57:022 Principles of Design II
Final Exam - May 13, 1993
Solutions

(I.) *Write the correct probability distribution in each blank below. Note that some distributions may apply in more than one case, while others not at all!*

Poisson a. the number of cars passing through an intersection during a 1-minute green light.
Binomial b. the number of trucks among the first 10 vehicles to arrive at an intersection during a red light
Normal c. The sum of ten N(0,1) random variables
2-**Erlang** d. the time until the arrival of the second car at an intersection during a red light
Normal e. the total weight of a group of persons on an elevator, when loaded to its capacity of 18 persons
Exponential f. The time between the arrivals of the first and second vehicle during a red light.
Exponential g. The interarrival time for the M/M/1 queueing system
Weibull h. the lifetime of an electronic device with several dozen components which might fail (each necessary for the device to function)
Bernoulli i. the result of tossing a single coin
Binomial j. number of defective items found when testing a batch of 10
Chi-square k. The sum of the squares of ten N(0,1) random variables
Poisson l. the number of items produced in order to obtain 4 acceptable items, if each is tested before producing the next
Gumbel m. the magnitude of the highest rate of flow into the Coralville Reservoir next year
Normal n. the completion time of a large project with random task durations

Probability distributions:

1. Bernouilli	8. Geometric
2. Binomial	9. Exponential
3. Poisson	10. Pascal (negative binomial)
4. Erlang (Gamma) with k>1	11. Normal
5. Gumbel	12. Uniform
6. Weibull	13. Chi-square
7. Beta	14. Triangular

(II.) Indicate "+" if True and "O" if False:

False a. If a component's lifetime has exponential distribution, its failure rate ("hazard rate") is decreasing.
False b. "Dummy" activities are unnecessary in the "Activity-on-Arrow" representation of a project.
False c. In a Poisson arrival process, the time between arrivals has the Poisson distribution.
False d. If 3 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.
True e. The "Inverse transformation" technique may be used to generate time between arrivals in a Poisson process.
False f. In an M/M/1 queueing system, with arrival rate 2/minute and service time averaging 20 seconds, we would expect the server to be busy more than 75% of the time.
False g. If 3 components of a system have a series configuration with respect to system reliability, then the second component replaces the first when it fails, and the system then fails when the second component fails.
False h. In an M/M/1/N queueing system, N represents the capacity of the waiting line.
True i. PERT assumes that the project duration has a Normal distribution.
False j. PERT assumes that each activity's duration has a Normal distribution.

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

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

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

True n. In an M/M/1 queueing system, π_0 represents the probability that the server is idle.

True o. The gamma function $\Gamma(n) = (n-1)!$ for positive integer values of n.

True p. For an infinite-capacity one-server queue (M/M/1), a steady state exists only if the arrival rate is less than the service rate.

True q. If 3 components of a system have a parallel configuration with respect to system reliability, then the system lifetime is the maximum of the component lifetimes.

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

False s. In an M/M/1 queueing system, with an average of 15 seconds between arrivals and an average of 2 customers in the system, we would expect the average time spent by a customer in the system to be at least 1 minute.

True t. The exponential distribution is a special case of a Weibull distribution.

False u. If we...
(i) test 100 lightbulbs, recording the failure time of each,
(ii) prepare a histogram indicating number of failures on five consecutive days (where the last failure occurred on the fifth day),
(iii) use the mean and standard deviation of the failure times to estimate the parameter of the Weibull distribution,
then we would assume 3 degrees of freedom when performing the Chi-Square goodness of fit test.

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

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

(III.) For each of the following statements about SLAM, **indicate True and False:**

True a. An assembly node is a special case of a SELECT node.

True b. 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.

False c. An AWAIT node is a special type of a queue node.

False d. A SLAM network requires at least one CREATE node.

True e. The activity preceding a queue node with blocking must be a service activity.

False f. When an entity arrives at a terminate node, the simulation ends.

True g. In SLAM, an assembly node is a special type of select node.

False h. A SLAM model of a project employs the "Activity-on-Node" rather than "Activity-on-Arrow" representation of the project.

True i. At an AWAIT node, entities may wait for either a gate or a resource.

False j. If, on two successive days, you run the same simulation model (i.e., with the same input file) in which some activities have random durations, you should expect to obtain slightly different statistics.

True k. A service activity cannot be pre-empted.

False l. Two AWAIT nodes must use different file numbers.

False m. The activity preceding a queue node with balking must be a service activity.

True n. Entities may balk when arriving at an AWAIT node with limited space to wait.

False o. Entities may wait at a QUEUE node for a GATE to open.

True p. When two entities are waiting for a gate to open, and the gate then opens, both entities simultaneously proceed to the next node.

True q. An activity following a queue node must be a service activity.

True r. A COLCT node is used to accumulate statistics in successive runs of a simulation model.

False s. INT(1) means that you wish statistics collected on the interarrival times of entities at this node.

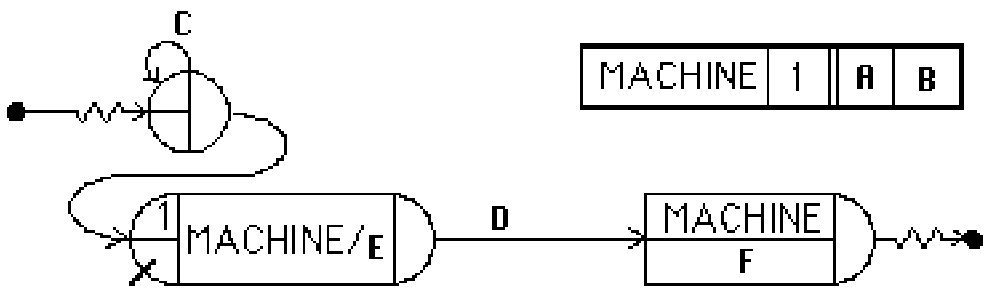
False t. When an entity arrives at a CLOSE node to close a gate, then any entities which follow it may not pass through that node until the gate is opened again.

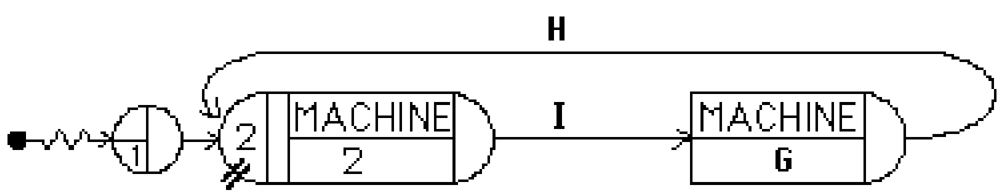
(IV.) Study the following SLAM network model, and choose from the list below appropriate values for parameters **A** through **S** in the 2 networks.

A. _1 (or 2)_	B. _2 (or 1)_	C. _EXPON(5)_
D. _RNORM(2,0.5)_	E. _1_	F. _1_
G. _1_	H. _EXPON(60)_	I. _UNFRM(5,10)_

(1.) 1	(2.) 2	(3.) 3
(4.) EXPON(5)	(5.) EXPON(10)	(6.) EXPON(60)
(7.) RNORM(2,0.5)	(8.) UNFRM(5,10)	(9.) 0 (i.e., zero)

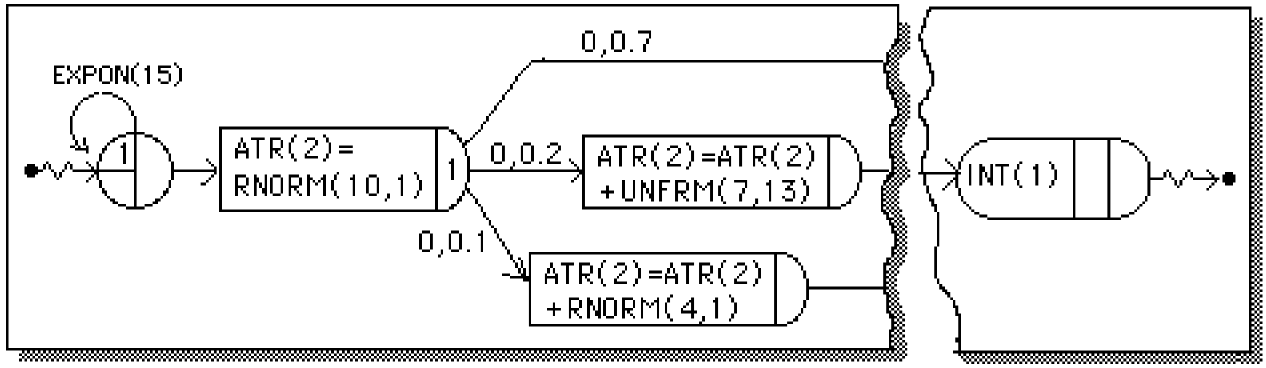
Job arrivals at a machine form a Poisson process, arriving at the rate of one every five minutes. They are processed, one at a time, on the machine, which is subject to breakdown. Processing time is normally distributed with mean 2 minutes and standard deviation $^1/_2$ minute. Breakdowns occur in a completely random fashion, an average of 1 per hour. When a breakdown occurs, job processing is interrupted while the machine is repaired. Repair times are uniformly distributed between 5 and 10 minutes.

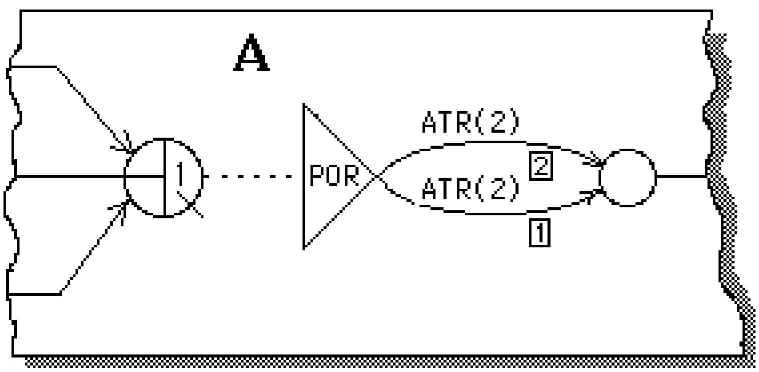


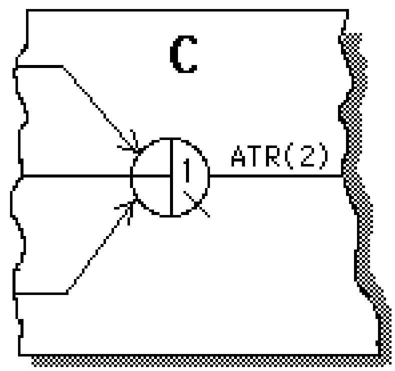


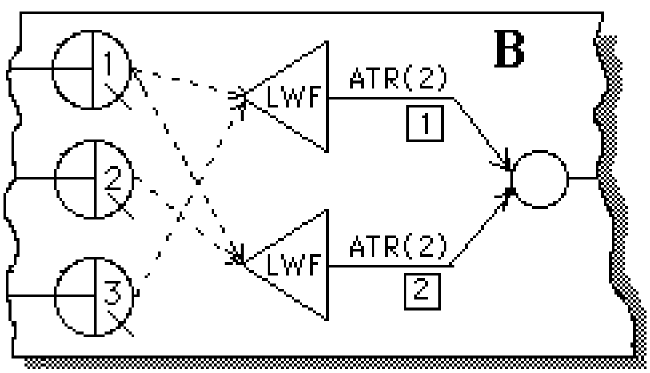
(V.) Customers arrive at a barber shop with 2 barbers. 70% of the customers want a haircut only, while 20% want a shave also, and 10% a shampoo also. The shop employs two barbers. The shop is modeled as a SLAM network as below. A portion has been removed.
For each case below, indicate the fragment (A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

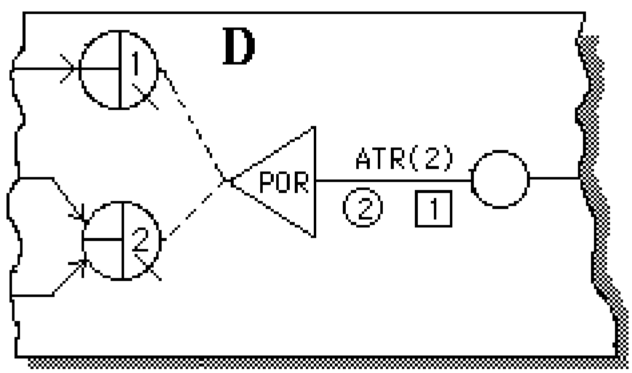
__**C**__ Both barbers are identical, and do all three functions
__**B**__ Barber #1 does not shave customers, and #2 does not shampoo hair
__**N**__ Customers requiring a shave or shampoo are served only by barber #2
__**A**__ Customers prefer barber #2 if both are available
__**D**__ Both barbers give priority to customers requiring 2 services





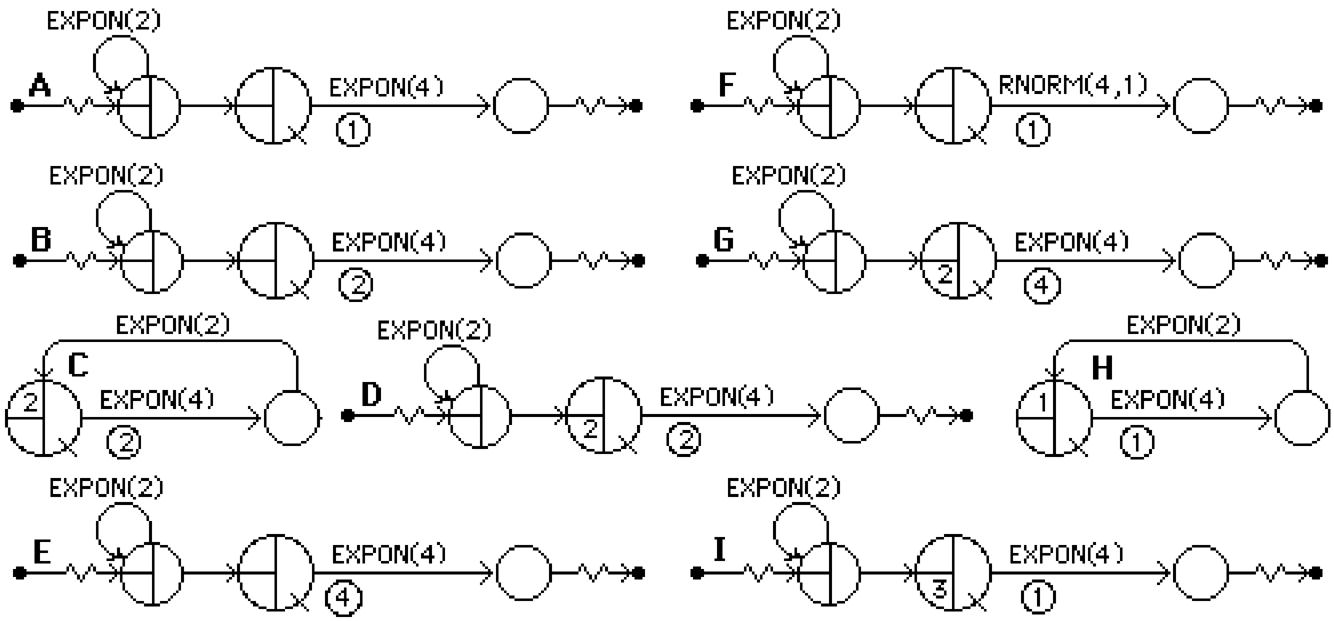






(VI.) Match SLAM diagram (**A** through **I**) & Queue Classification. If "none", indicate "N"

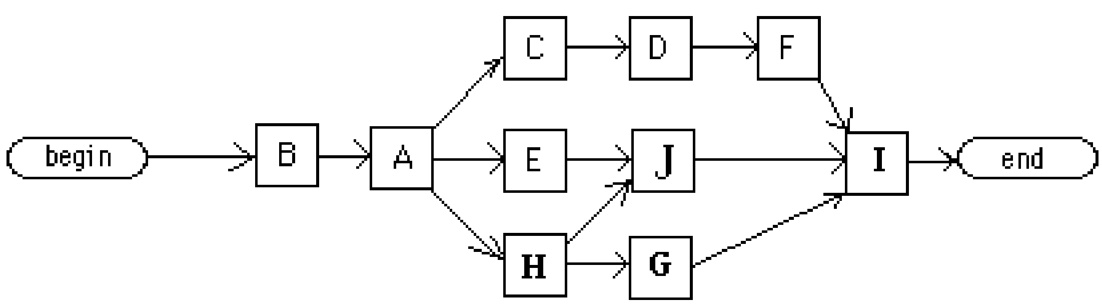
__**A**_ M/M/1 __**B**_ M/M/2
__**N**_ M/M/1/2 __**H**_ M/M/1/2/2
__**F**_ M/G/1 __**I**_ M/M/1/4
__**E**_ M/M/4 __**N**_ M/M/2/2
__**D**_ M/M/2/4 __**C**_ M/M/2/4/4



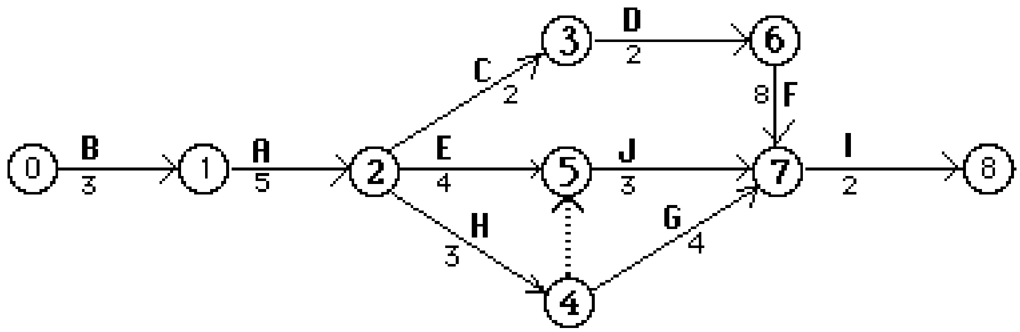
(VII.) Consider the project:

Activity	Description	Predecessor Activities	Duration (days) Mean	Std Dev
A	Walls & ceiling	B	5	2
B	Foundation	none	3	1
C	Roof timbers	A	2	1
D	Roof sheathing	C	2	1
E	Electrical wiring	A	4	2
F	Roof shingles	D	8	2
G	Exterior siding	H	4	1
H	Windows	A	3	1
I	Paint	F,G,J	2	1
J	Inside wall board	E,H	3	1

1. Complete the AON network by labeling the nodes:



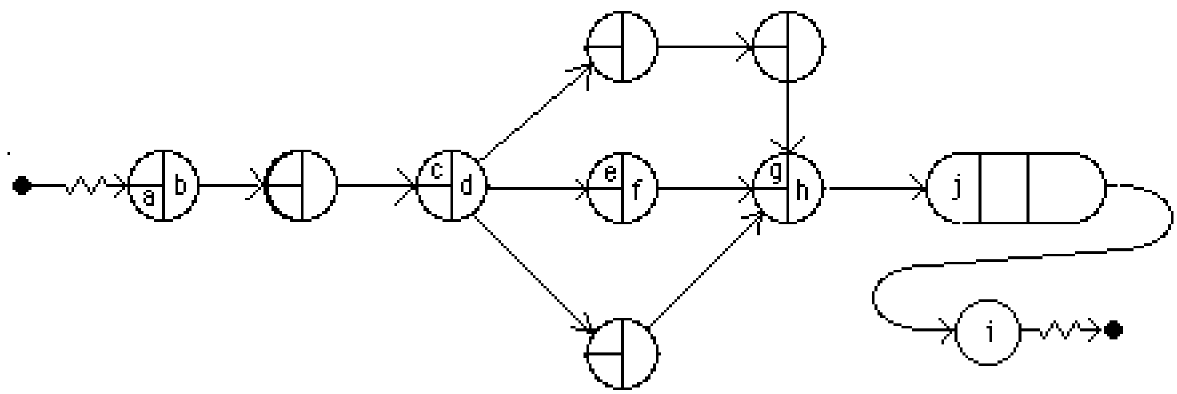
2. Complete the AOA & the corresponding SLAM networks below by inserting any "dummy" activities which are necessary, and labeling the nodes.



(Labels #3&4 might be interchanged; likewise, #5 & 6 may be interchanged.)

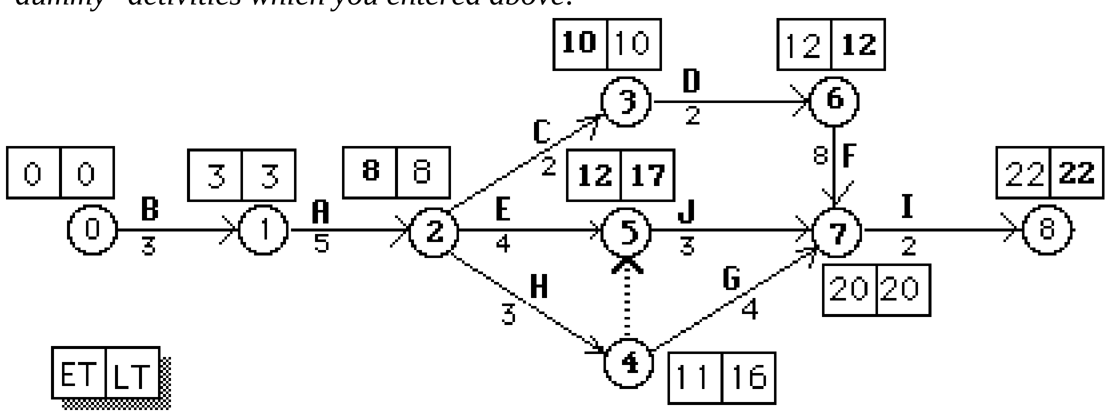
3. Give numerical values (0, 1, 2, 3, 4, or ∞) of "a" - "i" on the SLAM network below.

a _1_ b _1_ c _1_ d _3_ e _2_ f _1_ g _3_ h _1_ i _1_



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. *Don't forget any "dummy" activities which you entered above!*



6. What are the critical activities? (**A B C D F I**)

7. What is the "total slack" or "total float" in activity G? __**5**___

8. What is the expected completion time of the project? ___**22**__
... the standard deviation of the project completion time? __$\sqrt{12} = 2\sqrt{3}$

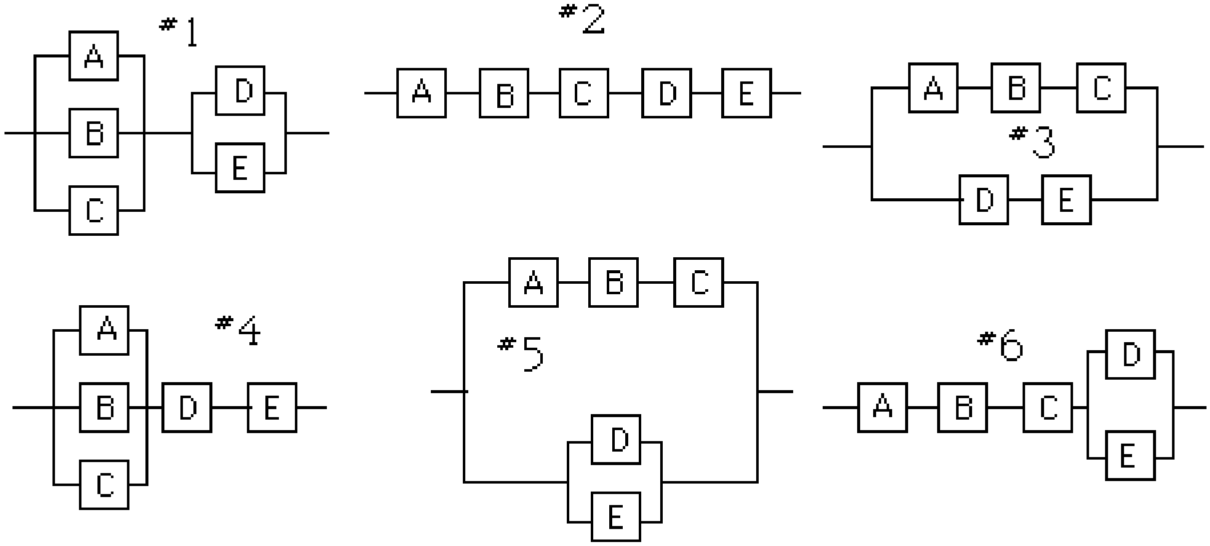
(VIII.) A system consists of five components (A,B,C,D, &E). The reliability (i.e., survival probability) during the first year of operation is 80% for A, B, and C, and 90% for D and E. For each alternative of (a) through (e), indicate:

- the number of the reliability diagram below which represents the system.
- the computation of the 1-year reliability

Diagram	Reliability	
_**3**_	_**9**_	a. The system can function if A, B, and C all function or if both D and E function.
_**6**_	_**5**_	b. The system requires all of A, B, & C, and at least one of D & E.
_**1**_	_**3**_	c. The system requires at least one of A ,B, &C, and at least one of D & E .
_**4**_	_**2**_	d. The system requires that D & E both function, and at least one of A, B, &C.

Reliabilities:

1. $(0.8)^3(0.9)^2$	2. $[1-(0.2)^3](0.9)^2$	3. $[1-(0.2)^3]\ [1-(0.1)^2]$
4. $1 - (0.2)^3(0.8)^2$	5. $(0.8)^3[1-(0.1)^2]$	6. $1- [1-(0.2)^3][1-(0.1)^2]$
7. $1-[\ 1-(.1)^2]\ [.8^3]$	8. $1-[1-(0.2)^3]\ [1-(0.1)^2]$	9. None of the above



Which of the six reliability diagrams corresponds to the SLAM model below? __**5**___