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 for grading.
2. Read all instructions and problems carefully. Points may 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. **Show ALL of your work on these pages.** 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. 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. Answers without supporting calculations may be discounted.
5. You are permitted one sheet (8 1/2 x 11, double-sided) of **handwritten** notes; photocopies, reductions, etc. are prohibited. Use of any other notes, books, or other resources is prohibited.
6. Calculators are permitted solely for the purpose of performing numerical computations. You are not allowed to use the calculator memory to store notes, etc.
7. This exam lasts for 65 minutes. Point values are listed for each problem to assist you in best using your time.

_____	Problem 1.	(20 points possible)
_____	Problem 2.	(24 points possible)
_____	Problem 3.	(16 points possible)
_____	Problem 4.	(24 points possible)
_____	Problem 5	(16 points possible)
_____	**TOTAL**.	(100 points possible)

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Problem 1. (20 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.

A. If a product fails during the "wear-out" portion of the bathtub reliability curve the most likely cause is which of the following? **a b c d**

(a) latent manufacturing defect
(b) random variation
(c) accumulated stress
(d) design error

B. A manufacturing process has an average defect rate of 2.3 defects per unit. Roughly what percentage of units will have exactly three defects? **a b c d**

(a) 10%
(b) 20%
(c) 30%
(d) 40%

C. Consider a TEST and REPAIR step in a multi-step manufacturing process. Assuming 100% test coverage, perfect repair, and incoming dpu = 3.25, how many TESTs are required on average to produce 100 good units? **a b c d**

(a) 100
(b) 200
(c) 325
(d) 425

D. A manufacturing line produce microprocessors whose average maximum operating clock speed is 750 MHz. Assuming a normal distribution of maximum operating speeds with a standard deviation of 50MHz, approximately what percentage of microprocessors have a maximum operating speeds between 700 and 850 MHz? **a b c d**

(a) 13.59%
(b) 81.86%
(c) 84.14%
(d) 97.73%

E. What values of Cp and Cpk were required by Motorola's Six Sigma design process to ensure robust design? **a b c d**

(a) $Cp \geq 1.0$, $Cpk \geq 1.0$
(b) $Cp \leq 2.0$, $Cpk \leq 1.5$
(c) $Cp \geq 2.0$, $Cpk \geq 1.5$
(d) $Cp \geq 2.0$, $Cpk \leq 2.0$

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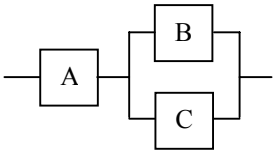
Problem 2. (24 points)

(2 points each) In lecture, the design of an RLC filter bank was described as an example of using experiment-based design methods to determine component values and tolerances. For each of the following statements, circle the more appropriate response in the right-hand column to indicate whether or not the statement is an accurate description of experiment-based design.

A.	Guaranteed to produce a globally optimal result.	**TRUE**	**FALSE**
B.	Accommodates complex component interactions.	**TRUE**	**FALSE**
C.	Goal is to produce a robust solution that tolerates normal manufacturing variation.	**TRUE**	**FALSE**
D.	Minimizes the number of simulations required.	**TRUE**	**FALSE**
E.	Assumes the system response varies "smoothly" as parameter values change.	**TRUE**	**FALSE**

For each of the following questions, you must show your work to receive maximum credit.

F. (2 points) 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_{SYSTEM} =

G. (4 points) A device is composed of two elements (J and K) with parallel reliabilities characterized by constant per unit failure rates of $\lambda_J = 1x10^{-4}$/hr and $\lambda_K = 5x10^{-3}$/hr. Assuming there are initially 5,000 devices, how many survive past 100 hours of their life?

Surviving = _____

H. (8 points) 1,000 systems are being operated for 500 hours. Each system consists of two serial sub-systems with reliabilities of 0.8 and 0.9 at 300 hours. How many of these systems have failed by 300 hours of operation? Assuming the sub-systems are characterized by constant per unit failure rates, how many of these systems are still operating at 500 hours?

Failed by 300 hrs = _____

Surviving at 500 hrs = _____

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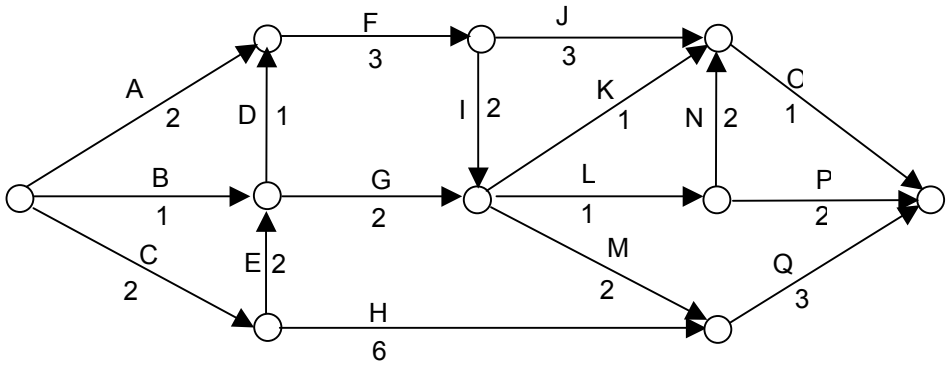
Problem 3. (16 points)

A. (6 points) Determine the critical path and its duration for the following CPM chart. State the path in terms of activity letters in order from start to finish. (example: path=AFJO, duration=9)



Critical Path = _____ Duration = _____

B. (6 points) Referring to the above CPM chart, determine the float for each of the activities listed below. Show your work.

(i) Activity F

Float F = _____

(ii) Activity G

Float G = _____

C. (4 points) Assume that for a slightly different diagram, a PERT chart, the project duration is 18 months and the variance is 16 months^2. Determine the probability that the project will require greater than 12 months to complete.

Probability = _____

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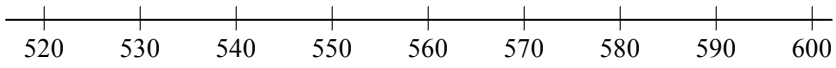
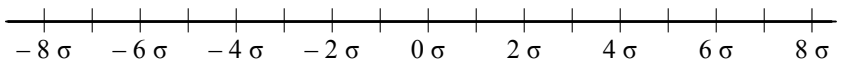
Problem 4. (24 points)

A. (16 points) Complete the following table. Assume design specifications are symmetric around the target mean and that the characteristics of the manufactured item are distributed according to a normal (Gaussian) distribution. You must show your calculations in the space below (or on the back of *this* page) in order to receive full credit.

Lower Spec Limit	**Target Mean**	**Upper Spec Limit**	**Actual Mean**	**Standard Deviation**	**Cp**	**Cpk**	**Defective (Below LSL)**	**Defective (Above USL)**
	550		560	12		0.5556		
	0 σ			σ			$Z(6.2) \approx 2.8\text{x}10^{-8}$ %	$Z(7.0) \approx 1.3\text{x}10^{-10}$ %

B. (8 points) Using the axes provided below, sketch these situations. Include (and label) the target mean, upper and lower specification limits, the actual mean, the standard deviation, and the probability distribution curve.





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Problem 5. (16 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. (2 points) List two characteristics generally associated with a profession as opposed to other types of jobs.

B. (2 points) What is generally stated as the primary justification for government regulation and licensure of engineers and other professionals?

C. (2 points) List two methods by which societies like IEEE support the practice of engineering as a profession.

D. (10 points) Unlike traditional engineering disciplines (e.g., electrical, mechanical, civil), most states have not required licensure in software engineering (which encompasses the design, coding, and testing of computer programs). Should software engineers be regulated and licensed like other engineers? Answer YES or NO, then briefly explain your choice. You should consider factors such as those mentioned in the questions above, ethical models, the nature of engineering practice, and related issues in justifying your decision. *There are many reasonable viewpoints, so you will be graded heavily on your ability to explain and justify your choice.*

Manufacturing-Related Formulas

$Cp = (USL - LSL) / (6\sigma)$ $Cpk = Cp(1 - k)$, $k = |\text{Actual Mean} - \text{Target Mean}| / ((USL - LSL) / 2)$

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

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