PRACTICE PROBLEMS BASED ON MAGNETIC DISK-

Problem-01:

Consider a disk pack with the following specifications- 16 surfaces, 128 tracks per surface, 256 sectors per track and 512 bytes per sector.

Answer the following questions-

1. What is the capacity of disk pack?
2. What is the number of bits required to address the sector?
3. If the format overhead is 32 bytes per sector, what is the formatted disk space?
4. If the format overhead is 64 bytes per sector, how much amount of memory is lost due to formatting?
5. If the diameter of innermost track is 21 cm, what is the maximum recording density?
6. If the diameter of innermost track is 21 cm with 2 KB/cm, what is the capacity of one track?
7. If the disk is rotating at 3600 RPM, what is the data transfer rate?
8. If the disk system has rotational speed of 3000 RPM, what is the average access time with a seek time of 11.5 msec?

Solution-

Given-

- Number of surfaces = 16
- Number of tracks per surface = 128
- Number of sectors per track = 256
- Number of bytes per sector = 512 bytes

<u>Part-01: Capacity of Disk Pack-</u>

Capacity of disk pack

= Total number of surfaces x Number of tracks per surface x Number of sectors per track x Number of bytes per sector

= 16 x 128 x 256 x 512 bytes

Part-02: Number of Bits Required To Address Sector-

Total number of sectors

= Total number of surfaces x Number of tracks per surface x Number of sectors per track

= 16 x 128 x 256 sectors

= 2^{19} sectors

Thus, Number of bits required to address the sector = 19 bits

Part-03: Formatted Disk Space-

Formatting overhead

= Total number of sectors x overhead per sector

= 2^{19} x 32 bytes

= 2^{19} x 2^{5} bytes

= 2^{24} bytes

= 16 MB

Now, Formatted disk space

= Total disk space – Formatting overhead

= 256 MB – 16 MB

= 240 MB

Part-04: Formatting Overhead-

Amount of memory lost due to formatting

= Formatting overhead

= Total number of sectors x Overhead per sector

= 2^{19} x 64 bytes

= 2^{19} x 2^{6} bytes

= 2^{25} bytes

= 32 MB

Part-05: Maximum Recording Density-

Storage capacity of a track

= Number of sectors per track x Number of bytes per sector

= 256 x 512 bytes

= 2^{8} x 2^{9} bytes

= 2^{17} bytes

= 128 KB

Circumference of innermost track

= 2 x π x radius

= π x diameter

= 3.14 x 21 cm

= 65.94 cm

Now, Maximum recording density

= Recording density of innermost track

= Capacity of a track / Circumference of innermost track

= 128 KB / 65.94 cm

= 1.94 KB/cm

Part-06: Capacity Of Track-

Circumference of innermost track

= 2 x π x radius

= π x diameter

= 3.14 x 21 cm

= 65.94 cm

Capacity of a track

= Storage density of the innermost track x Circumference of the innermost track

= 2 KB/cm x 65.94 cm

= 131.88 KB

≅ 132 KB

Part-07: Data Transfer Rate-

Number of rotations in one second

= (3600 / 60) rotations/sec

= 60 rotations/sec

Now, Data transfer rate

= Number of heads x Capacity of one track x Number of rotations in one second

= 16 x (256 x 512 bytes) x 60

= 2^4 x 2^8 x 2^9 x 60 bytes/sec

= 60 x 2^{21} bytes/sec

= 120 MBps

Part-08: Average Access Time-

Time taken for one full rotation

= (60 / 3000) sec

= (1 / 50) sec

= 0.02 sec

= 20 msec

Average rotational delay

= 1/2 x Time taken for one full rotation

= 1/2 x 20 msec

= 10 msec

Now, average access time

= Average seek time + Average rotational delay + Other factors

= 11.5 msec + 10 msec + 0

= 21.5 msec

Problem-02:

What is the average access time for transferring 512 bytes of data with the following specifications-

- Average seek time = 5 msec
- Disk rotation = 6000 RPM
- Data rate = 40 KB/sec
- Controller overhead = 0.1 msec

Solution-

Given-

- Average seek time = 5 msec
- Disk rotation = 6000 RPM
- Data rate = 40 KB/sec
- Controller overhead = 0.1 msec

Time Taken For One Full Rotation-

Time taken for one full rotation

= (60 / 6000) sec

= (1 / 100) sec

= 0.01 sec

= 10 msec

Average Rotational Delay-

Average rotational delay

= 1/2 x Time taken for one full rotation

= 1/2 x 10 msec

= 5 msec

Transfer Time-

Transfer time

= (512 bytes / 40 KB) sec

= 0.0125 sec

= 12.5 msec

Average Access Time-

Average access time

= Average seek time + Average rotational delay + Transfer time + Controller overhead + Queuing delay

= 5 msec + 5 msec + 12.5 msec + 0.1 msec + 0

= 22.6 msec

Problem-03:

A certain moving arm disk storage with one head has the following specifications-

- Number of tracks per surface = 200
- Disk rotation speed = 2400 RPM
- Track storage capacity = 62500 bits
- Average latency = P msec
- Data transfer rate = Q bits/sec

What is the value of P and Q?

Solution-

Given-

- Number of tracks per surface = 200
- Disk rotation speed = 2400 RPM
- Track storage capacity = 62500 bits

Time Taken For One Full Rotation-

Time taken for one full rotation

= (60 / 2400) sec

= (1 / 40) sec

= 0.025 sec

= 25 msec

Average Latency-

Average latency or Average rotational latency

= 1/2 x Time taken for one full rotation

= 1/2 x 25 msec

= 12.5 msec

Data Transfer Rate-

Data transfer rate

= Number of heads x Capacity of one track x Number of rotations in one second

= 1 x 62500 bits x (2400 / 60)

= 2500000 bits/sec

= 2.5 x 10^6 bits/sec

Thus, P = 12.5 and Q = 2.5 x 10^6

Problem-04:

A disk pack has 19 surfaces and storage area on each surface has an outer diameter of 33 cm and inner diameter of 22 cm. The maximum recording storage density on any track is 200 bits/cm and minimum spacing between tracks is 0.25 mm. Calculate the capacity of disk pack.

Solution-

Given-

- Number of surfaces = 19
- Outer diameter = 33 cm
- Inner diameter = 22 cm
- Maximum recording density = 200 bits/cm
- Inter track gap = 0.25 mm

Number Of Tracks On Each Surface-

Number of tracks on each surface

= (Outer radius – Inner radius) / Inter track gap

= (16.5 cm – 11 cm) / 0.25 mm

= 5.5 cm / 0.25 mm

= 55 mm / 0.25 mm

= 220 tracks

Capacity Of Each Track-

Capacity of each track

= Maximum recording density x Circumference of innermost track

= 200 bits/cm x (3.14 x 22 cm)

= 200 x 69.08 bits

= 13816 bits

= 1727 bytes

Capacity Of Disk Pack-

Capacity of disk pack

= Total number of surfaces x Number of tracks per surface x Capacity of one track

= 19 x 220 x 1727 bytes

= 7218860 bytes

= 6.88 MB

Problem-05:

Consider a typical disk that rotates at 15000 RPM and has a transfer rate of 50 x 10^6 bytes/sec. If the average seek time of the disk is twice the average rotational delay and the controller's transfer time is 10 times the disk transfer time. What is the average time (in milliseconds) to read or write a 512 byte sector of the disk?

Solution-

Given-

- Rotation speed of the disk = 15000 RPM
- Transfer rate = 50×10^6 bytes/sec
- Average seek time = 2 x Average rotational delay
- Controller's transfer time = 10 x Disk transfer time

Time Taken For One Full Rotation-

Time taken for one full rotation

= (60 / 15000) sec

= 0.004 sec

= 4 msec

Average Rotational Delay-

Average rotational delay

= 1/2 x Time taken for one full rotation

= 1/2 x 4 msec

= 2 msec

Average Seek Time-

Average seek time

= 2 x Average rotational delay

= 2 x 2 msec

= 4 msec

Disk Transfer Time-

Disk transfer time

= Time taken to read or write 512 bytes

$= 512$ bytes / (50×10^6 bytes/sec)

$= 10.24 \times 10^{-6}$ sec

= 0.01024 msec

Controller's Transfer Time-

Controller's transfer time

= 10 x Disk transfer time

= 10 x 0.01024 msec

= 0.1024 msec

Average Time To Read Or Write 512 Bytes-

Average time to read or write 512 bytes

= Average seek time + Average rotational delay + Disk transfer time + Controller's transfer time + Queuing delay

= 4 msec + 2 msec + 0.01024 msec + 0.1024 msec + 0

= 6.11 msec

Problem-06:

A hard disk system has the following parameters-

- Number of tracks = 500
- Number of sectors per track = 100
- Number of bytes per sector = 500
- Time taken by the head to move from one track to another adjacent track = 1 msec
- Rotation speed = 600 RPM

What is the average time taken for transferring 250 bytes from the disk?

Solution-

Given-

- Number of tracks = 500
- Number of sectors per track = 100
- Number of bytes per sector = 500
- Time taken by the head to move from one track to another adjacent track = 1 msec
- Rotation speed = 600 RPM

Average Seek Time-

Average seek time

= (Time taken by the head to move from track-1 to track-1 + Time taken by the head to move from track-1 to track-500) / 2

= (0 + 499 x 1 msec) / 2

= 249.5 msec

Time Taken For One Full Rotation-

Time taken for one full rotation

= (60 / 600) sec

= 0.1 sec

= 100 msec

Average Rotational Delay-

Average rotational delay

= 1/2 x Time taken for one full rotation

= 1/2 x 100 msec

= 50 msec

Capacity Of One Track-

Capacity of one track

= Number of sectors per track x Number of bytes per sector

= 100 x 500 bytes

= 50000 bytes

Data Transfer Rate-

Data transfer rate

= Number of heads x Capacity of one track x Number of rotations in one second

= 1 x 50000 bytes x (600 / 60)

= 50000 x 10 bytes/sec

= 5 x 10^5 bytes/sec

Transfer Time-

Transfer time

= (250 bytes / 5 x 10^5 bytes) sec

= 50 x 10^{-5} sec

= 0.5 msec

Average Time Taken To Transfer 250 Bytes-

Average time taken to transfer 250 bytes

= Average seek time + Average rotational delay + Transfer time + Controller overhead + Queuing delay

= 249.5 msec + 50 msec + 0.5 msec + 0 + 0

= 300 msec

Problem-07:

A hard disk has 63 sectors per track, 10 platters each with 2 recording surfaces and 1000 cylinders.

The address of a sector is given as a triple (c, h, s) where c is the cylinder number, h is the surface number and s is the sector number. Thus, the 0th sector is addressed as (0,0,0), the 1st sector as (0,0,1) and so on.

Part-01:

The address <400, 16, 29> corresponds to sector number-

1. 505035
2. 505036
3. 505037
4. 505038

Part-02:

The address of 1039 sector is-

1. <0, 15, 31>
2. <0, 16, 30>
3. <0, 16, 31>
4. <0, 17, 31>

Storage Design Based on Application Requirements and Disk Performance

Determining storage requirements for an application begins with determining the required storage capacity. This is easily estimated by the size and number of file systems and database components used by applications. The I/O size, I/O characteristics, and the number of I/Os generated by the application at peak workload are other factors that affect disk performance, I/O response time, and design of storage systems. The I/O block size depends on the file system and the database on which the application is built. Block size in a database environment is controlled by the underlying database engine and the environment variables.

The disk service time (TS) for an I/O is a key measure of disk performance; TS, along with disk utilization rate (U), determines the I/O response time for an application. As discussed earlier, the total disk service time (TS) isthe sum of the seek time (T), rotational latency (L), and internal transfer time (X):

TS = T + L + X.

Consider an example with the following specifications provided for a disk:

The average seek time is 5 ms in a random I/O environment; therefore, T = 5 ms.

Disk rotation speed of 15,000 revolutions per minute or 250 revolutions per second — from which rotational latency (L) can be determined, which is one-half of the time taken for a full rotation or L = (0.5/250 rps expressed in ms).

40 MB/s internal data transfer rate, from which the internal transfer time (X) is derived based on the block size of the I/O — for example, an I/O with a block size of 32 KB; therefore X = 32 KB/40 MB.

Consequently, the time taken by the I/O controller to serve an I/O of block size 32 KB is (TS) = 5 ms + (0.5/250) + 32 KB/40 MB = 7.8 ms.

Therefore, the maximum number of I/Os serviced per second or IOPS is (1/TS) = 1/(7.8 × 10-3) = 128 IOPS

Table 2-1: IOPS Performed by Disk Drive

BLOCK SIZE	$T_S = T + L + X$	$IOPS = 1/T_S$
4 KB	5 ms + (0.5/250 rps) + 4 K/40 MB = 5 + 2 + 0.1 = 7.1	140
8 KB	5 ms + (0.5/250 rps) + 8 K/40 MB = 5 + 2 + 0.2 = 7.2	139
16 KB	5 ms + (0.5/250 rps) + 16 K/40 MB = 5 + 2 + 0.4 = 7.4	135
32 KB	5 ms + (0.5/250 rps) + 32 K/40 MB = 5 + 2 + 0.8 = 7.8	128
64 KB	5 ms + (0.5/250 rps) + 64 K/40 MB = 5 + 2 + 1.6 = 8.6	116

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