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EE 16B Midterm 1
Spring 2018

Name:____

SID #:____

(after the exam begins add your SID# in the top right corner of each page)

Discussion Section and TA:______________________________

Discussion Section and TA:______________________________

Lab Section and TA:____________________________________

Name of left neighbor:__________________________________

Name of right neighbor:_________________________________

Instructions:

Show your work. An answer without explanation is not acceptable and does not guarantee any credit.

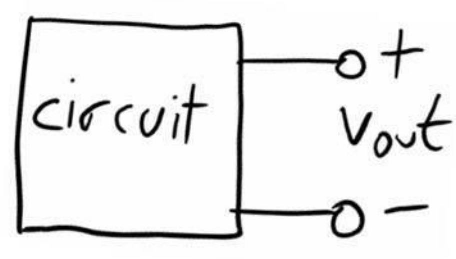
Only the front pages will be scanned and graded. Back pages won't be scanned; you can use them as scratch paper.

Do not remove pages, as this disrupts the scanning. If needed, cross out any parts that you don't want us to grade.

PROBLEM	MAX
1	15
2	25
3	15
4	20
5	25

SID#_______________________

Problem 1 *Warm up* (15 points)
a) Consider the following circuit.



a) For t≥0, the following equation applies to $\mathbf{v_{OUT}(t)}$. In addition, $\mathbf{v_{OUT}}(0) = V_0$ and $\frac{dv_{OUT}}{dt} = 0$ at t=0.

$$\frac{d^2 v_{out}}{dt^2} + \boldsymbol{A}\frac{dv_{out}}{dt} + \boldsymbol{B} v_{out} = 0$$

If $\boldsymbol{A} < 2\sqrt{\boldsymbol{B}}$, provide an expression for $v_{out}(t) \geq 0$. **(5 points)**

Solution:

$v_{out}(t) = K_1 e^{\lambda_1 t} + K_2 e^{\lambda_2 t}$

$\lambda_1 = \frac{-A}{2} + \sqrt{\left(\frac{A}{2}\right)^2 - B}$ $\quad K_1 = \frac{\lambda_2}{\lambda_2 - \lambda_1} V_0$

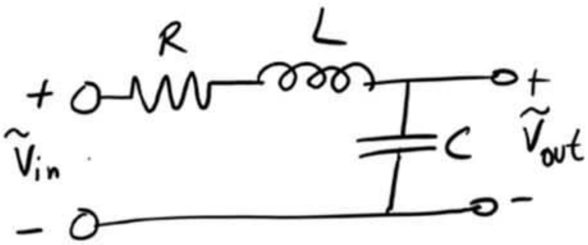
$\lambda_2 = \frac{-A}{2} - \sqrt{\left(\frac{A}{2}\right)^2 - B}$ $\quad K_2 = \frac{\lambda_1}{\lambda_1 - \lambda_2} V_0$

or

$$V_{out}(t) = e^{\frac{-At}{2}}\left[(K_1 + K_2)\cos\left(\sqrt{B - \left(\frac{A}{2}\right)^2}\, t\right) + j(K_1 - K_2)\sin\left(\sqrt{B - \left(\frac{A}{2}\right)^2}\, t\right)\right]$$

SID#______________________

b) Consider the circuit below.

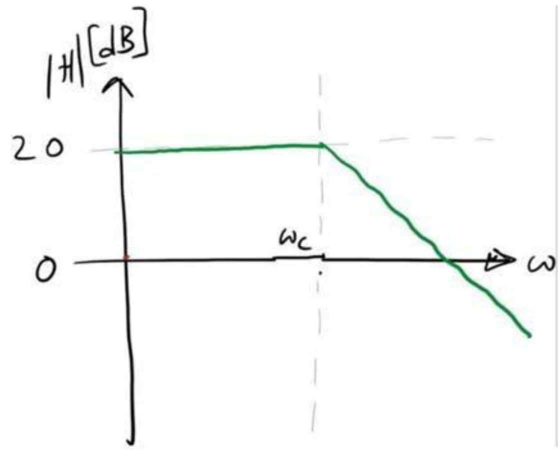


What is $\widetilde{\mathbf{H}}_{\text{out}}(\omega) = \frac{\widetilde{\mathbf{V}}_{\text{out}}(\omega)}{\widetilde{\mathbf{V}}_{\text{in}}(\omega)}$ for $\omega \to \infty$? **(5 points)**

Solution:

$\widetilde{\mathbf{H}}_{\text{out}}(\omega \to \infty) =$ 0

c) Consider the Bode plot below. **(5 points)**



This is a Bode magnitude plot of the transfer function $\widetilde{\mathbf{H}}(\omega)$. The expression for $\widetilde{\mathbf{H}}(\omega)$ is shown below.

$$\widetilde{\mathbf{H}}(\omega) = \frac{\widetilde{\mathbf{H}}_x(\omega)}{1 + j\left(\frac{\omega}{\omega_c}\right)}$$

What is $\widetilde{\mathbf{H}}_x(\omega)$?

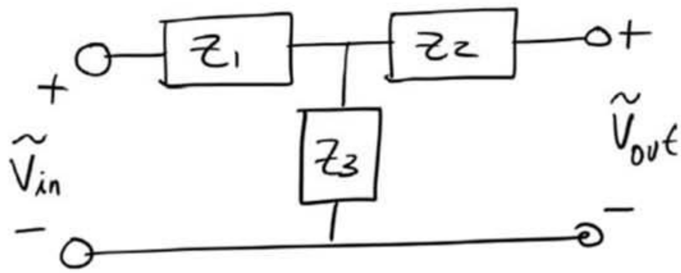
Solution:

$\widetilde{\mathbf{H}}_x(\omega) =$ ± 10

SID#________________________

Problem 2 *H's and Bodes…* (25 points)

Consider the circuit below. There is nothing connected to the **V$_{out}$** terminal. **(5 points)**



a) Provide an expression for $\widetilde{\mathbf{H}}_{\text{out}}(\omega) = \frac{\widetilde{\mathbf{V}}_{\text{out}}(\omega)}{\widetilde{\mathbf{V}}_{\text{in}}(\omega)}$

Solution:

$\widetilde{\mathbf{H}}_{\text{out}}(\omega) = \dfrac{Z_3}{Z_1 + Z_3}$

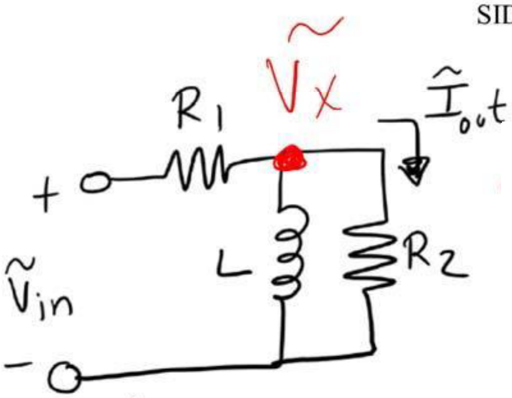
SID#___________________________

b) For this part of the problem, assume you have ONE capacitor, ONE inductor and ONE resistor. If $\mathbf{Z_2 = 0}$ for all ω, which components would you choose for $\mathbf{Z_1}$ and $\mathbf{Z_3}$ such that the filter response is a passive low pass filter with a slope of -20 dB/decade for frequencies beyond a single cutoff frequency? **(5 points)**

Solution:
Either combo is correct Circle ONE component to go into the Z_1 box: **Capacitor** **Inductor** **Resistor** Circle ONE component to go into the Z_3 box: **Capacitor** **Inductor** **Resistor**

SID#__________________________

c) Consider the following circuit:



We define a transfer function $\widetilde{\mathbf{H}}_{\text{out}}(\omega) = \dfrac{\tilde{\mathbf{I}}_{\text{out}}(\omega)}{\tilde{\mathbf{V}}_{\text{in}}(\omega)}$.

<u>LOOK AT THE DEFINITION OF THE TRANSFER FUNCTION CAREFULLY.</u>

Provide an expression in <u>*canonical form*</u> for $\widetilde{\mathbf{H}}_{\text{out}}(\omega)$. **(10 points)**

Solution:

$K = \dfrac{1}{R_1 R_2}$

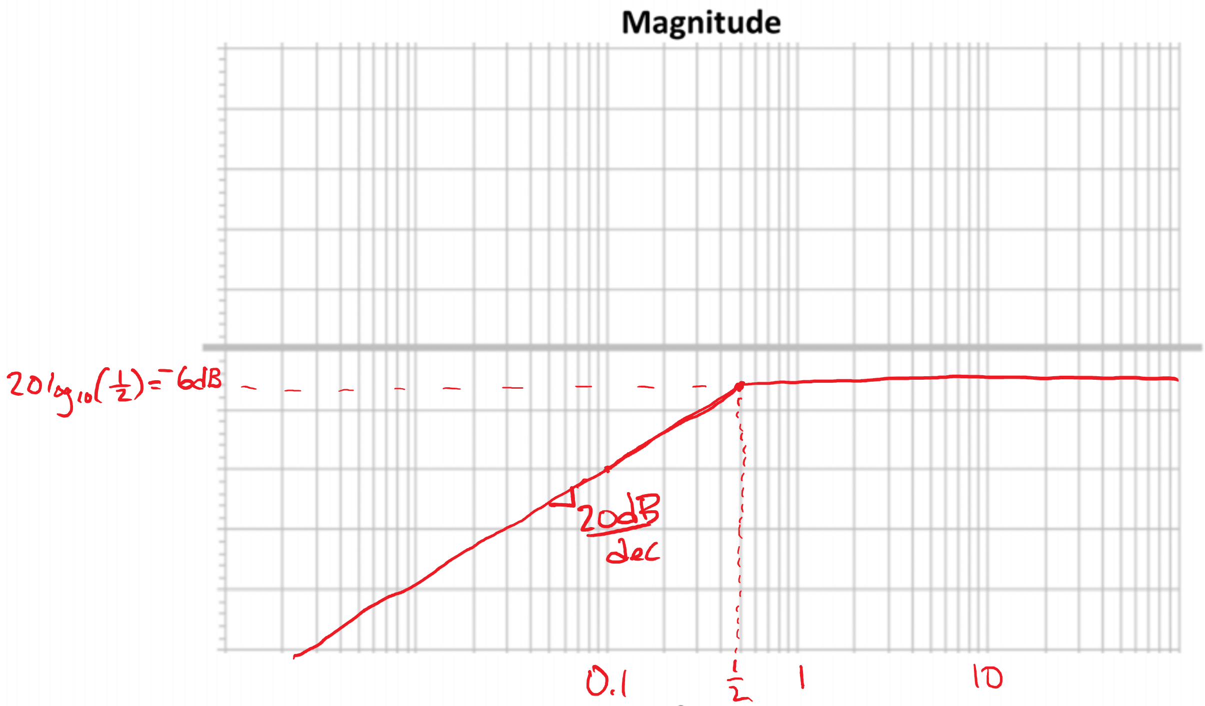
$\omega_{c1} = 1/L R_2^2$

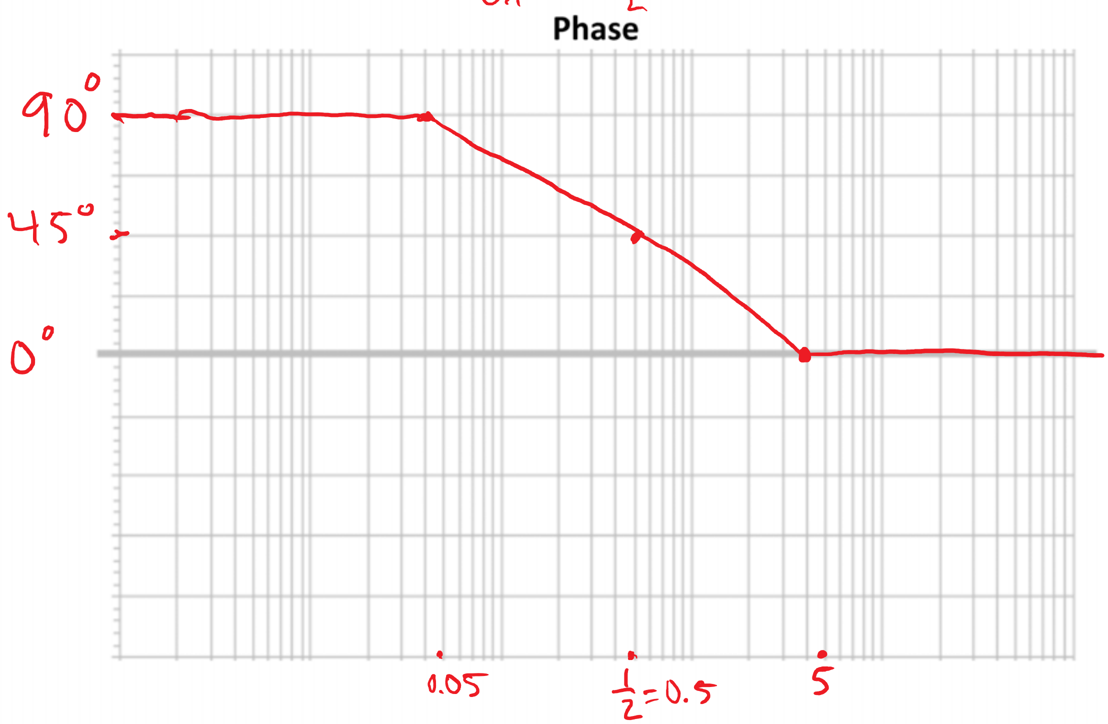
$\omega_{c2} = \dfrac{R_1 R_2}{L(R_1+R_2)}$

$\widetilde{\mathbf{H}}_{\text{out}}(\omega) =$

$= \dfrac{K\, j\, \omega/\omega_{c1}}{1 + j\omega/\omega_{c2}}$;

d) If L = 1 H and $R_1 = R_2 = 1\ \Omega$, provide below magnitude and phase Bode plots for $\mathbf{H}_{\text{out}}(\omega)$. **(5 points)**





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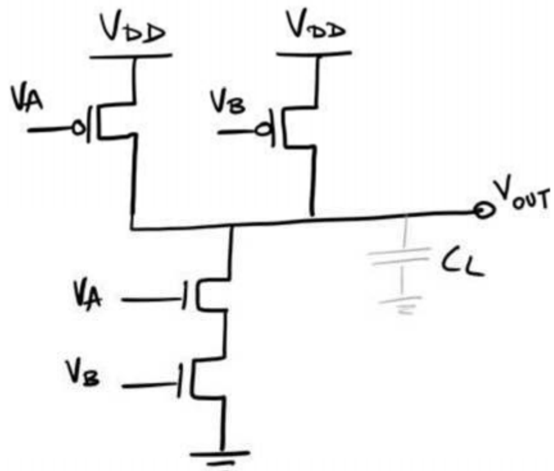
Problem 3 *Transistors and RC's* (15 points)
Consider the circuit below.



a) Fill in the truth table below for the circuit above. **V_A, V_B** and **V_{out}** are digital voltages that can only assume values of 0 or V_{DD}. **(5 points)**

V_A	V_B	V_{out}
0	0	VDD
0	VDD	VDD
VDD	0	VDD
VDD	VDD	0

SID#________________________

For this part, assume that $\mathbf{V_A} = \mathbf{V_B} = V_{DD}$ for $-\infty < t < 0$. At t=0, $\mathbf{V_A}$ and $\mathbf{V_B}$ switch instantly from V_{DD} to 0. Assume all transistors behave as resistors with the same value, R, if in the ON state and that all capacitances are already accounted for in the circuit above.

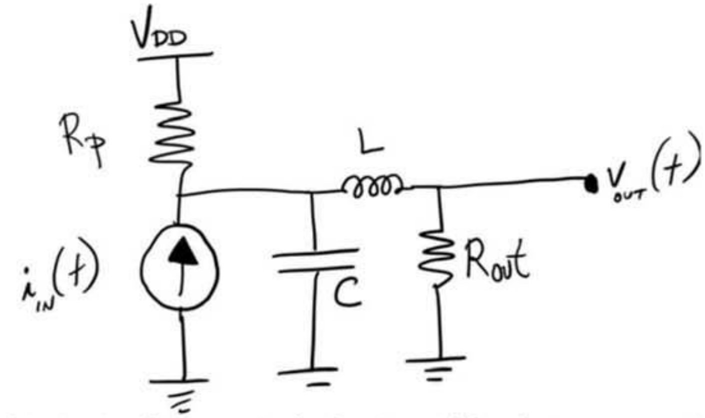
b) Provide an expression for $\mathbf{V_{out}}(t \geq 0)$. **(10 points)**

Solution:

$$V_{out}(t) = V_{DD}\left(1 - e^{-2t/RC_L}\right)$$

SID#________________________

Problem 4 *Phasors!* **(20 points)**
Consider the circuit below.



We are going to solve this circuit, which contains both a sinusoidal *and* a DC source using *superposition* and *phasors*.

a) Solve for $v_{OUT}(t)$ if $i_{IN}(t) = 0$ and V_{DD} = a non-zero constant. **(5 points)**

Solution:
$V_{out}(t) = \frac{R_{out}}{R_p + R_{out}} V_{DD}$

SID#____________________

b) Solve for $v_{OUT}(t)$ if $i_{IN}(t) = I_0\cos(\omega t)$ and $V_{DD} = 0$ V. **(10 points)**

Solution:

$$V_{out}(t) = \frac{I_0 R_{out} R_p}{\sqrt{(R_p + R_{out} - \omega^2 LCR_p)^2 + (\omega L + \omega CR_pR_{out})^2}} \cos\left(\omega t - \tan^{-1}\left(\frac{\omega L + \omega R_p R_{out}}{R_p + R_{out} - \omega^2 LCR_p}\right)\right)$$

SID#________________________

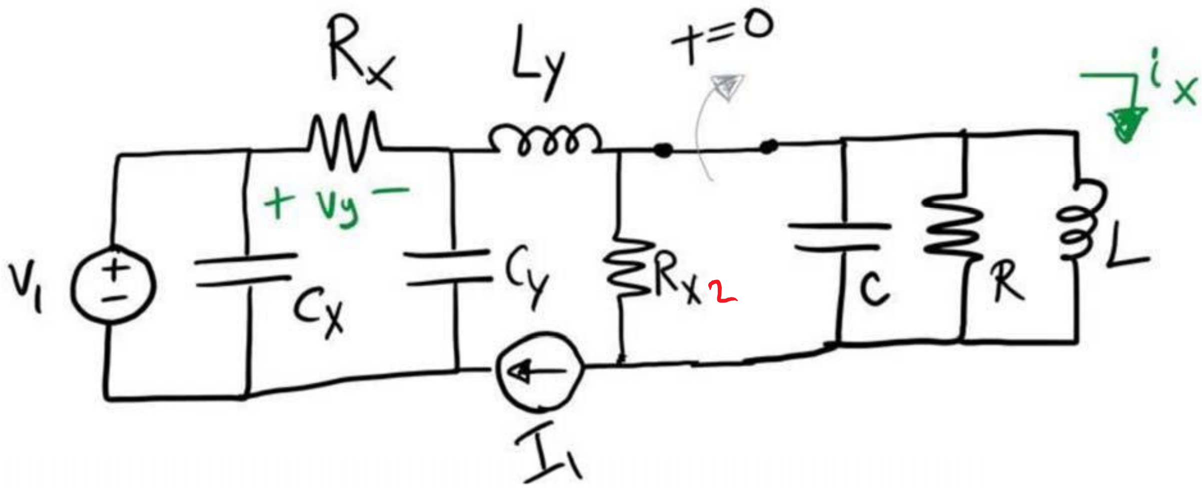
c) Solve for $v_{OUT}(t)$ if $i_{IN}(t) = I_0\cos(\omega t)$ and V_{DD} = a non-zero constant. **(5 points)**

Solution:
Vout(t) from (a) + Vout(t) from (b)

SID#________________________

Problem 5 (25 points)

a) Consider the following circuit. The switch is closed for t<0, then opens at t=0. Both of the independent sources have a DC value (i.e. they do not change with time).



a) What is $i_x(t<0)$? **(5 points)**

Solution:

I_1

b) What is $v_Y(t<0)$? **(5 points)**

Solution:

$V_y = R_x \cdot I_1$

c) Provide an equation in the variable $\mathbf{i_x(t)}$ that, when solved, would provide an expression for $\mathbf{i_x(t)}$ for $t \geq 0$.
<u>DO NOT SOLVE THE EQUATION.</u> **(10 points)**

Solution:
$i_x + \frac{L}{R}\frac{di_x}{dt} + CL\frac{d^2 i_x}{dt^2} = 0$

d) If Cx = Cy = C = 1 F and Rx = R = 1 Ω and Ly = L = 1 H, provide an expression for $\mathbf{i_x(t)}$ for $t \geq 0$. **(5 points)**

Solution:
$\mathbf{i_x(t)} =$ $C_1 e^{\lambda_1 t} + C_2 e^{\lambda_2 t}$ $\lambda_1 = -\frac{1}{2} + j\sqrt{3/4}$ $C_1 = \frac{\lambda_2}{\lambda_2 - \lambda_1} I_0$ $\lambda_2 = -\frac{1}{2} - j\sqrt{3/4}$ $C_2 = \frac{\lambda_1}{\lambda_1 - \lambda_2} I_0$

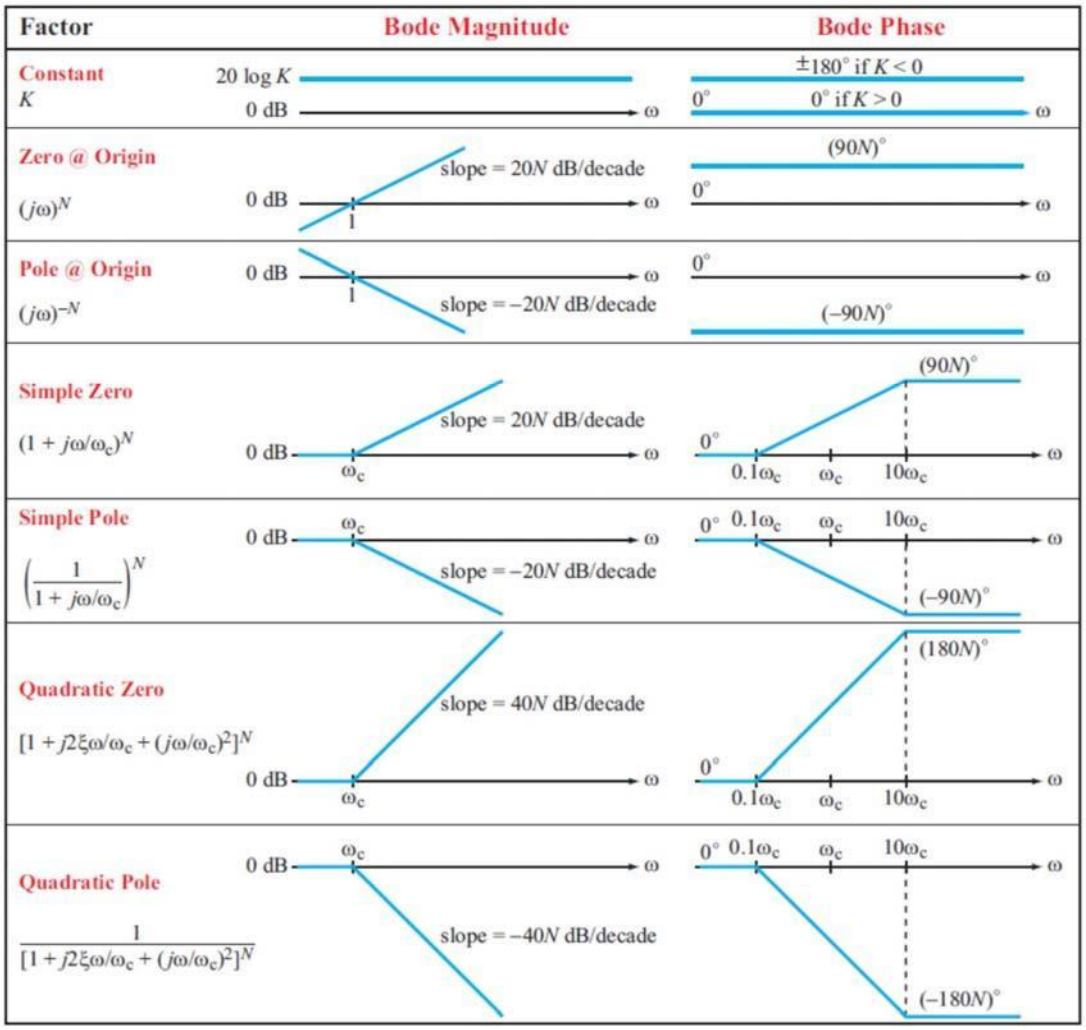
Or

$$i_x(t) = e^{-t/2}\left[(C_1 + C_2)\cos\left(\sqrt{\tfrac{3}{4}}\, t\right) + j(C_1 - C_2)\sin\left(\sqrt{\tfrac{3}{4}}\, t\right)\right]$$

SID#_________________________

Extra Space

SID#_________________________


Factor
Bode Magnitude
Bode Phase
Constant
K
20 log K
0 dB
ω
±180° if K < 0
0°
0° if K > 0
ω
Zero @ Origin
(jω)^N
0 dB
1
slope = 20N dB/decade
ω
(90N)°
0°
ω
Pole @ Origin
(jω)^−N
0 dB
1
slope = −20N dB/decade
ω
0°
(−90N)°
ω
Simple Zero
(1 + jω/ωc)^N
0 dB
ωc
slope = 20N dB/decade
ω
(90N)°
0°
0.1ωc
ωc
10ωc
ω
Simple Pole
(1/(1 + jω/ωc))^N
0 dB
ωc
slope = −20N dB/decade
ω
0°
0.1ωc
ωc
10ωc
(−90N)°
ω
Quadratic Zero
[1 + j2ξω/ωc + (jω/ωc)²]^N
0 dB
ωc
slope = 40N dB/decade
ω
(180N)°
0°
0.1ωc
ωc
10ωc
ω
Quadratic Pole
1/[1 + j2ξω/ωc + (jω/ωc)²]^N
0 dB
ωc
slope = −40N dB/decade
ω
0°
0.1ωc
ωc
10ωc
(−180N)°
ω