(5 pts) 1. a) For the differential equation below, write the corresponding transfer function in the box.

\[3\ddot{y} + \dot{y} + 10y = 5f(t)\]

\[\frac{Y(s)}{F(s)} = \]

(5 pts) b) For the transfer function below, write the corresponding ordinary differential equation in the box provided.

\[\frac{X(s)}{U(s)} = \frac{4}{2s^2 + s + 16}\]

where \(X(s) = \mathcal{L}(x(t))\)

\(U(s) = \mathcal{L}(u(t))\)

Differential Equation
2. The block diagram below represents an electric motor speed control. The operator sets the desired speed, $V_d(s)$, which is compared to the actual speed of the motor, $V(s)$, in order to develop the error, $E(s)$, which is the input to the control, $G_c(s)$.

![Block Diagram](image)

(5 pts) a) What is the open-loop system time constant of the motor?

(5 pts) b) For proportional control, $G_c(s) = K_p = 5$, what is the steady-state error in automobile speed when the desired speed corresponds to a “constant” step of amplitude, $v_d = 5$?

(5 pts) c) For proportional control, $G_c(s) = K_p = 5$, what is the closed-loop system time constant?

(5 pts) d) For proportional control, $G_c(s) = K_p = 5$, what is the closed-loop DC (or steady-state) gain?

(5 pts) e) For integral control, $G_c(s) = \frac{K_I}{s} = \frac{0.1}{s}$, what is the steady-state error in motor speed?
4. A car wash designer finds the following non-linear differential equation model for car velocity $v$ (m/sec) versus electric motor drive $e$ (volts) during the wash cycle.

$$\dot{v} = -9v - v^2 + 5ve$$

(5 pts) a) Find the equilibrium drive voltage $e = e_o$ corresponding to a car operating speed of $v = v_o = 1$ m/sec and enter it in the box below.

$$e_o = \text{volts}$$

(5 pts) b) Define a new set of variables about which a linear approximation for the above equation can be derived.

(10 pts) c) Find the linearized ordinary differential equation about the equilibrium point found in part a) and enter your result in the box below.

Linearized Differential Equation(s)
(15 pts) 5. For an open-loop system transfer function, \( kG(s)H(s) = \frac{ks}{(s + 2)^2 + 1^2(s + 4)} \), plot the root locus diagram on the axes below for \( 0 < k < \infty \). When they exist, how features such as asymptotes, breakaway points, angles of departure, instability frequencies, etc.
6. The open-loop system transfer function of an hydraulic actuator, \( KG(s) \) was measured for \( K = 1 \), at Radcliffe Engineering and the Bode Diagram below plotted.

![Bode Diagram](image)

(a) Is the closed-loop system stable at \( K = 1 \)?

YES or NO (circle one)

(b) What is the closed-loop system's Gain Margin?

\( GM = \) _______ dB

(c) What is the closed-loop system's Phase Margin?

\( PM = \) _______ deg

(d) What is the maximum closed-loop stable value of \( K \)?

\( K_{max} = \) _______ dB

(e) What value of \( K \) gives a phase margin of 60 degrees?

\( K_{45} = \) _______ dB

(f) For \( K = 1 \), what is the closed-loop system's steady-state error for a unit step input?

\( e(\infty) = \) _______________