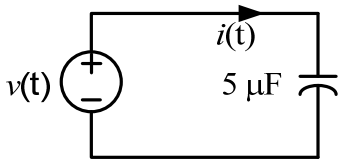
Problem 1: 20 points

a) For the circuit shown, write the expression for the current $i(t)$ for all t in the capacitor given that (15 points)

$$v(t)=\begin{cases}0, & t<0\\ 5t, & 0\le t\le 4\\ 20, & 4\le t\le 6\\ 50-5t, & 6\le t\le 10\\ 0, & t>10\end{cases}$$

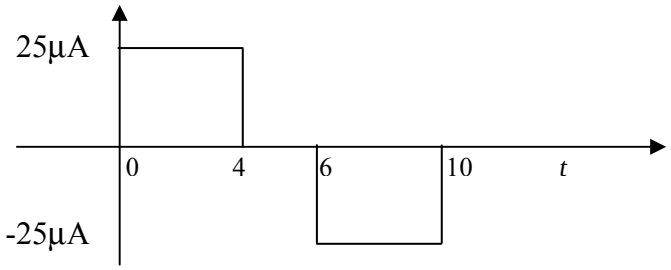


b) Sketch $i(t)$ for $0 \le t \le 15$ seconds (5 point)

a) Answer:

$$i(t)=5\times10^{-6}\,dv(t)/dt=\begin{cases}0, & t<0\\ 25\ \mu A, & 0\le t\le 4\\ 0, & 4\le t\le 6\\ -25\mu A, & 6\le t\le 10\\ 0, & t>10\end{cases}$$

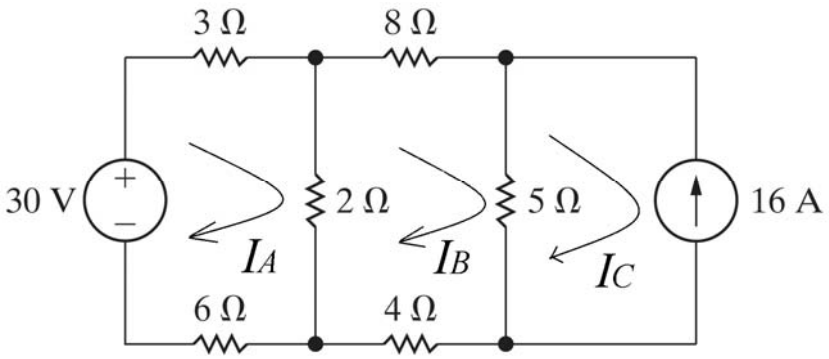
b) The sketch



Problem 2: 20 points

a) Write the mesh equations for the circuit shown and put them in the matrix form. (15 points)

b) Calculate the power absorbed by the 3Ω resistor. (5 points)



Answer:

a) The mesh equations are:

$$M1: 3IA + 2(IA - IB) + 6IA = 30$$

$$M2: 8IB + 5(IB - IC) + 4IB + 2(IB - IA) = 0$$

$$M3: IC = -16$$

Simplify

$$11IA - 2IB = 30$$

$$-2IA + 19IB - 5IC = 0 \quad or \quad -2IA + 19IB = -80$$

$$\begin{pmatrix} 11 & -2 \\ -2 & 19 \end{pmatrix}\begin{pmatrix} IA \\ IB \end{pmatrix} = \begin{pmatrix} 30 \\ -80 \end{pmatrix}$$

or

$$\begin{pmatrix} 11 & -2 & 0 \\ -2 & 19 & -5 \\ 0 & 0 & 1 \end{pmatrix}\begin{pmatrix} IA \\ IB \\ IC \end{pmatrix} = \begin{pmatrix} 30 \\ 0 \\ -16 \end{pmatrix}$$

Answer:

b) $IA = 2\text{A}$

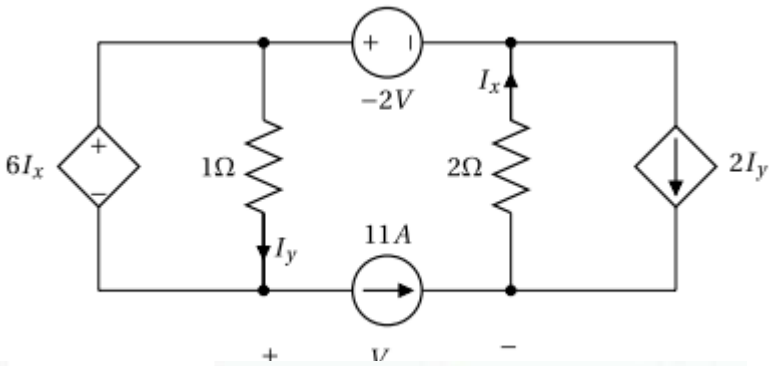
$IB = -4\text{ A}$

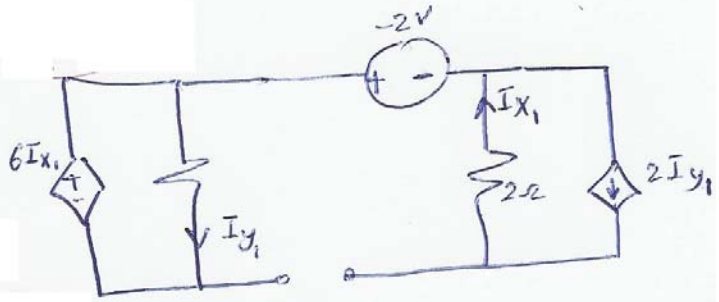
$P_{3\Omega} = 3IA^2 = 12W$

Problem 3: 20 points

Use the concept of superposition only to find the current I_x in the following circuit

Answer:
$I_x =$





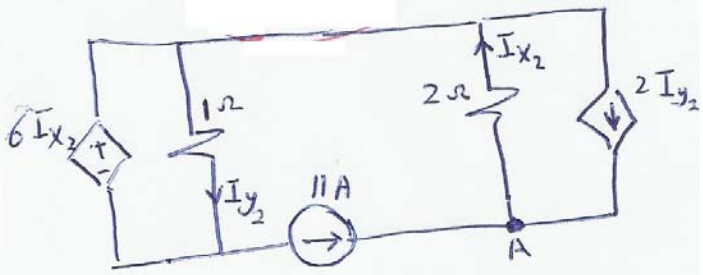
$I_{x_1} = 2I_{y_1}$ —①

$6I_{x_1} = I_{y_1} \cdot (1)$ —②

From ① and ② $I_{x_1} = I_{y_1} = 0$

ohm's law over the 1Ω resistor

$I_{y_2} = \frac{6I_{x_2}}{1}$ —③



KCL at node A

$11 + 2I_{y_2} = I_{x_2}$ —④

Solving ③ and ④

$I_{x_2} = -1$ A $\quad I_{y_2} = -6$ A

$I_x = I_{x_1} + I_{x_2} = -1$ A

$I_y = I_{y_1} + I_{y_2} = -6$ A

Problem 4: 20 points

For the Op-Amp circuit shown, answer the following

a) The circuit implements (performs as): Circle only one correct answer (2 points)

I. Inverting amplifier.
II. Difference amplifier.
III. Non inverting amplifier.
IV. Summing amplifier

b) Find the gain of the amplifier vo/v_g . (8 points)

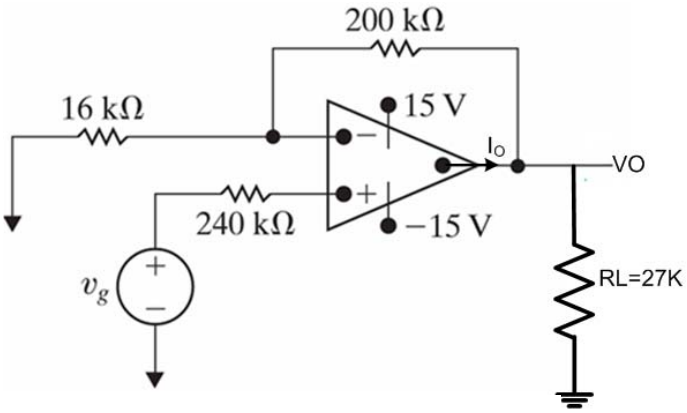
c) Find the range of the input vg for linear operation of the circuit, **show your steps** (5 points)

d) If v_g = 1V, find the output current of the amplifier, I_o . (5 points)

Answers
b) vo/v_g

c) $\leq v_g \leq$

d) I_o =



Solution to Problem 4

a) III non inverting amplifier

b) gain = $\frac{V_o}{V_g} = 1 + \frac{200}{16} = 13.5$

c) $V_{max} = \pm V_{sat} = \pm 15$

$\frac{V_o}{V_g} = 13.5$

$\frac{\pm 15}{V_g} = 13.5 \Rightarrow V_g = \pm \frac{15}{13.5} = \pm 1.11$

range of $V_g \Rightarrow -1.11 \leq V_g \leq 1.11$

d) $V_o = 13.5 * 1 = 13.5$

$I_o = I_L + I_f$

$= \frac{V_o}{R_L} + \frac{V_o - V_g}{200k}$

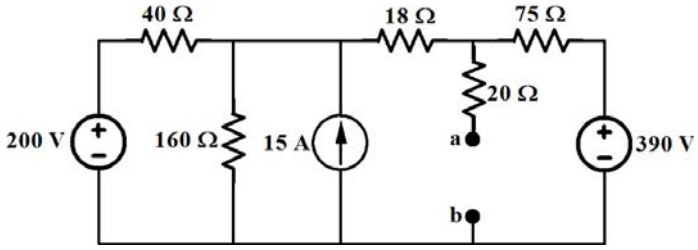
$I_o = \frac{13.5}{27k} + \frac{13.5 - 1}{200k} =$

$= 0.5mA + 0.06m \cong 0.56mA$

Problem 5: 20 points

a) Find the Thevenin's Equivalent between terminals a-b for the circuit shown below using **ONLY <u>source transformation method (from the beginning to the end)</u>**. (16 points)

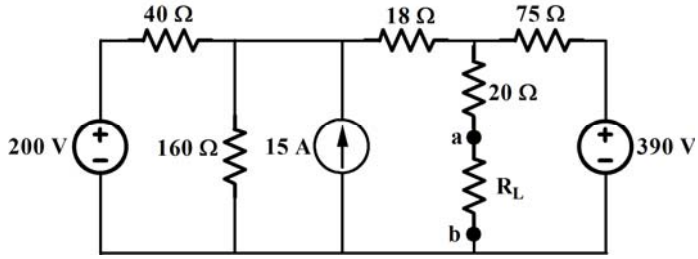
Answer: Thevenin's Equivalent is (Draw the circuit with its values):



b) If a load resistor R_L is connected between the terminals a-b as shown in the circuit below, then what is the value of R_L that will assure a maximum power transfer to it, and what is the maximum power it absorbs. (4 points)

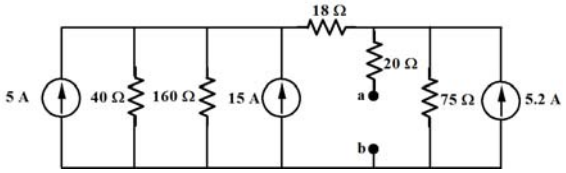
Answers:
R_L =

maximum power transfer to R_L =

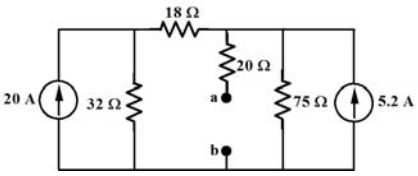


Part A: 8 simple stages of simplification

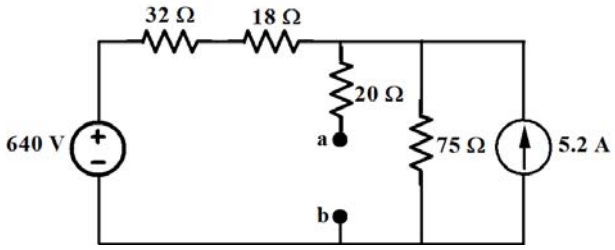
Stage 1: two independent source transformations from the left and the right.



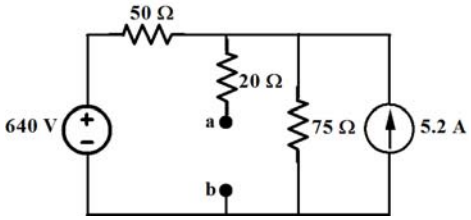
Stage 2 : 40//160 = 32 Ω & 5 + 15 = 20 A.



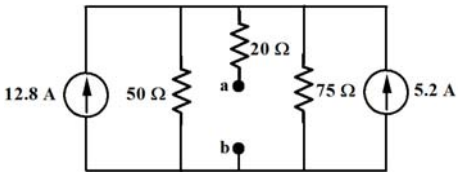
Stage 3 : source transformation from the left.



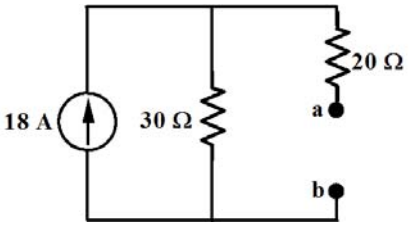
Stage 4 : 32 + 18 = 50 Ω.



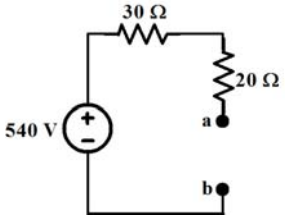
Stage 5 : source transformation from the left.



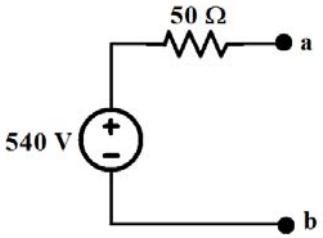
Stage 6 : 50//75 = 30 Ω **And** 12.8A//5.2A = 18A.



Stage 7 : source transformation from the left.



Stage 8 : 30 + 20 = 50 Ω.



Part B:

R_L that will achieve maximum power transfer is R_{th} = 50 Ω.

$P_{L,max} = (540)^2/(4 \times 50) = 1458$ W.