Key points:

- Device Basics
  - Status, command, and data registers
  - Polling
  - Interrupts
    - livelock
    - coalescing
  - Programmed I/O
  - DMA
- Interaction:
  - I/O instructions
  - memory-mapped IO
- Device drivers
- Hard disk drives
  - Block device (read/write in terms of fixed-size units)
    - Array abstraction
    - Atomic sector writes
  - Internals
    - Rotates at fixed speed (e.g., 7200 RPM)
    - Has r/w head
    - Has > 1 platter
      - comprised of tracks (concentric circles)
      - each platter has 2 surface (top and bottom)
  - Zones
  - Caching
  - Skew
- Disk operations
  - Seek
  - Rotate
  - Transfer
- Estimating performance
  - IO time = seek time + rotation time + transfer time
- Types of IO:
  - Sequential IO
  - Random IO
- Disk Scheduling
  - shortest job first (SSTF, NBF)
  - Elevator scan
  - SPTF
Homework Questions/Problems:

1. What is a device driver? What does a generic protocol between the system and the device look like?
2. How does the device driver know how to signal an interrupt the OS when a task is done?
3. When are interrupts better than polling?
4. What is the common principle behind DMA and interrupts?
5. What are the three components of I/O delay? Which components dominate the cost of a read/write?
6. Why is a sequential write better than a random write? Would it be true if you could only do one block in a single write operation?
7. Will disk bandwidth be higher than outer zones or inner zones?
8. Assume a disk has bandwidth of 100 MB/s. How long will it take to transfer 1 GB?
9. Assume the disk can do 150 random IOs per second. How long will it taken to transfer 1 GB that is scattered all over the disk?
10. Assume the disk takes 10 ms on average to read/write a random block. How many IO operations can it do per second?
11. Assume the disk takes 6 ms to do any seek, and 2 ms for any rotation. The disk bandwidth is 100 MB/s. The track size is 10 MB. Estimate how long it will take to read 100 tracks in order.
12. The RPM of a drive is 15000. How long does it take to finish one complete rotation?
13. If the disk has a transfer rate of 100 MB/s, how long does it take to transfer 4096 bytes?
14. All the algorithms we discussed are greedy: they simply pick the next best option. Why do you think this is the case?

Chapter 37 includes a disk.py (at the end of the chapter) that allows you to solve many such problems. Check it out and use it for practice!