Circuits

Final Exam

Fall 2020

1.	/50
2.	/50
Total	/100
Extra Credit	/5

Name ___________________

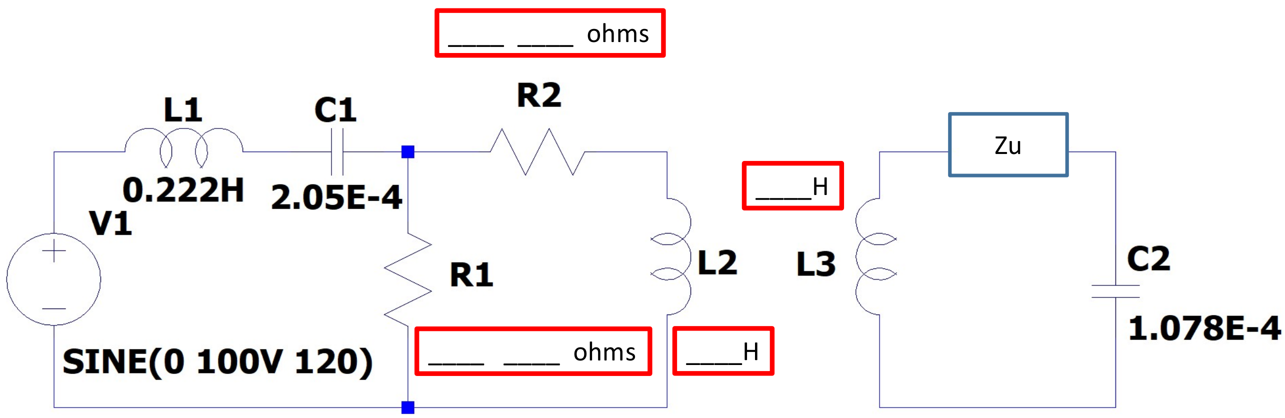
Notes:
1) If you are stuck on one part of the problem, choose 'reasonable' values on the following parts to receive partial credit
2) You don't need to simplify all your numerical calculations. For example, you can leave square root terms in radical form.

Please sign below:
I have not consulted any person or collaborated with anyone to complete this exam. I did not post and will not post any part of this exam to Chegg.com or any other equivalent websites. I understand that if my exam is found online, I will be given an F for the semester and the academic dishonesty process will be initiated. I did not look for answers on any website to this exam. If any signification portion of this exam is found to match with any other student, I will be given an automatic 0 for the entire exam. Further actions due to academic dishonesty may be warranted after discussion with all parties.

Signature: ____

1) Unit 1 and 3 (50 pts)

1.1: Use a combination of Unit 1 and Unit 3 concepts to find the value of Zu if the voltage across C2 is defined as shown in below the diagram. The coupling coefficient is 0.78. Choose values of the transformer self-inductances L2 and L3 between 1 and 5 H. Choose your values for R1 and R2 with two integers (1-9) i.e. 13 or 27 ohms. (The easiest way is to adjust the value of Zu at the end if needed which may mean adding resistance and a capacitor or inductor. If your answer is ridiculous but procedure is right...no problem..you willl still get full points!)



$V_{C2} = 50\cdot\cos(754t + 37deg)$

$\omega_1 := 120\cdot 2\cdot\pi = 753.982$

$V_1 := 100V$

$f := 120Hz$

$Z_{R1} := 36\Omega$

$L_2 := 2$

$L_3 := 1$

$C_1 := 2.05\cdot 10^{-4}$

$L_1 := 0.222$

$C_2 := 1.078\cdot 10^{-4}$

$Z_{R2} := 47\Omega$

$V_{C2} := (39.932 + 30.1j)V$

$50\cdot\cos(37deg) = 39.932$

$50\cdot\sin(37deg) = 30.091$

$\omega := 2\cdot\pi\cdot f$

$$Z_{C1} := \frac{-j\Omega}{C_1\cdot\omega_1} = -6.47i\Omega$$

$Z_{L1} := j\cdot\omega_1\cdot L_1\cdot 1\Omega = 167.384i\Omega$

$k := 0.78$

$$Z_{C2} := \frac{-j\Omega}{C_2\cdot\omega_1} = -12.303i\Omega$$

$M := k\cdot\sqrt{L_2\cdot L_3}$

$M = 1.103$

$Z_{L2M} := (L_2 - M)j\cdot 1\Omega\cdot\omega_1 = 676.257i\Omega$

$L_2 - M = 0.897$

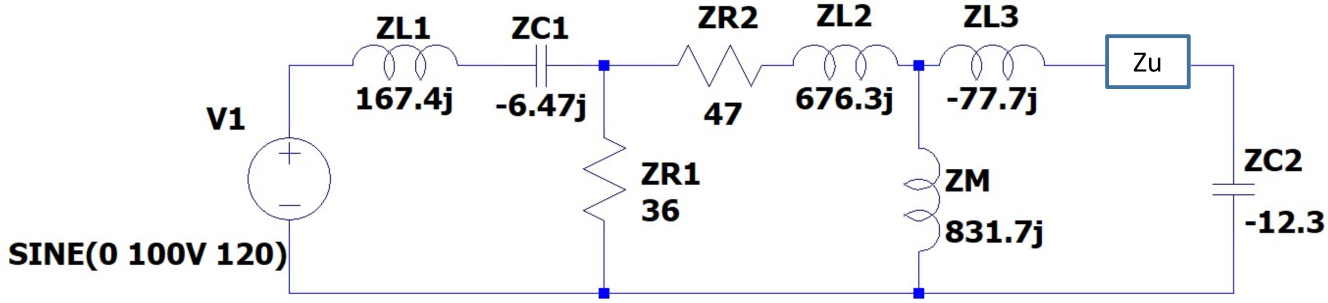
$L_3 - M = -0.103$

$Z_{L3M} := (L_3 - M)\cdot j\cdot 1\Omega\cdot\omega_1 = -77.725i\Omega$

$Z_M := M\cdot j\cdot 1\Omega\cdot\omega_1 = 831.708i\Omega$

To find VC1...can use circuit reduction and then voltage divider...make equal to find Zu

using thevenin with Zu and ZC2 as load (can use equivalent Unit 1 process)



Doing a double voltage divider to get VZM which is Vth

$$Z_M + Z_{L2M} + Z_{R2} = \left(47 + 1.508i \times 10^3\right)\Omega$$

$$Z_{R1R2L2M} := \frac{\left(Z_M + Z_{L2M} + Z_{R2}\right)\cdot Z_{R1}}{Z_M + Z_{L2M} + Z_{R2} + Z_{R1}} = (35.953 + 0.857i)\,\Omega$$

$$V_{R1R2L2M} := V_1\cdot\frac{Z_{R1R2L2M}}{Z_{L1} + Z_{C1} + Z_{R1R2L2M}} = (5.212 - 21.066i)\,V$$

$$V_M := V_{R1R2L2M}\cdot\frac{Z_M}{Z_M + Z_{R2} + Z_{L2M}} = (3.233 - 11.518i)\,V$$

$$V_{Th2} := V_M = (3.233 - 11.518i)\,V$$

$$Z_{TH} := \frac{\left[\frac{\left(Z_{L1} + Z_{C1}\right)\cdot Z_{R1}}{Z_{L1} + Z_{C1} + Z_{R1}} + Z_{R2} + Z_{L2M}\right]\cdot Z_M}{\frac{\left(Z_{L1} + Z_{C1}\right)\cdot Z_{R1}}{Z_{L1} + Z_{C1} + Z_{R1}} + Z_{R2} + Z_{L2M} + Z_M} + Z_{L3M} = (24.407 + 298.89i)\,\Omega$$

$$V_{C2} = (39.932 + 30.1i)\,V$$

$$V_{C2} = V_{Th2}\cdot\frac{Z_{C2}}{Z_{C2} + Z_u + Z_{TH}}$$

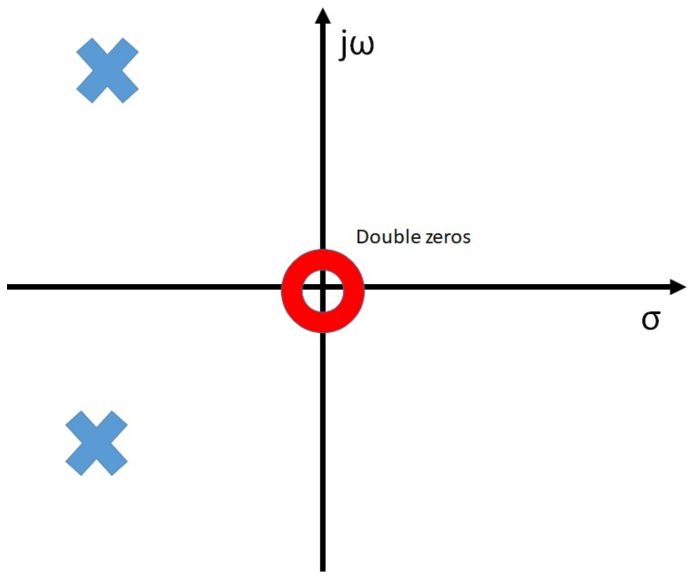
$$\frac{V_{Th2}\cdot Z_{C2}}{V_{C2}} - Z_{TH} - Z_{C2}$$

$$Z_u := \frac{V_{Th2} \cdot Z_{C2}}{V_{C2}} - Z_{TH} - Z_{C2} = (-27.149 - 285.516i)\,\Omega$$

Added resistor $R_{Zu} := -27.15\Omega$

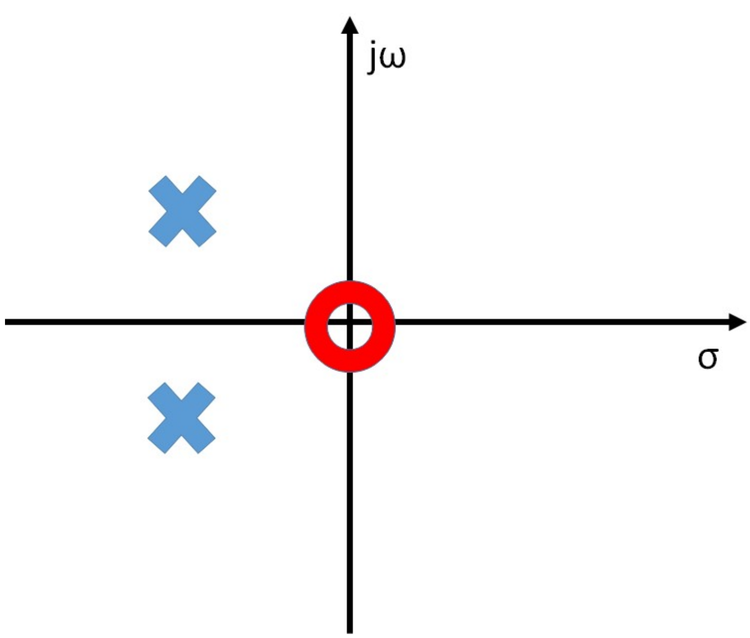
$$C_{Zu} := \frac{-j}{\omega_1 \cdot (-285.5j)} = 4.646 \times 10^{-6}$$

Problem 2) Unit 2 and Unit 4



Choice 1

NOTE: This one has double zeros!
Choose values on the x and y axis AND label them to start



Choice 2

NOTE: This one has a single zero!
Choose values on the x and y axis AND label them to start

Unit 4 Filter design - Choose one of the above pole zero diagrams.

2.1. Use your labeled axes to find your H(s).

Primary point considerations as a start of the rubric:	Identification of filter type from pole zero diagram to H(s) form (numerator and denominator) Alpha value correctly identfied ωo caluclation correct

ωc in this case doesn't mean corner frequency...I just put it there to name it differently from other omegas

if $\sigma := -2000$

$\omega_c := 5000$

Choice 1 HPF has a double zeros at zero

$\alpha := -\sigma = 2 \times 10^3$

Form of HPF is $\dfrac{s^2}{(s+\sigma+j\omega)(s+\sigma-j\omega)}$

$s_1 = \sigma + j\omega_c$

$s_2 = \sigma - j\omega_c$

$$\frac{s^2}{(s+2000+5000j)\cdot(s+2000-5000j)}$$

$$\frac{s^2}{s^2+4000s+2.9\cdot 10^7}$$

$RoverL := 2\cdot(\alpha) = 4 \times 10^3$

$\omega_{osquared} := \omega_c^{\,2} + \sigma^2 = 2.9 \times 10^7$

Choice 2

Your H(s)	

BPF

$$\frac{4000s}{s^2+4000s+2.9\cdot 10^7}$$

$\sigma := -2000$

$\omega_c := 5000$

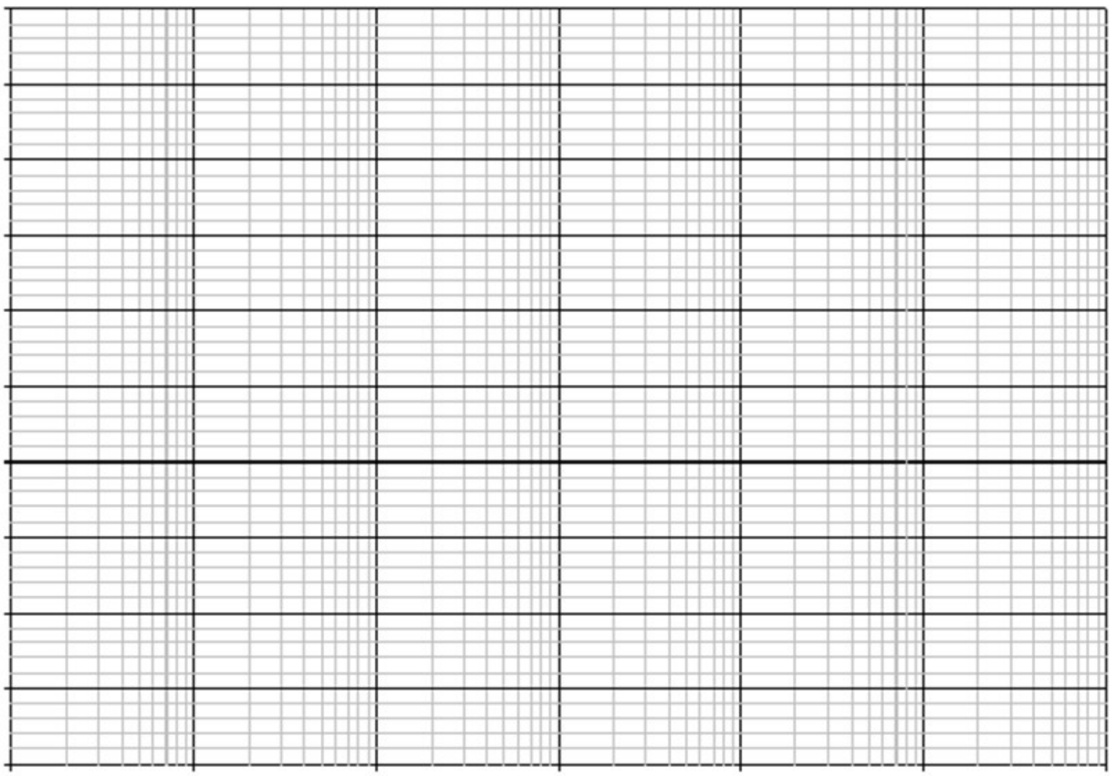
$RoverL := 2\cdot(-\sigma) = 4 \times 10^3$

$\omega_{osquared} := \omega_c^{\,2} + \sigma^2 = 2.9 \times 10^7$

$\alpha := -\sigma = 2 \times 10^3$

2.2. From this H(s) draw your magnitude and phase diagram. Note: If you cannot complete 2.1, write an ESTIMATED H(s) and plot below for partial credit.

Magnitude Bode Plot



Calculation for Magnitude Plot

Primary point considerations as a start of the rubric:

Cutoff/resonant frequency correctly labelled
Correct damping ratio equation used
Correct damping ratio
Correct pass band magnitude/Correct magnitude of straight line approximation
Correction or resonance at resonant or corner frequency correct
Rolloff correct

Note there are many more total points available than the total for this problem. Points were adjusted for minimum knowledge and class average knowledge. This means some students have extra credit.

<u>Choice 1:</u>

Underdamped HPF

$$\frac{s^2}{s^2 + 4000s + 2.9 \cdot 10^7}$$

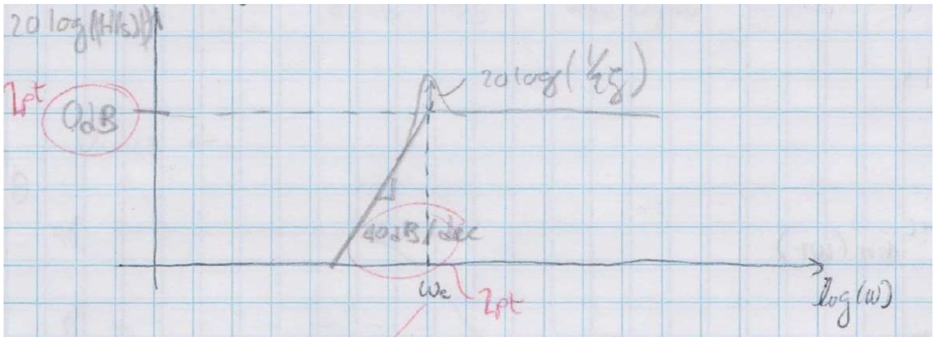
$$\zeta := \frac{\alpha}{\sqrt{\omega_{osquared}}} = 0.371$$

$$\omega_{o1} := \sqrt{\omega_{osquared}} = 5.385 \times 10^3$$

$$20\log\left(\frac{1}{2 \cdot \zeta}\right) = 2.583$$

this peak is just above 0 db at 2.583 db at ωo1

It should drop by +40 db/dec



All drawings below are created by TA Amelia Peterson and may have different labels for variables. Consider the shape of each as a reference point.

Choice 2:

Underdamped BPF

$$\frac{4000s}{s^2 + 4000s + 2.9 \cdot 10^7}$$

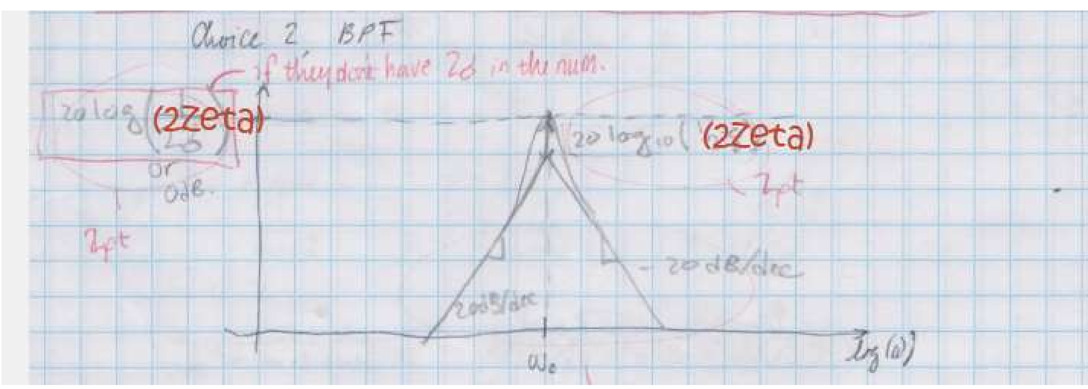
$$\zeta := \frac{\alpha}{\sqrt{\omega_{osquared}}} = 0.371$$

$$\omega_{o1} := \sqrt{\omega_{osquared}} = 5.385 \times 10^3$$

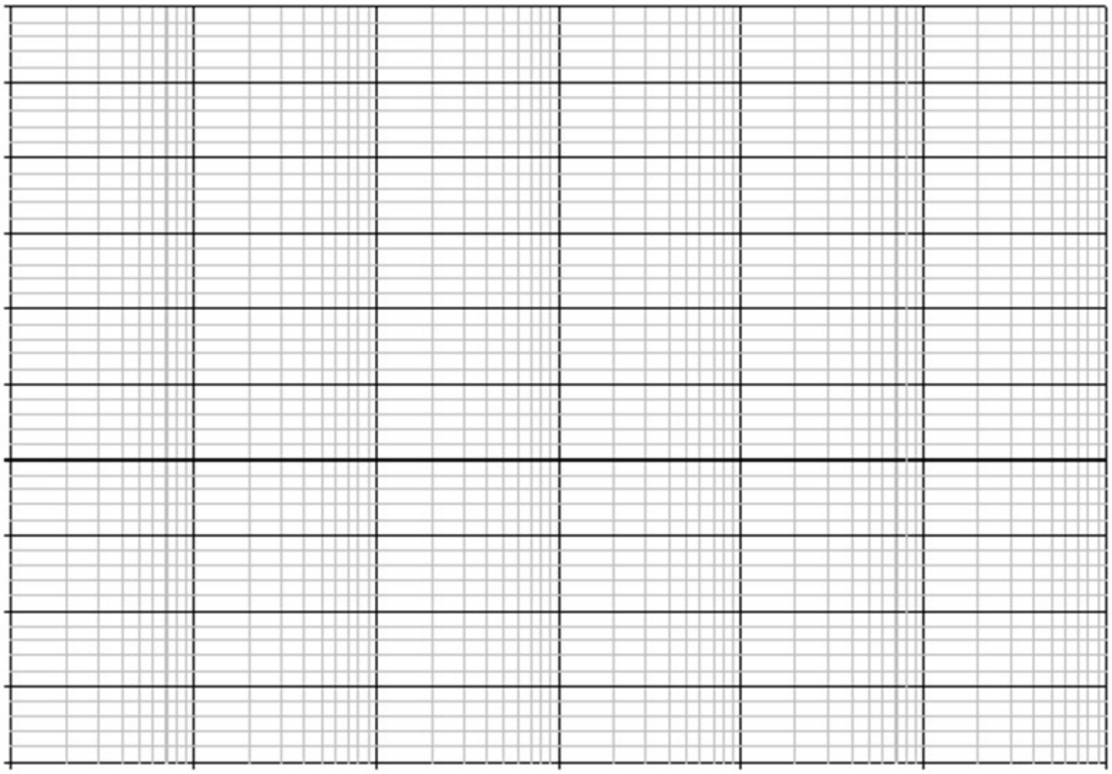
$$20\log((2\zeta)) = -2.583 \quad \text{db}$$

this v peak is just below 0 db at -2.583 db at ωo1 but it must go up to 0db at ω01 shouwing a very small resonant peak

rolloff is 20 db on both sides



Extra Credit (+5 pts) Phase Bode Plot



Points are all or nothing. Partial credit is only considered for very minor math errors. Work must be shown for credit.

Choice 1:

Underdamped HPF

$$\frac{s^2}{s^2 + 4000s + 2.9\cdot 10^7}$$

This is more of an estimation than a full calculation

ω<<ωo $\qquad \frac{(j\omega)^2}{2.9\cdot 10^7} \qquad 2\cdot(90deg) = 180deg$

ω>>>ωo $\qquad \frac{(j\omega)^2}{(j\omega)^2} \qquad \frac{2\cdot(90deg)}{2\cdot(90deg)} = 0deg$

Note: significanlty more math can be done to find this more accurately...you'd need to split the real and imaginary parts of the entire equation to get the calculation but this is an approximation.
https://youtu.be/4d4WJdU61Js?t=282

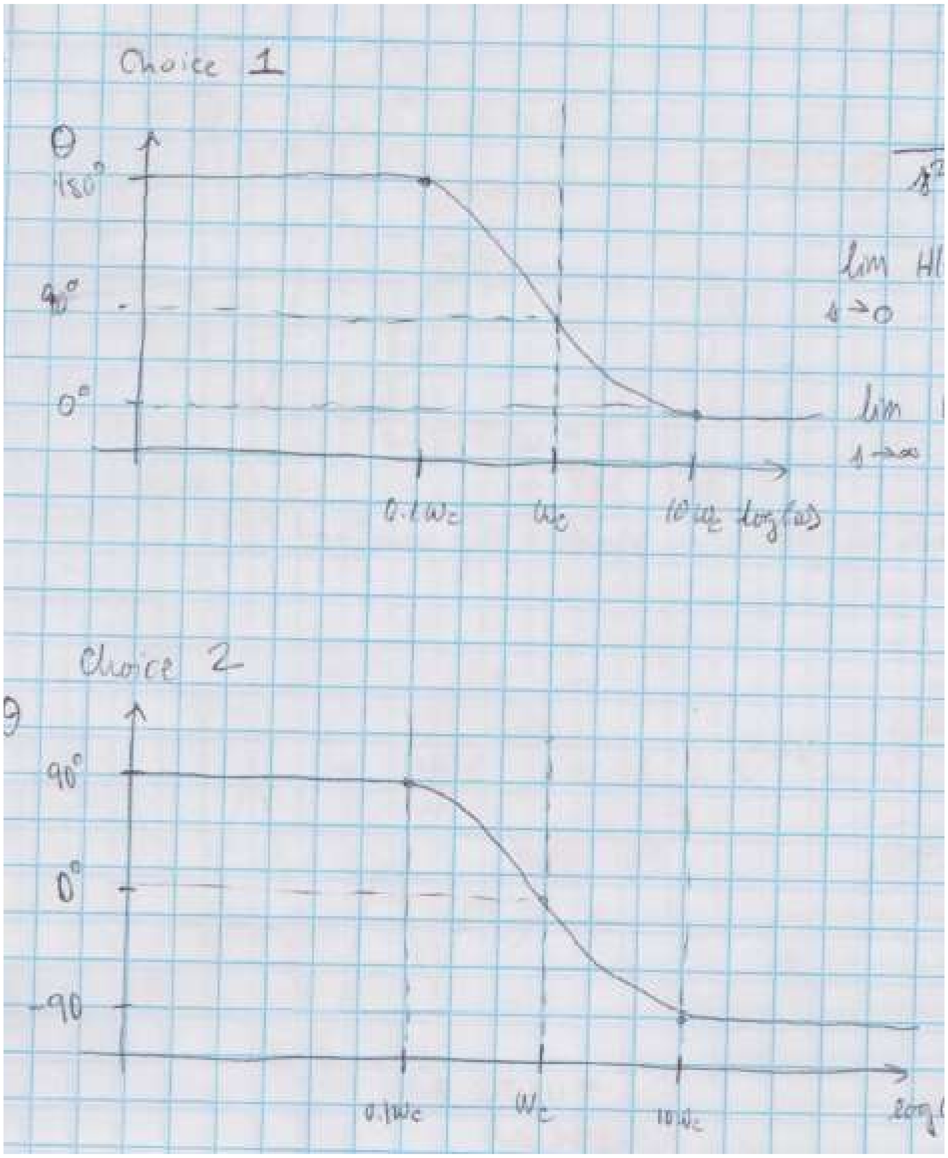
Choice 1:

Underdamped BPF

$$\frac{4000s}{s^2 + 4000s + 2.9\cdot 10^7}$$

ω<<ωo $\qquad \dfrac{(j\omega)}{2.9\cdot 10^{7}} \qquad (90deg) = 90deg$

ω>>>ωo $\qquad \dfrac{(j\omega)}{(j\omega)^{2}} \qquad \dfrac{(90deg)}{2\cdot(90deg)} = -90deg$



2.3. Draw a circuit schematic that represents your Bode plot, H(s), and pole diagram. You need to at least connect 2.2 and this problem for credit.

Primary point considerations as a start of the rubric:

L calcuation correct
C calculation correct
Schematic shown
Output of circuit correctly identified with transfer function

Note there are many more total points available than the total for this problem. Points were adjusted for minimum knowledge and class average knowledge. This means some students have extra credit.

<u>Choice 1</u>

HPF is a RLC measured across the inductor

$$\omega_{osquared} = 2.9 \times 10^7$$

choosing $R_1 := 1000$

$$\alpha = 2 \times 10^3$$

$$2\alpha = \frac{R}{L}$$

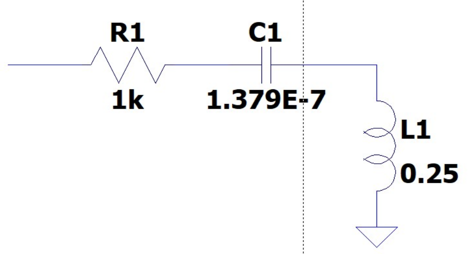
$$L := \frac{R_1}{2\alpha} = 0.25$$

$$C_{1RLC} := \frac{1}{L \cdot \omega_{osquared}} = 1.379 \times 10^{-7}$$

Choice 2

BPF is measured across the resistor...calcuations the same above.

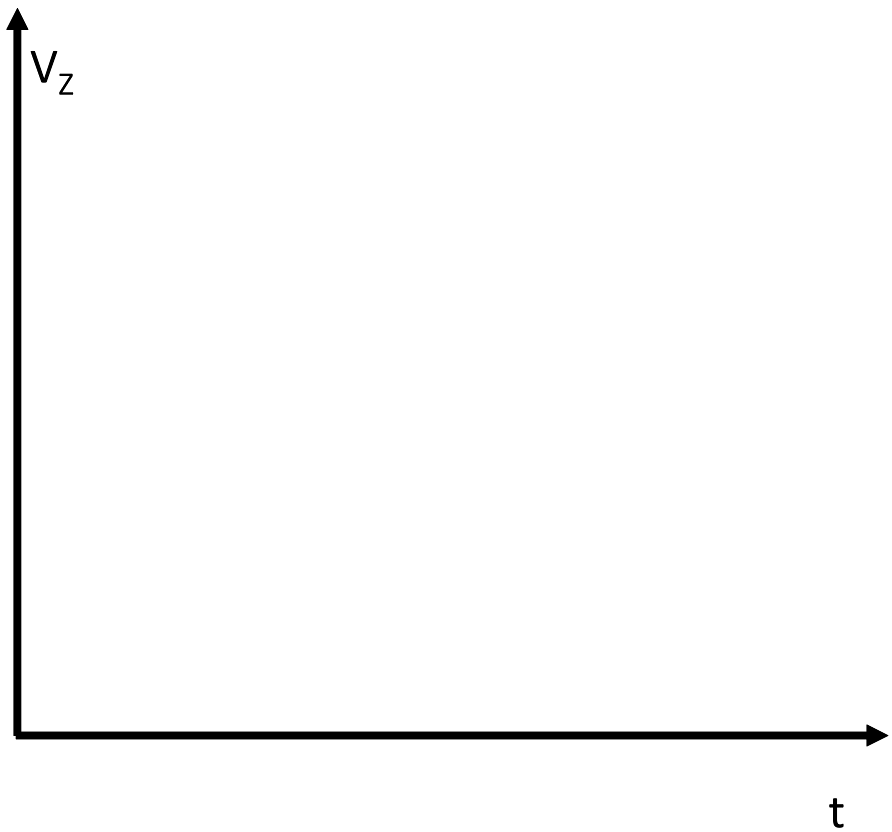
<u>Draw circuit schematic below:</u>



Probe across inductor for Choice 1
Probe across resistor for Choice 2

Unit 2 Transient Response - Choose *<u>the other pole zero</u>* diagram (If you chose Choice 1 Unit 4 filter problem choose Choice 2 now).

2.5: Using the labels on the pole zero diagram calculate as much of the plot as you can in the time domain. Points are given for the level of detail you can provide. The source is a step function and you may choose the value of your step function source.



Primary point considerations as a start of the rubric:

Points: Correct voltage at t= 0
- ***Correct general shape (decaying exponential around 0)***
- ***Calculation of β from ωo and α shown***
- ***Calculation for period from β shown with label on time axis***
- ***Identification of exponetial envelope and decay shown***
- ***Some calculation or explaination of amplitude attempted***

Note there are many more total points available than the total for this problem. Points were adjusted for minimum knowledge and class average knowledge. This means some students have extra credit.

$$e^{-\alpha t}\cdot\left(A_1\cdot\cos\beta t + A_2\cdot\sin\beta t\right) + A_3$$

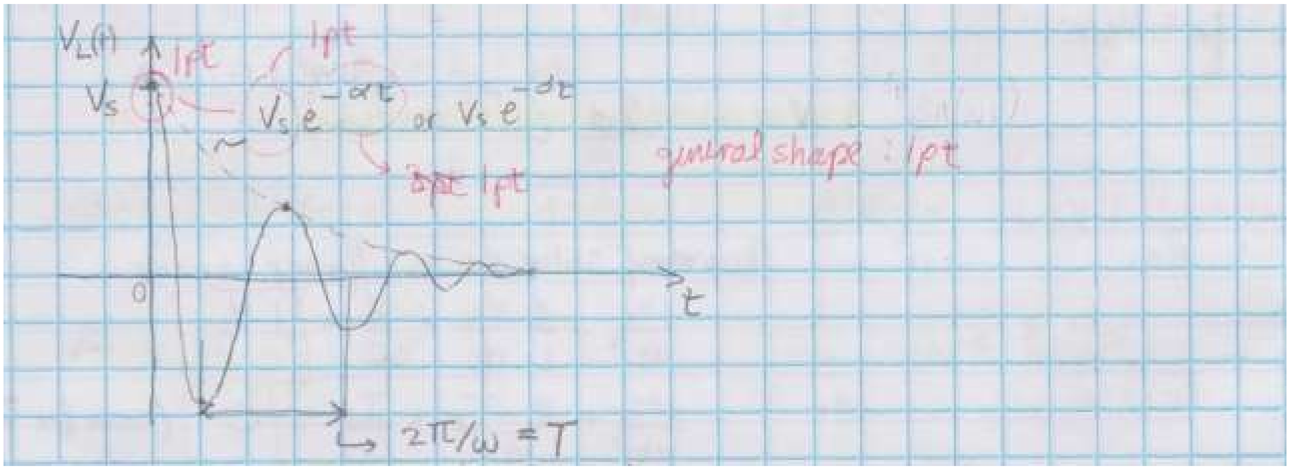
There is a conversation to get amplitude of this found in lecture 10 notes.

$$\beta := \sqrt{{\omega_{o1}}^2 - \alpha^2} = 5\times 10^3$$

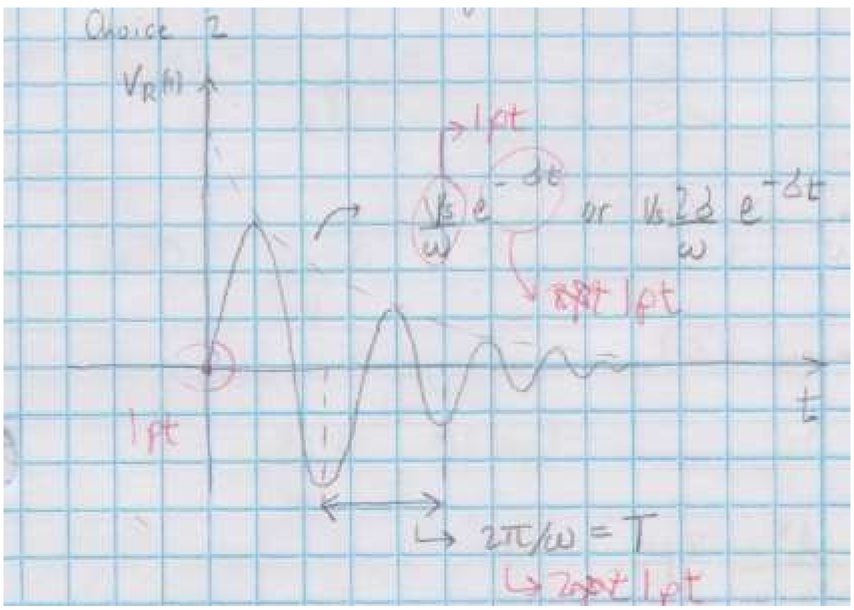
$$f_\beta := \frac{\beta}{2\cdot\pi} = 795.775$$ check this

$$\text{period} := \frac{1}{f_\beta} = 1.257\times 10^{-3}$$

Choice 1



Choice 2



2.4: Analytically calculate the circuit components that represent of the pole zero diagram. Show that these circuit components result in the time domain plot you calculated/estimated using methods **from Differential Equations**. The source is a step function and you may choose the value of your step function source.

Can use or find α and ωo and

$$\frac{d^2y}{dt^2} + 2\alpha \cdot \frac{dy}{dt} + \omega_o^{\,2} y = f(t)$$

Points: Used correct equations for α and ωo for RLC series or parallel circuit components
Circuit component output correct
Wrote the differential equation that defines the circuit
Identified correct solution to diff eq for RLC series or parallel circuit
Use step function input to find A1, A2 and A3
Used initial and final conditions
Attempts to identify and do math for amplitude A directly extra

$$\omega_{osquared} = 2.9 \times 10^{7}$$

$$\alpha = \frac{R}{2L}$$

for series

$$\alpha = 2 \times 10^{3}$$

$$R_1 := 1000$$

Given

$$\omega_{o1} = 5.385 \times 10^{3}$$

$$\omega_o = \frac{1}{\sqrt{LC}}$$

$$L := \frac{R_1}{2\alpha} = 0.25$$

$$C_{1RLC} := \frac{1}{L \cdot \omega_{osquared}} = 1.379 \times 10^{-7}$$

$$V_R(t) = e^{-\alpha t} \cdot \left(A_1 \cdot \cos(\beta t) + A_2 \cdot \sin(\beta t)\right) + A_3$$

if using step function $5\,u(t)$

use intial and final conditions to find A1 and A2.........

$$e^{-2000t} \cdot \left(A_1 \cdot \cos(5000t) + A_2 \cdot \sin(5000t)\right) + 5$$

Draw circuit schematic below:

RLC series with voltage across inductor or resistor for Choice 1 and Choice 2 respectively

2.6: Analytically calculate the circuit components that represent of the pole zero diagram. Show that these circuit components result in the time domain plot you calculated/estimated using methods from Laplace Transforms. The source is a step function and you may choose the value of your step function source.

Choice 2 (similar process of Choice 1)

$$\frac{4000s}{s^2 + 4000s + 2.9 \cdot 10^7}$$

Points: Circuit to transfer function method via s-domain components or conversion from diff eq. should be identified
Correct transfer fuction
Correct form of PFE (cover up or equivalent)
Correct coefficient A and A'
Correct inverse Laplace
some note that eulers can get back to sin and cos...not necessary to actually do extra

$$\frac{4000s}{(s + 2000 + 5000j)\cdot(s + 2000 - 5000j)}$$

$$\frac{A}{(s + 2000 + 5000j)} + \frac{A'}{(s + 2000 - 5000j)} = \frac{4000s}{(s + 2000 + 5000j)\cdot(s + 2000 - 5000j)}$$

for $s_1 := -2000 - 5000j$ $\qquad \dfrac{4000s\cdot(s + 2000 + 5000j)}{(s + 2000 + 5000j)\cdot(s + 2000 - 5000j)}$

$$\frac{4000(-2000 - 5000j)}{-2000 - 5000j + 2000 - 5000j} = 2 \times 10^3 - 800i$$

$$A = 2000 - 800j$$

$$A^* = 2000 + 800j$$

$$V_R(t) = e^{-(2000-800j)\,t} + e^{-(2000+800j)t}$$

using euler's law

$$V_R(t) = A\cdot\cos(800\cdot t)\cdot e^{-2000\cdot t}$$

I will need to confirm this answer later....

<u>Draw circuit schematic below:</u>