Mechanical Engineering 573, Probabilistic Methods in Mechanical Design	
--	--

Spring 2002

Text: Reference: Probabilistic Mechanical Design, Edward B. Haugen, [John Wiley and Sons Publishers]

Classtime: MWF 13:30-14:30, LOW 206

Instructor: Prof. Michael Jenkins, 685-7061, jenkinsm@u.washington.edu Office Hours: 09:30-11:20 MWF, MEB 305

## Website: http://courses.washington.edu/mengr573/ Webstreaming: http://www.engr.washington.edu/edge/me573/me573vd.html

Week 101 AprIntroduction + 1.1 to 1.3Scope of Course03 Apr1.3-1.5 + NotesTraditional vs. Probabilistic Design05 Apr2.1-2.4ProbabilityHW #1Week 2ProbabilityHW #108 Apr2.1-2.4 and NotesProbability and Algebra of ProbabilityHW #108 Apr2.5-2.9Algebra of ExpectationHW # 212 AprAlgebra of ExpectationHW # 2Week 3HW # 317 Apr3.1-3.13Load as a Random VariableHW # 319 Apr4.1-4.7Component Geometry as Random VariablesHW # 324 Apr5.1-5.20Stress as Random VariablesHW # 424 Apr5.1-5.20Stress as Random VariablesHW # 4Week 429 Apr8.10-8.13Mechanical Properties as Random VariablesHW # 4Week 529 Apr8.10-8.13Mechanical Properties as Random Variables10 May0.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories06 May10.1-10.1 + NotesProbabilistic Design and Analysis, Failure Theories10 May11.1ReliabilityConfidence on Differences of Random Variables17 May12.3Confidence on Differences of Random Variables17 May12.3Confidence on Differences of Random Variables17 May12.3Confidence on Di	Week	Book Sections	Topic	Problems
03 Apr 05 Apr1.3-1.5 + NotesTraditional vs. Probabilistic Design05 Apr2.1-2.4ProbabilityHW #1Week 208 Apr2.1-2.4 and NotesProbability and Algebra of Probability10 Apr2.5-2.9Algebra of ExpectationHW # 2Week 3 </td <td>Week 1</td> <td></td> <td>-</td> <td></td>	Week 1		-	
05 Apr2.1-2.4ProbabilityHW #1Weck 208 Apr2.1-2.4 and NotesProbability and Algebra of Probability10 Apr2.5-2.9Algebra of Expectation12 AprAlgebra of ExpectationHW # 2Week 3HW # 3HW # 215 Apr3.1-3.13Load as a Random Variable17 Apr3.1-3.13Load as a Random Variable19 Apr4.1-4.7Component Geometry as Random Variables24 Apr5.1-5.20Stress as Random Variables25 Apr5.1-5.20Stress as Random Variables26 Apr6.1-6.10Deflection as Random Variables26 Apr6.1-6.10Deflection as Random Variables26 Apr9.1-9.3Ductifity, Toughness, Resilience, Hardness, Fatigue as RV90 May9.1-9.3Ductifity, Toughness, Resilience, Hardness, Fatigue as RV91 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories98 May10.5-10.8Stress/strength Models, Fatigue10 May11.1Reliability10 May11.2Confidence on Differences of Random Variables11 May11.2Confidence on Reliability12 MayNotesDesign of Experiments22 MayNotesDesign of Experimental Analysis of Exp. Results24 MayNotesDesign of Experimental Results24 MayNotesDesign of Experimental Results25 MayNotesDesign of Experimental Results26 Apr5.10.8Design of Experimental Results<	-			
Week 208 Apr2.1-2.4 and NotesProbability and Algebra of Probability10 Apr2.5-2.9Algebra of Expectation12 AprAlgebra of ExpectationHW # 2Week 3ILoad as a Random Variable17 Apr3.1-3.13Load as a Random Variable19 Apr4.1-4.7Component Geometry as Random Variables24 Apr5.1-5.20Stress as Random Variables26 Apr5.1-5.20Stress as Random Variables26 Apr6.1-6.10Deflection as Random Variables26 Apr6.1-6.10Deflection as Random Variables29 Apr8.10-8.13Mechanical Properties as Random Variables01 May8.14-8.15 + NotesStressy as Random Variables & HW # 5Week 6PROJECT 1Ductility, Toughness, Resilience, Hardness, Fatigue as RV HW # 5Week 6PROJECT 1Offserences of Random Variables10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 7I1.1ReliabilityHW # 6Week 8PROJECT 2Confidence on Differences of Random VariablesHW # 7Week 8PROJECT 2Design of ExperimentsZ Amy NotesAnalysis of Exp. Results24 MayNotesDesign of Experimenta and Analysis of Exp. ResultsHW # 8Week 9Z/MayNotesAnalysis of Experimenta ResultsHW # 824 MayNotesRisk AssessmentY# 8	-			
08 Apr 08 Apr 10 Apr2.1-2.4 and Notes 2.5-2.9Probability and Algebra of Expectation Algebra of ExpectationHW # 212 AprAlgebra of ExpectationHW # 2Week 3IterationHW # 215 Apr3.1-3.13Load as a Random VariableHW # 319 Apr4.1-4.7Component Geometry as Random VariablesHW # 3Week 4IterationHW # 322 Apr5.1-5.20Stress as Random VariablesHW # 424 Apr5.1-5.20Stress as Random VariablesHW # 4Week 5IterationDeflection as Random VariablesHW # 4Week 5IterationStress as Random VariablesHW # 529 Apr8.10-8.13Mechanical Properties as Random VariablesHW # 501 May8.14-8.15 + NotesStrengths as Random Variables & Random ProcessesJulia 10.1-10.4 + Notes03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RV HW # 5HW # 6Week 6PROJECT 1Iteras/strength Models, FatigueHW # 606 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure TheoriesM# 6Week 7Iteras/strength Models, FatigueIteras/strength Models, FatigueHW # 6Week 8PROJECT 2Confidence on Differences of Random VariablesHW # 7Week 8PROJECT 2Confidence on ReliabilityHW # 7Week 8PROJECT 2Stepsin of ExperimentsZ20 MayNotesDesign of Experiments and Analysis of Exp. ResultsHW # 82	05 Apr	2.1-2.4	Probability	HW #1
10 Apr2.5-2.9Algebra of Expectation Algebra of ExpectationHW # 2Week 3	Week 2			
12 AprAlgebra of ExpectationHW # 2Week 3	-			
Week 3Image: Constraint of the system of the sy		2.52.9		
15 Apr3.1-3.13Load as a Random Variable17 Apr3.1-3.13Load as a Random Variable19 Apr4.1-4.7Component Geometry as Random VariablesHW # 3Week 422 Apr5.1-5.20Stress as Random VariablesHW # 4Week 529 Apr6.1-6.10Deflection as Random VariablesHW # 4Week 529 Apr8.10-8.13Mechanical Properties as Random Variables01 May8.14-8.15 + NotesStrengths as Random Variables & Random Processes03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RVHW # 5Week 6PROJECT 106 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10-5-10.8Stress/strength Models, FatigueHW # 6Week 7 </td <td>12 Apr</td> <td></td> <td>Algebra of Expectation</td> <td>HW # 2</td>	12 Apr		Algebra of Expectation	HW # 2
17 Apr3.1-3.13Load as a Random Variable19 Apr4.1-4.7Component Geometry as Random VariablesHW # 3Week 422 Apr5.1-5.20Stress as Random Variables				
19 Apr4.1-4.7Component Geometry as Random VariablesHW # 3Week 411 </td <td>-</td> <td></td> <td></td> <td></td>	-			
Week 422 Apr5.1-5.20Stress as Random Variables24 Apr5.1-5.20Stress as Random Variables26 Apr6.1-6.10Deflection as Random Variables29 Apr8.10-8.13Mechanical Properties as Random Variables01 May8.14-8.15 + NotesStrengths as Random Variables & Random Processes03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RV06 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10.5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 7ItalConfidence on Differences of Random Variables13 May11.1ReliabilityItal15 May11.2Confidence on ReliabilityHW # 7Week 8PROJECT 2Design of Experiments20 May20 MayNotesDesign of Experiments and Analysis of Exp. ResultsHW # 824 MayNotesAnalysis of Experimental ResultsHW # 8Week 97771 MayMemorial Day HolidayN/A29 MayNotesRisk AssessmentItal Assessment	-			
22 Apr5.1-5.20Stress as Random Variables24 Apr5.1-5.20Stress as Random Variables26 Apr6.1-6.10Deflection as Random Variables26 Apr6.1-6.10Deflection as Random Variables29 Apr8.10-8.13Mechanical Properties as Random Variables01 May8.14-8.15 + NotesStrengths as Random Variables & Random Processes03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RVWeek 6PROJECT 106 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10.5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 713 May11.1Reliability15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityHW # 7Week 8PROJECT 220 MayNotesDesign of Experiments24 MayNotesDesign of Experimental ResultsHW # 8Week 927 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment	19 Apr	4.1-4.7	Component Geometry as Random Variables	HW # 3
24 Apr5.1-5.20Stress as Random VariablesHW # 426 Apr6.1-6.10Deflection as Random VariablesHW # 4Week 5				
26 Apr Week 56.1-6.10Deflection as Random VariablesHW # 4Week 5				
Week 529 Apr8.10-8.13Mechanical Properties as Random Variables01 May8.14-8.15 + NotesStrengths as Random Variables & Random Processes03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RVHW # 5Week 6PROJECT 106 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10-5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 713 May11.1Reliability15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityWeek 8PROJECT 220 MayNotesDesign of Experiments22 MayNotesDesign of Experimental ResultsHW # 8Week 927 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment	-			<b>T T T T</b> II A
29 Apr8.10-8.13Mechanical Properties as Random Variables01 May8.14-8.15 + NotesStrengths as Random Variables & Random Processes03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RVHW # 5Week 6PROJECT 106 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10-5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 713 May11.1Reliability15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityHW # 7Week 8PROJECT 220 MayNotesDesign of Experiments22 MayNotesDesign of Experimental ResultsHW # 8Week 927 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment	26 Apr	6.1-6.10	Deflection as Random Variables	HW # 4
01 May8.14-8.15 + NotesStrengths as Random Variables & Random Processes03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RVHW # 5Week 6PROJECT 106 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10-5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 713 May11.1Reliability15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityHW # 7Week 8PROJECT 220 MayNotesDesign of Experiments22 MayNotesDesign of Experiments and Analysis of Exp. ResultsHW # 8Week 927 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment		0.40.0.40		
03 May9.1-9.3Ductility, Toughness, Resilience, Hardness, Fatigue as RVHW # 5Week 6PROJECT 106 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10-5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 713 May11.1Reliability15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityWeek 8PROJECT 220 MayNotesDesign of Experiments22 MayNotesDesign of Experimental ResultsHW # 8Week 927 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment	-			
Week 6PROJECT 106 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10-5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 7InterpretationInterpretation13 May11.1ReliabilityFracture15 May11.2Confidence on Differences of Random VariablesHW # 7Veek 8PROJECT 2Confidence on ReliabilityHW # 7Week 8PROJECT 2Design of ExperimentsAnalysis of Exp. Results20 MayNotesDesign of Experiments and Analysis of Exp. ResultsHW # 822 MayNotesAnalysis of Experimental ResultsHW # 8Week 9InterpretationN/AInterpretationInterpretation27 MayMemorial Day HolidayN/AN/AInterpretationInterpretation29 MayNotesRisk AssessmentInterpretationInterpretation				LIW # 5
06 May10.1-10.4 + NotesProbabilistic Design and Analysis, Failure Theories08 May10-5-10.8Stress/strength Models, FatigueHW # 610 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 7IterationReliabilityIteration13 May11.1ReliabilityFractureHW # 715 May11.2Confidence on Differences of Random VariablesHW # 7Veek 8PROJECT 2Confidence on ReliabilityHW # 7Week 8PROJECT 2Design of ExperimentsHW # 822 MayNotesDesign of Experiments and Analysis of Exp. ResultsHW # 8Week 9IterationMaysis of Experimental ResultsHW # 8Week 9IterationN/AIterationHW # 827 MayMemorial Day HolidayN/AN/AIteration29 MayNotesRisk AssessmentIterationIteration	-		Ductinity, Toughness, Resinence, Hardness, Parigue as RV	11 <b>vv</b> # J
08 May10-5-10.8Stress/strength Models, Fatigue10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 7				
10 May10.8-10.11Dynamic, Multi-axial, and FractureHW # 6Week 7	•			
Week 713 May11.1Reliability15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityHW # 7Week 8PROJECT 2Design of Experiments20 MayNotesDesign of Experiments22 MayNotesDesign of Experiments and Analysis of Exp. Results24 MayNotesAnalysis of Experimental ResultsHW # 8Week 927 MayMemorial Day HolidayN/A29 MayNotesRisk AssessmentImage: State				HW # 6
13 May11.1Reliability15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityHW # 7Week 8PROJECT 2Design of ExperimentsImage: Confidence on Reliability20 MayNotesDesign of ExperimentsImage: Confidence on Reliability22 MayNotesDesign of Experiments and Analysis of Exp. ResultsImage: Confidence on Reliability24 MayNotesNotesHW # 8Week 9Image: Confidence on ReliabilityImage: Confidence on Reliability27 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment	•	10.0 10.11	Dynamic, Watti axiai, and Fracture	1100 # 0
15 May11.2Confidence on Differences of Random Variables17 May12.3Confidence on ReliabilityHW # 7Week 8PROJECT 2Confidence on ReliabilityHW # 720 MayNotesDesign of ExperimentsF22 MayNotesDesign of Experiments and Analysis of Exp. ResultsHW # 824 MayNotesAnalysis of Experimental ResultsHW # 8Week 9		11.1	Delichility	
17 May12.3Confidence on ReliabilityHW # 7Week 8PROJECT 220 MayNotesDesign of Experiments22 MayNotesDesign of Experiments and Analysis of Exp. Results24 MayNotesAnalysis of Experimental Results24 MayNotesHW # 8Week 9Image: Contract of the system of the	•			
Week 8PROJECT 220 MayNotesDesign of Experiments22 MayNotesDesign of Experiments and Analysis of Exp. Results24 MayNotesAnalysis of Experimental Results24 MayNotesHW # 8Week 9				HW # 7
20 MayNotesDesign of Experiments22 MayNotesDesign of Experiments and Analysis of Exp. Results24 MayNotesAnalysis of Experimental ResultsHW # 8Week 9Image: State Sta	•			
22 MayNotesDesign of Experiments and Analysis of Exp. Results24 MayNotesAnalysis of Experimental ResultsHW # 8Week 9			Design of Experiments	
24 MayNotesAnalysis of Experimental ResultsHW # 8Week 927 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment	•			
Week 927 MayMemorial Day Holiday29 MayNotesRisk Assessment				HW # 8
27 MayMemorial Day HolidayN/A29 MayNotesRisk Assessment	•		r in in it	
29 May Notes Risk Assessment		Memorial Day Holiday	N/A	
•				
	31 May	11.1 to 11.5	Design Optimization	HW # 9
Week 10	-			
03 June 11.1 to 11.5 Design Optimization		11.1 to 11.5	Design Optimization	
05 June Class Notes / Handouts Extra Topics				
07 June Review / Final Preparation / Class Evaluations	07 June			

Comprehensive Final Exam: Monday, 10 June 2000, 14:30-16:20

Homework is due one week following assignment. Solutions will be available after the assigned homework has been turned in.

Grading: 50% Homework 25% Projects 25% Comprehensive Final

## ME 573 Probabilistic Methods in Mechanical Design

## **OVERVIEW**

<ul> <li>General Description: Probabilistic Methods in Mechanical Design (3 Credits)</li> <li>Study and implementation of probabilistic methods to design, primarily mechanical design. Course includes a review/introduction to probability, algebra of expectation, algebra of normal distribution statistics of arbitrary functions, and random variables. Loading, component geometry, stress, and strain/deflection are described in terms of random variables and compared to material properties/bein terms of random variables. Design, analysis, reliability, and risk assessment are conducted on constructures with results compared to conventional deterministic approaches. Student projects use probabilistic methods to optimize selected component designs. Three 1-hr lectures/week</li> </ul>		
Course Goals:	To give students (generally graduate standing) a basic understanding of the statistical nature of both component parameters as well as material properties and performance. The basic concepts are extended to 'real world' problems through class examples and student projects. Emphasis is placed on application to the optimization of engineering designs. Although emphasis is on mechanical design and structures, the concepts can be extended to other specialties in mechanical engineering (energy and fluids, and systems and dynamics).	
Course Outline:	Probability and Statistics Fundamentals Probability Considerations Algebra of Expectation Algebra of Normal Distributions Statistics of Arbitrary Functions Exponential, Normal, Log Normal, Weibull, and Gamma Distributions	
	Component Parameters as Random Variables Loading (force and moment) Random Variables Component Geometry and Stress Concentrations Random Variables Stress Random Variables (effects of geometry, axiality, dynamics, mode) Deflection Random Variables	
	Materials Properties/Behaviour as Random Variables Proportional Limit, Yield, Ultimate, and Fracture Tensile Strength Random Variables Shear Strength Random Variables Modulus of Toughness and Resilience as Random Variables Fracture Toughness and Resistance as Random Variables	
	Design, Analysis, Reliability and Risk Assessment Classical vs. Probabilistic Approach to Mechanical Design Monotonic and Fatigue Strength Optimization of Mechanical Designs Reliability and Confidence Intervals Risk Assessment including fault tree analysis	
Additional Reading		
Reliability I Mechanical	<u>n Engineering Design</u> , K.C. Kapur and L.R. Lamberson, John Wiley and Sons <u>Engineering in Systems Design and Operation</u> , Blabir S. Dhillon, Van Nostrand Reinhold <u>Survival: The use of reliability data</u> , J.H. Bompas-Smith, MacGraw-Hill <u>Design and Analysis of Engineering Experiments</u> , C. Lipson and N.J. Sheth, McGraw-Hill	
<u>Fatigue of M</u> Mechanical <u>Mechanical</u>	<u>Materials</u> , Subra Suresh <u>Behavior of Materials</u> , Thomas Courtney <u>Engineering Design</u> , Joseph Shigley and Larry Mitchell	
Stress, Stran Related Courses	n, and Strength, Robert Juvinall	
ENGR 31 STAT (M STAT (M IND E 31	<ul> <li>15, "Introduction to Probability and Statistics"</li> <li>IATH) 390, "Probability and Statistics in Engineering and Science"</li> <li>IATH) 394, 395, 396, "Probability I, II, and III"</li> <li>6, "Regression Analysis and Design of Experiments"</li> <li>20, "System Safety and Reliability Engineering"</li> </ul>	
EE 505, ' EE 508, ' IND E 52	23, "Reliability and Design Introduction to Probability and Random Processes" Stochastic Processes" 26, "Reliability in Product Design and Testing" "Random Processes"	