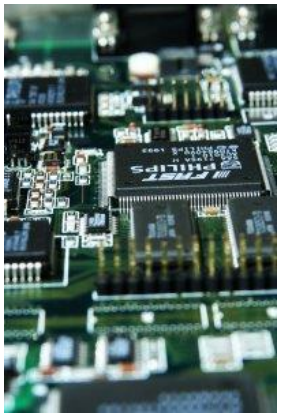
CSE 321b

Computer Organization (2)

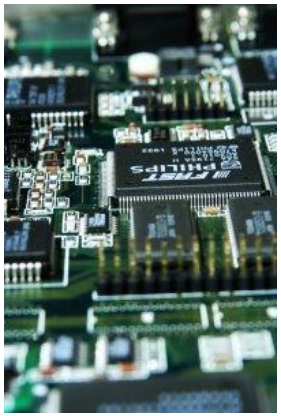
تنظيم الحاسب (2)



3rd year, Computer Engineering

Winter 2016

Lecture #3



Dr. Hazem Ibrahim Shehata

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Credits to Dr. Ahmed Abdul-Monem Ahmed for the slides

Adminstrivia

- Schedule:
  - Lectures: Monday 9:00am – 11:30am
  - Tutorials: Sunday 10:00am – 11:30am
  - Office hour: TBA
- Assignment #1:
  - To be released later on this week.
  - Due by the end of next week.
  - Work in groups of two.
  - Submit one report per group.

Website: http://www.bit.do/hshehata-courses-zu-cse321b
Office hours: TBA

Chapter 6. External Memory

Types of External Memory

- Magnetic Disk
  - —Magnetic Read and Write Mechanisms
  - —Data Organization and Formatting
  - —Physical Characteristics
  - —Disk Performance Parameters

- Redundant Array of Independent Disks (RAID)
- Solid-State Drive (SSD)
- Optical Disk
- Magnetic Tape

Magnetic Disk

- Foundation of external memory on computers.
- Disk substrate: circular platter constructed of nonmagnetic material.
- Substrate coated with magnetisable material (iron oxide or cobalt oxide).
- Substrate used to be aluminium or aluminium alloy. Now glass ➔ ...
  - Less **surface defects** ➔ less read/write errors.
  - Better **uniformity** of magnetic film ➔ more reliability.
  - Better **stiffness** to reduce disk dynamics.
  - Better **shock/damage** resistance.
  - Ability to support lower **fly heights** (see later).

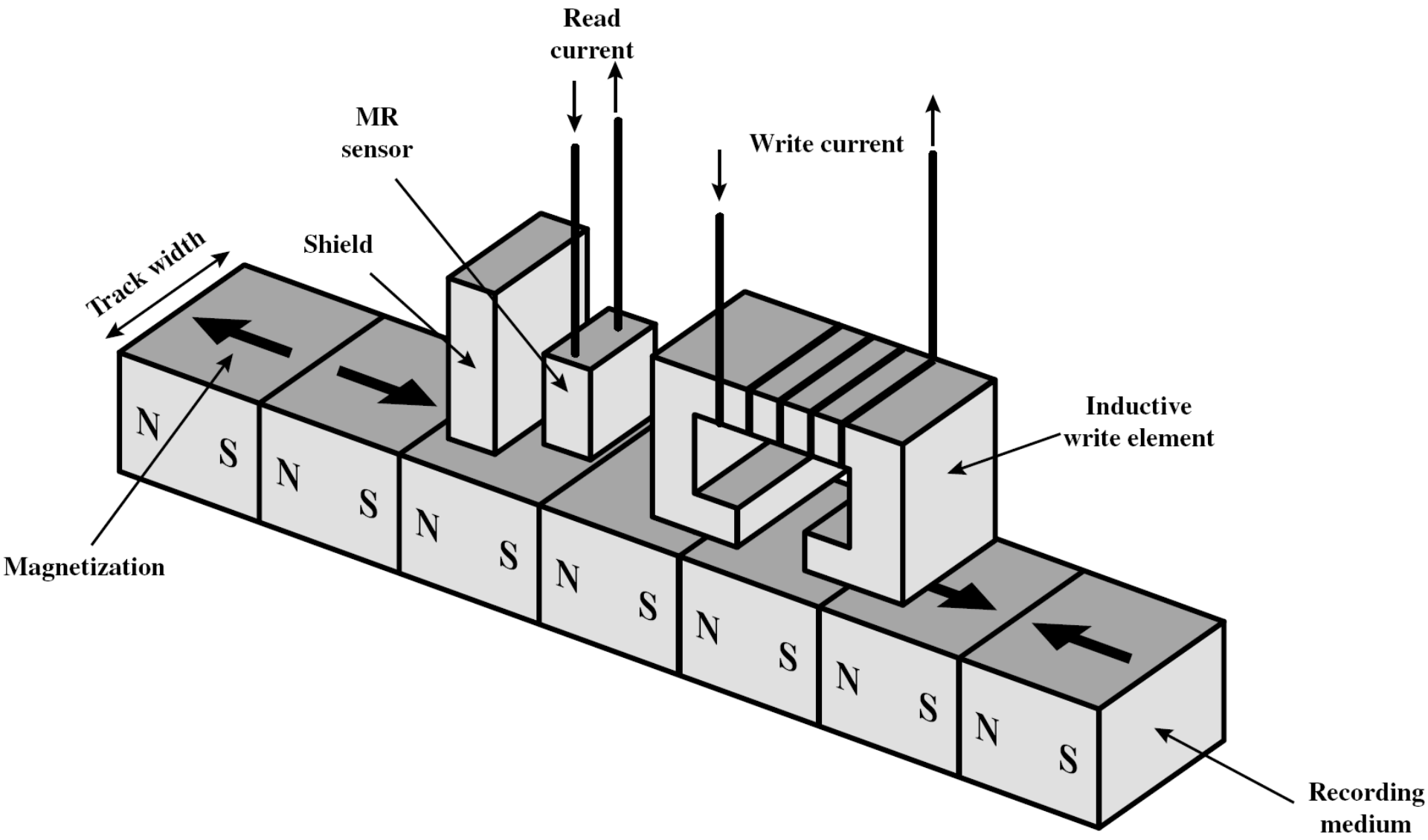
Read and Write Mechanisms (1)

- **Head**: Small device (conductive coil) that can read from or write to a portion of the platter rotating under it.
  - —May be single read/write head or separate ones.
  - —During read/write, head is stationary, platter rotates.
- **Write Operation**
  - —FACT: Current passing through coil produces a magnetic field whose direction depends on current direction.
  - —Pulses sent to head.
  - —Magnetic pattern recorded on surface below.

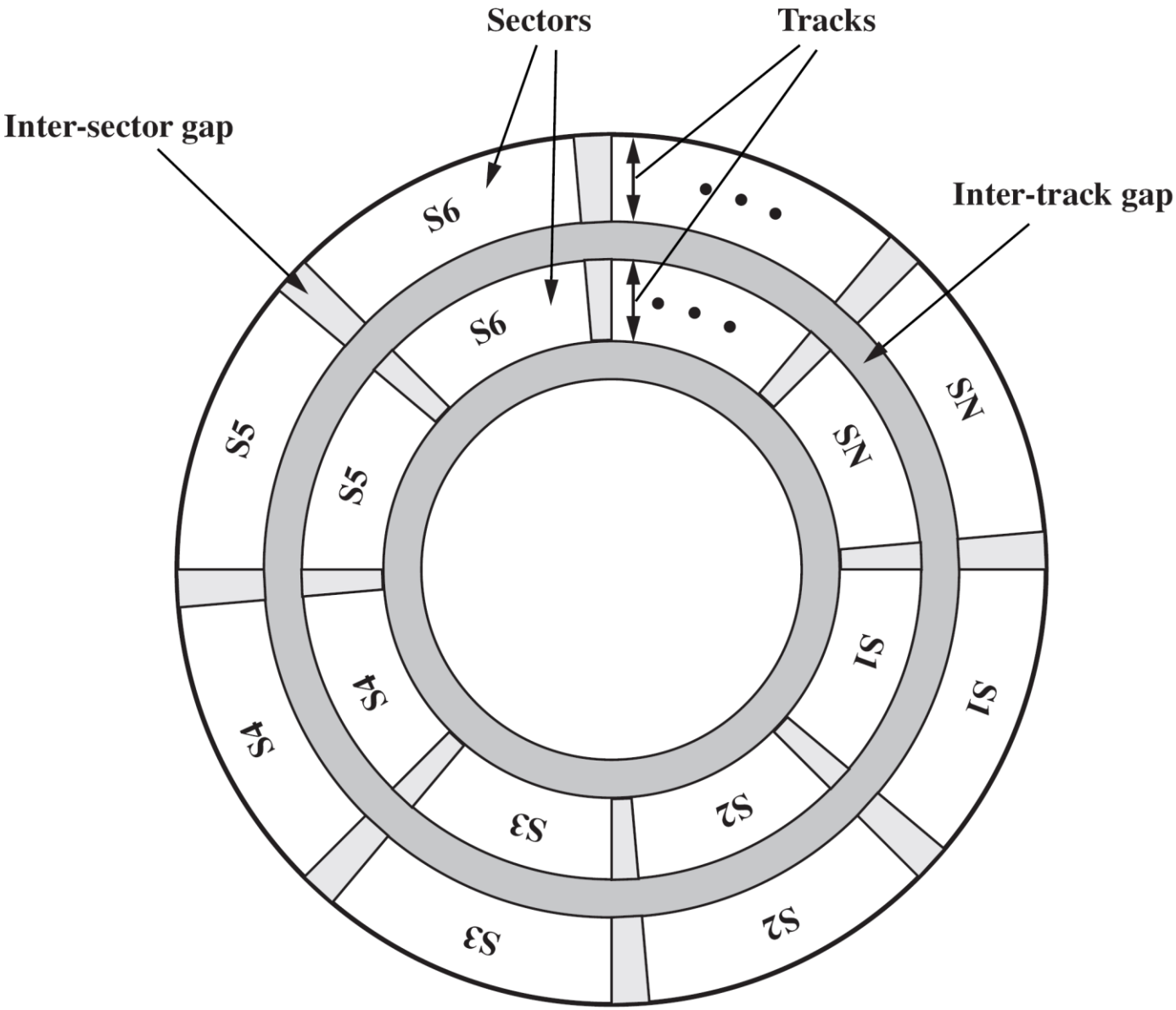
Read and Write Mechanisms (2)

- **Read Operation**
  - —Traditional - floppy and old disks
    - FACT: Magnetic field moving relative to a coil produces current in the coil.
    - Coil is the same for read and write
    - One read/write head.
  - —Contemporary
    - Separate read head, close to write head.
    - Partially shielded magnetoresistive (MR) sensor.
    - Electrical resistance depends on direction of magnetic field.
    - Current passing thru MR and resistance is read as voltage.
    - Much greater storage densities and higher operating speeds could be achieved.

Inductive Write - MR Read Head



Disk Data Layout



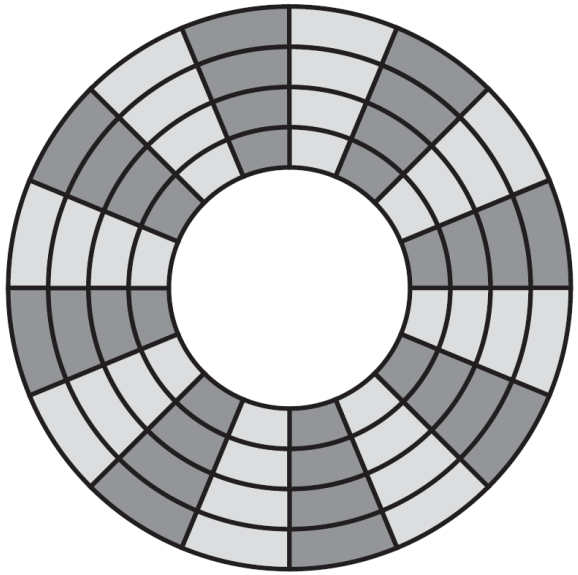
Data Organization and Formatting

- Tracks: concentric rings
  - —Typically thousands per surface
  - —Track's width = head's width.
  - —Inter-track gaps between adjacent tracks ➔ prevent errors due to misalignment of the head or interference.
- Sectors: tracks are divided into sectors.
  - —Typically hundreds per track.
  - —Fixed (512 bytes) or variable length.
  - —Inter-sector gaps ➔ relax precision requirements
  - —Usually data are read from or written to disks in blocks (of sectors).

Disk Velocity → Disk Layout

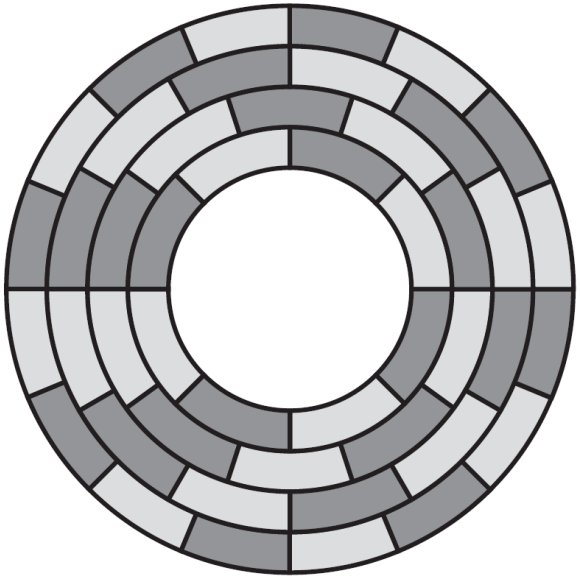
- Problem: bits on inner tracks pass under head slower than bits on outer tracks → How can we have a constant read/write rate?!
- Solution: increase spacing between bits stored on outer tracks and rotate disk at a fixed speed.
  - This technique is know as **Constant Angular Velocity (CAV).**

Constant Angular Velocity (CAV)



- Disk rotates at constant speed
  - —Constant angular velocity
- All tracks have same capacity
  - —Constant bits/track
  - —Assuming constant bits/sector
    - Constant sectors/track
    - Pie-shaped sectors
- Outer tracks have lower density
  - —Variable bits/meter
- **Pros:** Simple to locate sectors ➔ Move head to a given track and wait for a given sector.
- **Cons:** Waste of space on outer tracks

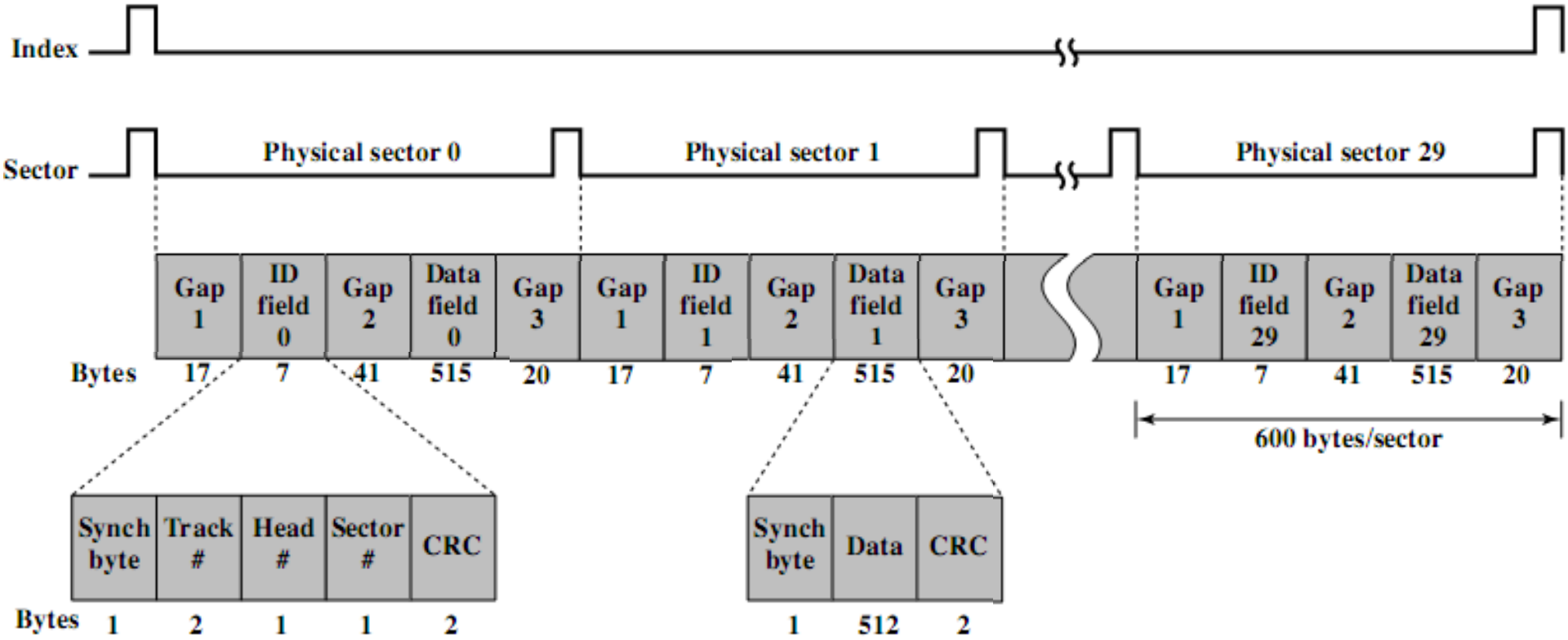
Multiple Zone Recording (or Zone Bit Recording)



- Tracks are grouped into zones
- Within a zone, tracks have same capacity
  - —Constant sectors/track in each zone
- Tracks in outer zones have higher capacities
  - —Sectors/track increase in outer zones
- **Pros:** Higher capacity for outer tracks ➔ Greater overall storage capacities.
- **Cons:** Harder to locate sectors ➔ more complex circuitry.

Finding Sectors

- Must be able to identify start of track and sector.
- Disk Format
  - Extra control data recorded on disk to mark tracks and sectors.
  - Used only by the disk drives, not accessible to the user.
- Seagate ST506 format



Physical Characteristics

1. Single or double sided.
2. Removable or not (fixed).
3. Single or multiple platter.
4. Fixed or movable head (w.r.t. radial direction).
5. Head mechanism
   - —Contact (Floppy).
   - —Fixed gap.
   - —Aerodynamic gap (Winchester).

1. Single or double sided

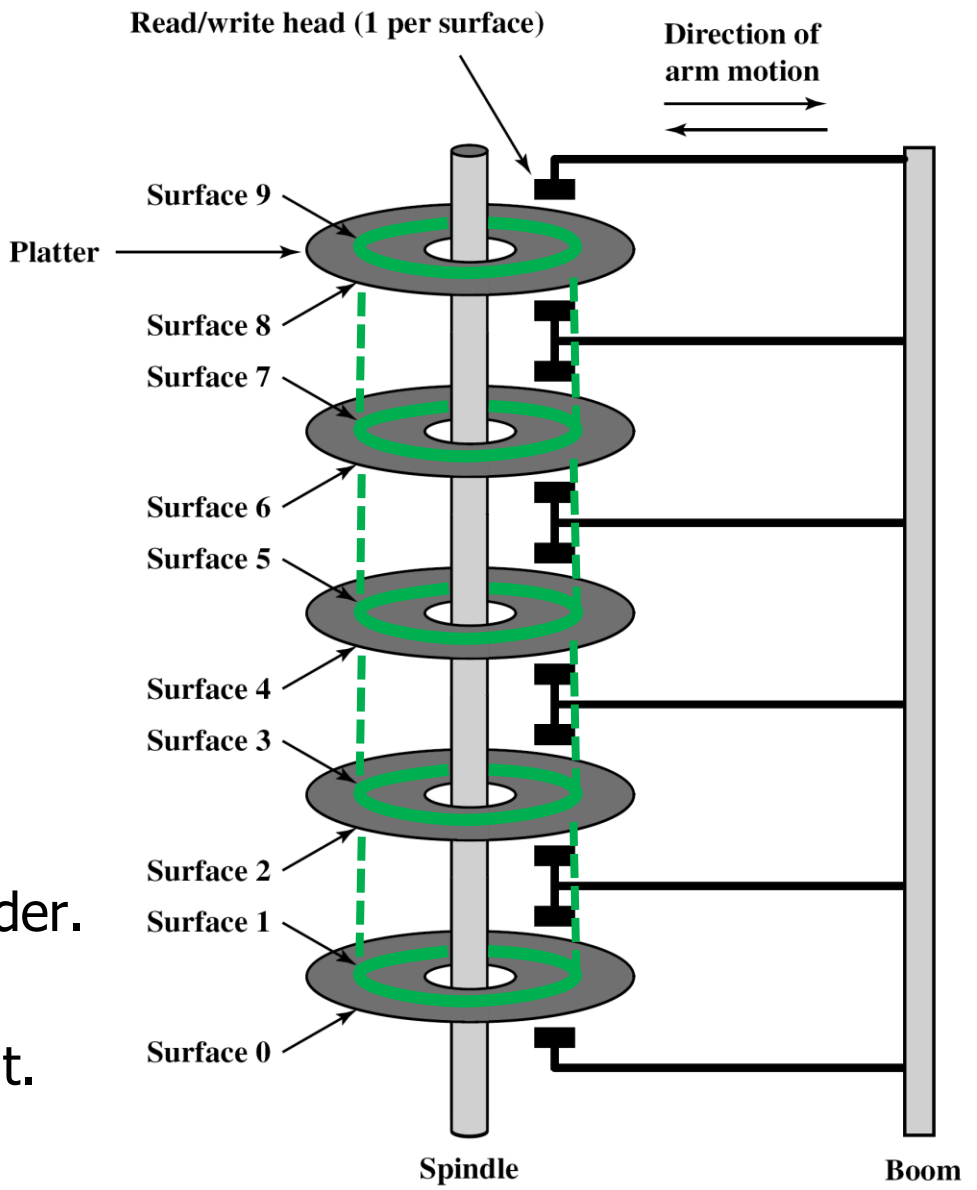
- Single-sided
  - —Magnetisable coating applied to one side of platter.
  - —Low expensive disk systems (e.g., floppy disks).
- Double-sided
  - —Magnetisable coating applied to both sides of platter.
  - —Each side has its own head.

2. Removable or Non-removable

- Removable disk
  - —Can be removed from drive and replaced with another disk.
  - —e. g., floppy disks.
  - —Provides unlimited storage capacity.
  - —Easy data transfer between systems.
  - —Obsoleted by CD-R and CD-R/W!
- Non-removable disk
  - —Permanently mounted in the drive.
  - —e. g., hard disks in personal computers.

3. Single or Multiple Platters (1)

- Multiple platters mounted on a spindle.
- Multiple heads
  - —joined and aligned
  - —One head per side.
- Aligned tracks on each platter form **cylinder**.
- Data is striped by cylinder.
  - — i.e., Rd/Wr cylinder by cylinder.
  - — Advantages:
    - – Reduces head movement.
    - – Increases transfer rate.



3. Single or Multiple Platters (2)

- Sector addressing methods:
  1. **Physical**
     - Cylinder-Head-Sector (CHS)
     - CHS triples ➔ $(0^+,0^+,1^+)$
     - Obsolete!
  2. **Logical**
     - Logical Block Address (LBA)
     - Integer number ➔ 0^+
- Given sectors per track (SPT) & heads per cylinder (HPC)
  - Convert **physical ➔ logical**

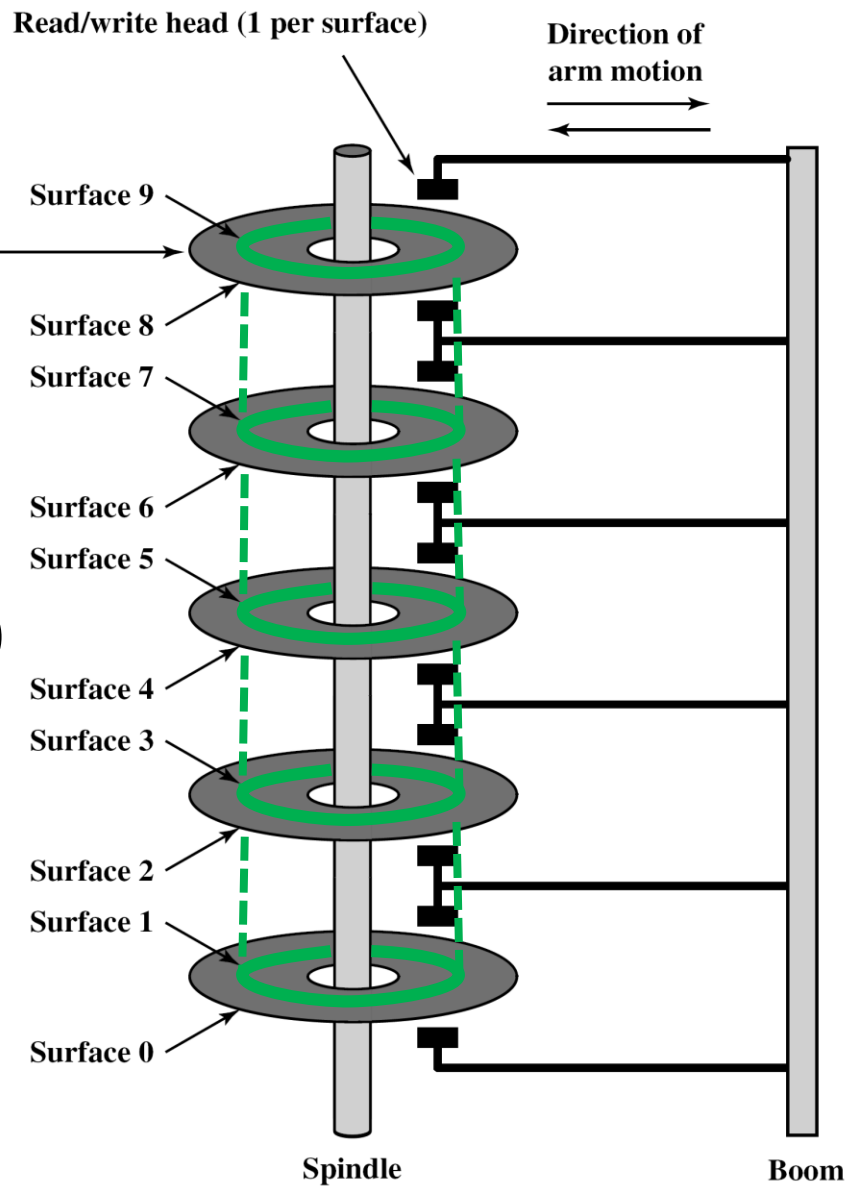
$$LBA = ((C * HPC) + H) * SPT + S - 1$$

  - Convert **logical ➔ physical**

$$C = LBA \div_{int} (SPT * HPC)$$

$$H = (LBA \div_{int} SPT) \bmod HPC$$

$$S = (LBA \bmod SPT) + 1$$



4. Fixed or Movable Head Disk

- Fixed head
  - —One read write head per track.
  - —Heads mounted on fixed ridged arm.
  - —Rare!
- Movable head
  - —One read/write head per side
  - —Mounted on a movable arm

5. Head Mechanism (1)

- Contact
  - —Head comes into physical contact with storage medium during read/write.
  - —Platter needs to be flexible.
  - —Used in floppy disks.
- Fixed gap
  - —Head positioned a fixed distance above platter.
  - —Used in early generations of hard disks.
- Aerodynamic gap (Winchester)
  - —<...next slide...>

Head Mechanism (2)

- Aerodynamic gap (Winchester)
  - Developed by IBM in Winchester (USA)
  - Head rests lightly on platter surface when disk is motionless.
  - As disk spins, head rises (flies on a thin layer of air) due its aerodynamic design.
  - Allow very small head-to-surface gap
    - Smaller heads ➔ narrower tracks ➔ higher density
    - Closer head proximity ➔ greater risk of errors due to impurities ➔ Winchester heads are housed in sealed containers (free of contaminants)
  - Used in contemporary hard disks

Disk Performance Parameters

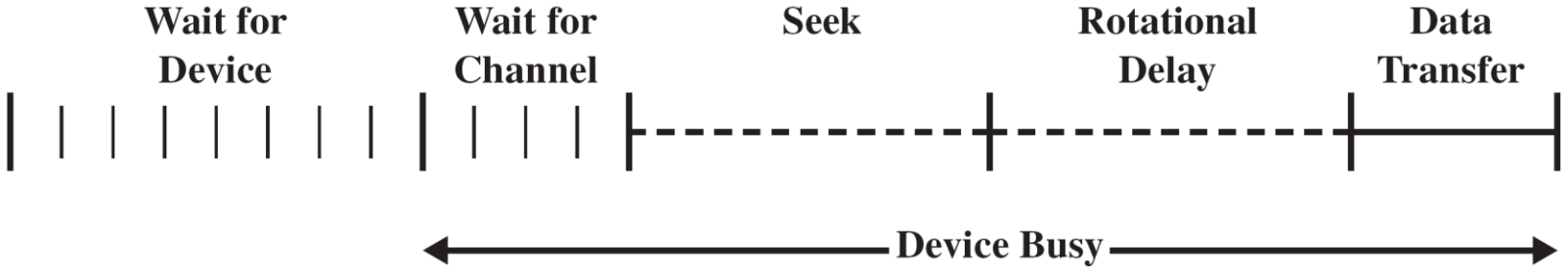
- Disk operation
  - Disk rotates at a constant speed.
  - To read/write, head is positioned at the desired track and at the beginning of the desired sector on that track.
- Seek time: time taken to move the disk arm (head) to the required track.
  - Equals: startup time + traversal time.
  - Average: less than 10 ms.
- Disk controller waits till the desired sector rotates to line up with the head.
- Rotational delay (latency): time taken for the beginning of the sector to reach the head.
  - Average: 1/2r, for r rpm ➔ less than 5ms if r=7200 rpm

Disk Performance Parameters (2)

- Access time = seek time + rotational delay
- Read/write performed as the sector moves under the head.
- Transfer time: time required for the transfer.

$$T = \frac{b}{rN}$$

  - T = transfer time,
  - b = number of bytes to be transferred,
  - r = rotational speed (r.p.s.),
  - N = number of bytes on a track.



Typical Hard Disk Drive Parameters

Characteristics	Constellation ES.2	Seagate Barracuda XT	Cheetah NS	Momentus
Application	Enterprise	Desktop	Network attached storage, application servers	Laptop
Capacity	3 TB	3 TB	400 GB	640 GB
Average seek time	8.5 ms read 9.5 ms write	N/A	3.9 ms read 4.2 ms write	13 ms
Spindle speed	7200 rpm	7200 rpm	10, 075 rpm	5400 rpm
Average latency	4.16 ms	4.16 ms	2.98	5.6 ms
Maximum sustained transfer rate	155 MB/s	149 MB/s	97 MB/s	300 MB/s
Bytes per sector	512	512	512	4096
Tracks per cylinder (number of platter surfaces)	8	10	8	4
Cache	64 MB	64 MB	16 MB	8 MB

Reading Material

- Stallings, Chapter 6:
  - Pages 185 – 195