# Statistics 567
## Statistical Reliability
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Exam 1

Name: ________________________________

This is a take-home exam. You must work by yourself but are welcome to ask me questions. This exam is due Wednesday, October 11. Please type any question involving discussion.

1. (This is Problem 1.12 in your textbook.) A telephone electronic switching system contains a large number of nominally identical circuit packs. When a circuit pack fails, only a small part of the system's functionality is lost. Failed packs are replaced, as soon as possible, with new circuit packs. All of the circuits have serial numbers and detailed records are kept so that the failure times are known for all the packs that fail and so that the running times are known for all of the packs that do not fail. In practice, to access circuit pack reliability, it would be common to treat the circuit packs in the system as a sample from a large population of circuit packs and use the data to make inferences about the larger population.
    a. List three distinct different *precise* definitions for the larger population or process that could be of interest to reliability engineers, design engineers, or financial managers.
    b. For each of the definitions in Part (a), state the assumptions that must be satisfied to make the desired inferences about the circuit pack life distribution. Comment on the reasonableness of these assumptions and how departures from these assumptions could result in misleading conclusions.
    c. Assume that you have given the above description of a switching system and have been asked to attend a meeting where a study is to be planned to monitor, continuously, the early-life reliability (defined as the first 1000 hours) of circuit packs. The purpose of the study is to determine the effect of recent design and manufacturing process changes on circuit pack reliability. Data will be obtained from three particular systems that are physically close to the design and manufacturing facilities of the circuit pack manufacturer. Before offering advice on the plan you will need further information. Prepare a list of questions that you would ask of design engineers, reliability engineers, and manufacturing engineers who will be attending the meeting.

2. (This is a modified version of Problem 2.7 in your textbook.) An electronic system contains 25 copies of a particular integrated circuit that is at risk to failure during operation. The manufacturer of the integrated circuit claims that its average hazard rate over the first 2 years of operation is 100 FITs. For the 2000 systems just put into operation, compute a prediction for the total number of these integrated circuits that will fail over the next 2 years of operation.

3. (This is Problem 2.1 in your textbook.) Although the diesel generator fan failure times in Appendix Table C.1 were reported as exact failures, the ties suggest that the data are really discrete due to rounding or because failures were found on inspection. Suggest appropriate partitioning of the time line to reflect the true discrete nature of the data. Explain how you arrived at this partitioning. Use this partitioning to develop an expression for the discrete-data likelihood.

4. In an experiment to gain information on the strength of a certain type of braided cord after weathering, the strength of 48 pieces of cord that had been weathered for a specified length of time were investigated. The intention was to obtain the strength of all 48 pieces of cord. However, seven pieces were damaged during the course of the experiment, thus yielding right-censored strength-values. The strengths of the remaining 41 pieces were satisfactorily observed. (You will find these data with the strength in coded units on the following URL: http://web.utk.edu/~leon/rel/class/jmptext/cord. A censor code of 0 means exact failure strength and a censor code of 1 means a right-censored observation.)
   a. The experimenter felt that it was important that even after weathering the cord strength should be above 53 in the coded units. Thus, an estimate of $S(53)$ is required. Use SLIDA to provide an nonparametric estimate of $S(53)$. What concerns about the data do you have that might make this estimate invalid?
   b. Use SLIDA to help decide which of the following distributions provides the best model for the data: Weibull, lognormal, or loglogistic. Explain you analysis.
   c. Fit a Weibull distribution to the data. Use SLIDA to estimate the distribution parameters either graphically or using SLIDA's the maximum likelihood facility. What do the estimated value of the parameters tell you about the distribution of strengths?

5. (This is an extended version of Problem 4.7 of your textbook.) Consider the Weibull hazard rate function *h(t)*. Show that
   a. When $\beta = 1$, *h(t)* is constant
   b. When $\beta = 2$, *h(t)* increases linearly
   c. When $0 < \beta < 1$, then *h(t)* is decreasing in t.
   d. When $1 < \beta < 2$, then *h(t)* is concave increasing
   e. When $\beta > 2$, then *h(t)* is convex increasing

   Imagine that you have analyzed some failure time data for an airplane engine. What would be the practical implications of each of the five situations above for a maintenance policy? Explain you answer in a language that an engineer would understand.
6. (This is a modified version of Problem 6.7 of your textbook. Use SLIDA to do this problem.) A sample of 100 specimens of a titanium alloy was subjected to a fatigue test to determine time to crack initiation. The test was run up to a limit of 100,000 cycles. The observed times to crack initiation (in units of 1000 cycles) were 18, 32, 39, 53, 59, 68, 77, 78, 93. No cracks had initiated in any of the other 91 specimens.
   a. Compute a nonparametric estimate, $\hat{F}(t)$, of the cdf *F(t).*
   b. Plot $\hat{F}(t)$ on linear axes.
   c. Plot $\hat{F}(t)$ in a Weibull plot
   d. Comment on the adequacy of the Weibull distribution
   e. Comment on the adequacy of the available data if the purpose of the experiment is to estimate $t_{.1}$.