1. (a) An audio CD lasts for about 75 minutes. The sound is stored as two 16 bit samples taken 44100 times a second. Estimate the amount of data on a CD in MB and the rate at which data must be read in kB/s.

   (b) Explain three of the following terms: 'page table', 'TLB', 'physical address', 'page fault', 'cache miss'.

   (c) Either describe the useful features provided by a virtual memory system, or give an example of how address translation takes place using the page table.

2. (a) Why would someone want to profile code? Describe some tools available for profiling.

   (b) Comment briefly on what tools like `make` and `RCS` can do to make a programmers life easier.

   (c) Figure 1 shows the graph of the performance of a 4 processor SMP machine, calculating large dot products of various sizes. The tests were done first running one process at a time and then running 4 processes at a time and plotting the performance of one of them. What can you say about the caches and memory system of the computer in question?

3. (a) Briefly describe what is commonly referred to as the Memory Hierarchy. Why are varying speeds of memory used?

   (b) Give a description of direct-mapped, fully-associative and set-associative caches. What is thrashing (in the context of caches)?

   (c) Give an example of code which would cause a 16kB, 2 way set associative cache to thrash.

4. (a) Explain three of the following unix system calls: `fork()`, `exec()`, `pipe()`, `wait()`.

   (b) Explain the terms preemptive multitasking and cooperative multitasking. Why is one necessary for a interactive multiuser system?

   (c) Explain how memory is usually allocated in C in terms of the stack and the heap. Be sure to mention how function calls, a function's local variables and `malloc` change the stack and heap.

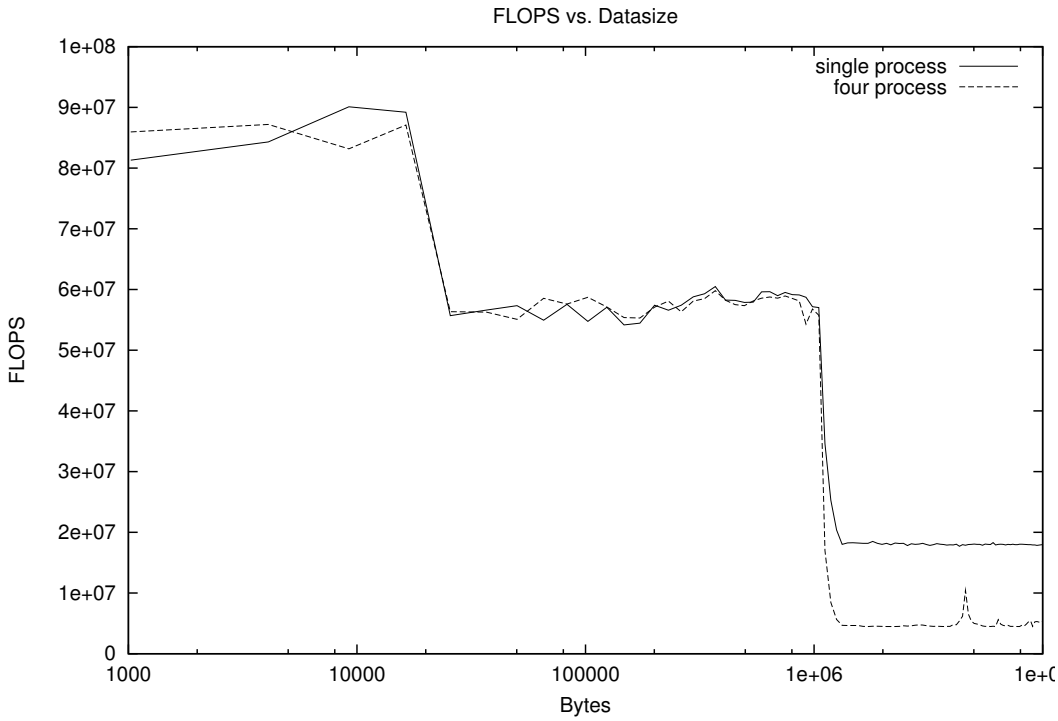

Figure 1: Performance on Large Dot Products