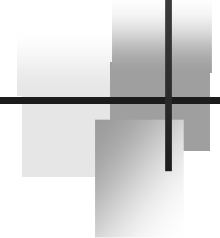


Device Management

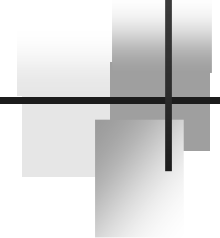
Taken from

Chapter 11, *Operating System Principles*, Bic and Shaw, 2003, Prentice Hall



Basic Issues

- I/O devices:
 - Communication devices
 - Input only (keyboard, mouse, joystick)
 - Output only (printer, display)
 - Input/output (network card)
 - Storage devices
 - Input/output (disk, tape)
 - Input only (CD-ROM)



Basic Issues

- Main tasks of I/O system:
 - Present logical (abstract) view of devices
 - Hide details of hardware interface
 - Hide error handling
 - Facilitate efficient use
 - Overlap CPU and I/O
 - Support sharing of devices
 - Protection when device is shared (disk)
 - Scheduling when exclusive access needed (printer)

A Hierarchical Model of I/O

Abstract I/O

interface:

Block devices,
character devices,
network

Device-independent

software:

Buffering,
scheduling, caching

Device-dependent

software:

I/O drivers
(supplied by device
manufacturer)

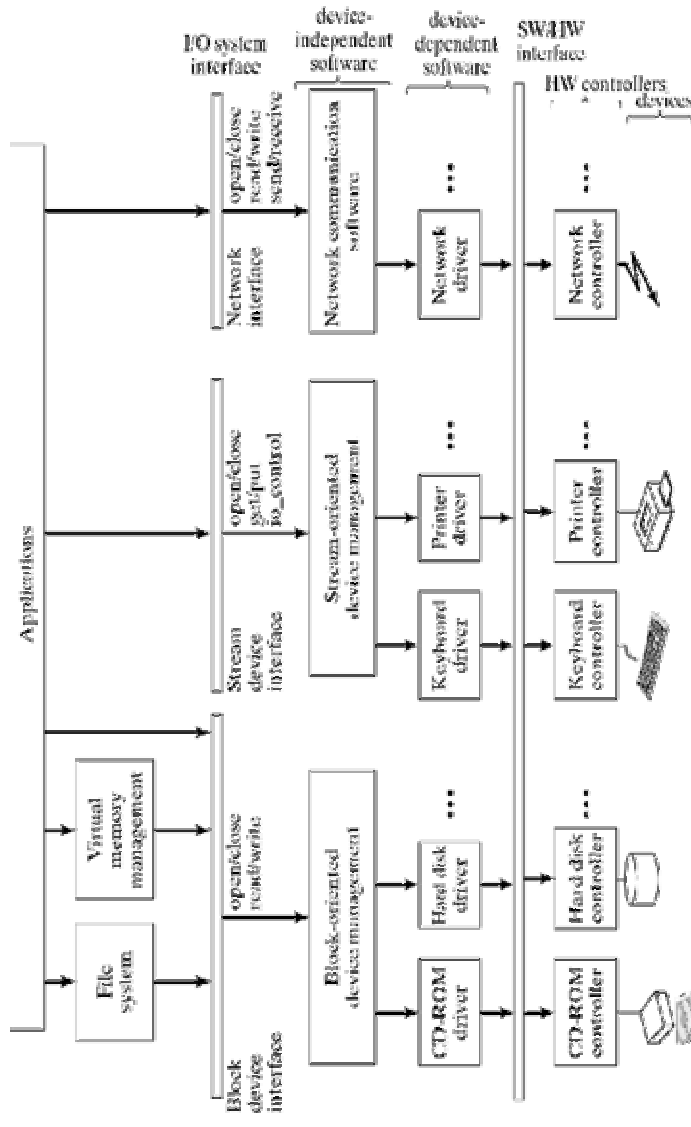
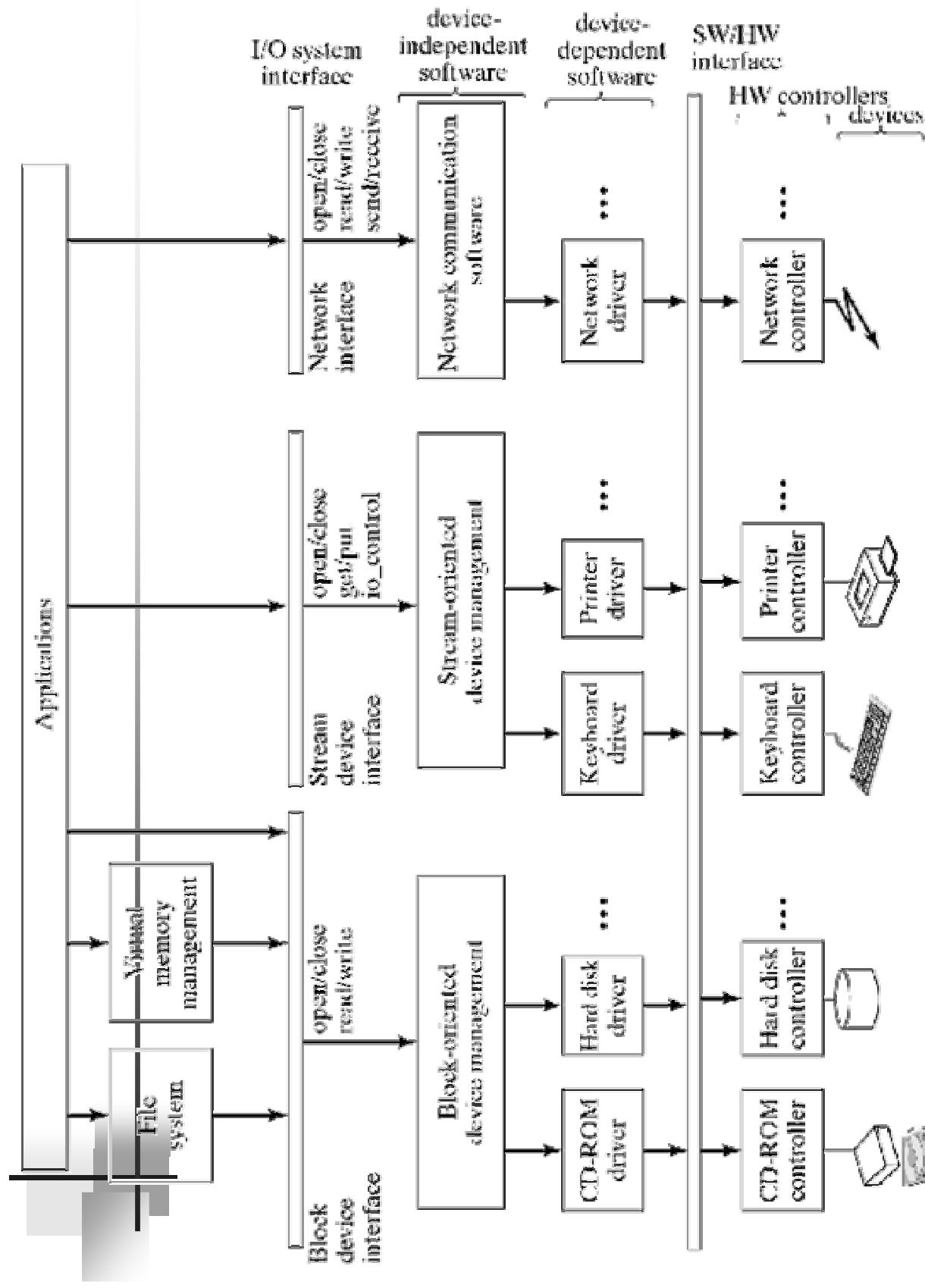


Figure 11-1



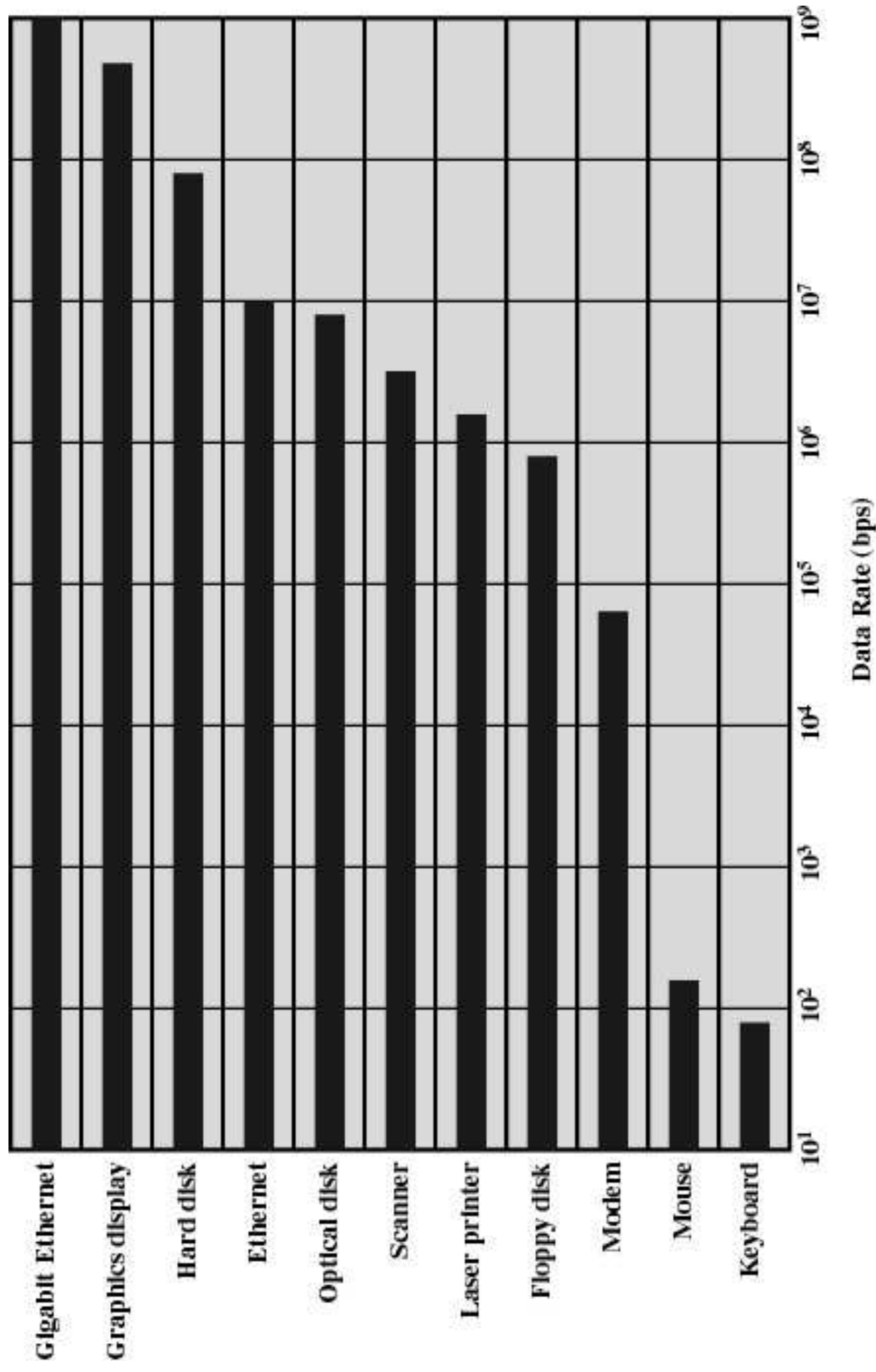
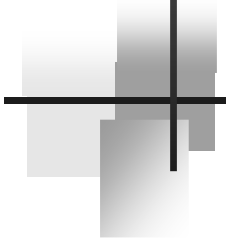


Figure 11.1 Typical I/O Device Data Rates



I/O System Interface

- Block-Oriented Device Interface
 - Operations: open, read, write, close
 - File System and Virtual Memory System
- Stream-Oriented Device Interface
 - = “character-device” interface
 - Operations: get, put
 - Also, open & close to reserve & to release
the exclusive access normally needed

(Tapes are both Block-Oriented and Stream-Oriented)
- Network Communications
 - Key abstraction: ***socket***
 - Protocols



I/O System Interface

- Block-Oriented Device Interface
- Stream-Oriented Device Interface
- Network Communications
 - Key abstraction: ***socket***
 - Protocols:
 - Connection-based (virtual circuits)
 - Connection-less (datagrams)
 - Operations: connect, accept, write/send, read/receive

I/O Devices

- Display monitors
 - Character or graphics oriented
 - Different data rates:
 - 25 x 80 characters
 - VS 800 x 600 x 256
 - 30-60 times/sec

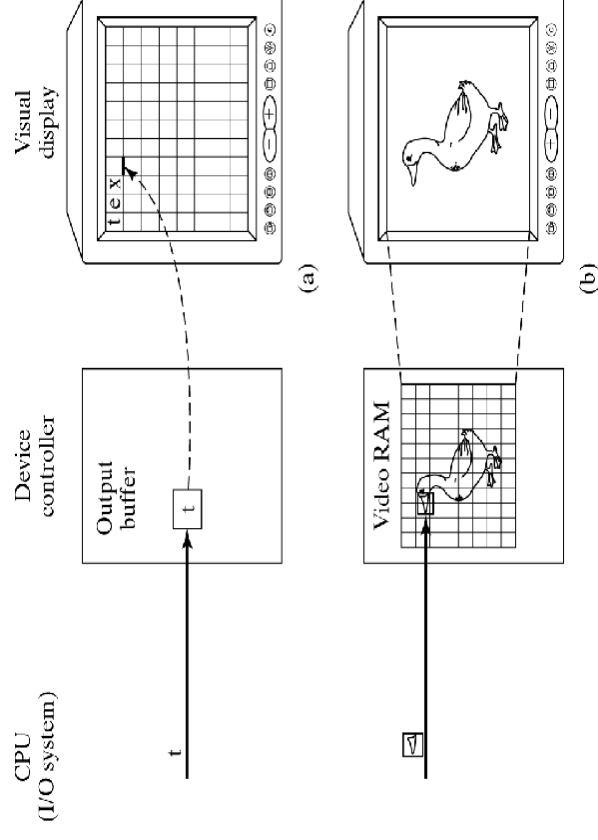
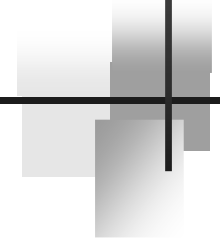


Figure 11-2



I/O Devices

- Keyboards
 - Most common: “**QWERTY**”
 - Very low data rate (<10 char/sec)
- Pointing devices
 - Mouse (optical, optical-mechanical)
 - Trackball
 - Joystick
 - Low data rate (hundreds of bytes/sec)



I/O Devices

- Printers
 - Line printers, dot-matrix, ink-jet, laser
 - Low data rates
 - Character-oriented
- Scanners
 - Digitize picture into bit map (similar to video RAM)
 - Low data rates

I/O Devices

- Floppy disks
 - Surface, tracks/surface, sectors/track, bytes/sector
 - All sectors numbered sequentially $0..(n-1)$
(physical location vs logical numbering)

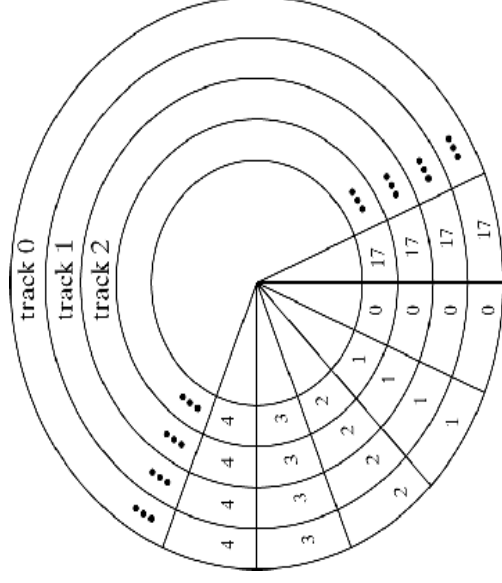


Figure 11-3(a) Physical

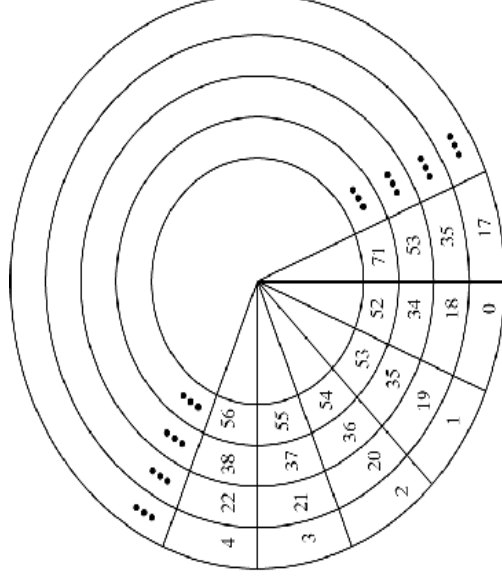


Figure 11-3(b) Logical

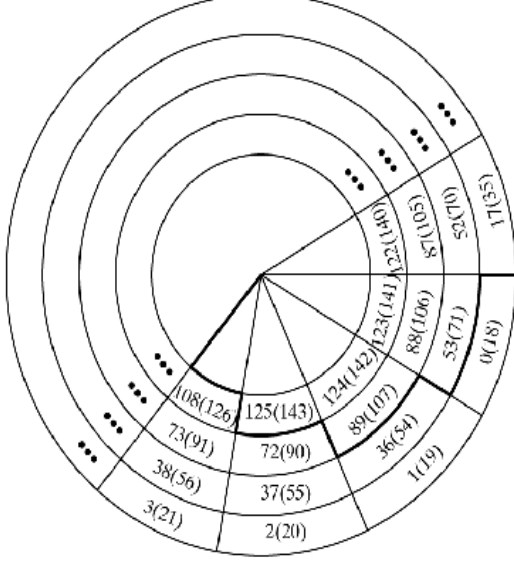
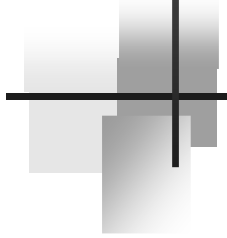


Figure 11-13(d)



I/O Devices

- Hard disks
 - Multiple surfaces
- Higher densities and data rates than floppy

	floppy	hard disk
bytes/sec	512	512-4096
sec/track	9,15,18, 36	100-400
tracks/surf	40, 80,160	1000-10,000
# surf	1-2	2-24
seek	30-100 ms	5-12 ms
rotation	400-700 rpm	3600-10,000 rpm

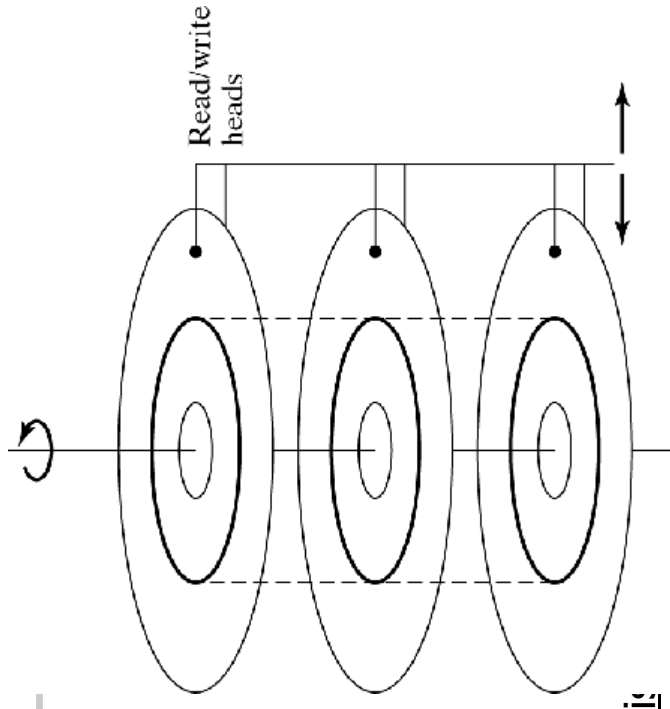
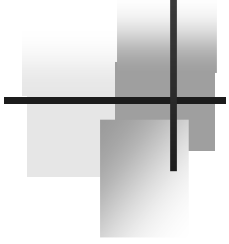
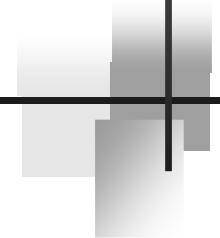


Figure 11-4



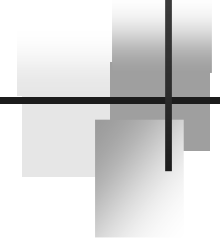
I/O Devices

- Optical disks
 - CD-ROM, CD-R (WORM), CD-RW
 - Originally designed for music
 - Data stored as continuous spiral, subdivided into sectors
 - Constant linear speed (200-530 rpm)
 - Higher storage capacity than magnetic disks:
0.66 GB/surface



I/O Devices

- Data transfer rates of disks
 - Sustained: continuous data delivery
 - Peek: transfer once read/write head is in place
 - Depends on rotation speed and data density
 - 1 revolution passes over all sectors of 1 track
 - Example: 7200 rpm, 100 sect/track, 512 B/sect
 - 7200 rpm: $60,000/7200 = 8.3$ ms/rev
 - $8.3/100 = 0.083$ ms/sector
 - 512 bytes transferred in 0.083 ms: $\sim 6\text{MB/s}$



I/O Devices

- Magnetic tapes (reel or cartridge)
 - Large storage capacity (GB)
 - Data transfer rate: ~ 2 MB/sec
- Networks (interface card)
 - Ethernet, token ring, slotted ring
 - Controller implements protocol to accept, transmit, receive packets
 - Modem
 - Convert between analog and digital (phone lines)
 - Character-oriented (like printer and keyboard)

Device Drivers

- Accept command from application
 - get/put character, read/write block, send/receive packet
- Interact with (hardware) device controller to carry out command
- Typical device controller interface: set of registers
- Example: serial or parallel port on PC
 - Generic driver reads/writes characters to registers

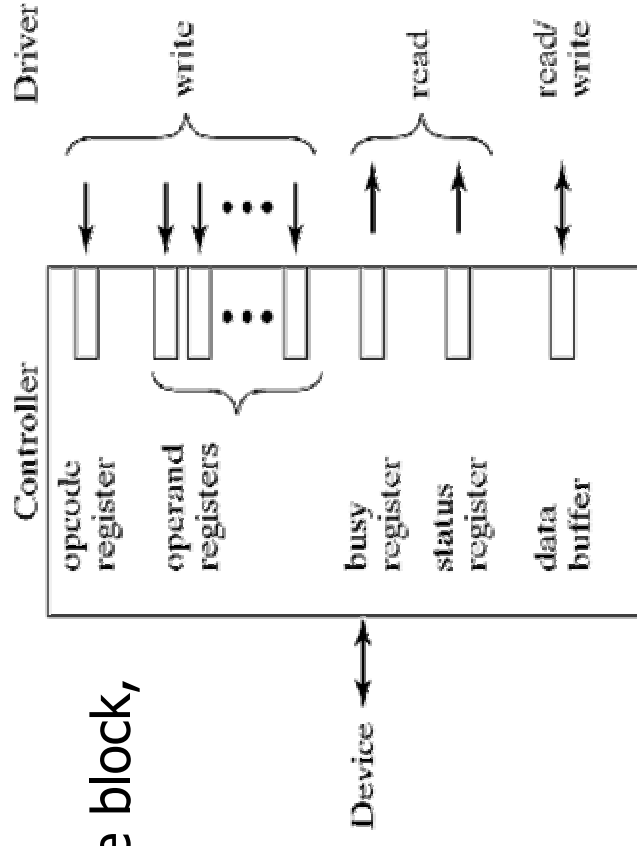
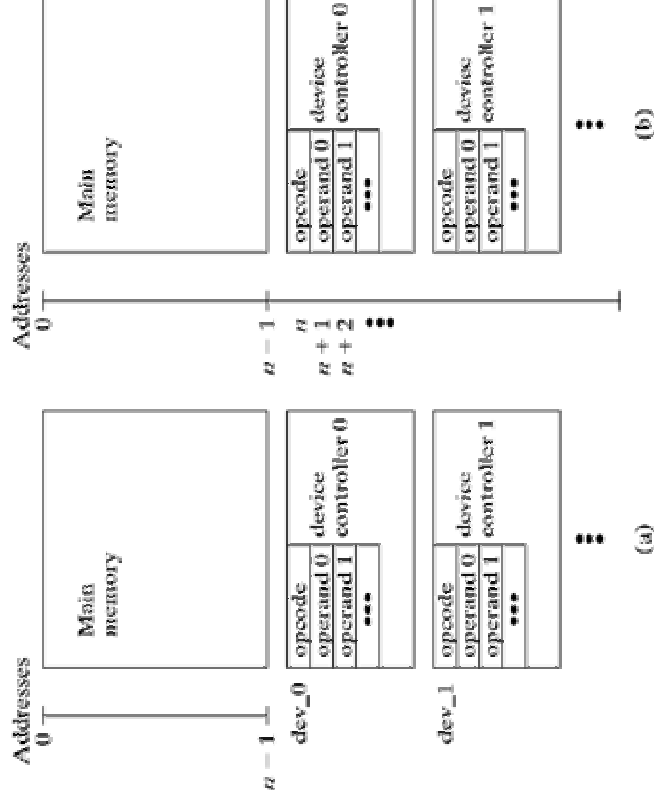


Figure 11-6

Device Drivers

- Memory-mapped vs Explicit device interface

- Similar idea to memory-mapped files



- Explicit: Special I/O instruction:

io_store cpu_reg, dev_no, dev_reg

- Memory-mapped: Regular CPU instruction:

store cpu_reg, n (n is a memory address)

Figure 11-7

Programmed I/O with Polling

- CPU is responsible for
 - Moving every character to/from controller buffer
 - Detecting when I/O operation completed
- Protocol to input a character:

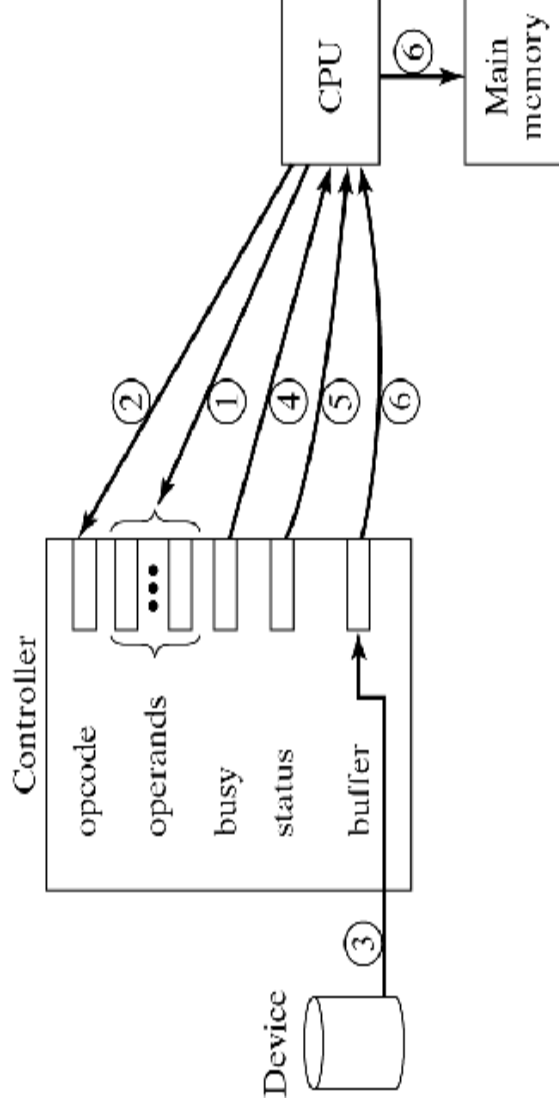


Figure 11-8

Programmed I/O with Polling

- Driver operation to input sequence of characters

```
i = 0;
do { write_reg(opcode, read);
    while (busy_flag == true) {...};
    mm_in_area[i] = data_buffer;
    increment i;
    compute;
} while (...)
```

Programmed I/O with Polling

- What to do while waiting?
 - Idle (busy wait)
 - Some other computation
 - How frequently to poll?
 - Give up CPU
 - Device may remain unused for a long time

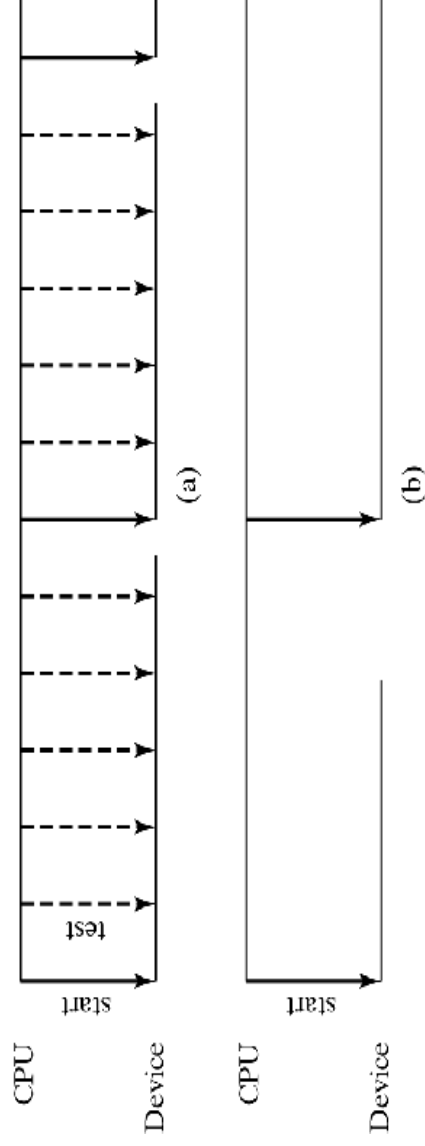


Figure 11-9

Programmed I/O with Interrupts

- CPU is responsible for
 - Moving characters to/from controller buffer, but
- Interrupt signal informs CPU when I/O operation completes
- Protocol to input a character:

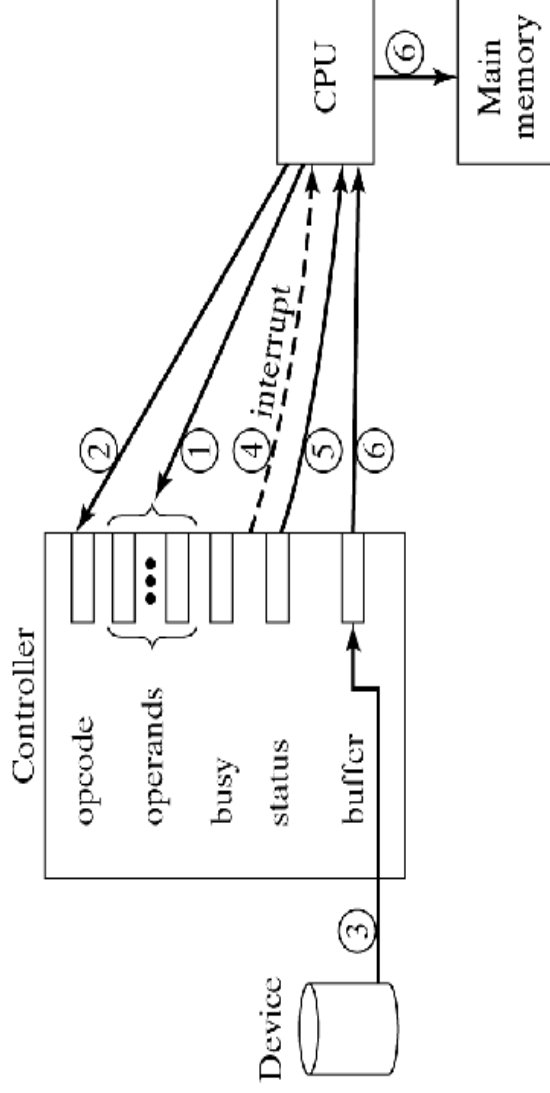


Figure 11-10

Programmed I/O with Interrupts

Compare Polling with Interrupts:

```
i = 0;
do { write_reg(opcode, read);
⇒⇒ while (busy_flag == true) {...};
    mm_in_area[i] = data_buffer;
    increment i;
    compute;
} while (...)
```

```
i = 0;
do { write_reg(opcode, read);
⇒⇒ block to wait for interrupt;
    mm_in_area[i] = data_buffer;
    increment i;
    compute;
} while (...)
```


DMA

- CPU only initiates operation
- DMA controller transfers data directly to/from main memory
- Interrupt when transfer completed
- Protocol to input data using DMA:

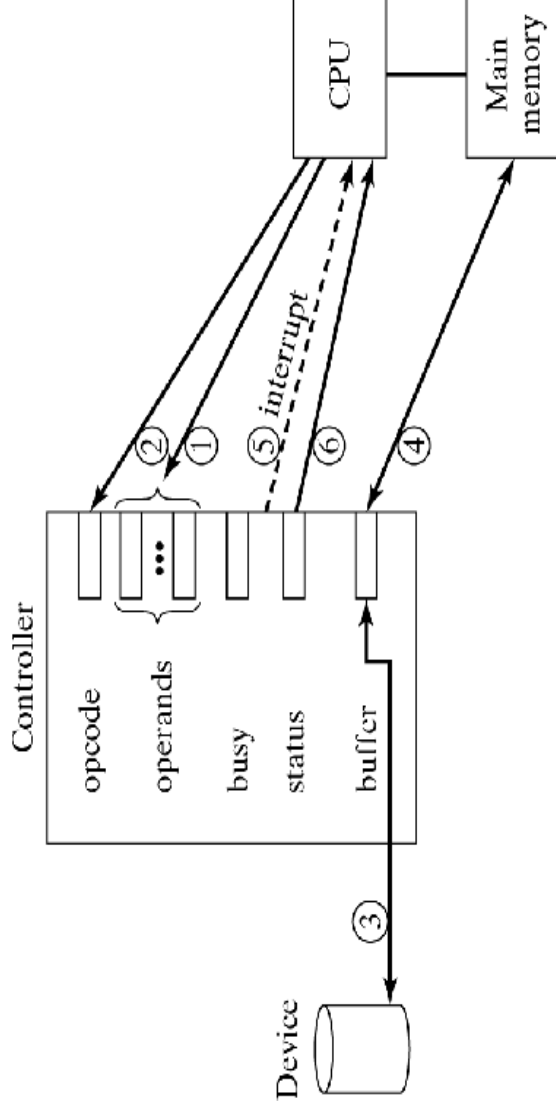


Figure 11-12

DMA

- Driver operation to input sequence of characters

```
write_reg(mm_buf, m);
write_reg(count, n);
write_reg(opcode, read);
block to wait for interrupt;
```
- Writing opcode triggers DMA controller
- DMA controller issues interrupt after n chars in memory
- I/O processor (channel)
 - Extended DMA controller
 - Executes I/O program in own memory

Device Management

- Device-independent techniques
- Reasons for buffering
 - Allows asynchronous operation of producers and consumers
 - Allows different granularities of data
 - Consumer or producer can be swapped out while waiting for buffer fill/empty

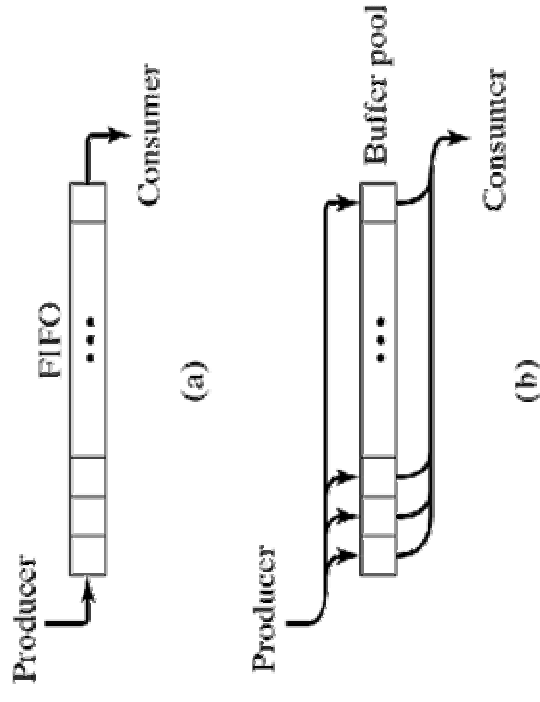


Figure 11-13

Device Management

- Single buffer operation
- Double buffer (buffer swapping)
 - Increases overlap
 - Ideal when: time to fill = time to empty = constant
 - When times differ, benefits diminish

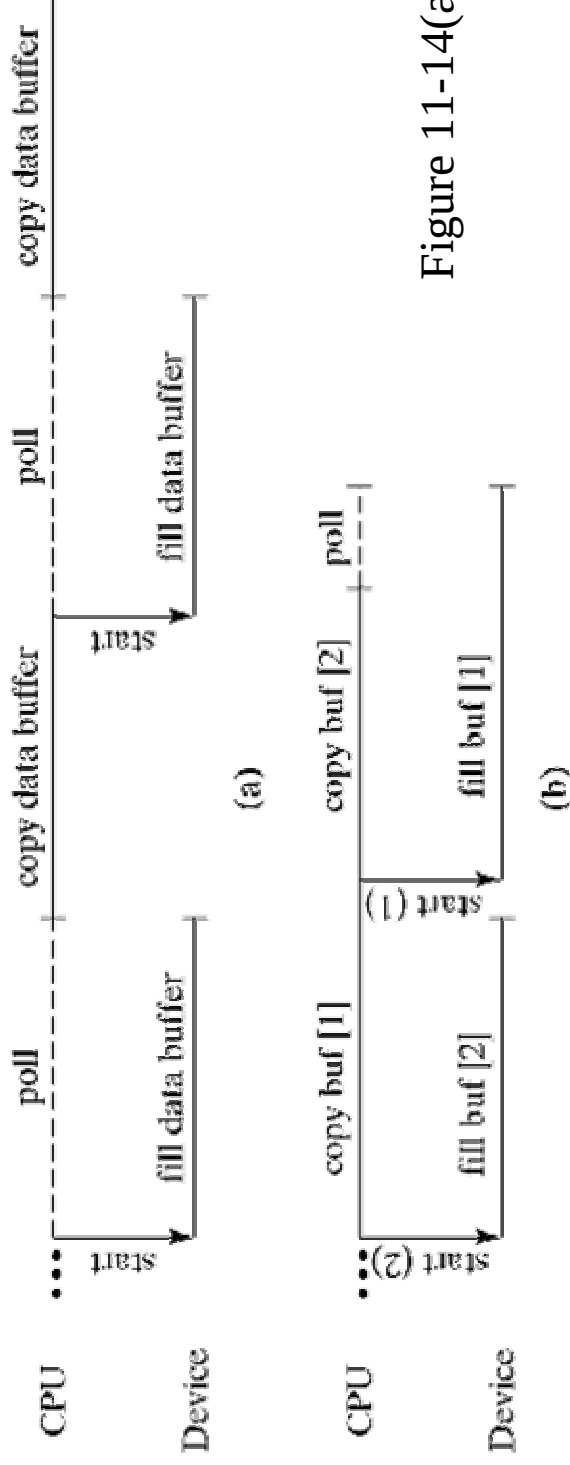
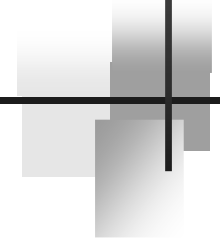
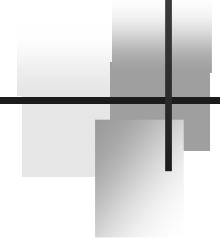


Figure 11-14(a,b)



Device Management

- Circular Buffer
 - When average times to fill and empty are comparable but vary over time: circular buffer absorbs bursts
 - Producer and consumer each use an index
 - **nextin** gives position of next input
 - **nextout** gives position of next output
 - Both are incremented modulo ***n*** at end of operation
- Buffer Queue
 - Variable size buffer for more efficient use of memory
 - Depends on linked data structures and dynamic memory management. More (CPU) time consuming.
- Buffer Cache: pool of buffers for repeated access

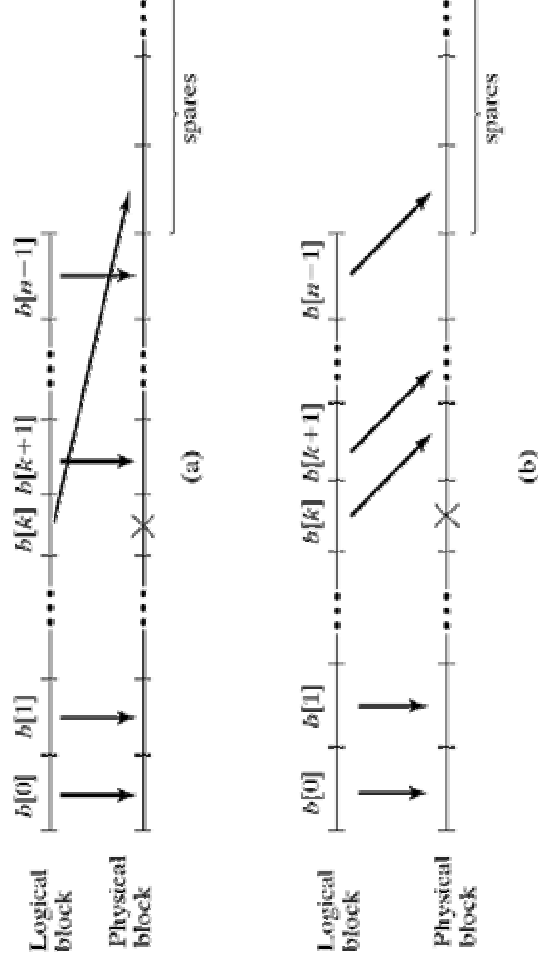


Device Management

- Error handling
 - Persistent *vs* Transient, SW *vs* HW
 - Persistent SW error
 - Repair/reinstall program
 - Other errors: Build in defense mechanisms
 - Examples:
 - Transient SW errors:
 - Error correcting codes, retransmission
 - Transient HW errors:
 - Retry disk seek/read/write
 - Persistent HW errors:
 - Redundancy in storage media

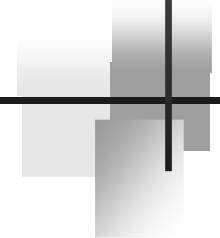
Device Management

- Bad block detection and handling
 - Block may be defective as a manufacturing fault or during use (a common problem)
 - Parity bit is used to detect faulty block
 - The controller bypasses faulty block by renumbering
 - A spare block is used instead
 - Two possible remappings:



- More work but contiguity of allocation preserved

Figure 11-17



Device Management

- Stable storage
 - Some applications cannot tolerate any loss of data (even temporarily)
 - Stable storage protocols:
 - Use 2 independent disks, A and B
 - Write: write to A; if successful, write to B
 - Read: read from A and B; if A!=B, go to Recovery
 - Recovery from Media Failure: A or B contains correct data; remap failed disk block
 - Recovery from Crash: if before writing A, B is correct; if after writing A, A is correct; recover from whichever is correct

Device Management

- RAID (Redundant Array of Independent Disks)

- Increased performance through parallel access
- Increased reliability through redundant data
- Maintain exact replicas of all disks
 - Most reliable but wasteful
- Maintain only partial recovery information
 - (e.g. error correcting codes)

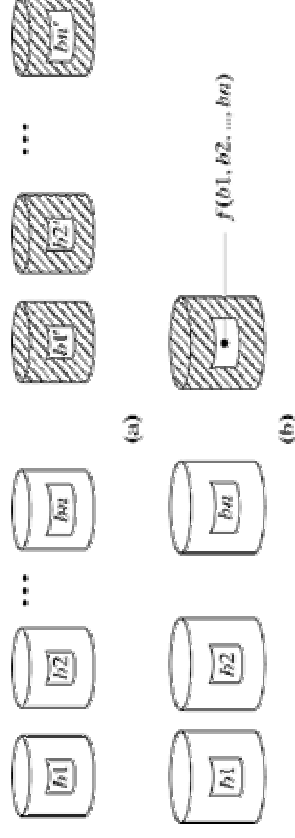
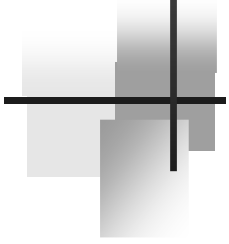


Figure 11-19



Device Management

- Disk Scheduling
 - Minimize seek time and rotational delay
 - Requests from different processes arrive concurrently:
 - Scheduler must attempt to preserve locality
 - Rotational delay:
 - Order requests to blocks on each track in the direction of rotation: access in one rotation
 - Proceed with next track on same cylinder

Device Management

- Minimizing seek time: more difficult
 - Read/write arm can move in two directions
 - Minimize total travel distance
 - Guarantee fairness
 - FIFO: simple, fair, but inefficient
 - SSTF: most efficient but prone to starvation
 - (Elevator) Scan: fair, acceptable performance

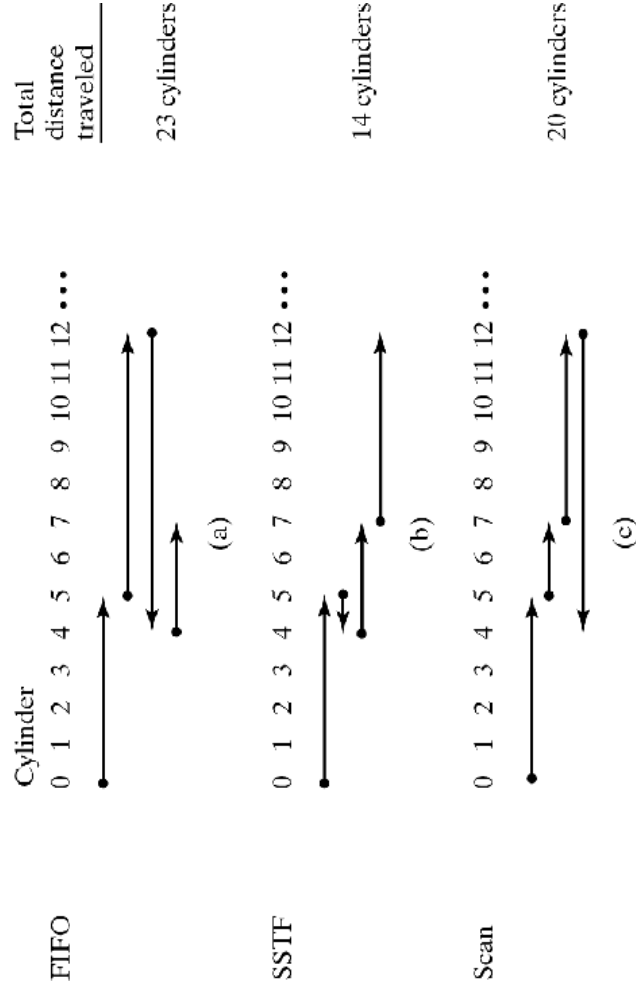


Figure 11-20