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for the electrotechnical, electronic
and information technology trades

Electrical Engineering

Tables

Standards

Formulas

3rd English edition

The German edition was written by teachers in vocational colleges and engineers from the production industry (see next page).

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Heinz O. Häberle co-founded the first edition of this manual in 1966, developed it both as an editor and an author, and shaped it until his death in 2017. His diverse literary works supported training and development of young people in the field of electrical engineering for decades. We would like to express our gratitude for his work.

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This 3rd English edition is based on the 29th German edition of *Tabellenbuch Elektrotechnik*, a leading compendium in German-speaking countries which is also available worldwide in various languages. This edition has been enhanced and supplemented by the topics of digitisation, Industry 4.0, smart grids, smart home, and requirements related to climate change. Standards were also modified. Despite the harmonisation of the most important European standards, local regulations may differ slightly from German standards under certain circumstances, which means that where safety matters are concerned, the user has to check whether any other local regulations exist.

Section F Fundamentals, Physics, Components	Formula symbols for electrical rotating machines, units and quantities, mathematical symbols, unit prefixes, force, moment of force, work, power, heat, charge, voltage, current, resistance, potentiometers, alternating quantities, three-phase current, unbalanced loads in the three-phase current, resistors, capacitors, diodes, transistors, thyristors, and magnetic field-dependent components.
Section TM Technical Documentation, Measuring	Technical drawing, circuits and circuit symbols, circuit diagrams, using reference identification, documentation, and operating instructions. Measuring instruments and systems, measuring categories, measurement in electrical installations, power meters, hydraulic and pneumatic components, symbols used in process engineering, markings used in electropneumatic controllers, electropneumatic basic circuits, AC/DC quantity gathering, oscilloscopes, sensors, light barriers.
Section EI Electrical Installations	Qualifications required for working in electrical installations, working in electrical installations, installation circuits, intercom systems, minimum equipment requirements for communication installations in residential buildings, types of dimmers, dimming LEDs, building management and automation, building automation via existing power lines, DALI, smart home systems, components for radio control, setting up control cabinets, house connection and sectioning the PEN conductor, calculating lines, cable lengths, length-related inductance and voltage drop, harmonics, separating communication cabling, overcurrent protection equipment, electrical installations, lighting engineering, LED lighting, LED tube lights/luminous bands.
Section SE Safety, Energy Supply	Workplace health and safety, current hazard due to DC, basic protection, fault protection, complementary protection, Protection Manager, residual currents, coordinating the equipment, types of power plants, high voltage direct current transmission, electricity trading, explosion-proof equipment, IC code, IK code, insulator classes, transformers, overhead power cables, underground cables, photovoltaic power plants, fuel cells, primary elements, accumulators, SCS systems, charging technologies for accumulators, charging stations for electric vehicles, lightning protection, compensation, measuring harmonics, THD values, controlling grid voltage and frequency, safety engineering, fire safety and wiring systems, heating consumption, energy harvesting, the German Energy Saving Ordinance, electrical energy efficiency, electricity tariffs.
Section IC Information and Communication Technology	Number systems, codes, sweep circuits, Windows keys, Excel, digitisation, Industry 4.0, Internet of Things, DA converters, AD converters, modulation and demodulation, information technology networks, Ethernet, wireless LAN, AS-I bus systems, M-Bus and smart metering, 3D printers, network communication, PROFINET, identification systems, Internet, antenna systems, satellite systems, telecontrol, remote maintenance, SIL functional safety, sensor wiring, malfunctions in radio transmissions, satellite receiver systems.
Section AC Automation, Drive and Control Systems	Operational amplifiers, converters, SMPS, control relays, programmable logic controllers PLC, library-capable PLC blocks, TIA Portal, GRAFCET, electrical equipment for machinery, contactors, engine protection, control technology, auxiliary circuits in control systems, AC motors, DC motors, efficiency of drive systems, servomotors, micro-motors, linear drives, selecting and setting up frequency converters, safety functions, electronic limit switches, soft starters.
Section MC Materials, Connection Technology	Periodic table, specific material values, steel standardisation, magnetic materials, insulators, cables and wires, underground cables, connectors, Cat7 connectors, solderless connection technology, threads, screws, bolts and nuts.
Section CE The Company and its Environment	Organisational structures of companies, teamwork, job planning, cost accounting and KPIs, implementation of projects, conflict management, communication with customers, business etiquette, statistical analyses, quality management, environmental terms, hazardous materials, standards, abbreviations, technical glossary, companies and departments.

It should be noted in general that standards allow different ways of representation, e.g. DIN EN 61082 (Documents in Electrical Engineering, Rules) allows the representation of electricity branching with or without a point. As usual in professional practice, we have taken advantage of this freedom also in this book.

The publisher and authors would like to thank users for their numerous comments, which have helped to improve this book. We would be grateful for future suggestions and constructive comments. You can send them per email to lektorat@europa-lehrmittel.de.

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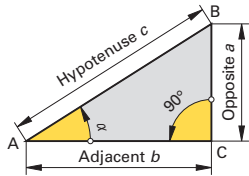
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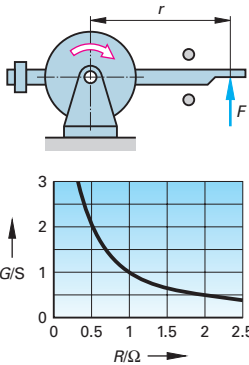
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Mathematics



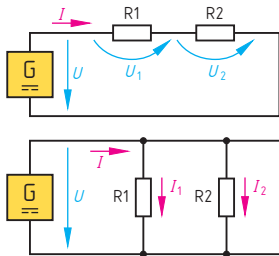
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Physics



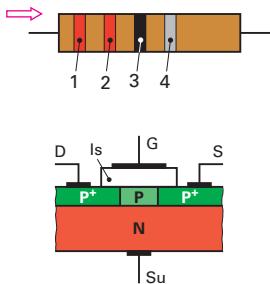
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Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
Lowercase letters		Capital letter		Greek lowercase letters	
<i>a</i>	1. acceleration 2. transformer ratio	<i>A</i>	1. area 2. attenuation ratio 3. cross section	α (alpha)	1. angle 2. temperature coefficient 3. firing angle
<i>c</i>	1. spec. thermal capacity 2. electrochemical equivalent 3. propagation velocity of waves 4. coefficient	<i>B</i>	1. magn. flux density 2. direct current ratio 3. number base	β (beta)	1. angle 2. short-circuit current amplification factor
<i>d</i>	1. diameter 2. distance 3. dissipation factor 4. duty cycle	<i>C</i>	1. capacitance 2. thermal capacity 3. constant 4. capital	γ (gamma)	1. angle 2. conductivity
<i>e</i>	elementary charge	<i>D</i>	1. deflection coefficient 2. electric flux density 3. attenuation factor 4. spring constant	δ (delta)	loss angle
<i>f</i>	1. frequency 2. filter factor	<i>E</i>	1. electric field strength 2. illuminance	ϵ (epsilon)	permittivity
<i>g</i>	acceleration of free fall, local gravity	<i>F</i>	1. force 2. factor 3. fault	ϵ_0	electric constant
<i>h</i>	height	<i>G</i>	1. conductance 2. amplification factor 3. gravitational force	ζ (zeta)	work ratio, utilisation ratio
<i>i</i>	1. time-controlled current 2. transmission ratio	<i>H</i>	magnetic field strength	η (eta)	efficiency
<i>j</i>	jerk	<i>I</i>	1. electric current 2. light intensity	λ (lamb-da)	1. wavelength 2. power factor
<i>l</i>	1. length 2. spacing, distance	<i>J</i>	1. current density 2. moment of inertia	μ (mü)	1. permeability 2. friction coefficient
<i>m</i>	1. mass 2. number of strands	<i>L</i>	1. inductance 2. level	μ_0	magnetic constant
<i>n</i>	1. speed, rotational frequency 2. integer 1, 2, 3, ... 3. refractive index	<i>M</i>	1. moment of force 2. memory capacity	ν (nü)	ordinal number
<i>o</i>	overdrive factor	<i>N</i>	number of turns	π (pi)	number 3.1415926...
<i>p</i>	1. number of pole pairs 2. pressure 3. percentage	<i>P</i>	active or effective power	σ (sigma)	1. leakage factor 2. stress
<i>r</i>	1. radius 2. rate 3. differential resistance	<i>Q</i>	1. electric charge 2. heat 3. reactive power 4. quality factor	τ (tau)	time constant
<i>s</i>	1. shunt current ratio 2. section 3. thickness 4. normalized slip 5. correction 6. sensitivity	<i>R</i>	1. active resistance 2. spring rate 3. rigidity	φ (phi)	angle, particularly phase-shift angle
<i>t</i>	time	<i>S</i>	1. susceptance (band-width) 2. apparent power 3. steepness 4. slip (absolute) 5. transmission quantity	ϑ (theta)	temperature in °C
<i>v</i>	1. time-controlled voltage 2. velocity	<i>T</i>	1. cycle duration 2. transmission factor 3. temperature in K	χ (kappa)	conductivity (optional symbol)
<i>w</i>	1. width 2. energy density 3. reference variable	<i>THD</i>	total harmonic distortion	ρ (rho)	1. specific resistance 2. density
<i>x</i>	controlled variable	<i>U</i>	voltage	ω (omega)	1. angular velocity 2. angular frequency
<i>y</i>	manipulated variable	<i>V</i>	1. volume 2. amplification factor	Greek capital letters	
<i>z</i>	integer, e. g. number of teeth of a gear	<i>W</i>	1. work 2. energy	Δ (Delta)	difference
		<i>X</i>	reactance	Θ (Theta)	current linkage
		<i>y</i>	apparent admittance	Σ (Sigma)	sum
		<i>Z</i>	1. impedance 2. wave impedance 3. oscillation impedance	Φ (Phi)	1. magnetic flux 2. luminous flux
				Ψ (Psi)	electric flux
				Ω (Omega)	solid angle

Special symbols are created by adding one or more subscripts or other signs to the symbol.





Subscript, Symbol	Meaning	Subscript	Meaning	Subscript	Meaning
Digits, characters		o	1. output 2. outer 3. oscillator	D	1. drain 2. data 3. discharge
0	1. idle 2. vacuum 3. reference variable	out	output, outgoing	E	1. emitter 2. earth
1	1. input 2. order, sequence	p	1. parallel; 2. pause; 3. pulse; 4. potential; 5. pressure; 6. power...;	F	1. forward 2. fault
2	1. output 2. order, sequence	perm	7. pre-permissible	G	1. gate 2. gravitational force 3. smoothing 4. gain
3, 4, ...	order, sequence	r	1. reactive	H	1. hysteresis 2. Hall...
$\wedge$, e.g. $\hat{u}$	peak value	rat	2. reception 3. rated... 4. rise		3. height 4. heat sink
$\vee$, e.g. $\check{u}$	minimum value	rt	5. resonance 6. remanence		cathode
$\hat{\wedge}$ e.g. $\hat{u}$	1. peak-to-peak value 2. oscillation width		right		
$'$, e.g. u'	1. related to 2. note; 3. derivation	s	1. starting/start-up... 2. sustained 3. shunt... 4. serial 5. signal... 6. series 7. specific	K	
Δ	delta connection	s, sc	short-circuit...	L	1. locked... 2. inductive 3. load 4. left 5. maximum permissible touch voltage 6. Lorentz... 7. loop
Y	star connection	st	step	N	nominal, rated...
Lowercase letters		t	1. tripping... 2. test...	O	operating...
a	1. breaking 2. leakage..., 3. discharge... 4. armature; 5. actual...	th	1. thermal 2. threshold	PF	positive feedback
b	1. bit; 2. brake...	tot	total	R	1. reverse 2. active resistance 3. right 4. red
c	1. cut-off...; 2. crest 3. comparison 4. centripetal...	u	voltage...	S	1. nominal... 2. shunt... 3. source 4. switch... 5. sector
d	1. referring to DC; 2. digit; 3. direction of displacement; 4. dissipation	v	visual	T	1. total; 2. threshold 3. transformer... 4. track 5. torque
des	desired...	w	1. command variable 2. wave... 3. wind... 4. width	V	1. voltmeter 2. volume
e	1. error; 2. evaporation	x	1. unknown variable 2. in x-direction	X	at the x-input
eff	1. effective 2. effective (active)	y	1. manipulated variable 2. in y-direction 3. y connection	Y	1. at the y-input 2. star connection (Y-connection)
f	1. frequency 2. fall, fusion 3. fusion...	z	zigzag connection	Z	1. Zener... 2. permissible
h	high, upper	Capital letter		Greek lowercase letters	
i	1. inner; 3. current...; 4. ideal; 5. DC link...	A	1. ammeter 2. aerial 3. anode 4. system earthing 5. sampling... 6. area 7. ambient	α (alpha)	in direction of the angle α
in	input, ingoing	B	1. breakaway... 2. base 3. system earthing (grid) 4. breakover	σ (sigma)	leakage
j	junction		1. collector; 2. capacitive 3. cycle; 4. cluster 5. coupling; 6. channel 7. charging; 8. cogging... 9. carrier	ϕ (phi)	phase-shift related
k	kinetic			Greek capital letters	
l	low, lower, loss			Δ (Delta)	difference
lt	left	C			
m	1. magentic; 2. mean 3. measured				
max	maximum				
mec	mechanical				
min	minimum				
n	1. nominal... 2. normal... 3. noise...				

Subscripts may be combined, e.g. U_{CE} for collector-emitter voltage. Subscripts that consist of several letters may be reduced to the first letter.



Quantity	Previous symbol	Symbol		Unit, Unit symbol
		Preferred symbol	Reserve symbol	
Current and related quantities				
Rated current	I_N	I_{rat}	I_N	Ampere, A
Nominal current	I_n	I_n or I_{nom}	–	
Sustained short-circuit current	I_{kd}	I_k	I_{SC}	
Maximum aperiodic short-circuit current	I_S	$\hat{I}_k$	$\hat{I}_{\text{SC}}$	
Initial periodic short-circuit current	i_S	I_{k0}	I_{SCO}	
Transient current	i	I'_k	I_{SC}'	
Subtransient current	i_S	I''_k	I_{SC}''	
Current load	I'	A	Not applicable	Amperes per metre, A/m
Voltage and related quantities				
Rated voltage	U_N	U_{rat}	U_N	Volt, V
Nominal voltage	U_n	U_n or U_{nom}	Not applicable	
Induced voltage	U_i	U_g		
Open-loop voltage	U_0	U_0		
Power and related quantities				
Rated power	P_N	P_{rat}	P_N	Watt, W
Rated apparent power	S_N	S_{rat}	S_N	Volt-ampere, VA
Nominal power	P_n	P_n or P_{nom}	Not applicable	Watt, W
Input power	P_1 or P_i	P_{in}		
Output power	P_2 or P_o	P_{out}		
Mechanical power	P	P_{mec}		
Power dissipation	P_d	P_t		
Power factor	$\cos \varphi$	λ (lambda)		One (no unit)
Active factor	–	$\cos \varphi$		
Torques, moments of force				
Torque, moment of force	M	T	M	Newton meter, Nm
Nominal moment/torque	M_n	T_{nom}	Not applicable	
Rated moment/torque	M_N	T_{rat}	M_{rat}	
Breakdown torque	M_K	T_b	M_b	
Holding torque	M_H	T_H	M_H	
Pull-up torque	M_S	T_u	M_u	
Breakaway torque	M_A	T_l	M_l	
nom = nominal, rat = rated, T = torque, active factor = cosine of fundamental (without harmonics), power factor = relation of active power to apparent power (with harmonics)				



Length, area, volume, angle			Electricity		
length l	metre (sea mile) (mile) (inch)	m 1 sm = 1,852 m 1 mi = 1,609.344 m 1" = 25.4 mm	electric charge Q , electric flux Ψ	coulomb	1 C = 1 A · 1 s = 1 As
area A	square metre	m ²	surface charge density σ , electric flux density D	coulombs per square metre	C/m ²
volume V	cubic metre (litre)	m ³ 1 l = 1 dm ³ = = 1/1,000 m ³	space charge density ρ	coulombs per cubic meter	C/m ³
angle (plane) (see page 20)	radian, RAD (degree, DEG)	rad 1° = $\frac{\pi}{180}$ rad,	electr. voltage U , electr. potential ϕ , V	volt	1 V = 1 J/C
solid angle Ω	steradian	sr	electr. field strength E	volts per metre	1 V/m = 1 N/C
Time, frequency, velocity, acceleration			electr. capacitance C	farad	1 F = 1 As/V = 1 C/V
time t	second (minute) (hour)	s 1 min = 60 s 1 h = 60 min = 3,600 s	current loading A	amperes per metre	A/m
	(day)	1 d = 24 h	permittivity, absolute permittivity ϵ	farads per metre	1 F/m = 1 C/(Vm)
frequency f	hertz	1 Hz = 1/s	electric current I	ampere	1 A = 1 C/s
speed, rotational frequency n	per second (per minute)	1/s = 60/min	electric current density J	amperes per m ²	A/m ²
angular frequency ω	per second	1/s	electric resistance, active resistance R , reactance X , impedance Z	ohm	1 Ω = 1 V/A
velocity v	metres per second (knot)	m/s 1 kn = 1 sm/h = 0.5144 m/s 1 km/h = $\frac{1}{3.6}$ m/s	electric effective conductance G , susceptance B , apparent admittance Y	siemens	1 S = $\frac{1}{1 \Omega}$
angular velocity ω	radians per second	rad/s	specific electric resistance ρ	ohmmetre	1 Ω m = 100 Ω cm 1 Ω mm ² /m = 1 $\mu\Omega$ m
acceleration a	–	m/s ²	electric conductivity γ	siemens per metre	1 Sm/mm ² = 1 MS/m
jerk j	–	m/s ³	power P	watt	1 W = 1 V · 1 A
Mechanics			reactive power Q	(var)	1 var = 1 V · 1 A
mass m	kilogram (carat) (tonne)	kg 1 Kt = 0.2 g 1 t = 1,000 kg	apparent power S	(VA)	1 VA = 1 V · 1 A
density ρ	–	kg/m ³ , kg/dm ³	inductance L	Henry	1 H = 1 Vs/A
moment of inertia J	–	kg · m ²	work W , energy E , W	joule (watt-hour) (electron volt)	1 J = 1 Ws 1 Wh = 3.6 kNm 1 eV = 0.1602 aJ
force F	newton	1 N = 1 kg · m/s ²	Magnetism		
torque, moment of force M	–	Nm	current linkage Θ	ampere	A
pulse p	newton sec.	1 Ns = 1 kg · m/s	magnetic field strength H	amperes per metre	A/m
pressure p	pascal (bar)	1 Pa = 1 N/m ² 1 bar = 0.1 MPa = 10 N/cm ²	magnetic flux Φ	weber	1 Wb = 1 T · 1 m ² = 1 Vs
surface pressure p , rigidity R_p , R_s , modulus of elasticity E	–	N/mm ²	magn. flux density B , magn. polarisation J	Tesla	1 T = 1 Wb/m ² = 1 Vs/m ²
work W , energy E , W	joule (electron volt)	1 J = 1 Nm = 1 Ws 1 eV = 0.1602 aJ	inductance L	henry	1 H = 1 Vs/A
power P	watt	1 W = 1 J/s = 1 Nm/s	permeability μ	henrys per metre	1 H/m = 1 Vs/(Am)
			magn. resistance R_m	–	1/H = A/Vs



Quantity, symbol	SI unit (other unit)	Unit symbol, unit equation	Quantity, symbol	SI unit (other unit)	Unit symbol, unit equation
Electromagnetic radiation (except light)			Nuclear reaction, ionising radiation		
radiant energy Q_e	joule	1 J = 1 Nm = 1 Ws	activity of a radioactive substance A	becquerel	1 Bq = 1/s
radiant power Φ_e	watt	1 W = 1 J/s	absorbed dose D	gray	1 Gy = 1 J/kg
radiant intensity I	watt/sterad.	W/sr	absorbed dose rate D'	grays per second	Gy/s
radiance L	–	W/(sr · m ²)	dose equivalent H	sievert	1 Sv = 1 J/kg
irradiance E	–	W/m ²	dose equivalent rate H'	sieverts per second	1 Sv/s = 1 J/(kg · s)
Light, optics			ion dose J	coulombs per kilogram	C/kg
light intensity I_v	candela	cd	ion dose rate J'	amperes per kilogram	1 A/kg = 1 C/(kg · s)
luminance L_v	candelas per m ²	cd/m ²	Acoustics		
luminous flux Φ_v	lumen	lm	sound pressure p	pascal	1 Pa = 1 N/m ²
luminous efficacy η_v	lumens per watt	lm/W	sound particle velocity v	metres per second	m/s
illuminance E_v	lux	1 lx = 1 lm/m ²	sound velocity (propagation velocity) c_s	metres per second	m/s
optical power of lenses D	– (diopetre)	1/m 1 dpt = 1/m	volume velocity q	–	1 m ³ /s = 1 m ² · 1 m/s
Heat			sound intensity I	–	W/m ²
centigrade temperature ϑ	degree centigrade	°C	specific sound impedance Z	–	Pa · s/m = Ns/m ³
thermodynamic temperature T	kelvin	K (0 K $\triangleq$ –273.15 °C)	acoustic impedance Z_F	–	N · s/m ³
temperature difference ΔT	kelvin	K	mechanical impedance Z_M	–	N · s/m = kg/s
heat Q , inner energy U	joule	1 J = 1 Ws	equivalent absorption area A	square metre	m ²
heat flow Φ	watt	1 W = 1 J/s	Other disciplines		
thermal resistance (of components) R_{th}	kelvins per watt	K/W	distance in astronomy l	(astronomical unit) parsec	1 AE = 149.6 Gm ¹ 1 pc = 30.857 Pm ¹
thermal conductivity λ	–	W/(K · m)	velocity of light c	km/s	$c \approx 300,000$ km/s
heat transfer coefficient h	–	W/(K · m ²)	light year l.y.	km	1 l.y. = 9.461 · 10 ¹² km
thermal capacity C , entropy S	joules per kelvin	J/K	mass in nuclear physics m	(nuclear mass unit)	1 u = 1.66 · 10 ^{–27} kg
specific thermal capacity c	–	J/(kg · K)	mass per unit length of textile fibres and threads $\bar{T}$	tex	1 tex = 1 g/km
Chemistry, molecular physics			area of plots of land A	are hectare	1 a = 100 m ² 1 ha = 100 a
quantity of substance n	mol	mol	¹ Unit prefixes G, P see page 18		
molar concentration c	–	mol/m ³			
molar	–	m ³ /mol			
molality b	–	mol/kg			
molar mass M	–	kg/mol			
molar thermal capacity c_p, c_v	–	J/(mol · K)			
diffusion coefficient D	–	m ² /s			



Symbol	Meaning	Example	Symbol	Meaning	Example
General symbols			∞	infinite	$n = 1, 2, 3, \dots, \infty$
$\dots n$	and so on until n	$k = 1, 2, 3, \dots, n$	$\rightarrow$	versus, approaches, exceeds	$x \rightarrow a$, x approaches the value a
$\dots$	and so on until infinity	$n = 1, 2, 3, \dots$ $\sqrt{2} = 1.41421 \dots$	$f(x)$	function of x	$f(I) = I^2 \cdot R$
			i or j	imaginary unit	$i^2 = j^2 = -1$
			Z	complex quantity Z	$Z = R + jX$
Boolean algebra			Geometry, vectors		
$\neg a, \bar{a}$	NOT a	$\overline{a \wedge b} = \neg (a \wedge b)$	$\parallel$	parallel	$g_1 \parallel g_2, R_1 \parallel R_2$
$\wedge$	AND	$a \wedge b$ or $\wedge (a, b)$	$\uparrow\uparrow$	parallel in the same dir.	$g \uparrow\uparrow h$
$\vee$	OR	$a \vee b$ or $\vee (a, b)$	$\uparrow\downarrow$	parallel in opposite dir.	$g_1 \uparrow\downarrow g_2$
$\overline{\wedge}$	NOT AND (NAND)	$a \overline{\wedge} b = \overline{a \wedge b}$	$\perp$	orthogonal, perpendicular	$g \perp h$
$\overline{\vee}$	NOT OR (NOR)	$a \overline{\vee} b = \overline{a \vee b}$	$\triangle$	triangle	$\triangle ABC$
Set theory			$\cong$	congruent,	$\triangle ABC \cong \triangle DEF$
$\in$	element of	$a \in M$: a is element of M	$\sim$	similar	$\triangle P_1P_2P_3 \sim \triangle ABC$
$\subset$	subset	$M_1 \subset M_2$: M_1 is subset of M_2	$\sphericalangle$	angle	$\triangle ABC = \sphericalangle (\overline{BA}, \overline{BC})$, $\sphericalangle (\vec{a}, \vec{b})$
$\cup$	union of sets	$\{1, 2\} \cup \{3, 4\} = \{1, 2, 3, 4\}$	$\overline{AB}$	line segment AB	$\overline{P_1P_2}$
$\Rightarrow$	from this follows that	$a \cdot b = c \Rightarrow a = c/b$	$\widehat{AB}$	arc AB	$\widehat{AB} = \sphericalangle \gamma$
Arithmetic			$\vec{A}, \vec{B}$	vector A , vector B	$\vec{C} = \vec{A} + \vec{B}$
			$ \vec{A} $	absolute value of vector A	$ \vec{F} = 50 \text{ N}$
$=$	equal to	$P = U \cdot I$	Differentiation, integration		
$\neq$	not equal, unequal	$4 \neq 5$	Δ	difference	$\Delta U = U_2 - U_1$
$\sim$	proportional	$u \sim r$	y'	y prime	y' is the first derivation of y , first derivative
$\approx$	approximately	$\pi \approx 3.14$	$\frac{dy}{dx}$	dy over dx	quotient $y' = dy/dx$
$\triangleq$	corresponds to	$1 \text{ cm} \triangleq 20 \text{ N}$	$\int$	integral	$\int f(x) dx, \int_a^b f(x) dx$
$<$	less than	$2 < 3$	Exponents, logarithms		
$>$	greater than	$5 > 2$	a^x	a to the power of x	$5^3, 10^x$
$\leq$	less than or equal to	$a \leq 10$	exp	exponential function	exp $x = e^x$, with $e = 2.718\dots$
$\geq$	greater than or equal to	$n \geq 7$	log	general logarithm	
$\ll$	considerably less than	$R \ll 100 \text{ k}\Omega$	$\log_a$	logarithm to the basis a	$\log_3 9 = 2$
$\gg$	considerably greater than	$R_x \gg R_n$	lg	common logarithm	$\lg 2 = 0.30103\dots$
$\cdot, \times$	times, multiplied	$a \cdot b = ab, 12 \times 3 = 36$	lb	dyadic logarithm	$\lg 8 = 3$
$-, /, :$	divided by	$\frac{7}{2} = 7/2 = 7 : 2$	ln	natural logarithm	$\ln 10 = 2.3025\dots$
%	per cent	$1\% = 10^{-2}, 50\% = 0,5$	Trigonometry		
‰	per thousand, per mil	$1\text{‰} = 10^{-3}, 8\text{‰} = 0,8\%$	sin	sine	$\sin \alpha$
$(), [], \{ }, < >$	round, squared, curly, pointed brackets	$[a(b - c) + d]^2$	cos	cosine	$\sin^2 \alpha + \cos^2 \alpha = (\sin \alpha)^2 + (\cos \alpha)^2 = 1$
$ z $	amount of z	$ 4 = 4, -7 = 7$	tan	tangent	$\tan \alpha = \sin \alpha / \cos \alpha$
$n!$	n factorial	$n! = 1 \cdot 2 \cdot 3 \cdot \dots \cdot n, 3! = 6$	cot	cotangent	$\cot \alpha = 1/\tan \alpha$
Σ	sum	$\Sigma I = I_1 + I_2 + I_3 + \dots$	arcsin	arc cosine	$\sin \alpha = x \Rightarrow \arcsin x = \alpha$
$\prod$	product	$\prod k = k_1 \cdot k_2 \cdot k_3 \cdot \dots$	arccos	arc cosine	$\cos \alpha = x \Rightarrow \arccos x = \alpha$
$\sqrt{\quad}$	square root of	$\sqrt{16} = 4$	arctan	arc tangent	$\tan \alpha = x \Rightarrow \arctan x = \alpha$
$\sqrt[n]{\quad}$	n th root of	$\sqrt[3]{8} = 2$	arccot	arc cotangent	$\cot \alpha = x \Rightarrow \text{arccot } x = \alpha$
π	pi	$\pi = 3.14159\dots$			



Exponents

Values less than 1 can be expressed by multiples of decimal powers with negative exponents.
Values greater than 1 can be expressed by multiples of decimal powers with positive exponents.

Value	0.001	0.01	0.1	1	10	100	1,000	10,000	100,000	1,000,000
Decimal powers	10^{-3}	10^{-2}	10^{-1}	10^0	10^1	10^2	10^3	10^4	10^5	10^6

Powers of two are used in digital engineering. The base here is 2.

Value	1/128	1/64	1/32	1/16	1/8	1/4	1/2	1	2	4	8	16	32	64	128
Powers of two	2^{-7}	2^{-6}	2^{-5}	2^{-4}	2^{-3}	2^{-2}	2^{-1}	2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7

Metric prefixes

Prefix symbol	Prefix	Meaning (factor)	Prefix symbol	Prefix	Meaning (factor)
y	yocto	10^{-24}	da	deca	10
z	zepto	10^{-21}	h	hecto	10^2
a	atto	10^{-18}	k	kilo	10^3
f	femto	10^{-15}	M	mega	10^6
p	pico	10^{-12}	G	giga	10^9
n	nano	10^{-9}	T	tera	10^{12}
μ	micro	10^{-6}	P	peta	10^{15}
m	milli	10^{-3}	E	exa	10^{18}
c	centi	10^{-2}	Z	zetta	10^{21}
d	deci	10^{-1}	Y	yotta	10^{24}

Binary prefixes

Prefix symbol	Prefix	Meaning (factor)	Prefix symbol	Prefix	Meaning (factor)
–	–	–	–	–	–
Ki	kibi	2^{10}	–	–	–
Mi	mebi	2^{20}	–	–	–
Gi	gibi	2^{30}	–	–	–
Ti	tebi	2^{40}	–	–	–
Pi	pebi	2^{50}	–	–	–
Ei	exbi	2^{60}	–	–	–
Zi	zebi	2^{70}	–	–	–
Yi	yobi	2^{80}	–	–	–

Prefixes may not be combined. You can assign only one prefix per unit.

Logarithms

Logarithmic division

The logarithm (log) indicates to which power a base has to be raised in order to obtain the logarithm argument. The following applies:

$$a^b = c, \log_a c = b$$

The common logarithm (lg) has the base 10. The natural logarithm (ln) has the base of the e-function ($e=2.718...$). The dyadic logarithm (lb) has the base 2.

Extensive number ranges can be represented in a more structured way when using a logarithmic scale.

$\log_a c = \frac{\ln c}{\ln a} = \frac{\lg c}{\lg a}$

$\log_a(cd) = \log_a c + \log_a d$
1

$\log_a \frac{c}{d} = \log_a c - \log_a d$
2

$\log_a(c^m) = m \cdot \log_a c$
3

$\lg_a \sqrt[n]{c} = \frac{1}{n} \log_a c$
4

$\lg x = \ln x / \ln 10$
5

$\ln x = \lg x / \lg e$
6

$\text{lb} x = \lg x / \lg 2$
7

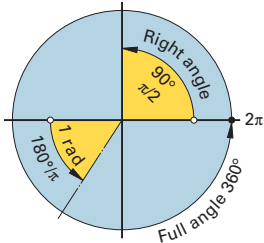
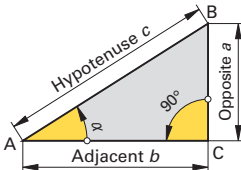
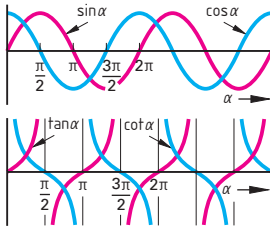
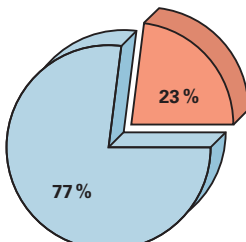
Calculation according to the rule of three

	Steps of approach	Example
Calculation acc. to the rule of three of a proportional relation	Proportional relation (unit obtained by division)	
	1. Statement	n elements have a weight of a kg
	2. Calculation for 1 object	1 element has a weight of a/n kg
	3. Calculation for z objects	z elements have a weight of $z \cdot a/n$ kg
	Inverted proportional relation (unit obtained by multiplication)	
	1. Statement	n workers need a hours
	2. Calculation for 1 object	1 worker needs $n \cdot a$ hours
	3. Calculation for z objects	z workers need $n \cdot a/z$ hours



Transmission factors and logarithmic unit decibel		
Term, definition	Formula, note	Comments, example
Transmission factor T Gain factor V Attenuation factor D	Increase > 1 and decrease < 1 : $T = V = S_2/S_1$ 1 $D = S_1/S_2$ 2	 S_1 , S_2 quantities referring to transmission
Power-related measures Gain ratio G Attenuation ratio A To identify the value as a logarithmic quantity dB is added instead of a unit. This is because the value, actually, has no unit.	Gain ratio $G = 10 \lg (P_2/P_1)$ 3 Attenuation ratio $A = 10 \lg (P_1/P_2)$ 4 $G = -A$ 5 $A = -G$ 6 dB refers to decibel (a unit named after the American scientist Alexander Graham Bell)	Example 1: A filter circuit has an input of 500 mW and an output of 250 mW. What is a) the attenuation factor D and b) the attenuation ratio A ? a) $D = S_1/S_2$ = 500 mW/250 mW = 2 b) $A = 10 \lg (500 \text{ mW}/250 \text{ mW})$ = 3.01 dB
Voltage-related measures, pressure-related measures Gain ratio G Attenuation ratio A Sound pressure transmission ratio T_p For these quantities, dB is also used instead of a unit.	Gain ratio $G = 20 \lg (U_2/U_1)$ 7 $G = -A$ 8 Attenuation ratio $A = 20 \lg (U_1/U_2)$ 9 $A = -G$ 10 Sound pressure transmission ratio $T_p = 20 \lg (p_2/p_1)$ 11	Example 2: An amplifier has an input of 3 mV and an output of 5 V. What is a) the gain factor, b) the attenuation ratio? a) $V = U_2/U_1 = 5 \text{ V}/3 \text{ mV} = \mathbf{1,667}$ b) $G = 20 \lg (U_2/U_1)$ = $20 \lg (5 \text{ V}/3 \text{ mV}) = \mathbf{64.4 \text{ dB}}$
Level in dB(*) * placeholder for additional specifications		
Sound level, general	This quantity expresses the ratio between two values, one of which is an agreed reference value.	The reference value should be indicated in level specifications.
Power level L_p Identified by dB (1 mW) or dBm, Voltage level L_U Identified by dB (1 μ V) or dB μ Sound pressure level L_p actually identified by dB (20 μ N/m ²)	Power level $L_p = 10 \lg (P/1 \text{ mW})$ 12 Voltage level $L_U = 20 \lg (U/1 \mu\text{V})$ 13 Sound pressure level $L_p = 20 \lg (p/20 \mu\text{N}/\text{m}^2)$ 14	The agreed reference values are 1 mW for L_p , 1 mV for L_U and 20 μ N/m ² for L_p . Example 3: An aerial has an output of 80 mV. $L_U = ?$ $L_U = 20 \lg (U/1 \mu\text{V}) = \mathbf{98 \text{ dB}\mu}$
Rated sound pressure level Identified by dB(A), dB(B) or dB(C), depending on the correction	The measured quantity is the sound pressure level. The measuring values are modified with the help of filters A, B or C for frequencies other than 1,000 Hz.	The rated sound pressure level in dB(A) corresponds to a great extent to the human noise level sensation in phon.
A attenuation ratio D attenuation factor G gain ratio L_p power level L_p sound pressure level	L_U voltage level $\lg$ common logarithm P power p pressure T transmission factor	U voltage V gain factor Subscripts: 1 input, 2 output of the transmission path



Figures	Explanations	Notes, formulas																														
Angles																																
	Units of measurement of angles are degrees, centesimal degrees, and radians. The <i>round angle</i> has a) 360° (degrees) b) 400 gon (centesimal degrees) c) 2π rad (radian) The unit radian corresponds to the proportion of the circular arc length to the radius in a circle. $\alpha_r = \alpha^\circ \cdot \frac{\pi}{180^\circ}$ 1 $1 \text{ rad} = \frac{360^\circ}{2\pi} = 57.296^\circ$	Important angles <table><tr><th>Round angle</th><th>Straight angle</th><th>Right angle</th></tr><tr><td>360°</td><td>180°</td><td>90°</td></tr><tr><td>2 π rad</td><td>π rad</td><td>$\frac{\pi}{2}$ rad</td></tr><tr><td>400 gon</td><td>200 gon</td><td>100 gon</td></tr></table> Still customary in survey engineering: 1 gon = (π/200) rad	Round angle	Straight angle	Right angle	360°	180°	90°	2 π rad	π rad	$\frac{\pi}{2}$ rad	400 gon	200 gon	100 gon																		
Round angle	Straight angle	Right angle																														
360°	180°	90°																														
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400 gon	200 gon	100 gon																														
Angle dimensions																																
Trigonometric functions																																
	The longest side (c) of the right-angled triangle is referred to as the <i>hypotenuse</i> . It is the side opposite the right angle. The two other sides (a and b) of the triangle form the right angle. These sides are referred to as the <i>catheti</i> . The leg (a) opposite the acute angle α is the opposite. The leg contiguous to the angle α is the <i>adjacent</i> (b).	An angle in a right-angled triangle can be defined by its angle degrees or as a <i>ratio of two triangle sides</i> . The ratio of the sides depends on the size of the angle. That is why the ratios of two sides in a right-angled triangle are referred to as <i>angle functions</i> (function = dependence) or trigonometric functions.																														
Right-angled triangle																																
	Sine = $\frac{\text{opposite}}{\text{hypotenuse}}$ Cosine = $\frac{\text{adjacent}}{\text{hypotenuse}}$ Tangent = $\frac{\text{opposite}}{\text{adjacent}}$ Cotangent = $\frac{\text{adjacent}}{\text{opposite}}$	$\sin \alpha = \frac{a}{c}$ 2 $\cos \alpha = \frac{b}{c}$ 3 $\tan \alpha = \frac{a}{b}$ 4 $\cot \alpha = \frac{b}{a}$ 5 <table><tr><th>α</th><th>0°</th><th>30°</th><th>45°</th><th>60°</th><th>90°</th></tr><tr><td>sin α</td><td>0</td><td>1/2</td><td>√2/2</td><td>√3/2</td><td>1</td></tr><tr><td>cos α</td><td>1</td><td>√3/2</td><td>√2/2</td><td>1/2</td><td>0</td></tr><tr><td>tan α</td><td>0</td><td>√3/3</td><td>1</td><td>√3</td><td>∞</td></tr><tr><td>cot α</td><td>∞</td><td>√3</td><td>1</td><td>√3/3</td><td>0</td></tr></table>	α	0°	30°	45°	60°	90°	sin α	0	1/2	√2/2	√3/2	1	cos α	1	√3/2	√2/2	1/2	0	tan α	0	√3/3	1	√3	∞	cot α	∞	√3	1	√3/3	0
α	0°	30°	45°	60°	90°																											
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cot α	∞	√3	1	√3/3	0																											
Trigonometric functions																																
Percentage calculation																																
	Per cent (pro cent in Latin) means "per hundred". The total quantity (basic quantity) is always equal to one hundred, the partial quantity (percentage) is expressed in per cent (= hundredths). 23% of 300 € equal to 69 € percentage basic value perc. amount $\text{percentage} = \frac{100\% \cdot \text{perc. amount}}{\text{basic value}}$ 8	Percentage calculation $p = \frac{P \cdot 100\%}{B}$ 6 Calculation of interest $I = \frac{C_0 \cdot p \cdot n}{100\%}$ 7 Calculation of compound interest $C_n = C_0 \cdot \left(1 + \frac{p}{100\%}\right)^n$ 9																														
a, b, c legs of a right-angled triangle B basic amount C ₀ starting capital C _n capital after n years	I interest per year n term in years P percentage amount p percentage in %, interest rate in %	α, β, γ angles in a triangle α° degrees of an angle α _r radian of an angle																														

