MCHE 485: Mechanical Vibrations
Spring 2020 Final Exam
Material Covered

Modeling
- Modeling and linearization of springs
- Linear, single DOF system modeling and free vibration
  - Undamped
  - Damped
- Equivalent springs
- Single DOF, rotational modeling and vibration
  - Linearization via small angles and Taylor-series expansion
  - Rotational springs

System Properties and Single Degree-of-Freedom Free Vibration
- Solving for time responses from equations of motion, including initial conditions
- Conversion between various forms of time responses (combination of sin and cos, exponential, sin or cos with phase shift, etc)
- System properties such as:
  - Natural frequency
  - Period of oscillation
  - Damped natural frequency
  - Damping ratio
  - Decay envelope
- Relationship between system properties and system parameters
  - ex) What effect does increasing mass have on frequency?
  - ex) Does doubling the spring constant double frequency?

Forced Responses for Single Degree-of-Freedom Systems
- Step inputs
  - Effect of damping on response
  - Settling time
  - Rise time
  - Overshoot
- Harmonic position (Seismic) inputs, with damping and without
  - Relationship between natural frequency and excitation frequency

  - General response trends
    - Magnitude
    - Phase
- Direct force harmonic excitation, with damping and without
  - Relationship between natural frequency and excitation frequency
  - General response trends
    - Magnitude
    - Phase
- Transfer Function form
- Rotating Imbalance
  - Relationship between natural frequency and rotation frequency
  - General Response Trends
- System ID
  - via Free Response
    - natural frequency
    - damping ratio via log. dec.
  - via Frequency response
    - Natural frequency via peak
    - Damping via:
      - Relationship between peak and static deflection
      - Half-power points
- Non-viscous damping
  - Dry Friction (Coulomb Damping)
    - Form of force
    - Response characteristics
    - Linear decay rate
    - Generally non-zero "stop" point
- Accelerometers and Seismometers
  - General structure
  - Parameter selection (and resulting design)
  - Accuracy of measurement

Fourier Analysis

- Fourier Analysis
  - Basic understanding
  - Superposition
  - Use to get response

Multi-Degree-of-Freedom Vibration

- Free response of undamped multi-mode systems
  - Matrix form of equations of motion
  - Solving the eigenvalue/eigenvector problem to get:
    - ⋆ Natural frequencies
    - ⋆ Mode shapes
  - Using eigenvalue/eigenvectors to describe response
    - ⋆ excitation at either eigenvector, only that vector is excited
    - ⋆ otherwise, both modes show up
- Forced response of undamped multi-mode systems
  - Matrix form
  - Using Matrix inverse to solve
- Ideal vibration absorbers
  - Design of absorber (match frequencies)
  - Design compromises
    - ⋆ more mass, higher k
    - ⋆ more robust, but heavier
- Real performance of vibration absorbers
  - Undamped vs damped
  - Influence of transient vs steady state
- "Zeros" in a Forced Response - Multi-DOF vibration-absorber-type response
  - Can I design N-mass system to keep m_n stationary?
  - At what frequency of input is m_n stationary?
- Orthonormal form of eigenvectors
  - Using orthonormal form to diagonalize and decouple equations of motion
- Multi-DOF damping
  - Influence of damping on frequency and mode shapes
  - Placing damped equations into state-space or symmetric form
  - Setting up state-space or symmetric form eigenvalue/eigenvector problem
- Repeated and Zero Frequencies

State-Space Forms

- Writing equations of motion as a system of first-order differential equations
- Linearizing the equations and writing in State-Space Form (matrix-form)