Question 1. *(15 points) Briefly explain whether each of the following actions requires the active process to be in kernel mode or whether user mode is sufficient.*

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.*

Question 2. *(10 points) One simple explanation of a system call we gave is "like a function call to the OS." That said, explain how a system call significantly* **differs** *from a regular function call.*

Question 3. *(10 pts) Consider the following statement: using an OS that supports multiprogramming, multiple programs are run at the same time 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 instead to minimize the chance of critical OS failure (e.g., due to buggy code in the OS)?*

Question 5. *(10 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 execution state transitions that occur during the following program. You may assume that this is the only process that the CPU has to execute. Separately from your list of states, how might* `printf` *buffering (as demonstrated in class) affect this sequence of state transitions?*

```
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. *(15 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 jobs arrive, they are placed at the* **front** *of the queue for jobs waiting to be scheduled (i.e., the ready queue). Fill in the table below with completion and waiting times.*

			Completion Time			Waiting Time		
Job	Arrival Time	Length	FCFS	RR	SJF	FCFS	RR	SJF
A	0	40						
B	5	15						
C	20	25						
D	40	20						