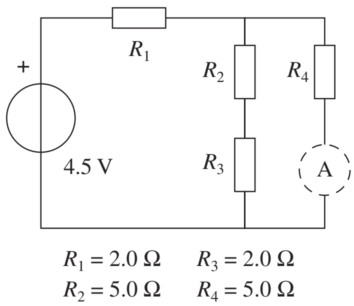
Exercises

Introductory_Problems	Electricity 1	3, 5, 6, 7, 9, 11, 16, 17
Exam_2000_01		1, 2, 6, 7, 10
Exam_2001_01		4
Exam_2001_02		1 (a–c), 2 (a and b)

Problems

1. A simple electric circuit

Initially, an electric circuit contains a 4.5 V battery and 4 resistors. Later, an ammeter will be added.



Tasks

For questions a, b and c, the ammeter is not present.

a. What must be the voltage across R_3?

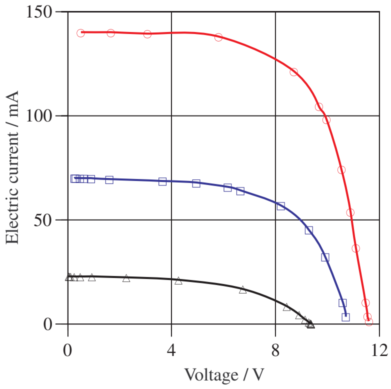
b. What is the electric current through the branch containing R_4?

c. What is the electric current through the battery?

d. Now, the ammeter is added to the circuit. The device has an internal resistance of 2.0 Ω. What is the current measured by the ammeter?

2. Characteristic of a photovoltaic module

A small photovoltaic panel consisting of 21 cells arranged in series is illuminated solar radiation (three different cases). It is connected to a load resistor with variable resistance. Voltage and electric current for the load resistor have been measured for different values of the resistance (see graph).



Tasks

a. Determine the short circuit current for these three cases.

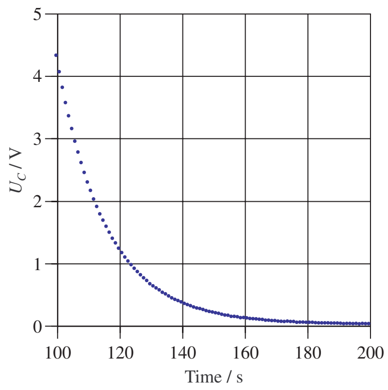
b. How large is the open circuit voltage?

c. Determine the resistance values of the load resistor for values of the voltage of 2.0 V, 4.0V, …, 10.0 V.

d. [Additional problem.] Use the model of PV cells to generate characteristic curves. Try to adjust the model parameters to fit the measured values (see file PSS-02_P2.xls).

3. Discharging a capacitor

A single capacitor is discharged through two resistors in series. Data of the voltage across the capacitor have been taken (see file PPS-02_P3.xls).

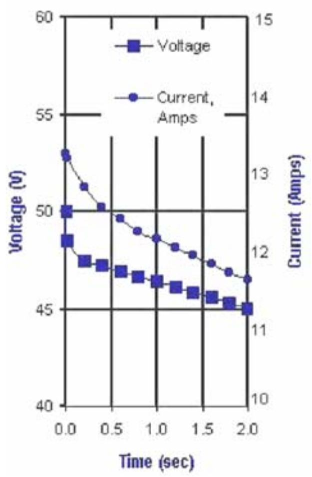


TASKS

a. Create a graph of the measured data as a function of time. In a second graph, use a logarithmic scale for the voltage.
b. Draw a circuit diagram of the experiment.
c. Use the graph to determine the (capacitive) time constant of the circuit.
d. Determine the capacitance of the capacitor.
e. Construct a system dynamics model of the circuit. Use the model and data to determine the capacitance of the capacitor.

4. Discharging a supercapacitor

In the diagram, data of the discharging of a supercapacitor through an external resistor are shown. Voltage across the supercapacitor and the electric current through the circuit used for discharging have been measured.



TASKS

a. Compare the voltage shown here with the voltage of discharging a simple standard capacitor (as in Problem 3). If necessary, create a logarithmic scale for the voltage. What do you note?
b. Estimate the resistance of the resistor that has been used for the experiment.
c. Do you think that the resistance has been constant over time? If not, why may it have changed?
d. Estimate the capacitance of the supercapacitor.

5. Charging and discharging a single capacitor

A single capacitor is discharged through two resistors in series. Data of the voltage across the capacitor have been taken with a voltage probe having an internal resistance of several MΩ (see photograph and file PPS-02_P5.xls).

A simple system dynamics model represents the circuit (see the figure below and file PSS-02_P5.stm).

TASKS

a. Make a graph of voltage measured in the experiment. Then introduce the data in the system dynamics model.

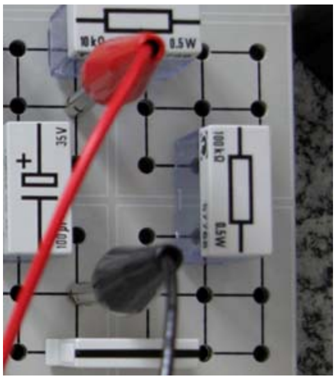
b. Draw a circuit diagram that corresponds to this experiment, and describe the experiment.

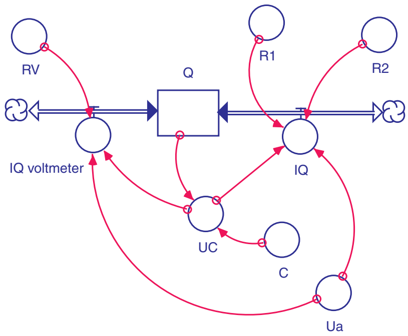
c. Investigate the model PSS-02_P5.stm. Explain the expressions for Ua and IQ.

d. Simulate the model and determine good values for the capacitance of the capacitor, and the resistance of the volt meter.

e. How large should the value of the resistance of R_2 be chosen so that the voltage during discharging takes a value of 2.50 V at $t = 500$ s? (Everything else in the experiment is to be left untouched.) Try a solution with the help of simulation of the model. Also try a formal solution on paper.

f. Additional assignment: Use the data for the phase of discharging. Determine as carefully as possible the capacitance of the capacitor (it will turn out to be variable!).





6. The systemic circuit for blood flow in a mammal represented as an electric circuit

The systemic circuit for blood flow that leads from the left ventricle of the heart through the aorta and the body back to the heart, is to be represented by an electric circuit. (See Case Study 01.)

TASKS

a. Draw an electric circuit diagram that represents the simple windkessel model of the systemic circuit. The left ventricle is modeled as a pump, the aorta as a windkessel, and vessels leading through the body as a pipe. What is the electric analogue of the aortic valve?

b. Divide the aorta into several sections. Each section stores blood and has some flow resistance. What is the hydraulic analog (made of pumps, containers, and pipes) of this system? Draw the diagram of an electric circuit that can model such a system.

c. The simple windkessel model is to be built as an analogous electric circuit. Assuming that you have a power supply for voltages up to about 10 V, what values of resistances and capacitance should you choose to get a behavior that resembles that of blood flow in a sheep? (See Case Study 01.)