Problem 3.58 Find the Thévenin equivalent circuit at terminals (a,b) of the circuit in Fig. P3.58.

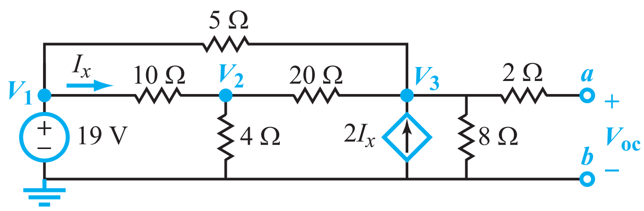


Figure P3.58: Circuit for Problems 3.58 and 3.59.

Solution:

$$V_1 = 19 \text{ V}$$

$$\frac{V_2 - V_1}{10} + \frac{V_2}{4} + \frac{V_2 - V_3}{20} = 0$$

$$\frac{V_3 - V_2}{20} + \frac{V_3}{8} + \frac{V_3 - V_1}{5} - 2I_x = 0$$

$$I_x = \frac{V_1 - V_2}{10}$$

Simultaneous solution of the above equations yields:

$$V_2 = 6.94 \text{ V}, \qquad V_3 = 17.49 \text{ V}.$$

$$V_{Th} = V_{oc} = V_3 = 17.49 \text{ V}.$$

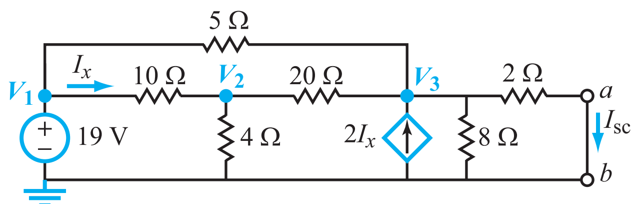
To find R_{Th}, we calculate I_{sc}:

$$V_1 = 19 \text{ V}$$

$$\frac{V_2 - V_1}{10} + \frac{V_2}{4} - \frac{V_2 - V_3}{20} = 0$$

$$\frac{V_3 - V_2}{20} + \frac{V_3}{8} + \frac{V_3}{2} + \frac{V_3 - V_1}{5} - 2I_x = 0$$

$$I_x = \frac{V_1 - V_2}{10}$$

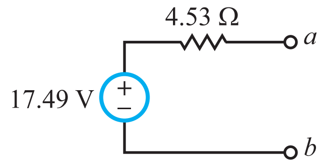


Solution is: $V_2 = 5.71$ V, $V_3 = 7.71$ V.

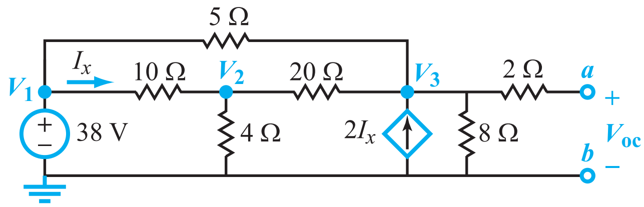
$$I_{sc} = \frac{V_3}{2} = \frac{7.71}{2} = 3.86 \text{ A}.$$

$$R_{Th} = \frac{V_{oc}}{I_{sc}} = \frac{17.49}{3.86} = 4.53\ \Omega.$$

Hence, the Thévenin circuit is


4.53 Ω
a
17.49 V
+
−
b

Problem 3.59 Find the Norton equivalent circuit of the circuit in Fig. P3.58 after increasing the magnitude of the voltage source to 38 V.



Solution:

$$V_1 = 38 \text{ V}$$

$$\frac{V_2 - V_1}{10} + \frac{V_2}{4} + \frac{V_2 - V_3}{20} = 0$$

$$\frac{V_3 - V_2}{20} + \frac{V_3}{8} + \frac{V_3 - V_1}{5} - 2I_x = 0$$

$$I_x = \frac{V_1 - V_2}{10}$$

Simultaneous solution of the above equations yields:

$$V_2 = 13.87 \text{ V}, \qquad V_3 = 35.0 \text{ V}.$$

$$V_{\text{Th}} = V_{\text{oc}} = V_3 = 35.0 \text{ V}.$$

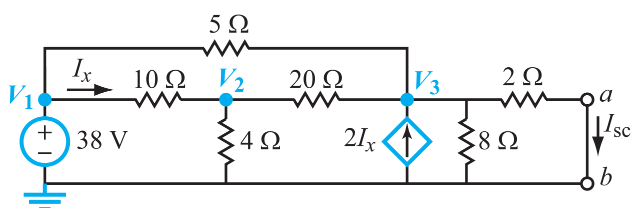
To find R_{Th}, we will calculate I_{sc}:

$$V_1 = 38 \text{ V}$$

$$\frac{V_2 - V_1}{10} + \frac{V_2}{4} + \frac{V_2 - V_3}{20} = 0$$

$$\frac{V_3 - V_2}{20} + \frac{V_3}{8} + \frac{V_3}{2} + \frac{V_3 - V_1}{5} - 2I_x = 0$$

$$I_x = \frac{V_1 - V_2}{10}$$

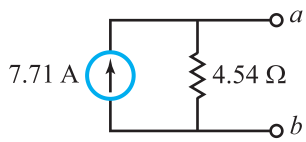


Solution is: $V_2 = 11.43$ V, $V_3 = 15.41$ V.

$$I_{\text{sc}} = \frac{V_3}{2} = \frac{15.41}{2} = 7.71 \text{ A}.$$

$$R_{\text{Th}} = \frac{V_{\text{oc}}}{I_{\text{sc}}} = \frac{35.0}{7.71} = 4.54\ \Omega.$$

Norton equivalent circuit is


7.71 A
4.54 Ω
a
b

Problem 3.65 What value of the load resistor R_L will extract the maximum amount of power from the circuit in Fig. P3.65, and how much power will that be?

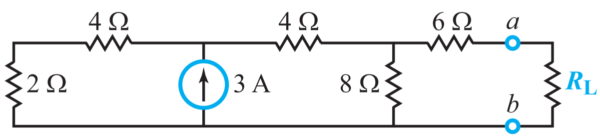


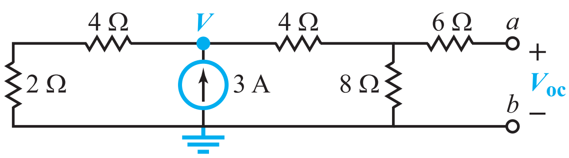
Figure P3.65: Circuit for Problem 3.65.

Solution: We start by obtaining the Thévenin equivalent circuit at terminals (a,b), as if R_L were not there. We first find V_{oc}:

$$\frac{V}{6} - 3 + \frac{V}{12} = 0$$

$$V = 12 \text{ V}.$$

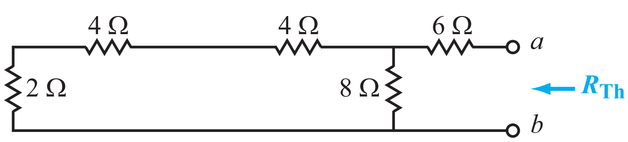
Hence,



Voltage division gives:

$$V_{Th} = V_{oc} = \left(\frac{8}{4+8}\right) V = \frac{8}{12} \times 12 = 8 \text{ V}.$$

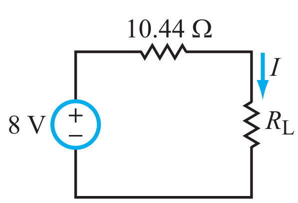
Next, we suppress the current source to find R_{Th}:



Simplification leads to:

$$R_{Th} = 10.44 \ \Omega.$$

Equivalent circuit:



For maximum power transfer to R_L,

$$R_L = R_{Th} = 10.44 \ \Omega$$

$$I = \frac{8}{2 \times 10.44} = 0.38 \text{ A}$$

$$P_{max} = I^2 R_L = (0.38)^2 \times 10.44 = 1.53 \text{ W}.$$

Problem 3.70 In the circuit shown in Fig. P3.70, a potentiometer is connected across the load resistor R_L. The total resistance of the potentiometer is $R = R_1 + R_2 = 5$ kΩ.

(a) Obtain an expression for the power P_L dissipated in R_L for any value of R_1.

(b) Plot P_L versus R_1 over the full range made possible by the potentiometer's wiper.

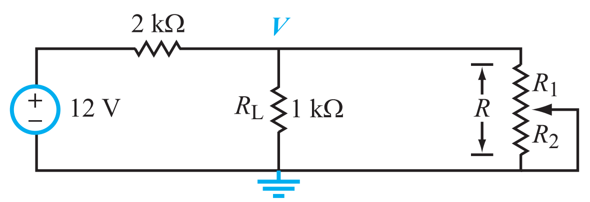


Figure P3.70: Circuit for Problem 3.70.

Solution:

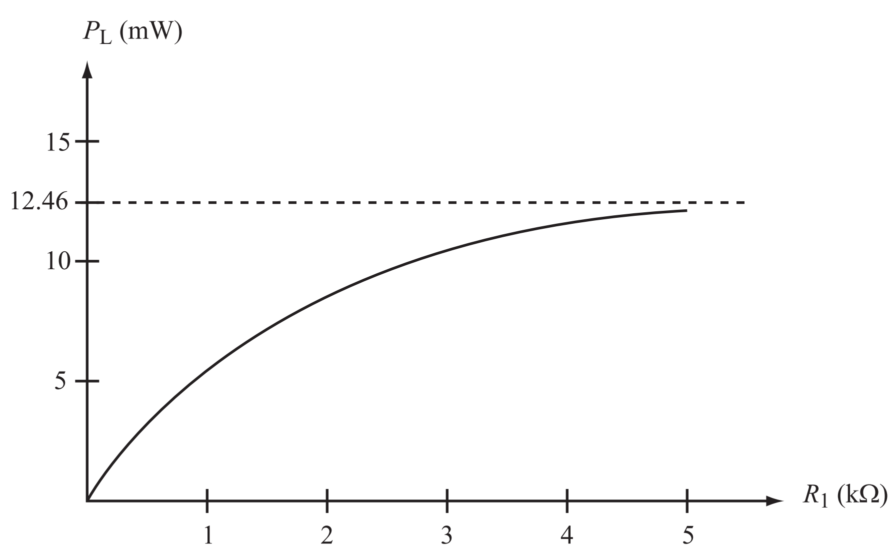
(a)

$$\frac{V-12}{2\text{k}} + \frac{V}{1\text{k}} + \frac{V}{R_1} = 0$$

$$V = \frac{12R_1}{3R_1+2}, \qquad \text{with } R_1 \text{ measured in k}\Omega.$$

$$P_L = \frac{V^2}{R_L} = \frac{V^2}{1\text{k}} = \left(\frac{12R_1}{3R_1+2}\right)^2 \times 10^{-3}$$

(b)



Problem 3.74 The circuit in Fig. P3.74 is a BJT ***common collector amplifier***. Find both the voltage gain ($A_V = V_{\text{out}}/V_{\text{in}}$) and the current gain ($A_I = I_{\text{out}}/I_{\text{in}}$). Assume $V_{\text{in}} \gg V_{\text{BE}}$.

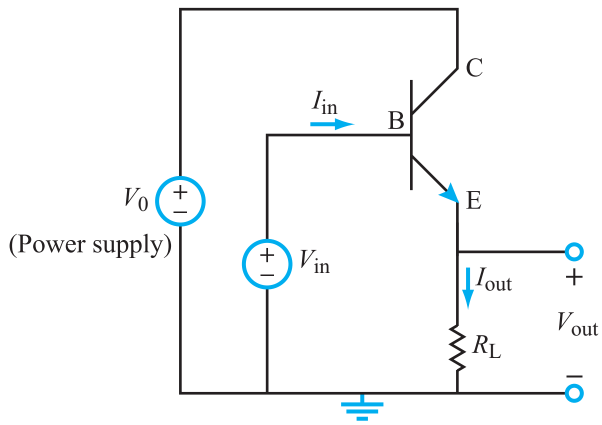


Figure P3.74: Circuit for Problem 3.74.

Solution: Upon replacing the BJT with its equivalent circuit model, we obtain the circuit shown in Fig. P3.74(b).

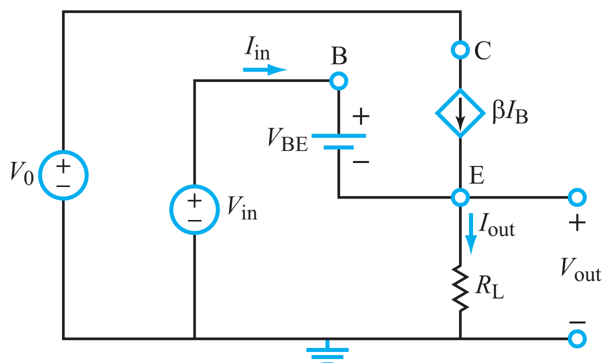


Fig. P3.74(b)

From

$$V_{\text{out}} = V_{\text{in}} - V_{\text{BE}},$$

$$A_V = \frac{V_{\text{out}}}{V_{\text{in}}} = 1 - \frac{V_{\text{BE}}}{V_{\text{in}}} \simeq 1 \qquad (\text{since } V_{\text{BE}} \ll V_{\text{in}}).$$

Also,

$$I_{\text{in}} = I_B,$$

$$I_{\text{out}} = I_{\text{in}} + \beta I_B = I_{\text{in}}(1+\beta).$$

Hence,

$$A_I = \frac{I_{\text{out}}}{I_{\text{in}}} = 1 + \beta \simeq \beta \qquad (\text{since } \beta \gg 1).$$

Problem 3.76 The circuit in Fig. P3.76 is a BJT ***common emitter amplifier***. Find V_{out} as a function of V_{in}.

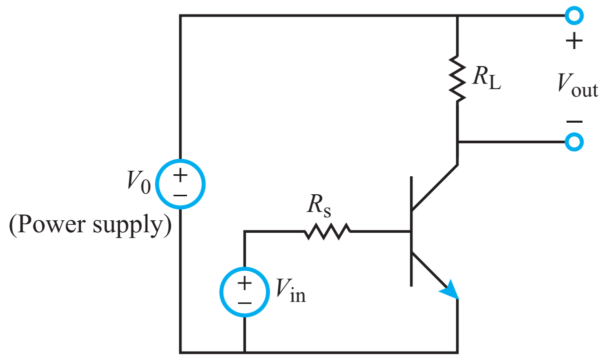


Figure P3.76: Circuit for Problem 3.76.

Solution: Upon replacing the BJT with its equivalent circuit model, we obtain the circuit in Fig. 3.76(b).

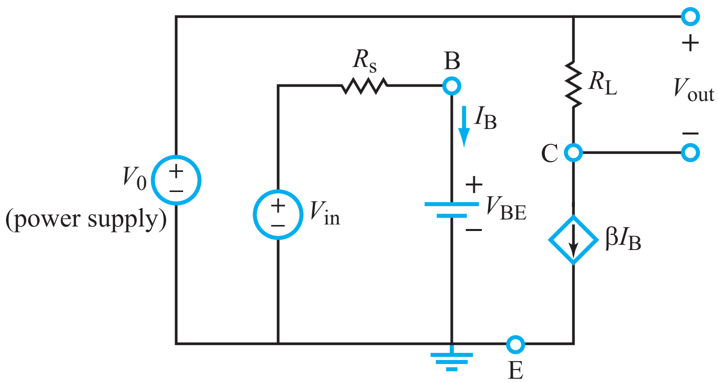


Fig. P3.76(b)

$$V_{out} = \beta I_B R_L,$$

$$I_B = \frac{V_{in} - V_{BE}}{R_s}.$$

Hence,

$$V_{out} = \beta \left(\frac{R_L}{R_s}\right)(V_{in} - V_{BE}) \simeq \left(\beta \frac{R_L}{R_s}\right) V_{in} \qquad (\text{if } V_{in} \gg V_{BE}).$$