

Name: _____

Recitation Section: L _____

Student Number: _____

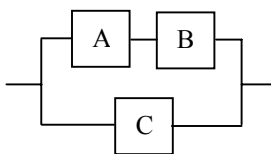
1. Verify that you have all 7 pages (cover, 5 problems, formula sheet) of the exam. This exam was distributed in multiple sections; when you finish, be sure to turn in all pages (except the formula sheet) for grading.
2. Read all instructions and problems carefully. Points will be deducted for failure to follow instructions.
3. PRINT your name and student number in the spaces at the top of ALL pages of this exam. Enter your recitation section in the indicated space above on this cover page.
4. The pages in this exam may be separated for grading; therefore, if you need extra space for a particular problem, write on the back of the page for that problem.
5. **Show ALL of your work on these pages.** Numeric answers without supporting calculations may be discounted. The instructions for a specific question may limit the amount of space allowed for an answer. For all multiple-choice questions, select the closest, or most appropriate, answer.
6. You are permitted one sheet (8 1/2 x 11, double-sided) of original **handwritten** notes; photocopies, reductions, etc. are prohibited. Use of any other notes, books, or other resources is prohibited.
7. Calculators are permitted solely for the purpose of performing numerical computations. You are not allowed to use the calculator memory to store notes, etc.
8. This exam lasts for 70 minutes. Point values are listed for each problem to assist you in best using your time.

_____	Problem 1.	(28 points possible)
_____	Problem 2.	(18 points possible)
_____	Problem 3.	(22 points possible)
_____	Problem 4.	(20 points possible)
_____	Problem 5	(12 points possible)
_____	TOTAL.	(100 points possible)

Problem 1. (28 points)

(4 points each) Answer the following multiple-choice questions by circling the letter in the right-hand column that corresponds to the most appropriate response. For part E, write the answer in the space provided.

- A. If a product fails during the “useful lifetime” portion of the bathtub reliability curve the most likely cause is which of the following? **a b c d**
- (a) latent manufacturing defects (c) accumulated stress
(b) random events or variations (d) design errors
- B. Which of the following factors is the most significant limitation of experiment-based design methods (e.g., the RLC filter bank example discussed in class)? **a b c d**
- (a) number of simulations required (c) not guaranteed to find global optimum
(b) only works for linear systems (d) not usable for discrete-valued parameters
- C. A manufacturing line produces microprocessors whose maximum operating speeds can be modeled as a normal distribution with a mean of 1500 MHz and a standard deviation of 75 MHz. The fraction of microprocessors with maximum operating speeds between 1350 and 1600 MHz is given by which of the following formulas? **a b c d**
- (a) $Z(1.33) + Z(2.00)$ (c) $Z(1.33) - Z(2.00)$
(b) $1 - Z(1.33) - Z(2.00)$ (d) none of the above
- D. A system has a mean-time-to-failure (MTTF) of one year. Assuming you start with 1000 systems, the number still working correctly after six months is closest to: **a b c d**
- (a) 400 (c) 600
(b) 500 (d) 700
- E. A system composed of three sub-systems has a reliability characterized by the series/parallel structure pictured below. Write an equation for the system reliability as a function of the individual sub-system reliabilities, R_A , R_B , and R_C .

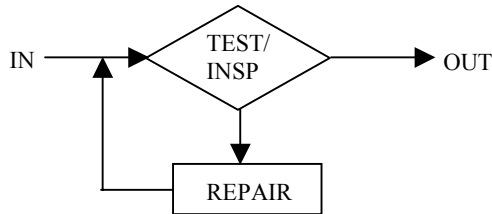
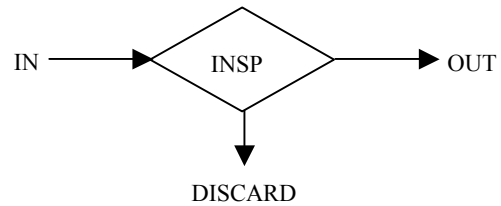


$R_{\text{SYSTEM}} =$

- F. Referring to the system in part E, which of the following relationships is true for all possible values of the individual sub-system reliabilities ($0 < R_{A,B,C} < 1$)? **a b c d**
- (a) $R_{\text{SYSTEM}} < R_A$ (c) $R_{\text{SYSTEM}} < R_C$
(b) $R_{\text{SYSTEM}} > R_B$ (d) $R_{\text{SYSTEM}} > R_C$
- G. Referring to the system in part E, if 70% of systems are still working correctly after 100 hours, what percentage of systems will have failed before 250 hours? **a b c d**
- (a) 38% (c) 59%
(b) 41% (d) 62%

Problem 2. (18 points)

A manufacturing process is characterized by an average of 2.1 defects per unit. Answer the following questions, which compare testing versus inspection and repair versus discarding of defective units. Assume the test or inspection has perfect defect coverage. The diagrams below illustrate the process for each part of this problem.

**Parts A and B****Part C**

For all parts of this problem, you **MUST** show your work (formulas and numeric values) to justify your answers.

A. TEST (with perfect repair)

- 1) (3 points) How many total tests must be performed to produce 5,000 defect-free units out?

- 2) (3 points) How many of the 5,000 units produced had only one test applied to them?

B. INSPECTION (with perfect repair)

- 1) (3 points) How many total inspections must be performed to produce 5,000 defect-free units out?

- 2) (3 points) How many of the 5,000 units produced had only one inspection applied to them?

C. INSPECTION (with defective units discarded)

- 1) (3 points) How many units must enter this step to produce 5,000 defect-free units out?

- 2) (3 points) What percentage of the units entering this step contain exactly three defects?

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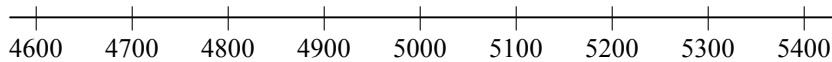
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Problem 3. (22 points)

For all parts, you **MUST** show your work (formulas and numeric values) and place the final answers in the boxes provided at the right margin. *NOTE: Part C does not depend on the answers to Part A or Part B.*

- A. (14 points) A company contracts with a manufacturer to produce a large quantity of 5000Ω resistors with a tolerance of $\pm 5\%$. Incoming inspection of a sample measures a mean value of 5080Ω and a standard deviation of 95Ω . Assume the manufacturing process produces a normal distribution of resistance values. Using the axis provided, sketch this situation in the space below. Include (and label) the target value, upper and lower specification limits, the actual mean, the standard deviation, and the probability distribution curve.

Compute the process capability index C_p , the shifted process capability index C_{pk} , and the percentage of manufactured resistors that are good (satisfy the tolerance specification).



C_p

C_{pk}

% good

- B. (4 points) For the situation from Part A, what percentage of the incoming resistors are within $\pm 1\%$ of 5000Ω ?

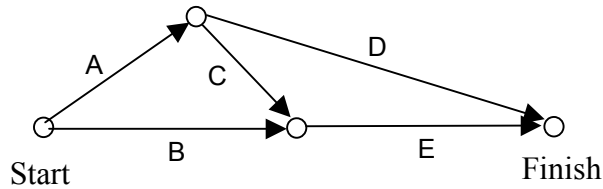
% within
 $\pm 1\%$

- C. (4 points) A manufacturing process is characterized by $C_p = 1.150$ and $C_{pk} = 1.063$. Calculate the defects per million opportunities (DPMO) for this process.

DPMO

Problem 4. (20 points)

A complete PERT chart for a project is shown below, along with a table of the optimistic, most likely, and pessimistic times (in months) for each activity. Show your work and place the final answers for each part on the lines provided at the right margin.



	t_o	t_m	t_p
A	1.3	2.4	3.1
B	2.6	4.2	4.6
C	2.0	3.2	4.2
D	3.4	4.2	4.8
E	1.3	2.5	3.7

- A. (8 points) Determine the expected time (in months) for each activity, then determine the critical path (specify the sequence of activity letters) and expected duration for the project.

Expected activity times:

- A: _____
 B: _____
 C: _____
 D: _____
 E: _____

Critical Path = _____

Expected Project Duration = _____

- B. (6 points) Determine the float for activity B and activity C.

Float B = _____

Float C = _____

- C. (6 points) The variance for the expected project duration is 0.384 months^2 . Determine the probability that the project can be completed in less than 9 months.

Probability = _____

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Problem 5. (12 points)

LEGIBLY write your answer to each question on the lines provided. Your answer for each part is limited to the space provided on the lines. **DO NOT** write (or continue) answers in the margins, on the back of this page, or anywhere else on this exam. Your answers will be graded on both appropriateness/correctness and quality/clarity.

A. (3 points) List three characteristics generally associated with a profession as opposed to other types of jobs.

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B. (3 points) List three substantially different methods by which professional societies like IEEE support the practice of engineering as a profession.

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C. (6 points) How do the codes of ethics of major engineering organizations (such as ABET, IEEE, or NCEES) compare to the moral theories (utilitarian, duty-based, rights-based, virtue-based) discussed earlier? Briefly identify and discuss key similarities and differences. *Do not exceed the space provided on these lines.*

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Manufacturing-Related Formulas

$$C_p = (USL - LSL) / (6 \sigma) \quad C_{pk} = C_p (1 - k), \quad k = | \text{Actual Mean} - \text{Target Mean} | / ((USL - LSL) / 2)$$

$$\text{First-time yield, FTY} = e^{-dpu} \quad \text{Prob} \{ k \text{ defects} \} = (dpu^k / k!) e^{-dpu}$$

Reliability-Related Formulas

Probability of failure by time t , $F(t) = \int_0^t f(\tau) d\tau$, where $f(t)$ is the failure density function

Reliability at time t , $R(t) = e^{-\int_0^t h(\tau) d\tau}$, where $h(t)$ is the per unit failure rate $R(t) = 1 - F(t)$

For constant per unit failure rate, λ : $R(t) = e^{-\lambda t}$ $N_S(t) = N_0 e^{-\lambda t}$ $MTTF = 1 / \lambda$

Tail-End Z-Table

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.00	.500000	.496011	.492022	.488033	.484047	.480061	.476078	.472097	.468119	.464144
0.10	.460172	.456205	.452242	.448283	.444330	.440382	.436441	.432505	.428576	.424655
0.20	.420740	.416834	.412936	.409046	.405165	.401294	.397432	.393580	.389739	.385908
0.30	.382089	.378281	.374484	.370700	.366928	.363169	.359424	.355691	.351973	.348268
0.40	.344578	.340903	.337243	.333598	.329969	.326355	.322758	.319178	.315614	.312067
0.50	.308538	.305026	.301532	.298056	.294598	.291160	.287740	.284339	.280957	.277595
0.60	.274253	.270931	.267629	.264347	.261086	.257846	.254627	.251429	.248252	.245097
0.70	.241964	.238852	.235762	.232695	.229650	.226627	.223627	.220650	.217695	.214764
0.80	.211855	.208970	.206108	.203269	.200454	.197662	.194894	.192150	.189430	.186733
0.90	.184060	.181411	.178786	.176186	.173609	.171056	.168528	.166023	.163543	.161087
1.00	.158655	.156248	.153864	.151505	.149170	.146859	.144572	.142310	.140071	.137857
1.10	.135666	.133500	.131357	.129238	.127143	.125072	.123024	.121001	.119000	.117023
1.20	.115070	.113140	.111233	.109349	.107488	.105650	.103835	.102042	.100273	.098525
1.30	.096801	.095098	.093418	.091759	.090123	.088508	.086915	.085344	.083793	.082264
1.40	.080757	.079270	.077804	.076359	.074934	.073529	.072145	.070781	.069437	.068112
1.50	.066807	.065522	.064256	.063008	.061780	.060571	.059380	.058208	.057053	.055917
1.60	.054799	.053699	.052616	.051551	.050503	.049471	.048457	.047460	.046479	.045514
1.70	.044565	.043633	.042716	.041815	.040929	.040059	.039204	.038364	.037538	.036727
1.80	.035930	.035148	.034379	.033625	.032884	.032157	.031443	.030742	.030054	.029379
1.90	.028716	.028067	.027429	.026803	.026190	.025588	.024998	.024419	.023852	.023295
2.00	.022750	.022216	.021692	.021178	.020675	.020182	.019699	.019226	.018763	.018309
2.10	.017864	.017429	.017003	.016586	.016177	.015778	.015386	.015003	.014629	.014262
2.20	.013903	.013553	.013209	.012874	.012545	.012224	.011911	.011604	.011304	.011011
2.30	.010724	.010444	.010170	.009903	.009642	.009387	.009137	.008894	.008656	.008424
2.40	.008198	.007976	.007760	.007549	.007344	.007143	.006947	.006756	.006569	.006387
2.50	.006210	.006037	.005868	.005703	.005543	.005386	.005234	.005085	.004940	.004799
2.60	.004661	.004527	.004397	.004269	.004145	.004025	.003907	.003793	.003681	.003573
2.70	.003467	.003364	.003264	.003167	.003072	.002980	.002890	.002803	.002718	.002635
2.80	.002555	.002477	.002401	.002327	.002256	.002186	.002118	.002052	.001988	.001926
2.90	.001866	.001807	.001750	.001695	.001641	.001589	.001538	.001489	.001441	.001395
3.00	.001350	.001306	.001264	.001223	.001183	.001144	.001107	.001070	.001035	.001001
3.10	.000968	.000936	.000904	.000874	.000845	.000816	.000789	.000762	.000736	.000711
3.20	.000687	.000664	.000641	.000619	.000598	.000577	.000557	.000538	.000519	.000501
3.30	.000483	.000467	.000450	.000434	.000419	.000404	.000390	.000376	.000362	.000350
3.40	.000337	.000325	.000313	.000302	.000291	.000280	.000270	.000260	.000251	.000242
3.50	.000233	.000224	.000216	.000208	.000200	.000193	.000185	.000179	.000172	.000165
3.60	.000159	.000153	.000147	.000142	.000136	.000131	.000126	.000121	.000117	.000112
3.70	.000108	.000104	.000100	.000096	.000092	.000088	.000085	.000082	.000078	.000075
3.80	.000072	.000070	.000067	.000064	.000062	.000059	.000057	.000054	.000052	.000050
3.90	.000048	.000046	.000044	.000042	.000041	.000039	.000037	.000036	.000034	.000033