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# **External Memory**

# Hierarchy List

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- Registers
- L1 Cache
- L2 Cache
- Main memory
- Disk cache
- Disk
- Optical
- Tape

# Performance

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- Access time
  - Time between presenting the address and getting the valid data
- Memory Cycle time
  - Time may be required for the memory to “recover” before next access
  - Cycle time is access + recovery
- Transfer Rate
  - Rate at which data can be moved

# Physical Types

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- Semiconductor
  - RAM
- Magnetic
  - Disk & Tape
- Optical
  - CD & DVD

# **Types of External Memory**

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- Magnetic Disk
  - RAID
  - Removable
- Optical
  - CD-ROM
  - CD-Recordable (CD-R)
  - CD-R/W
  - DVD
- Magnetic Tape

# Magnetic Disk

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- Disk substrate coated with magnetisable material (iron oxide)
- Substrate used to be aluminium
- Now glass
  - Improved surface uniformity
    - Increases reliability
  - Reduction in surface defects
    - Reduced read/write errors
  - Better stiffness
  - Better shock/damage resistance

# Read and Write Mechanisms

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- Recording & retrieval via conductive coil called a head
- May be single read/write head or separate ones
- During read/write, head is stationary, platter rotates
- Write
  - Current through coil produces magnetic field
  - Pulses sent to head
  - Magnetic pattern recorded on surface below
- Read (traditional)
  - Magnetic field moving relative to coil produces current
  - Coil is the same for read and write
- Read (contemporary)
  - Separate read head, close to write head
  - Partially shielded magneto resistive (MR) sensor
  - Electrical resistance depends on direction of magnetic field
  - High frequency operation
    - Higher storage density and speed

# **Data Organization and Formatting**

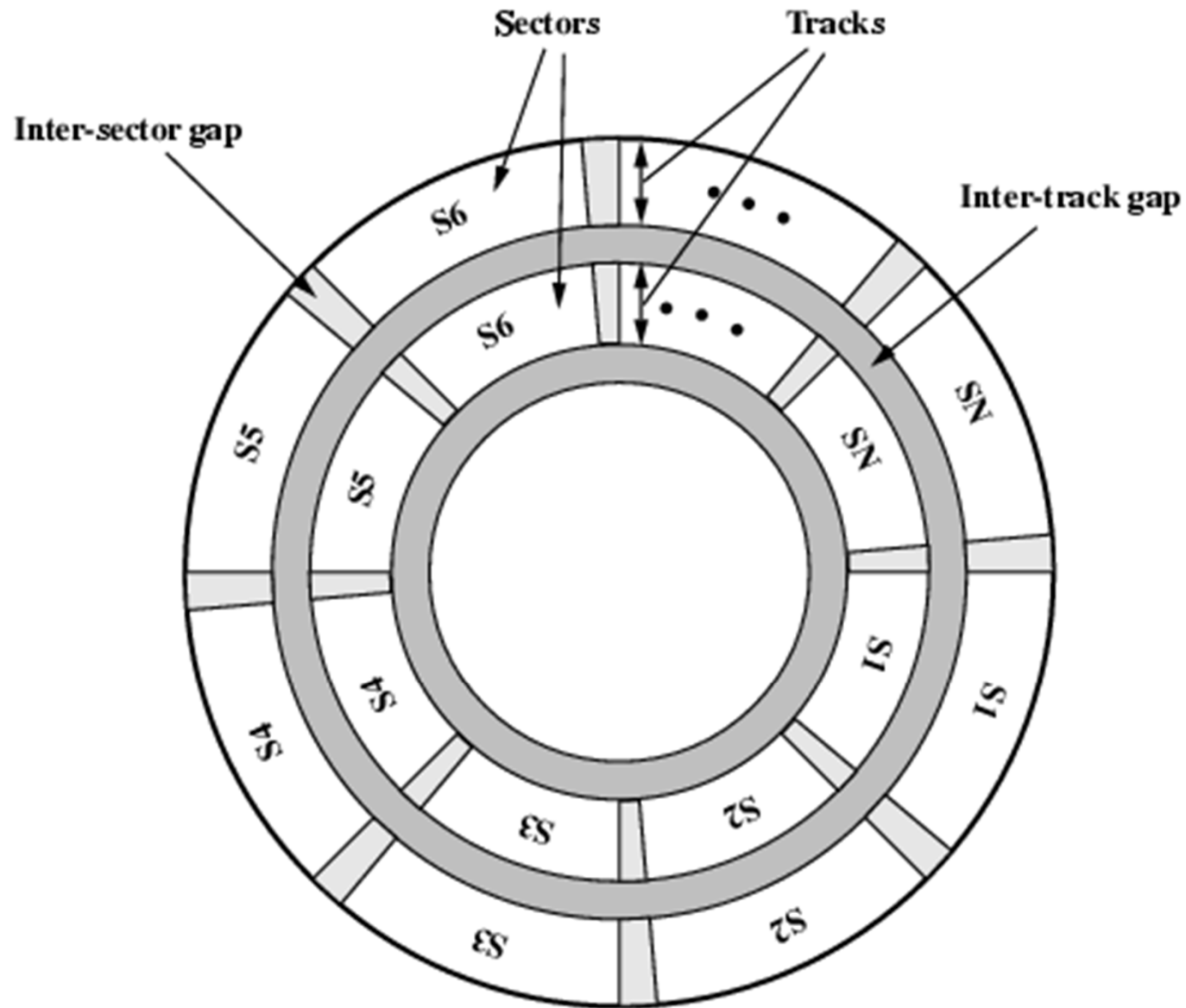
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- Concentric rings or tracks
  - Gaps between tracks
  - Reduce gap to increase capacity
  - Same number of bits per track (variable packing density)
  - Constant angular velocity
- Tracks divided into sectors
- Minimum block size is one sector



# Disk Data Layout

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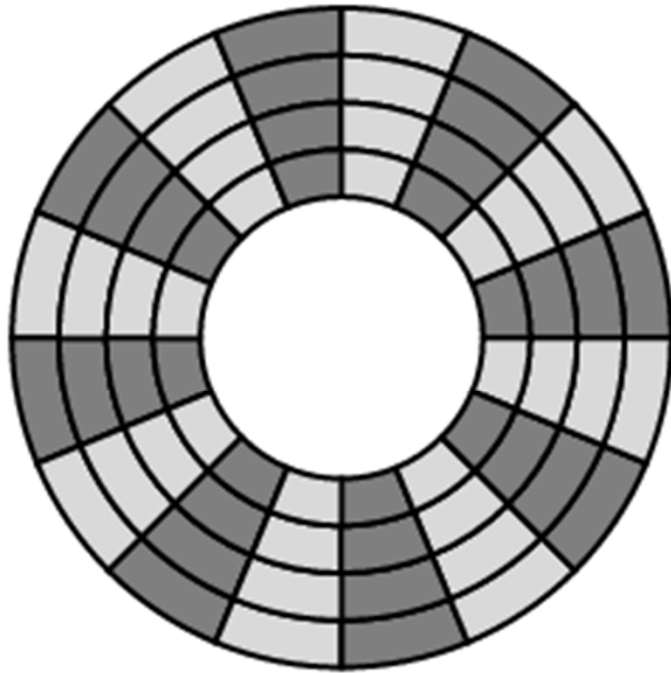
# Disk Velocity

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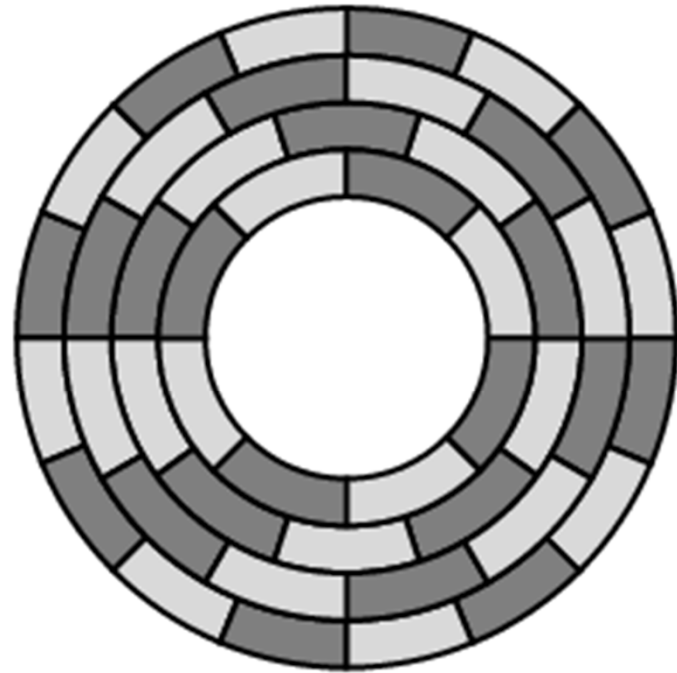
- Rotate disk at constant angular velocity (CAV)
  - Gives pie shaped sectors and concentric tracks
  - Individual tracks and sectors addressable
  - Move head to given track and wait for given sector
  - Waste of space on outer tracks
    - Lower data density
- Can use zones to increase capacity
  - Each zone has fixed bits per track
  - More complex circuitry

# Disk Layout Methods Diagram

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(a) Constant angular velocity



(b) Multiple zoned recording

## **Finding Sectors**

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- Must be able to identify start of track and sector
- Format disk
  - Marks tracks and sectors

# Characteristics

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- Fixed (rare) or movable head
- Removable or fixed
- Single or double (usually) sided
- Single or multiple platter
- Head mechanism
  - Contact (Floppy)
  - Fixed gap

# **Fixed/Movable Head Disk**

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- Fixed head
  - One read write head per track
  - Heads mounted on fixed ridged arm
- Movable head
  - One read write head per side
  - Mounted on a movable arm

## **Removable or Not**

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- Removable disk
  - Can be removed from drive and replaced with another disk
  - Provides unlimited storage capacity
  - Easy data transfer between systems
- Nonremovable disk
  - Permanently mounted in the drive

## **Multiple Platter**

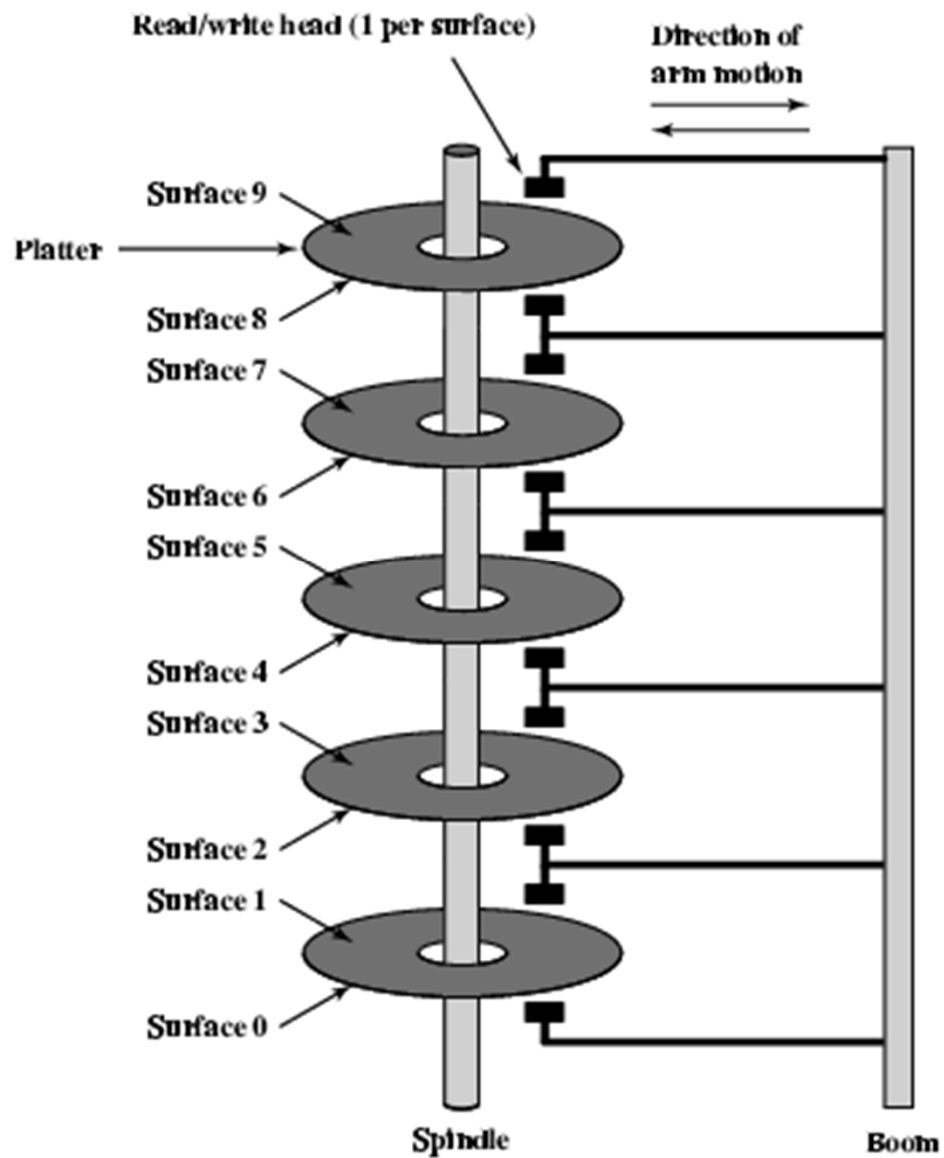
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- One head per side
- Heads are joined and aligned
- Aligned tracks on each platter form cylinders
- Data is striped by cylinder
  - reduces head movement
  - Increases speed (transfer rate)



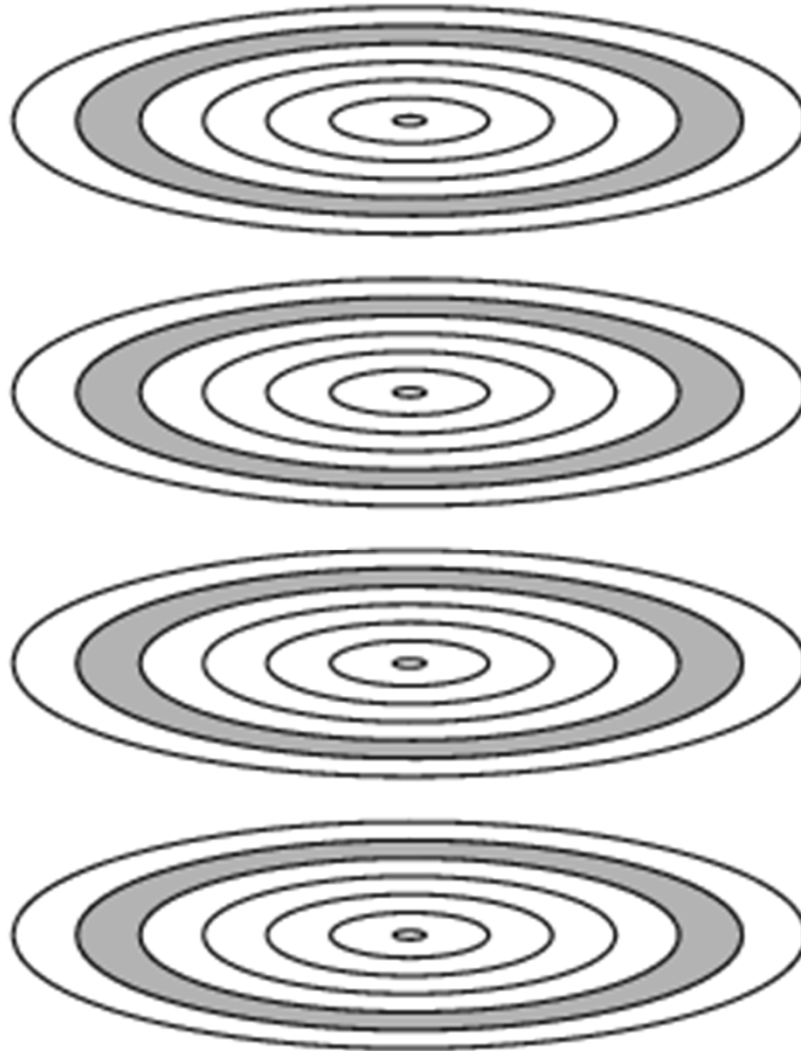
# Multiple Platters

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# Tracks and Cylinders

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# Disk Addressing

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- Need to know
  - Sector No.
  - Track No.
  - Surface No. (Head No.)
- Option I
  - surface : track : sector
- Option II
  - track : surface : sector

# Floppy Disk

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- 8", 5.25", 3.5"
- Small capacity
  - Up to 1.44Mbyte (2.88M never popular)
- Slow
- Universal
- Cheap
- Obsolete?

## **Winchester Hard Disk (1)**

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- Developed by IBM in Winchester (USA)
- Sealed unit
- One or more platters (disks)
- Heads fly on boundary layer of air as disk spins
- Very small head to disk gap
- Getting more robust

## **Winchester Hard Disk (2)**

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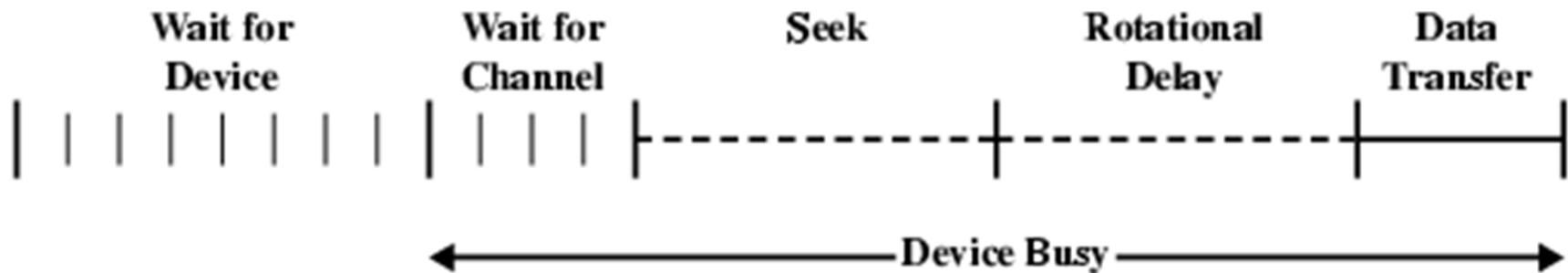
- Universal
- Cheap
- Fastest external storage
- Getting larger all the time
  - 250 Gigabyte now easily available

# Speed

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- Seek time
  - Moving head to correct track
- (Rotational) latency
  - Waiting for data to rotate under head
- Access time = Seek + Latency
- Transfer rate

# **Timing of Disk I/O Transfer**





# Time requirements

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- Transfer Time:
  - The transfer time to or from the disk depends on the rotation speed of the disk as:
    - $T = b/rN$
    - Where
    - $T$  = Transfer time
    - $b$  = number of bytes to be transferred
    - $N$  = number of bytes on a track
    - $r$  = rotational speed, in revolution per second
    - Total Time =  $T_s + 1/2r + b/rN$  ( $T_s$ : Average seek time)
- E.g., rotational speed = 15000 rpm, 512 bytes per sector with 500 sectors per track. Average seek time is 4 ms. File size= 1.28 Mbytes