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

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

$\frac{Y(s)}{F(s)} =$

Transfer Function

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

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

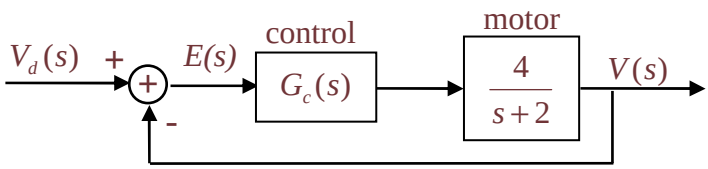
where $X(s) = \mathcal{L}(x(t))$

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

Differential Equation

_____/10 pt's

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, $G_c(s)$.



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

sec.

Open-Loop Motor Time Constant

(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, $v_d = 5$?

Steady-State Speed Error

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

sec.

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?

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?

Steady-State Speed Error

_____/25 pt's

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.

$e_0 =$	volts

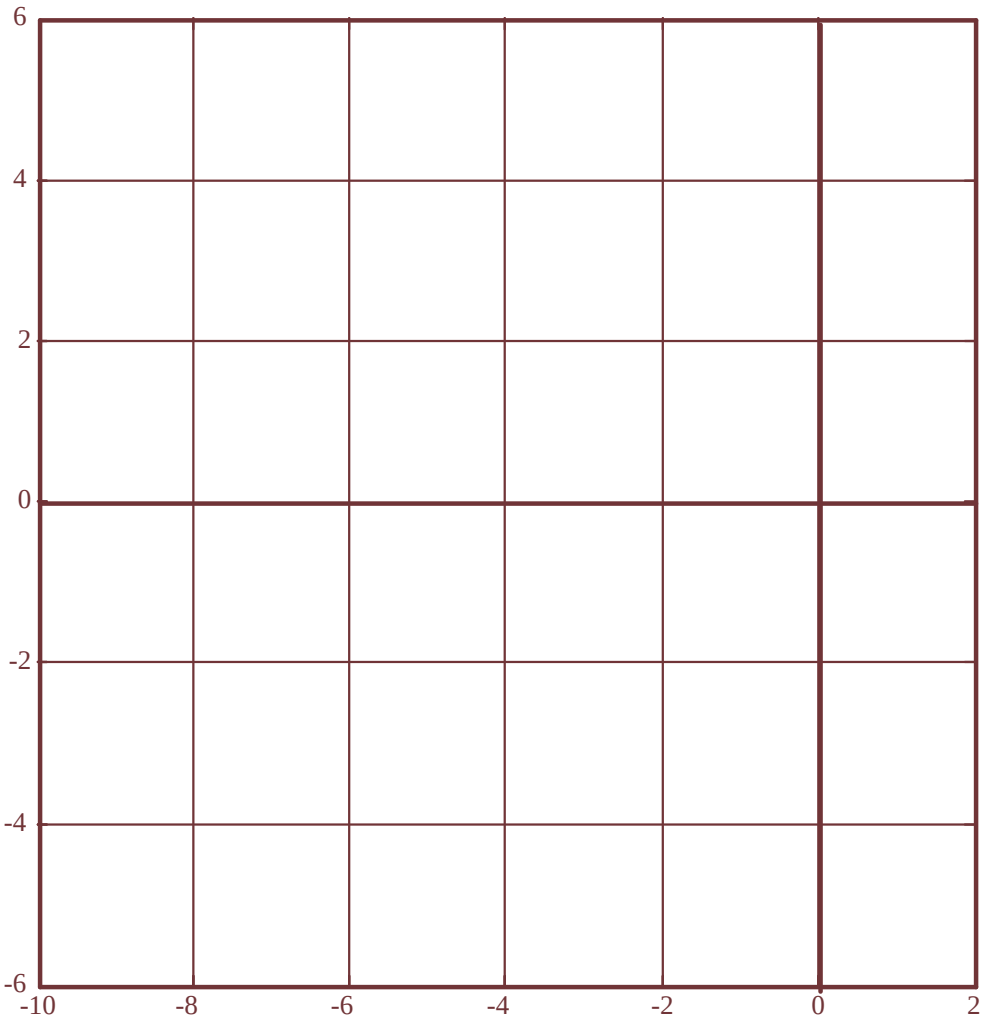
(5 pts) b) Define a new set of variables about which a linear approximation for the above equation can be derived.

(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)

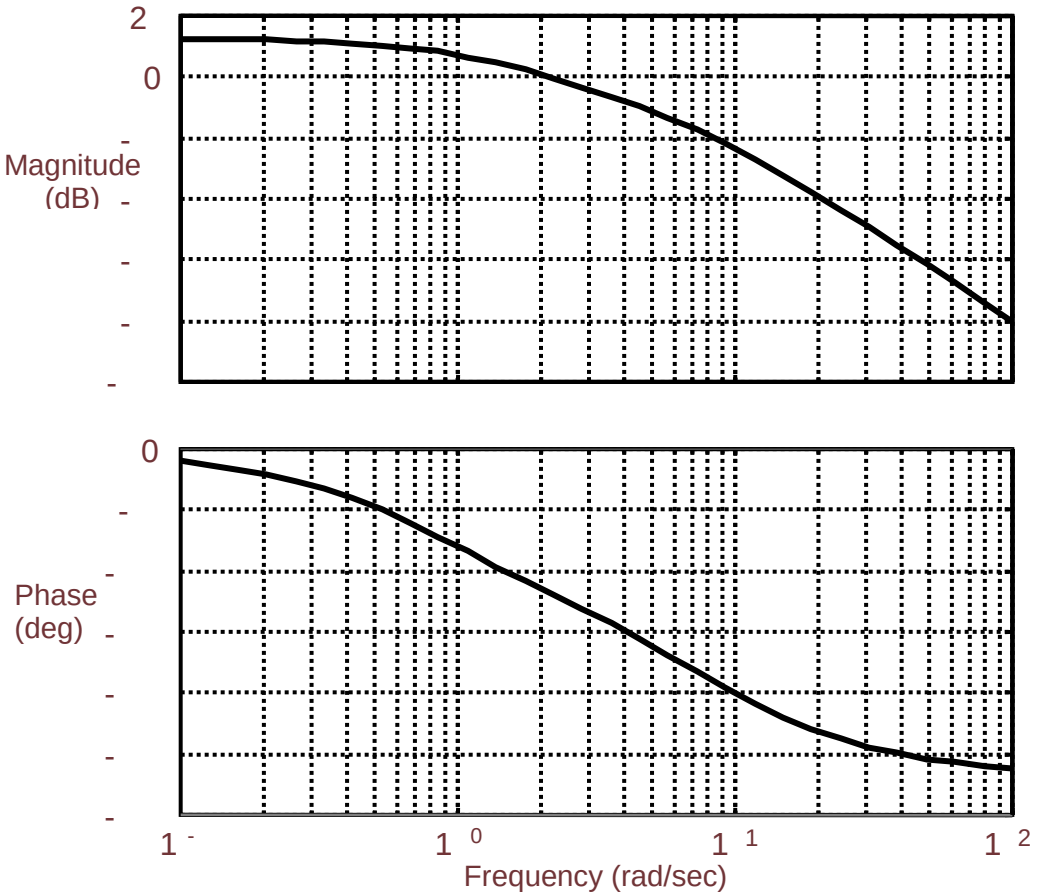
_____/20 pt's

(15 pts) 5. For an open-loop system transfer function, $kG(s)H(s) = \dfrac{ks}{\left((s+2)^2+1^2\right)(s+4)}$, 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.



_____/15 pt's

6. The open-loop system transfer function of an hydraulic actuator, *KG(s)* was measured for $\underline{K = 1}$, at Radcliffe Engineering and the Bode Diagram below plotted.



(5 pts) a) Is the closed-loop system stable at K = 1? YES or NO (circle one)

(5 pts) b) What is the closed-loop system's Gain Margin? GM = _____ dB

(5 pts) c) What is the closed-loop system's Phase Margin? PM = _____ deg

(5pts) d) What is the maximum closed-loop stable value of K? K_{max} = _____ dB

(5 pts) e) What value of K gives a phase margin of 60 degrees? K_{45} = _____ dB

(5 pts) f) For $K = 1$, what is the closed-loop system's steady-state error for a unit step input? e(∞) = _____

_____/30 pt's