Mid-term Exam

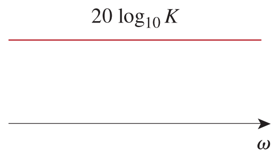
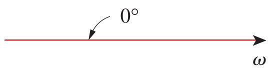
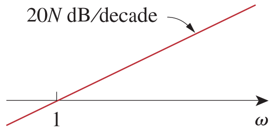
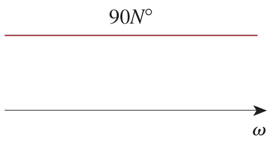
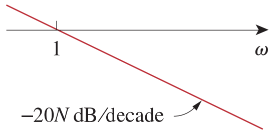
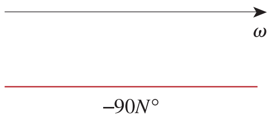
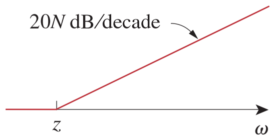
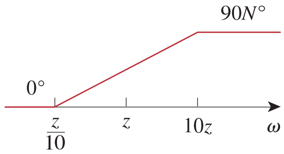
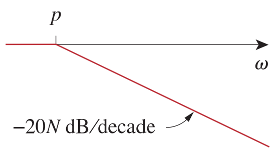
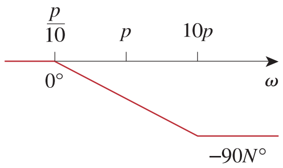
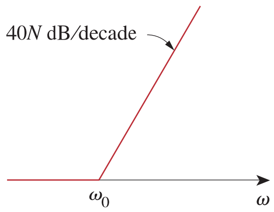
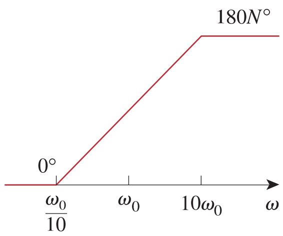
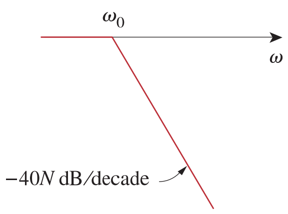
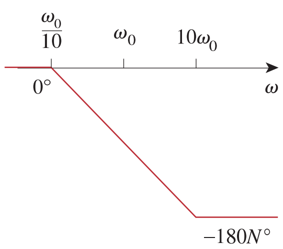
EE1C21 “Linear Circuits B”

Place:
Date:
Time:

- This exam consists of 4 exercises.
- Each exercise accounts for **10 points**; the total number of points to be obtained is **40**. The exam grade is obtained by dividing the total number of points by 4, rescaling linearly the result to the 1-10 scale and rounding off to 1 decimal.
- **Each exercise must be solved on a separate double-sheet.** Writing more solutions on the same sheet may result in only one of the solutions being graded!
- Indicate your name and study number on **each** submitted sheet. **You must hand in (blank) signed sheets even for the exercises that you do not handle.**
- Students benefitting of the “Extra Time” (ET) rule are entitled to a 20 minutes extension of their exam provided they produce the relevant supporting document.
- Should any question not be completely clear, you are allowed to ask the instructors in the exam hall; the answer will be confined to rephrasing the text of the exercise such that to make it more intelligible.
- Should a part of an exercise depend on a previous result, mistakes made at a previous step will only be penalised once.
- Give your solution as completely as possible and never state numerical results without indicating how you derived them. **Simply stating numerical results will yield no points.**
- **When requested, fill in the measure units for all calculated quantities.** This holds for intermediate results but definitely for the final ones.
- Write clearly and avoid messy solutions. Should errors occur in your solution, cross the erroneous part out and give clear indications on where the correct solution resumes.
- For this exam you are allowed to use:
    i. a simple calculator – programmable and graphic calculators are explicitly prohibited;
    ii. a handwritten, double-sided A4 sheet with formulas.
- The text of this exam is offered only in English. Inasmuch as possible, instructors will assist you with the Dutch translation of formulations that you may have difficulties to understand.

The Linear Circuits team wishes you a lot of success!

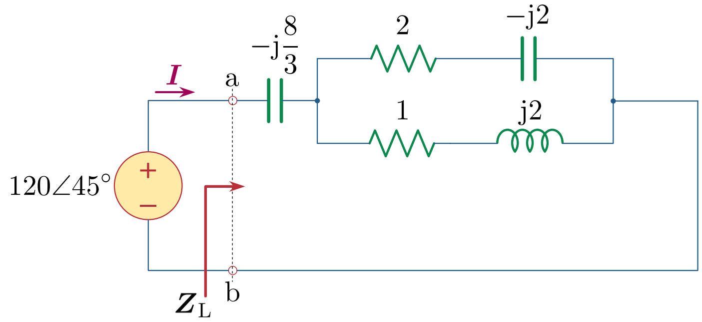
Summary of Bode straight-line magnitude and phase plots.

Factor	Magnitude	Phase
K		
$(j\omega)^N$		
$\frac{1}{(j\omega)^N}$		
$\left(1 + \frac{j\omega}{z}\right)^N$		
$\frac{1}{(1 + j\omega/p)^N}$		
$\left[1 + \frac{2j\omega\zeta}{\omega_0} + \left(\frac{j\omega}{\omega_0}\right)^2\right]^N$		
$\frac{1}{[1 + 2j\omega\zeta/\omega_0 + (j\omega/\omega_0)^2]^N}$		

- Take a new double-sheet -

Exercise 1

Consider the phasor-domain circuit in the figure below:

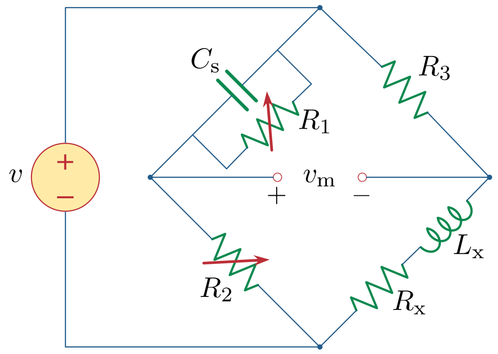


a) Calculate the impedance $\boldsymbol{Z}_\mathrm{L}$ seen between the a–b terminals. (3 points)

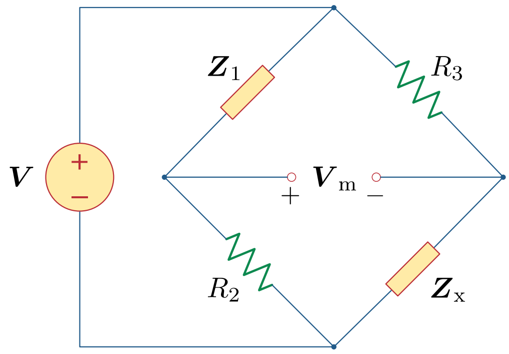
b) Calculate the phasor-domain current $\boldsymbol{I}$. (1 points)

c) By knowing that the angular frequency is $\omega = 10^3$ rad/s, determine the time-domain $i(t)$ correspondent of $\boldsymbol{I}$ – ***indicate the measure unit!*** (2 points)

The AC bridge shown in the figure below-left is known as a *Maxwell bridge* and is used for measuring the inductance and resistance of a coil in terms of a standard capacitance C_s. The figure at the right is the phasor-domain equivalent circuit of the bridge for $v(t) = \cos(\omega t)$ V. When the bridge is balanced, $\boldsymbol{V}_\mathrm{m} = 0$.



Maxwell bridge



Phasor-domain equivalent

d) Calculate the equivalent impedances $\boldsymbol{Z}_1$ and $\boldsymbol{Z}_\mathrm{x}$. If any expression is a fraction, simplify it to the form $(a_1 + jb_1)/(a_2 + jb_2)$, in which a_1, b_1, a_2 and b_2 are real values. (2 points)

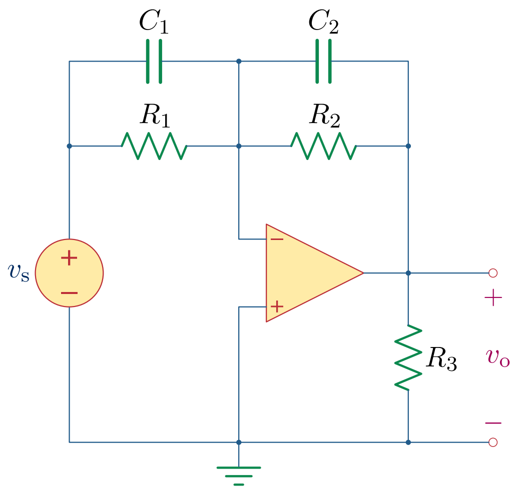
e) Use creatively the voltage division for establishing a simple expression relating $\boldsymbol{Z}_1$, R_2, $\boldsymbol{Z}_\mathrm{x}$ and R_3 when the bridge is balanced ($\boldsymbol{V}_\mathrm{m} = 0$). (2 points)

Avoid useless algebraic complications when evaluating complex expressions. Show all steps in your reasoning and never give numerical results without justification.

- Take a new double-sheet -

Exercise 2

The input to the op-amp circuit shown in figure is the source voltage, $v_s(t)$, and the output is the voltage across R_3, $v_o(t)$.



a) Write an analytical expression for the transfer function $\boldsymbol{H}(\omega) = \boldsymbol{V}_o(\omega)/\boldsymbol{V}_i(\omega)$. Simplify as much as possible. (2 points)

b) Write the gain, K; zero(s), z; and pole(s), p, in terms of the capacitances and resistances. (2 points)

Use the logarithmic graph paper provided on the next page for the following sub-questions:

c) Sketch the Bode magnitude diagram for $C_1 = 100\mu\text{F}$, $C_2 = 10\mu\text{F}$, $R_1 = 1\text{k}\Omega$ and $R_2 = 1\text{k}\Omega$. (2 points)
Hint: Make sure to label axes, magnitudes, and breakpoints.

d) Sketch the Bode magnitude diagram for $C_1 = 10\mu\text{F}$, $C_2 = 10\mu\text{F}$, $R_1 = 1\text{k}\Omega$ and $R_2 = 10\text{k}\Omega$. (2 points)
Hint: Make sure to label axes, magnitudes, and breakpoints.

e) Sketch the Bode phase diagram for part (d) where $C_1 = 10\mu\text{F}$, $C_2 = 10\mu\text{F}$, $R_1 = 1\text{k}\Omega$ and $R_2 = 10\text{k}\Omega$. (2 points)
Hint: Make sure to label axes, magnitudes, and breakpoints.

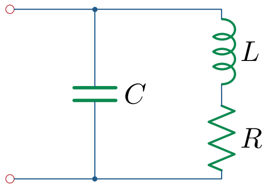
Indicate the measure units for all calculated quantities. Show all steps in your reasoning and never give numerical results without justification.

1 2 3 4 5 6 7 8 9 10 2 3 4 5 6 7 8 9 10 2 3 4 5 6 7 8 9 10

- Take a new double-sheet -

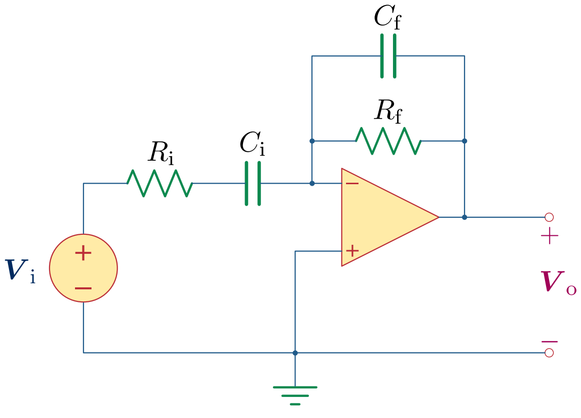
Exercise 3

Consider the circuit in the figure below:



a) Calculate its resonant frequency. (3 points)
Hint: Only the symbolic derivation of the value of resonant frequency is required, no discussions on its value is needed.

Now consider the following op-amp circuit:



b) Determine its transfer function $\boldsymbol{V}_o/\boldsymbol{V}_i$ ***in symbolic form***. (3 points)

c) Justify why this circuit behaves as a band-pass filter with the transfer function $\boldsymbol{V}_o/\boldsymbol{V}_i$, and determine the values of the two corner frequencies. (3 points)
Hint: To find the value of the two corner frequencies examine the denominator of the transfer function and think of its effect on Bode plot.

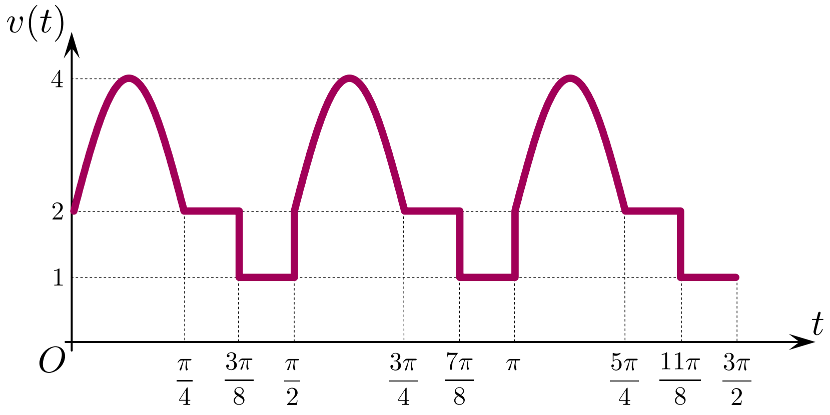
d) If the cut-off angular frequency related to the value of the resistor $R_f = 10\,\mathrm{k\Omega}$ is $\omega_c = 10^4$ rad/s, determine the corresponding value of C_f. (1 point)

Indicate the measure units for all calculated quantities. Show all steps in your reasoning and never give numerical results without justification.

- Take a new double-sheet -

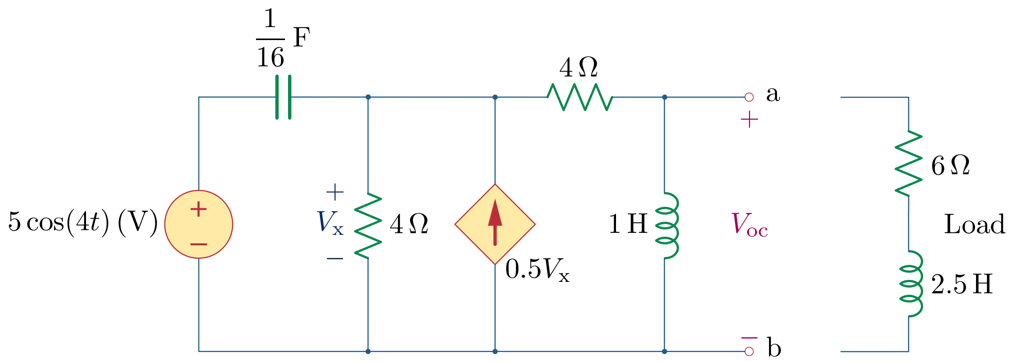
Exercise 4

Consider the time-dependent voltage illustrated in the plot below:



a) Calculate the rms value of the signal v(t) shown in the plot. (3 points)

Now consider the circuit in the figure below:



b) Transform this time-domain circuit to an equivalent circuit in the phasor domain and draw this circuit. (1 point)

c) Calculate $\boldsymbol{V}_{oc}$ phasor-domain correspondent to the V_{oc} voltage between the nodes a and b (without any load connected). (1 points)

d) Apply a test current source $\boldsymbol{I}_{test}$ between the nodes a and b to find the Thévenin impedance $\boldsymbol{Z}_{Th}$. (2 points)

e) Determine the value of the impedance $\boldsymbol{Z}_{L}$ that will absorb the maximum average power and calculate the value of the maximum power. (1 point)

f) Connect the load shown in the circuit above to the nodes a and b and calculate the average power absorbed by the 6 Ω resistor. (2 points)

Indicate the measure units for all calculated quantities. Show all steps in your reasoning and never give numerical results without justification.