

# STATISTICS (STAT)

Updated June 6, 2013

**Note:** The department/program code STAT replaces the former code 53. Students cannot hold credit in STAT-xxxx and the former 53.xxxx having the same course number (e.g., STAT-1201(6) and 53.1201(6)).

**Co-Chairs:** O.R. Oellermann, T. Visentin; Professor: H. A. Howlader; Associate Professors: J. Babb; M. Ghahramani; Assistant Professor: S. Hossain; Instructors: B. Bector, S. Khan

## DEGREES/PROGRAMS OFFERED

**3-Year BA**

**3-Year BSc**

**3-Year BSc (Business Stream)**

**4-Year BA**

**4-Year BSc**

**4-Year BSc (Business Stream)**

**Minor**

## INTRODUCTION

Statistics is the science of data collection, summarization, analysis, and interpretation. A central issue of statistics is how to make inferences about populations of interest, using data obtained from samples or designed experiments. Statistical techniques are applied extensively in virtually every branch of the physical, social, biological, and human sciences. Statistical methodologies and principles of inference are based heavily upon statistical theory, which, in turn has an essential underlying mathematical foundation. Computer software is typically used for statistical analysis of large data sets.

The Statistics Department offers 3-Year and 4-Year BA or BSc degree programs. Students pursuing a 3-year or 4-year BSc in Statistics also have the opportunity to take a Business Stream (see the "Science with a Business Stream" section of this Course Calendar).

As a student of Statistics, one may study theoretical statistics and probability theory, which focuses on the logical development of statistical methods. One may also take courses which focus on the application of statistical methodology to data sets from a variety of disciplines. The Statistics Department also offers courses in simulation, operations research, and stochastic modeling.

Students who are not Statistics majors will find that a background in statistics is valuable in many areas. Students considering graduate study in various fields may benefit from many of our applied courses. For some programs, certain Statistics courses are required. An understanding of statistical concepts is important for numerical literacy.

Statisticians often work collaboratively with specialists in other fields to develop methodologies and analyze data for research studies. They may assist economists in the analysis of consumer prices, or with the design and analysis of large-scale socioeconomic surveys. Statisticians may help biologists, chemists and engineers in the design and analysis of experiments, or work with medical researchers to test the effectiveness of new drugs. They may also work with researchers in fields such as agriculture, anthropology, climatology, education, epidemiology, and geography. Other opportunities can be found in finance, marketing, and quality management. Many statisticians find employment with private corporations and government agencies, including Statistics Canada.

## REQUIREMENTS FOR A 3-YEAR BA/BSc IN STATISTICS

**ADMISSION REQUIREMENT** Students must consult with a member of the Department in planning their course of study.

**GRADUATION REQUIREMENT** 90 credit hours

### RESIDENCE REQUIREMENT

Degree: Minimum 30 credit hours  
Major: Minimum 18 credit hours

### GENERAL DEGREE REQUIREMENT

Humanities: 12 credit hours in Humanities  
Writing: 3 credit hours of Academic Writing  
Maximum Introductory Courses: Students may use a maximum of 42 credit hours at the 1000 level. Of these, a maximum of 6 credit hours may be below the 1000 level.  
Distribution: Minimum three (3) credit hours from each of five (5) different subjects.

**MAJOR REQUIREMENT**

Single Major  
Double Major

Minimum 30 credit hours/Maximum 48 credit hours.

Minimum 30 credit hours in Statistics and specified number of credit hours in the other department/program.

Required courses:

Core Courses

<b>STAT-1301(3)</b>	Statistical Analysis I <u>AND</u>
<b>STAT-1302(3)</b>	Statistical Analysis II <u>OR</u> the former STAT-1201(6) Introduction to Statistical Analysis <u>OR</u>
<b>STAT-1501(3)</b>	Elementary Biological Statistics I <u>AND</u>
<b>STAT-2001(3)</b>	Elementary Biological Statistics II or the former STAT-1601(3) Elementary Biological Statistics II
<b>STAT-2301(3)</b>	Survey Sampling I
<b>STAT-2903(3)</b>	Introduction to Statistical Computing
<b>STAT-3103(3)</b>	Statistics in Research I
<b>STAT-3104(3)</b>	Statistics in Research II
<b>STAT/MATH-3611(3)</b>	Mathematical Statistics I
<b>STAT/MATH-3612(3)</b>	Mathematical Statistics II

6 credit hours from:

<b>STAT-2102(3)</b>	Business and Management Statistics
<b>STAT-2103(3)</b>	Intermediate Biological Statistics
<b>STAT-2104(3)</b>	Nonparametric Statistics
<b>STAT-2501(3)</b>	Statistical Quality Control
<b>STAT-3102(3)</b>	Applied Multivariate Methods
<b>STAT-3105(3)</b>	Time Series and Forecasting
<b>STAT-3401(3)</b>	Stochastic Processes
<b>STAT/MATH-3412(3)</b>	Introduction to Operations Research
<b>STAT-3501(3)</b>	Simulation

Combined Major:

Minimum 48 credit hours from 2 different majors with not less than 18 credit hours from each major subject.

Prescribed courses:

To be determined in consultation with the Department.

Students who have not obtained a grade of at least C in both **STAT-1301(3)** Statistical Analysis I AND **STAT-1302(3)** Statistical Analysis II or the former **STAT-1201(6)** Introduction to Statistical Analysis (OR **STAT-1501(3)** Elementary Biological Statistics I AND **STAT-2001(3)** Elementary Biological Statistics II (or the former **STAT-1601(3)** Elementary Biological Statistics II) are advised not to proceed in a Statistics major.

**MATH-2105(3)** Intermediate Calculus I and **MATH-2106(3)** Intermediate Calculus II or the former **MATH-2101(6)** Intermediate Calculus is a prerequisite for **STAT/MATH-3611(3)** (formerly STAT-3201(3)) Mathematical Statistics I.

**MATH-1201(3)** Linear Algebra I AND **MATH-2203(3)** Linear Algebra II or the former **MATH-2201(6)** Linear Algebra is a prerequisite for **STAT-3102(3)** Applied Multivariate Methods.

**MATH-1201(3)** Linear Algebra I AND **MATH-2203(3)** Linear Algebra II or the former **MATH-2201(6)** Linear Algebra is a prerequisite for **STAT/MATH-3412(3)** Introduction to Operations Research.

Students are advised to take **MATH-1103 (3)** Introduction to Calculus I AND **MATH-1104 (3)** Introduction to Calculus II or **MATH-1101(6)** Introduction to Calculus in their first year, and **MATH-2105(3)** Intermediate Calculus I and **MATH-2106(3)** Intermediate Calculus II or the former **MATH-2101(6)** Intermediate Calculus, **MATH-1201(3)** Linear Algebra I AND **MATH-2203(3)** Linear Algebra II or the former **MATH-2201(6)** Linear Algebra in their second year.

Students planning to go on to graduate studies are advised to consult with the Department before choosing second year courses.

Students planning to seek employment upon graduation with a Statistics major are strongly advised to take **STAT-2103(3)**

Intermediate Biological Statistics as part of the major, and to consider taking as many as possible of the following courses in Applied Computer Science or Mathematics: **MATH-3701(3)**, **ACS-1903(3)**, **ACS-1904(3)**.

## REQUIREMENTS FOR THE 3-YEAR BSc STATISTICS WITH A BUSINESS STREAM

Students must complete the requirements of the 3-year BSc in Statistics degree (see previous section) and the set of core courses indicated in the "Science with a Business Stream" section of the Calendar.

## REQUIREMENTS FOR A 4-YEAR BA/BSc IN STATISTICS

**ADMISSION REQUIREMENT**

30 credit hours previously completed in BA/BSc

**GRADUATION REQUIREMENT**

120 credit hours

**RESIDENCE REQUIREMENT**

Degree: 60 credit hours  
Major: 30 credit hours

### GENERAL DEGREE REQUIREMENT

Humanities: 12 credit hours in Humanities  
Social Sciences (BA only): 12 credit hours  
Writing: Minimum three (3) credit hours of Academic Writing.  
Maximum Introductory Courses: Students may use a maximum of 42 credit hours at the 1000 level. Of these, a maximum of 6 credit hours may be below the 1000 level.  
Distribution: Minimum three (3) credit hours from each of five (5) different subjects.

### MAJOR REQUIREMENT

Major: Minimum 48 credit hours/Maximum 66 credit hours.  
Double Major: Minimum 48 credit hours in each Major as specified by the department/program.  
Cognates: (BA only) Minimum 18 credit hours/Maximum 36 credit hours.  
Consult the Department for acceptable cognate courses.

#### Required Courses:

##### Core Courses

**STAT-1301(3)** Statistical Analysis I AND  
**STAT-1302(3)** Statistical Analysis II OR the former STAT-1201(6) Introduction to Statistical Analysis OR  
**STAT-1501(3)** Elementary Biological Statistics I AND  
**STAT-2001(3)** Elementary Biological Statistics II or the former STAT-1601(3) Elementary Biological Statistics II  
**STAT-2301(3)** Survey Sampling I  
**STAT-2903(3)** Introduction to Statistical Computing  
**STAT-3103(3)** Statistics in Research I  
**STAT-3104(3)** Statistics in Research II  
**STAT/MATH-3611(3)** Mathematical Statistics I  
**STAT/MATH-3612(3)** Mathematical Statistics II  
**STAT-4202(3)** Statistical Inference

18 credit hours from:

**STAT-2102(3)** Business and Management Statistics  
**STAT-2103(3)** Intermediate Biological Statistics  
**STAT-2104(3)** Nonparametric Statistics  
**STAT-2501(3)** Statistical Quality Control  
**STAT-3102(3)** Applied Multivariate Methods  
**STAT-3105(3)** Time Series and Forecasting

**STAT-3401(3)** Stochastic Processes  
**STAT/MATH-3412(3)** Introduction to Operations Research

3 credit hours from:

**STAT-4401(3)** Probability Theory  
**STAT-4601(3)** Statistical Design of Experiments

**MINOR REQUIREMENT:** 18 credit hours, at least 12 credit hours of which are above the first-year level, and at least 12 credit hours of which are taken at The University of Winnipeg

Residence Requirement: Minimum 12 credit hours in the Minor subject

Required courses: STAT-1301(3) and STAT-1302(3) (or the former STAT-1201(6))  
OR both STAT-1501(3) and STAT-2001(3) (formerly STAT-1601(3))  
STAT-2301(3) Survey Sampling

Any other nine credit hours at the 2000 level or higher (not including STAT-2001(3))  
Restrictions: Students cannot declare the same subject as a Major and a Minor.

Students who have not obtained a grade of at least C in both **STAT-1301(3)** Statistical Analysis I AND **STAT-1302(3)** Statistical Analysis II or the former **STAT-1201(6)** Introduction to Statistical Analysis (OR **STAT-1501(3)** Elementary Biological Statistics I AND **STAT-2001(3)** Elementary Biological Statistics II (or the former **STAT-1601(3)** Elementary Biological Statistics II) are advised not to proceed in a Statistics major.

**MATH-2105(3)** Intermediate Calculus I and **MATH-2106(3)** Intermediate Calculus II or the former **MATH-2101(6)** Intermediate Calculus is a prerequisite for **STAT/MATH-3611(3)** (formerly STAT-3201(3)) Mathematical Statistics I.

**MATH-1201(3)** Linear Algebra I AND **MATH-2203(3)** Linear Algebra II or the former **MATH-2201(6)** Linear Algebra is a prerequisite for **STAT-3102(3)** Applied Multivariate Methods.

**MATH-1201(3)** Linear Algebra I AND **MATH-2203(3)** Linear Algebra II or the former **MATH-2201(6)** Linear Algebra is a prerequisite for **STAT/MATH-3412(3)** Introduction to Operations Research.

Students are advised to take **MATH-1103 (3)** Introduction to Calculus I AND **MATH-1104 (3)** Introduction to Calculus II or **MATH-1101(6)** Introduction to Calculus in their first year, and **MATH-2105(3)** Intermediate Calculus I and **MATH-2106(3)** Intermediate Calculus II or the former **MATH-2101(6)** Intermediate Calculus, **MATH-1201(3)** Linear Algebra I AND **MATH-2203(3)** Linear Algebra II or the former **MATH-2201(6)** Linear Algebra in their second year.

Students planning to go on to graduate studies are advised to consult with the Department before choosing second year courses.

Students planning to seek employment on graduation with a Statistics major are strongly advised to take **STAT-2103(3)**

Intermediate Biological Statistics as part of the major, and to consider taking as many as possible of the following courses in Applied Computer Science or Mathematics: **MATH-3701(3)**, **ACS-1903(3)**, **ACS-1904(3)**.

Combined Major: Minimum 60 credit hours from 2 different majors with not less than 24 credit hours from each major subject.

Prescribed courses: To be determined in consultation with the Department.

## REQUIREMENTS FOR THE 4-YEAR BSc STATISTICS WITH A BUSINESS STREAM

Students must complete the requirements of the 4-year BSc in Statistics degree (see previous section) and the set of core courses indicated in the "Science with a Business Stream" section of the Calendar.

### REQUIREMENTS FOR A MINOR IN STATISTICS

Degree:	Students must complete a 4-year degree program in order to be eligible to hold the Minor.
Minor:	18 credit hours in the Minor subject, with a minimum of 12 credit hours above the 1000-level
Residence Requirement:	Minimum 12 credit hours in the Minor subject
Required courses:	STAT-1301(3) and STAT-1302(3) (or the former STAT-1201(6)) OR both STAT-1501(3) and STAT-2001(3) (formerly STAT-1601(3)) STAT-2301(3) Survey Sampling Any other nine credit hours at the 2000 level or higher (not including STAT-2001(3))
Restrictions:	Students cannot declare the same subject as a Major and a Minor.

### GENERAL INFORMATION

#### Prerequisites

Pre-Calculus Mathematics 40S or Applied Mathematics 40S.

## COURSE LISTINGS

<b>STAT-1301(3)</b>	Statistical Analysis I	<b>STAT-3103(3)</b>	Statistics in Research I
<b>STAT-1302(3)</b>	Statistical Analysis II	<b>STAT-3104(3)</b>	Statistics in Research II
<b>STAT-1501(3)</b>	Elementary Biological Statistics I	<b>STAT-3105(3)</b>	Time Series and Forecasting
<b>STAT-2001(3)</b>	Elementary Biological Statistics II	<b>STAT-3401(3)</b>	Stochastic Processes
<b>STAT-2102(3)</b>	Business and Management Statistics	<b>STAT/MATH-3412(3)</b>	Introduction to Operations Research
<b>STAT-2103(3)</b>	Intermediate Biological Statistics	<b>STAT-3501(3)</b>	Simulation
<b>STAT-2104(3)</b>	Nonparametric Statistics	<b>STAT/MATH-3611(3)</b>	Mathematical Statistics I
<b>STAT-2301(3)</b>	Survey Sampling I	<b>STAT/MATH-3612(3)</b>	Mathematical Statistics II
<b>STAT-2501(3)</b>	Statistical Quality Control	<b>STAT-4202(3)</b>	Statistical Inference
<b>STAT-2903(3)</b>	Introduction to Statistical Computing	<b>STAT-4401(3)</b>	Probability Theory
<b>STAT-3102(3)</b>	Applied Multivariate Methods	<b>STAT-4601(3)</b>	Statistical Design of Experiments

## COURSE DESCRIPTIONS

Students are advised to ensure that currently listed courses do not duplicate material studied previously under different course numbers.

**STAT-1301(3) STATISTICAL ANALYSIS I (Le3)** This course introduces students in the natural, physical, social and human sciences to elementary statistical analysis and its applications. Topics include descriptive statistics, probability theory including counting techniques, discrete random variables and their expected values and variances, normal distribution and applications, sampling distributions and estimation of parameters.

**PREREQUISITES:** Pre-Calculus Mathematics 40S or Applied Mathematics 40S.

**RESTRICTIONS:** Students may not receive credit for more than one of STAT-1301(3), STAT-1501(3) or the former STAT-1201(6)

**STAT-1302(3) STATISTICAL ANALYSIS II (Le3)** This course is an extension of STAT-1301(3). Topics includes review of sampling distributions and estimation of parameters; statistical testing and confidence intervals using  $z$ ,  $t$ ,  $F$ , and chi-square distributions; analysis of variance; goodness-of-fit tests and contingency tables; linear regression and correlation; and non-parametric procedures.

**PREREQUISITES:** STAT-1301(3) or STAT-1501(3)

**RESTRICTIONS:** Students may not receive credit for more than one of STAT-1302(3), STAT-2001(3), the former STAT-1201(6), or the former STAT-1601(3).

**STAT-1501(3) ELEMENTARY BIOLOGICAL STATISTICS I (Le3)** This is an elementary course providing students in biological and health sciences with an introduction to statistical analysis of data and the making of inferences about them. Topics include: descriptive statistics, probability and probability distributions, and tests of hypotheses and estimation. Applications are drawn from biology, chemistry and other sciences.

**PREREQUISITES:** Pre-Calculus Mathematics 40S or Applied Mathematics 40S.

**RESTRICTIONS:** A student may not receive credit for more than one of STAT-1301(3), STAT-1501(3) or the former STAT-1201(6)

**STAT-2001(3) ELEMENTARY BIOLOGICAL STATISTICS II (Le3)** This course is an extension of STAT-1501(3) for further aspects of statistical analysis. Topics include a review of one sample statistical testing and confidence intervals;

two sample inferences; analysis of variance including contrasts and multiple comparisons; analysis of qualitative data based on chi-square distribution; regression and correlation analyses; and nonparametric procedures. Applications are drawn from biology, chemistry and other sciences.

**PREREQUISITES:** STAT-1501(3) or STAT-1301(3)

**RESTRICTIONS:** Students may not receive credit for more than one of STAT-1302(3), STAT-2001(3), the former STAT-1201(6), or the former STAT-1601(3).

### **STAT-2102(3) BUSINESS AND MANAGEMENT**

**STATISTICS (Le3)** This course surveys quantitative management science techniques used in both the private sector and government. The contents include classical decision-making, utility for money, statistical and Bayesian decision-making, decision trees, index numbers and their properties, elementary quality control, and decomposition of time series and seasonal and cyclical analysis. Emphasis will be on having students communicate effectively through essays and term projects.

**PREREQUISITE:** STAT-1302(3) or the former STAT-1201(6) or both STAT-1501(3) and STAT-2001(3) or the former STAT-1601(3).

### **STAT-2103(3) INTERMEDIATE BIOLOGICAL STATISTICS**

**(Le3)** This course provides students with the underlying concepts and techniques for applying biometrical procedures to problems arising in biological and medical research. Topics include basic experimental designs and models for one-factor analysis of variance, multiple comparison procedures, data transformations, introductory multiple linear regression analysis, analysis of count data, Poisson index of dispersion, inference about the Poisson parameter, analysis of proportions, analysis of covariance with one factor and one covariate, and biological assay (analysis of quantal response, probit and/or logit transformations, parallel line assays and slope-ratio assays. Logistic regression with one regressor variable may also be covered.

**PREREQUISITES:** STAT-1302(3) or the former STAT-1201(6) or both STAT-1501(3) and STAT-2001(3) or the former STAT-1601(3).

**STAT-2104(3) NONPARAMETRIC STATISTICS (Le3)** This course considers statistical methods for analysing data when the distribution of the population is unknown and/or the measurement is on a nominal, ordinal, or interval scale. The contents include inference based on the binomial distribution, the Mann-Whitney-Wilcoxon test, the Wilcoxon signed rank test, measures of association for ranked data, the Kruskal-Wallis and Friedman tests, and elements of contingency table analysis.

**PREREQUISITE:** STAT-1302(3) or the former STAT-1201(6) or both STAT-1501(3) and STAT-2001(3) or the former STAT-1601(3).

**STAT-2301(3) SURVEY SAMPLING I (Le3)** This course emphasizes practical aspects of conducting sample surveys. The four most common sample survey designs, simple random sampling, stratified random sampling, systematic sampling, and cluster sampling are examined. The course also deals with ratio and regression type estimators. Either MINITAB or SAS is used to analyze data. Note: This course is of interest not only to Statistics majors but also to students of Business, Economics, Sociology and other social sciences as well as Environmental Studies.

**PREREQUISITES:** STAT-1302(3) or the former STAT-1201(6) or both STAT-1501(3) and STAT-2001(3) or the former STAT-1601(3). or permission of instructor.

### **STAT-2501(3) STATISTICAL QUALITY CONTROL (Le3)**

This course deals with modern statistical techniques used in various branches of industry to control and improve quality of production. Special attention is given to the techniques most

widely used in business and manufacturing industries. The contents include common control charts, sampling inspection by attributes and by variables, sampling plans for continuous production, OC and ASN functions, and curtailed inspections.

**PREREQUISITES:** STAT-1302(3) or the former STAT-1201(6) or both STAT-1501(3) and STAT-2001(3) or the former STAT-1601(3).

### **STAT-2903(3) INTRODUCTION TO STATISTICAL**

**COMPUTING (Le3, La3)** Students with limited computer experience are introduced to the use of modern statistical computer packages for data management and data analysis. Specifically, students learn how to use the computer for testing of pseudorandom numbers, simulation of discrete and continuous random variables, bootstrapping, analysis of single and multiple samples, linear and nonlinear regression, and analysis of contingency tables. Particular attention is paid to the effects of departures from standard assumptions.

**PREREQUISITES:** STAT-1302(3) or the former STAT-1201(6) or both STAT-1501(3) and STAT-2001(3) or the former STAT-1601(3).or permission of instructor.

### **STAT-3102(3) APPLIED MULTIVARIATE METHODS (Le3)**

This course is designed to provide an introduction to an important area in statistics which deals with the analysis of three or more intercorrelated random variables. It covers the following topics: Euclidian vector spaces, vector projections and orthogonalization methods, quadratic forms and symmetric positive (semi) definite matrices and their eigen structures (eigenroots/vectors), the bivariate and multivariate normal probability functions, principal components analysis, canonical correlation analysis, and multi-group classification.

**PREREQUISITES:** STAT-1302(3) or the former STAT-1201(6) or both STAT-1501(3) and STAT-2001(3) or the former STAT-1601(3)., MATH-2203(3) or the former MATH-2201(6) or MATH-2203(3) (formerly MATH-2221(3))

**COREQUISITES:** STAT/MATH-3612(3) (formerly STAT-3202(3)).

**RESTRICTIONS:** A student may not receive credit for this course and the former STAT-3101(6).

### **STAT-3103(3) STATISTICS IN RESEARCH I (Le3)**

This course is intended to provide an introduction to the practice of statistical research via concepts selected from applied regression analysis. Topics include linear and multiple linear regression, and related simultaneous inference procedures. Diagnostic methods and remedial measures for assessing the adequacy of regression models are presented in detail. Various criteria for model selection and validation are discussed. Topics may also include an introduction to nonlinear and logistic regression.

**PREREQUISITES:** STAT-2903(3) and either the former MATH-2201(6) or both MATH-1201(3) and MATH-2203(3) (formerly MATH-2221(3))

**RESTRICTIONS:** A student may not receive credit for this course and the former STAT-3101(6).

### **STAT-3104(3) STATISTICS IN RESEARCH II (Le3)**

This course provides further insight into the practice of statistical research. Emphasis is placed upon the development of various analysis of variance (ANOVA) models for single-factor and multi-factor studies. Topics include the design and analysis of completely randomized, randomized block, balanced complete block and Latin square designs. The analysis of covariance (ANCOVA) is also considered in detail as well as random and mixed effects models. Sample size selection, power analysis, ANOVA diagnostics and remedial measures are discussed. Time permitting, nested, partially nested and repeated measures designs are presented. STAT-3103 is a recommended prerequisite but is not mandatory. Students without STAT-3103 should consult the instructor for permission.



**PREREQUISITES:** STAT-2903(3), the former MATH-2201(6) or both MATH-1201(3) and MATH-2203(3) (formerly MATH-2221(3)) **RESTRICTIONS:** A student may not receive credit for this course and the former STAT-3101(6).

**STAT-3105(3) TIME SERIES AND FORECASTING (Le3)**

The course deals with the general problem of analysing data which is ordered over time, for the purpose of forecasting and statistical prediction. Such data do not represent an independent sample and thus can not be analyzed using other statistical methods. Topics include: trend analysis, smoothing by moving averages, seasonal indices; forecasting using exponential smoothing and Box-Jenkins models.

**PREREQUISITES:** STAT-2103(3).

**RESTRICTIONS:** A student may not receive credit for this course and the former STAT-2601(3).

**STAT-3401(3) STOCHASTIC PROCESSES (Le3)** This course is designed to introduce students to important aspects of stochastic modelling including Markov chains, Poisson processes, and renewal processes. Markov chains in both discrete and continuous time will be considered. This course emphasizes the application of theory to problems in manufacturing, telecommunications, and biological systems. **PREREQUISITES:** STAT-3611(3) (formerly STAT-3201(3) or the former STAT-2701(3)) and MATH-2203(3) or the former MATH-2201(6).

**STAT-3412(3) INTRODUCTION TO OPERATIONS RESEARCH (Le3)**

This course provides a practical introduction to the formulation and solution of some economics and industrial problems using Operations Research models. It emphasizes model-building and problem-solving using computer packages. Topics covered are chosen from linear programming, transportation, assignment and transshipment problems, network models, integer programming, nonlinear programming, decision making, inventory models, and queuing theory.

**PREREQUISITES:** MATH-1201(3) or the former MATH-2201(6) or ECON-3201(3) and permission of instructor.

**CROSS-LISTED:** Mathematics MATH-3412(3)

**STAT-3501(3) SIMULATION (Le3, LaV)** This course is designed to show students how a computer can be utilized to model phenomena with stochastic elements and how analysis can be carried out in the context of a simulation study. Topics will be drawn from the following: generating an arbitrary random variable; the discrete event simulation approach; variance reduction techniques; statistical validation techniques; bootstrapping and other resampling methods; statistical analysis of simulated data; and simulation languages.

**PREREQUISITES:** MATH-3611(3) or STAT-3611(3) (formerly STAT-3201(3) or the former STAT-2701(3)) and STAT-2903(3) or permission of the instructor.

**STAT-3611(3) MATHEMATICAL STATISTICS I (Le3)** The course is intended to give students a firm foundation in probability theory which is necessary for a complete understanding of any advanced statistics. Topics include counting, joint and conditional distributions, random variables, and special distributions.

**PREREQUISITES:** STAT-1301(3) and STAT-1302(3) or the former STAT-1201(6), or both STAT-1501(3) and STAT-1601(3) or STAT-2001(3), and MATH-2106(3) or the former MATH-2101(6).

**Restrictions:** A student may not receive credit for this course and the former STAT-2701(3) or the former STAT-3201(3).

**CROSS-LISTED:** Mathematics MATH-3611(3).

**STAT-3612(3) MATHEMATICAL STATISTICS II (Le3)** The course studies the continuous probability distributions and

their general properties, distributions of functions of random variables, sampling distributions, including  $t$ ,  $F$ ,  $\chi$  and introduction to estimation and theory of hypothesis testing.

**PREREQUISITES:** MATH-3611(3) or STAT-3611(3) (or the former STAT-3201(3) or the former STAT-2701(3)).

**RESTRICTIONS:** A student may not receive credit for this course and the former STAT-3201(6) or STAT-3202(3).

**CROSS-LISTED:** Mathematics MATH-3612(3).

**STAT-4102(3) SURVIVAL AND RELIABILITY ANALYSIS (Le3)**

Survival analysis deals with statistical methods for analyzing failure time data in biological organisms. Students are introduced to the estimation of survival functions using nonparametric and parametric methods. When the failure occurs in mechanical systems, the study is called Reliability Analysis in Engineering. Classical and Bayesian methods is introduced in order to estimate the reliability functions of some well known reliability models.

**PREREQUISITES:** MATH-3611(3) or STAT-3611(3) (or the former STAT-3201(3) or the former STAT-2701(3)).

**STAT-4202(3) STATISTICAL INFERENCE (Le3)** This course expands on Mathematical Statistics II (STAT/MATH-3612(3) (formerly STAT-3202(3))). Topics include the following: Theory of point and interval estimations; completeness and minimal sufficiency, Rao-Blackwell theorem; theory of tests of hypotheses; likelihood ratio tests; unbiased and invariant tests; sequential probability ratio tests; and Bayesian Inference.

**PREREQUISITE:** STAT/MATH-3612(3) (formerly STAT-3202(3)).

**STAT-4401(3) PROBABILITY THEORY (Le3)** This course is a continuation of Mathematical Statistics I (STAT-3611(3) (formerly STAT-3201(3) or the former Applied Probability STAT-2701(3)) and is intended to give students a firm foundation in probability theory. Topics include random walks, characteristic functions and central limit theorem concepts of convergence, laws of large numbers, and martingales and stochastic differential equations.

**PREREQUISITES:** STAT-3611(3) (formerly STAT-3201(3) or the former STAT-2701(3)) or permission of instructor.

**STAT-4601(3) STATISTICAL DESIGN OF EXPERIMENTS (Le3, LaV)**

This course explores basic principles of statistical experimental design including randomization; replication; blocking; confounding; nested versus crossed factors; split-plot designs; fixed; random and mixed models; and the contrast between designed experiments and observational studies. It investigates factorial and fractional factorial designs with an emphasis on  $2^k$  factorial designs and  $2^k$ -p fractional factorial designs. Other potential topics include robust parameter design,  $3^k$ -p fractional factorial designs, balanced incomplete block designs, mixture experiments, and response surface methodology.

**PREREQUISITE:** MATH-1201(3) and STAT-3104(3).