Solutions

Your name: ____

EECS 215 – Final Exam
April 24, 2017

This text consists of 7 problems with points as indicated to total 70 points.

Read through the entire exam before beginning.
Show all work (on the pages provided in this booklet) to earn partial credit. Briefly explain major steps, include units, and write your final answers in the areas provided.

No credit will be given if no work is shown.

Do not unstaple the pages.

Exam policies

- No food allowed during exam.
- This is a closed-book exam: No books allowed
- Table 14.3 (Bode plots) & exam 2 equation sheet attached
- One, two-sided, 8.5"x11" note page allowed
- Scientific calculators allowed (graphing calculators not permitted; enforced via CoE honor code).
- No communication of any kind is allowed. No use of cell phones, computers, or any devices besides calculators. Violation of this will be treated as an honor code violation.

In which section are you enrolled? ☐ **EECS 215-001 (Finelli)** ☐ **EECS 215-002 (Phillips)**

Write and sign the honor pledge ("I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code."):

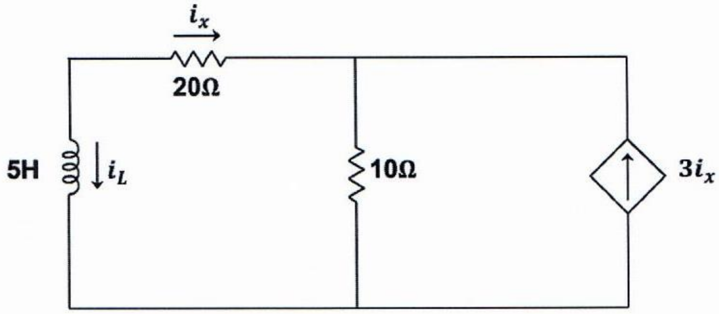
Signed: ____

Do not write in this space

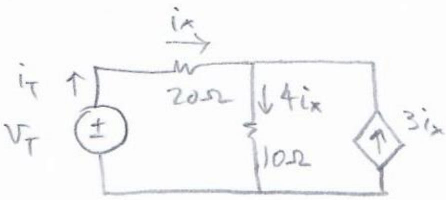
Problem 1: [ ]/10	Problem 5: [ ]/10
Problem 2: [ ]/10	Problem 6: [ ]/10
Problem 3: [ ]/10	Problem 7: [ ]/10
Problem 4: [ ]/10	

Total score [ ]/70

1. The RL circuit below is energized by a voltage source which is disconnected at $t = 0$ seconds. At that time, the initial inductor current is $i_L(0) = 25$ mA. Determine the current $i_L(t), t \geq 0$.



Use test source method to find $R_{TH} = \frac{v_T}{i_T}$ at inductor:



KVL, Left side

$$-v_T + 20i_x + (4i_x)10 = 0$$

$$v_T = 60i_x = 60i_T$$

$$\Rightarrow R_{TH} = \frac{v_T}{i_T} = 60\Omega$$

$$\tau = L/R = 5H/60\Omega = 1/12 \text{ sec}$$

$$i_L(t) = i_L(\infty) + (i_L(0) - i_L(\infty))e^{-t/\tau}$$

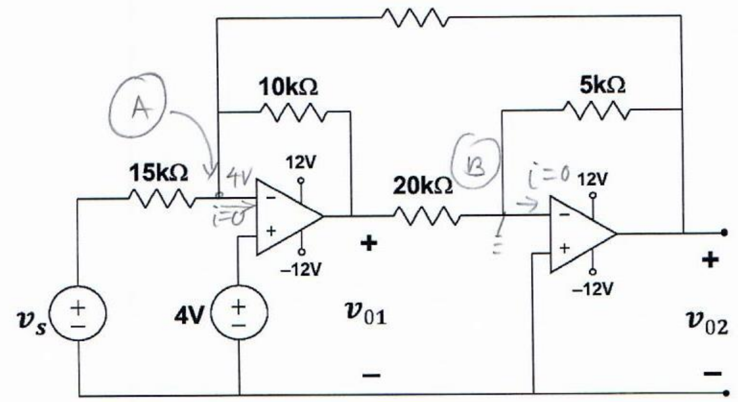
$$= \boxed{25e^{-12t} \text{ mA}}$$

Write your answer here:

$i_L(t), t \geq 0 =$ $25e^{-12t}$ mA

Problem 1 score: [ ]/10

2. For the cascaded op amp circuit shown below:
   a) Find the output voltage v_{o2}
   b) Determine the range of v_s for which the both op amps of the circuit will operate linearly.



KCL at node A: $\frac{4-v_s}{15k} + \frac{4-v_{o2}}{30k} + \frac{4-v_{o1}}{10k} = 0$

$\Rightarrow 24 - 2v_s - 3v_{o1} = v_{o2}$

KCL at node B: $\frac{0-v_{o1}}{20k} + \frac{0-v_{o2}}{5k} = 0 \Rightarrow v_{o1} = -4v_{o2}$

so... $24 - 2v_s - 3(-4v_{o2}) = v_{o2} \Rightarrow v_{o2} = \frac{24-2v_s}{11}$

device A operates linearly when $-12 \le v_{o1} \le 12 \Rightarrow -12 \le -4\left(\frac{24-2v_s}{11}\right) \le 12 \Rightarrow -4.5\,V \le v_s \le 28.5\,V$

device B operates linearly when $-12 \le v_{o2} \le 12 \Rightarrow -12 \le \frac{24-2v_s}{11} \le 12 \Rightarrow -54 \le v_s \le 78$

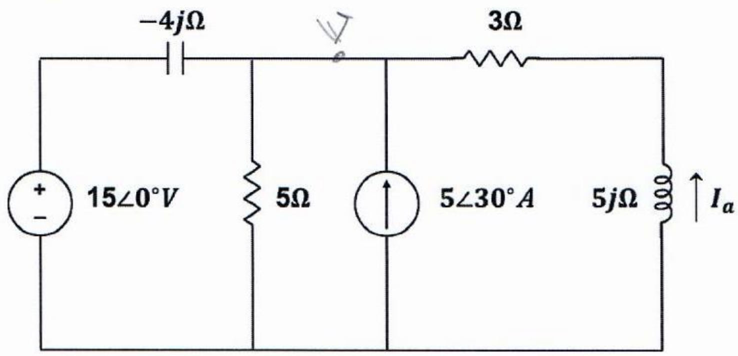
Write your answer here:

a) $v_{o2} = \frac{24-2v_s}{11}$

b) Range of v_s for linear operation: $-4.5V \le v_s \le 28.5V$

Problem 2 score: [ ]/10

3. The sources in the circuit below operate at a frequency of $\omega = 1{,}000$ rad/sec.
   a) Find the phasor current $\boldsymbol{I}_a$
   b) Determine the expression for $i_a(\mathrm{t})$.



KVL at top

$$\frac{\mathbb{V}-15\angle 0}{-4j} + \frac{\mathbb{V}}{5} - 5\angle 30° + \frac{\mathbb{V}}{3+5j} = 0$$

$$\mathbb{V}\left(\frac{1}{-4j} + \frac{1}{5} + \frac{1}{3+5j}\right) = 5(\cos 30 + j\sin 30) - \frac{15}{4j}$$

$$\mathbb{V}(2.882 + .1029j) \qquad = 4.33 + 2.5j + 3.75j$$

$$\mathbb{V} = \frac{4.33+6.25j}{2.882+.1029j}$$

$$\mathbb{V} = 20.19 + 14.47j$$

$$\mathbb{I}_a = \frac{-\mathbb{V}}{3+5j} = -3.91 + 1.69j$$
$$= 4.26\angle 156°$$

Write your answer here:

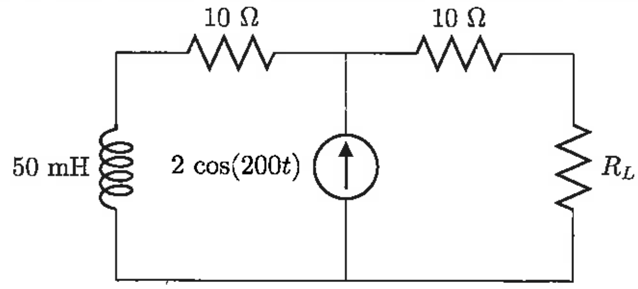
a) $\boldsymbol{I}_a =$ $4.26\angle 156°$ A

b) $i_a(t) =$ $4.26\cos(1000t + 156°)$ A

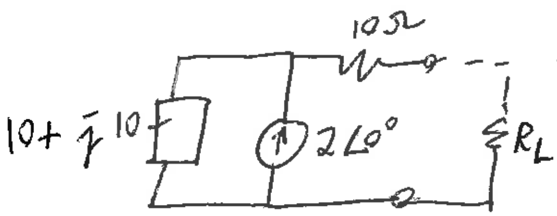
Problem 3 score: [ ]/10

4. Find the maximum power that can be delivered to R_L in the circuit below.

$\bar{j}\omega L = \bar{j}10$



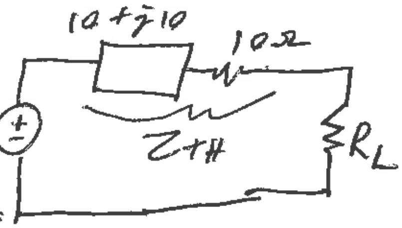
Max power when $R_L = |Z_{TH}| = \sqrt{R_{TH}^2 + X_{TH}^2}$



source trans. $\rightarrow$ $(2)(10+\bar{j}10)$

$V_{TH} = 20+\bar{j}20$

$V_{TH} = 20\sqrt{2}\angle 45^\circ$



$Z_{TH} = 20+\bar{j}10$

$R_L = |Z_{TH}| = \sqrt{20^2+10^2} = 22.36\ \Omega$

$P_{max} = \frac{1}{2}|I|^2 R_L$, $\quad I = \frac{V_{TH}}{Z_{TH}+R_L} = \frac{20\sqrt{2}\angle 45^\circ}{(20+\bar{j}10)+22.36 = 43.52\angle 13.28^\circ}$

$P_{max} = \frac{1}{2}(0.650)^2(22.36)$ $\quad I = 0.650\angle 31.72^\circ$

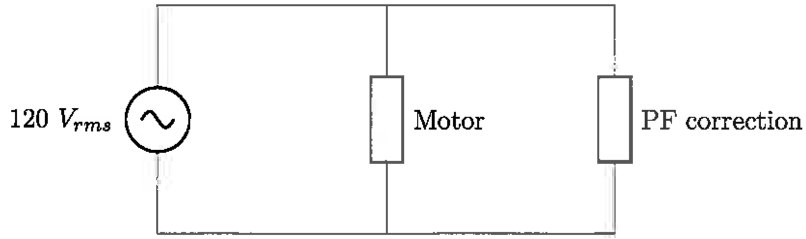
$= 4.724$ W

Write your answer here:

$P_{max} =$ 4.724 W

Problem 4 score: [ ]/10

5. The circuit below has a 120 V_{rms}, 60 Hz source connected to an inductive motor that dissipates real power of 5 kW at a power factor (PF) of 0.8 (lagging). Determine the capacitance required for PF correction to increase the PF to 0.96 lagging.



$$S = V_{rms} I^*_{rms} = P + jQ = S\angle\phi \qquad PF = \frac{P}{|S|}$$

$$\phi = \cos^{-1}(P/|S|) = \cos^{-1}(0.8) = 36.87°$$

$$|S| = P/PF = 5000/0.8 = 6{,}250 \text{ VA}$$

$$S = 6250\,\angle 36.87° = 5000 + j3750$$

Convert to $PF = 0.96 \rightarrow \phi = \cos^{-1}(0.96) = 16.26°$

$$S = \frac{5000}{0.96}\,\angle 16.26° = 5000 + j1458.3$$

$$\Delta Q = 1458.3 - 3750 = -2{,}291.7 \text{ VAR}$$

$$I^*_{cap,rms} = \frac{S}{V_{rms}} = \frac{\Delta Q}{V_{rms}} = \frac{-j2291.7}{120} = -j19.10 \text{ A}$$

$$Z = \frac{V}{I} = \frac{120}{j19.10} = -j6.284 = \frac{-j}{\omega C}$$

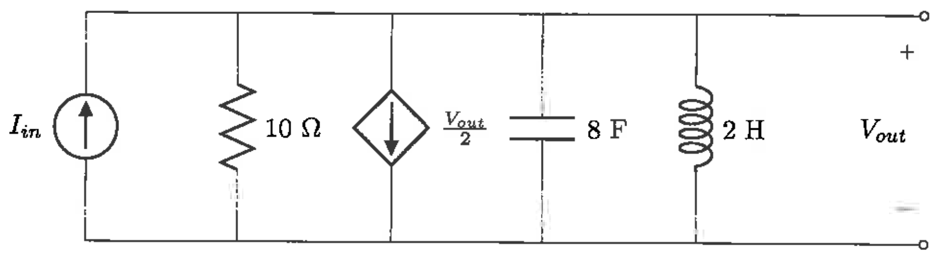
$$C = \frac{1}{(2\pi)(60)(6.284)} = 4.22\times10^{-4}\text{ F}$$

Write your answer here:

$C =$ 4.22×10^{-4} F $= 422\ \mu$F

Problem 5 score: [ ]/10

6. Determine the transfer function defined by $H(s) = V_{out}/I_{in}$ for the circuit below. Express the transfer function in standard form for Bode plots, e.g. $H(s)=N(s)/D(s)$ or $H(\omega) = N(\omega)/D(\omega)$ such that the numerator and denominator have clearly identifiable poles and zeros and are of the form represented on Table 14.3 (attached).



$$I_{in} = \frac{V_{out}}{10} + \frac{V_{out}}{2} + \frac{V_{out}}{(1/j\omega 8)} + \frac{V_{out}}{(j\omega 2)} = 0$$

$$(1/8s) \qquad (2s)$$

$$I_{in} = V_{out}\left(\frac{1}{10} + \frac{1}{2} + 8s + \frac{1}{2s}\right) \times \frac{2s}{2s}$$

$$= V_{out}\frac{\left(\frac{6}{10}(2s) + 16s^2 + 1\right)}{2s} = \frac{1.2s + 16s^2 + 1}{2s} V_{out}$$

$$H(s) = \frac{V_{out}}{I_{in}} = \frac{2s}{16s^2 + 1.2s + 1} = \frac{1}{8}\,\frac{s}{s^2 + 0.075s + 0.0625}$$

Write your answer here:

$H(s)$(OR) $H(\omega) = \frac{1}{8}\,\frac{s}{s^2 + 0.075s + 0.0625}$

Problem 6 score: [ ]/10

7. A transfer function for a circuit is given below.

$$H(s) = \frac{10{,}000s^2}{(s+10)(4s^2+32{,}000s)}$$

(OR)

$$H(\omega) = \frac{10{,}000(j\omega)^2}{(j\omega+10)(4(j\omega)^2+32{,}000j\omega)}$$

a) Identify all poles, zeros, and constant terms
b) Sketch the linear approximation to the magnitude Bode plot on the following graph on the next page. Full credit will only be granted for plots that are neat and that include clearly labeled axes and tick marks.
c) What type of filter does this circuit represent?

$$\frac{10{,}000s^2 \cdot \frac{1}{s}}{(s+10)(4s^2+32{,}000s)\cdot \frac{1}{s}} = \frac{10{,}000s}{(s+10)(4s+32{,}000)}$$

Convert to normal form:

$$\frac{10{,}000s}{10(1+\frac{s}{10})(32{,}000)(1+\frac{4s}{32{,}000})} = \frac{1}{32}\,\frac{s}{(1+\frac{s}{10})(1+\frac{s}{8{,}000})}$$

Zeros: $\omega = 0$

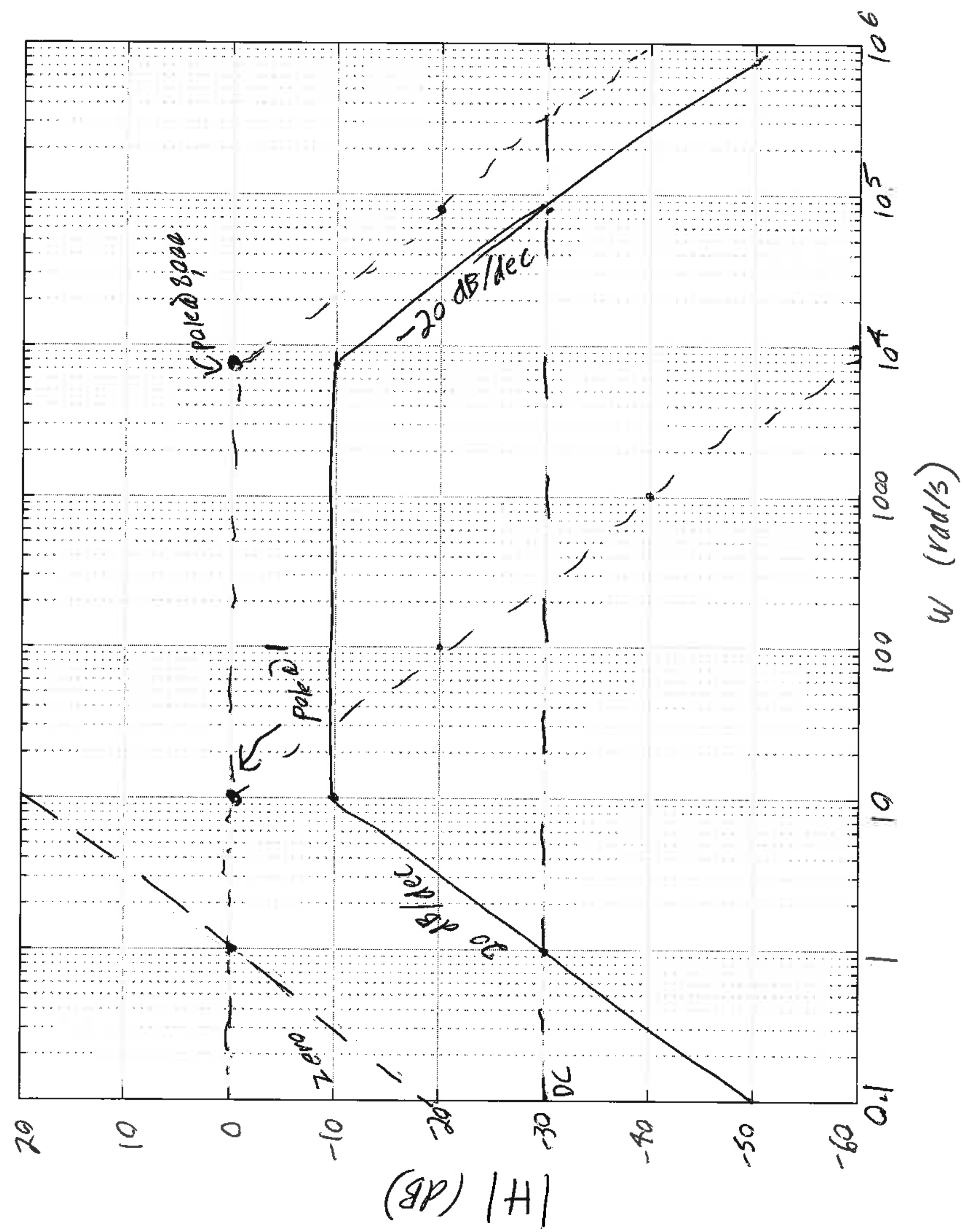
Poles: $\omega = 10; 8{,}000$

constant: $\frac{1}{32} = 20\log_{10}(\frac{1}{32}) = -30.1$ dB

Write your answer here:

a) Poles, zeros, constants = zero @ 0; poles @ 10, 8000; -30.1dB constant
c) Type of filter = Band pass filter

Problem 7 score: [ ]/10


|H| (dB)
20
10
0
-10
-20
-30
-40
-50
-60
w (rad/s)
0.1
1
10
100
1000
10^4
10^5
10^6
20 dB/dec
-20 dB/dec
zero
DC
pole @ 1
pole @ 8000