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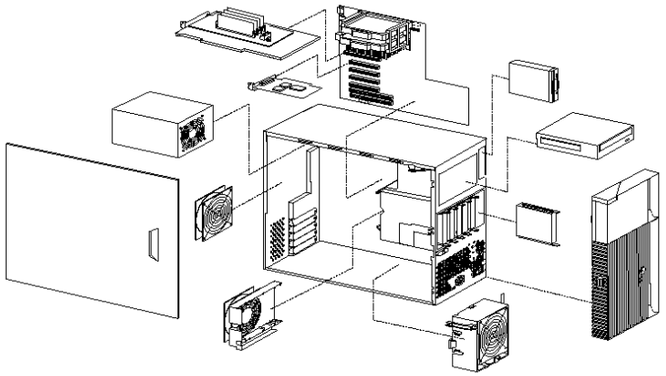
Department of Computer Science and Engineering
School of Science, Engineering & Technology



CSE 317: Computer Organization & Architecture

Art or draw = 5

Wahidul Alam, Lecturer, CSE, SoSET, EDU

Topic 8 – External Memory

- Magnetic Disk
- Optical Disk
- Magnetic Tape

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Types of External Memory

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

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Magnetic Disk

- Disk substrate coated with magnetizable material (iron oxide…rust)
- Substrate used to be aluminum
- Now glass — Improved surface uniformity
- Increases reliability — Reduction in surface defects

Reduced read/write errors

—Lower flight heights (See later)

—Better stiffness

—Better shock/damage resistance

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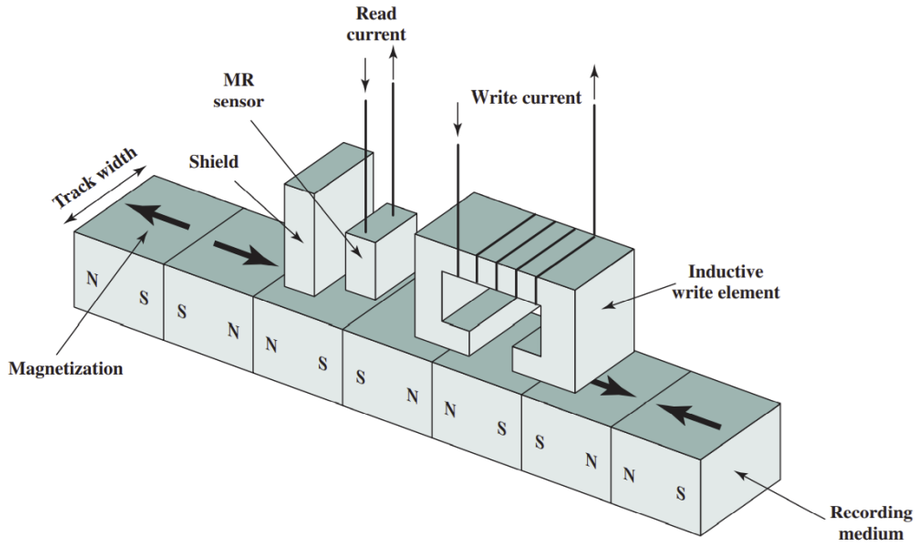
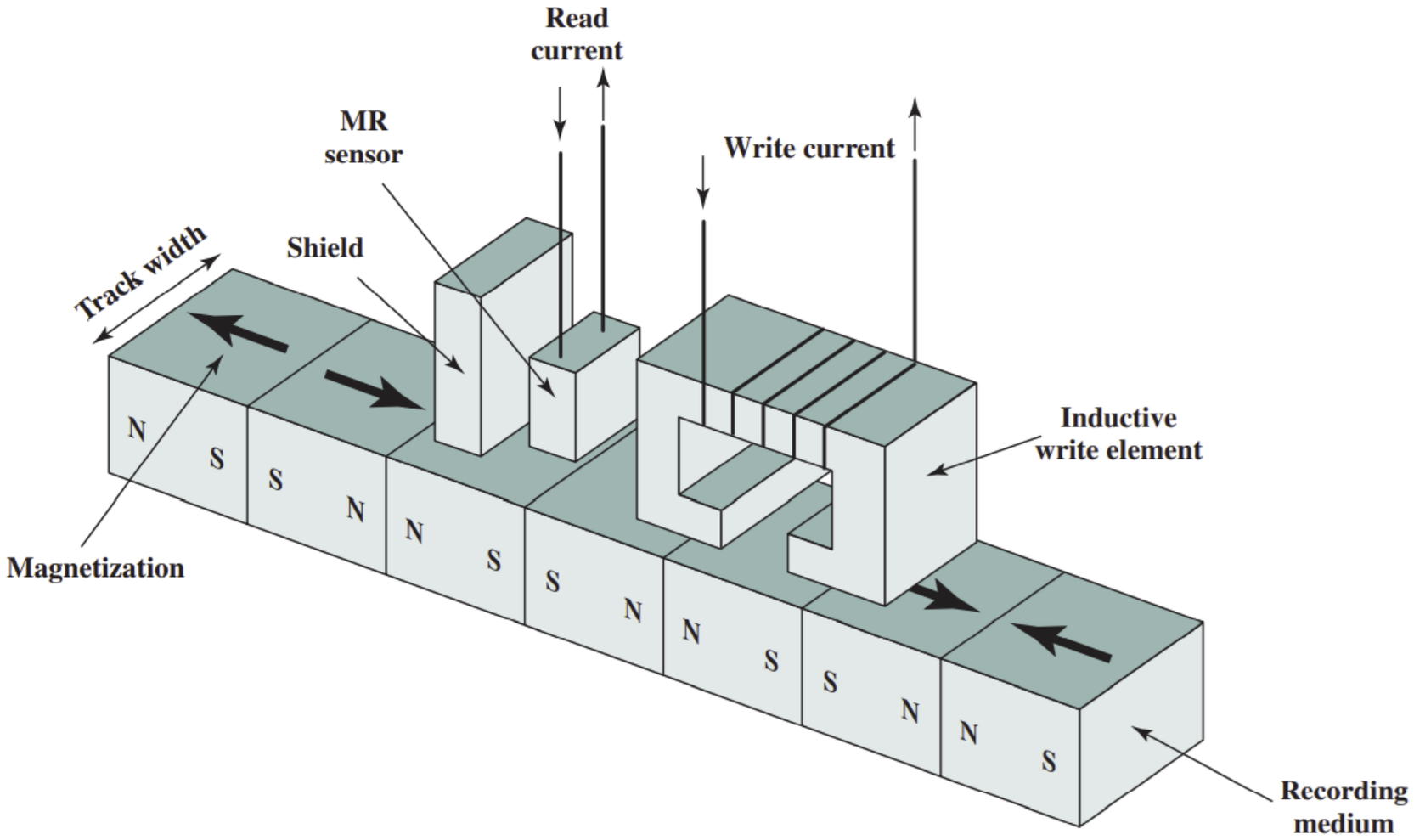
Read and Write Mechanisms

- 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
  - When surface of disk passes under head it produces a current of same polarity as one already recorded.
  - 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



Read and Write Mechanisms



Data Organization and Formatting

- 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
- May have more than one sector per block

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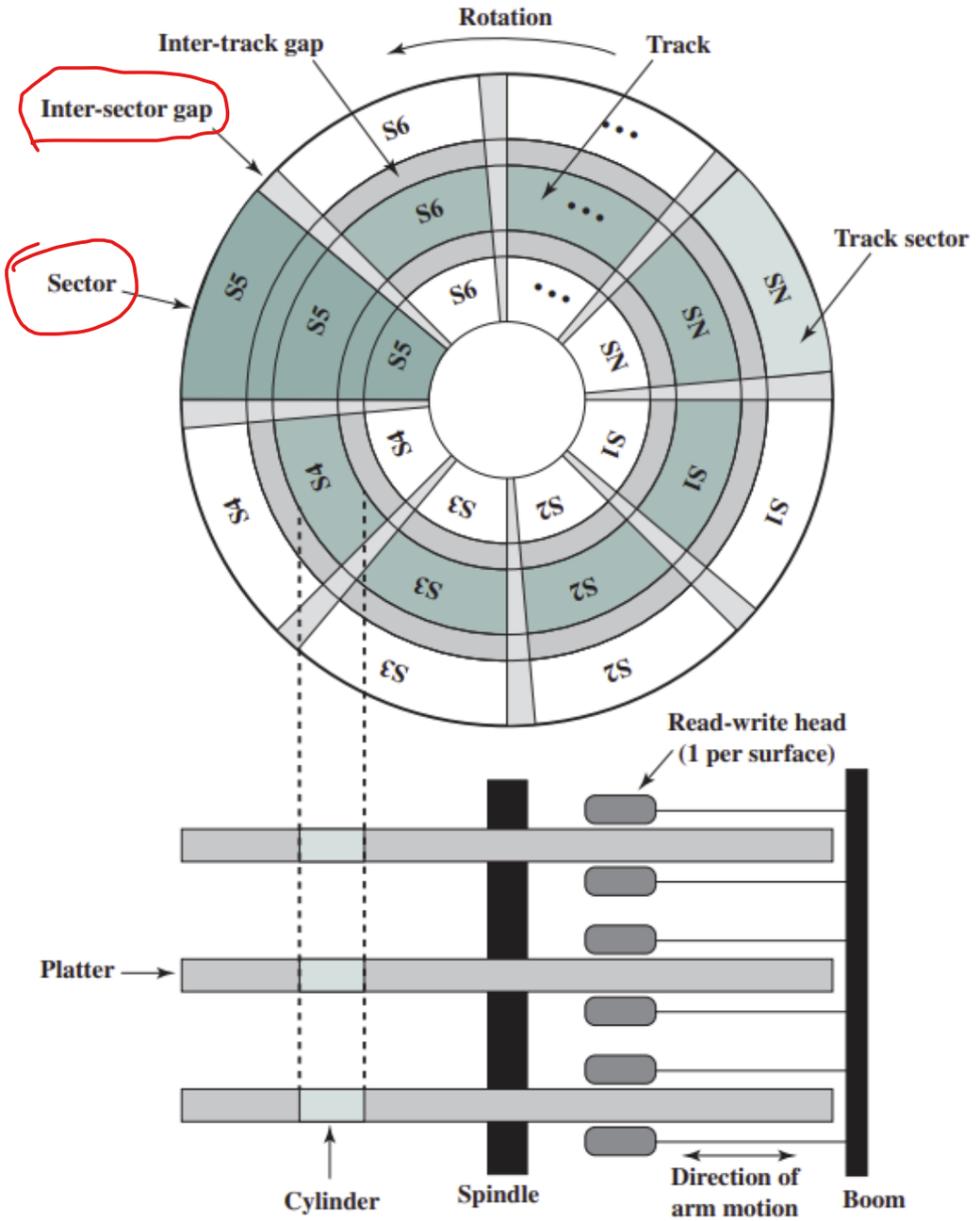
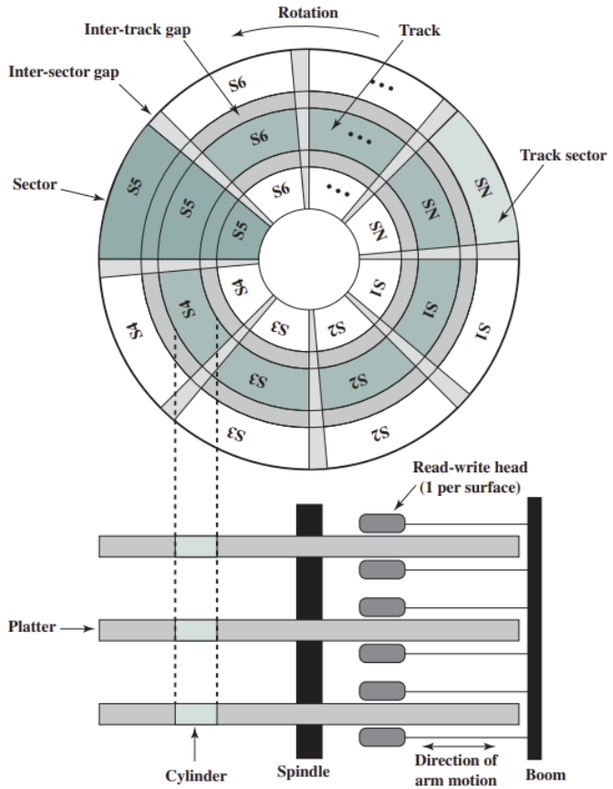
Disk Data Layout

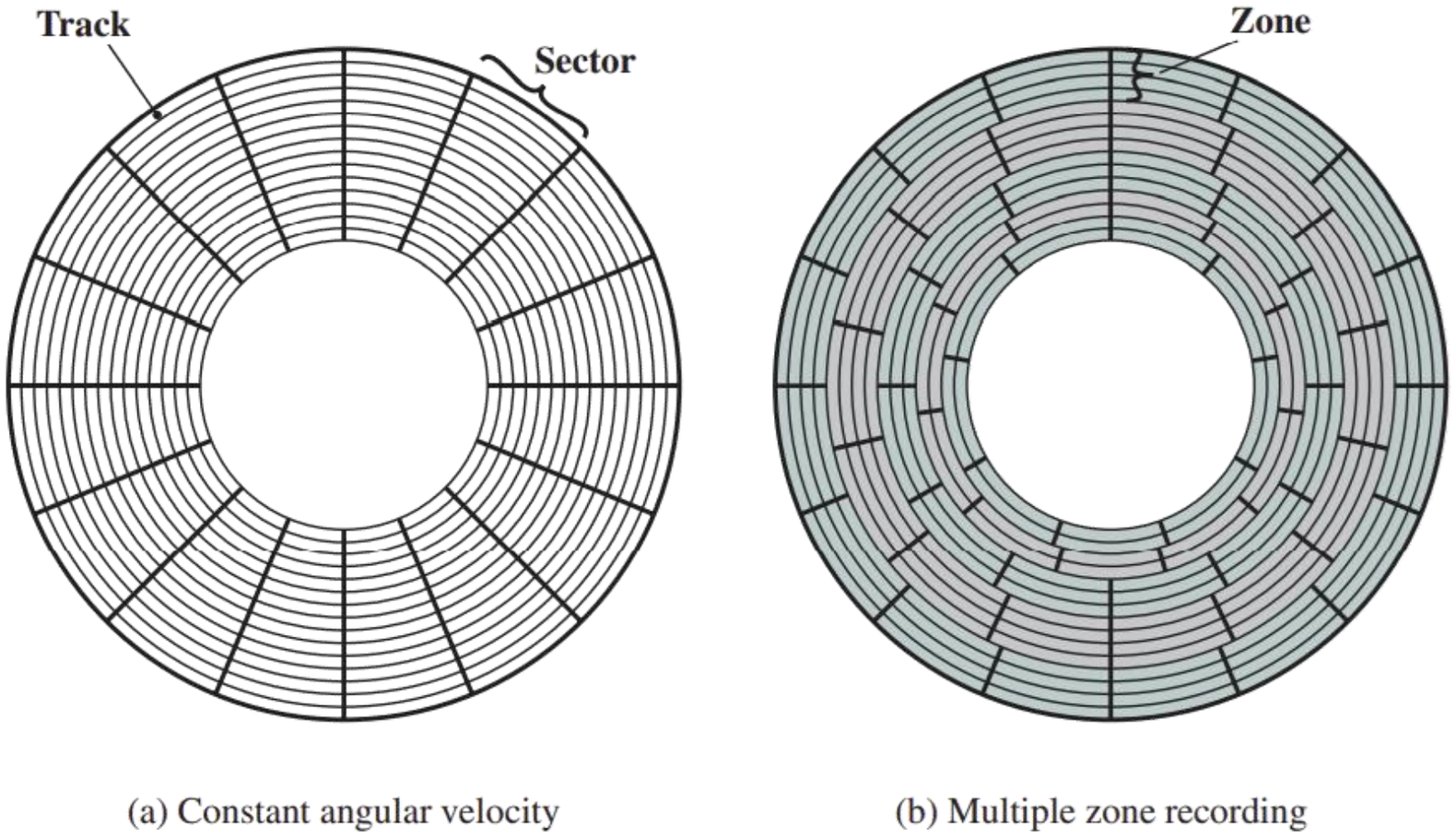


Disk Velocity

- Bit near center of rotating disk passes fixed point slower than bit on outside of disk
- Increase spacing between bits in different tracks
- 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



(a) Constant angular velocity

(b) Multiple zone recording

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Finding Sectors

Must be able to identify start of track and sector.

Format disk

—Additional information not available to user

—Marks tracks and sectors

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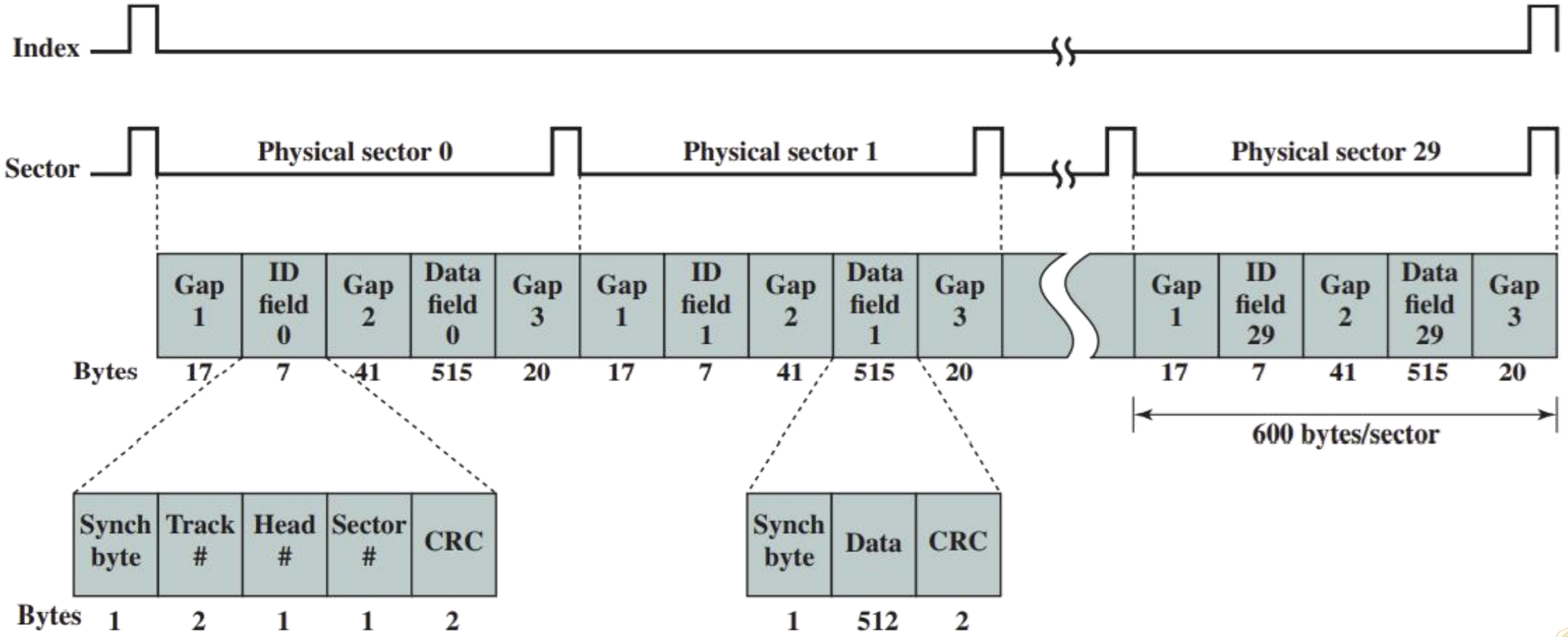
Winchester Disk Format Seagate ST506



Characteristics

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

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Fixed/Movable Head Disk

- **Fixed head**

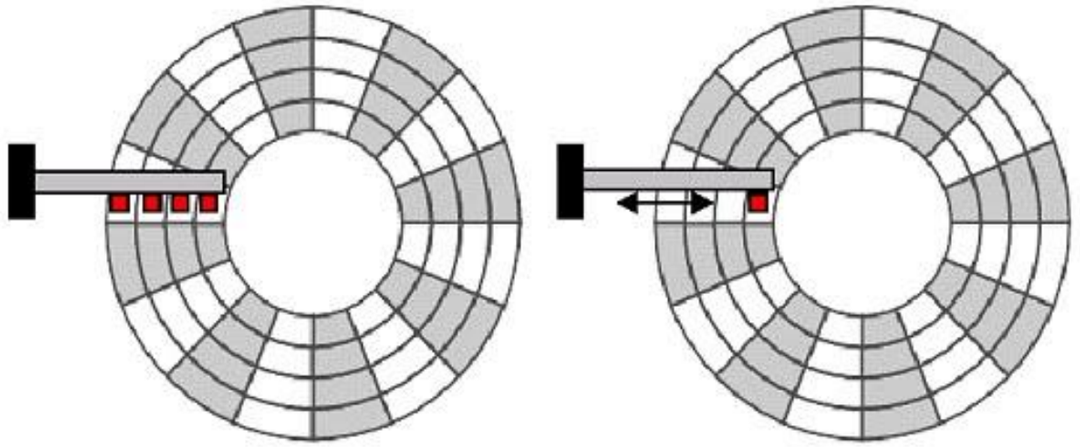
—One read write head per track

—Heads mounted on fixed ridged arm

- **Movable head**

—One read write head per side

—Mounted on a movable arm



(a) Fixed head (b) Movable head

Removable or Not

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

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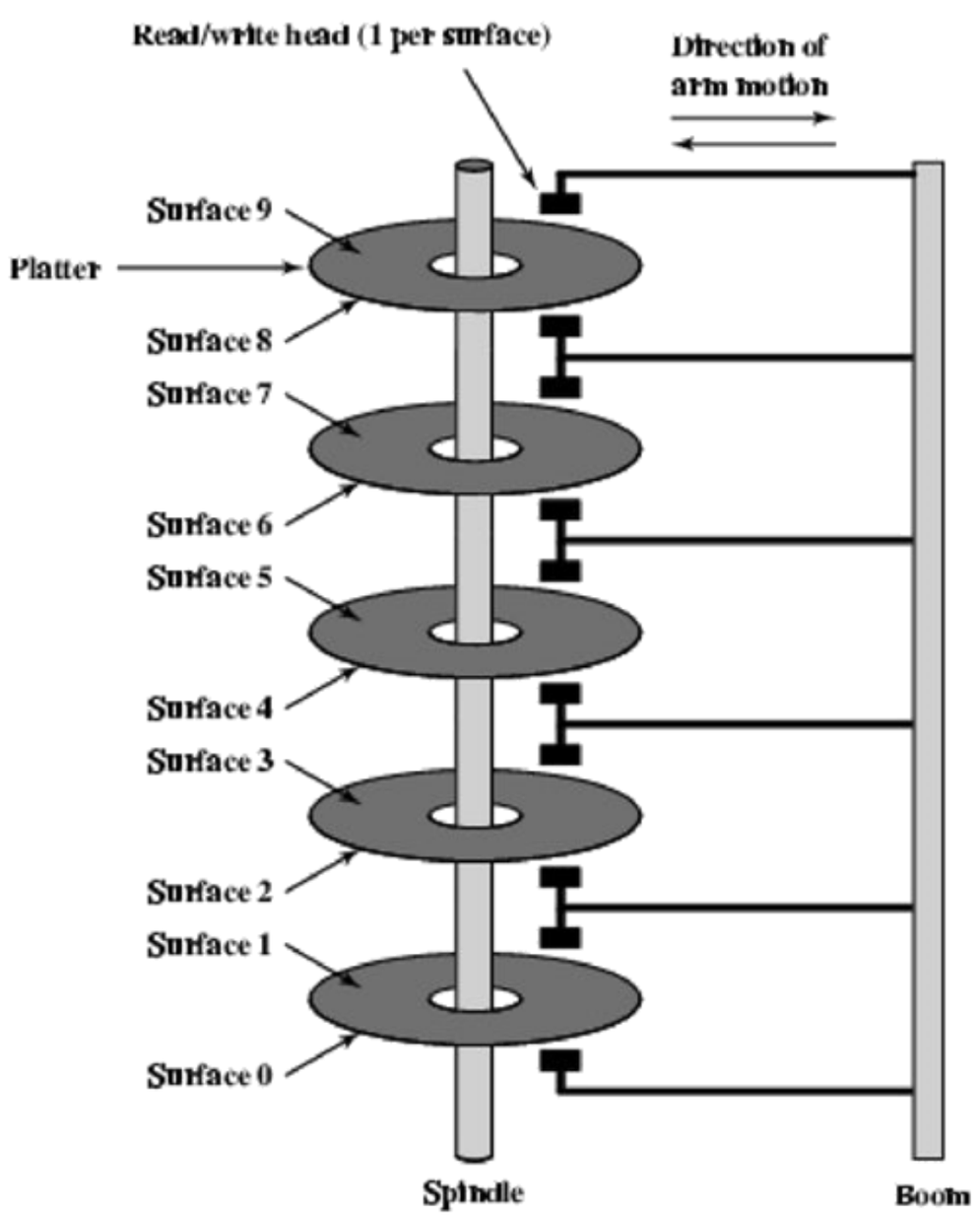
Multiple Platter

- 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)



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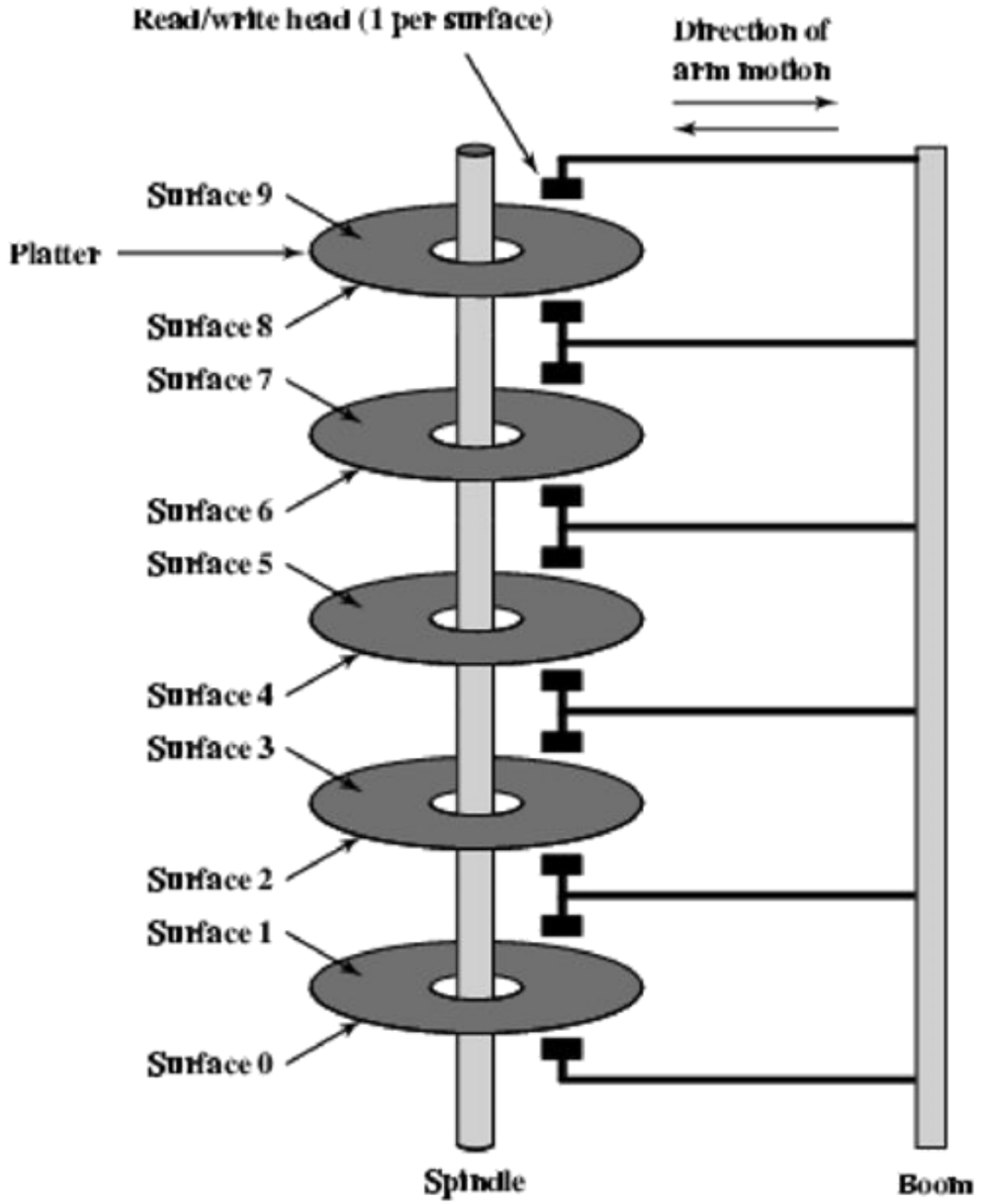

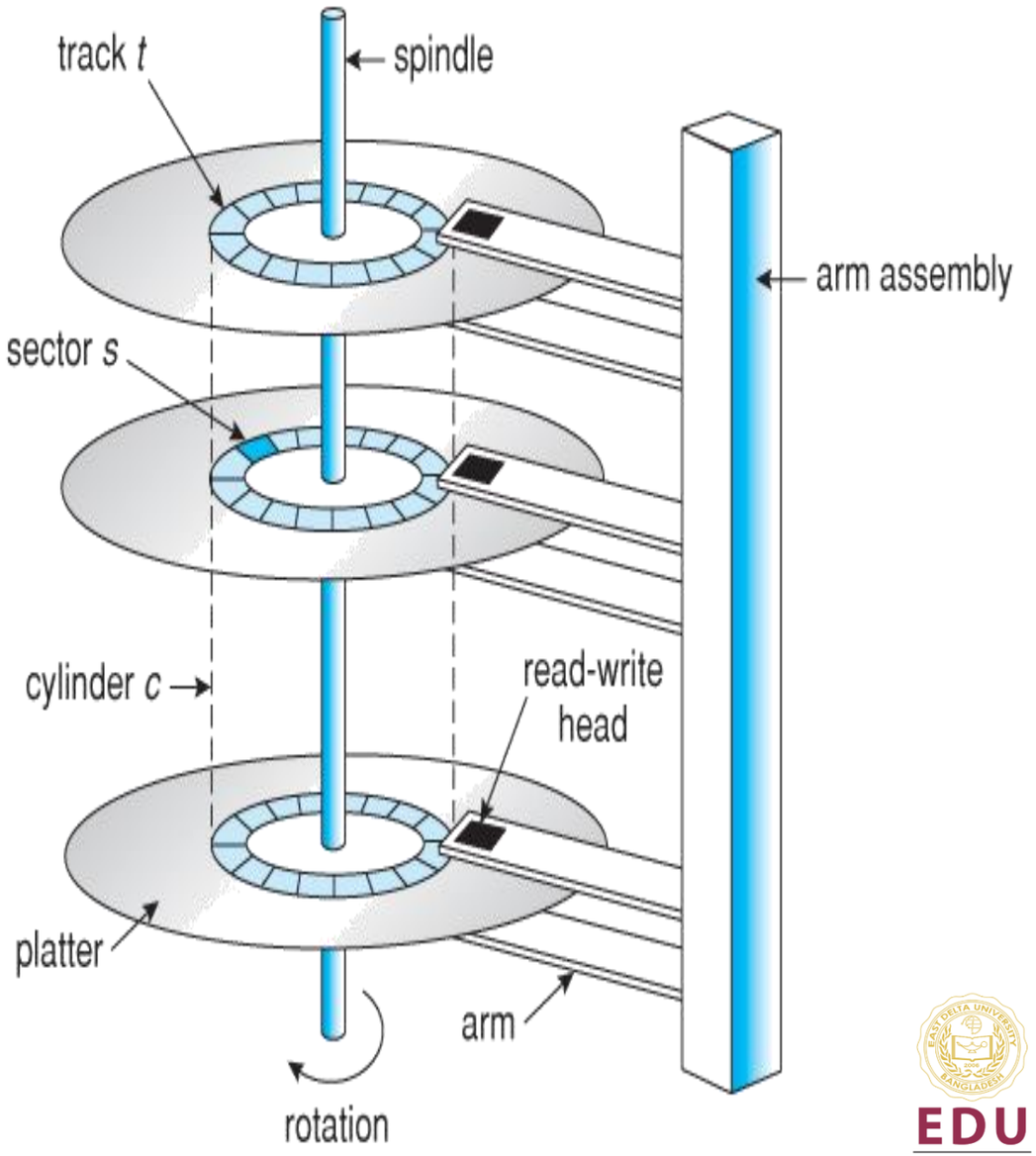

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Floppy Disk

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

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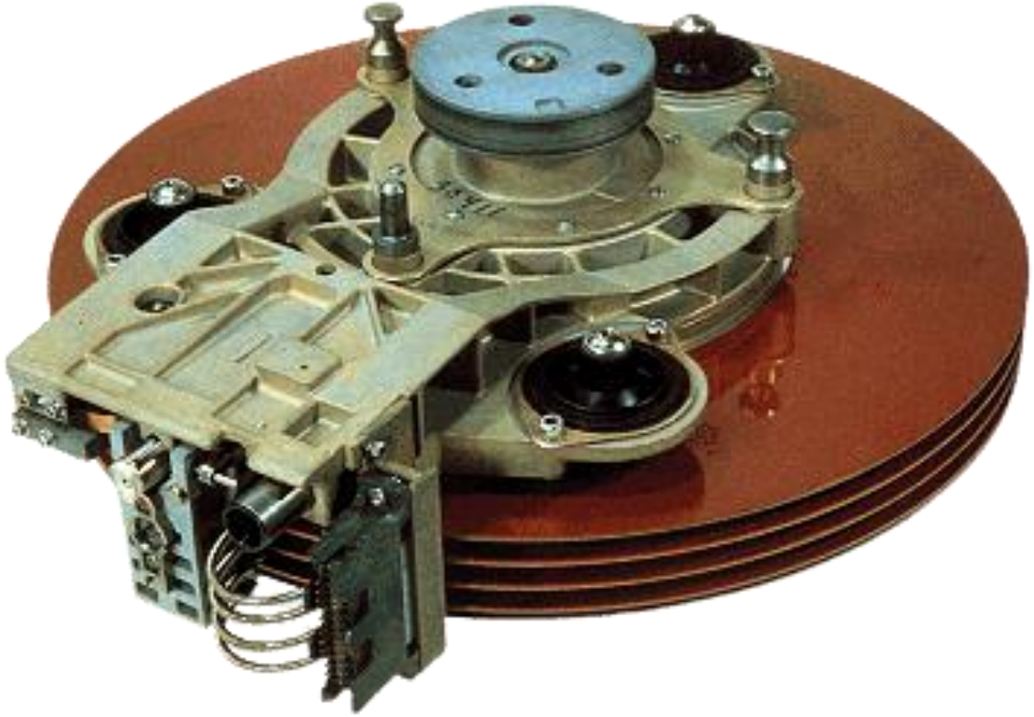
Winchester Hard Disk

- 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



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Winchester Hard Disk (2)

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

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Speed

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

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Recommended Watch

https://www.youtube.com/watch?v=oEORcCQ62nQ

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RAID

Copy or Duplicate

- Redundant Array of Independent Disks
- Redundant Array of Inexpensive Disks
- 6 levels in common use
- Not a hierarchy
- Set of physical disks viewed as single logical drive by O/S
- Data distributed across physical drives
- Can use redundant capacity to store parity information

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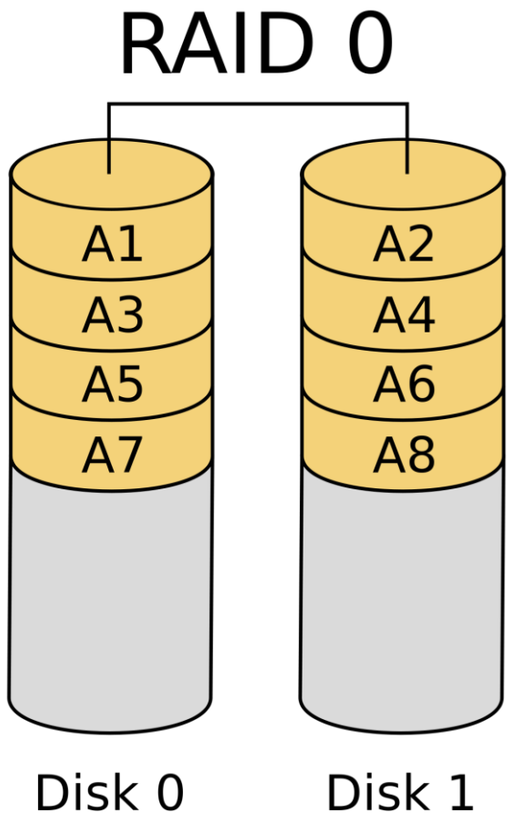
RAID 0

- No redundancy
- Data striped across all disks
- Increase speed
  - —Multiple data requests probably not on same disk
  - —Disks seek in parallel
  - —A set of data is likely to be striped across multiple disks



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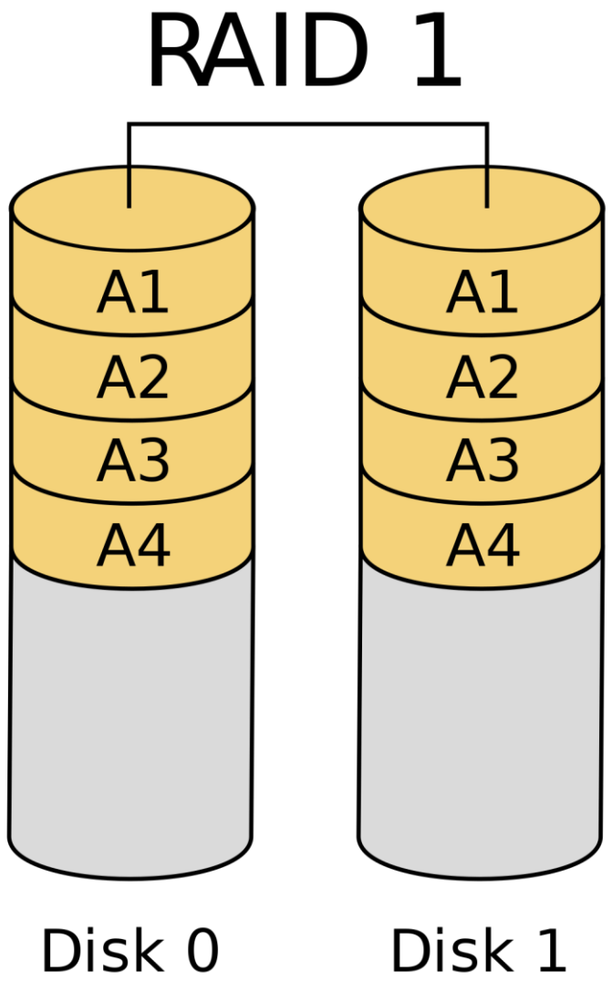
RAID 1

- Mirrored Disks
- Data is striped across disks
- 2 copies of each stripe on separate disks
- Read from either
- Write to both
- Recovery is simple
  - —Swap faulty disk & re-mirror
  - —No down time
- Expensive



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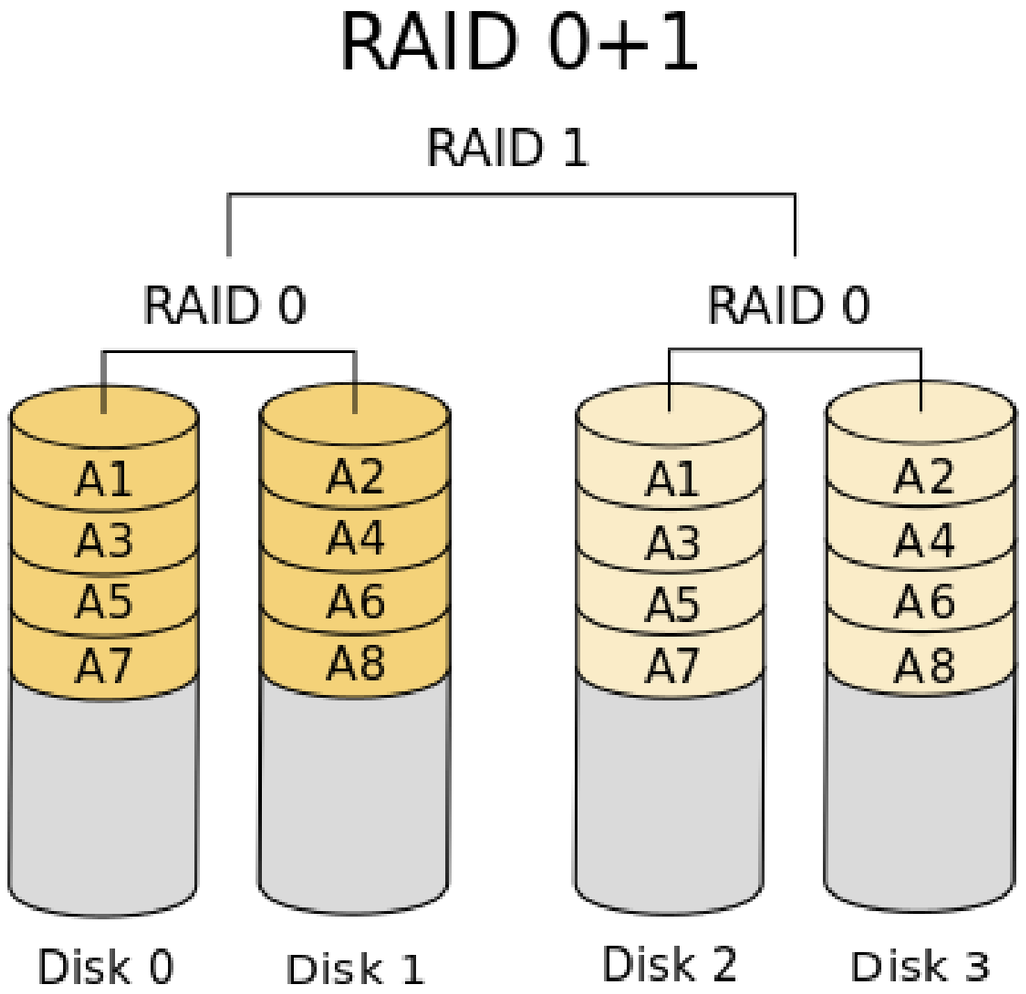
RAID 0+1



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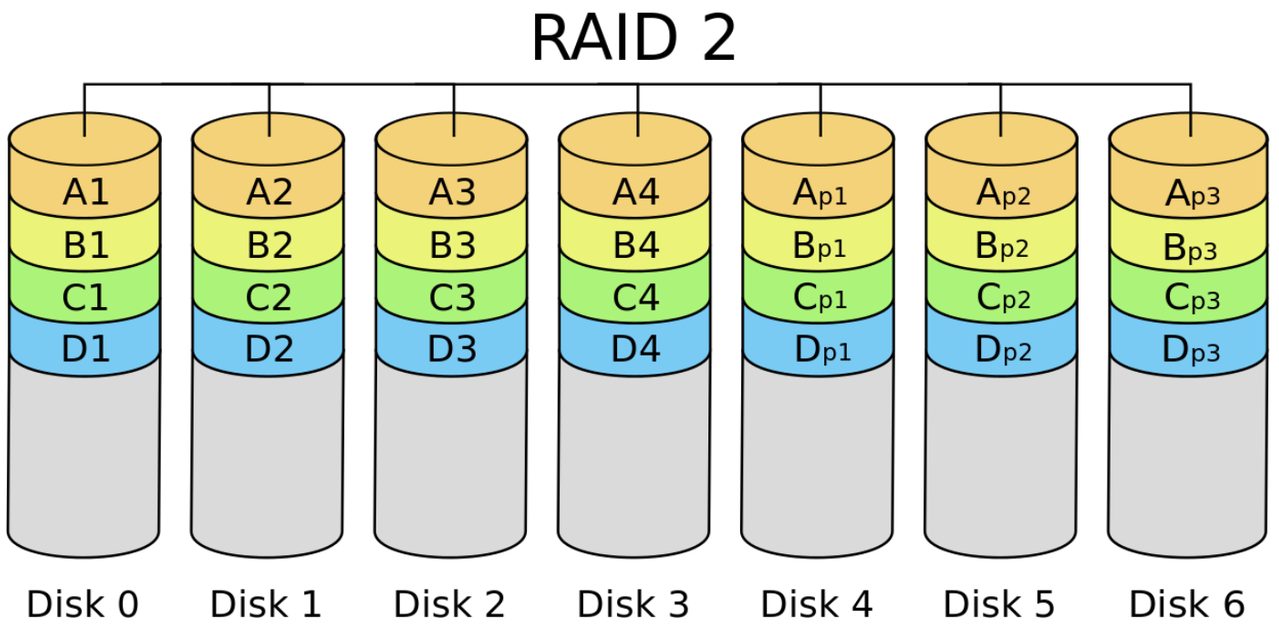
RAID 2

- Disks are synchronized
- Very small stripes - often single byte/word
- Error correction calculated across corresponding bits on disks
- Multiple parity disks store Hamming code error correction in corresponding positions
- Lots of redundancy
  - —Expensive
  - —Not used



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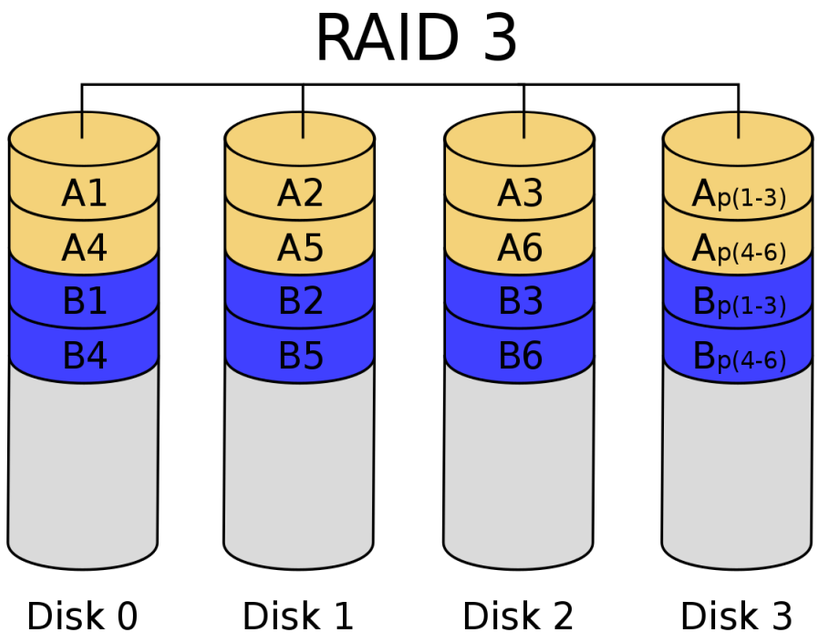
RAID 3

- Similar to RAID 2
- Only one redundant disk, no matter how large the array
- Simple parity bit for each set of corresponding bits
- Data on failed drive can be reconstructed from surviving data and parity info
- Very high transfer rates



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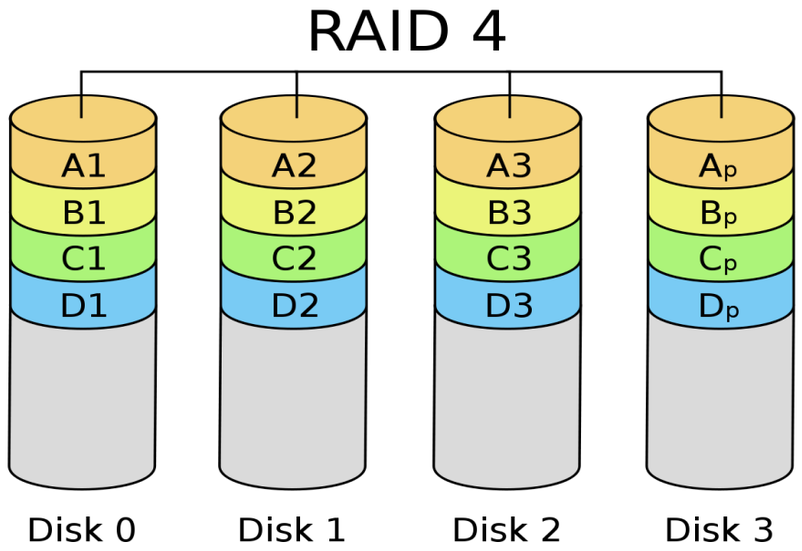
RAID 4

- Each disk operates independently
- Good for high I/O request rate
- Large stripes
- Bit by bit parity calculated across stripes on each disk
- Parity stored on parity disk



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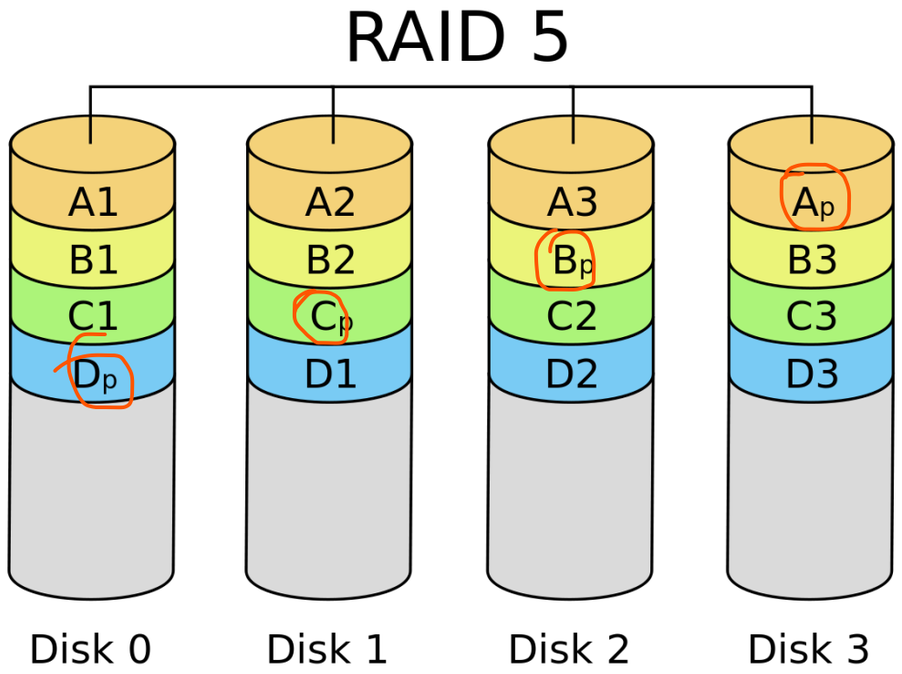
RAID 5

- Like RAID 4
- Parity striped across all disks
- Round robin allocation for parity stripe
- Avoids RAID 4 bottleneck at parity disk
- Commonly used in network servers

- N.B. DOES NOT MEAN 5 DISKS!!!!!



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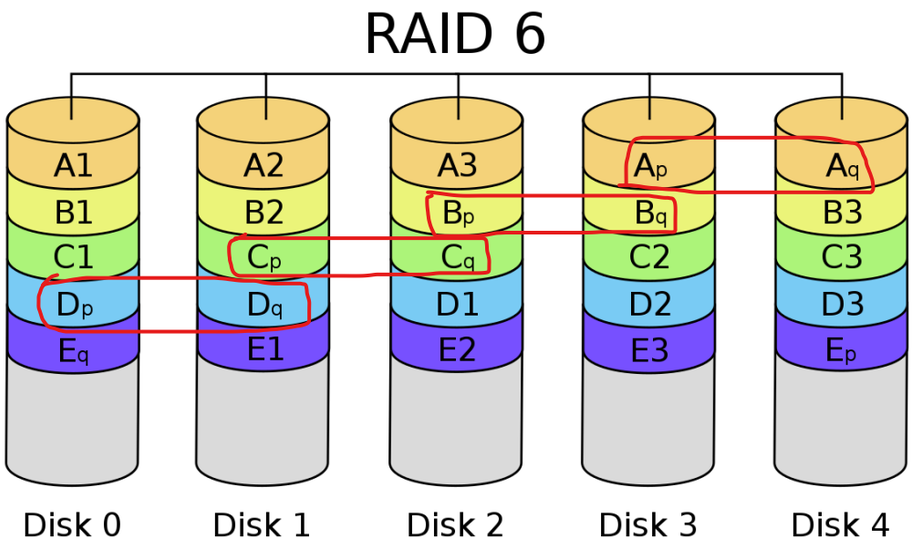
RAID 6

- Two parity calculations
- Stored in separate blocks on different disks
- User requirement of N disks needs N+2
- High data availability
  - —Three disks need to fail for data loss
  - —Significant write penalty



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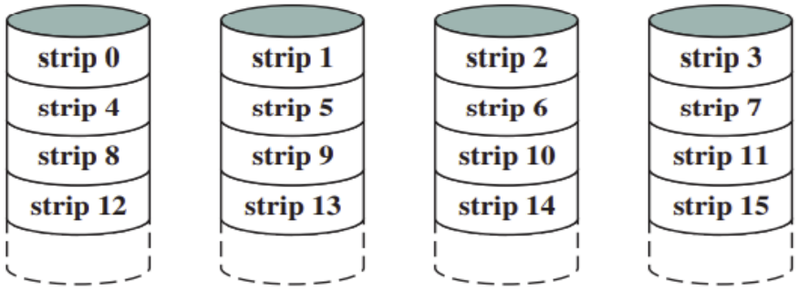
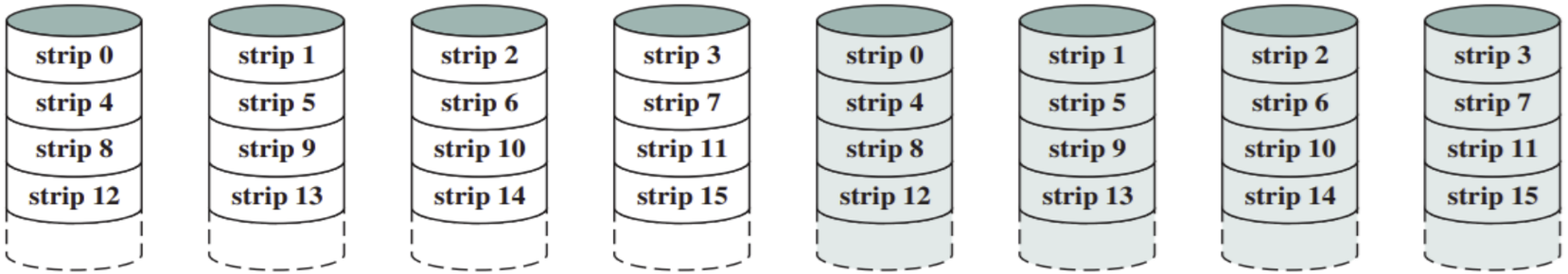
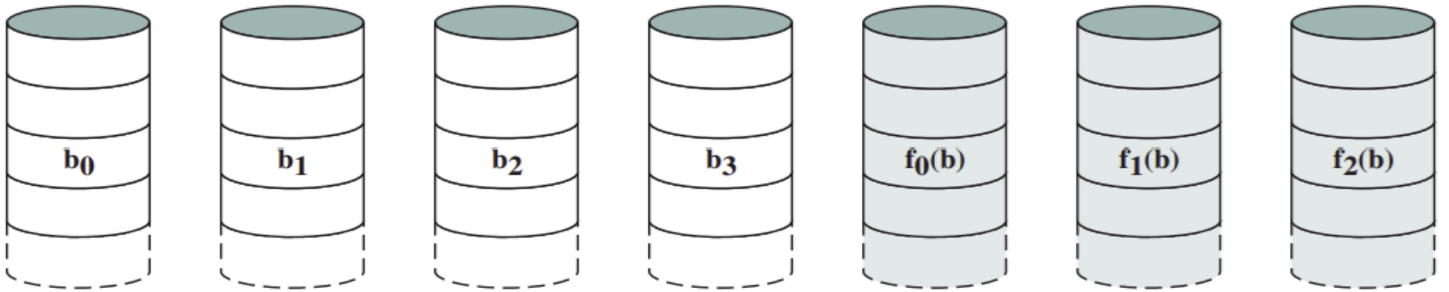
RAID 0, 1, 2



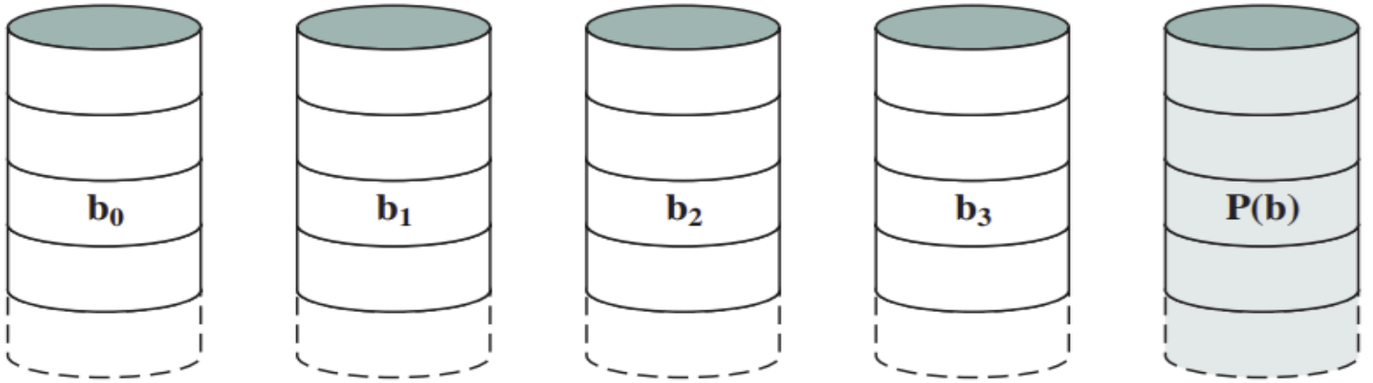
(a) RAID 0 (Nonredundant)



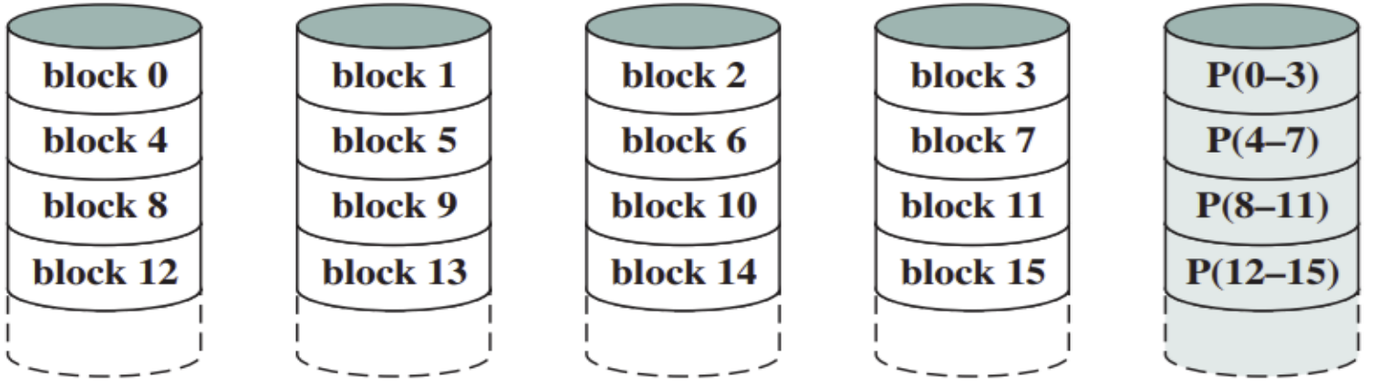
(b) RAID 1 (Mirrored)



RAID 3 & 4



(d) RAID 3 (Bit-interleaved parity)



(e) RAID 4 (Block-level parity)

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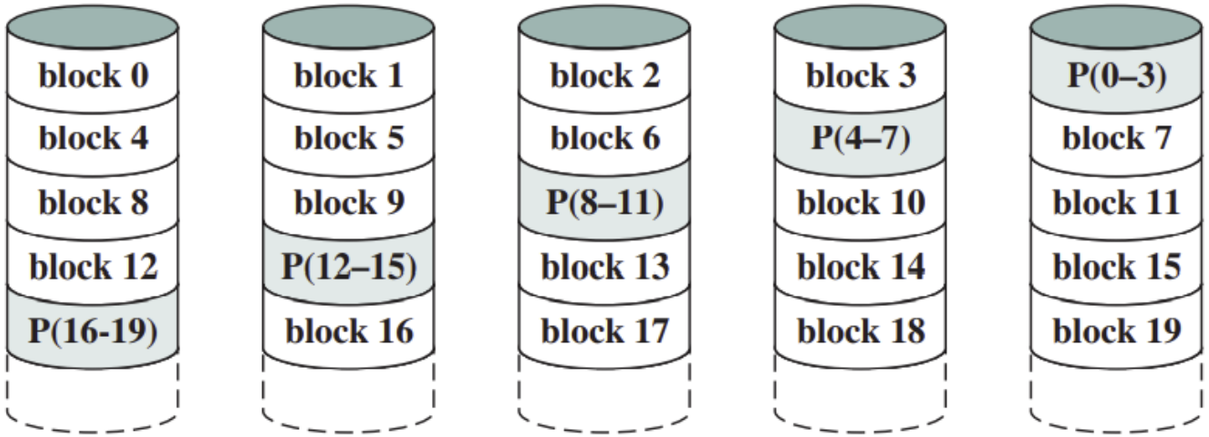
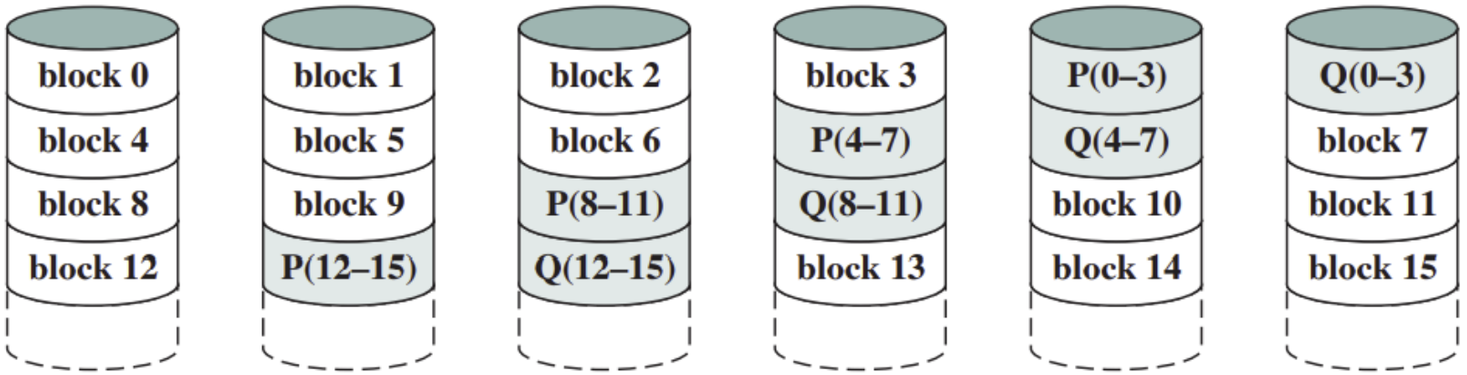
RAID 5 & 6



(f) RAID 5 (Block-level distributed parity)



(g) RAID 6 (Dual redundancy)

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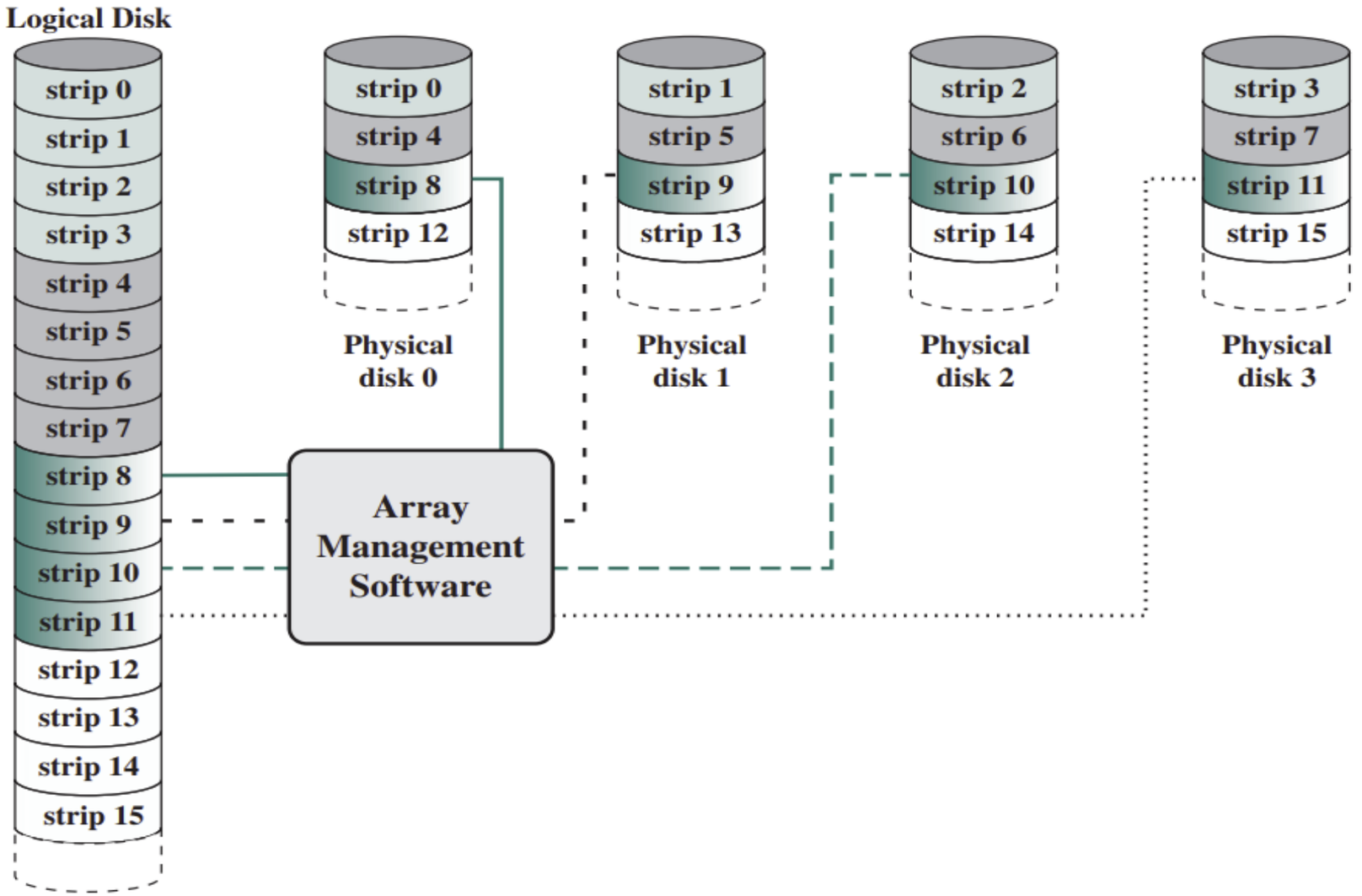
Data Mapping For RAID 0



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Optical Storage CD-ROM

- Originally for audio
- 650Mbytes giving over 70 minutes audio
- Polycarbonate coated with highly reflective coat, usually aluminum
- Data stored as pits
- Read by reflecting laser
- Constant packing density
- Constant linear velocity

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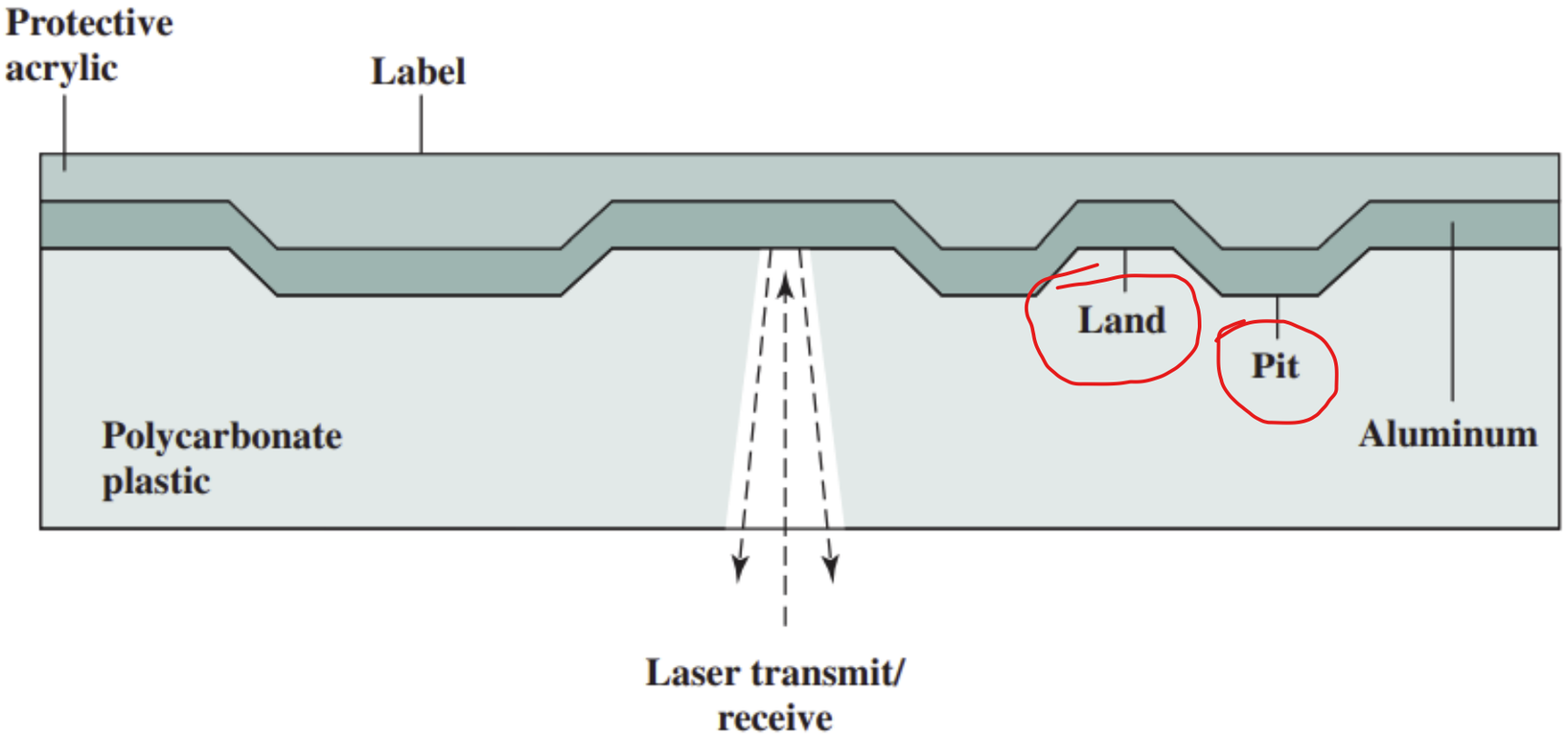
CD Operation



CD-ROM Drive Speeds

- Audio is single speed
  - —Constant linier velocity
  - —1.2 ms^{-1}
  - —Track (spiral) is 5.27km long
  - —Gives 4391 seconds = 73.2 minutes
- Other speeds are quoted as multiples
- e.g. 24x
- Quoted figure is maximum drive can achieve

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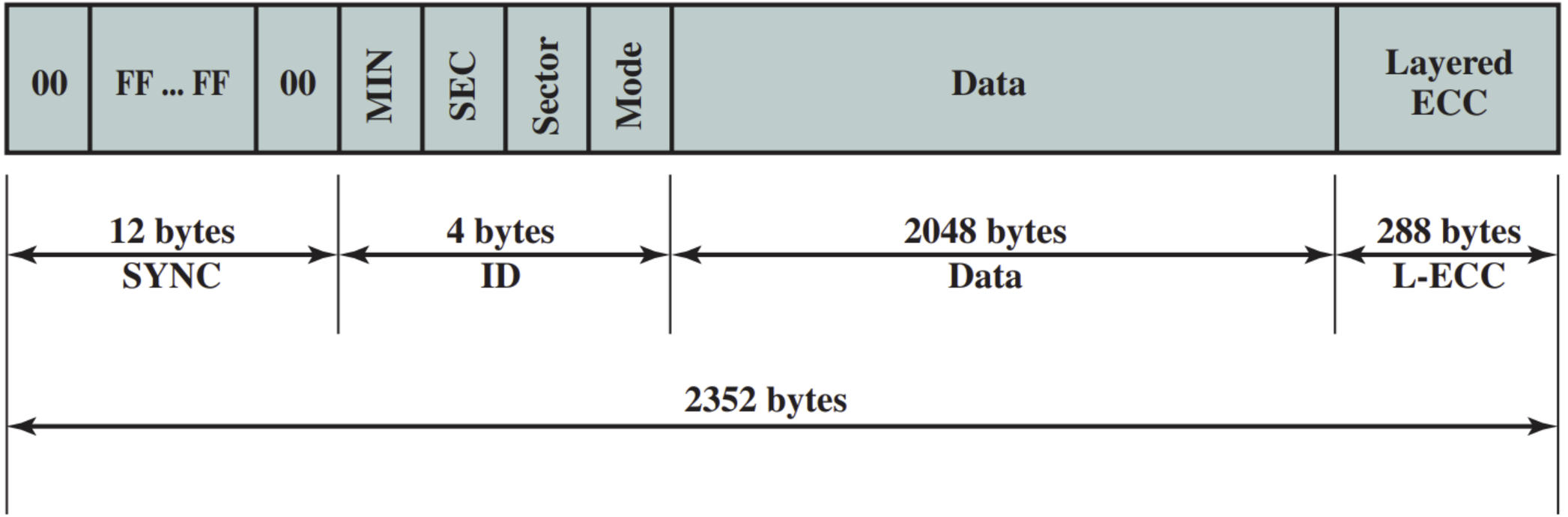
CD-ROM Format



- Mode 0=blank data field
- Mode 1=2048 byte data+error correction
- Mode 2=2336 byte data

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Random Access on CD-ROM

- Random Access on CD-ROM
- Difficult
- Move head to rough position
- Set correct speed
- Read address
- Adjust to required location
- (Yawn!)

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CD-ROM for & Against

- Large capacity (?)
- Easy to mass produce
- Removable
- Robust

- Expensive for small runs
- Slow
- Read only

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Other Optical Storage

- CD-Recordable (CD-R)
  - —WORM (Write Once Read Many)
  - —Now affordable
  - —Compatible with CD-ROM drives

- CD-RW
  - —Erasable
  - —Getting cheaper
  - —Mostly CD-ROM drive compatible
  - —Phase change
  - — Material has two different reflectivity's in different phase states

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DVD - What’s in a name?

- Digital Video Disk—Used to indicate a player for movies
- Only plays video disks
- Digital Versatile Disk—Used to indicate a computer drive
- Will read computer disks and play video disks

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DVD - Technology

- Multi-layer
- Very high capacity (4.7G per layer)
- Full length movie on single disk — Using MPEG compression
- Finally standardized
- Movies carry regional coding
- Players only play correct region films
- Can be “fixed”

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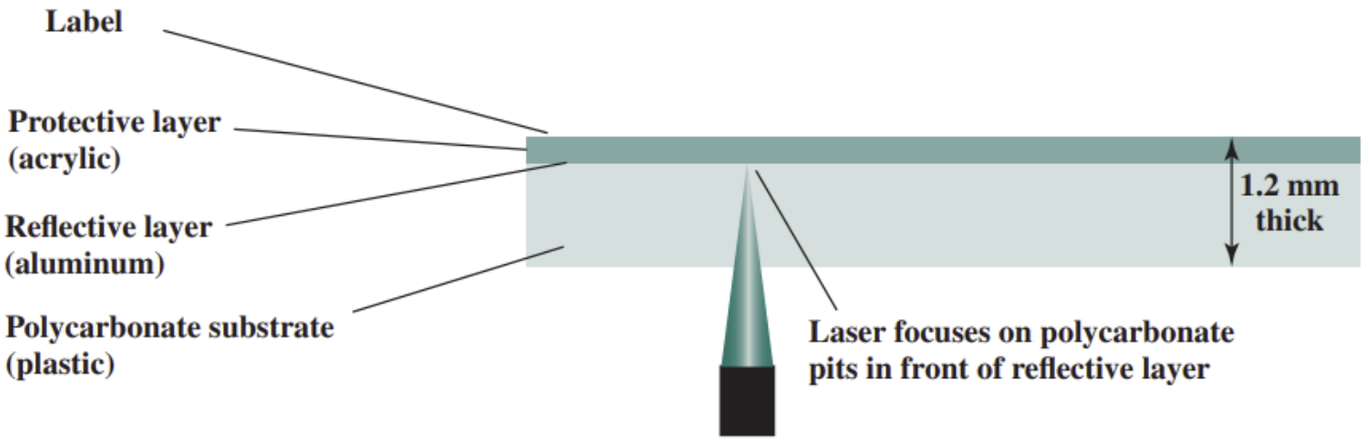
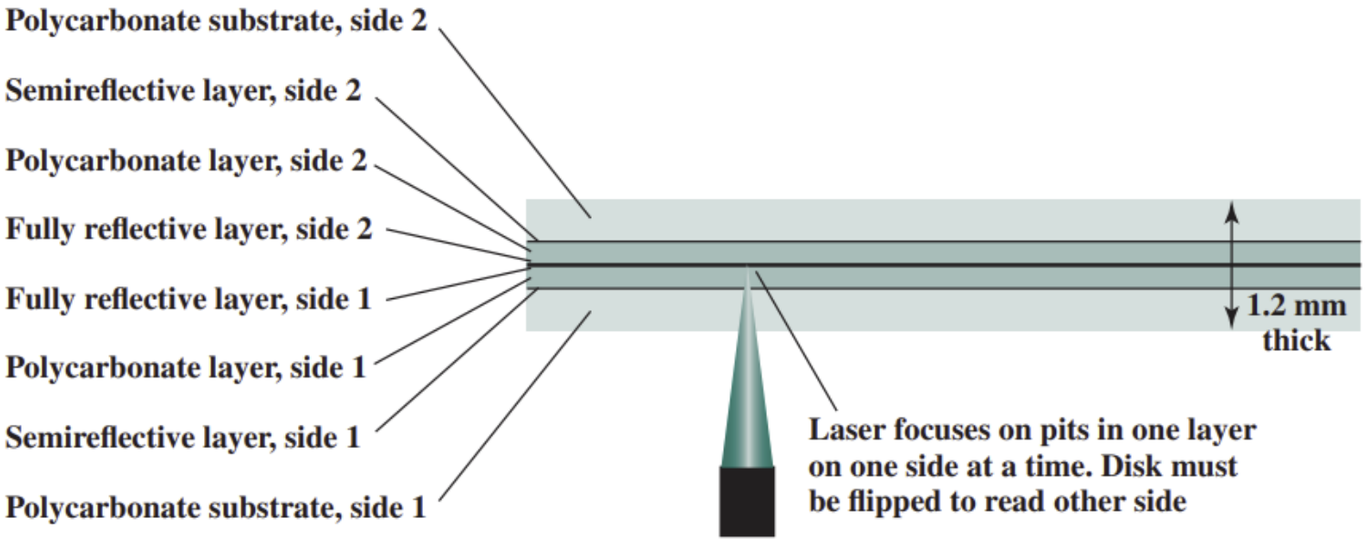
CD and DVD



(a) CD-ROM–Capacity 682 MB



(b) DVD-ROM, double-sided, dual-layer–Capacity 17 GB

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High Definition Optical Disks

- Designed for high definition videos
- Much higher capacity than DVD—Shorter wavelength laser
- Blue-violet range—Smaller pits
- HD-DVD—15GB single side single layer
- Blue-ray—Data layer closer to laser
- Tighter focus, less distortion, smaller pits
  —25GB on single layer
  —Available read only (BD-ROM), Recordable once (BR-R) and re-recordable (BR-RE)

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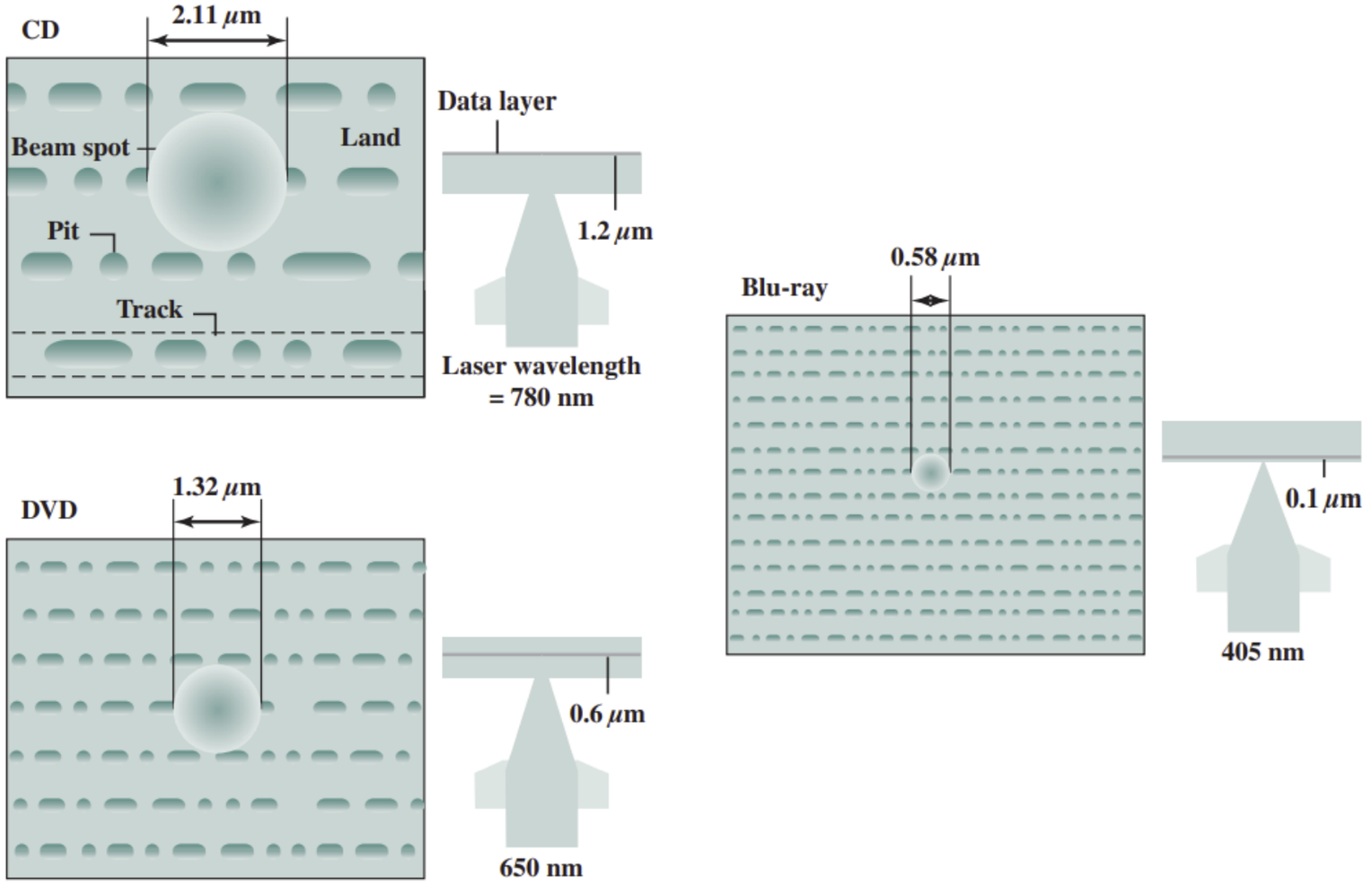
Optical Memory Characteristics



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Magnetic Tape

- Serial access
- Slow
- Very cheap
- Backup and archive
- Linear Tape-Open (LTO) Tape Drives
  - —Developed late 1990s
  - —Open source alternative to proprietary tape systems

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Linear Tape-Open (LTO) Tape Drives

	LTO-1	LTO-2	LTO-3	LTO-4	LTO-5	LTO-6	LTO-7	LTO-8
Release date	2000	2003	2005	2007	2010	2012	TBA	TBA
Compressed capacity	200 GB	400 GB	800 GB	1600 GB	3.2 TB	8 TB	16 TB	32 TB
Compressed transfer rate	40 MB/s	80 MB/s	160 MB/s	240 MB/s	280 MB/s	400 MB/s	788 MB/s	1.18 GB/s
Linear density (bits/mm)	4880	7398	9638	13,250	15,142	15,143		
Tape tracks	384	512	704	896	1280	2176		
Tape length (m)	609	609	680	820	846	846		
Tape width (cm)	1.27	1.27	1.27	1.27	1.27	1.27		
Write elements	8	8	16	16	16	16		
WORM?	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Encryption Capable?	No	No	No	Yes	Yes	Yes	Yes	Yes
Partitioning?	No	No	No	No	Yes	Yes	Yes	Yes

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Lets Watch More..

- https://www.youtube.com/watch?v=p3q5zWCw8J4
- https://www.youtube.com/watch?v=p3q5zWCw8J4

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