Problem 3.1
Determine the EOM relating the input $\theta_i$ to the output $\theta_{\text{LOAD}}$ for the torsional system shown. Neglect the mass of the gears.

A motor with a pinion (total rotary inertia $J$) drives a rack (mass $M$) that actuates a spool valve that is restrained by a spring $K$. The valve acts as an equivalent damper $D$. The pinion radius is $R$. The input torque from the motor is $T(t)$.

a) Find a differential equation relating the input torque to the output displacement of the rack, $x(t)$,  
b) Determine the natural frequency of the system,  
c) Determine the damping ratio of the system?

A fluid transmission can be represented by a damper $D$ that drives a load (moment of inertia $J$) and a spring $K$. Determine a differential equation relating the input $\theta_1$ to the output $\theta$.

Problem 3.4
For the system shown below, the input is $f_a(t)$ and the output variables are $x$, $\theta_1$, and $\theta_3$. Write the three differential equations of motion for the system in second order matrix form.