



# Understanding Computers

11<sup>th</sup> Edition

*TODAY AND TOMORROW*



## CHAPTER 3

## Storage



# Learning Objectives

- Explain the difference between storage systems and memory.
- Name several general properties of storage systems.
- Identify the two primary types of magnetic disk systems and describe how they work.
- Discuss the various types of optical disc systems available and how they differ from each other and from magnetic systems.



## Learning Objectives, *Cont'd*

- Explain what flash memory media and flash memory drives are and how they are used today.
- List at least three other types of storage systems.
- Summarize the storage alternatives for a PC, including which storage systems should be included on a typical PC and for what applications other storage systems are appropriate.



# Overview

- This chapter covers:
  - Overall characteristics of storage systems
  - How magnetic disk systems work
  - How optical disc systems work
  - What flash memory systems are and how they are used
  - Other types of storage systems
  - A comparison of storage alternatives



# Storage Systems Characteristics

- All storage systems have specific characteristics
  - Storage medium (what data is stored on)
    - Floppy disk, CD or DVD, etc.
    - Can be removable or nonremovable from the storage device
  - Storage device (device into which storage medium is inserted to be used)
    - Floppy disk drive, CD or DVD drive, etc.
    - Devices are identified by name or letter
    - Can be internal, external, or remote



CD and DVD drives are usually assigned letters after the hard drives (such as D and E, if there isn't a second hard drive).

The letter C is usually assigned to the first hard drive.

The letters A and B are usually reserved for floppy disk drives.



The various slots in a built-in flash memory card reader are typically assigned next, such as the letters F, G, H, and I, in this example.

Other letters, beginning with J in this example, would be used for any other drives attached to the PC.

**FIGURE 3-1**  
**Storage device identifiers.** To keep track of storage devices in an unambiguous way, the computer system assigns letters of the alphabet or names to each of them.



# Storage Systems Characteristics, *Cont'd*

## Nonvolatility

- When power to the device is shut off, data stored on the medium remains
- This is in contrast to most types of memory, which are **volatile**

## Access (usually random but can be sequential)

- ***Random access (direct access)***: data can be retrieved directly from any location on the storage medium, in any order
- ***Sequential access***: data can only be retrieved in the order in which it is physically stored on the medium (*tape drive*)



## Storage Systems Characteristics, *Cont'd*

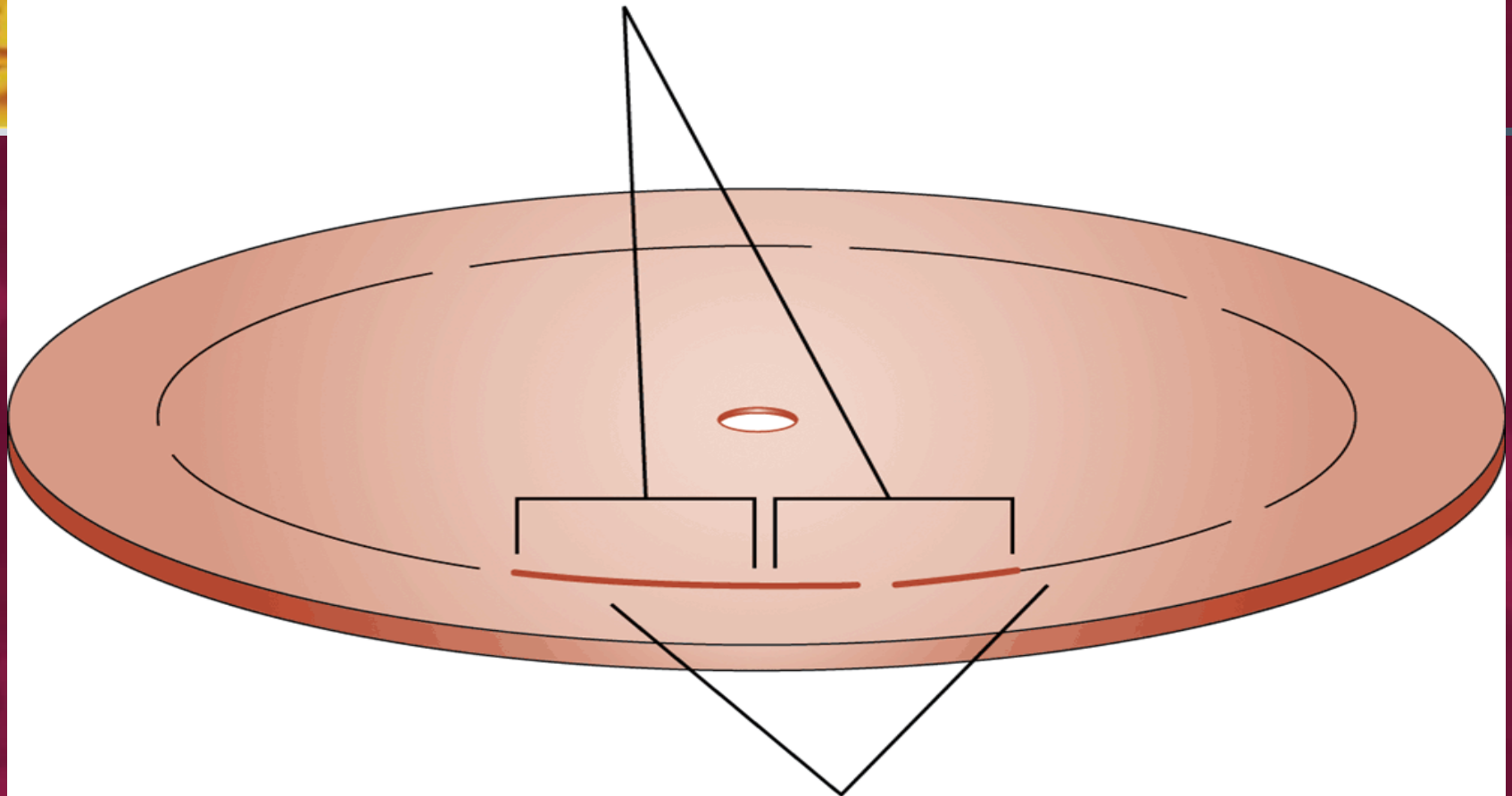
- *Logical file representation:* refers to the user's view of the way data is stored

- **File:** something stored on a storage medium, such as a program, document, or image
- **Filename:** name given to a file by the user
- **Folder:** named place on a storage medium into which files can be stored

- *Physical file representation:* actual physical way the data is stored on the storage media as viewed by the computer

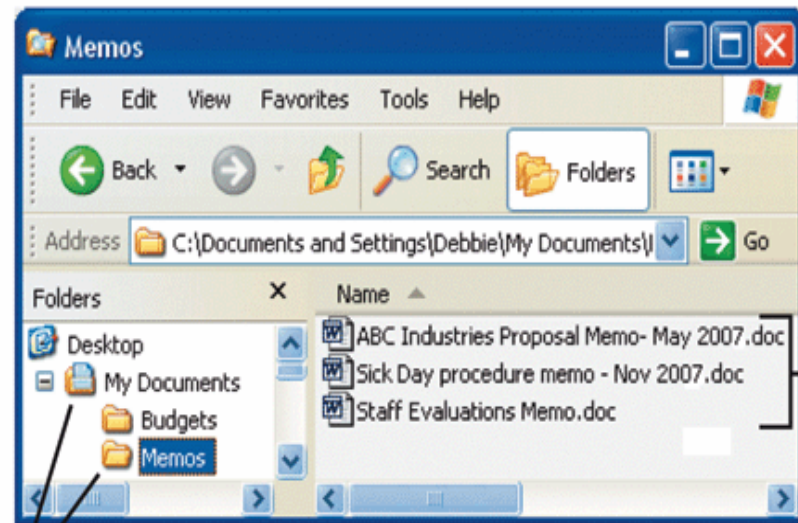
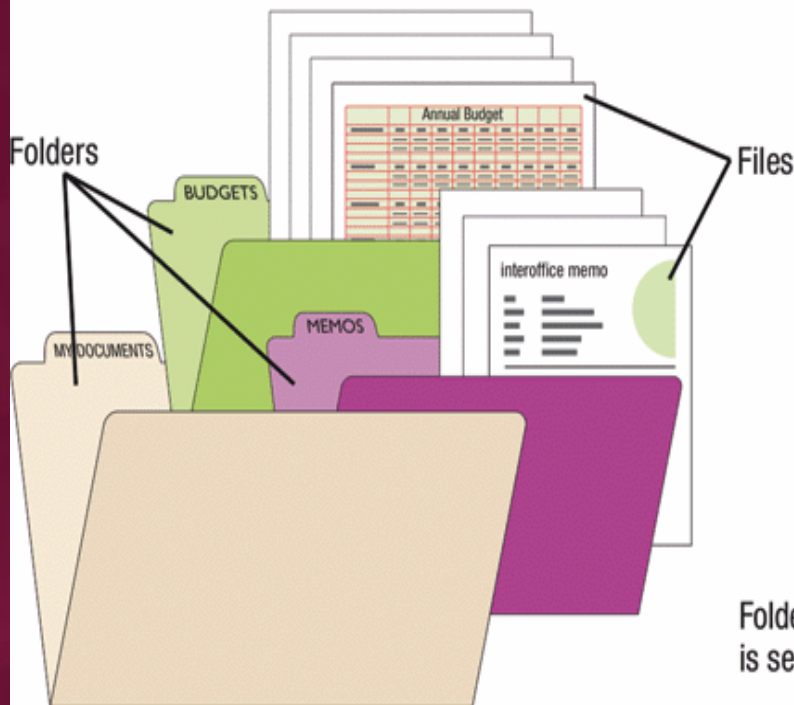


**Logical records correspond  
to natural divisions within the data**



**Physical records correspond  
to the size of a sector**

# Logical File Representation



**FIGURE 3-2**  
**Organizing data.**  
Folders can be used to organize related items on a storage medium.

Folders; Memos folder is selected.

Files in Memos folder.



## Storage Systems Characteristics, *Cont'd*

- Magnetic disks vs. optical discs
  - With *magnetic* media, such as floppy disks, data is stored magnetically; the data (0s and 1s) is represented using different magnetic alignments
  - *Optical* storage media (such as CDs and DVDs) store data optically using laser beams
  - Some storage systems combine magnetic and optical technology. Others represent data using *electrons*



# Quick Quiz –Storage System Characteristics

1、 Anything stored on a storage medium (such as a photograph or letter) is called a (n)

- folder
- File
- directory



## Quick Quiz –Storage System Characteristics

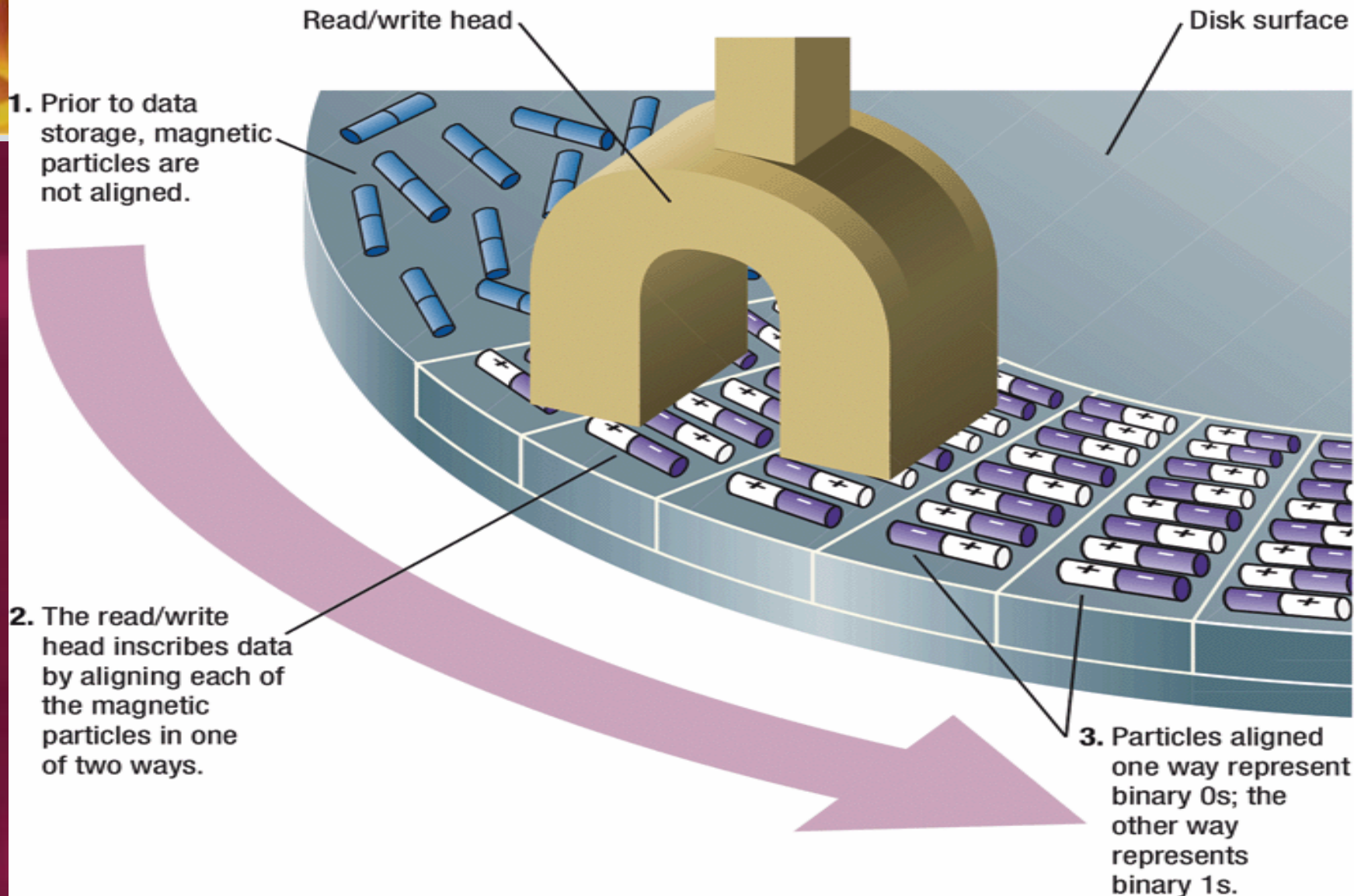
- 2、 True or False: A floppy disk is an example of a storage device, and a floppy drive is an example of a storage medium.
- 3、 Most storage systems today use \_\_\_\_\_ access.



# Magnetic Disk Systems

- **Magnetic disk:** storage medium that records data using magnetic spots on disks made of flexible plastic or rigid metal
- Most widely used storage medium on today's computers
- Two common types:
  - *Floppy disks* (common removable storage medium in the past; not widely used today)
  - *Hard disks* (included on nearly all PCs today)

**FIGURE 3-3**  
Storing data on magnetic disks.





# Floppy Disks and Drives

- **Floppy disk:** low capacity, removable magnetic disk made of flexible plastic permanently sealed inside a hard plastic cover
- **Floppy disk drive:** storage device that reads from and writes to floppy disks
- Sometimes referred to as a *legacy drive* and not included on all new PCs today



A write-protect square can prevent accidentally writing to the disk; the square's plastic window can be opened (for write-protection) and closed (for data storage) with your fingernail.

A hard plastic cover protects the disk from dirt and damage.

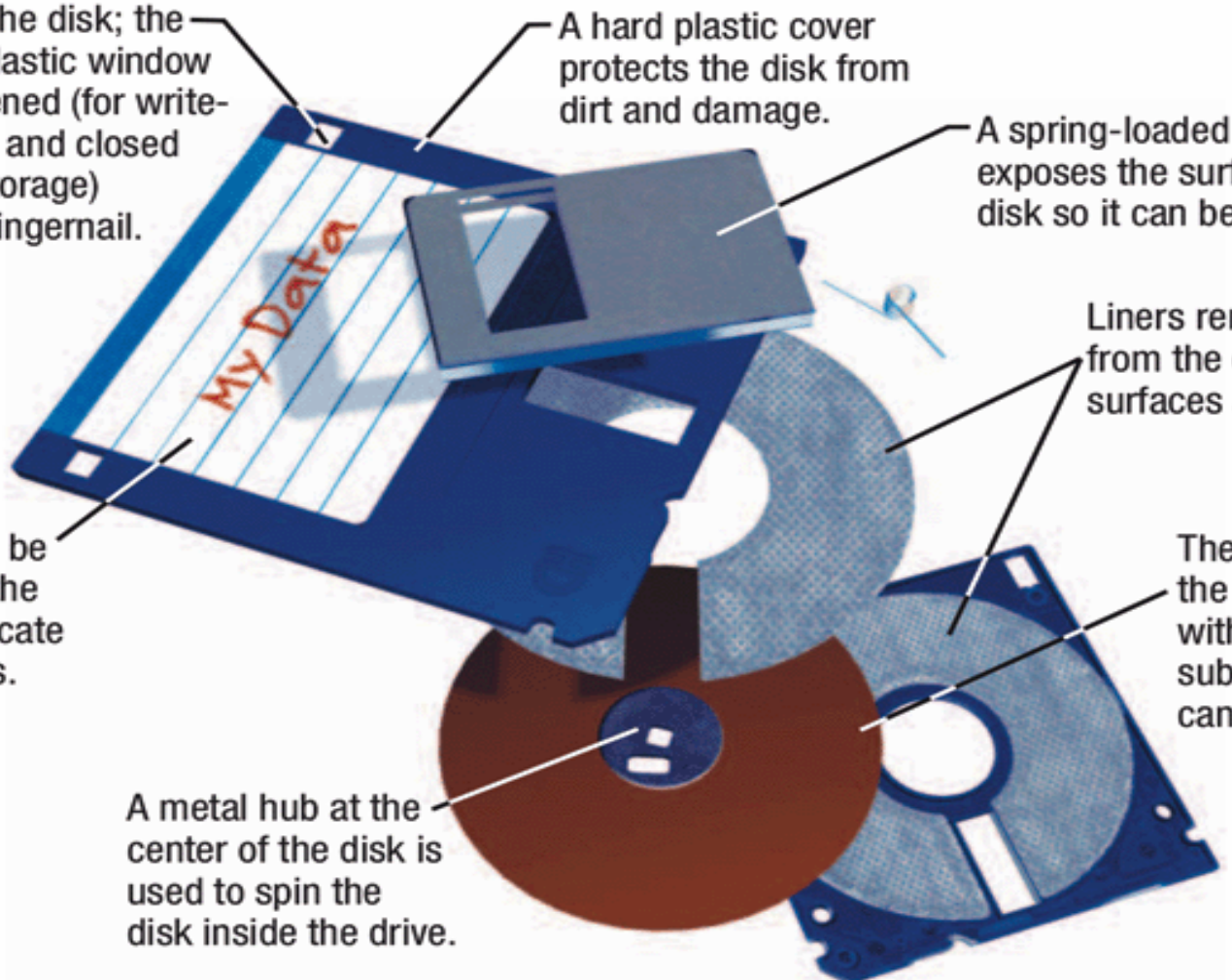
A spring-loaded shutter exposes the surface of a disk so it can be read from.

Liners remove dirt from the disk's surfaces as it spins.

The plastic surfaces of the disk are coated with a magnetizable substance so that data can be recorded.

A label can be placed on the disk to indicate its contents.

A metal hub at the center of the disk is used to spin the disk inside the drive.

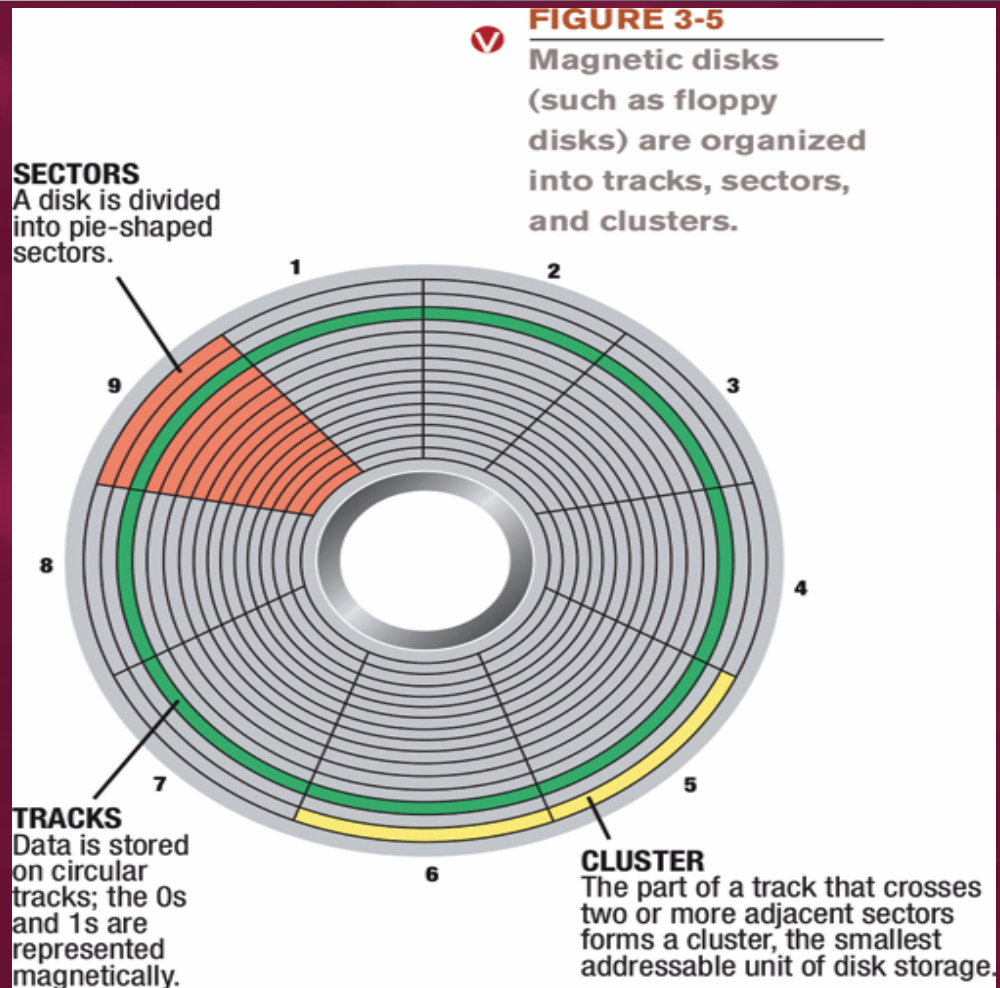


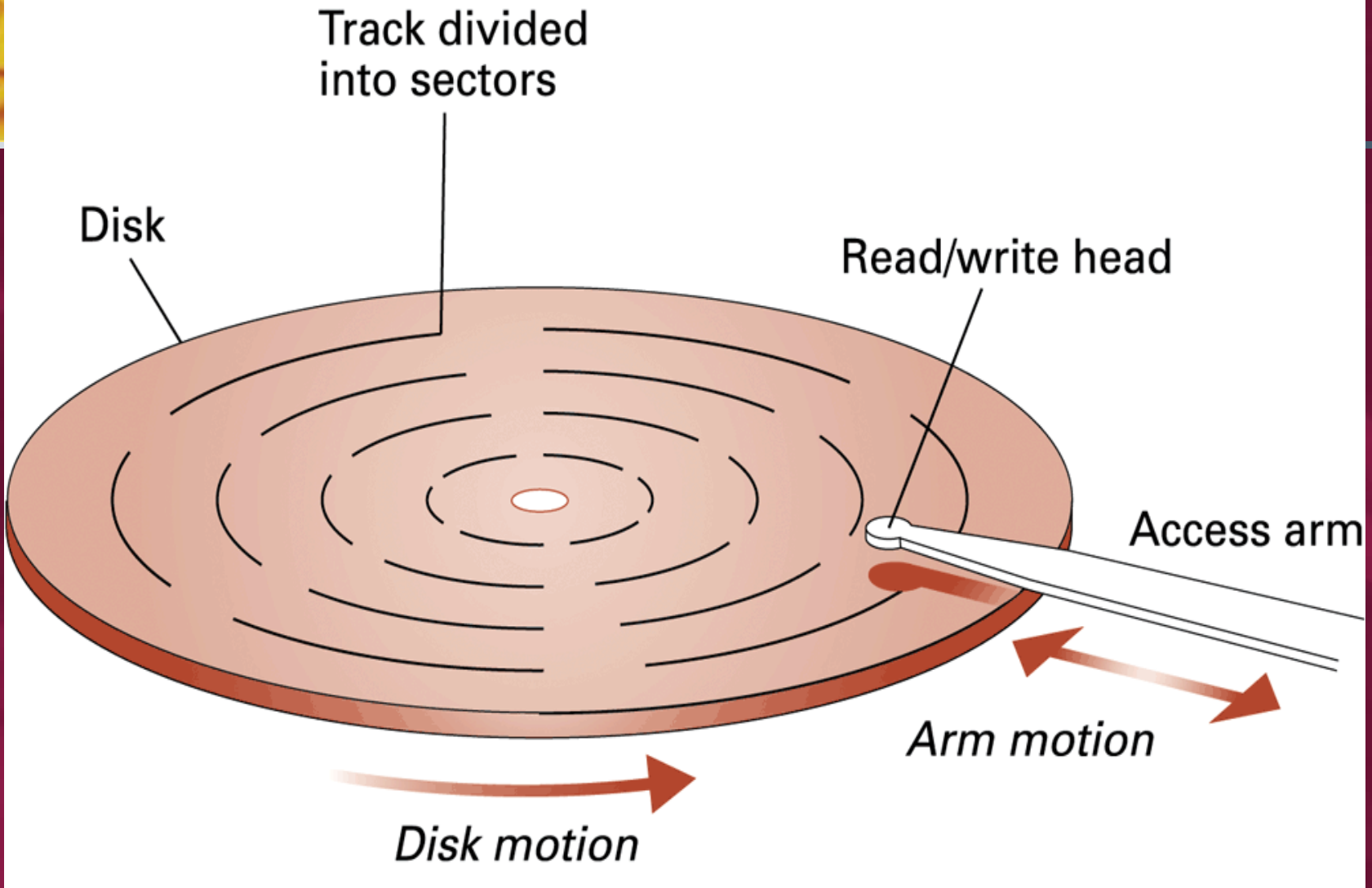
**FIGURE 3-4**  
The anatomy of a floppy disk.

# Floppy Disks and Drives, *Cont'd*

## Floppy disk characteristics

- 3½ inches in diameter
- Holds 1.44 MB of data
- Disk organized into **tracks, sectors, and clusters**
- All files take up at least one cluster of space on the disk







## Floppy Disks and Drives, *Cont'd*

- Using floppy disks
  - Must be inserted into a *floppy drive* (face up and with the disk shutter closest to the drive door)
  - Should not be removed when the disk is being accessed
  - If a disk is not *formatted*, the user must format it first before it can be used



# Hard Disk Drives

- **Hard disk drive (hard drive):** storage system consisting of one or more metal magnetic disks permanently sealed with an access mechanism inside its drive
- Hard drive characteristics
  - Stores data magnetically
  - One or more disks made out of metal
  - Disks are permanently sealed inside the hard drive to avoid contamination and to enable the disks to spin faster

### ACCESS MECHANISM

The access mechanism moves the read/write heads in and out together between the hard disk surfaces to access required data.

### MOUNTING SHAFT

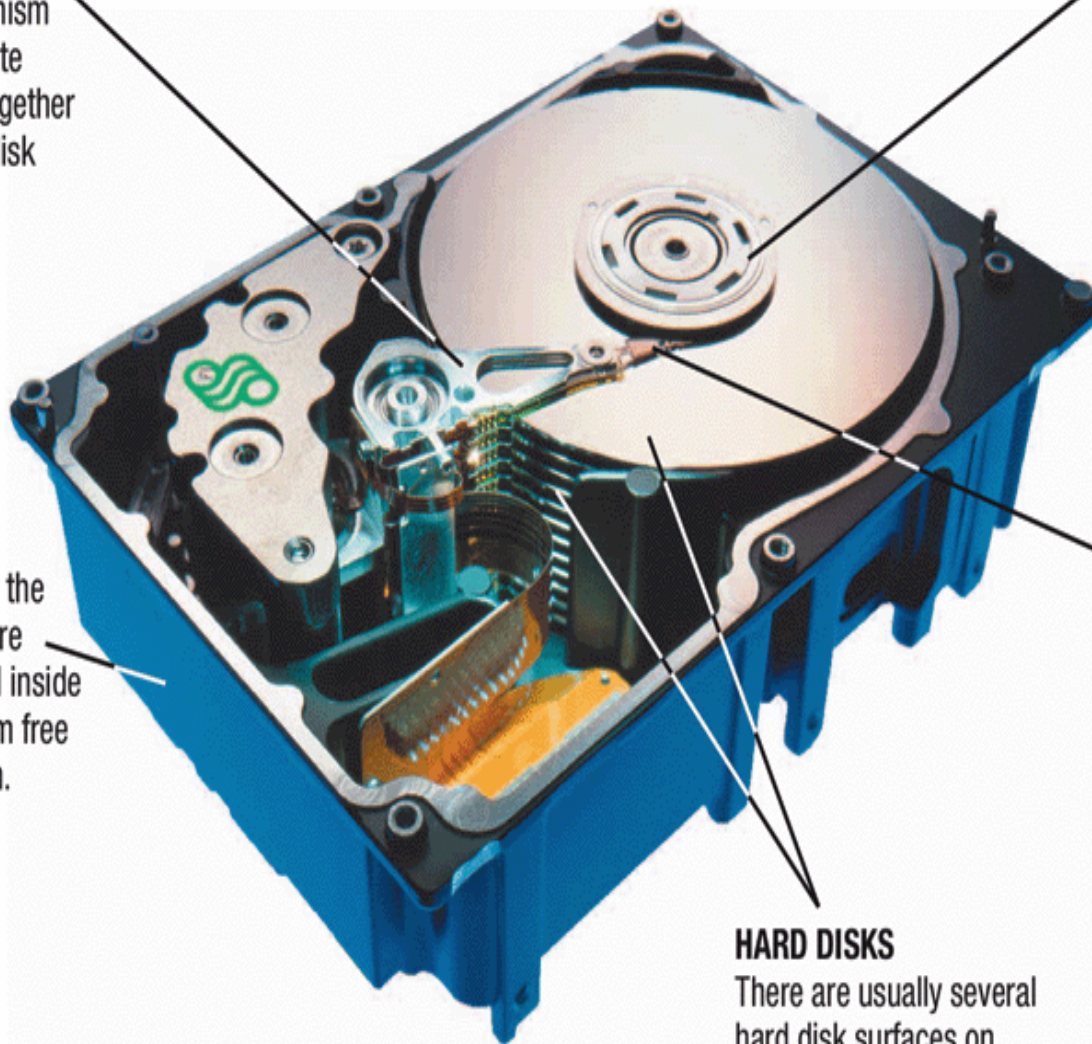
The mounting shaft spins the disks at a speed of several thousand revolutions per minute while the computer is turned on.

### SEALED DRIVE

The hard disks and the drive mechanism are hermetically sealed inside a case to keep them free from contamination.

### READ/WRITE HEADS

There is a read/write head for each disk surface. On most systems, the heads are positioned on the same track and sector on each disk so they can move in and out together.



### HARD DISKS

There are usually several hard disk surfaces on which to store data. Most hard drives store data on both sides of each disk.

## FIGURE 3-7

### Inside a hard drive.

The metal magnetic disks of a hard drive typically are sealed permanently inside the drive.



## Hard Disk Drives, *Cont'd*

- Hard drive characteristics, Cont'd
  - Organized into clusters, sectors, tracks, and **cylinders** (the collection of tracks located in the same location on a set of hard disk surfaces)
  - Read/write head doesn't touch the surface of the disk (cushion air)
  - If the PC is bumped while the hard drive is spinning or a foreign object gets onto the surface of the disk, a *head crash* occurs, which may permanently damage the hard drive



## Hard Disk Drives, *Cont'd*

- Hard drive speed
  - **Disk access time:** total time that it takes for a hard drive to read or write data
  
- **Evaluate disk system's performance:**
  - (1) **Seek time:** the time required to move the R/W heads from one track to another;





**(2)Rotation delay:** half the time required for the disk to make a complete rotation, which is the average amount of time required for the desired data to rotate around to the R/W head once the head has been positioned over the desired track;

**(3)Access time:** the sum of seek time and rotation delay;

**(4)Transfer rate:** the rate at which data can be transferred to or from the disk



## Hard Disk Drives, *Cont'd*

- **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)
  - The cluster size, maximum drive size, and maximum file size are determined by the *file system* being used



## Hard Disk Drives, *Cont'd*

- Hard drive interface standards
  - Determine how drive connects to the PC and other characteristics
  - Most common, for PCs:
    - *Serial ATA (SATA)* and *serial ATA II (SATA II)*
    - SCSI and the newer *serial attached SCSI (SAS)*
    - Fibre Channel
  - Hard drives can also connect via USB or FireWire



## Hard Disk Drives, *Cont'd*

- Usually are installed inside system unit but can also be external and portable
- *External hard drives:* connect to an external port on the PC (typically USB, FireWire, or via a wireless connection)
  - The entire drive can be moved from one PC to another PC when needed
  - Good for backup purposes
- *Portable hard drives:* specifically designed to be carried around and moved from one PC to another

✓ **FIGURE 3-11**  
External and portable hard drives.



**USB EXTERNAL HARD DRIVE**

This drive holds 250 GB and connects via a USB port.



**WI-FI EXTERNAL HARD DRIVE**

This hard drive holds 160 GB and connects via a wireless Wi-Fi connection.



**USB POCKET HARD DRIVE**

This hard drive holds 5 GB, connects via a USB port, and can be carried in a pocket.



**PC CARD HARD DRIVE**

This hard drive holds 5 GB and connects via a PC Card slot.



# High-Capacity Removable Magnetic Disks and Cartridges(\*)

- *Superdiskettes*: high-capacity removable storage media, usually *proprietary* (can only be used with their respective drives)
  - Most widely used = *Zip disk*; holds 100, 250, or 750 MB
- *Hard disk cartridges*: removable hard disk so higher capacity, but also *proprietary*
  - *REV disk* is one example; holds 35 GB



## Quick Quiz – Magnetic Disk Systems

- Of the following three options, the storage media that holds the most data is
  - A. an external hard drive.
  - B. a 3½-inch floppy disk.
  - C. a Zip disk.



## Quick Quiz – Magnetic Disk Systems

- True or False: The capacity of a conventional 3½-inch floppy disk is 1.44 MB.
- The circular rings on a magnetic disk on which data is stored are called \_\_\_\_\_.



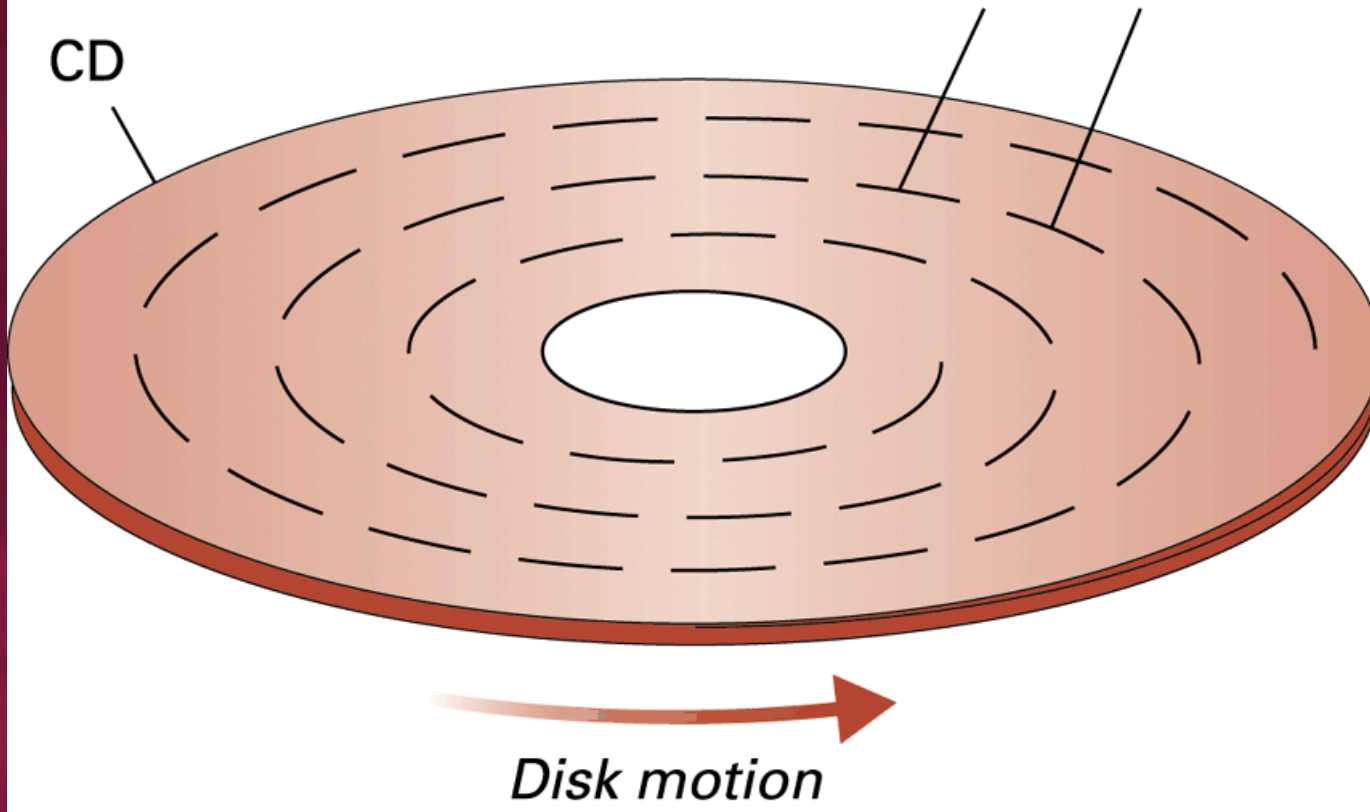


# Optical Disc Systems

- **Optical discs** (such as *CDs* and *DVDs*) store data *optically*—using laser beams—instead of magnetically
  - Typically 4½-inch circles, although smaller discs and custom shapes are also available
  - Divided into tracks and sectors like magnetic disks but use a single grooved spiral track
  - Can be read-only, recordable, or rewritable
  - High-capacity (usually at least 650 MB)



Data recorded on a single track, consisting of individual sectors, that spirals toward the outer edge

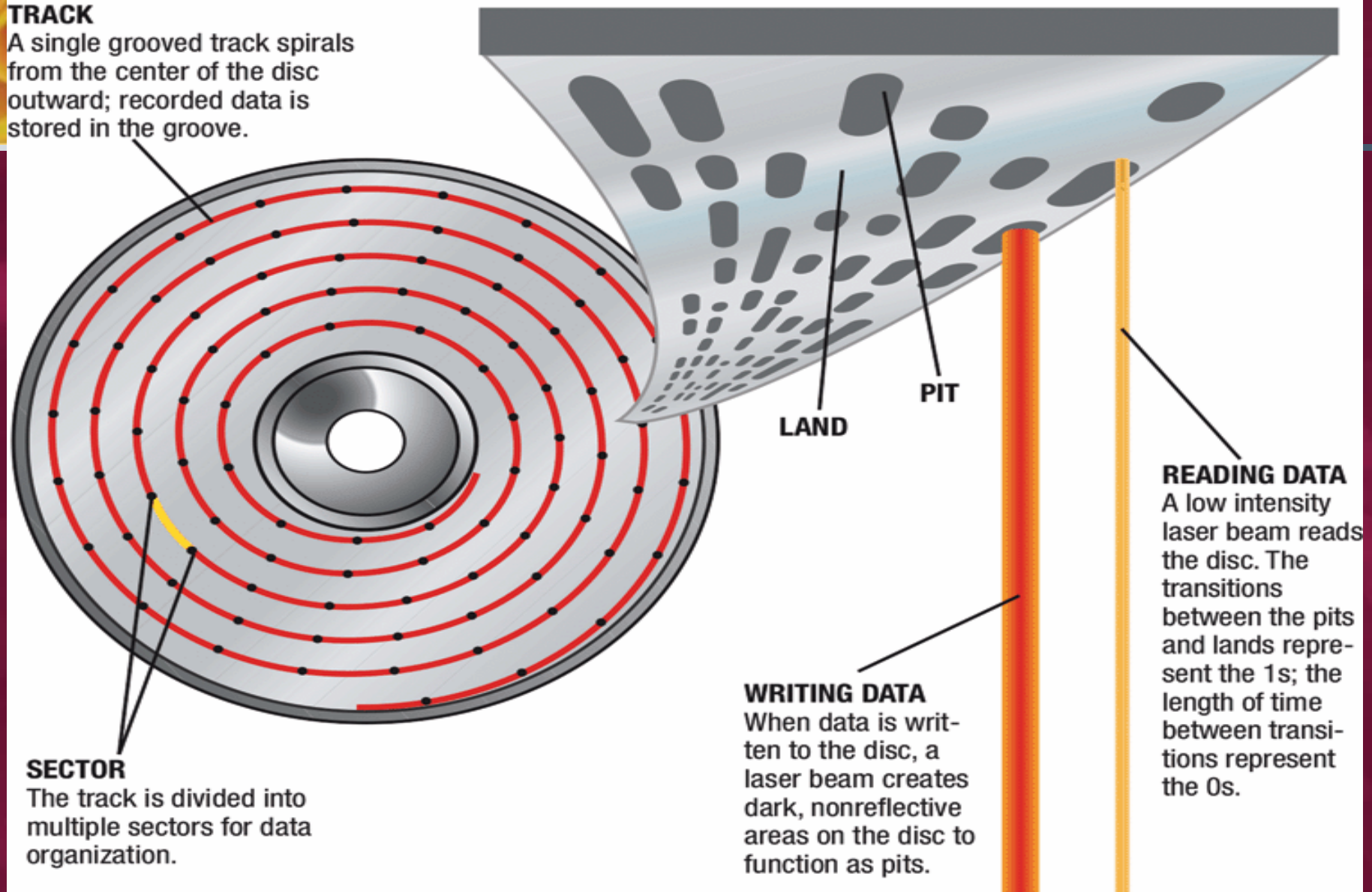




# Optical Disc Systems

- *Burning*: the process of recording data onto an optical disc
  - Spots on the disc (*pits*) are used to represent the data's 1s and 0s; the unchanged areas on the disc are called *lands*
  - 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

**FIGURE 3-13**  
How recorded optical discs work.



**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 dark, nonreflective areas on the disc to function as pits.

**READING DATA**  
A low intensity laser beam reads the disc. The transitions between the pits and lands represent the 1s; the length of time between transitions represent the 0s.



# Read-Only Discs: CD-ROM and DVD-ROM Discs

- Can be read from, but not written to, by the user
- **CD-ROM (compact disc read-only memory) disc**
  - Usually holds about 650 MB
- **DVD-ROM (digital versatile disc read-only memory) disc**
  - Holds 4.7 GB (single-sided); 8.5 GB (double-sided)



## Recordable Discs: CD-R, DVD-R, DVD+R, and DVD+R DL Discs

- Can be written to, but cannot be erased and reused
- Recordable CDs are typically **CD-R discs**; recordable DVDs are either **DVD-R discs** or **DVD+R discs**
- CD-R discs are commonly used for back up, sending large files to others, and creating custom music CDs.
- DVD-R/DVD+R discs are used for similar purposes when more storage space is needed, such as large backups and for home movies and other video files
- **DVD+R DL discs** use two recording layers (8.5 GB capacity)

**FIGURE 3-15**  
Recordable and rewritable CDs and DVDs.



**RECORDABLE DVD+R DL DISC**  
Dual-layer disc—holds 8.5 GB.



**REWRITABLE CD-RW DISC**  
Single-layer disc—holds 650 MB.



**REWRITABLE DVD-RAM DISC**  
Holds 9.4 GB.



**REWRITABLE BLU-RAY DISC**  
Holds 23.3 GB.



# Rewritable Discs: CD-RW, DVD-RW, DVD+RW, DVD-RAM, and Blue Laser Discs

- Can be recorded on, erased, and overwritten just like magnetic disks
- Most common: **CD-RW**, **DVD-RW**, and **DVD+RW discs**
- The newest rewritable technology uses **blue lasers** instead of **infrared** (CDs) or **red lasers** to store data more compactly (23 GB+)
- To record and erase rewritable optical discs, **phase-change** technology is used





# Quick Quiz – Optical Disc Systems

- The capacity of the typical CD disc is
  - 240 MB.
  - 650 MB.
  - 4.7 GB.



## Quick Quiz – Optical Disc Systems

- True or False: A CD-R disc can be written to and rewritten, similar to a magnetic floppy disk.
- The tiny depressions, dark areas, or otherwise altered spots on an optical disc that are used to represent data are called \_\_\_\_\_.



# Flash Memory Systems

- Use flash memory media
- No moving parts so more resistant to shock and vibration and require less power (solid state)
- Very small and so are very appropriate for use with digital cameras, digital music players, handheld PCs, notebook computers, smart phones, etc.



Flash memory stick

**DIGITAL CAMERAS**



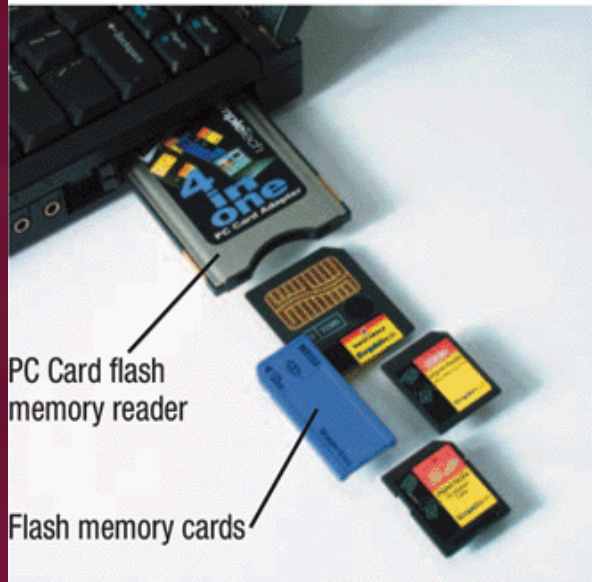
Flash memory drive

**DIGITAL MUSIC PLAYERS**



Secure Digital (SD) card

**DESKTOP COMPUTERS**



PC Card flash memory reader

Flash memory cards

**NOTEBOOK COMPUTERS**



Secure Digital (SD) card

**HANDHELD COMPUTERS**



MultiMedia Card (MMC)

**CELL PHONES**



# Flash Memory Media

- **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)*
  - *MultiMedia Card (MMC)*
  - *xD*
  - *Memory Stick*
- Read by flash memory card reader

**FIGURE 3-17**  
Flash memory cards. Shown here are four of the most widely used types of flash memory cards and a multiscard 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 CARD



XD PICTURE CARD



SECURE DIGITAL (SD) CARD



MEMORY STICK



# Flash Memory 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 mini drives*, *USB flash drives*, *thumb drives*, *jump drives*, and *key drives*
  - **Flash memory hard drives** (*solid state memory disks* or *SSDs*) that use flash memory instead of magnetic media are also available

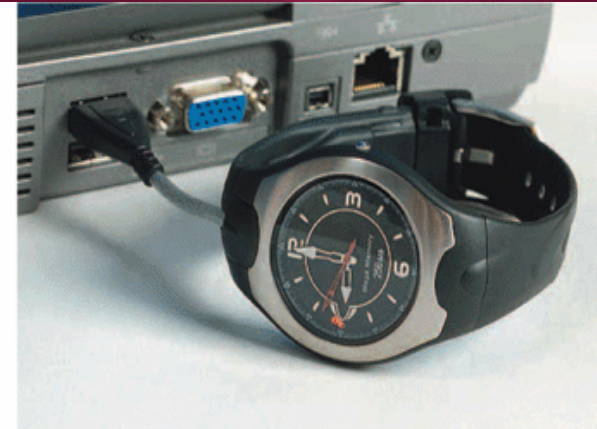
# Flash Memory Drives



**FLASH MEMORY DRIVE WITH NECKCHAIN**



**CONVENTIONAL FLASH MEMORY DRIVE**



**FLASH MEMORY WATCH**

**FIGURE 3-18**  
Flash memory drives. USB flash memory drives are becoming increasingly popular for portable personal storage.





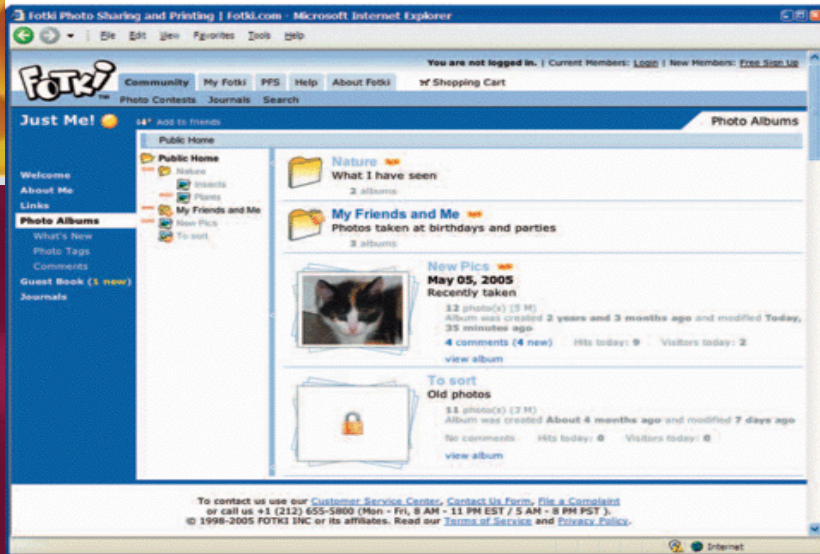
# Quick Quiz – Flash Memory Systems

- Which of the following is *not* a type of flash memory media?
  - SD
  - CompactFlash
  - Blue Laser
- True or False: Flash memory storage systems are called solid-state storage systems because they are nonvolatile.
- A storage device that contains flash memory and is plugged into a computer's USB port to be used is called a(n)  
\_\_\_\_\_.



# Other Types of Storage Systems

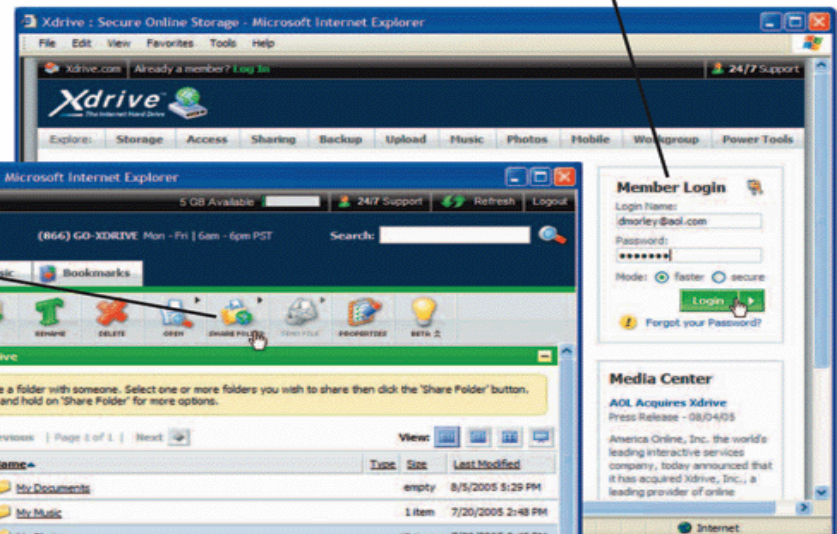
- **Remote storage** (using a storage device directly a part of the PC being used)
  - *Network storage*: accessible through a local network
  - *Online storage*: accessed via the Internet and used for
    - Backup
    - Transferring files to others or to another PC
    - Sharing files with others (online photo sites, etc.)



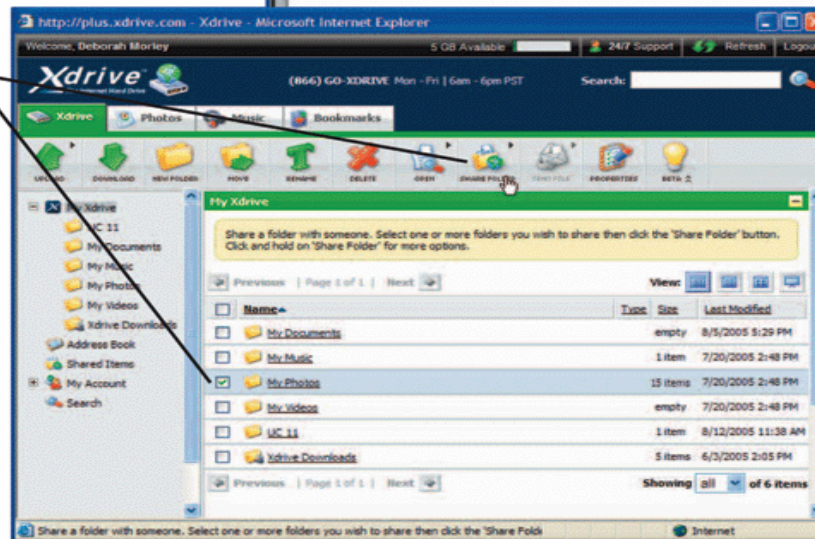
**ONLINE PHOTO SHARING COMMUNITY**  
 This site is designed to host online photo albums to be shared with others. Although albums can be password protected, many, such as the one shown here, are set up to be viewed by anyone.

**FIGURE 3-19**  
**Online storage.**  
 Online storage services allow you to upload and download files from any PC or device with Internet access; some services have the option of password protecting access to your files.

**LOGGING ON**  
 This site requires users to log on before seeing their personal files stored on the site's server.



**SHARING FILES**  
 The contents of the marked folder will be shared with a specific individual, once his or her e-mail address is supplied.



**SECURE ONLINE STORAGE**  
 This site is designed to securely store files for backup or to be shared with others. After logging on, users can upload, download, or delete files, as well as designate who is allowed to access files.



## Other Types of Storage Systems, *Cont'd*

- **Smart card:** Credit card-sized piece of plastic that contains some computer circuitry (processor, memory, and storage)
  - Store small amount of data: about 256 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*

**FIGURE 3-20**  
Smart cards.

**CONVENTIONAL SMART CARDS**

Used to store and retrieve personal information, as well as pay for items using digital cash loaded onto the card.



Smart card



Smart card reader

Smart card circuitry

**HIGH-CAPACITY SMART CARDS**

The StorCard smart card shown here contains a magnetic disk inside the card to increase storage capacity to 100 MB.





# Other Types of Storage Systems, *Cont'd*

- **Holographic storage:** Emerging type of 3D storage technology
  - Uses multiple blue laser beams to store data in three dimensions
  - 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



# Other Types of Storage Systems, *Cont'd*

Storage systems for large computer systems and networks

- Usually use a **storage server**: a hardware device containing multiple high-speed hard drives
- **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

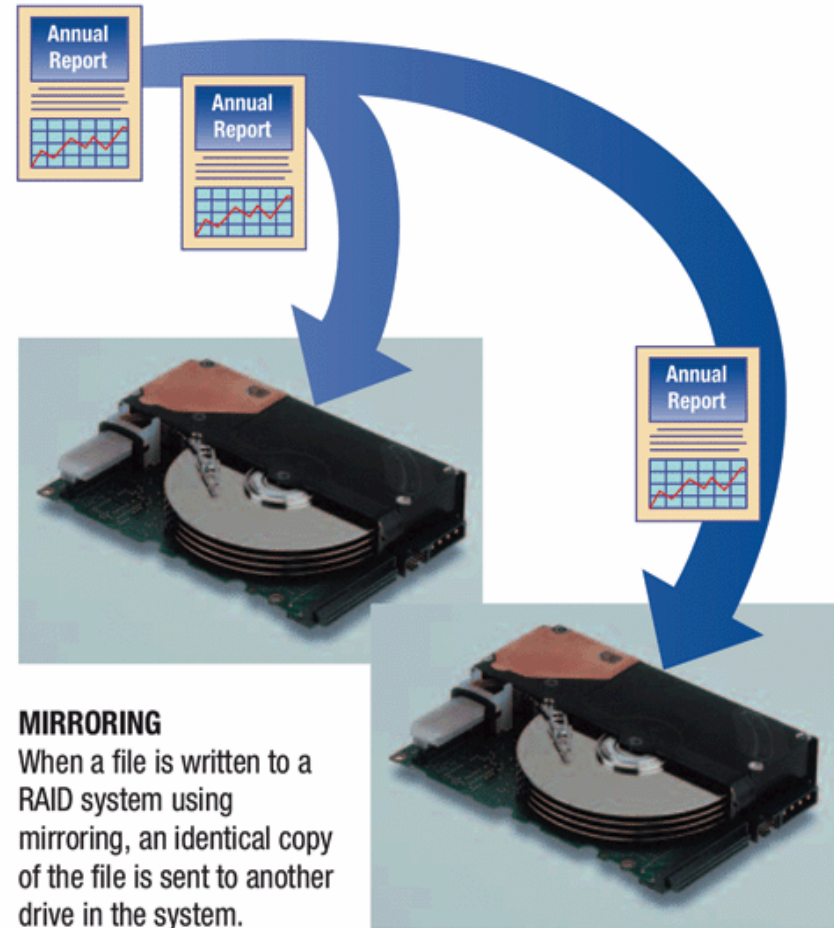
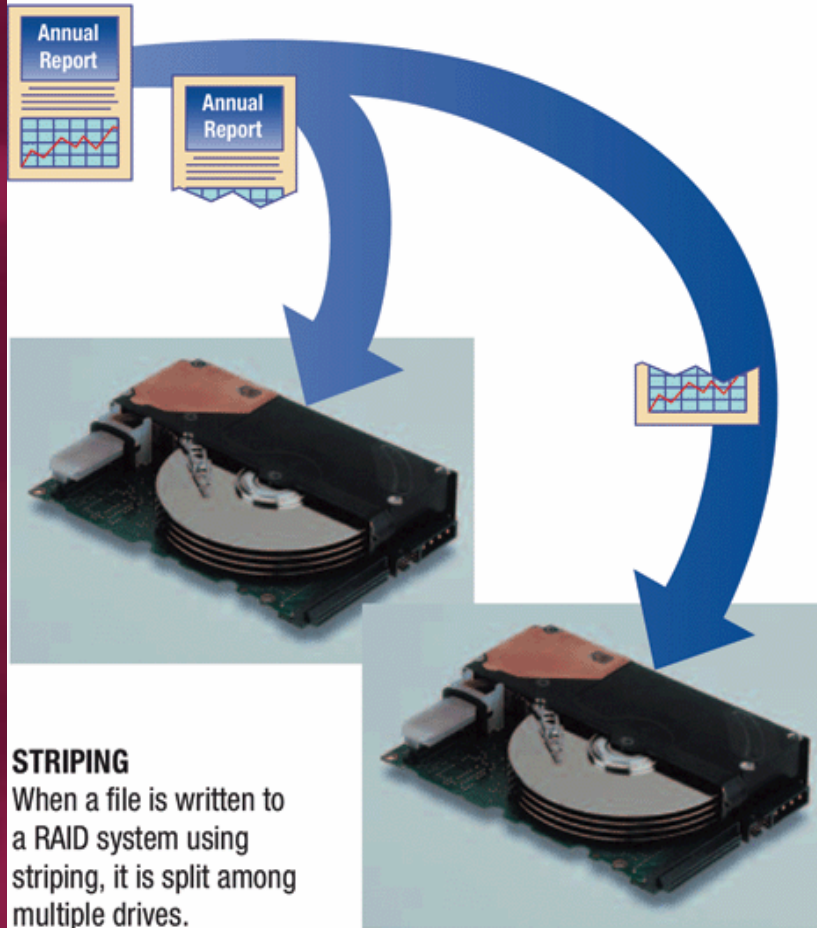


# Other Types of Storage Systems, *Cont'd*

- Storage systems for large computer systems and networks, *cont'd*
  - **RAID (redundant arrays of independent disks):** storage method that uses several small hard disks in parallel to do the job of a larger disk
    - Usually involves recording redundant copies of stored data
    - Helps to increase *fault tolerance*
    - Different levels of RAID, use combination of *disk striping* and *disk mirroring*



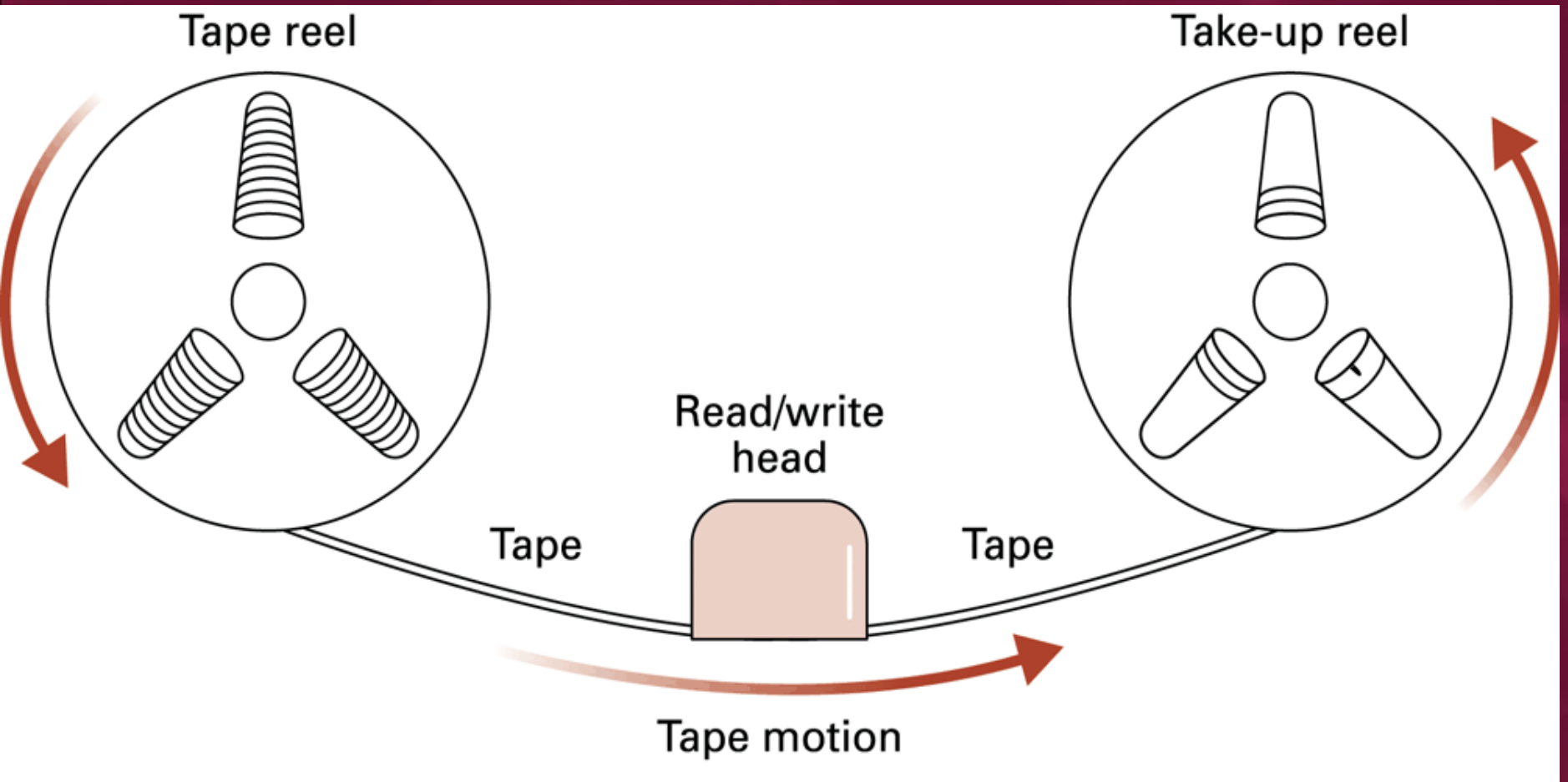
**FIGURE 3-23**  
**RAID.** The two main benefits of RAID are increased speed and the ability to recover easily from a disk crash.





## Other Types of Storage Systems, *Cont'd*

- **Magnetic tape:** plastic tape with a magnetizable surface that stores data as a series of magnetic spots
  - Uses: primarily for backup and archival purposes (sequential access only)
  - Advantage: low cost per megabyte
  - Most tapes today are in the form of *cartridge tapes*
  - Read from and written to via a *tape drive*





## Quick Quiz – Other Types of Storage Systems

- **An online photo sharing site is an example of**
  - **RAID.**
  - **remote storage.**
  - **magnetic storage.**
- **True or False: Smart cards today typically hold at least 1.44 MB of data.**
- **A type of high-capacity multidimensional storage that may be implemented in the future is \_\_\_\_\_ storage.**



# Comparing Storage Alternatives

- Factors to consider
  - Speed
  - Compatibility
  - Storage capacity
  - Convenience
  - Portability
- Most users require:
  - Hard drive
  - CD or DVD drive
  - Flash memory card reader and USB port for flash memory drive



## Quick Quiz – Comparing Storage Alternatives

- Which of the following storage media can only be written to by the user one time?
  - CD+RW
  - DVD-ROM
  - DVD+R
- True or False: A USB 2.0 flash memory drive would be faster than a USB 1.1 flash memory drive.
- A flash memory drive typically connects to a PC via a \_\_\_\_\_ port.



# Summary

- Storage Systems Characteristics
- Magnetic Disk Systems
- Optical Disc Systems
- Flash Memory Systems
- Other Types of Storage Systems
- Comparing Storage Alternatives