Name ______________________________

By writing or printing my name in the space above, I hereby affirm that I have neither given nor received assistance in preparing solutions for this exam.

EE 3340

Exam #2

There are four problems attached. Work ***all*** four.

Use any tools you wish, and please be sure to submit all details of each of your solutions. That is:

a. If you use LTspice, you should submit a copy of your netlist, and a copy of the table (or plot) of results from the computer screen. In that table (or plot), you must highlight the answer(s) to the problem.
b. If you use MATLAB, you should submit a copy of everything you enter, and a copy of the results obtained with the answer(s) to the problem highlighted.
c. If you use a calculator, explain what you did. Just copying the answer down onto your paper is insufficient and unacceptable.

If you do not show the details of your method and how you got your answer, full credit will not be given, even if the answer is correct. I must be able to see that you know how to work the problem, not just that you can find the answer somewhere. Lack of complete detail makes it appear that you might not know how to work the problem and may have copied the answer from someone else.

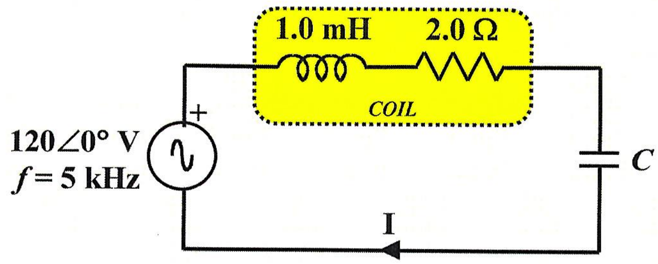
If you need polar or logarithmic graph paper, download it from the class website (at the bottom of the "Miscellaneous Supplements" page.

Your solutions are due by 9:30AM, Tuesday, February 29, 2022. Submit everything as a *single* PDF file with the pages in proper order and consistently oriented.

Solutions must be clean, clear, and complete if you wish to receive credit. Each page must have a clean white background. Dark shadows resulting from poorly-lighted photography make things hard to read, and are unacceptable, especially when you have twelve days to prepare and submit your results.

Each of the four problems is worth a maximum of 25 points.

1. (25 points) A coil with 1.0 mH inductance and 2.0 Ω series resistance is connected in series with a capacitor and a 120V, 5kHz sinusoidal power supply as shown below.



(a) [15 points] Determine the value of capacitance C that will cause the system to be in resonance.

At resonance, $\omega_R L = \frac{1}{\omega_R C}$. Here, $\omega_R = 2\pi f_R = 2\pi \times 5\text{kHz}$

$= 10\pi\ k\ \text{rad/s}$

$\Rightarrow C = \frac{1}{\omega_R^2 L}$

$= \frac{1}{(10k\pi)^2 (1mH)}$

$= 1.013\ \mu F$

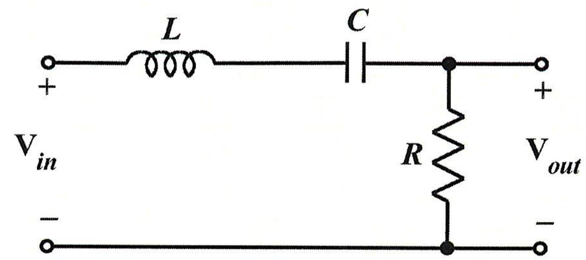
(b) [10 points] Determine the current **I** at the resonant frequency. Express it in polar form.

$I = \frac{120\angle 0^\circ\ V}{2.0\ \Omega} = 60\ A$

2. (25 points) Two filter circuits are shown below.
   (a) [15 points] The first is a *passive* bandpass filter. Find the voltage transfer function, and write your result in the form:

$$\mathbf{H}(\omega) \triangleq \frac{\mathbf{V}_{out}(\omega)}{\mathbf{V}_{in}(\omega)} = \frac{jA\omega}{(1 - B\omega^2) + jA\omega}$$

(i.e., define A and B in terms of R, L, and C).



$$H(\omega) = \frac{R}{j\omega L + \frac{1}{j\omega C} + R} = \frac{j\omega RC}{(1 - \omega^2 LC) + j\omega RC}$$

$$A = RC$$
$$B = LC$$

What is $\lim_{\omega \to 0} |\mathbf{H}(\omega)|$ in terms of R, L, and C?

0

What is $\lim_{\omega \to 0} \angle \mathbf{H}(\omega)$ in terms of R, L, and C?

$90°$

What is $\lim_{\omega \to \infty} |\mathbf{H}(\omega)|$ in terms of R, L, and C?

0

What is $\lim_{\omega \to \infty} \angle \mathbf{H}(\omega)$ in terms of R, L, and C?

$-90°$

Classify the filter as LP, HP, BP, or BS, and explain your reasoning.

BP

Low-frequency signals will be stopped, and high-frequency signals will be stopped.

(See next page for LTspice investigation and verification)

Spring 2022 EE 3340 Exam 2 Problem 2.cir

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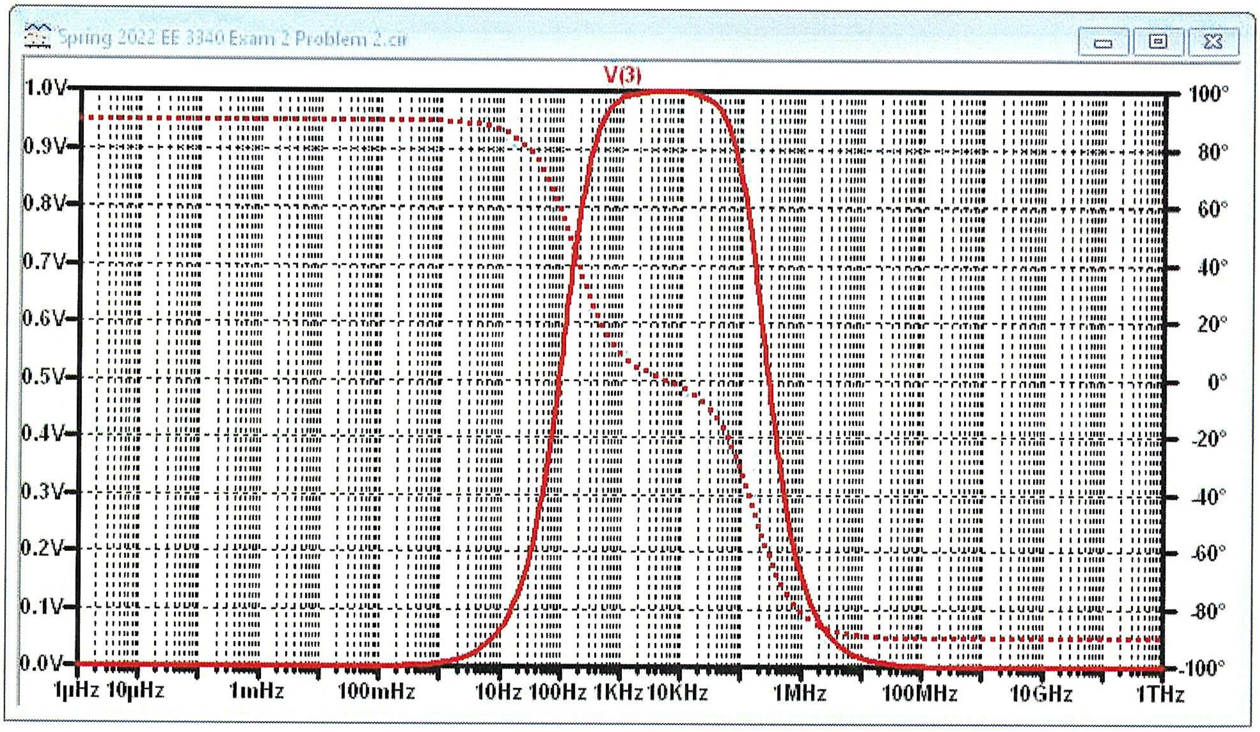
* Q:\Websites\RES\EE 3340\exams\Spring 2022 EE 3340 Exam 2 Problem 2.cir
Vin 1   0   AC  1   0
L   1   2   1m
C   2   3   1u
R   3   0   1k
.AC DEC 100 1u  1T
.end
```

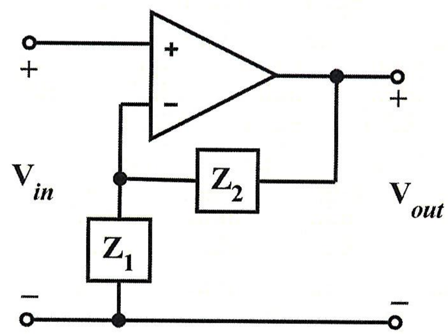
arbitrary choices



(b) [10 points] The second circuit is an *active* filter. If $\mathbf{Z}_1$ is a capacitor C, and $\mathbf{Z}_2$ is a parallel RC circuit, with elements R and C (this C has the same value as the C in $\mathbf{Z}_1$), determine an expression for the voltage transfer function. Write your result in the form:

$$\mathbf{H}(\omega) \triangleq \frac{\mathbf{V}_{out}(\omega)}{\mathbf{V}_{in}(\omega)} = \frac{1 + jA\omega}{1 + jB\omega}$$

(i.e., define A and B in terms of R and C).



$$Z_1 = \frac{1}{j\omega C}$$

$$Z_2 = \frac{R\left(\frac{1}{j\omega C}\right)}{R + \frac{1}{j\omega C}} = \frac{R}{1 + j\omega RC}$$

$$\frac{V_{out}}{V_{in}} = \frac{Z_2 + Z_1}{Z_1} = \frac{\frac{R}{1+j\omega RC} + \frac{1}{j\omega C}}{\frac{1}{j\omega C}}$$

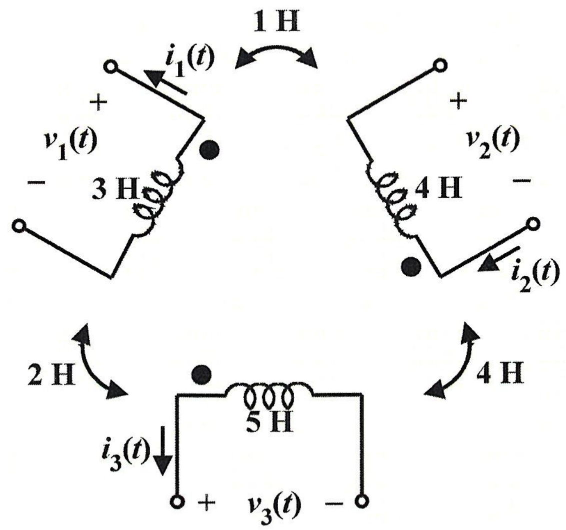
$$= \frac{j\omega RC + 1 + j\omega RC}{1 + j\omega RC}$$

$$= \frac{1 + j\omega 2RC}{1 + j\omega RC}$$

$A = 2RC$

$B = RC$

3. (25 points) The currents in the three mutually-coupled inductors shown below are $i_1(t) = 20\cos 10t$ A, $i_2(t) = 10\sin 10t$ A, and $i_3(t) = 5\cos 10t$ A.



(a) [20 points] Determine $v_2(t)$. Express it in terms of the cosine basis function.

$$v_2(t) = -4\frac{di_2}{dt} + 1\frac{di_1}{dt} + 4\frac{di_3}{dt}$$

$$= -4(100\cos 10t) + (-200\sin 10t) + 4(-50\sin 10t)$$

$$= -400\cos 10t - 400\sin 10t$$

$$= \sqrt{(-400)^2 + (-400)^2}\cos\left(10t + \tan^{-1}\frac{-400}{-400}\right)$$

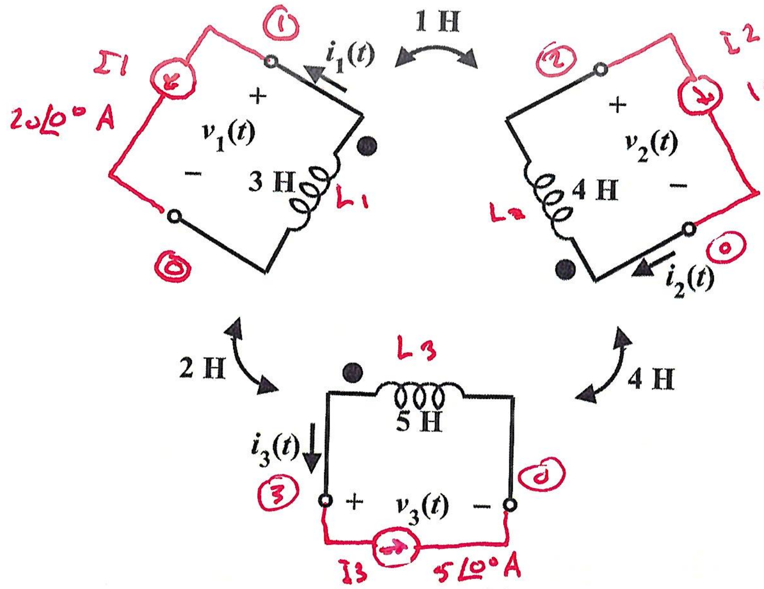
$$= \sqrt{320000}\cos(10t - 135°)$$

$$= 400\sqrt{2}\cos(10t - 135°) \quad \checkmark$$

(b) [5 points] Determine the effective value of $v_2(t)$.

$$V_{2,eff} = \frac{400\sqrt{2}}{\sqrt{2}} \approx 400\text{ V}.$$

(See attached page for LTspice simulation and verification)



$K_{12} = \frac{1}{\sqrt{3 \cdot 4}}$

$K_{13} = \frac{2}{\sqrt{3 \cdot 5}}$

$K_{23} = \frac{4}{\sqrt{4 \cdot 5}}$

Spring 2022 EE 3340 Exam 2 Problem 3.cir

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* Q:\Websites\RES\EE 3340\exams\Spring 2022 EE 3340 Exam 2 Problem 3.cir
I1  1   0   AC  20  0
I2  2   0   AC  10  -90
I3  3   0   AC  5   0
L1  1   0   3
L2  2   0   4
L3  3   0   5
k12 L1  L2  {1/sqrt(3*4)}
k13 L1  L3  {2/sqrt(3*5)}
k23 L2  L3  {4/sqrt(4*5)}
.AC LIN 1   {5/pi}  {5/pi}
.end
```
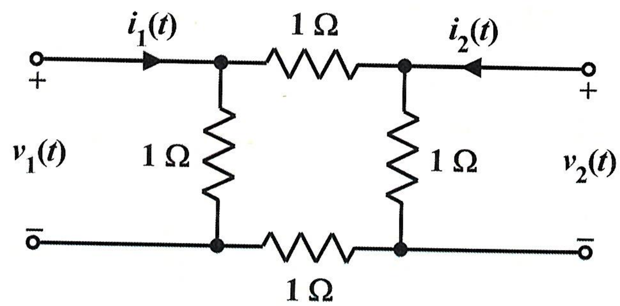

* Q:\Websites\RES\EE 3340\exams\Spring 2022 EE 3340 Exam 2 Problem 3.cir

```
       --- AC Analysis ---

frequency:      1.59155        Hz
V(1):           mag:   707.107 phase:   -98.1301°      voltage
V(2):           mag:   565.685 phase:       -135°      voltage
V(3):           mag:   763.217 phase:   -121.608°      voltage
I(L3):          mag:         5 phase:        180°      device_current
I(L2):          mag:        10 phase:         90°      device_current
I(L1):          mag:        20 phase:       -180°      device_current
I(I3):          mag:         5 phase:          0°      device_current
I(I2):          mag:        10 phase:        -90°      device_current
I(I1):          mag:        20 phase:          0°      device_current
```

4. (25 points) A two-port network is shown below.



(a) [16 points] Determine the hybrid-parameter (h-parameter) representation and express it in the standard matrix form.

$$h_{11} = \frac{v_1}{i_1}\Big|_{v_2=0} = \frac{1\Omega \cdot 2\Omega}{1\Omega + 2\Omega} = \frac{2}{3} \qquad h_{12} = \frac{v_1}{v_2}\Big|_{i_1=0} = \frac{1}{3}$$

$$h_{21} = \frac{i_2}{i_1}\Big|_{v_2=0} = -\frac{1}{3} \qquad h_{22} = \frac{i_2}{v_2}\Big|_{i_1=0} = 1 + \frac{1}{3} = \frac{4}{3}$$

$$\begin{bmatrix} v_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 2/3 & 1/3 \\ -1/3 & 4/3 \end{bmatrix} \begin{bmatrix} i_1 \\ v_2 \end{bmatrix}$$

(b) [9 points] Using those hybrid parameters, sketch an equivalent circuit consisting of resistors and dependent sources.