Problem Set #8. Position Control.

As an emerging engineering systems dominator, you are now in a position to control. To demonstrate your capability, please focus on the radar pedestal unit shown in Figure 1 below. One goal is to combine multi-port and block-diagram modeling of an engineering system that has both power and control subsystems. The control system positions the radar cone about a vertical axis. *(A separate control system, not considered here, controls the elevation angle of the radar cone.)* The radar unit is mounted on a large ring gear that provides both a support base and a means for applying a driving torque. The drive motor acts through a shaft and a pinion gear coupled to the ring gear. The motor input for control is the field voltage. The electric power to turn the pedestal actually comes through the armature port of the motor, which is modeled below as a special source.

**System parameters:**

**MOTOR:**
- \( L = 0.1 \)
- \( Re = 5.0 \)
- SEM: gain = 20.
- \([\text{torque/current}]\)
- \( Jm = 0.25 \)
- \( bm = 0.33 \)

**SHAFT:**
- \( Ks = 100. \)

**GEARS:**
- \( g = 30. \) (torque stepup)

**PEDESTAL LOAD:**
- \( Jp = 320. \)
- \( bp = 10.67 \)
Part 1. Open-loop study. No control subsystem. (See Figure 2.)

(a) Derive the state equations in symbolic form (e.g., keep L for inductance, J for moment of inertia, etc.). Then substitute numerical parameter values and evaluate the A and B matrices. Find the eigenvalues.

(b) Set the field input voltage (vE1) to be constant. Find the steady-state condition for pedestal angular velocity (wP) in symbolic form. Evaluate numerically for the case of an input voltage of 10 V.

(c) Investigate the time response for condition (b) above, assuming zero initial conditions. In particular, plot the pedestal position (theta_P) and velocity (wP). Verify your result from (b).

*Hint*. Relate theta_P to wP by a differential equation. Looks like a state equation, no?
Part 2. Closed-loop control. (See Figure 3.)

Now install a feedback control subsystem for the pedestal. Assume that the angular velocity, \( w_P \), is measured perfectly as shown. You can create the pedestal position, \( \theta_P \), by integrating \( w_P \). Compare the feedback signal to the command position, \( \theta_c \), and take action based on the error, \( e \).

Note that the actuator action is as follows: \( v_{E1} = kc_1 e \). In other words, the field voltage is proportional to the error signal, but SEE can deliver finite power.

Note also that you can create a more sophisticated control scheme by using both \( w_P \) and \( \theta_P \) as feedback signals, with suitable gain for each signal.

(a) Write a set of additional equations to model the control subsystem effect. Treat \( v_{E1} \) as an internal variable. Treat \( \theta_c \) as the input variable. Get \( A \) and \( B \) for the new closed-loop system. Find the eigenvalues.
ME457: Modeling of Mechatronic Systems

(b) Assume all initial conditions are zero. Let theta_c be a step of value 1.0 radian. Plot the response of theta_P and w_P versus time.