PhD Qualifying Examination
Dynamic Systems and Design Thematic Area

Examination Format

The examination will consist of 9 questions from the topics listed below. (The topic list should be considered a guideline and not an exhaustive list.) Students must answer 5 of the 9 questions. If the student answers more than 5 questions, the first 5 will be graded. Students should clearly mark answers they don't want included in their examination by writing "DO NOT GRADE" and marking a single line through the answer. Students will have 2.5 hours for the examination.

Reference Materials

Students taking the DSD qualifying exam are allowed to develop a four-page (two pages front and back), hand-written formula sheet to be used during the exam. The students can include anything they consider of interest to them. The two page formula sheet must be submitted to the Graduate Program Director at least three days before the qualifying exam. The formula sheet will be returned to the student at the start of the exam. If applicable, additional information sheets will be made available by the examiner depending on the subject matter.

Topics

1. **Dynamics**
    - 1.1. Constraints
        - 1.1.1. Holonomic, nonholonomic
        - 1.1.2. Scleronomic
        - 1.1.3. Rehonomic
        - 1.1.4. Catastatic, acatastatic
    - 1.2. Equations of motion
    - 1.3. Langrange's equations
    - 1.4. Absolute velocity and acceleration, dynamic forces
    - 1.5. D'Alembert's principle
    - 1.6. Virtual work
    - 1.7. Path description using unit vectors, radius of curvature

2. **Vibrations**
    - 2.1. System modeling
    - 2.2. Equations of motion
    - 2.3. First order systems
    - 2.4. Second order systems
    - 2.5. Free response
    - 2.6. Eigenvalues, eigenvectors
    - 2.7. Laplace transforms
    - 2.8. Forced response
    - 2.9. Transfer functions

- 2.10. Under-, critical-, and over-damped systems
- 2.11. Multi-degree of freedom systems
- 2.12. Numerical methods

3. Controls

- 3.1. Modeling Mechanical, Electrical, Rotational Systems
  - 3.1.1. Equations of Motion
  - 3.1.2. Laplace Transform
  - 3.1.3. Transfer Functions (TF)
  - 3.1.4. Time Domain
  - 3.1.5. State-Space (SS) Representation
  - 3.1.6. Converting from TF to SS, SS to TF
- 3.2. First and Second-Order Systems
  - 3.2.1. Poles, Zeros, and System Response
  - 3.2.2. Responses of First-Order Systems
  - 3.2.3. Responses of Second-Order Systems
  - 3.2.4. Natural Frequency and Damping Ratio
  - 3.2.5. Types of Second-Order Systems
- 3.3. Reduction of Multiple Subsystems
  - 3.3.1. Block Diagrams
  - 3.3.2. Analysis and Design of Feedback Systems
  - 3.3.3. Signal-Flow Graphs
  - 3.3.4. Mason's Rule
- 3.4. Stability of Systems
  - 3.4.1. BIBO Principle
  - 3.4.2. Routh-Hurwitz Criterion
  - 3.4.3. Stability in State Space
- 3.5. Steady-State Errors
  - 3.5.1. Definitions and Sources of State-State Errors
  - 3.5.2. Steady-State Error for Unity Feedback Systems
  - 3.5.3. Static Error Constants and System Type
  - 3.5.4. Steady-State Error Specifications
  - 3.5.5. Steady-State Error for Disturbances
- 3.6. Root Locus Techniques
  - 3.6.1. Vector Representation of Complex Numbers
  - 3.6.2. Root Locus Definition
  - 3.6.3. Root Locus Properties
  - 3.6.4. Sketch the Root Locus
  - 3.6.5. Design via the Root Locus
    - 3.6.5.1. Lag, Lead, PID Design
    - 3.6.5.2. Feedback Compensation
- 3.7. Frequency Response Techniques
  - 3.7.1. Bode Plots
  - 3.7.2. Sketch Bode Plots