Chapter 0
Introduction to Electronics

Microelectronic Circuit Design

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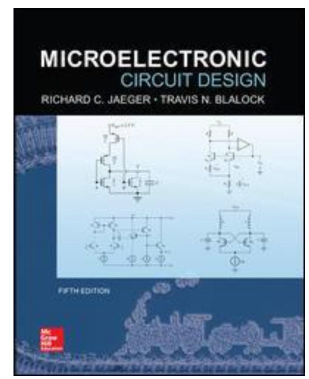


BT 1

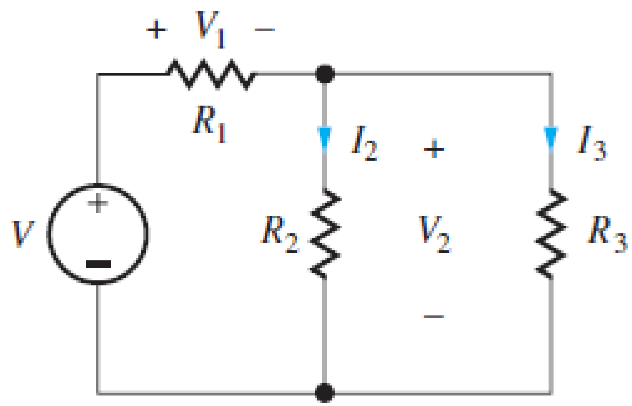
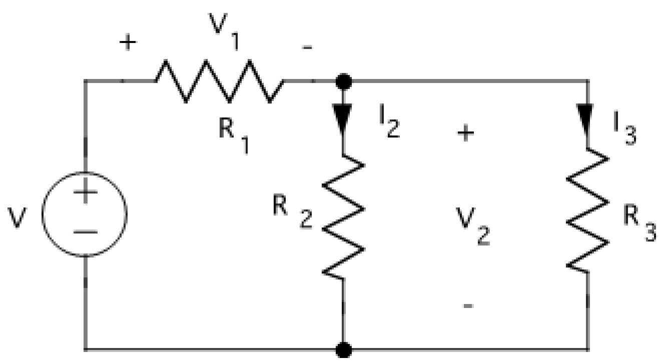


Figure P1.22

Use voltage and current division to find V_1, V_2, I_2, and I_3 in the circuit in Fig. P1.22 if $V = 8$ V, $R_1 = 30$ kΩ, $R_2 = 24$ kΩ, and $R3 = 15$ kΩ

BT 1 (Sol.)



V = 8 V, R_1 = 30 kΩ, R_2= 24 kΩ and R_3 = 15 kΩ.

$$V_1 = 8V\,\frac{30k\text{W}}{30k\text{W}+\left(24k\text{W}\|15k\text{W}\right)} = 8V\,\frac{30k\text{W}}{30k\text{W}+9.23k\text{W}} = 6.12\ V$$

$$V_2 = 8V\,\frac{24k\text{W}\|15k\text{W}}{30k\text{W}+\left(24k\text{W}\|15k\text{W}\right)} = 1.88\ V \qquad \text{Checking: } 6.12+1.88 = 8.00\ V$$

$$I_2 = I_1\frac{R_3}{R_2+R_3} = \left(\frac{8V}{30k\text{W}+9.23k\text{W}}\right)\frac{15k\text{W}}{24k\text{W}+15k\text{W}} = 78.4\ mA$$

$$I_3 = I_1\frac{R_2}{R_2+R_3} = \left(\frac{8V}{30k\text{W}+9.23k\text{W}}\right)\frac{24k\text{W}}{24k\text{W}+15k\text{W}} = 125\ mA$$

$$\text{Checking: } I_1 = \frac{8V}{30k\text{W}+9.23k\text{W}} = 204\ mA \quad \text{and} \quad I_1 = I_2 + I_3$$

BT 2

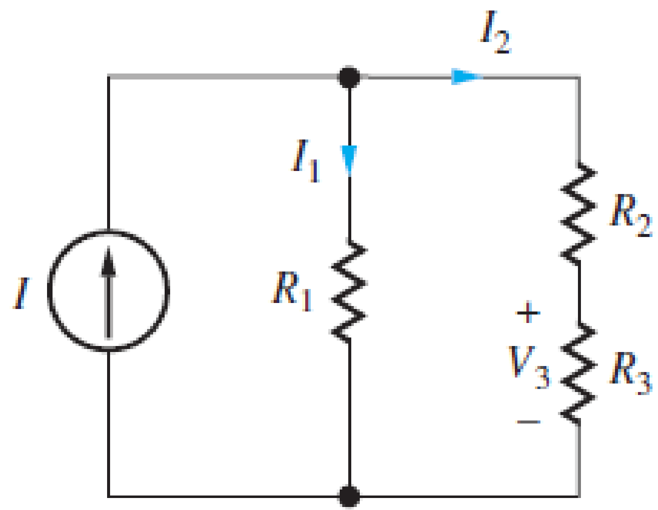


Figure P1.24

Use current and voltage division to find I_1, I_2, and V_3 in the circuit in Fig. P1.24 if $I = 200\ \mu A$, $R_1 = 150\ k\Omega$, $R_2 = 68\ k\Omega$, and $R_3 = 82\ k\Omega$.

BT 2 (Sol.)

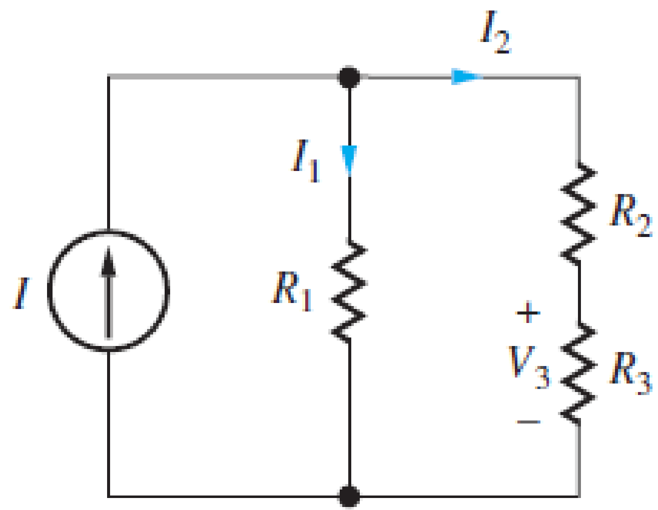


Figure P1.24

$$I_2 = 200 mA\left(\frac{150k\mathrm{W}}{150k\mathrm{W}+150k\mathrm{W}}\right) = 100\ mA \qquad I_3 = 200 mA\left(\frac{150k\mathrm{W}}{150k\mathrm{W}+150k\mathrm{W}}\right) = 100\ mA$$

$$V_3 = 200 mA\left(150k\mathrm{W} \| 150k\mathrm{W}\right)\left(\frac{82k\mathrm{W}}{68k\mathrm{W}+82k\mathrm{W}}\right) = 8.2V$$

$$\text{Checking: } I_1 + I_2 = 200\ mA \quad \text{and} \quad I_2R_2 = 100 mA\left(82k\mathrm{W}\right) = 8.2\ V$$

BT 3

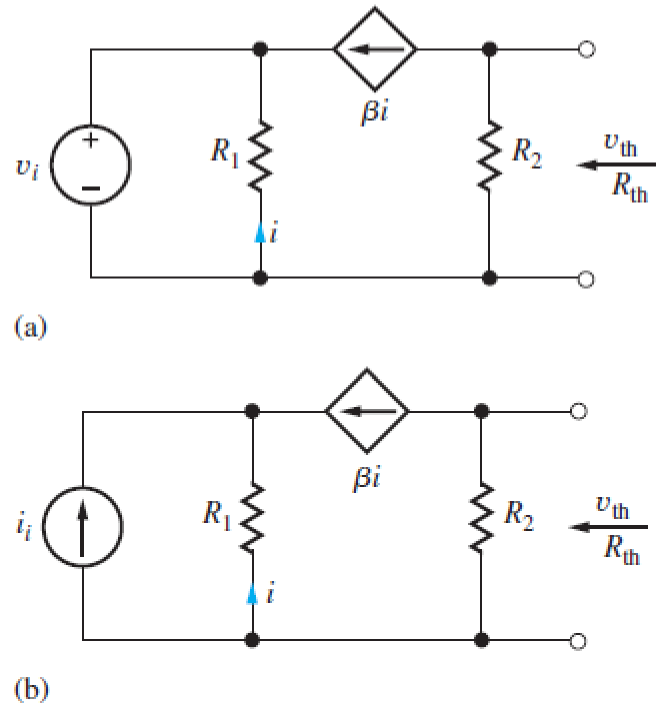
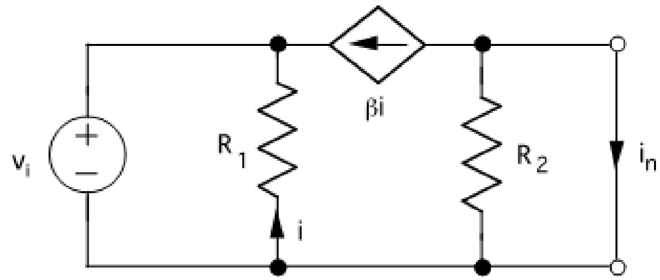


Figure P1.27

a) Find the Norton equivalent representation of the circuit in Fig. P1.27(a, b) if $\beta = 150$, $R1 = 39$ kΩ, and $R2 = 100$ kΩ.

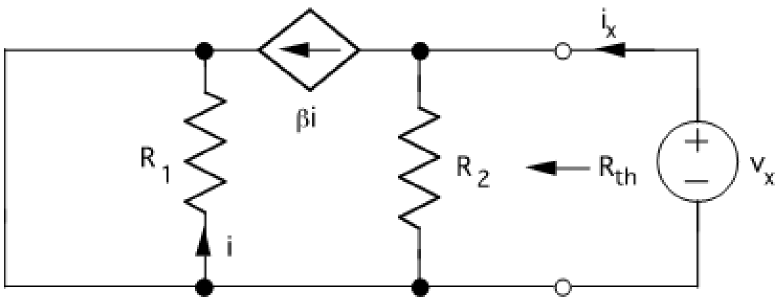
b) Find the Th´evenin equivalent representation of the circuit in Fig. P1.27(a,b) if $\beta = 120$, $R1 = 56$ kΩ, and $R2 = 75$ kΩ.

BT 3 (Sol. Norton a)



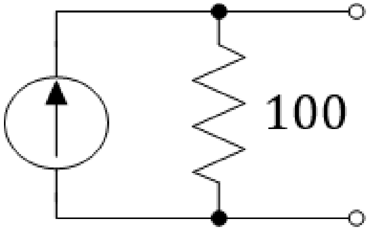
(a)

$$i_n = -\beta i \quad \text{but} \quad i = -\frac{v_i}{R_1} \quad \text{and} \quad i_n = \frac{\beta}{R_1} v_i = \frac{150}{39k\Omega} v_i = 3.85\ x\ 10^{-3}\, v_i$$



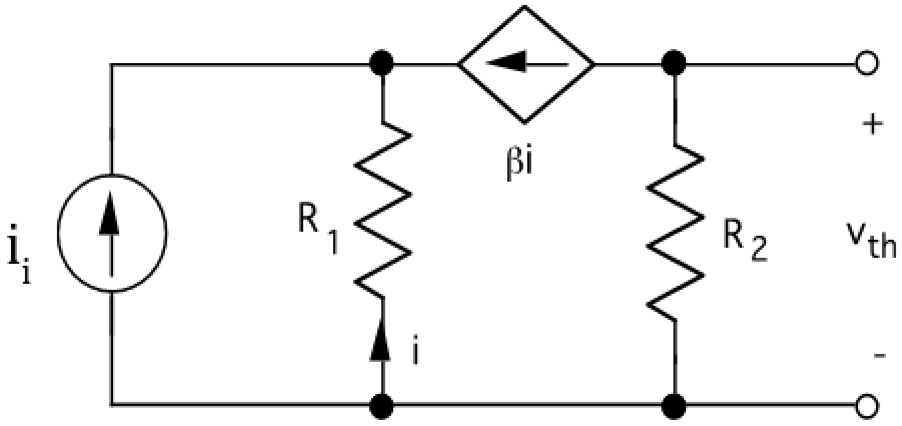
$$R_{th} = \frac{v_x}{i_x} \quad ; \quad i_x = \frac{v_x}{R_2} + \beta i \quad \text{but} \quad i = 0 \quad \text{since} \quad v_{R_1} = 0. \qquad R_{th} = R_2 = 100\ k\Omega$$

3.85 x 10^{-3}

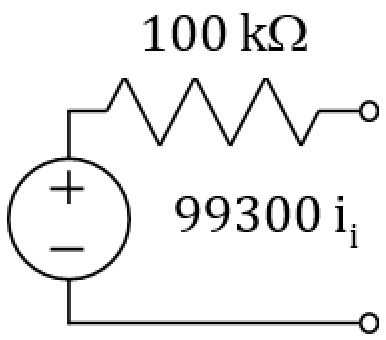


Noton equivalent circuit:

BT 3 (Sol. Norton b)



(b)

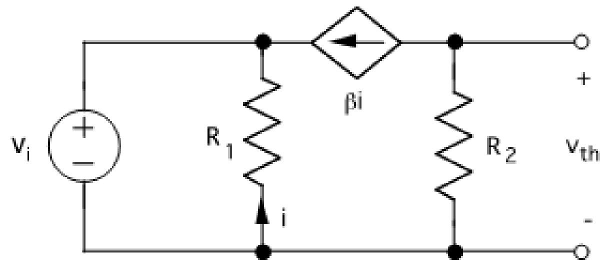


$v_{th} = v_{oc} = -\beta i R_2$ where $i + \beta i + i_i = 0$ and $v_{th} = R_2 \left(\dfrac{\beta}{\beta+1} \right) i_i = 100k\Omega \left(\dfrac{150}{151} \right) i_i = 99300 i_i$

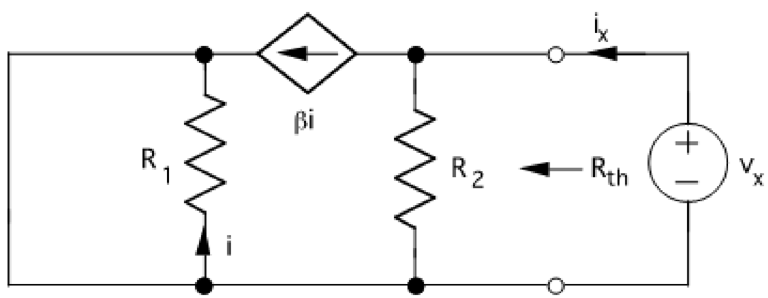
R_{th} is found in part (a).

BT 3 (Sol. Thevenin a)

(a)

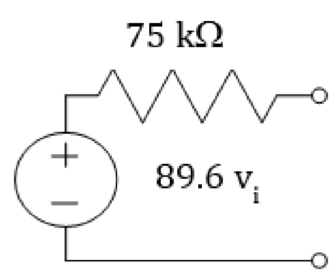


$v_{th} = v_{oc} = -\beta\, i\, R_2$ but $i = -\dfrac{v_i}{R_1}$ and $v_{th} = \beta\, v_i \dfrac{R_2}{R_1} = 120\, v_i \dfrac{56k\Omega}{75k\Omega} = 89.6\, v_i$

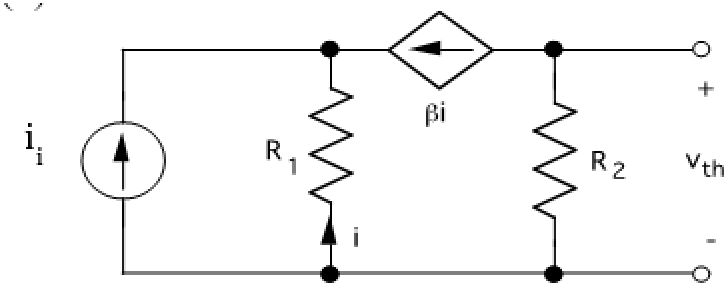


$R_{th} = \dfrac{v_x}{i_x}$; $i_x = \dfrac{v_x}{R_2} + \beta i$ but $i = 0$ since $v_{R_1} = 0$. $R_{th} = R_2 = 75\ k\Omega$

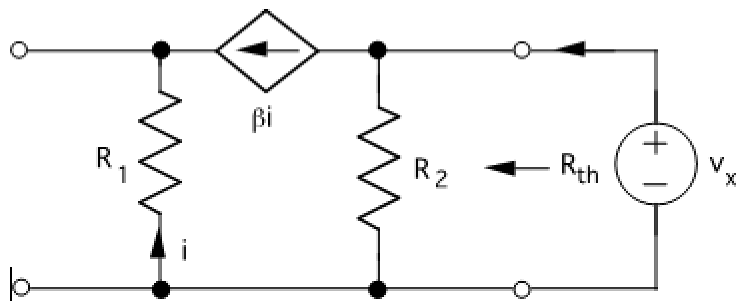
Thévenin equivalent circuit:



BT 3 (Sol. Thevenin b)

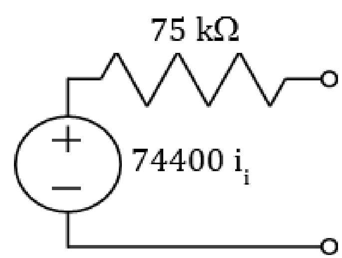


$v_{th} = v_{oc} = -\beta\ i\ R_2$ where $i + \beta i + i_i = 0$ and $v_{th} = R_2\left(\dfrac{\beta}{\beta+1}\right) i_i = 75k\Omega\left(\dfrac{120}{121}\right) i_i = 74400\ i_i$



$R_{th} = \dfrac{v_x}{i_x}$; $i_x = \dfrac{v_x}{R_2} + \beta i$ but $i + \beta i = 0$ so $i = 0$ and $R_{th} = R_2 = 75\ k\Omega$

Thévenin equivalent circuit:



BT 4

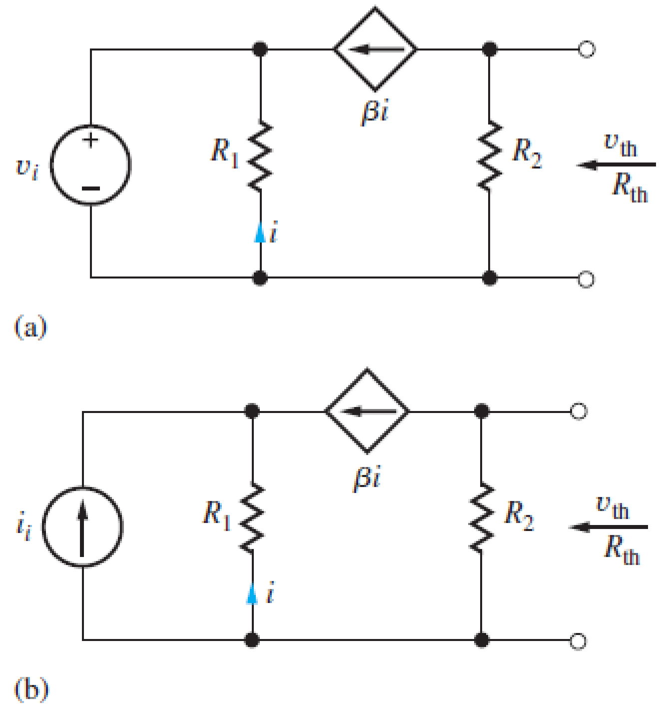
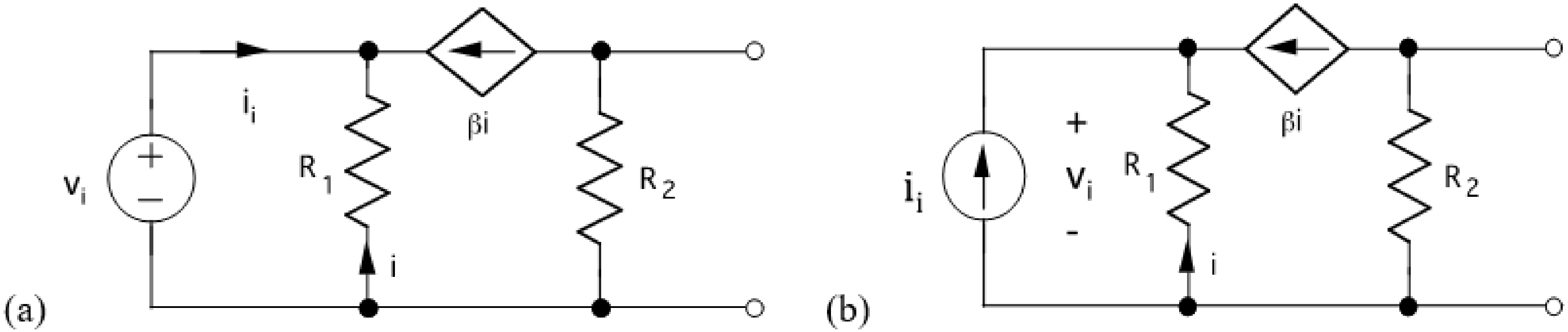


Figure P1.27

What is the resistance presented to source $\boldsymbol{v_i}$ by the circuit in Fig. P1.27(a,b) if $\beta = 75$, $R_1 = 100\ \text{k}\Omega$, and $R_2 = 39\ \text{k}\Omega$?

BT 4 (Sol.)



(a) $i_i = \dfrac{v_i}{R_1} - \beta i = \dfrac{v_i}{R_1} + \beta \dfrac{v_i}{R_1} = v_i \dfrac{\beta+1}{R_1}$ $\quad R = \dfrac{v_i}{i_i} = \dfrac{R_1}{\beta+1} = \dfrac{100k\Omega}{76} = 1.32\ k\Omega$

(b) Source is i_i in part (b).

$v_i = -iR_1$ and $i_i = -i - \beta i = -(\beta+1)i$ $\quad R = \dfrac{v_i}{i_i} = -\dfrac{-1}{\beta+1} R_1 = \dfrac{100k\Omega}{76} = 1.32\ k\Omega$

BT 5

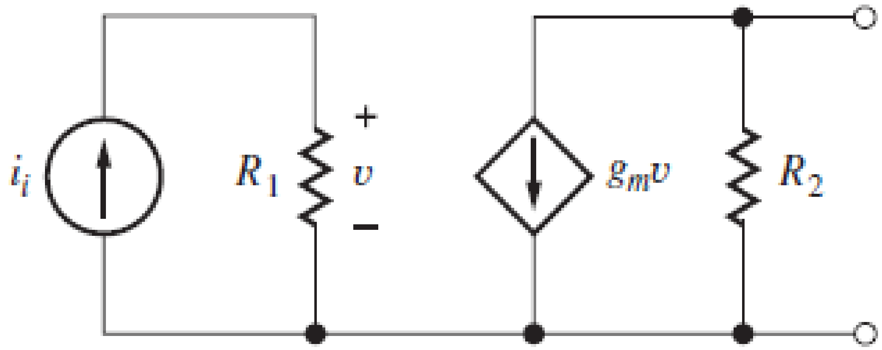


Figure P1.30

Find the Th'evenin equivalent representation of the circuit in Fig. P1.30 if $g_m = .0025$ S, $R1 = 200$ kΩ, and $R2 = 2$ MΩ

BT 5 (Sol.)

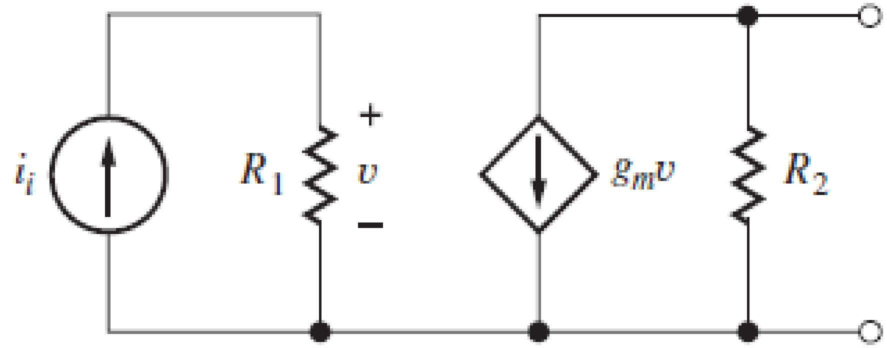


Figure P1.30

The open circuit voltage is $v_{th} = -\, g_m v\, R_2$ where $v = +i_i R_1$.

$$v_{th} = -\, g_m R_1 R_2 i_i = -\,(0.0025)\left(2x10^5\right)\left(2x10^6\right) i_i = 1.0\ x\ 10^9 i_i$$

For $i_i = 0$, $v = 0$, and $R_{th} = R_2 = 2\ M\text{W}$

BT 6

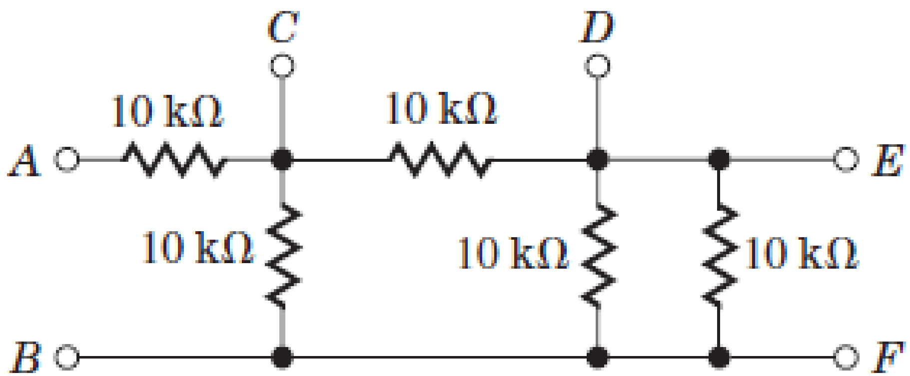


Figure P1.31

(a) What is the equivalent resistance between terminals *A* and *B* in Fig. P1.31?
(b) What is the equivalent resistance between terminals *C* and *D*?
(c) What is the equivalent resistance between terminals *E* and *F*?
(d) What is the equivalent resistance between terminals *B* and *D*?

BT 6 (Sol.)

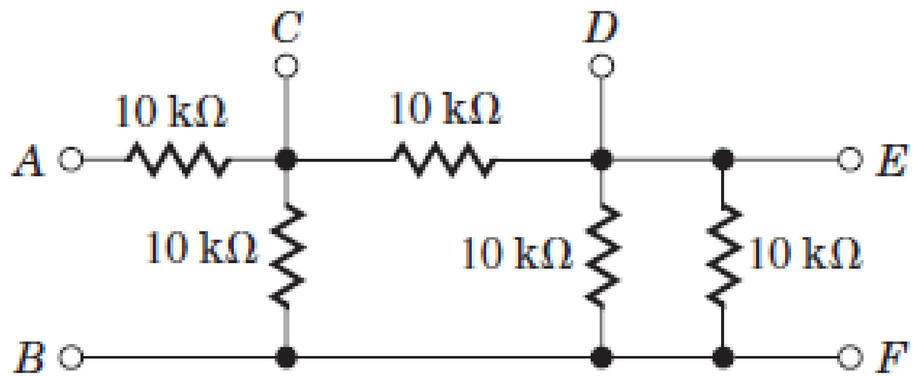


Figure P1.31

$$(a)\ R_{AB} = 10k\Omega + 10k\Omega \| \left[10k\Omega + \left(10k\Omega \| 10k\Omega\right)\right] = 16\ k\Omega$$

$$(b)\ R_{CD} = 10k\Omega \| \left[10k\Omega + \left(10k\Omega \| 10k\Omega\right)\right] = 6\ k\Omega$$

$$(c)\ R_{EF} = 10k\Omega \| 10k\Omega \| \left(10k\Omega + 10k\Omega\right) = 4\ k\Omega$$

(d) Terminals B & D are the same as E & F. $R_{BD} = 4\ k\Omega$

BT 7

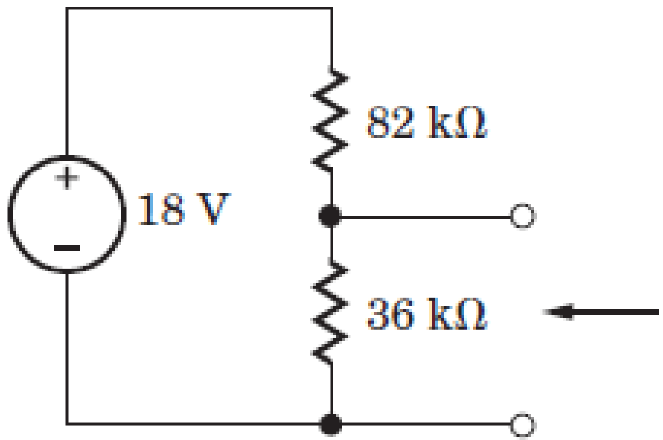


Figure P1.32

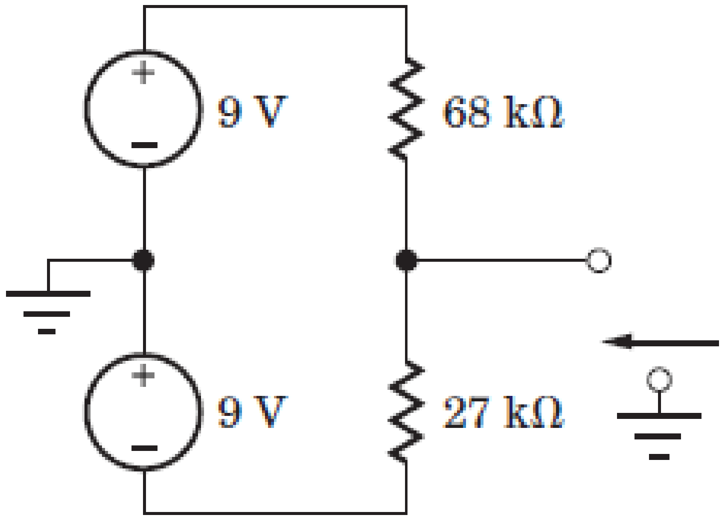


Figure P1.33

(a) Find the Th´evenin equivalent circuit for the network in Fig. P1.32, 33.
(b) What is the Norton equivalent circuit?

BT 7 (Sol. Fig. 1.33)

(a) The open-circuit voltage is $v_{th} = 18V \dfrac{36k\Omega}{82k\Omega + 36k\Omega} = 5.49\ V$

The Thévenin equivalent resistance is $R_{th} = 36k\Omega \| 82k\Omega = 25.0\ k\Omega$

(b) The short-circuit current is $i_n = \dfrac{18V}{82k\Omega} = 220\ \mu A$

The Thévenin equivalent resistance is $R_{th} = 36k\Omega \| 82k\Omega = 25.0\ k\Omega$

Checking: $i_n R_{th} = 5.49\ V$ which equals v_{th} and is correct.

BT 7 (Sol. Fig. 1.32)

(a) The open - circuit voltage is $v_{th} = -9V + I\ x\ 27k\Omega = -9V + \left(\dfrac{18V}{68k\Omega + 27k\Omega}\right)27k\Omega = -3.88\ V$

The open - circuit voltage is also $v_{th} = +9V - I\ x\ 68k\Omega = -9V + \left(\dfrac{18V}{68k\Omega + 27k\Omega}\right)68k\Omega = -3.88\ V$

Using voltage division yields $v_{th} = -9V + 18V\left(\dfrac{27k\Omega}{68k\Omega + 27k\Omega}\right) = -3.88\ V$

Using voltage division yields $v_{th} = +9V - 18V\left(\dfrac{68k\Omega}{68k\Omega + 27k\Omega}\right) = -3.88\ V$

The The′venin equivalent resistance is $R_{th} = 27k\Omega \| 68k\Omega = 19.3\ k\Omega$

(b) The short - circuit current is $i_n = \dfrac{9V}{68k\Omega} - \dfrac{9V}{27k\Omega} = -201\ \mu A$

The The′venin equivalent resistance is $R_{th} = 27k\Omega \| 68k\Omega = 19.3\ k\Omega$

Checking : $i_n R_{th} = -3.88\ V$ which equals v_{th} and is correct.