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Exercise:
Resistors, Capacitors, Thévenin

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Exercise 1: Electric Car

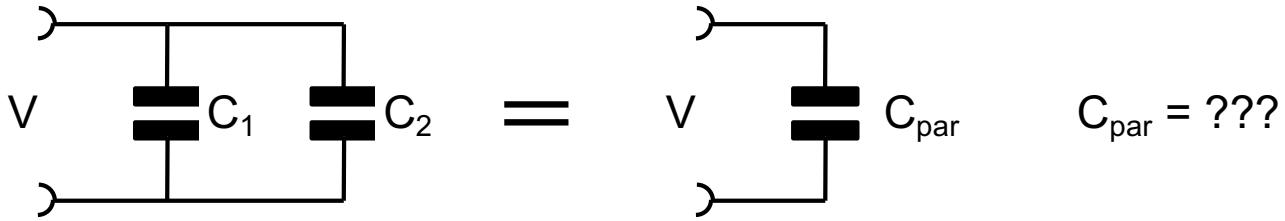
- An electric car has a battery of E_{Bat} = 50 kWh and operates at a voltage of V_{Bat}. Assume V_{Bat} = 100 V for a start.
- It is charged from an ideal voltage source (of V_{Bat}) through a pair of L_{Cable} = 2 × 3 m long copper cables of massive cylindrical shape with D_{cable} = 1 cm diameter.
- The resistivity of copper is $\rho_{Cu} = 1.68 \times 10^{-8}$ Ωm.

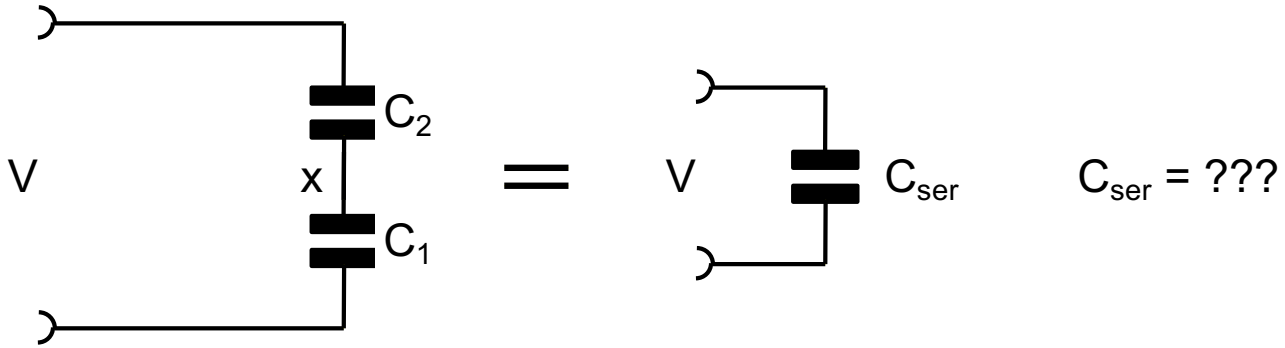
- How much current would you need to load an empty battery fully in 15 Minutes (if the battery would support that..)?
- How much voltage drop does this current produce in the cable? So what fraction of energy is lost in the cable?
- What power (in Watt) is dissipated in the cable?

- How does this change for V_{Bat} = 500 V?

Exercise 2

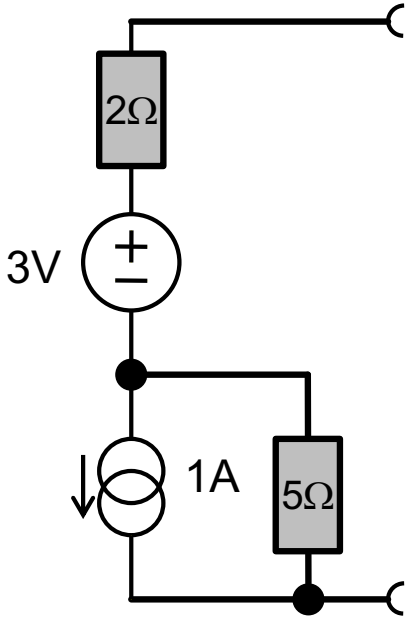
- Derive the expressions for the series and parallel connection of capacitors
- Use charge conservation (at node x)





Exercise 3

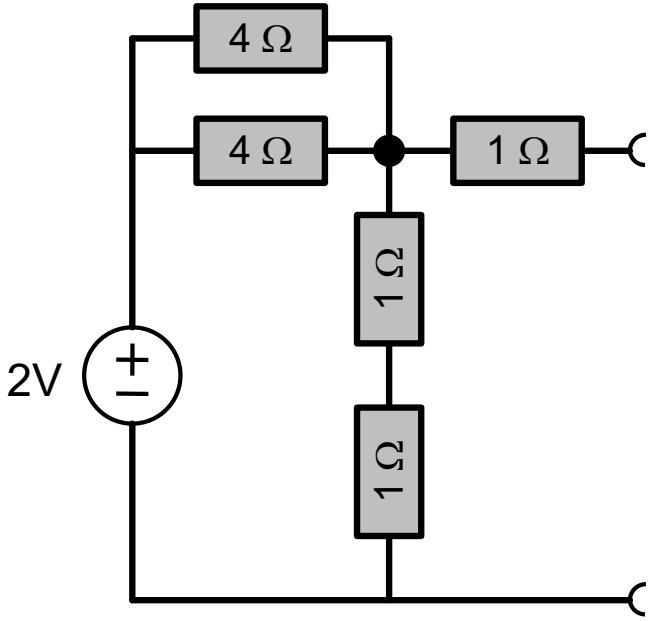
- Derive the Thévenin Equivalent for the following circuit:



- Try two different methods:
  - Use the Open/Short method with Kirchhoff's rules
  - Convert the I-source part to a voltage source first…

Exercise 4

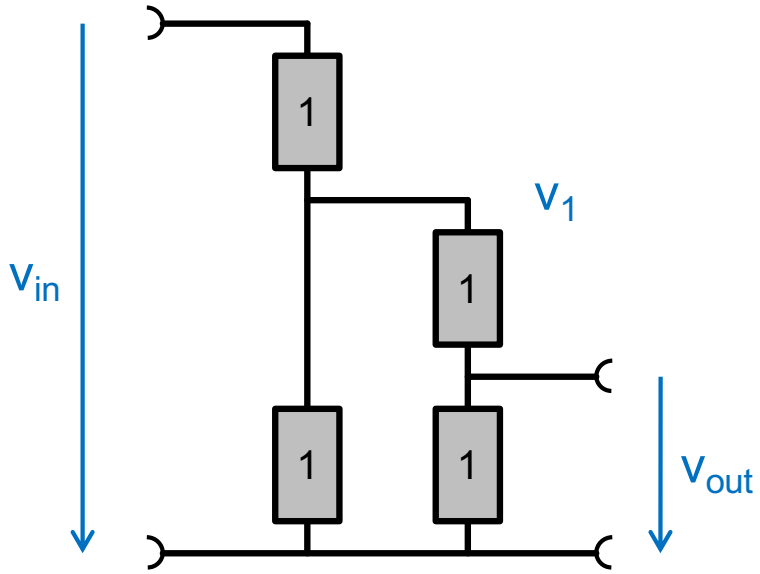
- What is the Thévenin Equivalent of the following circuit?



- Use two methods to find the result:
  - parallel / series connection of resistors and your knowledge about the voltage divider
  - short/open method

Exercise 5

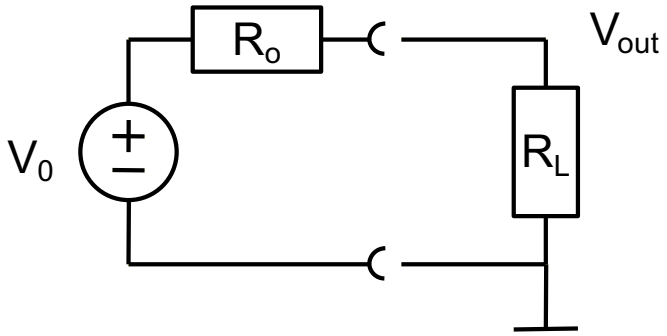
- What is the ‘gain’ (attenuation) of the following voltage divider (all resistors have 1 Ohm):



- Try 3 different methods:
  - Your knowledge of parallel / serial connection of resistors
  - Kirchhoff’s law
  - Use your knowledge about the Thévenin equivalent of a voltage divider

Exercise 6

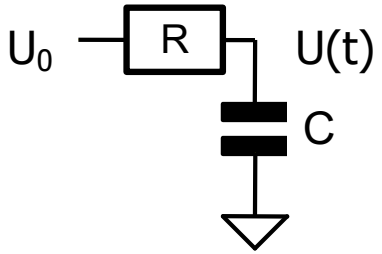
- A voltage source with voltage V_0 and output resistance R_0 is loaded by a resistor R_L:

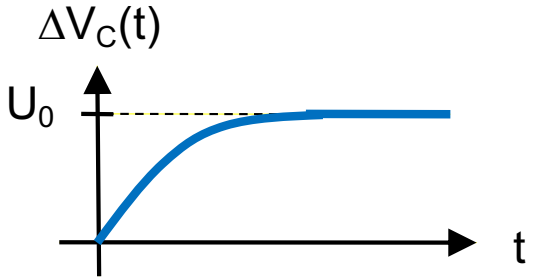


- What is the output voltage V_{out} ?
- Which current flows in R_L ?
- What power (P = U I) is dissipated in R_L ?
  - Check that noting is dissipated for R_L=0 and $R_L \rightarrow \infty$
- For which value of R_L is the dissipation maximized?
  - What is the dissipation?

Exercise 7

- We consider charging of a capacitor C though a resistor R to a voltage U_0.

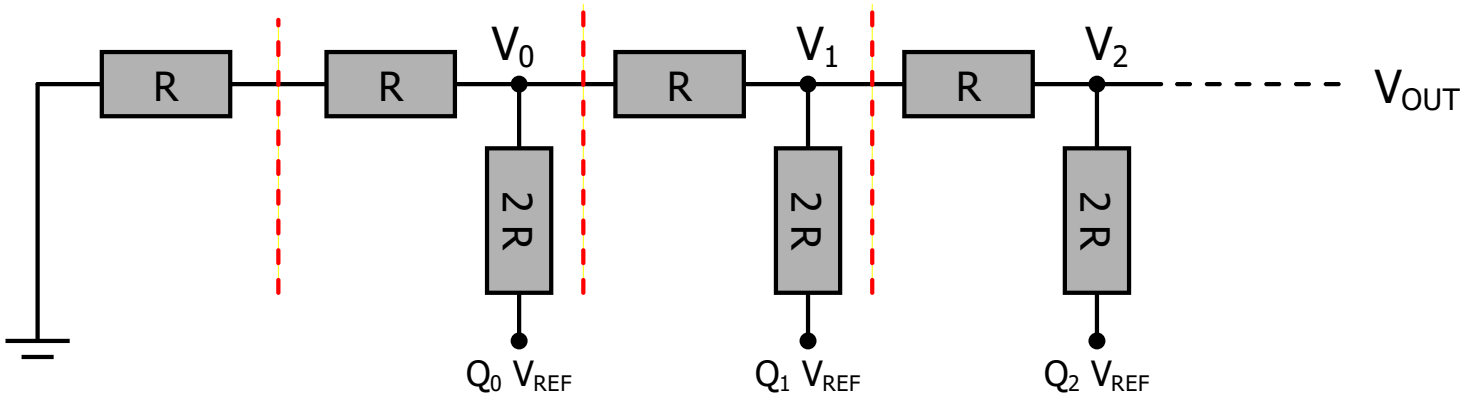




- Show that $U(t) = U_0 - U_0\, e^{-\frac{t}{RC}}$ satisfies the differential equation
- Simplify U(t) for small times t<<RC.
- What is the initial slope ?
- Derive this slope directly (assuming U(0) = 0).

Exercise 8: R-2R DAC

- Digital-Analog-Converters (DACs) convert a digital (normally binary coded) value into a voltage (or current) which is a normally proportional to the digital value.
- A simple circuit is the R-2R DAC:



  - The input voltages at the lower side of the 2R resistors is either 0V or some V_{REF}, depending of the binary bit (Q_0 is the Least Significant Bit, LSB).
- Show that the output voltage of a R-2R DAC with an arbitrary number N of bits is proportional to Q!
  - Hint: Replace the circuit by Thévenin equivalents at the red lines from left to right.