Ref No: Ex/EE/T/423C/2019

B.E. ELECTRICAL ENGINEERING FOURTH YEAR SECOND SEMESTER EXAMINATION, 2019

RELIABILITY ENGINEERING

Full Marks 100

Time: Three hours (50 marks for each part)

Use a separate Answer-Script for each part

Question No. PART- I Marks

Answer any *TWO* questions

1. (a) An electronic system consists of three subsystems *a*, *b* and c connected in series. The strength of each subsystem to withstand the effect of current through it, varies randomly with the current value, with density functions shown in Fig. [A], for the three subsystems. The failures of the three subsystems are statistically independent. What is the reliability of the complete system if the current is 0.75 A, and the probability of failure if the current is 1 A. 6

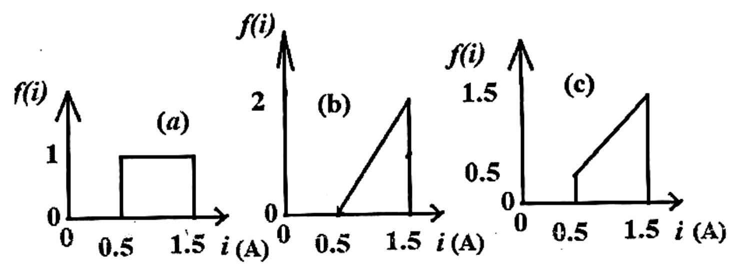

Fig. [A]

(b) An engineering system consists of three subsystems in complete (i.e. parallel) redundancy. Each subsystem is operating in its useful life period, but the hazard rates are different. Derive expressions for the reliability function and the mean-time-to-failure (MTTF) of the system, in terms of the hazard rates of the subsystems. 8

(c) A newly developed logarithmic amplifier module is tested at two different temperatures: 450 K and 500K. A *Weibull distribution* was found with a *shaping parameter* of 1.18 and a *characteristic life* of 1450 hours and 1280 hours at the two temperatures, respectively. Based upon the Arrhenius model, what will be the product reliability at 500 hours, if normal usage is at 35° C? Derive the expression for the reliability function of Weibull distribution. 11

[Turn over

PART I

2. (a) **A particular type of timer IC is subjected to one-at-a-time sequential life testing, and a host of units are placed on test. On the basis of a point-estimated MTTF of 500 hours, find the estimated test time for 15 units to fail, considering a constant failure rate model. Also obtain the two-sided 90 % confidence interval for a design life with a reliability of 0.92. For this purpose consider the estimated test time as the actual, and the number of failures as 15. Use the Chi-square table attached.** ***Use linear interpolation wherever necessary. Derive the expressions used for the point estimate and the interval estimate.*** **10**

(b) **Preventive maintenance is to be performed every 5 days on a system having time-to-failure uniformly distributed over 0 to 100 days. Determine the expression for the reliability function of the system under preventive maintenance. Compare the reliability and the MTTF at 17 days, with and without preventive maintenance.** ***The probability of maintenance-induced failure during every preventive maintenance, is 0.1.*** **Derive the expression for the reliability under preventive maintenance, used for this purpose.** **10**

(c) **Distinguish clearly between mission-oriented and continuously operated systems.** **5**

3. (a) **The life of an industrial exhaust pump is exponentially distributed with a mean of 1000 hours. There is a standby pump, whose lifetime is also exponentially distributed with a mean of 900 hours, and is independent of that of the original. The changeover sensor & switch combination has a failure probability of 0.2.** **10**

(i) **What is the probability of survival of the combination of these pumps for a period of 550 hours?**

(ii) **What is the MTTF of the combination?**

Derive the expressions used.

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PART- I

(b) **Explain with relevant derivations, how the expression for the point-availability of a repairable system can be obtained from a knowledge of the probability density functions of the time-to-failure and the time-to-repair. Consider the alternate renewal process model. *Results of analysis of renewal process (considering negligible repair time) may be utilized without proof.*** **10**

(c) **A repairable electrical system has an MTTF of 1000 hours and a mean-time to repair (MTTR) of 200 hours. Determine the following.** **5**

- (i) **The point availability of the system at 1700 hours.**
- (ii) **The steady-state availability.**
- (iii) **The instantaneous repair rate at 100 hours.**

4. Write short notes on *any two* of the following.

(a) **Concepts of a posteriori failure probability and the shape of the hazard function on the reliability of systems.** **12 ½ +**

(b) **Binomial distribution and its application for the assessment of reliability of engineering systems.** **12 ½**

(c) **Simultaneous life testing of engineering systems.**

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PART- I

CHI-SQUARE TABLE

$$\chi^2_{q,K}$$

K\ q	0.05	0.10	0.20	0.40	0.60	0.80	0.90	0.95	0.975
1	0.0039	0.0158	0.0642	0.275	0.708	1.642	2.706	3.841	5.024
2	0.103	0.211	0.446	1.022	1.833	3.219	4.605	5.991	7.378
3	0.352	0.584	1.005	1.869	2.946	4.642	6.251	7.815	9.348
4	0.711	1.064	1.649	2.753	4.045	5.989	7.779	9.488	11.143
5	1.145	1.610	2.343	3.655	5.132	7.289	9.236	11.070	12.833
6	1.635	2.204	3.070	4.570	6.211	8.558	10.645	12.592	14.449
7	2.167	2.833	3.822	5.493	7.283	9.803	12.017	14.067	16.013
8	2.733	3.490	4.594	6.423	8.351	11.030	13.362	15.507	17.535
9	3.325	4.168	5.380	7.357	9.414	12.242	14.684	16.919	19.023
10	3.940	4.865	6.179	8.295	10.473	13.442	15.987	18.307	20.483
11	4.575	5.578	6.989	9.237	11.530	14.631	17.275	19.675	21.920
12	5.226	6.304	7.807	10.182	12.584	15.812	18.549	21.026	23.337
13	5.892	7.042	8.634	11.129	13.636	16.985	19.812	22.362	24.736
14	6.571	7.790	9.467	12.078	14.685	18.151	21.064	23.685	26.119
15	7.261	8.547	10.307	13.030	15.733	19.311	22.307	24.996	27.488
16	7.962	9.312	11.152	13.983	16.780	20.465	23.542	26.296	28.845
17	8.672	10.085	12.002	14.937	17.824	21.615	24.769	27.587	30.191
18	9.390	10.865	12.857	15.893	18.868	22.760	25.989	28.869	31.526
19	10.117	11.651	13.716	16.850	19.910	23.900	27.204	30.144	32.852
20	10.851	12.443	14.578	17.809	20.951	25.038	28.412	31.410	34.170
22	12.338	14.041	16.314	19.729	23.031	27.301	30.813	33.924	36.781
24	13.848	15.659	18.062	21.652	25.106	29.553	33.196	36.415	39.364
26	15.379	17.292	19.820	23.579	27.179	31.795	35.563	38.885	41.923
28	16.928	18.939	21.588	25.509	29.249	34.027	37.916	41.337	44.461
30	18.493	20.599	23.364	27.442	31.316	36.250	40.256	43.773	46.979
40	26.509	29.051	32.345	37.134	41.622	47.269	51.805	55.758	59.342
60	43.188	46.459	50.641	56.620	62.135	68.972	74.397	79.082	83.298
80	60.391	64.278	69.207	76.188	82.566	90.405	96.578	101.879	106.629
100	77.929	82.358	87.945	95.808	102.946	111.667	118.498	124.342	129.561
x	-1.645	-1.282	-0.841	-0.253	0.253	0.841	1.282	1.645	1.960

***Note*:**

If **X is a χ^2 random variable with K degrees of freedom,**

$$\Pr\left(X \le \chi^2_{q,K}\right) = q$$

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BACHELOR OF ELECTRICAL ENGINEERING EXAMINATION, 2019

(4th Year, 2nd Semester, Supplementary)

RELIABILITY ENGINEERING

Time: Three Hours Full Marks: 100

(50 marks for each part)

Use a separate Answer-script for each Part

PART-II

Answer any three questions

(Two marks are reserve for neatness and well organized answers)

1. a) Calculate SAIFI, SAIDI, CAIDI, ASUI, ASAI, ENS AND AENS, ENS and AENS for the distribution system shown in the Fig. 1, below. The number of customers and average load connected to each load point are shown in Table-1. The reliability parameters are given in Table-2 13

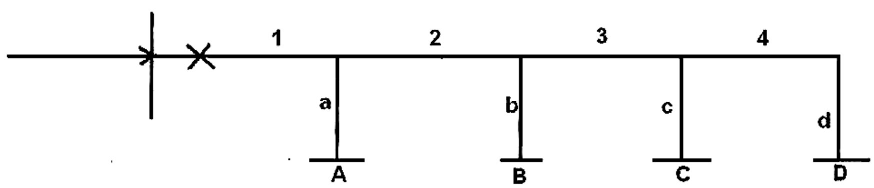

Fig. 1

Table - 1

Load Point	Number of Customer	Average Load Connected (MW)
A	500	4
B	600	6
C	700	7
D	200	2

Table - 2

Component	λ (f/yr)	r (hrs.)
1	0.2	2
2	0.2	2
3	0.1	2
4	0.2	2
a	0.2	3
b	0.5	3
c	0.4	3
d	0.3	3

b) Show that for a two component repairable parallel system, the total annual outage time is given by - $\lambda_1\lambda_2 r_1r_2/8760$ hours. 3

2. a) *Define the following terms:*
i) Active failure ii) Passive failure and iii) Stuck condition of breaker 6

b) For the system shown in Fig. 2, compute the average repair time, annual outage duration and failure rate of load point L1 and L2 with the following condition.
   i) isolation of failed component not possible
   ii) isolation of failed component is possible

Considering the failure rate of 0.2 failure/yr, repair time of 50 hours and switching time of 2 hours for each transformer. 10

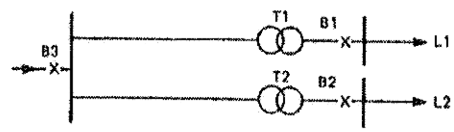

Fig. 2

3. a) A system contains three 100 MW units and two 150 MW units each having F.O.R. = 0.01. Construct the capacity outage probability table rounded off to 150 MW steps. 8

b) Using the rounded off table constructed impart (a) construct a new capacity outage probability table when another 75 MW unit is added to the system. Use method of recursion. 8

4. a) A power system contains the following generating capacity
1×60 MW thermal unit F.O.R. = 0.02
3×40 MW thermal unit F.O.R. = 0.05
1×50 MW thermal unit F.O.R. = 0.02.
The annual daily peak load variation curve is given by a straight line from 100% to the 40% points. Calculate the loss of load expectation for the peak load of 200 MW. 10

b) Explain why 'loss of largest unit' is preferred to 'percentage reserve' while computing risks in two almost similar systems. 6

5. a) Show that the frequency of encountering a state can be expressed as: $f = A.\lambda$ or as: $f = U.\mu$ with usual nomenclature. 6

b) A system contains 5×60 MW unit with the following parameters: failure rate = 0.01 failures/day and repair rate = 0.49 repairs/day. Draw the state space diagram and compute the capacity outage probability table including rate of departure & frequency. 10