Question 1. *(20 points) State whether each of the following actions requires the active process to be in kernel mode or whether user mode is sufficient. Briefly justify.*

1. *Adding two numbers stored in registers together.*

2. *Halting the machine.*

3. *Creating a new process.*

4. *Writing data to a file stored on a disk.*

5. *Invoking a system call to read a file stored on a disk.*

Question 2. *(10 points) Explain the purpose of a system call. Describe how control passes to the kernel when executing a system call.*

Question 3. *(10 pts) Consider the following statement: using an OS that supports multiprogramming, multiple programs are run concurrently on the machine. Is this statement fully, partially, or not at all accurate? Explain.*

Question 4. *(10 pts) Suppose you are designing an OS in which your primary objective is to make the OS as low-overhead as possible. What type of OS kernel organizational approach would you choose and why? What if your primary objective was to minimize the chance of critical OS failure (e.g., due to buggy code in the OS)?*

Question 5. *(15 pts) What happens during a context switch? Do we want the OS to perform many or few context switches? Explain your answer.*

Question 6. *(10 pts) Write down the list of process state transitions that occur during the following program. You may assume that this is the only process that the CPU has to execute.*

```
1     int main() {
2       int i = 1;
3       while (i < 5) { i++; }
4       printf("%d\n", i);
5       printf("%d\n", i - 1);
6       return 0;
7     }
```

Question 7. *(25 points) For the following mix of jobs, lengths, and arrival times, determine the scheduling order and average wait time for the First Come First Served (FCFS), Round Robin (RR), and non-preemptive Shortest Job First (SJF) schedulers. For the RR scheduler, use a 5 unit time slice and assume no context switch cost. Assume that when new tasks arrive, they are placed at the* **front** *of the queue for jobs waiting to be scheduled. Fill in the table below with completion and waiting times. You can use the reported average wait times to check your answers.*

Job	Arrival Time	Length	Completion Time FCFS	RR	SJF	Waiting Time FCFS	RR	SJF
A	0	40						
B	5	15						
C	20	25						
D	40	20						
					Average Wait Time:	27.5	36.25	26.25