



UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN (UANL)  
Facultad de Ingeniería Mecánica y Eléctrica (FIME)  
Graduate Program in Systems Engineering (PISIS)

**Program of study for the admission exam to the Doctoral Program**

The doctoral admission exam consists of two parts. A basic test that includes assessing fundamental knowledge in the areas of calculus, linear algebra, and programming. An advanced part, which consists in a deeper evaluation (master level) of modeling, analysis and solution of deterministic systems, and stochastic optimization systems: linear programming, network flow programming, probability and stochastic processes. This outline and recommended bibliography is intended to serve to the candidate as a general study guide.

**Part I: Basic Test**

**AREA 1: LINEAR ALGEBRA**

Agenda:

1. Matrices: addition, subtraction, multiplication of matrices; transpose, inverse matrix; determinants.
2. Systems of linear equations, Gauss.
3. Vector spaces: spaces and subspaces; linear independence; bases and dimension.
4. Linear Transformations: linear transformations and matrices, and operations with linear transformation

Bibliography:

- Strang, Gilbert. *Linear Algebra and its Applications*. Harcourt Brace Jovanovich, Orlando, FL (1988).
- Grossman, Stanley I. *Elementary linear algebra*. Saunders College Pub., 1991.

## AREA 2: CALCULUS

### Agenda:

1. Real numbers: algebraic and order properties, absolute value.
2. Basic functions: polynomials, trigonometric, exponential and logarithmic functions.
3. Derivation: derivation of sum, product and quotient of functions; chain rule, higher order derivatives; application to maxima and minima of functions.
4. Vectors in  $\mathbb{R}^2$  and  $\mathbb{R}^3$ : scalar product.
5. Curves in  $\mathbb{R}^n$ .
6. Derivation in  $\mathbb{R}^n$ : partial derivatives, directional derivatives, partial derivatives, tangent plane; Jacobian and Hessian matrix; Extreme function, extreme restricted and Lagrange multipliers.

### Bibliography:

- Leithold, Louis. *The calculus with analytic geometry*, 1986.
- Marsden, Jerrold E., and Anthony Tromba. *Vector calculus*. Macmillan, 2003.
- Spivak, Michael. *Calculus*. 4<sup>th</sup>. Edition. 2008.

## AREA 3: PROGRAMMING

### Agenda:

1. Logic programming.
2. Flowcharts and pseudocode.
3. Variables and data types (integers, floats, etc.).
4. Arithmetic operations (addition, subtraction, multiplication, division) and logical (and, or, etc.).
5. Control Instructions (Conditional if, cycles do, while, for) .
6. Functions or subroutines.
7. Handling vectors and matrices.

### Bibliography:

- Kernighan, B. W., and Ritchie, Dennis M. *The C Programming Language*. 2<sup>nd</sup>. Edition. Prentice-Hall, 1988.
- Stroustrup, Bjarne. *Programming: Principles and Practice Using C++*. 2<sup>nd</sup>. Edition. Addison-Wesley Professional, 2014.

## Part II: Advanced Exam

### AREA 1: DETERMINISTIC SYSTEMS

#### Agenda:

- 1) Linear programming.
  - a) Mathematical formulation of optimization problems.
  - b) Simplex Algorithm (primal, dual and revised).
  - c) Duality theory.
  - d) Optimality conditions and sensitivity analysis.
- 2) Network flows programming.
  - a) Mathematical formulation of problems.
  - b) Shortest path and maximum flow problems.
  - c) Minimal cost flow problems.
- 3) Optimization in general.
  - a) Formulation and solution of mixed integer programs.
  - b) Formulation and solution of continuous nonlinear optimization problems.

#### Bibliography:

- 1) R. K. AHUJA, T. L. MAGNANTI Y J. B. ORLIN. Network Flows. Prentice-Hall, Englewood Cliffs, 1993.
- 2) M. S. BAZARAA, H. D. SHERALI Y C. M. SHETTY. Nonlinear Programming: Theory and Algorithms. Wiley, New York, 1993.
- 3) D. P. BERTSEKAS. Network Optimization: Continuous and Discrete Models. Athena Scientific, Belmont, Massachusetts, 1998.
- 4) D. BERTSIMAS Y J. N. TSITSIKLIS. Introduction to Linear Optimization. Athena Scientific, Belmont, Massachusetts, 1997.
- 5) G. B. DANTZIG. Linear Programming and Extensions. Princeton University Press, Princeton, 1999.
- 6) E. L. LENSTRA, A. H. RINNOOY-KAN Y D. B. SHMOYS (editors). The Traveling Salesman Problem: A Guided Tour of Combinatorial Optimization. Wiley, New York, 1985.
- 7) K. G. MURTY. Linear Programming. Wiley, New York, 1983.
- 8) G. L. NEMHAUSER Y L. A. WOLSEY. Integer Programming and Combinatorial Optimization. Wiley, New York, 1988.

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## AREA 2: PROBABILITY AND STOCHASTIC PROCESSES

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Probability agenda:

1. Conditional probability.
2. Functions of probability distributions.
3. Joint distribution of random variables.
4. Expectancy, moment-generating functions.
5. Multivariate random variables.
6. Distributions and asymptotic properties.

Bibliography:

- H. J. LARSON. Introduction to Probability. Addison-Wesley, Reading, Massachusetts, 1995.
- R. A. ROBERTS. An Introduction to Applied Probability. Addison-Wesley, Reading, Massachusetts, 1992.
- S. M. ROSS. A First Course in Probability. Prentice-Hall, Englewood Cliffs, 1998.
- S. M. ROSS. Introduction to Probability Models. Academic Press, Orlando, 1997.

Stochastic Processes agenda:

- 1) Bernoulli Processes.
- 2) Poisson and exponential processes.
- 3) Markov chains.
- 4) Continuous Markov chains.
- 5) Birth and death processes.
- 6) Queue theory.

Bibliography:

- 1) E. CINLAR. Introduction to Stochastic Processes. Prentice-Hall, Englewood Cliffs, 1975.
- 2) I. GIKHMAN Y A. V. SKOROKHOD. Introduction to the Theory of Random Processes. Dover Publications, Mineola, New York, 1997.
- 3) E. KAO. An Introduction to Stochastic Processes. Duxbury Press, Belmont, California, 1996.
- 4) S. ROSS. Introduction to Probability Models. Academic Press, Orlando, 1997.
- 5) H. M. TAYLOR Y S. KARLIN. An Introduction to Stochastic Modeling. Academic Press, Orlando, 1998.