage: Using a storage device not directly a part of the PC being used
  - Network storage: Accessible through a local network
  - Online storage: Accessed via the Internet
    - Backup
    - Transferring files to others or to another PC
    - Sharing files with others (online photo sites, etc.)
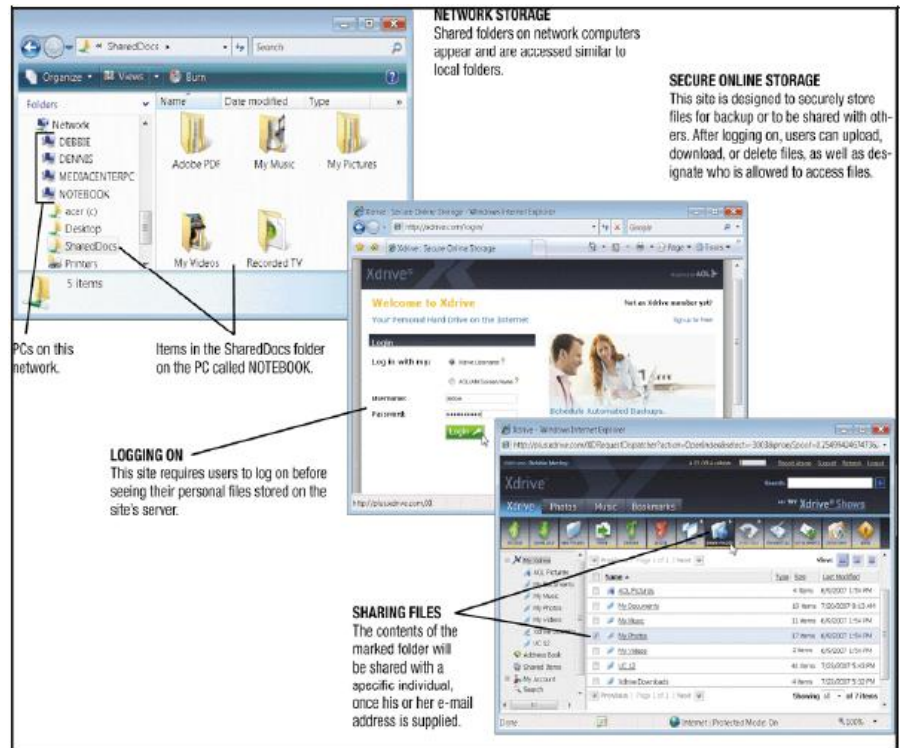
## Other Types of Storage Systems

- Smart card: Credit card-sized piece of plastic that contains some computer circuitry (processor, memory, and storage)
  - Store small amount of data (about 64 KB or less)
  - Commonly used to store prepaid amounts of digital cash or personal information
  - Smart card readers are built into or attached to a PC, keyboard, vending machine, or other device
  - Some smart cards store biometric data
  - Can be used in conjunction with encryption and other security technologies

Smart Cards. Smart Card can be used to log on to computers

and networks, access facilities, pay for goods and services, and so forth

Other Types of Storage Systems

- Holographic storage: Store data as holograms
  - Emerging type of 3D storage technology
  - Uses two blue laser beams to store data in three dimensions
    - Reference beam
    - Signal beam
  - Potential initial applications for holographic data storage systems include:
    - High-speed digital libraries
    - Image processing for medical, video, and military purposes
    - Any other applications in which data needs to be stored or retrieved quickly in large quantities but rarely changed
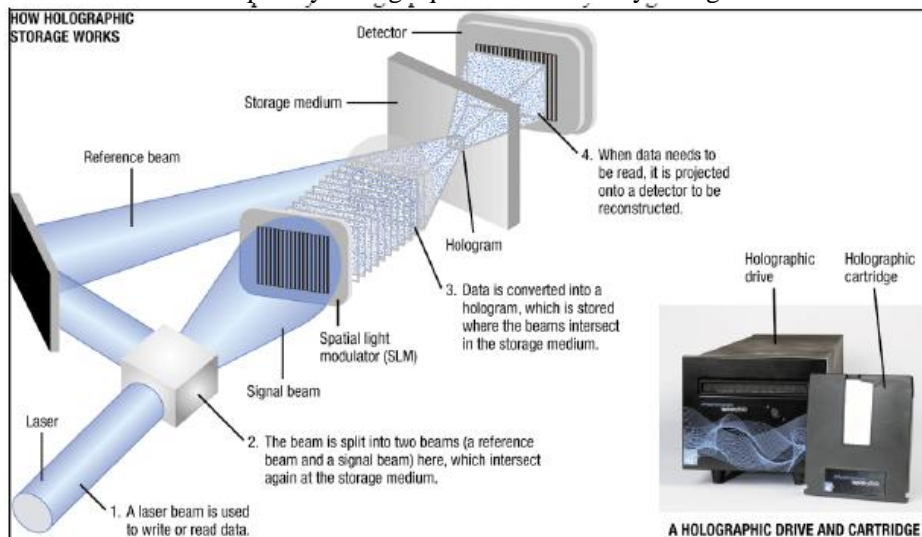
Holographic Storage. Hologrpahic drives store upto one million bits of data in

a single flash of light

Storage Systems for Large Computer Systems and Networks

- Usually use a storage server: a hardware device containing multiple high-speed hard drives
- Businesses have to storage tremendous amounts of data
  - Business data
  - Employee and customer data
  - E-discovery data
  -

HARD DRIVES
Each drive chassis holds up to 40 individual hard drives that can store up to 750 GB each.

STORAGE SERVER
This server can manage up to 2,560 hard drives located in up to 8 cabinets like the one shown here, for a total capacity of 600 TB in a single system.

Storage Servers. Storage systems are usually scalable

so additional hard drives can be added as needed
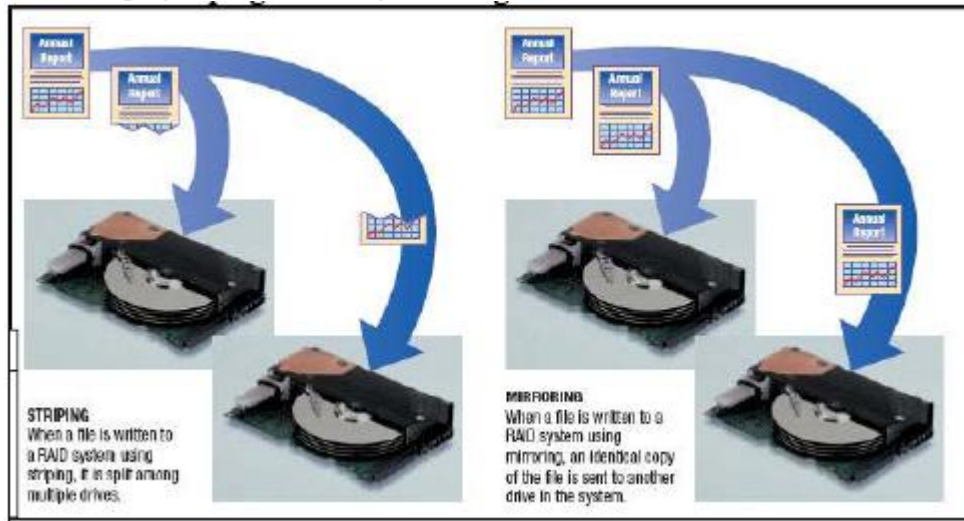
NASs and SANs

- Network attached storage (NAS): High-performance storage server individually connected to a network to provide storage for computers on that network
- Storage area network (SAN): Network of hard drives or other storage devices that provide storage for another network of computers

The Wirless NAS device holds 1 TB of data

RAID

- RAID (redundant arrays of independent discs): Method of storing data on two or more hard drives that work together to do the job of a larger drive
    - Usually involves recording redundant copies of stored data
    - Helps to increase fault tolerance
    - Disk striping and disk mirroring

STRIPING
When a file is written to a RAID system using striping, it is split among multiple drives.

MIRRORING
When a file is written to a RAID system using mirroring, an identical copy of the file is sent to another drive in the system.

RAID. The two main benefits of RAID are increased speed and the ability

to recover easily from a disk crash

Magnetic Tape Systems

- Magnetic tape: Plastic tape with a magnetizable surface that stores data as a series of magnetic spots
    - Primarily used for backup and archival purposes
    - Sequential access only
    - Low cost per megabyte
    - Most tapes today are in the form of cartridge tapes
    - Read from and written to via a tape drive
    - Tape libraries contain multiple tape drives

A magnetic tape cartridge