1. The field of a DC servomotor is excited by means of a DC amplifier with gain \( K_A = 90 \) volts/volt as shown in Figure 1. The field has an inductance of \( L = 2 \) Henry's, and a resistance of \( R = 50 \) ohms.

![Figure 1](image)

Figure 1:

(a) Calculate the time constant of this system. 
(b) Determine the 5% settling time for a unit step input voltage.

To improve the time behavior of the system, a voltage proportional to the field current is fed-back to the amplifier input as shown in Figure 2.

![Figure 2](image)

Figure 2:

(c) Determine the feedback proportionality constant \( k \) to reduce the time constant to 4 milliseconds. 
(d) Find the sensitivity of the transfer function with respect to \( k \) for the \( k \) determined in part (1c) and for \( \omega = 50 \).
(e) Determine the steady state error voltage when the input voltage is a unit step.
2. A feedback system employing an output rate damping is shown in Figure 3.

![Feedback system diagram]

Figure 3:

(a) In the absence of the derivative feedback ($K_H = 0$), determine the damping ratio, the natural frequency, the rise time and the 2% settling time for the unit step response. (10pts.)

(b) Calculate the steady state error (with $K_H = 0$) resulting from a unit ramp input. (5pts.)

(c) Determine the derivative feedback constant $K_H$ which will give a damping ratio equal to 0.6. (10pts.)

(d) Determine the steady state error to a unit ramp input with this value of $K_H$. (5pts.)

(e) Compute the parameters $K_A$ and $K_H$ again to maintain a damping ratio of 0.6, while reducing the steady state error to a unit ramp input to the value calculated in part (2b). (15pts.)

3. A system oscillates with a frequency $\omega$, if it has poles at $s_{1,2} = \pm j\omega$ and no right half-plane poles. For the system shown in Figure 4, choose $K$ and $T$, so that the system oscillates with frequency $\omega = 3$ rad/sec. (20pts.)

![System oscillation diagram]

Figure 4:
#1  
\[ a_{11} \text{ Time constant } = 40 \, \text{ms} \]  
\[ b_{11} \text{ 5\% settling time } t_s = 120 \, \text{ms} \]  
\[ c_{11} \quad k = 0.1 \]  
\[ d_{11} \quad S_{ss} = \frac{9\sqrt{26}}{52} \]  
\[ e_{11} \quad e_{ss} = 0.1 \]  

#2  
\[ a_{11} \quad T_c = \frac{\sqrt{10}}{10} \approx 0.316 \quad ; \quad w_n = \sqrt{10} \approx 3.162 \]  
\[ b_{11} \quad e_{ss} = 0.2 \]  
\[ c_{11} \quad k_4 \approx 1.795 \]  
\[ d_{11} \quad e_{ss} = 0.379 \]  
\[ e_{11} \quad k_4 = 5.2 \quad ; \quad k_9 = 36 \]  

#3  
\[ K = 7 \quad , \quad T = 10/9 \]