Factcheck

Adapting quality of VET offer to the need of industry – manufacturing sector

European training module for electrical professions - electronics technician for industrial engineering

Testing electrical systems and devices

Periodic testing of electrical equipment

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bsw Bildungswerk der Sächsischen Wirtschaft gGmbH

Structure of the training module

1 Check-in knowledge test

2 Self-study phase

2.1 Electrical basics

2.2 Laws, ordinances

2.3 Testing mobile devices

Application example

4 Check-out knowledge test

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Learning objectives

1. Fundamentals of electrical engineering and structure of an electrical circuit
2. Recognising the dangers of electric current and its effects on the human body
3. Familiarise yourself with basic laws, ordinances and regulations
4. Testing electrical installations and systems. Procedure for the periodic inspection of mobile devices

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Check in knowledge test

Question

- Which symbol is used to indicate the electrical voltage?

Answers

- W
- S
- A
- U

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Check in knowledge test

Question

- The movement of charged particles (mostly electrons) is also called ...

Answers

- voltage
- Watt
- electricity
- Volt

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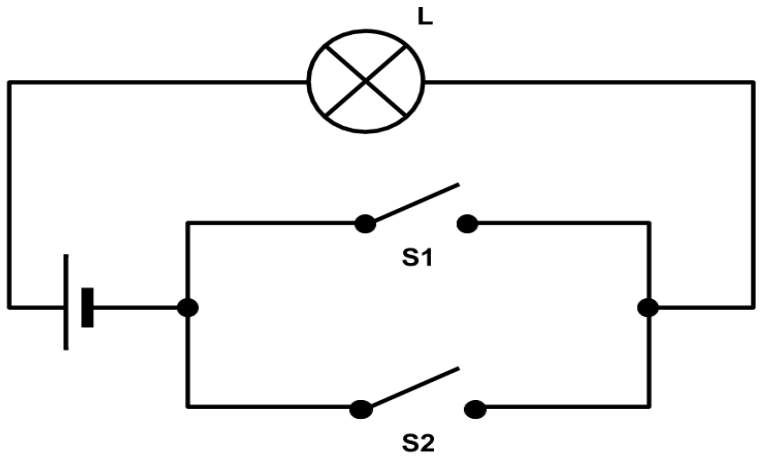
Check in knowledge test

Question

At which switch position does the lamp light up



Answers

- S1 is closed and S2 is open
- S1 and S2 are closed
- S1 is open and S2 is closed
- S1 and S2 are both open

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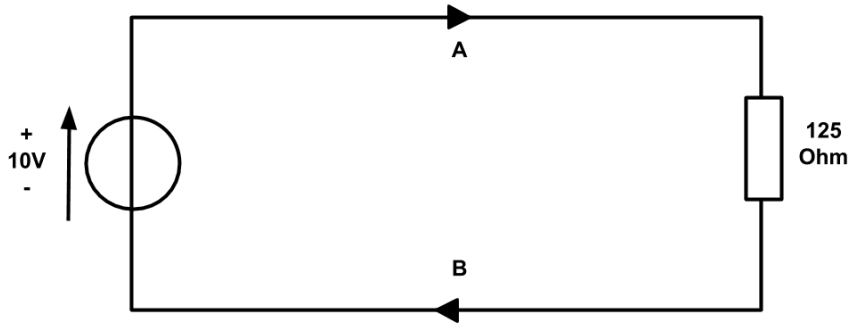
Check in knowledge test

Question

How high is the current under A?



Answers

- 10 A
- 0,08 A
- 1 A
- 0,1 A

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Check in knowledge test

Question

- Which mathematical function is usually used to calculate the electrical current in an AC voltage network?

Answers

- Sawtooth function
- Midnight function
- Square function
- Sine function

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Check in knowledge test

Question

- Calculate the resistance at a voltage of 360 volts and a current of 0.2 amperes.

Answers

- 54
- 1800
- 1600
- 72

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Check in knowledge test

Question

- An atom consists of an atomic nucleus and a shell composed of ...

Answers

- Nutrones
- Neutrons
- Protons
- Electrons

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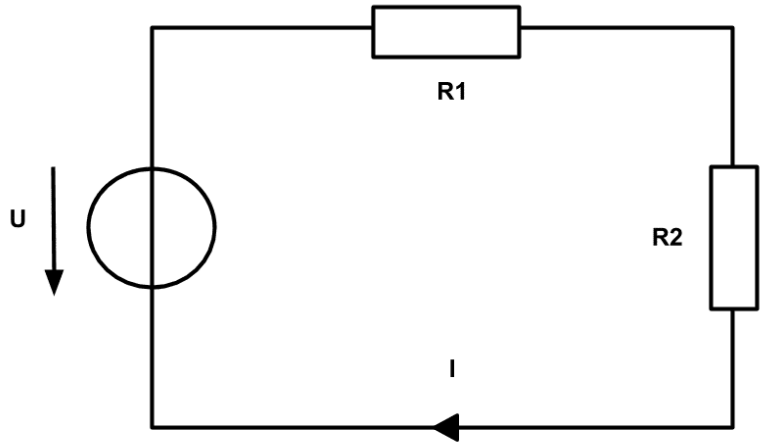
Check in knowledge test

Question

What current flows through the resistors when U = 10V and R = 100 Ohm?



Answers

- 1000 A
- 0,1 A
- 0,01 A
- 1 A

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Check in knowledge test

Question

- What voltage is normally applied to sockets in the EU?

Answers

- 320 V
- 24 V
- 500 V
- 230 V

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Check in knowledge test

Question

- In which unit is the electrical power measured?

Answers

- Ampere
- Watt
- Ohm
- Volt

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Your result

9-10 points: You already know your way around very well!
7-8 points: You still have a few gaps in your knowledge.
5-6 points: ??
0-4 points: Not a good result, but that's what our training is for!

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2nd self-study phase Basics of electrical engineering

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Factcheck
Adapting quality of VET offer to the need of industry – manufacturing sector

1 Electrical basics

1.1 Electrical circuit

- A simple electrical circuit basically consists of a voltage source, a load and an electrically conductive connection between the two. A simple electrical circuit is explained using the "inner workings" of a torch as an example (Fig. 1.1):
- When the contact spring plate is moved to the "ON" position, the circuit is connected from the positive pole (+) of the battery (voltage source) via the filament of the light bulb (load) to the metal housing of the torch and via the spring to the negative pole (-) of the battery. Because the circuit is closed - there is a continuous electrically conductive connection - the light bulb lights up.

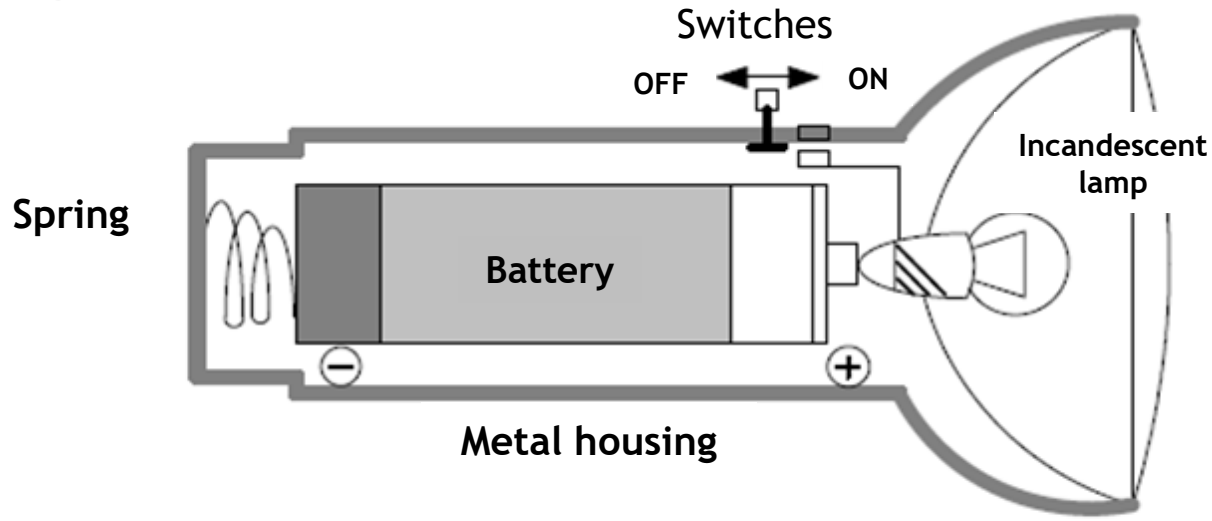

Fig. 1.1: "Inner workings" of a torch

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1.1 Electrical circuit

- For a better overview, a circuit is shown in simplified form with symbols (Fig. 1.2).

- The term "consumer" is misleading. This is because electricity is not consumed, but electrical energy is converted into another form of energy in the "consumer". In a light bulb into light, in an electric motor into movement, in a loudspeaker into sound, etc.

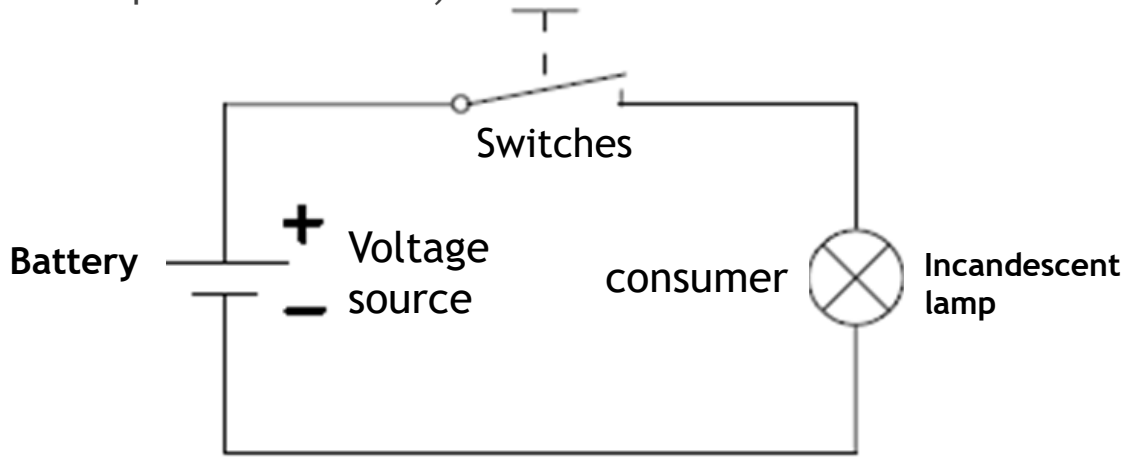

Fig. 1.2: Circuit diagram of a torch

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1.2 Electrical voltage

For electrons to move in an electric circuit, there must be a difference in charge. Such a charge difference is called voltage, and a component or device that generates or provides a charge difference is called a voltage source. A charge difference, i.e. a voltage, always exists between two points, connections or lines (Fig. 1.6).

As a common return line is often used for different switching groups in a comprehensive circuit, such as the chassis in a car, the return line is referred to as earth and is labelled with the symbol in the circuit drawing.

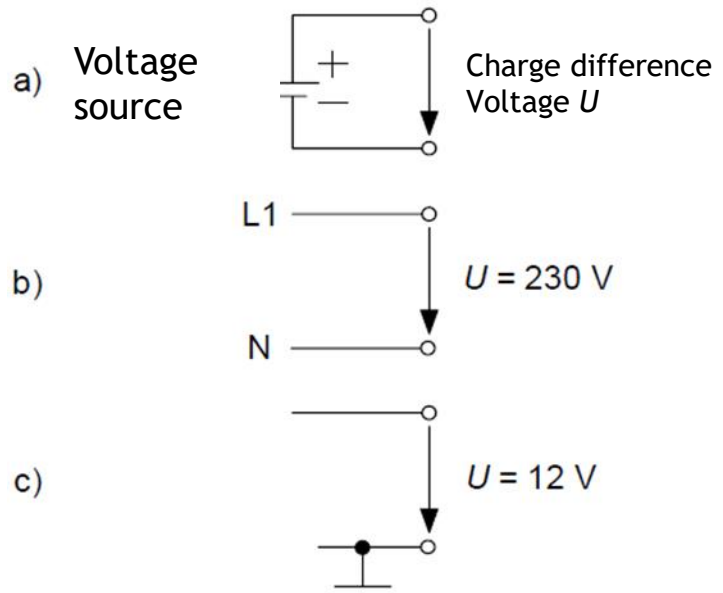

Fig. 1.6: Voltage specification

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1.2 Electrical voltage

Physical quantity: **Voltage**
Formula symbol: ***U***
Unit: **Volt** (derived from the Italian physicist Volta)
Unit abbreviation: **V**

Parts and multiples:

1 µV (1 Mikrovolt) = 0,000 001 V = $1 \cdot 10^{-6}$ V
1 mV (1 Millivolt) = 0,001 V = $1 \cdot 10^{-3}$ V
1 kV (1 Kilovolt) = 1000 V = $1 \cdot 10^{3}$ V
1 MV (1 Megavolt) = 1 000 000 V = $1 \cdot 10^{6}$ V

Examples from practice:

- Mono cell *U* = 1.5 V
- Car battery *U* = 12 V
- Alternating voltage *U* = 230 V
- Three-phase current *U* = 400 V
- High voltage *U* = 360 kV

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1.3 Electricity

The directional movement of charge carriers is called an electric **current.** However, a current can only flow if

1. a voltage is present *and*
2. the circuit is closed (Fig. 1.11).

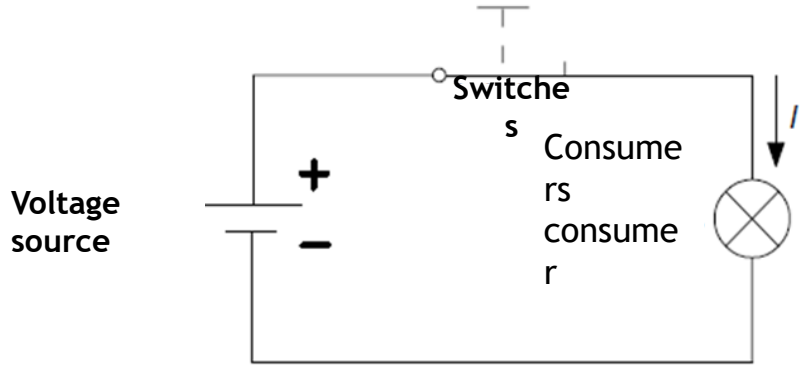

Fig. 1.11: Closed circuit

Physical quantity: **Current**
Formula symbol: ***I***
Unit: Ampere (derived from the French Ampère)
Unit abbreviation: **A**

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1.3 Electricity

Ammeters, also known as ammeters, are used to determine the level of a current. Because the charge carriers flow in the circuit, the ammeter must be connected in series to the load, as shown in (Fig. 1.12), the ammeter must be connected in series to the load.

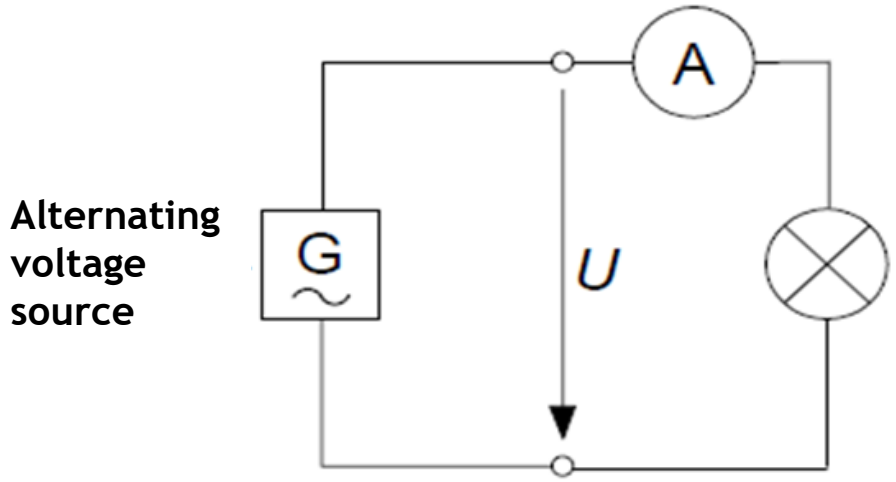

Fig. 1.12: Current measurement

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1.4 Electrical resistance

Consumers made of different materials will cause different amounts of current to flow in a circuit at the same voltage. They therefore oppose the directional movement of the electrons with a **resistance.**

Internationally it is fixed:

Physical quantity:	Resistance	
Formula symbol:	*R*	(from resistor = resistance)
Unit:	Ohm	(in honour of the German physicist G. S. Ohm)
Unit abbreviation:	Ω	(Greek capital letter Omega)
Switching symbol:		

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1.4 Electrical resistance

Parts and multiples:

1 mΩ (1 milliohm) = 0.001 Ω = 1-10^{-3} Ω
1 kΩ (1 kiloohm) = 1000 Ω = 1-10^{3} Ω
1 MΩ (1 megohm) = 1 000 000 Ω = 1-10^{6} Ω

Examples from practice:

- Resistance of a supply line R = 1.2 mΩ
- Resistance of a loudspeaker R = 4 Ω
- Insulation resistance R = 12 MΩ

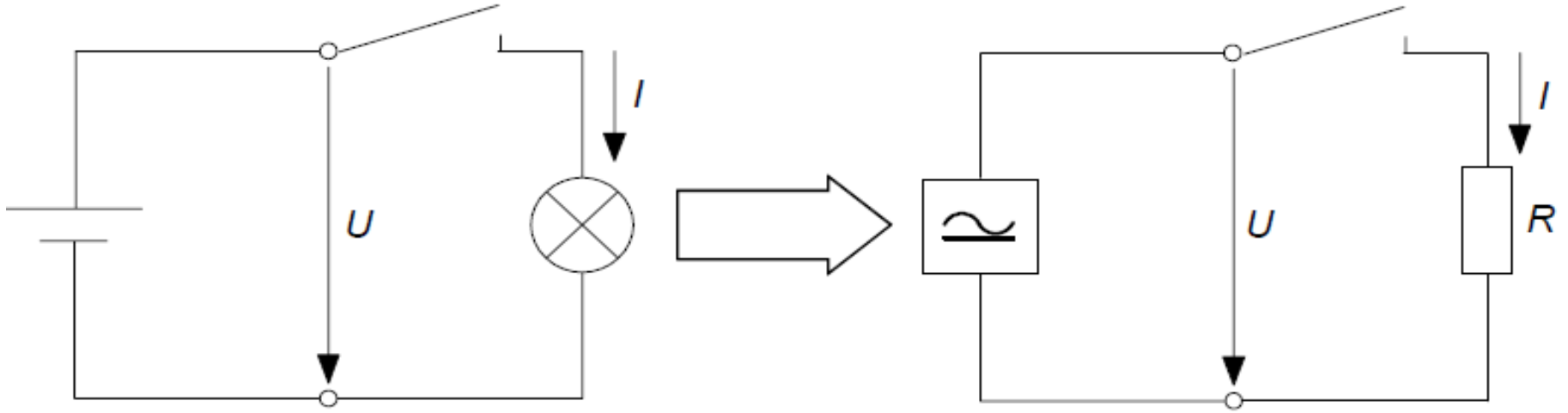

Fig. 1.13: Circuit with resistor

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1.4 Electrical resistance

The resistance value of a consumer can be measured ***directly*** with a **resistance meter**, also known as an ohmmeter **(Fig. 1.14)**.
When determining the resistance in this way, it must be ensured that that no external voltage must be present.

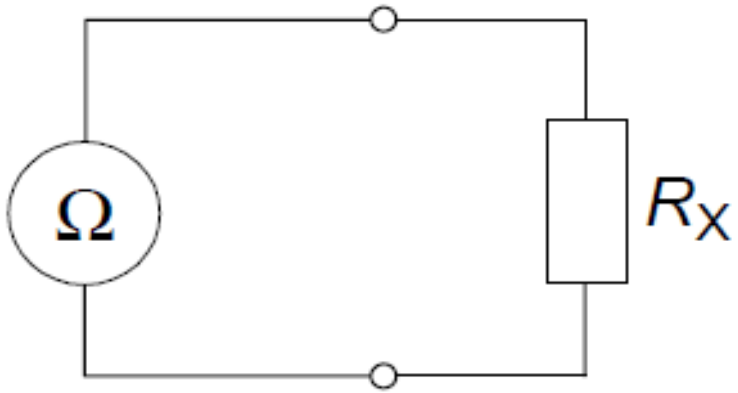

Fig. 1.14: Direct resistance measurement

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1.5 Ohm's law

As early as 1825, the German physicist **Georg Simon Ohm** (1789-1854) investigated the relationship between the electric current and the electric voltage in various metal wires. In May 1827, he published **Ohm's law, which was** later named after him.

He discovered that the magnitude of the current changes with the same voltage and different materials. The different materials conduct the current better or worse. Ohm discovered that the current is directly related to the voltage, but inversely related to the resistance:

$$I = \frac{U}{R}$$

Ohm's law

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1.5 Ohm's law

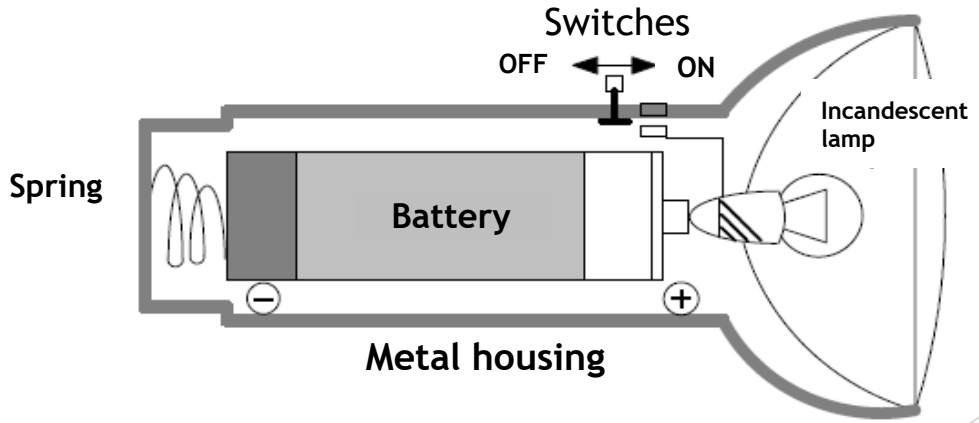
The resistance is therefore the quotient of voltage and current:

$$R = \frac{U}{I}$$

The resistance of the incandescent lamp in the torch example **(Fig. 1.1)** has a value of :

$$R = \frac{U}{I} = \frac{1{,}5\ \text{V}}{0{,}5\ \text{A}}$$

$$R = 3\ \text{V/A} = 3\ \Omega$$



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1.6 Electrical power

Electrical devices convert electrical energy into other forms of energy. A light bulb converts it into light, a motor converts it into mechanical energy (rotary motion) and an electric heater converts it into heat. All of these devices are rated for certain outputs and therefore the voltage applied and the current flowing through them must not exceed certain values.

internationally it was determined as follows:

Physical quantity:	Power
Formula symbol:	***P*** (from *power*)
Unit:	Watt (derived from the inventor of the steam engine, the Englishman J. Watt)
Unit abbreviation:	**W**

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1.6 Electrical power

Parts and multiples:

1 mW (1 milliwatt) = 0.001 W = $1\text{-}10^{-3}$ W
1 kW (1 kilowatt) = 1000 W = $1\text{-}10^{3}$ W

Examples from practice:

- Output power of an MP3 player P = 800 mW
- Power of an incandescent lamp P = 100 W
- Power of a washing machine P = 2.4 kW

The power converted in the device depends on the level of the applied voltage and of the current flowing through it:

$$P = U \cdot I$$

Electrical power

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1.6 Electrical power

The power of an appliance is the product of the voltage applied and the current flowing.

The power consumption of an appliance can be determined by a simple voltage and current measurement as shown in Fig. 1.19.

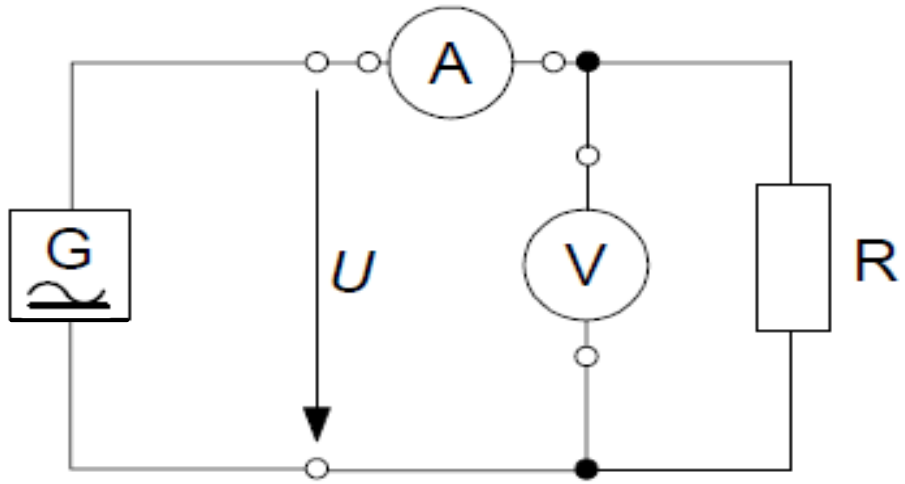

Fig. 1.19: Determining the electrical power

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laws, ordinances, regulations and provisions

General information

For the installation and operation of electrical systems as well as the manufacture and sale of electrical equipment, there are laws and regulations that must be complied with and various rules and regulations that are recommended to be observed..

Fig. 5.1 shows the standards in our legal system (Germany). In the legal system, standards are below laws and ordinances and, as generally recognised rules, are part of the "non-statutory regulations". The development of standards is therefore independent of the state and the professional associations.

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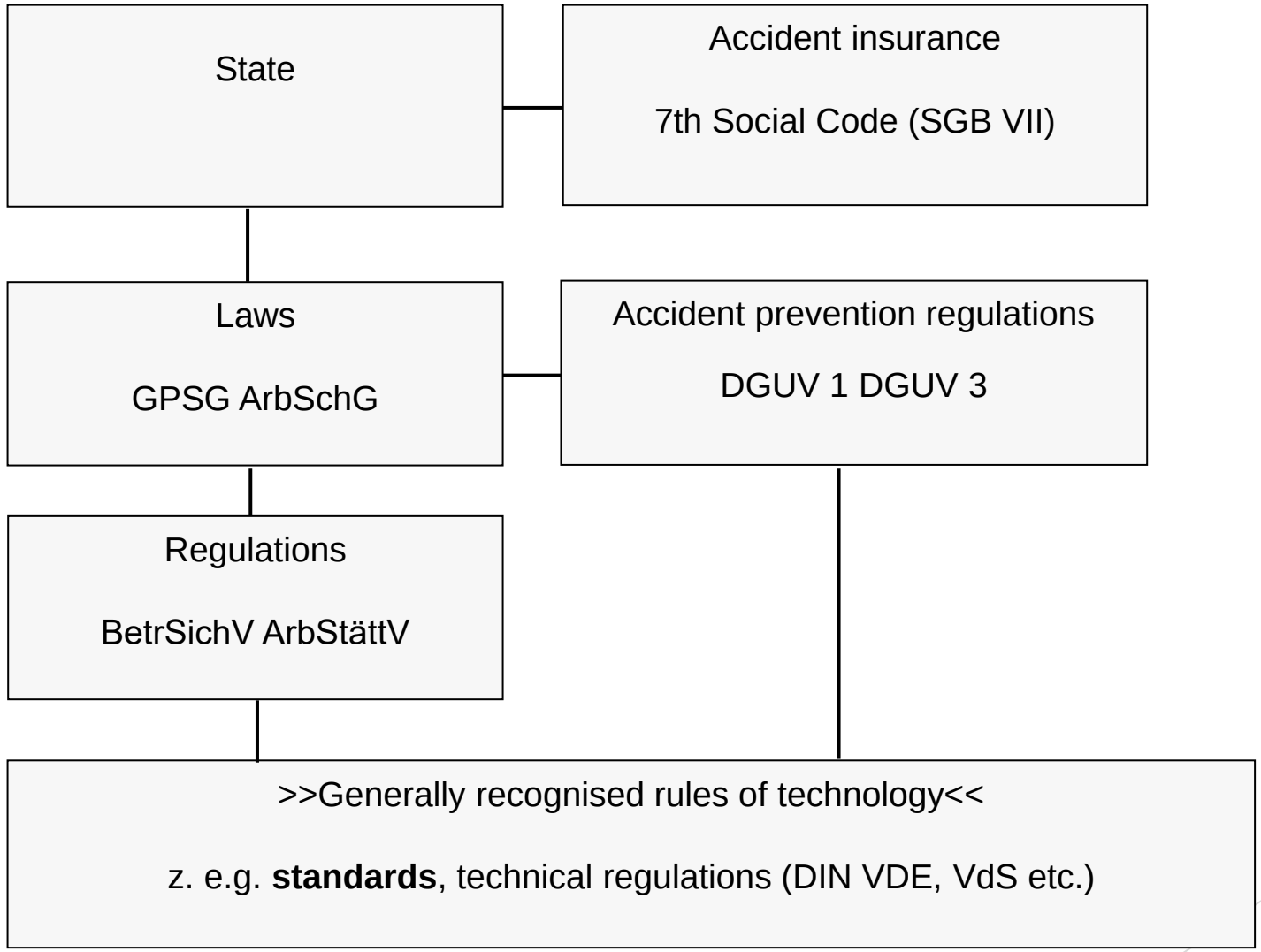

Fig. 5.1: Classification of the standards in our legal system

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laws, ordinances, regulations and provisions in Germany

The **accident prevention regulations (UVV)** are binding technical regulations that are approved by the Federal Minister of Labour and Social Affairs prior to publication. They prescribe mandatory technical, organisational and personal measures for the employer and the insured persons. The legal basis is formed by the Occupational Health and Safety Act and the Social Security Code VII.

A distinction must be made between the

- Accident prevention regulations **"DGUV", "BGV"** and the **rules "BGR", "BGI", "BGG" and ZH1"** of the industrial employers' liability insurance associations
- Accident prevention regulations **"VSG"** of the agricultural employers' liability insurance associations and
- Accident prevention regulations **"GUV"** of the municipal accident insurance associations or accident insurance funds.

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Occupational safety in electrical engineering

Dangers due to electric current

Electric current can lead to accidents in humans due to **electric shock, arcing and secondary effects**.

The degree of injury cannot be estimated in advance. For this reason, all indications of defective electrical systems and equipment should be taken seriously and possible causes of accidents should be eliminated immediately.

Mains voltage of 230/400V and a frequency of 50Hz can lead to fatal accidents and if the current flow is high enough, a muscle will cramp. If the muscles in a hand are affected, it is no longer possible to let go of a grasped object. If the chest is affected, respiratory arrest occurs. Cardiac arrest can be triggered or the regular sequence of individual heart muscle movements can be disrupted, resulting in a disorganised movement without a pumping effect - ventricular fibrillation.

The effect of the electric current depends on the current intensity, the path of the current in the body, the duration of exposure and the frequency.

The employer must instruct his employees regularly, but at least once a year, on the dangers of handling electrical current.

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Occupational safety in electrical engineering

- In order to minimise risks and hazards for the electrician, the five safety rules must be observed when working on electrical systems to ensure that they are de-energised.

The five safety rules for working in a de-energised state

1.unlock:

Enabling all parts of the system to be worked on

Switch off the circuit breaker, remove the fuses

2. secure against restarting

Secure the operating mechanism of switching devices, e.g. circuit breakers, with a lock, take fuse links with you, affix prohibition signs

3. determine absence of voltage

Ensure that the system is de-energised by a specialist, check the system with a two-pole voltage tester

4.earthing and short-circuiting

Always earth first, then connect to the short-circuiting active parts (must be visible from the workplace).

Rule 4 does not apply to systems below 1000 V, e.g. in cable systems, with the exception of overhead lines.

5.Cover or cordon off neighbouring live parts

For systems below 1 kV, insulating cloths, hoses and moulded parts are sufficient for covering; above 1 kV, additional separating panels, ropes and warning signs are required.

Wear body protection, e.g. hard hat with face protection, close-fitting clothing and gloves.

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Occupational safety in electrical engineering

takes place through

- Insulation of active parts
- Covering or wrapping
- Obstacles
- Distance

takes place through

- Classification of passive parts in systems over 1Kv
- Switch-off or message
- Protective insulation
- Non-conductive rooms
- Earth-free local potential equalisation
- Protective separation

takes place through

- Safety extra-low voltage
- Functional extra-low voltage

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Initial and periodic testing of electrical systems

According to DGUV regulation 3, companies are obliged to have their portable devices tested. Portable electrical equipment must be tested before initial commissioning and before recommissioning after modifications and repairs.

According to DGUV 3, mobile devices are characterised by the following features:

they can be easily moved during operation due to their weight, they can be easily transported from one place to another while connected to a supply network.

Portable devices include, for example

-Electric hand tools (drill, jigsaw)

-Office equipment (printer, monitor)

-Household appliances used in the company (kettle, coffee machine)

-extension cable

In accordance with Section 5 (1) No. 1 DGUV Regulation 3, the employer must ensure that his electrical systems and devices

before initial commissioning, after modifications or repairs, at certain intervals

have them checked for proper condition as part of an electrical appliance test.

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Test procedure

In principle, portable appliances are tested according to a fixed schedule:

Visual inspection

Continuity of the protective conductor, if present and testable

Insulation test

Protective conductor currents (leakage currents via the protective condu

Contact currents (other leakage currents)

Testing of other protective measures, such as residual current device (R(

Functional test of the device for proper function

Documentation

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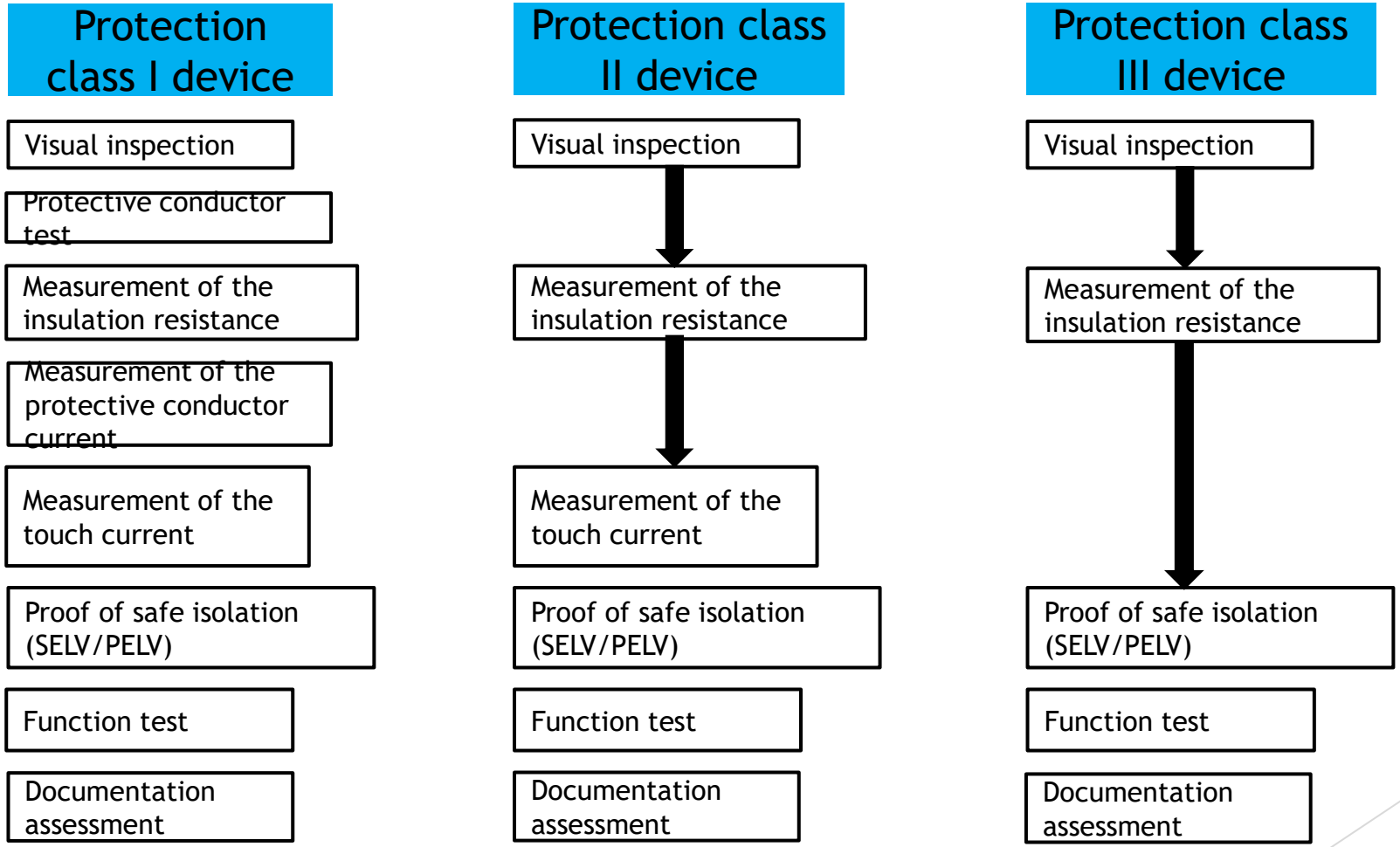
Test procedure

- Test procedure for periodic testing of electrical equipment according to DIN VDE 0701-0702



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Electrical operating equipment of protection class (SK) Scope of testing (5.1)*	Protection class I (with protective conductor) • Extension and device connection cables • Electrical equipment, e.g. electrical hand tools	Protection class II (without protective conductor) • Device connection cables • Electrical equipment, e.g. electrical hand tools	Protection class III
Visual inspection (5.2)* For externally recognisable damage: • Termination cable including plug connection • Housing • Strain relief • Bending and kink protection	X	X	X
Testing the protective conductor (5.3)* Continuity between the earthing contact of the mains plug and touchable conductive parts of the appliance or the appliance coupler	For cables with a rated current ≤16A Up to 5 m: ≤ 0.3 Ω The more 7.5 m additionally 0.1 Ω max. 1 Ω For cables with higher rated currents, the calculated ohmic resistance value applies	—	—
Measurement of the insulation resistance (5.4)*	≥1MΩ ≥2MΩ for proof of safe isolation (e.g. transformer) ≥3MΩ for appliances with heating elements with an output of '3.5kW	≥2MΩ	≥0.25MΩ
Measurement of the protective conductor current (5.5)*	≤ 3.5 mA on conductive components with protective conductor connection 1mA/kW to max. 10 mA for appliances with heating elements with a total output of more than 3.5 kW	—	—
Measurement of the touch current (5.6)*	≤ 0.5 mA on conductive components without protective conductor connection	≤ 0.5 mA on conductive components	—
Proof of safe isolation (SELV/PELV) (5.7)* "For devices that generate a SELV or PELV voltage through a safety transformer or a switching power supply unit "*.	Verification of the rated voltage (compliance with SELV/PELV specifications) • Measurement of the insulation resistance (primary / secondary) • Measurement of the insulation resistance (between touchable conductive parts and active parts of the SELV/PELV circuit)		
Function test (5.8; 5.10)	Function of safety devices and functional test		
	Evaluation, assessment, documentation		

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Test protocol

Measured values

Nr.	Stromkreis	Leitungsart	Leiteranzahl	Leiterquerschnitt	Charakteristik	Nennstrom	ZS_IK	ZI_IK	RISO	RCD_IN	RCD_IDN	IF_ID	IDN_TA	IF_UB	RLO	Bestanden
1	**B0000002 Mustergebäude - D0000003 UV - Muster**														**0 Ohm**	Ja
2	Zuleitung L1	NYM-J	5	6.0	gL/gG <1s	35A	186 mOhm / 1,23 kA	200 mOhm / 1,15 kA								Ja
3	Zuleitung L2	NYM-J	5	6.0	gL/gG <1s	35A	179 mOhm / 1,28 kA	198 mOhm / 1,16 kA								Ja
4	Zuleitung L3	NYM-J	5	6.0	gL/gG <1s	35A	173 mOhm / 1,33 kA	191 mOhm / 1,2 kA								Ja
5	F13 - E-Herd L1	NYM-J	5	1.5	B/L	16A			163 MOhm > 500 MOhm 157 MOhm	40A	30mA	22,5 mA	38 ms	0,1 V		Ja
6	F14 - E-Herd L2	NYM-J	5	1.5	B/L	16A			163 MOhm > 500 MOhm 157 MOhm	40A	30mA	22,5 mA	38 ms	0,1 V		Ja
7	F15 - E-Herd L3	NYM-J	5	1.5	B/L	16A			163 MOhm > 500 MOhm 157 MOhm	40A	30mA	22,5 mA	38 ms	0,1 V		Ja
8	F16 - Steckdosen Küche rechts	NYM-J	3	1.5	B/L	16A		419 mOhm / 549 A	163 MOhm > 500 MOhm 157 MOhm	40A	30mA	22,5 mA	38 ms	0,1 V 0,1 V		Ja
9	F17 - Steckdosen Küche links	NYM-J	3	1.5	B/L	16A			163 MOhm > 500 MOhm 157 MOhm	40A	30mA	22,5 mA	38 ms	0,1 V 0,1 V		Ja
10	F18 - Geschirrspühlmaschine	NYM-J	3	1.5	B/L	16A		429 mOhm / 536 A	163 MOhm > 500 MOhm 157 MOhm	40A	30mA	22,5 mA	38 ms	0,1 V 0,1 V		Ja
11	F19 - Beleuchtung Küche	NYM-J	3	1.5	B/L	16A			163 MOhm > 500 MOhm 157 MOhm	40A	30mA	22,5 mA	38 ms	0,1 V		Ja

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Application example

- A portable electrical appliance must be checked for electrical safety after a repair before it is handed over to the customer. In the commercial sector, this test must be repeated at certain intervals. The inspection intervals are set depending on the trade. This is intended to prevent any safety defects from being recognised. A special measuring device is required for the tests (Fig. 1).

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Check-out knowledge test

Name three basic steps in testing in accordance with DIN VDE 0701 and DIN VDE 0702.

After an electrical appliance has been repaired, a visual inspection is carried out first. Specify important parts that must be taken into account during the visual inspection.

- Housing
- Cables and wires
- Buttons and switches
- Strain relief for the connecting cable
- Mains plug

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a) Complete the connection of the test leads in Figure 2 when measuring the protective conductor resistance.

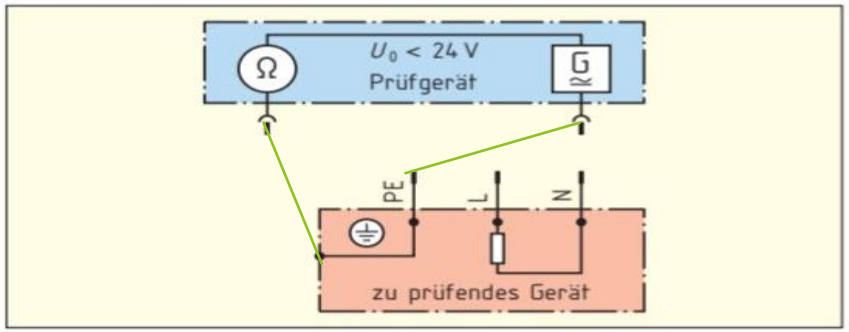


Figure 2: Measurement of the protective conductor resistance

b) Calculate the maximum permissible value for the protective conductor resistance if the connecting cable has a conductor cross-section of 1.5 mm2.

Anschlussleitung: $R_{PEmax\,5\,m}$ = **0,3 Ohm**

Verlängerung Anschlussleitung: $R_{PEmax\,7{,}5\,m}$ = **0,4 Ohm**

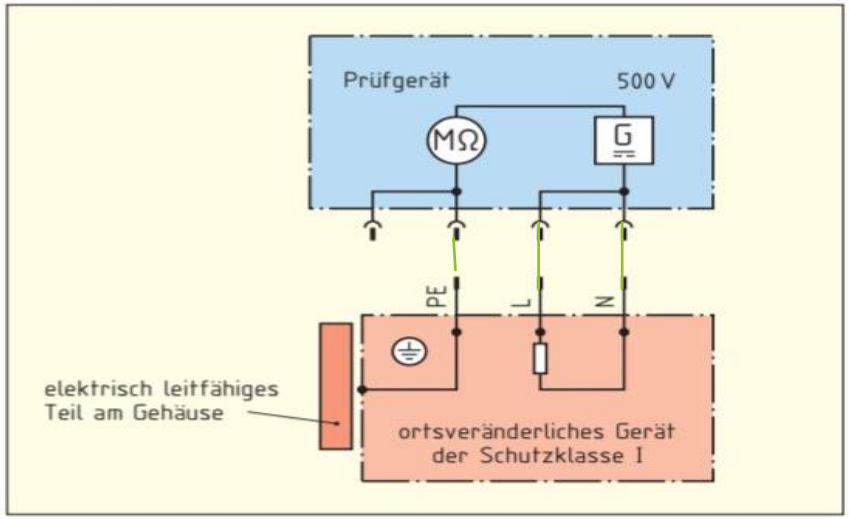
$R_{PEmax\,12\,m} \approx R_{PEmax\,5\,m} + R_{PEmax\,7\,m}$

$R_{PEmax\,12\,m} \approx$ **0,5 Ohm**

c) Why does the connecting cable have to be moved during measurement?

- To localise any cable breaks

a) Complete the connection of the test leads in Figure 3 when measuring the insulation resistance.



c) Fill in the missing values for the minimum insulation resistances for the various protection classes (SC).

SK1 without heating elements: 1 megohm

SK2: 2 megohms

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Check-out knowledge test

The touch current must be measured on conductive parts that are not connected to the protective conductor.
State the maximum value for the touch current according to DIN VDE 0701 (DIN EN 50678).

- 30 mA

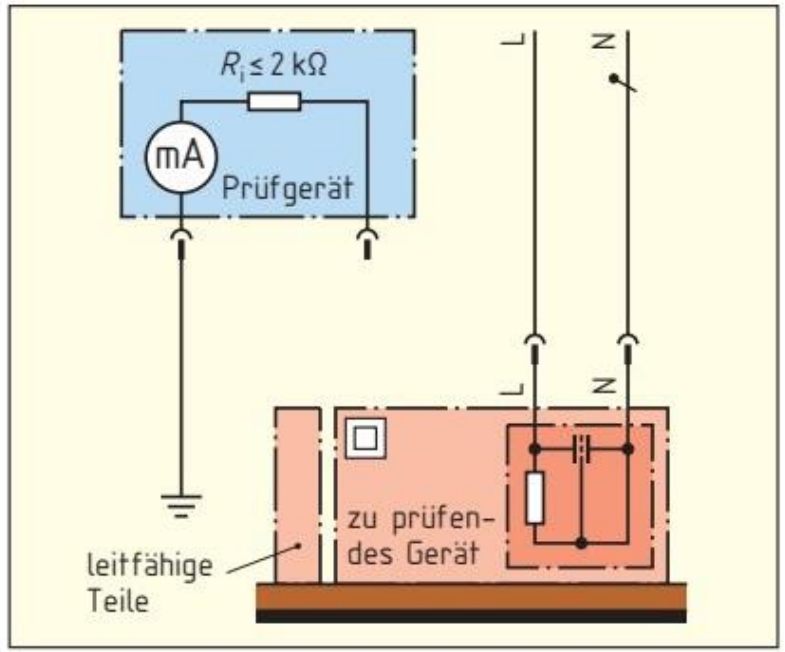

Figure 2: Measurement of the touch current

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Complete the test procedure **(Figure 3)** for the repeat test in accordance with DIN VDE of a portable electrical appliance of protection class I and II.

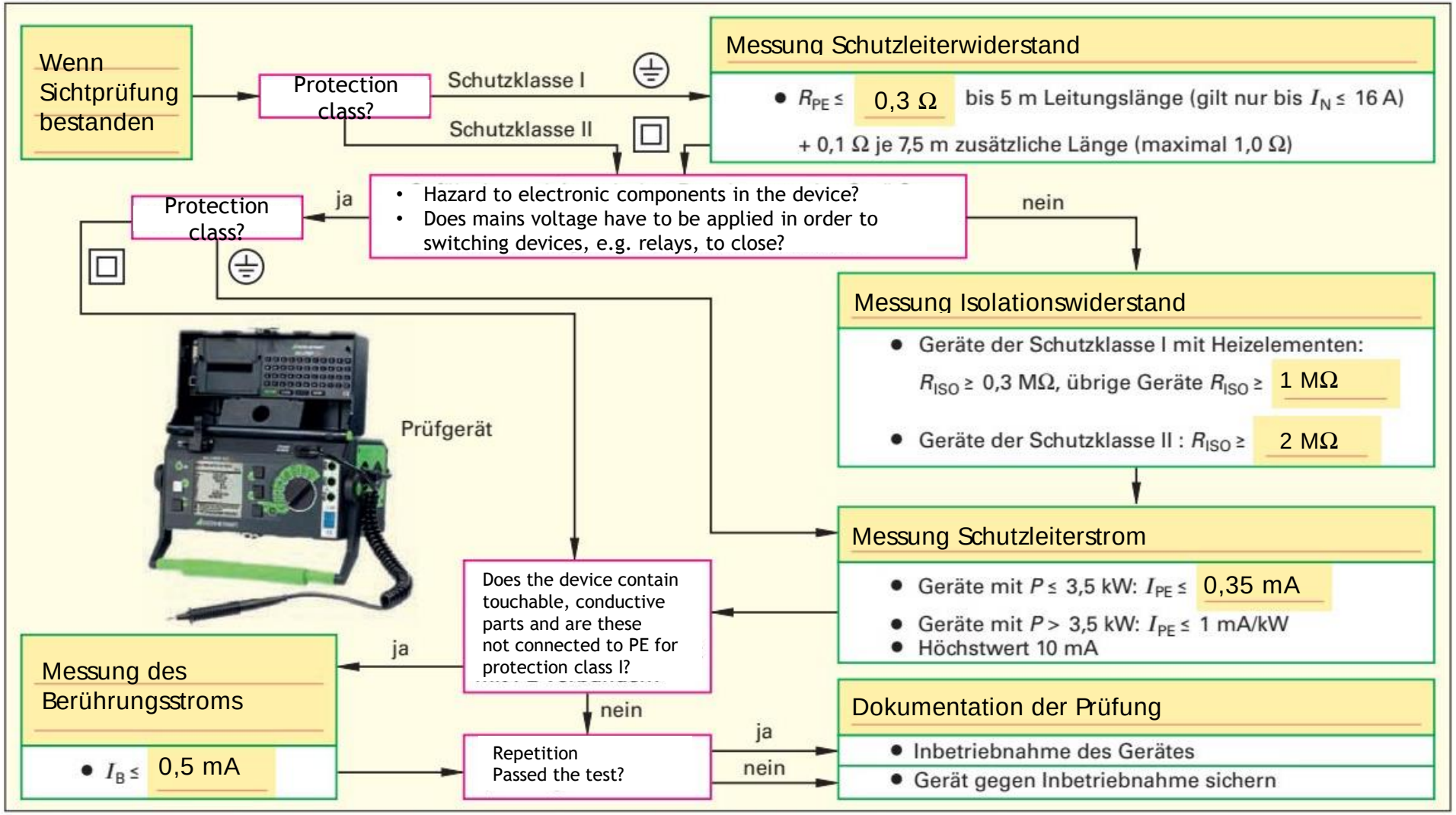

Figure 3: Overview of the periodic test according to DIN VDE for portable devices of protection class I and II

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Check-out knowledge test

What should I pay particular attention to when connecting flexible cables?

1. Professional clamp connections
2. Perfect strain relief
3. Carrying a protective conductor
4. Correct wire colours
5. High quality coat

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Check-out knowledge test

Electrical appliances must be tested in accordance with DIN VDE 0701. Which statement applies?

1. Electrical devices may only be tested by qualified electricians
2. Electrical household appliances are only to be checked at the express request of the customer
3. All electrical devices must be checked at 2-year intervals
4. ectrical household appliances must be tested after repair
5. Appliances must be tested every 5 years after manufacture at annual intervals

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Check-out knowledge test

A circuit breaker is used as a switching device in an electrical system. what task can such a circuit breaker fulfil?

1. Switch short-circuit currents safely.
2. Only suitable for low-voltage systems.
3. Switch off rated currents safely.
4. Can only be used for earthing and short-circuiting.
5. Create a visible disconnection point (interruption point).

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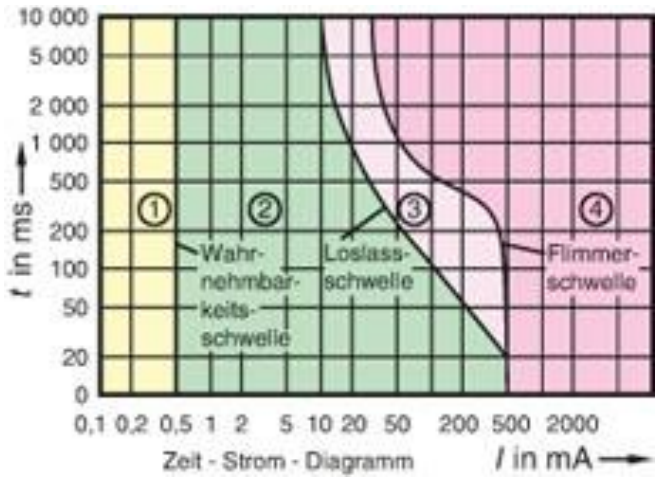
Check-out knowledge test

The diagram shows the effect of electric current on the human body. Please analyse the message of this diagram.



1. The current effect depends on the current intensity and the exposure time.
2. The current effect shows that currents above 10 mA are always fatal.
3. The effect of the current depends only on the exposure time of the current.
4. The current effect depends only on the current intensity.
5. The current effect depends only on the voltage.

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Check-out knowledge test

Three resistors R1 = 180 Ohm, R2 = 150 Ohm and R3 = 300 Ohm are connected in series and the total voltage is 240 V. What is the largest partial voltage?

1. U = 58 V
2. U = 2.6 V
3. U = 394 V
4. U = 114 V
5. U = 70 V

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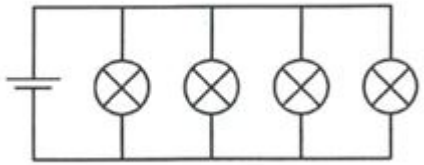
Check-out knowledge test

Four light bulbs are connected to a battery, as shown in the picture. The battery still has four hours of energy available for this light bulb. Which statement is correct if two light bulbs are removed?



1. The two remaining bulbs shine twice as brightly and burn out after a short time.
2. The bulb that is connected closer to the battery burns brighter than the second bulb.
3. The two remaining bulbs light up less brightly and go out after four hours.
4. The two remaining bulbs emit a weaker light.
5. The two remaining bulbs light up with the same intensity and glow for eight hours.

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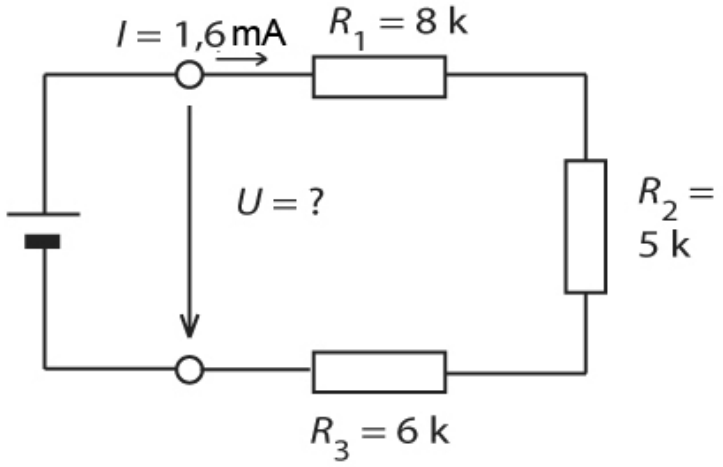
Check-out knowledge test

Calculate the voltage in the series circuit shown opposite.what is the value of the voltage U (in V)?

I



1. U = 3.4 V
2. U = 11.9 V
3. U = 9.6 V U = 12.8 V
4. U = 30.4 V

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Check-out knowledge test

A person touches a supply voltage of 230 V to earth.

Human body resistance: 1 kΩ,

Site contact resistance 25 kΩ

How high is the contact voltage?

1. 8,85 V
2. 120 V
3. 25,6 V
4. 230 V
5. 50 V

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Factcheck

Adapting quality of VET offer to the need of industry – manufacturing sector

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