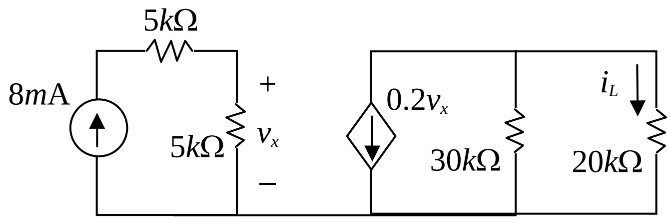
1. Find the load current i_L.



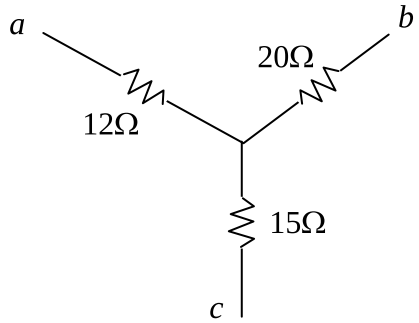
Solution:

The voltage $v_x = 8\times10^{-3}\times5\times10^{3} = 40$ V

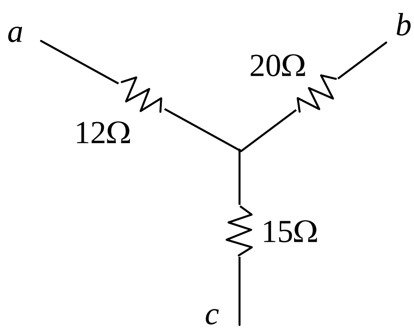
The load current

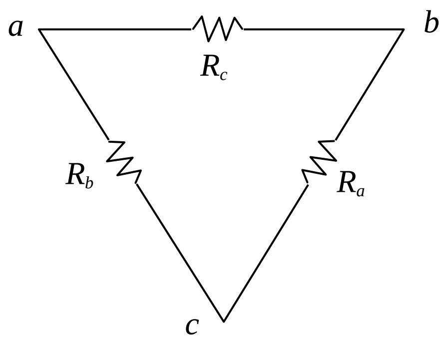
$$i_L = -0.2\,v_x\times\frac{30\times10^3}{30\times10^3+R_L} = -0.2\times40\times\frac{30\times10^3}{30\times10^3+20\times10^3} = -4.8\text{ A}$$

2. Transform the circuit from Y to Δ.



Solution:





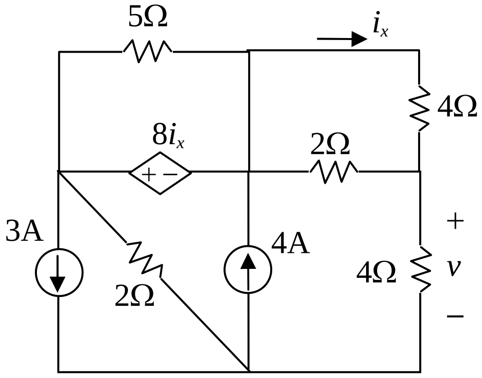
According to the transformation formula, we have

$$R_a = \frac{R_1R_2+R_2R_3+R_3R_1}{R_1} = \frac{12\times20+20\times15+15\times12}{12} = \frac{720}{12} = 60\ \ \Omega$$

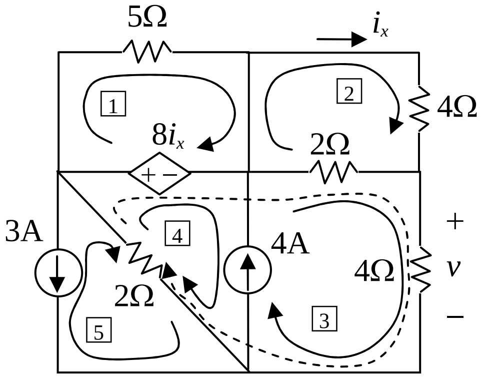
$$R_b = \frac{R_1R_2+R_2R_3+R_3R_1}{R_2} = \frac{12\times20+20\times15+15\times12}{20} = \frac{720}{20} = 36\ \ \Omega$$

$$R_c = \frac{R_1R_2+R_2R_3+R_3R_1}{R_3} = \frac{12\times20+20\times15+15\times12}{15} = \frac{720}{15} = 48\ \ \Omega$$

3. Based on the mesh-current method, write a set of mesh current equations and determine the voltage v in the circuit.



Solution:



First, number the mesh current i_1, i_2, i_3, i_4 and i_5.

There is a supermesh containing 3 and 4. The mesh current equations are

KVL1: $5i_1 - 8i_x = 5i_1 - 8i_2 = 0$ (1)

KVL2: $4i_2 + 2(i_2 - i_3) = 6i_2 - 2i_3 = 0$ (2)

Supermesh34: KCL: $i_3 - i_4 = 4$ (3)

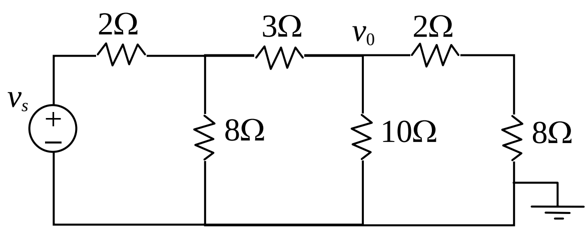
KVL: $2(i_4 - i_5) + 8i_2 + 2(i_3 - i_2) + 4i_3 = 6i_2 + 6i_3 + 2i_4 - 2i_5 = 0$ (4)

KCL5: $i_5 = -3$ (5)

From (3)+(4)/2+(5), we have $3i_2 + 4i_3 = 1$ (6)

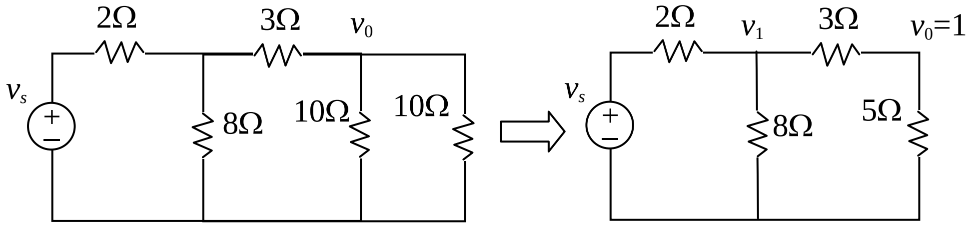
From (6)–(2)/2, we have $5i_3 = 1$, i.e., $i_3 = 0.2$. Therefore, v =0.8 V.

4. (A) For the circuit below, if v_0=1V, then find the source voltage v_s.
(B) Based on linearity, if v_s=10V, determine v_0.

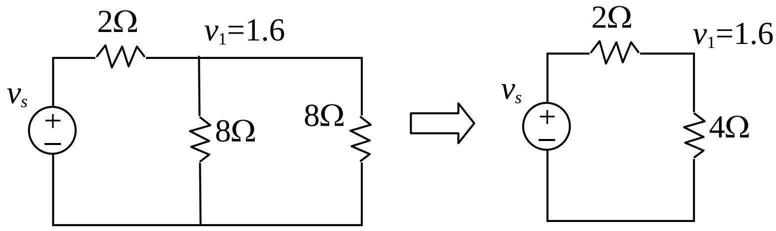


Solution:

(A) The circuit can be simplified as below:



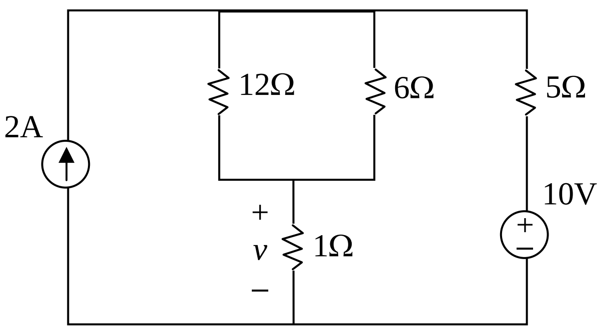
where $v_1 = \frac{8}{5} v_0 = 1.6\text{ V}$. The circuit can be further simplified as below:



where $v_s = \frac{2+4}{4} v_1 = 2.4\text{ V}$.

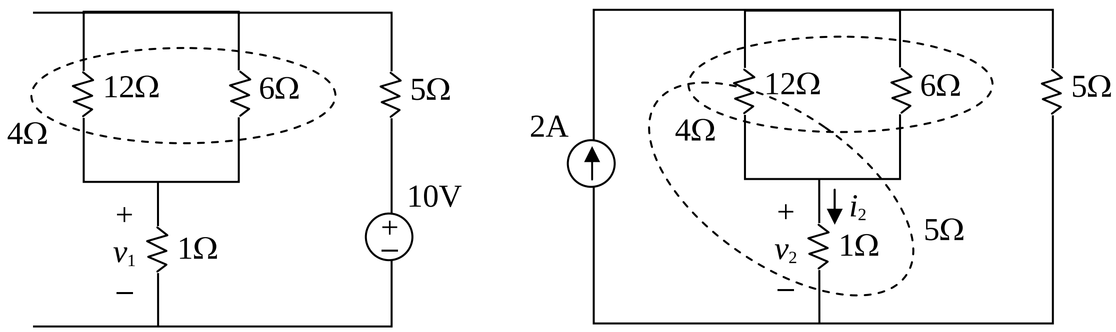
(B) From the linearity, if $v_s = 10\text{ V}$, increased by a ratio 10/2.4 to the value of v_s in (A), then the voltage v_0 will be also increased by the same ratio, i.e., $v_0 = 1 \times 10/2.4 = 25/6\text{ V}$.

5. Use superposition to find *v*.



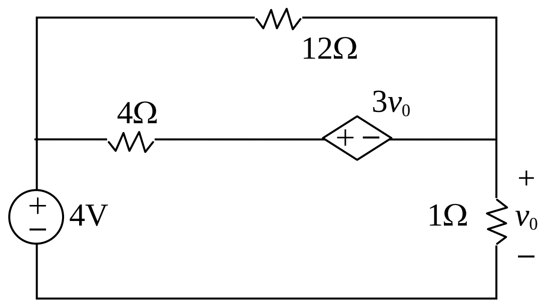
Solution:

The circuit can be solved by two cases. One takes away the current source and the other deletes the voltage source, shown as below:

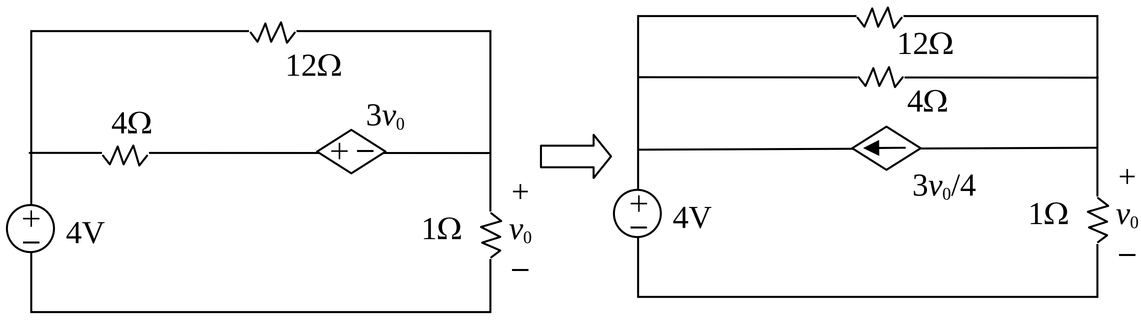


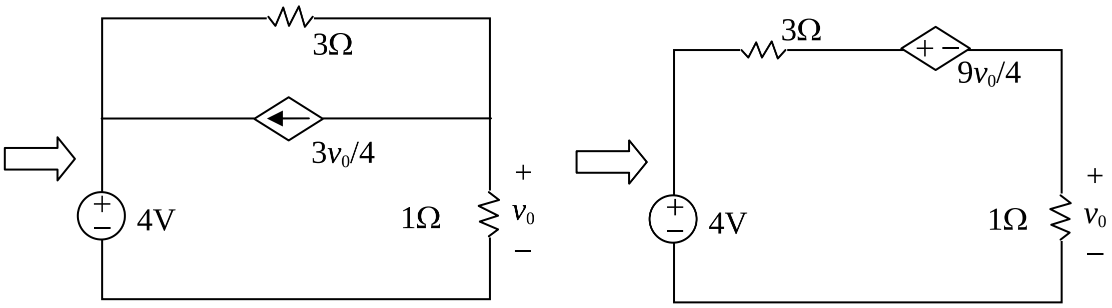
The parallel resistances are equivalent to $\left(\frac{1}{12}+\frac{1}{6}\right)^{-1}=\frac{12}{1+2}=4\,\Omega$. Then, the series resistances 4Ω and 1Ω are equivalent to 5Ω, as shown in the above circuits. Hence, from voltage division, we have $v_1=10\times\frac{1}{5+4+1}=1$. From current division, we have $i_2=2\times\frac{5}{5+5}=1$ and $v_2=1\times i_2=1$. Based on superposition, the voltage $v=v_1+v_2=1+1=2$ V. then choose the reference point and number the node voltages v_1, v_2 and v_3.

6. Use source transformation to find v_0.



Solution:

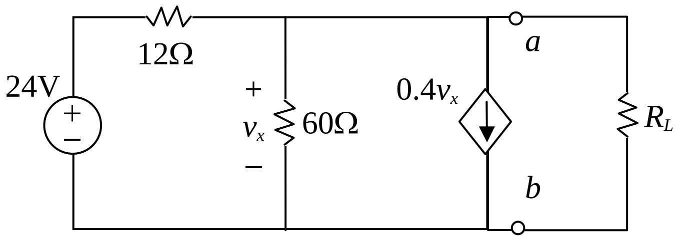




Since the voltage across 1Ω is v_0, we know the voltage across 3Ω is $3v_0$. Hence, we have

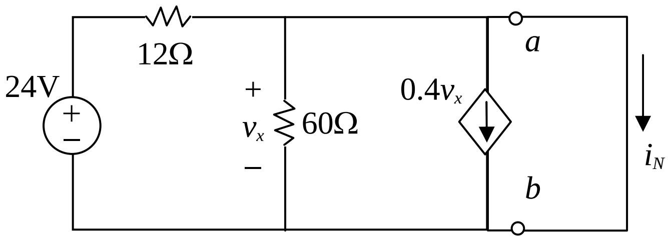
$$3v_0 + 9v_0/4 + v_0 = 4 \quad \Rightarrow \quad v_0 = 0.64\text{ V}$$

7. Find the Norton equivalent circuits with respect to terminals *a* and *b*. What is the maximum power transferred to the load R_L.



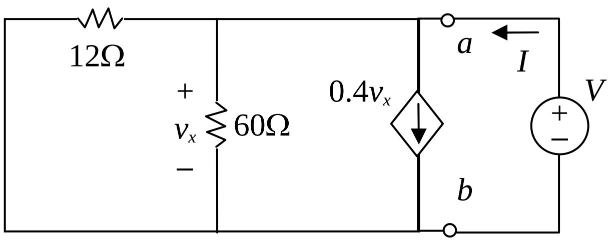
Solution:

First, find the Norton equivalent current i_N from the following circuit:



Clearly, v_x=0 and thus i_N is the same as the current through 12Ω, i.e., $i_N = \dfrac{24}{12} = 2\text{ A}$.

The Norton resistance R_N can be determined by adding an extra voltage V as below:



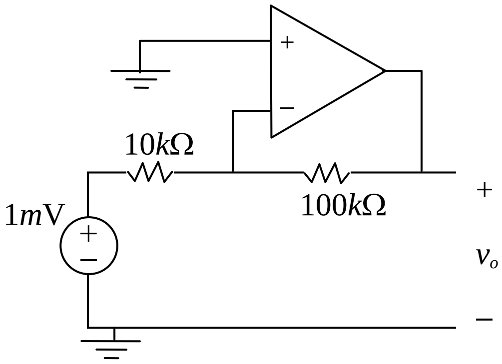
It is easy to find that $I = \dfrac{V}{12} + \dfrac{V}{60} + 0.4v_x = \dfrac{V}{12} + \dfrac{V}{60} + 0.4V = 0.5V$

which leads to $R_N = \frac{V}{I} = 2\ \ \Omega$

Therefore, when $R_L = R_N = 2\Omega$, the power transferred to the load is maximal and the maximum power is

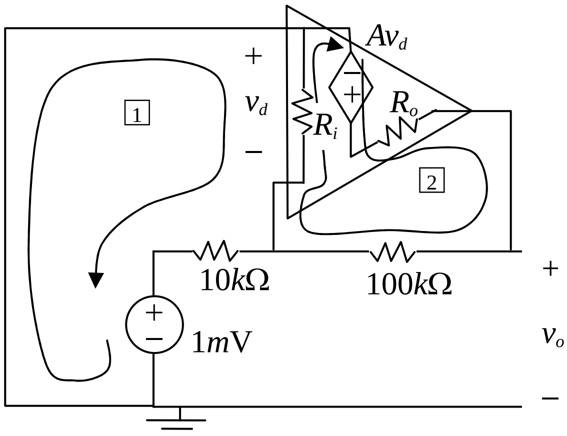
$$P_{max} = R_N \left(\frac{1}{2} i_N\right)^2 = 2\left(\frac{1}{2}\times 2\right)^2 = 2\ \ \mathrm{W}$$

8. The following op amp has R_i=100$k\Omega$, R_o=100Ω, A=1000. Find the output voltage v_0.



Solution:

The equivalent circuit is



Hence, based on mesh current method, we have

$$10^5(i_1 - i_2) + 10^4 i_1 + 10^{-3} = 0$$

$$10^5(i_2 - i_1) - 10^3 \times 10^5 (i_1 - i_2) + 100 i_2 + 10^5 i_2 = 0$$

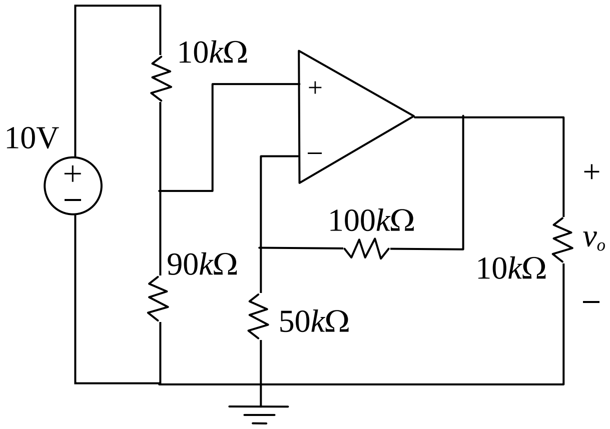
which can be rewritten as

$$11 i_1 - 10 i_2 + 10^{-7} = 0 \quad \text{and} \quad i_1 = 1.001 i_2$$

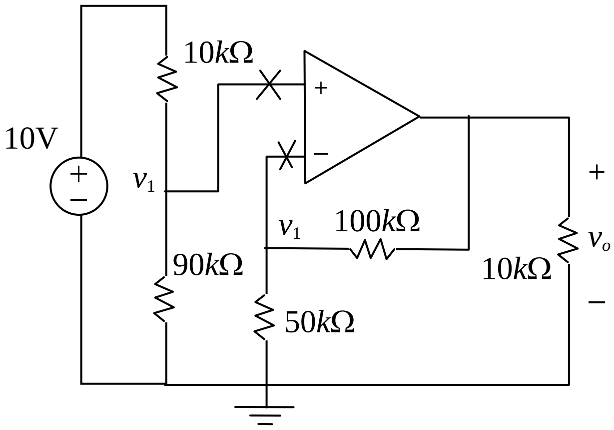
Hence, $i_1 \approx -0.9901\times 10^{-7}$ and $i_2 \approx -0.9891\times 10^{-7}$.

We have $v_o = 10^5 i_2 + 10^4 i_1 + 10^{-3} \approx -0.0099\,\mathrm{V}$.

9. The following circuit contains an ideal op amp, find the output voltage v_0.



Solution:



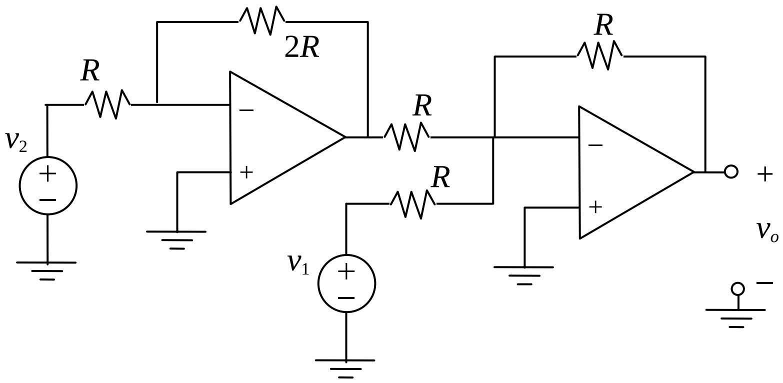
Since the input currents to the op amp is negligible, we have $v_1 = 10 \times \frac{90}{90+10} = 9$.

Hence, the output voltage

$$v_o = v_1 \times \frac{50+100}{50} = 3v_1 = 27 \quad \text{V.}$$

10. Use two op amps, design a circuit such that $v_0 = 2v_2 - v_1$, where v_1 and v_2 are inputs and v_0 is output.

Solution:


2R
R
R
R
R
v2
v1
vo
+
−