Answer all six problems.

**Problem 1:** (15 pts) Briefly explain the following terms giving, where appropriate, their impact on OS design:

1. Batch Multiprogramming
2. Swapping
3. Symmetric multiprocessor

**Problem 2:**
(a) (9 pts) Order the following in terms of overhead cost: interrupt service, user-level thread switch, kernel-level thread switch, procedure calls, and process switch. Explain.
(b) (6 pts) Explain why system calls (such as I/O requests) are implemented in the OS rather than as a procedure call.

**Problem 3:** (20 pts) Consider a multiple feedback scheduler with three levels. The first level has a quantum of 5ms, the second has a quantum of 10ms, and the third is FCFS. You have a set of processes with a run time of 9ms, 16ms, 4ms, 20ms, and 7ms that arrive at times 0, 3, 6, 8 and 10 ms respectively. What is the average normalized turnaround time for the processes? Show your work, including the state of the queues whenever they change.

**Problem 4:** (20 pts) You are part of a promising start up company that is building the new operating system **Chimera**. Chimera allow users to log onto a machine directly into their favorite operating system. For example, you can have three users time sharing the machine, one using Windows 98, another using unix and a third using VMS. Suggest an implementation framework for this OS highlighting any advantages, disadvantages and difficulties clearly.

**Problem 5:** (15 pts) You are the technical leader of the scheduler design group in Chimera. Two fellow graduates of CS350 working in your group come to you with proposals about the scheduler. Both proposals use a variant of Round Robin with a variable quantum size. However, the first proposal advocates that long processes should be given a longer time quantum (say, by making the quantum a percentage of the process run time), while the other thinks that short processes should be given a longer quantum. You need to pick a policy for the OS; which one do you pick? Explain your decision.

**Problem 6:** (15 + 5 bonus) Give an “engineering” estimate of the number of barbers/hairdressers in the US. Clearly state your assumptions.