**Task**

To connect up two batteries, first in series and then in parallel, and examine the effect that this has on the voltage and the current strength.

**Equipment**

| | | |
|---|---|---|
| Plug-in board | 06033.00 | 1 |
| On/off switch | 39139.00 | 1 |
| Wire building block | 39120.00 | 4 |
| Lamp holder E10 | 17049.00 | 1 |
| Battery holder | 39115.01 | 2 |
| Connecting cable, 25 cm, red | 07313.01 | 2 |
| Connecting cable, 25 cm, blue | 07313.04 | 2 |
| Round-cell battery, 1.5 V, R14 | 07922.01 | 2 |
| Filament lamp, 6V/0.5 A, E10, 1 pc. | 35673.03 | (1) |
| Multi-range meter | 07028.01 | 2 |

**Set-Up and Procedure**

First Experiment

— Connect up the circuit as shown in Fig. 1; select the 3 V- and 300 mA- measurement ranges.
— With the switch open, measure the voltage $U_L$ (at rest) and enter the measured value in Table 1, line 1.
— Close the switch, measure the current strength I and voltage $U_B$ (under load) and observe the brightness of the lamp; note your observation and measured values in line 1 of Table 1.
— Open the switch; remove wire building blocks 1 and 2, then connect the second round-cell battery in series with the one positioned in the circuit (connect the positive pole of the first one to the negative pole of the second one).
— Again measure the voltage at rest $U_L$ and enter the measured value in line 2 of Table 1.
— Close the switch, measure $U_B$ and I, and observe the brightness of the lamp; note the measured values and your observation in line 2 of Table 1.
— Open the switch; turn one of the batteries round by 180° so that the two positive poles (or negative poles) are connected to each other.
— As previously, measure first the voltage at rest $U_L$ and then $U_B$ and I under load, and observe the lamp; note the results in line 3 of Table 1.
— Open the switch.

Second Experiment

— Change the circuit to that shown in Fig. 2; in doing this, ensure that the poles of the same name (sign) are connected to each other.
— With the switch open, measure the voltage at rest $U_L$ and note the measured value in Table 2.
— Close the switch, measure the voltage $U_B$ and the current strength I under load, and observe the lamp; note the measured values and observation in Table 2.
— Open the switch.

Fig. 1

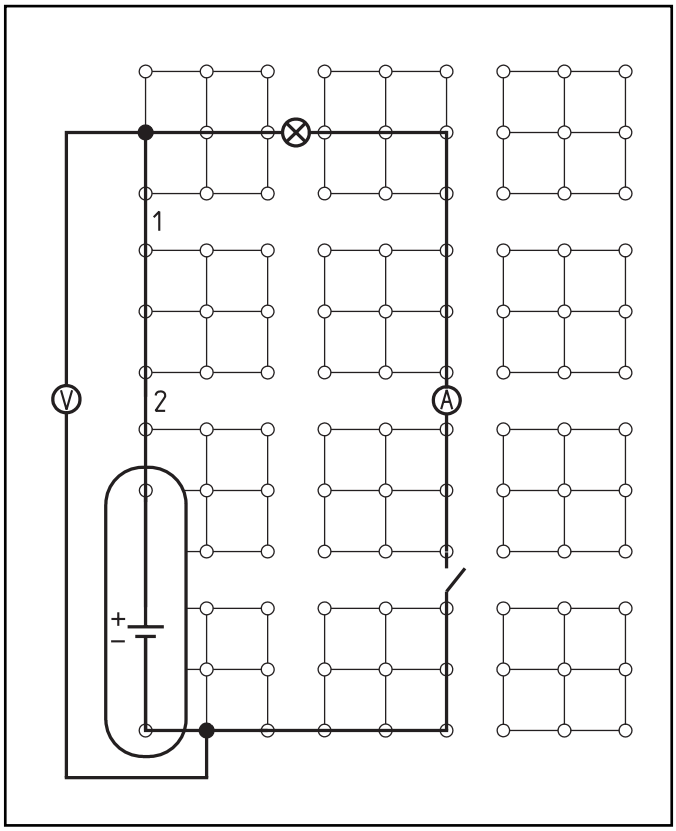
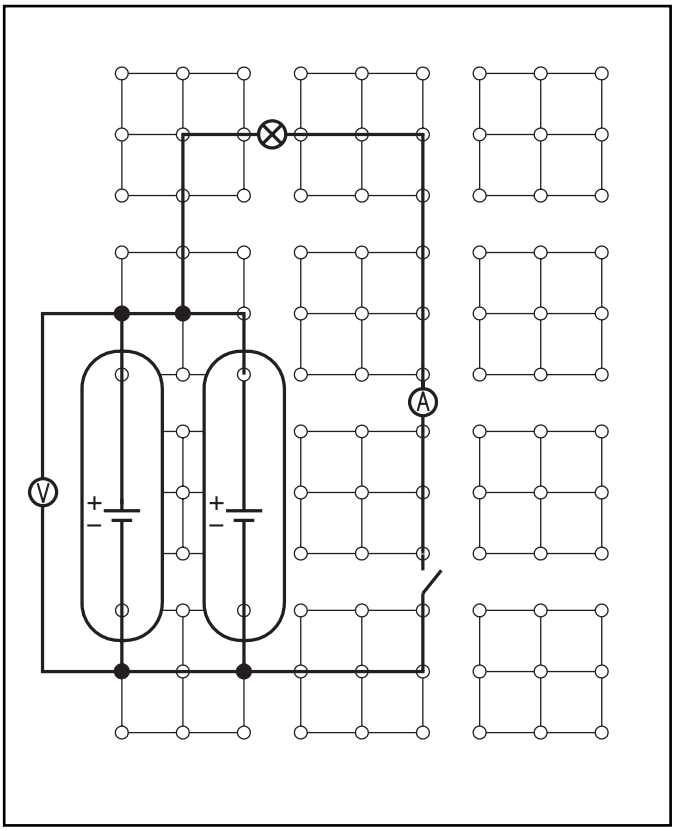



Fig. 2



| S | EEP 1.7 | What can be achieved by connecting sources of voltage in series and in parallel? | PHYWE |
|---|---|---|---|

**Observations and Measurement Results**

Table 1 (series connection)

| | at rest | under load | | |
|---|---|---|---|---|
| | $U_L$ / V | $U_B$ / V | I /mA | Lamp shines |
| 1 cell | | | | |
| 2 cells (+ to -) | | | | |
| 2 cells (+ to +) | | | | |

Table 2 (parallel connection)

| | at rest | under load | | |
|---|---|---|---|---|
| | $U_L$ / V | $U_B$ / V | I /mA | Lamp shines |
| 2 cells | | | | |

**Evaluation**

1. What is achieved by with a series connection of single-cell batteries – and in general with sources of voltage?

2. Which relationship is given in a series connection between the total voltage $U_G$ and the voltages $U_1$ and $U_2$ of the batteries?

3. Attempt to formulate an explanation why no voltage is present with the other (false) connection of the poles (refer to line 3, Table 1).

4. Compare the voltages at rest with those under load.
   a) What can be generally ascertained?

   b) Which benefit is given by the parallel connection of voltage sources?

5. What is therefore achieved by the parallel connection of voltage sources?

(What can be achieved by connecting sources of voltage in series and in parallel?)

It frequently occurs in practice that single-cell batteries must be connected together to act as a power supply for portable and mobile electrical and electronic devices (drills, torches, hearing aids, radios etc.).
The students should discover which objectives one can fulfil with a series or parallel connection of single-cell batteries.

**Notes on Set-Up and Procedure**
The 6 V/0.5 A lamp is recommended, because it has a relatively low resistance, so that measurable voltage drops are to be expected under load.

**Observations and Measurement Results**
Table 1 (series connection)

| | at rest | under load | | |
|---|---|---|---|---|
| | $U_L$/ V | $U_B$/ V | I /mA | Lamp shines |
| 1 cell | 1.5 | 1.40 | 140 | weakly |
| 2 cells (+ to -) | 3.0 | 2.80 | 230 | stronger |
| 2 cells (+ to +) | 0 | 0 | 0 | not at all |

Table 2 (parallel connection)

| | at rest | under load | | |
|---|---|---|---|---|
| | $U_L$/ V | $U_B$/ V | I /mA | Lamp shines |
| 2 cells | 1.5 | 1.45 | 143 | weakly |

**Evaluation**
1. The connection of the sources of voltage in series results in an increase in the voltage.
2. The relationship given is $U_G = U_1 + U_2$.
3. The voltages of the single-cell batteries are directed towards each other and so cancel each other out.
4. a) The voltage drops under load.
   b) When the voltage sources are connected in parallel, the voltage drops less under load.
5. The parallel connection of voltage sources enables a greater current strength to be obtained. Or: When sources of voltage are connected in parallel, the load can be greater without a greater drop in the operating voltage.

**Remarks**
The explanation why the operating voltage (voltage under load) is smaller than the voltage at rest can first be given, when the influence of the internal resistance of a voltage source and its load-carrying ability has been worked on.
The measured values which the students obtain can differ relatively greatly from each other and from the values given here, as they are dependent on the condition of the single-cell batteries. The fresher (less used) the batteries are, the less effect the load has on the voltage.
According to the make, the single-cell batteries can have a voltage which is above 1.5 V. In this case, a higher measurement range must possibly be used.

| T | EEP 1.7 | Series and parallel connection of sources of voltage | PHYWE |
|---|---|---|---|

(What can be achieved by connecting sources of voltage in series and in parallel?)

Room for notes