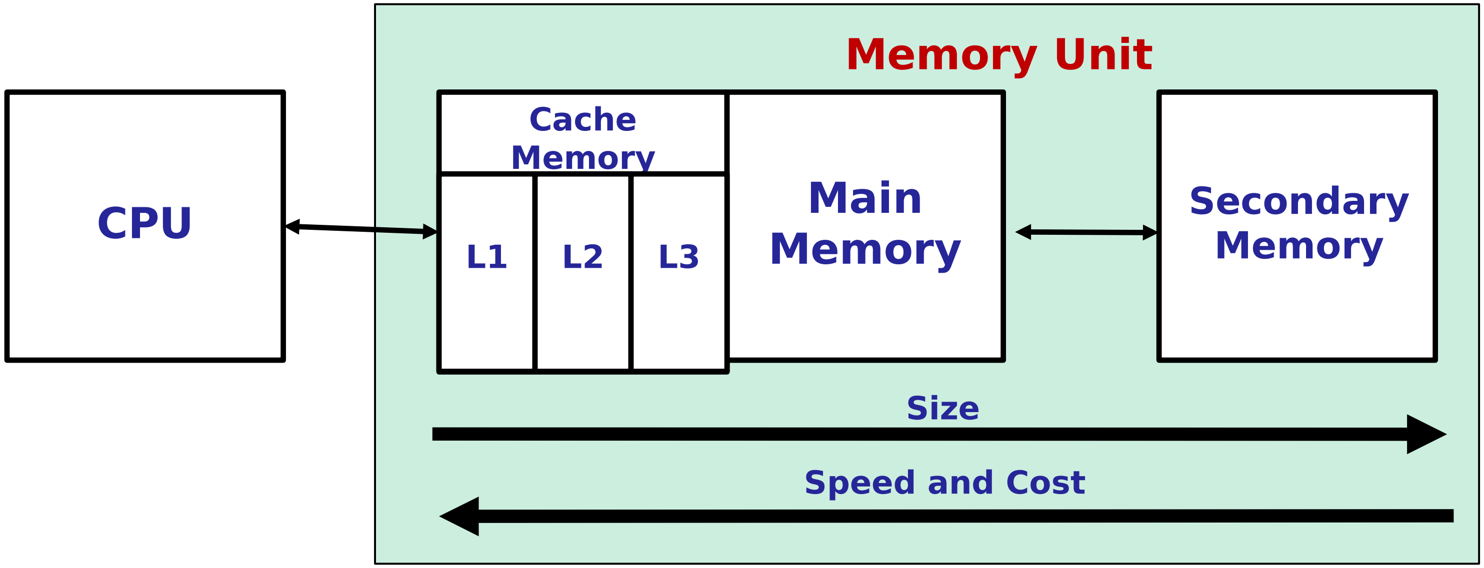
Memory Unit

Memory Hierarchy



- Processor processes instructions and data faster than it can be fetched from memory unit
- Memory access time is the bottleneck
- One way to reduce memory access time is to use faster memory
  - A small and faster memory bridge the gap between processor and main memory

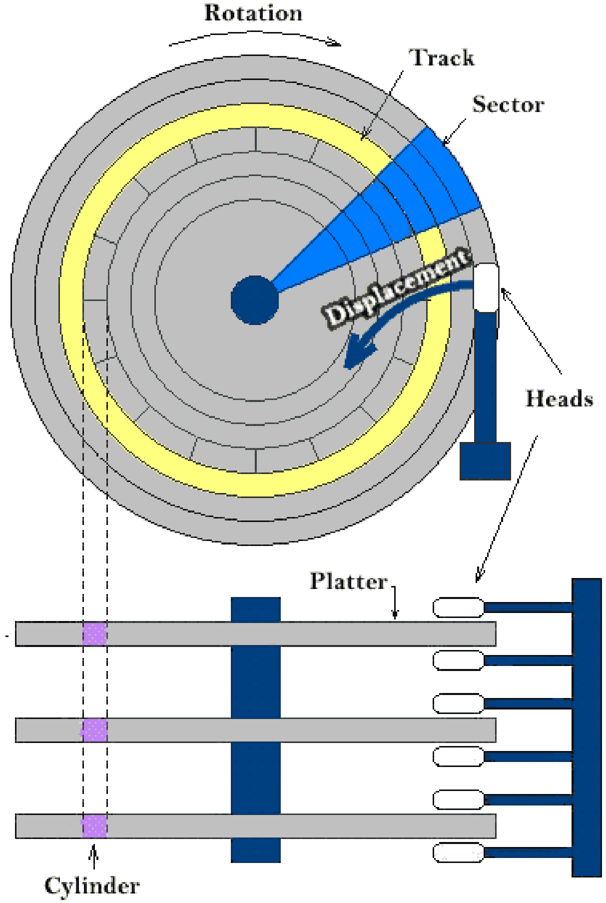
Secondary Storage

Secondary Storage

- Secondary storage include:
  - Magnetic disks:
    - Example: Hard disks
    - Used in personal computers
  - Redundant Array of Independent Disks (RAID):
    - Uses disk arrays to achieve greater performance and higher availability
    - Multiples disks are used as a parallel array of data storage devises built with redundancy to compensate for dis failures
    - Used in servers and large systems
  - Optical disks:
    - Uses optical storage technology
    - Examples: CDROM and DVD

Magnetic Disks

- A disk is a circular platter constructed of nananomagnetic material, called substrate
- Usually both the sides are coated with a magnetisable material



- Data are recorded on and retrieved from the disk via a conducting coil called head
- Read/write head
- Each head consists of a magnetic yoke and magnetisable coil
- Floppy disk
- Winchester disk (Hard disk)

Read and Write Mechanism

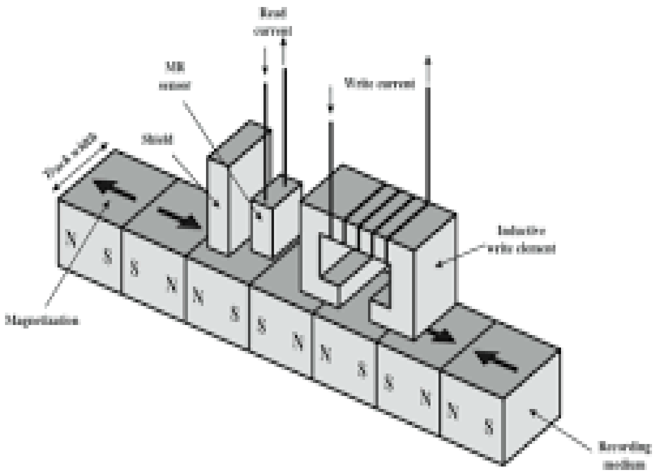


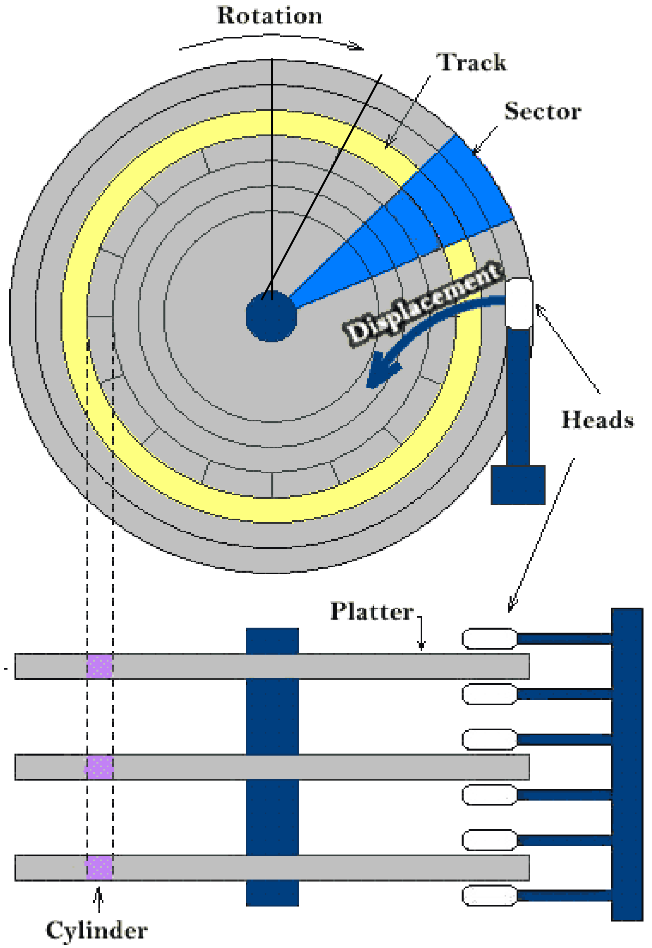
Figure 6.1 Inductive Write/Magnetoresistive Read Head

Write mechanism

- Electricity flowing through the coil (head) produces magnetic field
- This induced magnetic field magnetises the small area of the recording medium
- Different patterns of positive and negative current indicates 1 and 0

- Read mechanism
  - It exploits the fact that magnetic field moving relative to a coil produces an electric current in the coil (head)
  - When the surface of the disk passes under the head, it generates a current of the same polarity as the one already recorded

Data Organization on the Disk



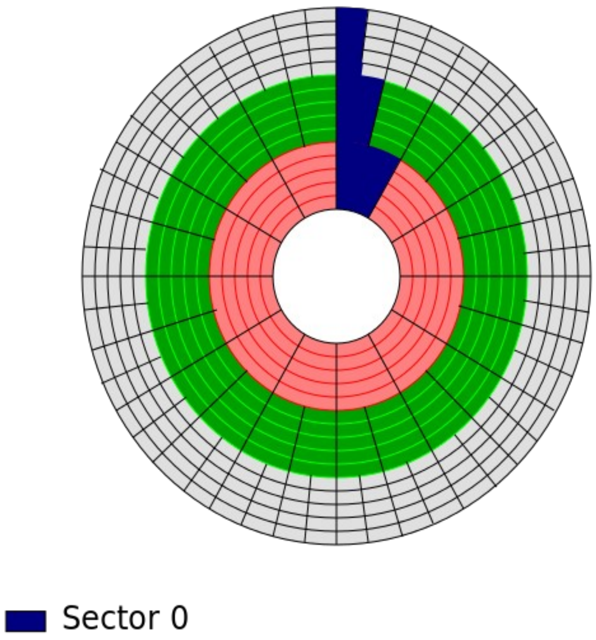
- Track:
  - Concentric set of rings on the platter
  - Each track is of the same width as head
- Sector:
  - The tacks are divided into hundreds of sectors per track
  - Each sector stores 512 bytes of information
- Cylinder:
  - The set of all the tracks in the same relative position on the patters

Multuple zone recording

It is proposed to increase the density of data in outer track

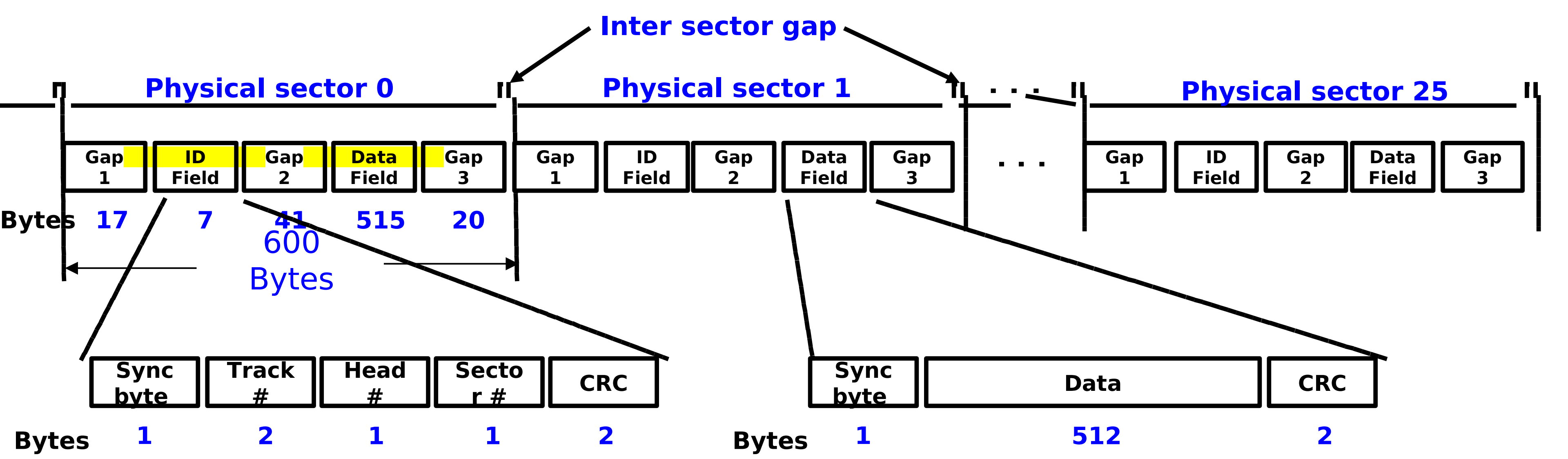
It has advantage over CAV (Constant angular velocity)

Data tranfer from outer tracks will be higher. Hence OS fill its own files in outer tracks



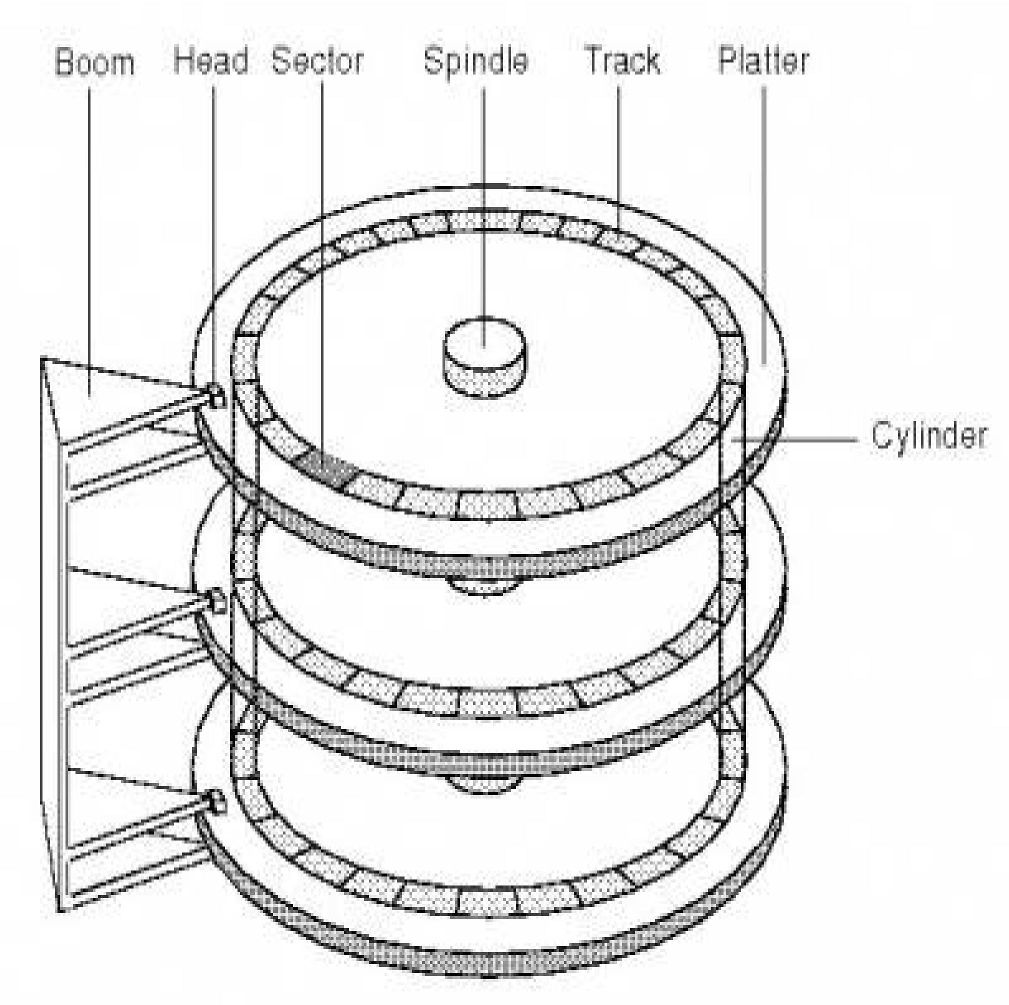
Winchester Disk Format

- Some means needed to locate sector positions with in a track – identifying start and end of each sector
- This is handled using control data recorded on the disk
- Formatted disk
  - Some extra data (control data) used only by the disk controller
  - Operating system does the formatting of disk
- Each sector holds 512 bytes of data and control information



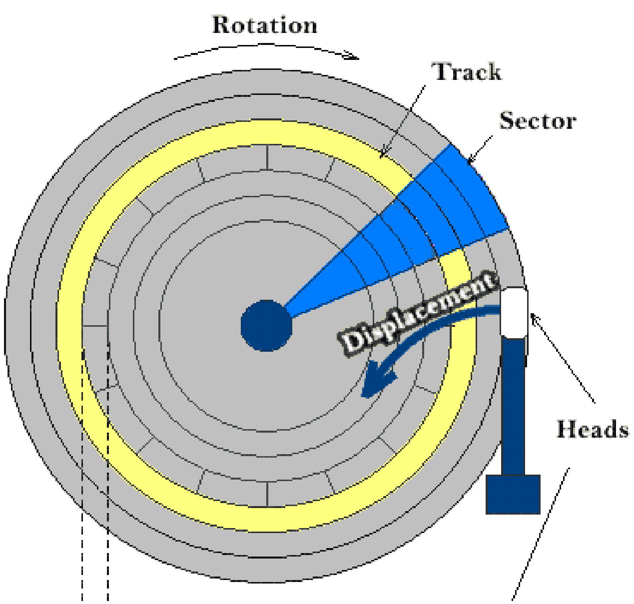
cyclic redundancy control (CRC)

Component of Disk Drive



Disk Performance Parameters

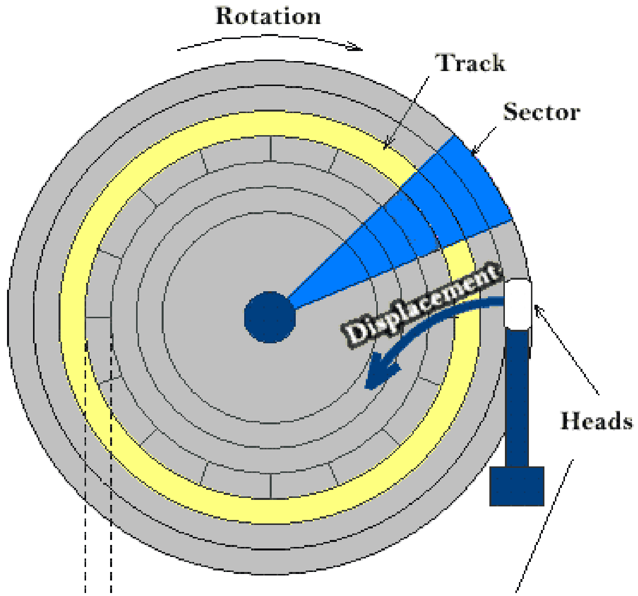
- When the disk drive is operating, the disk is rotating at a constant speed
- During read or write operation, the head must be positioned at the desired track and at the beginning of the desired sector on that track



- Seek time (T_s):
  - Time required to move or position the head to the required track
  - It depends on where is the initial position
  - We consider average seek time
- Track-to-track seek time:
  - Time to move the head from one track to an adjacent track

Disk Performance Parameters

- Rotational delay or Rotational latency (T_r):
  - Time taken for the beginning of the sector to read by the head
  - Average time needed for the required sector to pass under the head once the head has positioned at the correct track
  - Let r is the rotation speed measured in revolutions per sec



$$T_r = \frac{1}{2r}$$

Disk Performance Parameters

- Transfer time (T):
  - Time taken to transfer b bytes of data to or from a track of the disk
  - b : Number of bytes to be transferred
  - r : Rotational speed
  - N : Number of bytes on the track

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

- Total time to access the data
  - Sum of the average seek time, rotational delay and transfer time

$$\boxed{T_a = T_s + T_r + T}$$

Hard Disk Parameter

- Example: **Segate Barracuda ES.2**
  - Capacity : 1TB
  - Track-to-track seek time : 0.8 ms
  - Average seek time : 8.5 ms
  - Spindle speed : 7200 rpm
  - Average rotational delay : 4.16 ms
  - Maximum transfer rate : 3GB/sec
  - Bytes per sector : 512
  - Tracks per cylinder : 8 (4 platters)

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RAID Systems

Mass Storage

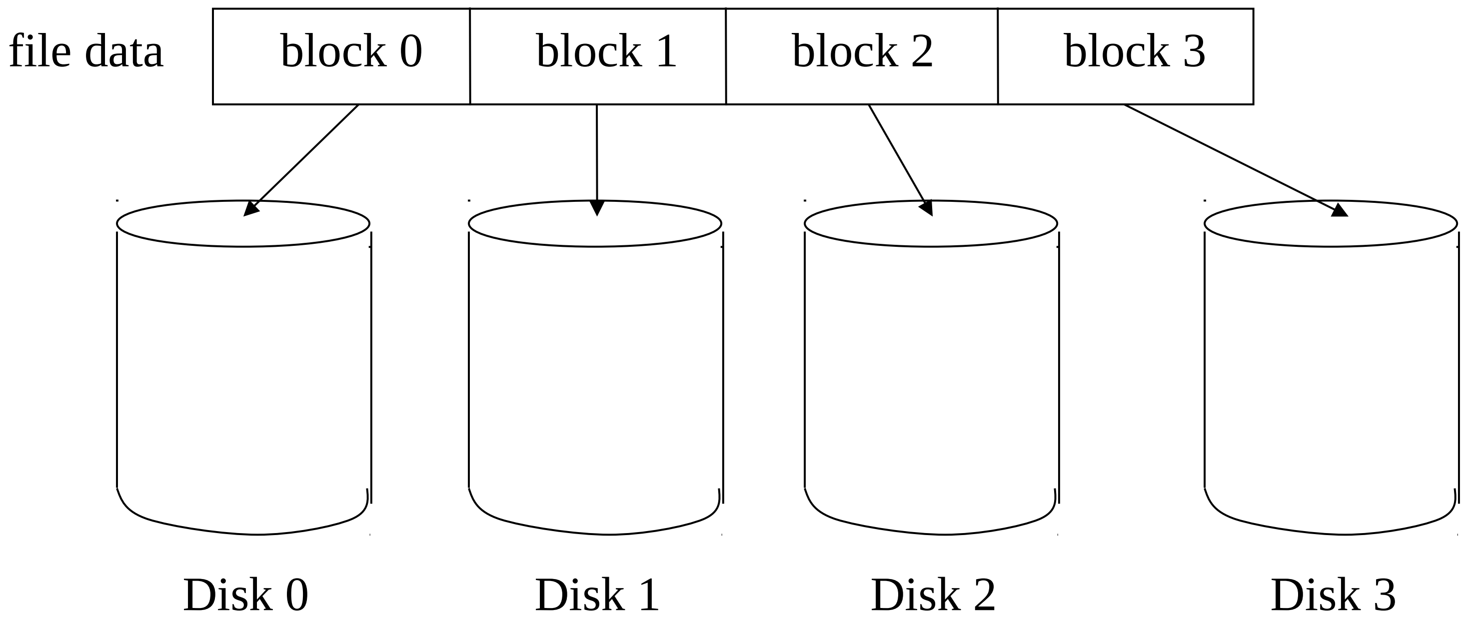
- Many systems today need to store many terabytes of data
- Don’t want to use single, large disk
  - too expensive
  - failures could be catastrophic
- Would prefer to use many smaller disks

RAID

- Redundant Array of Inexpensive Disks
- Basic idea is to connect multiple disks together to provide
  - large storage capacity
  - faster access to reading data
  - redundant data
- Many different levels of RAID systems
  - differing levels of redundancy, error checking, capacity, and cost

Striping

- Take file data and map it to different disks
- Allows for reading data in parallel



Parity

- Way to do error checking and correction
- In the event of drive failure, Parity drive is accessed and data is reconstructed from the remaining devices
- Considered an array of five drives
- X0 through X4 contain data and X4 is the parity disk
- Using exclusive-OR function, the parity bit is computed as
- $$X4(i) = X3(i) \otimes X2(i) \otimes X1(i) \otimes X0(i)$$
- Suppose X1 has failed then it can be recovered as

$$X1(i) = X4(i) \otimes X2(i) \otimes X1(i) \otimes X0(i)$$

Mirroring

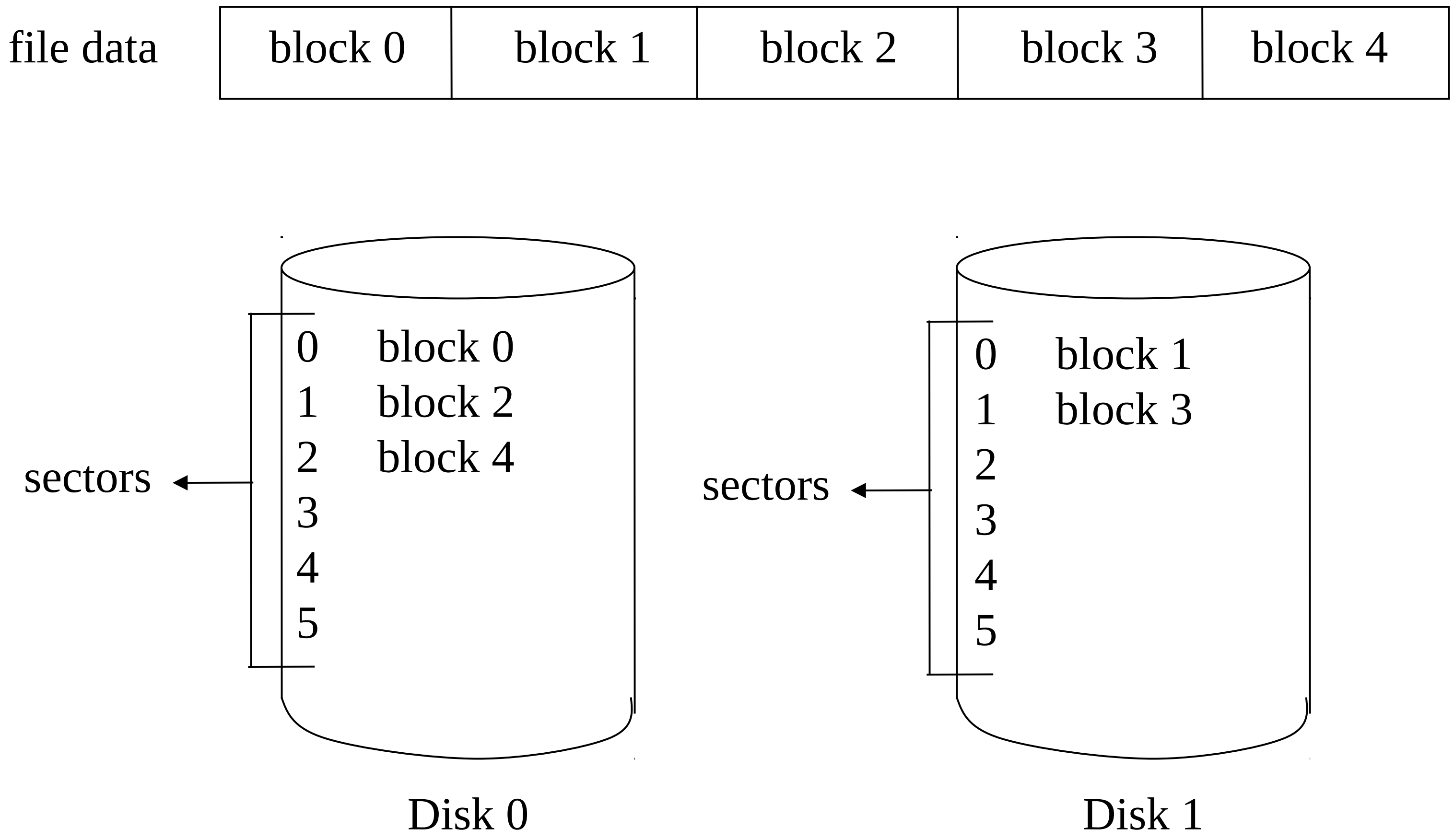
- Keep to copies of data on two separate disks
- Gives good error recovery
  - if some data is lost, get it from the other source
- Expensive
  - requires twice as many disks
- Write performance can be slow
  - have to write data to two different spots
- Read performance is enhanced
  - can read data from file in parallel

RAID Level-0

- Often called striping
- Break a file into blocks of data
- Stripe the blocks across disks in the system
- Simple to implement

- provides no redundancy or error detection

RAID Level-0

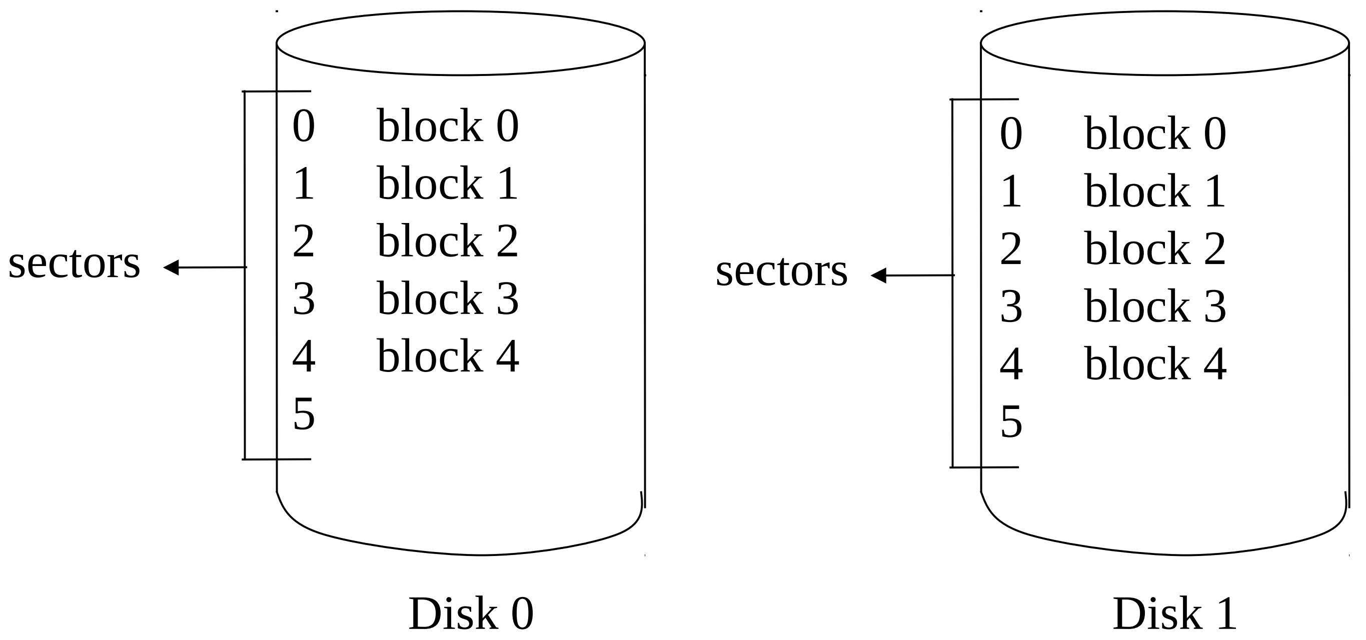

file data
block 0
block 1
block 2
block 3
block 4
sectors
0
1
2
3
4
5
block 0
block 2
block 4
sectors
0
1
2
3
4
5
block 1
block 3
Disk 0
Disk 1

RAID Level-1

- A complete file is stored on a single disk
- A second disk contains an exact copy of the file
- Provides complete redundancy of data
- Read performance can be improved
  - file data can be read in parallel
- Write performance suffers
  - must write the data out twice
- Most expensive RAID implementation
  - requires twice as much storage space

RAID Level-1

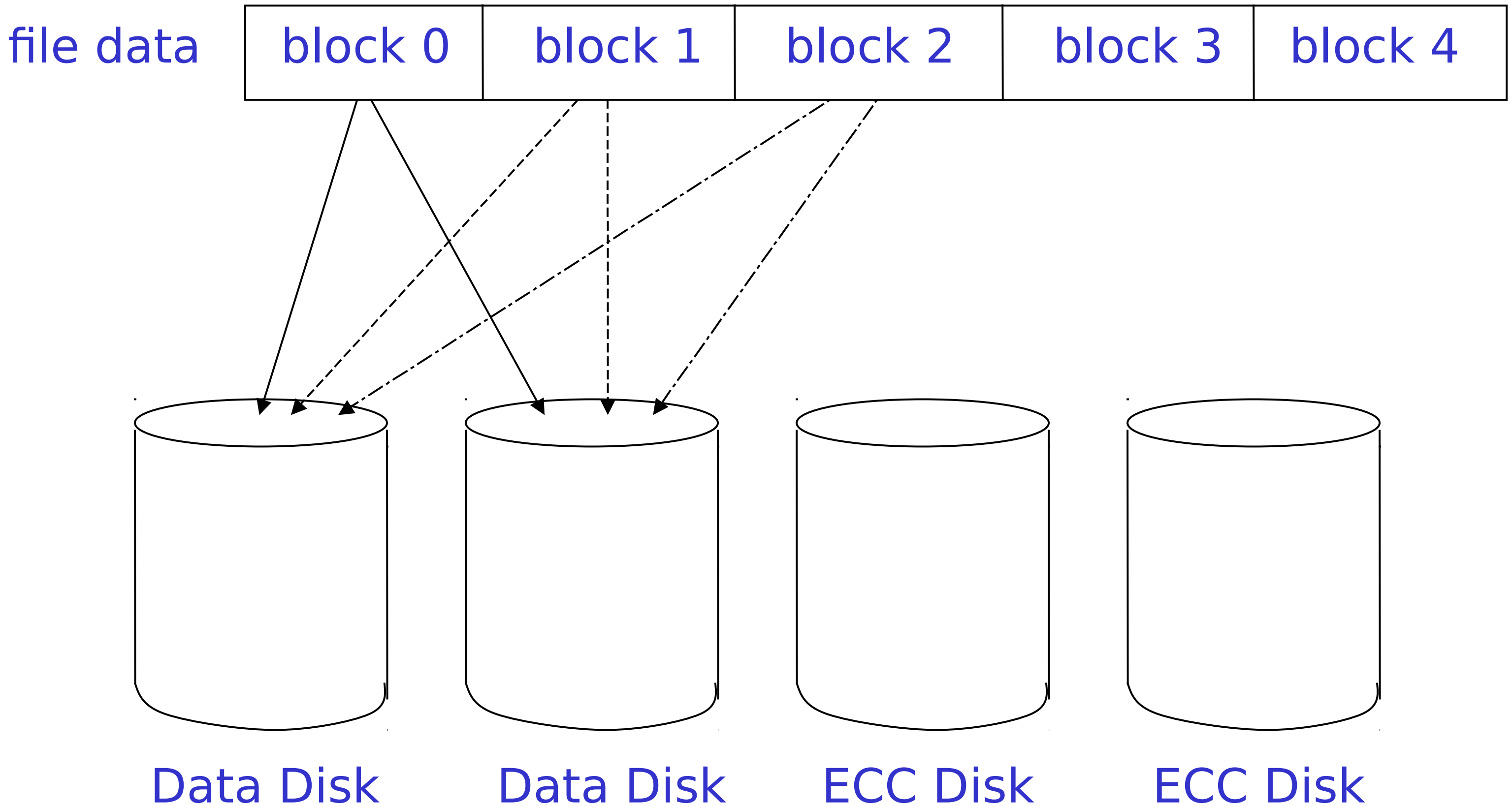
file data					
file data	block 0	block 1	block 2	block 3	block 4



RAID Level-2

- Stripes data across disks similar to Level-0
  - difference is data is bit interleaved instead of block interleaved
- Uses ECC to monitor correctness of information on disk
- Multiple disks record the ECC information to determine which disk is in fault

RAID Level-2


file data
block 0
block 1
block 2
block 3
block 4
Data Disk
Data Disk
ECC Disk
ECC Disk

RAID Level-2

- Requires fewer disks than Level-1 to provide redundancy
- Still needs quite a few more disks
  - for 10 data disks need 4 check disks
- Big problem is performance
  - must read data plus ECC code from other disks
  - for a write, have to modify data, ECC,
- Another big problem is only one read at a time
  - while a read of a single block can be done in parallel
  - multiple blocks from multiple files can't be read because of the bit-interleaved placement of data

RAID Level-3

- One big problem with Level-2 are the disks needed to detect which disk had an error
- Modern disks can already determine if there is an error
  - using ECC codes with each sector
- So just need to include a parity disk
  - if a sector is bad, the disk itself tells us, and use the parity disk to correct it

RAID Level-4

- Big problem with Level-2 and Level-3 is the bit interleavening
  - to access a single file block of data, must access all the disks
  - allows good parallelism for a single access but doesn't allow multiple I/O's
- Level-4 interleaves file blocks
  - allows multiple small I/O's to be done at once

- RAID Level-05:

- RAID Level-09:
- RAID Level-10: The most expensive system