1. Diagrams of the partitions after the OS has placed the 4 processes using different algorithms.

P1 – 212 KB, P2 – 417 KB, P3 – 112 KB, P4 – 426 KB

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Free | P 10 | **P 1** | **P 3** | Free | P 11 | Free | P 12 | Free | P 13 | **P 2** | Free |
| 100 KB | 30 KB | **212 KB** | **112 KB** | 176 KB | 30 KB | 200 KB | 30 KB | 300 KB | 30 KB | **417 KB** | 183 KB |

**First-Fit**: P4 could not be placed because there were no free spots that could hold 426 KB

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Free | P 10 | **P 2** | Free | P 11 | **P 3** | Free | P 12 | **P 1** | Free | P 13 | **P 4** | Free |
| 100 KB | 30 KB | **417 KB** | 83 KB | 30 KB | **112 KB** | 88 KB | 30 KB | **212 KB** | 88 KB | 30 KB | **426 KB** | 174 KB |

**Best-Fit**: All the process could be placed

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Free | P 10 | **P 2** | Free | P 11 | Free | P 12 | Free | P 13 | **P 1** | **P 3** | Free |
| 100 KB | 30 KB | **417 KB** | 83 KB | 30 KB | 200 KB | 30 KB | 300 KB | 30 KB | **212 KB** | **112 KB** | 276 KB |

**Worst-Fit**: P4 could not be placed because there were no free spots that could hold 426 KB

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Free | P 10 | **P 1** | Free | P 11 | Free | P 12 | Free | P 13 | **P 2** | **P 3** | Free |
| 100 KB | 30 KB | **212 KB** | 288 KB | 30 KB | 200 KB | 30 KB | 300 KB | 30 KB | **417 KB** | **112 KB** | 71 KB |

**Next-Fit**: P4 could not be placed because there were no free spots that could hold 426 KB

1. Page numbers and offsets for a system with 1KB (1024 bytes or 210 bytes):

|  |  |  |
| --- | --- | --- |
| **Address** | **Page Number** | **Offset (10 bits)** |
| 2375 | 0010 00 | 11 0111 0101 |
| 19366 | 0001 1001 00 | 11 0110 0110 |
| 30000 | 0011 0000 00 | 00 0000 0000 |
| 256 | 00 | 10 0101 0110 |
| 16385 | 0001 0110 00 | 11 1000 0101 |

1. For a 32-bit (22 bytes) logical address space, 4 KB (212 bytes) page size and 512 MB (229 bytes) physical memory system:
   1. Conventional Single-Level Page Table:

# of entries = **1,048,576 entries = 220** = (232 / 212)

* 1. Inverted Page Table:

# of entries = **524,288 entries = 219** = (229 \* 22/ 212)

1. A direct memory reference (ma) takes 200ns
   1. Single-Level Page Table:

It will take **400ns** to locate and reference a page in memory. 200ns to access the page table + 200ns to access the word in memory, thus in total it will take 400ns.

* 1. If a TLB is added:

75% (0.75) TLB Hit (p)

10ns TLB search time (tlbs)

Effective memory-access time = (1 – p) \* (tlbs + 2 \* ma) + p \* (tlbs + ma)

Effective memory-access time = (1 – 0.75) (10 + 2\*200) + 0.75 (10 + 200)

= 0.25 \* 410 + 0.75 \* 210 = 260ns

The effective access time is **260ns** if we add a TLB.

1. 3 Frames in physical memory.

Page Reference string: 1, 2, 3, 4, 2, 1, 5, 6, 2, 1, 2, 3, 7, 6, 3, 2, 1, 2, 3, 6

**Yellow** – Fault **Green** – No Fault **Red** – Least Recently Used Page

Using LRU algorithm:

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

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

**Thus, 15 page faults using LRU**

**Yellow** – Fault **Green** – No Fault

Using Optimal Replacement algorithm:

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

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

**Thus, 11 page faults using OPT**

1. Code in file pagesim.cpp
2. Code in file impl.cpp