4

3.72

Find the Norton equivalent circuit of the circuit in `Fig. P3.71` after increasing the magnitude of the voltage source to $38\ V$.

✓ **Answer**

With i_1 as the bottom left loop, i_2 as the top loop, i_3 as the center bottom loop, and i_4 is the encircling loop, and i_5 the short-loop when ab is shorted, all clockwise.

$$\begin{bmatrix} 14 & -10 & -4 & 0 \\ -10 & 35 & -20 & 5 \\ -4 & -20 & 24 & 0 \\ 0 & 5 & 0 & 13 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ -2i_1 + 2i_2 \\ i_4 \end{bmatrix} = \begin{bmatrix} 38 \\ 0 \\ v_3 \\ 38 \end{bmatrix}$$

$$I = \begin{bmatrix} -\frac{19}{14} \\ -\frac{475}{126} \\ -\frac{304}{63} \\ \frac{551}{126} \end{bmatrix}$$

$$V = \begin{bmatrix} 38 \\ 0 \\ -\frac{2204}{63} \\ 38 \end{bmatrix}$$

This makes the voltage across a and b: $\frac{2204}{63}\ V$

$$\begin{bmatrix} 14 & -10 & -4 & 0 & 0 \\ -10 & 35 & -20 & 5 & 0 \\ -4 & -20 & 24 & 0 & 0 \\ 0 & 5 & 0 & 13 & -8 \\ 0 & 0 & 0 & -8 & 10 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ -2i_1 + 2i_2 \\ i_4 \\ i_5 \end{bmatrix} = \begin{bmatrix} 38 \\ 0 \\ v_3 \\ 38 \\ 0 \end{bmatrix}$$

$$I = \begin{bmatrix} -\frac{703}{286} \\ -\frac{133}{26} \\ -\frac{760}{143} \\ \frac{2755}{286} \\ \frac{1102}{143} \end{bmatrix}$$

$$V = \begin{bmatrix} 38 \\ 0 \\ -\frac{2204}{143} \\ 38 \\ 0 \end{bmatrix}$$

This makes our current across a and b: $\frac{1102}{143}\ A$

We can then calculate our Norton equivalent: $R_N = \frac{286}{63}\ \Omega$ and $I_N = \frac{1102}{143}\ A$

3.83

Determine the maximum power that can be extracted by the load resistor from the circuit in `Fig. P3.83`.

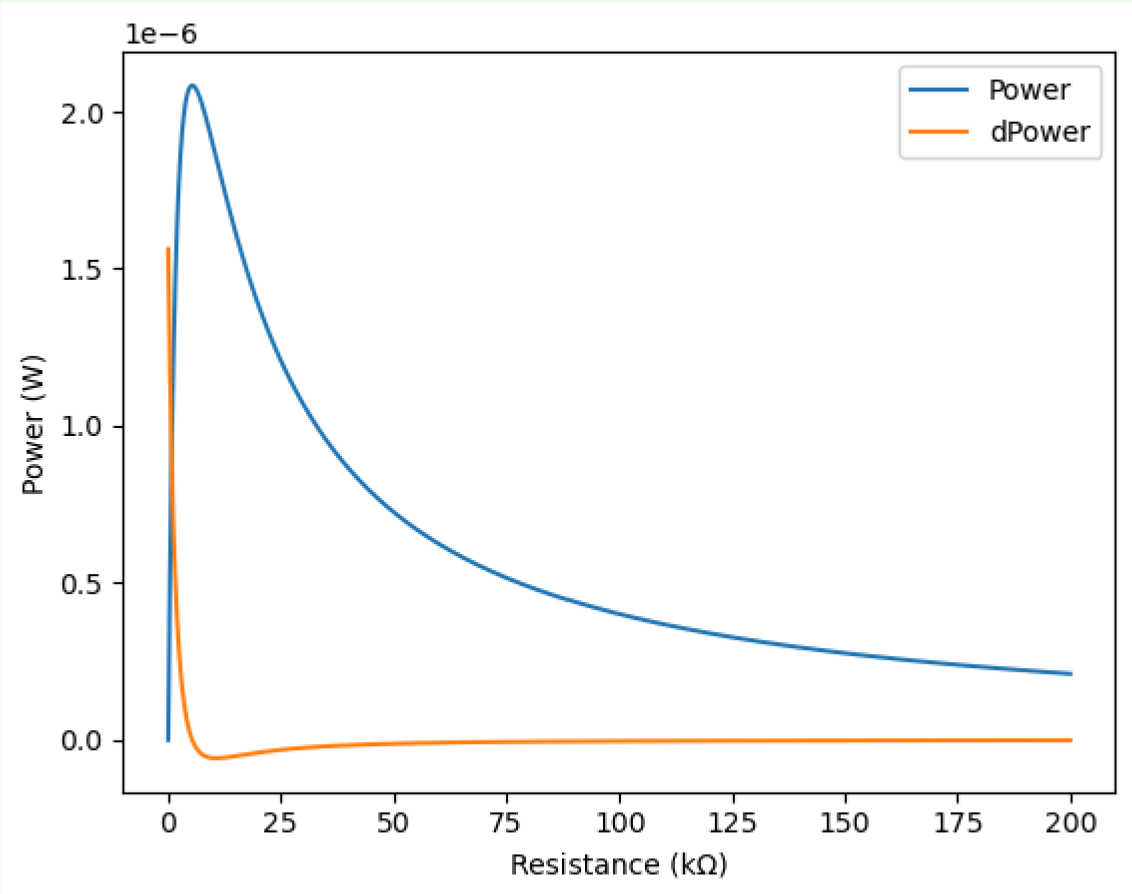
✓ **Answer**

$$\begin{bmatrix} 9000 & -6000 \\ -6000 & 1000R_L + 10000 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 15 \\ -2000i_1 + 2000i_2 \end{bmatrix}$$

$$I = \begin{bmatrix} \frac{R_L+8}{600R_L+3200} \\ \frac{1}{150R_L+800} \end{bmatrix}$$

$$P = \frac{R_L}{(150R_L+800)^2}$$

$$\frac{dP}{dR_L} = -\frac{300R_L}{(150R_L+800)^3} + \frac{1}{(150R_L+800)^2}$$



$$R_{Lmax} = \frac{16}{3}$$
$$P_{max} = \frac{1}{48000} = 2.08\ mW$$

$$[9000]\,[i_1] = [15]$$
$$i_1 = \frac{1}{600}\ A$$

$V_{Th} = (6000 - 2000)i_1 = \frac{20}{3}\ V$

$$\begin{bmatrix} 9000 & -6000 \\ -6000 & 1000R_L + 10000 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 15 \\ -2000i_1 + 2000i_2 \end{bmatrix}$$

$I_N = i_2 = \frac{1}{800}$

$\frac{V_{Th} I_N}{4} = \frac{1}{480}\ W = 2.08\ mW$

4.6

The inverting-amplifier circuit shown in `Fig. P4.6` uses a resistor R_f to provide feedback from the output terminal to the inverting-input terminal.

b

Determine the value of G for $R_s = 10\Omega$, $R_i = 10\ M\Omega$, $R_f = 1\ k\Omega$, $R_o = 50\Omega$, $R_L = 1k\Omega$, and $A = 10^6$.

✓ **Answer**

$$\begin{bmatrix} R_i + R_s & -R_s & 0 \\ -R_s & R_f + R_l + R_s & -R_l \\ 0 & -R_l & R_l + R_o \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} -V_s \\ V_s \\ -AR_i i_1 \end{bmatrix}$$

$$I = \begin{bmatrix} \frac{-R_f R_l V_s - R_f R_o V_s - R_l R_o V_s}{AR_i R_l R_s + R_f R_i R_l + R_f R_i R_o + R_f R_l R_s + R_f R_o R_s + R_i R_l R_o + R_i R_l R_s + R_i R_o R_s + R_l R_o R_s} \\ \frac{AR_i R_l V_s + R_i R_l V_s + R_i R_o V_s}{AR_i R_l R_s + R_f R_i R_l + R_f R_i R_o + R_f R_l R_s + R_f R_o R_s + R_i R_l R_o + R_i R_l R_s + R_i R_o R_s + R_l R_o R_s} \\ \frac{AR_f R_i V_s + AR_i R_l V_s + R_i R_l V_s}{AR_i R_l R_s + R_f R_i R_l + R_f R_i R_o + R_f R_l R_s + R_f R_o R_s + R_i R_l R_o + R_i R_l R_s + R_i R_o R_s + R_l R_o R_s} \end{bmatrix}$$

$$G = 1000 \frac{R_i R_o - AR_f R_i}{AR_i R_l R_s + R_f R_i R_l + R_f R_i R_o + R_f R_l R_s + R_f R_o R_s + R_i R_l R_o + R_i R_l R_s + R_i R_o R_s + R_l R_o R_s}$$

$G = -99.988891222631\ \frac{V}{V}$

c

Simplify the expression for G obtained in (a) by letting $A \to \infty$, $R_i \to \infty$, and $R_o \to 0$ (ideal op-amp model).

✓ **Answer**

$-\frac{R_f}{R_s} = -100\ \frac{V}{V}$

d

Evaluate the approximate expression obtained in (c) and compare the result with the value obtained in (b).

✓ **Answer**

They are very close, to the point of error.

3.93

Obtain an expression for V_{out} in terms of V_{in} for the common emitter-amplifier circuit in `Fig. P3.93`. Assume $V_{in} \gg V_{BE}$.

✓ **Answer**

Current through the battery: I

$I_{R_E} = (1 + \beta)I$

$I_{R_L} \rightarrow \beta I$

We assume $\beta \gg 1$

Thus, $V_{R_s} \approx 0$

Thus, $V_{R_E} = V_{in}$

$I_{R_E} \approx \beta I = I_{R_L}$

$V_{R_E} = I_{R_L} R_E = V_{in}$

$V_{out} = V_{R_L} = I_{R_L} R_L = \frac{V_{in} R_L}{R_E}$

$V_{out} = \frac{V_{in} R_L}{R_E}$

4.11

Determine the output voltage for the circuit in `Fig. P4.11` and specify the linear range for v_s, given that $V_{cc} = 15\ V$ and $V_0 = 0$.

✓ **Answer**

$\frac{-V_s}{2k} + \frac{-V_o}{200k} =$

$V_o = -100 V_s$

$G = -100\ \frac{V}{V}$

$V_{cc} = V_o$

$V_s = -\frac{15}{100} = -0.15\ V$