chapter 7

Secondary Storage

Why should I read this chapter?

If you don't have the right secondary storage, your computer will slow to a crawl, your digital camera won't take pictures, and your phone won't be able to run apps. In the future, that will likely not be a problem as we will see storage types that can hold the entire U.S. Library of Congress on a single disk the size of a coin and store information in holograms or even organic molecules.

This chapter covers the things you need to know to be prepared for this ever-changing digital world, including:

- Hard drives—get the right hard drive on your computer to meet all your needs.
- Optical discs—share digital information on Blu-ray, CD, or DVD.
- Solid-state storage—make your portable electronics faster and use less power.
- Cloud storage—store your information safely and securely on the Internet.

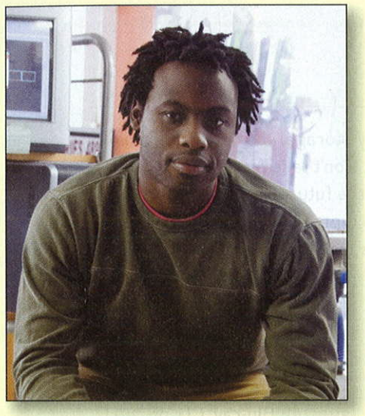
Learning Objectives

After you have read this chapter, you should be able to:

1. Distinguish between primary and secondary storage.
2. Identify the important characteristics of secondary storage including media, capacity, storage devices, and access speed.
3. Describe hard-disk platters, tracks, sectors, cylinders, and head crashes.
4. Compare internal and external hard drives.
5. Compare performance enhancements including disk caching, RAID, file compression, and file decompression.
6. Define optical storage including compact discs, digital versatile discs, and Blu-ray discs.
7. Define solid-state storage including solid-state drives, flash memory cards, and USB drives.
8. Define cloud storage and cloud storage services.
9. Describe mass storage, mass storage devices, enterprise storage systems, and storage area networks.

Introduction

"Hi, I'm James, and I'm a disaster recovery specialist. I'd like to talk with you about secondary storage, one of the most critical parts of any computer system. I'd also like to talk about various cloud storage services."



Secondary storage devices are used to save, back up, and even transport files consisting of data or programs from one location or computer to another. At one time, almost all files contained only numbers and letters. The demands for saving these files were easily met with low-capacity storage devices.

Data storage has expanded from text and numeric files to include digital music files, photographic files, video files, and much more. These new types of files require secondary storage devices that have much greater capacity.

Secondary storage devices have always been an indispensable element in any computer system. They have similarities to output and input devices. Like output devices, secondary storage devices receive information from the system unit in the form of the machine language of 0s and 1s. Rather than translating the information, however, secondary storage devices save the information in machine language for later use. Like input devices, secondary storage devices send information to the system unit for processing. However, the information, since it is already in machine form, does not need to be translated. It is sent directly to memory (RAM), where it can be accessed and processed by the CPU.

To efficiently and effectively use computers, you need to be aware of the different types of secondary storage. You need to know the capabilities, limitations, and uses of hard disks, solid-state drives, optical discs, cloud storage, and other types of secondary storage. Additionally, you need to be aware of specialty storage devices for portable computers and to be knowledgeable about how large organizations manage their extensive data resources.

Storage

An essential feature of every computer is the ability to save, or store, information. As discussed in Chapter 5, random-access memory (RAM) holds or stores data and programs that the CPU is presently processing. Before data can be processed or a program can be run, it must be in RAM. For this reason, RAM is sometimes referred to as **primary storage.**

Unfortunately, most RAM provides only temporary or volatile storage. That is, it loses all of its contents as soon as the computer is turned off. Its contents also are lost if there is a power failure that disrupts the electric current going into the system unit. This volatility results in a need for more permanent or nonvolatile storage for data and programs. We also need external storage because users need much more storage capacity than is typically available in a computer's primary or RAM memory.

Secondary storage provides permanent or nonvolatile storage. Using **secondary storage devices** such as a hard-disk drive, data and programs can be retained after the computer has been shut off. This is accomplished by *writing* files to and *reading* files from secondary storage devices. Writing is the process of saving information *to* the secondary storage device. Reading is the process of accessing information *from* secondary storage. This chapter focuses on secondary storage devices.

These are important characteristics of secondary storage:

- **Media** are the physical material that holds the data and programs. (See Figure 7-1.)
- **Capacity** measures how much a particular storage medium can hold.
- **Storage devices** are hardware that reads data and programs from storage media. Most also write to storage media.
- **Access speed** measures the amount of time required by the storage device to retrieve data and programs.

Most desktop personal computer systems have hard-disk and optical disc drives, as well as ports where additional storage devices can be connected.

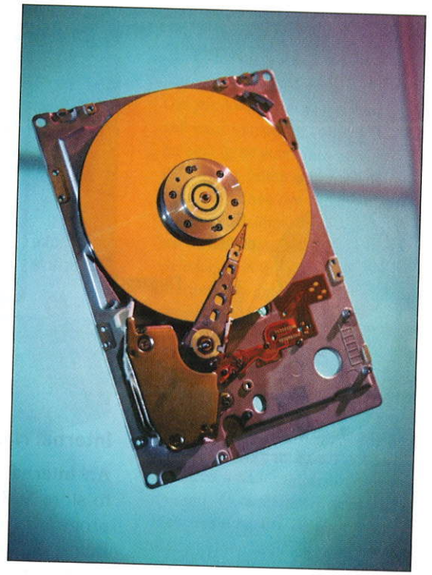


Figure 7-1 Secondary storage media

Hard Disks

Hard disks save files by altering the magnetic charges of the disk's surface to represent 1s and 0s. Hard disks retrieve data and programs by reading these charges from the magnetic disk. Characters are represented by positive (+) and negative (−) charges using the ASCII, EBCDIC, or Unicode binary codes. For example, the letter A would require a series of 8 charges. (See Figure 7-2.) **Density** refers to how tightly these charges can be packed next to one another on the disk.

Hard disks use rigid metallic **platters** that are stacked one on top of another. Hard disks store and organize files using tracks, sectors, and cylinders. **Tracks** are rings of concentric circles on the platter. Each track is divided into invisible wedge-shaped sections called **sectors.** (See Figure 7-3.) A **cylinder** runs through each track of a stack of platters. Cylinders are necessary to differentiate files stored on the same track and sector of different platters. When a hard disk is formatted, tracks, sectors, and cylinders are assigned.

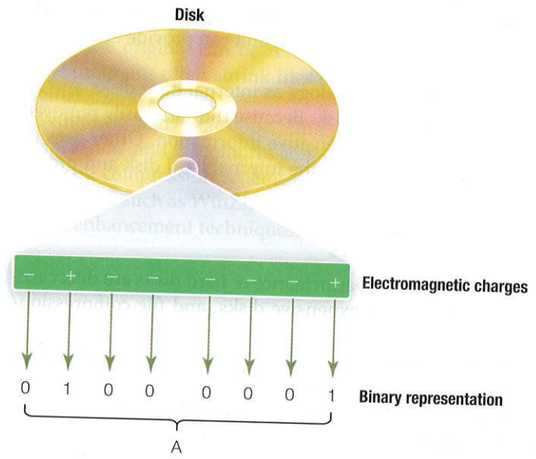


Figure 7-2 How charges on a disk surface store the letter A

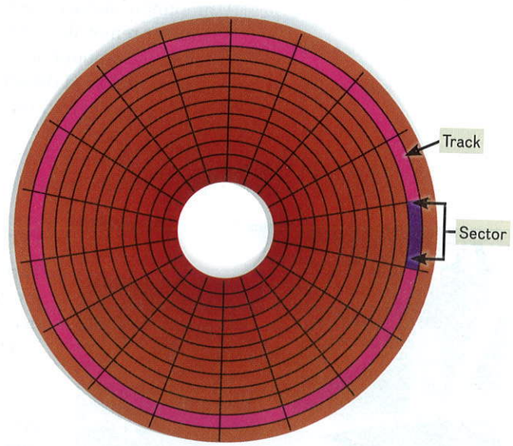


Figure 7-3 Tracks and sectors

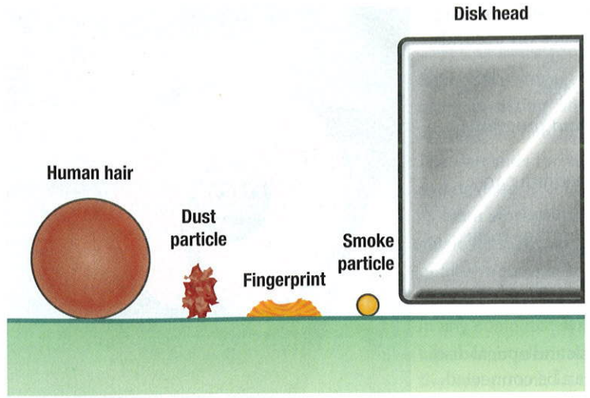


Figure 7-4 **Materials that can cause a head crash**

Hard disks are sensitive instruments. Their read/write heads ride on a cushion of air about 0.000001 inch thick. It is so thin that a smoke particle, fingerprint, dust, or human hair could cause what is known as a head crash. (See Figure 7-4.)

A **head crash** occurs when a read-write head makes contact with the hard disk's surface or with particles on its surface. A head crash is a disaster for a hard disk. The disk surface is scratched, and some or all of the data is destroyed. At one time, head crashes were commonplace. Now, fortunately, they are rare.

There are two basic types of hard disks: internal and external.

Internal Hard Disk

An **internal hard disk** is located inside the system unit. These hard disks are able to store and retrieve large quantities of information quickly. They are used to store programs and data files. For example, nearly every personal computer uses its internal hard disk to store its operating system and major applications such as Word and Excel.

To ensure adequate performance of your internal hard disk and the safety of your data, you should perform routine maintenance and periodically make backup copies of all important files. For hard-disk maintenance and backup procedures, refer to Chapter 4's coverage of the Windows utilities File History, Disk Cleanup, and Optimize Drives.

External Hard Drives

While internal hard disks provide fast access, they have a fixed amount of storage and cannot be easily removed from the system unit. External hard disks provide slower access and are typically connected to a USB or Thunderbolt port on the system unit and are easily removed. Like an internal hard disk, external hard disks have a fixed amount of storage. However, since each removable hard disk can be easily replaced by another removable hard disk, a single port on the system unit can provide access to an unlimited amount of storage. (See Figure 7-5.)

External hard drives use the same basic technology as internal hard disks and are used primarily to complement an internal hard disk. Because they are easily removed, they are particularly useful to protect or secure sensitive information. Other uses for external drives include backing up the contents of the internal hard disk and providing additional hard-disk capacity.

Figure 7-5 **External hard drive**

Performance Enhancements

Three ways to improve the performance of hard disks are disk caching, redundant arrays of inexpensive disks, and file compression/decompression.

Disk caching improves hard-disk performance by anticipating data needs. It performs a function similar to cache memory discussed in Chapter 5. While cache memory improves processing by acting as a temporary high-speed holding area between memory and the CPU, disk caching improves processing by acting as a temporary high-speed holding area between a secondary storage device and the CPU. Disk caching requires a combination of hardware and software. During idle processing time, frequently used data is automatically identified and read from the hard disk into the disk cache. When needed, the data is then accessed directly from memory. The transfer rate from memory is much faster than from the hard disk. As a result, overall system performance is often increased by as much as 30 percent.

Redundant arrays of inexpensive disks (RAID) improve performance by expanding external storage, improving access speed, and providing reliable storage. Several inexpensive hard-disk drives are connected to one another. These connections can be by a network or within specialized RAID devices. (See Figure 7-6.) The connected hard-disk drives are related or grouped together, and the computer system interacts with the RAID system as though it were a single large-capacity hard-disk drive. The result is expanded storage capability, fast access speed, and high reliability. For these reasons, RAID is often used by Internet servers and large organizations.

Figure 7-6 **RAID storage device**

File compression and **file decompression** increase storage capacity by reducing the amount of space required to store data and programs. File compression is not limited to hard-disk systems. It is frequently used to compress files on DVDs, CDs, and flash drives as well. File compression also helps to speed up transmission of files from one computer system to another. Sending and receiving compressed files across the Internet is a common activity.

File compression programs scan files for ways to reduce the amount of required storage. One way is to search for repeating patterns. The repeating patterns are replaced with a token, leaving enough tokens so that the original can be rebuilt or decompressed. These programs often shrink files to a quarter of their original size.

Windows and Mac operating systems provide compression and decompression utilities. For more advanced compression schemes, you can use specialized utilities such as WinZip. For a summary of performance enhancement techniques, see Figure 7-7.

Technique	Description
Disk caching	Uses cache and anticipates data needs
RAID	Linked, inexpensive hard-disk drives
File compression	Reduces file size
File decompression	Expands compressed files

Figure 7-7 **Performance enhancement techniques**

privacy

Did you know that when you sell your computer, you might be selling all your data as well? When you delete a file, the computer does not remove the data. It simply makes that hard-disk space available to be written on in the future. If you accidentally delete a file, file recovery software is available to check the hard disk to see if the data is still there and has not been overwritten yet. In the same way that data can be recovered when accidentally deleted, thieves can recover data that was intentionally deleted. To confidently delete files, use a secure deletion utility before selling a computer.

concept check

- Discuss four important characteristics of secondary storage.
- What are the two types of hard disks? Briefly describe each.
- What is density? What are tracks, sectors, cylinders, and head crashes?
- List and describe three ways to improve the performance of hard disks.

environment

Did you know that traditional, magnetic hard-disk storage requires more energy than solid-state storage? Unlike solid-state drives, which have no moving parts, hard drives have to rotate their magnetic disks in order to save or retrieve data. Fujitsu, which manufactures various storage devices, estimates that its high-end solid-state drives will consume 40 percent less power than comparable hard drives. For large data centers, this can result in a significant reduction in energy needs.

Solid-State Storage

Unlike hard disks, which rotate and have read/write heads that move in and out, **solid-state storage** devices have no moving parts. Data and information are stored and retrieved electronically directly from these devices much as they would be from conventional computer memory.

Solid-state storage devices provide access to **flash memory,** also known as **solid-state storage.** As we discussed in Chapter 5, flash memory offers a combination of features of RAM and ROM. Like RAM it can be updated and like ROM it does not lose information when a computer is turned off. Flash memory is a little slower than traditional memory but much faster than traditional hard disks.

Solid-State Drives

Solid-state drives (SSDs) are designed to be connected inside a personal computer system the same way an internal hard disk would be but contain solid-state memory instead of magnetic disks to store data. (See Figure 7-8.) SSDs are faster and more durable than hard disks. SSDs also require less power, which can lead to increased battery life for laptops and mobile devices. SSDs are more expensive and generally have a lower capacity than hard disks, but this is changing as the popularity of SSDs continues to increase. SSDs are widely used in tablets, smartphones, and other mobile devices. Computer manufacturers have developed hybrid systems that contain both SSDs and magnetic disks in an attempt to gain the speed and power benefits of SSDs while still having the low cost and large capacity of magnetic hard drives. Typically, these systems store the operating system and applications on the SSD drive and videos, music, documents, and folders on the magnetic hard drive.

Figure 7-8 **Solid-state drive**

Flash Memory Cards

Flash memory cards are small solid-state storage devices widely used in portable devices. Some of the cards are used within devices such as laptops, smartphones, and GPS navigation systems. (See Figure 7-9.) Other cards provide removable storage. For example, flash memory is used to store images captured from digital cameras and then to transfer the images to desktop and other computers. Flash memory is used in digital media players like the iPod to store and play music and video files.

USB Drives

USB drives, or **flash drives,** are so compact that they can be transported on a key ring. (See Figure 7-10.) These drives conveniently connect directly to a computer's USB port to transfer files and can have capacities ranging from 1 GB to 256 GB, with a broad price range to match. Due to their convenient size and large capacities, USB drives have become a very popular option for transporting data and information between computers, specialty devices, and the Internet.

tips

Have you ever accidentally deleted or lost important files from your flash drive? Do you have a USB flash drive that is no longer being recognized by your computer? Here are a few suggestions that might help:

1. **Recovery/undelete software.** If you accidentally deleted files from a USB drive, it is unlikely that you can recover them using your operating system or searching through your recycle bin. Fortunately, there are several recovery (or undelete) programs that might help, and some are even free. For example, two free programs are *Undelete 360* and *Recuva.* These programs will scan your flash drives for deleted files and offer you a chance to recover the ones you want back.
2. **Testing USB ports.** If your computer does not recognize your USB flash drive, there could be a problem with your USB port. Try plugging another device into that same port to see if it works. If this device does not work, then your computer's USB is most likely defective and needs to be replaced. If the device works, then most likely your USB flash drive is damaged and you should try the professional recovery services discussed in the next step.
3. **Professional recovery services.** For damaged flash drives, there is a possibility that your data could be recovered by several companies that are dedicated to data recovery. Although the fees are high, they can rescue data from the actual memory chip, even if the drive or supporting circuits are damaged.

Figure 7-9 **Flash memory card**

Figure 7-10 **USB drive**

concept check

- What is solid-state storage? How is it different from hard-disk drives?
- What are solid-state drives? What are they used for?
- What are flash memory cards? What are USB drives? What are they used for?

Optical Discs

Today's **optical discs** can hold over 128 gigabytes of data. (See Figure 7-11.) That is the equivalent of millions of typewritten pages or a medium-sized library all on a single disc. Optical discs are very common, with most software and many movies available on optical disc.

In optical disc technology, a laser beam alters the surface of a plastic or metallic disc to represent data. Unlike hard disks, which use magnetic charges to represent 1s and 0s, optical discs use reflected light. The 1s and 0s are represented by flat areas called **lands** and bumpy areas called **pits** on the disc surface. The disc is read by an **optical disc drive** using a laser that projects a tiny beam of light on these areas. The amount of reflected light determines whether the area represents a 1 or a 0.

Like hard disks, optical discs use tracks and sectors to organize and store files. Unlike the concentric tracks and wedge-shaped sectors used for hard disks, however, optical discs typically use a single track that spirals outward from the center of the disc. This single track is divided into equal-sized sectors.

The most widely used optical discs are CD, DVD, and Blu-ray discs.

- **Compact discs** (**CD**s) were the first widely available optical format for PC users. Typically, CD drives store 700 MB (megabytes) of storage. Optical discs that store music are often CDs.
- **Digital versatile discs** (**DVD**s) are the standard optical discs in PCs. DVDs are very similar to CDs except that

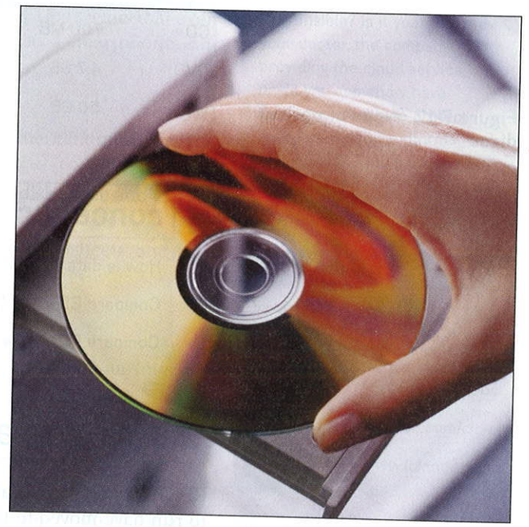


Figure 7-11 **Optical disc**

typical DVD discs can store 4.7 GB (gigabytes)—seven times the capacity of CDs. Optical discs that store movies or software are often DVDs. DVD drives and CD drives look very similar.

- **Blu-ray discs (BDs)** are the newest form of optical storage designed to store **hi def (high definition)** video, which uses the HD 720 and HD 1080 resolutions discussed in Chapter 6. The name Blu-ray comes from a special blue-colored laser used to read the discs that gives them a typical capacity of 50 GB—ten times the capacity of DVDs. Optical discs that store hi def video and the newest video games are often Blu-ray discs.

Each of these optical discs has three basic formats: read only, write once, and rewritable.

- **Read-only (ROM** for **read-only memory) discs** are discs that cannot be written on or erased by the user. Optical discs that you buy in a store, such as music CDs, DVD movies, and Blu-ray video games, are often read only.
- **Write-once (R** for **recordable) discs** can be written on once. After that, the disc can be read many times but cannot be written on or erased. These discs are ideal for creating permanent archives, such as CD-R, often used for storing family photos, and DVD-R, often used to store home movies.
- **Rewritable (RW** for **rewritable** or **RAM** for **random-access memory) discs** are similar to write-once discs except that the disc surface is not permanently altered when data is recorded. These changeable, portable storage options are popular for storing and sharing audio, video, and large multimedia presentations.

Some optical discs, referred to as double-sided discs, contain information on both sides of the disc and need to be flipped over to read the other side, effectively doubling the storage capacity of the disk. For example, a double-sided DVD can store 9.4 GB, or twice as much as a single-sided DVD. Another way to add capacity to an optical disc is by adding multiple recording layers. These discs store information on several layers sandwiched together on one side of the disc. For example, some Blu-ray discs have multiple layers that increase storage capacity from 50 GB to 128 GB.

For a summary of the different types of optical discs, see Figure 7-12.

Format	Typical Capacity	Description
CD	700 MB	Once the standard optical disc
DVD	4.7 GB	Current standard
Blu-ray	50 GB	Hi-def format, large capacity

Figure 7-12 Types of optical discs

concept check

- How is data represented on optical discs?
- Compare CD, DVD, BD, and formats.
- Compare ROM, R, and RW discs.

Cloud Storage

Recently, many applications that would have required installation on your computer to run have moved to the web. As we discussed in Chapter 2, this is known as **cloud computing,** where the Internet acts as a "cloud" of servers that supply applications

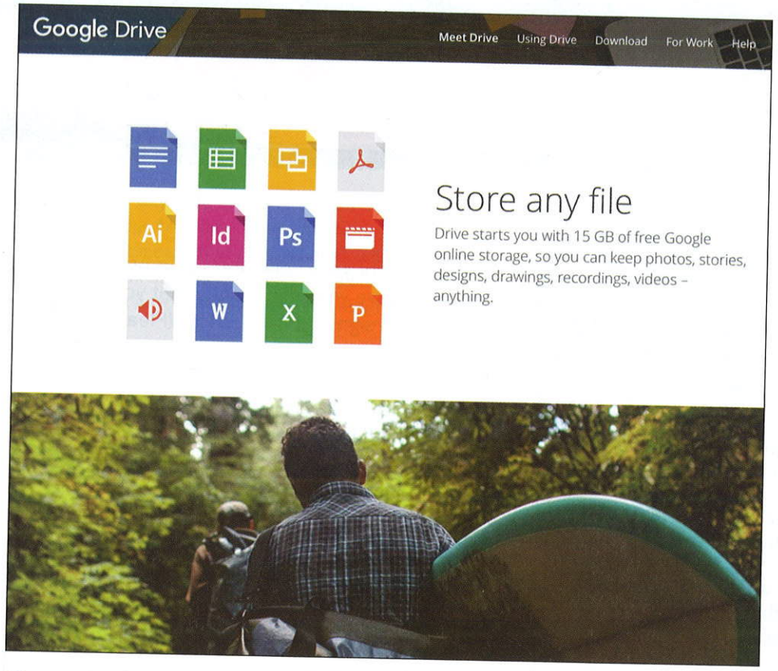


Figure 7-13 Google Drive Docs

to clients as a *service* rather than a *product.* Additionally, these servers provide **cloud storage,** also known as **online storage.**

If you have used Google Drive Docs to create a word processing document or a spreadsheet, you have already used cloud computing. (See Figure 7-13.) The service provider's server runs the applications and your computer displays results. The applications and data can be accessed from any Internet-ready device. This means that even devices with little storage, memory, or processing power, such as a smartphone, can run the same powerful applications as a desktop computer.

The benefits to this arrangement are numerous:

- Maintenance—The cloud service will take care of disk defragmentation, backups, encryption, and security.
- Hardware upgrades—The cloud service will never run out of disk space and can replace failed hard disks without interruption to the user.
- File sharing and collaboration—Users can share documents, spreadsheets, and files with others from anywhere with an Internet connection.

Of course, there are some disadvantages of cloud storage:

- Access speed—The data transfer rate is dependent upon the speed of your Internet connection, which most likely is not as fast as a user's internal network.
- File security—Users are dependent upon the cloud service's security procedures, which may not be as effective as your own.

There are numerous websites that provide cloud storage services. (See Figure 7-14.) To learn more about how you could use cloud storage, see Making IT Work for You: Cloud Storage on pages 182–183.

ethics

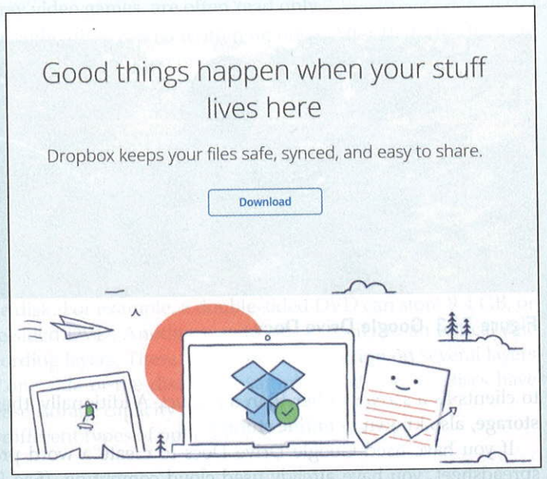
Cloud storage has created some interesting legal and ethical questions regarding the storage of sensitive and privileged information. Who is responsible for maintaining security and privacy of sensitive and confidential information? What if your attorney or doctor stored confidential information about you in the cloud and it somehow became widely distributed across the Internet? Clearly, you suffer any related consequences, but who is responsible? Is it your attorney, your doctor, the company providing the cloud service, or do you somehow have the responsibility to protect personal sensitive information?

Company	Location
Dropbox	www.dropbox.com
Google	drive.google.com
Microsoft	www.skydrive.com
Amazon	amazon.com/cloud
Apple	www.icloud.com

Figure 7-14 Cloud storage services

CLOUD STORAGE

Have you ever found yourself e-mailing files back and forth between two of your computers as a way to transport them? Do you keep forgetting your USB drive at school or work? Have you ever wished that you had some of your files readily available on your smartphone? If so, then you should sign up for Dropbox. (Please note that the web is continually changing, and some of the specifics presented below may have changed.)

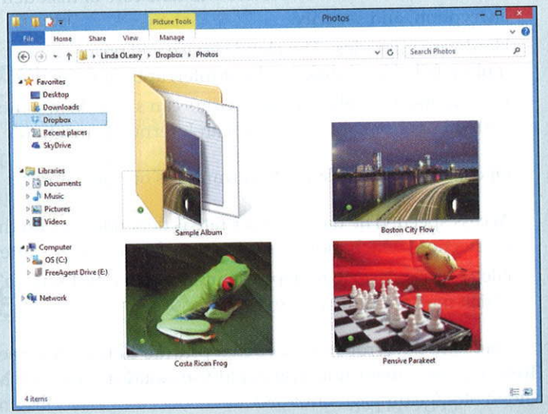


Getting Started To use Dropbox, you need to create an account. To take advantage of the synchronization feature, you will need to install the software on each of your computers.

1. **Go to www.dropbox.com, and click the *Download Dropbox* button.**
2. **Select the "I don't have a Dropbox account" option during the installation process (if this is your first installation).**
3. **Enter your information to create a new account.**
4. **Select the *Free* option when asked for a Dropbox size, and then choose the *Typical* setup.**
5. **Continue clicking the *Next* button to view the important tour.**

If you have a tablet or smartphone, be sure to install its free app in order to access your files.

The Dropbox Folder After installation, a folder named "Dropbox" will be created on your hard drive and connected to your computer's user account. This folder is the basis for all synchronization—any files placed here will immediately be uploaded to your Dropbox account and will be kept synchronized between all your computers. A good use of this folder would be to place all of your schoolwork and favorite photos, so that you can access them from any Internet-connected computer, tablet, or smartphone. Follow these steps to use your Dropbox folder:



1. **Open Windows Explorer, and look at your *Favorites* area.**
2. **Click the *Dropbox* folder, and notice the files and folders already in there. Open the *Photos* subfolder.**
3. **Create a subfolder in this location named "Practice" (this will serve as a photo gallery or album).**
4. **Copy any photo from your computer, and paste it in this new folder.**

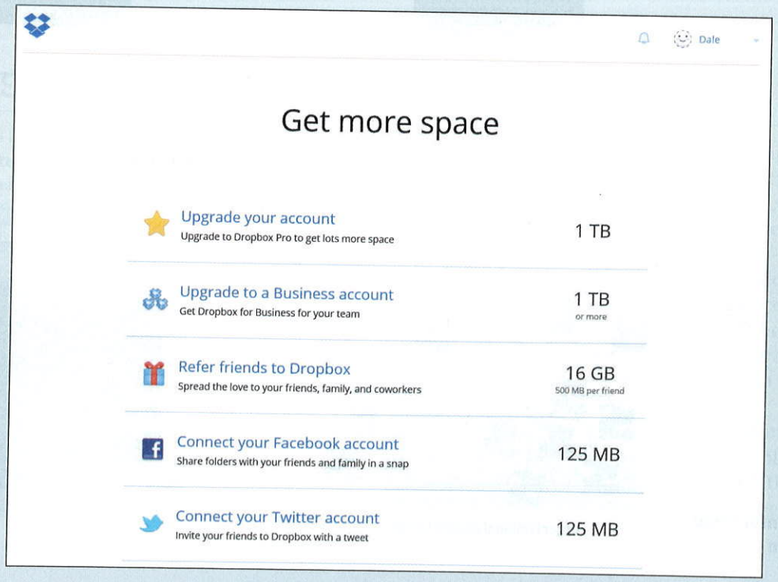
Notice the tiny, blue *synchronization icon* at the bottom left of your file. When this icon turns into a green check mark, it means that the file has finished uploading to the Dropbox server. The same system is used for the Dropbox icon in your Windows notification area.

Sharing Files Any file or folder in your Dropbox account can be shared with anyone via a unique link. This method is superior to sending large e-mail attachments that can be subject to the limits of the e-mail service. To share a file or folder:

1. **Go to your Dropbox folder using Windows Explorer.**
2. **Right-click any file or folder, and click *share Dropbox link*. A URL link to that file or folder will be copied to your clipboard.**
3. **Paste the link into an e-mail to share that file or folder with someone else. That individual will just follow the link in his or her Internet browser to get the file.**

Getting More Storage Space Dropbox's free service includes all its features, but with a limited amount of storage space. You can increase that space with a paid account or by inviting friends and colleagues to join. (Dropbox increases your storage each time one of them signs up.)

1. **Go to www.dropbox.com/getspace and log into your account.**
2. **Click the *Refer friends to Dropbox* and follow the instructions to invite others to use Dropbox.**



concept check

- What is cloud computing?
- What is cloud storage?
- What are some of the advantages and disadvantages of cloud storage?

Mass Storage Devices

It is natural to think of secondary storage media and devices as they relate to us as individuals. It may not be as obvious how important these matters are to organizations. **Mass storage** refers to the tremendous amount of secondary storage required by large organizations. **Mass storage devices** are specialized high-capacity secondary storage devices designed to meet organizational demands for data storage. These mass storage solutions allow large corporations and institutions to centralize their maintenance and security of data, thereby reducing costs and personnel.

Enterprise Storage System

Most large organizations have established a strategy called an **enterprise storage system** to promote efficient and safe use of data across the networks within their organizations. (See Figure 7-15.) Some of the mass storage devices that support this strategy are:

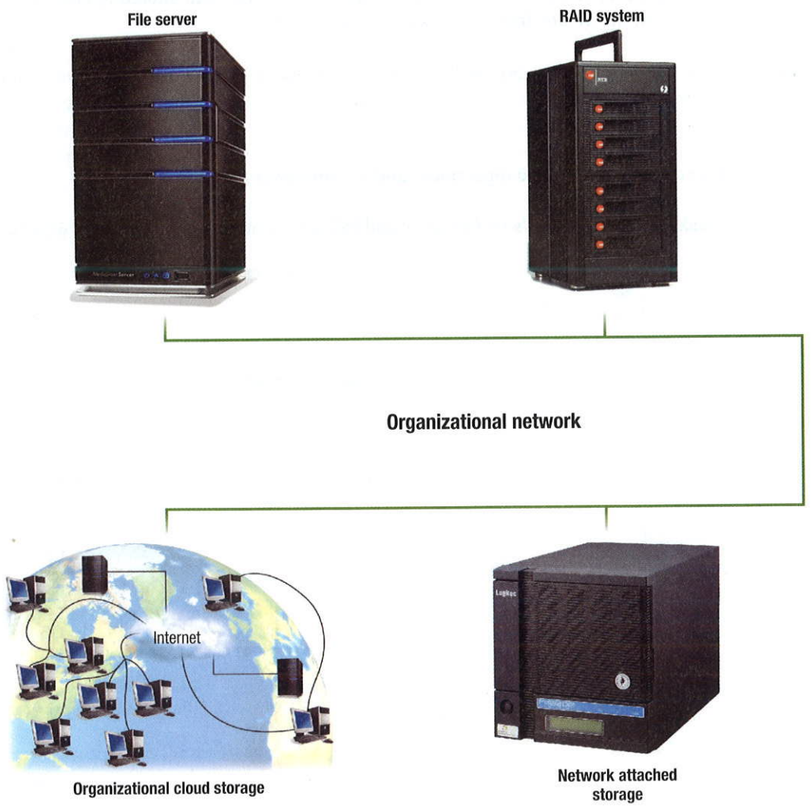


Figure 7-15 Enterprise storage system

- **File servers**—dedicated computers with very large storage capacities that provide users access to fast storage and retrieval of data.
- **Network attached storage (NAS)**—a type of file server designed for homes and small businesses. NAS is less expensive, easier to set up, and easier to manage than most file servers. However, it does not include powerful management tools and features found in many large-scale file servers.
- **RAID systems**—larger versions of the specialized devices discussed earlier in this chapter that enhance organizational security by constantly making backup copies of files moving across the organization's networks.
- **Organizational cloud storage**—high-speed Internet connection to a dedicated remote storage facility. These facilities contain banks of file servers to offer enormous amounts of storage.

Storage Area Network

A recent mass storage development is **storage area network (SAN)** systems. SAN is an architecture to link remote computer storage devices, such as enterprise storage systems, to computers such that the devices are as available as locally attached drives. In a SAN system, the user's computer provides the file system for storing data, but the SAN provides the disk space for data.

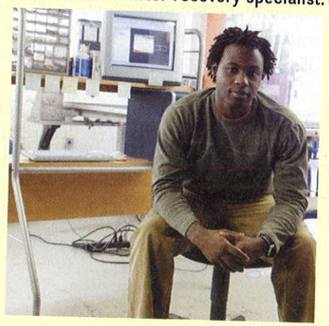
The key to a SAN is a high-speed network, connecting individual computers to mass storage devices. Special file systems prevent simultaneous users from interfering with each other. SANs provide the ability to house data in remote locations and still allow efficient and secure access.

concept check

- Define mass storage and mass storage devices.
- What is an enterprise storage system?
- What is a storage area network system?

Careers in IT

"Now that you've learned about secondary storage, let me tell you a little bit about my career as a disaster recovery specialist."



Disaster recovery specialists are responsible for recovering systems and data after a disaster strikes an organization. In addition, they often create plans to prevent and prepare for such disasters. A crucial part of that plan is to use storage devices and media in order to ensure that all company data is backed up and, in some cases, stored off-site.

Employers typically look for candidates with a bachelor's or associate's degree in information systems or computer science. Experience in this field is usually required, and additional skills in the areas of networking, security, and database administration are desirable. Disaster recovery specialists should possess good communication skills and be able to handle high-stress situations.

Disaster recovery specialists can expect to earn an annual salary of $70,000 to $88,000. Opportunities for advancement typically include upper-management positions. With so many types of threats facing organizations, demand for these types of specialists is expected to grow.

A LOOK TO THE FUTURE

Next-Generation Storage

Have you already started to use a cloud storage service for your files? Have your friends and family members used one also? With millions of individuals and businesses all signing up for these services, how do these companies keep up with the amount of storage required to accommodate all these users? The answer is simple: They keep adding more hard drives. Although hard drives have been around a long time, the technology underlying these tools is undergoing incredible improvements. Recently, terabyte hard drives have become commonplace, using existing magnetic storage methods. In the future, your movies and photos may be stored using heat, organic compounds, or even holograms. Technology has been making better storage, and will continue to evolve to improve our lives as we look to the future.

The first product that will receive a huge improvement is the hard drive. When it comes to the primary storage of your computer and the millions of servers throughout the world, nothing beats hard drives. They are the most affordable solution when it comes to the price per gigabyte. Therefore, researchers are looking at ways of increasing their capacity without increasing their size. Current hard drive technology will max out at approximately 128 GB per square inch. Seagate, a manufacturer of hard drives, is working on two new technologies that hope to increase that limit: heat-assisted magnetic recording (HAMR) and bit-patterned media (BPM). The idea is to keep making the bits smaller so that more of them fit in the same area. Once these technologies are implemented, the capacity could reach 6.25 TB (or 6,250 GB) per square inch. With a density like that, Seagate estimates that you could hold the entire contents of the U.S. Library of Congress on a disk that is no bigger than a coin.

The latest optical disc, Blu-ray, is commercially available as 25- or 50-GB discs. Although several companies have achieved higher limits by adding more layers, a ceiling will soon be hit. GE Global Research is currently developing a disc made up of tiny holograms, stored over dozens of layers, that react to light. These discs will store 1 TB of data, and the drives that read them will also be able to read your DVD and Blu-ray discs.

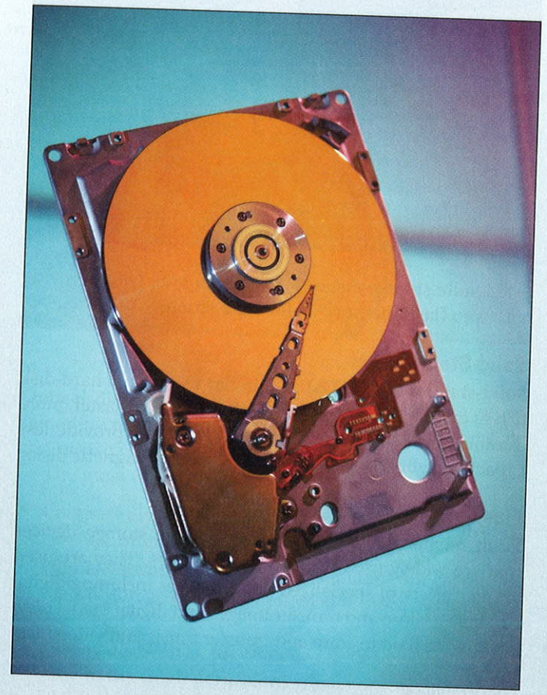
Advancements in chemistry have led to the speculation that circuits and storage media could soon be working with carbon-containing molecules. Researchers have discovered that a group of compounds known as metallofullerenes can be oriented in various ways, allowing them to represent 0 and 1 bits just as other storage media currently do. The biggest advantage with organic molecules involves size. These molecules are so small that storage devices created with them could be extremely tiny, allowing the creation of much smaller computers and gadgets.

You may be wondering why solid-state storage, or flash memory, has not yet been mentioned. This type of media has definitely been improving over the years. Your flash drives and memory cards keep getting smaller and capacities keep going up. However, the price per gigabyte is still much higher than that of hard drives. In the past, they have a limited life span because they can support only approximately 10,000 write operations. These two issues may not be a problem for individuals, but they make it impossible for large businesses and cloud storage companies to rely on them. However, recent innovations in the way solid-state storage writes information has shown dramatic improvements and SSD stability concerns are likely to be a thing of the past.

Now that several types of future technologies have been explored, which do you see yourself using in five years? Do you believe that solid-state storage will completely replace the hard drive in desktop and laptop computers? Do you think that molecule-sized storage solutions will ever be affordable enough to be used in all computers?

VISUAL SUMMARY | Secondary Storage

STORAGE



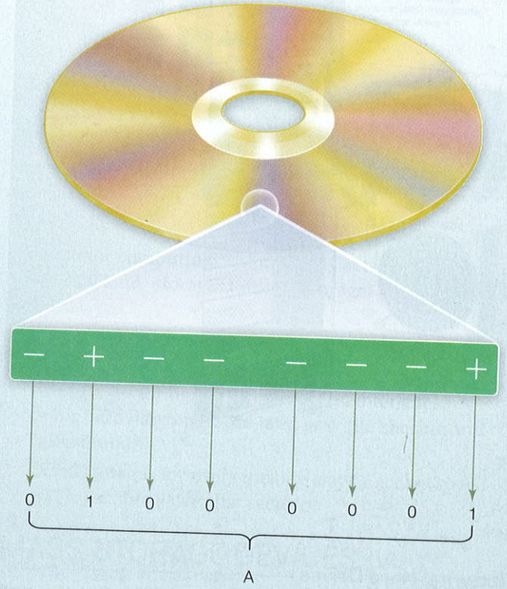
RAM is **primary storage.** Most RAM is volatile, meaning that it loses its contents whenever power is disrupted. **Secondary storage** provides nonvolatile storage. Secondary storage retains data and information after the computer system is turned off.

Writing is the process of saving information to **secondary storage devices.** Reading is the process of accessing information.

Important characteristics include

- **Media**—actual physical material that retains data and programs.
- **Capacity**—how much a particular storage medium can hold.
- **Storage devices**—hardware that reads and writes to storage media.
- **Access speed**—time required to retrieve data from a secondary storage device.

HARD DISKS



Hard disks use rigid metallic **platters** that provide a large amount of capacity. They store data and programs by altering the electromagnetic charges on the platter's surface. Files are organized according to

- **Tracks**—concentric rings on the platter.
- **Sectors**—wedge-shaped sections.
- **Cylinders**—run through each track of a stack of platters.

Density refers to how tightly electromagnetic charges can be packed next to one another on the disk.

A **head crash** occurs when the hard disk makes contact with the drive's read-write heads.

Two types are internal and external hard disks.

Internal Hard Disk

Internal hard disks are located within the system unit. Used to store programs and data files.

To efficiently and effectively use computers, you need to be aware of the different types of secondary storage. You need to know their capabilities, limitations, and uses. There are four widely used storage media: hard disk, solid state, optical disc, and cloud storage.

HARD DISKS

External Hard Drives

Unlike internal hard disks, **external hard drives** are removable. External drives use the same basic technology as internal disks.

Performance Enhancements

Three ways to improve hard-disk performance are disk caching, RAID, and file compression and decompression.

- **Disk caching**—provides a temporary high-speed holding area between a secondary storage device and the CPU; improves performance by anticipating data needs and reducing time to access data from secondary storage.
- **RAID (redundant array of inexpensive disks)**—several inexpensive hard-disk drives are connected together; improves performance by providing expanded storage, fast access, and high reliability.
- **File compression and decompression**—files are compressed before storing and then decompressed before being used again; improves performance through efficient storage.

SOLID-STATE STORAGE

Solid-state storage devices have no moving parts; provide access to **flash memory (solid-state storage).**

Solid-State Drives

Solid-state drives (SSDs) are similar to internal hard-disk drives except they use solid-state memory; are faster, more durable, and more expensive; and generally provide less capacity. Hybrid systems contain SSD and magnetic disks.

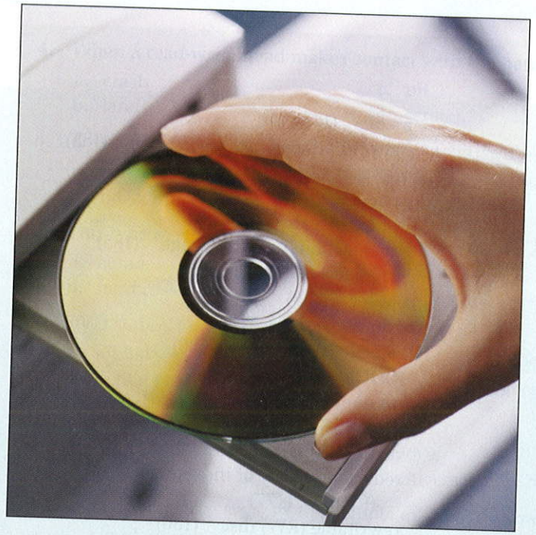
Flash Memory Cards

Flash memory cards are small solid-state storage devices that are widely used with portable devices. They are used with a variety of specialized input devices including digital cameras to store and transfer images and digital media players like the iPod to store and transfer music and video files.

USB Drives

USB drives (flash drives) are so small that they fit onto a key ring. These drives connect to a computer's USB port and are widely used to transfer data and information between computers, specialty devices, and the Internet.

OPTICAL DISCS



Optical discs use laser technology. 1s and 0s are represented by **pits** and **lands. Optical disc drives** project light and measure the reflected light.

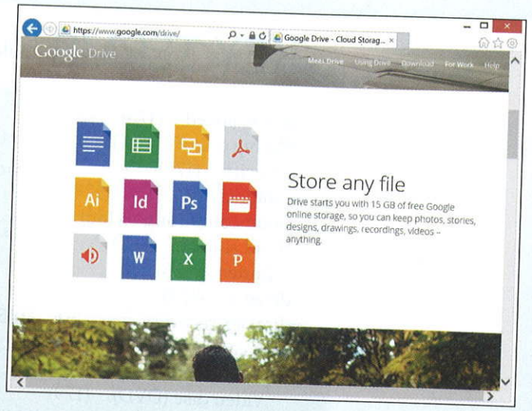
The most widely used optical discs are:

- **Compact discs** (**CD**s) were the first; typical storage 700 MB; often used to store music.
- **Digital versatile discs** (**DVD**s); standard optical discs; typical storage 4.7 GB; often used to store movies and software.
- **Blu-ray discs (BDs)** are the newest; designed to store **hi def (high definition)** video; typical storage 50 GB; often used to store hi def video and video games.

Each of these optical discs has three basic formats:

- **Read-only** (**ROM** for **read-only memory**) discs cannot be written on or erased by the user.
- **Write-once** (**R** for **recordable**) discs can be written on once. After that, they can be read many times but cannot be written on or erased.
- **Rewritable** (**RW** for **rewritable** or **RAM** for **random-access memory**) discs are similar to write-once discs except that the disc surface is not permanently altered when data is recorded.

CLOUD STORAGE



With **cloud computing,** the Internet acts as a "cloud" of servers. **Cloud storage (online storage)** is supplied by these servers.

- Cloud servers provide storage, processing, and memory.
- Advantages for users include less maintenance, fewer hardware upgrades, and easy file sharing and collaboration.
- Disadvantages for users include slower access speed and less control over file security.

MASS STORAGE DEVICES

Mass storage refers to the tremendous amount of secondary storage required by large organizations. **Mass storage devices** are specialized high-capacity secondary storage devices.

Most large organizations have established a strategy called an **enterprise storage system** to promote efficient and safe use of data.

Mass storage devices that support this strategy are **file servers, network attached storage (NAS), RAID systems,** and **organizational cloud storage.** A **storage area network (SAN)** is a method of using enterprise-level remote storage systems as if they were local to your computer.

CAREERS in IT

Disaster recovery specialists are responsible for recovering systems and data after a disaster strikes an organization. Bachelor's or associate's degree in information systems or computer science, experience, and additional skills in the areas of networking, security, and database administration are desirable. Salary range is $70,000 to $88,000.

KEY TERMS

access speed (175)
Blu-ray disc (BD) (180)
capacity (175)
compact disc (CD) (179)
cloud computing (180)
cloud storage (181)
cylinder (175)
density (175)
disaster recovery specialist (185)
disk caching (176)
digital versatile disc or digital video disc (DVD) (179)
enterprise storage system (184)
external hard drive (176)
file compression (177)
file decompression (177)
file server (185)
flash drive (178)
flash memory (178)
flash memory card (178)
hard disk (175)
head crash (176)
hi def (high definition) (180)
internal hard disk (176)
land (179)
mass storage (184)
mass storage devices (184)
media (175)
network attached storage (NAS) (185)
online storage (181)
optical disc (179)
optical disc drive (179)
organizational cloud storage (185)
pit (179)
platter (175)
primary storage (174)
recordable (R) disc (180)
RAID system (185)
random-access memory (RAM) disc (180)
read-only memory (ROM) disc (180)
redundant array of inexpensive disks (RAID) (177)
rewritable (RW) disc (180)
secondary storage (174)
secondary storage device (174)
sector (175)
solid-state drive (SSD) (178)
solid-state storage (178)
storage area network (SAN) (185)
storage device (175)
track (175)
USB drive (178)
write-once disc (180)

MULTIPLE CHOICE

Circle the letter of the correct answer.

1. RAM is sometimes referred to as:
   a. primary storage
   b. ratio active memory
   c. read-only memory
   d. secondary storage

2. The actual physical material that holds the data and programs.
   a. primary storage
   b. media
   c. capacity
   d. access

3. Measures how tightly the magnetic charges can be packed next to one another on the disk.
   a. density
   b. cylinders
   c. tracks
   d. sectors

4. When a read-write head makes contact with the hard disk's surface, it causes a head:
   a. crash
   b. land
   c. pit
   d. scratch

5. This hard-disk performance enhancement anticipates data needs.
   a. disk caching
   b. file compression
   c. file decompression
   d. RAID

6. This type of storage uses pits and lands to represent 1s and 0s.
   a. cloud
   b. hard disk
   c. optical
   d. solid state

7. DVD stands for:
   a. digital versatile disc
   b. digital video data
   c. dynamic versatile disc
   d. dynamic video disc

8. USB drives are also known as:
   a. flash drives
   b. optical drives
   c. ports
   d. universal state bus

9. An organizational strategy to promote efficient and safe use of data across the networks.
   a. cloud dynamic
   b. data mission statement
   c. enterprise storage system
   d. RAID

10. Specialized high-capacity secondary storage devices designed to meet organizational demands.
    a. CD devices
    b. flash drives
    c. mass storage devices
    d. platters

MATCHING

Match each numbered item with the most closely related lettered item. Write your answers in the spaces provided.

a. DVD
b. file compression
c. hi def
d. network attached storage
e. secondary storage
f. sectors
g. solid-state drives
h. storage area network
i. storage devices
j. tracks

___ 1. Provides permanent or nonvolatile storage.
___ 2. Hardware that reads data and programs from storage media.
___ 3. Concentric rings on a hard-disk platter.
___ 4. Each track is divided into invisible wedge-shaped sections called _____ .
___ 5. Increases storage capacity by reducing the amount of space required to store data and programs.
___ 6. Optical disc most common on today's personal computers.
___ 7. The next generation of optical discs.
___ 8. Similar to internal hard-disk drives except they use solid-state memory.
___ 9. Mass storage device widely used for home and small business storage.
___ 10. Architecture to link remote storage devices to computers such that the devices are as available as locally attached drives.

OPEN-ENDED

On a separate sheet of paper, respond to each question or statement.

1. Compare primary storage and secondary storage, and discuss the most important characteristics of secondary storage.
2. Discuss hard disks including density, platters, tracks, sectors, cylinders, head crashes, internal, external, and performance enhancements.
3. Discuss solid-state storage including solid-state drives, flash memory, and USB drives.
4. Discuss optical discs including pits, lands, CDs, DVDs, Blu-ray, and hi def.
5. Discuss cloud computing and cloud storage.
6. Describe mass storage devices including enterprise storage systems, file servers, network attached storage, RAID systems, organizational cloud storage, and storage area network systems.

DISCUSSION

Respond to each of the following questions.

1 Making IT Work for You: CLOUD STORAGE

Have you ever found yourself e-mailing files back and forth between two of your computers or with others as a way to transport them? Review the Making IT Work for You: Cloud Storage on pages 182–183. Then respond to the following: (a) Have you ever used Dropbox or a similar service? If so, what service have you used, and what do you typically use it for? If you have not used Dropbox or a similar service, describe how and why you might use one. (b) If you do not have a Dropbox account, set up a free one and create a Dropbox folder. Use Dropbox to either (1) access a file from another computer or (2) share a file with one of your classmates. Describe your experience. (c) Try a few of Dropbox's features, and describe your experience with these features. (d) Do you see yourself using Dropbox on an everyday basis? Why or why not?

2 Privacy: SECURE DATA DELETION

Once you've deleted a file it's gone forever, right? Wrong. Deleted files can often be recovered and your private information compromised. Review the Privacy box on page 177, and then respond to the following: (a) Have you ever used a secure deletion utility? If so, what one did you use? If not, do you think you might use one in the future? (b) What kinds of files would you consider deleting permanently? Be specific. (c) Even if you are not planning to sell your computer, do you think it would be a good practice to periodically use a secure deletion utility? Why or why not? (d) How would you find a secure deletion utility? Do you think there are any free ones?

3 Ethics: CLOUD STORAGE AND CONFIDENTIALITY

When individuals and businesses store files using cloud services, they expect the cloud company to behave ethically by providing adequate security to protect confidential files. What if this expectation is not met? Review the Ethics box on page 181, and then respond to the following: (a) Would you be comfortable if your attorney stored digital copies of your legal documents in the cloud? What about your doctor or psychologist? Why or why not? (b) Who should be responsible if files stored in the cloud are stolen or viewed by hackers or unethical employees? Who would suffer the consequences? Defend your position. (c) Should laws be created that require cloud storage companies to operate ethically and to assume responsibility for security and confidentiality of stored data? Why or why not? (d) Cloud computers are not necessarily located within the borders of the United States and therefore may not be subject to the same regulations as U.S.-based computers. Do you think that all U.S. companies should be required to keep their cloud servers in this country? Defend your response. (e) How do you feel about storing personal and confidential information in the cloud? Do you currently do it? Why or why not?

4 Environment: SOLID-STATE STORAGE

Did you know that traditional, magnetic hard-disk storage requires more energy than solid-state storage? Review the Environment box on page 178, and then respond to the following: (a) Why do you suppose that less energy is required for solid-state drives? (b) Why are not all hard drives being replaced with solid-state drives? (c) Do you think hard drives will become obsolete in the near future? Why or why not? (d) Would you be willing to pay more for a solid-state drive? If so, how much? If not, why not?

PHOTO CREDITS

CHAPTER 7

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