Problem

1. Investigate the relationship between current and voltage for a light-emitting diode in forward and reverse direction as well as the electrical power received by the diode.
2. Test the suitability of light-emitting diodes for determining the type of current and the polarity of the current source.

Equipment

Plug-in board	06033.00	1
Changeover switch	39169.00	1
Resistor, 47 Ω	39104.62	1
Resistor, 100 Ω	39104.63	2
Light-emitting diode, red	39154.50	2
Wire building block	39120.00	4
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 25 cm, blue	07360.04	1
Connecting cables, 50 cm, red	07361.01	2
Connecting cables, 50 cm, blue	07361.04	2
Multi-range meter	07028.01	2
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

Set-Up and Procedure

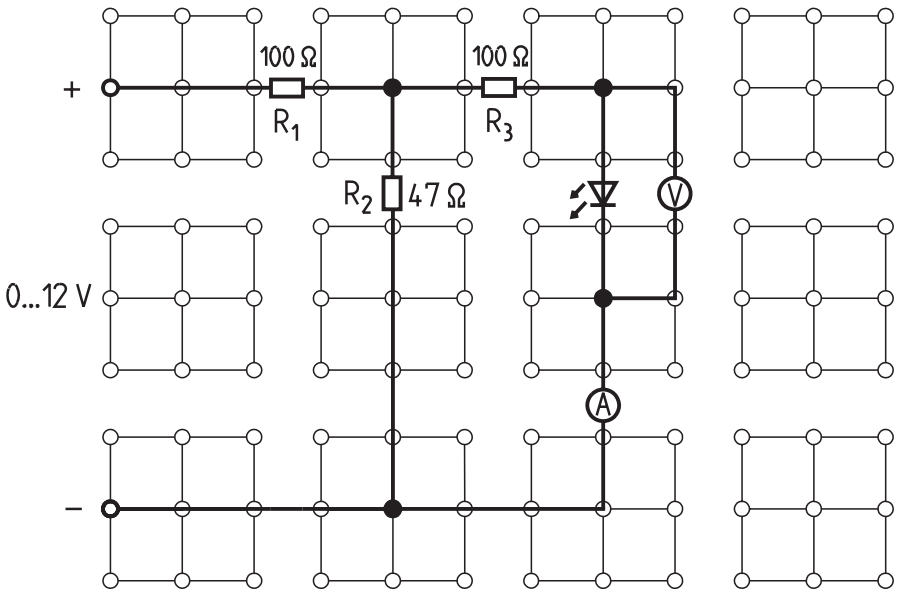
First Experiment

— Set up experiment as shown in Fig. 1. Set measurement ranges to 10 V- and 30 mA-.
— Switch on power supply unit and gradually increase voltage starting at 0 V. Enter measurements for current and diode voltage in Table 1.
— Switch power supply unit off. Plug the LED into the circuit with reverse polarity.
— Switch on power supply unit and determine measurements for current and voltage as before. Enter values in Table 2.
— Switch power supply unit off.

Second Experiment

— Set up experiment as shown in Fig. 2. Set direct voltage on power supply unit to 6 V.
— Observe the light-emitting diode, then re-plug it after turning it through 180° and again observe it; note your observations under (1).
— Switch connection cable on power supply unit from direct voltage over to 6 V alternating voltage.
— Carry out the same observations and re-plugging of the light-emitting diode as with direct voltage; note your observations under (2).
— Switch power supply unit off.

Fig. 1



Observations and Measurement Results

Table 1: LED in forward direction

Set voltage at power supply unit U_P/V	0	2	4	6	8	10	12
Voltage at the LED U_F/V							
Current I_F/mA							

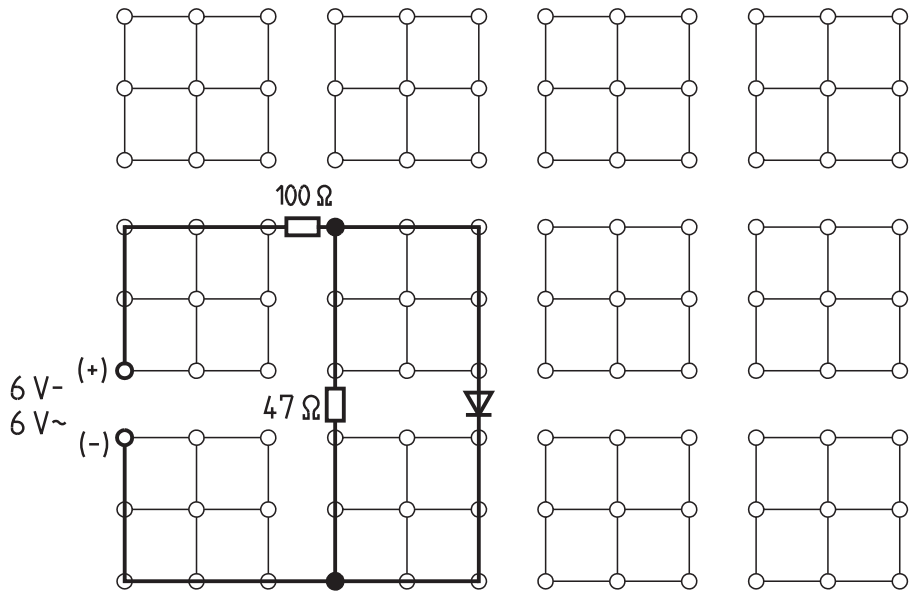
Table 2: LED in reverse direction

Set voltage at power supply unit U_P/V	0	2	4	6	8	10	12
Voltage at the LED U_R/V							
Current I_R/mA							

(1)

(2)

Fig. 2

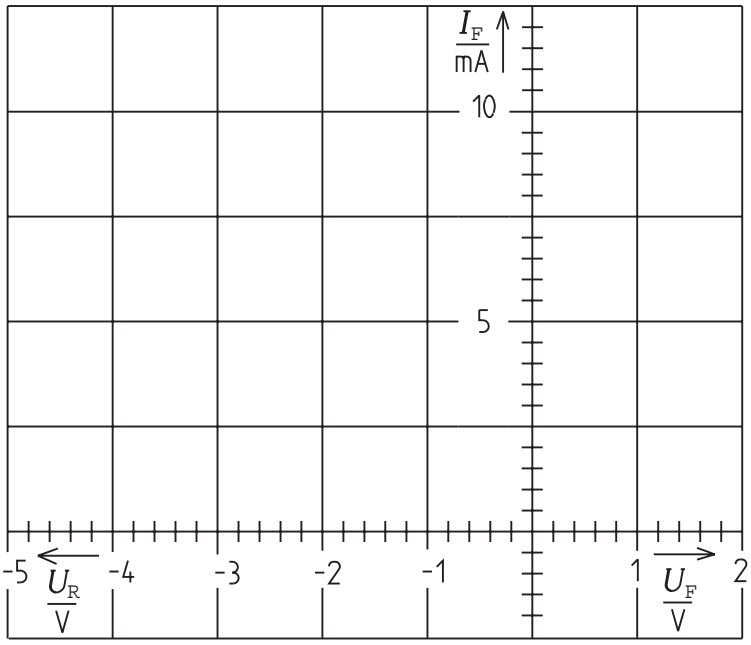


Evaluation

1. Draw a graph to show the relationship between current and voltage at the LED. Enter the values for voltage and current in the reverse direction in the negative range (Fig. 3).
2. Describe the characteristic curve in general and in relation to the lighting up of the LED. Compare this characteristic curve with that of a normal silicone diode.

3. How high is the maximum electrical power received by the LED? Draw a comparison between this value and the electrical power of a filament lamp for small voltages.

Fig. 3



4. Explain the behavior of the LED when the changeover switch is toggled back and forth (Observation (1)).

5. How do you explain Observation (2)?

6. How must one proceed, to use a light-emitting diode to recognize the type of voltage and, in the case of direct voltage, to additionally determine its polarity?

(What are the characteristics of light-emitting diodes and what are they used for?)

Light-emitting diodes (LEDs) are pn junctions composed of GaAs or GaP. Depending on the desired wavelength of light, the substrates are doped with various elements. When the pn junctions are connected to a current source in the forward direction, electrons and holes flood the barrier layer and recombine there. When they do, the expended energy is released in the form of visible or infra-red light.
In the reverse direction, LEDs behave the same as normal diodes. However, the maximum reverse voltage is quite small. For some LED types, it is even less than 10 V.

Notes on Set-Up and Procedure
A voltage divider consisting of R_1 and R_2 is used to make it easier to set the voltage in the forward voltage range, which is about 1 V to 2 V. This makes it possible to vary the voltage on the power supply unit U_P from 0 V to 12 V without overloading the LED in the forward direction or exceeding the maximum reverse voltage. LEDs may only be operated with a preconnected resistor. The resistor limits the forward current to the admissible value, which is I_R = 20 mA for the diode type used in this experiment. It can be calculated using the following formula:

$$R_P = (U_P - U_F)/I_{F,\,max}$$

Observations and Measurement Results
See Table 1 and Table 2
(1) When the changeover switch is toggled back and forth, the two LEDs blink on and off alternately.
(2) The diode lights up, regardless of how it is plugged in.

Evaluation
1. See Fig. 3.
2. The forward current does not start flowing until the voltage U_F reaches 1.2 V. When forward current is flowing, the diode emits red light which gets brighter and brighter as the flow of current increases.
   In the reverse direction, current does not start flowing until the voltage reaches approx. 4 V.
   The characteristic curve for LEDs is similar to that of a silicone diode. The forward voltage is about twice as much, though.
3. The maximum power received by the LED is

$$P_{max} = U_{D,\,max} \cdot I_{D,\,max}$$

$$P_{max} = 1.7\ V \cdot 10.5\ mA = 17.85\ mW.$$

The filament lamps used in the experiment set have a nominal power of

$$P_1 = 12\ V \cdot 0.1\ A = 1.2\ W$$

and

$$P_2 = 6\ V \cdot 0.5\ A = 3\ W$$

and

$$P_3 = 4\ V \cdot 0.04\ A = 160\ mW.$$

respectively.

The LEDs require considerably less electrical energy.

Table 1: LED in forward direction

Set voltage at power supply unit U_P/V	0	2	4	6	8	10	12
Voltage at the LED U_F/V	0	0.65	1.25	1.60	1.65	1.70	1.70
Current I_F/mA	0	0	0	1.2	4,0	7.2	10.5

Table 2: LED in reverse direction

Set voltage at power supply unit U_P/V	0	2	4	6	8	10	12
Voltage at the LED U_R/V	0	0.65	1.25	1.95	2.5	3.1	3.7
Current I_R/mA	0	0	0	0	0	0	0

(What are the characteristics of light-emitting diodes and what are they used for?)

4. Toggling the changeover switch back and forth switches the connection of both LEDs, connected in parallel, between the positive or negative pole of the current source. Only the LED connected in the forward direction for the respective polarity selected lights up.
5. When an alternating voltage is applied, then the connection of the diode rapidly alternates between the forward and reverse directions, independently of how it is connected in the circuit. It therefore lights up in both cases.
6. The diode is connected to the source of current with preconnected resistor, and then turned through 180° and again connected. When it lights up in both cases, then we are dealing with a source of alternating current. When it only lights up in one case, then we have a source of direct current and the positive pole is indicated by the anode of the diode, when it lights up.

Remarks

The determination of the type and polarity of a source of current can only be achieved in the way described, when the voltage is at least high enough to light up the diode, but does not exceed the permissible reverse voltage of the diode. When the voltage is too high, it can be adjusted to a voltage which is safe for the diode by using a voltage divider.

Fig. 3