**Assignment 5**

**CIS355** – Spring Term 2018

**Point Value**: 100 points

**Assignment Due Date**: **In class Thursday, April 19, 2018**

**Submission Instruction**

Please write the questions and your answers to those questions on a Microsoft Word document. The name of the file should be HW5\_YourLastname\_YourFirstname.docx. Please submit the file .docx on Schoology by 11:59pm and a hard copy of the .docx file to the instructor in lecture.

**Short answers**

1. What is virtual memory **(2 points)?** What is the purpose of virtual memory **(2 points)?** Where is the virtual memory stored? (**1 points**)

* **Memory that appears to exist as main storage although most of it is supported by data held in secondary storage. It is a set of techniques and hardware allowing us to execute a program even when not entirely in memory.**
* **Virtual memory combines your computer's RAM with temporary space on your hard disk. When RAM runs low, virtual memory moves data from RAM to a space called a paging file.**
* **Pages of process memory may be displaced from the RAM to the disk. This is called swapping or paging. The data is moved to the swap space, and loaded back from the swap space when it is needed.**

1. Under what circumstances do page faults occur **(5 points)?** Describe the actions taken by the OS when a page fault occurs. Please use 1, 2, 3, … to indicate the order of the actions taken by the OS. (**10 points**)

* **A page fault occurs when a page is referenced, but that page is not in memory**
* **The actions taken by the OS when a page fault occurs:**

1. **Selects a page to replace an existing page (page replacement policy)**
2. **Starts to load new page into memory from disk**
3. **Context switches to another process while I/O is being done**
4. **Gets interrupt that page is loaded in memory**
5. **Updates the page table entry**
6. **Continues the process that causes the page fault**
7. Considering the following page reference string:

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

Assuming demand paging with three frames, how many page faults would occur for the following replacement algorithms

**LRU (10 points):**

* 7, 2, 3, 1, 2, 5, 3, 4, 6, 7, 7, 1, 0, 5, 4, 6, 2, 3, 0, 1
* **18 page faults**
* **highlighted numbers are hits that occurred**

**FIFO (10 points):**

* 7, 2, 3, 1, 2, 5, 3, 4, 6, 7, 7, 1, 0, 5, 4, 6, 2, 3, 0, 1
* **17 page faults**
* **highlighted numbers are hits that occurred**

**OPT: (10 points):**

* 7, 2, 3, 1, 2, 5, 3, 4, 6, 7, 7, 1, 0, 5, 4, 6, 2, 3, 0, 1
* **13 page faults**
* **high lighted numbers are hits that occurred**

1. In addition to LRU, there is a similar page replacement algorithm called Least Frequently Used (LFU). Under LFU, when the memory is full and a new page will be brought into memory, the page with the least reference frequency will be replaced. Describe a situation in which a least frequently used (LFU) page replacement algorithm generates fewer page faults than the least recently used (LRU) page replacement algorithm**? (10 points)**

* **The following sequence of memory accesses in a system that can hold four pages in memory: 1, 1, 2, 3, 4, 5, 1.**
* **When page 5 is accessed, the LFU page-replacement algorithm would replace a page other than 1, and therefore would not experience a page fault**
* **On the other hand, for the sequence, when page 1 is accessed again. The following sequence “1, 2, 3, 4, 5, 2,” then the LRU algorithm performs better**

1. A given system provides three frames to a program. The system uses single-layer paging (one page table) stored in memory but also has a TLB. TLB hit rates are 88%. Assume a TLB access takes 20ns, a memory access requires 200ns, and a page fault costs 8,000,000ns. Provide the amount of time a program with the reference string below spends accessing memory when using second chance FIFO. (**20 points**)

Reference String: 7, 0, 1, 2, 0, 3, 0, 4, 2, 3, 0, 3, 2, 1, 2, 0, 1, 7, 0, 1

|  |  |  |
| --- | --- | --- |
| **Page in** | **7** |  |
| **Frame 1** | **7** | **0** |
| **Frame 2** | **-** |  |
| **Frame 3** | **-** |  |
| **Page out** | **-** |  |
| **Page in** | **0** |  |
| **Frame 1** | **7** | **0** |
| **Frame 2** | **0** | **0** |
| **Frame 3** | **-** |  |
| **Page out** | **-** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **1** |  |
| **Frame 1** | **7** | **0** |
| **Frame 2** | **0** | **0** |
| **Frame 3** | **1** | **0** |
| **Page out** | **-** |  |
| **Page in** | **2** |  |
| **Frame 1** | **2** | **0** |
| **Frame 2** | **0** | **0** |
| **Frame 3** | **1** | **0** |
| **Page out** | **7** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **0** |  |
| **Frame 1** | **2** | **0** |
| **Frame 2** | **0** | **1** |
| **Frame 3** | **1** | **0** |
| **Page out** | **-** |  |
| **Page in** | **3** |  |
| **Frame 1** | **2** | **0** |
| **Frame 2** | **0** | **0** |
| **Frame 3** | **3** | **0** |
| **Page out** | **1** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **0** |  |
| **Frame 1** | **2** | **0** |
| **Frame 2** | **0** | **1** |
| **Frame 3** | **3** | **0** |
| **Page out** | **-** |  |
| **Page in** | **4** |  |
| **Frame 1** | **4** | **0** |
| **Frame 2** | **0** | **0** |
| **Frame 3** | **3** | **0** |
| **Page out** | **2** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **2** |  |
| **Frame 1** | **4** | **0** |
| **Frame 2** | **2** | **0** |
| **Frame 3** | **3** | **0** |
| **Page out** | **0** |  |
| **Page in** | **3** |  | |
| **Frame 1** | **4** | **0** | |
| **Frame 2** | **2** | **0** | |
| **Frame 3** | **3** | **1** | |
| **Page out** | **0** |  | |

|  |  |  |
| --- | --- | --- |
| **Page in** | **0** |  |
| **Frame 1** | **0** | **0** |
| **Frame 2** | **2** | **0** |
| **Frame 3** | **3** | **1** |
| **Page out** | **4** |  |
| **Page in** | **3** |  |
| **Frame 1** | **0** | **0** |
| **Frame 2** | **2** | **0** |
| **Frame 3** | **3** | **1** |
| **Page out** | **-** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **2** |  |
| **Frame 1** | **0** | **0** |
| **Frame 2** | **2** | **1** |
| **Frame 3** | **3** | **1** |
| **Page out** | **-** |  |
| **Page in** | **1** |  |
| **Frame 1** | **1** | **0** |
| **Frame 2** | **2** | **1** |
| **Frame 3** | **3** | **1** |
| **Page out** | **0** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **2** |  |
| **Frame 1** | **1** | **0** |
| **Frame 2** | **2** | **2** |
| **Frame 3** | **3** | **1** |
| **Page out** | **-** |  |
| **Page in** | **0** |  |
| **Frame 1** | **0** | **0** |
| **Frame 2** | **2** | **2** |
| **Frame 3** | **3** | **1** |
| **Page out** | **0** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **1** |  |
| **Frame 1** | **1** | **0** |
| **Frame 2** | **2** | **2** |
| **Frame 3** | **3** | **1** |
| **Page out** | **0** |  |
| **Page in** | **7** |  |
| **Frame 1** | **7** | **0** |
| **Frame 2** | **2** | **2** |
| **Frame 3** | **3** | **1** |
| **Page out** | **1** |  |

|  |  |  |
| --- | --- | --- |
| **Page in** | **0** |  |
| **Frame 1** | **0** | **0** |
| **Frame 2** | **2** | **2** |
| **Frame 3** | **3** | **1** |
| **Page out** | **7** |  |
| **Page in** | **1** |  |
| **Frame 1** | **1** | **0** |
| **Frame 2** | **2** | **2** |
| **Frame 3** | **3** | **1** |
| **Page out** | **0** |  |

**20+200+(8,000,000\*10 PAGE FAULTS)=800,000,220 NS**

1. Please explain what is a reference bit in the second chance algorithm? **(5 points)** What is the modified/dirty bit in the enhanced second chance algorithm? **(5 points)**

* **A reference bit refers to each page. Each time a memory frame is referenced, set the reference bit to 1, this will give the frame a second chance. This algorithm checks to see if its referenced bit is set. If it is not set, the page is swapped out. Otherwise, the referenced bit is cleared, the page is inserted at the back of the queue (as if it were a new page) and this process is repeated. In other words, On a page fault, the OS checks the reference bit of the next frame. If the reference bit is 0, replace the page, and set its bit to 1. If the reference bit is 1, set bit to 0, and advance the pointer to the next frame.**
* **A modified/dirty bit is kept by the hardware when a frame is modified. 1= modified, and 0 = page is the same as the copy on the disk**

1. We use 5-bit logical addresses which allows 32 possible locations. The higher 3 bits are used for the page number and the lower 2 bits are used for the page offset. What is the size of a frame? **(5 points)** How many pages are in the page table? **(5 points)**

* **2^5 = 32**
* **3 higher bits used for page numbers**
* **2^3 = 8 pages in the page table**
* **2 lower bits for offset**
* **2^2 = size of frame = 4 bytes**