

2.14/2.140 Problem Set 3

Assigned: Thurs. Feb. 22, 2007

Due: Thurs. March 1, 2007, in class

Reading: Nise Ch. 3; Notes from course web page on state-space to transfer function conversion.

The following problems are assigned to both 2.14 and 2.140 students.

Nise Ch. 3, Problem 4 Use the mass positions and velocities as the state variables.

Nise Ch. 3, Problem 6 Use the inertia rotary positions and velocities as the state variables.

Nise Ch. 3, Problem 11a Carry out the requested calculations by hand; do not use Matlab or other computational tools.

Nise Ch. 3, Problem 13

Nise Ch. 3, Problem 14a

Nise Ch. 3, Problem 19

Nise Ch. 3, Problem 24 This problem considers the dynamics of electrical contact to the catenary wire by the pantograph pickup on top of an electric passenger train.

- a) Write the requested state equations, using the position and velocity of the two masses as the state variables. Note that the element K_f has been inadvertently omitted from Figure 2.35b in the text.
- b) Use Matlab to calculate the eigenvalues (poles) of the system, and plot these poles on the complex plane. Use Matlab to solve for the associated eigenvectors. Can you use the eigenvector directions to explain the mode-shapes associated with the poles? Draw diagrams showing the modes shapes in terms of relative motions of the mass elements.
- c) Use Matlab to make a Bode plot of the transfer function $Y_{cat}(s)/F_{up}(s)$. Indicate how the mode frequencies and damping ratios affect the plot. What is the numerical value of the largest Bode gain on the plot (including units), and the associated frequency ω_{max} ? If $F_{up}(t)$ is a 1 Newton sine wave at this frequency $F_{up}(t) = \sin \omega_{max} t$ N, write an expression for $y_{cat}(t)$ which has the correct amplitude and phase shift.

Archive Problem 13.1 a–d only

The following problem is assigned to only 2.140 students. Students in 2.14 are welcome to work these, but no extra credit will be given.

Problem G1 Consider the quarter-car suspension discussed in lecture on 2/22. As in class, this quarter of a car is represented by a mass M with suspension stiffness k and damping constant b . In the models developed in class, the mass m of the wheel played no role, and we did not obtain the contact force N between the wheel and ground. But the contact force N is a

crucial measure of performance, because it is directly related to the tangential force that the wheel can sustain relative to the ground without gross slip.

Derive transfer function and state-space models for the quarter car with the ground undulation q_0 as input and the contact force N as output. Make a Bode plot (qualitatively). Does this model tell us anything about the importance of wheel mass in vehicle handling?