Question 1

a. **Define a page-replacement algorithm using this basic idea. Specifically address these problems:**

   i.   The initial value of the counters is 0.
   ii. The counters will be increased when there is a new page coming to associate with the page frame.
   iii. The counters will be decreased when there is a page that associates with the page frame is not required.
   iv. -   In *FIFO* algorithm, the earliest (first-in) page will be replaced.
        -   In *LRU* algorithm, the page will be replaced when it has not been used for the longest time.
        -   In *Optimal Page Replacement* algorithm, the page will be replaced when it will not be used for the longest time in the future.

b. **How many page faults for your algorithm for the following reference string, for four page frames?**

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

FIFO algorithm:

1	1	1	1	5	5	5	5	5	5	8	8	8	8	8	8	8	8	8	8	8	2
	2	2	2	2	2	2	1	1	1	1	1	1	9	9	9	9	9	9	9	9	9
		3	3	3	3	3	3	6	6	6	6	6	6	6	6	6	5	5	5	5	5
			4	4	4	4	4	4	7	7	7	7	7	7	7	7	7	4	4	4	4
M	M	M	M	M	H	H	M	M	M	M	H	H	M	H	H	H	M	M	H	H	M

So, there are 13 page faults when using *FIFO* algorithm.

LRU algorithm:

1	1	1	1	5	5	5	5	6	6	6	6	6	6	6	6	6	5	5	5	5	5
	2	2	2	2	2	2	1	1	1	1	1	1	9	9	9	9	9	9	9	9	9
		3	3	3	3	3	3	7	7	7	7	7	7	7	7	7	4	4	4	4	
			4	4	4	4	4	4	8	8	8	8	8	8	8	8	8	8	8	2	
M	M	M	M	M	H	H	M	M	M	M	H	H	M	H	H	H	M	M	H	H	M

So, there also have 13 page faults when using *LRU* algorithm.

c. **What's the minimum number of page faults for an optimal page replacement strategy for the reference string in part b with four page frames?**

1	2	3	4	5	3	4	1	6	7	8	7	8	9	7	8	9	5	4	5	4	2
1	1	1	1	1	1	1	1	6	6	8	8	8	8	8	8	8	8	8	8	8	2
	2	2	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		3	3	3	3	3	3	3	7	7	7	7	7	7	7	7	7	4	4	4	4
			4	4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9	9	9
M	M	M	M	M	H	H	H	M	M	M	H	H	M	H	H	H	H	M	H	H	M

So, there are 11 page faults when using *optimal page replacement* algorithm.