ME 132 Fall 2020 Midterm 2

NAME:

ID # :

# 1	# 2	# 3	# 4	# 5	#6	#7	#8	TOTAL
14	10	9	10	4	8	14	12	81

Instructions:

1 Write your name and student ID number.

2 Read the questions carefully.

3 This exam has 8 questions worth 81 points.

4 Please write your solution clearly.

Problem # 1 (4 +4+3+3 = 14 points)

Explain your answers.

(a) Find eigenvalues (including multiplicity) of the matrix $A = \begin{bmatrix} I_4 & B \\ 0 & -I_3 \end{bmatrix}$.

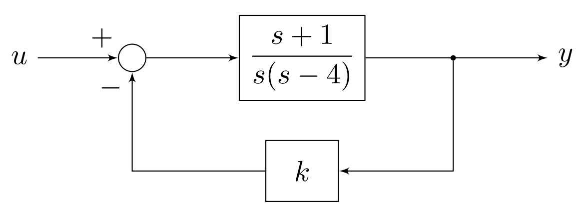
Here I_4 is the 4×4 identity matrix and I_3 is the 3×3.

Answer:

(b) Compute A^{100} for the matrix $A = \begin{bmatrix} I_4 & B \\ 0 & -I_3 \end{bmatrix}$.

Answer:

(c) Consider the block diagram shown below.



- Find the value of the gain k so that the free response of the closed loop system exhibits **undamped** sinusoidal oscillations, i.e. the free response looks like $M\cos(\omega t + \phi)$ where M and ϕ are constants.

$k =$

- What is the frequency ω of these oscillations in radians/second?

$\omega =$

Problem # 2 (4+4+2 = 10 points)

No partial credit.

(a) Find the natural frequency ω_n and damping ξ of the transfer function $H(s)$ with realization Σ.

$$H(s) \sim \Sigma \left[\begin{array}{cc|c} 0 & 1 & 0 \\ -1 & -1 & 1 \\ \hline 4 & 5 & 6 \end{array}\right]$$

$\omega_n =$	$\xi =$

(b) Find the controllable canonical form realization for $H(s) = \dfrac{2s^3 + 3}{s^3}$.

$A =$	$B =$	$C =$	$D =$

(c) Consider two vectors in $\mathbb{R}^2$ given by

$$v = \begin{bmatrix} \alpha \\ 1 \end{bmatrix}, \quad w = \begin{bmatrix} 1 \\ \alpha \end{bmatrix}$$

Find all values of α for which v and w are linearly dependent.

Answer:

Problem # 3 (3+3 +3= 9 points)

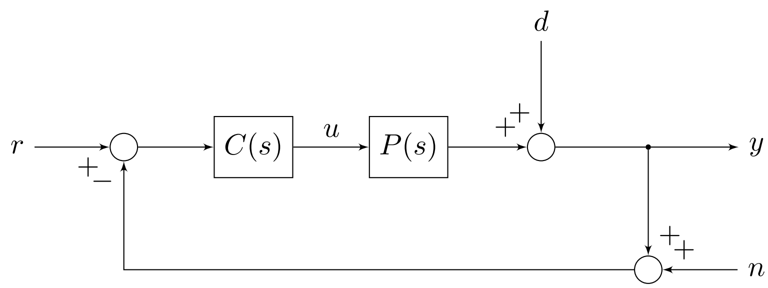
Show your work for partial credit.

Consider the plant $P(s) = \dfrac{1}{s+1}$. Design a controller $C(s) = \dfrac{K_1 s + K_2}{s+p}$ such that

(a) The feedback system system is stable

(b) The feedback system rejects constant disturbances.

(c) The feedback system is critically damped with a natural frequency of 1 rad/sec.

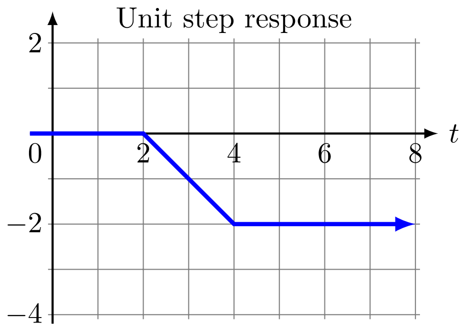


$p =$	$K_1 =$	$K_2 =$

Problem # 4 (2 + 4 + 4 = 10 points)

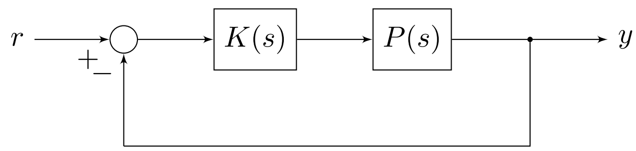
Show your work for partial credit.

Suppose $H(s)$ is a linear time invariant system.
Its **unit** step response with zero initial conditions is plotted below.
Find $H(s)$.



$H(s) =$

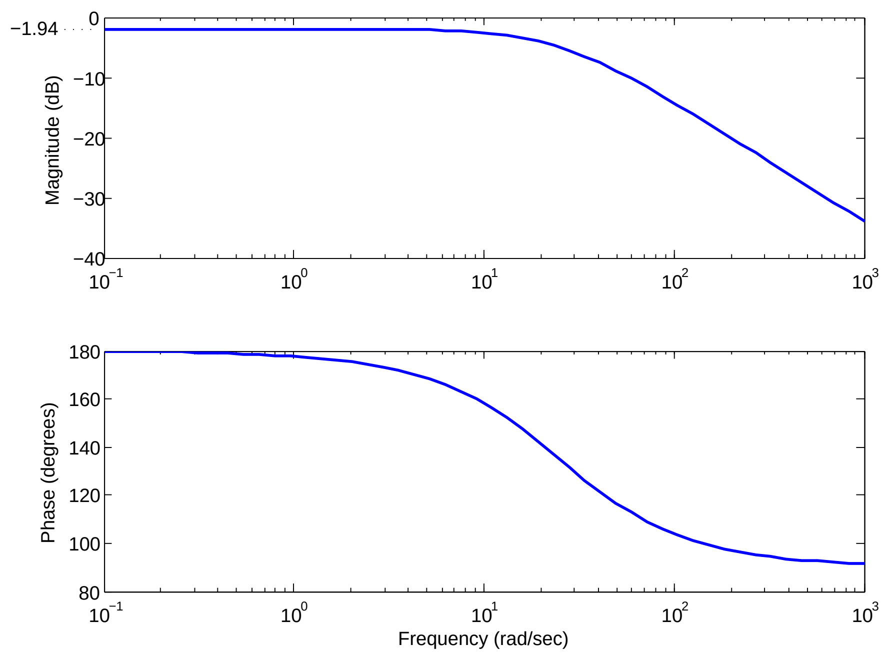
Problem # 5 (4 points)



Consider the closed loop system shown above.
Here $P(s)$ and $K(s)$ are single-input single-output transfer functions.
Assume the feedback system is stable.

Plotted below is the magnitude and phase frequency response of the **loop gain** $L(s) = P(s)K(s)$.
Calculate the DC gain of the **closed-loop system** from r to y.

No partial credit.



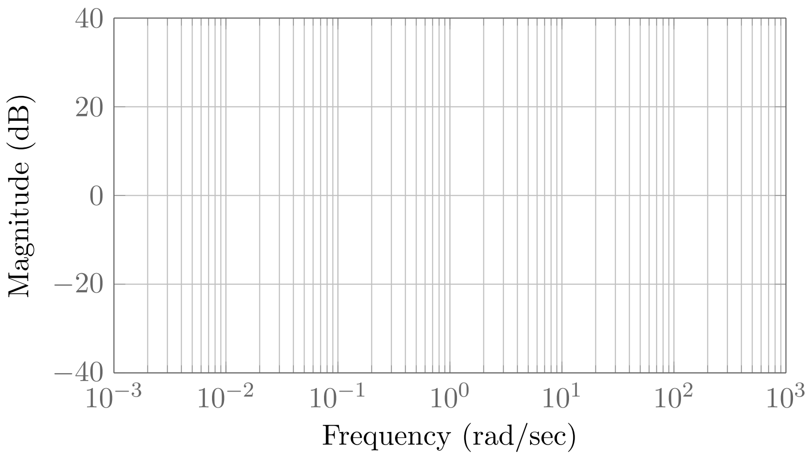
DC gain =

Problem 6 (4+4 = 8 points)

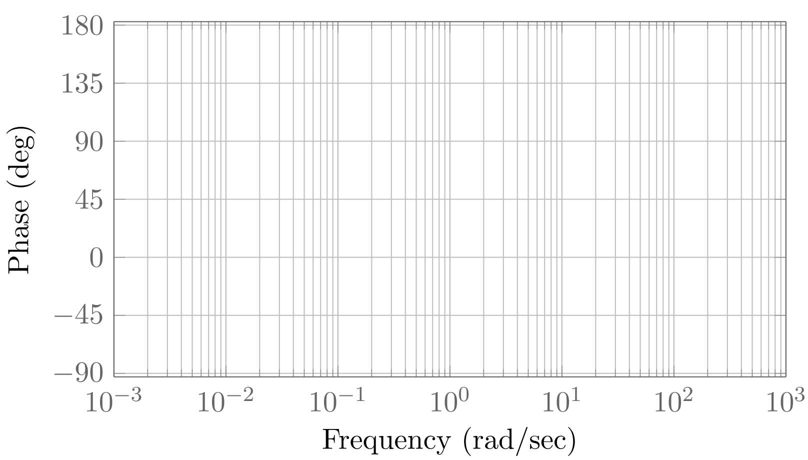
Consider the first-order LTI system

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

(a) Sketch the straight-line approximation of the magnitude frequency response plot of $C(s)$ on the graph paper below.



(b) Sketch the straight-line approximation of the phase frequency response plot of $C(s)$ on the graph paper below.



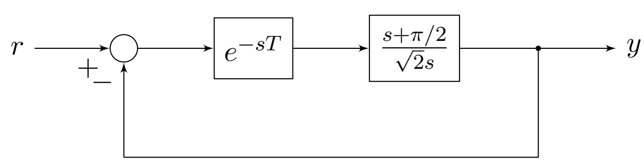
Problem # 7 (14 points)

Show your work for partial credit.

Find the delay margin for the system with nominal loop gain

$$L^o(s) = \frac{s + \pi/2}{\sqrt{2}s}$$

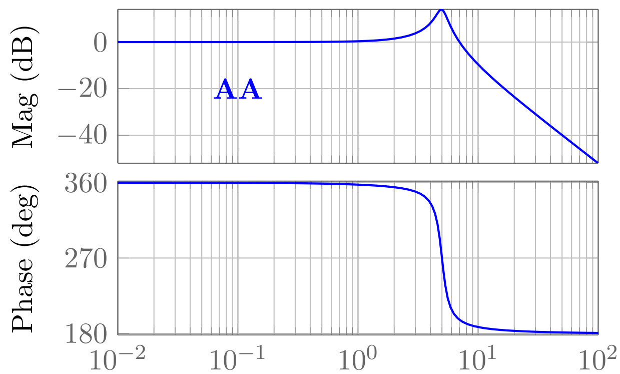
In other words, find the maximum delay $T_{\max}$ for which the feedback system shown below is stable. **You answer must be expressed in closed-form. So you have to do this problem by hand, and Matlab won't help.**

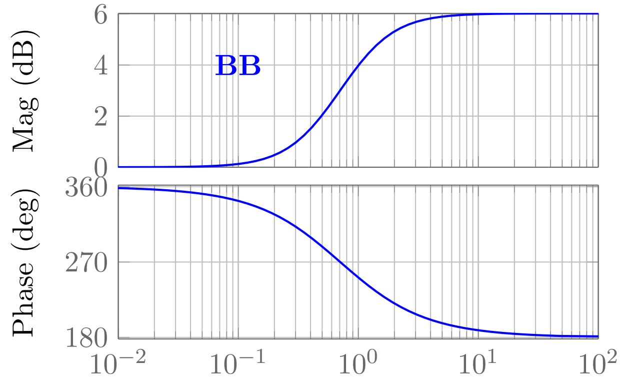


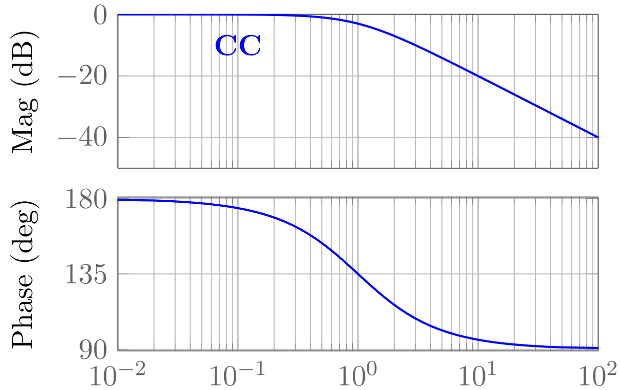
$T_{\max} =$

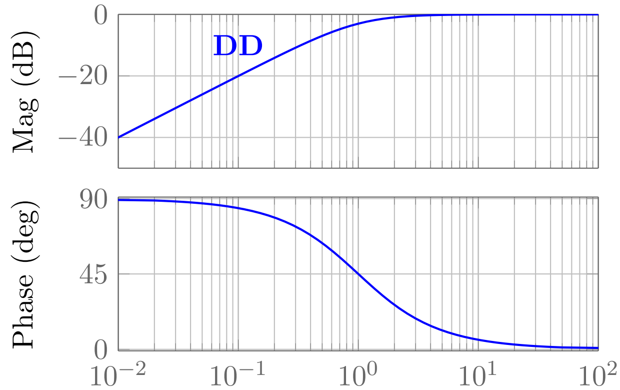
Problem # 8 (12 points)

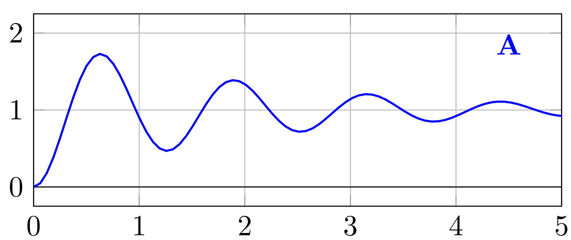
Match the correct unit step response for each frequency response plot given below.
Correct answers get 3 points. Incorrect answers receive −2 points, so you should not guess.
No explanations are necessary.

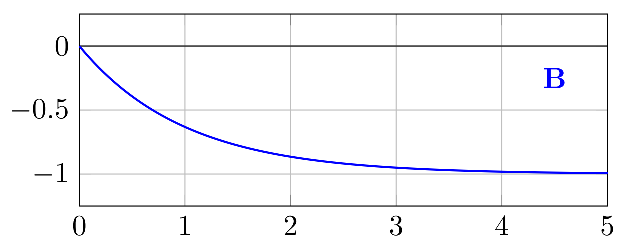


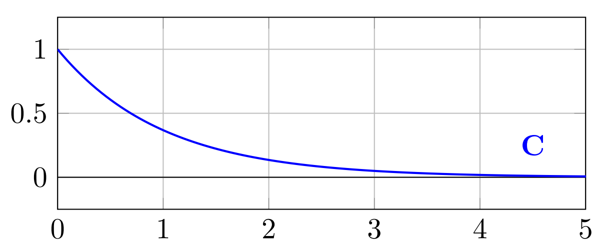


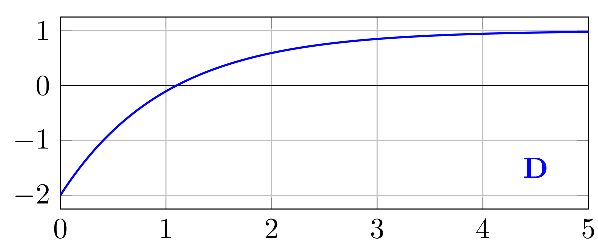












A =	B =	C =	D =