«»«»«»«»«» 57:022 Principles of Design II «»«»«»«»«»
Homework Assignments, Fall 1995
Prof. Dennis L Bricker, Dept. of Industrial Engineering

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #1 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

Be sure to state what probability distribution you assume in each problem. You may find the necessary probabilities in tables, compute them manually with a calculator, or use the APL workspace "PROBLIB" .

1. A telephone exchange contains 8 lines. A line can be busy or available for calls and all lines act independently. Each line is busy 75% of the noon period (so that the probability that a line will be busy at any given time during the noon period is 75%).
   a. What is the probability of there being at least *three* free lines at any given time during this period?
   b. What is the expected number of free lines at any time during this period?
   c. You need to make three calls to this exchange, and each time you receive a busy signal you try again. What is the probability that you require exactly *six* tries in order to complete your three calls?

2. The foreman of a casting section in a certain factory finds that on the average, 1 in every 6 castings made is defective.
   a. If the section makes 10 castings a day, what is the probability that 2 of these will be defective?
   b. What is the probability that 3 or more defective castings are made in one day?

3. Advertising states that, for a certain lottery ticket, "every fourth ticket carries a prize". If you buy four tickets...
   a. what is the probability that you get *exactly* one winning ticket?
   b. what is the probability that you get *at least* one winning ticket?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #2 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

Be sure to state what probability distribution you assume in each problem. You may find the necessary probabilities in tables, compute them manually with a calculator, or use the APL workspace "PROBLIB" .

1. Suppose that X is a *discrete* random variable with probability mass function given by:

$$p(1) = 0.1 \qquad p(2) = 0.3 \qquad p(3) = 0.2 \qquad p(4) = 0.3 \qquad p(5) = 0.1$$

   (a.) Plot the probability mass function p(x).
   (b.) Compute and plot the CDF (cumulative distribution function) F(x).
   (c.) Compute $P\{1.4 \leq X \leq 4.2\}$.

2. Suppose that X is a *continuous* random variable with probability density function given by:

$$f(x) = \begin{cases} 4x & 15.5 \leq x \leq 17.0 \\ 0 & \text{otherwise} \end{cases}$$

   (a.) Plot the density function f(x).
   (b.) Plot the CDF (cumulative distribution function) F(x).
   (c.) Compute $P\{X \leq 16.0\}$.
   (d.) Compute $P\{X = 16.0\}$.

3. Along highway I-80 in Iowa, the probability that each passing car stops to pick up a hitchhiker is p=3%; different drivers, of course, make their decisions whether to stop or not independently of each other.

a. Each car may be considered as a "trial" in a ____________ process, with "success" defined as the car's stopping to pick up the hitchhiker.

b. Given that a hitchhiker has counted 20 cars passing him without stopping, what is the probability that he will be picked up by the 25^{th} car *or before?*

Suppose that the arrivals of the cars form a Poisson process, at the average rate of 10 per minute. Define "success" for the hitchhiker to occur at time t provided that *both* an arrival occurs at t *and* that car stops to pick him up. Let T_1 be the time (in seconds) of the first "success", i.e., the time that he finally gets a ride, when he begins his wait at time T_1=0.

c. What is the arrival rate of "successes"? ______________

d. What is the name of the probability distribution of T_1? _______________

e. What is the value of $E(T_1)$?________ What's the value of $Var(T_1)$?_________

f. What is the probability that he must wait less than 5 minutes for a ride ($P\{T_1 < 5\}$?

g. What is the probability that he must wait more than 5 minutes for a ride($P\{T_1 > 5\}$?

h. What is the probability that he must wait *exactly* 5 minutes for a ride? ($P\{T_1 = 5\}$?
Note that your answers in f, g, and h must have a sum equal to 1!

i. Suppose that after 4 minutes (during which 42 cars have passed by) he is still there waiting for a ride. Compute the *conditional* expected value of T_1 (expected *total* waiting time, given that he has already waited 4 minutes).

4. A bearing in a Grass Chopper mower's PTO mechanism fails randomly, with an expected lifetime of 200 hours. Assume that the lifetime of the bearing has an exponential distribution.

(a.) What is the probability that the bearing lasts longer than 200 hours?
(b.) If the mower has operated for 150 hours, what is the probability that the bearing will last longer than 200 hours?
(c.) If the bearing experiences its first failure at 238 hours and is replaced (with an identical bearing), what is the probability distribution, mean value, and variance of the time until the second failure?
(d.) What is the probability that the bearing will fail three or more times in 500 hours of mowing?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #3 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

1. **Generating Arrival Times in Poisson Process.** Suppose, in preparation for performing a manual simulation of the arrivals in a Poisson process (e.g., parts randomly arriving at a machine to be processed), you wish to generate some inter-arrival times, where the arrival rate is 4/hour. First, you need some uniformly-distributed random numbers. To obtain these, select a column from the table which appeared in the Hypercard stack:

1	2	3	4	5	6	7	8	9	0
3821	4876	3071	5268	8684	0169	1746	6658	8605	9638
0218	3519	0707	3695	6478	3977	2017	3644	7993	5547
5105	8147	7365	2901	7228	2307	7241	4225	6078	9344
4549	1468	4395	3808	9446	5954	6851	2930	9217	5668
6758	7233	0503	0981	5955	4881	5916	3197	8532	9810
8431	5742	0744	3115	4411	5132	2175	8044	5668	3463
5072	1129	0723	1390	0722	6669	8144	0434	3014	9675
1797	8050	3603	9301	2162	8267	6733	5878	9918	3984
5280	5063	6663	6449	6400	0863	2414	4309	0851	3393
7223	4603	1542	9279	7217	2279	4575	5332	0000	6645

Select a column based upon the last digit of your ID#: if 1, use column #1; if 2, use column #2; ... if 0, use column #10.

a. What is the name of the probability distribution of the time T_1 of the first arrival?

b. What will be the probability distribution of the time t_i between arrivals of parts i-1 and i (where i>1)?

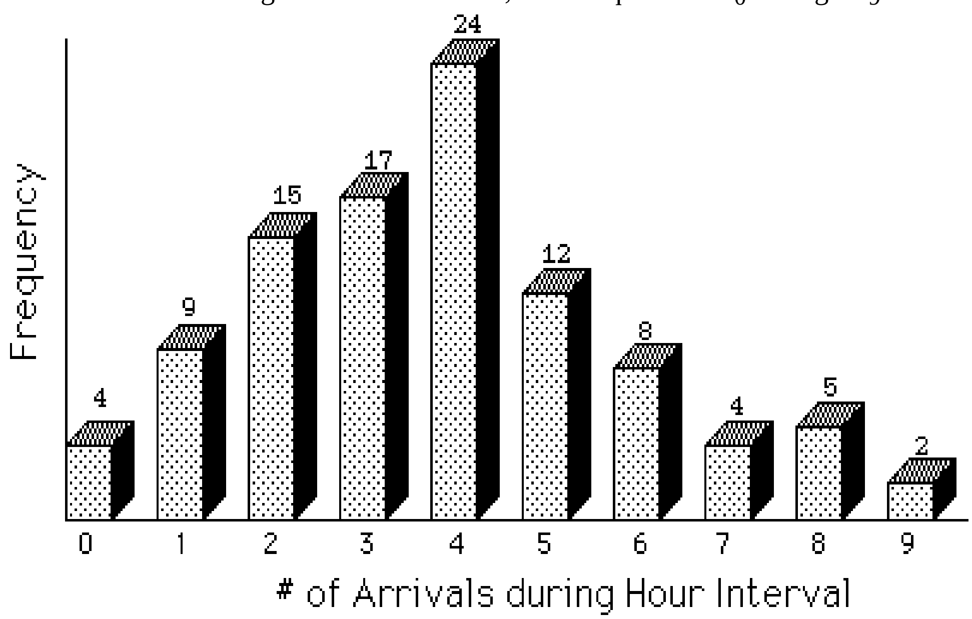
c. Use the inverse-transformation method to obtain (pseudo-)random inter-arrival times t_1, t_2, … t_8 (where $T_1 = t_1$).

d. What are the arrival times (T_1, T_2, … T_8) of the first eight parts in your simulation?

e. The expected number of arrivals in the first hour should, of course, be 4. In your simulation of the arrivals, however, what is the number of arrivals during the first hour?

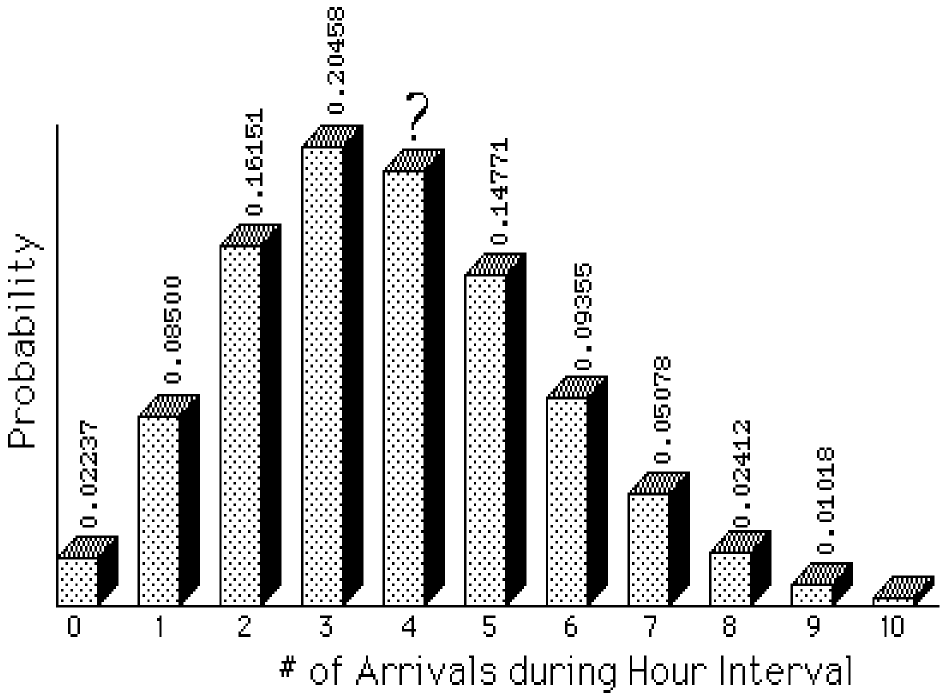
2. **Manual Simulation of Drive-In Teller Window.** In the Hypercard stack, the arrival of the first three autos at the drive-in teller window was manually simulated. Repeat the simulation manually up to the departure of the 10^{th} auto, except reverse the sequence of the 25 randomly-generated inter-arrival times. (That is, the first arrival should now be at t=3, the second 1 minute later, etc., so that Ta = {3, 1, 4, 1, 11, 7, 6, 3, 6, 5, 2, 1, 4, 8, 4, 5, 4, 13, 3, 1, 2, 2, 1, 6, 5}. Give the event log and the event schedule at that time. What was the maximum length of the waiting line during the simulation?

3. The numbers of arrivals during 100 hours of what is believed to be a Poisson process were recorded. The observed numbers ranged from zero to nine, with frequencies O_0 through O_9:



The average number of arrivals was 3.8/hour. We wish to test the "goodness-of-fit" of the assumption that the arrivals correspond to a Poisson process with arrival rate 3.8/hour.
The first step is to compute the probability of each observed value, 0 through 9:

i	P{N=i}
0	0.0223708
1	0.0850089
2	0.161517
3	0.204588
4	
5	0.147713
6	0.0935513
7	0.050785
8	0.0241229
9	0.0101852



a. What is the value missing above? (That is, the probability that the number of arrivals is exactly 4.)

b. Now, we can compute the expected number of observations of each of the values 0 through 9, which we denote by E_0 through E_9. What is the expected number of times in which we would observe five arrivals per hour? Did we observe more or fewer than the expected number?

c. Complete the table below:

i	P{N=i}	E_i	O_i	$(E_i-O_i)^2$	$\frac{(E_i-O_i)^2}{E_i}$
0	0.0223708	2.23708	4	3.1079	1.38927
1	0.0850089	8.50089	9	0.249107	0.0293037
2	0.161517	16.1517	15	1.32641	0.0821218
3	0.204588	20.4588	17	11.9634	0.584756
4			24		
5	0.147713	14.7713	12	7.67991	0.519922
6	0.0935513	9.35513	8	1.83639	0.196298
7	0.050785	5.0785	4	1.16317	0.229037
8	0.0241229	2.41229	5	6.69625	2.77589
9	0.0101852	1.01852	2	0.9633	0.945782

d. Ignoring the suggestion that cells should be aggregated so that they contain at least five observations, what is the observed value of

$$D = \sum_i \frac{(E_i-O_i)^2}{E_i} \ ?$$

e. Keeping in mind that the assumed arrival rate l=3.8/hour was estimated from the data, what is the number of "degrees of freedom"?

f. Using a value of a = 5%, what is the value of $\chi^2_{5\%}$ such that D exceeds $\chi^2_{5\%}$ with probability 5% (if the assumption is correct that the arrivals form a Poisson process with arrival rate 3.8/hour)?

g. Is the observed value greater than or less than $\chi^2_{5\%}$? Should we accept or reject the assumption that the arrival process is Poisson with rate 3.8/hour?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #4 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

(1.) Consider again the proposed drive-up bank teller window in the Hypercard Stack "Intro. to Simulation". The SLAM model, together with output, appears below. According to this output...

a. How many cars were unable to enter the queue each day, because the queue was filled to capacity?

b. What fraction of the time was the teller busy each day?

c. Estimate the mean (average) time in the system for the customers.

It has been suggested that a customer's time in the system will have exponential distribution, given that the service times have exponential distribution.

d. Test the "goodness-of-fit" of the exponential probability distribution having the mean value in (c). (Use alpha = 10%, and group the cells as necessary so that there are at least 5 observations in each cell.)

e. What fraction of the customers spend more than 5 minutes (total of both waiting and being served) at the bank?

```
GEN,BRICKER,BANKTELLERS,2/11/1993,,,,,,,72;
LIM,2,1,50;
INIT,0,480;
NETWORK;
      CREATE,EXPON(5.0),,1;
      QUE(1),0,4,BALK(OVFLO);
      ACT(1)/1,EXPON(2.0);
      COLCT,INTVL(1),CUSTOMER_TIME,20/.5/.5;
      TERM;
OVFLO COLCT,FIRST;
      TERM,1;
      END;
FIN;
```

```
              S L A M   I I   S U M M A R Y   R E P O R T
 SIMULATION PROJECT BANKTELLERS               BY BRICKER

 DATE  2/ 1/1993                              RUN NUMBER    1 OF    1


 CURRENT TIME   0.4081E+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

CUSTOMER_TIME   0.303E+01 0.286E+01 0.944E+00 0.345E-01 0.110E+02    88
                0.408E+03 0.000E+00 0.000E+00 0.408E+03 0.408E+03     1

           **FILE STATISTICS**

FILE                   AVERAGE  STANDARD   MAXIMUM  CURRENT AVERAGE
NUMBER  LABEL/TYPE     LENGTH   DEVIATION  LENGTH   LENGTH  WAIT TIME

   1         QUEUE        0.300     0.724       4        4      1.317
```

```
   2                   0.000     0.000       0        0      0.000
   3         CALENDAR  1.439     0.496       3        2      2.669

          **SERVICE ACTIVITY STATISTICS**

 ACT ACT 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      1   0.439   0.50    1    0.00   17.35   29.23   88
                         **HISTOGRAM NUMBER 1**
                              CUSTOMER_TIME

 OBS  RELA   UPPER
 FREQ FREQ  CELL LIM 0        20        40        60        80       100
                     +    +    +    +    +    +    +    +    +    +    +
  10 0.114 0.500E+00 +******                                           +
   9 0.102 0.100E+01 +*****     C                                      +
  16 0.182 0.150E+01 +*********          C                             +
  13 0.148 0.200E+01 +*******                   C                      +
   4 0.045 0.250E+01 +**                           C                   +
   7 0.080 0.300E+01 +****                             C               +
   5 0.057 0.350E+01 +***                                C             +
   1 0.011 0.400E+01 +*                                   C            +
   3 0.034 0.450E+01 +**                                    C          +
   0 0.000 0.500E+01 +                                      C          +
   2 0.023 0.550E+01 +*                                      C         +
   1 0.011 0.600E+01 +*                                      C         +
   3 0.034 0.650E+01 +**                                       C       +
   0 0.000 0.700E+01 +                                         C       +
   4 0.045 0.750E+01 +**                                         C     +
   1 0.011 0.800E+01 +*                                           C    +
   2 0.023 0.850E+01 +*                                            C   +
   2 0.023 0.900E+01 +*                                             C  +
   2 0.023 0.950E+01 +*                                              C +
   2 0.023 0.100E+02 +*                                               C+
   0 0.000 0.105E+02 +                                                C+
   1 0.011    INF    +*                                                C
 ---                 +    +    +    +    +    +    +    +    +    +    +
  88                 0        20        40        60        80       100

          **STATISTICS FOR VARIABLES BASED ON OBSERVATION**

                   MEAN    STANDARD  COEFF. OF  MINIMUM   MAXIMUM  NO.OF
                   VALUE   DEVIATION VARIATION   VALUE     VALUE    OBS

 CUSTOMER_TIME   0.303E+01 0.286E+01 0.944E+00 0.345E-01 0.110E+02    88
Fortran STOP
```

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #5 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

1. The failure time of a light bulb is the minimum of the failure times of the individual elements (all nonnegative random variables). We will therefore assume that the failure time of the light bulb has approximately a Weibull distribution. Suppose that 500 of a new type of bulb are operated simultaneously, and every 100 hours the total number of failed bulbs is recorded. These are:

time (hrs.)	# failures
100	42
200	98
300	141

400	177
500	214
600	248

The manufacturer wants to determine:

a.) the expected lifetime of the bulb
b.) the standard deviation of the lifetime
c.) the probability that the bulb will fail during its first 100 hours of operation.

To estimate the expected lifetime (and its standard deviation) by recording the failure times of all 500 bulbs would require an excessive amount of time, since typically the last few surviving bulbs fail at a low rate. Hence, we wish to estimate the Weibull parameters u & k from the data above, and use these to estimate μ and s.

a. Enter the observed values of t and R (failure time & reliability, i.e., the fraction surviving) into the Cricket Graph program.

b. Using "transform" on the menu:
- compute ln t and place it into column 3 of the data matrix.
- compute R^{-1} and place it into column 4 of the data matrix.
- compute ln R^{-1} and place it into column 5 of the data matrix.
- compute ln (ln R^{-1}) and place it into column 6 of the data matrix.

c. Plot the scatter graph of the data, with ln t (column 3) on the horizontal axis, and ln (ln R^{-1}) (column 6) on the vertical axis. Do the points appear to lie on a straight line?

d. Fit a line to the points, using the Cricket Graph program. What is the line? What is its slope and y-intercept?

e. Based upon the fitted line, what are the parameters u & k of the Weibull distribution?

f. According to these estimates of u & k, at what time should 5% of the bulbs have failed? ... 50% of the bulbs? ... 90% of the bulbs?

g. According to the value of k, is the failure rate *increasing* or *decreasing* with time?

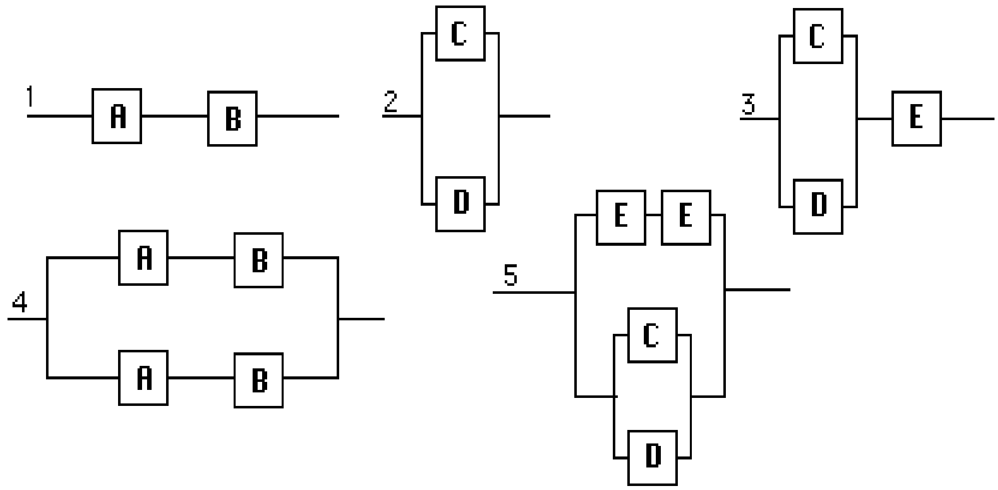
h. Suppose that 6 of these bulbs are installed in ceiling lamps in an office. What is the probability that, after 150 hours of continuous operation, at least 3 bulbs are still functioning? *Hint: Use the binomial distribution... what is the probability p that a single bulb has not failed after 150 hours? What is the probability of 3 "successes" in 6 "trials"?*

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #6 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

1. Devices A through E are basic components of five different systems (#1 through #5). They are subject to failure, with the probability that each fails during its first year of use:

Device	Failure Probability
A	10%
B	5%
C	20%
D	25%
E	15%

Compute, for each system below, the reliability, i.e., the probability that it will survive for at least one year.



2. A system has 6 components which are subject to failure, each having lifetimes with exponential distributions. The average lifetimes are:

Component	Average Lifetime
A	2000 days
B	3000 days
C	800 days
D	800 days
E	500 days
F	500 days
G	500 days

The system will fail if any one of the following situations occurs:

- A fails
- B fails
- Both C and D fail
- Components E, F, and G all fail.

a. Draw a diagram showing the series/parallel configuration of the components, as in the previous exercise.

b. Suppose that the system is required to survive for 1000 days. What is the reliability of each component, i.e., the probability that it survives 1000 days?

c. What is the reliability of the system, i.e., the probability that the system survives 1000 days?

d. Draw a SLAM network which can simulate the lifetime of this system. (At a later time, you may be required to perform the simulation.)

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #7 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

Project Scheduling. A building contractor is preparing a project schedule for the construction of a house. The activity descriptions and estimated durations for the project are:

Activity	Description	Predecessor(s)	Duration: optimistic	Duration: most likely	Duration: pessimistic	Mean	Std Dev'n
A	Excavate foundations	none	1	2	3	____	____
B	Pour footings	A	-	1	-	1	0
C	Pour foundations, including placing & removing forms	B	3	5	8	____	____
D	Framing floors, walls, & roof	C	8	10	14	____	____

E	Construct brick chimney	C	2	3	4	____	____
F	Install drains & rough plumbing	D	2	3	4	____	____
G	Pour basement floor	F	-	1	-	1	0
H	Install rough wiring	D	1	2	3	____	____
I	Install water lines	D	2	3	5	____	____
J	Install heating ducts	D,E,G	4	5	7	____	____
K	Lath & plaster walls	H,I,J	7	10	12	____	____
L	Finish flooring	K	-	2	-	2	0
M	Install kitchen equipment	L	1	2	4	____	____
N	Install bath plumbing	L	-	1	-	1	0
O	Cabinetwork	M,N	4	6	8	____	____
P	Lay roofing	D	1	2	4	____	____
Q	Install downspouts & gutters	P	-	1	-	1	0
R	Paint walls & trim	O	3	4	5	____	____
S	Sand & varnish floors	R	1	2	3	____	____
T	Install electric fixtures	H,O	2	3	5	____	____
U	Grade lot	C,Q	1	2	4	____	____
V	Landscape	U	4	5	8	____	____
W	End	S,T,V	-	0	-	0	0

a. Draw the AON (activity-on-node) network representing this project.

b. Draw the AOA (activity-on-arrow) network representing this project. Explain the necessity for any "dummy" activities which you have included.

c. Label the nodes of the AOA network, so that i<j if there is an activity with node i as its start and node j as its end node.

In questions (d) through (h), use the "most likely" as the duration:

d. Perform the forward pass through the AOA network to obtain for each node i, ET(i) = earliest possible time for event i.

e. What is the earliest completion time (# work days) for this project?

f. Perform the backward pass through the AOA network to obtain, for each node i, LT(i) = latest possible time for event i (assuming the project is to be completed in the time which you have specified in (e).)

g. For each activity, compute:

ES = earliest start time EF = earliest finish time
LS = latest start time LF = latest finish time
TF = total float (slack)

Activity	Description	ES	EF	LS	LF	TF
A	Excavate foundations	____	____	____	____	____
B	Pour footings	____	____	____	____	____
C	Pour foundations, including placing & removing forms	____	____	____	____	____
D	Framing floors, walls, & roof	____	____	____	____	____
E	Construct brick chimney	____	____	____	____	____
F	Install drains & rough plumbing	____	____	____	____	____
G	Pour basement floor	____	____	____	____	____
H	Install rough wiring	____	____	____	____	____
I	Install water lines	____	____	____	____	____

J	Install heating ducts					
K	Lath & plaster walls					
L	Finish flooring					
M	Install kitchen equipment					
N	Install bath plumbing					
O	Cabinetwork					
P	Lay roofing					
Q	Install downspouts & gutters					
R	Paint walls & trim					
S	Sand & varnish floors					
T	Install electric fixtures					
U	Grade lot					
V	Landscape					
W	End					

h. Which activities are "critical", i.e., have zero float ("slack")? Place an * beside these in the table above.

i. Schedule this project by entering the AON network into MacProject II (found on the Macintoshes in the computer lab on 3rd floor of the Engineering Building.) Specify that the start time for the project will be November 15, 1995.
What is the earliest completion time for the project? _______________ (Note that 5-day work weeks and days off on holidays are assumed by default. This can be modified if you choose)
What are the critical activities? _______________________ (Does this agree with your answer in (h)?)

Now, assume that the durations are random, with triangular distribution.

j. What are the *expected value & standard deviation* of each critical activity's duration? (Specify in the first table above.)

k. What is the expected value of the duration of the critical path found in (h)? _________
What is the standard deviation of this duration? ________

m. Using the PERT technique, what is the probability that the project duration will not exceed the expected duration by more than 5 days?

@@@
To appear in Homeowrk #8, due November 8:

n. Draw a SLAM network to simulate this project, and simulate it 1000 times.

o. What is the average duration of the project according to SLAM? (Compare it to your answer in (k).)

p. What is the standard deviation of the project duration according to SLAM? (Compare it to your answer in (k).)

q. According to the SLAM simulation, what is the probability that the project duration will not exceed the expected duration by more than five days?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #8 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

1. Refer to the project scheduling problem in Homework #7.

a. Draw a SLAM network to simulate this project, and simulate it 1000 times. (Use either beta or triangular distribution for the random durations.... triangular is more convenient.)

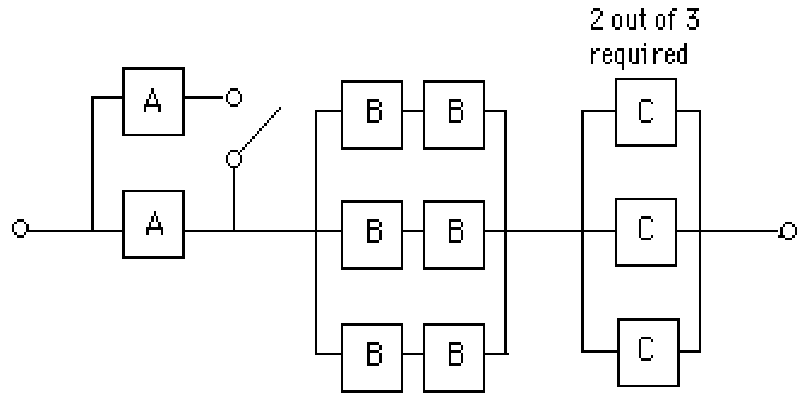
b. What is the average duration of the project according to SLAM? (Compare it to your answer in (k) in HW#7.)

c. What is the standard deviation of the project duration according to SLAM? (Compare it to your answer in (k) in HW#7.)

d. According to the SLAM simulation, what is the probability that the project duration will not exceed the expected duration by more than five days?

@@@

2. A system has 3 types of components (A, B, & C) which are subject to failure. As shown below, the system requires at least one of component A, one pair of components B, and at least two of the three components C. One of component A is in stand-by. When the first component A has failed, the second is to be switched on, and until then does not "age" or fail. Assume that the sensor/switch has 98% reliability.



The lifetime distributions of the three component types are:

Component A: Erlang, being the sum of five random variables, each having exponential distribution with mean 100 days.
Component B: Exponential, with expected lifetime 300 days.
Component C: Exponential, with expected lifetime 250 days.

a. Draw a SLAM network which can simulate the lifetime of this system.

b. Enter the network into the computer, and simulate the system 1000 times, collecting statistics on the time of system failure. Request that a histogram be printed. Specify about 15-20 cells, with HLOW and HWID parameters which will give you a "nice" histogram with the mean approximately in the center and with small tails.

Note: Be sure to specify on the GEN statement that you do NOT want intermediate results, and that the SUMMARY report is to be printed only after the 1000th run. Also specify on the INITIALIZE statement that the statistical arrays should not be cleared between runs.

c. What is the average lifetime of this system?

d. Suppose that the system is required to survive for a 100-day mission. What is the reliability of the system, i.e., the probability that the system survives 100 days?

e. Suppose you will offer a warranty on this system, and want to be confident that 95% of the systems will survive past the length of the warranty. What should be the length of the warranty?

Note: Homework #5 of Spring '94 has a somewhat similar exercise, with the SLAM code given in the solutions document. If you are having difficulty coding the SLAM statements, refer to that document.

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #9 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

«»