Department of Mechanical Engineering
Cleveland State University

MCE 441: Introduction to Linear Control Systems
Midterm Exam - Spring 2007

Name:

Duration: 90 minutes — Closed books and notes.
WORK ON 4 QUESTIONS.

1. (25 pts)
The level of water in a tank is regulated to a desired value using a feedback control system. Water flow into the tank is regulated using a motorized flow control valve, while water flows out of the tank according to an unpredictable demand. A sensor provides current water level measurement. An operator is able to select a desired level setting using a numeric keypad, while a microprocessor realizes all control computations.

- Draw a block diagram of the feedback system, labeling each component and its role in the feedback system (desired output, actuator, controller, etc.)
- Suppose the feedback system is operating in a satisfactory way. Explain what would happen if the polarity of the sensor terminals is reversed. How would you represent the reversal in the diagram?

2. (25 pts)
For the transfer function

$$G(s) = \frac{300(\frac{1}{9}s + 1)}{(s^2 + 2s + 5)(s^2 + 22s + 120)}$$

Sketch the unit step response, clearly indicating settling time, rise time, final value, peak value and percent overshoot.

3 (25 pts) A DC motor and a reducing gearbox are used to drive a machine-tool spindle. The motor drives the gearbox, which in turn drives the spindle and workpiece, as shown in Fig. 1. The DC motor is modeled by the equation

$$\dot{w} + \frac{1}{\tau}w = aV - \frac{T_L}{J}$$

where $\tau = 0.1$ sec. is the time constant, $a = 1200$ Volt^{-1}sec^{-2} is the voltage constant, T_L is the load torque in N.m and $J = 0.1$ kg-m^2 is the motor's moment of inertia. The gearbox has a velocity reduction ratio of $n = 10$. A torque is generated by the cutting forces acting on the workpiece. The cutting torque is proportional to the velocity of the workpiece:

$$T_c = kw_p$$

where $k = 2$ N.m.sec and w_p is the angular velocity of the workpiece in rad/s. Consider that the spindle and workpiece have negligible rotational inertia.

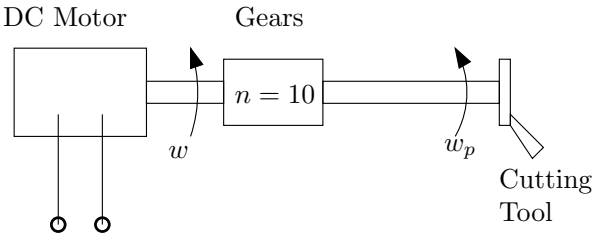

Figure 1: Problem 1

1. Find the transfer function from V to w_p.
2. Find the steady-state workpiece velocity in rpm when the input is a 400-volt step.

4 (25 pts) Obtain the transfer function $Y(s)/R(s)$ corresponding to the block diagram of Fig. 2.

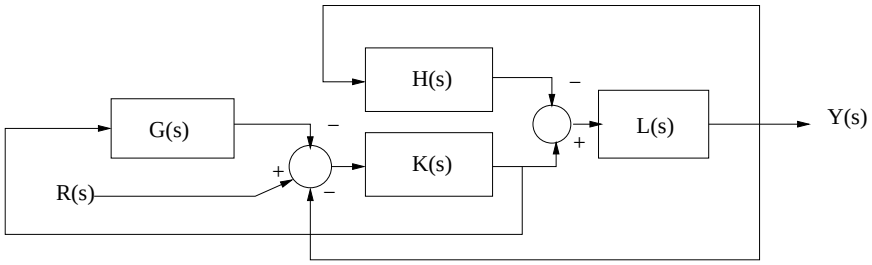

Figure 2: Problem 4

5 (25 pts) Sketch the unit step response of the **closed-loop** system shown in Fig. 3 to the step input $R(s) = 2/s$. Find final value, percent overshoot, settling time and peak value and clearly indicate them in the sketch.

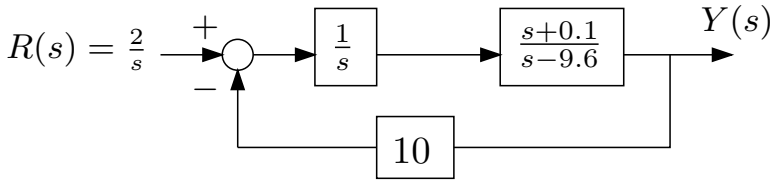

Figure 3: Problem 5