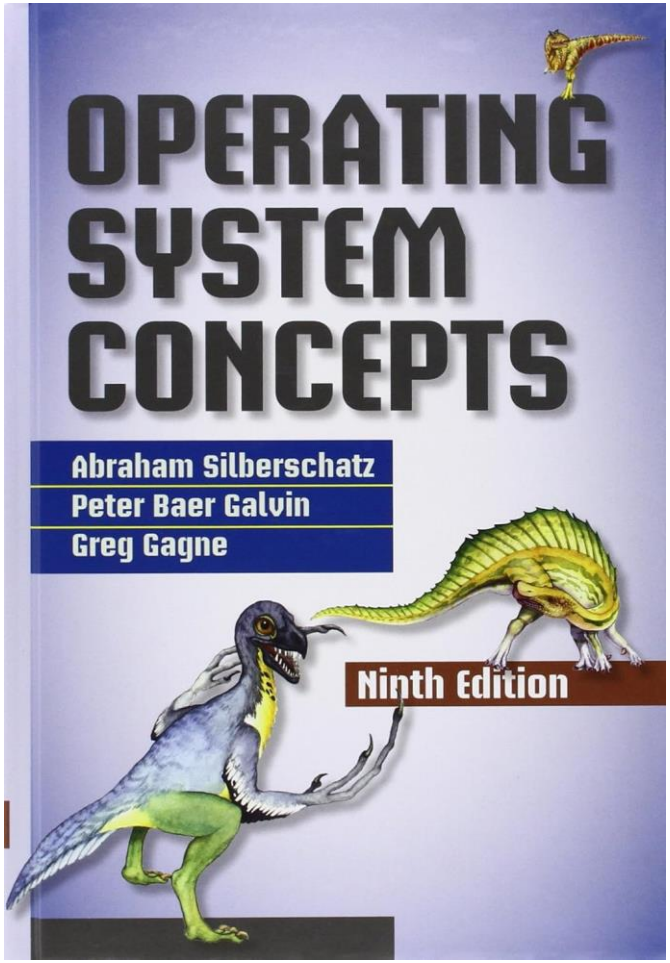
Operating System - CS402

Lecture 1
Mass Storage in Operating Systems

2025

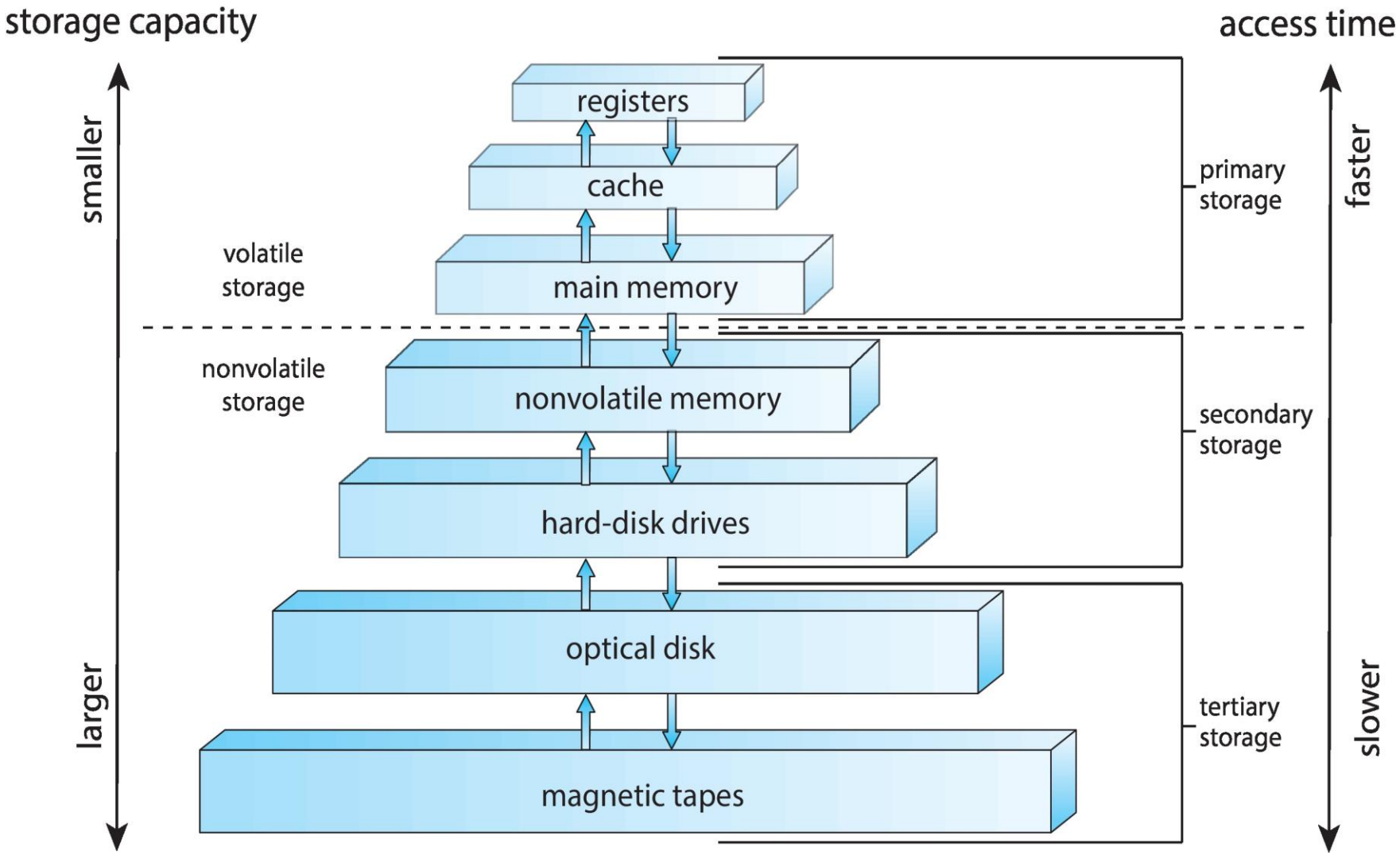
Reference Book



Learning Objectives

- Understand different types of mass storage devices.
- Learn key performance metrics.
- Explore basic storage management concepts.
- Data protection using RAID (Redundant Array of Independent Disks)

Storage-Device Hierarchy



Storage-Device Hierarchy

Storage Type	Characteristics
Registers	Smallest, fastest, stores CPU instructions
Cache	Very fast memory close to CPU, stores frequently used data
Main Memory (RAM)	Larger but volatile, used for active applications
Non-Volatile Memory (SSD)	Fast, retains data after power-off, no moving parts
Hard Disk Drives (HDDs)	Slower than SSDs, larger capacity, mechanical parts
Optical Disks (CD/DVD/Blu-ray)	Used for media and software storage, slow access
Magnetic Tapes 	Very large capacity, slowest, used for backups & archives

Introduction to Mass Storage

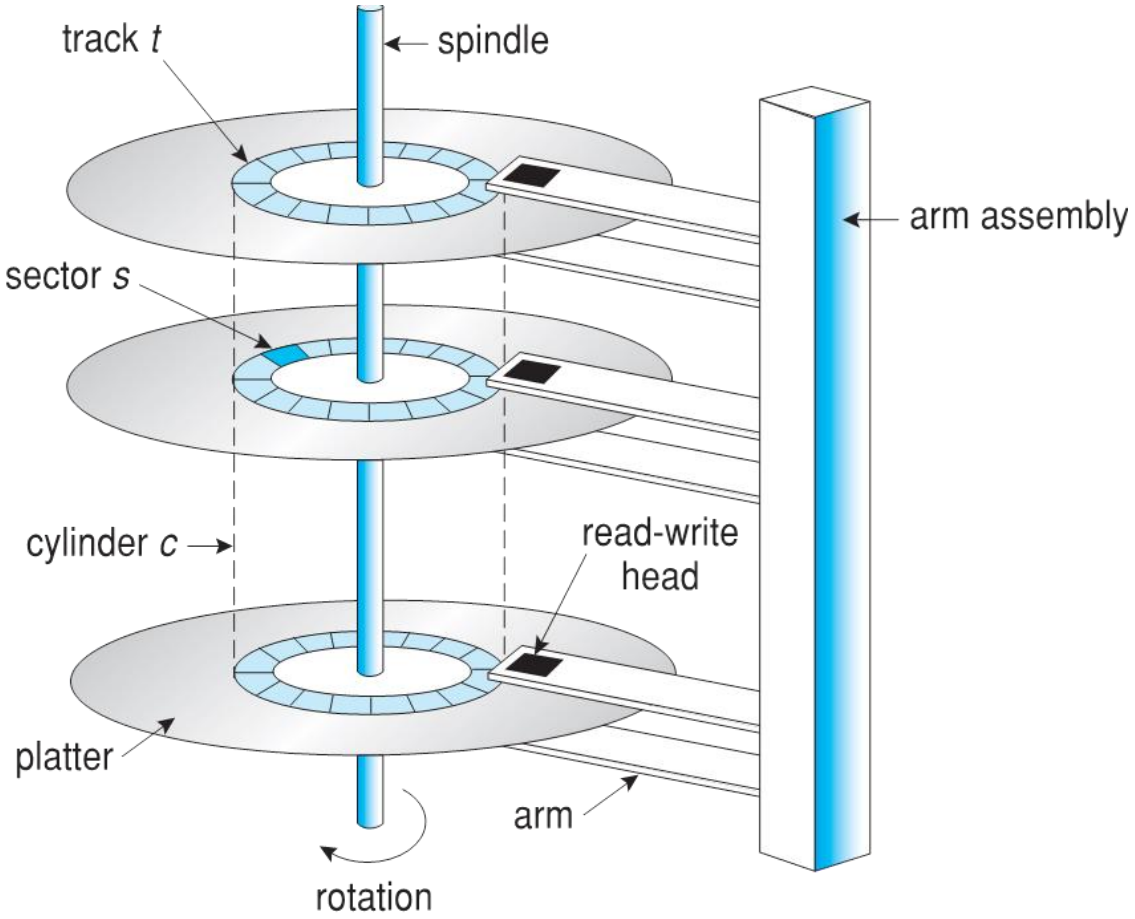
- **Definition**: Mass storage refers to non-volatile storage used for long-term data retention.
- **Key Metrics**:
  - **Latency**: Time delay before data transfer begins
  - **Throughput**: Data transfer speed over time
  - **Seek Time**: Time taken to locate the correct track on disk
- **Importance**: Efficient storage management enhances system performance and reliability.

Types of Mass storage

- **Magnetic Storage:** Hard Disk Drives (HDDs), Magnetic Tapes
- **Solid-State Storage:** Solid-State Drives (SSDs), Flash Drives
- **Optical Storage:** CDs, DVDs, Blu-ray Discs
- **Cloud Storage:** Google Drive, Amazon S3
- **Hybrid Storage Solutions:**
  - Combines SSD and HDD technologies to balance speed and cost.
- **Network-Attached Storage (NAS):**
  - A dedicated storage device connected to a network for multiple users.
- **Storage Area Network (SAN):**
  - A high-speed network providing block-level storage access.
  - SAN runs on high-speed Fiber channel.

Hard Disk Drives (HDDs)

- A hard disk drive (HDD) is a type of storage device used in computers for storing and retrieving digital data.
- **Structure:** Platters, Read/Write Heads, Spindle, Actuator Arm



Hard Disk Drives (HDDs) (Cont.)

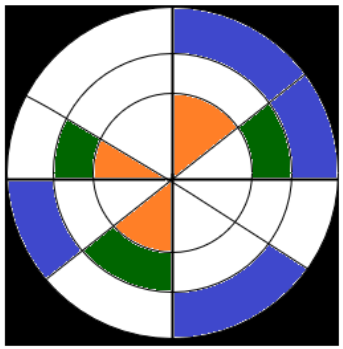
- **Platters:** Circular disks coated with a magnetic material where data is stored. These disks spin at high speeds (typically 5,400 to 7,200 revolutions per minute) while the computer is in use.
- **Read/Write Heads:** Small electromagnets mounted on an actuator arm that moves across the platters to read from or write data to specific locations on the disk.
- **Actuator Arm:** Mechanism that positions the read/write heads over the correct location on the spinning platters.
- **Controller:** manages the operation of the HDD, controlling data read and write operations, managing data flow, and handling communication with the computer's operating system.
- **Interface:** The connection interface (e.g., SATA, SAS) that allows the HDD to communicate with the computer's motherboard.

How does a hard drive work? Operation

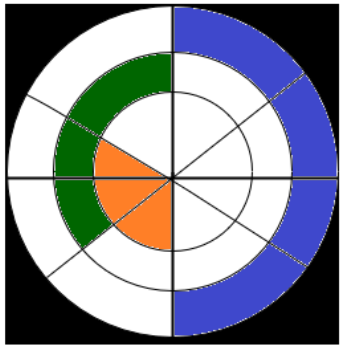
- **Reading Data:** When data needs to be read, the HDD controller determines the location of the data on the platter. The actuator arm positions the read/write head over the correct track, and the platter spins at a high speed.
- **Writing Data:** When data needs to be written, the controller sends signals to the read/write head to modify the magnetic orientation of the sectors on the platter, encoding the new data.

Fragmentation and Defragmentation

- **Fragmentation:**
  - As data is written, modified, and deleted over time, the free space on the platter becomes fragmented.
  - If there is not enough contiguous space to hold, complete files on a hard drive, files can become fragmented and the storage algorithms on the disk separate the data to fit it inside the available space.
- **Defragmentation:**
  - To increase speed and improve performance, defragmentation reorganizes fragmented data so that related parts of files are stored closer together and in contiguous blocks on the platter.



Before Defragmentation



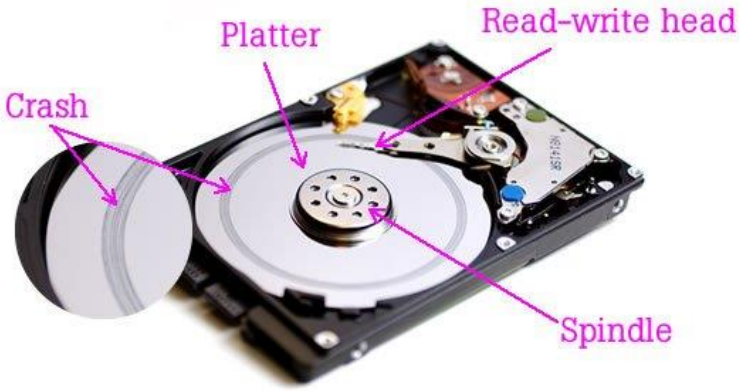
After Defragmentation

A head crash

- Head crash results from disk head making contact with the disk surface.

Causes of a Head Crash

- Physical Shock
- Manufacturing Defects
- Power Failures



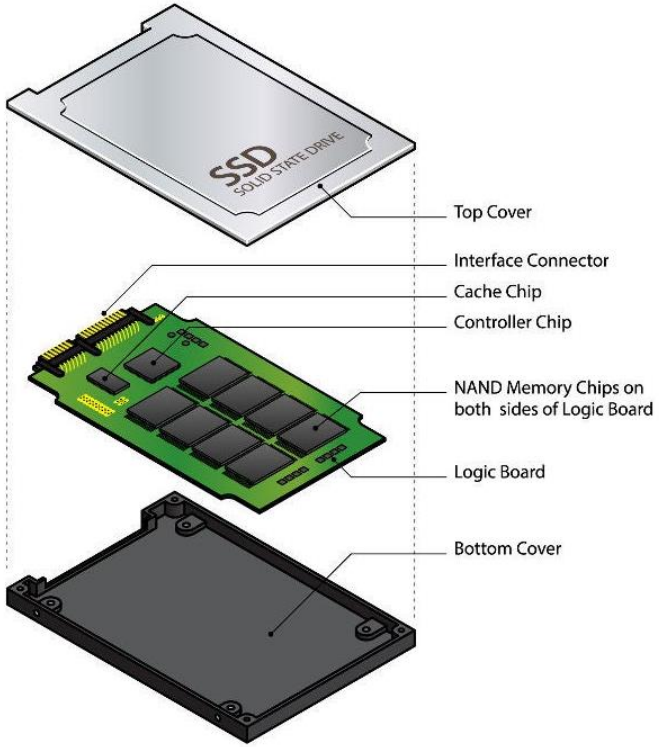
Prevention of Head Crashes

- Use **shock-resistant** mounting and avoid sudden movements.
- Keep the system in a **clean environment** to prevent dust buildup.
- Use **uninterruptible power supplies (UPS)**
- Regularly **back up** important data to prevent loss.

Solid-State Drive (SSD)

Solid-state drive (SSD) is a solid-state storage device that uses integrated circuit assemblies as memory to store data.

- No moving parts, so no seek time or rotational latency.
- Lower latency.
- More resistant to physical shock.
- Can be more reliable than HDDs.
- Run silently
- Have quicker access time.



Disadvantages of SSD

- **Cost:** SSDs are more expensive than regular hard drives.
- **Storage choices:** Because of the expense, SSDs are often sold in smaller sizes.
- **Life expectancy:** Some SSDs, such as those based on NAND memory-flash chips, can only be written a limited number of times, which is often less than that of HDDs.
- **Performance:** SSDs' performance degrades over time due to write cycle limitations.

Disadvantages of SSD (Cont.)

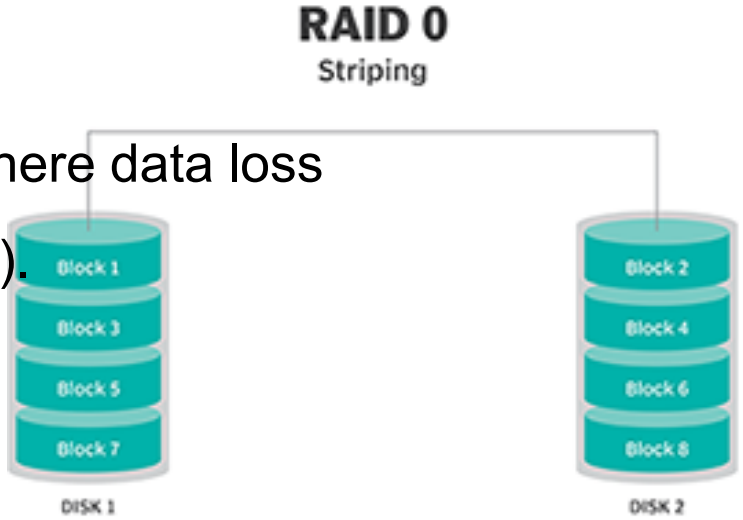
- Have characteristics that present challenges
- Read and written in “page” increments (think as sector) but can’t overwrite in place
- Must first be erased, and erases happen in larger ”block” increments
- Can only be erased a limited number of times before worn out – ~ 100,000
- SSD Life span measured in **Drive Writes Per Day (DWPD)**
  - A 1TB NAND drive with rating of 5DWPD is expected to have 5TB per day written within warrantee period without failing.

RAID

- **RAID** (Redundant Array of Independent Disks) a data storage virtualization technology that combines multiple physical hard drives (HDDs or SSDs) into a single logical unit.
- **Purpose:** Improve performance and reliability via redundancy.
- **RAID Levels:** RAID is implemented in different levels, each offering a balance of **speed**, **redundancy**, and **storage capacity**.

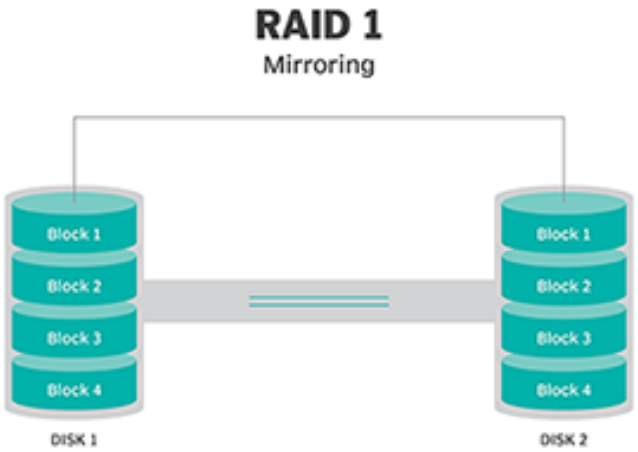
RAID 0 (Striping)

- **RAID 0 (Striping) – Performance Only**
- **How it Works**: Splits (stripes) data across multiple disks without redundancy.
- **Advantage**: **Fastest performance** (parallel read/write).
- **Disadvantage**: **No fault tolerance** (if one disk fails, all data is lost).
- **Use Case**: High-speed applications where data loss isn't critical (gaming, temporary storage).



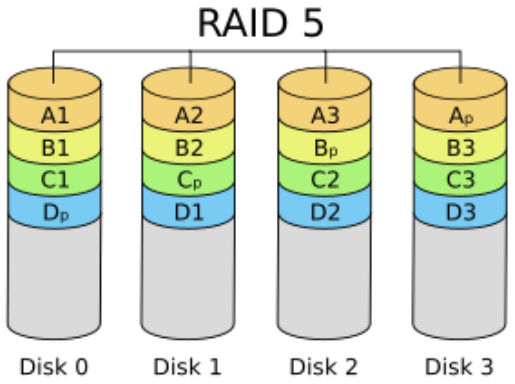
RAID 1 (Mirroring)

- **RAID 1 (Mirroring) – Data Redundancy**
- **How it Works**: Copies (mirrors) data onto two or more disks, providing redundancy but reducing storage efficiency.
- **Advantage**: **Complete redundancy** (one disk fails, data is safe).
- **Disadvantage**: **Storage capacity is halved** (e.g., 2 × 1TB = 1TB usable).
- **Use Case**: Critical data storage (databases, financial records).



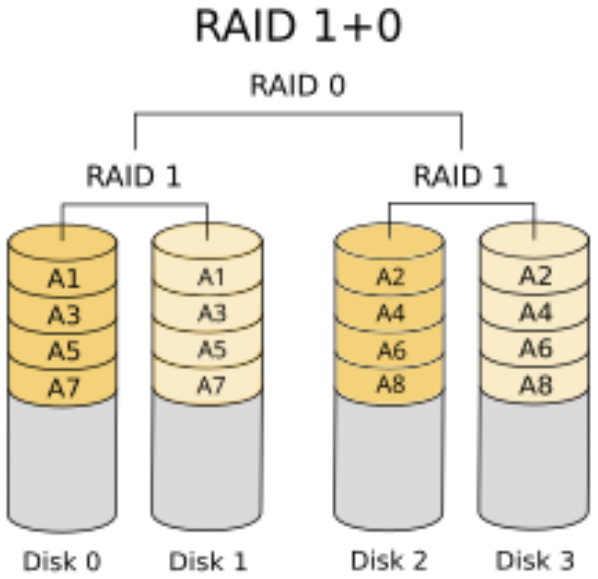
RAID 5

- **RAID 5 (Striping + Parity) – Performance + Fault Tolerance**
- **How it Works**:
  - Data is striped across disks, with an additional parity information for redundancy.
  - Balances performance and fault tolerance by distributing parity information across disks.
  - It require at least three disk.
  - Upon failure of a single drive, subsequent reads can be calculated from the parity with no data loss.
- **Advantage**: Can **tolerate one disk failure** without data loss.
- **Disadvantage**: **Rebuilding** after failure can be slow.
- **Use Case**: Balanced **speed, redundancy, and storage efficiency** (file servers, web hosting).



RAID 10

- **RAID 10 (Combination of RAID 1 and RAID 0):** Combines mirroring and striping for both speed and redundancy.
- **How it Works**: Combines **RAID 1 (mirroring) and RAID 0 (striping)**.
- **Advantage**: **High performance + redundancy** (fast and secure).
- **Disadvantage**: Requires **at least 4 disks** and halves usable storage.
- **Use Case**: **Critical applications** (databases, virtual machines)



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