Worksheet 9.1: Virtual Memory, Problem Solving

Q1. Consider a virtual memory system with 8 pages (0 through 7) and 3 frames (0, 1, 2). Trace the state of the system for the sequence of page accesses shown below using the Least Recently Used (LRU) page replacement algorithm. Show the contents of the three frames after each page request (as done in class), and then give the number of page faults.

	6	2	6	5	5	4	1	2	3
f1	6	6	6	6	6	6	1	1	1
f2		2	2	2	2	4	4	4	3
f3				5	5	5	5	2	2

Number of page faults: 7

Q2. Consider a demand-paging system with a paging disk that has an average access and transfer time of 8 milliseconds. Addresses are translated through a page table in **main memory**. Main memory access time is 5 microseconds per access. The system also has a Table-Lookaside Buffer (TLB) with a negligibly small access time. Assuming that 90% of the memory accesses hit in the TLB, all the accesses that hit in the TLB do not cause page faults and only 2% of the accesses that miss in the TLB (0.2% of the total) result in page faults, compute the **effective access time (EAT)** for a memory operation. Make sure that you account for the right number of memory accesses in the case of a TLB miss. You may neglect the memory access time when a page fault happens. First, calculate the time for each of the three different cases shown below, and then use those times to calculate the EAT. Show your calculations **clearly**. A final answer with no calculations will get zero credit even if it happens to be correct.

Time for accesses that hit in the TLB = 0.9 x M = 0.9 x 5 = 4.5 μs

Time for accesses that miss in the TLB and don't cause page faults = 0.1 x 0.98 x 2M
= 0.098 x 2 x 5 ≈ 1 μs

Time for accesses that miss in the TLB and cause page faults = 0.1 x 0.02 x 8 x 10^3 = 16 μs

Effective access time = 4.5 + 1 + 16 = 21.5 μs

Q3. A program has one loop. The code outside the loop accesses 200 pages and the code inside the loop sequentially accesses 10 pages. The loop is executed 50 times, and all 10 pages are accessed sequentially in every iteration of the loop. Assume for simplicity that the pages accessed inside the loop are distinct from the pages accessed outside the loop (no overlap). The program accesses 100 words in each page. Assuming **pure demand paging** and the **LRU** page replacement policy, calculate the page fault rate for each of the following cases. Show your calculations **clearly**.

1. The process has 12 frames allocated to it.

$$\frac{\textit{Number of page faults}}{\textit{Number of memory accesses}} = \frac{200+10}{100(200+50\times 10)} = \frac{210}{70000} = \frac{3}{1000}$$

2. The process has 8 frames allocated to it.

$$\frac{\textit{Number of page faults}}{\textit{Number of memory accesses}} = \frac{200+10\times 50}{100(200+50\times 10)} = \frac{700}{70000} = \frac{1}{100}$$