

Conversion to Semesters: Statistics Program

This document presents a set of notes representing current progress (as of June 12, 2009) towards converting the statistics program from the quarter system to the semester system. The main issues that need to be addressed are: (1) Statistics service courses, (2) Converting and combining individual statistics courses and (3) programs of study (MS and BS). This document also contains drafts of semester versions of some of our current courses syllabi in the Appendices.

- I. **Service Courses:** Our primary service courses are STT 160, STT 264/5 and STT 363 at the undergraduate level.
 - a. STT 160: Munsup is working on the conversion of STT 160. We anticipate that the semester version of this class will have an Excel lab and will become a 4 credit hour, 1 semester course.
 - b. STT 264/5: Mak and Shuxia have been working on STT 264 and STT 265. See Appendices A and B for draft syllabi for a 2-semester conversion of STT 264/5. These syllabi represent fairly straightforward conversions of the current quarter courses. Depending on the needs of the degrees these courses serve (biology and EES), we may need to convert the 2 quarter courses into a single semester course. This will be determined based on discussions with various departments (hopefully this summer).
 - c. STT 363 Engineering Statistics: This course could get folded into the semester version of STT 360. However, the semester version of STT 360 may have very little statistical content (which is the case for the quarter version of the class); this course is currently primarily a probability course. When we re-vamped STT 363 a few years ago, we introduced quite a bit of statistical inference and modeling at the request of the mechanical engineering department. Appendix C has a draft syllabus of the semester version of STT 363. Note that this converted course now introduces Matlab whereas before there was no software component to the course.
- II. **Conversion of Other Undergraduate Courses.** This section deals with the conversion of other undergraduate statistics courses. However the current 400-level courses will be discussed under graduate courses with their 600-level counterpart.
 - a. STT 360/1: See Appendices D and E for draft syllabi for semester versions of these classes. These two classes are currently required courses for the statistics major and also serve as electives for math majors. One idea we have briefly discussed is changing STT 360 to a 100-level freshman course so that statistics majors can take a statistics course early in their studies and perhaps also making this 100-level course a general education course which would provide an introduction to statistical thinking concepts and

probability. Converting STT 360/1 will require dialogue with other programs that either require these courses or list them as electives. Because they are required for the statistics major, most likely these courses will convert to a 2-semester sequence instead of a 1-semester course.

b. STT 492 Senior Seminar course. This course will coincide with the MTH 491 and MTH 492 conversion most likely.

III. Graduate Level Statistics Courses. This section provides details on converting graduate level (including 400-level) statistics courses to semesters. Note that many graduate level courses have not been addressed yet in this section.

a. STT 661 & STT 662. Conversion of the theory course. Here we propose a draft list of topics for a 2-semester conversion of these two courses.

Fall Semester (15 weeks - 45 lectures)

1. Review of elementary probability theory , random variables, random vector, concept of probability distribution, expected values, mean , variance. (1 week)
2. Cumulative distribution function , moment and cumulant generating functions, characteristic function , moment and cumulant sequences , bivariate distributions, marginal and conditional distributions, moments of bivariate distribution., marginal and conditional means, covariance (1 week)
3. Some discrete and continuous probability distributions and their properties Bernoulli, Binomial, Multinomial, Hypergeometric, Negative Binomial, Poisson, Geometric, Uniform, Normal, Exponential, Gamma, Beta, Weibull, Pareto, t, F, Chi-squared and non-central chi-squared distribution, non-central t, Exponential family of distributions (7 weeks)
4. Multivariate Normal Distribution (1 week)
5. Concept of finite mixture distributions and compound distributions. (1 week)
6. Transformation of variables with applications to some of the distributions from (3) above. (2 weeks)
7. Limiting distributions, convergence in distribution, CLT, weak convergence (1 week)
8. Review and Exams (1 week)

Spring Semester (15 weeks - 45 lectures)

1. Random sampling from a univariate population, statistics, sampling distribution of statistics, properties of sampling distribution of a statistics, sampling from a normal and non-normal populations (1 week)
2. Order statistics , distributions of order statistics, examples of order statistics from some of the distributions covers during the fall quarter. (1 week)
3. Point estimation (scalar parameter) - Properties of estimators, evaluation of estimators of the parameters of some distributions covered in STT 661.
4. The UMVUE, Cramer-Rao lower bound, sufficiency and completeness, efficiency. Exponential class of distribution (3 weeks)

5. Likelihood and maximum likelihood estimation. Some computational problems associated with maximum likelihood estimation.
6. Estimation of parameters of some distributions covered in STT 661.
7. Estimation of parameters of mixture distributions. EM algorithm (1 week)
8. Single Parameter - Interval estimation (1 week)
9. Hypothesis Testing: power, one-sided and two-sided tests, most powerful tests, UMP tests, Neyman-Pearson Lemma, likelihood ratio tests (2 weeks)
10. Sampling from the multivariate normal distribution (1 week)
11. Random Vectors and Distributions: covariance matrices, linear and quadratic forms, distribution of AY , where A is a matrix, independence of quadratic forms, Cochran-Fisher theorem (1 week)
12. Hypothesis Testing (vector of parameters): $A*b = C$ for a matrix A and vector and vector of parameters. (2 weeks)
13. Interval Estimation (vector of parameters): confidence intervals, prediction intervals, simultaneous C.I.'s (Scheffe, Bonferroni, Tukey) (1 week)

b. STT 666 & STT 667 Methods courses.

Fall Semester (15 weeks – 45 lectures)

1. Remove the topics listed as first three bullets from the current syllabus (Students are expected to know these either as pre-requisites)
2. Review of tests of hypothesis methods including non-parametric methods (one week)
3. Simple Linear Regression (Review – to be covered in 3 lectures-one week)
4. Matrix approach for regression (3 lectures--- one week)
5. Multiple Regression (12 lectures - four weeks)
6. Nonparametric Methods (including regression analysis (4-5 lectures)
7. One-Way and Two – Way ANOVA Models (without interaction) (15 lectures 5 weeks)
8. Introduction to the Theory of Linear Models (6 lectures – 2 weeks) (math. derivations will be minimal).
9. Exams and Review (3-4 lectures)

Note : Students will be assigned 5 or 6 data analysis projects for which writing a systematic project report will be a requirement (SAS will be a preferred software for such projects)

Spring Semester (15 weeks – 45 lectures)

1. Two-way ANOVA Models with interaction (3 lectures -1 week)
2. Repeated Observations (1 week)
3. Basic design principles: randomization, replication, blocking, factorial design (1-week)
4. Randomized complete block designs: data plot, ANOVA, multiple comparisons (1-week)
5. Single-factor ANOVA for random effects: estimation and testing of variance components (2 weeks)
6. Multi-factor experiments (2 weeks)

7. Mixed- and random-effects models, including repeated measures (2-weeks)
8. Introduction to confounding and partial confounding for 2^k factorial experiments: design, analysis (1 week)
9. Topics in Theory of Linear Models (3 weeks) (math derivations will be minimal)
10. Review and Exams (1 week)

Note: Students will be assigned 5 or 6 data analysis projects for which writing a systematic project report will be a requirement (SAS will be a preferred software for such projects)

- c. Combine Quality Control STT 624 and Survival Analysis STT 626** (Suggested by Mak): "... consider the methods for survival analysis methods as the same as those for the reliability studies these two courses have commonality - namely applications in engineering... Therefore, combining these courses as one course with 4 semester credit hours with an appropriate title may work.

Advantages :

1. Students get to learn both QC , reliability and survival analysis in one semester. This may bring more students in the course.
2. We can offer such course every year, rather than the alternate year.
3. Move this course as a summer C course to two separate courses as Summer A and Summer B courses with appropriate credit hours (for example, two credit hour per course).
4. If we move such course in summer we can teach Time-Series Analysis (3 credit hour course) during regular academic year rather than as a summer course. Certain components of QC can also be discussed in TS course.
5. If we do not want a TS course on a regular basis we can put in other courses that are or current interest.

- d. Combine Stochastic Processes (STT 702) and Applied Time Series (STT 611)** as a 4 semester credit hour course (Suggested by Mak).

Advantage :

“(Mac) I have taught STT 702 during 1980's and early 1990's. In general, our students are not very much likely to use STT 702 course material unless they plan to go to Ph.D. program and take more stochastic process courses and related applications. Therefore, combining with TS course will look their transcript much better. What to do with STT 411? Delete STT 411. Generally, in my experience there is hardly one student who takes STT 411 once in a while.” (Thad’s Comments): Most of the undergraduate students that have majored in statistics over the last few years have done so with the motivation of becoming actuaries. The Time Series course now counts as credit for the actuarial education program (the so-called VEE) so we may want to keep time series at the undergraduate level too.

- e. **Sampling Design** Question: What should we do with the sampling design course? Can we combine it with another topic such as design of experiments? My thinking is that an entire semester course on sampling may not be the best use of student's time in our program. Also, if we scale back the course, we could think about making it a 400/600 type course so that undergraduates have access to it – this would give our undergraduates more flexibility. I think the mathematical level of the course over the last several offerings may not be beyond the reach of our undergraduates...does this sound right?
- f. **Combine Categorical Data Analysis (STT 740) with Topics in Linear Models (STT 762).** The idea here is to make this new course a course that covers the basics of generalized linear models and categorical data analysis.

IV. Bachelor's of Science in Statistics. This section provides details on the semester version of the BS in Statistics. We list the old quarter version of the major and the proposed semester version. Note – this section is mostly unfinished.

OLD CHECKLIST FOR BS DEGREE

262, 271, 281, 291, or URS 200	4
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GENERAL EDUCATION (62-66 hours)

Area I: Communication and Mathematical Skills

ENG 101	Freshman Composition I	4
ENG 102	Freshman Composition II	4
MTH 229	Calculus I	5
MTH 230	Calculus II	5

Area II: Cultural-Social Foundations

<i>Choose one:</i>		
CLS 150, HST 101, 102, or 103		4
<i>Choose one (all are WI):</i>		
CSE 250, CST 221, 231, 232, 241, 242, 243, 251, HLT 202, RSE 260, RST 261,		

Area III: Human Behavior

Select 2 courses from different categories

Note: Honors course UH 202 can be substituted for any one Area III course.

EC	EC 200, EC 290	
	<i>Note 1: Some sections of EC 200 are WI</i>	
	<i>Note 2: EC 204 and 205 together can be used in place of EC 200 (neither is WI)</i>	4
PLS 200	Political Life	4
PSY 105	Psychology: The Sci of	

	Behavior	
SOC/WM S	SOC 200 or WMS 200 <i>(All are WI)</i>	

Area IV: Human Expression

Choose one course.

*Possible substitution: Honors UH 201
(WI)*

Great Books (all 4 are WI): CLS 204, ENG 204, PHL 204, REL 204	4
Fine and Performing Arts: ART 214, MUS 214, MUS 290, TH 214, or MP 131 <i>Note: MUS 121 and 122 together can substitute for MUS 214.</i>	

Two Additional Courses

*(Select two additional courses from Areas II, III,
or IV, one course from two of these three areas.
Except for Area II, the course selected must
come from a different subcategory than the
course(s) chosen to meet the area requirement.)*

	4
	4

Area V: Natural Sciences

<i>Choose three (lecture + lab), 1 must be WI:</i>	
<i>Some section offerings are WI.</i>	—

BIO 105, 106, 107, CHM 105, 106, 107, GL 105, 106, 107, PHY 240/200, 242/202, 244/204 See the catalog for possible substitutions for these courses (except for Physics)	— —
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**Area VI: College Component
GRADE**

HRS

*Note: Students who complete an Area VI
course in one college and then transfer to
another may not need to take another
Area VI course.*

<i>Choose one (all are WI):</i> AFS 200, ATH 241, ATH 242, ED 210, EH 205, FIN 205, HST 220, HST 221, PHL 200, PSY 110, or SM 205	4
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**DEPARTMENTAL REQUIREMENTS (61
hours)**

Required Courses:

MTH 231	Calculus III	5
MTH 232	Calculus IV	5
MTH 255	Linear Algebra	3
MTH 280	Intro to Math. Proof (WI)	3
MTH 355	Advanced Linear Algebra	3
STT 360	Applied Statistics I	4
STT 361	Applied Statistics II	4

STT 461	Theory of Statistics I	4
STT 462	Theory of Statistics II	4
STT 466	Statistical Methods I	4
STT 467	Statistical Methods II	4
STT 492	Statistics Seminar (WI)	3

Departmental Electives – Choose at least 15 hours:

(NOTE: Must include at least two 400-level courses from the following list, at least one must be a STT course.)

STT 401†	Nonparametric Methods	4
STT 411†	Applied Time Series	4
STT 424*	Statistical Control Methods	4
STT 426*	Reliability and Life Data	4
STT 428†	Queuing Theory	4
STT 464	Computational Statistics	4
STT 469*	Experimental Design	4
MTH 233	Differential Equations	5
MTH 306	Mathematical Modeling	3
MTH 314	Intro to Math Software	3
MTH 316	Numerical Methods I	3
MTH 317	Numerical Methods II	3
MTH 332	Complex Variables	3
MTH 333	Partial Differential Equations	3
MTH 381	Number Theory	3

MTH 407	Optimization Techniques	3
MTH 410	Theoretical Fnds of Computing	3
MTH 415	Intro to Scientific Computation	3
MTH 419	Cryptography & Data Security	3
MTH 431*	Real Variables I	3
MTH 432*	Real Variables II	3
MTH 433	Real Variables III	3
MTH 451	Intro to Modern Algebra I	3
MTH 452	Intro to Modern Algebra II	3
MTH 456	Coding Theory	3
MTH 457	Combinatorics	3
MTH 458	Applied Graph Theory	3
MTH 471	Geometry	3
MTH 476	Computer Graphics I	4
MTH 477	Computer Graphics II	4
MTH 480	Appl Math:Geometric Mthds	3
MTH 481	Appl Math:Differential Eqs	3
MTH 482	Appl Math:Integral Methods	3
CS 470	Systems Simulation	4

RELATED COURSE REQUIREMENTS (24 hours)

CS 141	Programming I	4
CS 142 or CS 240	Programming II Computer Science I	4

Cognate Area – With your advisor’s approval, select at least 16 hours in any area in which statistics may be applied (of which, at least 9 hrs. must be at 300-level or above).

Course	Hrs	Course	Hrs

GENERAL ELECTIVES (32-36 hours)

To earn a bachelor’s degree at WSU, you must fulfill the following requirements:

- A minimum of 183 credit hours must be earned in approved courses.
- At least a minimum cumulative GPA of 2.0 must be earned for courses taken at WSU.
- For this particular degree program, at least a 2.0 GPA must be earned for courses numbered 300 or higher that are used to satisfy departmental requirements.
- A minimum of 45 credit hours must be earned at WSU. At least 15 of the last 45 hours of credit must be earned at WSU. A minimum of 30 hrs. of courses numbered 300 or above must be earned at WSU.
- Complete a total of eight Writing Intensive (WI) courses: ENG 101, ENG 102, four other WI courses in General Education and two in the major.

NEW SEMESTER BASED BS CHECKLIST – this still needs to be completed:

GENERAL EDUCATION (? hours)

To be determined

DEPARTMENTAL REQUIREMENTS (61 hours)

Required Courses:

MTH ?	Calculus III	4?
MTH ?	Calculus IV	4?
MTH ?	Linear Algebra	3
MTH ?	Intro to Math. Proof (WI)	3?
STT 360	Applied Statistics I	3
STT 361	Applied Statistics II	3
STT 461	Theory of Statistics I	3
STT 462	Theory of Statistics II	3
STT 466	Statistical Methods I	3
STT 467	Statistical Methods II	3
STT 492	Statistics Seminar (WI)	??

Departmental Electives – Choose at least 15 hours:

(NOTE: Must include at least two 400-level courses from the following list, at least one must be a STT course.)

STT 401†	Nonparametric Methods	4
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STT 411†	Applied Time Series	
STT 424*	Statistical Control Methods	
STT 426*	Reliability and Life Data	
STT 428†	Queuing Theory	
STT 464	Computational Statistics	
STT 469*	Experimental Design	
MTH 233	Differential Equations	
MTH 306	Mathematical Modeling	
MTH 314	Intro to Math Software	
MTH 316	Numerical Methods I	
MTH 317	Numerical Methods II	
MTH 332	Complex Variables	
MTH 333	Partial Differential Equations	
MTH 381	Number Theory	
MTH 407	Optimization Techniques	
MTH 410	Theoretical Fnds of Computing	
MTH 415	Intro to Scientific Computation	
MTH 419	Cryptography & Data Security	
MTH 431*	Real Variables I	
MTH 432*	Real Variables II	

MTH 433	Real Variables III	
MTH 451	Intro to Modern Algebra I	
MTH 452	Intro to Modern Algebra II	
MTH 456	Coding Theory	
MTH 457	Combinatorics	
MTH 458	Applied Graph Theory	
MTH 471	Geometry	
MTH 476	Computer Graphics I	
MTH 477	Computer Graphics II	
MTH 480	Appl Math:Geometric Mthds	
MTH 481	Appl Math:Differential Eqs	
MTH 482	Appl Math:Integral Methods	
CS 470	Systems Simulation	

GENERAL ELECTIVES (32-36 hours)

To earn a bachelor’s degree at WSU, you must fulfill the following requirements:

- A minimum of 120 credit hours must be earned in approved courses.
- At least a minimum cumulative GPA of 2.0 must be earned for courses taken at WSU.
- For this particular degree program, at least a 2.0 GPA must be earned for courses numbered 3000 or higher that are used to satisfy departmental requirements.
- A minimum of 30 credit hours must be earned at WSU. At least 10 of the last 30 hours of credit must be earned at WSU. A minimum of 20 hrs. of courses numbered 3000 or above must be earned at WSU.
- Complete a total of 5 or 6??? Writing Intensive (WI) courses: ENG 101, ENG 102, four other WI courses in General Education and two in the major.

RELATED COURSE REQUIREMENTS (24 hours)

CS 141	Programming I	
CS 142 or CS 240	Programming II Computer Science I	

Cognate Area – With your advisor’s approval, select at least 12? hours in any area in which statistics may be applied (of which, at least 9 hrs. must be at 3000-level or above).

Course	Hrs	Course	Hrs
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V. Master of Science in Applied Statistics. The plan here is to have the master degree program remain a two-year program. The first year students will take the cores statistics courses, the converted theory and methods sequence which will also incorporate topics from the design of experiments and theory of linear models. Students will still be required to pass a comprehensive exam after their first year (see Appendix G for the current quarter version of the core topics for the comprehensive exams). The second year of the program, students will take advanced courses in statistics which will consist of current quarter-based courses combined to make semester-based courses.

- A statistical consulting course will still be required.
- We may consider introducing a thesis option for the master degree.

APPENDIX A: Conversion of STT 264 Syllabus

For sections meeting three times a week (each class of 50 mins)

Guidelines: Quarter – 4 credit hours (3 lectures + 1 lab (75mins.) converted to (2 lectures ([formula: 3 (lectures)*(2/3) = 2 lectures + 75 mins lab *(2/3) = 50 mins lab) = 3 semester credit hours] – Total number of days (classes) over 15 weeks = 45 days

(Every 3rd class is either a lab or a review or an exam –to be held in 170MM)

(For sections meeting two times a week (each class of 75 mins.) the 2nd class be held in 170 MM and the lab hour could be adjusted by the instructor.)

STT 264 Syllabus

Statistics, 11th Edition , by McClave and Sincich

Class	Section	Topic Name
1	1.1-1.5	Statistics, Data and Statistical Thinking
2	2.1/2.2	Graphical Methods for Describing Data
3	Lab1	Introduction to Minitab and Data Sets in Minitab Library
4	2.4	Measures of Central Tendency
5	2.5	Measures of Variability
6	Lab 2	Charts and Graphs
7	2.6/2.7	Interpretation of Standard Deviation/percentiles
8	2.8	Methods of Detecting Outliers
9	Lab3	Calculating Descriptive Statistics
10	3.1	Events, Sample Space ,Probability
11	3.2	Union and Intersections
12	Review	Chapters 1 and 2
13	3.3	Complementary Events

Class	Section	Topic Name
14	3.4	Additive and Multiplicative Rules
15	Exam1	Exam #1
16	3.5	Conditional Probabiity
17	3.6	Multiplicative Rule and Independent Events
18	Lab 4	Descriptive Statistics , Box-Plots
19	3.7	Random Sampling
20	4.1	Random Variables
21	Lab5	Probability-Problem Solving
22	4.2	Probability Distribution for Discrete Random Variables
23	4.3	Expected Values
24	Lab6	Probability Distributions and Their Properties
25	4.4	The Binomial Random Variable
26	4.4	The Binomial Distribution
27	Exam2	Exam 2
28	5.1	Continuous Probability Distribution
29	5.2	The Uniform Distribution
30	Lab 7	Binomial Distribution
31	5.3	The Normal Distribution
32	5.3	The Normal Distribution(to be continued)
33	Lab8	Normal Distribution
34	5.5	Approximation Binomial with Normal Distribution
35	6.1	Sample Statistic/Sampling Distribution

Class	Section	Topic Name
36	Lab9	Random sampling
37	6.1	Sample Statistic/Sampling Distribution
38	6.2	Properties of Sampling Distribution
39	Exam 3	Exam 3
40	6.3	Central Limit Theorem (CLT)
41	6.3	Central Limit Theorem(continuation)
42	Lab 10	Properties of Sample Mean and its Large Sample Distribution (Application of CLT)
43	7.1	Identifying the Population parameters and related sample statistics
44	7.1	Introduction to Statistical Inference
45	Review	Overall Review of Chapters 1 through 6

Revised May 23, 2009 – for conversion from quarter to semester academic system

APPENDIX B: Conversion of STT 265 Syllabus

For sections meeting three times a week (each class of 50 mins.)

Guideline s: Quarter – 4 credit hours (3 lectures + 1 lab (75mins.) converted to (2 lectures ([formula: 3 (lectures)*(2/3) = 2 lectures + 75 mins. lab *(2/3) = 50 mins. lab) = 3 semester credit hours] – Total number of days (classes) over 15 weeks = 45 days

(Every 3rd class is either a lab or a review or an exam –to be held in 170MM)

(For sections meeting two times a week (each class of 75 mins.) the 2nd class be held in 170 MM and the lab hour could be adjusted by the instructor.)

STT 265 Syllabus

Statistics, 11th Edition , by McClave and Sincich

Class	Section	Topic Name
1	7.1	Parameters and Statistics – Target Population/Sample
2	7.2	Large Sample C.I. for the Population Mean
3	Lab1	Normal, t and Chi-squared Distributions
4	7.3	Small Sample C.I. for the Population Mean
5	7.4	Large Sample C.I. for the Population Proportion
6	Lab 2	Confidence Interval for Population Mean
7	8.1	The Elements of Test of Hypothesis
8	8.1	The Elements of Test of Hypothesis (continued)
9	Lab3	Confidence Interval for Population Proportion
10	8.2	Large Sample Test of Hypothesis for the Population Mean
11	8.3	p-values
12	Review	
13	8.4	Small Sample Test of Hypothesis for the Population Mean
14	8.5	Large Sample Test of Hypothesis for the Population Proportion

Class	Section	Topic Name
15	Exam1	Exam1
16	9.1	Identifying the Target Parameter
17	9.1	Identifying the Target Parameter(continued)
18	Lab 4	Inference on Population Mean
19	9.2	Comparing Two Population Means-Independent Sampling
20	9.2	Comparing Two Population Means-Independent Sampling(continuation)
21	Lab5	Two Independent Means
22	9.3	Paired Difference Experiments
23	9.3	Paired Difference Experiments(continuation)
24	Review	
25	10.1	Elements of Design of Experiments
26	10.1	Elements of Design of Experiments (continuation)
27	Exam2	Exam 2
28	10.2	Completely Randomized Design
29	10.2	Completely Randomized Design(continuation)
30	Lab 7	Paired Data Experiments
31	10.3	Multiple Comparison
32	10.5	Factorial Experiment
33	Lab8	One –Way ANOVA
34	11.1	Probability Model
35	11.2	Fitting the Model-Least Squares Approach
36	Lab9	Simple Linear Regression I

Class	Section	Topic Name
37	11.3/11.4	Model Assumption/Inference about the Slope
38	11.5/11.6	Estimation and Prediction/correlation
39	Exam 3	Exam 3
40	13.1	Chi-squared Distribution
41	13.1	Multinomial Distribution
42	Lab 10	Simple Linear Regression II
43	13.2	Contingency Tables
44	13.3	Contingency Tables (continued)
45	Review	

APPENDIX C: Conversion of Engineering Statistics STT 363

Week	Topic(s)
1	Introduction, Introduce Matlab for data analysis, Descriptive Statistics, Graphics
2	Probability: properties of probability, conditional probability
3	Discrete random variables, probability distributions, expected value, variance and standard deviation.
4	Binomial distribution and introduction of hypothesis testing for a proportion, p -values computed exactly using Matlab and the binomial distribution.
5	Poisson, hypergeometric, and multinomial distributions
6	Continuous distributions, probability density functions, computing probabilities via integration, expected value, variance, and standard deviation.
7	Normal distribution, use Matlab to compute normal probabilities. Exponential distribution
8	Review and midterm
9	Central limit theorem, confidence intervals for the mean and the t-distribution, use Matlab to obtain critical values.
10	Hypothesis tests for the mean, p -values
11	Multivariate statistics: covariance, correlation, random vectors, covariance matrix (include a brief review of matrix algebra basics)
12	Simple linear regression, least squares, matrix approach, use Matlab to compute least-squares estimates and plot data, inference for the slope of the line.
13	Multiple regression, polynomial regression
14	2-independent sample comparisons: t-tests, confidence intervals; paired t-test, boxplots
15	Analysis of variance and factorial designs

APPENDIX D: Conversion of STT 360/560

STT 360/560, Applied Statistics I
 Syllabus (for the session that meets three hours a week for 15 weeks)
 (Revised May 2009)

Textbook: Probability & Statistics for Engineers & Scientists, 8th Edition, 2007, Walpole, Myers, Myers and Ye.

Day	Section	Topic	Homework	Page
1	1.1—1.3			
2	1.4--1.6			
3	1.7--1.9			
4	2.1-2.2	Sample Space	1, 4, 5, 7, 8abc	38
		Events	10, 18, 20	39
5	2.3	Counting Sample Points	27, 31, 36, 41, 45, 48	47
6	2.4-2.5	Probability of an Event	60, 61, 62	56
		Additive Rules	54, 55, 65	56
7	2.6-2.7	Conditional Probability	77, 79, 81	65
		Multiplicative Rule	91, 93, 95, 97	67
8	2.8	Bayes Rule	105, 106	73
9	3.1	Random Variables	1, 3, 4	88
10	3.2	Discrete Distributions	8, 11, 13, 15, 16, 24, 25	88
11	3.3	Continuous Distributions	7, 14, 18, 19, 20	88
12-13	3.4	Joint Distributions ¹	37,38, 39, 46, 48, 49, 50, 56, 57	101
14		Review		
15		Exam on Chapters 1, 2 and 3		
16	4.1	Mean of a Random Variable	2, 7, 9, 12, 18, 20, 21, 23	113
17	4.2 ²	Variance and Covariance	34, 36, 42, 43, 45	122
18	4.3	Properties of Expectation	52, 54, 55, 58, 64, 65	134
19	4.4	Chebyshev's Theorem		
20	5.1-5.2	Motivation		
		Discrete Uniform Distribution	1, 3	150
21-22	5.3	Binomial & Multinomial Distribution	4, 9 11, 13, 15, 21	150
23	5.4	Hypergeometric Distribution	29, 31, 35, 36, 45	157
24	5.5	Negative Binomial Distribution		
25	5.6	Poisson Distribution	59, 62, 64, 70, 71	165
26	6.1-6.2	Continuous Uniform Distribution	20, 21, 22	187
		Normal Distribution		
27	6.3	Area Under Normal Curve	1, 2, 3, 4, 6	185??
28	6.4	Applications of Normal Distribution	9, 10, 11ade, 13, 15	186
29	6.5	Normal Approximation to Binomial	24, 29, 33, 34	193
30	6.6	Gamma and Exponential Distribution	39	204
31	6.7	Applications of Gamma & Exponential	42, 44, 45, 46 51, 56	205
32	6.8	Chi-squared Distribution		
33	6.9	Lognormal Distribution		
34		Review		
35		Exam on Chapters 4, 5 and 6		
36	7.2	Transformation of Discrete r.v.		
37	8.1	Random Sampling	1, 2	235
38	8.2	Some Important Statistics	5, 8, 11, 12, 15	235
39	8.3-8.4	Data Display (read on own, SAS)		
		Sampling Distribution (SAS)		
40		Computer workshop	SAS Lab	
41	8.5	Sampling Distributions of Means	18, 20, 23, 25, 30	251
42	8.6	Sampling Distribution of Variance	39, 41bc, 43, 44	265

43	8.7	t-distribution	46, 47, 48, 50, 52	265
44	8.8	F-distribution	53, 54, 55	265
45		Review	59, 64	266

¹Skip continuous case for joint probability distribution in Chapters 3 & 4.

²Section 4.2 lacks problems to compute the mean and variance of continuous random variables.

APPENDIX E: Conversion of STT 361/561, Applied Statistics II

Syllabus (for the session that meets three hours a week for 15 weeks)
(Revised May 2009)

Textbook: Probability & Statistics for Engineers & Scientists, 8th Edition, 2007, Walpole, Myers, Myers and Ye.

Day	Section	Topic	Homework	Page
1	9.1-3	Estimation	1, 2, 3	285
2	9.4	Confidence interval for mean	4, 5	285
3	9.5--6	Confidence interval, standard error Prediction interval	6, 7, 8, 10, 12, 14	286
4	9.8	Difference between two means	36, 38, 40, 42, 43, 46	297
5	9.9	Paired observations	44, 4	298
6	9.10	A proportion	52, 54, 56, 58, 60, 6, 64	304
7	9.11	Difference between two proportions	66, 68, 70	305
8	9.12--13	Estimating variance Ratio of two variances	71, 72, 73 77, 78, 79	310 310
9		Review	88, 89, 91, 93, 95^1	310
10	10.1-2	Testing hypotheses	1, 2	336
11	10.3-4	One- and two-tailed test P-values	14, 15, 16	337
12	10.5-7	Single sample tests	19, 21, 23, 25, 29	357
13	10.8	Tests on two means	27, 30, 31, 35, 38, 43, 54	358
14	10.9	Choice of sample size	48, 50, 51, 52	361
15	10.11	Tests on a single proportion	55, 57	366
16	10.12	Tests on two proportions	63, 65	366
17	10.13	Tests on variances	67, 69, 71, 73, 76, 77	371
18-19	10.14-15	Goodness of Fit, Independence tests	79, 80, 83, 90, 91, 92, 93	383
20		Review	101, 102, 105	385
21		Exam on Chapter 9 and 10		
22	11.1-3	Simple linear regression	2, 3, 5, 7	398
23	11.4	Least squares estimators		
24	11.5	Inferences on regression coefficients	18, 19, 21, 23	413
25	11.6	Prediction	24, 27, 28	413
26	11.12	Correlation	49, 50, 52	438
27	12.1-2	Introduction of MLR and Estimation		
28	12.3	Linear regression using matrices		
29	12.4	Properties of lse		
30	12.5	Inferences in MLR		
31	13.1-2	Analysis of variance	5, 7	523
32	13.3	One-way anova		
33	13.5	Single comparisons	12, 13	533
34	13.6	Multiple comparisons	15, 17, 23	534
35	13.7	Comparing with a control		
36	13.13	Random effects model		
37		Review	54, 58b, 63	567
38	14.1-2	Two-way Anova		
39	14.3	Two-way Anova	1, 8	587
40	14.5	Random and mixed effects model		
41	16.1	Nonparametric tests		
42	16.2	Signed-rank test		
43	16.3	Wilcoxon rank-sum test		
44	16.4	Kruskal-Wallis test		

^1 Find a 90% confidence interval, instead of a 95% confidence interval, in order to use F table

APPENDIX F: Statistical Consulting STT 791

Course Information

Course: STT 791 Statistical Consulting

Prerequisites: STT 662, STT 667, and instructor permission

Reading

Requirements: 1. *Statistical Consulting Center (SCC)*

Handouts

2. *Your Statistical Consultant*, by Rae Newton and Kjell Rudestam (this text can be borrowed from the SCC library)

3. Supplementary Notes

Instructor: Harry J. Khamis

130 MM Building; 775-2433; Fax 775-2081;

email: harry.khamis@wright.edu

http://www.math.edu/People/Harry_Khamis/index.html

Office Hours: ***** drop in or by appointment *****

Grading Criteria: Satisfactory performance on the final exam and consulting activities. in

Throughout the quarter, you will engage in a variety of statistical consulting activities. All of your work will be done under the supervision of a professional consultant. You are required to keep a

"consulting portfolio" documenting your activities in the SCC. The final version of this document should be only one page, listing the clients that you worked with and the general activities that you engaged in. I will review this portfolio at the end of the quarter; it will help me assess your work in the SCC.

The final exam is given at the end of the quarter; it is closed book, but you must have a calculator. The final exam will be based on the reading materials and on your experiences in the SCC.

Course Syllabus

This course combines elements of an independent reading course and a practicum. Throughout this quarter you will be performing various consulting duties under the supervision of a professional statistical consultant in the Statistical Consulting Center (SCC). You will be asked to attend initial consulting meetings, write initial consulting reports, manage data, perform analyses, communicate with the client, write final consulting reports, etc. The goal of this course is for you to learn about, and experience, statistical consulting. In addition to technical knowledge (most of which has been acquired through your previous coursework), you will be called upon to use your communication skills, teaching skills, and your interpersonal and social skills.

You are required to attend a weekly staff meeting and to check your email and SCC mailbox regularly. Keep careful track of the hours that you spend working for the SCC, since this documentation is needed for the monthly time reports.

In addition to the consulting experience, there is a required reading assignment for this course, as follows.

1. Your Statistical Consultant

You are to read the entire book EXCEPT:

- (i) pages 77 (starting with "HOW DO I INTERPRET AN EFFECT SIZE")
to page 96.
- (ii) Page 214 (starting with the fourth full paragraph, "To get a
more complete understanding ...") to page 217.
- (iii) Page 222, (starting with the second full paragraph, "Porter
and Raudenbush ...") to page 225.

- (iv) Page 252 (starting with “WHAT ARE STEPWISE AND HIERARCHICAL ...”) to page 262.
- (v) Page 285 (starting with the second full paragraph, “Meta-analysis is not without its critics ...”) to page 290, middle of page.

NOTE: FOR A SEMESTER COURSE, THIS READING COMPONENT MAY BE EXPANDED.

2. SUPPLEMENTARY NOTES TO ACCOMPANY THE TEXT

These notes point out errors in the text, and provide additional “rules of thumb” for the consulting statistical scientist.

You are strongly urged to set up a regimen for completing the above reading assignments within the ten-week period. Just as in an independent reading course, it is your responsibility to complete the required reading independently.

NOTE: FOR A SEMESTER COURSE, ADDITIONAL SUPPLEMENTARY NOTES MAY BE ADDED.

Finally, you will be scheduled to attend a shortcourse in SAS techniques to bolster your SAS skills.

Feel free to come and see me whenever you have questions.

OPTIONAL:

1. There are four videotapes in the SCC library, each about 30 minutes long, which focus on nontechnical aspects of statistical consulting – how to ask questions, how to communicate effectively, how to run a successful consulting meeting, how to work within a team, etc. You may check these videotapes out of the SCC library to watch at home, or arrangements can be made for you to view them in the SCC library. The material in these videotapes will not be included on the final exam.
2. Article: What Educated Citizens Should Know About Statistics and Probability, by Jessica Utts, *The American Statistician* **57**, 2003.

Appendix G: Comprehensive Core Topics: Quarter Version

Core Topics for Theory of Statistics (STT 661-662)

- Definition of Probability: properties (sample space, events, compound events, mutually exclusive, independence, Additive Rule, Multiplication Rule, Bayes Rule), counting techniques, conditional probability
- Random Variables and Distributions: discrete (Binomial, Multinomial, Hypergeometric, Negative Binomial, Poisson, Geometric), continuous (uniform, normal, exponential, gamma, beta, Weibull, t, F, chi-square), expected values, MGF, location and scale parameters
- Joint Distributions: independence, conditional distributions, correlation, conditional expectation
- Functions of Random Vectors: transformation methods, sums of random variables, order statistics
- Limiting Distributions: convergence in distribution, CLT, asymptotically normal distributions, properties of weak convergence (Slutsky)
- Statistics: sampling distributions, point estimation and confidence intervals, evaluation of estimators-UMVUE, Cramer-Rao lower bound, sufficiency and completeness, exponential class
- Hypothesis Testing: power, one-sided and two-sided tests, most powerful tests, UMP tests, Neyman-Pearson Lemma, likelihood ratio tests

Core Topics for Statistical Methods (STT 666-667)

- Graphical Display of Data: Interpretation of histograms, stem-and-leaf plots, scatterplots, boxplots.
- One- and Two-Sample Inference: z and t tests and confidence intervals for two independent samples and paired data. Wilcoxon signed-rank test and Mann-Whitney/Wilcoxon rank test; power, sample size.
- Categorical Data Analysis: One- and Two-dimensional tables; chi-squared tests and Fisher's exact test.
- Simple Linear Regression: Least squares, inference regarding slope and intercept, confidence and prediction intervals.
- Diagnostic and Remedial Measures: Residual plots, residual diagnostics, transformations.
- Multiple Regression Model: Parameter estimation, overall F-test, tests for a single parameter and for subsets of parameters, coefficient of determination, general linear test approach, multicollinearity, lack of fit test, qualitative predictor variables, interaction regression models, residual analysis.
- Matrix Approach to Linear Regression: Random vectors and matrices; matrix notation for regression, general linear regression model; matrix results for least squares estimators, residuals, and fitted values; hat matrix.
Single Factor ANOVA: Relation between ANOVA and regression, assumptions (e.g., homoscedasticity), fitting ANOVA model, F test for equality of factor levels, ANOVA table, analysis of factor levels (Tukey, Scheffé, and Bonferroni), residual analysis, transformations, nonparametric rank test.

- Two-Factor ANOVA: Interpreting interaction terms and main effects, ANOVA table, F tests, residual analysis, regression approach to two-factor ANOVA, analysis of factor effects in two-factor studies (Tukey, Scheffé, and Bonferroni), one observation per cell, unequal sample sizes in two-factor studies.
- Analysis Covariance (*For students taking STT 667 Winter quarter 2003 or later*)
- (Optional) More Recent Methods: Logistic regression, bootstrapping, randomization/permutation tests.
- **Note:** Use of SAS and interpreting SAS output is done throughout the course.

Core Topics for Design of Experiments (STT 669)

- Basic design principles: randomization, replication, blocking, factorial design
- Randomized complete block designs: data plot, ANOVA, multiple comparisons
- Single-factor ANOVA for random effects: estimation and testing of variance components
- Multi-factor experiments
- Mixed- and random-effects models, including repeated measures
- Nested factors and split-plot designs
- (Optional) Incomplete block designs: existence, construction, estimability, connectivity, data plot, ANOVA, multiple comparisons
- Confounding and partial confounding for 2^k factorial experiments: design, analysis
- $2^{(k-p)}$ fractional factorial designs: design, analysis
- Note: Use of SAS and interpreting SAS output is done throughout the course

Core Topics for Theory of Linear Model (STT 761)

- Random Vectors and Distributions: covariance matrices, linear and quadratic forms, distribution of AY , where A is a matrix, independence of quadratic forms, Cochran-Fisher theorem
- The Linear Model: least squares estimates, full rank models, less than full rank models (conditional inverse, reparametrization), estimability in full and less than full rank models, Gauss-Markov theorem, BLUE
- Hypothesis Testing: EY in a linear subspace, $A*b = C$ for a matrix A and vector C , power of test (definition and sample size considerations)
- Interval Estimation: confidence intervals, prediction intervals, simultaneous confidence intervals (Scheffe, Bonferroni, Tukey)
- Examples: multiple regression, one-way ANOVA, two-way ANOVA

<http://www.math.wright.edu/statistics/programs/GSH/08coreTopics.htm> - Page%20Top

Appendix H: A list of math requirements by programs within CoSM (compiled by Richard).

Biology

Biological Sciences/BS: MTH 228, STT 264, 265 or MTH 229, 230, 231

Exercise Biology/BS: MTH 130, STT 264, 265

Clinical Laboratory Science/BS: MTH 128, STT 264, 265

Pre-Med Option/BS: MTH 228, STT 264, 265 or MTH 229, 230, 231

Bioinformatics Option/BS: MTH 229, 230, 253, 257

Biology/Chemistry Dual Major/BS: MTH 229, 230, 231

Biological Sciences/BA: MTH 130, STT 264, 265 or MTH 145

Chemistry

Chemistry/BS: MTH 229, 230, 231

Chemistry/BS - Pre-Med Option: MTH 229, 230, 231

Chemistry/BA: MTH 229, 230, 231

Earth and Environmental Sciences

EES/BS - Earth Sciences option: MTH 229, 230, electives include MTH 231, STT 264, STT 265, STT 360, STT 361

EES/BS - Environmental Sciences option: MTH 228, STT 264, STT 265

EES/BA - Earth Sciences option: 10 hours MTh 128 or higher

EES-Education/BA - Earth Science/Chemistry: MTH 229, 230, 231

EES-Education/BA - Life & Earth Sciences: MTH 228, STT 264

EES-Education/BA - Earth & Space Sciences: MTH 228, STT 264

Physics

Physics/BS: MTH 229, 230, 231, 232, 233, 253, 332, 333

Physics/BS- Computing option: MTH 229, 230, 231, 232, 233, 253, 257, 332, 333

Physics/BA: MTH 229, 230, 231, 232, 233, 253

Physics Education/BA (all options): MTH 229, 230, 231, 232, 233, 253

Engineering Physics/BS: MTH 229, 230, 231, 232, 235

Psychology

Psychology/BS: MTH 128 or 129, STT 160

Psychology/BA: MTH 126 or 127, STT 160

Other

Integrated Science for Educators/BS: MTH 229, MTH 230, STT 160

Appendix I: Math/Stat Requirements for CECS degrees

Biomedical Engineering

Biomedical Engineering/BS – A:Traditional: MTH 229, 230, 231, 235,
(ISE 301)

Biomedical Engineering/BS – B:PreMed: MTH 229, 230, 231, 232, (ISE 301)

Computer Engineering

Computer Engineering/BS (all options): MTH 229, 230, 231, 233 or 235,
253,

MTH 257, STT 360 or STT 363 or ISE 301

Computer Science

Computer Science/BS – (all options): MTH 229, 230, 231, 253, 257,
STT 360 or STT 363 or ISE 301

Computer Science/BA – (all options): MTH 228, 257, STT 160

Electrical Engineering

Electrical Engineering/BS: MTH 229, 230, 231, 232, 235, STT 363 or ISE
301

Engineering Physics

Engineering Physics/BS: MTH 229, 230, 231, 232, 235

Industrial and System Engineering

Industrial and System Engineering/BS: MTH 229, 230, 231, 232, 235,
(ISE 301)

Mechanical and Materials Engineering

Mechanical Engineering/BS: MTH 229, 230, 231, 232, 235, STT 363

Materials Science and Engineering/BS: MTH 229, 230, 231, 232, 235

Conversion from Quarters to Semesters: Statistics Courses

Conversion factor: # Semester Hours = $(2/3)(\# \text{ Quarter Hours})$

Course	Quarter System	Semester System
STT 160	1 Quarter 5 Credit Hours	1 Semester 4 credit hours (?) Karen Brackenridge
STT 264/265	2 Quarters 4 & 4 Credit hours	2 Semesters 3 & 3 credit hours Should we retain the lab?
STT 363	1 Quarter, 3 credit hours	1 semester, 3 credit hours
STT 367 (Intro SAS)	2 Credit Hours	Delete?
STT 567		

STT 386 (Reading)	Variable	Variable
STT 396 (Topics)	Variable	Variable
STT 360/361 (Appl Stats)	2 Quarters	2 Semesters
STT 560/561	4 & 4 credit hours	3 & 3 Credit hours
STT 401 (Nonparametric)	1 Quarter	Delete? Incorporate some of the primary methods into our methods course?
STT 601	4 Credit Hours	
STT 411 (Time Series)	1 Quarter	1 Semester
STT 611	4 Credit Hours	3 Credit hours
STT 424 (Quality Control)	1 Quarter	Combine with another course?
STT 624	4 Credit Hours	
STT 426 (Survival)	1 Quarter	1 Semester
STT 626	4 Credit Hours	3 Credit Hours
		Delete? When did we last teach this course?

STT 428 (Queueing Thry)	1 Quarter	
STT 628	4 Credit Hours	1 Semester
		3 Credit Hours
STT 430 (Biostats)	1 Quarter	(This may be a required course for certain majors)
STT 630	4 Credit Hours	
ES706		
BMS991-05		Combine STT 661, 662, and 761 into a two semester sequence of theory and linear models.
STT 461/462 (Theory)	2 Quarters	
STT 661/662	4 & 4 Credit hours	Combine STT 666, 667 and 469 into a two semester methods & design sequence
STT 761 (Linear Models)	1 Quarter, 4 Credit Hours	4 & 4 Credit Hours
STT 466/467 (Methods)	2 Quarters	
STT 666/667	4 & 4 Credit hours	Variable
STT 469 (Design)	1 Quarter, 4 Credit Hours	
STT 486 (Reading)	Variable	1 Semester
STT 586		3 Credit Hours?
		Needs to be coordinated with MTH 491/492

<p>STT 492 (Capstone)</p>	<p>1 Quarter 3 Credit Hours</p>	<p>Variable</p>
<p>STT 496 (Topics) STT 596</p>	<p>Variable</p>	<p>1 Semester 3 Credit Hours (Can we combine this course with our STT 630 course?)</p>
<p>STT 520 (Biostat Health) CMH 620 Harry: Does this still have a STT listing?</p>	<p>1 Quarter 4 Credit Hours</p>	<p>Delete?</p>
<p>STT 568 Design of Sample Surveys (?)</p>	<p>1 Quarter 4 Credit hours</p>	<p>How do we convert this?</p>
<p>STT 591 (Methods for Nursing Research)</p>	<p>1 Quarter ½ Credit hour</p>	<p>2 Semester Sequence 3 & 3 Credit Hours</p>

<p>STT 646 (Methods for Engineers)</p> <p>STT 647</p>	<p>2 Quarter Sequence</p> <p>4 & 4 Credit Hours</p>	<p>1 Semester</p> <p>3 Credit Hours</p>
<p>STT 464 (Computational Statistics)</p> <p>STT 646</p> <p>BMS 664</p>	<p>1 Quarter</p> <p>4 Credit Hours</p>	<p>Variable</p> <p>Variable</p>
<p>STT 686 (Reading)</p>		<p>1 Semester</p> <p>3 Credit Hours</p>
<p>STT 696 (Topics)</p>	<p>Variable</p>	
<p>STT 702 (Stochastic)</p>	<p>Variable</p> <p>1 Quarter</p> <p>4 Credit Hours</p>	<p>1 Semester</p> <p>3 Credit Hours</p> <p>Modifications based on discussion with ES program</p>
<p>STT 714 (Environmental)</p> <p>ES 714</p> <p>BMS 991</p>	<p>1 Quarter</p> <p>4 Credit Hours</p>	<p>Can we convert this to a 400/600-level equivalent class so undergraduates and other</p>

<p>STT 721 (Sampling)</p>	<p>1 Quarter 4 Credit Hours</p>	<p>degree students can take it? Should this class be combined with another course?</p> <p>1 Semester 3 Credit Hours</p> <p>1 Semester 3 Credit Hours</p>
<p>STT 740 (Categorical)</p>	<p>1 Quarter 4 Credit Hours</p>	<p>SEE ABOVE</p>
<p>STT 744 (Multivariate)</p>	<p>1 Quarter 4 Credit Hours</p>	<p>1 Semester 3 Credit Hours</p>
<p>STT 761 (Theory Linear Models)</p>	<p>SEE ABOVE</p>	<p>Have we taught this class before?</p>
<p>STT 762 (Topics in Linear Models)</p>		

		1 Semester
	1 Quarter	3 Credit Hours
STT 764 (Topics in Experimental Design)	4 Credit Hours	Variable
	1 Quarter	
STT 767 (Regression)	4 Credit Hours	Variable
		Variable
STT 786 (Reading)	1 Quarter	Variable
	4 Credit Hours	
STT 791 (Consulting)	Variable	
STT 796 (Topics)		
	Variable	
STT 899		
	Variable	
	Variable	

NOTES:

- What are the essential topics for our graduate students that are not part of the theory and methods sequence currently?
- What is a full-time load for a graduate student? 3 courses, 3 credit hours each?
- Can we implement a 5-year master degree for our statistics undergraduates?
- Can we combine the generalized linear models material in STT 762 (e.g. logistic regression) with categorical data analysis?
- **New Course Idea:** A general education statistical thinking course with only an algebra requirement, freshman level. The idea is to cover some basic ideas of statistics so that our students can get exposure to statistics early on, before their junior year. Also, make the course appealing to analytically inclined students throughout the university.
- **New Course Idea:** Advanced Biostatistics. Our current biostatistics is basically an accelerated STT 264/5 course with SAS, some sample size/power material, and a little nonparametrics. We currently do not offer courses that cover modern advanced topics in biostatistics that have been developed over the last decade or two such as: missing data techniques (e.g. multiple imputation), propensity scores, Intention to Treat (ITT), non-compliance, instrumental variables, longitudinal models, GEE,