Examination Cover Sheet

COURSE: ELEC	NUMBER: 273	SECTION(S): D, R	
EXAMINATION: __X_ **FINAL** ___ ALTERNATE ___ DEFERRED __ MID TERM **VERSION**: __________	**DATE**: December 14, 2018	TIME: 2:00-5:00 Exam Length: 3 hours	PAGES: 4 Including cover
INSTRUCTOR(S): Dr. C. W. Trueman, Dr. F. Fayyaz		DIVISION:	
MATERIALS ALLOWED: __X__ Booklets ____ IBM (Scantron) ___ Blue ___ Green ____ Printed Translation Dictionary Other_________ **__X__** Calculator _X__ENCS Approved ____ Other ___________________________________		INSTRUCTIONS: **_X__** Return all ___ Answer on Exam ___ Open book ___ Crib sheet Details_______________	

Please print your name, I.D. number and section in the appropriate spaces below.

STUDENT NAME: ____

I.D. NO. _________________________ **SECTION**: __________________________________

SPECIAL INSTRUCTIONS:

Closed book exam. No books or notes are permitted.

Do not tear pages out of the exam booklet.

Cell phones or other electronic devices are forbidden in final examinations.

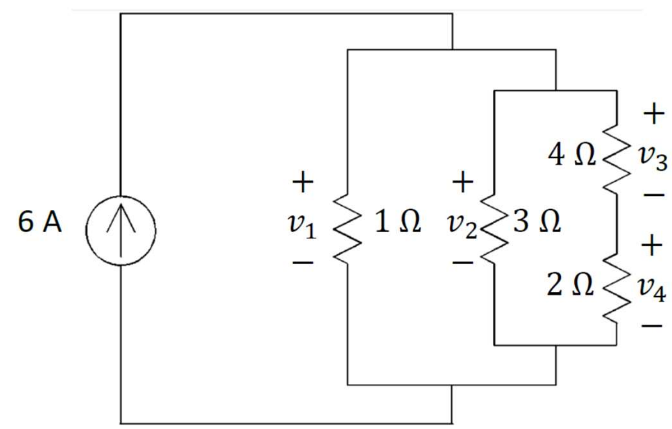


Figure 1a

1a) Find the voltages v_1, v_2, v_3, and v_4 in the circuit of Figure 1a. (4 marks)

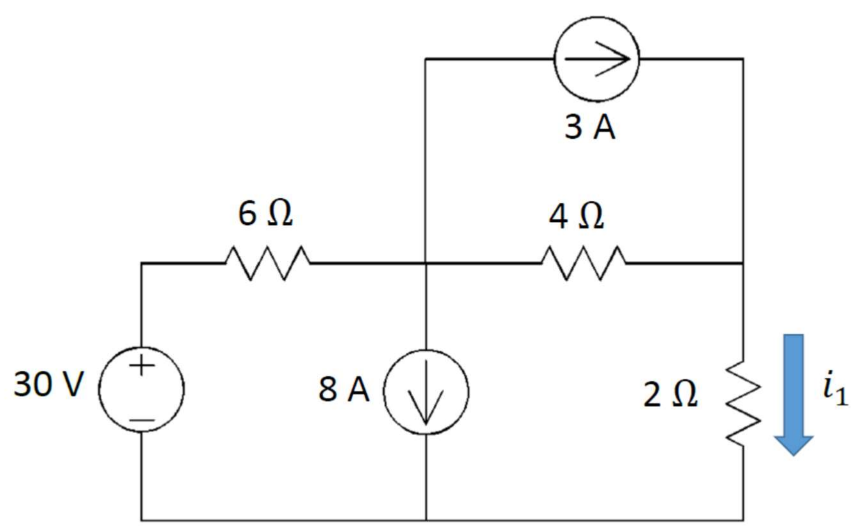


Figure 1b

1b) For the circuit of Figure 1b, calculate current through 2Ω resistor using superposition theorem. (6 marks)

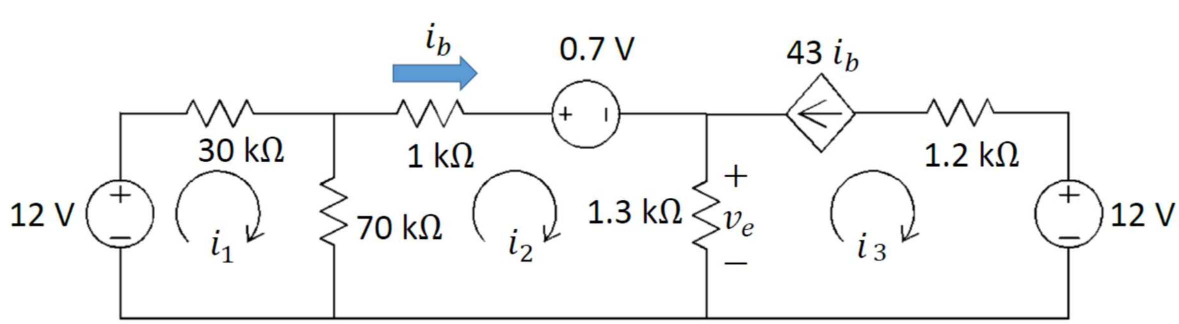


Figure 2

2a) For the circuit of Figure 2, write a set of mesh equations using mesh currents $i_1,\ i_2$ and i_3. (6 marks)

2b) Solve the mesh equations to find i_b. (2 marks)

2c) Find the value of v_e. (2 marks)

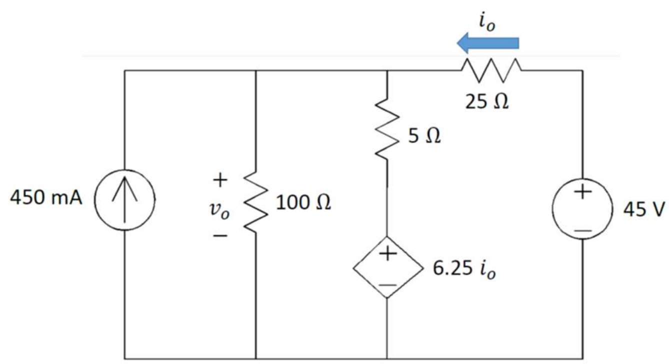


Figure 3

3a) For the circuit of Figure 3, find the value of v_o using nodal analysis. (6 marks)

3b) Find the value of i_o. (4 marks)

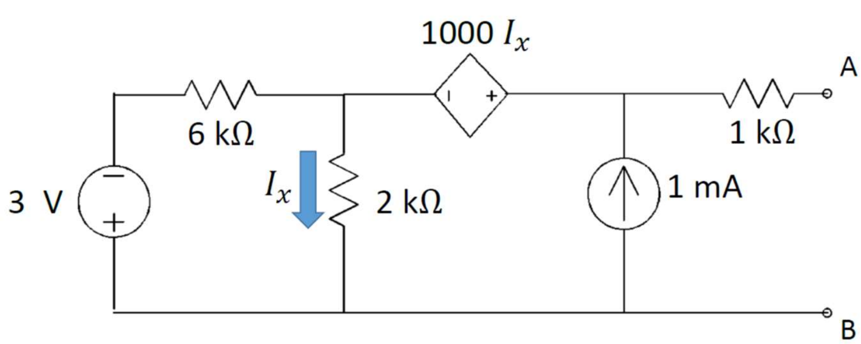


Figure 4

For the circuit of Figure 4:

4a) Find the open circuit voltage across terminals AB. (3 marks)

4b) If terminals AB are connected together by a short circuit, find the current flowing in the short circuit. (3 marks)

4c) Find the Thevenin Equivalent Circuit at terminals AB. (2 marks)

4d) If a load resistor of 2 kΩ is connected across terminals AB, what is the voltage across the load resistor? (2 marks)

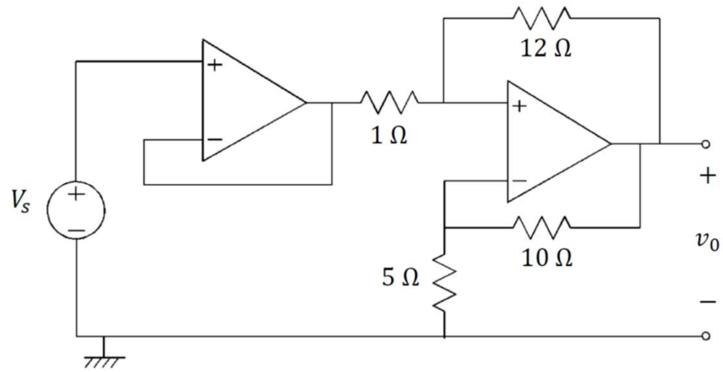


Figure 5

5. Find the output voltage v_o of the operational amplifier circuit of Figure 5, with $V_s = 5$ volts. Assume that the op-amps are ideal with infinite gain. (10 marks)

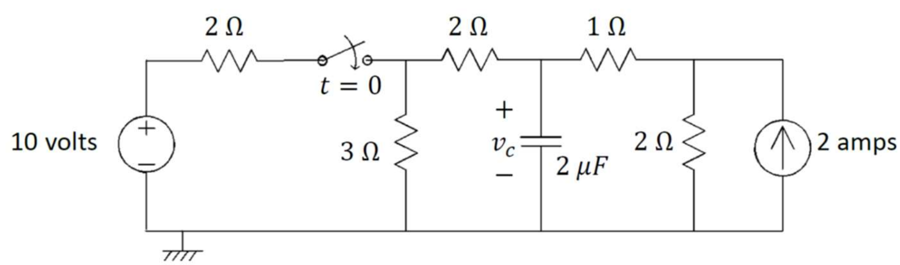


Figure 6

In the circuit of Figure 6, the switch has been open for a long time. At $t = 0$ the switch closes and remains closed for $t > 0$.

6a) Find the initial value of the capacitor voltage v_c just after the switch closes. (2 marks)

6b) Find the final value of the capacitor voltage v_c as $t \to \infty$. (2 marks)

6c) Find the time constant τ. (2 marks)

6d) Write the equation giving the capacitor voltage $v_c(t)$ as a function of time for $t > 0$. (2 marks)

6e) What is the value of the capacitor voltage at $t = 2.2\tau$? (2 marks)

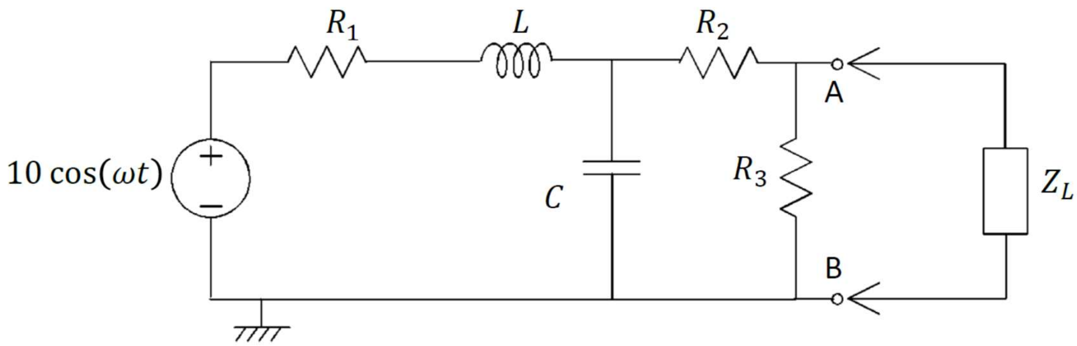


Figure 7

In the circuit of Figure 7, the operating frequency is 60 Hz. The component values are $R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$, $R_3 = 2\ \Omega$, $L = 2.653$ milliHenries, and $C = 1{,}326$ microFarads.

7a) With the load impedance Z_L removed, find the Thevenin equivalent circuit at terminals AB. (6 marks)

7b) With a load impedance Z_L connected to terminals AB, what value of Z_L dissipates the maximum amount of average power? (2 marks)

7c) With Z_L chosen as in question 7b, how much power does Z_L dissipate? (2 marks)

Solution to the ELEC 273 Final Exam 2018

December 18, 2018

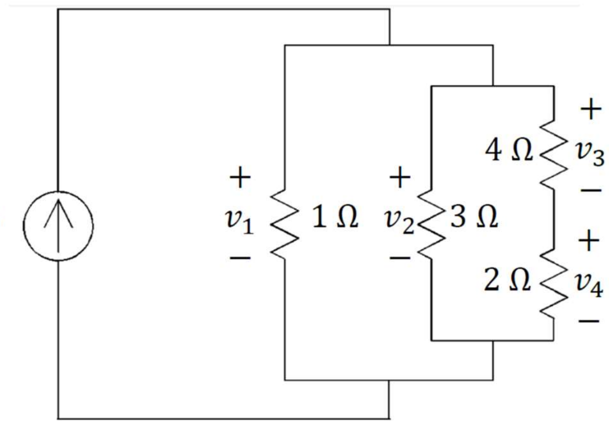
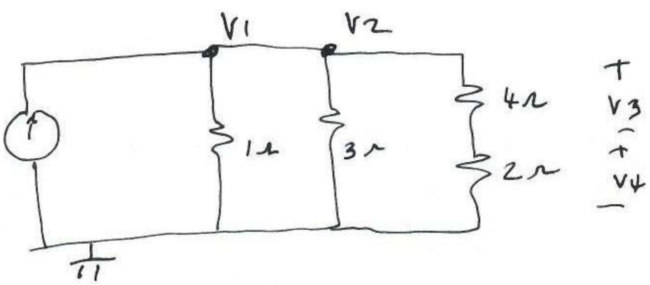


Figure 1a

1a) Find the voltages v_1, v_2, v_3, and v_4 in the circuit of Figure 1a. (4 marks)



$$R_{IN} = 1 \| 3 \| (4+2)$$

$$1 \| 3 = \frac{1 \times 3}{1+3} = \frac{3}{4}$$

$$\frac{3}{4} \| 6 = \frac{\frac{3}{4} \times 6}{\frac{3}{4} + 6} = \frac{18}{27} = \frac{6}{9} = \frac{2}{3}$$

$$V_1 = V_2 = 6\,A \times \frac{2}{3}\,\Omega = \frac{12}{3}\,V = 4\,V.$$

$$V_3 = V_2 \times \frac{4}{6} = \frac{4 \times 4}{6} = \frac{16}{6} = \frac{8}{3}\,V.$$

$$V_4 = V_2 \times \frac{2}{6} = \frac{4 \times 2}{6} = \frac{8}{6} = \frac{4}{3}\,V.$$

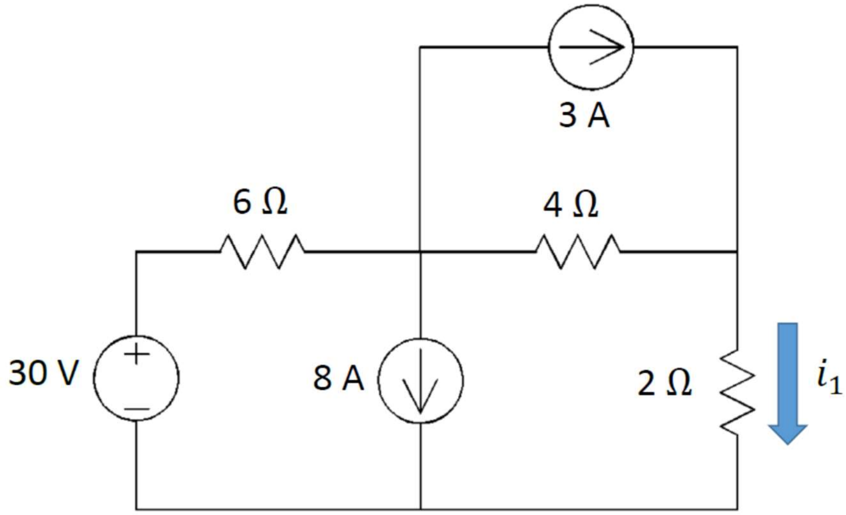
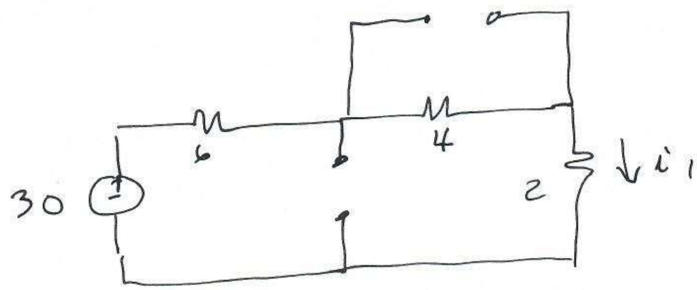


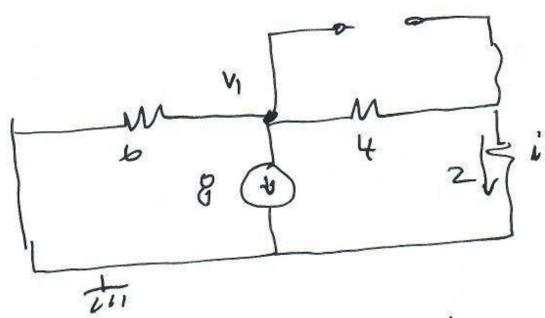
Figure 1b

1b) For the circuit of Figure 1b, calculate current through 2Ω resistor using superposition theorem. (6 marks)

1b)



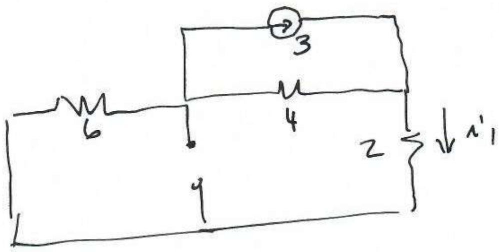
$$i_1 = \frac{30}{2+4+6} = \frac{30}{12} = \frac{5}{2} \text{ A.}$$

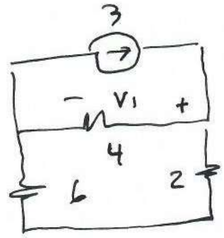


$$6 \,||\, (2+4) = 6 \,||\, 6 = \frac{36}{12} = 3\ \Omega$$

$$v_1 = -3 \times 8 = -24 \text{ V.}$$

$$i_1 = \frac{v_1}{6} = \frac{-24}{6} = -4 \text{ A.}$$





$4 \| (2+6) = 4 \| 8 = \frac{32}{12} = \frac{8}{3}\ \Omega$

$v_1 = 3 \times \frac{8}{3} = 8$ volts

$i_1 = \frac{v_1}{8} = 1$ A.

Superposition

$i_1 = \frac{5}{2} - 4 + 1 = \frac{5-8+2}{2} = -\frac{1}{2}$

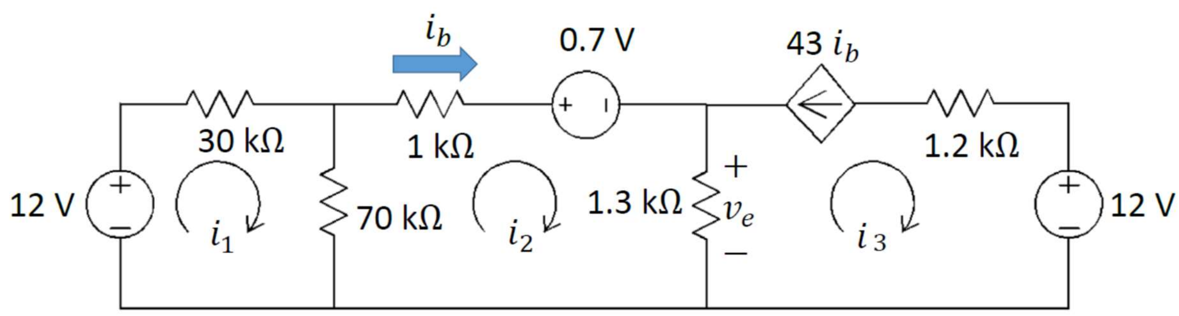


Figure 2

2a) For the circuit of Figure 2, write a set of mesh equations using mesh currents i_1, i_2 and i_3. (6 marks)

2b) Solve the mesh equations to find i_b. (2 marks)

2c) Find the value of v_e. (2 marks)

2a) (I) $12 - 30 i_1 - 70(i_1 - i_2) = 0$

(II) $70(i_1 - i_2) - i_2 - 0.7 - 1.3(i_2 - i_3) = 0$

Constraint $i_3 = -43 i_b$

where $i_b = i_2$

so $i_3 = -43 i_2$

2b) Solve

(I) $-30 i_1 - 70 i_1 + 70 i_2 = -12$

$+100 i_1 - 70 i_2 = 12$

(II) $70 i_1 - 70 i_2 - i_2 - 1.3 i_2 + 1.3 i_3 = 0.7$

$70 i_1 - 72.3 i_2 + 1.3 i_3 = 0.7$

Since $i_3 = -43 i_2$

$$70 i_1 - 72.3 i_2 + 1.3(-43) i_2 = -0.7$$

$$70 i_1 - 72.3 i_2 - 55.9 i_2 = -0.7$$

$$70 i_1 - 128.2 i_2 = -0.7$$

$$i_1 = \frac{-0.7 + 128.2 i_2}{70}$$

(I) $$100\left(\frac{-0.7 + 128.2 i_2}{70}\right) - 70 i_2 = 12$$

$$100(-0.7 + 128.2 i_2) - 4900 i_2 = 840$$

$$-70 + 12820 i_2 - 4900 i_2 = 840$$

$$7920 i_2 = 770$$

$$i_2 = 0.096977 \text{ mA}$$

$$i_n = i_2 = 0.096977 \text{ mA}$$

$$V_e = 1.3(i_2 - i_3)$$

$$= 1.3(i_2 - (-43 i_2))$$

$$= 1.3(44 i_2)$$

$$= 57.2 i_2$$

$$= 57.2 \times 0.096977$$

$$V_e = 5.547 \text{ volts}$$

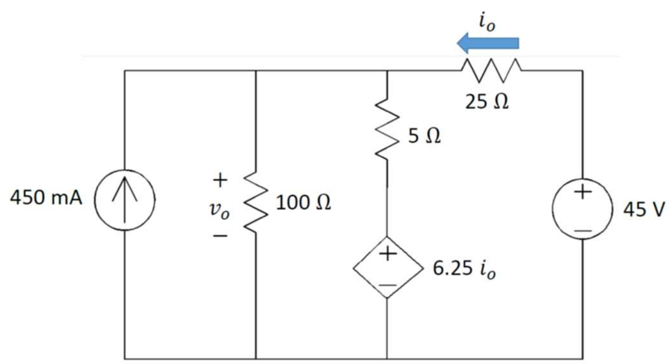
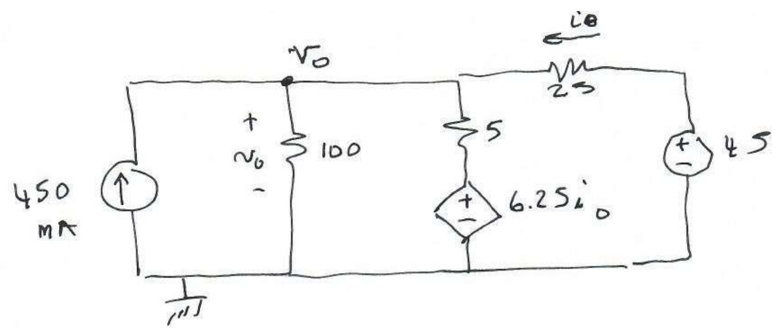


Figure 3

3a) For the circuit of Figure 3, find the value of v_o using nodal analysis. (6 marks)

3b) Find the value of i_o. (4 marks)

3)



(I) $$0.45 - \frac{V_o}{100} - \frac{V_o - 6.25 i_o}{5} - \frac{V_o - 45}{25} = 0$$

Constraint $$i_o = \frac{45 - V_o}{25}$$

(I) $$45 - V_o - 20 V_o + 125 i_o - 4 V_o + 180 = 0$$

$$-25 V_o + 125 i_o = -225$$

$$-25 V_o + 125\left(\frac{45 - V_o}{25}\right) = -225$$

$$-25 V_o + 225 - 5 V_o = -225$$

$$-30 V_o = -450$$

$$V_o = 15 \text{ volts}$$

$$i_o = \frac{45 - V_o}{25} = \frac{45 - 15}{25} = \frac{30}{25} = \frac{6}{5} \text{ A.}$$

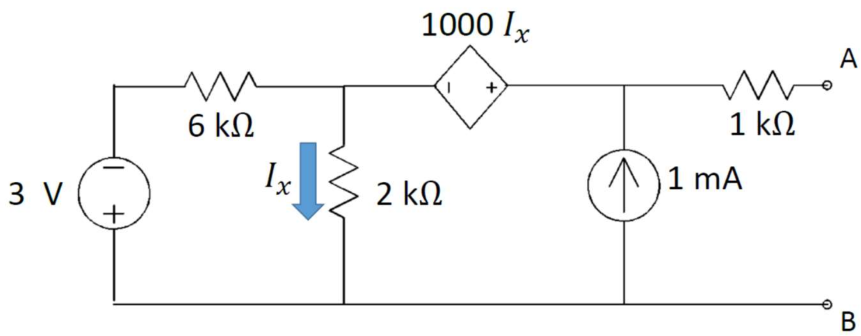


Figure 4

For the circuit of Figure 4:

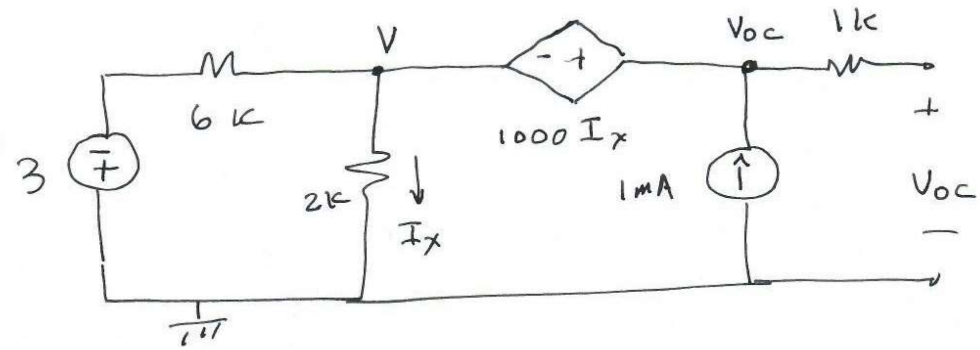
4a) Find the open circuit voltage across terminals AB. (3 marks)

4b) If terminals AB are connected together by a short circuit, find the current flowing in the short circuit. (3 marks)

4c) Find the Thevenin Equivalent Circuit at terminals AB. (2 marks)

4d) If a load resistor of 2 kΩ is connected across terminals AB, what is the voltage across the load resistor? (2 marks)

4)



Use volts, amps and ohms.

$$\frac{-3-V}{6000} - \frac{V}{2000} + 0.001 = 0$$

$\times 6000$ $\quad -3 - V - 3V + 6 = 0$

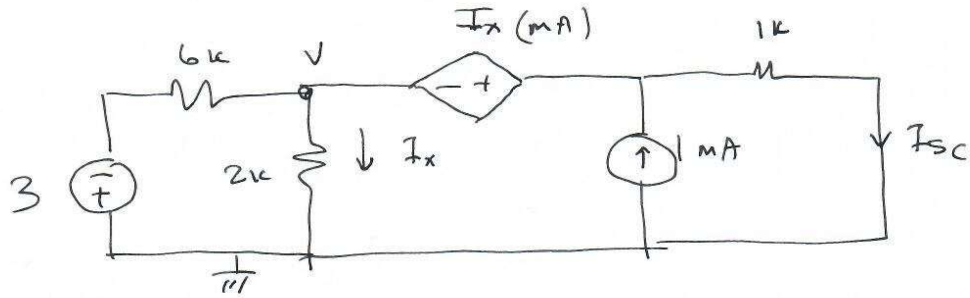
$$-4V = -3$$

$$V = \frac{3}{4} \text{ volts}$$

$$I_x = \frac{V}{2000} = 3.75 \times 10^{-4} \text{ Amps}$$

$$V_{oc} = V + 1000\, I_x$$

$$= \frac{3}{4} + 0.375 = 1.125 \text{ volts}$$



$$\frac{-3-V}{6000} - \frac{V}{2000} + 0.001 - \frac{V + 1000 I_x}{1000} = 0$$

× 6000

$$-3 - V - 3V + 6 - 6V - 6000\, I_x = 0$$

$$-10\, V - 6000\, I_x = -3$$

$$I_x = \frac{V}{2000}$$

$$-10\, V - 6000 \frac{V}{2000} = -3$$

$$-10\, V - 3V = -3$$

$$V = \frac{3}{13} \text{ volts}$$

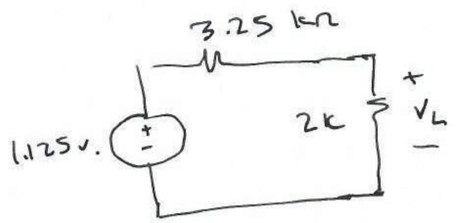
$$= 0.2308 \text{ volts}$$

$$I_{sc} = \frac{V + 1000\, I_x}{1000} = \frac{V + 1000 \frac{V}{2000}}{1000}$$

$$I_{sc} = \frac{\frac{3}{2} V}{1000} = \frac{\frac{3}{2} \times \frac{3}{13}}{1000} = 3.46 \times 10^{-4} \text{ Amps}$$

$$= 0.346 \text{ mA}$$

$$R_T = \frac{V_{oc}}{I_{sc}} = \frac{1.125}{0.346} = 3.25 \text{ k}\Omega$$



$$V_L = 2 \frac{1.125}{2 + 3.25} = 0.429 \text{ volts}$$

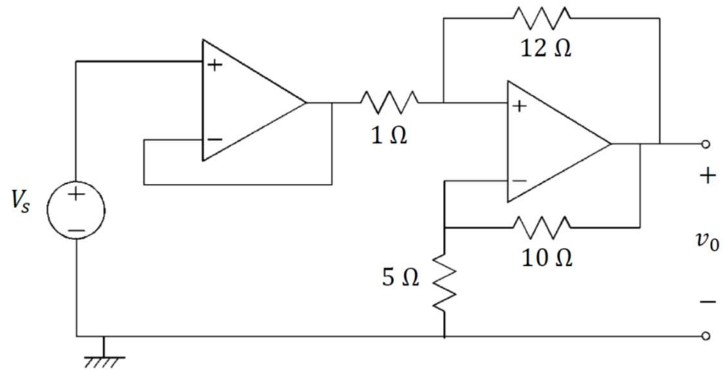
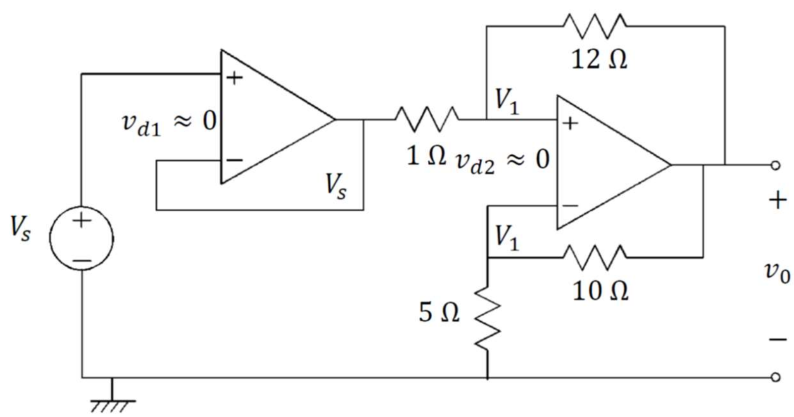


Figure 5

5. Find the output voltage v_o of the operational amplifier circuit of Figure 5, with $V_s = 5$ volts. Assume that the op-amps are ideal with infinite gain. (10 marks)

SOLUTION



The first op-amp is a "current blocker" and provides a high input resistance to source V_s, the output voltage is V_s.

$$\text{(I)} \quad \frac{V_s - V_1}{1} - \frac{V_1 - V_o}{12} = 0$$

$$\text{(II)} \quad -\frac{V_1}{5} - \frac{V_1 - V_o}{10} = 0$$

(I) $$12 V_S - 12 V_1 - V_1 + V_0 = 0$$

$$13 V_1 - V_0 = 12 V_S$$

(II) $$-2 V_1 - V_1 + V_0 = 0$$

$$-3 V_1 = -V_0$$

$$V_1 = \frac{V_0}{3}$$

(I) $$13 \left(\frac{V_0}{3} \right) - V_0 = 12 V_S$$

$$13 V_0 - 3 V_0 = 36 V_S$$

$$10 V_0 = 36 V_S$$

$$V_0 = 3.6 V_S$$

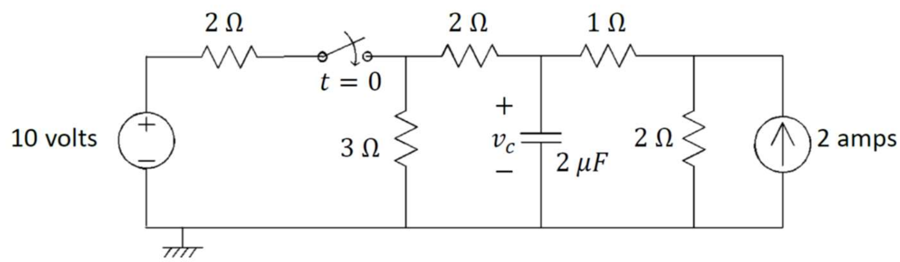


Figure 6

In the circuit of Figure 6, the switch has been open for a long time. At $t = 0$ the switch closes and remains closed for $t > 0$.

6a) Find the initial value of the capacitor voltage v_c just after the switch closes. (2 marks)

6b) Find the final value of the capacitor voltage v_c as $t \to \infty$. (2 marks)

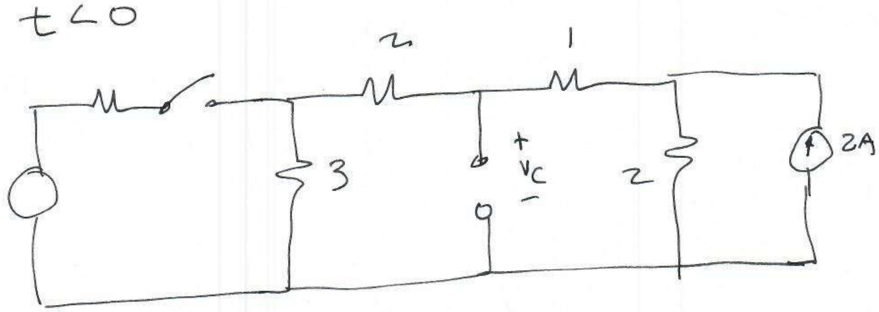
6c) Find the time constant τ. (2 marks)

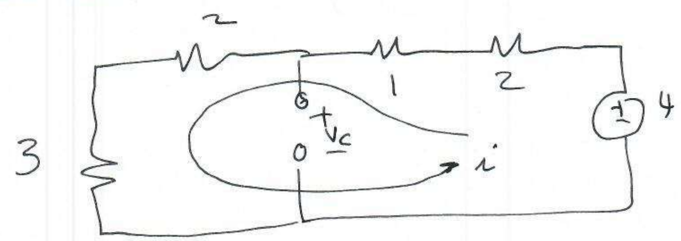
6d) Write the equation giving the capacitor voltage $v_c(t)$ as a function of time for $t > 0$. (2 marks)

6e) What is the value of the capacitor voltage at $t = 2.2\tau$? (2 marks)

6 $t < 0$

6.1)

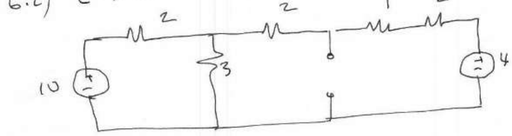


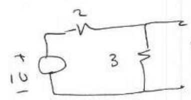


$i = \frac{4}{8} = \frac{1}{2}$ A.

$V_c = 5i = \frac{5}{2}$ V. so $V_c(0) = \frac{5}{2}$ volts

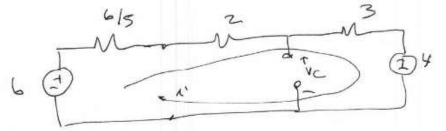
6.2) $t \to \infty$





$V_{oc} = 3 \times \frac{10}{5} = 6$ volts

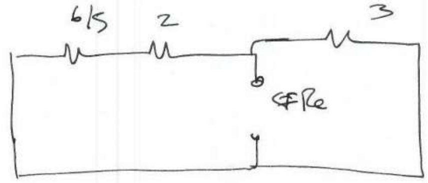
$R_e = 3 \| 2 = \frac{2 \times 3}{2+3} = \frac{6}{5}\ \Omega$



$i = \frac{6-4}{\frac{6}{5}+2+3} = \frac{2 \times 5}{6+25} = \frac{10}{31}$ A

$V_C = 3i - 4 = \frac{30}{31} + 4 = \frac{30+124}{31} = \frac{154}{31}$ V.

6.3)



$R_e = \left(2 + \frac{6}{5}\right) \| 3 = \frac{16}{5} \| 3$

$= \frac{\frac{16}{5} \times 3}{\frac{16}{5} + 3} = \frac{48}{31}\ \Omega$

$\tau = R_e C = \frac{48}{31} \times 2\mu F$

$= \frac{96}{31}\ \mu s = 3.097\ \mu s.$

6.4) $V_C(t) = V_{final} + (V_{initial} - V_{final})\ e^{-t/\tau}$

$= \frac{154}{31} - \left(\frac{5}{2} - \frac{154}{31}\right) e^{-t/3.097}$

$= 4.968 - 2.468\ e^{-t/3.097}$

6.5) $t = 2.2\tau$

$V_C(3.2\tau) = 4.968 - 2.468\ e^{-2.2}$

$=$ ~~4.867~~ 4.695 volts

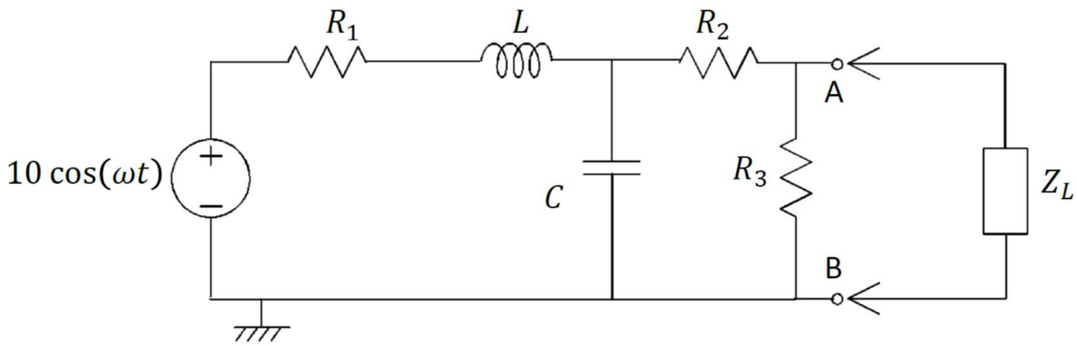


Figure 7

In the circuit of Figure 7, the operating frequency is 60 Hz. The component values are $R_1 = 1\,\Omega$, $R_2 = 2\,\Omega$, $R_3 = 2\,\Omega$, $L = 2.653$ milliHenries, and $C = 1{,}326$ microFarads.

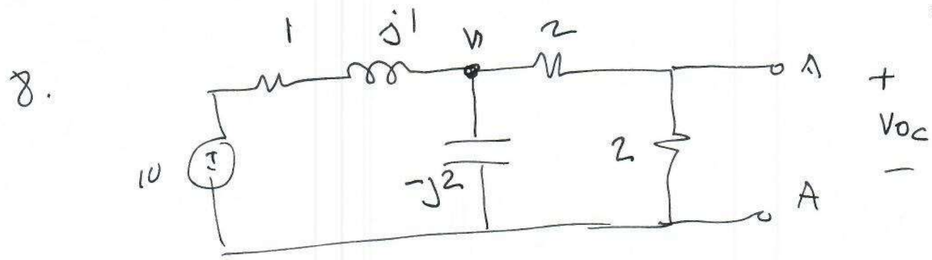
7a) With the load impedance Z_L removed, find the Thevenin equivalent circuit at terminals AB. (6 marks)

7b) With a load impedance Z_L connected to terminals AB, what value of Z_L dissipates the maximum amount of average power? (2 marks)

7c) With Z_L chosen as in question 7b, how much power does Z_L dissipate? (2 marks)

8-1

8.



$\omega = 2\pi f = 376.99$

$j\omega L = j\,376.99 \times 2.653 \times 10^{-3} = j1$

$$\frac{-j}{\omega C} = \frac{-j}{376.99 \times \sout{5,305}\ 1{,}326 \times 10^{-6}} = -j\,\sout{0.5}\ 2.$$

$$\frac{10 - V_1}{1+j} - \frac{V_1}{-j2} - \frac{V_1}{4} = 0$$

$$V_1\left(\frac{1}{1+j} + \frac{1}{-j2} + \frac{1}{4}\right) = \frac{10}{1+j}$$

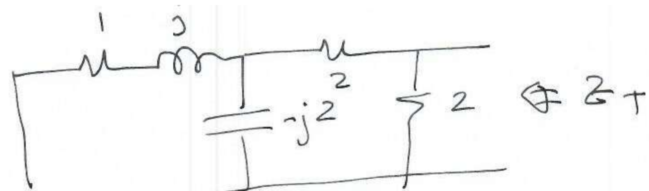
$$V_1\left(\frac{(-j2)4 + (1+j)4 + (1+j)(-j2)}{(1+j)(-j2)4}\right) = \frac{10}{1+j}$$

$$V_1 \frac{-8j + 4 + 4j - 2j + 2}{-8j} = 10$$

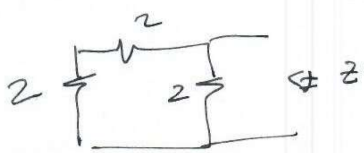
$$V_1 = \frac{10 \times (-8j)}{6 - 6j} = \frac{-80j}{6(1-j)}$$

$$V_{oc} = \frac{V_1}{2} = \frac{-40j}{6(1+j)} = 3.33 - 3.33j$$

$$= 4.71 \angle -45^\circ$$

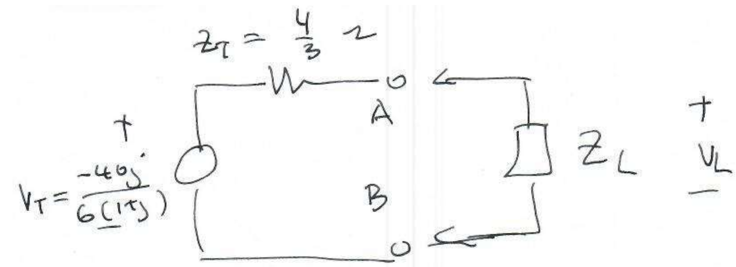


$$(1+j) \parallel (-j2) = \frac{(1+j) \times (-j2)}{1+j-j2} = \frac{2-j2}{1-j} = \frac{2(1-j)}{1-j} = 2$$



$$2 \parallel 4 = \frac{2 \times 4}{2+4} = \frac{8}{6} = \frac{4}{3}\,\Omega$$

P-2



$= 4.71 \angle -45^\circ$

Choose $Z_L = Z_T = \frac{4}{3}\,\Omega$

Then $I = \dfrac{V_T}{Z_T + Z_L} = \dfrac{4.71 \angle -45^\circ}{\frac{4}{3} + \frac{4}{3}}$

$$= \frac{3 \times 4.71 \angle -45}{8} = 1.768 \angle -45^\circ$$

$$V_L = Z_L I = \frac{4}{3} \times 1.768 \angle -45^\circ$$

$$= \overset{2.357}{\cancel{1.667}} \angle -45^\circ$$

$$P_{av} = \frac{1}{2} Re\,(V I^*)$$

$$= \frac{1}{2} Re\,\left(1.667 \angle -45^\circ \times \overset{2.357}{\cancel{1.768}} \angle +45^\circ\right)$$

$$= \frac{1.667 \times 2.357}{2}$$

$$= 1.965 \text{ watts}$$