# Memory

Main memory consists of a number of storage locations, each of which is identified by a **unique address**

Each location stores a **word** i.e. the number of bits that can be processed by the CPU in a single operation. **Word length** may be typically 16, 24, 32 or as many as 64 bits.
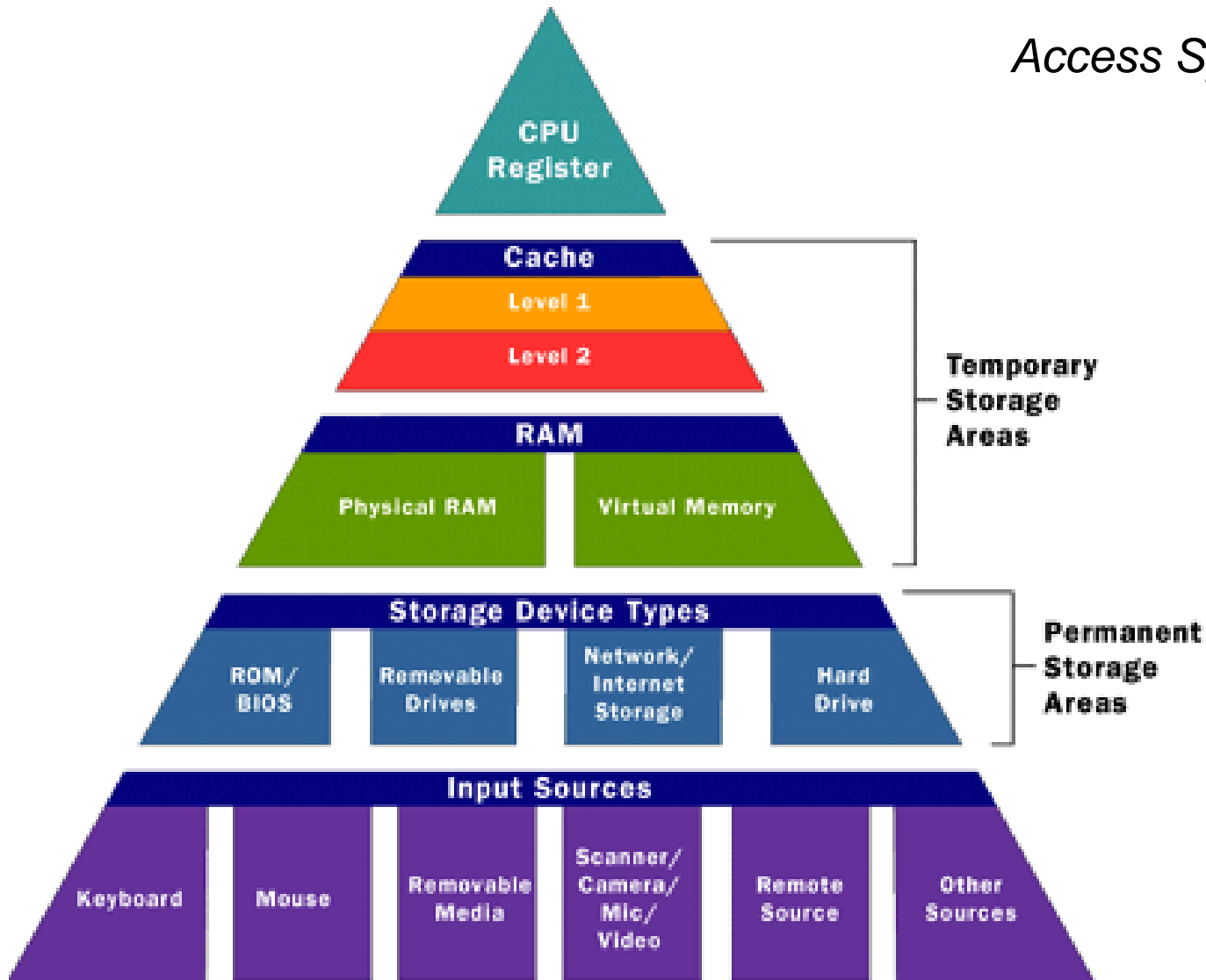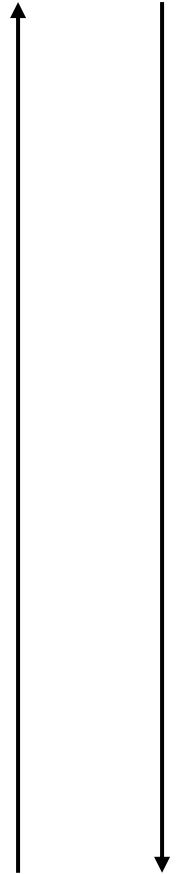
A large word length **improves system performance**, though may be less efficient on occasions when the full word length is not used

# Memory Hierarchy



*Cost/Bit*

*Access Speed*

**CPU Register**

**Cache**
Level 1
Level 2

Temporary Storage Areas

**RAM**
Physical RAM | Virtual Memory

**Storage Device Types**
ROM/ BIOS | Removable Drives | Network/ Internet Storage | Hard Drive

Permanent Storage Areas

**Input Sources**
Keyboard | Mouse | Removable Media | Scanner/ Camera/ Mic/ Video | Remote Source | Other Sources
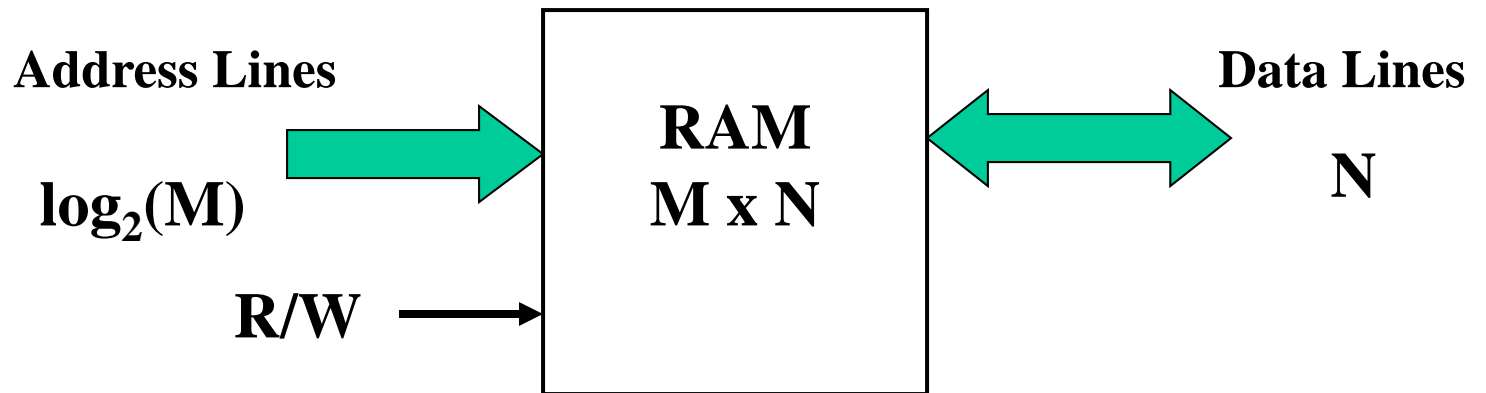
*Capacity*

# Types of main memory

There are two types of main memory, **Random Access Memory** (RAM) and **Read Only Memory** (ROM)

**Random Access Memory (RAM)**

✓ holds its data as long as the computer is switched on

✓ All data in RAM is lost when the computer is switched off

✓ Described as being **volatile**

✓ It is **direct access** as it can be both written to or read from in any order

Its purpose is to temporarily hold programs and data for processing.  In modern computers it also holds the **operating system**

# Block diagram of RAM

**Address Lines**

$\log_2(\text{M})$

**R/W**

**RAM M x N**

**Data Lines**

**N**

Where **M** locations and **N** bits per location

# Types of RAM

**1. Dynamic Random Access Memory** (DRAM)

- Contents are constantly refreshed 1000 times per second
- The memory cell of DRAM created by one transistor + capacitor (per bit)
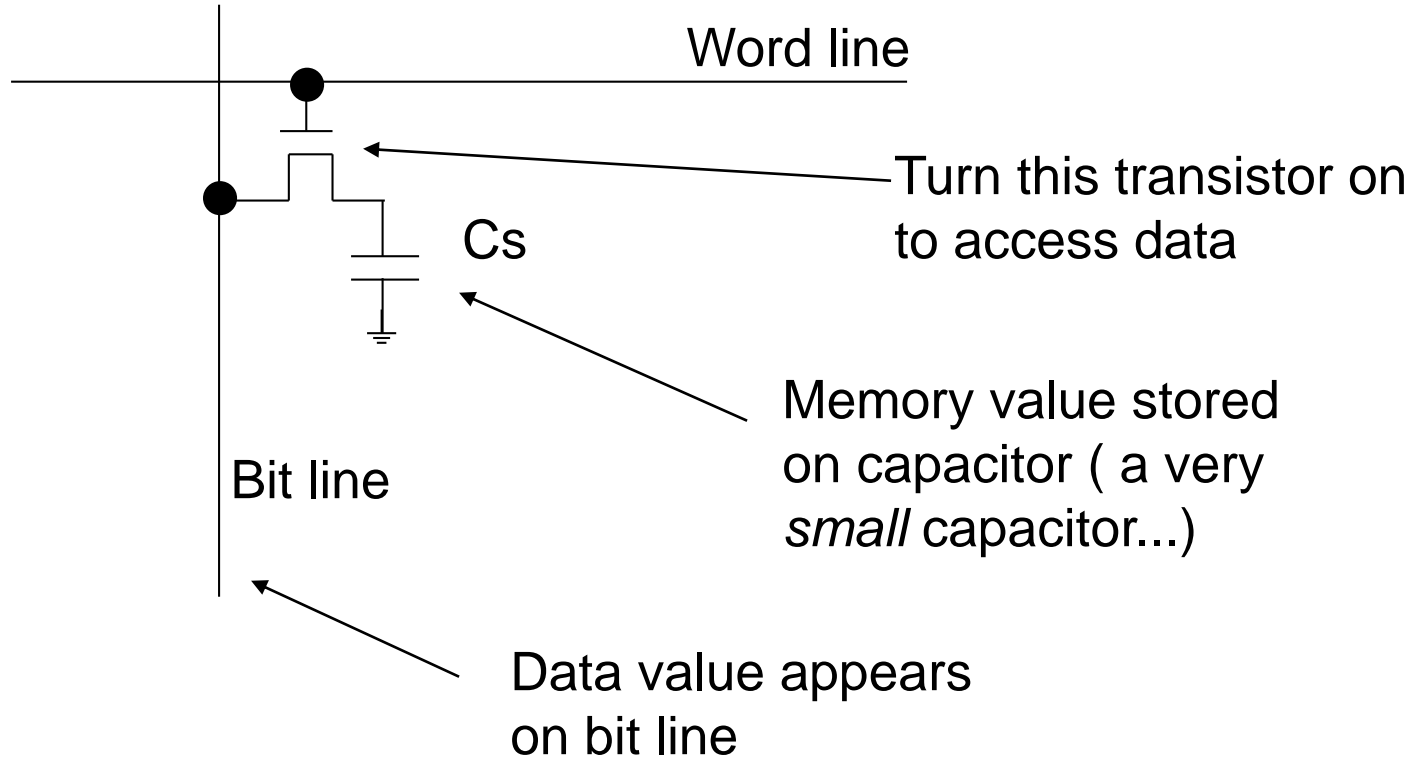
- Access time 60 – 70 nanoseconds

**2. Synchronous Dynamic Random Access Memory** (SDRAM)

- Faster than DRAM

- Access time less than 60 nanoseconds

**3. Direct Rambus Dynamic Random Access Memory** (DRDRAM)

- New type of RAM architecture

- Access time 20 times faster than DRAM

- More expensive

# DRAM Memory Cell

Word line

$C_s$

Turn this transistor on
to access data

Memory value stored
on capacitor ( a very
*small* capacitor...)

Bit line

Data value appears
on bit line

# DRAM Modules



SIMM – Single In-line
Memory Module    72 pins



DIMM – Dual In-line
Memory Module

168 or 184 pins



SODIMM –  Small Outline
Dual In-line Memory Module
144 or 200 pins

# Types of RAM

**4. Static Random Access Memory** (SRAM)

• Doesn't need refreshing

• Retains contents as long as power applied to the chip

• Access time around 10 nanoseconds

• Used for **cache** memory

• Also for date and time settings as powered by small battery

• The memory cell of SRAM created

by flip-flop (per bit)

A flip-flop for a memory cell
takes four or six transistors
along with some wiring, but
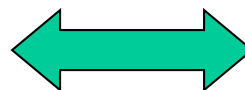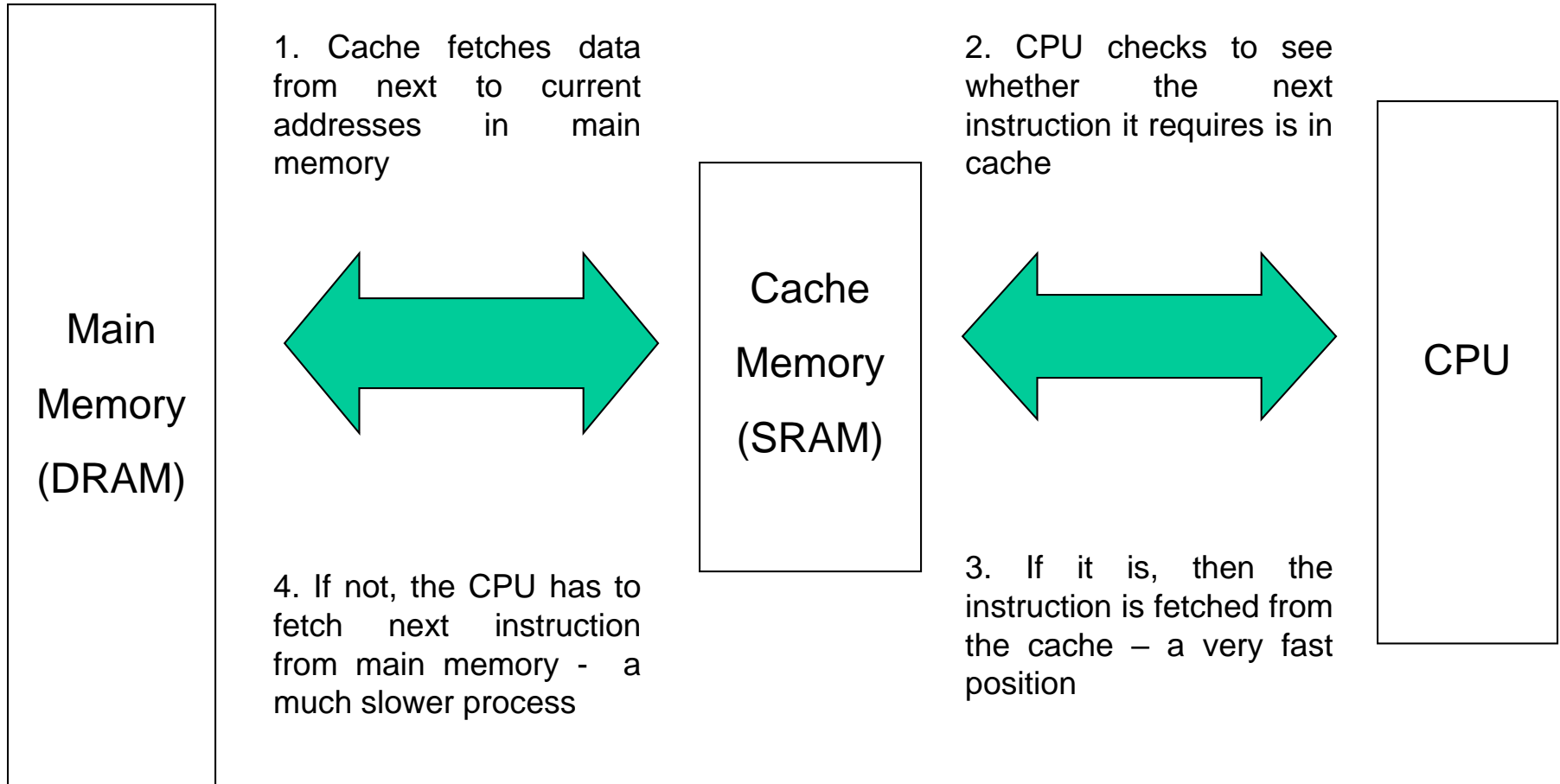never has to be refreshed
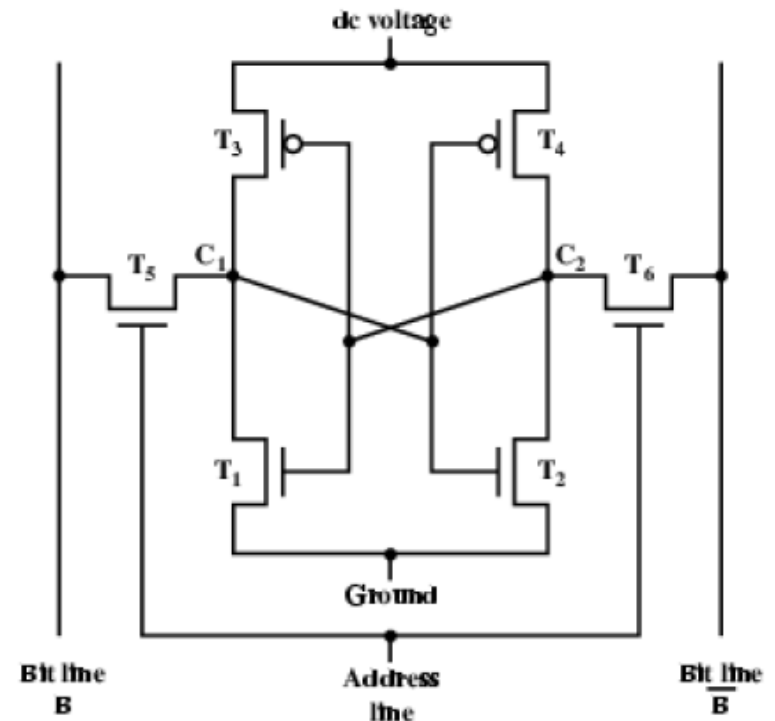
# Types of RAM

**5. Cache memory**

- Small amount of memory typically 256 or 512 kilobytes

- Temporary store for often used instructions

- **Level 1** cache is built within the CPU (internal)

- **Level 2** cache may be on chip or nearby (external)

- Faster for CPU to access than main memory

# The operation of cache memory

Main Memory (DRAM)

1. Cache fetches data from next to current addresses in main memory

2. CPU checks to see whether the next instruction it requires is in cache

Cache Memory (SRAM)

CPU

4. If not, the CPU has to fetch next instruction from main memory - a much slower process

3. If it is, then the instruction is fetched from the cache – a very fast position

= Bus connections

# Types of RAM

**6. Video Random Access memory**

- Holds data to be displayed on computer screen

- Has two data paths allowing READ and WRITE to occur at the same time

- A system's amount of VRAM relates to the number of colours and resolution

- A graphics card may have its own VRAM chip on board

**7. Virtual memory**

- Uses backing storage e.g. hard disk as a **temporary location** for programs and data where insufficient RAM available

- Swaps programs and data between the hard-disk and RAM as the CPU requires them for processing

- A cheap method of running large or many programs on a computer system

- Cost is speed: the CPU can access RAM in nanoseconds but hard-disk in milliseconds.

- Virtual memory is much slower than RAM

# Read only memory (ROM)

✓ ROM holds programs and data **permanently** even when computer is switched off

✓ Data can be read by the CPU in any order so ROM is also **direct access**

✓ The contents of ROM are fixed at the time of manufacture

✓ Stores a program called the **bootstrap loader** that helps start up the computer

✓ Access time of between 10 and 50 nanoseconds

# Block diagram of ROM

**Address Lines**

$\log_2(M)$

**Read**

**ROM**
**M x N**

**Data Lines**

**N**
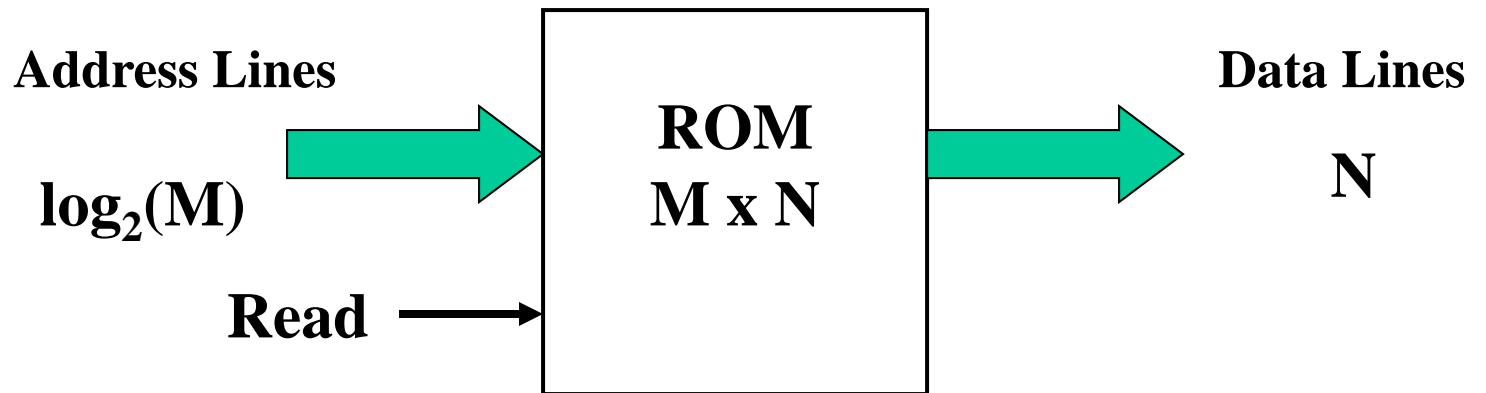
Where **M** locations and **N** bits per location

# Types of ROM

**1. Programmable Read Only Memory (PROM)**

- Empty of data when manufactured

- May be permanently programmed by the user

**2. Erasable Programmable Read Only Memory (EPROM)**

- Can be programmed, erased and reprogrammed

- The EPROM chip has a small window on top allowing it to be erased by shining ultra-violet light on it

- After reprogramming the window is covered to prevent new contents being erased

- Access time is around 45 – 90 nanoseconds

# Types of ROM

**3. Electrically Erasable Programmable Read Only Memory (EEPROM)**

- Reprogrammed electrically **without** using ultraviolet light

- Must be removed from the computer and placed in a special machine to do this

- Access times between 45 and 200 nanoseconds

**4. Flash ROM**

- Similar to EEPROM

- However, can be reprogrammed while still in the computer

- Easier to upgrade programs stored in Flash ROM

- Used to store programs in devices e.g. modems

- Access time is around 45 – 90 nanoseconds

**5. ROM cartridges**

- Commonly used in games machines

- Prevents software from being easily copied

- **Memory  Devices** (RAM,ROM,PROM,EPROM)

- **Storage Devices (Auxiliary Storage** ):

**Devices-Magnetic Tape:**
 (Hard Disk  ,  Floppy Disk )
- Converts electrical signals into magnetic charges
    - Captures magnetic charge on a storage medium
    - Later regenerates electrical current from stored magnetic charge
- Polarity of magnetic charge represents bit values zero and one

**Optical Disks:**
 (CD-R Drive, CD-RW disks, DVD, Blue ray Discs)
- Store bit values as variations in light reflection
- Higher a real density & longer data life than magnetic storage

# Large Units Of Measurement (Memory, Storage)

- Note: powers of two are used because computer memory and storage are based on the basic unit (bit)

- Kilobyte (KB) – a thousand bytes (1,024 = $2^{10}$)

- Megabyte (MB) - a million (1,048,576 = $2^{20}$)

- Gigabyte (GB) – a billion (1,073,741,824 = $2^{30}$)

- Terabyte (TB) – a trillion (1,099,511,627,776 = $2^{40}$)