Problem 1

Consider the graphic equalizer circuit (from Lab 11) shown on the diagram.

Part 1 (5 points)

Do NOT assume that the op amp is ideal. In other words, **do NOT assume the "Golden rules".**

Write the equations for node voltages:

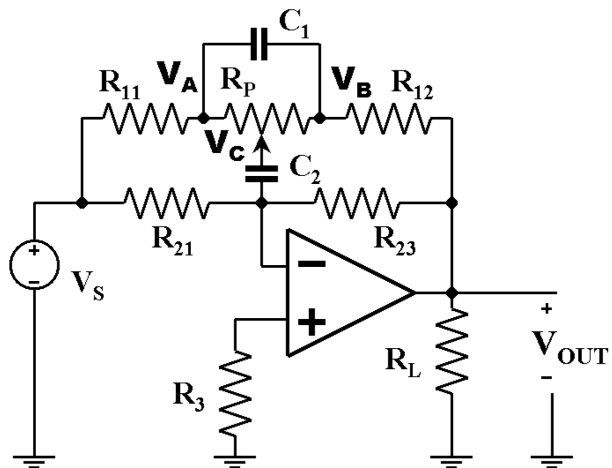
V_A (where R11 is connected to RP and C1)

V_B (where R12 is connected to RP and C1)

V_C (the potentiometer's tap, which is connected to C2)

V-

V+



Clearly label on the circuit diagram and list in your solution all currents that you need as well as the parts of the potentiometer.

Part 2 (5 points)

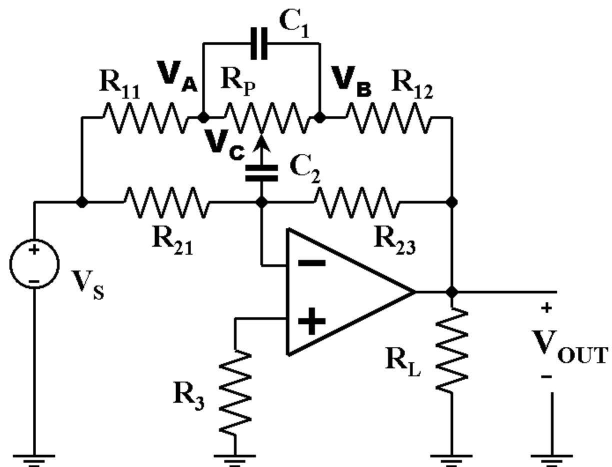
Assume an ideal op amp for which the "Golden rules" apply.

Clearly explain which terms of the equations you wrote can be simplified, and how.

Write the node voltage equations assuming the "Golden rules".

Do NOT solve the equations.

WORKSPACE FOR PROBLEM 1:



Write the equations for node voltages:

V_A (where R11 is connected to RP and C1)

V_B (where R12 is connected to RP and C1)

V_C (the potentiometer's tap, which is connected to C2)

V-

V+

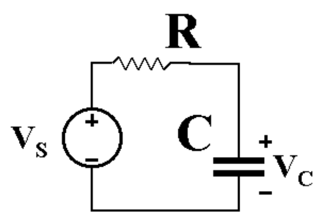
Clearly label on the circuit diagram and list in your solution all currents that you need as well as the parts of the potentiometer.

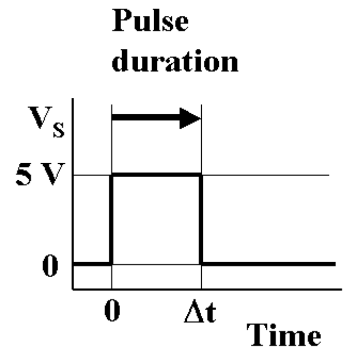
ADDITIONAL WORKSPACE FOR PROBLEM 1: Page # ______

Student's name: ____

Problem 2

The circuit shown on the diagram (familiar from classroom discussions and a previous exam) can be studied as a simple model of a digital device (such as a disk controller) that receives a digital signal (a rectangular pulse shown on the sketch) from a source (such as the clock generator).





In order for the device to recognize that the signal corresponds to digital "1", the capacitor voltage V_C should exceed a threshold value such as 3.5 volts. This requirement limits the range of resistance R and/or capacitance **C.**

The goal of your calculations is to determine the ranges of R and C of such that the maximal capacitor voltage $V_C^{MAX} \geq$ **3.5 volts.**

As you know from classroom discussions and a previous exam, if we assume DC steady-state conditions at time t = 0- such that V_C (t = 0-) = 0 then the capacitor voltage equals

$$V_C = 5\,V \cdot \left(1 - e^{-t/RC}\right) \quad for\ 0 \leq t \leq \Delta t$$

$$V_C = 5\,V \cdot \left(1 - e^{-\Delta t/RC}\right) \cdot e^{-(t-\Delta t)/RC} \quad for\ t \geq \Delta t$$

Part 1 (2 points)

Obtain the algebraic expression for V_C^{MAX} = the maximal V_C **(t)** reached at **t >0.** Explain your result. Write your answer in the box below:

V_C^{MAX} =

Part 2 (4 points)

Consider **Δt = 0.25 nsec = 2.5·10^{-10} sec.** This pulse duration corresponds to the clock frequency of 2 GHz typical of today's computers. Assume **R = 1 kΩ** and determine the range of capacitance values **C** such that $V_C^{MAX} \geq$ **3.5 volts.**

Express your result in picofarads (1 pF = $\mathbf{1 \cdot 10^{-12}\ F}$). Write your answer in the box:

(keep 4 significant digits)

Show all steps of your work.

Part 3 (4 points)

For the same pulse duration, $\mathbf{\Delta t = 0.25\ nsec,}$ assume $\mathbf{C = 10\ pF}$ and determine the range of resistance values $\mathbf{R}$ such that $\mathbf{V_C^{MAX} \geq 3.5\ volts.}$
Write your answer in the box:

(keep 4 significant digits)

Show all steps of your work.

WORKSPACE FOR PROBLEM 2

ADDITIONAL WORKSPACE FOR PROBLEM 2: Page #_____

Student's name:

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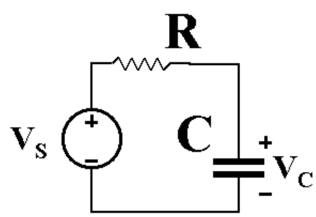
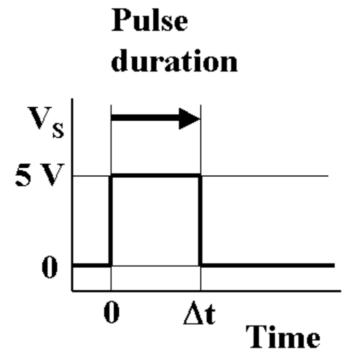
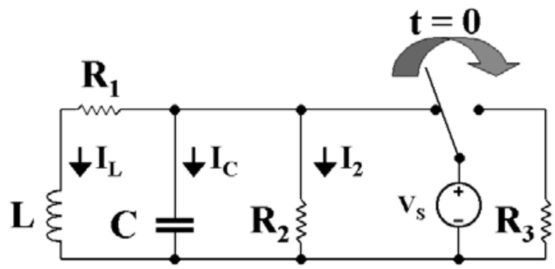




Problem 3

Consider the circuit shown on the diagram, which is familiar from the previous exam.
Consider the following component values:

L = 10 mH =10^{-2} H
C = 100 pF =10^{-10} F
R_1 =1 kΩ
R_2 =100 kΩ
R_3 =1 MΩ = 10^6 Ω



From the previous exam, you know that under these conditions,

ω_0 **= 1.005·10^6 rad/sec** and α **= 10^5 rad/sec** thus the response is under-damped, and the inductor current I_L as a function of time t equals:

$$I_L = \left(A \cdot \cos\left(\omega_d \cdot t\right) + B \cdot \sin\left(\omega_d \cdot t\right)\right) \cdot e^{-\alpha \cdot t}$$

Part 1 (4 points)

Calculate the frequency of damped oscillations ω_d = ______________ **rad/sec.**

Assume **V_S = 5 volts** and calculate the coefficients **A** and **B.**

Carefully label on the circuit diagram all voltages, etc. that you need.

Show all steps of your work. Express your results in milliamps:

A = ________________

B = ________________

Part 2 (2 points)

Calculate the period **T** of damped oscillations in microseconds **(1 μsec = 10^{-6} sec).**
Show all steps of your work.

T = __________________

Part 3 (4 points)

At time **t = 2 μsec,** calculate the following values with 4 significant digits:

$A \cdot \cos\left(\omega_d \cdot t\right) =$ ______________________________

$B \cdot \sin\left(\omega_d \cdot t\right) =$ ______________________________

$e^{-\alpha \cdot t} =$ ______________________________

$I_L =$ ______________________________

Show all steps of your work.
Write your numerical results along with the units of measure in the box above.

ADDITIONAL WORKSPACE FOR PROBLEM 3: Page # ________

Student's name: ______________________

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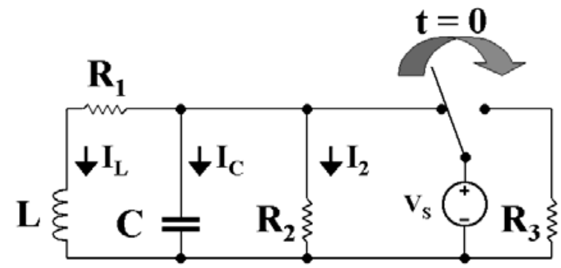
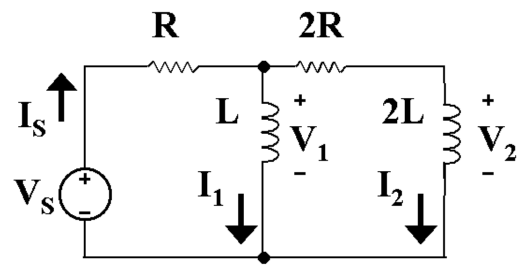


L = 10 mH; C = 100 pF; R_1 =1 kΩ; R_2 =100 kΩ; R_3 =1 MΩ; V_S = 5 volts

Problem 4

Consider the circuit shown on the diagram.



Derive the differential equation for the current $\mathbf{I_1}$.

Obtain algebraic expressions for ω_0 and α.

Determine the type of response (under-damped, critically damped, or over-damped).

Write your results in the box below:

Your differential equation for the current $\mathbf{I_1}$ is:

Your algebraic expression: $\omega_0 =$ ______________________________

Your algebraic expression: $\alpha =$ ______________________________

The type of response is (circle one):

Under-damped Critically damped Over-damped

Show all steps of your work.

WORKSPACE FOR PROBLEM 4

Student's name:

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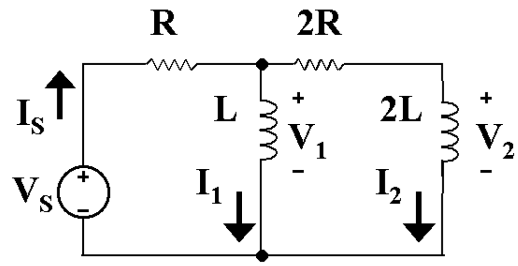


ADDITIONAL WORKSPACE FOR PROBLEM 4: Page # ________

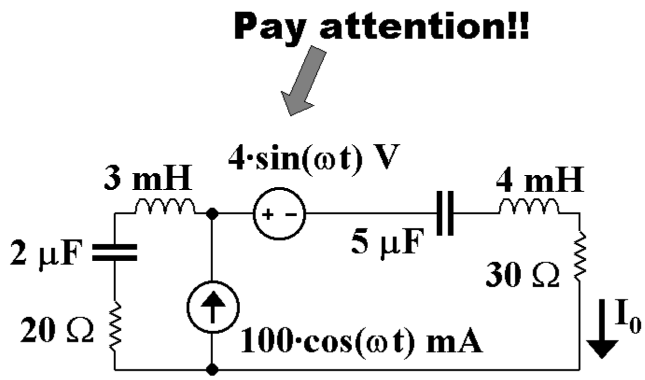
Problem 5

Consider the circuit shown on the diagram.

Assume $\omega = 10^4$ **rad/sec.**

Use source transformation to obtain the current $\mathbf{I_0}$.

Express your answer in milliamps, both in the phasor notation (rectangular form)
and
in the time domain in the form $I_0 = I_{0,\,max} \cdot \cos(\omega \cdot t + \varphi)$ where the angle φ is in degrees.



Write your answers in the box below:

$\hat{I}_0 = (\_\_\_\_\_\_\_\_ + j\ \_\_\_\_\_\_\_\_)$ mA

$I_0 = \_\_\_\_\_\_\_\_\_\_\_\_ \cdot \cos(\omega \cdot t + \_\_\_\_\_\_\_\_\_^{o})$ mA

<u>Show all steps of your work.</u> Make sure to redraw the circuit after each step of the source transformation and clearly label all sources and impedances.

WORKSPACE FOR PROBLEM 5

ADDITIONAL WORKSPACE
FOR PROBLEM #5
Page # ________

Student's name:

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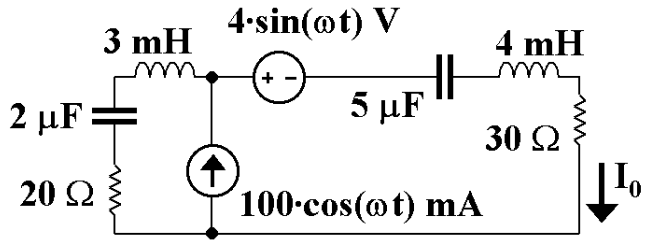
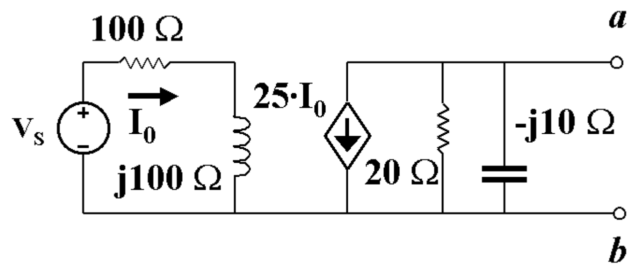


Problem 6

Consider the circuit shown on the diagram. Assume the voltage source $V_S = 10\angle 0^o$ mV.



Calculate the Thevenin and Norton equivalent circuits at the terminals ***a*** and ***b***.

Write your results in the rectangular form, along with the units of measure.

Open circuit voltage equals ____ (units!)

Short circuit current equals ____ (units!)

Thevenin equivalent resistance equals ______________________________ (units!)

Show all steps of your work.

Sketch the equivalent circuits. Carefully label the voltage, current, impedance.

Thevenin equivalent circuit	Norton equivalent circuit

Student's name:

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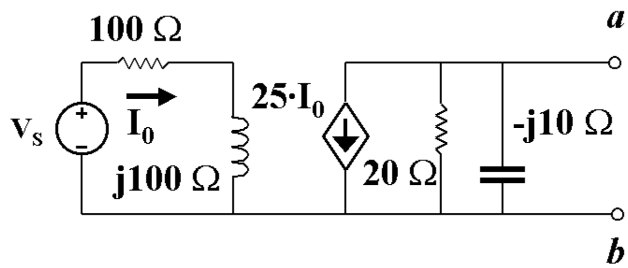
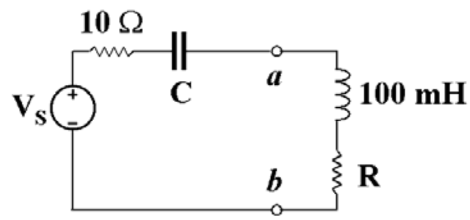


ADDITIONAL WORKSPACE FOR PROBLEM 6

Page # _______

Problem 7

The source, which is shown as its Thevenin equivalent on the circuit diagram, is connected to the load at the terminals ***a*** and ***b.***



Consider $\mathbf{V_S = 10 \cdot \cos(\omega t)}$ volts.

Assume $\omega = \mathbf{10^4}$ **rad/sec.**

Determine the equivalent capacitance **C** of the source in nanofarads **(1 nF = 10^{-9} F)** and the load resistance **R** in ohms that ensure the maximal transfer of the average power to the load.

Calculate the current through the load and express your result in the form $I = I_{max} \cdot \cos(\omega \cdot t + \varphi)$ where the current I_{max} is in milliamps and the angle φ is in degrees.

Calculate the maximal value of the average power (in watts) dissipated in the load.

Write your answers in the box below:

C = ______________ nF ; R = _______________ Ω

$I =$ _____________ $\cdot \cos(\omega \cdot t +$ _________ ^{o}) mA

The maximal value of the average power dissipated in the load is ______________ watts.

Show all steps of your work.

WORKSPACE FOR PROBLEM 7

Student's name:

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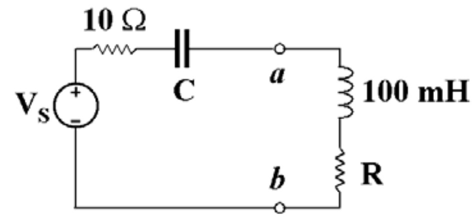
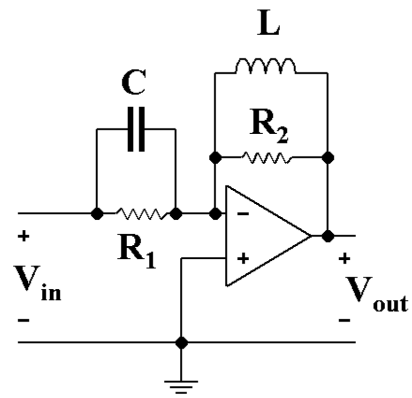


ADDITIONAL WORKSPACE FOR PROBLEM 7: Page # ________

Problem 8

Consider the filter circuit shown on the diagram.



Derive the transfer function $\hat{H}(\omega) = \frac{\hat{V}_{out}}{\hat{V}_{in}}$

Express the transfer function in the standard form.

Identify the constant, the poles and zeros.

Determine the type of the filter (low-pass, high-pass, band-pass, band-stop).

Write your results in the box:

The transfer function is:

$$\hat{H}(\omega) = \frac{\hat{V}_{out}}{\hat{V}_{in}} =$$

The transfer function in the standard form is:

$$\hat{H}(\omega) = \frac{\hat{V}_{out}}{\hat{V}_{in}} =$$

The constant equals ________________

The poles are at ____

The zeros are at ____

The type of the filter is (circle one):

Low-pass High-pass Band-pass Band-stop

Show all steps of your work.

Student's name:

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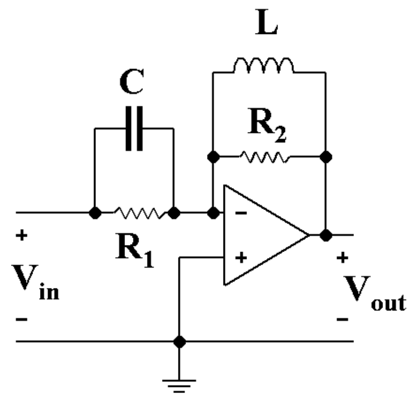
ADDITIONAL WORKSPACE FOR PROBLEM 8



Page # _______

Problem 9

Consider the transfer function

$$H(\omega) = \frac{10,000 + j\omega}{100 + j\omega}$$

Express the transfer function in the standard form.
Identify the constant, the poles and zeros.
Write your results in the box:

The transfer function in the standard form is:

The constant equals:

The poles are at ______________________________________ rad/sec

The zeros are at ______________________________________ rad/sec

Use the grids to sketch the Bode plots for both the magnitude and the phase of the transfer function over the range from $\mathbf{10^0}$ to $\mathbf{10^6}$ **rad/sec.**

On each grid, draw only one curve.
Use one row of grids for each of the components of the transfer function, and one row for the transfer function as a whole.

Clearly label the axes of each grid.
The frequency axes should be logarithmic.
The vertical axis of the magnitude plot should be in decibels.
The vertical axis of the angle plot should be in degrees.

Clearly label the slope of each part of each plot; include the sign and the units of measure.

Use extra pages with grids if needed.

WORKSPACE FOR PROBLEM 9

WORKSPACE FOR PROBLEM 9

Magnitude plots

Phase plots

ADDITIONAL WORKSPACE FOR PROBLEM 9 Page # ______

Student's name: ____

Magnitude plots

Phase plots

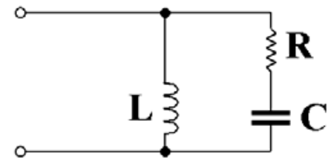
Student's name: ____

ADDITIONAL WORKSPACE FOR PROBLEM 9 Page # ______

$$H(\omega) = \frac{10,000 + j\omega}{100 + j\omega}$$

Problem 10

Consider the circuit shown on the diagram.



Obtain the algebraic expression for the resonant frequency in hertz in this circuit.

Write your result in the box:

f =

Show all steps of your work.

Obtain the algebraic expression for the inductance **L** that ensures resonance at the desired frequency **f** in hertz, for the given values of the resistance **R** and capacitance **C.**

Write your result in the box:

L =

Show all steps of your work.

Assume **R = 100 Ω** and **C = 1 μF = 10^{-6} F.**
Calculate the inductance **L** that ensures resonance at **f = 1 kHz.**

Express your answer in millihenry.
Write your result in the box:

L =

Show all steps of your work.

Student's name:

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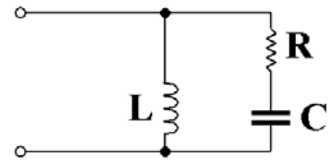

ADDITIONAL WORKSPACE FOR PROBLEM 10 Page #_______