QUESTIONS

1. Consider the survival data given in the following table. Compute and plot the estimated survivorship function, the probability density function, and the hazard function.

Year of Follow-up	Number Alive at Beginning of the Interval	Number Dying in the Interval
$0-1$	1100	240
$1-2$	860	180
$2-3$	680	184
$3-4$	496	138
$4-5$	358	118
$5-6$	240	60
$6-7$	180	52
$7-8$	128	44
$8-9$	84	32
≥ 9	52	28

2. The following is a life table for the total population (of 100000 live births) in the United States, 1959−1961. Compute the estimated survivorship function, the probability density function, and the hazard function.

Age Interval	Number living at beginning of age interval	Number dying in age interval
$0-1$	100000	2593
$1-5$	97407	409
$5-10$	96998	233
$10-15$	96765	214
$15-20$	96551	440
$20-25$	96111	594
$25-30$	95517	612
$30-35$	94905	761
$35-40$	94144	1080
$40-45$	93064	1686
$45-50$	91378	2622
$50-55$	88756	4045
$55-60$	84711	5644
$60-65$	79067	7920
$65-70$	71147	10290
$70-75$	60857	12687
$75-80$	48170	14594
$80-85$	33576	15034
85 and over	18542	18542

3. Consider a clinical trial in which 10 lung cancer patients are followed to death. The following table lists the survival time t in months and number of deaths i. Find the estimate of survivorship function, draw its graph and comment.

t	4	5	6	8	8	10	10	11	12
i	1	2	3	4	5	6	7	8	9

4. Suppose 10 patients join a clinical study at the beginning of 2000. During that year, 6 patients die and 4 patients survive. At the end of the year, 20 additional patients join the study. In 2001, 3 patients who entered in the beginning of 2000 and 15 patients who entered later die, leaving one and five survivors, respectively. Suppose that the study terminates at the end of 2001. Find the estimate of survivorship function and draw its graph.

5. Suppose that the following remission durations are observed from 10 patients ($n = 10$) with solid tumors. Six patients relapse at 3.0, 6.5, 6.5, 10, 12, and 15 months; 1 patient is lost to follow-up at 8.4 months; and 3 patients are still in remission at the end of the study after 4.0, 5.7, and 10 months.

   (i) Find the product limit estimate of the survival function.

   (ii) Find $var(\widehat{S(10)})$ and estimate the standard error.

6. Remission times for two groups of leukemia patients, one given drug 6-MP and other a placebo are as follows.

   6-MP : 6, 6, 6, 6+, 7, 9+, 10, 10+, 12+, 13, 16, 17+, 19+, 20+, 22, 23, 25+, 32+, 32+, 34+, 35+

   placebo : 1, 1, 2, 2, 3, 4, 4, 5, 5, 8, 8, 8, 8, 11, 11, 12, 12, 15, 17, 22, 22

   (i) Find Kaplan-Meier product limit estimate for two groups.

   (ii) Find $var(\widehat{S(16)})$ for the group given the drug 6-MP.

   (iii) Draw the survival function for the two groups.

7. In order to estimate the mean burning time of a particular brand of bulb, 30 bulbs were left burning. The bulbs that failed are not replaced upon failure. The following burning time (in hours) were recorded:

   20, 27, 52, 61, 110, 122, 214, 232, 238, 371, 393, 426, 445, 472, 503, 526, 581, 627, 798, 805, 909, 976, 1001, 1016, 1033, 1086, 1192, 1322, 1681, 1723.

   Calculate the maximum likelihood estimate and minimum variance unbiased estimate of $R(t)$ at $t = 900$ hrs.

8. Consider an experiment with 10 electric bulbs of a particular brand. The experimenter decides to continue the study until the failure of the first 5 bulbs and then the experiment is terminated. The survival times of the first 5 bulbs are 4, 5, 8, 9 and 10 weeks.

   Assuming that the failure of these bulbs follow exponential distribution with mean λ,

   (i) Identify the type of censoring and justify.

   (ii) Estimate the survival rate and mean survival time.

   (iii) Estimate the probability that a bulb will survive longer than 8 weeks.

   (iv) If the survival times for 10 bulbs are 4, 5, 8, 9, 10, 10, 10, 10, 10, 10; estimate the survival rate for this case.

9. The time in days of development of a tumor for rats exposed to a carcinogen follows Weibull distribution with $p = 2$ and $\lambda = 0.001$.

   (a) What is the probability that a rat will be tumor free at 30 days ? 45 days ? 60 days ?

   (b) Find the hazard rate of the time to tumor appearance at 30 days, 45 days and 60 days.

   (c) Find the median time to tumor.

10. Consider a small study with 8 objects. The event times were recorded as follows:

    $$1,\ 3,\ 2+,\ 3+,\ 2,\ 5+,\ 6+,\ 3.$$

    Here "1" means the exact event time is 1. "2+" means the subject is censored at time 2 and its event time is greater than 2.

    (a) Calculate the Kaplan-Meier estimates for the survival function $S(t)$.

    (b) Make a plot of the survival function based on the estimates obtained in part (a).

    (c) Find out the estimate of the variance of estimate of the survival function at $t = 3$.