57:022 Principles of Design II
Final Exam - May 9, 1994

Part:	I.	II.	III.	IV.	V.	VI.	VII.	Total
Pts.	60	34	15	15	48	26	12	210
Score								

(I.) Indicate "+" if True and "O" if False. (Score = 2 x # correct.)

___ a. A sum of the squares of random variables having normal distributions will have a normal distribution.

___ b. In an M/M/1 queueing system, with an average of 20 seconds between arrivals and an average time spent by a customer waiting to be served is 1 minute, we would expect the average length of the queue to be less than 4.

___ c. The exponential distribution is a special case of a Gumbel distribution.

___ d. In an M/M/1 queueing system, with arrival rate 3/minute and service time averaging 15 seconds, we would expect the server to be idle 25% of the time.

___ e. If 2 components of a system have a series configuration with respect to system reliability, then the second component begins to operate when the first fails, and the system then fails when the second component fails.

___ f. PERT assumes that each activity's duration has a Normal distribution.

___ g. The "Inverse transformation" technique may be used to generate the duration of a project task having a triangular distribution.

___ h. PERT assumes that the project duration has a Normal distribution.

___ i. If a random variable X has a Beta distribution, then it has no upper bound, i.e., for any U, $P\{X \geq U\} > 0$.

___ j. If a random variable X has a normal distribution, then it has no upper bound, i.e., for any U, $P\{X \geq U\} > 0$.

___ k. The Erlang distribution is a special case of an exponential distribution.

___ l. In an M/M/2/2 queueing system, at most 2 customers may be in the system at any time.

___ m. For a finite-capacity one-server queue (M/M/1/N), a steady state exists only if the arrival rate is less than the service rate.

___ n. In an M/M/1 queueing system, the greek letter ρ is the probability that the server is busy.

___ o. If 2 components of a system have a parallel configuration with respect to system reliability, then the system lifetime is the minimum of the component lifetimes.

___ p. In an M/M/1/N queueing system, N represents the capacity of the waiting line.

___ q. In an M/M/1 queueing system, $1-\pi_0$ represents the probability that the server is busy.

___ r. The gamma function $\Gamma(n) = n!$ for positive integer values of n.

___ s. If a component's lifetime has exponential distribution, its failure rate ("hazard rate") is constant.

___t. The "Rejection" technique may be used to generate time between arrivals in a Poisson process.

___ u. In a Poisson arrival process, the time between arrivals has the Poisson distribution.

___ v. If 2 components of a system have a parallel configuration with respect to system reliability, then both are required to function in order for the system to function.

___ w. In a Poisson arrival process, the number of arrivals during an hour has the Poisson distribution.

___ x. A sum of random variables having normal distributions will also have a normal distribution.

___ y. In a Poisson arrival process, the time of the second arrival has an Erlang distribution.

___ z. The "Rejection" technique may be used to generate the duration of a project task having a triangular distribution.

___ aa. "Dummy" activities are unnecessary in the "Activity-on-Arrow" representation of a project.

___ bb. If we...

(i) test 100 lightbulbs, recording the failure time of each,

(ii) prepare a histogram indicating number of failures on six consecutive days (where the last failure occurred on the *sixth* day),

(iii) use the mean and standard deviation of the failure times to estimate the parameters of the Weibull distribution, then we would assume 3 degrees of freedom when performing the Chi-Square goodness of fit test.

___ cc. If we plot the lifetimes of the 100 lightbulbs in (bb) on Weibull probability paper, and the lifetimes do in fact have a Weibull distribution, the result will be (approximately) a straight line with y-intercept equal to the "shape" parameter k.

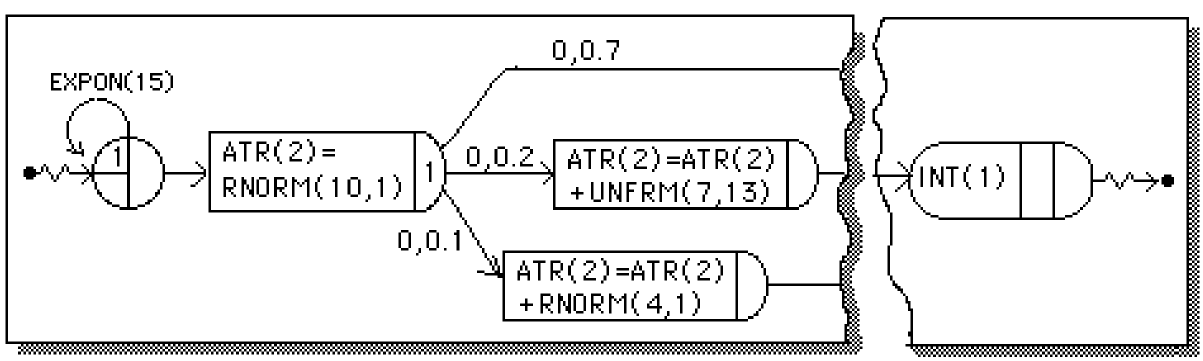
___ dd. Estimating the Weibull parameters by plotting the failure times on Weibull probability paper as in (cc) requires that the test continue until all 100 lightbulbs have failed.

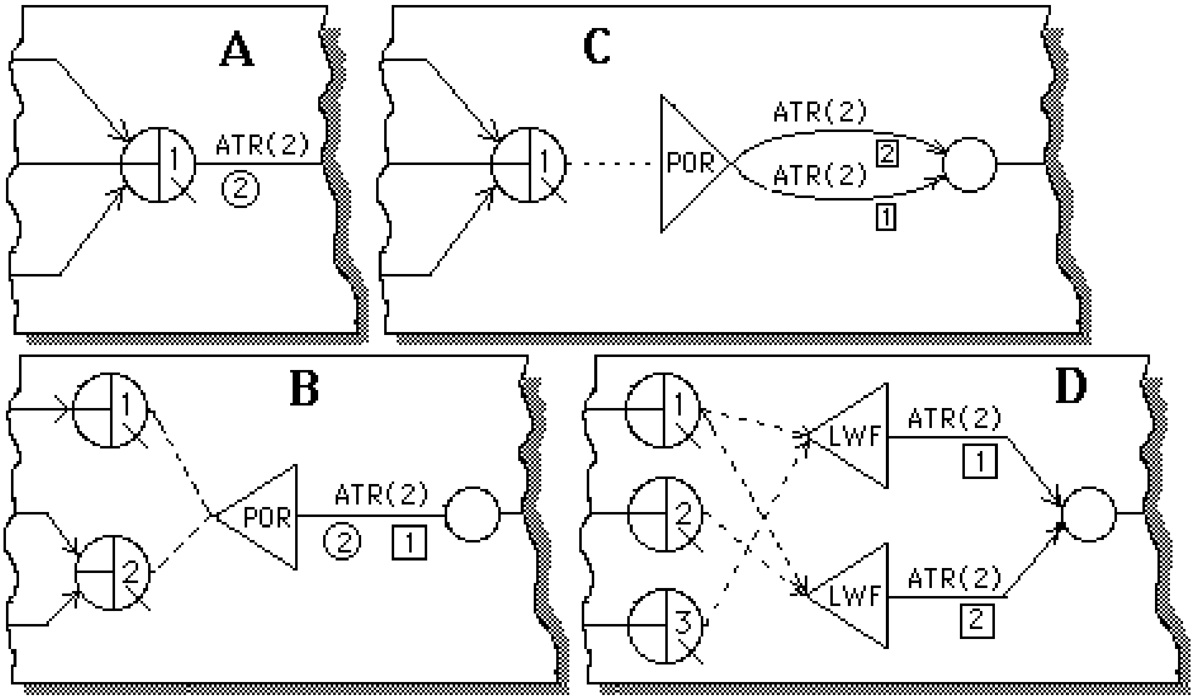
(II.) For each of the following statements about SLAM, **indicate "+" if True and "O" if False.** (Score = 2 x # correct.)

___ a. An activity following a queue node must be a service activity.
___ b. When an entity arrives at a terminate node, the entity is destroyed.
___ c. A SLAM model of a project employs the "Activity-on-Node" rather than "Activity-on-Arrow" representation of the project.
___ d. At an AWAIT node, entities may wait for either a gate or a resource.
___ e. A service activity cannot be pre-empted.
___ f. The activity preceding a queue node with balking must be a service activity.
___ g. Entities may balk when arriving at an AWAIT node with limited space to wait.
___ h. Entities may wait at a QUEUE node for a GATE to open.
___ i. A queue node with two identical servers may also be modeled as an AWAIT node followed by a FREE node, with 2 units of resource.
___ j. When two entities are waiting for a gate to open, and the gate then opens, both entities simultaneously proceed to the next node.
___ k. In SLAM, an assembly node is a special type of SELECT node.
___ l. A SLAM network requires at least one CREATE node.
___ m. An AWAIT node is a special type of a queue node.
___ n. The activity preceding a queue node with blocking must be a service activity.
___ o. If, on two successive days, you run the same simulation model (i.e., with the same input file), you should expect to obtain identical statistics, even if some activities have random durations.
___ p. An ACCUMULATE node is used to accumulate statistics in successive runs of a simulation model.
___ q. When an entity arrives at a CLOSE node to close a gate, then any entities which follow it may not pass through that node until the gate is opened again.

(III.) Customers arrive at a barber shop with 2 barbers. 70% of the customers want a haircut only, while 20% want haircut & shave, and 10% a haircut & shampoo. The shop employs two barbers. The shop is modeled as a SLAM network as below. A portion has been removed.
For each case below, indicate the fragment (A through D) of the network which should be inserted, or indicate **N** if "none" is appropriate.

_____ Barber #1 does not shave customers, and #2 does not shampoo hair.
_____ Customers requiring a shave or shampoo are served only by barber #2.
_____ If both barbers are available, a customer will prefer barber #2.
_____ Both barbers can perform all three functions, and both work at the same rate.
_____ Both barbers give priority to customers requiring more than only a haircut.

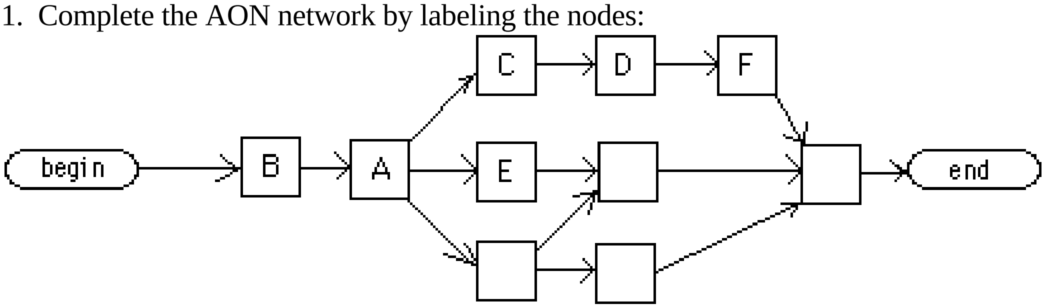




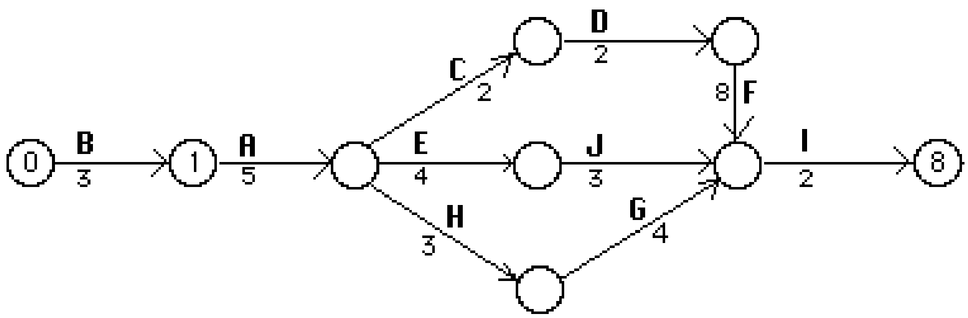
(IV.) Consider the project:

Activity	Description	Predecessor Activities	Duration (days) Mean	Std Dev
A	Walls & ceiling	B	5	2
B	Foundation	none	4	1
C	Roof timbers	A	2	1
D	Roof sheathing	C	2	1
E	Electrical wiring	A	4	2
F	Roof shingles	D	2	1
G	Exterior siding	H	4	1
H	Windows	A	4	1
I	Paint	F,G,J	3	1
J	Inside wall board	E,H	3	1

1. Complete the AON network by labeling the nodes:

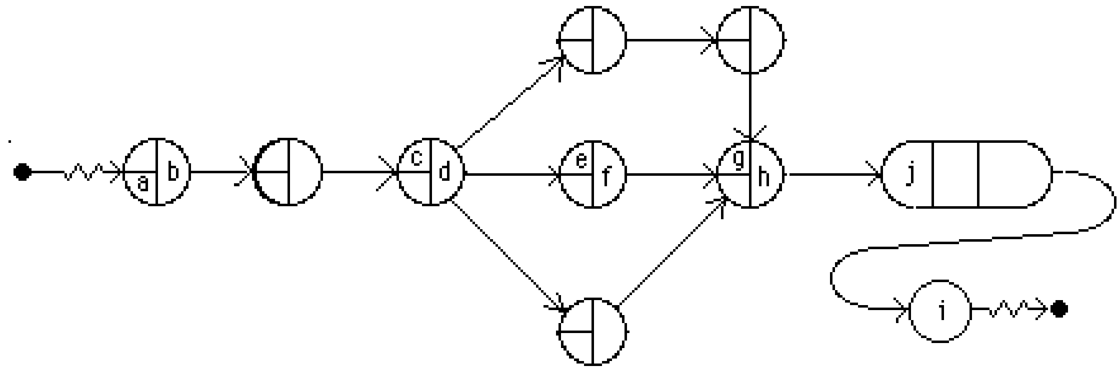


2. Complete the AOA & the corresponding SLAM networks below by inserting any "dummy" activities which are necessary, and labeling the nodes.



3. Give numerical values (0, 1, 2, 3, 4, or ∞) of "a" - "i" on the SLAM network below.

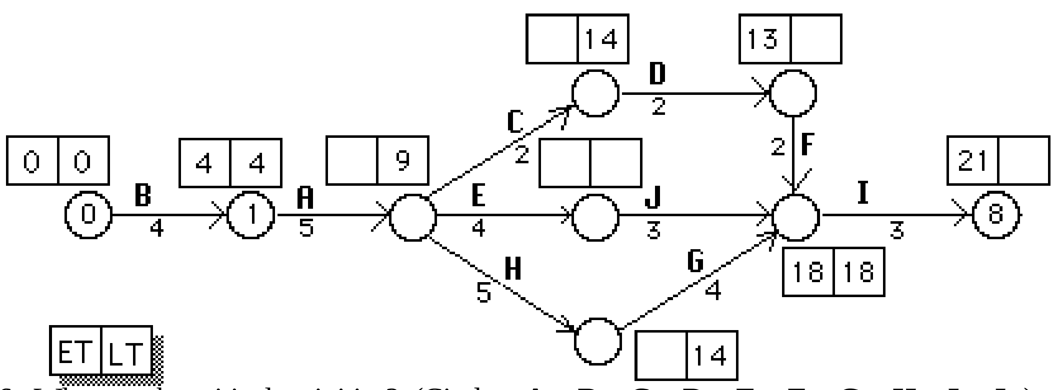
a ___ b ___ c ___ d ___ e ___ f ___ g ___ h ___ i ___



4. "j" on the SLAM network above should indicate which type of statistic?

Circle: LAST INT(1) BETWEEN FIRST

5. Complete the ETs (earliest times) & LTs (latest times) in the network below, using the expected activity durations, as indicated. *Don't forget any "dummy" activities which you entered above!*



6. What are the critical activities? (Circle: **A B C D E F G H I J**)

7. What is the "total slack" or "total float" in activity D? ______

8. What is the expected completion time of the project? _____ ...the standard deviation? ______

(V.) Five systems are described below. Also there are five SLAM networks which each models one of these systems. For each system, select a network and give the number corresponding to the appropriate values of each of the parameters A, B, ..., Z, AA, BB, ... JJ *(omitting "O" & "OO")*..

____ A.	____ B.	____ C.	____ D.
____ E.	____ F.	____ G.	____ H.
____ I.	____ J.	____ K.	____ L.
____ M.	____N.	____ P.	____ Q.
____ R.	____ S.	____ T.	____ U.

____ V.	____ W.	____ X.	____ Y.
____ Z.	____ AA.	____ BB.	____ CC.
____ DD.	____ EE.	____ FF.	____ GG.
____ HH.	____ II.	____ JJ.	____ KK.
____ LL.	____ MM.	____ NN.	____ PP.
____ QQ.	____ RR.	____ SS.	____ TT.
____ UU.	____ VV.	____ WW.	____ XX.

Answers:

0. 0	10. 0.01	20. TRIAG(1.,2.,4.)
1. 1	11. 0.25	21. ATR(1)
2. 2	12. 0.75	22. ATR(2)
3. 3	13. 0.99	23. INT(1)
4. 4	14. EXPON(0.5)	24. TNOW.LT.60
5. 5	15. EXPON(1.0)	25. TNOW.GE.60
6. 6	16. EXPON(2.0)	26. NNQ(1).GT.0
7. 60	17. RNORM(1,0.5)	27. TNOW
8. 100	18. RNORM(2,0.5)	28. X(1)
9. ∞	19. UNFRM(1.,3.)	29. XX(1)
	30. **NONE OF THE ABOVE**	

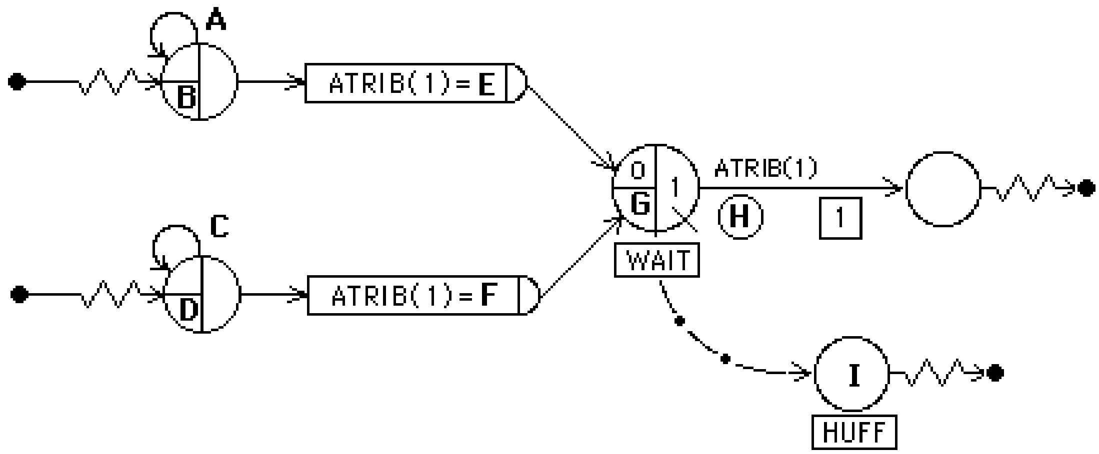
System #1. Entities arrive exactly once every 2 minutes, and try to join a queue with capacity of 4. If this queue is full, the entities are destroyed. Otherwise, they are processed by server #1, which requires exactly 2 minutes, and then by server #2, which requires a time having normal distribution with average 2 minutes, standard deviation 30 seconds. There is no space to wait for server #2, and so if an entity is finished by server #1 and server #2 is busy, then server #1 must wait until server #2 is completed before he can begin the next entity. Entities processed by server #2 are then returned to the queue for server #1.

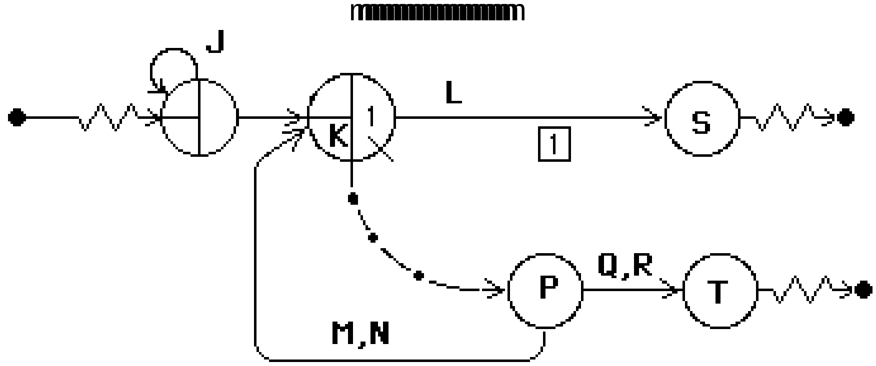
System #2. Customers arrive at a bank which has two drive-up teller windows, each with a lane in which up to 2 cars can wait, and an indoor teller window. The drive-up windows open at 8 a.m., but the bank opens at 9 a.m. If both of the drive-up lanes are filled and it is past 9 a.m., the customer parks and uses the indoor teller. The parking lot, however, has space for only 6 vehicles, and when full, customers depart without parking. Arrivals of customers wishing to use the drive-up tellers is a Poisson process with rate 1/minute. Arrivals of customers who wish to use the indoor teller begin at 9 a.m., and is a Poisson process with rate 1 per two minutes. The time for each teller (indoor & outdoor) to serve a customer has normal distribution with mean 2 minutes and standard deviation 30 seconds.

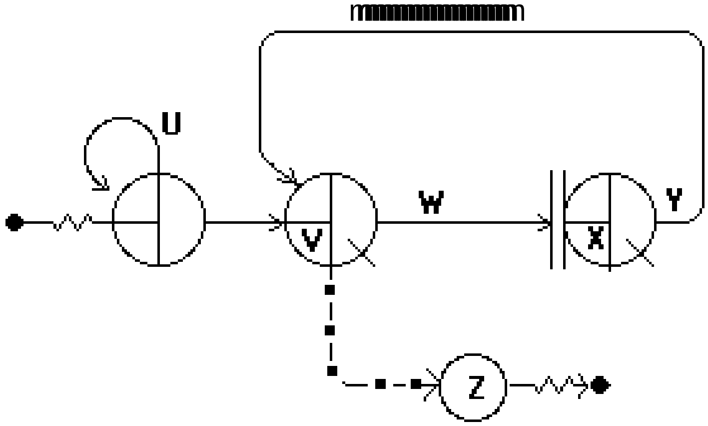
System #3. A power plant has three primary generators. Each generator is subject to random failure, an average of once every 100 days. When one fails, a spare generator is switched on while the primary generator is being repaired. (The switch fails to function with probability 1%, in which case the system fails.) Repair time is uniformly distributed between 1 and 3 days. During this repair, the spare generator is also subject to random failure, and will operate an average of 2 days before failing. If either the spare generator or a second primary generator fails before the first is repaired, the system also fails.

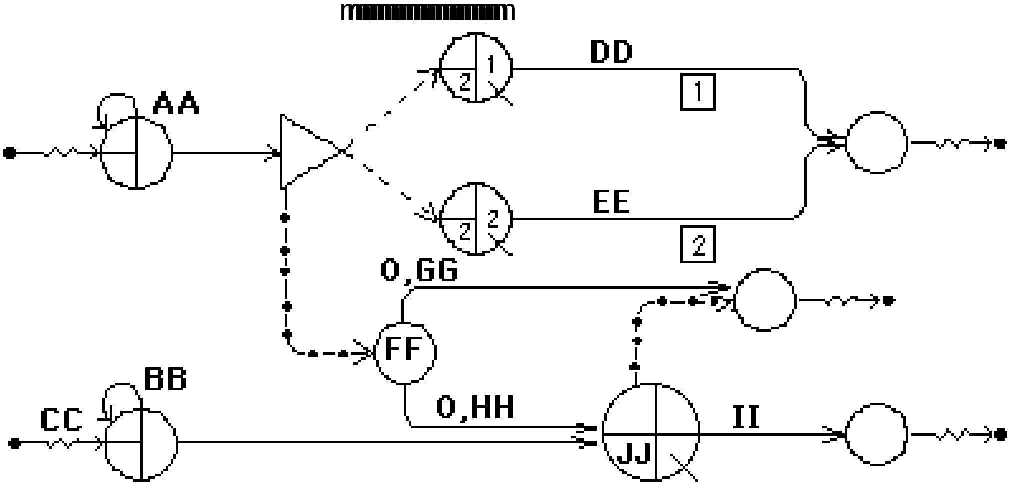
System #4. At a drive-in bank, with only one teller, there is space for 5 waiting cars. Customers arrive according to a Poisson process at the average rate of 1 every 2 minutes. The time spent by a customer at the teller window is normally distributed with average 1 minute and standard deviation 30 seconds. If a customer arrives when the waiting line is full, then with probability 75% the customer will choose to drive around the block (which requires an amount of time having normal distribution with average 2 minutes and standard deviation 30 seconds) and tries to join the waiting line again; with 25% probability, he will not try again. Initially, no customers are waiting, and the teller is idle. The simulation is to be terminated when 100 cars have been served.

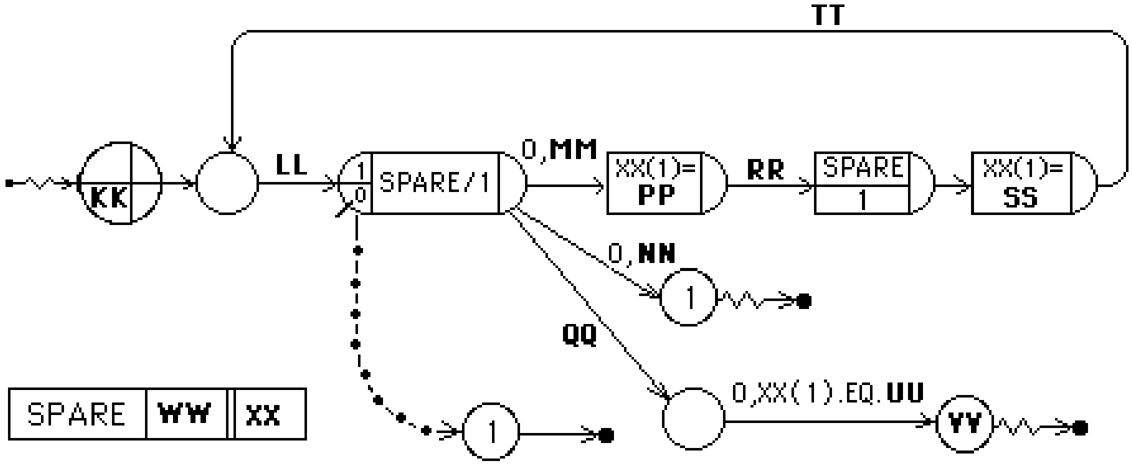
System #5. Sixty each of two types of parts arrive in a Poisson process with average rate 2/minute. Processing times are exponentially distributed with mean 1 minute for type 1 and 2 minutes for type 2. Two machines process the parts, but there is only enough space for 4 parts to wait. Any part which arrives when there are already 4 parts waiting will be sent to storage. The simulation terminates when 100 parts have been sent to storage.


A
B
C
D
ATRIB(1)=E
ATRIB(1)=F
0
1
G
ATRIB(1)
H
1
WAIT
I
HUFF


J
K
1
L
1
S
P
Q,R
T
M,N


U
V
W
X
Y
Z


AA
1
2
DD
1
2
2
EE
2
0,GG
FF
BB
CC
0,HH
JJ
II

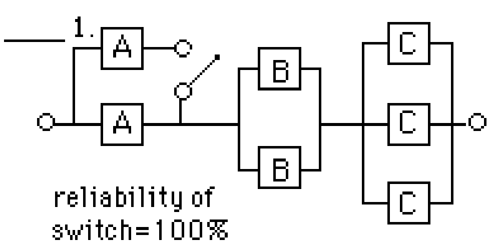


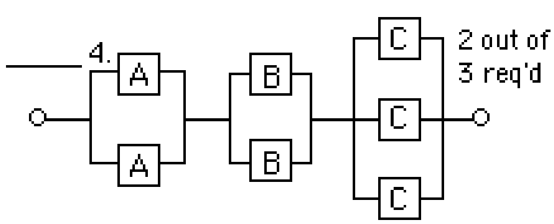
(VI.) An assembly line has two stations, each assigned two tasks. The tasks, and the time required for a worker to perform tasks are normally distributed [N(μ,σ)]:

Station #1:	task A: N(4,1)	task B: N(3,1)
Station #2:	task C: N(5,2)	task D: N(3,1)

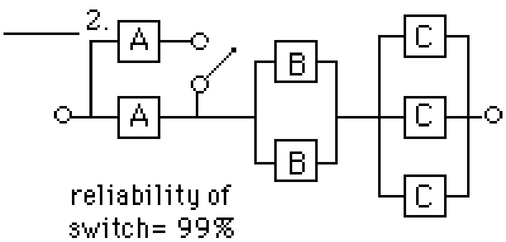
The cycle time for the line is 8 minutes. If a worker has not finished his assembly tasks on a unit when the conveyor moves the next unit to the station, the unfinished unit is set aside to be completed later. Draw a SLAM network model, making use of <u>resources</u> &/or <u>gates</u>, to simulate this assembly line, so that statistics can be collected on the number of units completed as well as the remaining time for the unfinished tasks at each station.

(VII.) For each system reliability diagram #1-6 below, write the letter (A-H) of the SLAM network which simulates the system lifetime. The switch in the diagram indicates that the back-up copy of A is switched into the system (possibly with less than 100% reliability) when the first copy of A fails. Assume that A, B, C, etc. in the SLAM network represent the lifetime distributions of devices A, B, C, etc.

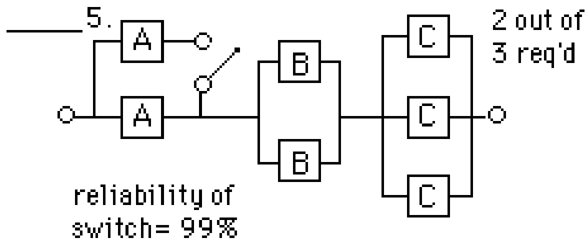




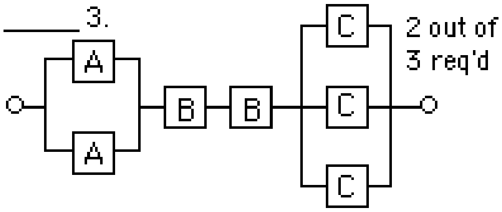
_____ 2.



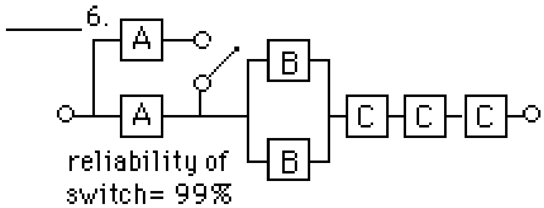
_____ 5.



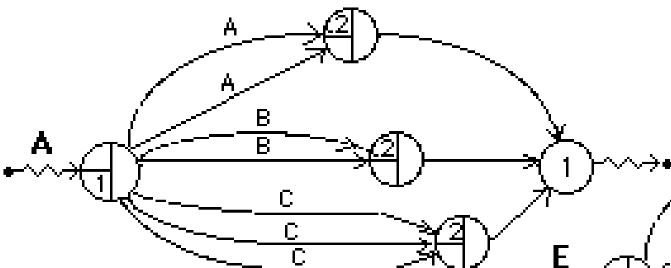
_____ 3.



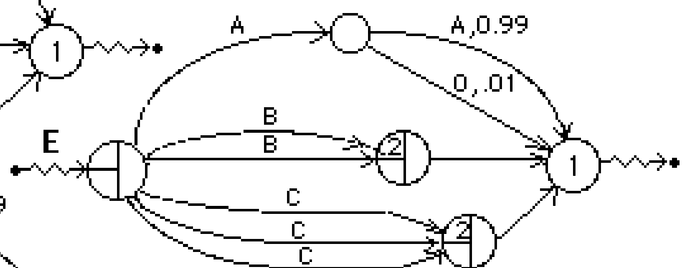
_____ 6.



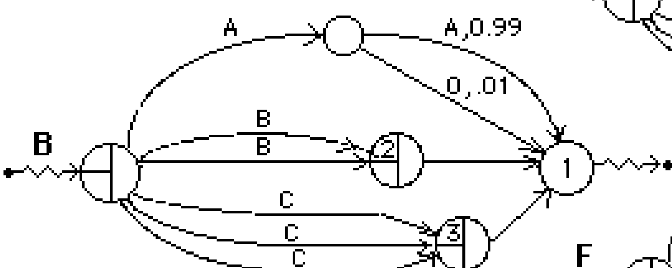
A



E



B



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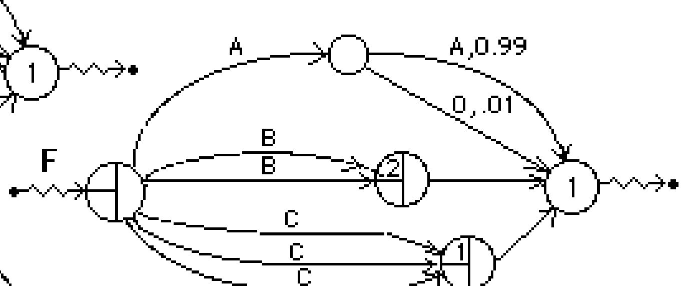
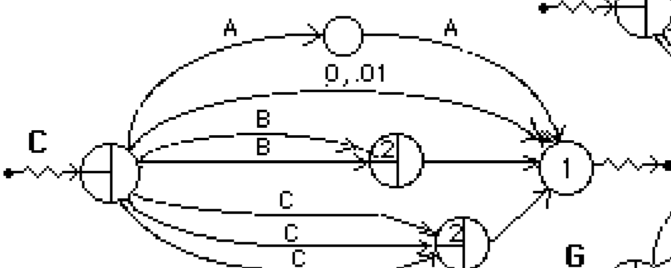
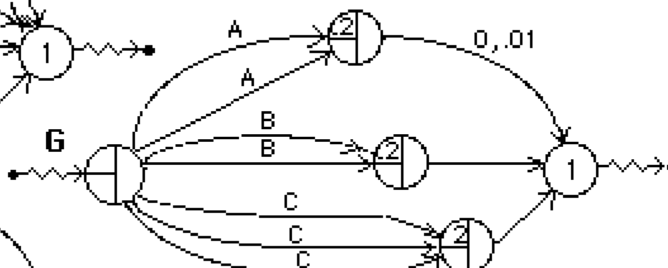


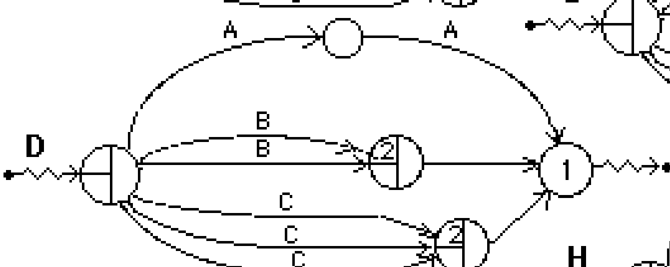
C



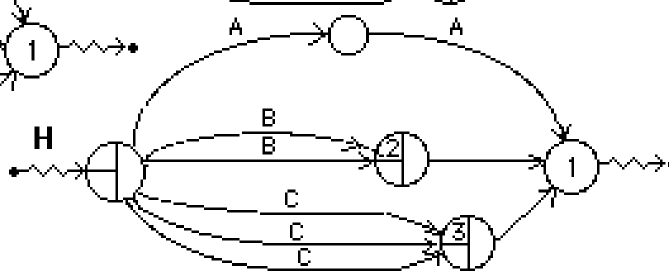
G



D



H



I: None of the above