# Electric Circuits

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# Summary of Lecture 1 and 2

**1. Define charge, current, voltage, resistance and power**

**2. Combine resistors in series and parallel**

$$R_{series} = R_1 + R_2 + R_3 + \ldots \qquad \frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

**3. Use dimensional analysis to verify the consistency of equations involving these quantities**

**4. Use the voltage divider and current splitter to analyse simple circuits**

$$V_2 = V \frac{R_2}{R_1 + R_2}, I_2 = I \frac{R_1}{R_1 + R_2}$$

***5. State Kirchhoff's laws and apply them to construct a set of simultaneous equations to find the unknown current in a circuit.***

# Lecture 3

- **Aims and Objectives**

  **In this lecture we will be looking at source characteristics and the consequences of internal resistance.**

- **Material covered**

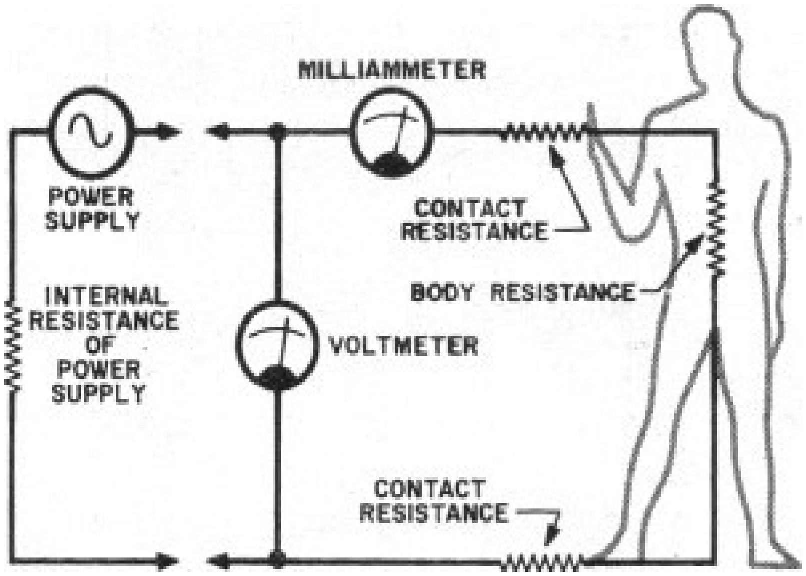
  **Ideal source characteristics.**

  **Real (practical) source characteristics.**

  **Maximum power transfer theorem.**

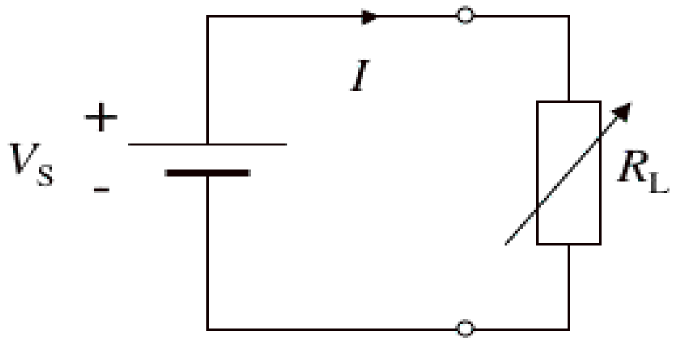
  **Thévenin's theorem.**

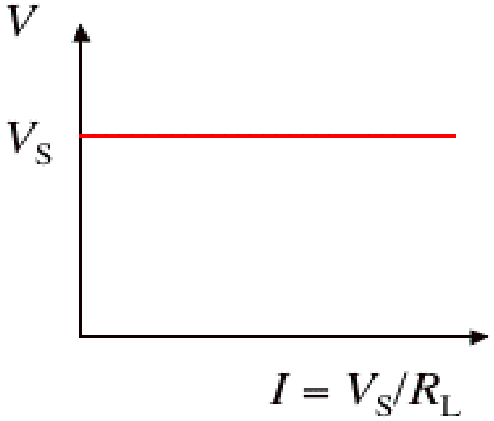
  **Thévenin's procedure and examples.**



# The I-V characteristics of ideal sources

## IDEAL VOLTAGE SOURCE

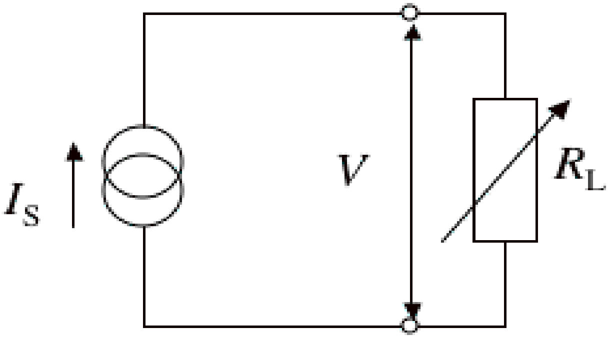


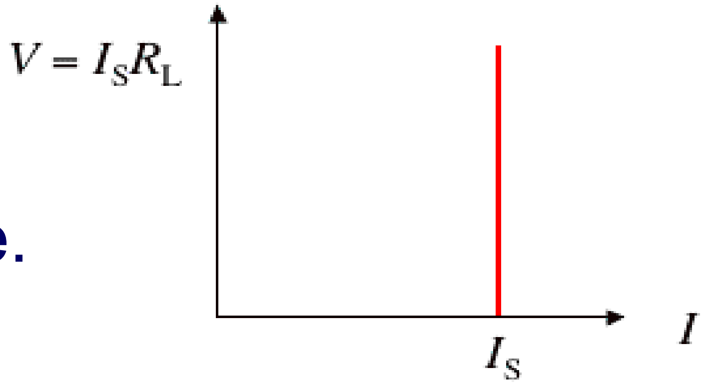

- Constant potential difference.
- The current drawn drawn from the voltage source depends on the load resistance.

# The I-V characteristics of ideal sources

## IDEAL CURRENT SOURCE




- Constant current.
- The potential difference across the current source depends on the load resistance.



# What happens if...

**Constant voltage**

$R_L = 0$ ?

$I = ?$

Infinite energy!

$I = \infty$ !!!

$V = \infty$ !!!

**Constant current**

$R_L = \infty$ ?

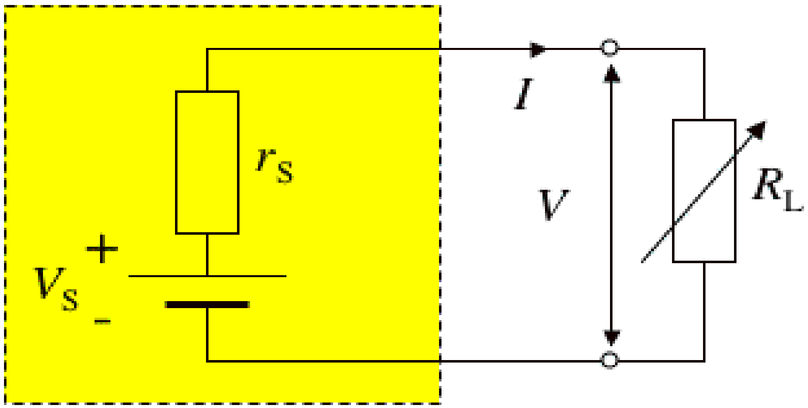
$V = ?$

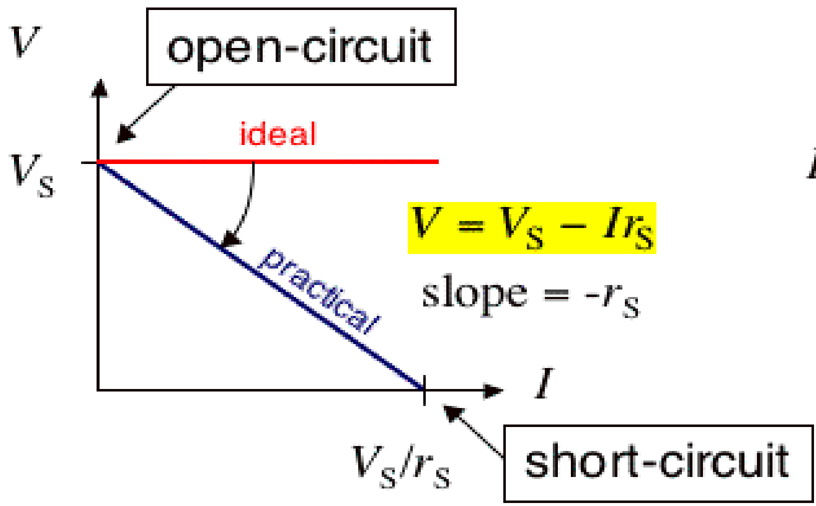


Real sources have internal resistance

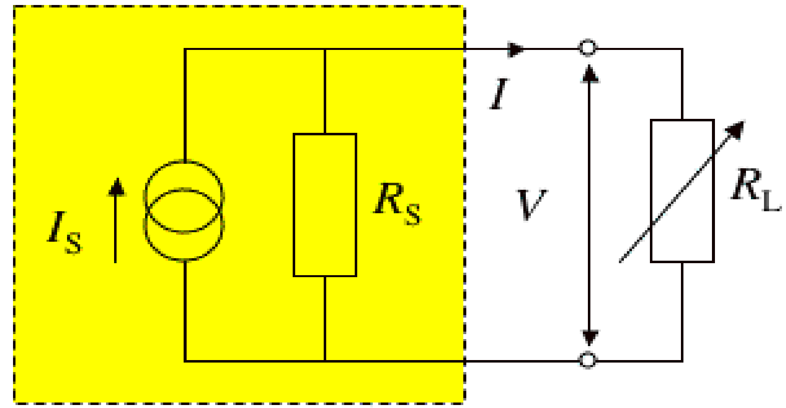
# Real (practical) source characteristics

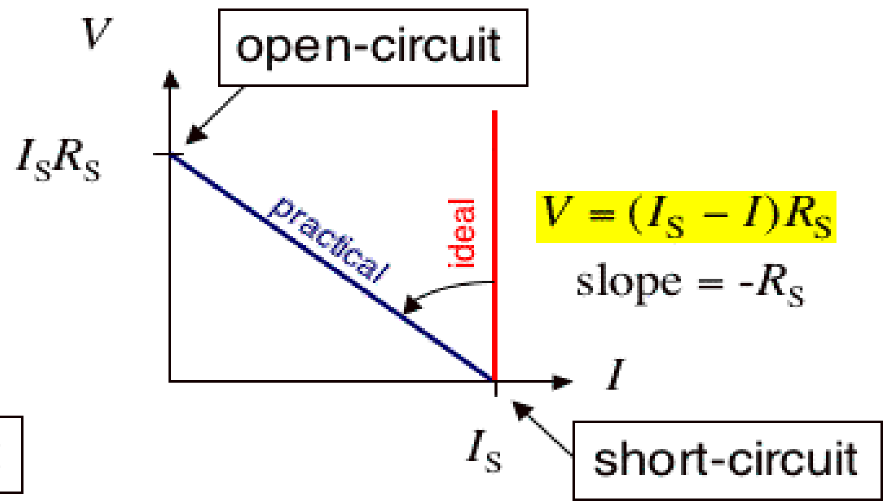
- **Practical voltage source**



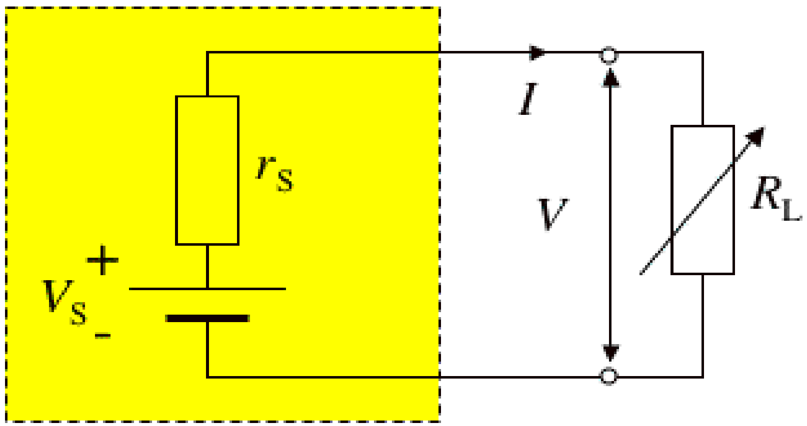

- **Practical current source**

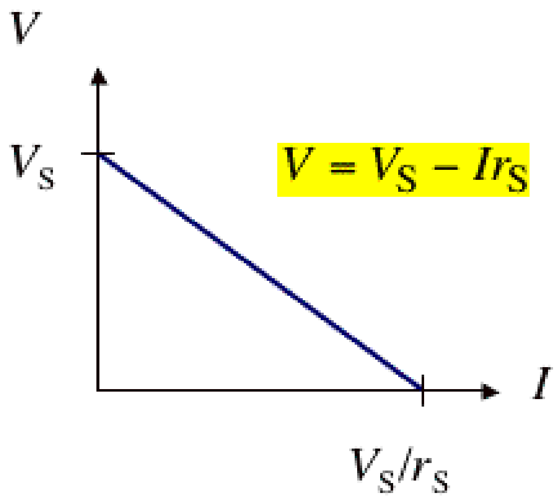


# Maximum power transfer theorem

- Practical voltage source




- Power in the load

$$P_L = I^2 R_L = \left(\frac{V_S}{r_S + R_L}\right)^2 R_L$$

For max or min $\dfrac{dP_L}{dR_L} = 0$

***Result $R_L$=$r_S$*** , *For the detailed calculation see 03_Lecture_Notes on Canvas*

- Power transfer efficiency

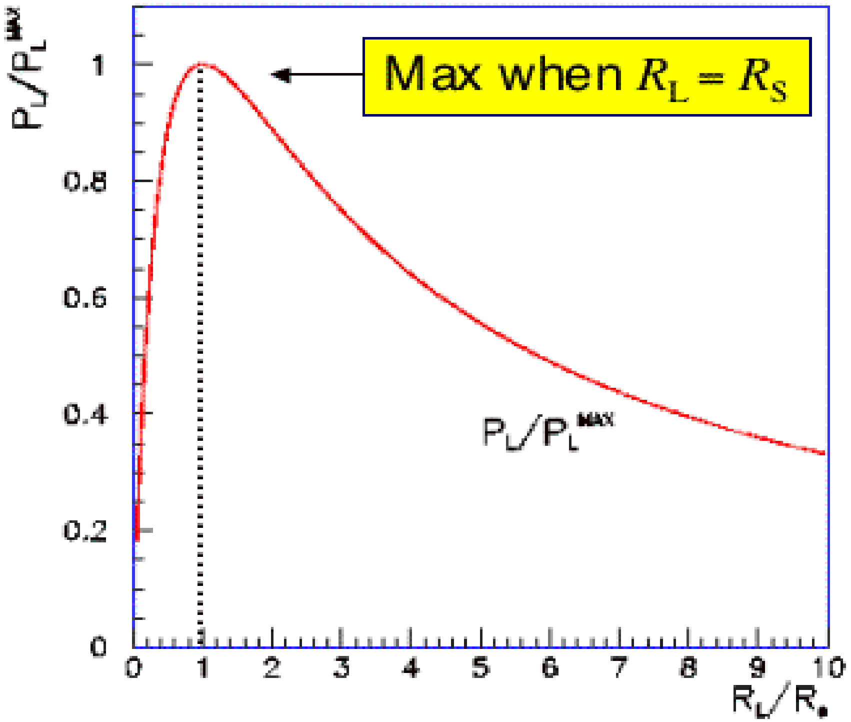
$$\eta = \frac{P_L}{P_{TOT}} = \frac{I^2 R_L}{I^2 (r_S + R_L)}$$

$$\eta = \frac{R_L}{(r_S + R_L)}$$

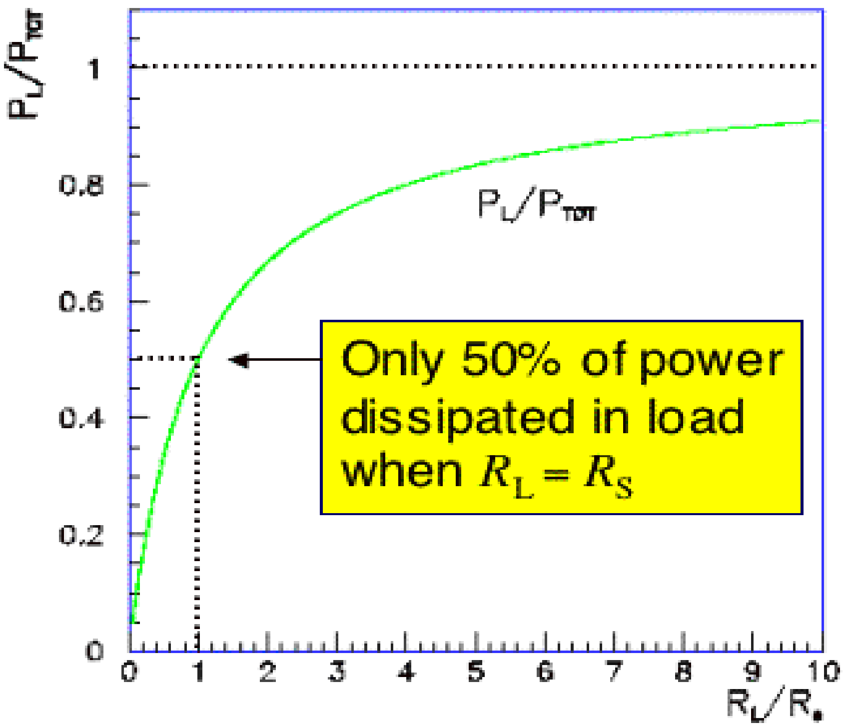
$P_L^{MAX}(R_L = r_S) \rightarrow$ *"impedance matching"*

# Power transfer and power transfer efficiency

- **Power transfer**




- **Transfer efficiency ($\eta$)**

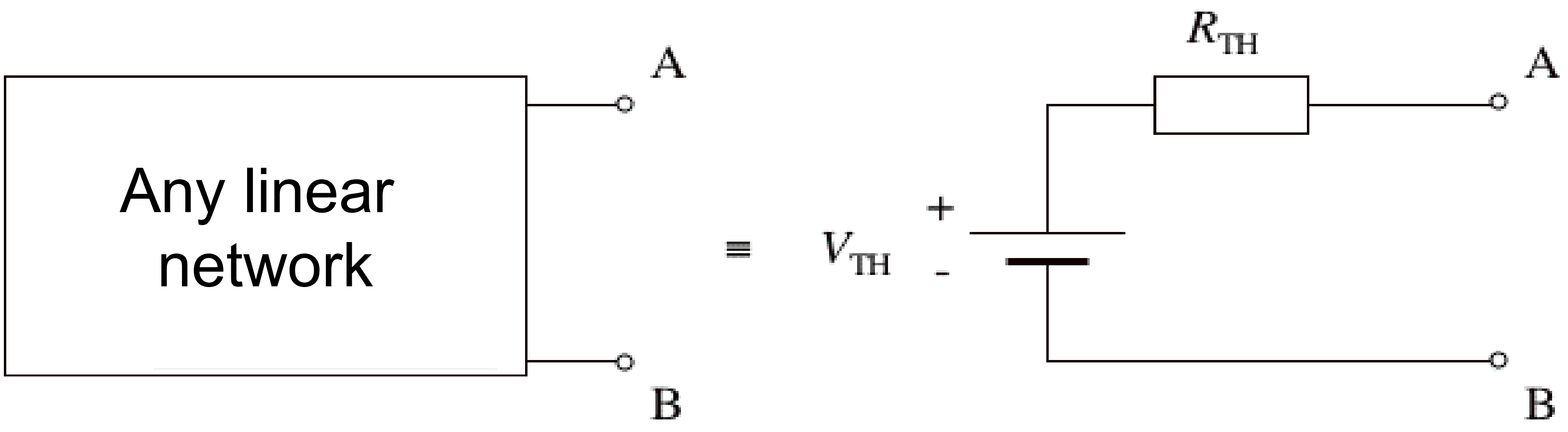



Maximum power is delivered to the load when when $R_L = R_S$.
But, only 50% of the power delivered by the battery is dissipated in the load.

# Equivalent circuits

- **Thévenin's theorem**

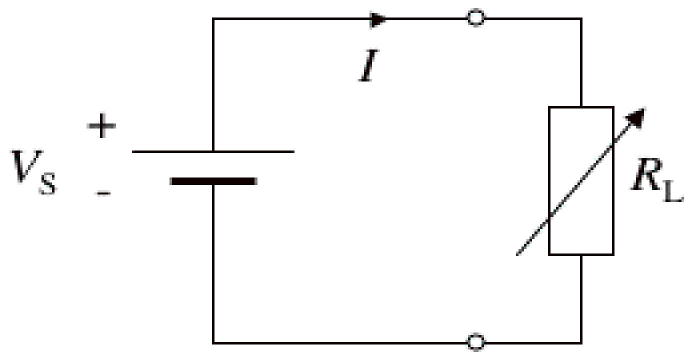
Any linear network of voltage and current sources and resistors with output terminals, can be replaced at those terminals by a single voltage generator in series with a single resistor (i.e. a practical voltage source).



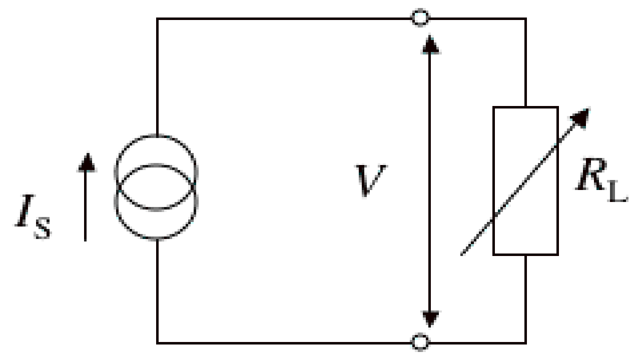

$V_{TH}$ is the open circuit voltage between the terminals A and B.
$R_{TH}$ is the resistance looking back into the terminals A and B.
when all generators are removed.
(Voltage generators → s/c, Current generators → o/c)

# Removing sources

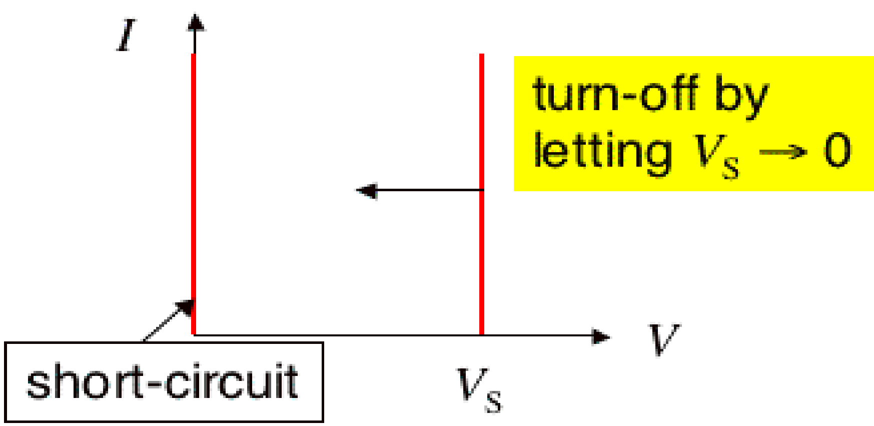
- Ideal voltage source
- Ideal current source

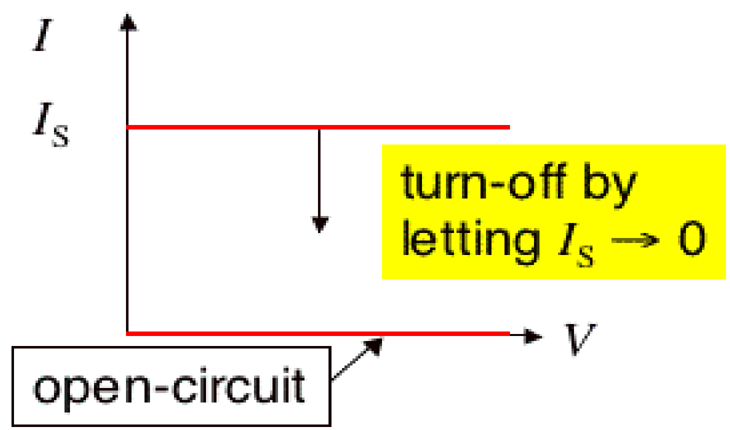



$V_S$ constant for any load




$I_S$ constant for any load



# Thévenin's procedure example

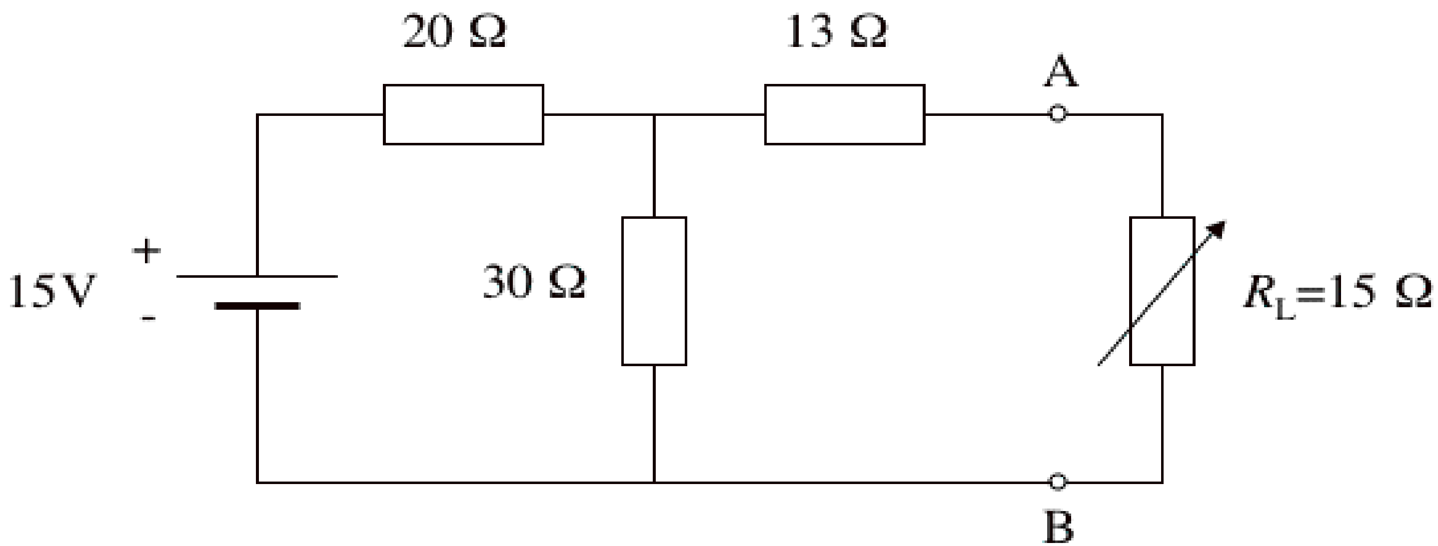
- **Use Thévenin's theorem to find the current in the variable load and the maximum power than can be transferred.**

Method: 1. Remove the load resistor, $R_L$.

2. Find the Thévenin equivalent of the remaining circuit.

3. Replace the load resistor.

4. Maximum power is transferred when $R_L = R_{TH}$.




Answer: $I = 0.225$ A, $P = 0.81$ W when $R_L = 25\ \Omega$

# Thévenin example 2

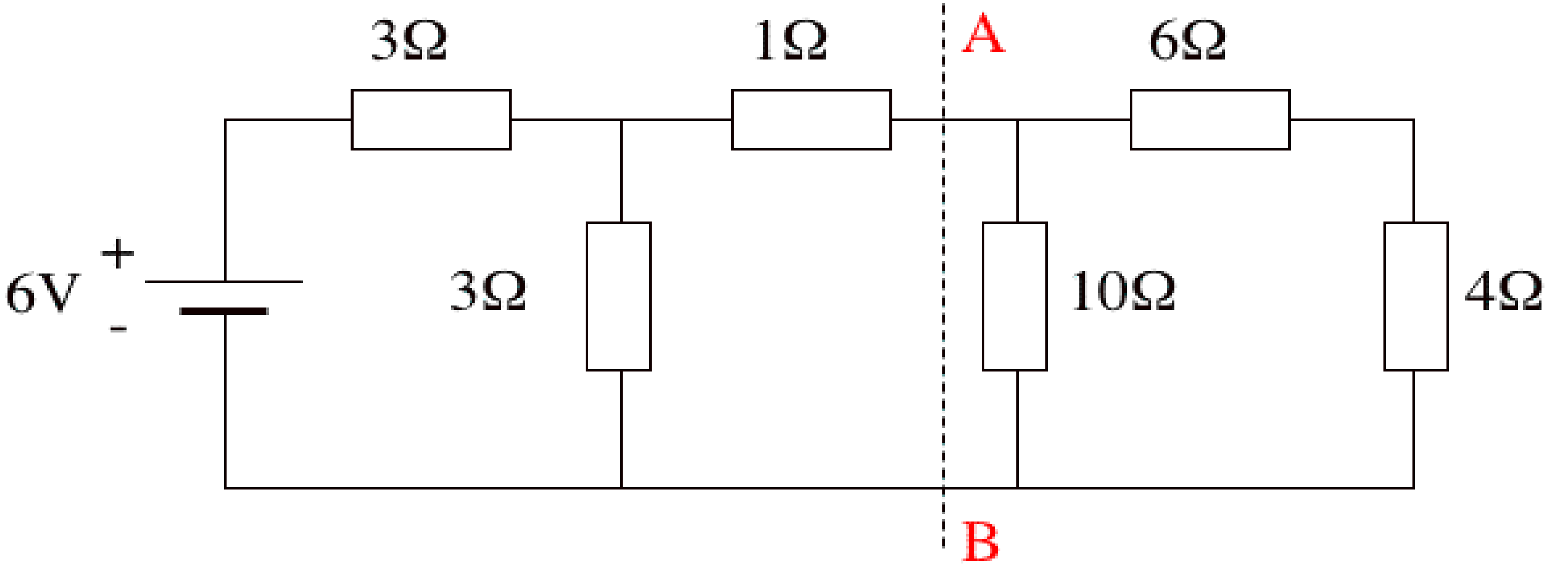

- **Find the current in the 10Ω resistor**

Method: 1. find the Thévenin equivalent of the circuit to the left of AB

2. combine the resistances to the right of AB

3. calculate the current drawn by the combined resistances

4. use the current divider rule to find the current in the 10 Ω




Answer: $V_{TH} = 3$ V, $R_{TH} = 2.5$ Ω, $I_{10\Omega} = 0.2$ A

# Summary of Lecture 3

**At the end of this lecture you should be able to:**

1. **Understand the conditions for maximum power transfer to an external circuit by a practical generator.**

2. **Quote Thevenin's theorem and understand how to derive the Thevenin's equivalent circuit.**

3. **Apply Thevenin's theorem in order to simplify the analysis of complex networks when only the current in part of the circuit (usually the load) is required.**

*Further reading: Powell Chapters 3.6 and 3.7*
*Tipler 25-3:Energy in electric circuit*