List of Topics for the Controls Part of the Qual Examination

1) Mathematical background: theory of linear differential and difference equations, Laplace transform, Z-transform, linear algebra and matrix theory.

2) Transfer functions and block diagrams: impulse response and transfer functions of linear systems, block diagrams, signal flow graphs.

3) Root-locus technique: basic properties, construction of the complete root loci, design of the phase-lead and phase-lag controllers using root-locus method.

4) Frequency domain analysis: Bode plots, basic frequency characteristics of linear systems (such as the peak resonance, resonant frequency, bandwidth, damping ratio, natural frequency, phase margin, gain margin, etc.), Nyquist stability criterion, design of the phase-lead and phase lag controllers using Bode plots.

5) State-space analysis: state-space models, basic Lyapunov stability theory for linear systems, controllability and observability, design of linear feedback control, observers and estimators.

Recommended textbooks:

- "Modern Control Systems" (10th Edition) by Richard C. Dorf and Robert H Bishop, Prentice Hall, 2004.
- "Automatic Control Systems" by Benjamin C. Kuo and Farid Golnaraghi, Wiley, 2002.
- "Modern Control Theory" (3rd Edition) by William L. Brogan, Prentice Hall, 1990.
- "Linear System Theory and Design" (Oxford Series in Electrical and Computer Engineering) (Hardcover) by Chi-Tsong Chen, Oxford University Press, 1998.

Ph.D. Qualification Exam in Control Systems

1. A single input-single output system is described by the following transfer function:

$$G(s) = \frac{1}{s(s+1)} = \frac{Y(s)}{U(s)}$$

where $Y(s)$ and $U(s)$ denote Laplace transform of the output and the input to the system, respectively.

a) Find matrices A, B, and C such that the following state-space representation of the system:

$$\dot{x} = Ax + Bu, \ y = Cx$$

is in the controllable canonical form.

b) Compute elements of the gain matrix K such that the static-feedback control law $u = Kx$ stabilizes the system by placing the closed-loop eigenvalues at $\lambda_{1,2} = -1 \pm i$.

c) Assume that the feedback control law is given by $u = Kw$ where

$$w = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} y \\ q \end{bmatrix}, \ \dot{q} = -2q - 2y + u$$

Then, prove that the error signal $e(t) = x(t) - w(t)$ converges to zero as time approaches infinity, that is, $\lim_{t \to \infty} e(t) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$.

2. The open-loop transfer function of a unity feedback control system is given by

$$W(s) = \frac{1}{(s+1)^3}$$

Compute both gain margin and phase margin for this system.

Course Syllabus

GE 413, Engineering Design Optimization

Spring 2009, 1-2:20 Tu Th, 204 TB

Instructor: Professor Scott Burns
Office Address: 405 Transportation Building
Office Phone: 333-1618 (This number will ring at my home when I am not in the office.)
Office Hours: 12:00-12:50 Tu Th, or right after class, or other times by appointment.
Email: ge413@scottburns.us

Description: This course focuses on the application of optimization techniques to engineering design problems. Emphasis is placed on problem formulation across several engineering disciplines, but emphasizing structural and mechanical engineering applications. Important theoretical results and numerical optimization methods are covered. Weekly computer programming assignments using the Matlab programming language are assigned to develop software to solve nonlinear mathematical programming formulations and case studies presented in the course.

Text: *Engineering Optimization, Methods and Applications,* by Ravindran, Ragsdell, and Reklaitis, 2nd Edition, John Wiley and Sons, 2006.

Prerequisites: GE 310, 330, and a computer programming course, or consent of instructor.

Grading:

Homework	10%	(generally weekly)
Project and project-related homework	30%	(due date TBA)
Hourly exams (2)	40%	(Mar 5th and April 23rd)
Final Exam	20%	(May 11th, 1:30-4:30 p.m.)

Homework: Reading assignments should be completed before class. Homework is due at the beginning of class; late homework is generally not accepted. Homework should be done on clean 8-1/2 x 11 loose leaf paper and stapled together in the upper-left corner. Use only the front side of each page. Your name, the date, and the assignment number should appear in the upper-right corner of the front page. For each problem solved, present the problem statement with any associated drawings, a summary of assumptions, a solution presented in a logical and organized sequence, and the answer(s) clearly identified. Sketches or free body diagrams should be presented when appropriate.

Exam dates are listed above. Any conflict with these dates should be brought to the attention of the instructor immediately. Job interviews and plant trips must be scheduled around these exam dates.

University of Illinois at Urbana-Champaign

Department of Mechanical and Industrial Engineering

IE411 Optimization of Large-Scale Linear Systems

Spring 2009

Lectures: 204 TB   Monday, Wednesday, Friday 2-2:50pm

Instructor: Dr. Xin Chen

Office: 216C TB   **Fax:** 244-6534

Phone: 244-8685   **Email:** xinchen@illinois.edu

Office hours: M 11am-12pm W 3pm-4pm

Website: https://netfiles.uiuc.edu/xinchen/www/

Course website: Illinois Compass

Overview: This course is about large-scale linear optimization, which is an important discipline to modeling and solving engineering and business problems. We will cover both the theory and computation of linear optimization and touch upon some important applications. Some important topics are: LP geometry; the simplex method; the interior point method; the decomposition principle and column generation; numerical implementation issues; duality theory and applications; and sensitivity analysis.

Objectives: The main objective is for you to gain a good understanding of theory and computation of linear optimization, in particular, the theory and computational issues related to the simplex method and the interior point method.

Textbook: **1.** Bertsimas and Tsitsiklis, *Introduction to Linear Optimization,* Athena Scientific (1997). (required)

2. Vanderbei, *Linear Programming: Foundations and Extensions (second edition)* http://www.princeton.edu/~rvdb/LPbook/ (downloadable)

3. Bazaraa, Jarvis and Sherali, *Linear Programming and Network Flows (second edition)*, John Wiley and Sons (1990). (optional)

Lecture Notes: Lecture notes will be posted on Illinois Compass before the lectures.

IE 411 cont'd

Software: Excel Solver and Matlab will be the main tools used for this course. We will also use NEOS Solver *http://www-neos.mcs.anl.gov/neos/*, which allows you to submit your optimization problems to the Solver and returns optimal solutions to you.

Grading Policies: There will be an individual homework every other week. Most of the exercises are going to be from the textbook. Some homework assignments will be computational. You are encouraged to discuss homework problems in groups. However, you have to write your own solutions. ***No late homework is allowed.***

We will have one midterm and the final exam.

The homework will form 30% of the grade. The midterm 35% and the final exam will contribute 35%.

Qualifying Exam Fall 2008

IE 411 - Optimization of Large Systems

I. Consider the standard form polyhedron $P = \{x | Ax = b, x \geq 0\}$. Suppose that the matrix A has dimensions $m \times n$ and that its rows are linearly independent. For each one of the following statements, state whether it is **true** or **false**.

1. If $n = m + 1$ then P has at most two basic feasible solutions.
2. At every optimal solution, no more than m variables can be positive.
3. If there is more than one optimal solution, then there are uncountably many optimal solutions.
4. In the primal simplex method, if one of the reduced costs is negative, then the current basic feasible solution is not optimal.
5. Consider the problem of minimizing $\max\{c^T x, d^T x\}$ over the set P. If this problem has an optimal solution, it must have an optimal solution which is an extreme point of P.
6. Suppose that a basic solution is degenerate. Then there exists a degenerate adjacent basic solution.
7. Let x^* be a basic feasible solution. Suppose that for every basis corresponding to x^*, the associated basic solution to the dual is infeasible. Then the optimal cost must be strictly less than $c^T x^*$.
8. Let p_i be the dual variable associated with the ith equality constraint in the primal. Eliminating the ith primal equality constraint is equivalent to introducing the additional constraint $p_i = 0$ in the dual problem.
9. If the unboundedness criterion in the primal simplex algorithm is satisfied, then the dual problem is infeasible.
10. In the dual simplex method, we add an artificial constraint and solve it to optimality. If we end up with $x^*_{n+1} = 0$, then the original primal problem is unbounded.

II. Consider the following linear program in standard form:

$$\min c^T x \text{ s.t. } Ax \geq b, x \geq 0.$$

Suppose we know the following two facts about this problem:

- its solution exists and the optimal objective value is zero
- all components of the right hand side b are strictly positive

1. Write the dual of this linear program.
2. Show that the dual has optimal solution 0 (you may use well-known lemmas, theorems, etc. in this proof but you must state what these results are by name).
3. Show that $c \geq 0$.

IE 410: Qualifying Examination Fall, 2008

September 3, 2008

1. A coin, having a probability p of showing an "heads", is to be successively flipped till the appearance of an "heads." Using a conditioning argument, compute the expected number of flips required. [15]

2. Consider a Markov chain with states $\{0, 1, 2, 3, 4\}$ with transition matrix P given by

$$P = \begin{pmatrix} \frac{1}{2} & \frac{1}{2} & 0 & 0 & 0 \\ \frac{1}{2} & \frac{1}{2} & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{2} & \frac{1}{2} & 0 \\ 0 & 0 & \frac{1}{2} & \frac{1}{2} & 0 \\ \frac{1}{4} & \frac{1}{4} & 0 & 0 & \frac{1}{2} \end{pmatrix}.$$

Specify the recurrent and transient states of the Markov chain. Also provide the system of equations needed to obtain the stationary distribution of the chain (do not solve). [10]

3. Consider a gambler who at each play has probability p of winning one unit and $1 - p$. Assuming independence between plays and the starting wealth is i units, what is the probability that the fortune reaches N units before it reaches 0?

   (a) If X_n represents the fortune of the player at time n, then X_n is a Markov chain. What are the states associated with this Markov chain? Comment on their recurrence/transience. What is the transition matrix associated with this chain? [7]

   (b) Let P_i denote the probability of reaching N starting at i. Prove that [5]

   $$P_i = pP_{i+1} + qP_{i-1}, \quad i = 1, \ldots, N-1.$$

   (c) Finally, prove that [13]

   $$P_i = \begin{cases} \frac{(1-(q/p)^i)}{(1-(q/p))} P_1, & \text{if } (q/p) \neq 1, \\ iP_1, & \text{if } (q/p) = 1. \end{cases}$$

   Using $P_N = 1$, provide an expression for P_1 and therefore for $P_i, i = 2, \ldots, N-1$.

   (d) (Extra-credit) Provide an expression for P_i as $N \to \infty$. [5]

STOCHASTIC PROCESSES AND THEIR APPLICATIONS (IE 410)

1) Suppose that the number of packages that arrive to a mailroom, X, is distributed geometric with parameter p. However, p is itself a random variable which is distributed U (.9,1.0).
a) Determine the (unconditional) probability mass function for X.
b) Determine a closed form expression (not in terms of a summation or a limit) for E[X].

2) Consider a (S,s) inventory system with S = 15 and s = 3. Suppose that the demand probability mass function is as follows: P(D = 3) = 1/2, P(D = 6) = 1/3, P(D = 9) = 1/6.
a) Determine the one-step transition matrix for the stochastic process of inventory levels. Explain.
b) Classify the states as being transient or recurrent. What are their classes? Their periods? Explain.
c) Set up the system of equations needed to solve for the long run fraction of time that the inventory system is at each of the different levels. Explain how you obtained these equations.

3) Suppose that calls arrive to a call center from 9AM to 5PM (labeled from t = 0 hours to t = 8 hours) according to a Poisson process with intensity function $\eta(t) = 10+20t$ calls per hour for $0 \leq t \leq 3$, $\eta(t) = 70$ calls per hour for $3 < t \leq 7$, and $\eta(t) = 50(8-t) + 10$ calls per hour for $7 < t \leq 8$.
a) Compute the expected number of calls that arrive from between 9AM and 5PM?
b) Compute the expected number of calls that arrive from between 2:30PM and 4:30PM?
c) If a homogenous Poisson process is created to generate observations from this Poisson process, with intensity function $\eta(t)$, what would the rate of this homogenous Poisson process need to be? Also, given its rate value, what would the acceptance probability be at 4:48PM?

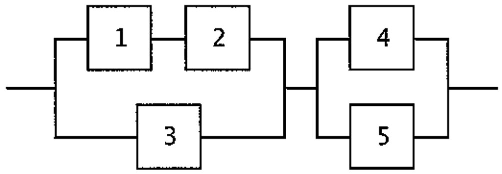
GE411

IESE Ph.D Qualifying Exam, Fall 2008 **Quality and Reliability Area** Name: ____________

Problem 3 (25 points):

Answer the following short-answer questions on this page. Show all work. Use the reverse if necessary. Assume random variables are statistically independent.

3.A Draw a fault tree for the reliability block diagram shown, with system failure as the top event.



3.B Find the exact reliability equation for the system if $R_1 = \ldots = R_5 = R$. Evaluate it for $R = 0.8$.

R_{sys} equation = ________________

R_{sys} value = ________________

3.C List the minimal cut sets for the system in A and calculate the corresponding bound on reliability if the component reliabilities are all 0.8.

Min. Cut Sets = ________________

$R_{sys} \geq$ ________________

3.D Suppose the diagram in A is a network of components that fail by a "short," i.e., unrestricted flow, each with P(short) = 0.2. List the minimal cut sets for a shorted system and find the corresponding bound on reliability.

Min. Cut Sets (system short) = ________________

Rel (against system short) $\geq$ ________________

IESE Ph.D. Qualifying Exam, Fall 2008 **Quality and Reliability Area** Name: ___________

Problem 4 (25 points): Note: A formula sheet is attached.

A mechanical device will fail if: (1) $S > R$ (fracture), or (2) $S < X$ (disengagement). S, R and X are random variables. An AFOSM design-point analysis gives the following results for each failure mode, at convergence:

(1) $g_1 = R - S$: $\mu_R' = 50$ N, $\sigma_R' = 8$ N; $\mu_S' = 30$ N, $\sigma_S' = 6$ N (N = Newtons)

(2) $g_2 = S - X$: $\mu_S' = 28$ N, $\sigma_S' = 4$ N; $\mu_X' = 19$ N, $\sigma_X' = 3$ N

Assume the two limit state equations ($g_1 = 0$ and $g_2 = 0$) are linear in Unit Normal Space, and F_1 and F_2 are failure events in mode 1 and mode 2, respectively.

4.A Find β_1 and β_2, the reliability indices for the two limit states, g_1 and g_2.

4.B Estimate the correlation coefficient ρ_{12} between the two limit states, i.e., between g_1 and g_2.

4.C Assume $\rho_{12} = 0.7$, $P(F_1) = 0.01$, and $P(F_2) = 0.02$. Find simple bounds on the series-system probability of failure, i.e., the union probability $P(F_1 \cup F_2)$.

Note: Do not use Ditlevson bounds because of time constraints.

Formulas

$$\alpha_i = \frac{(\frac{\partial g}{\partial z_i})_*}{\sqrt{(\frac{\partial g}{\partial z_1})_*^2 + (\frac{\partial g}{\partial z_2})_*^2 + \ldots + (\frac{\partial g}{\partial z_n})_*^2}}$$

$$\alpha_i = \frac{a_i \sigma_i'}{\sqrt{\Sigma (a_i \sigma_i')^2}}$$

$$(\frac{\partial g}{\partial z_i})_* = (\frac{\partial g}{\partial x_i} \cdot \frac{\partial x_i}{\partial z_i})_* = (\frac{\partial g}{\partial x_i})_* \, \sigma_{Xi}$$

$$\beta' = \frac{g(\mu_X')}{\sqrt{\Sigma a_i^2 (\sigma_i')^2}} = \frac{\Sigma a_i \mu_i'}{\sqrt{\Sigma a_i^2 (\sigma_i')^2}}$$

$$\alpha_R = \frac{\sigma_{R'}}{\sqrt{\sigma_{R'}^2 + \sigma_{S'}^2}} \qquad \alpha_S = \frac{-\sigma_{S'}}{\sqrt{\sigma_{R'}^2 + \sigma_{S'}^2}}$$

$$P(A) = \Phi(-\beta_i)\, \Phi(-\gamma_i)$$

$$r^* = \mu_{R'} - \alpha_R \, \beta' \, \sigma_{R'} \qquad s^* = \mu_{S'} - \alpha_S \, \beta' \, \sigma_{S'}$$

$$x_i^* = \mu_i' - \alpha_i \, \beta' \, \sigma_i', \qquad i = 1, 2, \ldots n$$

$$z_i^* = -\alpha_i \, \beta', \qquad i = 1, 2, \ldots n$$

$$\sigma_R' = \frac{\phi(\Phi^{-1}[F_R(r^*)])}{f_R(r^*)}$$

$$\rho_{ij} = \sum_k \alpha_{ik} \, \alpha_{jk} = \sum_{c.r.v.} \alpha_{ik} \, \alpha_{jk}$$

$$\mu_R' = r^* - \sigma_R' \, \Phi^{-1}[F_R(r^*)]$$

$$\sigma_Y' = \frac{\phi\left\{\Phi^{-1}\left[\Phi(\frac{\ln y^* - \lambda_Y}{\zeta_Y})\right]\right\}}{\frac{1}{y^* \zeta_Y} \, \phi(\frac{\ln y^* - \lambda_Y}{\zeta_Y})} = y^* \zeta_Y$$

$$\gamma_i = \frac{\beta_j - \rho \beta_i}{\sqrt{1 - \rho^2}}$$

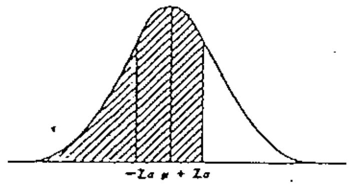
$$\mu_Y' = y^* \, (1 - \ln y^* + \lambda_Y)$$

$$F_Y(y^*) = \Phi(\frac{\ln y^* - \lambda_Y}{\zeta_Y})$$

$$f_Y(y^*) = \frac{1}{y^* \zeta_Y} \, \phi(\frac{\ln y^* - \lambda_Y}{\zeta_Y})$$

THE CUMULATIVE STANDARD NORMAL DISTRIBUTION FUNCTION

$$\Phi(u) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{u} e^{-z^2/2}\, dz \text{ for } 0.00 \leq (u = z\sigma) \leq 4.99$$



u	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7703	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.90147
1.3	0.90320	0.90490	0.90658	0.90824	0.90988	0.91149	0.91309	0.91466	0.91621	0.91774
1.4	0.91924	0.92073	0.92220	0.92364	0.92507	0.92647	0.92785	0.92922	0.93056	0.93189
1.5	0.93319	0.93448	0.93574	0.93699	0.93822	0.93943	0.94062	0.94179	0.94295	0.94408
1.6	0.94520	0.94630	0.94738	0.94845	0.94950	0.95053	0.95154	0.95254	0.95352	0.95449
1.7	0.95543	0.95637	0.95728	0.95818	0.95907	0.95994	0.96080	0.96164	0.96246	0.96327
1.8	0.96407	0.96485	0.96562	0.96638	0.96712	0.96784	0.96856	0.96926	0.96995	0.97062
1.9	0.97128	0.97193	0.97257	0.97320	0.97381	0.97441	0.97500	0.97558	0.97615	0.97670
2.0	0.97725	0.97778	0.97831	0.97882	0.97932	0.97982	0.98030	0.98077	0.98124	0.98169
2.1	0.98214	0.98257	0.98300	0.98341	0.98382	0.98422	0.98461	0.98500	0.98537	0.98574
2.2	0.98610	0.98645	0.98679	0.98713	0.98745	0.98778	0.98809	0.98840	0.98870	0.98899
2.3	0.98928	0.98956	0.98983	$0.9^{2}0097$	$0.9^{2}0358$	$0.9^{2}0613$	$0.9^{2}0863$	$0.9^{2}1106$	$0.9^{2}1344$	$0.9^{2}1576$
2.4	$0.9^{2}1802$	$0.9^{2}2024$	$0.9^{2}2240$	$0.9^{2}2451$	$0.9^{2}2656$	$0.9^{2}2857$	$0.9^{2}3053$	$0.9^{2}3244$	$0.9^{2}3431$	$0.9^{2}3613$
2.5	$0.9^{2}3790$	$0.9^{2}3963$	$0.9^{2}4132$	$0.9^{2}4297$	$0.9^{2}4457$	$0.9^{2}4614$	$0.9^{2}4766$	$0.9^{2}4915$	$0.9^{2}5060$	$0.9^{2}5201$
2.6	$0.9^{2}5339$	$0.9^{2}5473$	$0.9^{2}5604$	$0.9^{2}5731$	$0.9^{2}5855$	$0.9^{2}5975$	$0.9^{2}6093$	$0.9^{2}6207$	$0.9^{2}6319$	$0.9^{2}6427$
2.7	$0.9^{2}6533$	$0.9^{2}6636$	$0.9^{2}6736$	$0.9^{2}6833$	$0.9^{2}6928$	$0.9^{2}7020$	$0.9^{2}7110$	$0.9^{2}7197$	$0.9^{2}7282$	$0.9^{2}7365$
2.8	$0.9^{2}7445$	$0.9^{2}7523$	$0.9^{2}7599$	$0.9^{2}7673$	$0.9^{2}7744$	$0.9^{2}7814$	$0.9^{2}7882$	$0.9^{2}7948$	$0.9^{2}8012$	$0.9^{2}8074$
2.9	$0.9^{2}8134$	$0.9^{2}8193$	$0.9^{2}8250$	$0.9^{2}8305$	$0.9^{2}8359$	$0.9^{2}8411$	$0.9^{2}8462$	$0.9^{2}8511$	$0.9^{2}8559$	$0.9^{2}8605$
3.0	$0.9^{2}8650$	$0.9^{2}8694$	$0.9^{2}8736$	$0.9^{2}8777$	$0.9^{2}8817$	$0.9^{2}8856$	$0.9^{2}8893$	$0.9^{2}8930$	$0.9^{2}8965$	$0.9^{2}8999$
3.1	$0.9^{3}0324$	$0.9^{3}0646$	$0.9^{3}0957$	$0.9^{3}1260$	$0.9^{3}1553$	$0.9^{3}1836$	$0.9^{3}2112$	$0.9^{3}2378$	$0.9^{3}2636$	$0.9^{3}2886$
3.2	$0.9^{3}3129$	$0.9^{3}3363$	$0.9^{3}3590$	$0.9^{3}3810$	$0.9^{3}4024$	$0.9^{3}4230$	$0.9^{3}4429$	$0.9^{3}4623$	$0.9^{3}4810$	$0.9^{3}4991$
3.3	$0.9^{3}5166$	$0.9^{3}5335$	$0.9^{3}5499$	$0.9^{3}5658$	$0.9^{3}5811$	$0.9^{3}5959$	$0.9^{3}6103$	$0.9^{3}6242$	$0.9^{3}6376$	$0.9^{3}6505$
3.4	$0.9^{3}6631$	$0.9^{3}6752$	$0.9^{3}6869$	$0.9^{3}6982$	$0.9^{3}7091$	$0.9^{3}7197$	$0.9^{3}7299$	$0.9^{3}7398$	$0.9^{3}7493$	$0.9^{3}7585$
3.5	$0.9^{3}7674$	$0.9^{3}7759$	$0.9^{3}7842$	$0.9^{3}7922$	$0.9^{3}7999$	$0.9^{3}8074$	$0.9^{3}8146$	$0.9^{3}8215$	$0.9^{3}8282$	$0.9^{3}8347$
3.6	$0.9^{3}8409$	$0.9^{3}8469$	$0.9^{3}8527$	$0.9^{3}8583$	$0.9^{3}8637$	$0.9^{3}8689$	$0.9^{3}8739$	$0.9^{3}8787$	$0.9^{3}8834$	$0.9^{3}8879$
3.7	$0.9^{3}8922$	$0.9^{3}8964$	$0.9^{4}0039$	$0.9^{4}0426$	$0.9^{4}0799$	$0.9^{4}1158$	$0.9^{4}1504$	$0.9^{4}1838$	$0.9^{4}2159$	$0.9^{4}2468$
3.8	$0.9^{4}2765$	$0.9^{4}3052$	$0.9^{4}3327$	$0.9^{4}3593$	$0.9^{4}3848$	$0.9^{4}4094$	$0.9^{4}4331$	$0.9^{4}4558$	$0.9^{4}4777$	$0.9^{4}4988$
3.9	$0.9^{4}5190$	$0.9^{4}5385$	$0.9^{4}5573$	$0.9^{4}5753$	$0.9^{4}5926$	$0.9^{4}6092$	$0.9^{4}6253$	$0.9^{4}6406$	$0.9^{4}6554$	$0.9^{4}6696$
4.0	$0.9^{4}6833$	$0.9^{4}6964$	$0.9^{4}7090$	$0.9^{4}7211$	$0.9^{4}7327$	$0.9^{4}7439$	$0.9^{4}7546$	$0.9^{4}7649$	$0.9^{4}7748$	$0.9^{4}7843$
4.1	$0.9^{4}7934$	$0.9^{4}8022$	$0.9^{4}8106$	$0.9^{4}8186$	$0.9^{4}8263$	$0.9^{4}8338$	$0.9^{4}8409$	$0.9^{4}8477$	$0.9^{4}8542$	$0.9^{4}8605$
4.2	$0.9^{4}8665$	$0.9^{4}8723$	$0.9^{4}8778$	$0.9^{4}8832$	$0.9^{4}8882$	$0.9^{4}8931$	$0.9^{4}8978$	$0.9^{5}0226$	$0.9^{5}0655$	$0.9^{5}1066$
4.3	$0.9^{5}1460$	$0.9^{5}1837$	$0.9^{5}2199$	$0.9^{5}2545$	$0.9^{5}2876$	$0.9^{5}3193$	$0.9^{5}3497$	$0.9^{5}3788$	$0.9^{5}4066$	$0.9^{5}4332$
4.4	$0.9^{5}4587$	$0.9^{5}4831$	$0.9^{5}5065$	$0.9^{5}5288$	$0.9^{5}5502$	$0.9^{5}5706$	$0.9^{5}5902$	$0.9^{5}6089$	$0.9^{5}6268$	$0.9^{5}6439$
4.5	$0.9^{5}6602$	$0.9^{5}6759$	$0.9^{5}6908$	$0.9^{5}7051$	$0.9^{5}7187$	$0.9^{5}7318$	$0.9^{5}7442$	$0.9^{5}7561$	$0.9^{5}7675$	$0.9^{5}7784$
4.6	$0.9^{5}7888$	$0.9^{5}7987$	$0.9^{5}8081$	$0.9^{5}8172$	$0.9^{5}8258$	$0.9^{5}8340$	$0.9^{5}8419$	$0.9^{5}8494$	$0.9^{5}8566$	$0.9^{5}8634$
4.7	$0.9^{5}8699$	$0.9^{5}8761$	$0.9^{5}8821$	$0.9^{5}8877$	$0.9^{5}8931$	$0.9^{5}8983$	$0.9^{6}0320$	$0.9^{6}0789$	$0.9^{6}1235$	$0.9^{6}1661$
4.8	$0.9^{6}2067$	$0.9^{6}2453$	$0.9^{6}2822$	$0.9^{6}3173$	$0.9^{6}3508$	$0.9^{6}3827$	$0.9^{6}4131$	$0.9^{6}4420$	$0.9^{6}4696$	$0.9^{6}4958$
4.9	$0.9^{6}5208$	$0.9^{6}5446$	$0.9^{6}5673$	$0.9^{6}5889$	$0.9^{6}6094$	$0.9^{6}6289$	$0.9^{6}6475$	$0.9^{6}6652$	$0.9^{6}6821$	$0.9^{6}6981$

Example: $\Phi(3.57) = 0.9^{3}8215 = 0.9998215$

IE 431

IESE Ph.D. Qualifying Exam, Fall 2008 **Quality and Reliability Area** Name:

Problem 1 (25 points):

An engineer wants to "prove" that his software results in shorter times to register the product over the internet on average than the current software. Suppose six people are available for the study.

1. A How many factors, response variables, and levels are involved? (7 pts)

1. B Analyze the data given in the table by comparing t_0 and t_critical, and draw your conclusion. (18 pts)

New software (y1)	Old software (y2)
John – 35.6 sec	Jay – 45.2 sec
Tim – 38.2 sec	Kem – 43.1 sec
Phil – 29.1 sec	Marci – 42.7 sec

Formula and lookup table

$$t_0 = \frac{\bar{y}_1 - \bar{y}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$$df = round\left[\frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}\right]$$

Values of $t_{critical} = t_{\alpha,df}$

df	Alpha = 0.05
1	6.31
2	2.92
3	2.35
4	2.13

IESE Ph.D. Qualifying Exam, Fall 2008 **Quality and Reliability Area** Name:

Problem 2 (25 points):

Suppose a company is manufacturing blood pressure monitoring equipment (USL = 59 PSI, LSL = 46 PSI) and would like to use Xbar & R charts to monitor the consistency of equipment. Also, an inspector has measured the pressure compared to a reference for 100 units over 25 periods (inspecting 4 units each period). The average of the characteristic (X_barbar) is 55.0 PSI. The average range (R_bar) is 2.5 PSI. Suppose that during the trial period it was discovered that one of the subgroups with average 62.0 and range 4.0 was influenced by a typographical error and the actual values for that period are unknown (thus eliminate this subgroup). Determine the revised limits and Cpk. Interpret the Cpk for a threshold value 1.33.

Formula and lookup table

n	d_2	D_1	D_2
2	1.128	0	3.686
3	1.693	0	4.358
4	2.059	0	4.698
5	2.326	0	4.918

$$\sigma_0 = R_{bar}/d_2$$

$$UCL_{Xbar} = X_{barbar} + 3.0\frac{\sigma_0}{\sqrt{n}}, CL_{Xbar} = X_{barbar}$$

$$LCL_{Xbar} = X_{barbar} - 3.0\frac{\sigma_0}{\sqrt{n}}, UCL_R = D_2\sigma_0$$

$$CL_R = R_{bar}, LCL_R = D_1\sigma_0$$

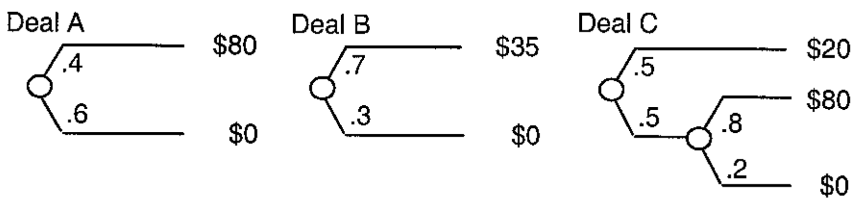
$$Cpk_U = \frac{USL - X_{barbar}}{3\sigma_0} \quad Cpk_L = \frac{X_{barbar} - LSL}{3\sigma_0}$$

Cpk = min (Cpk_L, Cpk_U)

Decision Analysis – Qualifying Exam – FALL 2008

1) The Five Rules:

Andrew follows the axioms of expected utility theory (five rules of actional thought), and prefers more money to less, and has a certain equivalent of $35 for a 50-50 chance at $80 or $0. Give Andrew's preference ordering for the following three deals:

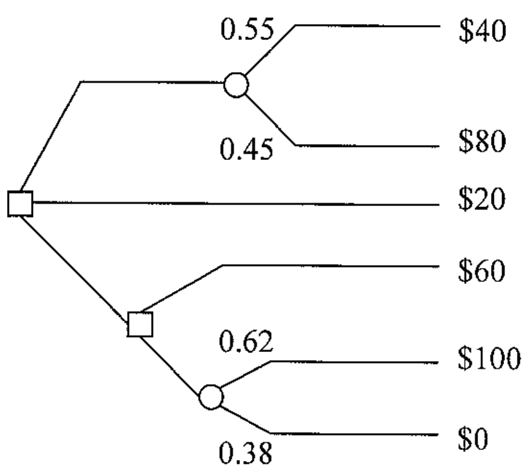


2) Valuing Uncertain Deals

The following chart displays Torsten's preference probabilities for several possible outcomes of deals having $100 as the best outcome and $0 as the worst outcome.

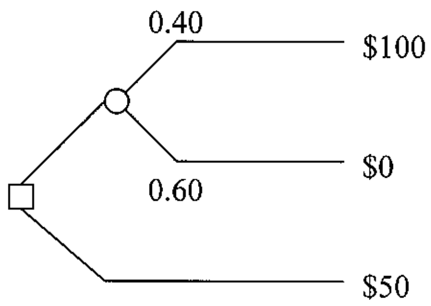
$ value	Utility (Preference Probability)
$0	0.00
$20	0.48
$40	0.63
$60	0.77
$80	0.89
$100	1.00

What is Torsten's certain equivalent for the following decision opportunity?



a) Between $40 and $60
b) $60
c) Between $60 and $80
d) There is not enough information to solve this problem.

3) Charlie's certain equivalent for the following deal is \$60.



From this information, which of the following can we reasonably conclude about Charlie's preferences?

I. Charlie's preferences violate the order principle.
II. Charlie is risk-preferring.
III. Charlie would act irrationally if he buys the deal.

a) I and II only.
b) II and III only.
c) II only.
d) None of the above.