

1. We will not discuss this question during class. The answer to this question is given at the end of this tutorial sheet. You should work out the answer yourself by tracing through the algorithms.

Consider the following page reference string:

1 2 3 4 2 1 5 6 2 4 2 3 7 6 3 2 1 2 3 6

How many page faults would occur for the following replacement algorithms: (i) LRU, (ii) FIFO, (iii) Optimal, if we have two frames, four frames, and six frames respectively? Assuming that all frames are initially empty.

2. A computer has four page frames. The time of loading, time of last access, and the  $R$  and  $M$  bits for each page are as shown below (the times are in clock ticks):

frame	loaded	last ref.	$R$	$M$
0	126	280	1	0
1	230	265	0	1
2	140	270	0	0
3	110	285	1	1

Which page will be replaced if the following algorithm is used: (i) NRU (ii) FIFO (iii) LRU (iv) Second Chance (assuming we start with the “clock hand” pointing to 0 and proceed in the order of 0, 1, 2, 3).

3. Suppose that we define the working set of a process as all page referenced within the last two ticks. Consider the WSclock page replacement algorithm with the following system state:

frame	time of last used	$R$	$M$
0	6	0	1
1	9	1	0
2	9	1	1
3	7	0	0

Suppose that a page fault occurs at tick 10 due to a read request to page 4. Show the contents of the new table entries. Explain. You can assume we start with the “clock hand” pointing to 0 and proceed in the order of 0, 1, 2, 3.

4. Sketch the graph plotting how CPU utilization changes as the degree of multiprogramming (number of running processes) increases.
5. A computer system that uses demand paging is suffering from a low CPU utilization (25%). Upon measurement, the system designers found that I/O from the paging disk has a utilization of 99%, while other I/O devices has utilization of 5%.

The designers held a meeting and discussed how to improve the CPU utilization. Knowing that you have taken CS2106, they invited you to join the meeting. A list of actions are suggested to improve the utilizations. Which of the following actions do you approve? Explain.

- (a) upgrade to a faster CPU
- (b) upgrade to a larger paging disk
- (c) decrease the degree of multi-programming
- (d) install more RAM

- (e) use solid state drive (SSD) (which is faster than hard disk) as paging disk
- (f) enable pre-paging
- (g) use a larger page size

6	4	2	
8	11	18	LRU
10	11	18	FIFO
7	8	15	Optimal