CS520 Simulation Programming Project
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1)

```
one '=' means one second.
5.3 FCFS
P1========P1P2====P2P3=P3
5.3 SJF
P1========P1P3=P3P2====P2
5.12 FCFS
P1==========P1P2=P2P3==P3P4=P4P5=====P5
5.12 SJF
P2=P2P4=P4P3==P3P5=====P5P1==========P1
```

2/a)
FCFS
cpuRuntime = 1685.424s sumRuntime = 2298.765s
Average waiting time = 678.3916s
Average turnaround time = 1985.4347s
CPU utilization = 73.3187%
Throughput = 0.004350 processes/sec

SJF index = 1
cpuRuntime = 1685.424s sumRuntime = 2051.943s
Average waiting time = 453.3849s
Average turnaround time = 1799.6087s
CPU utilization = 82.138%
Throughput = 0.0048734 processes/sec

SJF index = 0.5
cpuRuntime = 1685.424s sumRuntime = 2052.132s
Average waiting time = 430.5888s
Average turnaround time = 1801.2696s
CPU utilization = 82.1304%
Throughput = 0.0048730 processes/sec

SJF index = 1/3
cpuRuntime = 1685.424s sumRuntime = 2048.232s
Average waiting time = 396.3888s
Average turnaround time = 1821.0266s
CPU utilization = 82.2868%
Throughput = 0.00488226 processes/sec

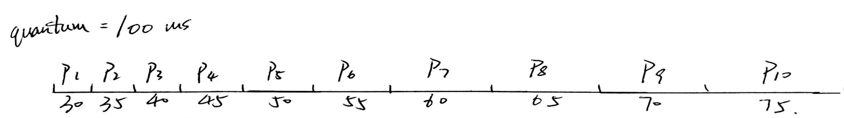
2/b)
In round-robin algorithm, Optimized situation is that 80 percent of the CPU bursts should be shorter than the time quantum.
when the quantum is above 80 percent of the CPU bursts, causes the average waiting time to decrease with decreasing quantum.

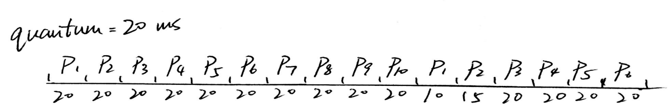
Above 80 percent process can finish their work in one time slice, then be pushed into io queue. They don't need to wait in the waiting queue. when the quantum is shorter than 80 percent of the CPU bursts, causes average waiting time to increase with decreasing quantum.
Under this condition, processes cannot finish their current work in one time slice, these processes be pushed into ready queue again and waiting for the CPU. Therefore increase the total waiting time.

2/c)
Theoretically, the quantum should be longer than 80 percent of the CPU burst. So in my program, the quantum which is longer than 80 percent of the CPU burst of ten processes is 65ms. Except the quantum is 5 ms, other conditions whose CPU utilization is between 50 and 90 percent (apart from quantum is 5 ms).

As the graph, when the quantum is above 40 ms, cause the average waiting time to decrease with decreasing quantum.
When the quantum is lower than 40 ms, cause average waiting time to increase with decreasing quantum.

Gantt charts :(In the program, CPU bursts are all random. The CPU burst in the graph is average CPU burst time of every process.)





quantum(ms)	Waiting time(s)	CPU utilization
250	5322.495	80.7457
200	4998.751	81.3988
150	4752.928	81.8346
130	4635.595	81.9714
100	4441.832	82.2273
90	4352.032	82.2183
80	4295.689	82.2146
70	4302.874	82.4113
60	4211.049	82.6041
55	3932.161	82.6791
50	4230.280	82.8828
45	3914.431	83.0053
44	4078.583	82.907
43	4005.579	83.0231
42	3966.821	83.0954
40	4106.355	83.1041
38	3959.722	83.1903
32	4035.029	83.5955
30	3977.197	83.8654
25	3964.772	84.3088
20	4105.414	85.0694
15	4311.378	86.1816
10	5041.593	88.6708
5	7422.816	94.8812