Chemical Engineering 150A **October 2nd, 2019**

Midterm #1

(85) 1. Movable Cart Restrained by a Spring (after White 3.39)

Consider the movable cart in Figure 1 below that is restrained by a Hookean spring. A free water jet in plug flow impinges on the cart with known velocity v_1 and cross section area A_1 and is deflected through an angle θ. Exit velocity is v_2 across area $A_2 = A_1$. friction against the cart wall is negligible and the cart is at rest. Note that a free jet is one that is open to the atmosphere.

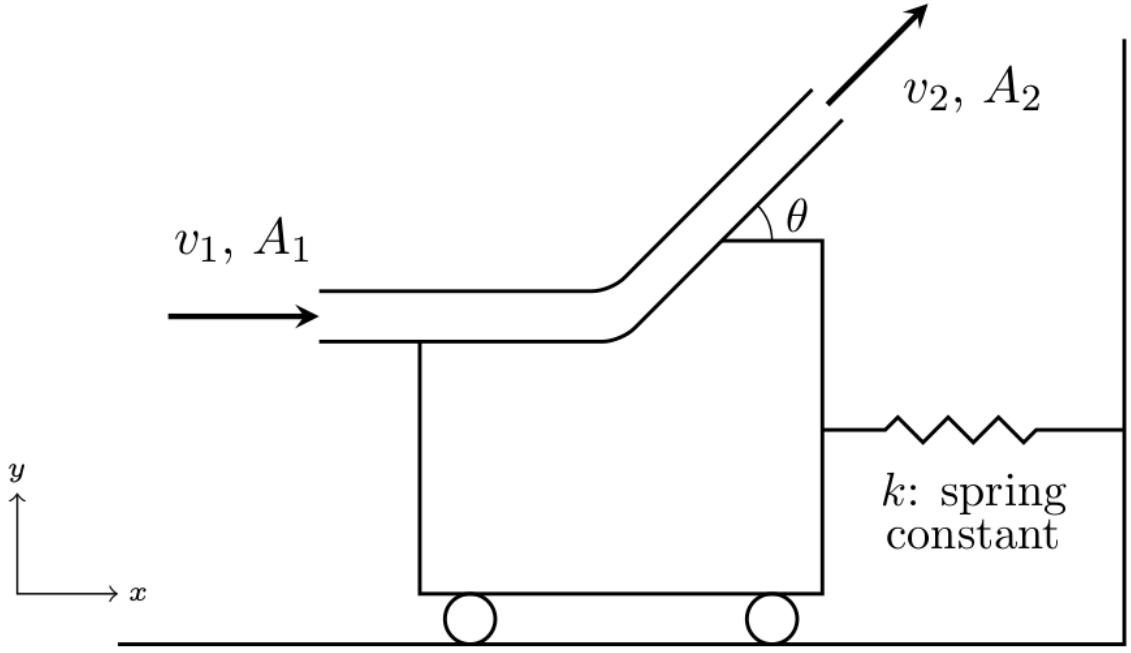

Figure 1. Movable cart impinged by a free water jet and restrained by a Hookean spring. The spring force constant is k.

(15) a Based on the coordinate system diagramed in Figure 1, in which direction does the spring force act? Explain. There is no need to solve any equations here.

(45) b Given the known spring constant k, compute the spring deflection relative to its unstressed (i.e., no flow) position x_o.

(25) c. Let m represent the mass of the cart and water in the tube before flow is initiated. Derive an equation for the weight of the cart with steady flow.

(60) 2. Shear Removal of Plaque Deposited in an Artery

Consider a cylindrical artery, which has plaque build-up on the walls such that the radius through which blood flows, R, is less than the original radius. Assume blood is a Newtonian fluid with viscosity μ. Also assume unidirectional flow in the artery along the axial direction *z* with a velocity profile given by

$$v_z = v_{max}\left[1 - \left(\frac{r}{R}\right)^2\right]$$

There is a critical shear stress, τ_c, that plaque can withstand before it detaches from the arterial wall. Breakoff and subsequent blockage elsewhere is a leading cause of heart attacks.

(20) a. The fluid flowing in the constricted plaque region exerts a shear force on the plaque build-up. What component(s) of the shear stress tensor are involved? In what direction do they act?

(30) b. Find the critical radius R_c at which plaque detaches from the wall.

(10) c. Does the plaque detach for $R > R_c$ or $R < R_c$? Explain.