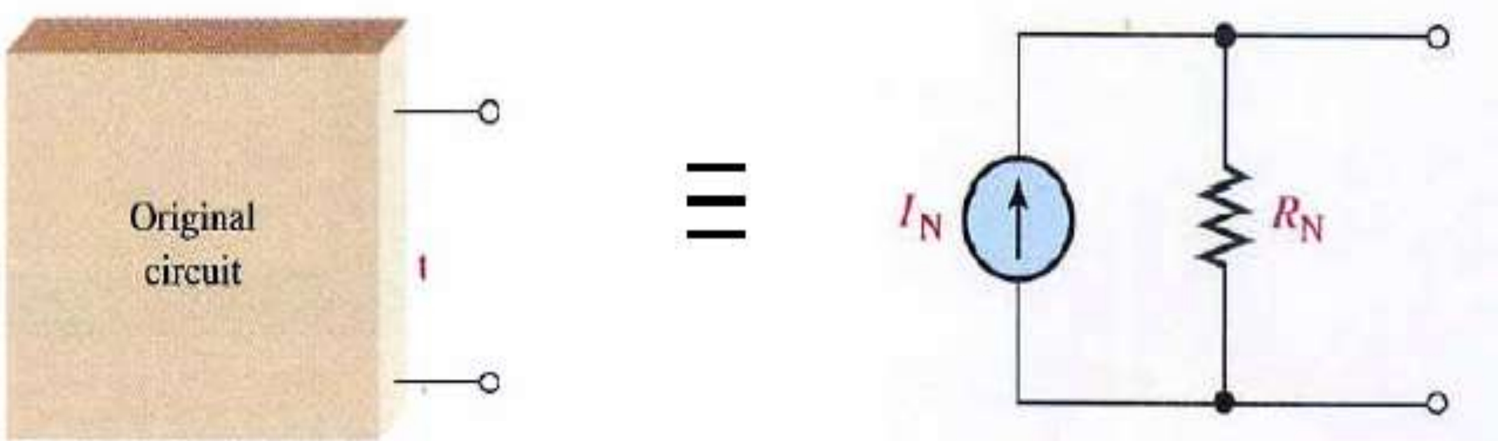
UNIT 1: DC CIRCUITS

Prepared By:
Krishan Arora
Assistant Professor and Head

Norton's Theorem

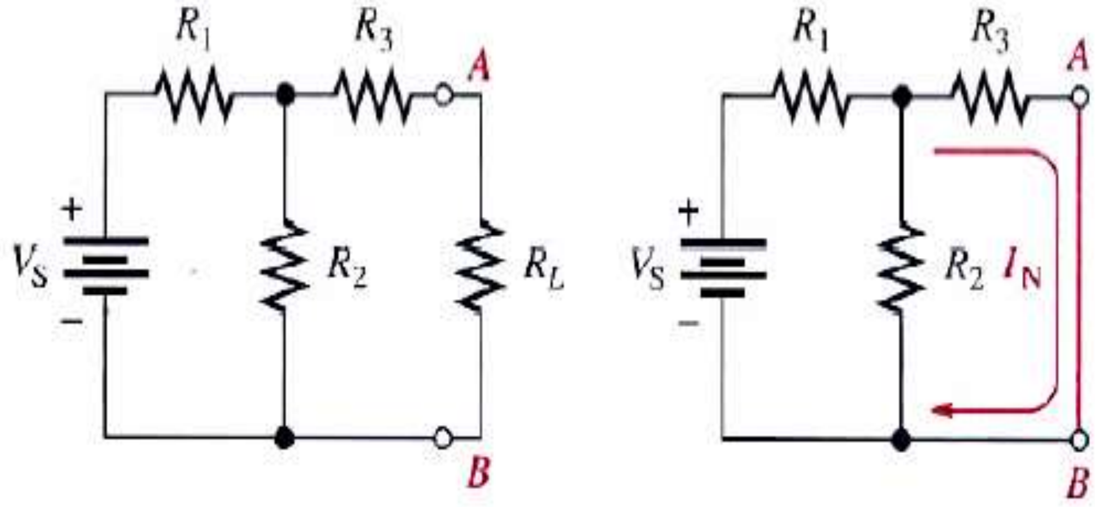
Like Thevenin's theorem, Norton's theorem provides a method of reducing a more complex circuit to a simpler equivalent form.



Norton's Theorem

Norton's Equivalent Current (I_N)

Norton's equivalent current (I_N) is the short-circuit current between two output terminals in a circuit.



(a) Original circuit

(b) Short the terminals to get I_N.

QUICK QUIZ (Poll 1)

- The Norton current is the________
  a) Short circuit current
  b) Open circuit current
  c) Open circuit and short circuit current
  d) Neither open circuit nor short circuit current

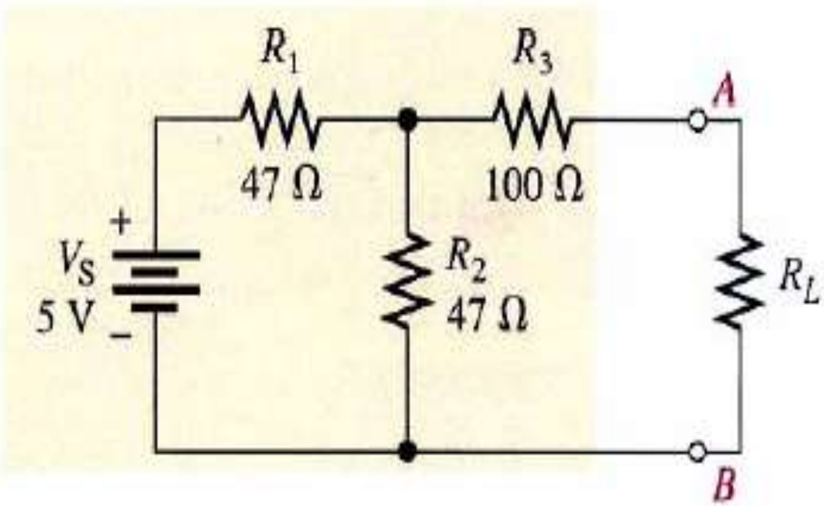
QUICK QUIZ (Poll 2)

- Norton resistance is found by?
  a) Shorting all voltage sources
  b) Opening all current sources
  c) Shorting all voltage sources and opening all current sources
  d) Opening all voltage sources and shorting all current sources

Norton's Theorem

Norton's Equivalent Current (I_N)

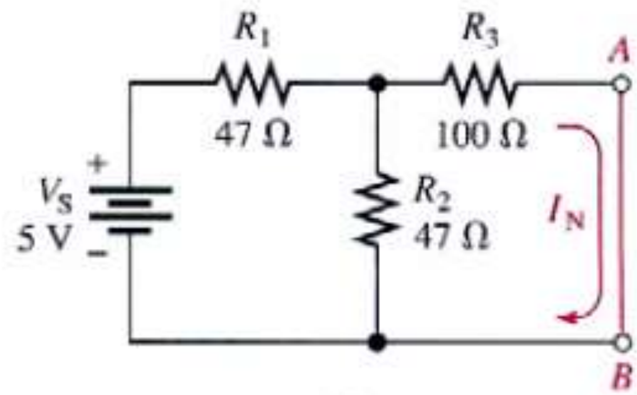
EXAMPLE Determine I_N for the circuit within the beige area.



(a)

Norton's Theorem

Norton's Equivalent Current (I_N)



(b)

Solution

Short terminals A and B. I_N is the current through the short. First, the total resistance seen by the voltage source is

$$R_T = R_1 + \frac{R_2R_3}{R_2 + R_3} = 47\ \Omega + \frac{(47\ \Omega)(100\ \Omega)}{147\ \Omega} = 79\ \Omega$$

The total current from the source is

$$I_T = \frac{V_S}{R_T} = \frac{5\ \text{V}}{79\ \Omega} = 63.3\ \text{mA}$$

Now apply the current-divider formula to find I_N (the current through the short).

$$I_N = \left(\frac{R_2}{R_2 + R_3}\right)I_T = \left(\frac{47\ \Omega}{147\ \Omega}\right)63.3\ \text{mA} = \mathbf{20.2\ mA}$$

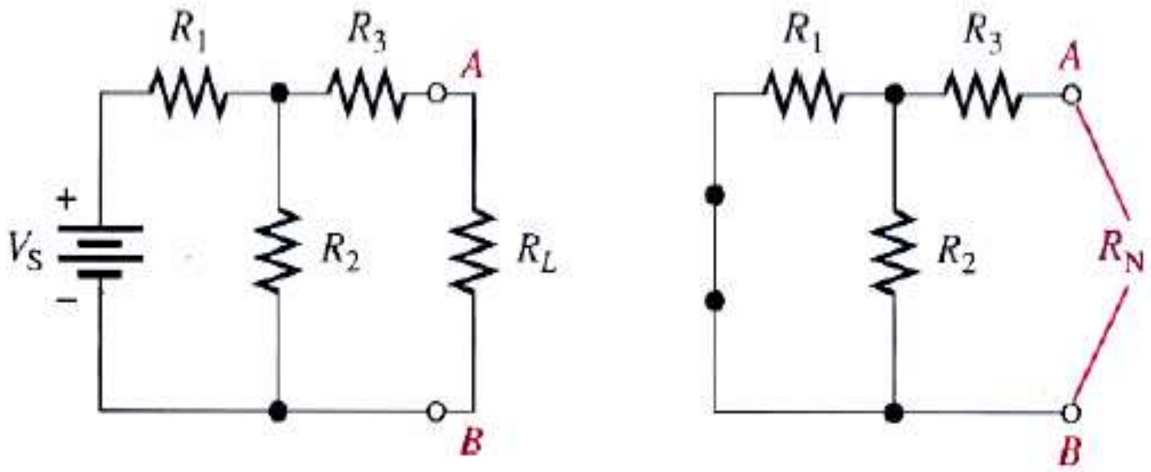
This is the value for the equivalent Norton current source.

Norton's Theorem

Norton's Equivalent Resistance (R_N)

Norton's equivalent resistance (R_N) is defined in the same way as R_{TH}.

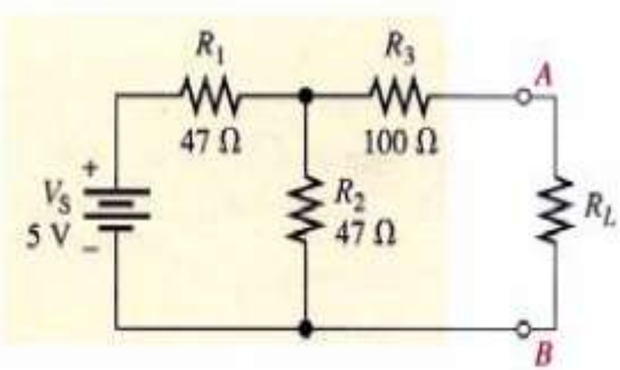
The Norton equivalent resistance, R_N, is the total resistance appearing between two output terminals in a given circuit with all sources replaced by their internal resistances.

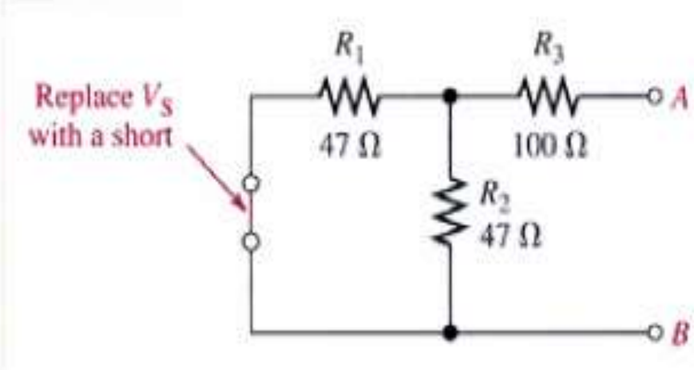


Norton's Theorem

Norton's Equivalent Resistance (R_N)

EXAMPLE Find R_N for the circuit within the beige area





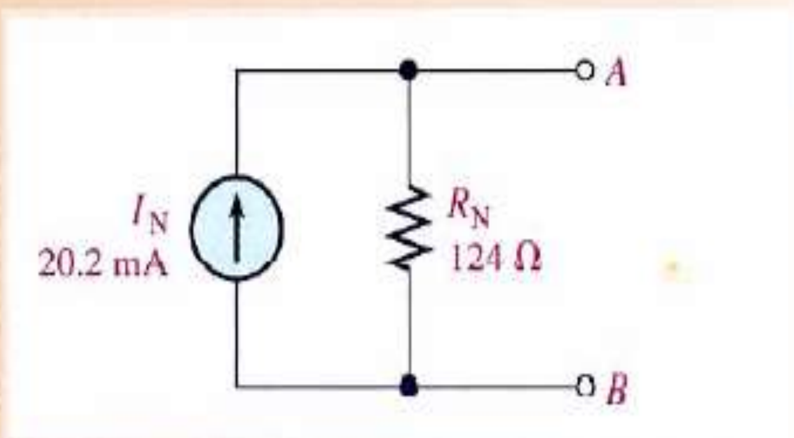
Solution

$$R_N = R_3 + \frac{R_1}{2} = 100\ \Omega + \frac{47\ \Omega}{2} = \mathbf{124\ \Omega}$$

Norton's Theorem

EXAMPLE Draw the complete Norton equivalent circuit for the original circuit that $I_N = 20.2$ mA and $R_N = 124\ \Omega$.

Solution



Norton's Theorem

Summary of Norton's Theorem

Step 1. Short the two terminals between which you want to find the Norton equivalent circuit.

Step 2. Determine the current (I_N) through the shorted terminals.

Step 3. Determine the resistance (R_N) between the two open terminals with all sources replaced with their internal resistances (ideal voltage sources shorted and ideal current sources opened). $R_N = R_{TH}$.

Step 4. Connect I_N and R_N in parallel to produce the complete Norton equivalent for the original circuit.

QUICK QUIZ (Poll 3)

- Norton’s theorem is true for ___________
  a) Linear networks
  b) Non-Linear networks
  c) Both linear networks and nonlinear networks
  d) Neither linear networks nor non-linear networks

QUICK QUIZ (Poll 4)

Short circuit current Isc is found across the _______________ terminals of the network.

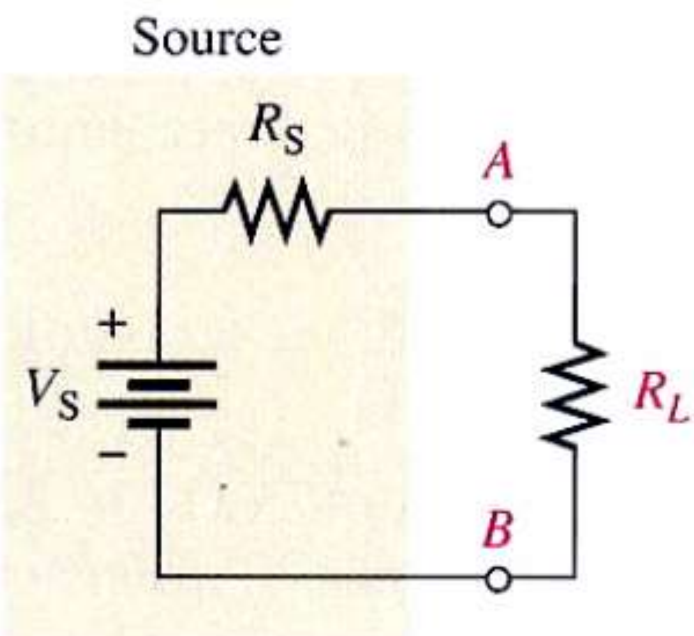
a) Input
b) Output
c) Neither input nor output
d) Either input or output

Maximum Power Transfer Theorem

The maximum power transfer theorem is important when you need to know the value of the load at which the most power is delivered from the source.

The **maximum power transfer** theorem is stated as follows:

For a given source voltage, maximum power is transferred from a source to a load when the load resistance is equal to the internal source resistance.



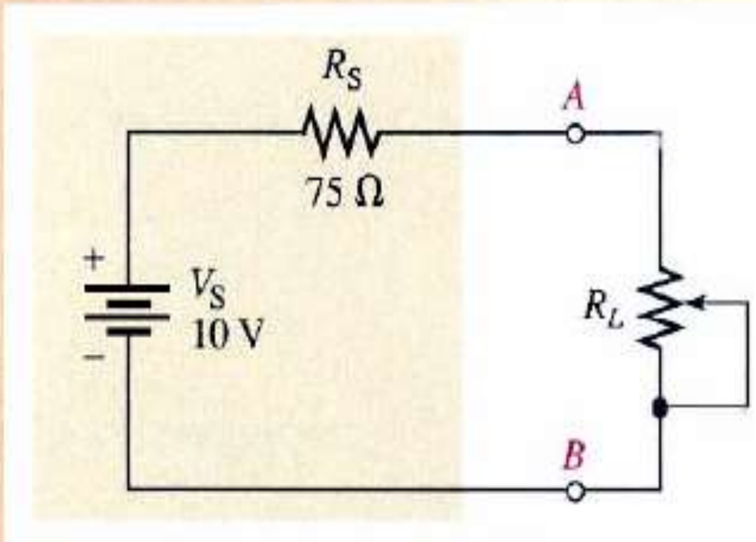
Maximum power is transferred to the load when $R_L = R_S$.

Maximum Power Transfer Theorem

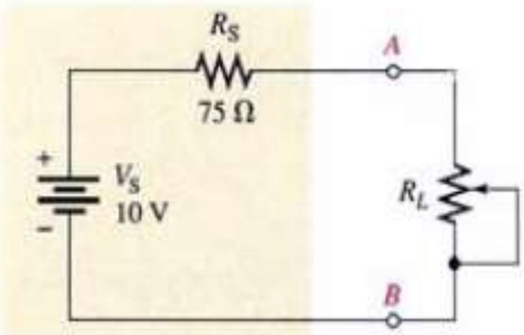
EXAMPLE The source has an internal source resistance of 75 Ω. Determine the load power for each of the following values of load resistance:

(a) 0 Ω **(b)** 25 Ω **(c)** 50 Ω **(d)** 75 Ω **(e)** 100 Ω **(f)** 125 Ω

Draw a graph showing the load power versus the load resistance.



Maximum Power Transfer Theorem



Solution

Use Ohm's law ($I = V/R$) and the power formula ($P = I^2R$) to find the load power, P_L, for each value of load resistance.

(a) For $R_L = 0\ \Omega$,

$$I = \frac{V_S}{R_S + R_L} = \frac{10\text{ V}}{75\ \Omega + 0\ \Omega} = 133\text{ mA}$$

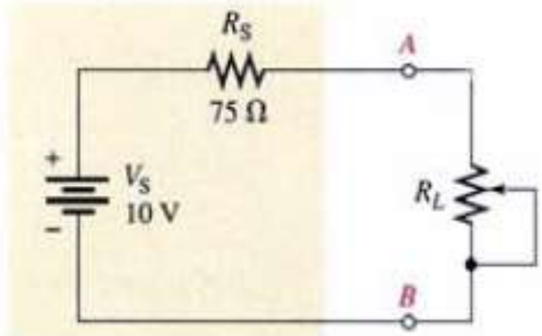
$$P_L = I^2R_L = (133\text{ mA})^2(0\ \Omega) = \mathbf{0\ mW}$$

(b) For $R_L = 25\ \Omega$,

$$I = \frac{V_S}{R_S + R_L} = \frac{10\text{ V}}{75\ \Omega + 25\ \Omega} = 100\text{ mA}$$

$$P_L = I^2R_L = (100\text{ mA})^2(25\ \Omega) = \mathbf{250\ mW}$$

Maximum Power Transfer Theorem



(c) For $R_L = 50\ \Omega$,

$$I = \frac{V_S}{R_S + R_L} = \frac{10\ \text{V}}{125\ \Omega} = 80\ \text{mA}$$

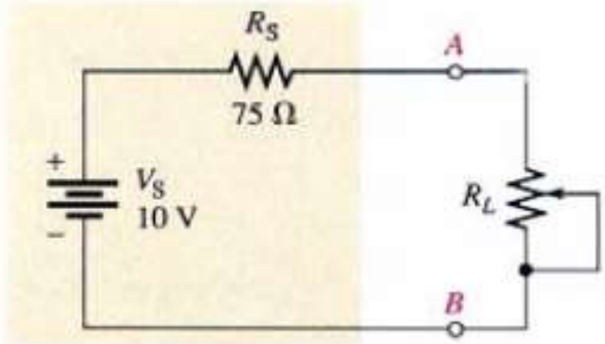
$$P_L = I^2 R_L = (80\ \text{mA})^2(50\ \Omega) = \mathbf{320\ mW}$$

(d) For $R_L = 75\ \Omega$,

$$I = \frac{V_S}{R_S + R_L} = \frac{10\ \text{V}}{150\ \Omega} = 66.7\ \text{mA}$$

$$P_L = I^2 R_L = (66.7\ \text{mA})^2(75\ \Omega) = \mathbf{334\ mW}$$

Maximum Power Transfer Theorem



(e) For $R_L = 100\ \Omega$,

$$I = \frac{V_S}{R_S + R_L} = \frac{10\text{ V}}{175\ \Omega} = 57.1\text{ mA}$$

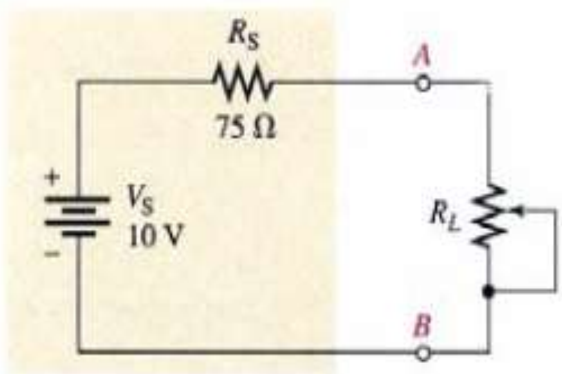
$$P_L = I^2R_L = (57.1\text{ mA})^2(100\ \Omega) = \mathbf{326\ mW}$$

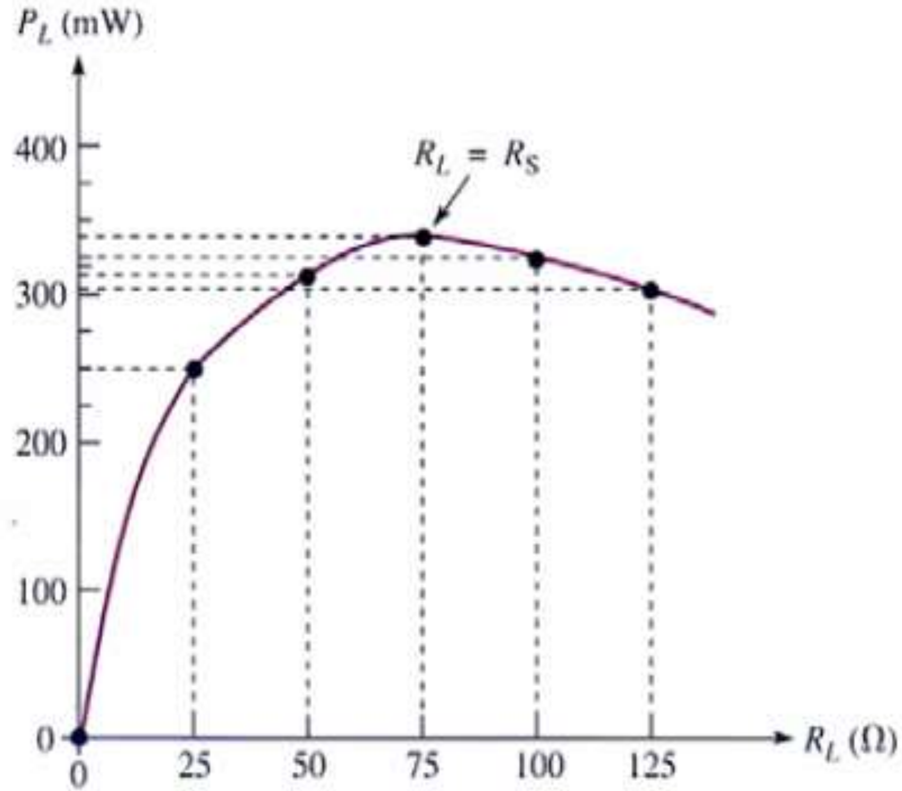
(f) For $R_L = 125\ \Omega$,

$$I = \frac{V_S}{R_S + R_L} = \frac{10\text{ V}}{200\ \Omega} = 50\text{ mA}$$

$$P_L = I^2R_L = (50\text{ mA})^2(125\ \Omega) = \mathbf{313\ mW}$$

Maximum Power Transfer Theorem





The load power is greatest when $R_L = 75\ \Omega$, which is the same as the internal source resistance.

QUICK QUIZ (Poll 5)

- For maximum transfer of power, internal resistance of the source should be

A. Equal to the load resistance

B. Less than the load resistance

C. Greater than the load resistance

D. None of the above