NATIONAL UNIVERSITY OF ENGINEERING
COLLEGE OF INDUSTRIAL AND SYSTEMS ENGINEERING
SYSTEMS ENGINEERING PROGRAM

SYLLABUS - ST133 SYSTEMS DYNAMICS

I. GENERAL INFORMATION

CODE	:	ST133
SEMESTER	:	6
CREDITS	:	3
HOURS PER WEEK	:	4 (Theory – Practice)
PREREQUISITES	:	ST103 Systems General Theory
CONDITION	:	Compulsory
INSTRUCTOR	:	Celedonio Mendez, Daniel Llanos

II. COURSE DESCRIPTION

System Dynamics is a theoretical-practical course aiming to form within the student the knowledge and skills for the modeling and analysis of dynamical systems as well as to develop the capacities for analyzing and solving problems using the systemic approach. The course includes the following topics: fundamentals of dynamical systems, construction of causal diagrams, Forrester diagrams, first order and superior order systems, materials and information delays, applications to real –world problems.

III. COURSE OUTCOMES

1. Explore, systematize and document the main aspects of a real situation where a dynamical system develops.
2. Construct models of dynamical systems using historic information for defining variables and identifying their relationships.
3. Represent phenomena in abstract ways using causal diagrams.
4. Apply the Forrester representation to transform abstract models into computable model.
5. Simulate, analyze and explain the behavior and response of a dynamical system using proper software tools as well as analyze its sensitivity to parameter and conditions changes.
6. Integrate quantitative and qualitative variables and incorporates the effect of delays in the models of dynamical systems.

IV. LEARNING UNITS

1. DYNAMIC SYSTEMS AND THEIR MODELING / 8 HOURS

Dynamic systems / General concepts / Models definition / Classification / Decisional models / Mathematical models / Economic and social phenomena modeling / Modeling process.

2. DYNAMIC MODELING / 8 HOURS

Principles to formulate dynamical models of systems / Construction steps of dynamical models / Study of a simple application / Components / Causal diagrams / Diagram types / Circularity / Anomalies / Examples.

3. BEHAVIOR PATTERNS AND FORRESTER DIAGRAMS / 8 HOURS

Exponential growing / Objectives attainment / Oscillations / S type growing / Explosions and collapse / Forrester diagrams / Forrester symbols (levels, flows, auxiliary variables, sources and final goal) / Mathematical representation / Identifications of stocks and flows / Design of Forrester diagrams / Equilibrium types.

4. FIRST ORDER DYNAMICAL SYSTEMS / 8 HOURS

Systems order / Positive feedback and exponential growing / Negative feedback and exponential decay / Sigmoidal growing / Systems and first order equations / Basic structures / Relationship between level and regulation variables.

5. HIGH ORDER DYNAMICAL SYSTEMS / 8 HOURS

Second order systems / Third order systems / Fourth order systems / Special behaviour in higher order systems / Relationship between level and regulation variables / Modular feedback and integration / Behavior analysis.

6. MATERIAL AND INFORMATION DELAYS / 8 HOURS

Delay concept in dynamical systems / First order material delays / Delay response / Representation of first-order and higher order delays / Information delays / First order information delays / Higher order information delays.

7. VALIDATION AND SIMULATION / 8 HOURS

Results validation / Model structure and details / Systems behavior characteristics / Models testing / Variables aggregation / Change of auxiliary variables / Acceptable variations / Results prediction for changes in design, structure and conditions of the model / Sensitivity analysis.

V. LABORATORIIES AND PRACTICAL EXPERIENCES:

Laboratory 1: Using software tools
Laboratory 2: Forrester modeling
Laboratory 3: First order systems
Laboratory 5: Second order systems
Laboratory 6: Material delays
Laboratory 7: Information delays
Laboratory 8: Sensitivity analysis

VI. METHODOLOGY

The course develops in theory, practice and computing laboratory sessions. In theory sessions, the instructor introduces the concepts, methodologies and applications. In practice sessions, students solve diverse problems and cases, analyze and defend their solutions. In computing sessions, students use specialized simulation software such as Stella, VenSim or PowerSim to analyze the response of the models. At the end of the academic semester, student teams present and defend a complete report. In all sessions, active student participation is encouraged.

VII. EVALUATION FORMULA

The average grade PF is calculated as follows:

$$PF = (PC1 + PC2 + PC3 + TF) / 4$$

PC#: Graded quizzes TF: Final report

VIII. BIBLIOGRAPHY

1. **ARACIL, JAVIER AND GORDILLO, FRANCISCO**
   Systems Dynamics
   Alliance Editorial, Madrid, 2007

2. **GARCIA, JUAN MARTIN**
   Theory and Exercises of Systems Dynamics.
   Alfa y Omega Editorial, 2003

3. **STERMAN, JOHN**
   Business Dynamics: Systemic Thinking and Modeling for a Complex World
   McGraw-Hill, 2000.