1) Chapter 1, problems 16-22

2) Develop the Linear EOM (linearize about $x=x_0$ and $v=0$) for the rack and pinion

Assume no slip between
The rack and pinion

$F_s = kx^3$

3) A propeller a fluid coupler (like a torque converter). The damping losses of the propeller are of the from $b\omega^2$ and the shaft has a torsional stiffness of the form $k\theta^3$. Ignore the losses in the bearings. Develop the EOM and Linear EOM (linearize about the steady state - $\Delta\theta$ and $\omega$) for the propeller problem given below

4) Derive the non-linear equations of motion for the following system. Assume the spring and damper forces remain horizontal and neglect the inertia of the beam. Linearize the equations about $\theta=0$ and about $\theta=\theta_{ss}$
Matlab Assignment (Due Tuesday 9/26/17 in Class).

A non-uniform pendulum (a car) swings freely on a perfect pivot at a frequency equal to 1/4 Hz. The car weighs 15,000 Newtons and its CG is 1.5 meters from the pin.

a) Derive the non-linear equations of motion

b) Linearize the EOM about $\theta=0$. Solve the linearized differential equation and calculate the yaw mass moment of inertia about the CG ($I_{CG}$) of the vehicle.

c) Plot the analytical solution (of the linearized EOM) vs. the numerical integration (of the full non-linear equations of motion) on one plot with an initial angle offset of 10 degrees

d) Repeat part (c) with an initial angle of 45 degrees. Why do the results not agree as well as in part (c)?

e) Solve for and plot the reaction forces at the pin.

Note to linearize about $\theta=0$ use the relationships (know as the small angle approximation) shown below:

\[
\sin(\theta) \approx \theta \\
\cos(\theta) \approx 1
\]
Derive the EOM for the gear

Calculate the output torque as a function of the input torque

Neglect friction between the ball and beam