

EE 16B Midterm 1
Fall 2017

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.

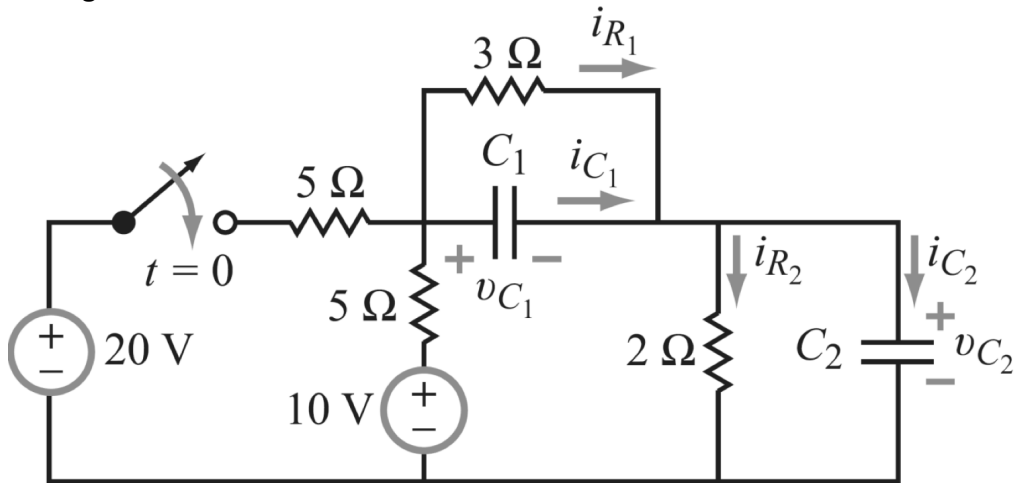
Do not remove pages, as this disrupts the scanning. If needed, cross out any parts that you don't want us to grade.

PROBLEM	MAX
1	n
2	n
3	n
4	n
5	n

"Bueller?... Bueller?... Bueller?"

- Ferris Bueller's Day Off

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



a) What is $i_{C_1}(t=0)$? Show your work!

Solution: $i_{C_1}(t=0^-) = 0\ \text{A}$

b) What is $i_{R_1}(t=0)$? Show your work!

Solution: $i_{R_1}(t=0^-) = 1\ \text{A}$

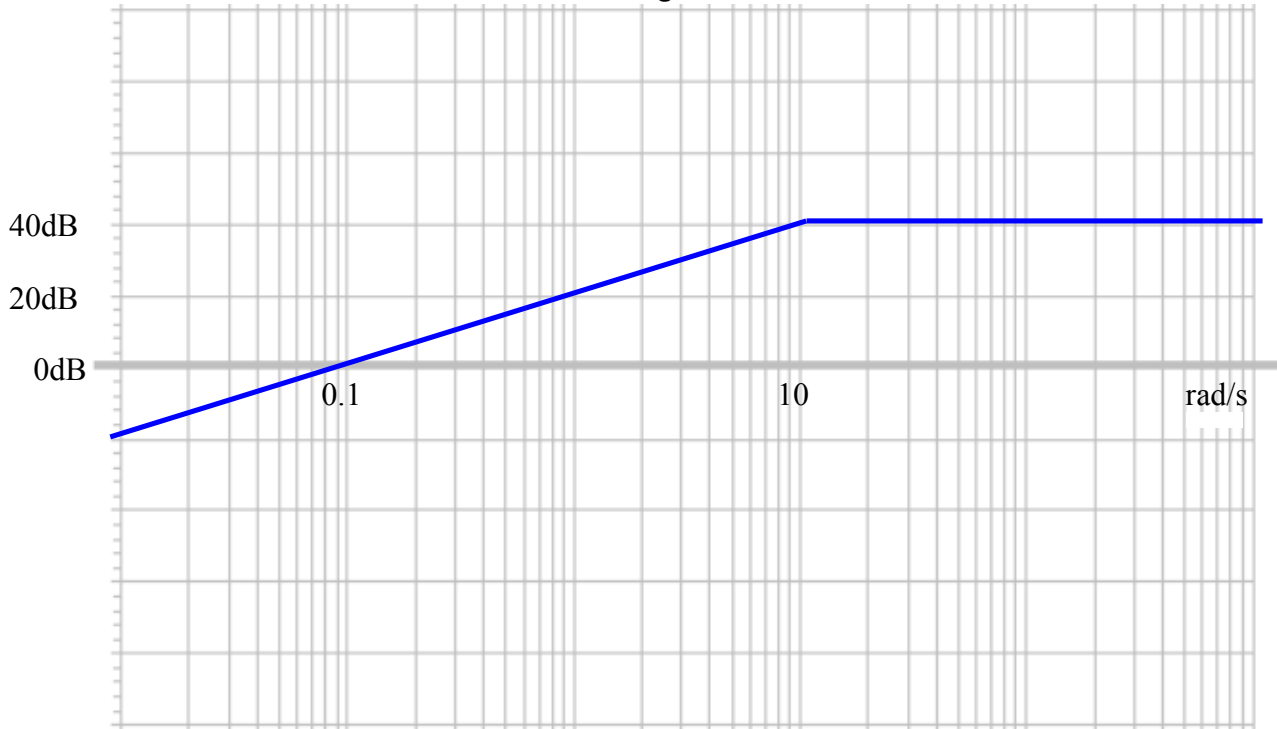
c) What is $v_{C_1}(t=\infty)$? Show your work!

Solution: $v_{C_1}(t=\infty) = 6\ \text{V}$

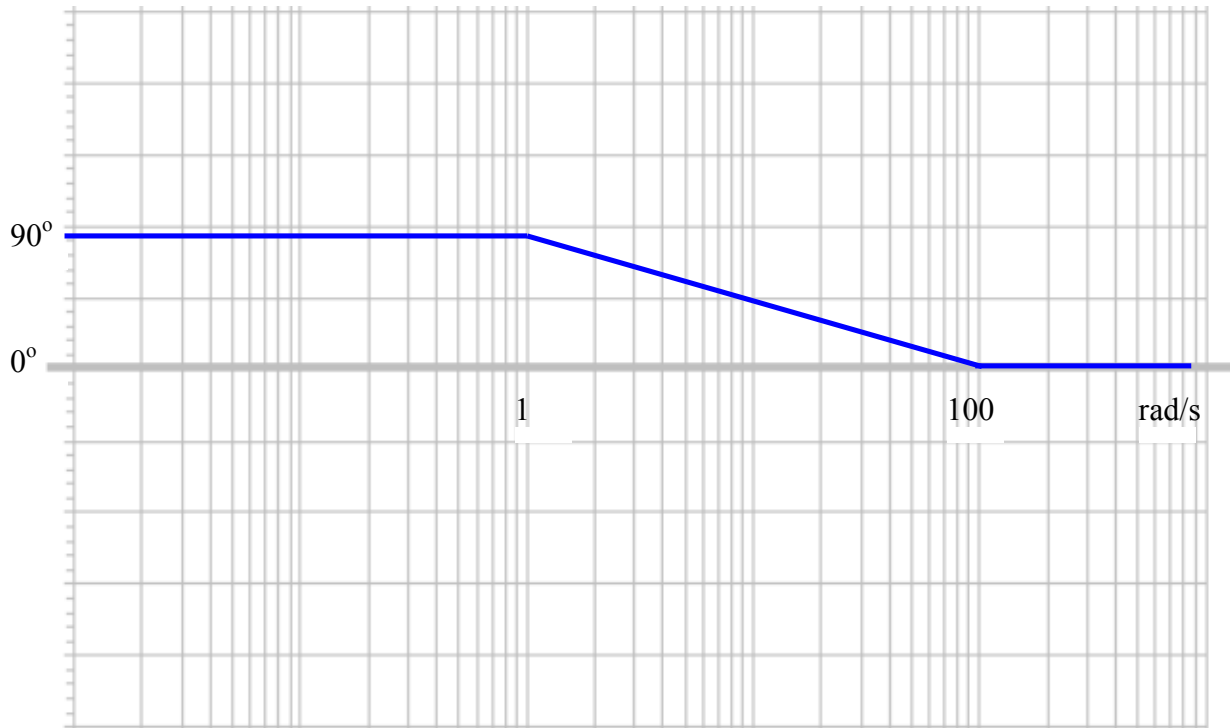
d) Generate a Bode magnitude and phase plot for the following transfer function. Properly label all axes.

$$\mathbf{H}(\omega) = \frac{j100\omega}{10 + j\omega}$$

Magnitude



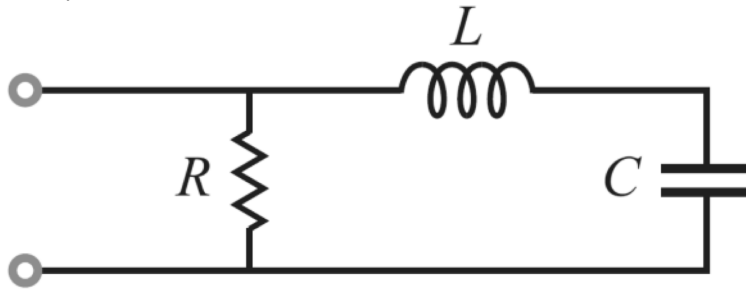
Phase



"Ash: I can't lie to you about your chances, but... you have my sympathies."

- Alien

Problem 2 Resonance (n points)



At what frequency or frequencies does the impedance across the two terminals become purely real? You must show your work to get full credit.

Solution:

$$\omega = 0 \text{ rad/s}, \frac{1}{\sqrt{LC}} \text{ rad/s}$$

"O-Ren Ishii: You didn't think it was gonna be that easy, did you?"

The Bride: You know, for a second there, yeah, I kinda did.

O-Ren Ishii: Silly rabbit.

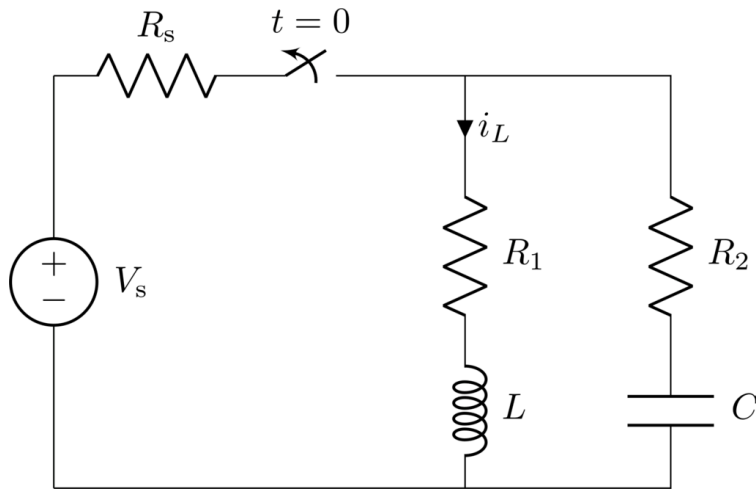
The Bride: Trix are...

O-Ren Ishii: ...for kids."

- Kill Bill Vol. 1

Problem 3 *Time, time, time...* (n points)

Consider the circuit below. Assume the switch was closed for all time until $t = 0$, when it was opened.



a) Provide a symbolic equation in one variable *that can be solved* to determine $v_C(t)$ for $t \geq 0$.

Solution:

$$\frac{d^2 V_C}{dt^2} + \frac{R_1 + R_2}{L} \frac{dV_C}{dt} + \frac{V_C}{LC} = 0$$

b) What is $v_C(0)$? Show your work.

Solution:

$$v_C(0) = V_S \frac{R_1}{R_1 + R_S}$$

c) What is $i_L(0)$? Show your work.

Solution:

$$i_L(0) = \frac{V_S}{R_S + R_1}$$

d) What is $v_C(\infty)$? Show your work.

Solution:

$$V_C(\infty) = 0V$$

e) What is $i_L(\infty)$? Show your work.

Solution:

$$i_L(\infty) = 0A$$

“There is a theory which states that if ever anyone discovers exactly what the Universe is for and why it is here, it will instantly disappear and be replaced by something even more bizarre and inexplicable.

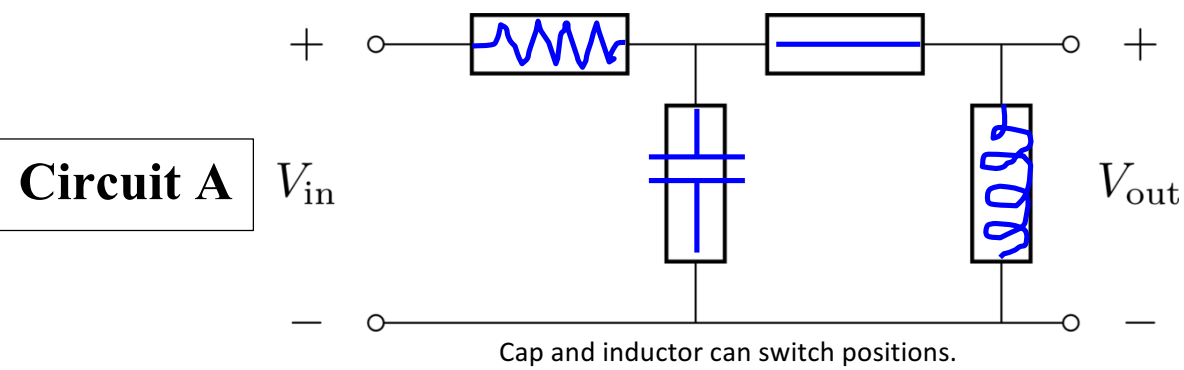
There is another theory which states that this has already happened.”

— Douglas Adams, *The Restaurant at the End of the Universe*

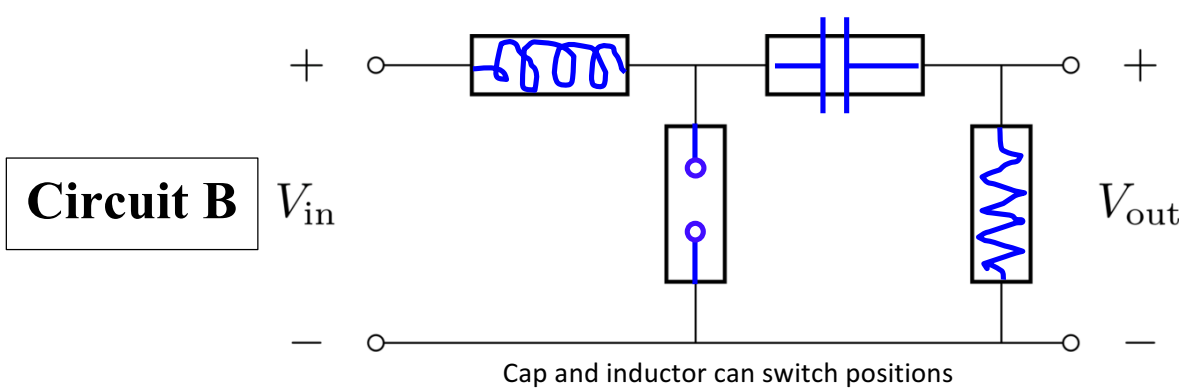
Problem 4 (n points)

You have three components on your workbench: a resistor, an inductor and a capacitor. Their values are $R = 5 \Omega$, $L = 20 \text{ mH}$, and $C = 0.5 \mu\text{F}$. You also have a short circuit and an open circuit. Wire them up inside the box below, making sure to connect all four wires below to your circuit such that the box acts as a bandpass filter.

WE STRONGLY SUGGEST YOU SHOW YOUR SYMBOLIC WORK BELOW (FOR PARTIAL CREDIT IF WRONG)!



OR



a) What is ω_0 (the natural frequency) of your circuit?

Solution:

Circuit A and Circuit B: $\omega_0 = 10^4 \text{ rad/s}$

b) What are the -3 dB (cutoff) frequencies?

Solution:

$$\text{Circuit A: } \omega_{c2} = 2 * 10^5 + \sqrt{4 * 10^{10} + 10^8} \frac{\text{rad}}{\text{s}}, \omega_{c1} = -2 * 10^5 + \sqrt{4 * 10^{10} + 10^8} \frac{\text{rad}}{\text{s}}$$
$$\text{Circuit B: } \omega_{c2} = 125 + \sqrt{125^2 + 10^8} \approx 125 + 10^4 \frac{\text{rad}}{\text{s}}, \omega_{c1} = -125 + \sqrt{125^2 + 10^8} \approx -125 + 10^4 \frac{\text{rad}}{\text{s}}$$

c) What is the bandwidth of your filter?

Solution:

$$\text{Circuit A: } B = 4 * 10^5 \text{ rad/s}$$

$$\text{Circuit B: } B = 250 \text{ rad/s}$$

d) What is the Q?

Solution:

Circuit A: $Q = 0.025$

Circuit B: $Q = 40$

e) Is it possible to double the magnitude of Q by changing the values of L and/or C , while keeping ω_0 and R unchanged?

Circle one:

YES

NO

If yes, propose such values. If no, why not?

Solution:

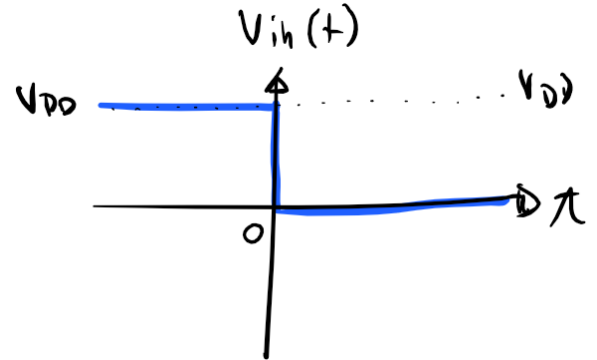
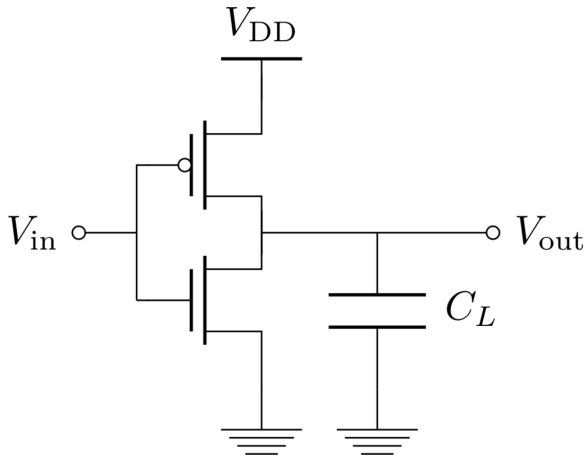
Circuit A: $L = 10\text{mH}, C = 1\mu\text{F}$
Circuit B: $L = 40\text{mH}, C = 0.25\mu\text{F}$

“And so it goes...”

— Kurt Vonnegut Jr., *Slaughterhouse-Five*

Problem 5 (n points)

Consider the circuit below. Please apply the “switch with resistor” model of a transistor when solving this problem. Assume R_{DS} is the ‘on’ resistance and $|V_{th,n}| = |V_{th,p}| \ll V_{DD}$.



a) If $v_{in}(t)$ is as plotted above, please provide a differential equation in $v_{out}(t)$. (5 points)

Solution:

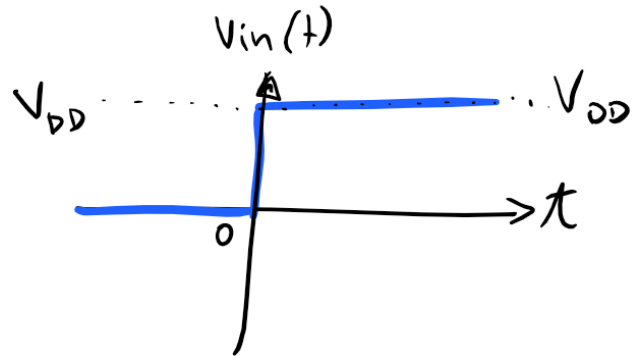
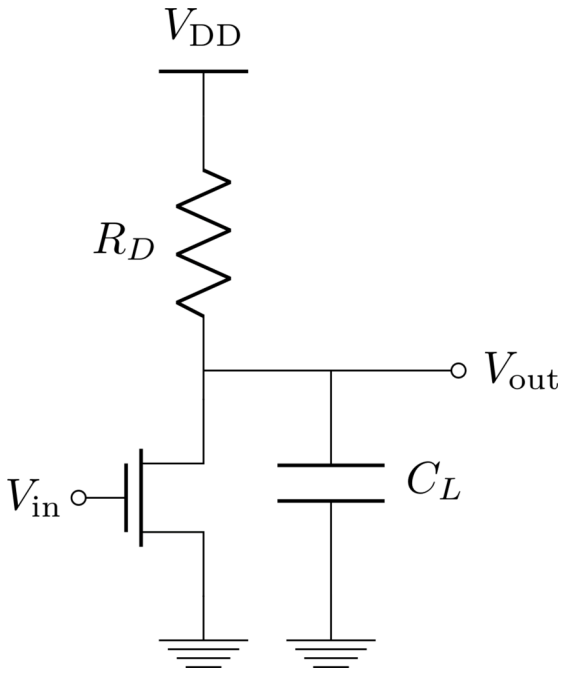
$$\frac{dv_c}{dt} + \frac{1}{R_{DS}C} = \frac{V_{DD}}{RC}$$

b) Please provide an expression for $v_{out}(t)$. (5 points)

Solution:

$$V_c(t) = V_{DD}(1 - e^{-t/RC})$$

c) Consider the circuit below. Please apply the “switch with resistor” model of a transistor when solving this problem. Assume $|V_{th,n}| = |V_{th,p}| \ll V_{DD}$.



If $v_{in}(t)$ is as plotted above, please provide a differential equation in $v_{out}(t)$. (5 points)

Solution:
$\frac{dv_c}{dt} + \left(\frac{1}{R_D C} + \frac{1}{R_{DS} C} \right) v_c = \frac{V_{DD}}{R_D C}$

Extra Space

SID# _____

Factor	Bode Magnitude	Bode Phase
Constant K	$20 \log K$ 0 dB	$\pm 180^\circ$ if $K < 0$ 0° if $K > 0$
Zero @ Origin $(j\omega)^N$	slope = $20N$ dB/decade 0 dB	$(90N)^\circ$ 0°
Pole @ Origin $(j\omega)^{-N}$	slope = $-20N$ dB/decade 0 dB	$(-90N)^\circ$ 0°
Simple Zero $(1 + j\omega/\omega_c)^N$	slope = $20N$ dB/decade 0 dB	$(90N)^\circ$ 0°
Simple Pole $\left(\frac{1}{1 + j\omega/\omega_c}\right)^N$	slope = $-20N$ dB/decade 0 dB	$(-90N)^\circ$ 0°
Quadratic Zero $[1 + j2\xi\omega/\omega_c + (j\omega/\omega_c)^2]^N$	slope = $40N$ dB/decade 0 dB	$(180N)^\circ$ 0°
Quadratic Pole $\frac{1}{[1 + j2\xi\omega/\omega_c + (j\omega/\omega_c)^2]^N}$	slope = $-40N$ dB/decade 0 dB	$(-180N)^\circ$ 0°