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Directions:

0) Closed book exam. One 8.5"x11" summary sheet is permitted.

1) Place your initials and page number in the top, right hand corner of every page and your name on the cover page of the test.

2) Provide sufficient explanation so that I can follow your solution.

3) Problems are not given in the order of difficulty. Point values for each problem are indicated in parentheses. Spend your time accordingly.

Problem 1 (10 Points)
Consider a buddy system with 5 different block sizes ($2^0$ through $2^4$ bytes). Assume the following sequence of block sizes are requested: 1, 2, 4, 2 bytes. What are the binary addresses of the blocks that are allocated assuming that lowest numbered blocks are allocated first? Note: The binary address of a block is the lowest address of a byte in a block.

Problem 2 (10 Points)
Consider a paged virtual address space composed of 32 pages of 2 KB each which is mapped into a 1 MB physical memory space.

a) How many bits should be allocated for the page number, and how many bits should be allocated for the page offset? Explain.

b) What is the difference between a Translation Lookaside Buffer (TLB) and a page table?

Problem 3 (10 Points)
Consider the following page reference sequence:

1, 3, 3, 3, 3, 3, 3, 3, 1, 1, 0, 3, 3, 3, 2, 4, 2, 3, 3, 2, 3, 3, 3, 3, 2, 2, 2

Suppose that the process is allocated 3 frames and that all frames are initially empty.

a) Which page references will cause a page fault if the LRU page replacement algorithm is used?

b) What will be the page fault rate if an LRU page replacement algorithm is used?

Problem 4 (10 Points)
The basic clock page replacement algorithm (R-bit only) is only an approximation to the LRU algorithm. Give a simple example where the first page selected for replacement will be different for the two algorithms when a process is allocated 3 frames and the reference string contains page numbers from the set 0, 1, 2, 3.
Problem 5 (10 Points)
Consider the working set model with a window size of $\Delta = 3$ and the following page reference sequence for a process:

$$3, 2, 2, 2, 2, 2, 3, 3, 0, 2, 2, 2, 3, 4, 3, 4, 1, 1, 4, 2, 2, 1, 1$$

a) Give one example of the largest working set that the process will have.

b) Why is it hard to implement the working set model in a practical system?

Problem 6 (15 Points)
Suppose that there are $N$ jobs numbered 1 to $N$, and job $i$ has a CPU service demand of $s(i)$. For each of the following statements, indicate if the statement is true or false. If the statement is true, use 1 or 2 sentences to explain why? If the statement is false, either explain why or give a counter example.

a) If all $N$ jobs arrive at the same time, the CPU will be busy for a time equal to $\sum_{i=1}^{N} s(i)$ for Round Robin (RR) scheduling if the context switching time is negligible.

b) If all $N$ jobs arrive at the same time, the average turnaround time for FCFS scheduling will be smaller than for SJF (Shortest Job First) scheduling.

c) RR scheduling for any quantum size less than the largest service demand $s(i)$ is fairer than FCFS scheduling if context switching time is negligible.

Problem 7 (10 Points)
Consider a disk drive with the following geometry and speed characteristics: 100 cylinders; 20 tracks per cylinder (i.e., 20 heads); 100 512-byte sectors per track; 10,000 rotations per minute (RPM); and 40 msec average random seek time.

a) What is the approximate capacity of this disk drive in bytes?

b) Approximately how long does it take to do a single read of a 10-sector block at a random location?

Problem 8 (10 Points)
A signal can not be lost when using counting semaphores but it can when using condition variables.

a) How is it possible to lose a signal when using condition variables?

b) How does a counting semaphore avoid the situation in Part a?
Problem 9 (10 Points)

Below is a reader/writer algorithm. Assume that there are an arbitrary number of readers and writers.

```c
int       X = 0;
Semaphore: Y = 1, Z = 1;
```

**Reader Process:**

```c
Wait (Y);
    X = X + 1;
    if (X == 1) Wait(Z);              // Place A
Signal (Y);
... Read object ...
Wait (Y);
    X = X - 1;
    if (X == 0) Signal (Z);          // Place B
Signal (Y);
```

**Writer Process:**

```c
Wait (Z);
... Write object ...
Signal (Z);
```

a) What is the purpose of each of the semaphores Y and Z?

b) What is the purpose of the statements labeled **Place A**, and **Place B**?