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

$$5\ddot{z} + \dot{z} + 10z = 2f(t)$$

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

Transfer Function

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

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

Differential Equation

(5 pts) c) For the state-equations below, write the transfer function $X_2(s)/U(s)$ in the box provided. Simplify your result as much as possible and put it in the box provided.

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & -2 \\ 1 & -4 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 3 \\ 1 \end{bmatrix} u(t)$$

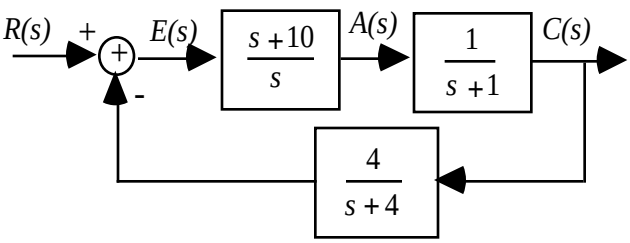
$\frac{X_2(s)}{U(s)} =$

Transfer Function

(5 pts) d) For the block diagram below, what is the system transfer function $C(s)/R(s)$. <u>Simplify as much as possible and express the result as the ratio of two polynomials.</u>

$\frac{C(s)}{R(s)} =$

Transfer Function



_____/20 pt's

2. A automobile designer measures the total drag of his vehicle and sets up the following non-linear differential equation model for velocity v (mph) for input throttle position T (deg.)

$$1500\dot{v} + 10v + v^2 = 5vT$$

(5 pts) a) Find the equilibrium input throttle position $T = T_o$ corresponding to an vehicle operating speed of 65 mph and enter it in the box below.

T_o = deg

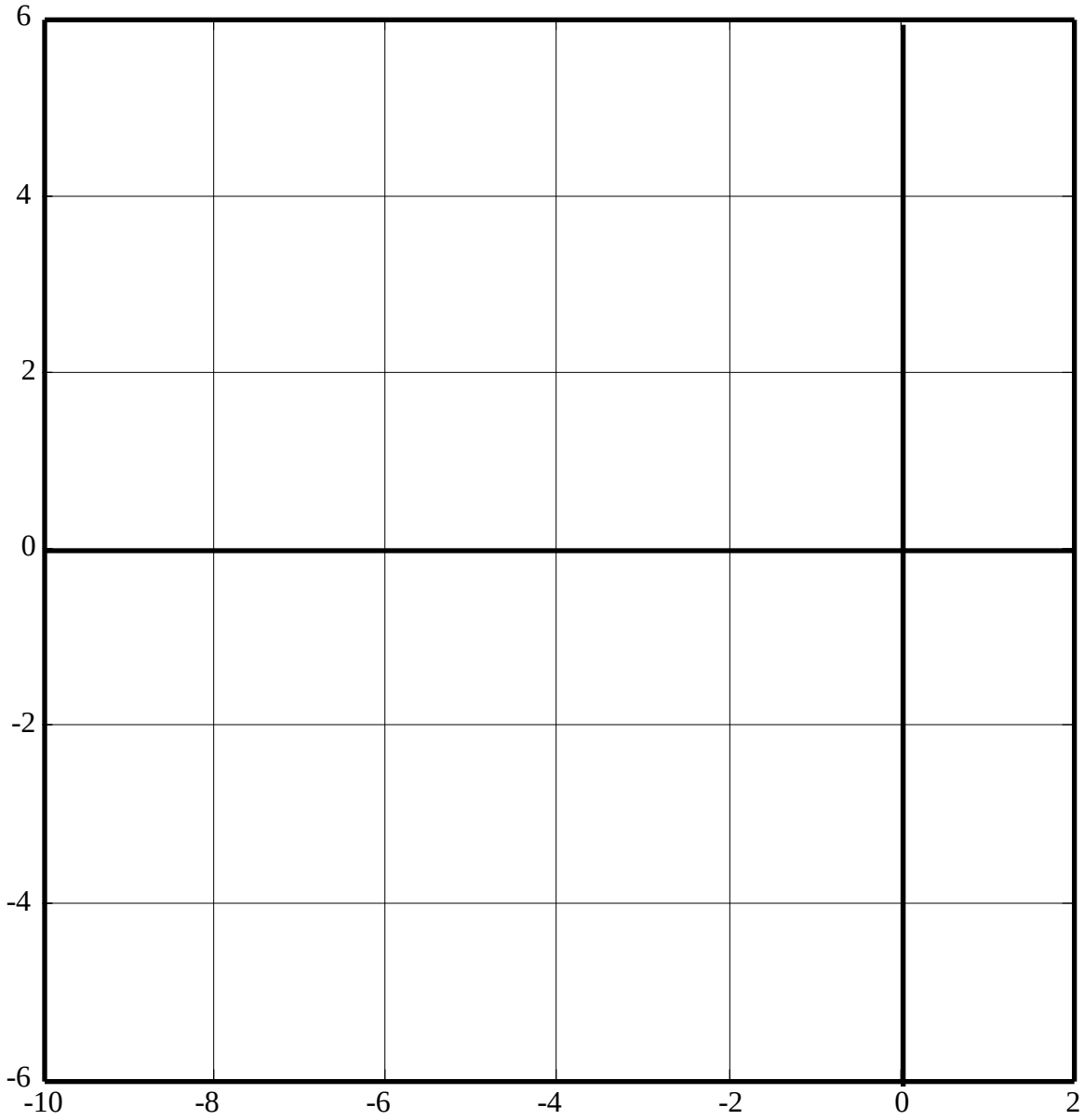
(5 pts) b) Define a new set of variables about which a linear approximation for the above equation can be derived.

(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)

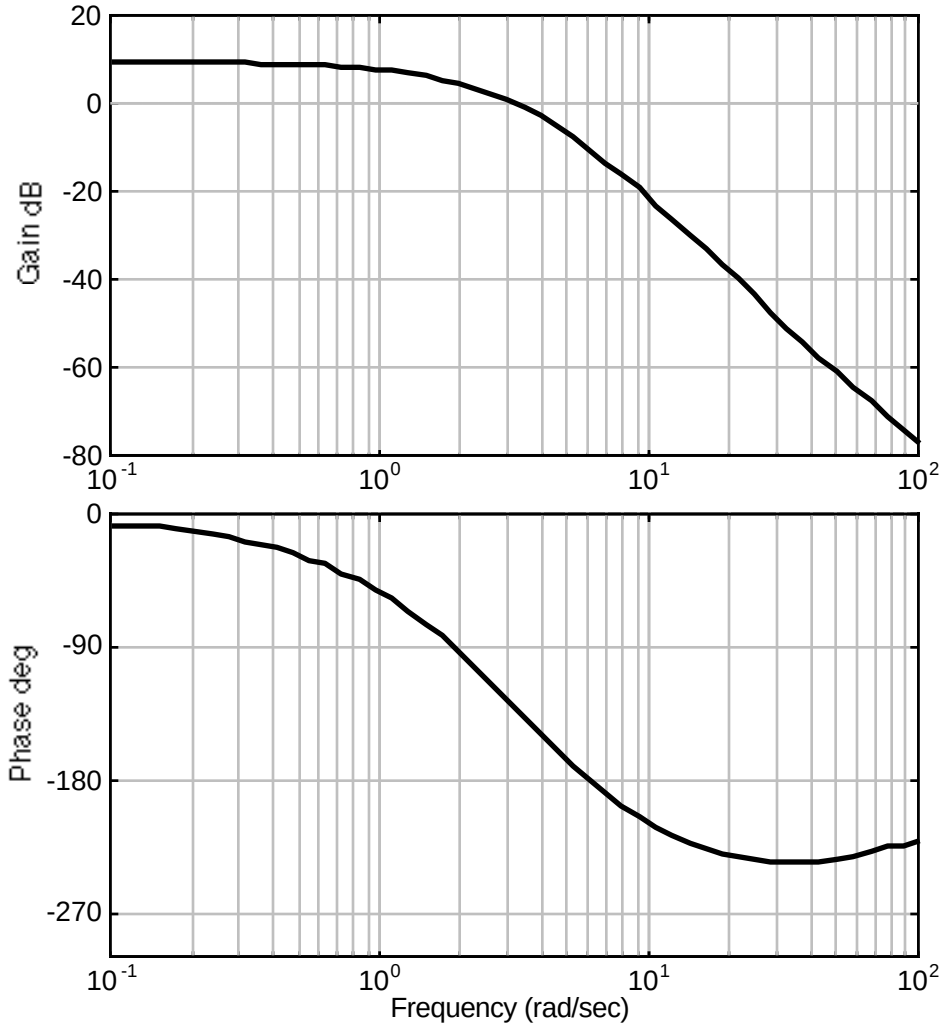
_____/20 pt's

(10 pts) 3.For an open-loop system transfer function, $KG(s) = \frac{K(s+4)}{s\left((s+2)^2 + 2^2\right)}$, 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.



_____/10 pt's

4. For an open-loop system transfer function, $KG(s) = \dfrac{K(s+100)}{\left((s+4)^2+1^2\right)(s+2)}$, with $K = 1$, the Bode Diagram below was plotted.



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

(3 pts) b) What is the Gain Margin? GM = _____ dB

(3 pts) c) What is the Phase Margin? PM = _____ deg

(3 pts) d) What is the maximum stable value of K? K_{max} = _____ (linear)

(4 pts) e) What value of K gives a phase margin of 90 degrees? K_{90} = _____ dB

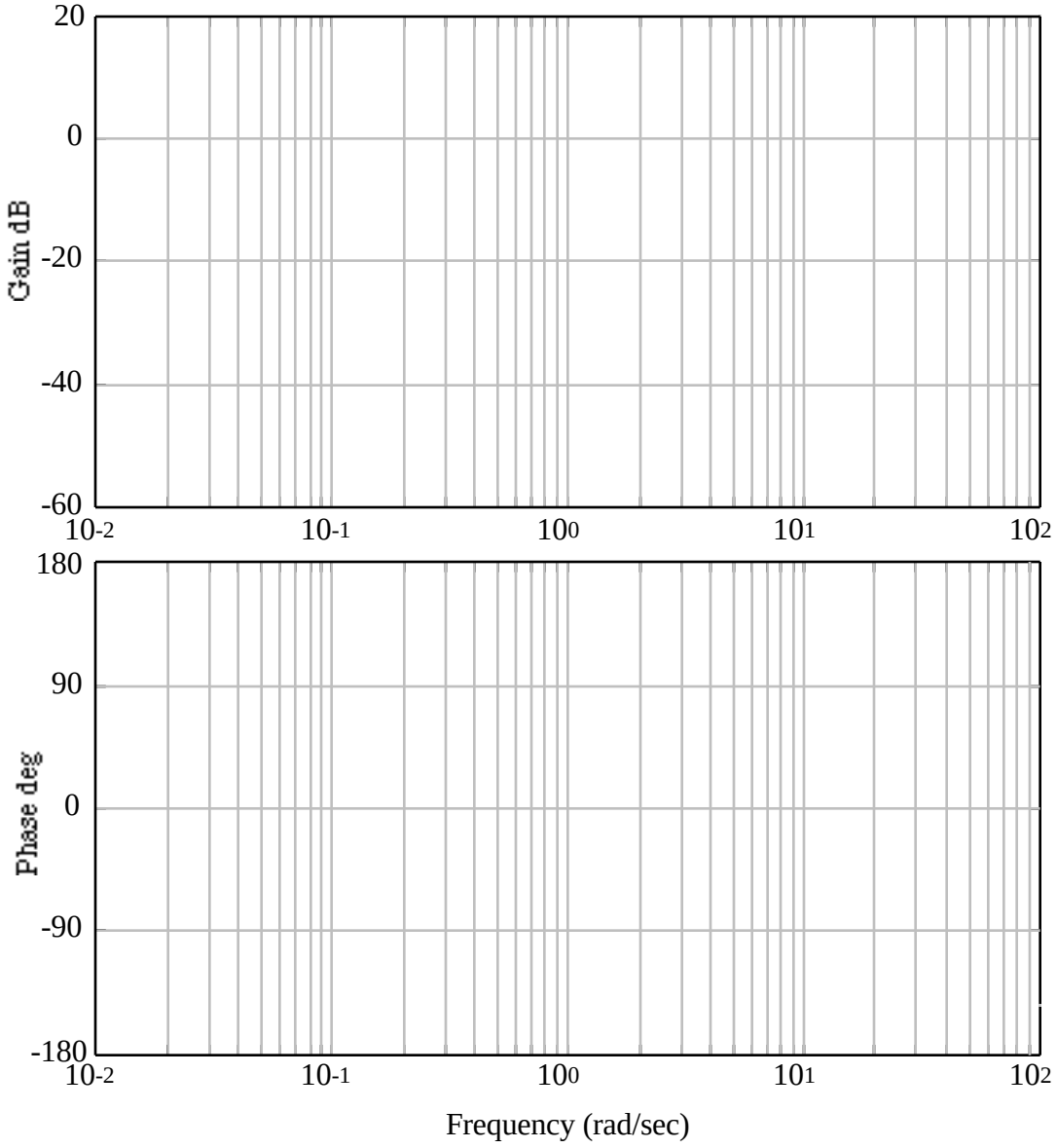
(4 pts) f) For K=1, what process delay τ would cause the closed-loop instability τ = _____ sec

_____/20 pt's

5. For the transfer function,

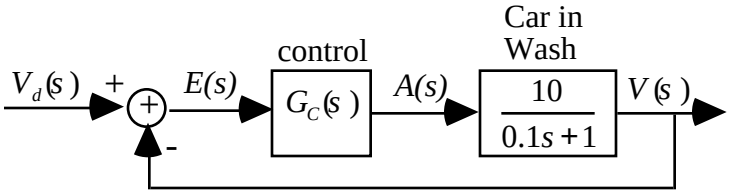
$$G(s) = \frac{(s+10)}{(s+1)}$$

(10pts) Sketch the Bode Diagram on the graph below first using straight line asymptotes for magnitude and phase, then sketching the "exact " response.



_____/10 pt's

6. The block diagram below represents an car wash system speed control. The desired speed $V_d(s)$ is compared to the actual speed $V(s)$ of the car in the wash in order to develop the error $E(s)$ which is the input to the control, $G_c(s)$.



(5 pts) a) For proportional control, $G_C(s) = K_p = 4$, what is the steady-state automobile speed error for a unit step input?

Steady-State Speed Error

(5 pts) b) For proportional control, $G_C(s) = K_p = 4$, what is the system time constant?

(sec)

System Time Constant

(5 pts) c) For integral control, $G_C(s) = \frac{K_I}{s} = \frac{1}{s}$, what is the steady-state automobile speed error for a unit step input?

Steady-State Speed Error

(5 pts) d) For integral control, $G_c(s) = \frac{K_I}{s}$, what is the range of stable values of K_I ?

K_I =

_____/20 pt's