**COMPSCI 3SH3 Operating System Homework Assignment 3**

1. **CPU Scheduling:**
2. Time quantum of 1 millisecond:

Calculating CPU utilization: 1 ms \* 11 = 11ms

We know that every task must use up the time quantum value. Thus, the I/O operations fro the I/O bound tasks will return just in time for their next turn. We must also factor non utilizations, which are the context switches of 11 \* 0.1 ms = 1.1ms.

Therefore, the total time is 1.1ms + 11 ms = 12.1ms total time. 11 ms / 12.1 ms = 0.91 % CPU utilization

1. Time quantum of 10 millisecond:

Time taken by I/O bound task is 10 + 0.1 = 10.1 ms. We have to add this result to the time to cycle through all processes in a round robin fashion: 10.1 ms + 11ms = 21.1 ms.

CPU utilization: (20/21.1) \* 100 = 94.786%

1. **Virtual Memory**

**LRU replacement:**

**3 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  | **4** |  |  | **5** |  |  | **1** |  |  | **7** |  |  | **2** |  | **-** |  |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  | **6** |  |  |  | **3** |  |  | **-** |  |  |  | **-** |  |
| **Frame 3** |  |  | **3** |  |  | **1** |  |  | **2** |  | **-** |  |  | **6** |  |  | **1** |  |  | **6** |

Total page faults: 15

**4 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  |  |  | **-** |  |  |  | **6** |  |  |  |  |  | **-** |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** |  | **-** |  |  |  |  | **-** |  | **-** |  |  |
| **Frame 3** |  |  | **3** |  |  |  | **5** |  |  |  |  | **3** |  |  | **-** |  |  |  | **-** |  |
| **Frame 4** |  |  |  | **4** |  |  |  | **6** |  |  |  |  | **7** |  |  |  | **1** |  |  |  |

Total page faults: 10

**5 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  |  |  | **-** |  |  |  |  |  |  | **-** |  |  |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** |  | **-** |  |  |  |  | **-** |  | **-** |  |  |
| **Frame 3** |  |  | **3** |  |  |  |  | **6** |  |  |  |  |  | **-** |  |  |  |  |  | **-** |
| **Frame 4** |  |  |  | **4** |  |  |  |  |  |  |  | **3** |  |  | **-** |  |  |  | **-** |  |
| **Frame 5** |  |  |  |  |  |  | **5** |  |  |  |  |  | **7** |  |  |  |  |  |  |  |

Total page faults: 8

**6 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  |  |  | **-** |  |  |  |  |  |  | **-** |  |  |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** |  | **-** |  |  |  |  | **-** |  | **-** |  |  |
| **Frame 3** |  |  | **3** |  |  |  |  |  |  |  |  | **-** |  |  | **-** |  |  |  | **-** |  |
| **Frame 4** |  |  |  | **4** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Frame 5** |  |  |  |  |  |  | **5** |  |  |  |  |  | **7** |  |  |  |  |  |  |  |
| **Frame 6** |  |  |  |  |  |  |  | **6** |  |  |  |  |  | **-** |  |  |  |  |  | **-** |

Total page faults: 7. This is the fewest we can have with 7 frames

**Fifo Replacement:**

**3 Frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  | **4** |  |  |  | **6** |  |  |  | **3** |  |  | **-** | **2** |  | **-** |  | **6** |
| **Frame 2** |  | **2** |  |  | **-** | **1** |  |  | **2** |  | **-** |  | **7** |  |  |  | **1** |  |  |  |
| **Frame 3** |  |  | **3** |  |  |  | **5** |  |  | **1** |  |  |  | **6** |  |  |  |  | **3** |  |

Total page faults: 16

**4 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** | **5** |  |  |  |  | **3** |  |  | **-** |  | **1** |  |  |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  | **6** |  |  |  |  | **7** |  |  |  |  |  | **3** |  |
| **Frame 3** |  |  | **3** |  |  |  |  |  | **2** |  | **-** |  |  | **6** |  |  |  |  |  | **-** |
| **Frame 4** |  |  |  | **4** |  |  |  |  |  | **1** |  |  |  |  |  | **2** |  | **-** |  |  |

Total page faults: 14

**5 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  | **6** |  |  |  |  |  | **-** |  |  |  |  |  | **-** |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** | **1** |  |  |  |  |  |  | **-** |  |  |  |
| **Frame 3** |  |  | **3** |  |  |  |  |  |  |  | **2** |  |  |  |  | **-** |  | **-** |  |  |
| **Frame 4** |  |  |  | **4** |  |  |  |  |  |  |  | **3** |  |  | **-** |  |  |  | **-** |  |
| **Frame 5** |  |  |  |  |  |  | **5** |  |  |  |  |  | **7** |  |  |  |  |  |  |  |

Total page faults: 10

**6 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  |  |  | **-** |  |  | **7** |  |  |  |  |  |  |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** |  | **-** |  |  |  |  | **-** | **1** |  |  |  |
| **Frame 3** |  |  | **3** |  |  |  |  |  |  |  |  | **-** |  |  | **-** |  |  | **2** |  |  |
| **Frame 4** |  |  |  | **4** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **3** |  |
| **Frame 5** |  |  |  |  |  |  | **5** |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Frame 6** |  |  |  |  |  |  |  | **6** |  |  |  |  |  | **-** |  |  |  |  |  | **-** |

Total page faults: 10. This is the fewest we can have with 7 frames

**Optimal Replacement**

**3 Frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  |  |  | **-** |  | **3** |  |  | **-** |  |  |  | **-** |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** |  | **-** |  | **7** |  |  | **2** |  | **-** |  |  |
| **Frame 3** |  |  | **3** | **4** |  |  | **5** | **6** |  |  |  |  |  | **-** |  |  | **1** |  |  | **6** |

Total page faults: 11

**4 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  |  |  | **-** |  |  | **7** |  |  |  | **1** |  |  |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** |  | **-** |  |  |  |  | **-** |  | **-** |  |  |
| **Frame 3** |  |  | **3** |  |  |  |  |  |  |  |  | **-** |  |  | **-** |  |  |  | **-** |  |
| **Frame 4** |  |  |  | **4** |  |  | **5** | **6** |  |  |  |  |  | **-** |  |  |  |  |  | **-** |

Total page faults: 8

**5 frames:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **1** | **2** | **3** | **4** | **2** | **1** | **5** | **6** | **2** | **1** | **2** | **3** | **7** | **6** | **3** | **2** | **1** | **2** | **3** | **6** |
| **Frame 1** | **1** |  |  |  |  | **-** |  |  |  | **-** |  |  |  | **-** |  |  | **-** |  |  |  |
| **Frame 2** |  | **2** |  |  | **-** |  |  |  | **-** |  | **-** |  |  |  |  | **-** |  | **-** |  |  |
| **Frame 3** |  |  | **3** |  |  |  |  |  |  |  |  | **-** |  |  | **-** |  |  |  | **-** |  |
| **Frame 4** |  |  |  | **4** |  |  |  |  |  |  |  |  | **7** |  |  |  |  |  |  |  |
| **Frame 5** |  |  |  |  |  |  | **5** | **6** |  |  |  |  |  | **-** |  |  |  |  |  | **-** |

Total page faults: 7. This is the best we can do with 6 or 7 frames as well