Q1. Please see textbook

Q2i.

FIFO

|  |  |  |  |
| --- | --- | --- | --- |
| Access | Hit/Miss | Evict | Pages in Memory |
| 1 | miss |  | 1 |
| 2 | miss |  | 1,2 |
| 3 | miss |  | 1,2,3 |
| 1 | hit |  | 1,2,3 |
| 4 | miss |  | 1,2,3,4 |
| 5 | miss | 1 | 2,3,4,5 |
| 6 | miss | 2 | 3,4,5,6 |
| 1 | miss | 3 | 4,5,6,1 |
| 3 | miss | 4 | 5,6,1,3 |
| 2 | miss | 5 | 6,1,3,2 |

LRU

|  |  |  |  |
| --- | --- | --- | --- |
| Access | Hit/Miss | Evict | Pages in Memory |
| 1 | miss |  | 1 |
| 2 | miss |  | 1,2 |
| 3 | miss |  | 1,2,3 |
| 1 | hit |  | 2,3,1 |
| 4 | miss |  | 2,3,1,4 |
| 5 | miss | 2 | 3,1,4,5 |
| 6 | miss | 3 | 1,4,5,6 |
| 1 | hit |  | 4,5,6,1 |
| 3 | miss | 4 | 5,6,1,3 |
| 2 | miss | 5 | 6,1,3,2 |

Q2ii)

FIFO

|  |  |  |  |
| --- | --- | --- | --- |
| Access | Hit/Miss | Evict | Pages in Memory |
| 1 | miss |  | 1 |
| 3 | miss |  | 1,3 |
| 3 | hit |  | 1,3 |
| 2 | miss |  | 1,3,2 |
| 1 | hit |  | 1,3,2 |
| 4 | miss |  | 1,3,2,4 |
| 5 | miss | 1 | 3,2,4,5 |
| 6 | miss | 3 | 2,4,5,6 |
| 7 | miss | 2 | 4,5,6,7 |
| 8 | miss | 4 | 5,6,7,8 |
| 9 | miss | 5 | 6,7,8,9 |
| 1 | miss | 6 | 7,8,9,1 |
| 2 | miss | 7 | 8,9,1,2 |

LRU

|  |  |  |  |
| --- | --- | --- | --- |
| Access | Hit/Miss | Evict | Pages in Memory |
| 1 | miss |  | 1 |
| 3 | miss |  | 1,3 |
| 3 | hit |  | 1,3 |
| 2 | miss |  | 1,3,2 |
| 1 | hit |  | 3,2,1 |
| 4 | miss |  | 3,2,1,4 |
| 5 | miss | 3 | 2,1,4,5 |
| 6 | miss | 2 | 1,4,5,6 |
| 7 | miss | 1 | 4,5,6,7 |
| 8 | miss | 4 | 5,6,7,8 |
| 9 | miss | 5 | 6,7,8,9 |
| 1 | miss | 6 | 7,8,9,1 |
| 2 | miss | 7 | 8,9,1,2 |

Q3.

a. possible: may still be in the main memory

b. possible: when page is not in the main memory

c. possible: ideal case

d. possible: page can be present but still be dirty

Q4. We are given a disk with 2MB/track and we need to read 500B from the disk. We are also given that rotation time is 10ms

Hence, we need (500B/2MB) \* 10ms time to transfer this amount, which is our T\_trasfer = 0.0025ms

T = seek time + avg. rotation latency + transfer time

= 5ms + (10/2)ms + 0.0025ms

= 10.0025ms

Q6. Virtual address 11123456 in binary 0001 0001 0001 0010 0011 0100 0101 0110

Page table size 2^32 / 2^12 = 2^20. Hence, upper 20 bits to encode page table entry and frame number, and lower 12 bits for offset.

Please see textbook for software/hardware operations

Q7. 100ns \* (1 - PF) + 0.7 \* 20ms \* PF + 0.3 \* 8ms \* PF <= 200ns

Q5.

a. 2,6,9,2,4,2,1,7,3,0,5,2,1,2,9,5,7,3,8,5

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **FIFO** | | **LRU** | | **OPT** | |
| **Access** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** |
| 2 | miss | 2 | miss | 2 | miss | 2 |
| 6 | miss | 2,6 | miss | 2,6 | miss | 2,6 |
| 9 | miss | 2,6,9 | miss | 2,6,9 | miss | 2,6,9 |
| 2 | hit | 2,6,9 | hit | 6,9,2 | hit | 2,6,9 |
| 4 | miss | 6,9,4 | miss | 9,2,4 | miss | 2,9,4 |
| 2 | miss | 9,4,2 | hit | 9,4,2 | hit | 2,9,4 |
| 1 | miss | 4,2,1 | miss | 4,2,1 | miss | 2,9,1 |
| 7 | miss | 2,1,7 | miss | 2,1,7 | miss | 2,1,7 |
| 3 | miss | 1,7,3 | miss | 1,7,3 | miss | 2,1,3 |
| 0 | miss | 7,3,0 | miss | 7,3,0 | miss | 2,1,0 |
| 5 | miss | 3,0,5 | miss | 3,0,5 | miss | 2,1,5 |
| 2 | miss | 0,5,2 | miss | 0,5,2 | hit | 2,1,5 |
| 1 | miss | 5,2,1 | miss | 5,2,1 | hit | 2,1,5 |
| 2 | hit | 5,2,1 | hit | 5,1,2 | hit | 2,1,5 |
| 9 | miss | 2,1,9 | miss | 1,2,9 | miss | 1,5,9 |
| 5 | miss | 1,9,5 | miss | 2,9,5 | hit | 1,5,9 |
| 7 | miss | 9,5,7 | miss | 9,5,7 | miss | 1,5,7 |
| 3 | miss | 5,7,3 | miss | 5,7,3 | miss | 1,5,3 |
| 8 | miss | 7,3,8 | miss | 7,3,8 | miss | 1,5,8 |
| 5 | miss | 3,8,5 | miss | 3,8,5 | hit | 1,5,8 |
| **Page Faults** | **18** |  | **17** |  | **13** |  |

b. 0,6,3,0,2,6,3,5,2,4,1,3,0,6,1,4,2,3,5,7

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **FIFO** | | **LRU** | | **OPT** | |
| **Access** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** |
| 0 | miss | 0 | miss | 0 | miss | 0 |
| 6 | miss | 0,6 | miss | 0,6 | miss | 0,6 |
| 3 | miss | 0,6,3 | miss | 0,6,3 | miss | 0,6,3 |
| 0 | hit | 0,6,3 | hit | 6,3,0 | hit | 0,6,3 |
| 2 | miss | 6,3,2 | miss | 3,0,2 | miss | 6,3,2 |
| 6 | hit | 6,3,2 | miss | 0,2,6 | hit | 6,3,2 |
| 3 | hit | 6,3,2 | miss | 2,6,3 | hit | 6,3,2 |
| 5 | miss | 3,2,5 | miss | 6,3,5 | miss | 5,3,2 |
| 2 | hit | 3,2,5 | miss | 3,5,2 | hit | 5,3,2 |
| 4 | miss | 2,5,4 | miss | 5,2,4 | miss | 4,3,2 |
| 1 | miss | 5,4,1 | miss | 2,4,1 | miss | 4,3,1 |
| 3 | miss | 4,1,3 | miss | 4,1,3 | hit | 4,3,1 |
| 0 | miss | 1,3,0 | miss | 1,3,0 | miss | 4,0,1 |
| 6 | miss | 3,0,6 | miss | 3,0,6 | miss | 4,6,1 |
| 1 | miss | 0,6,1 | miss | 0,6,1 | hit | 4,6,1 |
| 4 | miss | 6,1,4 | miss | 6,1,4 | hit | 4,6,1 |
| 2 | miss | 1,4,2 | miss | 1,4,2 | miss | 4,6,2 |
| 3 | miss | 4,2,3 | miss | 4,2,3 | miss | 4,6,3 |
| 5 | miss | 2,3,5 | miss | 2,3,5 | miss | 4,6,5 |
| 7 | miss | 3,5,7 | miss | 3,5,7 | miss | 4,6,7 |
| **Page Faults** | **16** |  | **19** |  | **13** |  |

c. 3,1,4,2,5,4,1,3,5,2,0,1,1,0,2,3,4,5,0,1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **FIFO** | | **LRU** | | **OPT** | |
| **Access** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** |
| 3 | miss | 3 | miss | 3 | miss | 3 |
| 1 | miss | 3,1 | miss | 3,1 | miss | 3,1 |
| 4 | miss | 3,1,4 | miss | 3,1,4 | miss | 3,1,4 |
| 2 | miss | 1,4,2 | miss | 1,4,2 | miss | 2,1,4 |
| 5 | miss | 4,2,5 | miss | 4,2,5 | miss | 5,1,4 |
| 4 | hit | 4,2,5 | hit | 2,5,4 | hit | 5,1,4 |
| 1 | miss | 2,5,1 | miss | 5,4,1 | hit | 5,1,4 |
| 3 | miss | 5,1,3 | miss | 4,1,3 | miss | 5,1,3 |
| 5 | hit | 5,1,3 | miss | 1,3,5 | hit | 5,1,3 |
| 2 | miss | 1,3,2 | miss | 3,5,2 | miss | 2,1,3 |
| 0 | miss | 3,2,0 | miss | 5,2,0 | miss | 2,1,0 |
| 1 | miss | 2,0,1 | miss | 2,0,1 | hit | 2,1,0 |
| 1 | hit | 2,0,1 | hit | 2,0,1 | hit | 2,1,0 |
| 0 | hit | 2,0,1 | hit | 2,1,0 | hit | 2,1,0 |
| 2 | hit | 2,0,1 | hit | 1,0,2 | hit | 2,1,0 |
| 3 | miss | 0,1,3 | miss | 0,2,3 | miss | 3,1,0 |
| 4 | miss | 1,3,4 | miss | 2,3,4 | miss | 4,1,0 |
| 5 | miss | 3,4,5 | miss | 3,4,5 | miss | 5,1,0 |
| 0 | miss | 4,5,0 | miss | 4,5,0 | hit | 5,1,0 |
| 1 | miss | 5,0,1 | miss | 5,0,1 | hit | 5,1,0 |
| **Page Faults** | **15** |  | **16** |  | **11** |  |

d. 4,2,1,7,9,8,3,5,2,6,8,1,0,7,2,4,1,3,5,8

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **FIFO** | | **LRU** | | **OPT** | |
| **Access** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** |
| 4 | miss | 4 | miss | 4 | miss | 4 |
| 2 | miss | 4,2 | miss | 4,2 | miss | 4,2 |
| 1 | miss | 4,2,1 | miss | 4,2,1 | miss | 4,2,1 |
| 7 | miss | 2,1,7 | miss | 2,1,7 | miss | 7,2,1 |
| 9 | miss | 1,7,9 | miss | 1,7,9 | miss | 9,2,1 |
| 8 | miss | 7,9,8 | miss | 7,9,8 | miss | 8,2,1 |
| 3 | miss | 9,8,3 | miss | 9,8,3 | miss | 8,2,3 |
| 5 | miss | 8,3,5 | miss | 8,3,5 | miss | 8,2,5 |
| 2 | miss | 3,5,2 | miss | 3,5,2 | hit | 8,2,5 |
| 6 | miss | 5,2,6 | miss | 5,2,6 | miss | 8,2,6 |
| 8 | miss | 2,6,8 | miss | 2,6,8 | hit | 8,2,6 |
| 1 | miss | 6,8,1 | miss | 6,8,1 | miss | 8,2,1 |
| 0 | miss | 8,1,0 | miss | 8,1,0 | miss | 0,2,1 |
| 7 | miss | 1,0,7 | miss | 1,0,7 | miss | 7,2,1 |
| 2 | miss | 0,7,2 | miss | 0,7,2 | hit | 7,2,1 |
| 4 | miss | 7,2,4 | miss | 7,2,4 | miss | 4,2,1 |
| 1 | miss | 2,4,1 | miss | 2,4,1 | hit | 4,2,1 |
| 3 | miss | 4,1,3 | miss | 4,1,3 | miss | 3,2,1 |
| 5 | miss | 1,3,5 | miss | 1,3,5 | miss | 5,2,1 |
| 8 | miss | 3,5,8 | miss | 3,5,8 | miss | 8,2,1 |
| **Page Faults** | **20** |  | **20** |  | **16** |  |

e. 0,1,2,3,4,4,3,2,1,0,0,1,2,3,4,4,3,2,1,0

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **FIFO** | | **LRU** | | **OPT** | |
| **Access** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** | **Hit/Miss** | **Pages in Memory** |
| 0 | miss | 0 | miss | 0 | miss | 0 |
| 1 | miss | 0,1 | miss | 0,1 | miss | 0,1 |
| 2 | miss | 0,1,2 | miss | 0,1,2 | miss | 0,1,2 |
| 3 | miss | 1,2,3 | miss | 1,2,3 | miss | 3,1,2 |
| 4 | miss | 2,3,4 | miss | 2,3,4 | miss | 3,4,2 |
| 4 | hit | 2,3,4 | hit | 2,3,4 | hit | 3,4,2 |
| 3 | hit | 2,3,4 | hit | 2,4,3 | hit | 3,4,2 |
| 2 | hit | 2,3,4 | hit | 4,3,2 | hit | 3,4,2 |
| 1 | miss | 3,4,1 | miss | 3,2,1 | miss | 3,1,2 |
| 0 | miss | 4,1,0 | miss | 2,1,0 | miss | 0,1,2 |
| 0 | hit | 4,1,0 | hit | 2,1,0 | hit | 0,1,2 |
| 1 | hit | 4,1,0 | hit | 2,0,1 | hit | 0,1,2 |
| 2 | miss | 1,0,2 | hit | 0,1,2 | hit | 0,1,2 |
| 3 | miss | 0,2,3 | miss | 1,2,3 | miss | 3,1,2 |
| 4 | miss | 2,3,4 | miss | 2,3,4 | miss | 3,4,2 |
| 4 | hit | 2,3,4 | hit | 2,3,4 | hit | 4,3,2 |
| 3 | hit | 2,3,4 | hit | 2,4,3 | hit | 4,3,2 |
| 2 | hit | 2,3,4 | hit | 4,3,2 | hit | 4,3,2 |
| 1 | miss | 3,4,1 | miss | 3,2,1 | miss | 1,4,2 |
| 0 | miss | 4,1,0 | miss | 2,1,0 | miss | 0,4,2 |
| **Page Faults** | **12** |  | **11** |  | **11** |  |