SECONDARY MEMORY
(SECONDARY STORAGE DEVICES)

- The secondary memory stores data and instructions **permanently**.
- It is a **non-volatile** memory.
- It provides ***back-up storage*** for data and instructions.
- **E.g.**Magnetic tape drives, magnetic disk drives, optical disk drives and magneto-optical disk drives

Access Types Of Storage Devices

The information stored in storage devices can be accessed in two ways—

1. **Sequential access**
   - Sequential access means that computer must **access data in sequence**, *starting from the beginning, in order* to locate a particular piece of data.
   - E.g. Magnetic tape
2. **Direct access**
   - Direct access devices are the ones in which *any piece of data can be retrieved in a* ***non-sequential*** *manner* by locating it using the data's address.
   - It **accesses the data directly**, from a desired location.
   - E.g. Magnetic disks and optical disks

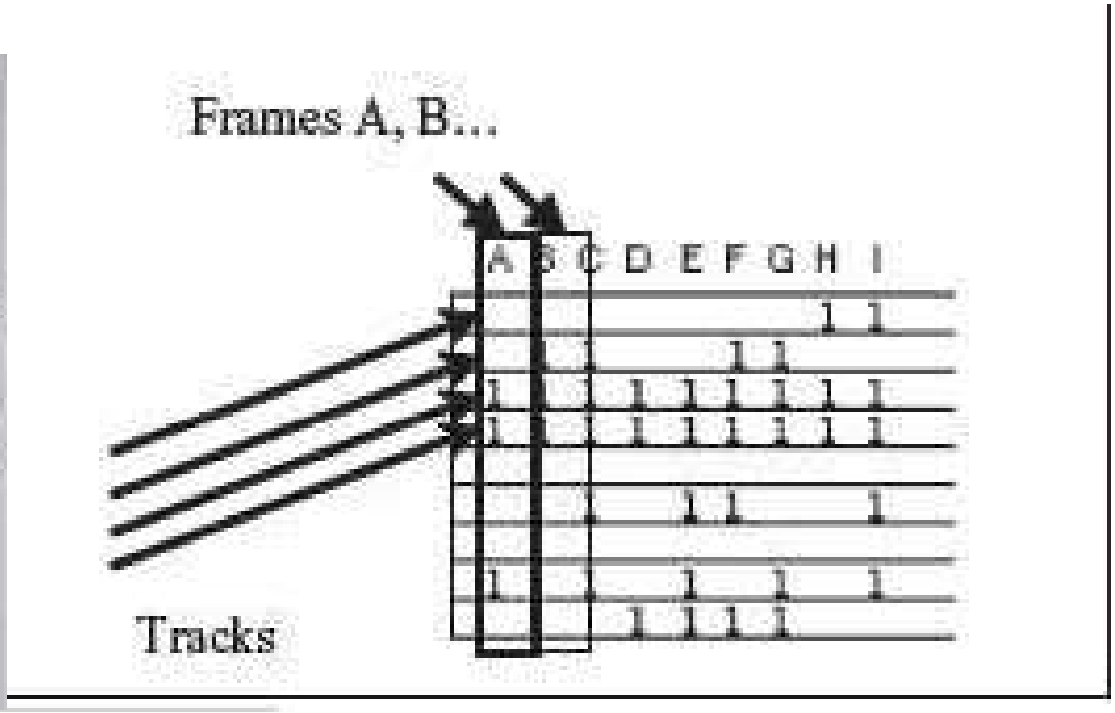
Secondary Storage Devices

- Magnetic Tape
- Magnetic Disk
  - **Floppy disk**
  - **Hard disk**
  - **Zip disk**
- Optical Disk
  - **read-only optical disks**
    - CD-ROM, DVD-ROM
  - **recordable optical disks.**
    - CD-R
    - CD-RW
    - DVD-R
- Magneto-optical disk

Magnetic Tape

- Sequential storage devices
- Tape needs to *rewind or move forward* to the location of the data
- A storage medium on a large open reel or in a smaller cartridge or cassette .
- They are Durable, Written, erased, and rewritten
- ***Not suitable*** for data files which are ***updated frequently***
  - Generally used to store backup data which are not used often

Magnetic Tape(contd..)



A 10.5-inch reel of 9-track tape

A portion of magnetic tape

Magnetic tape is divided horizontally into tracks (7 or 9) and vertically into frames

Magnetic Tape(contd..)

- Data is recorded in the form of blocks .
- Each block is read continually
- There is an Inter Record Gap(IRG) between two blocks
  - This provides time for the tape to be stopped and started between records

Magnetic Tape(contd..)

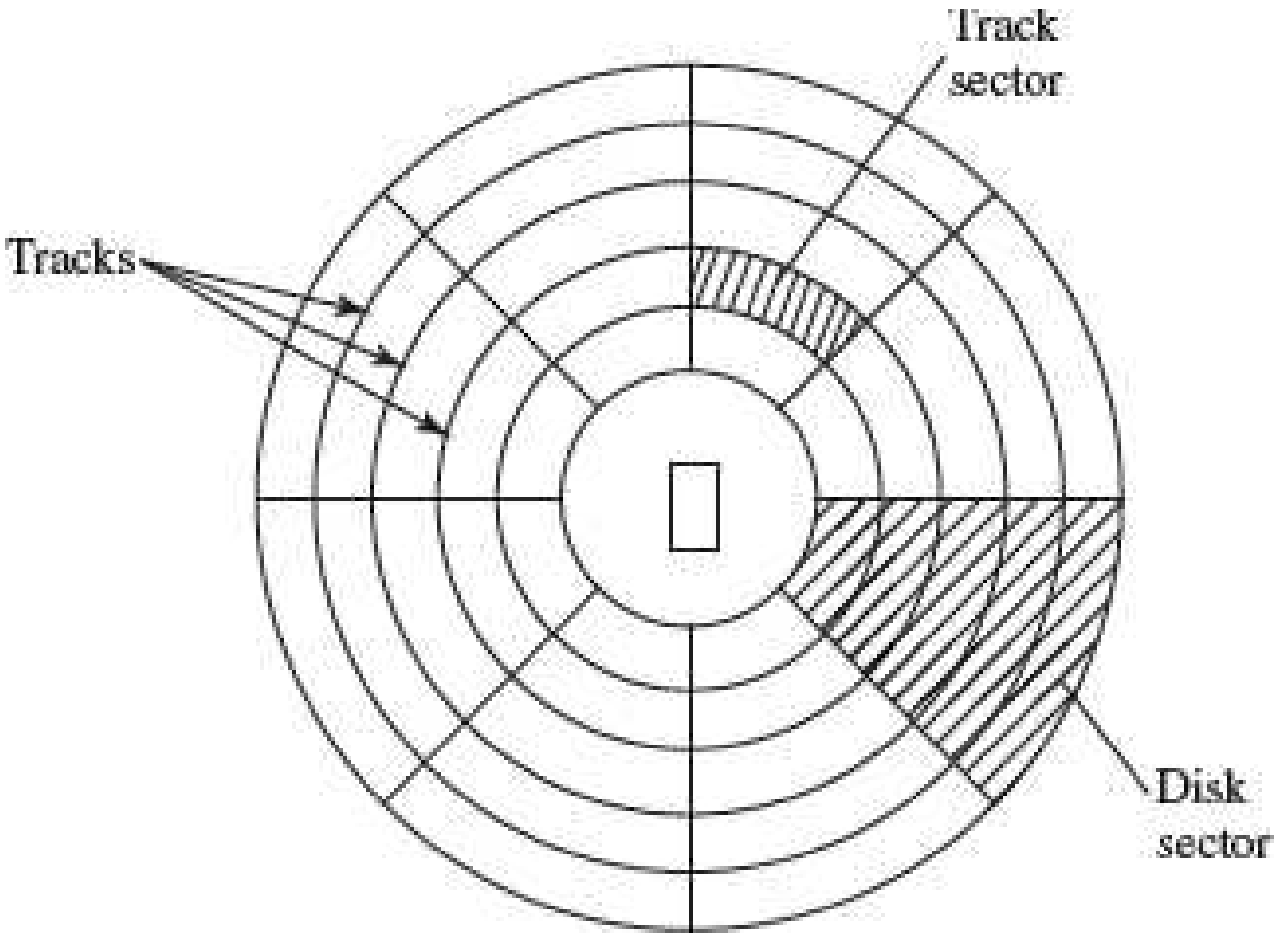
The features of magnetic tape are—

- Inexpensive storage device
- Can store a large amount of data
- Easy to carry or transport
- Not suitable for random access data
- Slow access device
- Needs dust prevention, as dust can harm the tape
- Suitable for back-up storage or archiving.

Magnetic Disk

- Magnetic disk is a direct access secondary storage device.
- It is a thin plastic or metallic circular plate *coated with* ***magnetic oxide*** and encased in a protective cover.
- Data is stored on magnetic disks as ***magnetized spot***s.
  - The ***presence*** of a magnetic spot represents the bit **1** and its absence represents the bit 0.

Magnetic Disk



Magnetic Disk (Contd..)

- The surface of disk is divided into *concentric circles* known as **tracks**.
- The outermost track is numbered 0 and the innermost track is the last track.
- Tracks are further divided into ***sectors***
- A set of same tracks on all disks forms a ***cylinder***.
- The read/write head is positioned to the desired track where the data is to be read from or written to.

Magnetic Disk(Contd..)

- The time taken to ***move*** *the read/write head* ***to the desired track*** is called the **seek time.**

- Once the read/write head is at the right track, then the head ***waits for right sector*** to come under it .
  - The time taken for *desired sector of the track to come under read/write head* is called the **latency time.**

- Once the read/write head is positioned at the right track and sector, the data has to be written to disk or read from disk.
  - The rate at which ***data is written to disk or read from disk*** is called **data transfer rate.**
- ***Access time of disk = Seek time + Latency time + Data transfer time***

Magnetic Disk(Contd..)

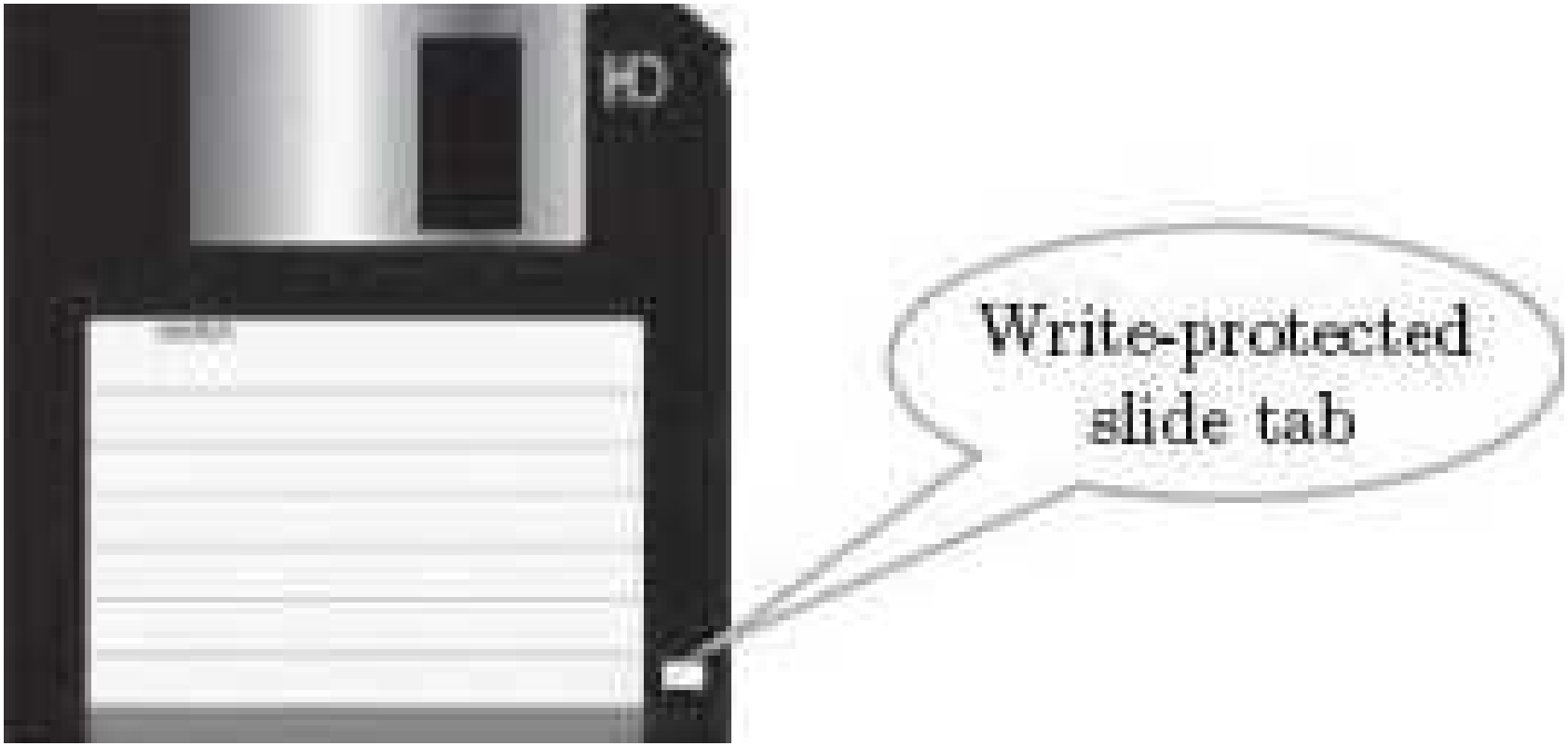
- The features of magnetic disk are—
  - Cheap storage device
  - Can store a large amount of data
  - Easy to carry or transport
  - Suitable for frequently read/write data
  - Fast access device
  - More reliable storage device
  - To be prevented from dust, as the read/write head flies over the disk.
    - Any dust particle in between can corrupt the disk.

- *Magnetic disk E,g.* ***Floppy disk, hard disk ,zip disk***

Floppy Disk

- Floppy disk (FD) is a flat, round, single disk made of ***Mylar*** plastic and enclosed in *square plastic jacket.*
- Floppy Disk Drive (FDD) is the disk drive for floppy disk.
- The floppy disk is inserted into the floppy disk drive to read or write data to it.
- Floppy disk has a ***write-protect slide tab*** that prevents a user from writing to it.
- A floppy disk may be single-sided or double-sided disk, i.e., data can be read and written on one and both sides of floppy disk, respectively.

Floppy Disk (Contd..)



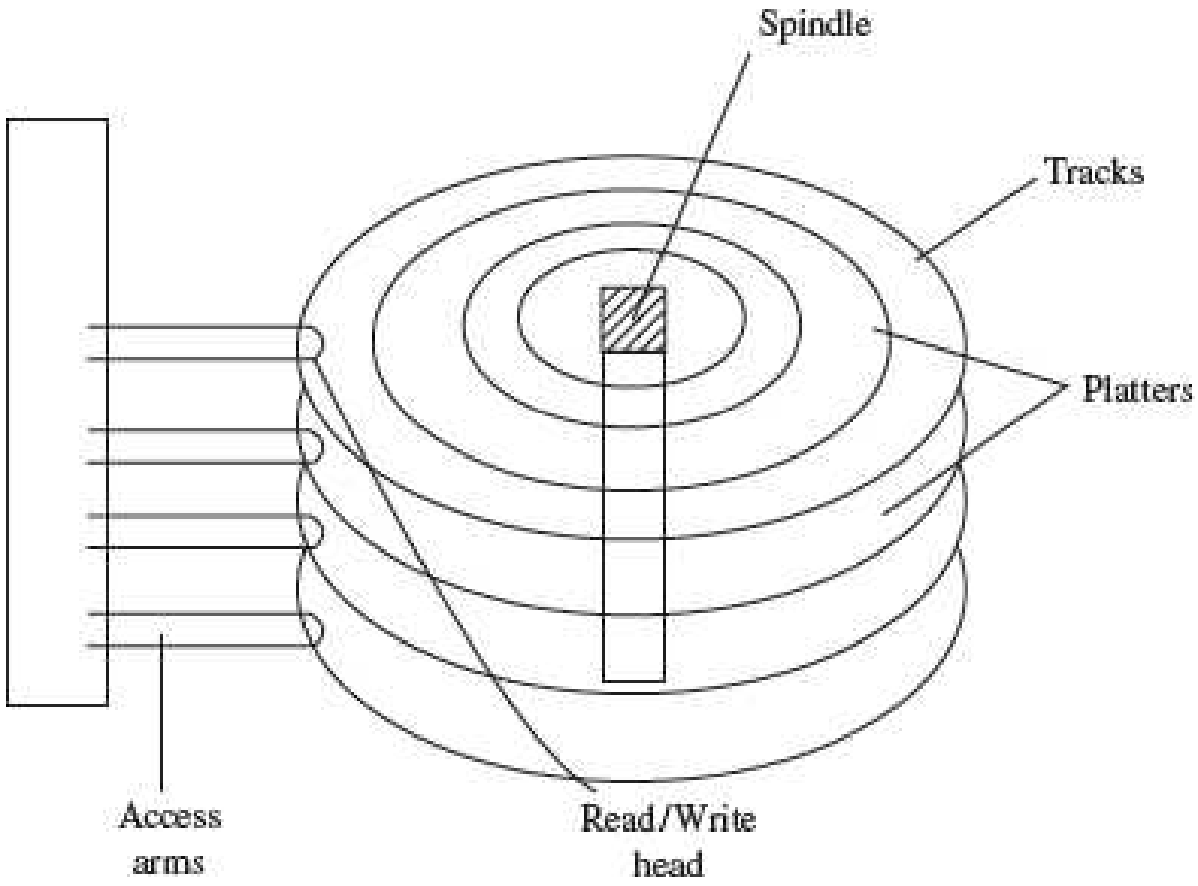
Floppy Disk(Contd..)

- They are ***portable***.
  - They can be removed from the disk drive, carried or stored separately.
- They are small and inexpensive.
- Floppy disks are ***slower*** to access than hard disk.
- They have less storage capacity.
- They come in two basic sizes—5-¼ inch and 3-½ inch.
  - The 3-½ inch disk has capacity of 400 KB to 1.44 MB.

Hard Disk

- A hard disk (HD) consists of one or more platters divided into ***concentric tracks and sectors.***
- It is mounted on a *central spindle*, like a stack.
- It can be read by a *read/write head.*
- The data is stored on the platters covered with ***magnetic coating***
- Hard disk is a **fixed disk.**
- The disk is ***not removable from the drive***.
- The hard disk and Hard Disk Drive (HDD) is a single unit.

Hard Disk

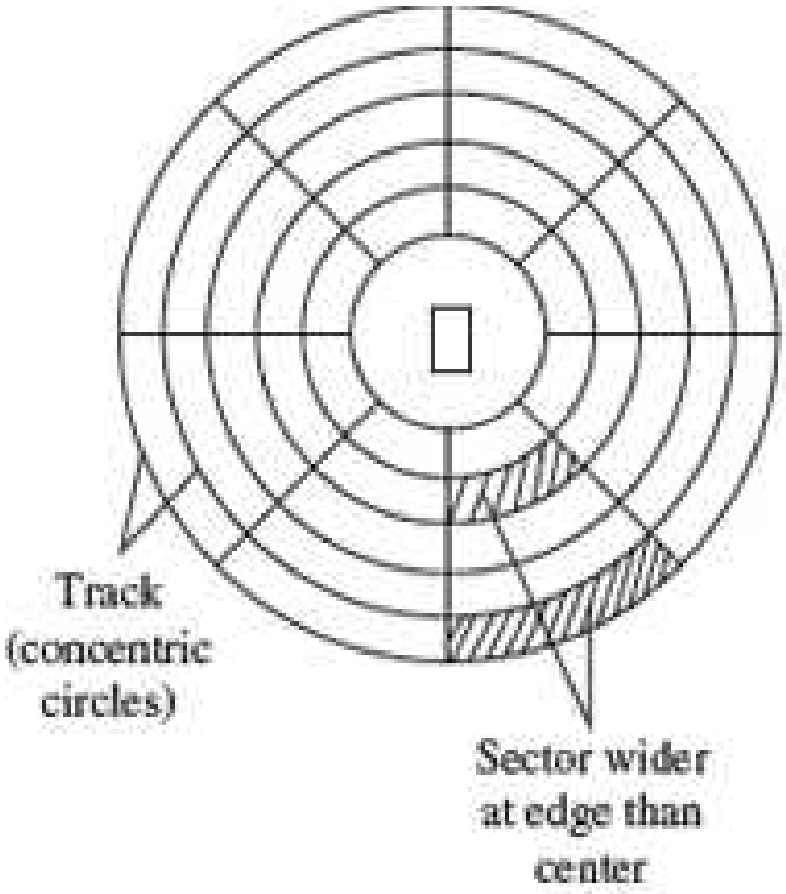


Zip Disk

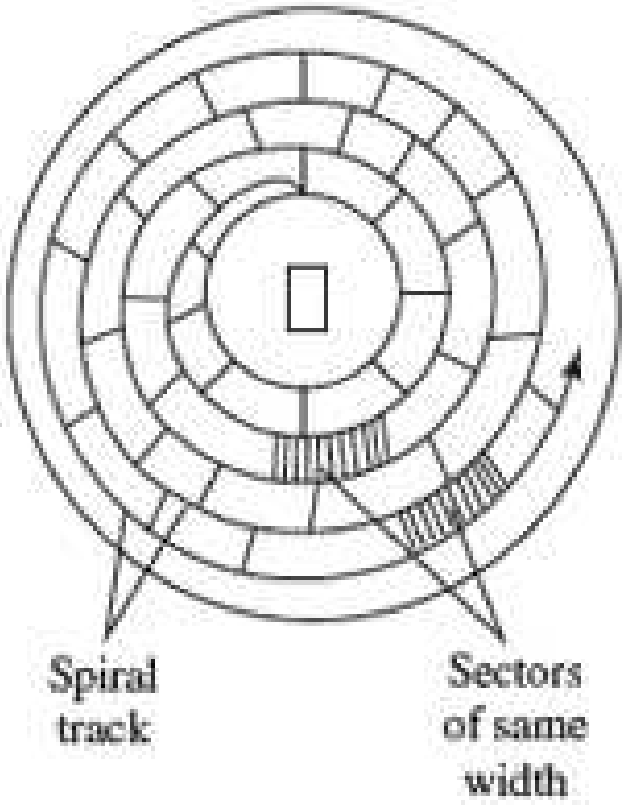
- They are high-capacity removable disk and drive.
- They have the *speed and capacity* of hard disk and *portability* of floppy disk.
- Zip disk are of the same size as floppy disk, i.e., 3–½ inch but have a much *higher capacity* than the floppy disk.

Optical Disk

- Optical disk is a flat and circular disk which is coated with ***reflective plastic material*** that can be ***altered by laser light*****.**
- Optical disk ***does not use magnetism***.
- The bits **1** and 0 are stored as spots that are relatively **bright** and light, respectively.
- The *tracks* on optical disk are further divided into *sectors* which are of **same length.**
- Thus, the *sectors near the centre* of *disk wrap around the disk longer than* the sectors on the edges of disk.



Magnetic disk



Optical disk

Optical disk

- Optical disk
  - read-only optical disks
    - CD-ROM, DVD-ROM
  - recordable optical disks.
    - CD-R
    - CD-RW
    - DVD-R

CD-ROM

- CD-ROM is *written on by the manufacturer* of the CD-ROM *using the laser light.*
- CD-ROM is an optical disk that can **only be read** and cannot be written..
- A CD-ROM drive reads data from the compact disk.

- Data is stored as **pits** (depressions) and **lands** (flat area) on CD-ROM disk.

- When the laser light is focused on the disk, the *pits scatter the light (*interpreted as 0) and the *lands reflect the light* to a sensor (interpreted as 1).

CD-ROM (Contd..)

- Since there is no head touching the disk, but a laser light, CD-ROM *does not get worn* out easily.
- The storage density of CD-ROM is very high and cost is low as compared to floppy disk and hard disk.
- Access time of CD-ROM is less.
  - CD-ROM drives can read data at 150Kbps.
- They come in multiples of this speed like—2x, 4x, 52x, 75x, etc.
- It is a commonly used medium for distributing software and large data.

CD-ROM

DVD-ROM

- **Digital Video Disk**-Read Only Memory (DVD-ROM) is an optical storage device used to *store digital video or computer data*
- It improves on CD technology.
- It is a high-density medium with increased track and bit density.
- DVD-ROM **uses both sides of the disk** and special data compression technologies.
- Each side of DVD-ROM can store 4.7 GB of data, so a single DVD can store 9.4 GB of data.
- New DVD-ROMs use layers of data track, to double its capacity.
  - Such dual layer disks can store 17 GB of data.


DVD
1 DVD

Recordable Optical Disk

- Compact Disk-Recordable (**CD-R**) is a Write Once-Read Many (WORM) disk.
  - A CD-R disk allows the user to write data permanently on to the disk.
- Compact Disk-ReWritable (**CD-RW**) allows data to be ***written, erased and re-written .***
  - The capacity of CD-RW is same as a CD.
- Digital Video Disk-Recordable(**DVD-R**) allows ***recording*** of data on a DVD.
  - A DVD writer device is required to write the data to DVD.
  - The data once written on a DVD ***cannot be erased or changed.***

MAGNETO-OPTICAL DISK

- Magneto-optical disks use *laser beam* to read data and magnetic field to write data to disk.
- These are optical disks where data can be written, erased and re-written.
- They are expensive and outdated.
- They were used during the mid 1990s.
- They have now been replaced by CD-RW and DVD-R.

Secondary Storage Devices

- Magnetic tape
- Magnetic disk
  - Floppy disk
  - Hard disk
  - Zip disk
- Optical disk
  - read-only optical disks
    - CD-ROM, DVD-ROM
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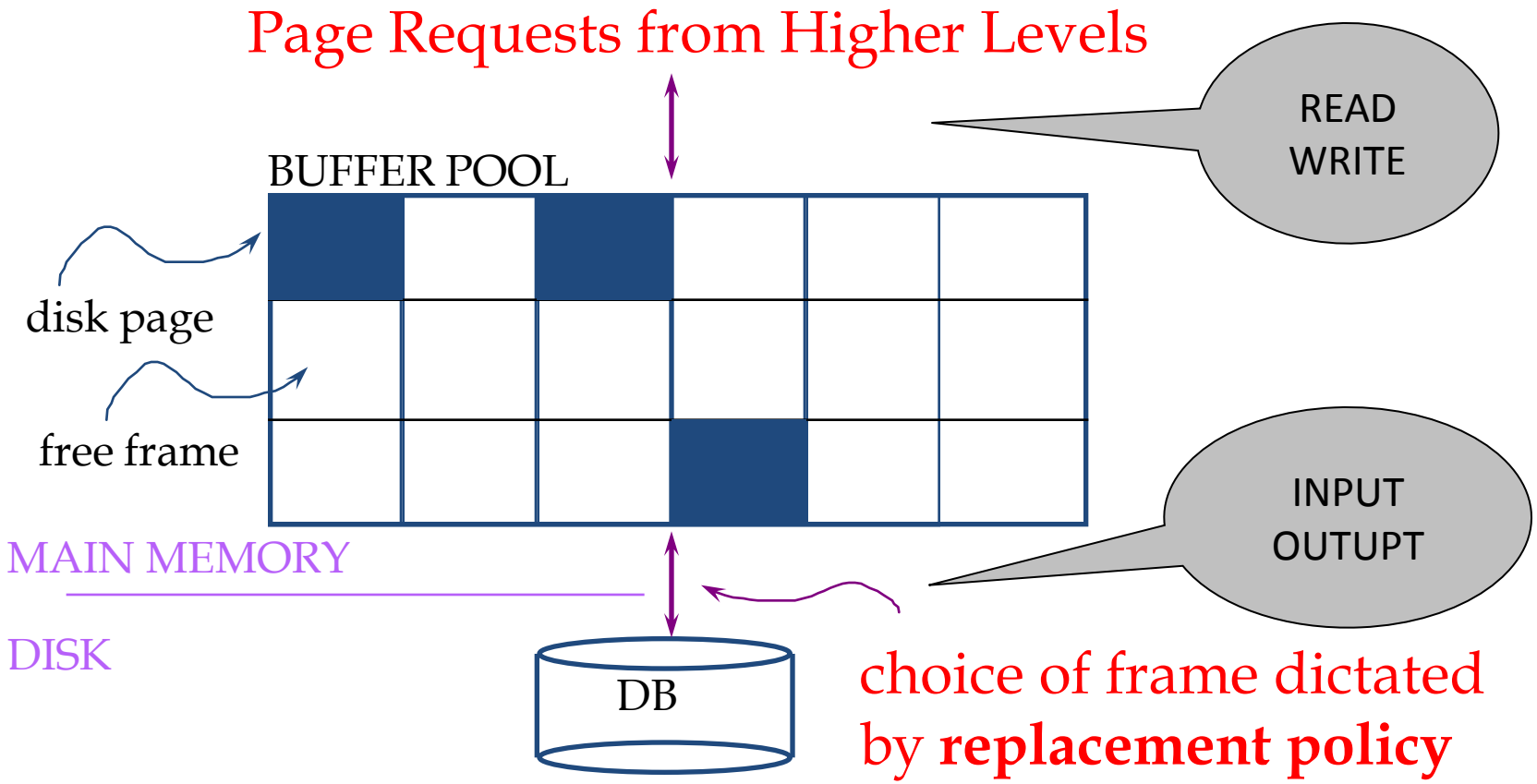
    - CD-R
    - CD-RW
    - DVD-R
- Magneto-optical disk

Buffer Managers

Buffer manager intelligently shuffles data from main memory to disk:
It is transparent to higher levels of DBMS operation

Buffer Management in a DBMS



- Data must be in RAM for DBMS to operate on it!
- Table of <frame#, pageid> pairs is maintained

When a page is requested…

- A *page* is the unit of memory we request
- If Page in the pool
  - Great no need to go to disk!

- If not? Choose a frame to replace.
  - If there is a free frame, use it!
    - **Terminology**: We pin a page (means it's in use)
  - If not? We need to choose a page to remove!
  - How DBMS makes choice is a **replacement policy**

Once we choose a page to remove

- A page is *dirty*, if its contents have been changed after writing
  - Buffer Manager keeps a dirty bit

- Say we choose to evict P
  - If P is *dirty,* we write it to disk
  - If P is not dirty, then what?

How do we pick a frame?

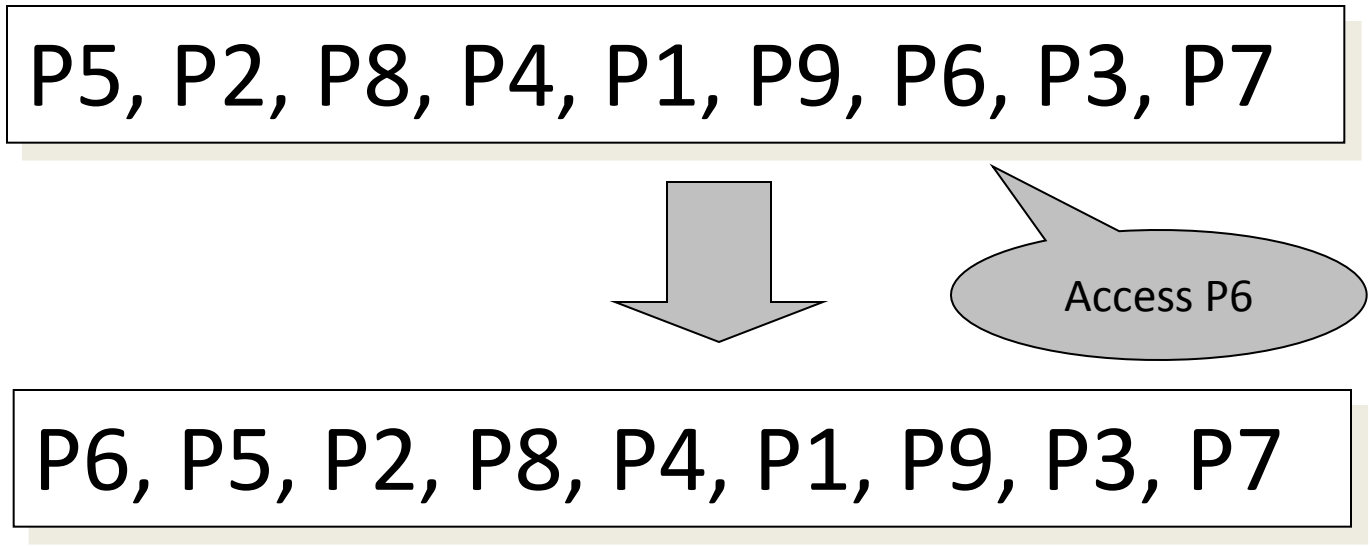
Needs to decide on page replacement policy

- Examples: LRU, Clock algorithm, MRU

Some work well in OS, but not always in DB… more later

Least Recently Used (LRU)

- Order pages by the time of last accessed
- Always replace the least recently accessed



LRU is expensive (why ?)

The Clock Approximation

- Instead we maintain a “last used clock”
  - Think of pages ordered 1…N around a clock
  - “The hand” sweeps around
  - Pages keep a “ref bit”
- Whenever a page is referenced, set the bit
- If current is has ref bit == false choose it
- If current is referenced, then unset ref bit and move on

“Approximates LRU” since referenced pages less likely

MRU

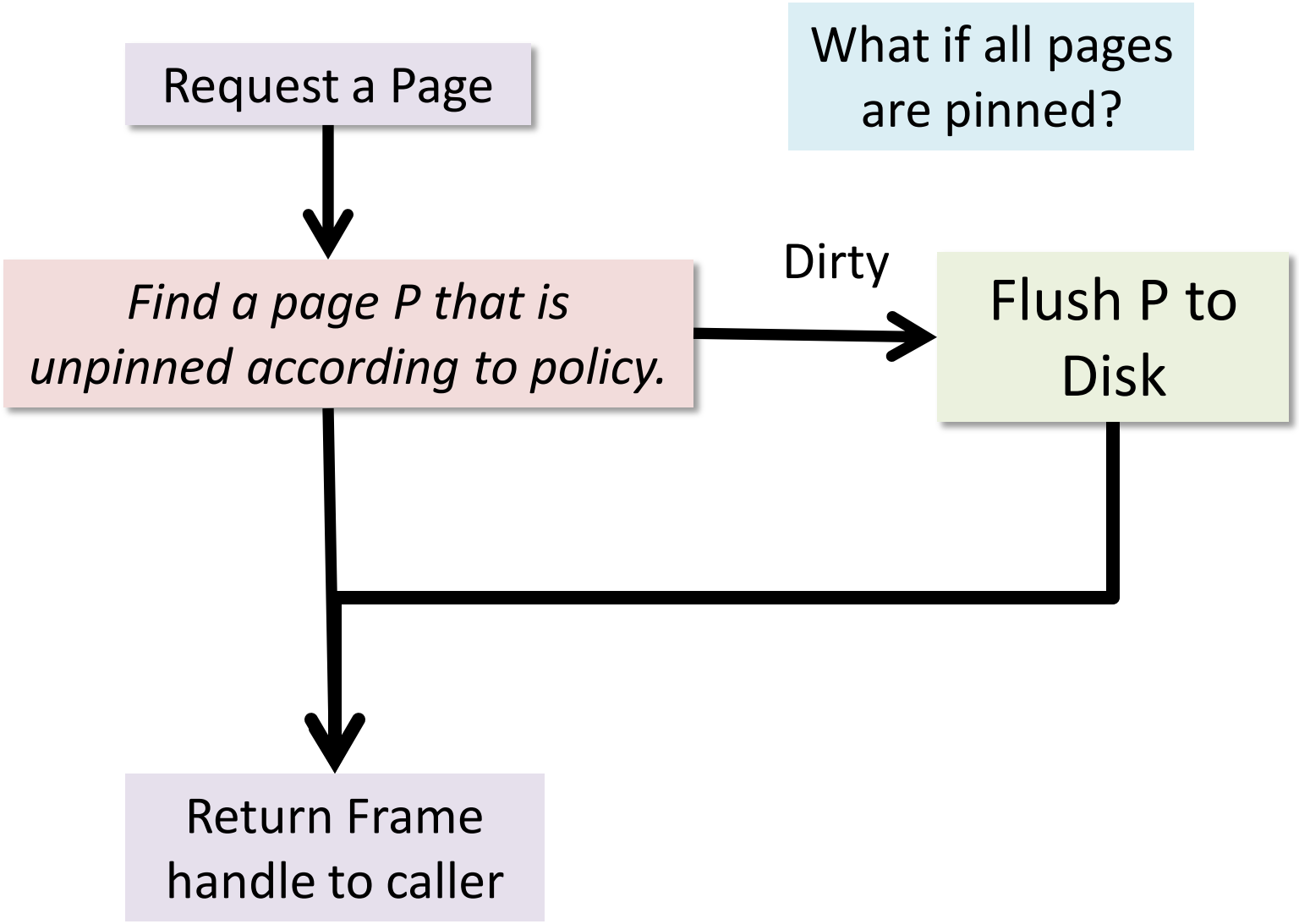
- **M**ost **R**ecently **U**sed.

- Why would you ever want to use this?

Hint: Consider scanning a relation that has 1 Mn pages, but we only have 1000 buffer pages…

This nasty situation is called *Sequential Flooding.* Each page request causes an I/O.

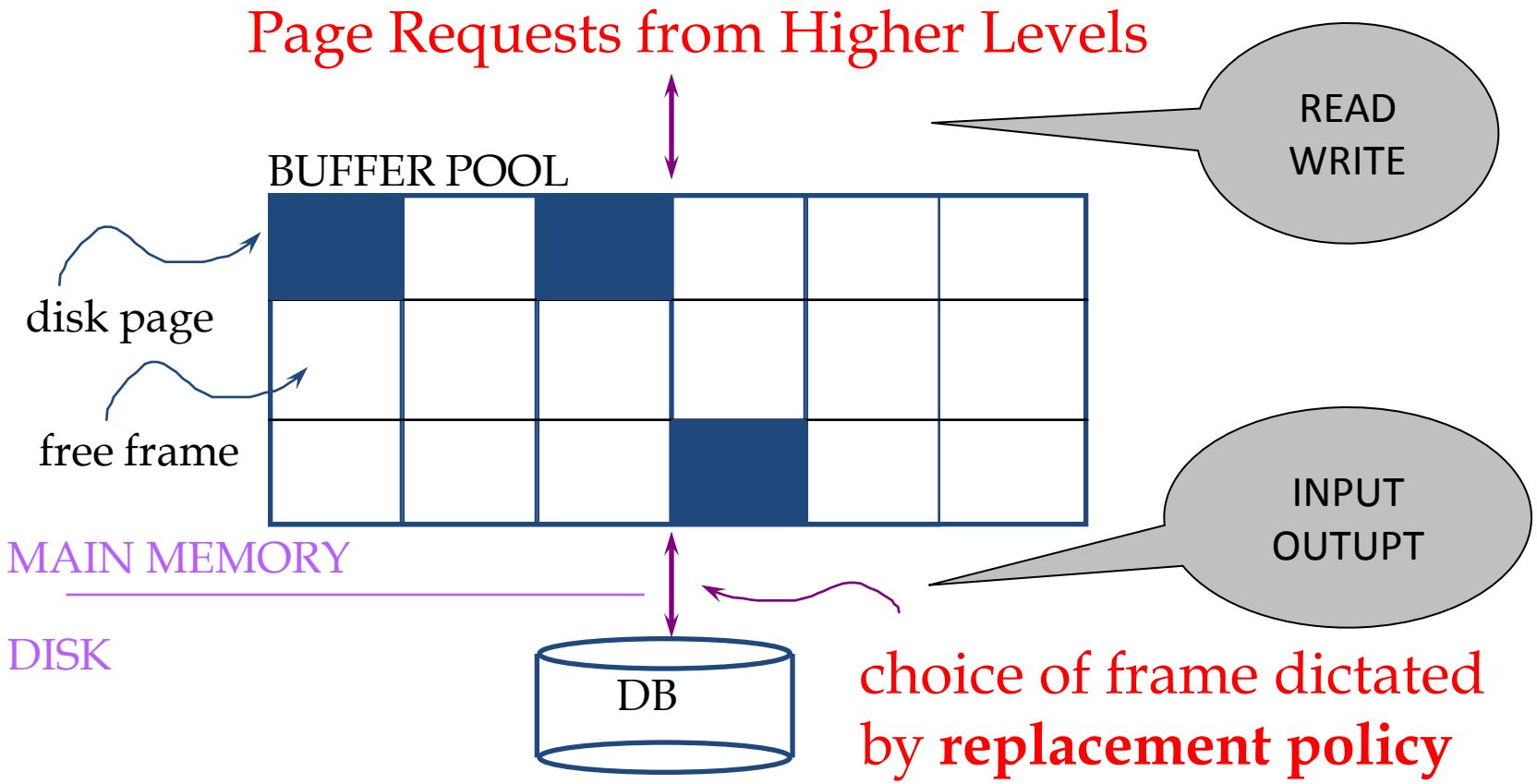
Simplified Buffer Manager Flowchart



Doesn't the OS manage Pages too?

- *Portability*: Different OS, Different support
  - Journaling, nothing, something crazy
- Limitations in OS: files cannot span disks.
- DBMS requires ability to *force pages* to disk
  - Recovery (much later)
- DBMS is better able to predict *page reference patterns*
  - Prefetching is harder

Buffer Management Summary



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Records

- Fixed and variable length records
- Records contain fields which have values of a particular type
  - E.g., amount, date, time, age
- Fields themselves may be fixed length or variable length
- Variable length fields can be mixed into one record:
  - Separator characters or length fields are needed so that the record can be “parsed.”

Blocking

- **Blocking**:
  - Refers to storing a number of records in one block on the disk.
- Blocking factor (**bfr**) refers to the number of records per block.
- There may be empty space in a block if an integral number of records do not fit in one block.
- **Spanned Records**:
  - Refers to records that exceed the size of one or more blocks and hence span a number of blocks.

Files of Records

- A **file** is a *sequence* of records, where each record is a collection of data values (or data items).
- A **file descriptor** (or **file header**) includes information that describes the file, such as the *field names* and their *data types*, and the addresses of the file blocks on disk.
- Records are stored on disk blocks.
- The **blocking factor bfr** for a file is the (average) number of file records stored in a disk block.
- A file can have **fixed-length** records or **variable-length** records.

Files of Records (contd.)

- File records can be **unspanned** or **spanned**
  - **Unspanned**: no record can span two blocks
  - **Spanned**: a record can be stored in more than one block
- The physical disk blocks that are allocated to hold the records of a file can be *contiguous, linked, or indexed*.
- In a file of fixed-length records, all records have the same format. Usually, unspanned blocking is used with such files.
- Files of variable-length records require additional information to be stored in each record, such as **separator characters** and **field types**.
  - Usually spanned blocking is used with such files

Operation on Files

- Typical file operations include:
  - **OPEN**: Readies the file for access, and associates a pointer that will refer to a *current* file record at each point in time.
  - **FIND**: Searches for the first file record that satisfies a certain condition, and makes it the current file record.
  - **FINDNEXT**: Searches for the next file record (from the current record) that satisfies a certain condition, and makes it the current file record.
  - **READ**: Reads the current file record into a program variable.
  - **INSERT**: Inserts a new record into the file & makes it the current file record.
  - **DELETE**: Removes the current file record from the file, usually by marking the record to indicate that it is no longer valid.
  - **MODIFY**: Changes the values of some fields of the current file record.
  - **CLOSE**: Terminates access to the file.
  - **REORGANIZE**: Reorganizes the file records.
    - For example, the records marked deleted are physically removed from the file or a new organization of the file records is created.
  - **READ_ORDERED**: Read the file blocks in order of a specific field of the file.