Problem 1 (Disks) [70 Points (10 each)]

Given a disk with the following configurations:

- There are 5 (double-sided) platters, each surface has 8,000 tracks, 208 sectors per track
- A sector holds 512 Bytes
- Disk rotates at 5400 rpm
- Seek time: A warm-up time is 1ms, and then the arm movement covers 500 tracks per ms
- Reading one sector takes 0.05 ms
- A disk block is of size 8KB

Hint: 1KB = 1024 Bytes, 1MB = 1024 KB, etc.

Q1: Compute the disk capacity in GBs. (10 points)

2 x 5 x 8,000 x 208 x 512 = 7.93 GB
If you approximate to 8GB, that is fine too.

Q2: Compute the disk capacity in terms of the number of blocks it can hold. (10 points)

**Note that a single data block cannot be divided over two tracks.
- Each block requires 16 sectors (8*1024/512) ➔ So a track can hold 13 blocks (208/16)
- Total number of blocks = 13 * Number of tracks*num platters*2=
= 13 * 2 *5 * 8000 = 1,040,000

Q3: What is the minimum, maximum, and average time needed to read one block from the disk? You need to divide the time into its three components (seek, rotation latency, transfer).

Minimum: **(3 points)**
Transfer time only for one block = (8KB/ 512) * 0.05 = (8 *1024/512) * 0.05 = 0.8 ms

Maximum: **(3 points)**
Full seek + one complete rotation + transfer time =
(1 + 8,000/500) + (1/90 * 1000) + 0.8 = 17 + 11.11 + 0.8 = 28.91 ms

Average: **(3 points)**
Warm up seek + ½ seek + ½ rotation + transfer time =
1 + 8 + 5.55 + 0.8 = 15.35 ms

Q4: Given a file that consists of 100,000 records, and each record is 128 bytes. No record is allowed to span multiple blocks.

- How many records fit in one block? 8KB/128 = 64 Records **(3 points)**
- How many blocks are needed to store the file? Ceiling (100,000/64) = 1563 Blocks **(3 points)**
- How many sectors are needed to store the file? 1563 * 16 = 25008 sectors **(3 points)**

Q5: Assume Blocks B1, B2, B3, …., B10, are stored on the same track (track number 100) and on adjacent sectors. If the disk head is positioned at track 0, what is the disk delay (time) needed to read these 10 blocks? (Assume a half rotation is needed to reach the first block of these 10 blocks) (10 points)

Warm-up seek time + Seek time for 100 tracks + ½ rotation + 10 * transfer time =

1 + 1/5 + 5.55 + (10 * 0.8) = 14.75 ms

Another possible solution:

Warm-up seek time + Seek time for 100 tracks + ½ rotation =
1 + 1/5 + 5.55 = 6.75 ms

Q6: To optimize the reading of the file, we may store adjacent blocks, e.g., B1, B2, B3, …, on the same cylinder. Given the disk configuration above, how many blocks can be aligned on the cylinder position to be read by the disk arms at the same time? (10 points)

10 Blocks can be aligned to be read at the same time

Q7: Assume the file will be read sequentially, i.e., B1, B2, B3, ….until the last block B_{last}. Describe the best way to store these blocks on disk to speed up the sequential read. Then measure out the average time needed to read the file given this organization.
Hint: Make use of cylinders. Note that if Blocks B1 and B2 are aligned under each other in the same cylinder, then the transfer time to read B1, B2, or both is the same.

The best organization is to put each adjacent 10 blocks (starting from B1) under each other on the same cylinder. Then the next 10, will be adjacent to them, and so on. **(5 points)**

The file has 1563 Blocks ➔ So we have 157 cylinder-aligned blocks (each alignment has 10, except the last)

Each track can hold at most 13 blocks, thus we need to use 12.02 ➔13 Tracks to store the file.

Average time: **(5 points)**
Step 1: Reach first byte = Warm up seek + seek 4000 tracks (now we reached the 1st desired track) + ½ Rotation (now we reached B1)
= 1 + 4000/500 + 5.55 = 14.55 ms

Step 2: Read one block takes 0.8 ms, we will read 157 cylinder-aligned blocks → Total transfer time = 157* 0.8 = 125.6

Another possible solution (If you assume you read based on tracks):
Read one complete track (13 Blocks) = 13 * transfer time = 13 * 0.8 = 10.4 ms
We will read complete tracks 13 times ➔ Total transfer time = 13 * 10.4 =135.2 ms

Step 3: For the 13 tracks, we will make 12 warm-up seek times + 12 seek movement (1 track each)
(12 * 1) + (12 * 1/500) = 12.024 ms
Total Time = Step 1 + Step 2 + Step 3

Problem 2 (Record Organization) [30 Points (10 each)]

Assume a database tables with the following fields:

ID (4 bytes), Name (25 bytes), age (4 bytes), DoB (10 bytes), gender (1 Byte), Address (60 bytes), state (2 bytes).

Each record on disk has a header part of size 8 bytes.

Q1: What will be the record size if each field has to start at 4-byte boundaries? (10 points)

8 + 4 + 28 + 4 + 12 + 4 + 60 + 4 = 124 Bytes

Q2: What will be the record size if each field has to start at 8-byte boundaries? (10 points)

8+ 8 + 32 + 8 + 16 + 8 + 64 + 8 = 152 Bytes

Q3: Assuming a disk block of size 4KB, the block uses 64 bytes of its own header (block header). How many records can fit in one block? Report the number under the 4- and 8-bytes boundaries.

Block data part = 4 * 1024 – 64 = 4032 Bytes **(3 points)**

For 4-boundary records = 4032 /124 = 32 Records **(3 points)**

For 8-boundary records = 4032 /152 = 26 Records **(3 points)**