Tutorial #3
ELL-225: Control Engineering

Session: Semester-II (2022-23)

1. During ascent the space shuttle is steered by commands generated by the computer's guidance calculations. These commands are in the form of vehicle attitude, attitude rates, and attitude accelerations obtained through measurements made by the vehicle's inertial measuring unit, rate gyro assembly, and accelerometer assembly, respectively. The ascent digital autopilot uses the errors between the actual and commanded attitude, rates, and accelerations to gimbal the space shuttle main engines (called thrust vectoring) and the solid rocket boosters to effect the desired vehicle attitude. The space shuttle's attitude control system employs the same method in the pitch, roll, and yaw control systems. A simplified model of the pitch control system is shown in Fig. 2.

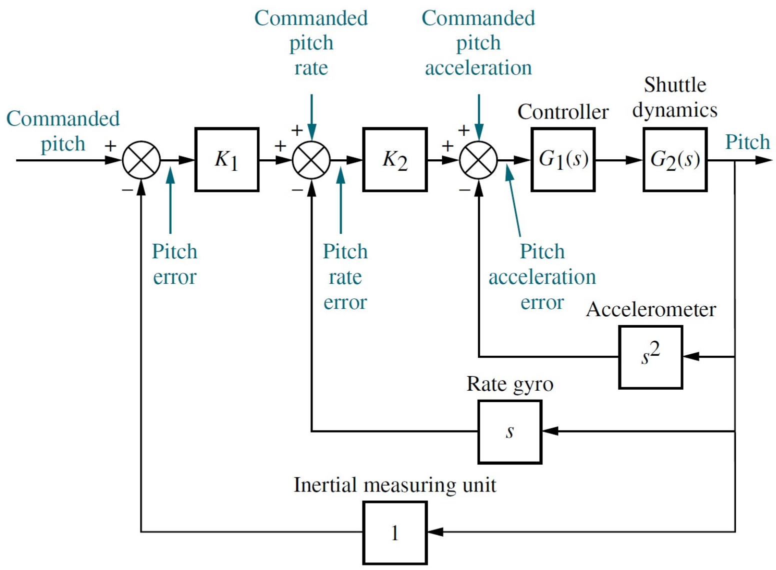

Figure 1: Simplified diagram of space shuttle pitch control system.

   (a) Find the closed-loop transfer function relating actual pitch to commanded pitch. Assume all other inputs are zero.

   (b) Find the closed-loop transfer function relating actual pitch rate to commanded pitch rate. Assume all other inputs are zero.

2. In the plate dispenser system given in tutorial 2, find the effect of spring constant (K) on the system. Also find the below characteristics of the system when weight of each plate (ω_d) is 0.2N, mass of piston and plate system (M) is 5kg, total viscous damping coefficient (f_v) is 0.15Pa.s and spring constant (K) is 2000N/m.

   (a) Find the damping factor(ζ).

   (b) Natural (ω_n) and damped (ω_d) frequencies.

   (c) Peak time (T_p).

   (d) % Overshoot.

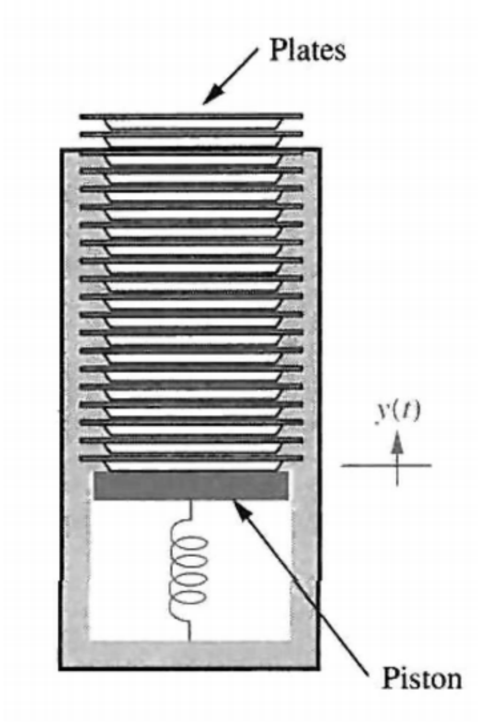

Figure 2: plate dispenser

(e) Settling time (T_s) for 2% tolerance band.

(f) Find the time period of the oscillation.

3. Many will be familiar with the objective of balancing a pen (or a rod) on the tip of one's finger. It is a difficult control task and it illustrates many of the difficulties associated with real world control problems. This can be modelled as a typical inverted pendulum on a moving cart as shown in Figure 3. Obtain the mathematical model for the given system and linearize it around the equilibrium point.

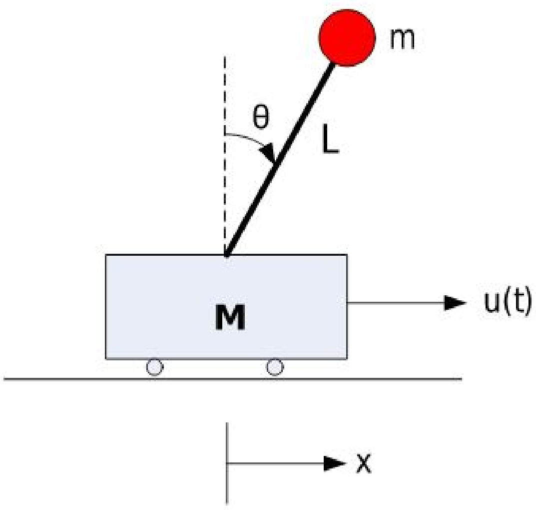

Figure 3: Inverted pendulum on a moving cart

4. Consider the block diagram representation given in the Figure 4;

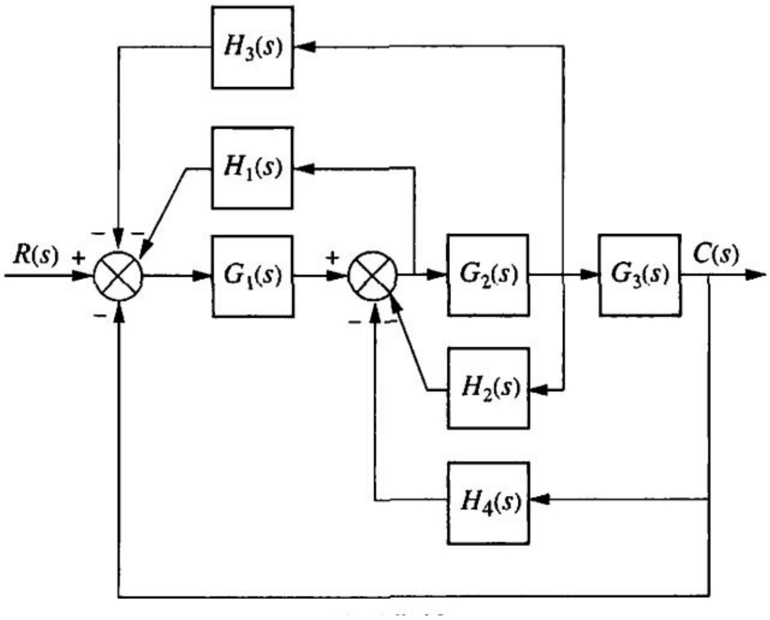

Figure 4: Block Diagram representation of a System

(a) Reduce the block diagram shown in Figure 4 to a single block representing the transfer function, $T(s) = \frac{C(s)}{R(s)}$.

(b) Find the transfer function $T(s)$ using Mason's gain formula.