57:022 Principles of Design II
Midterm Exam - Spring 1993 - Solutions

Note: there are 3 versions of the exam, with questions &/or answers simply shuffled, except for Part IV.

PART I

We wish to simulate persons arriving at an elevator on the first floor of the Engineering Building at the average rate of 5/minute in a completely random fashion, starting at time t=0. Eighty percent of the persons are engineering students.

Write the alphabetic letter corresponding to the name of the probability distribution which each of the following random variables has. Warning: some distributions may apply in more than one case, while others not at all!

_h_ 1. the time of arrival of first person
_i_ 2. the number of persons arriving during the first minute
_h_ 3. the time between arrival of first and second persons
_b_ 4. the sequence number of the first non-engineering student.
_d_ 5. the number of engineers among the first 10 persons to arrive
_e_ 6. the total weight of the passengers when the elevator is full
_g_ 7. the weight of the heaviest passenger when the elevator is full
_j_ 8. the time of arrival of the fourth passenger

a. uniform	b. geometric	c. Bernouilli	d. binomial
e. normal	f. Weibull	g. Gumbel	h. exponential
i. Poisson	j. Erlang	k. chi-square	
	m. none of the above		

Write the alphabetic letter below corresponding to the numerical value of the following probabilities:

_o_ 9. probability that the first passenger has already arrived at time t=0.1
_q_ 10. probability that exactly 5 passengers arrive during the first minute.
_r_ 11. probability that four of the first five passengers are engineers.
_w_ 12. probability that the first non-engineer is the fifth person to arrive.

n. $\frac{(0.8)^5}{4!} e^{-5}$	o. $1 - e^{-0.5}$	p. e^{-5}	q. $\frac{5^5}{5!} e^{-5}$
r. $\binom{5}{4}\left(\frac{4}{5}\right)^4\left(\frac{1}{5}\right)$	s. $\left(\frac{1}{5}\right)^4\left(\frac{4}{5}\right)$	t. $1 - e^{-5}$	u. $e^{-0.5}$
v. $\binom{5}{4}\left(\frac{1}{5}\right)^4\left(\frac{4}{5}\right)$	w. $\left(\frac{4}{5}\right)^4\left(\frac{1}{5}\right)$	x. none of the above	

PART II

A system consists of five components (A,B,C,D, & E). The probability that each component *survives* the first year of operation is 80% for A, B, & C, and 90% for D & E. For each alternative of (1) through (4), indicate:

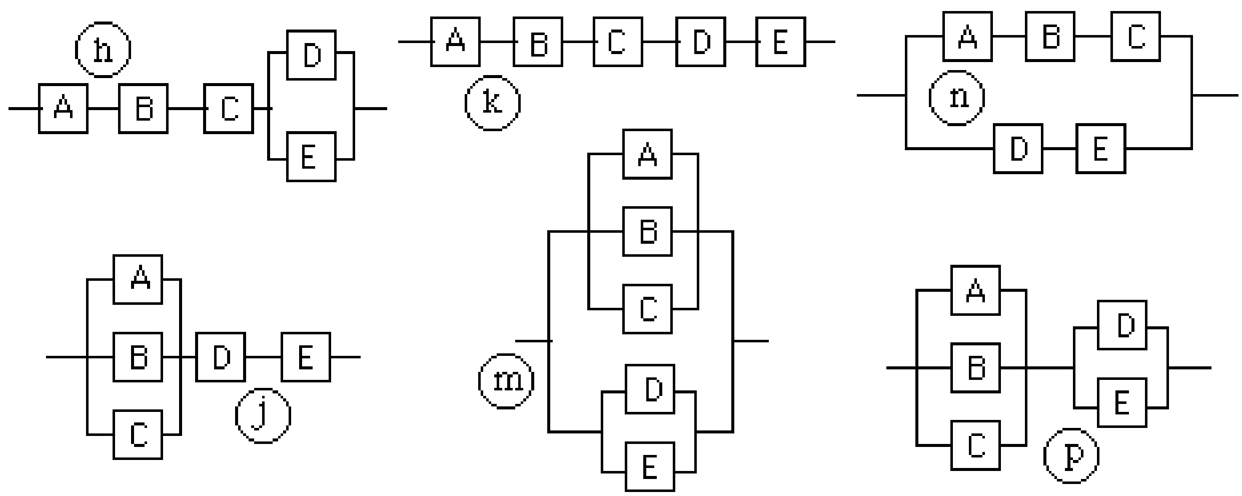
(i) the letter of the reliability diagram below which represents the system
(ii) the letter of the SLAM network model which represents the system
(iii) the letter with the computation of the 1-year reliability (i.e., survival probability)

i.	ii.	iii.	
_n_	_t_	_f_	1. The system can function only if A, B, & C all function or if D & E both function.
_p_	_r_	_b_	2. The system requires at least one of A, B, & C, and at least one of D & E.
_j_	_s_	_e_	3. The system requires at least one of A ,B, & C, and both of D & E .
_h_	_q_	_c_	4. The system requires all of A, B, & C, and at least one of D & E.

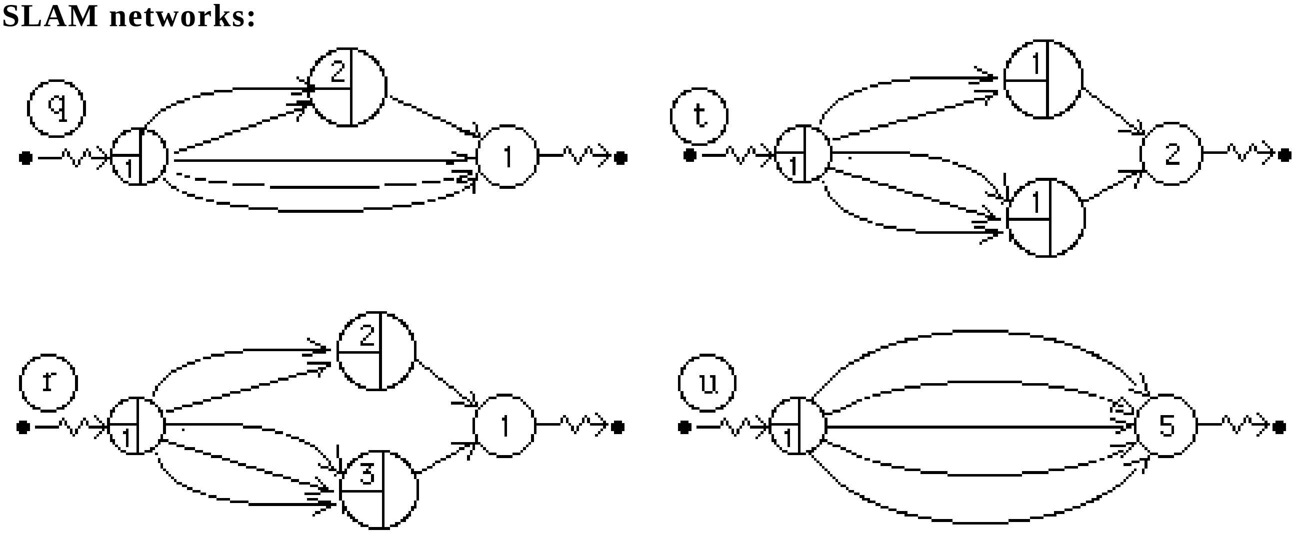
Reliabilities:

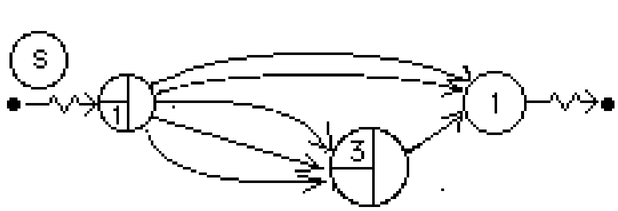
a. $1 - (0.2)^3(0.1)^2$
b. $[1-(0.2)^3]\ [1-(0.1)^2]$
c. $(0.8)^3[1-(0.1)^2]$
d. $(0.8)^3(0.9)^2$
e. $[1-(0.2)^3](0.9)^2$
f. $1- [1-(0.8)^3][1-(0.9)^2]$
g. None of the above

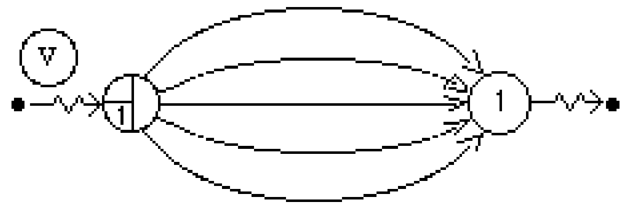
Diagrams:



SLAM networks:







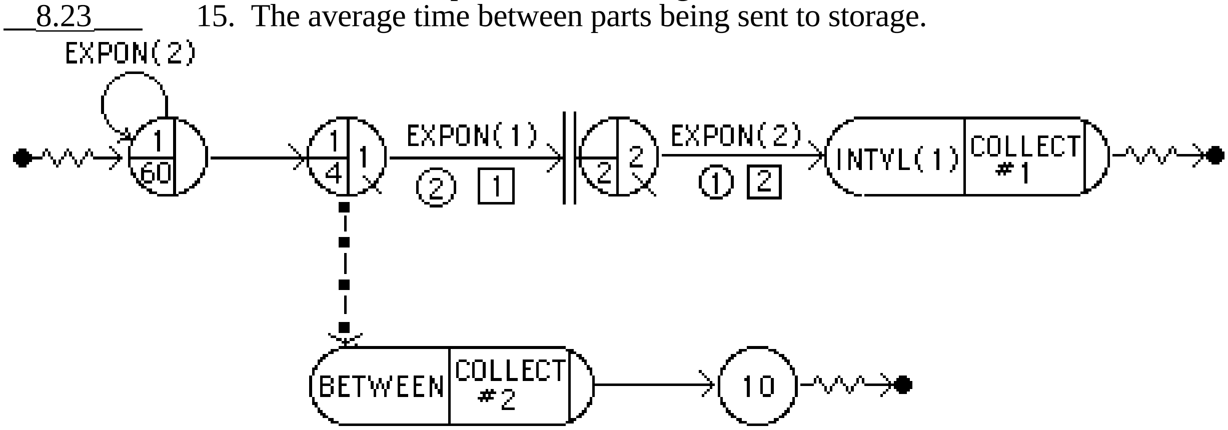
PART III

Consider the SLAM II network and its output below. Arriving parts must be processed at two machine centers. Each machine center has limited storage space for waiting parts. Parts which arrive and cannot be stored at the first machine center are sent elsewhere for storage, to be processed at a later time.

2 or 1.856	1. The average time between arrivals. (Expected time between arrivals was specified to be 2; actual average time between arrivals was 102.1/55= 1.856.)
3	2. The total number of servers in the system.
3	3. The number of entities in the system initially. (1 in first queue, 2 in first service activity)
4	4. The capacity of the first queue.
0.1885	5. The fraction of the time that the first server(s) is/are busy. (0.377/2)
0.005	6. The fraction of the time that the second server(s) is/are idle.
13.3	7. The average time which entities spend in the system. (not including those sent to storage.)
8.172	8. The average time which entities spend in the queues. (3.952+4.220)
59	9. The number of entities which are created during the simulation.

43	observed at first collect node
+10	departed through 2nd collect node
+6	in first queue & server at end of simulation
+3	in 2nd queue & server at end of simulation
-3	initially in queue & servers
=59	

20.8	10. The longest time that any entity spent in the system.
3.836	11. The average number of entities waiting in the system.
101.31	12. The longest stretch of time which the second server(s) worked without a break.
102.1	13. The time at which the simulation ended.
10	14. The number of parts sent to storage.
8.23	15. The average time between parts being sent to storage.



SLAM II SUMMARY REPORT

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                                                 RUN NUMBER    1  OF  1
CURRENT TIME   0.1021E+03
STATISTICAL ARRAYS CLEARED AT TIME  0.0000E+00

                 **STATISTICS FOR VARIABLES BASED ON OBSERVATION**

                 MEAN     STANDARD   COEFF.OF   MINIMUM  MAXIMUM     NO.OF
                VALUE    DEVIATION  VARIATION    VALUE    VALUE       OBS
COLLECT#1     0.133E+02  0.461E+01  0.347E+00  0.369E+00  0.208E+02  43
COLLECT#2     0.823E+01  0.111E+02  0.134E+01  0.607E+00  0.331E+02   9

                               **FILE STATISTICS**

FILE                 AVERAGE      STANDARD   MAXIMUM  CURRENT     AVERAGE
NO.    LABEL/TYPE   LENGTH      DEVIATION   LENGTH   LENGTH     WAIT TIME
1     QUEUE          1.935        1.453        4        4        3.952
2     QUEUE          1.901        0.383        2        2        4.220
3     CALENDAR       2.372        0.581        5        2        0.868

                         **SERVICE ACTIVITY STATISTICS

ACTACT LABEL OR SER    AVERAGE   STD   CUR AVERAGE MAX IDL  MAX BSY   ENT
NUM START NODE  CAP      UTIL    DEV  UTIL  BLOCK  TME/SER  TME/SER   CNT
1      QUEUE     2      0.377   0.59    0    1.39    2.00     2.00    46
2      QUEUE     1      0.995   0.07    1    0.00    0.45   101.31    43
Fortran STOP
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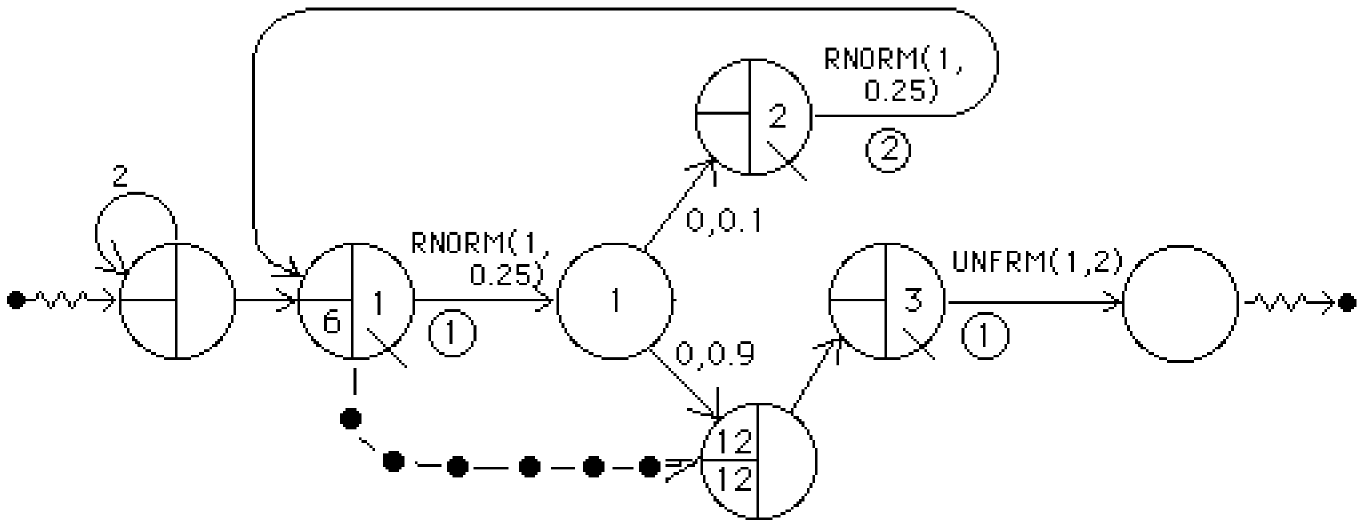
PART IV

There were two different systems described in different versions of the exam.

Complete the SLAM network below which could be used to model the following system (or draw your own network "from scratch"):

- Widgets come off an assembly line at a constant rate of 2/minute to be inspected, adjusted if necessary, and packaged for shipment.
- There are two inspectors, and inspection time is normally distributed with mean 1 minute, and standard deviation 0.25 minute.
- An average of 5% of the widgets will fail inspection and must be sent to be adjusted by a single worker. Adjustment time is normally distributed with mean 2 minutes and standard deviation 0.5 minute.
- After adjustments, the widgets are sent to be packaged (without reinspection).
- A maximum of 12 widgets can await inspection; any arriving widgets while 12 widgets already await inspection are sent directly to be packaged, without inspection.
- Widgets are packaged in cartons, with 6 widgets/carton. After the carton is filled, it is prepared by a single shipping clerk for shipping, requiring between 1 and 2 minutes (uniformly distributed).



- Widgets come off an assembly line at a constant rate of one every two minutes to be inspected, adjusted if necessary, and packaged for shipment.
- There is one inspector, and inspection time is normally distributed with mean 1 minute, and standard deviation 0.25 minute.
- An average of 10% of the widgets will fail inspection and must be sent to be adjusted by two workers. Adjustment time is normally distributed with mean 1 minutes and standard deviation 0.25 minute.
- After adjustments, the widgets are sent back to be re-inspected.
- A maximum of 6 widgets can await inspection; any arriving widgets while 6 widgets already await inspection are sent directly to be packaged, without inspection.
- Widgets are packaged in cartons, with 12 widgets/carton. After the carton is filled, it is prepared by a single shipping clerk for shipping, requiring between 1 and 2 minutes (uniformly distributed).