Please read:

You may discuss this problem set with other students as long as you do not share/verify answers. However, you must also write the names of other students you discussed any problem with. You must write up your answers on your own showing your work. Each problem has a different weight. Please state any assumptions you are making in solving a given problem. Late assignments will not be accepted with prior arrangements. By submitting this assignment, you acknowledge that you have read the course syllabus and abiding to the copyright (e.g., no posting) and Honor Code (e.g., not using note sharing sites such as Chegg, OneClass, CourseHero, etc.) requirements.

Problem 1

Consider a disk subjected to I/O requests arriving at an average rate of λ requests/sec. It was observed that on average, there was about 5 requests waiting for service in the queue and that each request waits in the queue for about 10 msec, on average. What is the effective arrival rate λ for this disk? [4 pts]

(1)

average requests waiting in the queue = 5
average time spent in the queue by request = 10ms
.01 sec

little's law

average # of requests in the system = arrival rate * average time spent in the system

we only care about queue

$\frac{5}{.01} = \frac{\lambda * .01}{.01}$ $100(5) = \lambda = \boxed{500 \text{ request/sec}}$

Problem 2

Consider a CPU that services processes arriving at an average rate λ of 20 process/sec. Assume that the average service time for the processes is 30 milliseconds. Answer the following questions: [3 pts each]

(a) What is the utilization of the CPU?

(b) If you observed that on average there are 4.5 processes waiting in the Ready Queue for the CPU, what is the average number of processes you expect to see in the system (waiting in the Ready Queue and getting service from the CPU)?

(2)

(A) $\lambda = 20 / \text{sec}$

$T_s = 30 \text{ ms} \rightarrow .03 \text{ secs}$

$\rho = \lambda / \mu = \lambda * T_s \qquad \mu = 1/T_s$

$\boxed{\rho = 20 * .03 = .6}$

the server is 60% utilizied on average

little's law

(B) Average # of process in ready queue = Average Arrival rate * Average time in ready queue

$4.5 = 20 * T_w$

$\frac{4.5}{20} = T_w = .225 \leftarrow$ average time in ready queue

Average response time = .225 + .03 = .255

Average number of processes in the system =

$.255 * \lambda = .255 * 20 = 5.1$

average process we expect to see in the system

5.1

Problem 3

Assume processes arrive to the CPU based on a Poisson distribution with an arrival rate λ of 5 processes per second. Assume also that the service times are exponential. Given that the CPU is, on average, busy 75% of the time. What is the average turnaround time of these processes? How many processes you expect to see waiting, on average, in the Ready Queue? [4 pts]

(3) $\lambda = 5/sec$ $\rho = .75$ turn around = ?

Service time = .2 secs per process

$T_q = T_w + T_s$

$T_s = 1/\mu$

$5 * .75 = \mu$

$\mu = 3.75$

$\frac{(T_s)\,3.75}{3.75} = \frac{\frac{1}{T_s}\,(T_s)}{3.75}$

$T_s = 1/3.75$

$T_s = .2667$

A) $T_q = q/\lambda$

$q = \frac{.75}{1-.75}$ turn around time

$\boxed{T_q = 3/5 = .6}$

B) find w

$q = w + \rho$

$q - \rho = w$ $3 - .75 = \boxed{2.25 = w}$

# of processes in the ready queue

Problem 4

A system is composed of CPU, Disk and Network. The execution of a process proceeds as follows:

1. The process uses the CPU and then with probability 0.2 proceeds to step 2, with probability 0.3 proceeds to step 3, and with probability 0.5 proceeds to step 4.
2. The process performs Disk I/O and then with probability 0.3 proceeds to step 1, and with probability 0.7 proceeds to step 4.
3. The process performs Network I/O and then with probability 0.4 proceeds to Step 1 and with probability 0.6 proceeds to step 4.
4. The process leaves the system (perhaps due to an I/O error).

The following information is known about this system:

• Processes arrive according to a Poisson process with an average rate of 40 processes per second.
• The service time of the CPU is exponentially distributed with an average of 15 msec.
• The service time of the Disk is exponentially distributed with an average of 50 msec.
• The service time of the Network is exponentially distributed with an average of 60 msec.

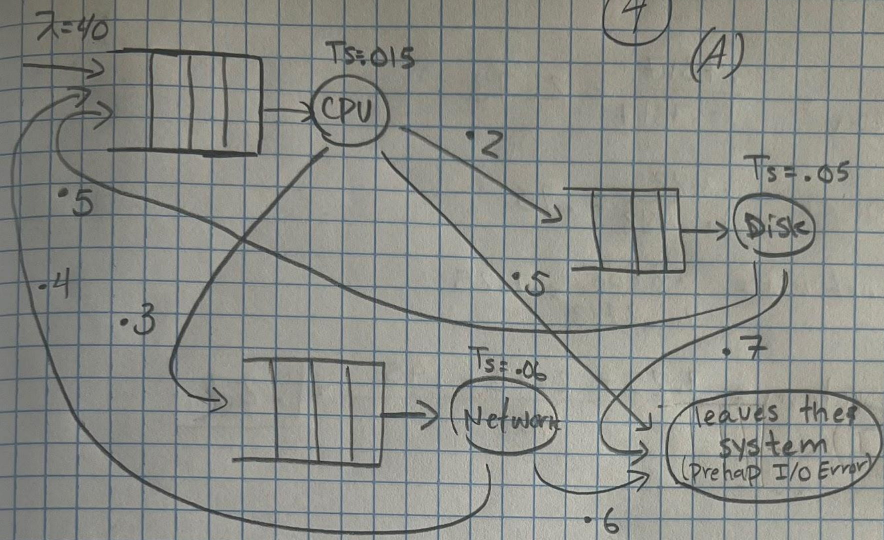
• All buffers are of infinite sizes.

Answer the following questions [3 points each]:
(a) Draw a queuing diagram depicting the system above.
(b) Which resource is the bottleneck resource?
(c) What is the average total turnaround time for a process submitted to the above system?
(d) What is the probability that a process would not experience any waiting time once it gets submitted to the CPU?

(e) What arrival rate would render this system unstable?

4

(A)



(B)

$\lambda_{CPU} = 40 + (.3 * \lambda_{Disk}) + (.4 * \lambda_{network})$

$\lambda_{Disk} = .2 * \lambda_{cpu}$

$\lambda_{network} = .3 * \lambda_{cpu}$

$\lambda_{CPU} = 40 + (.3 * .2 * \lambda_{cpu}) + (.4 * .3 * \lambda_{CPU}) \approx 48.78$

$\lambda_{Disk} \approx 9.76$

$\lambda_{network} \approx 14.63$

$\rho_{cpu} = .7317$

$\rho_{Disk} = .488$

$\rho_{network} = .8788$

$\boxed{\text{network will bottleneck}}$

(C) $T_{q\,cpu} = \frac{.7317}{1-.7317} = 2.73$

$T_q\ \text{Disk} = \frac{.488}{1-.488} = .95$

$T_q\ \text{network} = \frac{.8788}{1-.8788} = 7.25$

$T_q\ \text{system} = \frac{7.25 + 2.73 + .95}{40} = \boxed{.27}$

(D) $1 - \rho\ \text{cpu} = 1 - .7317 = .2683 \approx \boxed{27\%}$

(E) $X * .06 = 1$

$X = 1/.06 = 16.67$

$.3 * \lambda\text{cpu} \approx 16.67$

$\lambda\text{cpu} = 16.67/.3 \approx 55.56$

$55.56 = \lambda + (.03 * .02 * 55.56) + (.4 * .3 * 55.56)$

$\boxed{\lambda = 45.556}$ ← make system ustable

Problem 5

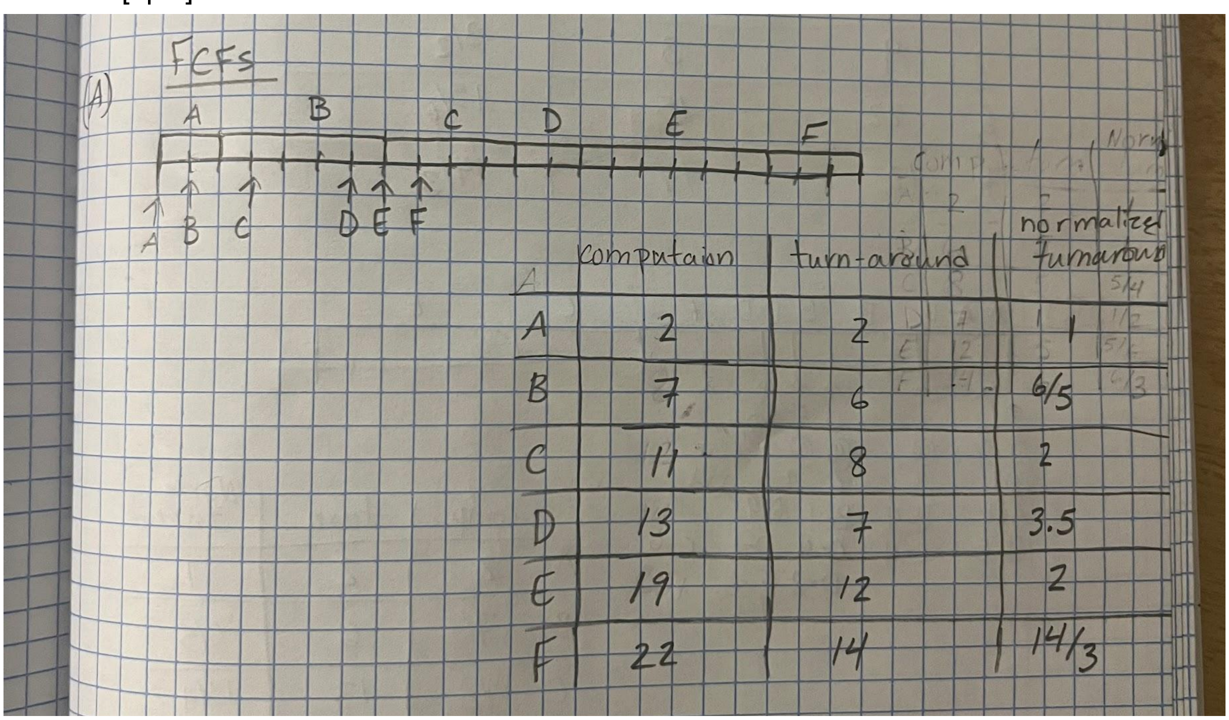
Consider the following processes:

Process Arrival Time Processing Time

Process	Arrival Time	Processing Time
A	0	2
B	1	5
C	3	4
D	6	2
E	7	6
F	8	3

Show how the above processes execute over time on a single CPU system. Compute the completion time for each process, and the average turnaround time for all processes under each of the following schedulers:

A- FCFS [5pts]



	computaion	turn-around	normalized turnaround
A	2	2	1
B	7	6	6/5
C	11	8	2
D	13	7	3.5
E	19	12	2
F	22	14	14/3

B- Round Robin with (q=1) [5pts]

R. Robin

A	B	A	B	C	B	C	D	B	E	C	F	D	B	E	C	F	E	F	E	E	E

A B C D E F

A - ~~2~~ - ~~1~~ - 0

B - ~~5~~ - ~~4~~ - ~~3~~ - ~~2~~ - ~~1~~ - 0

C - ~~4~~ - ~~3~~ - ~~2~~ - ~~1~~ - 0

D - ~~2~~ - ~~1~~ - 0

E - ~~6~~ - ~~5~~ - ~~4~~ - 3

F - ~~3~~ - ~~2~~ - ~~1~~ - 0

~~A~~ B

B D C

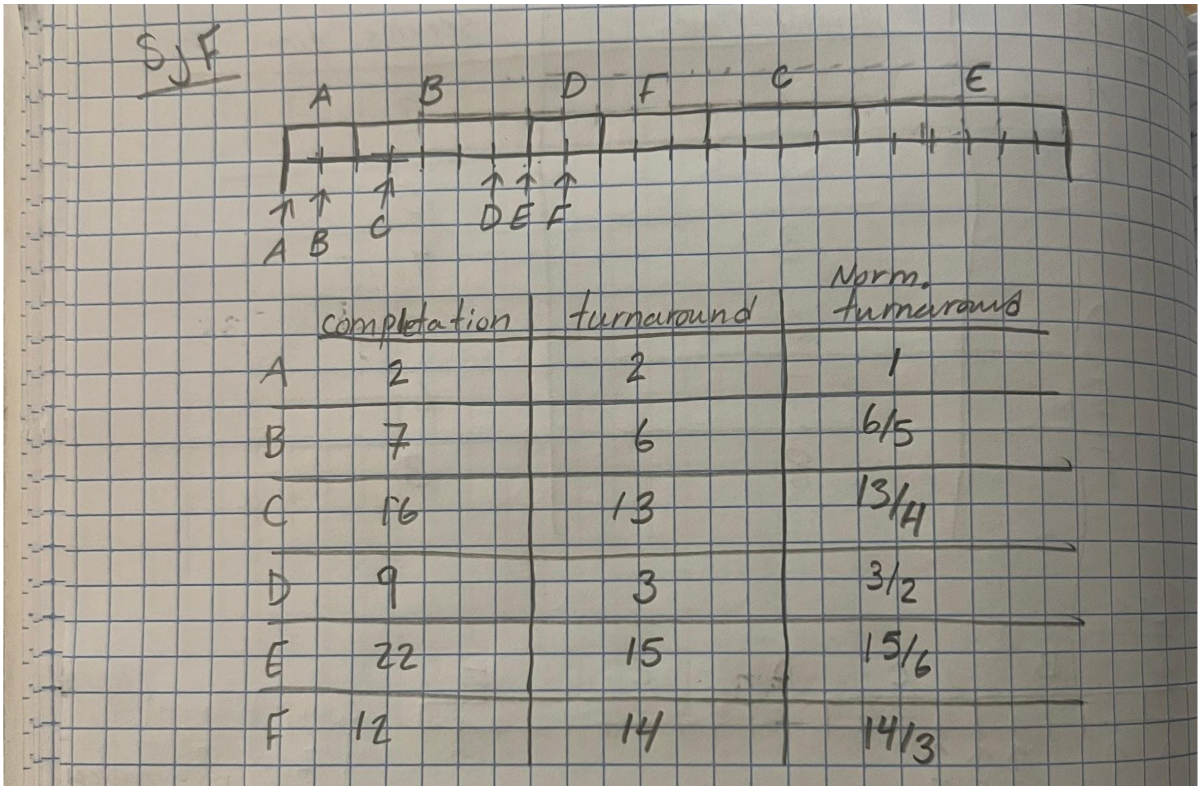
C E B D

~~D~~ ~~F~~ ~~C~~ ~~E~~ B

C B

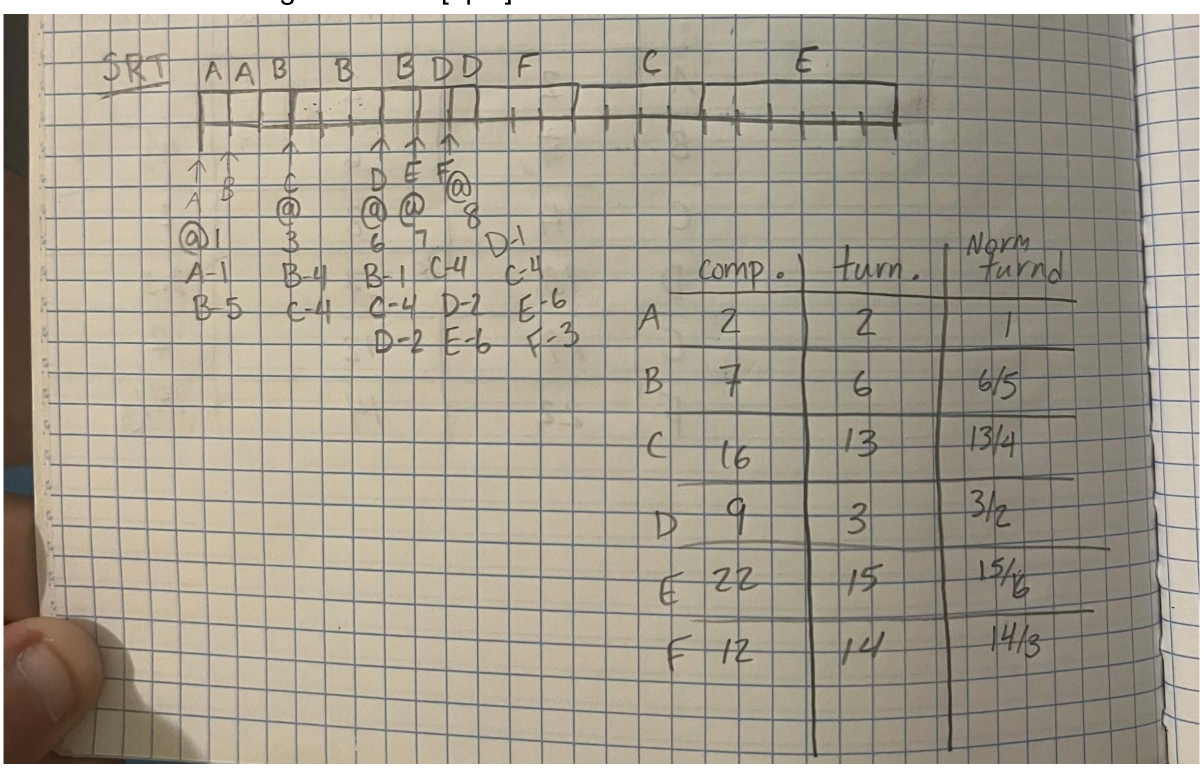
	Completion	turn around	Norm turnaround
A	3	3	3/2
B	14	13	13/5
C	16	13	13/4
D	13	7	7/2
E	22	15	15/6
F	19	11	11/3

C- Shortest Job First [5pts]



	completation	turnaround	Norm. turnaround
A	2	2	1
B	7	6	6/5
C	16	13	13/4
D	9	3	3/2
E	22	15	15/6
F	12	14	14/3

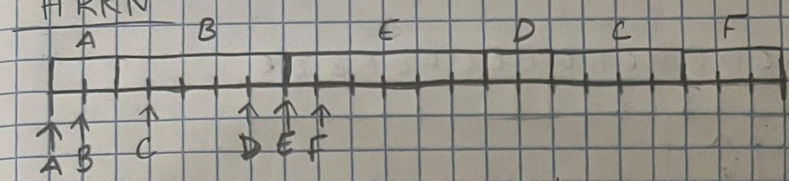
D- Shortest Remaining Time First [5pts]



	comp.	turn.	Norm turnd
A	2	2	1
B	7	6	6/5
C	16	13	13/4
D	9	3	3/2
E	22	15	15/6
F	12	14	14/3

E- HRRN [5pts]

HRRN



$C_r = \frac{4+4}{4} = 2$

$D_r = \frac{1+2}{2} = 3/2$

$E_r = \frac{0+6}{6} = 6$

$C_r = \frac{10+4}{4} = 14/4$

$D_r = \frac{7+2}{2} = 4.5$

$F_r = \frac{5+3}{3} = 8/3$

$C_r \; \frac{12+4}{4} \; 16/4 = 4$

$F_r = \frac{7+3}{3} = 3.33$

	Comple.	turn.	Norm. turn.
A	2	2	1
B	7	6	6/5
C	19	16	4
D	15	9	4.5
E	13	6	1
F	22	14	14/3