Final
EE40
Spring 2014

NAME:_____________________________ SSID:_____________________________

Instructions

Read all of the instructions and all of the questions before beginning the exam.

There are 6 problems in this exam. The total score is 130 points. Points are given next to each problem to help you allocate time. Do not spend all your time on one problem.

Unless otherwise noted on a particular problem, you must show your work in the space provided, on the back of the exam pages or in the extra pages provided at the back of the exam.

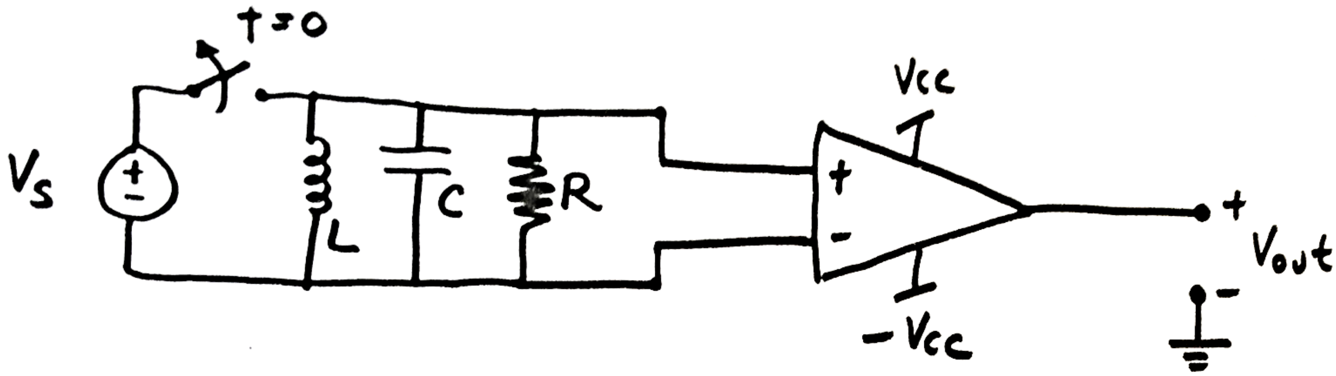
Be sure to provide units where necessary.

GOOD LUCK!

PROBLEM	POINTS	MAX
1		20
2		24
3		20
4		20
5		16
6		30

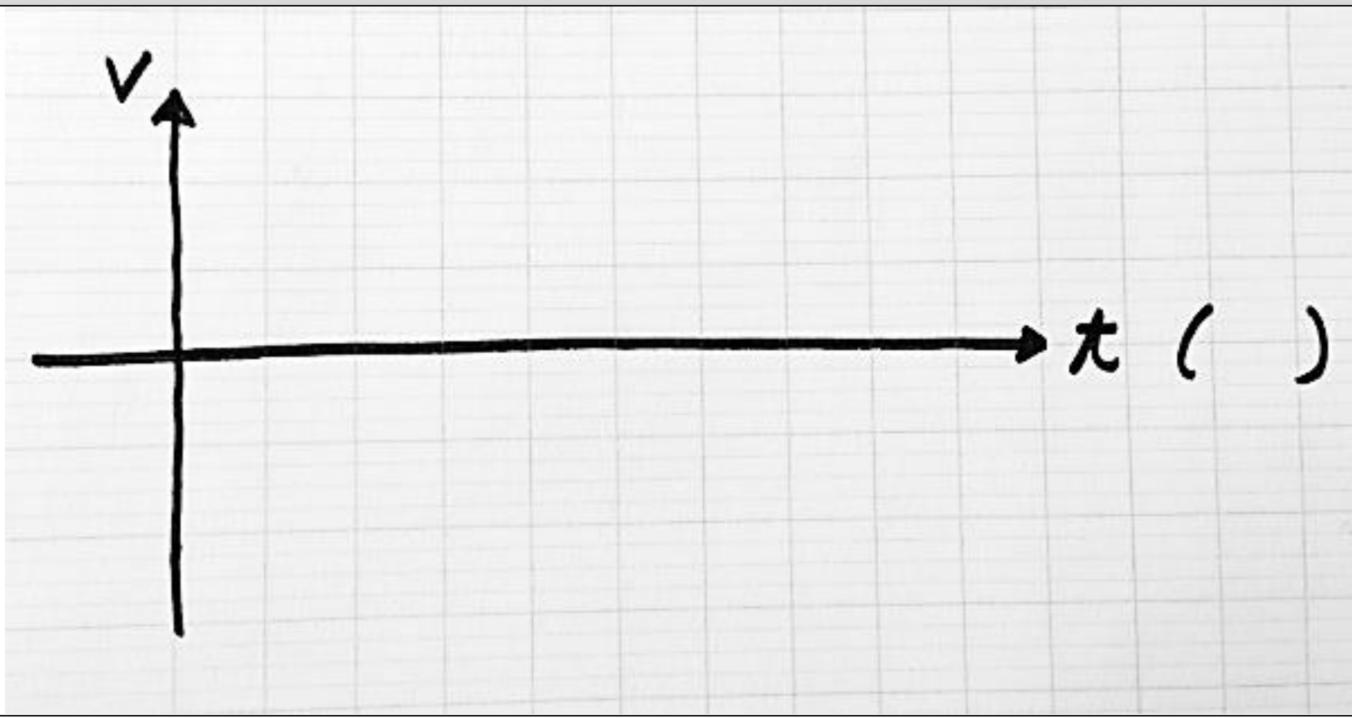
Bill: How do I look?
The Bride: You look ready.
- Kill Bill, Vol. 2

Problem 1 *Warm up (20 points)*
a) Consider the circuit below. C = 25.33 nF; L = 1 μH; R = 1MΩ; Vs = 10 mV; V_{CC} = 5V. The input impedance of the amp is 1 GΩ, the output impedance is 1 Ω and the internal open loop voltage gain, A_V, is 10^6.

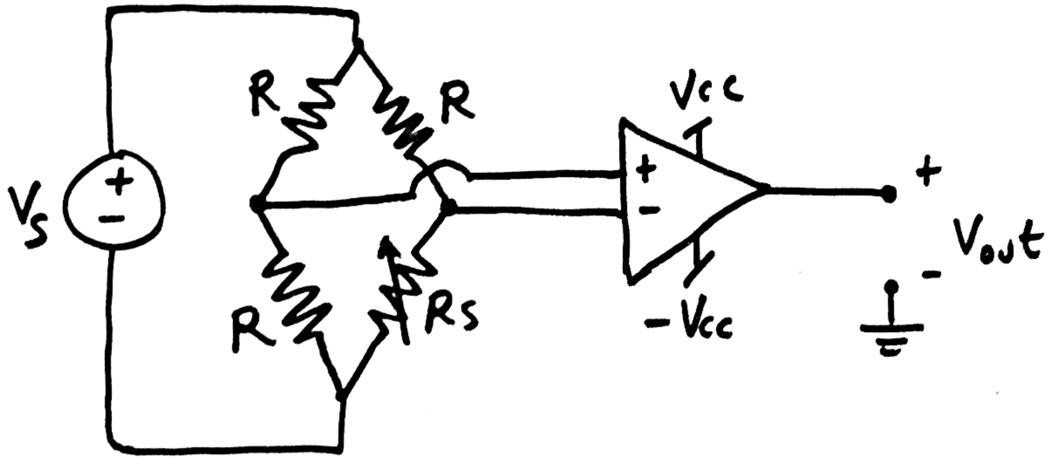


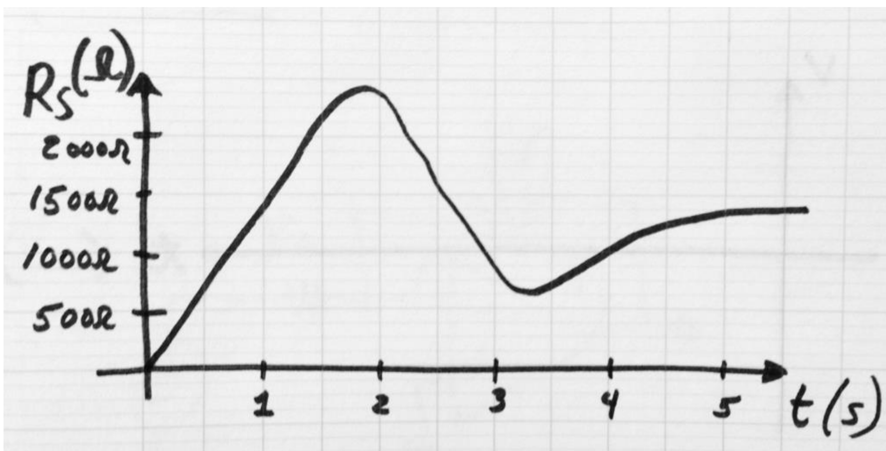
Plot V_{Out} for t > 0.

Solution:



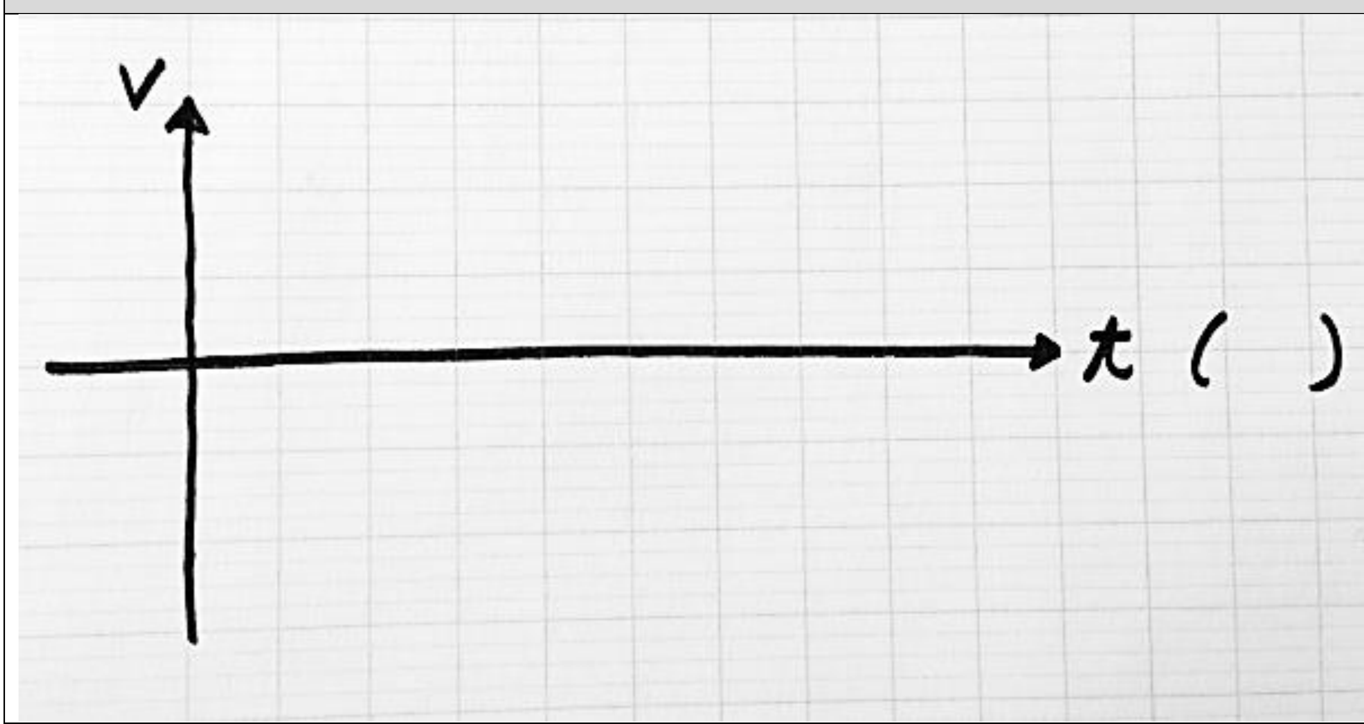
b) Consider the circuit below. R = 1500Ω; Vs = 100 mV; V_{CC} = 5V. R_S is a sensor whose value changes as shown in the plot below. The input impedance of the amp is 1 GΩ, the output impedance is 1 Ω and the internal open loop voltage gain, A_V, is 10^6.



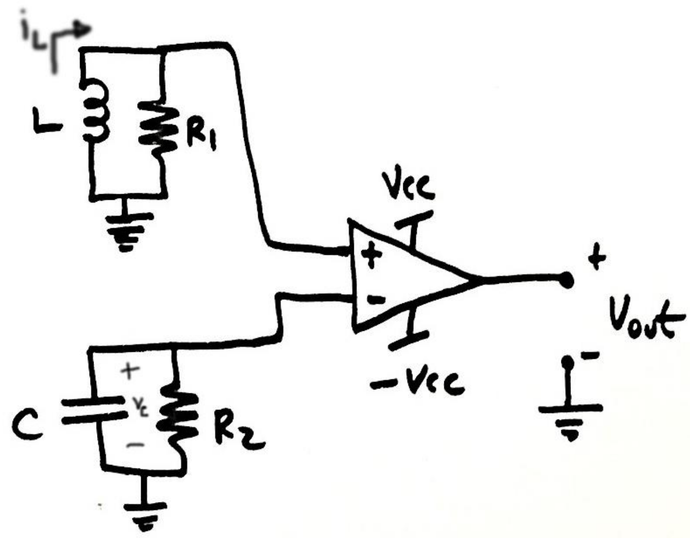


Plot V_{Out} for t > 0.

Solution:

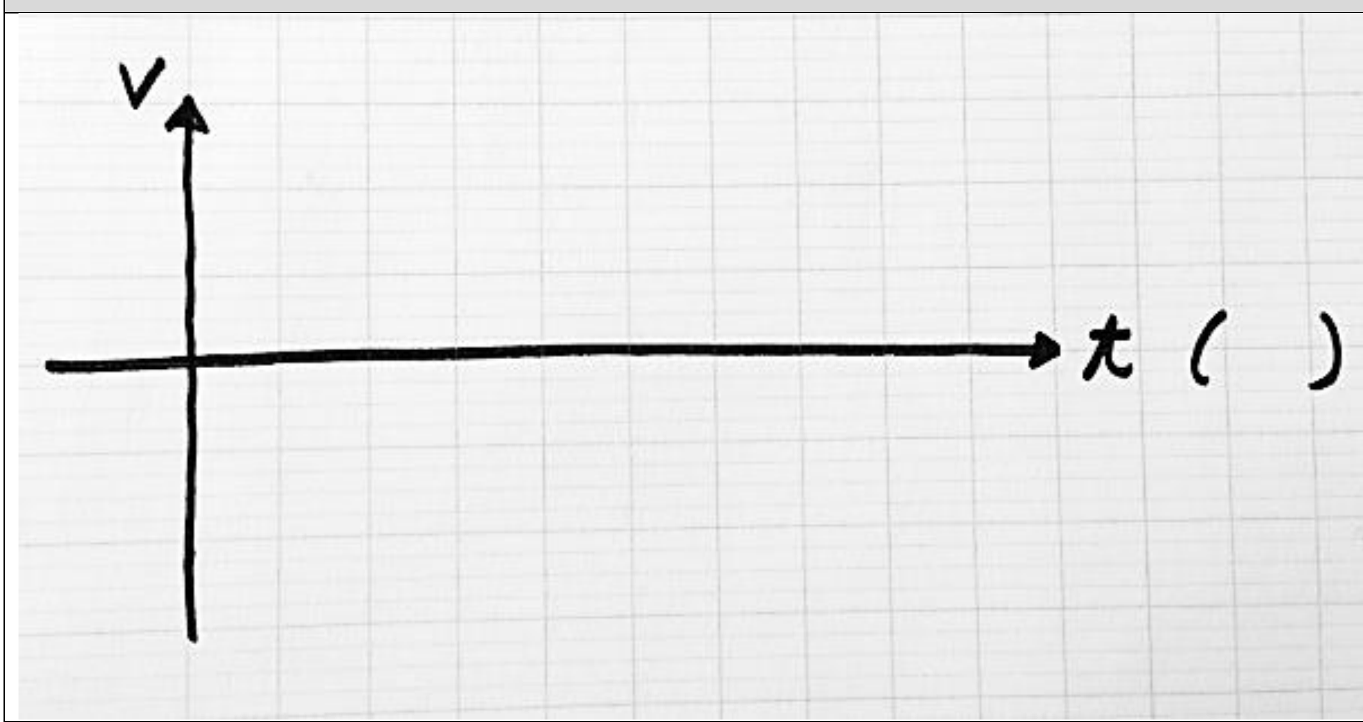


c) Consider the circuit below. R1 = 1 kΩ ; R2 = 1 kΩ; C = 1 µF; L = 1mH. The voltage across C at t = 0 is 0.5 V; the current through L at t = 0 is 1 mA. For t>0 the circuits are not forced. The input impedance of the amp is 1 GΩ, the output impedance is 1 Ω and the internal open loop voltage gain, A_V, is 10^6.

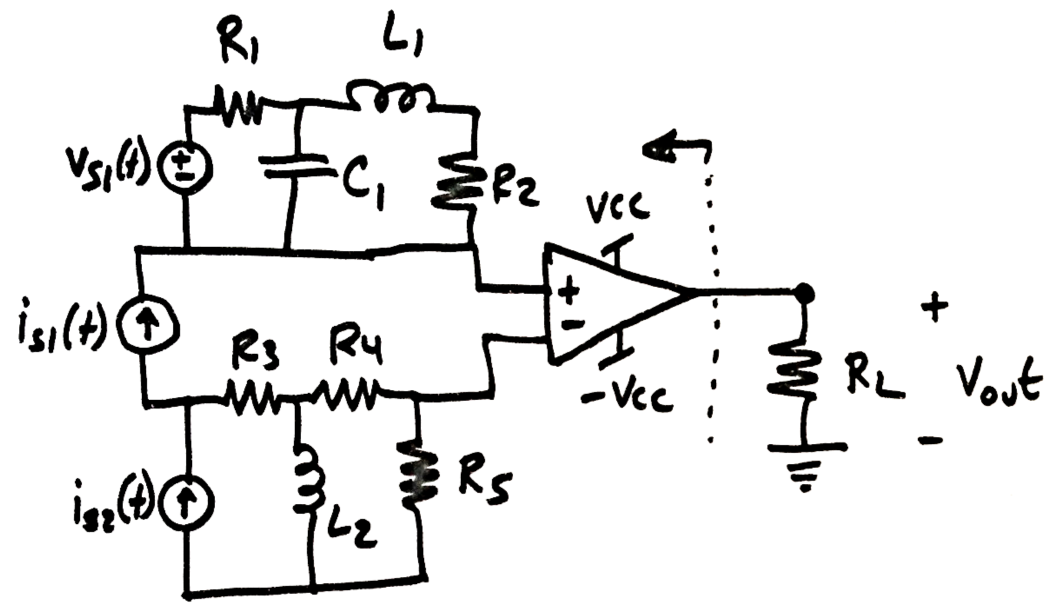


Plot V_{Out} for 0 < t < 5 µs.

Solution:



d) Consider the circuit below. R1 = 1 MΩ ; R2 = 3 kΩ; R3 = 20 kΩ; R4 = 3 MΩ; R5 = 1.5 kΩ; C1 = 100 µF; L1 = 1 mH; L2= 1 mH. $v_{S1}(t)$ = 10cos(ωt + 45°) mV; $i_{S1}(t)$ = 15cos(ωt + 135°) mA; $i_{S1}(t)$ = 5cos(ωt + 95°) mA; ω = 10000 rad/s. The input impedance of the amp is 1 GΩ, the output impedance is 1 Ω and the internal open loop voltage gain, A_V, is 10^6. What is the Thevenin equivalent resistance of this circuit looking out from V_{out} (to the left, below)?



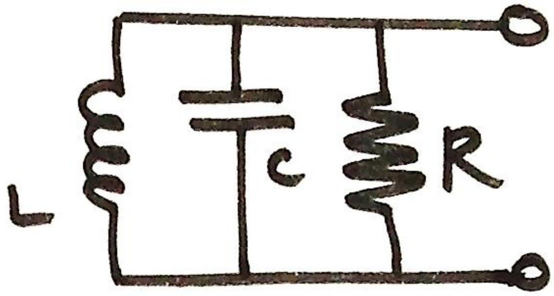
Solution:

Man in Black: You've made your decision then?
Vizzini: Not remotely. Because iocane comes from Australia, as everyone knows, and Australia is entirely peopled with criminals, and criminals are used to having people not trust them, as you are not trusted by me, so I can clearly not choose the wine in front of you.
Man in Black: Truly, you have a dizzying intellect.

- The Princess Bride

Problem 2 *(24 points)*

a) Consider the circuit below. C = 100 nF; L = 15 μH; R = 100 Ω.
Is the concept of a quality factor, Q, meaningful for this circuit? (Yes/No below). If Yes, what is the value?



Solution:		
Circle one:	Yes	No
Q =		

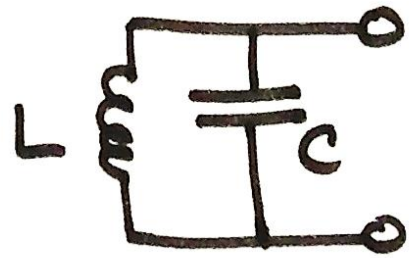
b) For the circuit above, assume $i_L(t=0)$ = 3 mA. In the time domain, is the natural response of this circuit such the voltage across the resistor will oscillate with time for t > 0?

Solution:		
Circle one:	Yes	No

c) What would be the frequency of that oscillation?

Solution:

d) Consider the circuit below. Is the concept of a quality factor, Q, meaningful for this circuit? (Yes/No below). If Yes, what is the value? [Use the same component values as part a)]



Solution:
Circle one: Yes No
Q =

e) For the circuit above, assume $i_L(t=0) = 3$ mA. In the time domain, is the natural response of this circuit such the voltage across the resistor will oscillate with time for $t > 0$?

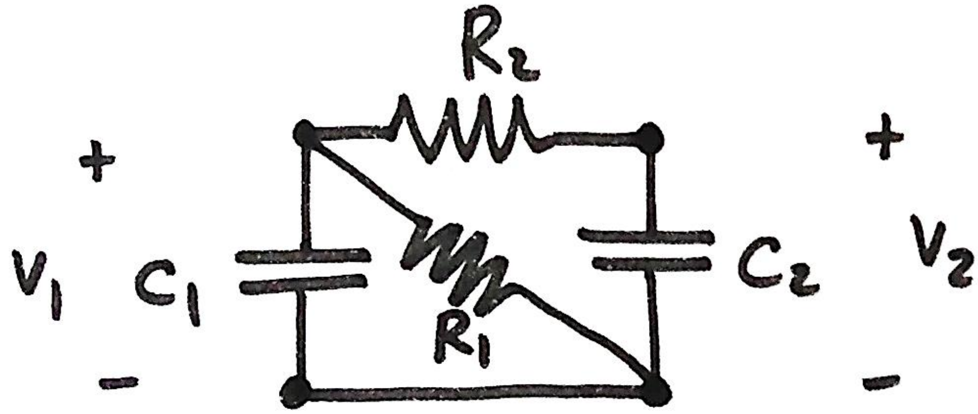
Solution:
Circle one: Yes No

f) What would be the frequency of that oscillation?

Solution:

Dave Bowman: Open the pod bay doors, HAL.
HAL: I'm sorry, Dave. I'm afraid I can't do that.
Dave Bowman: What's the problem?
HAL: I think you know what the problem is just as well as I do.
- *2001: A Space Odyssey (1968)*

Problem 3 *(20 points)*
Consider the circuit below. For t < 0, both capacitors are charged to different voltages. For t > 0 there is no forcing on this circuit. Find **a single equation** that can be solved to obtain $v_1(t)$ for t > 0. No need to find boundary / initial conditions and NO NEED TO SOLVE IT.



Solution:

Captain Lee 'Apollo' Adama: I thought we were sparring.
Commander William Adama: That's why you don't win.
- Battlestar Galactica

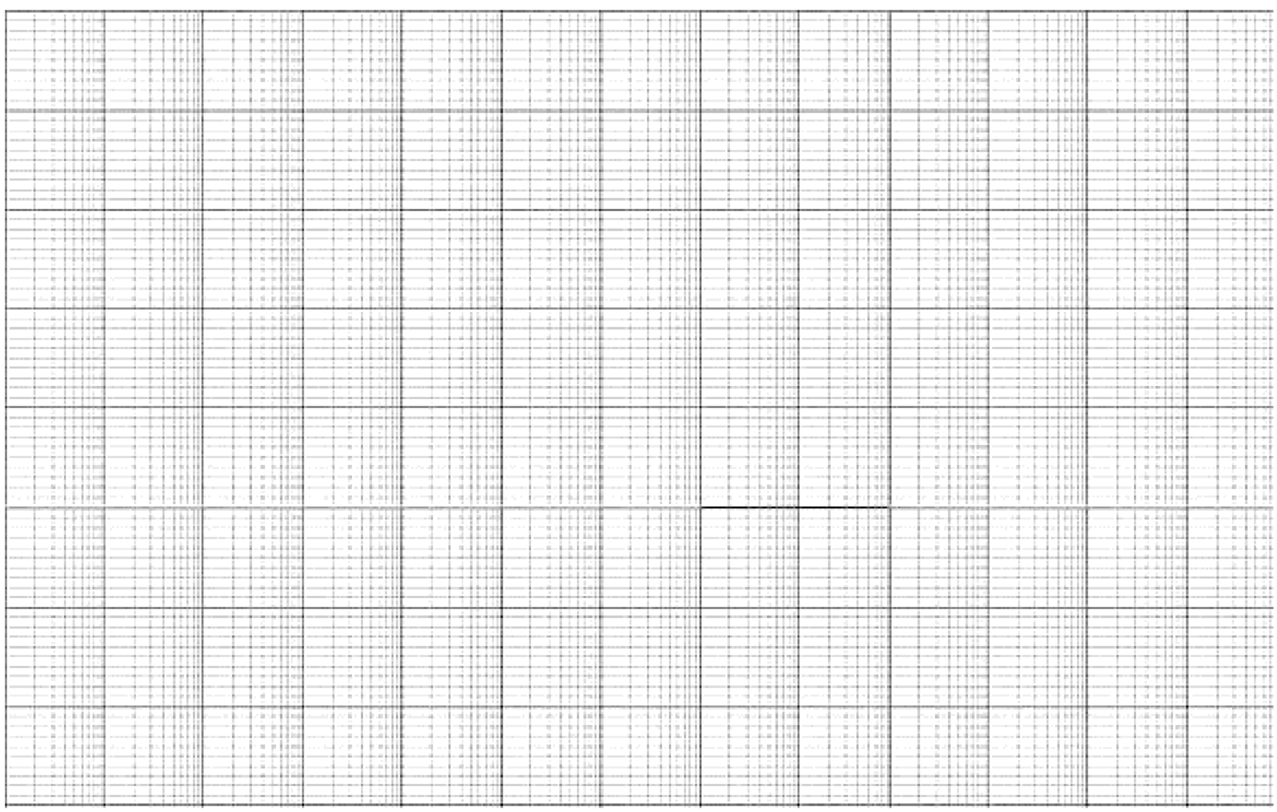
Problem 4 *(20 points)*
Consider the black box below. It receives signals from neural probes implanted into a mammalian cortex. We wish to filter this signal and output the result as Vout.

Specifically:

- We need to lower the magnitude of signals above 3 kHz by at least 10x
- We care only about signals below ~200 Hz

a) Plot the magnitude Bode plot of the transfer function, $H(\omega) = V_{out}/V_{in}$ of the black box.

PLEASE LABEL YOUR AXES AND ANY IMPORTANT FEATURES!



b) Provide an expression for the transfer function, H(ω).

Solution:

c) Draw a circuit with this transfer function. Keep all components symbolic.

Solution:

d) Provide component values in the box below.

Solution:

I must not fear. Fear is the mind-killer. Fear is the little-death that brings total obliteration. I will face my fear. I will permit it to pass over me and through me. And when it has gone past I will turn the inner eye to see its path. Where the fear has gone there will be nothing. Only I will remain.

- Dune (1965)

Problem 5 *(16 points)*

Let's work on another filter. This time, I need to filter an incoming voltage signal, v_{in}, with a passive bandstop filter. The specs are:

- The half power frequencies are at 990 and 1010 MHz.
- The center is at 1 GHz

a) Draw a circuit that can accomplish this. Clearly label v_{in} and v_{out} and keep all components symbolic.

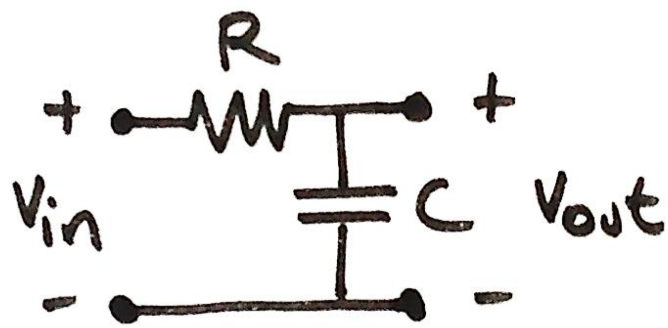
Solution:

b) Provide component values.

Solution:

The Old Man: Nice shooting, son. What's your name?
RoboCop: Murphy.
- last lines of *Robocop (1987)*

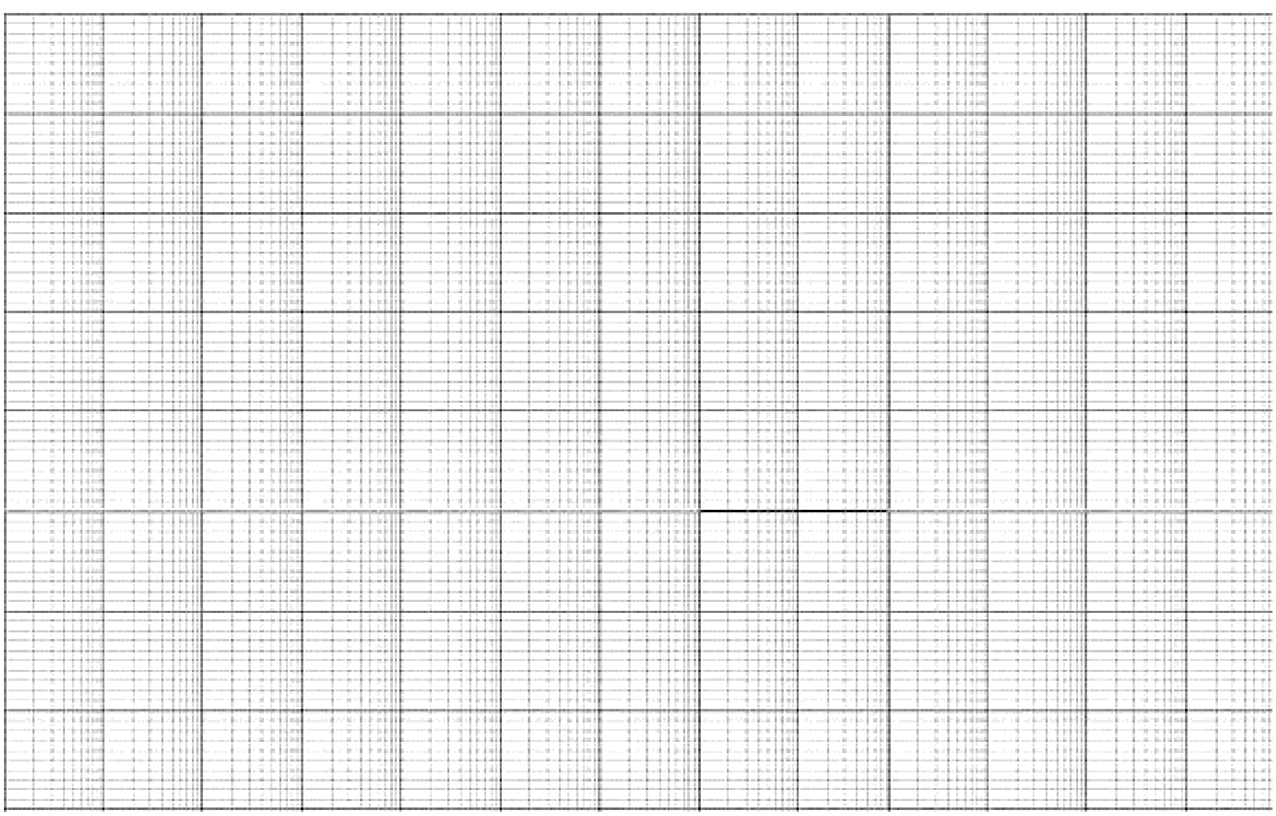
Problem 6 *(30 points)*
Consider the following circuit.



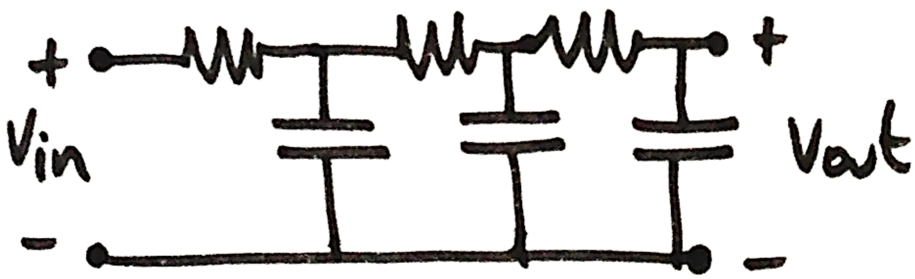
a) What is H(ω)?

Solution:

b) Provide the Bode plot.

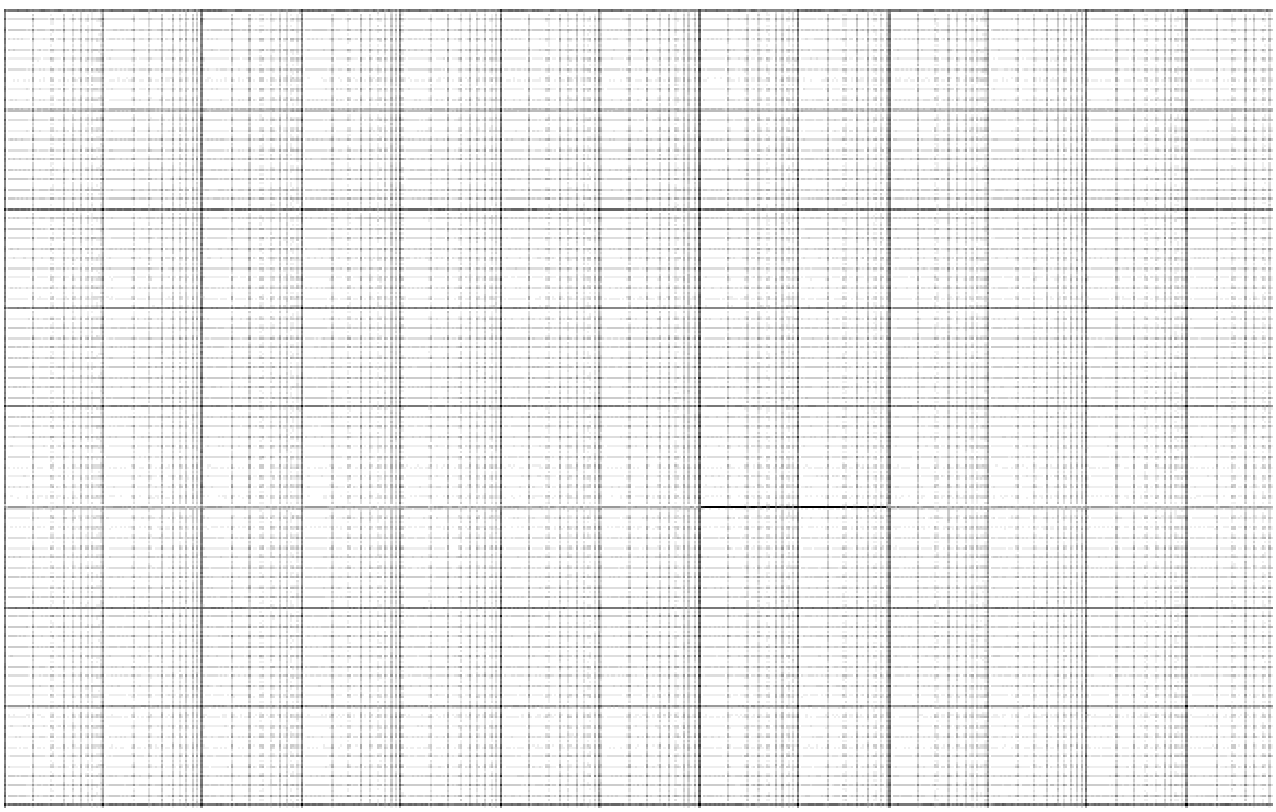


Consider the following circuit.

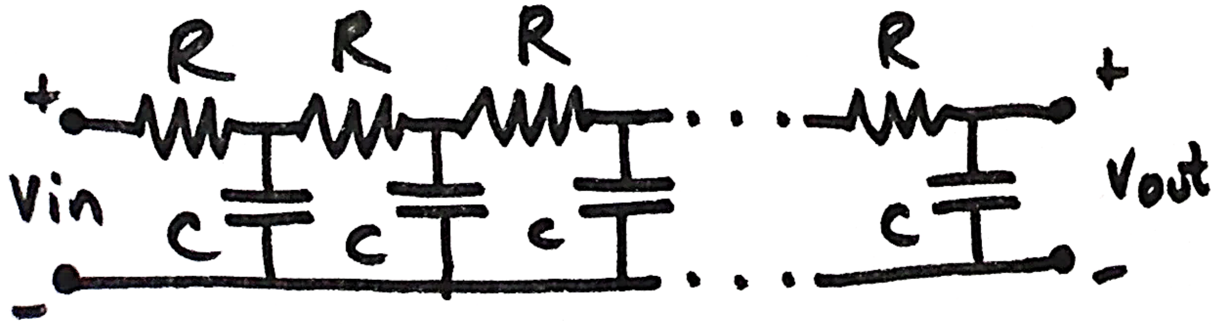


c) What is H(ω)?

d) Provide the Bode plot.

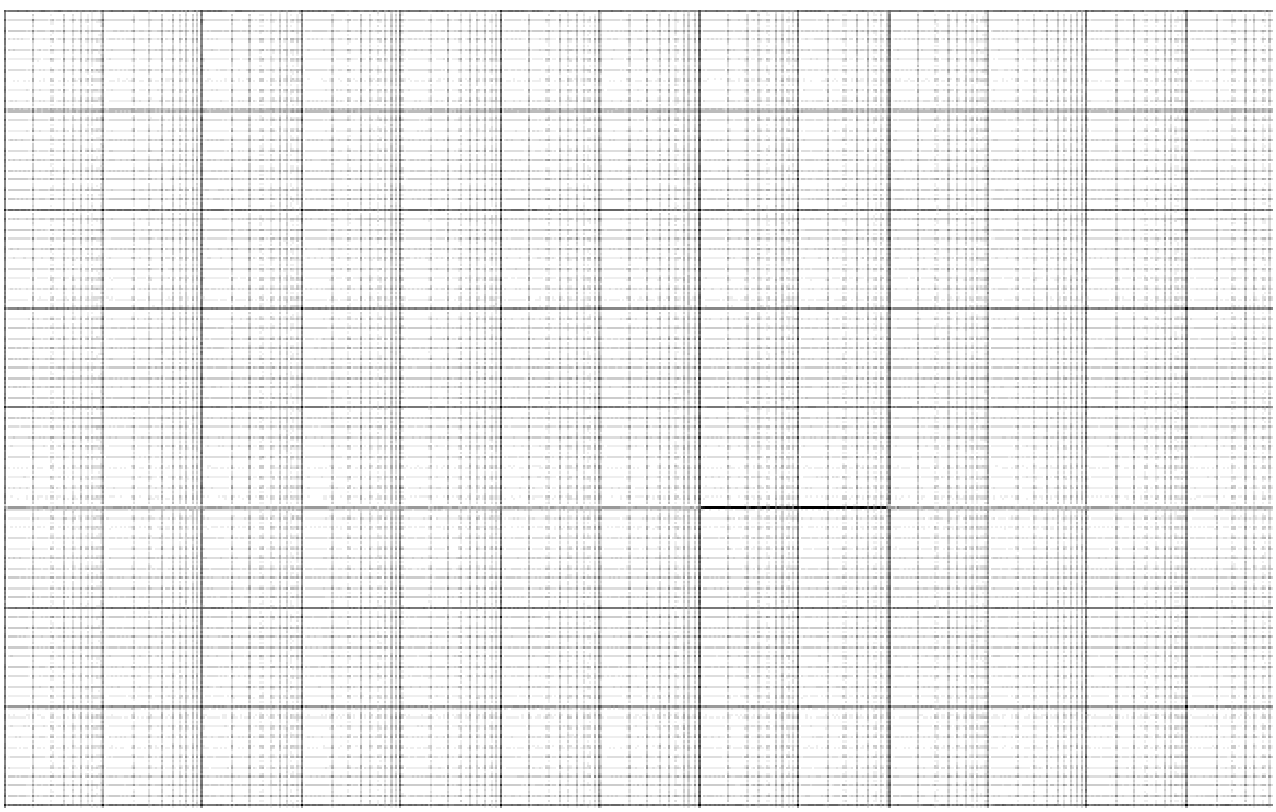


Consider the following circuit. There are N repeats of the components this time, where N is arbitrary.



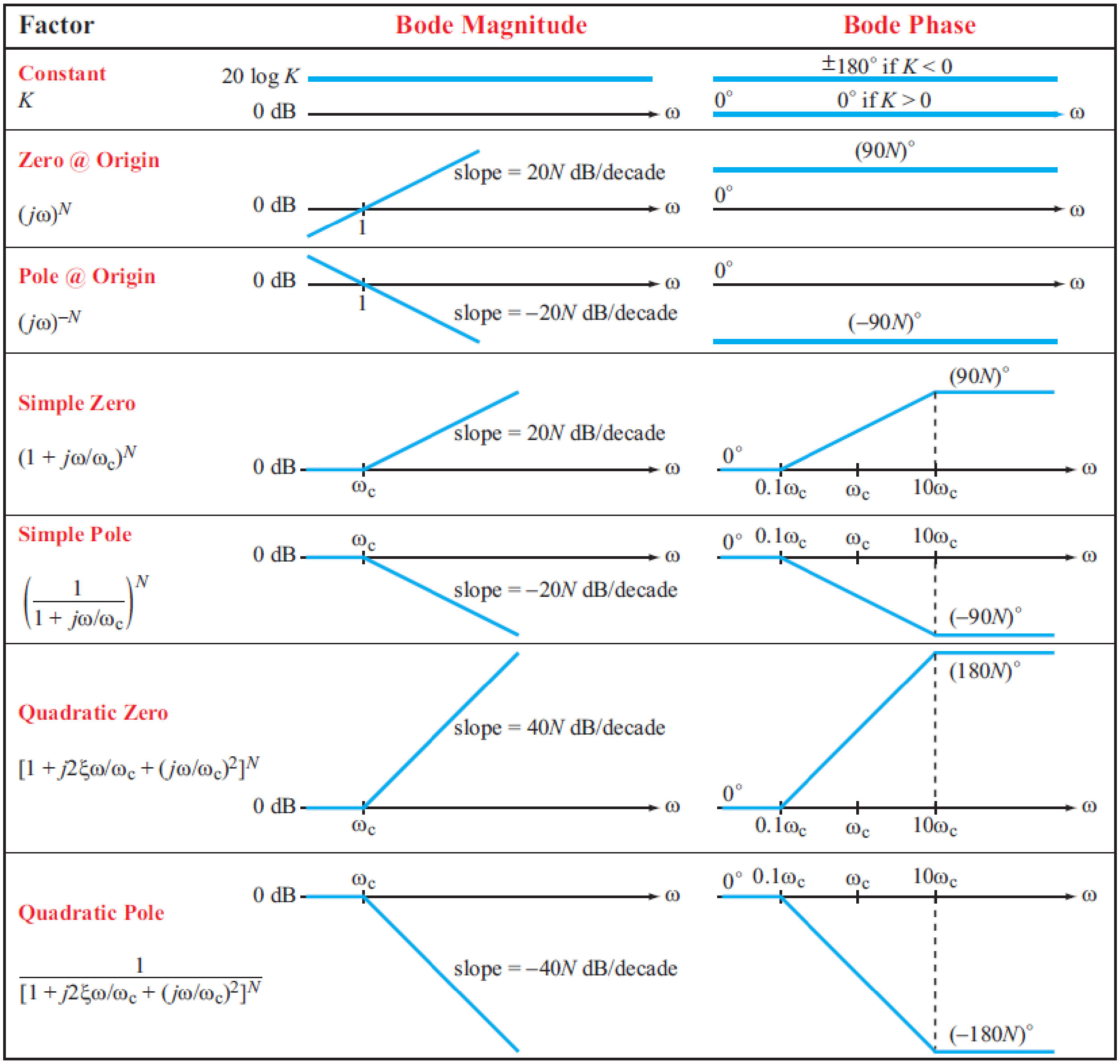
e) What is H(ω)?

f) Provide the Bode plot.



Scratch

Scratch



Factor
Bode Magnitude
Bode Phase
Constant
K
$20 \log K$
0 dB
ω
$\pm 180^\circ$ if $K < 0$
0°
0° if $K > 0$
ω
Zero @ Origin
$(j\omega)^N$
slope = $20N$ dB/decade
0 dB
1
ω
$(90N)^\circ$
0°
ω
Pole @ Origin
$(j\omega)^{-N}$
0 dB
1
ω
slope = $-20N$ dB/decade
0°
ω
$(-90N)^\circ$
Simple Zero
$(1 + j\omega/\omega_c)^N$
slope = $20N$ dB/decade
0 dB
ω_c
ω
$(90N)^\circ$
0°
$0.1\omega_c$
ω_c
$10\omega_c$
ω
Simple Pole
$\left(\frac{1}{1 + j\omega/\omega_c}\right)^N$
0 dB
ω_c
ω
slope = $-20N$ dB/decade
0°
$0.1\omega_c$
ω_c
$10\omega_c$
ω
$(-90N)^\circ$
Quadratic Zero
$[1 + j2\xi\omega/\omega_c + (j\omega/\omega_c)^2]^N$
slope = $40N$ dB/decade
0 dB
ω_c
ω
$(180N)^\circ$
0°
$0.1\omega_c$
ω_c
$10\omega_c$
ω
Quadratic Pole
$\frac{1}{[1 + j2\xi\omega/\omega_c + (j\omega/\omega_c)^2]^N}$
0 dB
ω_c
ω
slope = $-40N$ dB/decade
0°
$0.1\omega_c$
ω_c
$10\omega_c$
ω
$(-180N)^\circ$