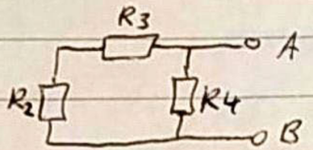
Problem 1A

a) The equivalent resistance will be smaller than R_4 because R_4 is in parallel with the rest and parallel resistance is always lower / $\frac{1}{R} = \frac{1}{R_4} + \frac{1}{\dots} + \dots$ is larger than $\frac{1}{R_4}$, so R is smaller.

b) Replace the sources by their internal resistance and we have:

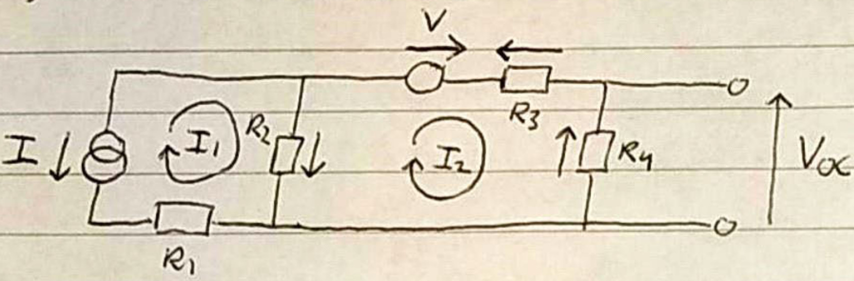


Note that R_1 falls out because the current source has infinite resistance.

Then $R_{Th} = R_4 // (R_2 + R_3) = \dfrac{R_4(R_2+R_3)}{R_2+R_3+R_4}$

I A

c) Draw the arrow conventions and the mesh currents.



Mesh 1: $I_1 = -I$ (current source)

Mesh 2: $V - V_{R3} - V_{R4} - V_{R2} = 0$ (KVL)

$\Rightarrow -V + I_2 R_3 + I_2 R_4 + (I_2 - I_1) R_2 = 0$

$\Rightarrow -V + I_2 (R_2 + R_3 + R_4) + I R_2 = 0$ (using mesh I eq.)

$\Rightarrow I_2 = (V - I R_2) \frac{1}{R_2 + R_3 + R_4}$

We need $V_{Th} = V_{OC} = V_{R4} = I_2 R_4 = (V - I R_2) \frac{R_4}{R_2 + R_3 + R_4}$

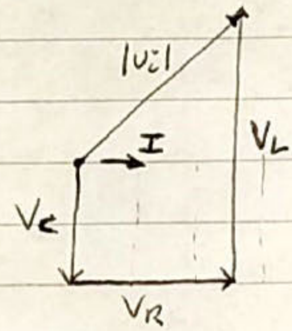
Problem 2A

a) The magnitudes of the voltages are

$V_L = IX_L$, $V_C = IX_C$, $V_R = IR$

So $V_C = 4V$, $V_L = 9V$, $V_R = 5V$.

And the phasor diagram:



b)

- As the input resistance of the voltmeter is comparable in magnitude to the magnitude of the impedance of the circuit, it will significantly load the circuit. The voltage measured will therefore be too low.

- Not entirely complete response: the voltmeter has an impedance comparable in size to the inductor.

c) The circuit acts as a high-pass filter:
- the capacitor
  - cannot change voltage instantaneously, so these are passed to A
  - or - has a low reactance for high frequencies
  - or - acts as a high-pass filter and DC blocker

2 [A] c) (continued)

and • the inductor – cannot change current instantaneously, so that high frequency voltages appear in v_o and low frequencies do not

or – has a high reactance to high frequencies, so that these appear in v_o

or – acts as a low-pass filter: dc signals are attenuated in v_o and high-f rather appear in v_o.

d) For high f, or ω, $\frac{v_o}{v_i} \rightarrow \frac{1}{C\omega^2}$

so the voltage gain per frequency decade is

$$20 \log_{10}\left(\frac{\frac{1}{C(10)^2}}{\frac{1}{C(1)^2}}\right) = 20 \log_{10} 10^{-2} = -40 \text{ dB / decade}.$$

This is negative as the gain falls with high frequency.

e) Note that the question involves two constants C, which can lead to confusion. Redefine the constant C as C_1.

The transfer function is a voltage divider here:

$$v_o = v_i \frac{Z_L}{Z_R + Z_C + Z_L} \Rightarrow \frac{v_o}{v_i} = \frac{j\omega L}{R + \frac{1}{j\omega C} + j\omega L}$$

$$\text{So } \frac{v_o}{v_i} = \frac{1}{\frac{R}{L}\frac{1}{j\omega} - \frac{1}{LC}\frac{1}{\omega^2} + 1}$$

$$= \frac{1}{1 + -j\frac{1}{\omega}\frac{R}{L} - \frac{1}{\omega^2}\frac{1}{LC}}$$

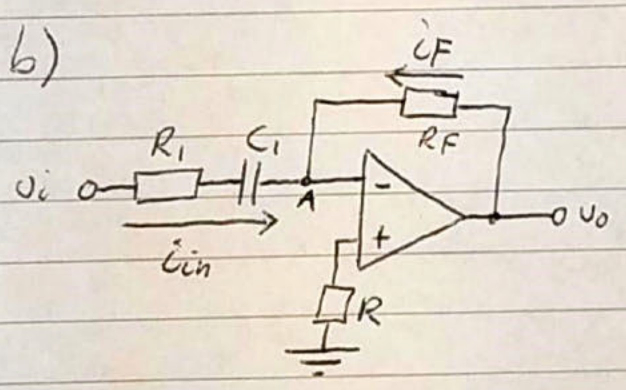
so $E = -\frac{R}{L}$ and $F = -\frac{1}{LC}$ and $C_1 = D = 0$.

Note that this also shows the high-pass characteristic.

Problem 3A

a) There is no current going into an ideal opamp, so there is no voltage drop across R. Therefore, v_+ is at ground potential.

b)



Using KCL (method 1):

$v_+ = 0$ (ground), $v_+ = v_-$, so $v_- = 0$ (virtual ground)

Then, impose KCL in node A: $i_{in} + i_F = 0$

$$\Rightarrow \frac{v_i}{R_1 + Z_{C1}} + \frac{v_o}{R_F} = 0 \Rightarrow \frac{v_o}{v_i} = -\frac{R_F}{R_1 + Z_{C1}} = -\frac{R_F}{R_1 + 1/j\omega C_1}$$

3A b) (continued)

Or using superposition (method 2):

$$v_- = \frac{R_F}{R_1 + Z_{C1} + R_F} v_i + \frac{R_1 + Z_{C1}}{R_1 + Z_{C1} + R_F} v_o \quad (1) \text{ (voltage dividers)}$$

$v_+ = 0$, $v_- = v_+$, so $v_- = 0$ (virtual earth)

$$\Rightarrow (1) = 0 \Rightarrow \quad \frac{v_o}{v_i} = -\frac{R_F}{R_1 + Z_{C1} + R_F} \frac{R_1 + Z_{C1} + R_F}{R_1 + Z_{C1}}$$

$$= -\frac{R_F}{R_1 + Z_{C1}} = -\frac{R_F}{R_1 + 1/j\omega C_1}$$

c) For a non-ideal opamp, there is a small amount of input bias current and R can be used to mitigate the effects of this: the input bias current will lead to a small bias voltage on v_-, and this can be (partially) corrected by creating an equal bias voltage on v_+ through the resistor R.

Problem 4.1

A a) E

AB \ CD	00	01	11	10
00	0	1	0	0
01	0	0	X	0
11	X	1	X	1
10	1	0	X	X

$$E = \bar{A}\bar{B}\bar{C}D + AB + A\bar{D}$$

B a) H

AB \ CD	00	01	11	10
00	X	1	X	X
01	X	X	1	X
11	0	0	X	0
10	1	0	1	X

$$H = \bar{A} + CD + \bar{B}\bar{D}$$

C a) V

AB \ CD	00	01	11	10
00	X	1	0	X
01	1	X	1	0
11	0	X	0	X
10	1	0	0	X

$$V = \bar{A}\bar{C} + \bar{B}\bar{D} + \bar{A}BD$$

4.2 A) 0, 4, 2, 1, 5, 3

⇒ Need 3 stages.

Decimal	Q_3	Q_2	Q_1	Q_3	Q_2	Q_1	J_3	K_3	J_2	K_2	J_1	K_1
0	0	0	0	1	0	0	1	X	0	X	0	X
4	1	0	0	0	1	0	X	1	1	X	0	X
2	0	1	0	0	0	1	0	X	X	1	1	X
1	0	0	1	1	0	1	1	X	0	X	X	0
5	1	0	1	0	1	1	X	1	1	X	X	0
3	0	1	1	0	0	0	0	X	X	1	X	1
6	1	1	0	X	X	X	X	X	X	X	X	X
7	1	1	1	X	X	X	X	X	X	X	X	X

Kmaps

J_3

Q_3 \ Q_2Q_1	00	01	11	10
0	1	1	0	0
1	X	X	X	X

K_3

Q_3 \ Q_2Q_1	00	01	11	10
0	X	X	X	X
1	1	1	X	X

J_2

Q_3 \ Q_2Q_1	00	01	11	10
0	0	0	X	X
1	1	1	X	X

K_2

Q_3 \ Q_2Q_1	00	01	11	10
0	X	X	1	1
1	X	X	X	X

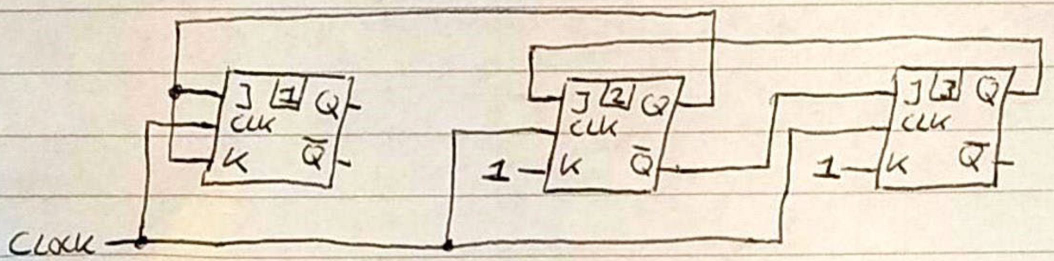
J_1

Q_3 \ Q_2Q_1	00	01	11	10
0	0	X	X	1
1	0	X	X	X

K_1

Q_3 \ Q_2Q_1	00	01	11	10
0	X	0	1	X
1	X	0	X	X

4.2 A | 0, 4, 2, 1, 5, 3



$J_3 = \overline{Q}_2$

$K_3 = 1$

$J_2 = Q_3$

$K_2 = 1$

$J_1 = Q_2$

$K_1 = Q_2$

Grading Rubric Electronics and Signal Processing 2019-2020 Exam April 7

Important: for any and all points given the line of reasoning should be there. Just the final answer does not yield any points.

Problem 1 2.5 point	Novice	Intermediate	Competent	Master
a)	**0 point** incorrect answer	-	-	**0.5 point** correct, complete explanation mentioning the series or parallel nature of the resistor involved with respect to the rest
b)	**0 point** more than 2 mistakes from "competent" level **or**, no resulting circuit drawn or explanation in words given (even if correct final answer)	**0.25 point** 2 mistakes from "competent" level **or**, multiple mistakes within one such level	**0.5 point** mistake in internal resistances **or**, mistake in parallel/series combination leading to final answer **or**, final answer with parallel operator "//"	**0.75 point** sources correctly replaced by internal resistance provides the resulting circuit, or explains this in words correct derivation of parallel/series combination leading to final answer final answer does not show parallel operator "//"
c) Circuit & definitions	**0 point** more than 1 mistake from "intermediate" level	**0.25 point** directions of loop currents missing **or**, direction of voltage arrow convention missing **or**, V_Th incorrectly defined	-	**0.5 point** defines all loop current directions defines all relevant voltage arrow conventions used defines V_Th = V_OC in correct way
c) Loop equations & solving	**0 point** no answer **or**, mistakes in every "master" level point	**0.25 point** multiple mistakes from "master" level **or**, showing understanding of KCL and mesh, but missing complete answer	**0.5 point** correct signs of voltages going through loop, or 1 mistake **or**, correct loop currents (or subtractions thereof) used, or 1 mistake	**0.75 point** correctly sets loop current to I of current source (if present) correct signs of voltages going through loop correct loop currents (or subtractions thereof) used for these voltages combines loop equations to find loop current expression

Problem 2 2.5 point	Novice	Intermediate	Competent	Master
a)	**0 point** does not know how to calculate voltage magnitudes and how a phasor diagram is constructed	**0.25 point** mistake in phasor directions or magnitude **or**, phasor combination not drawn correctly	-	**0.5 point** correct calculation of voltage magnitudes correct drawing of phasors: direction and (approximate) length correct connection of phasors, including input voltage
b)	**0 point** does not correctly infer accuracy of the masurement. Does not compare circuit resistance to resistance of device	**0.25 point** only compares voltmeter impedance magnitude to that of the element it is connected across	-	**0.5 point** correctly compares voltmeter impedance magnitude with that of circuit and explains that this results in voltage drop, or that this results in significant loading of the circuit and therefore voltage drop
c)	**0 point** does not explain even partial functioning of filter correctly, from either C or L	**0.25 point** can only explain capacitor or inductor contribution to filter **or**, 1 mistake in the way capacitor or inductor contributes	-	**0.5 point** correct statement of type of filter explains contributions from both capacitor and inductor to this result
d)	**0 point** more than 1 mistake from "intermediate" level	**0.25 point** mistake in limit **or**, mistake in conversion to decibels **or**, sign error	-	**0.5 point** correctly takes the limit to high or low frequency, finding a quadratic dependence correctly converts this quadratic dependency to decibels/decade correct sign of answer
e)	**0 point** does not arrive at transfer function through voltage divider	**0.25 point** 1 or 2 mistakes in transfer function or constants D, E, F, G	-	**0.5 point** uses voltage divider to write transfer function correctly writes transfer function in terms of omega provides resulting constants D, E, F, G

Problem 3 2.5 point	Novice	Intermediate	Competent	Master
a)	**0 point** incorrect answer	**0.25 point** mentions that ideal opamp has no input bias current, or that opamp has infinite input resistance, but does not adequately explain mechanism		**0.5 point** correctly recalls that an ideal opamp has no input current, meaning that no voltage drops across R
b)	**0 point** more than 2 mistakes of "master" level	**0.5 point** 2 mistakes of "master" level	**1 point** uses KCL, but no clear definition of current directions **or**, mistake in rewriting **or**, final answer contains parallel operator "//"	**1.5 point** { uses KCL, defining the direction of the currents **or**, uses superposition theorem } invokes v+=v-, ground potential arrives at vo/vi equation through rewriting no parallel operator "//" used in final answer
c)	**0 point** incorrect answer	**0.25 point** mentions that R can be used for correction of input bias current, but does not adequately explain mechanism		**0.5 point** states that non-ideal opamp has input bias current explains that this leads to a non-ground potential at v- explains that R can be used to correct potential at v+ to reduce effect of the input bias current on the output

Problem 4.1 1 point	Novice	Intermediate	Competent	Master
a)	**0 point** more than 2 mistakes in rectangles **or** simplified expressions given correctly, but no supporting evidence in K-map	**0.3 point** 2 mistakes in rectangles **or** all do-not-care conditions covered by rectangles as well **or** additonal, superfluous rectangle drawn (covering the 1s)	**0.6 point** 1 mistake in rectangles leading to either one product term too large or an additional rectangle necessary	**1 point** correct, fully simplified sum-of-products expression supported by drawn rectangles
Problem 4.2 b) 1.5 point				
Excitation table	**0 point** entirely different counter from book **or** all mistakes from "competent" ->	**0.25 point** ordering of states is wrong **or** multiple mistakes from "competent" level ->	**0.5 point** minor "sloppy" mistakes present **or** not all states are present and correct **or** coherent mistakes in next states **or** coherent mistakes in J-K input conditions	**0.75 point** all states are present and correct (including unused states) next states are labelled and correct (including do not cares) J-K input conditions are correct (including do not cares)
Input Boolean expressions	**0 point** more than 2 mistakes **or** K-maps missing and Boolean expressions incorrect	**0.25 point** 1 or 2 mistakes in the simplified expressions (in the presence of K-maps)	-	**0.5 point** correct, simplified expressions (not necessarily using K-maps)
Diagram Drawing	**0 point** multiple mistakes from "intermediate" level ->	**0.1 point** Clock line not drawn **or** minor mistakes converting Booleans into drawing **or** no clear distinction between crossing lines and connecting lines	-	**0.25 point** Clock line present correct drawing of Boolean expressions clear distinction between crossing lines and connecting lines