MSc Course in

Optimization Theory and Modern Reliability from a Practical Approach

Sample exam assignments (Reliability part), by
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Rules

- May give 2 to 4 tasks (can be solved without using special software tools, apart from Excel)
- The reliability part counts for 50% score of the course, with another 50% from the optimization theory part
- Time is flexible within the framed 4 hours of the course exam
- All usual helping aids are allowed, i.e. books, notes, calculator, computer, etc.
- All communication equipment and computer communication protocols must be turned off.
- Use of Internet is not allowed.
- Questions should be answered in English.

Tasks

Task No. 1

A bronze bushing of a car gearbox is guaranteed for 3,000 operational cycles with normal ΔT = 90 °C. The number of cycle to failure versus ΔT follows an inverse power law with an exponent constant of - 4.75. Find the equivalent end of life at severe operation condition of ΔT = 125 °C, assuming one cycle per day.

Task No. 2

An electronic power supply for laptop PC comprises:

A. a main fuse
B. a 4-diode main rectifier
C. 3 dc-link capacitors in parallel
D. 2 main power switches
E. a transformer
F. a 2-diode secondary rectifier
G. an output filter
H. a power indicator LED

Hypotheses:

1. All the above parts but the LED are needed to operate correctly.
2. Diodes 1 and 3 or diodes 2 and 4 are sufficient to make the main rectifier operate correctly.
3. 2 dc-link capacitors out of 3 are sufficient to keep the power supply working;
4. Both main switches are needed to properly operate;
5. The transformer and the output filter can be supposed to have infinite lifetime;
6. One diode in the secondary rectifier is sufficient to properly operate;

7. all the remaining parts (e.g. power cord, plastic enclosure, laptop cord & plug) are supposed to have infinite lifetime in respect to the ones listed above.

1) Sketch up the reliability block diagram of the system.
2) The failures of each subsystem are distributed according to the following statistical distribution:
   A – Exponential, λ = 20.0 failures per million hours
   B (single diode) – Weibull, β = 1.5, η = 30.000 hours
   C (single capacitor) – Normal, μ = 20000 hours, σ = 3000 hours
   D (single switch) – Lognormal, μ = 9, σ = 4
   F (single diode) – exponential, λ = 175 failures per million hours
   H – Exponential, λ = 10.0 failures per million hours

Calculate the system reliability at:
   a) t = 1 month;
   b) t = 1 year.

Task No. 3

For the system introduced in Task No. 2:
1) Try to identify cut sets and tie sets.
2) Starting from the found cut sets, try to build up an FTA (fault-tree analysis) of the event "PC power supply not working"

Task No. 4

The bolts of a horizontal heat sink experience cyclic stress at the base-plate connection due to the thermal expansion of the heat sink itself.

Accelerated data was taken on bolts where a cyclical stress was applied to the bolts whereby the metal at the base plate came under a continuous cyclical stress range of -6.0 MPa to +6.0 MPa with a mean tensile stress of zero. The bolts failed at the base plate connection after 10,000 cycles. Assuming a power-law exponent of m = 3.5 for the cycling, a metal tensile strength of 7.4 MPa and no defined elastic range:
   a) Estimate the number of cycles-to-failure CTF that would be expected in real use if the stress is between -2.5 MPa to +2.5 MPa.
   b) Estimate the number of cycles-to-failure CTF that would be expected in real use if the stress is between -2.5 MPa to +2.5 MPa but the heat sink is mounted vertically, producing mean tensile offset of r_{mean} = 1.8 MPa.

Task No. 5

A gear was tested in the laboratory to determine its fatigue life. The test results were as follows:

Stress level ($\times 10^2$ Nm)	3.4	7.2	12.0	15.3
Mean cycles to failure ($\times 10^6$)	10.9	4.5	0.76	0.23

The gear will operate in a real gearbox with the most relevant stress levels occurring in the following proportions, respectively:

Proportion of cycles	0.5	0.3	0.15	0.05

a) In case of 100 cycles per hour, what will be the expected time to failure in service?

b) what will it be in case of 1000 cycles per hour?

Task No. 6

8 paper clips are tested with 180º bending angle, and the cycles to failure for each clip are recorded as: 20, 50, 40, 10, 30, 80, 70, and 60.

1) State the relationship between accumulated failure and time in Weibull distribution.
2) Arrange these time-to-failure numbers by using median ranking method.
3) Plot the ranking number as listed in (b) and the cycles to failure in the attached Weibull paper below. Please find out the values for β and η, respectively.
4) Explain how to identify the values of β and η in the Weibull plot.

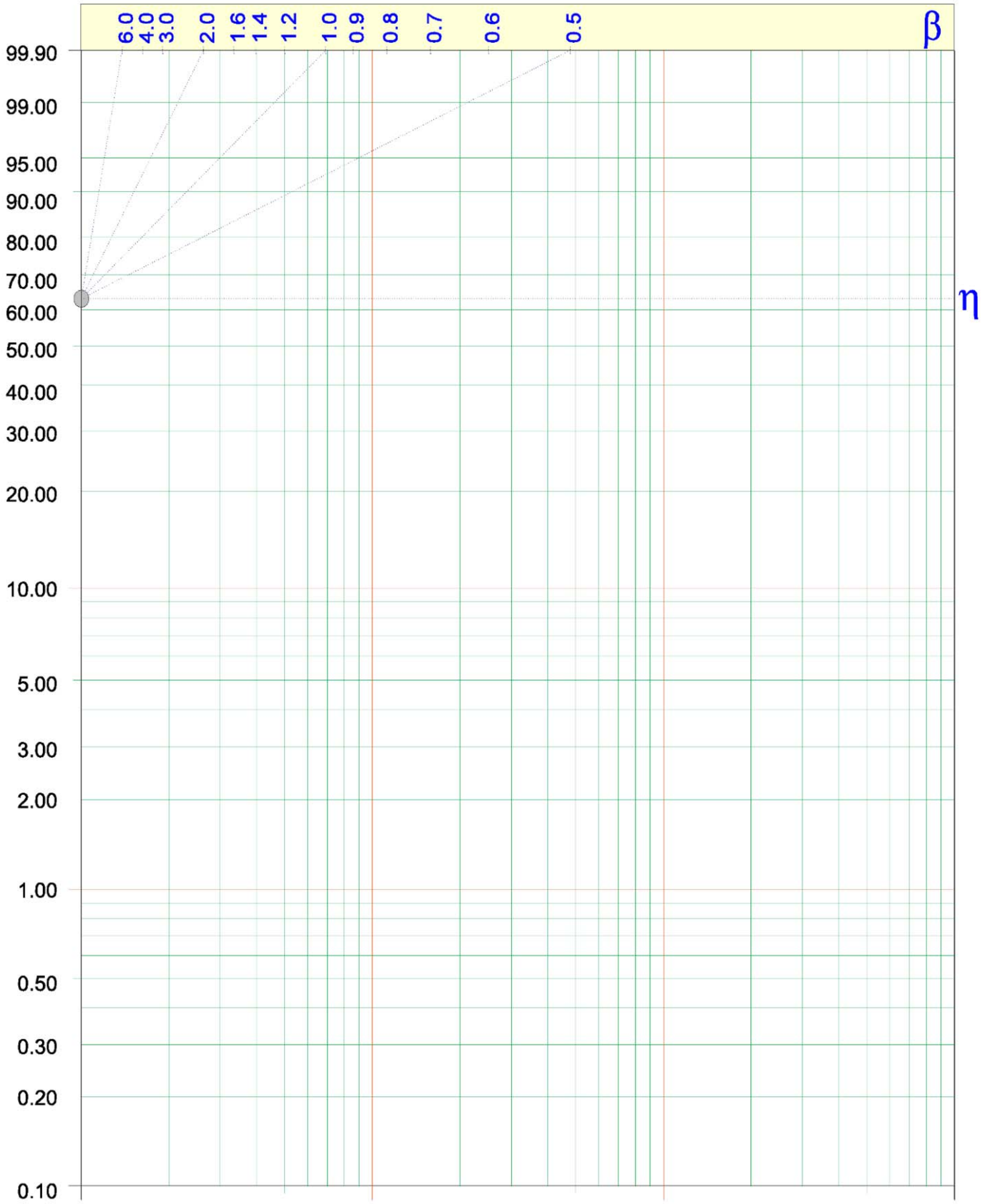
Appendix I – Median rank table

sample size = n

failure rank = i

n

i	1	2	3	4	5	6	7	8	9	10
1	.5000	.2929	.2063	.1591	.1294	.1091	.0943	.0830	.0741	.0670
2		.7071	.5000	.3864	.3147	.2655	.2295	.2021	.1806	.1632
3			.7937	.6136	.5000	.4218	.3648	.3213	.2871	.2594
4				.8409	.6853	.5782	.5000	.4404	.3935	.3557
5					.8706	.7345	.6352	.5596	.5000	.4519
6						.8906	.7705	.6787	.6065	.5481
7							.9057	.7979	.7129	.6443
8								.9170	.8194	.7406
9									.9259	.8368
10										.9330



Task No. 7

Compare reliability values for the two products, Product A with exponentially distributed life and product B with Weibull distributed life. The parameters are $MTBF_A = \eta_B = 1000$ h. Compare the reliabilities at 300 hours for:

$\beta_B = 0.5$
$\beta_B = 1.0$
$\beta_B = 3.0$
How would you describe the effect of the Weibull shape parameter β on the reliability if the scale parameter remains the same?