CSE 450 Operating Systems
Homework on CPU scheduling

Partial Solution (60 points in total)

Question 1. [40 points] Consider the following process arrival list:

Name	Arrival Time	Service Time
A	0	4
B	3	9
C	5	2
D	7	5
E	11	3
F	13	1
G	21	4

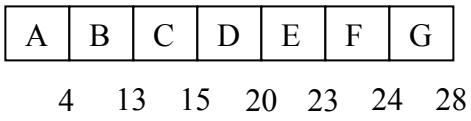
Consider the following scheduling methods:

(a) First-come first-served (FCFS)
(b) Shortest-job first (SJF)
(c) Shortest remaining time first (SRTF)
(d) Round-robin (RR), quantum = 5

Draw a Gantt chart (time line) showing which process is executing over time and calculate the average waiting time and average completion time.

Notes : (1) In SRTF, if a process arrives with service time equal to the remaining service time of the process currently being served, the current process is not interrupted. (2) In RR, if a process arrives at the same time a quantum finishes, the running process is preempted and the new arrival executes. The preempted process goes to the end of the ready queue. (3) *Waiting time* and *completion time* is defined as in the slides.

8 points for each correct Gantt chart, 1 point for the correct average waiting time formula and 1 point for correct average completion time formula.
(a) First-come first-served (FCFS)



Average waiting time = {0 + (4 – 3) + (13-5) + (15-7) + (20-11)+(23-13)+(24-21)}/7 = 39/7
Average completion time = {4 + (13-3) + (15-5) + (20-7)+(23-11)+(24-13)+(28-21)}/7 = (4+10+10+13+12+11+7)/7 = 67/7

(b) Shortest-job first (SJF)

Time (ms)	4	9	1	2	3	5	4
Process	A	B	F	C	E	D	G

4 13 14 16 19 24 28

Average waiting time = {0 + (4 – 3) + (14-5) + (19-7) + (16-11)+(13-13)+(24-21)}/7 = 30/7
Average completion time = {4+(13-3)+(16-5)+(24-7)+(19-11)+(14-13)+(28-21)}/7 =(4+10+11+17+8+1+7)/7 = 58/7

(c) Shortest remaining time first (SRTF)

Time (ms)	4	1	2	5	1	1	2	8	4
Process	A	B	C	D	E	F	E	B	G

4 5 7 12 13 14 16 24 28

Average waiting time = {0 + (4 – 3) + (16-5)+ (5-5) + (7-7) + (12-11)+(14-13)+ (13-13)+(24-21)}/7 = 17/7
Average completion time = {4+ (24-3)+(7-5)+(12-7)+(16-11)+(14-13)+(28-21)}/7 = (4+21+2+5+5+1+7)/7 =45/7

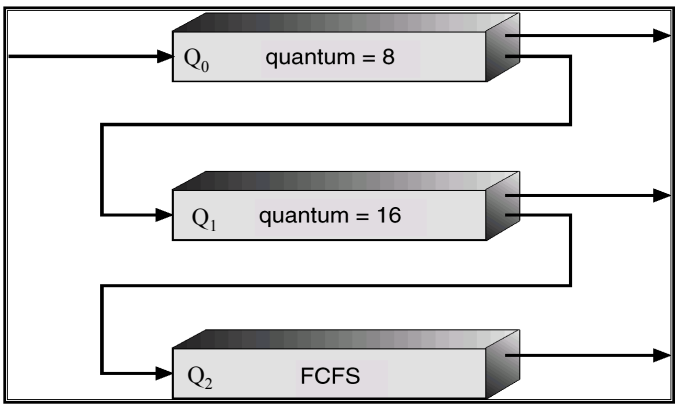
(d) Round-robin (RR), quantum = 5

Time (ms)	4	5	2	5	4	3	1	4
Process	A	B	C	D	B	E	F	G

4 9 11 16 20 23 24 28

Average waiting time = {0+(4-3)+(16-9)+(9-5)+(11-7)+(20-11)+(23-13)+(24-21)}/7 = (1+8+4+4+9+10+3)/7 = 38/7
Average completion time = {4+(20-3)+(11-5)+(16-7)+(23-11)+(24-13)+(28-21)}/7 = (4+17+6+9+12+11+7)7 = 66/7

Question 2. [20 points] Multilevel queues use multiple queues with different priorities as shown in the diagram below. The scheduler first executes all processes in Q_0. Only when Q_0 is empty will it execute processes in Q_1, and only when Q_0 and Q_1 are empty will it execute processes in Q_2. A process arriving for Q_0 will preempt a process in Q_1 or Q_2, and a process arriving for Q_1 will preempt a process in Q_2; a process preempted in this case is put back to the head of the same queue and next time when the scheduler execute this process it can still execute for the remaining of its allocated time quantum. A process entering the ready queue is put in Q_0 and is given a time quantum of 8 milliseconds. If it does not finish within this time, it is preempted and moved to the tail of Q_1. If Q_0 is empty, the process at the head of Q_1 is given a time quantum of 16 milliseconds. If it does not finish within this time, it is preempted and moved to the tail of Q_2. Processes in Q_2 are run on an FCFS basis.



Task	Arrival Time	Service Time
A	0	25
B	5	28
C	19	11
D	25	19
E	36	33

Given the following arrival time and CPU burst of processes A, B, C, D, and E as shown in table below.

a) Show the status of each queue along the time line during the running of the system. You only need to show the status of the system when either 1) a new process arrives, or 2) a process is preempted, or 3) a process terminates. The status includes time stamp, the name of the process and its remaining time in each queue. For example, at time 0, process A is in Q_0 and it has 25 time units toward finishing. Q_1 and Q_2 are empty. You are asked to complete the table with time moment and status of each queue. Moreover, B(x) A(y) shows A is at the head of the queue and B is at the tail of the queue. You can add new rows to the table if you think the table is not enough to accommodate all the events.

Time	Q_0	Q_1	Q_2
0	**A(25)**	**---**	**---**
5	B(28)A(20)	----	----
8	B(28)	A(17)	----
16	----	B(20)A(17)	----
19	C(11)	B(20)A(14)	----
25	D(19)C(5)	B(20)A(14)	----
27	D(19)	C(3)B(20)A(14)	----
35	-----	D(11)C(3)B(20)A(14)	----
36	E(33)	D(11)C(3)B(20)A(13)	----
44	-----	E(25)D(11)C(3)B(20)A(13)	----
56	-----	E(25)D(11)C(3)B(20)	A(1)
72	-----	E(25)D(11)C(3)	B(4)A(1)
75	-----	E(25)D(11)	B(4)A(1)
86	-----	E(25)	B(4)A(1)
102	-----	-----	E(9)B(4)A(1)
103	-----	-----	E(9)B(4)
107	-----	-----	E(9)
116	-----	-----	-----