Electrical Engineering Textbook

1st edition

Prepared and revised by teachers at vocational colleges and by engineers (see next page)
## Guide to the Electrical Engineering Textbook

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Dear Reader,

The Electrical Engineering Textbook is intended for use in initial and continuing training in the profession of electrical engineering. This first English edition is based on the 29th German edition of the established and reliable textbook “Fachkunde Elektrotechnik.” It is used for the teaching of basic and technical knowledge, in particular in the field of energy technology. It is aimed at everyone who is active in this profession.

Target groups (examples)
- Electronics engineers for energy technology and building technology, automation technology, machine and drive technology, industrial engineering, equipment and systems
- Industrial electricians
- Electric systems technicians
- Electrical engineers
- Students

Structure and use of the book
- The book was created by an experienced team of authors made up of teachers, master electricians and engineers.
- It has 17 chapters and is structured systematically according to subjects.
- The book is useful for skills-oriented and practical training.
- It can also be used as a reference work.
- Numerous multi-colored images, tables and charts help with the explanations.
- You will find explanations and uniform representations of important formulas of electrical engineering.
- Formulas and legends form a unit and are highlighted in color inside a frame.
- In the information section, you will find information on electro-technical symbols, characteristics and laying instructions for cables and lines.
- The “Review” pages consolidate and deepen the knowledge you have acquired.
- The results of the calculation tasks from the “Review” can be found on page 631.
- Practical tip pages will be of great support in professional activities.

Note on the standards
The book is based on European and German standards such as DIN, DIN EN, DIN EN ISO and DIN VDE. It is important to note that in some countries other standards, laws and regulations are valid that must be observed.

Auxiliary tool supplementing the Electrical Engineering Textbook
As supplementary technical literature, we recommend for the deepening and completion of your knowledge the book entitled “Electrical Engineering Tables, Standards, Formulas,” also published by Europa-Lehrmittel.

What can we make even better for you? Drop us a line at: info@europa-lehrmittel.de
The team of authors and the publishing house Europa-Lehrmittel Winter 2016
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A new project is starting!

A systematic approach is necessary in order to complete projects or orders professionally, e.g. the creation of a circuit installation (next page). The Overview below shows steps in the processing of a project or an order. They can be translated to any application you wish. Not all project steps are always required. It depends on the job.
Stages of a customer order: Creating an electrical installation connection

1. Customer meeting for planning
   - Customer wishes/requirements
   - Technical options
   - Rules
   - Room lighting
   - Energy saving
   - Job flow

2. Order planning
   - On-off circuit
   - Series circuit
   - Two-way circuit
   - Impulse circuit
   - Stairway timer switch
   - Sheathed cable
   - Flat-wedged cable
   - Wire cable
   - Plastic cable
   - Melting fuse
   - Line protection switch
   - Surface-mounted
   - Flush-mounted
   - In plaster
   - In tube
   - DIN VDE regulations
   - Preparing a quotation
   - Circuit symbols
   - Installation diagram
   - Circuit diagram
   - Parts lists
   - Organization
   - Tools, material
   - Network operator

3. Order implementation
   - DIN VDE regulations
   - Safety rules
   - Accident Prevention Regulations
   - Occupational safety
   - Perform installation
   - Construction site meeting
   - Provide materials, tools
   - Disposal of line, cable residues
   - Fluorescent lamps to hazardous waste
   - Recycling
   - Surveillance
   - Assignment of protection devices

4. Order evaluation
   - Function O.K.
   - Right rotating field
   - Trigger time
   - RCD
   - Grounding resistance
   - Loop impedance
   - Insulation resistance
   - Protective conductor resistance
   - Color codes
   - Covers
   - Protective conductor connections
   - Line selection
   - Assignment of protection devices
   - Clean construction site
   - Dispose of line, cable residues
   - Disposal
   - Fluorescent lamps to hazardous waste
   - DIN VDE regulations
   - Safety rules
   - Accident Prevention Regulations
   - Occupational safety
   - Perform installation
   - Construction site meeting
   - Provide materials, tools

- Customer meeting for planning
- Order planning
- Order implementation
- Order evaluation
1 Occupational safety and health protection 1)

1.1 Safety and health protection in the workplace

Electrical accidents can be largely ascribed to technical defects, e.g. missing protective barriers or incorrect insulation. In addition, organizational shortcomings, e.g. missing or inadequate work instructions, as well as human errors, e.g. faulty actions, can lead to accidents. The personal protective equipment at the workplace is of great importance for protection against injury and illness. Personal protective equipment refers to all items (e.g. protective clothing and hardhat) that protect the body against health-endangering effects.

The Ordinance on Industrial Safety and Health (see Overview) has established directions for the provision and use of work equipment. Occupational Safety and Health Act. This law has been designed to ensure and improve the safety and health of employees at their workplace, through measures of occupational safety. The employer is responsible for safety and health protection in the workplace. By law, he is required to conduct a risk analysis (page 19) in order to record and assess the specific risks of the work equipment and systems, of the working conditions for the employees, and of the risks to the environment.

Accident Prevention Regulations oblige employers to take measures for the prevention of work accidents, occupational illnesses, and work-related health hazards as well as for effective first aid. The accident prevention regulations issued by trade associations and the public accident insurers are called the Trade Associations’ Regulations for safety and health at work.

1.2 Product Safety Act

The Product Safety Act regulates the requirements for the safety of products as well as their inspection and labeling (e.g. CE label). It applies when products are made available, presented, or used on the market for the first time within the scope of business operations. Products include, for instance, machines, home improvement equipment and household appliances, tools, leisure and sports equipment, all textiles, furniture, toys and personal protective equipment.

Overview: Laws and regulations (examples)

- DIN VDE regulations
- Ordinance on Industrial Safety and Health
- Occupational Safety and Health Act
- Accident Prevention Regulations
- Rules and regulations of the Social Accident Insurance
  e.g. – Regulation 1 Principles of Prevention
  – Regulation 2 Occupational Physicians and Specialists for Occupational Safety
  – Regulation 3 Electrical Systems and Equipment
  – Regulation 7 Occupational Medical Precautions
- Technical Rules for Operational Safety
- Product Safety Act
- Ordinance on Hazardous Substances

Safety in the workplace

- Work safely and carefully.
- Apply passive safety.
- Wear personal protective equipment.
- Comply with prohibitions, e.g. no drinking, no smoking, no unauthorized entry.
- Report or eliminate safety deficiencies or states of danger immediately.
- Do not use operating equipment, working devices, or work equipment without authorization.
- Maintain tidiness in the workplace.

Definitions of terms from the Product Safety Act

- Products are goods, materials and compounds produced by a manufacturing process.
- Presenting means the offering, displaying, or demonstrating of products for purposes of advertising or provision on the market.
- Provision on the market is any paid or free-of-charge provision of a product for distribution, consumption or use on the market of the European Union (EU) in the course of a commercial operation.
Products reaching the market within the European Union must comply with the safety requirements of the EC Directives. As a sign of compliance, such products bear the CE label (Figure a). The manufacturer thereby declares the compliance (conformity) of the product with the essential safety requirements, and affixes the CE label to the product at his own responsibility.

By affixing the CE label, the manufacturer confirms that the product meets the requirements of EU legislation.

In addition to the CE label, products may also bear the GS symbol (Figure b), meaning that it has been tested for safety. The GS symbol is based on the Product Safety Act. Manufacturers may have their products voluntarily tested at testing centers, e.g. TÜV² and VDE³.

Products with the GS symbol ensure that the safety and health of the user is not at risk. Affixing this symbol is allowed only subsequent to a test by the GS test centers.

1.3 Ordinance on Hazardous Substances

The Ordinance on Hazardous Substances (GefStoffV) applies to the marketing of substances, mixtures, and products, as well as to the protection of employees and other persons from risks to their health and safety from hazardous substances, and to the protection of the environment from damage caused by substances. Hazardous substances and mixtures, in particular, have to be correctly packaged and labeled. On the basis of a globally harmonized system (GHS⁴), chemical substances are classified and labeled according to identical criteria throughout the world. The GHS system was introduced in the EU in tandem with the CLP⁵ regulation, i.e. the Regulation on Classification, Labeling and Packaging of substances and mixtures.

Most notable is the change in the labeling symbols. Instead of the danger symbols, nine hazard pictograms – a red-edged rhombus (diamond) with a black symbol on a white background (Table) – are now used. Three pictograms have been added: the gas cylinder, the exclamation point, and the body symbol (human torso and star). For further labeling, the signal words “Caution” and “Hazard” were introduced.

- **Caution**: Signal word indicating less severe hazard categories.
- **Hazard**: Signal word indicating severe hazard categories.

<table>
<thead>
<tr>
<th>Table: Identification of hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physico-chemical hazards</strong></td>
</tr>
<tr>
<td>Old</td>
</tr>
<tr>
<td>New</td>
</tr>
<tr>
<td>Compressed gases</td>
</tr>
</tbody>
</table>

1 CE, abbreviation for: Communauté Européenne (French) = European Community
2 TÜV, abbreviation for “Technischer Überwachungsverein” (Technical Inspection Authority)
3 VDE, abbreviation for “Verband der Elektrotechnik Elektronik Informationstechnik e.V.” (Association for Electrical Engineering, Electronics and Information Technologies)
4 GHS, abbreviation for: Globally Harmonized System
5 CLP, abbreviation for Classification, Labeling and Packaging
A substance that has been classified and packaged as dangerous has to bear an identification label (Figure 1) with the following elements.

![Image of a safety label]

### 1.4 Safety symbols

Technical guidelines of the Workplace Ordinance describes the requirements for safety and hazard protection marking in workplaces. **Safety symbols** are used for safety and health protection marking. They warn against risks, provide guidance in dangerous situations, and give handling instructions. This also includes the identification of prohibitions. Each symbol has the purpose of calling attention quickly and without ambiguity to objects and situations that can cause hazards.

The combination of **shape** and **safety color** alone indicates immediately whether a symbol is related to information on prohibitory, mandatory action, warning, emergency or fire protection (Table). In addition, safety symbols have a corresponding **icon**.

- **Prohibitory symbols** prohibit any kind of behavior that might cause a hazard, e.g. Do not switch (Figure 2).
- **Mandatory action symbols** prescribe a specific behavior, e.g. Use Hardhat.
- **Warning symbols** warn against risks or hazards, e.g. warning against a laser beam.
- **Emergency symbols** mark escape routes or emergency exits or the route to a first aid facility.
- **Fire protection symbols** identify the locations of fire detection or fire extinguishing facilities.
- **Additional symbols** (Figure 2) may be used only in combination with a safety symbol. They provide additional information by words or texts.

![Table: Shape, color, and meaning of safety symbols]

**Table: Shape, color, and meaning of safety symbols**

<table>
<thead>
<tr>
<th>Geometrical shape</th>
<th>Meaning</th>
<th>Safety color</th>
<th>Application example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle with diagonal bar</td>
<td>Prohibition</td>
<td>RED</td>
<td>No smoking</td>
</tr>
<tr>
<td>Circle</td>
<td>Mandatory action</td>
<td>BLUE</td>
<td>Use head protection</td>
</tr>
<tr>
<td>Equilateral triangle with rounded corners</td>
<td>Warning</td>
<td>YELLOW</td>
<td>Warning of flammable substances</td>
</tr>
<tr>
<td>Square</td>
<td>Safeness</td>
<td>GREEN</td>
<td>Emergency telephone</td>
</tr>
<tr>
<td>Square</td>
<td>Fire protection</td>
<td>RED</td>
<td>Fire extinguisher</td>
</tr>
</tbody>
</table>

![Figure 2: Prohibitory symbols with additional symbols]
1.5 First aid

First aid refers to assistance on the spot, before the injured or sick person is cared for by a doctor.

The life of a wounded person often depends on first aid (Figure 2) being administered as quickly as possible directly at the scene of the accident. The employer (contractor) is responsible for effective first aid. He must take the required measures. This includes, in particular, the appointment of a sufficient number of first aiders, ensuring appropriate training, and the provision of suitable first aid equipment.

In the event of an accident caused by electric current, self-protection must be borne in mind. The current flowing through the victim must be interrupted.

With regard to low voltage systems (usual household and industrial voltage, from 230/400 V to a maximum of 1000 V), the interruption of the circuit is performed, for instance, by switching off, pulling out the plug, or removing the fuse. If the circuit cannot be interrupted, the victim must be separated from the live parts by means of a non-conducting object, e.g. an insulated rod.

With high voltage systems (1000 V and more, systems marked by the lightning arrow symbol, Figure 1), the emergency doctor has to be called immediately, and qualified personnel must be notified. Rescue from high voltage systems is performed solely by qualified personnel. Therefore only competent staff in possession of a switching authorization are allowed to switch off the circuit.

If the voltage is not known, as with high voltage systems, a safety distance of at least 5 m has to be maintained. The same measures have to be taken as in the case of high voltage.

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Figure 1: Warning of dangerous voltage

Figure 2: First-aid measures

1 The European emergency call number is valid in all EU countries, as well as in Iceland, Liechtenstein, Norway and Switzerland
Assessment of risk

Instructions for conducting a risk assessment

Every activity involves accident risks and health hazards. In order to keep the risks to a minimum, a risk assessment **has to be** performed in workplaces, as per the Occupational Safety and Health Act together with the Ordinance on Industrial Safety and Health. A technical rule for industrial safety describes the basic process of identification and assessment of hazards, and the derivation of appropriate measures.

Understanding the company organization

Structuring the company into understandable areas of work, e.g. administration, workshop, warehouse, and activities

Understanding the safety organization of the company

e.g. organization of first aid, handling hazardous materials, safety officers ...

Understanding and identifying possible hazards and exposures

Hazards, or exposures, can be divided into, e.g.
- **Mechanical hazards**, e.g. stumbling, slipping, falling...
- **Electrical hazards**, e.g. electric current running through the body due to defective devices
- **Hazards due to hazardous substances**, e.g. inhaling or swallowing toxic substances
- **Biological hazards**, e.g. risk of infection with micro-organisms
- **Physical hazards**, e.g. the impact of noise, vibrations, radiation
- **Hazards due to physical stress**, e.g. heavy physical work
- **Hazards caused by deficiencies in the safety organization**, e.g. deficient provision of first aid, marking of escape routes, personal protective equipment, instructions, operating manuals.

Assessment of the hazards

Assessment of how the identified hazards can affect employee health.

Are the safety and health of employees at risk?

Determination and implementation of measures

Measures must be determined in accordance with the general principles of the Occupational Safety and Health Act.

This results in the ranking of the technical, organizational, and personal (TOP) protective measures which have to be defined.

- **Technical protective measures**, e.g. exhaust systems, position switches.
- **Organizational protective measures**, e.g. organization of first aid, training, occupational medicine, hygiene.
- **Personal protective measures**, e.g. personal protective equipment (safety goggles, gloves), are employed only if the technical measures do not suffice to protect employees.

Who does what, and when?

Documentation

The documentation must include:
- The result of the risk assessment.
- The defined occupational safety measures.
- The outcome of their review.
- Accidents in the workplace, as a result of which an employee is killed, or else injured so badly that he dies, or is completely or partially unable to work for more than three days.
1. a) Which defects or faults usually cause electrical accidents? Name examples. b) What are the requirements regarding technical equipment which can be inferred?

2. a) What is personal protective equipment? b) What is the purpose of personal protective equipment? c) Give examples of personal protective equipment.

3. a) What is the purpose of conducting a risk assessment? b) List the steps to take for the practical implementation of a risk assessment.

4. Which obligations arise for the employer from the Accident Prevention Regulations?

5. What is the meaning of the following abbreviations: a) CLP, b) GHS?

6. What do the a) CE label and b) GS symbol on products mean?

7. Which regulation is designed to protect workers against risks to their health from hazardous substances?

8. Name the designations for the hazard pictograms shown in Figure 1 from a) to g).

9. Which information has to be present on the packaging of hazardous substances?

10. What is the assessment called by means of which accident and health risks in workplaces are kept as low as possible?

11. What are the obligations arising for companies from the Accident Prevention Regulation “Safety and Health Protection Labeling at the Workplace”?

12. What are the prerequisites for allowing products to be brought onto the market, and by means of which symbol is this indicated?

13. What are the two characteristics that distinguish safety symbols?

14. Name safety colors a) to d) for the safety symbols specified in the Table.

<table>
<thead>
<tr>
<th>Safety color</th>
<th>a)</th>
<th>b)</th>
<th>c)</th>
<th>d)</th>
</tr>
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<tbody>
<tr>
<td>Prohibition</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Mandatory action</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Warning</td>
</tr>
<tr>
<td>Fire protection</td>
<td>Safeness</td>
<td>—</td>
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</tr>
</tbody>
</table>

15. a) Which safety symbols can be distinguished, and b) which information can be learned from the respective symbols?

16. Name the safety symbols depicted in Figure 2, and describe their meaning.

17. Why are additional symbols frequently used together with safety symbols?

18. What information is it imperative to provide in an emergency call?

19. What is first aid?

20. What are the immediate measures to be taken in the event of accidents caused by electric current?

21. How can you help someone who has suffered an accident caused by electric current if the circuit cannot be interrupted?

22. Describe the first aid measures when you come upon an injured person who is a) responsive or b) non-responsive.