Q1: Given six memory partitions of M1: 300 KB, M2: 600 KB, M3: 350 KB, M4: 200 KB, M5: 750 KB, and M6: 125 KB (in order) and five processes P1: 115 KB, P2: 500 KB, P3: 358 KB, P4: 200 KB, and P5: 375 KB (in order).
Find the allocation mapping for **First-fit, Best-fit and Worst-fit** algorithms. Also indicate if any requests cannot be satisfied.

Allocation Technique	P1	P2	P3	P4	P5
First fit	M1	M2	M5	M3	M5/M9 (newly created)

Allocation Technique	P1	P2	P3	P4	P5
Best fit	M6	M2	M5	M4	M5/M9 (newly created)

Allocation Technique	P1	P2	P3	P4	P5
Worst fit	M5	M5/ M7 (newly created)	M2	M3	NA

Q2: Assuming a 1-KB page size, what are the page numbers and offsets for the following address references (provided as decimal numbers)?
(a) 21205 (b) 164250 (c) 121357

Page number = Floor_of(address/page_size)
Offset = address mod page_size

a. 21205: page number: 20, offset: 725
b. 164250: page number: 160, offset = 410
c. 121357: page number: 118, offset: 525

Q3: A processor has a cycle time of 1μs. It costs an additional 1μs to access a page other than the current one. One percent of all instructions executed access a page other than the current page. Of these 80% access a page already in memory, while the remaining 20% causes a page fault. The page table is memory resident, and the memory access time is 1 ms.

Each page is 4KB in size. If a page is not in memory, it must be fetched from a secondary drum memory. The drum rotates at 3000 RPM and transfers data at 1 million words/second. Each word is 4 bytes, and assume the average rotational latency.

The system also has a translation lookaside buffer (TLB) with a 99% hit ratio and an access time of 100μs.

Calculate and clearly mention your answer with in a box

a. The total time required to fetch a page from the drum when a page fault occurs (seek time and controller overhead are negligible).
b. Calculate the effective access time (EAT) for an instruction without TLB
c. Calculate the effective access time (EAT) with TLB

This solution assumes that the only component contributing to page fault service time is the drum access, with all other factors considered negligible.

Step 1: Time to fetch a page from the Drum = Average Rotational latency + Transfer time

Rotational latency = 60/3000 = 0.02 seconds = 20 ms
Average rotational latency = 20 ms / 2 = 10 ms

Page size is 4 KB = 1024 words (1 word = 4 bytes)
Transfer time = 1024 words / (1,000,000 words per second) = 0.001024 sec = 1.024 ms
Total time to fetch a page from the drum is 10 ms + 1.024 ms = **11.024 ms**

Step 2: Effective access time without TLB

1. Instruction accesses the current page:
   This happens with a probability of 99% i.e., 0.99 * 1 microsecond
2. Instruction access to a page other than the current page
   This occurs with a probability of 1 % = 0.01
   a. Page already in memory (80% = 0.8) i.e., 0.8 * (1ms + 1 ms). Page table access time and memory access time
   b. Page not in memory (20% = 0.2) i.e., 0.2 * (1ms + 1 ms + page fault service time). Page table access time, memory access time and page fault service time.

EAT = 0.01 * (1 microsecond + 0.8 * (1 ms + 1ms) + 0.2 * (1 ms + 1 ms + 11.024 ms))

Final EAT without TLB is 0.99 * 1 microsecond + 0.01 * (1 microsecond + 0.8 * (1 ms + 1ms) + 0.2 * (1 ms + 1 ms + 11.024 ms)) = **43.048 microseconds**

Step 3: Effective access time with TLB

TLB hit ratio is 99% i.e., 0.99 * (100 microseconds + 1 ms)

TLB miss ratio is 1% i.e., 0.01 * (100 microseconds + 1 ms + 1 ms)

0.99 * 1 microsecond + 0.01 * (1 microsecond + 0.8 * (0.99 * (100 microseconds + 1 ms) + 0.01 * (100 microseconds + 1 ms + 1 ms)) + 0.2 * (100 microseconds + 1 ms + 11.024 ms)) = **35.128 microseconds**

Q4: Suppose that during a seek the disk accelerates the disk arm at a constant rate for the first half of the seek and decelerates the disk arm at the same rate for the second half of the seek. Suppose a disk drive has 5,000 cylinders, numbered 0 to 4999. The drive is currently serving a requisition at cylinder 143, and previous request was at cylinder 125. The queue of pending requests, in FIFO order is:

86, 1470, 913, 1774, 948, 1509, 1022, 1750, 130

Assume that the disk arm can perform a seek to an adjacent cylinder in 1 millisecond and full stroke seek over all 5,000 cylinders in 18 milliseconds.

Calculate the total seek time to serve all the requests for each of the following schedules:

a. **FCFS** b. **SSTF** c. **SCAN**

Hint: $T_{seek} = T_{adjacent} + (T_{\text{full stroke}} - T_{\text{adjacent}}) * \sqrt{\frac{cylinders\ to\ move}{Total\ cylinders}}$

Substituting the values in the formulae gives 1+0.24 * $\sqrt{cylinders\ to\ move}$

For FCFS

$$9+0.24\,(\sqrt{143-86} + \sqrt{1470-86} + \sqrt{1470-913} + \sqrt{1774-913} + \sqrt{1774-948} + \sqrt{1509-948} + \sqrt{1509-1022} + \sqrt{1750-1022} + \sqrt{1750-130}) =$$

66.412

For SJF

$$9+0.24\,(\sqrt{143-130} + \sqrt{130-86} + \sqrt{913-86} + \sqrt{948-913} + \sqrt{1022-948} + \sqrt{1470-1022} + \sqrt{1509-1470} + \sqrt{1750-1509} + \sqrt{1774-1750}) =$$

33.312

For SCAN

$$9+0.24\,(\sqrt{913-143} + \sqrt{948-913} + \sqrt{1022-948} + \sqrt{1470-1022} + \sqrt{1509-1470} + \sqrt{1750-1509} + \sqrt{1774-1750} + \sqrt{1774-130} + \sqrt{130-86}) =$$

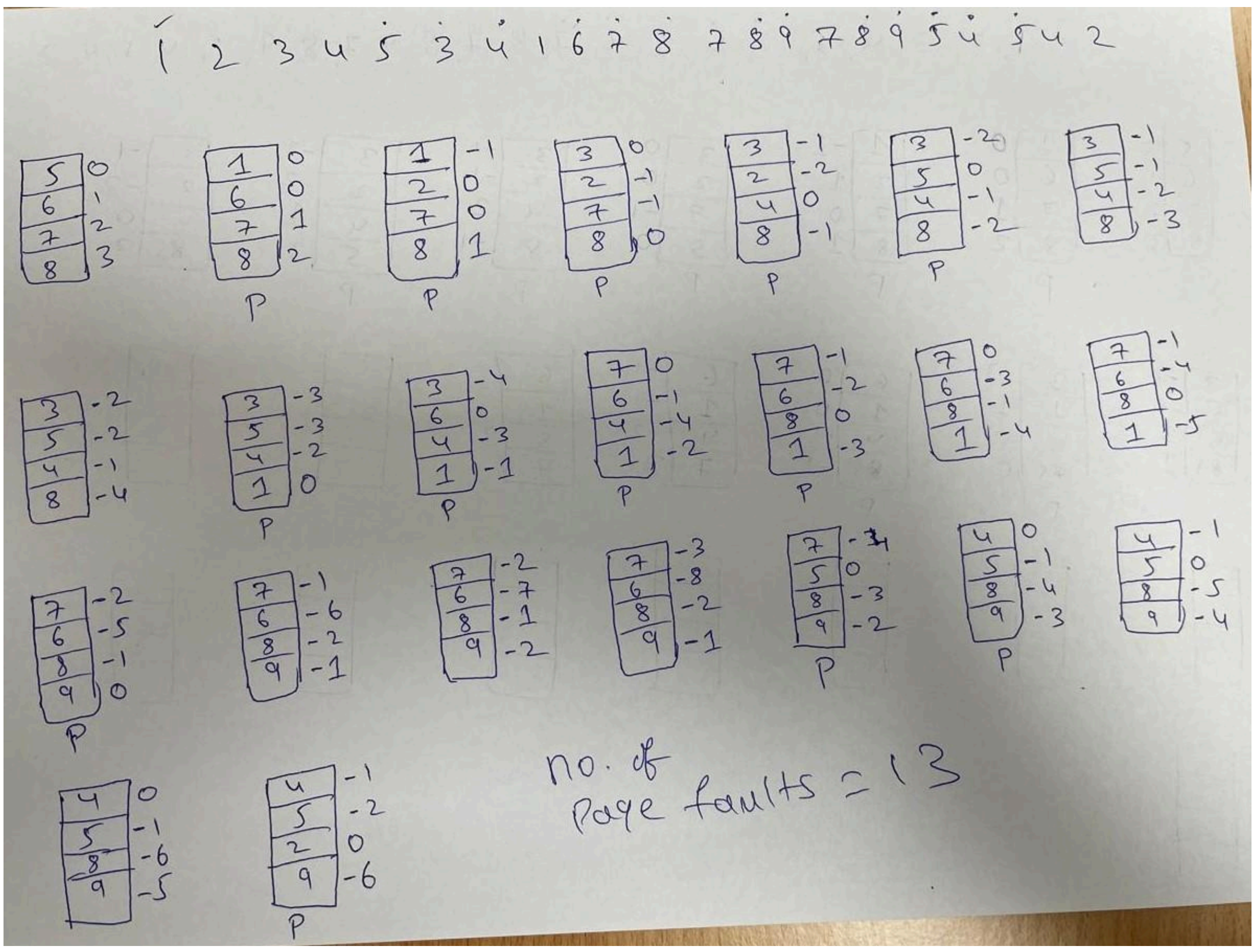
41.911

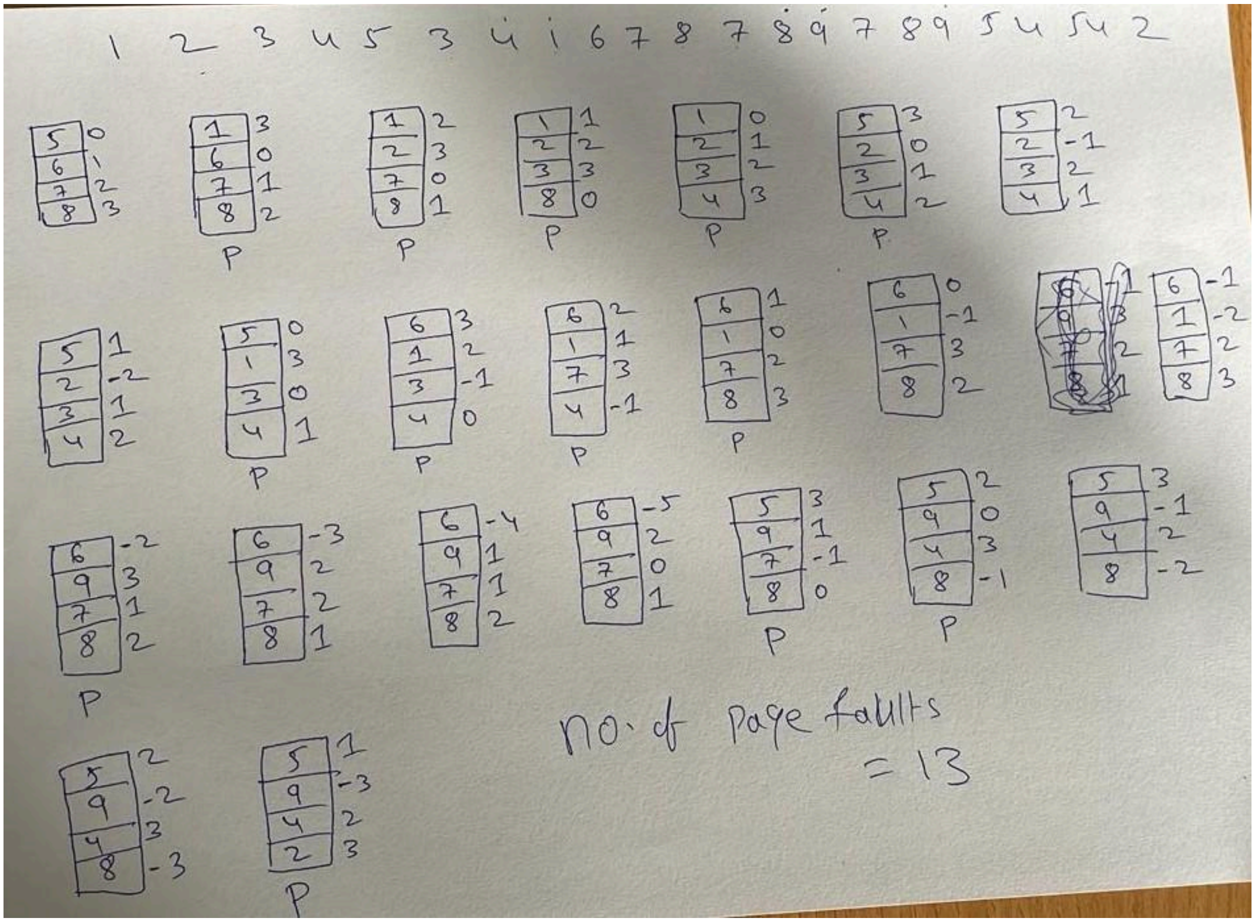
Q5: In a certain page-replacement algorithm, each page frame is associated with a counter. During a page fault, the page frame with the smallest counter value is replaced, and its counter is **reset**. When a page in memory is referenced, its associated counter is **incremented**. During both page faults and memory references, the counters of all page frames other than the referenced page are **decremented**.

How many page faults occur for the following reference string with **four** page frames and has a current configuration shown in the table on the **next column**.

1, 2, 3, 4, 5, 3, 4, 1, 6, 7, 8, 7, 8, 9, 7, 8, 9, 5, 4, 5, 4, 2

If multiple page frames share the **same** counter value, apply the least recently used (LRU) strategy to select a page frame for replacement. Marks will be awarded only for accurately depicting each page frame along with counter values at every step in a clear pictorial format **and** correctly determining the total number of page faults.





Q6: Consider the following people. Alice, Bob and Evil. Alice sends a message “**m**” to Bob through an insecure medium which might be intercepted by Evil. Draw the flow diagram of securing the communication between Alice and Bob using

a. Symmetric cryptography (1 mark)
b. Asymmetric cryptography with digital signatures (2 marks)

Clearly represent the keys used for encryption, decryption, and digital signatures in an appropriate manner.

Will be evaluated if your flow diagram conveys the following.

a. Alice and Bob use a symmetric key “k” to encrypt and decrypt the message
b. Alice uses Bob’s public key to encrypt the message and uses its private key to sign the message. Bob uses its private key to decrypt the message and uses Alice’s public key to verify the signature.