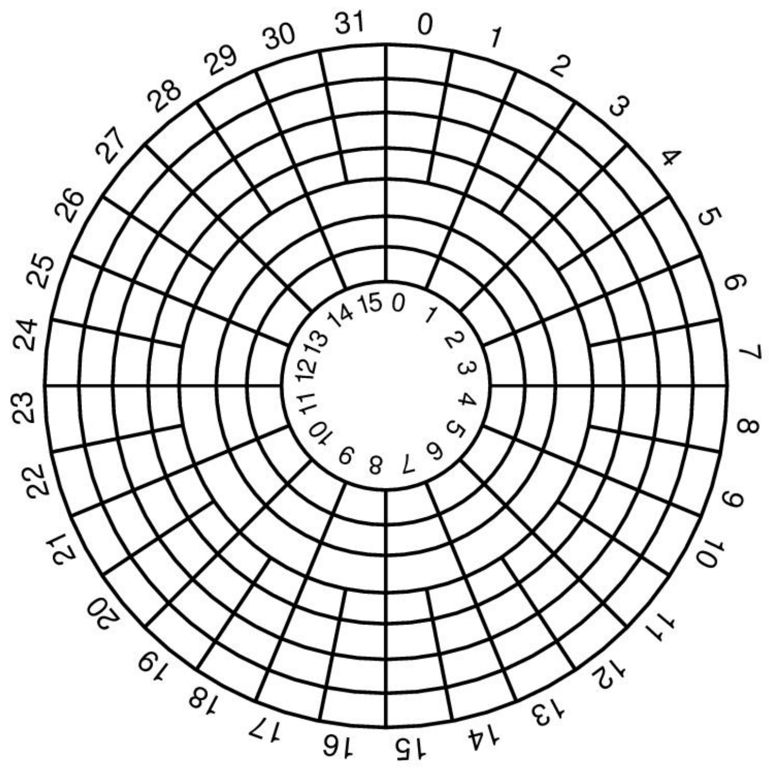
Disk I/O Management

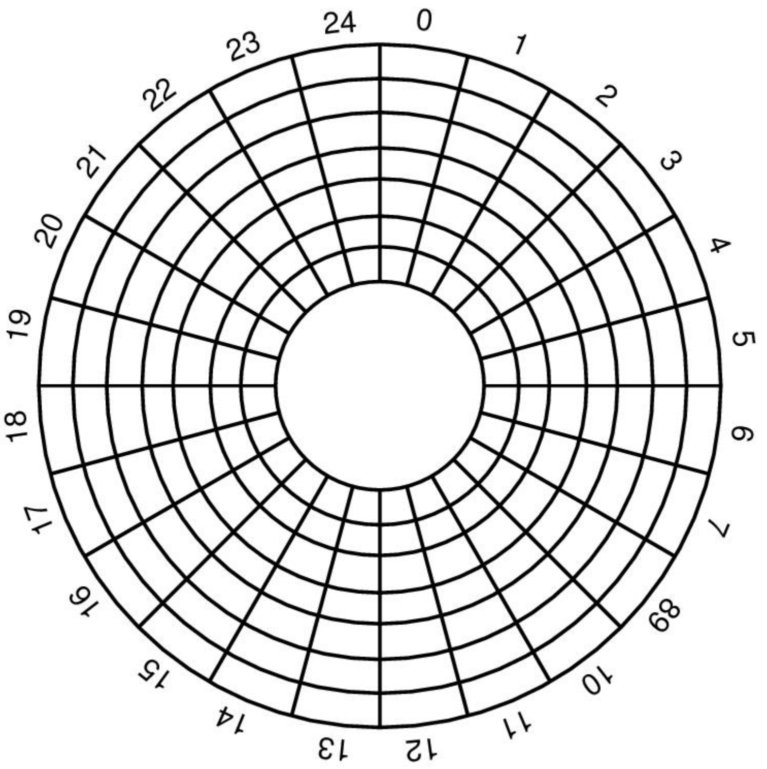
Chapter 5

Disk Management

- Management and ordering of disk access requests is important:
  - Huge speed gap between memory and disk
  - Disk throughput is extremely sensitive to
    - Request order ⇒ Disk Scheduling
    - Placement of data on the disk ⇒ file system design
  - Disk scheduler must be aware of *disk geometry*

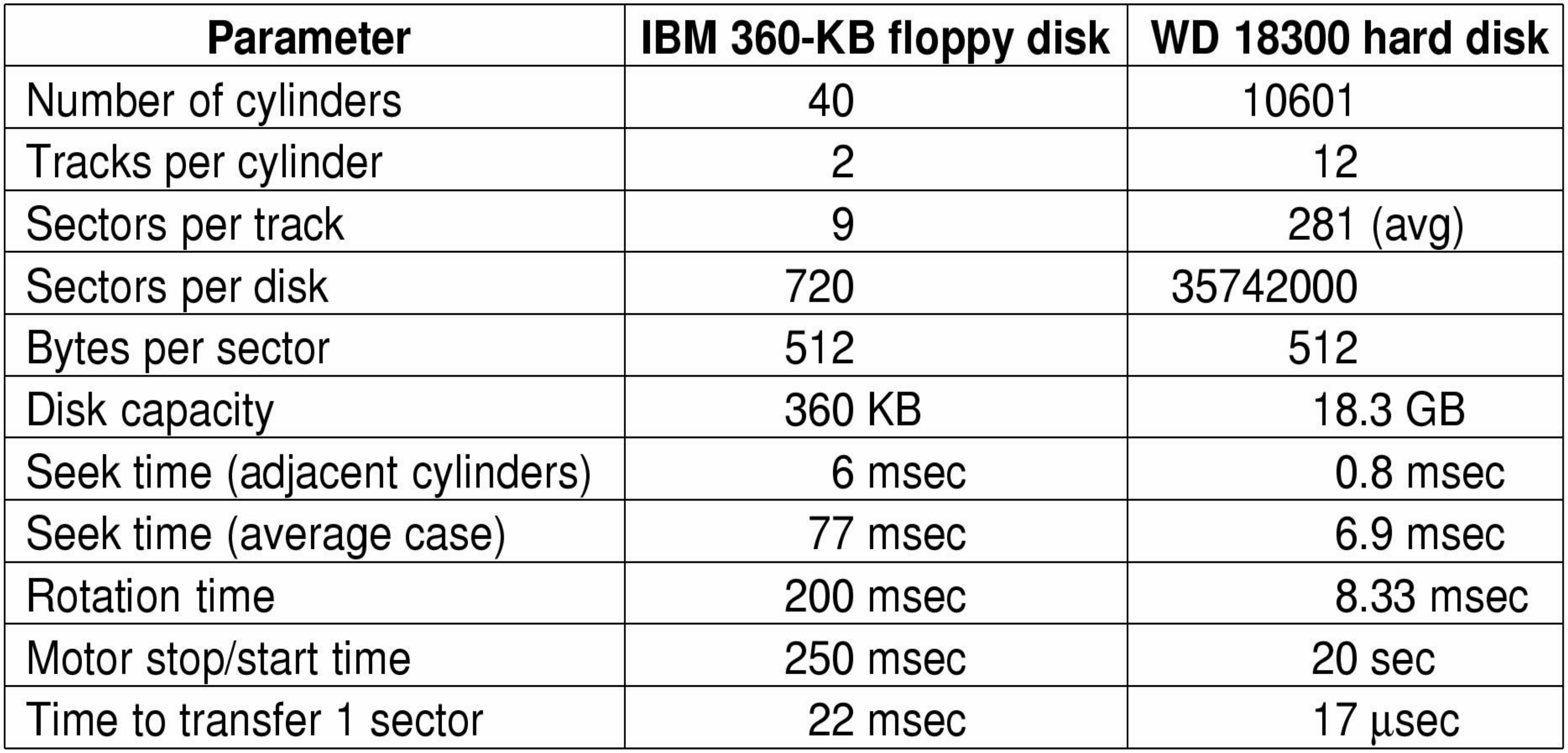
Disk Geometry





- Physical geometry of a disk with two zones
  - Outer tracks can store more sectors than inner without exceed max information density
- A possible virtual geometry for this disk

Evolution of Disk Hardware



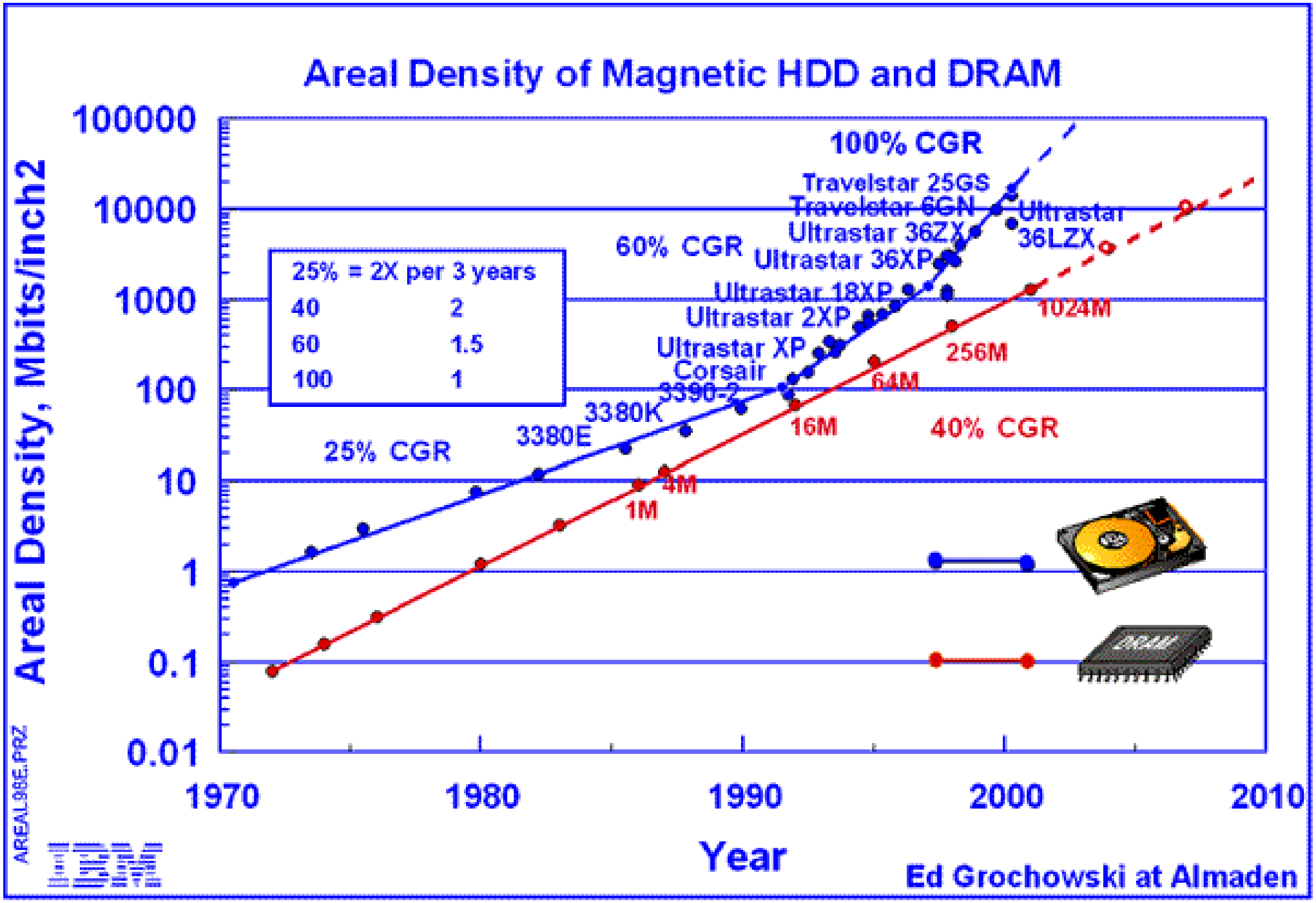
Parameter	IBM 360-KB floppy disk	WD 18300 hard disk
Number of cylinders	40	10601
Tracks per cylinder	2	12
Sectors per track	9	281 (avg)
Sectors per disk	720	35742000
Bytes per sector	512	512
Disk capacity	360 KB	18.3 GB
Seek time (adjacent cylinders)	6 msec	0.8 msec
Seek time (average case)	77 msec	6.9 msec
Rotation time	200 msec	8.33 msec
Motor stop/start time	250 msec	20 sec
Time to transfer 1 sector	22 msec	17 µsec

Disk parameters for the original IBM PC floppy disk and
a Western Digital WD 18300 hard disk

Things to Note

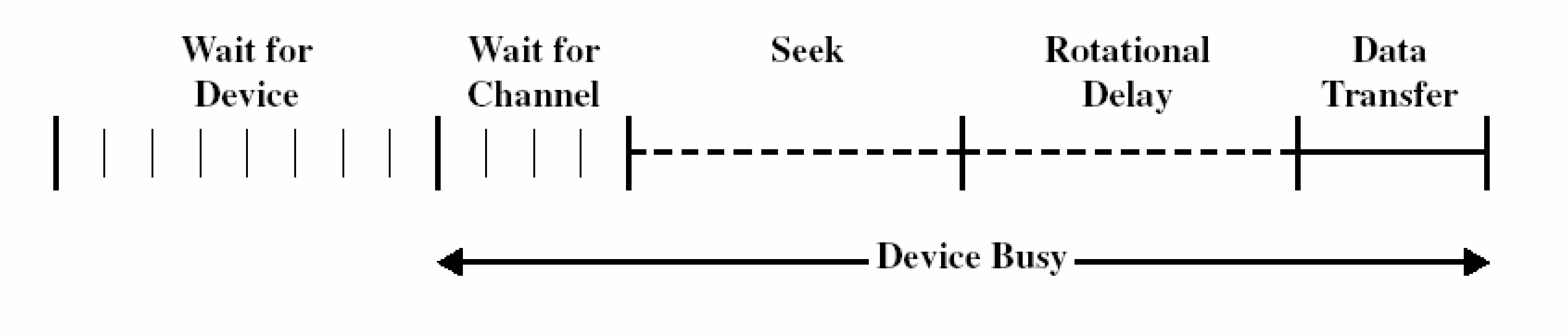
- Average seek time is approx 12 times better
- Rotation time is 24 times faster
- Transfer time is 1300 times faster
  - Most of this gain is due to increase in density
- Represents a gradual engineering improvement

Storage Capacity is 50000 times greater



Disk Performance

- Disk is a moving device ⇒ must be positioned correctly for I/O
- Execution of a disk operation involves
  - Wait time: the process waits to be granted device access
    - Wait for device: time the request spend in wait queue
    - Wait for channel: time until a shared I/O channel is available
  - Access time: time hardware need to position the head
    - Seek time: position the head at the desire track
    - Rotational delay (latency): spin disk to the desired sector
  - Transfer time: sectors to be read/written rotate below head



Estimating Access Time

- *Seek time* T_s: Moving the head to the required track
  - ⋆ not linear in the number of tracks to traverse:
    - ➜ startup time
    - ➜ settling time
  - ⋆ Typical average seek time: a few milliseconds
- *Rotational delay:*
  - ⋆ rotational speed, r, of 5,000 to 10,000rpm
  - ⋆ At 10,000rpm, one revolution per 6ms $\Rightarrow$ average delay 3ms
- *Transfer time:*

  to transfer b bytes, with N bytes per track: $T = \dfrac{b}{rN}$

Total average access time: $T_a = T_s + \dfrac{1}{2r} + \dfrac{b}{rN}$

A Timing Comparison

- $T_s = 2$ ms, $r = 10,000$ rpm, 512B sect, 320 sect/track
- Read a file with 2560 sectors (= 1.3MB)
- File stored compactly (8 adjacent tracks):

Read first track

Average seek	2ms
Rot. delay	3ms
Read 320 sectors	6ms
	11ms

⇒ All sectors: $11 + 7 * 8 = 67\ ms$

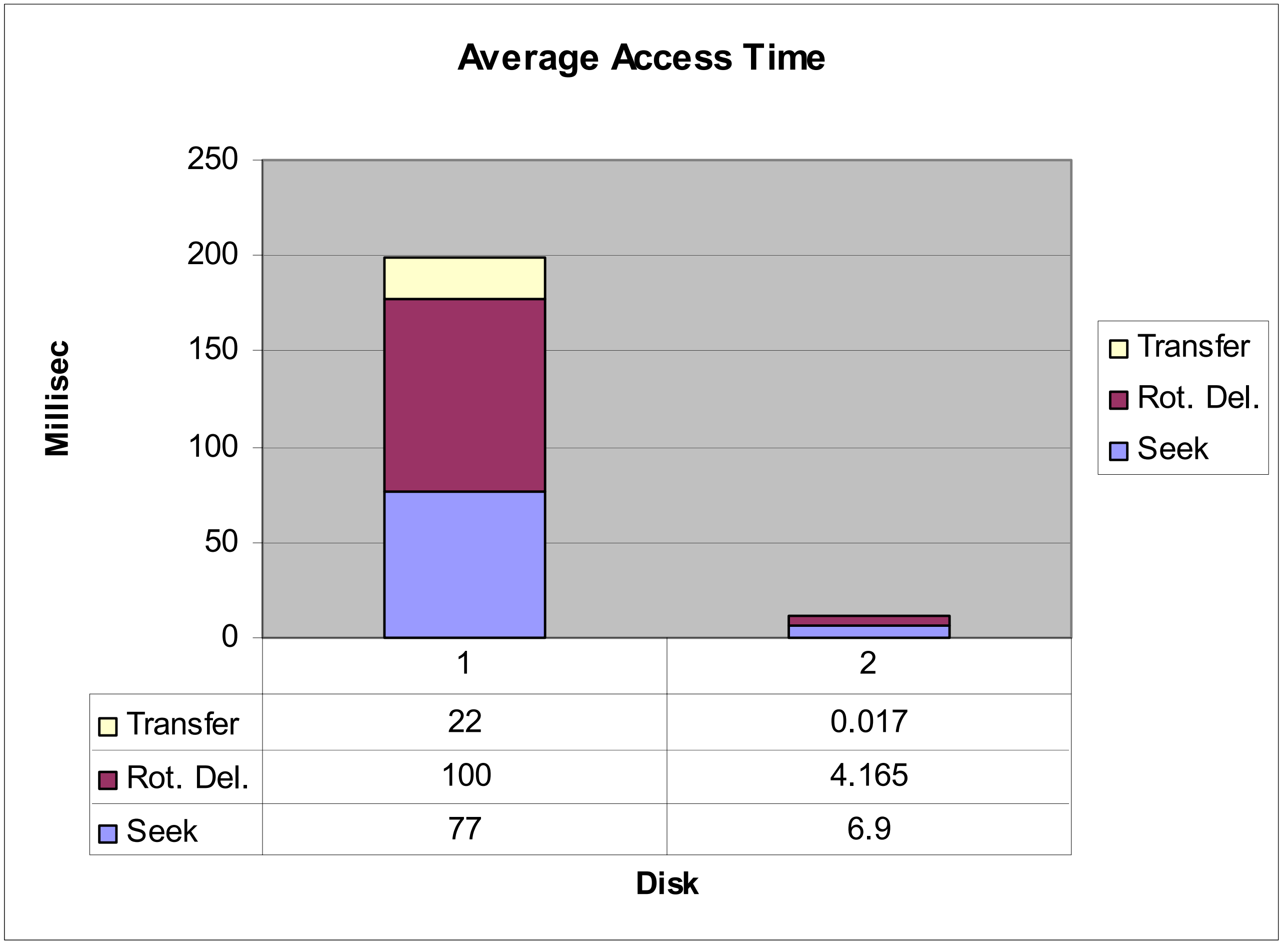
- Sectors distributed randomly over the disk:

Read any sector

Average seek	2ms
Rot. delay	3ms
Read 1 sector	0.01875ms
	5.01875ms

⇒ All: $2560 * 5.01875 = 20,328ms$

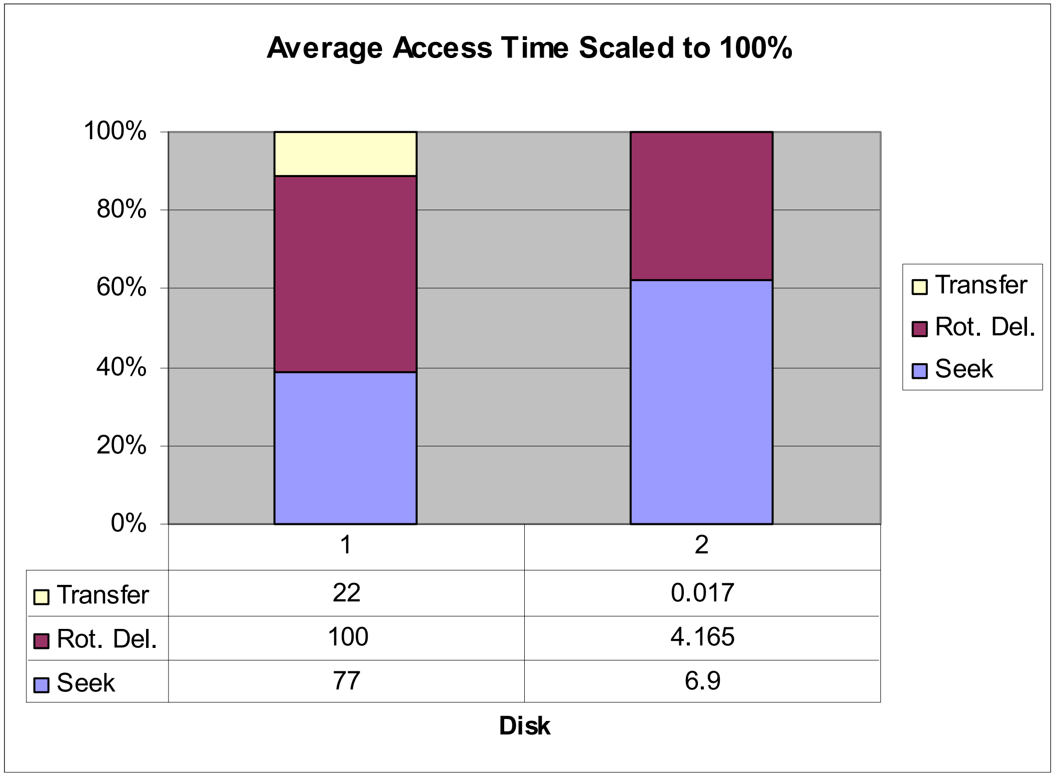
Disk Comparative Performance



	1	2
□ Transfer	22	0.017
■ Rot. Del.	100	4.165
■ Seek	77	6.9

Disk Performance is Entirely Dominated by Seek and Rotational Delays

- Will only get worse as capacity increases much faster than increase in seek time and rotation speed
  - Note it has been easier to spin the disk faster than improve seek time
- Operating System should minimise mechanical delays as much as possible



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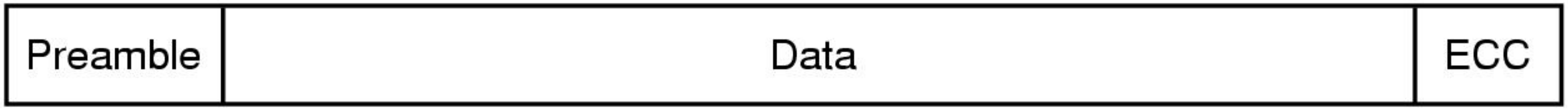
Low-level Disk Formatting



Preamble

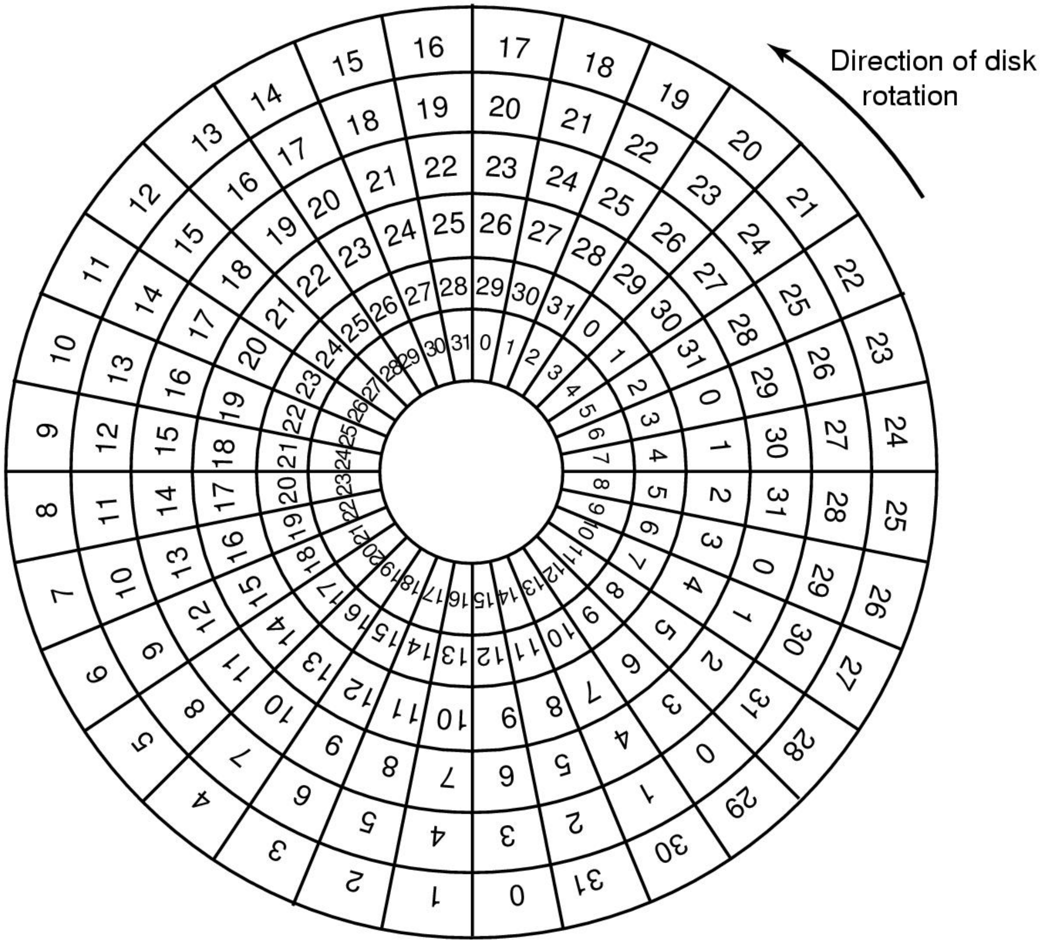
Data

ECC

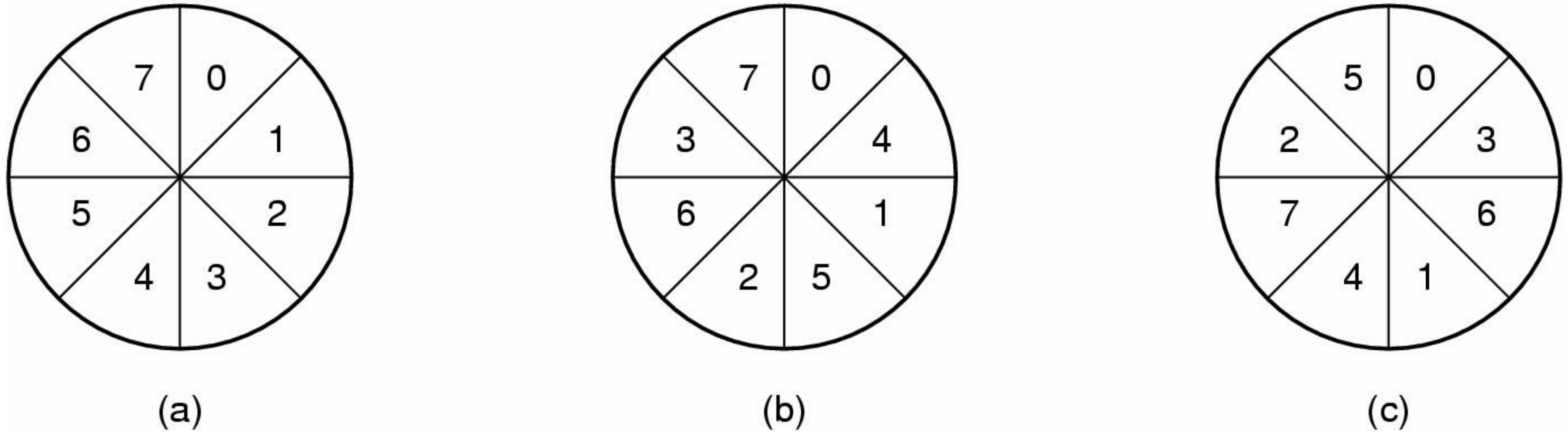
A disk sector

Low-level Disk Formatting

- When reading sequential blocks, the seek time can result in missing block 0 in the next track
- Disk can be formatted using a cylinder *skew* to avoid this



Low-Level Disk Formatting



- Issue: After reading one sector, the time it takes to transfer the data to the OS and receive the next request results in missing reading the next sector
- To overcome this, we can use interleaving

a) No interleaving

b) Single interleaving

c) Double interleaving

Low-Level Disk Formatting

- Modern drives overcome interleaving type issues by simply reading the entire track (or part thereof) into the on-disk controller and caching it.

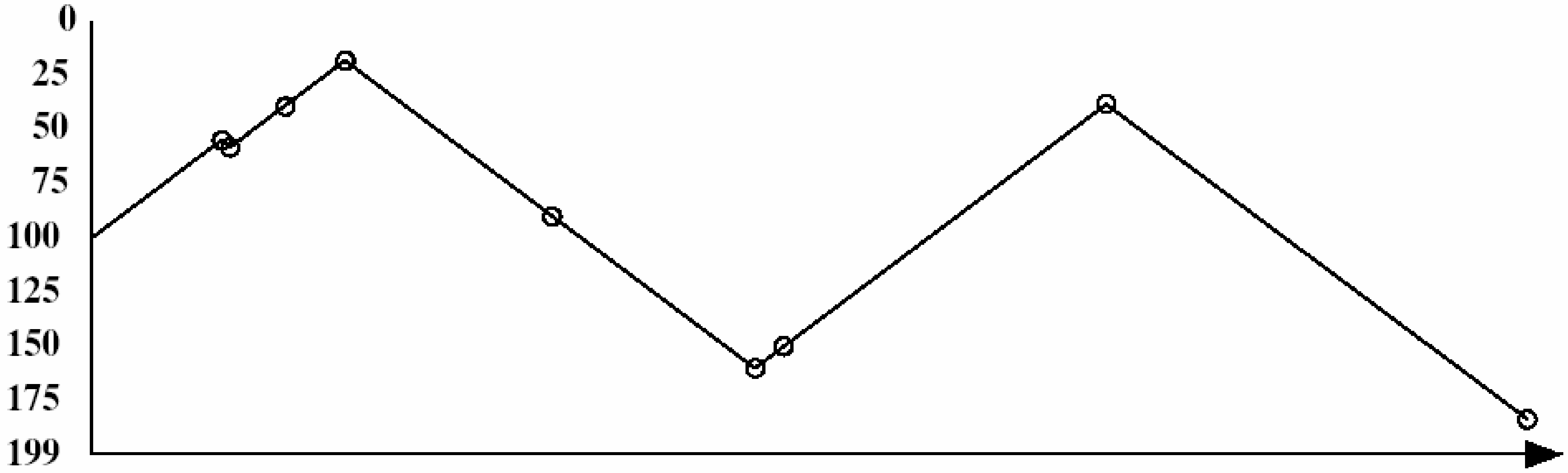
Disk Arm Scheduling Algorithms

- Time required to read or write a disk block determined by 3 factors
  1. Seek time
  2. Rotational delay
  3. Actual transfer time
- Seek time dominates
- For a single disk, there will be a number of I/O requests
  - Processing them in random order leads to worst possible performance

First-in, First-out (FIFO)

- Process requests as they come
- Fair (no starvation)
- Good for a few processes with clustered requests
- Deteriorates to random if there are many processes

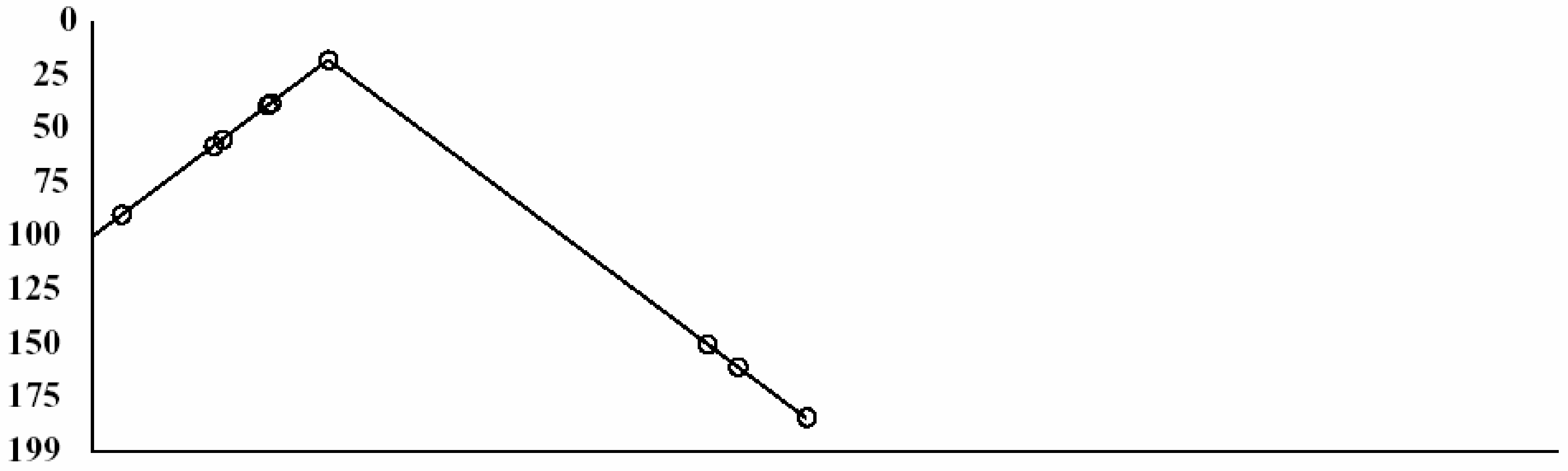
Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184



Shortest Seek Time First

- Select request that minimises the seek time
- Generally performs much better than FIFO
- May lead to starvation

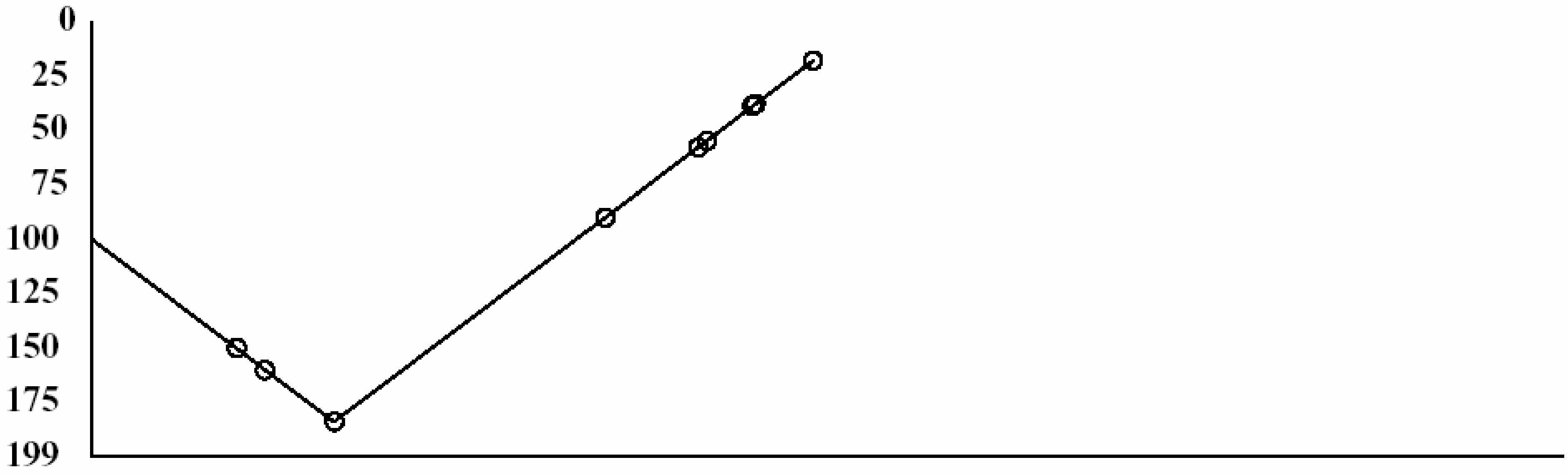
Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184



Elevator Algorithm (SCAN)

- Move head in one direction
  - Services requests in track order until it reaches the last track, then reverses direction
- Better than FIFO, usually worse than SSTF
- Avoids starvation
- Makes poor use of sequential reads (on down-scan)

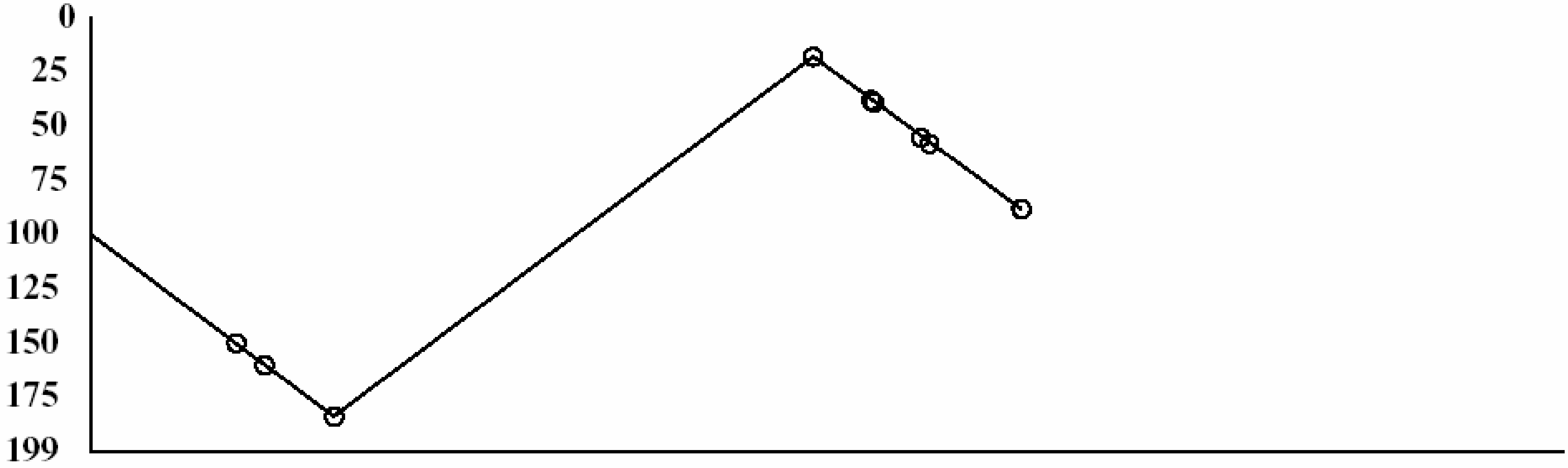
Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184



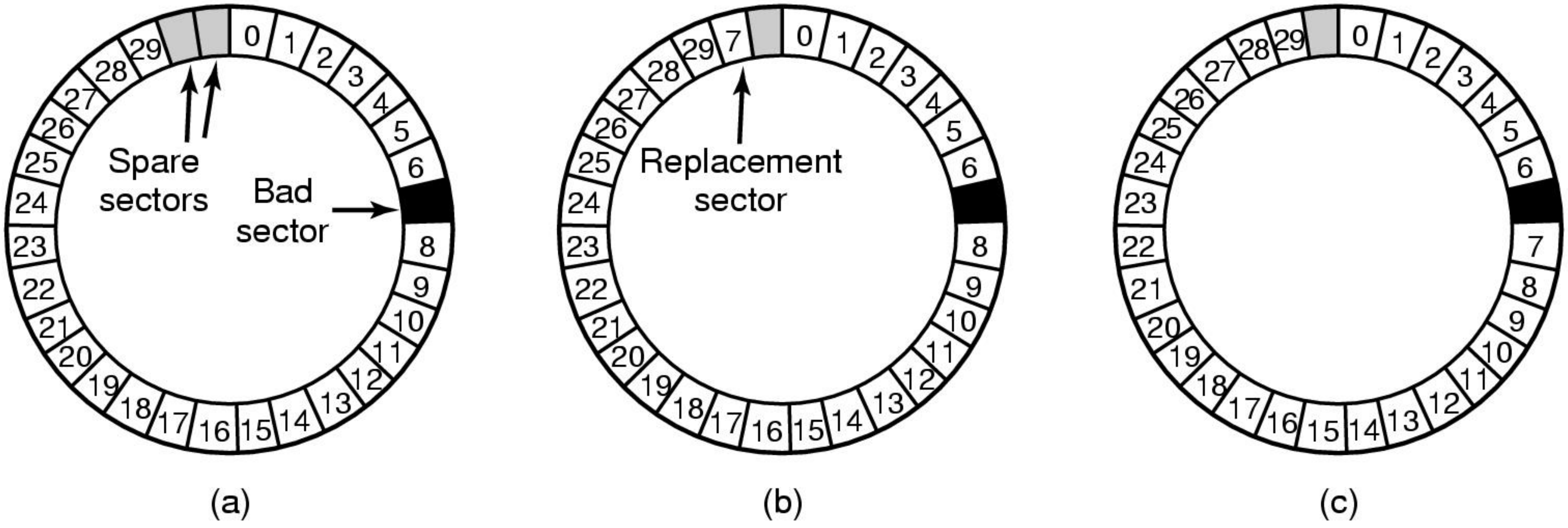
Modified Elevator (Circular SCAN, C-SCAN)

- Like elevator, but reads sectors in only one direction
  - When reaching last track, go back to first track non-stop
- Better locality on sequential reads
- Better use of read ahead cache on controller
- Reduces max delay to read a particular sector

Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184



Error Handling



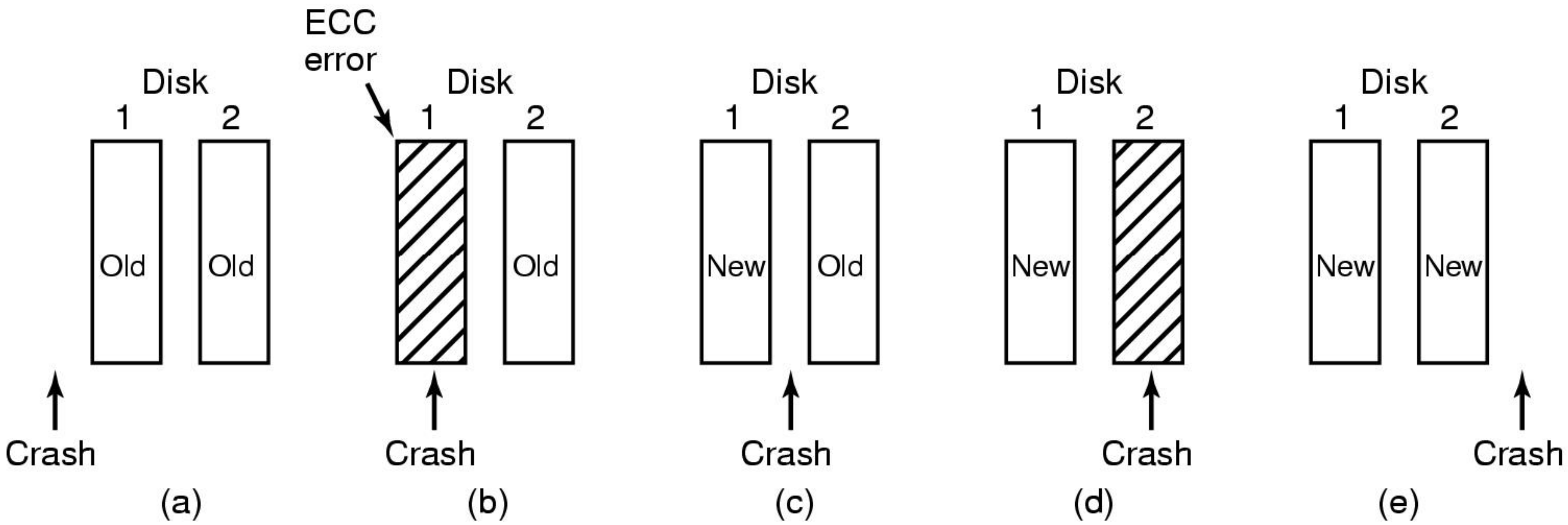
a) A disk track with a bad sector

b) Substituting a spare for the bad sector

c) Shifting all the sectors to bypass the bad one

- Bad blocks are usually handled transparently by the on-disk controller

Implementing Stable Storage



- Use two disks to implement stable storage
  - Problem is when a write (update) corrupts old version, without completing write of new version
  - Solution: Write to one disk first, then write to second after completion of first