Final-term Examination

Notice: Please **turn off any types of handheld devices**, and leave them far from reach. Use only standalone calculators for calculation if it is needed. The examination takes **100 minutes**.只需繳回答案紙，題目紙請同學保留。

1. (10%) Find Norton equivalence of the circuit shown in Fig.1.

$V_{oc} = V_x = 1k\, i_s = 1.25V$
$5 = 1k\, i_s + 3k\, i_s = 4k\, i_s$
$i_s = 1.25mA$
$I_{sc} = 25\, i_s = 125mA$ ※
$5 = 1k\, i_s \Rightarrow i_s = 5mA$
$R_N = \frac{1.25}{125m} = 0.1k\Omega$ ※

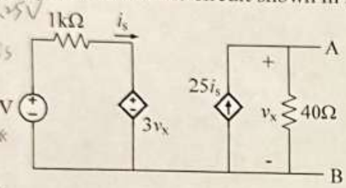


Fig. 1

2. (10%) Given that $0 \le R \le \infty$ in the circuit of Fig. 2, consider two observations:
   a. Observation 1: When $R = \cancel{5}\,2\Omega$ then $v_R = \cancel{15}\,4V$ and $i_R = \cancel{3}\,2A$.
   b. Observation 2: When $R = \cancel{8}\,6\Omega$ then $v_R = \cancel{16}\,6V$ and $i_R = \cancel{12}\,1A$.

   Determine the maximum value of $p_R = i_R v_R$ and the value of R that causes p_R to be maximal.

$\frac{V_{th}}{2+R} = 2 \Rightarrow V_{th} = 4+2R$
$\frac{V_{th}}{6+R} = 1 \Rightarrow V_{th} = 6+R$
$R = 2 \Rightarrow V_{th} = 8V$
$2 \times \frac{1}{2} \times \frac{8}{4} = 4 \times 2 = 8W$ ※

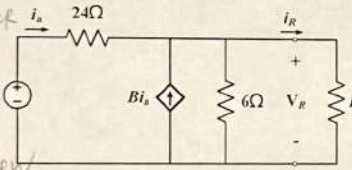


Fig. 2

3. (10%) Find the Thévenin equivalent circuit for the circuit shown in Fig. 3.

$V_{oc} = -V_A$
$\frac{6 - V_{oc}}{8} + 0.75 V_{oc} = \frac{V_{oc}}{4}$
$6 - V_{oc} + 6V_{oc} = 2V_{oc}$
$3V_{oc} = -6$
$V_{oc} = -2V$ ※
$6 = 8 I_{sc} \Rightarrow I_{sc} = \frac{6}{8}$
$R_{th} = \frac{-2}{\frac{6}{8}} = -\frac{8}{3}\Omega$ ※

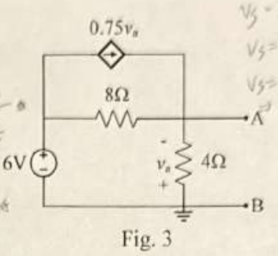


Fig. 3

$V_{oc} = 4 i_a$
$V_s = 8 i_a + 4 i_a = 12 i_a = 3V_{oc}$
$V_s = 3 \times 8 = 24V$ ※
$V_s = 12 i_a$
$i_a = 2A$
$4 i_a = I_{sc} R_2$
$8 = 2R_2 \Rightarrow R_2 = 4\Omega$ ※
$\frac{8}{8} \times 8 \times \frac{1}{2} = 4W$ ※

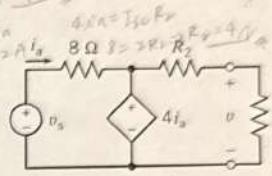


Fig. 4

4. For the circuit shown in Fig. 4, the open circuit voltage is $v_{oc} = 8V$, and short-circuit current is $i_{sc} = 2A$. Determine:
   a. (6%) The voltage source voltage v_s and the resistance R_2.
   b. (6%) The resistance R that maximizes the power delivered to the resistor to the right of the terminals, and the corresponding maximum power.

5. (14%) Figure 5 shows a voltage-controlled current source (VCCS) structured by an OP amplifier. Derive solutions of v_{out} and i_{out} in terms of v_{in}, R_1, R_2, R_3, R_4 and R_L.

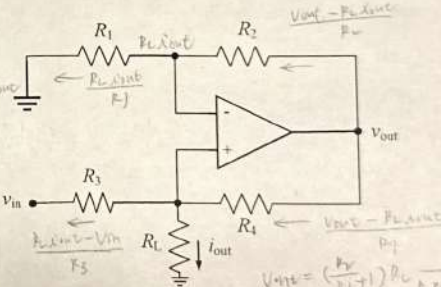


Fig. 5

$\frac{V_{out} - R_L i_{out}}{R_2} = \frac{R_L i_{out}}{R_1}$
$V_{out} = R_2\left(\frac{1}{R_1} + \frac{1}{R_L}\right) R_L i_{out} = \left(\frac{R_2}{R_1} + 1\right) R_L i_{out}$
$\frac{V_{out} - R_L i_{out}}{R_4} = i_{out} + \frac{R_L i_{out} - V_{in}}{R_3}$
$\frac{V_{out}}{R_4} = \left(\frac{R_L}{R_4} + 1 + \frac{R_L}{R_3}\right) i_{out} - \frac{V_{in}}{R_3}$
$\left(\frac{R_2}{R_1} + 1\right)\frac{R_L}{R_4} i_{out} = \left(\frac{R_L}{R_4} + 1 + \frac{R_L}{R_3}\right) i_{out} - \frac{V_{in}}{R_3}$
$\left[\frac{R_L}{R_4} + 1 + \frac{R_L}{R_3} - \frac{R_L}{R_4}\left(\frac{R_2}{R_1} + 1\right)\right] i_{out} = \frac{V_{in}}{R_3}$
$\left[\frac{R_L R_3 + R_4 R_3 + R_L R_4}{R_4 R_3} - \frac{R_3 R_L\left(\frac{R_2}{R_1}+1\right)}{R_4 R_3}\right] i_{out} = \frac{V_{in}}{R_3}$
$i_{out} = \frac{R_4 R_3}{R_3\left[R_L R_3 + R_4 R_3 + R_L R_4 - R_3 R_L\left(\frac{R_2}{R_1}+1\right)\right]} V_{in} = \frac{R_4}{R_L R_3 + R_4 R_3 + R_L R_4 - R_3 R_L\left(\frac{R_2}{R_1}+1\right)} V_{in}$
$V_{out} = \left(\frac{R_2}{R_1}+1\right) R_L \frac{R_4 V_{in}}{R_L R_3 + R_4 R_3 + R_L R_4 - R_3 R_L\left(\frac{R_2}{R_1}+1\right)} = \frac{(R_2+R_1) R_L R_4 V_{in}}{R_1\left[R_L R_3 + R_4 R_3 + R_L R_4 - R_3 R_L\left(\frac{R_2}{R_1}+1\right)\right]}$

6. (11%) Find v_o and i_o for the circuit of Fig. 6.

6. $3m + 2m + \frac{V_o}{3k} + \frac{V_o}{6k} = 0 \Rightarrow V_o = -15V$

$\frac{-15}{3k} + i_o + \frac{-15}{6k} = 0 \Rightarrow i_o = 5m + 2.5m = 7.5mA$

7. $0.3m + \frac{3-V_o}{3k} + 0 + 0.9m = \frac{V_o}{30k} \Rightarrow V_o = 12V$

$\frac{3-12}{30k} = i_o + \frac{12}{30k}$

$-9 = 30k\, i_o + 12$

$i_o = \frac{-21}{30k} = -0.7\ mA$

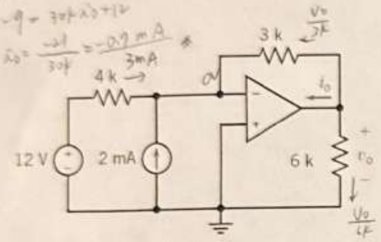


Fig. 6

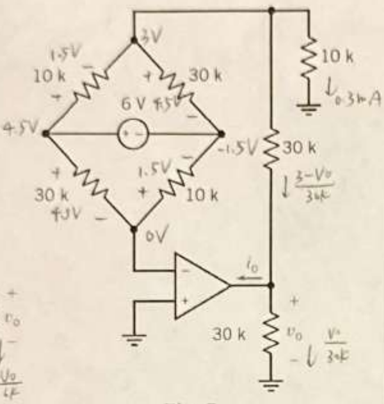
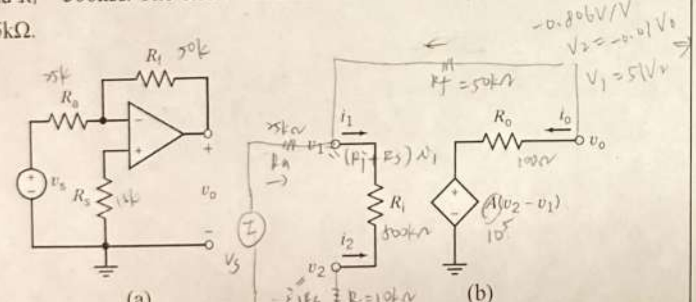


Fig. 7

7. (11%) Find v_o and i_o for the circuit shown in Fig. 7.

8. (11%) For the OP amplifier circuit in Fig. 8(a), calculate alternatively v_o/v_s with a finite gain model illustrated in Fig. 8(b) given $A = 10^5$, $R_o = 100\Omega$, and $R_i = 500k\Omega$. The circuit resistors are $R_s = 10k\Omega$, $R_f = 50k\Omega$, and $R_a = 25k\Omega$.

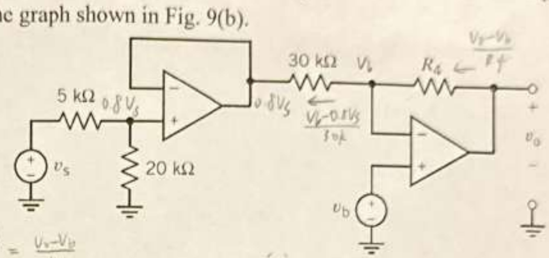
$-0.806V/V$



(a) (b)

Fig. 8

9. (11%) In the circuit shown in Fig. 9(a), a voltage v_b is used to adjust the relationship between the input v_s and output v_o. Determine values of R_4 and v_b that cause the circuit input and output to have the relationship specified by the graph shown in Fig. 9(b).



(a)

$\frac{V_b - 0.8V_s}{30k} = \frac{V_o - V_b}{R_4}$

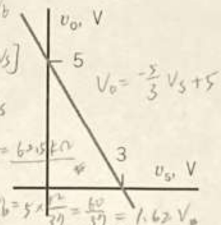
$R_4 V_b - 0.8 R_4 V_s = 30k V_o - 30k V_b$

$V_o = \frac{1}{30k}\left[(R_4 + 30k) V_b - 0.8 R_4 V_s\right]$

$= \left(\frac{R_4}{30k} + 1\right) V_b - \frac{0.8 R_4}{30k} V_s$

$\frac{0.8 R_4}{30k} = \frac{5}{3} \Rightarrow R_4 = \frac{5}{3} \times \frac{30k}{0.8} = 62.5k\Omega$

$\left(\frac{62.5k}{30k} + 1\right) V_b = 5 = \frac{37}{12} V_b \Rightarrow V_b = 5 \times \frac{12}{37} = \frac{60}{37} = 1.62\ V$



$V_o = -\frac{5}{3} V_s + 5$

(b)

Fig. 9

$\frac{V_s - i_1(R_i + R_s)}{25k} + \frac{V_o - i_1(R_i + R_s)}{50k} = i_1$

$\frac{V_s - i_1 \times 510k}{25k} + \frac{V_o - i_1 \times 510k}{50k} = i_1 \Rightarrow \frac{V_o}{50k} = \left(\frac{510k}{50k} + 1 + \frac{510k}{25k}\right) i_1 - \frac{V_s}{25k}$

$\frac{V_o - i_1 \times 510k}{50k} + \frac{V_o - 10^5[i_1 R_s - i_1(R_s + R_i)]}{100} = 0$

$\left(\frac{1}{100} + \frac{1}{50k}\right) V_o = \left[\frac{510k}{50k} - 10^3 \cdot 10k - 510k \cdot 10^3\right] i_1$

$\frac{501}{50000} V_o = -510M\, i_1$

$i_1 = \frac{501\, V_o}{5 \times 10^4 (-510M)} = 1.96 \times 10^{-11} V_o$

$\frac{V_o}{50k} = \frac{158}{5} \times 1.96 \times 10^{-11} - \frac{V_s}{25k}$