Secondary Storage

• Nonvolatile
• Frequently mobile
• Frequently large (B = Byte = 8 bits)
  – kB \( (2^{10} = 1024 \text{ which is close to 1000 Bytes}) \)
  – MB (mega, \( 10^6, \text{ million} \)) CDs
  – GB (giga, \( 10^9, \text{ billion} \)) Hard drives, Flash drives, DVDs
  – TB (tera, \( 10^{12}, \text{ trillion} \)) Hard drives
  – PB (peta, \( 10^{15}, \text{ quadrillion} \))
  – EB (exa, \( 10^{18}, \text{ quintillion} \))
Important Factors

• Fixed or removable
• Capacity
• Read-Only, Write-Once or Rewritable
• Access speed
  – Time to find or deliver data
• Transfer rate
  – Time to move data to and from device
• Reliability
  – How long will medium reliably hold data?

Hard Disks

• Can be fixed or removable
• High capacity (in TB range)
• Read/Write
• High access speed and transfer rate
• Reliable (3 – 5 years or more)
• Use magnetic storage
Hard Disks: Magnetic Storage

- Circular aluminum, glass, or plastic disk
- Coated with magnetic particles

Orientation of magnetic particles represent binary numbers, 0 or 1

Vertical orientation stores more data than horizontal
Organization: Tracks and Sectors

- Data is organized using concentric rings called “tracks”
- Disk divided into sectors to help locate data

Hard Disks: Multiple Platters

- Hard drive contains many disks -- platters
- R/W heads read top and bottom of each platter
- Similar tracks on all platters make up a cylinder
Hard Disks: Read/Write Heads

- Don’t touch platter
- Cushion of air between head and platter
- VERY close
- Disk must be enclosed in dust-free container

Hard Disks: Cache

- Similar to CPU cache
- Memory chips on hard disk drive
- Store frequently used instructions and data
- Retrieving information from cache faster than from platters
- Cache size: 2 MB – 64MB
Hard Disk Care

• Don’t drop it
  – Usually, but not always, will survive
• Defragment the disk every now and then
  – As much as possible, data is written so that it is easy for R/W heads to find
  – Multiple write/erase/write cycles scatter data
    • Takes longer to find
  – Defragmentation rearranges data in blocks so that it is easy to find

Hard Disks: RAID

• Redundant array of independent disks
  – Several hard disks that behave as one
  – Blocks of files spread across multiple disks
  – Error-catching information for one disk is stored on another
• If a disk fails, can replace it without shutting down drive
  – Data on disk is automatically regenerated
• Frequently used for enterprise storage
Hard Disks: Network-Attached Storage

- NAS
- A server (or servers) attached to network and dedicated to storage
  - Basically a box of hard drives
  - High capacity: usually in the multi-TB range
- All users have access to the storage
- Wofford has a NAS in both data centers

Optical Storage

- CD, DVD, Blu-Ray DVD
- Removable
- Medium capacity (700 MB – 50 GB)
- Read-only, record once, rewritable available
- Medium speed and transfer rate
- Long lifetime for DVDs
  - At least 100 years*
  - Probably longer for recordable variety

*"Care and Handling Guide for the Preservation of CDs and DVDs - A joint Council on Library and Information Resources (CLIR) and NIST project"
Optical Storage

• Data stored on optical disk with pits and lands
• Read with a laser beam
  – Lands reflect laser beam
  – Pits do not

Compact Disks (CD)

• Hold about 700 MB
• Pits and lands in an aluminum layer
CD-R

- Recordable CDs
- Don’t have pits and lands
- Replace aluminum layer with layer of reflective silver or gold
- Cover reflective layer with transparent dye

![Diagram of CD-R structure]

CD-R

- High power laser heats up dye in places
- Makes it opaque ("pits")
- Low power laser reads reflections in spots where light still passes through dye layer

![Diagram of CD-R with pits and lands]
CD-RW

• Can write more than once
• Use special dye that can be made transparent again
• Three laser powers
  – Write power: makes dye opaque
  – Erase power: makes dye transparent again
  – Reading power: reads disk

DVDs

• Work like CDs
• Uses red laser, but with smaller wavelength
  – 650 nm vs 780 nm for CD
• Pits can be closer
• Single-layer: 4.7 GB
• Double-layer: 8 GB
Blu-Ray DVDs

- Use blue laser
  - Even smaller wavelength (405 nm)
- Double-layer Blu-Ray holds 50 GB

Magnetic Tape

- Read and write
- Slow
- High capacity (TB range)
- Mainly used for backup of servers
USB Flash Drives

- Thumb drives
- Solid-state
- 2 – 100 GB ($$$)

Smart Cards

- Have an embedded microprocessor
- More secure than magnetic stripe cards
  - Magnetic stripe is easy for criminals to read
  - Microprocessor is not
- Common in Europe
- Just taking off in US
Cloud-Based Services

- Network diagrams frequently represent the Internet as a cloud
- Cloud-based services are available through the Internet

What is the “Cloud”?  

- Based on “server farms” – data centers with thousands of servers
- Server farms can be enormous
  - Estimate: Google maintains 450,000 servers
  - Major Google centers in California, Iowa, Virginia, North Carolina, Georgia, Ireland, Belgium, Switzerland, and China.
What is the “Cloud”?  

- The “cloud” refers to any group of computers distributed among these server farms  
- Available to anyone on the Internet  
  - Sometimes at a price, generally not a high one  
- “Cloud computing” refers to resources delivered over the Internet  
  - New model  
  - IT organizations no longer need to supply the resources locally

Cloud-Based Applications  

- Run on a distributed cluster of servers located in different server farms  
- Several advantages to this  
  - Resilient, robust and reliable  
    - Data shared over many widely distributed servers  
  - IT organizations manage only the connection with the cloud resources, not the servers  
  - Cheaper
Cloud-Based Applications

• Familiar applications use the cloud as a platform
  – Google
  – YouTube
  – Amazon
  – Flickr
  – Quicken Online
• Most common cloud-based applications at colleges are Gmail and Google Apps

Cloud-Based Applications

• Available anywhere with an Internet connection
• Ideal for mobile users
  – Many cloud apps run on iPads and iPhones as well as laptops
• Ideal for collaboration
• Cloud proponents predict that 90% of computing eventually will reside in the cloud
Cloud Storage

• Example: Dropbox
  – www.dropbox.com

• Good for
  – Transfer of large files
  – Keeping files in sync on multiple computers
  – Sharing files with colleagues