Problems

Lecture Examples

1. Exponential Distribution

Assume that the mean time to failure of an engineering system is 1500 hours.

(a) Calculate the probability of failure of the engineering system during a 500-hour mission.

2. Failure / Survival / Conditional Probability

The failure time (t) of an electronic circuit board follows an exponentially distribution with failure rate $\lambda = 10^{-4}$/h.

(a) What is the probability that it will fail before 1000 h ?

(b) What is the probability that it will survive at least 10,000 h

(c) What is the probability that it will fail between 1000 and 10,000 h ?

(d) Suppose that the device has been successfully operated for 8000 hours. What is the probability that it will fail during the next 1500 hours of operation?

3. Distribution Law

The reliability data of a machine is given:

TTF (days)	0	100	200	300	400	500	600	700	900
R(t)	1	0.76	0.52	0.32	0.2	0.2	0.13	0.08	0.04

(a) Determine if this lifetime law follows an exponential distribution?

4. Weibull distribution

The following table summarizes the lifetime in hours of a sample of 9 products of the same type, used under the same conditions until failure.

Sample #	1	2	3	4	5	6	7	8	9
TTF (h)	152	245	405	310	785	500	570	660	910

(a) Plot the 'distribution function' on a Weibull paper and find the Weibull parameters.

(b) Express the Reliability function.

(c) Calculate the reliability for a mission of 562.4 hours

(d) Calculate the MTBF.

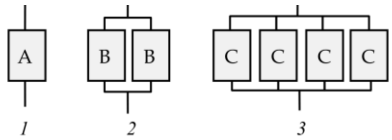
5. Predictive reliability: Reliability block diagram

A personal computer consists of 4 basic subsystems: motherboard (MB), hard disk (HD), power supply (PS) and processor (CPU). The reliabilities of the subsystems for a mission of 1000 hours are 0.98, 0.95, 0.91 and 0.99 respectively. All subsystems need to be functioning for the overall system success.

(a) What is the system reliability for a mission of 1000 hours ?

6. Predictive reliability & Redundancy

We consider three components A, B and C of respective prices 150, 75 and 45 €. At a given moment, FA = 0.1, FB = 0.3 and FC = 0.4 the respective failures of the three components.

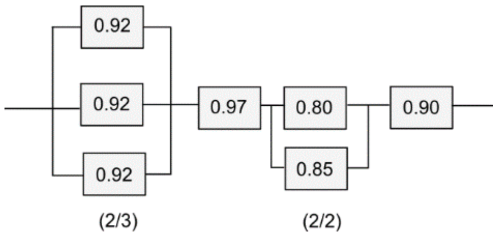


(a) Which of the following three systems has the highest reliability?

(b) Which of the three systems has the best reliability/price ratio?

7. Predictive reliability

The given values correspond to the reliability of the components at a given time.
Show that the predictive reliability of this system is Rsys = 0.583.



Tutorials

8. Survival probability

What is the survival probability of an electronic device that has been working for a period of time equal to the MTTF ?

9. Reliability Estimators

A batch of 85 solenoid valves subjected to continuous testing at a rate of 210 pulses/minute was tested. After 45 operating hours, 17 solenoid valves have failed and after 62 hours, there are 51 solenoid valves in working order.

(a) Estimate the failure and reliability functions for a mission duration of 45 hours.

(b) Estimate the failure rate per hour and per solenoid valve between t=45 and t=62 hours.

(c) Deduct the failure rate per pulse and per solenoid valve over the same interval.

(d) Estimate the density of failure per hour and per solenoid valve between 45 and 62 hours.

(e) Estimate the average lifetime E(t) per valve over the entire period of observation.

(d) $f_{[45;62[} = 0.0117$

(e) $E(t)_{[45;62[} = 68.02$ hours

10. Reliability Estimators

18 units were subjected to a reliability test, together and under identical operating conditions. 6 hours after start of test 14 units continue to operate normally. During the next 2 hours, 2 units failed.

(a) Estimate the failure and reliability functions for a mission duration of 6 hours

(b) Estimate the density of failure f(t) over the interval [6 ; 8[

(c) Estimate the failure rate over the interval [6 ; 8[

Solution

(a) $R(t1)=0.8$

(b) $f[t1;t2[=0.054$

(c) $\lambda[6;8[=0.068$

11. Improvement of reliability

An injection system is considered at a given time. It is composed of a pipeline of reliability Rp=0.98 and a nozzle of reliability Rn=0.9

(a) Calculate the reliability of the system

(b) A group of experts considers that the failure of the injection system is too high. It is then decided to improve its reliability by adding a redundant injection system. Calculate the new system reliability.

(c) The reliability is always considered insufficient, a 3rd nozzle is added which only works if the others are failing.
What would be the reliability of the third nozzle, if the reliability of the system were to be 0.999?

12. Modelling Reliability

Consider at a given moment a system formed by the following components:

- 2 diodes, each having a reliability Rd = 0.9
- 1 engine having a reliability Rm = 0.8
- 1 amplifier having a reliability Ra = 0.9
- 1 preamplifier having a reliability Rpa = 0.92

The diodes must provide a voltage to the engine with amplification using the amplifier and preamplifier. The system can operate with a single diode, but a failure of the engine, preamplifier or amplifier will cause the system to fail.

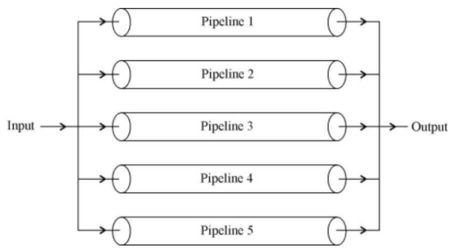
(a) Plot the reliability diagram of this system and calculate its reliability.

(b) What type of failure is it if a diode fails? Engine fails?

(c) A saving would be appreciable if we use cheaper diodes of reliability Rd = 0.8. Can we accept this solution if the reliability of the system should not fall by more than 5%?

13. Predictive reliability: Redundancy

Consider a piping system having 5 pipes connected in parallel as shown in the figure bellow. Assume that all pipes are identical and independent. The system is said to work successfully if at least 3 pipelines perform their intended function successfully.



If reliability of smooth flow of the liquid from each pipeline is 0.80 for a mission of 1 year, evaluate the reliability of the system working successfully.

14. Conditional Reliability

A CPU fan has a constant failure rate $\lambda = 2.45 .10^{-4}$ hours^{-1}

(a) Calculate the probability that the fan survives 4500 days in continuous operation.

(b) Suppose that the fan has been functioning without failure during its first 3000 days in operation. Calculate the probability that the pump will fail during the next 950 days.

15. Failure rate

A 5-ton truck has a MTBF of 1,750 miles when used in cross country terrain. Assuming constant failure rate, what is the reliability for a 75-mile mission?

16. Failure rate

A sighting system consists of a north seeking gyro, laser designator, A/D converter, digital computer, and transmitter. This entire system is assumed to have an exponential distributed time-to-failure with a mean of 130 hours.

(a) What is the failure rate for the system?

(b) What is the probability that the system were surviving 10 hours of use?

(c) How long can the system be used such that there is 90% reliability?

17. Fail / Survival probability

A power electronic component has a constant failure rate of 0.333 per 1000 hours of operation (one failure every 3000 hours).

(a) What is the probability that a component will survive after 3000 hours?

(b) What is the probability that the component will last between 1000 and 3000 hours?

(c) c) What is the probability that the component will last another 1000 hours after 3000 hours of operation?

Solution

(a) $R(1) = 0.3679$

(b) Last between 1000 and 3000 hours <=> 1 – (fail between 1000 and 3000 hours) = 0.6515

(c) Conditional reliablity
$R(1/5) = 0.367$

18. Failure rate

The reliability service of a given vehicle brand, reported 15 failures on a 45-car lot followed during the period of 80,000 to 90,000 km.

(a) Calculate the failure rate per vehicle and per km estimated over that period.

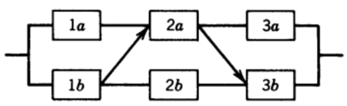
(b) Deduct the average duration between two failures estimated over this period.

Solution

(a) $\lambda[80,000 ; 90,000[= 3.26.10^{-5}$ failure per car per km

(b) $MTTF = 1/\lambda$

19. Reliability of complex system



$R_{1a} = R_{2b}$
$R_{2a} = R_{2b}$
$R_{3a} = R_{3b}$

Calculate the reliability of the system

Solution

$P\{S\} = (2R_1 - R^2_1) \times (2R_3 - R^2_3) \times R_2 + R_1 \times R_2 \times R_3 \times (1-R_2)$