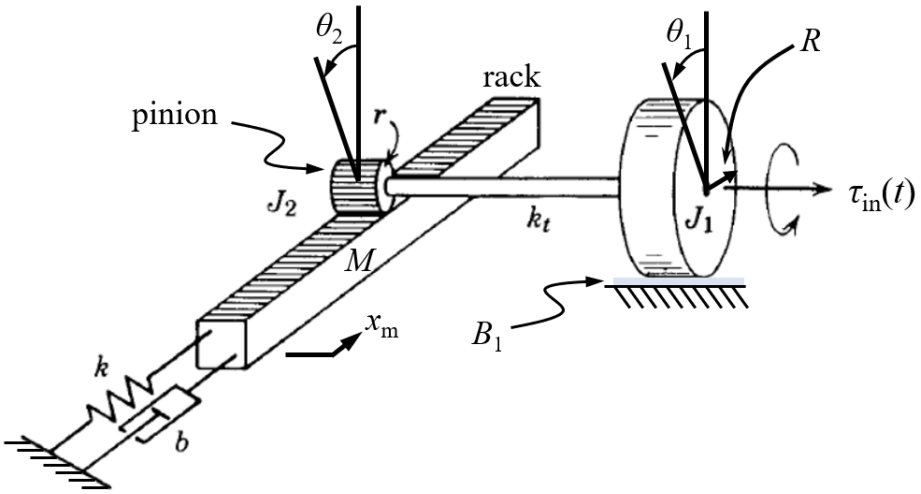
DYNAMIC SYSTEMS AND CONTROLS

ME 344—Fall 2021

Simulation Project 2

Due 5 November 2020
25 POINTS

Use the sketch of the rack-and-pinion system shown here to answer the questions below. Note that B_1 represents a rotational damping coefficient due to friction on the input gear and b is the linear damping coefficient representing sliding friction on the mass of the rack.



1. (5 pts) Draw the bond graph for the rack-and-pinion system shown above. Include assignment of causality and clearly number your bonds sequentially.

2. (2.5 pts) Specify the independent state variables and system order. Identify any bonds that may be in derivative causality.

3. (5 pts) Write a set of state equations and express them in matrix form: $\dot{\vec{x}} = [\mathbf{A}] \cdot \vec{x} + [\mathbf{B}]\,\vec{u}$.

4. (10 pts) Simulate the system response using the following parameter values: $J_1 = 2.2$ kg·m^2/rad, $J_2 = 1$ kg·m^2/rad, $B_1 = 3$ kg·m^2/(s·rad), $k_t = 2$ N·m/rad, $M = 16$ kg, b=2 N·s/m, $k = 20$ N/m, $R = 0.5$ m, $r = 0.1$ m. Assume that the system is initially at rest and that the input torque is a time-limited step function starting at $t = 0$ and ending at $t = 25$ sec with a value of $\tau_{in} = 5$ N·m. Simulate the response for a time span of 0 to 50 seconds. Provide two plots (or one figure with two subplots). The first should show the angle of twist of the input shaft, $\theta = \theta_1 - \theta_2$, and the displacement of the mass, x_m, both as a function of time. The second plot should show the rate of twist of the input shaft, $\omega = \omega_1 - \omega_2$, and the velocity of the mass v_m as a function

of time. Clearly label the plot axes and provide a legend or arrows indicating which curves represents which state variable, also as a function of time. Include the scripts and the figures for full credit.

5. (2.5 pts) Conceptual question: What alterations could you make to the system model to eliminate the derivative causality identified in point 2? If those changes were made to remove derivative causality, what would be the order of the resulting system?