COURSE NUMBER: Vm360	**COURSE TITLE:** Modeling, Analysis, and Control of Dynamic Systems
CREDIT: 4	**PREREQUISITES:** Vm240
TEXTBOOKS/REQUIRED MATERIAL: "System Dynamics," K. Ogata OR "Modeling, Analysis, and Control of Dynamic Systems" by W. Palm III	**PREPARED BY:** Robert Parker **DATE OF PREPARATION:** October 10, 2012 **DATE OF UC APPROVAL:** Oct. 30, 2013
INSTRUCTOR(S): Rob Parker	**SCIENCE/DESIGN:** n/a
CATALOG DESCRIPTION: Unified approach to abstracting real mechanical, fluid, and electrical systems into proper models in graphical and state equation form to meet engineering design and control system objectives. Introduction to system analysis (eigenvalues, time and frequency response) and linear feedback control. Synthesis and analysis by analytical and computer methods.	**COURSE TOPICS:** • MODELING: Mechanical, electrical, fluid, thermal, and mixed-domain systems (e.g. DC motors) • MODELING: State space system equations • ANALYSIS: Linearity (superposition) and linearization • ANALYSIS: Laplace transforms and transfer functions; block diagrams • ANALYSIS: Solving ODE using complementary and particular solutions • ANALYSIS: System poles (or roots of the characteristic equation). Understanding how each pole has a time constant and (if complex) damped/undamped natural frequencies. Transient responses for different pole locations in the complex plane. • ANALYSIS: Solving for the response (e.g., impulse, step) of first, second, and higher order linear, time-invariant systems • ANALYSIS: Numerical simulation of linear and nonlinear systems (e.g., with Matlab/Simulink) • ANALYSIS: Identifying the free, forced, transient, and steady state responses of linear, time-invariant systems • ANALYSIS: Accurately sketching the response of linear, time-invariant systems based on the system poles (eigenvalues), initial conditions, and calculated steady state (i.e., particular solution) responses • ANALYSIS: Frequency response; Deriving and interpreting frequency response (Bode) plots • ANALYSIS: Vibration of multiple degree of freedom mechanical systems o Mass and stiffness matrix representation of equations o Natural frequencies and vibration modes from eigenvalue problem o Mode orthogonality and system response using modal analysis. o Frequency response for multiple degree of freedom systems • CONTROL: System performance measures in the time and frequency domains: rise time, overshoot, settling time, etc. • CONTROL: Feedback control: P, PI, PD control; reference tracking and disturbance rejection
COURSE STRUCTURE/SCHEDULE: Lecture: twice per week, 90 minutes each	

COURSE OBJECTIVES [Course Outcomes in brackets]	1. To teach students elementary tools of modeling of mechanical, electrical, fluid, and thermofluid systems [1, 2, 6, 8, 13] 2. To teach a basic understanding of behavior of first-, second-, and higher-order linear time-invariant dynamic systems [2-8, 10-13] 3. To teach basic concepts of Laplace transforms, ODE solution methods, transfer functions, and frequency response analysis [3-8, 10, 12, 13] 4. To introduce the use of feedback control to actively control system behavior and understand stability of dynamic systems [9, 11, 12] 5. To provide examples of real-world systems to which modeling and analysis tools are applied (e.g., DC motor) for the purpose of design [1, 2, 5, 11, 12] 6. To introduce an appreciation for decision-making skills needed to devise models that adequately represent relevant behaviors yet remain simple [1, 2, 5, 11, 12, 13] 7. To teach basic concepts in numerical integration and computer simulation of mathematical models [13]

COURSE OUTCOMES [Program Outcomes in brackets]	After completing Vm360, students should be able to: 1. Given a description of a real-world system, make educated decisions about how to model it in terms of idealized, lumped elements [a, e, k] 2. Given a simple system containing some combination of mechanical, electrical, thermal, and fluid elements, write differential equations describing its input/output behavior [a, d, e, k] 3. Given a first-,second-, or higher-order LTI system, predict its step response and free response [a, e, k] 4. Given a LTI system and a sinusoidal input, predict the magnitude and phase of the steady-state output as a function of input frequency. Given frequency response (Bode) plots, understand how to use them to calculate system response or design for a desired behavior [a, e, k] 5. Given certain desired performance characteristics for a system (such as maximum overshoot due to a step input), translate specifications into design parameters necessary to provide those characteristics [a, c, e, k] 6. Given a physical description of a system and a graphical representation of its time-domain response (step, frequency, etc.), estimate system parameters (e.g. mass, stiffness, damping, time constant, natural frequency, etc.) [a, e, k] 7. Given LTI differential equation(s) and an arbitrary input composed of steps, ramps, and other simple functions, find the solution using Laplace transforms, the complementary/particular solution method for solving ODE, and state space methods. Understand how to accurately sketch the response of such systems without going through an analytical solution [a, c, e, k] 8. Given a mechanical system of multiple masses, inertias, and stiffness elements, formulate a mathematical model and use matrix methods to calculate its response and interpret the response in terms of vibration modes [a, e, k] 9. Describe basic applications of proportional, integral, and derivative feedback in control systems to improve performance or stability [a, c, e, k] 10. Given a system composed of mixed mechanical/electrical/thermofluid components, write the transfer function describing input-output behavior. Understand block diagrams with transfer function blocks and formulate such diagrams for given dynamic systems. [a, e, k] 11. Given a system with given performance, describe (qualitatively and quantitatively) how behavior can be improved according to specifications such as overshoot and settling time, using some combination of parameter tuning and feedback control [a, c, e, k] 12. Describe how changes in parameter values will affect damping ratio and natural frequency for a system, and how these characteristics are manifested in the system behavior [a, c, e, k] 13. Implement a mathematical model into commercial simulation software, and exercise the model to make engineering assessments and achieve design objectives [a, c, e, k]
ASSESSMENT TOOLS [Course Outcomes in brackets]	Homework [1-13] Exams [1-12 (not every Course Outcome can be tested in each exam)]