

Please write in your own words and be sure to show all your work and write down any assumptions you make.

1. [10 points] Memory management:
 - (a) The PowerPC uses a hardware managed TLB with an inverted page table. Discuss its advantages and disadvantages. i.e., What are the implications of the inverted page table on the size of each page table entry? What about a page table walk (how many memory references are potentially required on a TLB miss)? Are per-process page tables necessary or can they be eliminated?
 - (b) A stack page replacement algorithm is one that satisfies the inclusion property, i.e., one for which it can be shown that at any given time, the set of pages in memory for n frames is always a subset of the set of pages that would be in memory with $n + 1$ frames for the same sequence of accesses. Prove that OPT and LRU (least recently used) are stack algorithms.
2. [15 points] I/O interface:
 - (a) Consider the following I/O scenarios on a single-user PC:
 - i. a mouse used with a graphical user interface
 - ii. a disk drive containing user files
 - iii. a graphics card with direct memory bus connection, accessible via memory-mapped I/OFor each of these I/O scenarios, would you use polled I/O or interrupt-driven I/O? Would you design the operating system to use buffering, spooling, caching, or a combination?
 - (b) The operating system normally performs resource accounting in order to determine, for instance, the amount of CPU time that a process has already consumed for scheduling purposes. Discuss why interrupts and execution in kernel mode could complicate this process.
3. [10 points] Disk I/O: Consider a magnetic disk with N cylinders rotating at a speed of R revolutions per minute. The sector size on the disk is constant. Requests for sectors arriving from the file system can be located anywhere on the disk with equal probability and the locations of the requested sectors are independent of each other.
 - Under these assumptions, on average, over how many disk cylinders will the head have to seek to get from one requested sector to the next?
 - On average, once the head is positioned over the right cylinder, how long will it take before the head is positioned at the beginning of the right sector?
 - Say the disk (one platter) has 1000 cylinders and a sector size of 1024 bytes. The transfer time per sector is 0.1 milliseconds (i.e., the raw data rate is 10 Megabytes per second). The rotation speed is 7200 revolutions per minute. The time to seek over X cylinders is given by the formula $5 + X/100$ milliseconds. Under the same assumptions above, what will the maximum effective data rate be? What percentage is this of the “raw” data rate? What effect would changing the sector size to 4 Kilobytes have?
4. [15 points] File system interface and implementation:
 - (a) Under a Unix file system, how many disk accesses would be required in order to access a file, presuming no caching has been performed?
 - (b) Describe the difference between a hard and soft (symbolic) link. Can hard links cause an infinite loop during path name lookup? If yes, why? If not, are there other operations where this might be a problem?

- (c) For your file system, you have chosen a block size of 4096 bytes, and have made a decision to use 2-level indexed allocation, with 4-byte block pointers.
- i. What is the maximum file size allowed?
 - ii. What is the maximum file system size?
 - iii. Suppose you have a disk subsystem that can hold more data than the above maximum file system size. List at least two ways in which you might utilize all the available space.