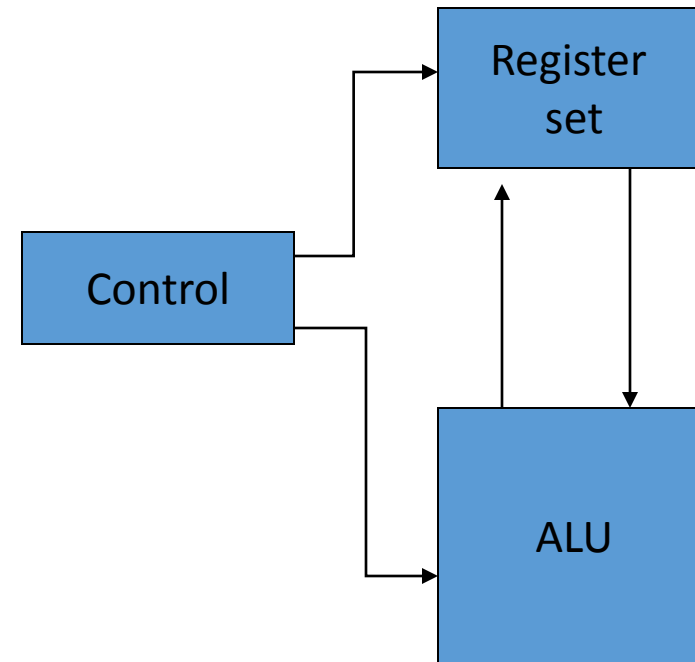


Central Processing Unit & Memory Hierarchy

Introduction: Central Processing Unit

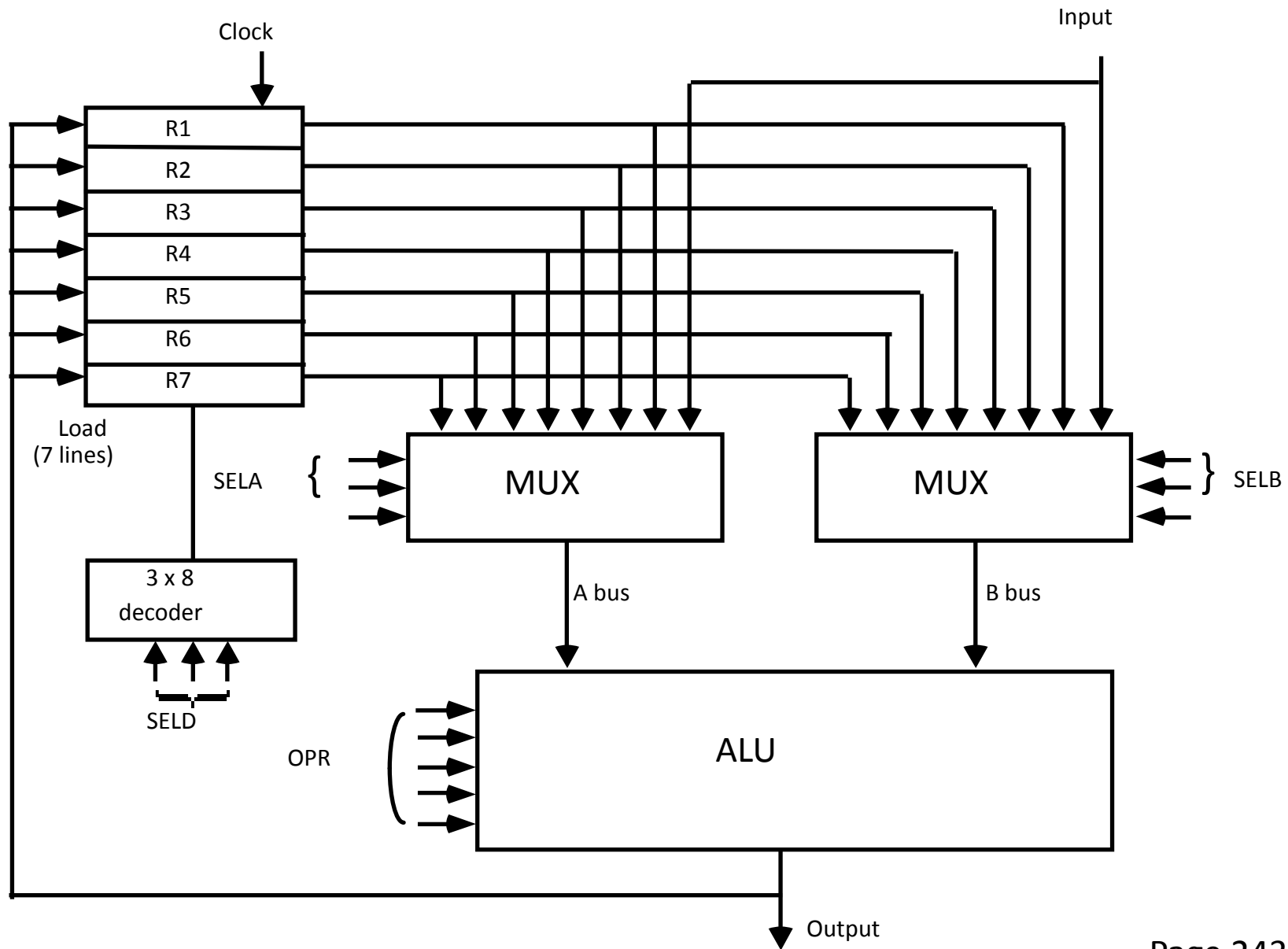
- The part of the computer that performs the bulk of data processing operations is called the central processing unit and is referred to as CPU.
- The **registers set** stores intermediate data used during the execution of the instructions
- The **ALU** performs the required micro operations for executing the instructions.
- The **Control unit** supervises the transfer of information among the registers and instructs the ALU as to which operation to perform.



Major Components of CPU

GENERAL REGISTER ORGANIZATION

- Memory locations are needed for storing pointers, Return addresses etc.
 - Referring to memory locations for such applications is time consuming because memory access is most time consuming operation in computer.
 - So, it is more convenient and efficient to store these intermediate values in processor registers
 - When large number of registers are included in the CPU it is efficient to connect them through common bus system.
 - Because registers communicate with each other not only for direct data transfers, but also while performing various microoperations
- **What is BUS**
 - Digital computers have many registers and path must be provided to transfer information from one register to another.
 - No. of wires will be excessive if separate lines are used between each register. Most efficient way is to have Common bus system.
 - Bus structure consists of a set of common lines, one for each bit of registers, through which binary information is transferred one at a time.
 - Control signals determine which register is selected by the bus during each particular register transfer



- **General Register Organization:—**

- When a large number of registers are included in the CPU, it is most efficient to connect them through a common bus system. The registers communicate with each other not only for direct data transfers, but also while performing various micro-operations. Hence it is necessary to provide a common unit that can perform all the arithmetic, logic and shift micro-operation in the processor.

- **A Bus organization for seven CPU registers:—**
- **Reference Diagram: Page Number 243 by M Morris Mano**
- The output of each register is connected to true multiplexer (mux) to form the two buses A & B. The selection lines in each multiplexer select one register or the input data for the particular bus. The A and B buses forms the input to a common ALU. The operation selected in the ALU determines the arithmetic or logic micro-operation that is to be performed. The result of the micro-operation is available for output and also goes into the inputs of the registers. The register that receives the information from the output bus is selected by a decoder. The decoder activates one of the register load inputs, thus providing a transfer both between the data in the output bus and the inputs of the selected destination register.
- The control unit that operates the CPU bus system directs the information flow through the registers and ALU by selecting the various components in the systems.
- $R1 \rightarrow R2 + R3$
- (1) MUX A selection (SEC A): to place the content of R2 into bus A
- (2) MUX B selection (sec B): to place the content of R3 into bus B
- (3) ALU operation selection (OPR): to provide the arithmetic addition ($A + B$)
- (4) Decoder destination selection (SEC D): to transfer the content of the output bus into R1
- These form the control selection variables are generated in the control unit and must be available at the beginning of a clock cycle.

ALU

- **Arithmetic:**
- Addition, Subtraction, Multiplication, Division
- **Logic:**
- Comparisons

Control Unit

- Reads & Interprets Program Instructions
- Directs the Operation of the Processor
- Controls the flow of programs and data into and out of memory

- CU consists of two decoders, a counter and a number of ctrl logic gates.
- An instruction read from memory is placed in instruction register (IR) where it is divided into three parts:
 - I bit
 - Opcode
 - 0-11 bits ----
- Operation code in bits 12 thru 14 are decoded with a 3*8 decoder

Central Processing Unit

- Machine Cycle
 - Fetch
 - Decode
 - Execute
 - Store
- Fetch
 - Calls an instruction into memory
 - Decode
 - Figures out what the instruction is trying to do
 - Execute
 - Does the decoded instruction
 - Add 2+2
 - Store
 - Puts the answer 4 into memory for use by another instruction

Memory

- Memory unit is needed for storing programs and data.
- Memory units that communicate directly with CPU is called MAIN MEMORY
- Devices that provide backup storage is called auxiliary memory
- Most common auxiliary memory is magnetic disks and magnetic tapes. They are used for storing programs, large data files, and other backup information.
- Only programs and data that are currently needed by the processor will reside in main memory
- All other information is stored in auxiliary memory and transferred to main memory when needed

- **Auxiliary memory**

- Slow
- High Capacity



- **Main memory**

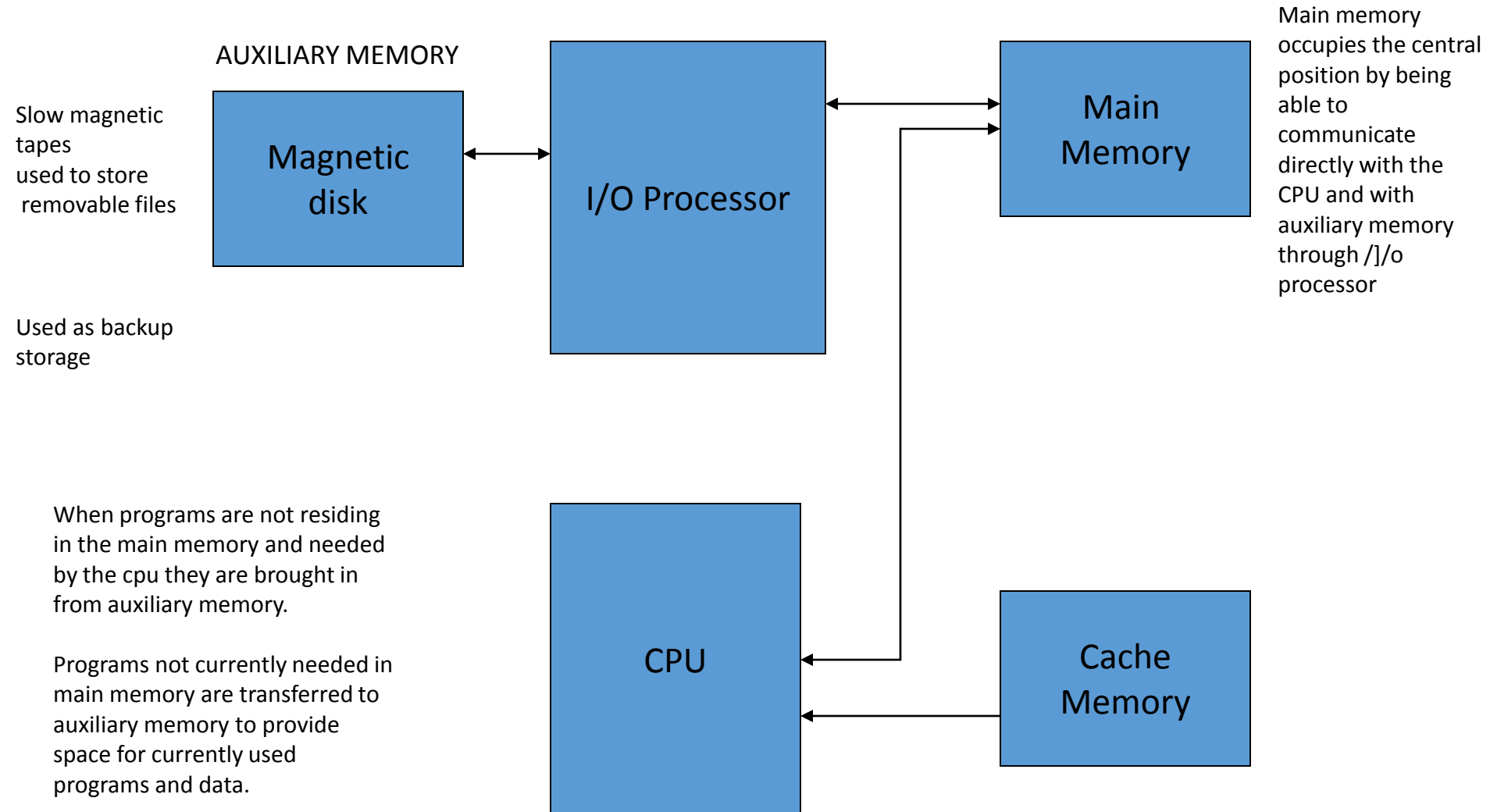
- Small but relatively faster than auxiliary **memory**



Cache memory

Smaller and faster

Memory hierarchy in computer system



CACHE MEMORY

- a special very high speed memory called is sometimes used to increase the speed of the processing by making current programs and data available to the CPU at the rapid rate.
- The cache memory is employed in computer systems to compensate the speed differential between main memory access time and logic.
- CPU logic is usually faster than main memory access time, with the result that processing speed is limited primarily by the speed of the main memory.
- A Technique used to compensate for the mismatch in operating speeds is to employ an extremely fast, small cache between the CPU and main memory whose access time is close to processor logic clock cycle time.
- The cache is used for storing segments of programs currently being executed in the CPU and temporary data frequently needed in the present calculations
- By doing this the performance rate of the computer also increases

Main Memory / Primary Memory units

- **RAM (Random Access Memory)**
- **ROM (Read-only Memory)**
- – They work in different ways and perform distinct functions
- – CPU Registers
- – Cache Memory
- • Also termed as 'auxiliary' or 'backup' storage, it is typically used as a
- supplement to main storage. It is much cheaper than the main storage and
- stores large amount of data and instructions permanently. Hardware devices
- like magnetic tapes and disks fall under this category.

Secondary Memory/Auxiliary Memory

- Also termed as 'auxiliary' or 'backup' storage, it is typically used as a supplement to main storage.
- It is much cheaper than the main storage and stores large amount of data and instructions permanently.
- Hardware devices like magnetic tapes and disks fall under this category

Random Access Memory

- RAM or Random Access Memory is the central storage unit in a computer system.
- It is the place in a computer where the operating system, application programs and the data in current use are kept temporarily so that they can be accessed by the computer's processor.
- The more RAM a computer has, the more data a computer can manipulate.
- Random access memory, also called the Read/Write memory, is the temporary memory of a computer.
- It is said to be 'volatile' since its contents are accessible only as long as the computer is on.
- The contents of RAM are cleared once the computer is turned off.
- Types of RAM
 1. STATIC RAM
 2. DYNAMIC RAM
- **STATIC RAM:** CONSISTS OF INTERNAL FLIP FLOPS THAT STORES THE BINARY INFORMATION . The stored information remains valid as long as the power is applied to the unit.
- **DYNAMIC RAM:** stores the binary information in the form of electric charges that are applied to the capacitors. (capacitors are attached to transistors) The capacitors are provided by the inside the chip by the MOS (metal oxide transistor) transistors. The stored charge on the capacitors tend to discharge with time and the capacitors must be periodically recharged by refreshing the dynamic memory.
- Static memory is easy to use.

ROM

- ROM or Read Only Memory is a special type of memory which can only be read and contents of which are not lost even when the computer is switched off.
- It typically contains manufacturer's instructions.
- Among other things, ROM also stores an initial program called the '**bootstrap loader**' whose function is to start the computer software operating, once the power is turned on.
- Contents of ROM remains unchanged after the power is turned off and on again.
- Read-only memories can be manufacturer-programmed or user-programmed.
- **PROM**
 - While **manufacturer-programmed** ROMs have data burnt into the circuitry, **user programmed** ROMs can have the user load and then store read-only programs.
- **EPROM**
 - Information once stored on the ROM or PROM chip cannot be altered. However, another type of memory called EPROM (Erasable PROM) allows a user to erase the information stored on the chip and reprogram it with new information.

ROM Types

- PROM
 - EPROM
 - EEPROM
-
- Each type has unique characteristics, but they are all types of memory with two things in common:
 - Data stored in these chips is nonvolatile -- it is not lost when power is removed.
 - Data stored in these chips is either unchangeable or requires a special operation to change (unlike RAM, which can be changed as easily as it is read).

- ROM chips are fundamentally different from RAM chips. While RAM uses [transistors](#) to turn on or off access to a [capacitor](#) at each intersection, ROM uses a **diode**

AUXILIARY MEMORY

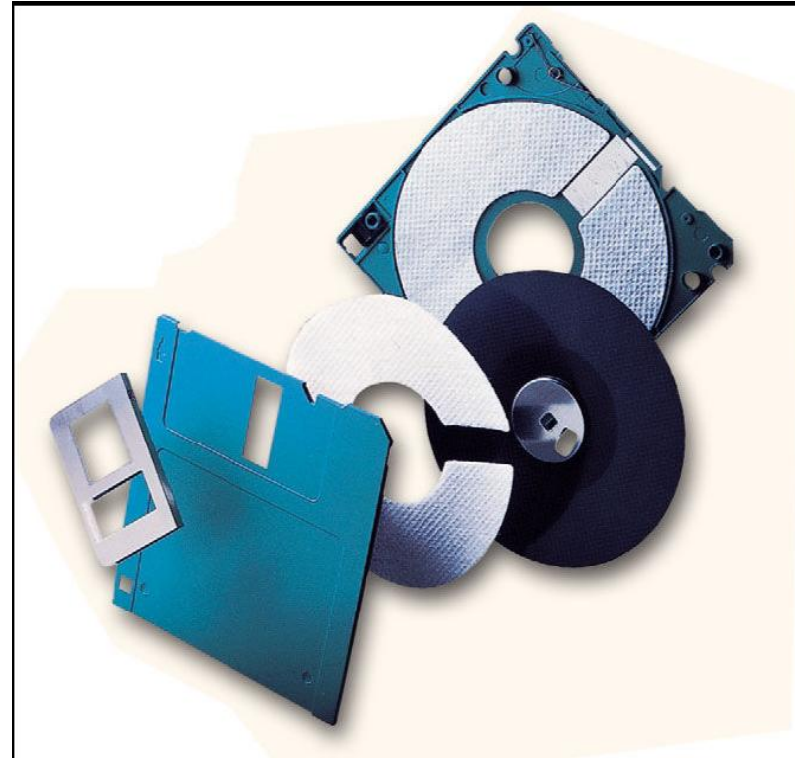
- RAM is volatile memory having a limited storage capacity.
Secondary/auxiliary storage is storage other than the RAM.
- These include devices that are peripheral and are connected and controlled by the computer to enable permanent storage of programs and data.
- The memory is specifically meaning the RAM. This keeps the information for a shorter period of time (usually volatile), is faster and more expensive.
- By Storage we mean the Hard disk. Here the information is retained longer (nonvolatile), It's Slower and Cheaper

Auxiliary Storage Devices-Magnetic Tape, Floppy Disk, Hard Disk.

- The Magnetic Storage Exploits duality of magnetism and electricity. It converts electrical signals into magnetic charges, captures magnetic charge on a storage medium and then later regenerates electrical current from stored magnetic charge. Polarity of magnetic charge represents bit values zero and one.
- **Magnetic Disk**
- The Magnetic Disk is Flat, circular platter with metallic coating that is rotated beneath read/write heads. It is a Random access device; read/write head can be moved to any location on the platter.

Floppy Disk

- These are small removable disks that are plastic coated with magnetic recording material. Floppy disks are typically 3.5" in size (diameter) and can hold 1.44 MB of data. This portable storage device is a rewritable media and can be reused a number of times.
- Floppy disks are commonly used to move files between different computers. The main disadvantage of floppy disks is that they can be damaged easily and, therefore, are not very reliable.



HARD DISK

- Another form of auxiliary storage is a hard disk. A hard disk consists of one or more rigid metal plates coated with a metal oxide material that allows data to be magnetically recorded on the surface of the platters.
- The hard disk platters spin at a high rate of speed, typically 5400 to 7200 revolutions per minute (RPM).
- Storage capacities of hard disks for personal computers range from 10 GB to 120 GB (one billion bytes are called a gigabyte).



Optical Drives

- CD's (Compact Disk)
- Their storage:
- ~ 700 MB storage
- Their Types:
 - – CD-ROM (read only)
 - – CD-R: (record) to a CD
 - – CD-RW: can write and erase CD to reuse it (re-writable)
 - – DVD(Digital Video Disk)

Assignment

- Explain CPU and its architecture.
- Explain memory hierarchy.