Problem 1 (8 points)

The energy delivering to the circuit element and the charge flowing through the element are given below:

$$E(t) = e^{t^2} \sin(2t^2)\ J$$

$$q(t) = t^2\ C$$

(a) Determine the voltage at the terminals of the element.

(b) Determine the power supplied to the element.

1. (a). $V = \frac{dE}{dq} = \frac{d[e^{t^2}\sin(2t^2)]}{d(t^2)} = e^{t^2}\sin(2t^2) + 2e^{t^2}\cos(2t^2)\ V$

(b). $P = \frac{dE}{dt} = 2t e^{t^2}\sin(2t^2) + 4t e^{t^2}\cos(2t^2)\ W$.

Problem 2 (12 points)

Use the principle of superposition to find the current i_0 in the circuit shown in Fig. 2.

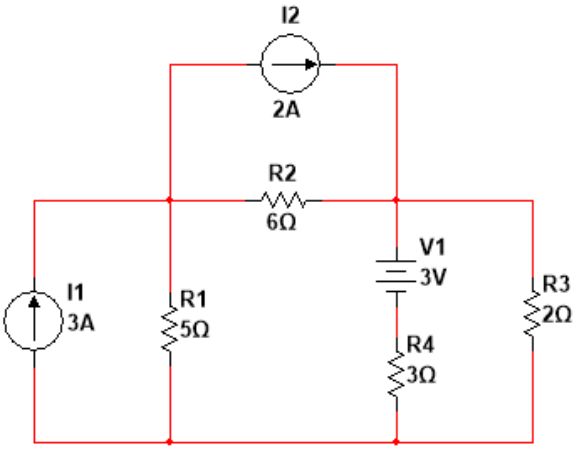
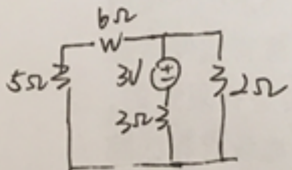
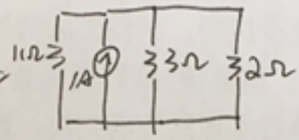


Fig. 2 $\qquad \leftarrow i_0$

2. Open I_1, I_2:

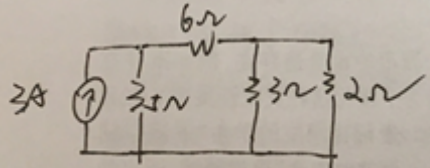


$\Rightarrow$

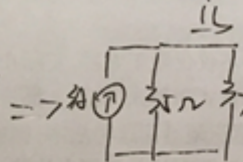


$\Rightarrow i_{o_1} = \frac{33}{61} A \simeq 0.54A$

Short V_1, Open I_2:

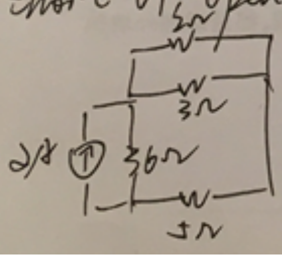


$\Rightarrow$



$\Rightarrow i_1 = \frac{75}{61} A \Rightarrow i_{o_2} = \frac{45}{61} A \simeq 0.7A$

Short V_1, Open I_1:



$\Rightarrow i_{o_3} = \frac{6}{6+6.2} \times 2 \times \frac{3}{5} = \frac{36}{61} A \simeq 0.59A.$

$i_o = i_{o_1} + i_{o_2} + i_{o_3} = \frac{114}{61} A \simeq 1.87A$ (1.86A 也对)

Problem 3 (12 points)

Find voltage difference value V_{ab} between node a and b from Fig. 3.

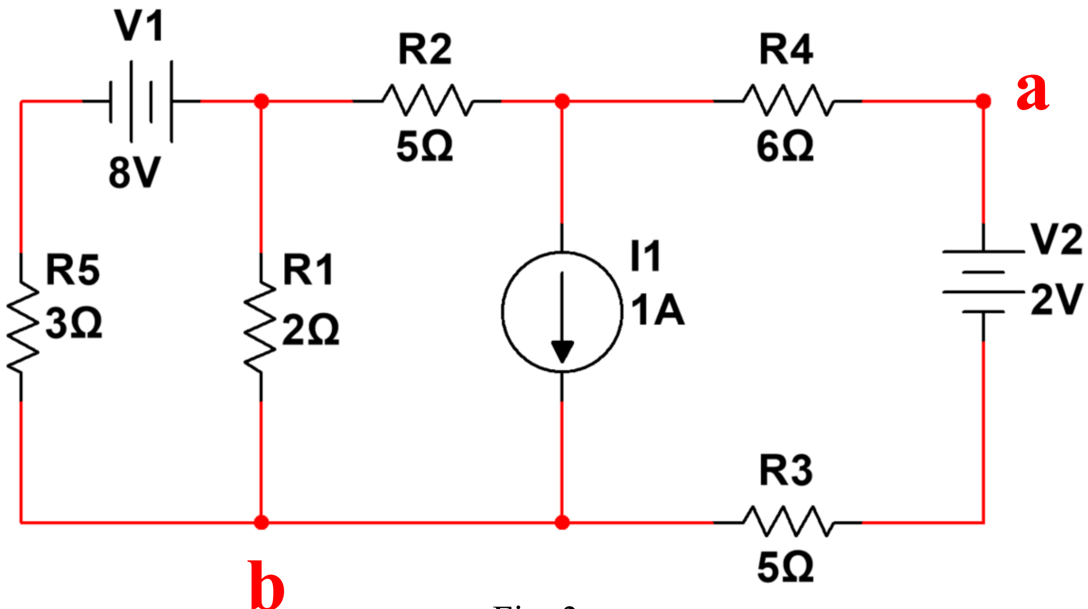
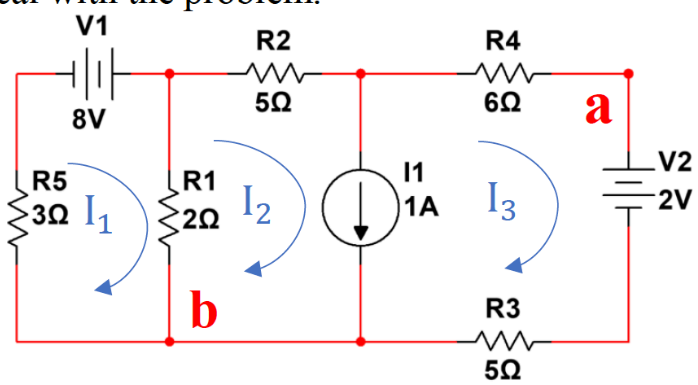


Fig. 3

Use supermesh to deal with the problem.



$$(2+3)I_1 - 2I_2 - 8 = 0$$

$$(5+2)I_2 + (6+5)I_3 - 2I_1 + 2 = 0 \text{ Supermesh}$$

$$I_2 - I_3 = 1A$$

$$\Rightarrow I_1 = \frac{81}{43}A, I_2 = \frac{61}{86}A, I_3 = -\frac{25}{86}A$$

$$V_{ab} = 2V + 5\Omega * \left(-\frac{25}{86}A\right) = \frac{47}{86}A \approx 0.547A$$

Problem 4 (12 points)

In the circuit of Fig. 4, the maximum power delivered to R_L is 10W. When R_L equals Thevenin equivalent resistance, the power of R_L reaches maximum. Find the current I_1 in Fig. 4 so that the power delivered to R_L is maximum.

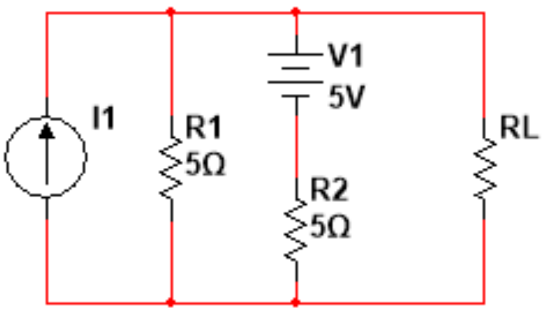
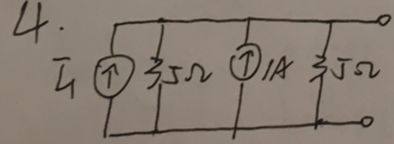


Fig. 4

4.



$\Rightarrow \frac{V_{Th}^2}{4R_L} = 10 \Rightarrow V_{Th} = \pm 10V \Rightarrow I_{Th} = \pm 4A$

$I_1 + 1A = I_{Th} \Rightarrow I_1 = 3A$ 或 $-5A$.

Problem 5 (12 points)

In the circuit shown in Fig. 5, find the Thevenin equivalent circuit for the net work to the left of ab.

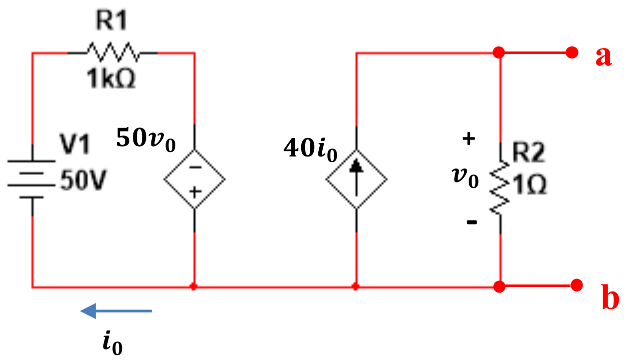
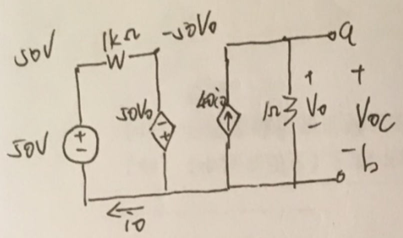


Fig. 5

5.



求 ab 左侧戴维南等效:

1. V_{oc} : 断路求电压:

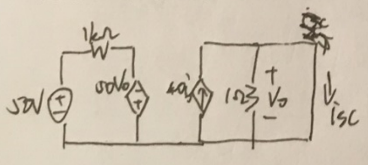
$V_o = 40 i_o$

$\Rightarrow 50V_o = 2000 i_o$.

$\Rightarrow i_o = \frac{50-(-50V_o)}{1000} = \frac{50+2000i_o}{1000} \Rightarrow i_o = -0.05A$.

$\Rightarrow V_{oc} = V_o = 40 i_o = -2V$.

I_{sc} : 短路求电流 :

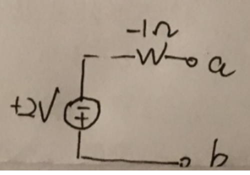


$V_o = 0V \Rightarrow 50V_o = 0V$.

$\Rightarrow i_o = \frac{50-(-50V_o)}{1000} = 0.05A$.

$\Rightarrow i_{sc} = +2A$.

$\Rightarrow R_{Th} = \frac{V_{oc}}{i_{sc}} = \frac{-2V}{2A} = -1\Omega \Rightarrow$



Problem 6 (12 points)

In the circuit shown in Fig. 6, find the voltage V_0.

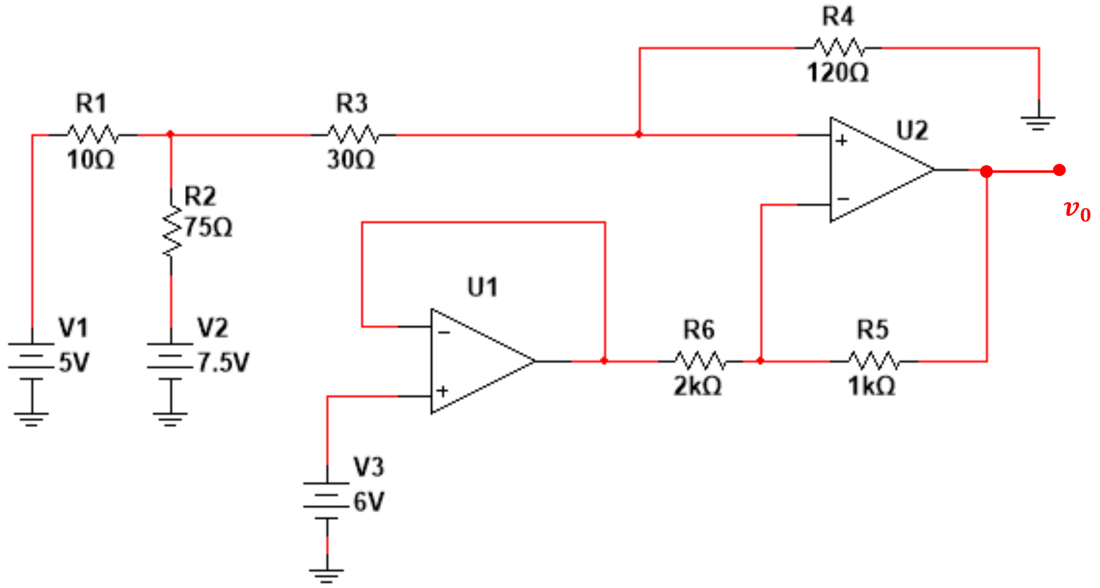
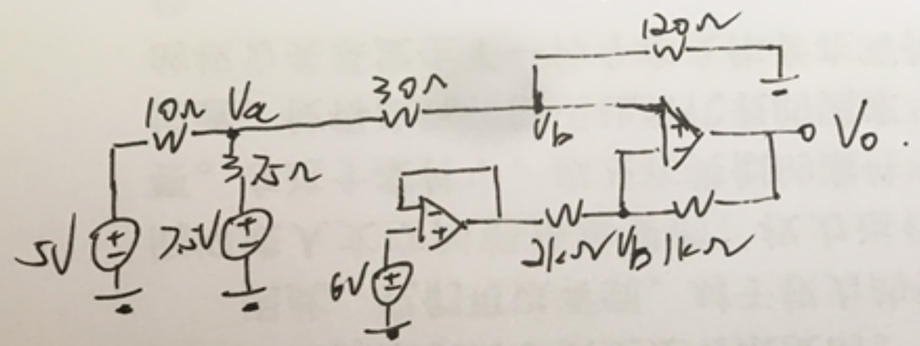


Fig. 6

6



$$\frac{5-V_a}{10} + \frac{7.5-V_a}{75} + \frac{0-V_a}{150} = 0.$$

$$\Rightarrow V_a = 5V.$$

$$V_b = 5 \times \frac{4}{5} = 4V.$$

$$\frac{6-4}{2k} + \frac{V_o-4}{1k} = 0$$

$$\Rightarrow V_o = 3V$$

Problem 7 (12 points)

In the circuit shown in Fig. 7, find the output voltage V_{OUT}.

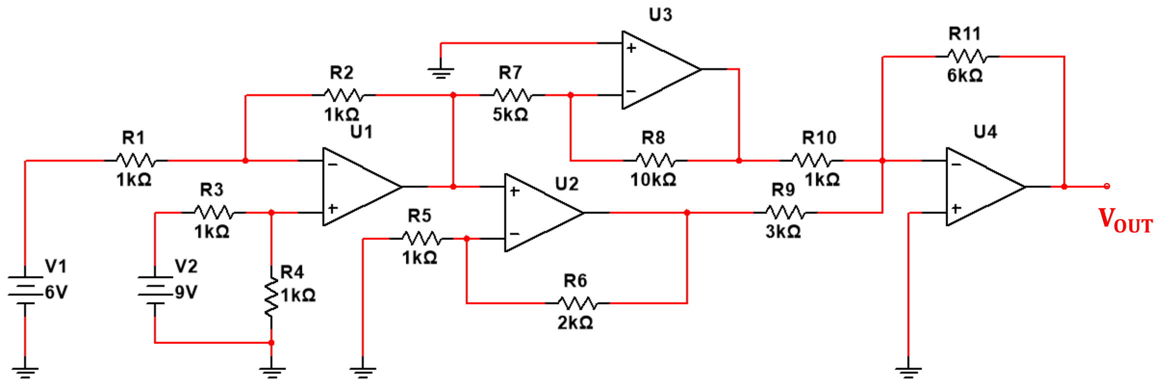


Fig. 7

7. U_1 is a difference amplifier.

$\Rightarrow U_{1(out)} = \frac{R_2}{R_1}(V_2 - V_1) = 3V$.

U_2 is a noninverting amplifier.

$\Rightarrow U_{2(out)} = (1+\frac{R_6}{R_5})\cdot U_{1(out)} = 9V$.

U_3 is an inverting amplifier.

$\Rightarrow U_{3(out)} = -\frac{R_8}{R_7}\cdot U_{1(out)} = -6V$.

U_4 is a summer amplifier.

$\Rightarrow U_{4(out)} = -(\frac{R_{11}}{R_{10}}U_{3(out)} + \frac{R_{11}}{R_9}U_{2(out)})$

$= -(6\times(-6) + 2\times 9) = 18V$.

Problem 8 (16 points)

The circuit inside the shaded area in Fig. 8 is a constant current source for a limited range of R_L. (You can assume that $i_n = i_p \approx 0$ under all operation conditions.)

(a) Find the value of i_L for $R_L = 4k\Omega$.

(b) Find the maximum value for R_L for which i_L will have the value in (a).

(c) Assume that $R_L = 16k\Omega$. Explain the operation of the circuit.

(d) Find the relation between i_L and R_L for $0 \le R_L \le 16k\Omega$, and sketch it out in a plot.

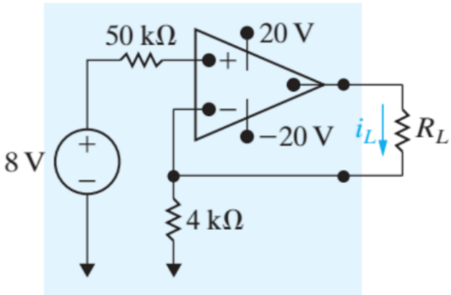


Fig.8

[a] Assume the op-amp is operating within its linear range, then

$$i_L = \frac{8}{4000} = 2\,\text{mA}$$

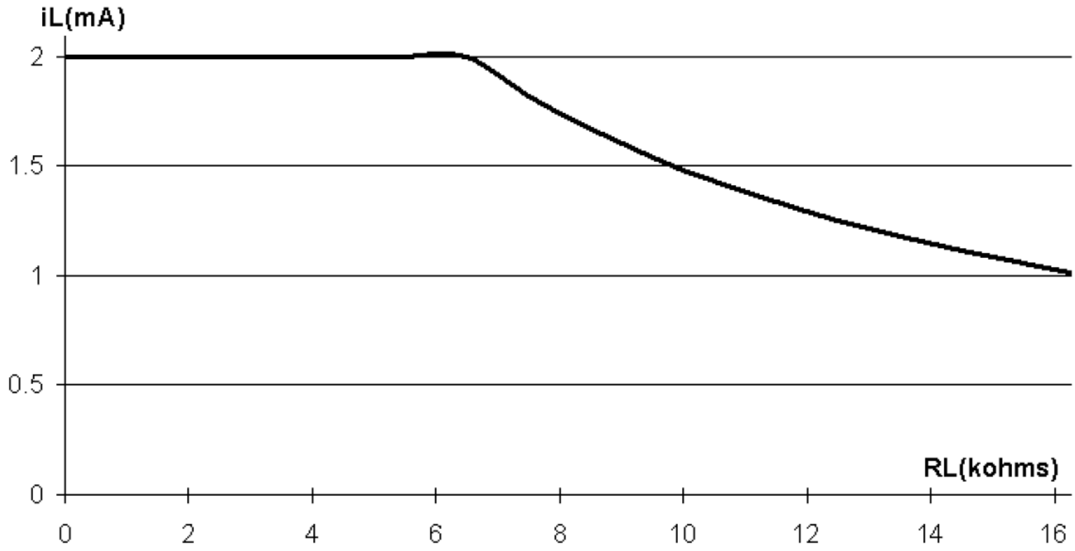
For $R_L = 4\,\text{k}\Omega$ $\qquad v_o = (4+4)(2) = 16\ \text{V}$

Now since $v_o < 20$ V our assumption of linear operation is correct, therefore

$$i_L = 2\,\text{mA}$$

[b] $20 = 2(4 + R_L); \qquad R_L = 6\,\text{k}\Omega$

[c] As long as the op-amp is operating in its linear region i_L is independent of R_L. From (b) we found the op-amp is operating in its linear region as long as $R_L \le 6\,\text{k}\Omega$. Therefore when $R_L = 6\,\text{k}\Omega$ the op-amp is saturated. We can estimate the value of i_L by assuming $i_p = i_n \ll i_L$. Then $i_L = 20/(4000 + 16{,}000) = 1\,\text{mA}$. To justify neglecting the current into the op-amp assume the drop across the 50 kΩ resistor is negligible, since the input resistance to the op-amp is at least $500\,\text{k}\Omega$. Then $i_p = i_n = (8-4)/(500 \times 10^3) = 8\,\mu\text{A}$. But $8\,\mu\text{A} \ll 1\,\text{mA}$, hence our assumption is reasonable.


iL(mA)
2
1.5
1
0.5
0
RL(kohms)
0
2
4
6
8
10
12
14
16