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for the electrotechnical, electronic
and information technology trades

Electrical Engineering

Tables, Standards, Formulas

2nd English edition

Prepared and revised by teachers in vocational colleges and
engineers from the production industry (see next page).

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This edition is based on the 26th German edition of "Tabellenbuch Elektrotechnik", a leading compendium in German-speaking countries. The English edition addresses professionals in the various fields of electrical engineering, such as power and building engineering, field engineering, automation systems, machinery, drive systems, components and other electronic systems. This book is intended to

- prepare professionals for an activity in an international environment and
- help make the world's leading work processes and standards known outside of the German-speaking region.

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.

The book is divided into the following main sections focusing on the specified subjects:

- **Section M: mathematics, physics, theory of circuits, components** Formula symbols, units and quantities, mathematical symbols, exponents, unit prefixes, logarithmic unit decibel, force, moment of force, motion rules, work, power, heat, charge, voltage, current, resistance, electric and magnetic fields, alternating quantities, switching capacitors and coils, three-phase current, diodes, transistors, IGBTs, thyristors, magnetic field-dependent and photoelectronic components.
- **Section TM: technical documentation, measuring** Technical drawing, dimensioning, circuit diagrams, circuit symbols, comparison of circuit symbols, preparing documentation, measuring instruments and systems, measuring categories, measurement in electrical installations, power meters, bidirectional watt meters, ripple control receivers, oscilloscopes, measuring with sensors.
- **Section EI: electrical installations** Working in electrical installations, laying of cables, cable routing, installation circuits, intercom systems, types of dimmers, electrical installation with low-voltage halogen lamps, field-reducing electrical installation, building management and automation, project design based on KNX, house connection, foundation earth electrode, electrical installations in residential buildings, calculation of circuit loading, ampacity of cables and wires, lighting engineering, LED lighting.
- **Section SE: safety, energy supply** First aid, workplace health and safety, personal protective equipment, signs for accident prevention, differential current devices, basic protection, fault protection, additional protection, conductors for protective measures, types of power stations, insulator classes, transformers, overhead power cables, buried cables, private power generating systems, smart grids, fuel cells, primary cells, accumulators, UPS systems, electromagnetic compatibility EMC, lighting protection, quality of power supply, harmonics, power factor correction, smoke alarms, AFDD, AFCl, security and monitoring devices, energy conservation directive, energy efficiency, household appliances, electricity tariffs.
- **Section IC: information and communication technology systems** Number systems, codes, Boolean algebra, flip-flops, D/A converters, A/D converters, modulation and demodulation, IT networks, components for data networks, Ethernet, wireless LAN, AS-i bus system, interbus, PROFIBUS, identification systems, connection to the telephone network, internet, aerial systems, satellite systems, safe communication across different field busses.
- **Section AC: automation, drive and control systems** Rectifier, switch-mode power supplies, multivibrators, control relays, programmable logic controllers PLC, word processing in PLCs, control engineering, auxiliary circuits, sequence control with GRAFCET, contactors, motor protection, electrical equipment of machines, automatic control engineering, three-phase motors, single-phase A.C. motors, D.C. motors, efficiency of drive systems, servomotors, micro-motors, linear drives, design of automation systems, EC Machinery Directive.
- **Section MC: materials, connection, joining and bonding** Periodic table, specific material values, steel standardisation, magnetic materials, insulators, cables and wires, buried cables, connectors, solderless connection technology, ISO threads, screws, bolts and nuts, dowels and plugs.
- **Section CE: the company and its environment, environmental technology, annex** Organisational structures of companies, teamwork, job planning, cost accounting and key numbers, skills of electrical specialists, realisation of projects, conflict management, communication with customers, environmental terms, hazardous materials, electronic waste products, standards, glossary, subject index.

We have integrated modifications of standards, e.g. in the terms taken from DIN VDE 0100-200. It should be noted in general that standards allow different ways of representation, e.g. DIN EN 610892 (Documents in Electrical Engineering, Rules) allows the representation of electricity branching with or without a point. As in professional practice, we have taken advantage of this freedom also in the book.

The publisher and authors would be grateful for any suggestions and constructive comments.

Summer 2015

The authors' working group

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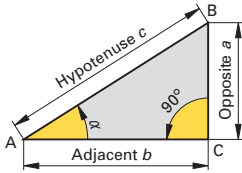
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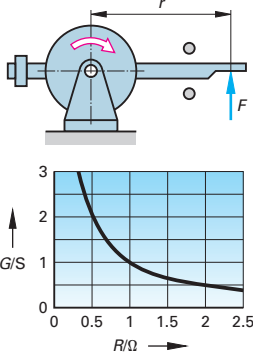
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Mathematics



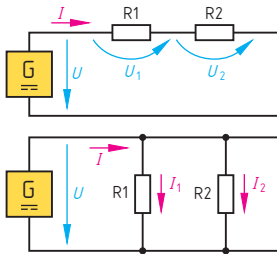
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Physics



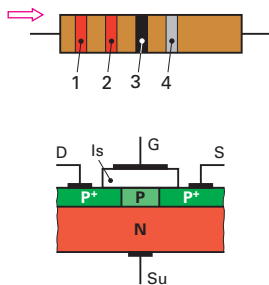
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Symbols in this Book

M

Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
Lower-case letters		Upper-case letters		Lower-case Greek letters	
<i>a</i>	acceleration	<i>A</i>	1. area, 2. cross section 3. attenuation constant	α (alpha)	1. angle 2. temperature coefficient 3. triggering angle
<i>c</i>	1. spec. heat capacity 2. electrochemical equivalent 3. propagation velocity of waves 4. coefficient	<i>B</i>	1. magn. flux density 2. current gain 3. number base 4. phase of three-phase system	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. coupling factor 5. phase of three-phase system	γ (gamma)	1. angle 2. conductivity
<i>e</i>	elementary charge	<i>D</i>	1. electric flux density 2. damping factor 3. deflection coefficient	δ (delta)	angle for losses
<i>f</i>	1. frequency 2. filter factor	<i>E</i>	1. electric field strength 2. illuminance	ϵ_0	electric field constant
<i>g</i>	1. gravitational acceleration, position	<i>F</i>	1. force, 2. factor, 3. fault	ϵ (epsilon)	permittivity
<i>h</i>	height	<i>G</i>	1. conductance 2. amplification factor 3. gravitational force	ζ (zeta)	work ratio, utilisation ratio
<i>i</i>	time-controlled current	<i>H</i>	magnetic field strength	η (eta)	efficiency
<i>l</i>	1. length 2. spacing	<i>I</i>	1. electric current 2. light intensity	κ (kappa)	conductivity (optional symbol)
<i>m</i>	1. mass 2. number of strands	<i>J</i>	1. current density 2. mass moment of inertia	ϑ (theta)	temperature in °C
<i>n</i>	1. speed, number of revolutions 2. integer 1, 2, 3, ... 3. refractive index	<i>L</i>	1. level 2. inductance	λ (lambda)	wavelength
<i>o</i>	overdrive factor	<i>M</i>	1. moment of force 2. memory capacity	μ (mu)	1. permeability 2. friction coefficient
<i>p</i>	1. number of pole pairs 2. pressure 3. percentage rate	<i>N</i>	number of turns	μ_0	magnetic field constant
<i>q</i>	1. quantity 2. shunt current ratio	<i>P</i>	1. active or effective power 2. process value in controller circuits, often also PV	π (pi)	number 3.1415926...
<i>r</i>	1. radius 2. rate 3. differential resistance	<i>Q</i>	1. electric charge 2. heat 3. reactive power 4. resonant circuit quality	ρ (rho)	1. specific resistance 2. density
<i>s</i>	1. section, strength 2. normalized slip 3. correction	<i>R</i>	1. active resistance 2. spring rate 3. rigidity	σ (sigma)	1. leakage factor 2. stress
<i>t</i>	1. time 2. transformation ratio	<i>S</i>	1. susceptance 2. steepness 3. slip (absolute) 4. transmission quantity 5. set value in controller circuits, often also SV	τ (tau)	time constant
<i>v</i>	1. velocity 2. time-controlled voltage	<i>T</i>	1. cycle time 2. transmission factor 3. temperature in K 4. torque	φ (phi)	angle, particularly phase-shift angle
<i>w</i>	1. width 2. energy density 3. command variable	<i>U</i>	voltage	ω (omega)	1. angular velocity 2. angular frequency
<i>x</i>	controlled variable	<i>V</i>	volume	Upper-case Greek letters	
<i>y</i>	correcting variable	<i>W</i>	1. energy 2. work	Δ (Delta)	difference
<i>z</i>	integer, e.g. number of teeth of a gear	<i>X</i>	reactance	Θ (Theta)	current linkage, (phase-shift angle in NA)
		<i>Y</i>	admittance	Φ (Phi)	1. magnetic flux 2. luminous flux
		<i>Z</i>	1. impedance 2. wave impedance 3. oscillation impedance	Ψ (Psi)	electric flux
				Ω (Omega)	1. solid angle 2. resistance

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

Subscripts and Signs for Formula Symbols in this Book

Subscript, sign	Meaning	Subscript	Meaning	Subscript	Meaning
Numerals, symbols		max	maximum	F	1. forward, 2. fault 3. (negative) feedback
0	1. idle 2. vacuum 3. reference variable	mec	mechanical	G	gate
1	1. input	min	minimum	H	1. hysteresis 2. Hall, 3. height 4. heat sink
2	1. order, sequence	o	oscillator	K	cathode
3, 4, ...	order, sequence	off	switch off, turn off	L	1. inductive 2. load 3. left 4. Lorentz 5. loop
$\hat{\ } , \text{ e.g. } \hat{u}$	peak value	out	output	N	nominal, rated
$\check{\ } , \text{ e.g. } \check{u}$	minimum value	p	1. parallel, 2. pause 3. pulse, 4. potential 5. pressure, 6. pre-	O	1. operation, 2. operational earthing (network)
$\hat{\ } , \text{ e.g. } \hat{u}$	1. peak-to-peak value 2. oscillation width	per	permissible	P	positive feedback
$' , \text{ e.g. } u'$	1. related to 2. note 3. derivation	q	quality	R	1. reverse, reward 2. active resistance 3. right 4. regular 5. red
Δ	delta connection	r	1. reactive quantity 2. relative, related to 3. rise, 4. resonance 5. remanence, retentivity 6. reception	S	1. source, 2. saddle ... 3. smoothing 4. switching 5. sluice ... 6. sector 7. system earthing 8. scanning
Y	star connection	s	1. screen... 2. signal... 3. specific	T	1. transformer ... 2. transverse 3. track 4. test ...
Lower-case letters		sh	short circuit	V	voltage meter
a	1. armature, 2. ambient, 3. actual	st	step	W	weight
ab	absorbed	t	1. test, 2. transverse 3. time	X	at the x-port
adm	admissible	th	thermal, heat ...	Y	1. at the y-port 2. star connection
del	delivered	tot	total	Z	Zener ...
amb	ambient air ...	v	1. voltage 2. visual		
b	1. bit 2. brake ...	w	1. command variable 2. wind... 3. wave ...		
c	1. cut-off, 2. crest, 3. comparison 4. centripetal...	x	1. unknown variable 2. in x-direction		
d	1. referring to DC 2. duration, 3. digit 4. damping, 5. direction 6. desired 7. derivation, derived	y	1. correcting variable 2. in y-direction		
e	1. exterior, 2. effective, 3. error	z	zigzag connection		
eff	effective value	Upper-case letters		Lower-case Greek letters	
f	1. frequency 2. fall ...	A	1. ammeter 2. aerial 3. armature, 4. anode 5. acceleration, 6. area 7. amplifier, amplifying	α (alpha)	in direction of the angle α
h	high, upper	B	1. base 2. building	σ (sigma)	leakage
i	1. inner, internal 2. induced, 3. current 4. ideal, 5. intermediate 6. impulse	C	1. collector, 2. capacitive 3. clock pulse, 4. coercive 5. cluster, 6. channel 7. maximum (max) contact voltage 8. carrier	φ (phi)	phase-shift related
in	input	D	1. drain, 2. data, 3. discharge	Upper-case Greek letters	
j	junction	E	1. emitter 2. environment 3. earth	Δ (Delta)	1. referring to a difference 2. configuration of a three-phase system
k	kinetic				
l	1. low, lower, 2. loss				
m	1. magnetic 2. mean value 3. measuring, measured				

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

Quantity	Symbol until September 2010	Symbol after September 2010		Unit, unit symbol
		Preferred symbol	Reserve symbol	
Current and related quantities				
Rated current	I_n	I_{rat} or I_r	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}_{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} or U_r	U_N	Volt, V
Nominal voltage	U_n	Not applicable	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} or P_r	P_N	Watt, W
Rated apparent power	S_N	S_{rat} or S_r		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}		
Dissipation	P_v	P_t		
Power factor (P.F.)	$\cos \varphi$	λ (lambda)		
Active factor	–	$\cos \varphi$		One (no unit)
Moments of force, torques				
Torque, moment of force	M	T	M	Newton meter, Nm
Nominal moment/torque	M_n	Not applicable	Not applicable	
Rated moment/torque	M_N	T_{rat} or T_r	M_{rat} or M_r	
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 overtones), power factor (P.F.) = relation of wattage to apparent power (with overtones)				

Quantities and Units 1

Quantity	SI unit (other unit)	Unit symbol, unit equation	Quantity	SI unit (other unit)	Unit symbol, unit equation
Length, area, volume, angle			Electricity		
length	metre (sea mile) (mile) (inch) (foot)	m 1 sm = 1,852 m 1 mi = 1,609.344 m 1" = 25.4 mm 1 ft = 12 x 1" = 0.3048 m	electric charge, electric flux	coulomb	1 C = 1 A · 1 s = 1 As
area	square metre	m ²	electric charge density, electric flux density	coulombs per square metre	C/m ²
volume	cubic metre (litre)	m ³ 1 l = 1 dm ³ = 1/1000 m ³	space charge density	coulombs per cubic metre	C/m ³
angle (plane) (see page 20)	radian (degree)	rad 1° = $\frac{\pi}{180}$ rad	electr. voltage, electr. potential	volt	1 V = 1 J/C
solid angle	steradian	sr	electr. field strength	volts per metre	1 V/m = 1 N/C
Time, frequency, velocity, acceleration			electr. capacitance	farad	1 F = 1 As/V = 1 C/V
time	second (minute) (hour) (day)	s 1 min = 60 s 1 h = 60 min = 3,600 s 1 d = 24 h	current loading	amperes per metre	A/m
frequency	hertz	1 Hz = 1/s	permittivity, dielectric constant	farads per metre	1 F/m = 1 C/(Vm)
rotational speed-rotational frequency	per second (per minute)	1/s = 60/min	electric current	ampere	1 A = 1 C/s
angular frequency	per second	1/s	electric current density	amperes per m ²	A/m ²
velocity	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 resistance, active resistance, reactance, impedance	ohm	1 Ω = 1 V/A
angular velocity	radians per second	rad/s	electric conductance, susceptance, admittance	siemens	1 S = $\frac{1}{1 \Omega}$
acceleration	–	m/s ²	specific electric resistance	ohmmetre	1 Ωm = 100 Ωcm 1 Ωmm ² /m = 1 μΩm
Mechanics			electric conductivity	siemens per metre	1 Sm/m ² = 1 MS/m
mass	kilogram (carat) (tonne)	kg 1 Kt = 0.2 g 1 t = 1,000 kg	power	watt	1 W = 1 V · 1 A
density	–	kg/m ³ , kg/dm ³	reactive power	(var)	1 var = 1 V · 1 A
moment of inertia	–	kg · m ²	apparent power	(VA)	1 VA = 1 V · 1 A
force	newton	1 N = 1 kg · m/s ²	inductance	henry	1 H = 1 Vs/A
moment of force, torque	–	Nm	work, energy	joule (watt-hour) (electron volt)	1 J = 1 Ws 1 Wh = 3.6 kNm 1 eV = 0.1602 aJ
impulse	newton sec.	1 Ns = 1 kg · m/s	Magnetism		
pressure	pascal (bar)	1 Pa = 1 N/m ² 1 bar = 0.1 MPa = 10 N/cm ²	current linkage	ampere	A
surface pressure, rigidity, modulus of elasticity	–	N/mm ²	magnetic field strength	amperes per metre	A/m
work, energy	joule (electron volt)	1 J = 1 Nm = 1 Ws 1 eV = 0.1602 aJ	magnetic flux	weber	1 Wb = 1 T · 1 m ² = 1 Vs
power	watt	1 W = 1 J/s = 1 Nm/s	magn. flux density magn. polarisation	tesla	1 T = 1 Wb/m ² = 1 Vs/m ²
			inductance	henry	1 H = 1 Vs/A
			permeability	henrys per metre	1 H/m = 1 Vs/(Am)
			magn. resistance	–	1/H = A/Vs

Quantities and Units 2

M

Quantity	SI unit (other unit)	Unit symbol, unit equation	Quantity	SI unit (other unit)	Unit symbol, unit equation
Electromagnetic radiation (except light)			Nuclear reaction, ionising radiation		
radiant energy	joule	1 J = 1 Nm = 1 Ws	activity of a radioactive substance	becquerel	1 Bq = 1/s
radiant power	watt	1 W = 1 J/s	absorbed dose	gray	1 Gy = 1 J/kg
radiant intensity	watt/sterad.	W/sr	absorbed dose rate	grays per second	Gy/s
radiant intensity	–	W/(sr · m ²)	dose equivalent	sievert	1 Sv = 1 J/kg
irradiance	–	W/m ²	dose equivalent rate	sieverts per second	1 Sv/s = 1 J/(kg · s)
Light, optics			ion dose	coulombs per kilogram	C/kg
light intensity	candela	cd	ion dose rate	amperes per kilogram	1 A/kg = 1 C/(kg · s)
luminance	candelas per m ²	cd/m ²	Acoustics		
luminous flux	lumen	lm	sound pressure	pascal	1 Pa = 1 N/m ²
luminous efficacy	lumens per watt	lm/W	sound particle velocity	metres per second	m/s
illuminance	lux	1 lx = 1 lm/m ²	sound velocity (propagation velocity)	metres per second	m/s
optical power of lenses	– (diopetre)	1/m 1 dpt = 1/m	volume velocity	–	1 m ³ /s = 1 m ² · 1 m/s
Heat			sound intensity	–	W/m ²
centigrade temperature	degree centigrade	°C	specific sound impedance	–	Pa · s/m
thermodynamic temperature	kelvin	K (0 K ≐ – 273.15 °C)	acoustic impedance	–	Pa · s/m ³
temperature difference	kelvin	K	mechanical impedance	–	N · s/m
heat, inner energy	joule	1 J = 1 Ws	equivalent absorption area	square metre	m ²
heat flow	watt	1 W = 1 J/s	Chemistry, molecular physics		
thermal resistance (of components)	kelvins per watt	K/W	quantity of substance	mol(e)	mol
thermal conductivity	–	W/(K · m)	concentration of quantity of substance	–	mol/m ³
heat transfer coefficient	–	W/(K · m ²)	molar volume	–	m ³ /mol
thermal capacity, entropy	joules per kelvin	J/K	molality	–	mol/kg
specific thermal capacity	–	J/(kg · K)	molar mass	–	kg/mol
Chemistry, molecular physics			molar thermal capacity	–	J/(mol · K)
Chemistry, molecular physics			diffusion coefficient	–	m ² /s
Chemistry, molecular physics			Other disciplines		
Chemistry, molecular physics			distance in astronomy	(astronomical unit) parsec	1 AU = 149.6 Gm 1 pc = 30.857 Pm
Chemistry, molecular physics			velocity of light	km/s	c = 3 × 10 ⁸ m/s ≈ 300,000 km/s
Chemistry, molecular physics			light year l.y.	km	1 l.y. = 9.461 · 10 ¹² km
Chemistry, molecular physics			mass in nuclear physics	(nuclear mass unit)	1 u = 1.66 · 10 ⁻²⁷ kg
Chemistry, molecular physics			mass per unit length of textile fibres and threads	tex	1 tex = 1 g/kg
Chemistry, molecular physics			area of plots of land	are hectare	1 a = 100 m ² 1 ha = 100 a

Mathematical Symbols

Mathematical Symbols					
Symbol	Meaning	Example	Symbol	Meaning	Example
General symbols					
... n ...	and so on until n and so on until infinity	$k = 1, 2, 3, \dots, n$ $n = 1, 2, 3, \dots$ $\sqrt{2} = 1.41421 \dots$	∞ \rightarrow $f(x)$ i or j \underline{Z}	infinite versus, approaches, exceeds function of x imaginary unit complex quantity Z	$n = 1, 2, 3, \dots, \infty$ $x \rightarrow a$, x approaches the value a $f(I) = I^2 \cdot R$ $i^2 = j^2 = -1$ $\underline{Z} = R + jX$
Boolean algebra					
$\neg a, \bar{a}$ \wedge \vee $\overline{\wedge}$ $\overline{\vee}$	NOT a AND OR NOT AND (NAND) NOT OR (NOR)	$\overline{a \wedge b} = \neg (a \wedge b)$ $a \wedge b$ or $\wedge (a, b)$ $a \vee b$ or $\vee (a, b)$ $a \overline{\wedge} b = \overline{a \wedge b}$ $a \overline{\vee} b = \overline{a \vee b}$	Geometry, vectors		
\in \subset \cup \Rightarrow	element of subset union of sets from this follows that	$a \in M$: a is element of M $M_1 \subset M_2$: M_1 is subset of M_2 $\{1, 2\} \cup \{3, 4\} = \{1, 2, 3, 4\}$ $a \cdot b = c \Rightarrow a = c/b$	\parallel $\uparrow\uparrow$ $\uparrow\downarrow$ \perp \triangle \cong \sim \sphericalangle \overline{AB} \widehat{AB} \vec{A}, \vec{B} $ \vec{A} $	parallel parallel in the same dir. parallel in opposite dir. orthogonal, perpendicular triangle congruent similar angle line segment AB arc AB vector A , vector B absolute value of vector A	$g_1 \parallel g_2$, $R_1 \parallel R_2$ $g \uparrow\uparrow h$ $g_1 \uparrow\downarrow g_2$ $g \perp h$ $\triangle ABC$ $\triangle ABC \cong \triangle DEF$ $\triangle P_1P_2P_3 \sim \triangle ABC$ $\sphericalangle ABC = \sphericalangle (BA, BC)$ $\sphericalangle (\vec{a}, \vec{b})$ $\overline{P_1P_2}$ $\widehat{AB} = \sphericalangle \gamma$ $\vec{C} = \vec{A} + \vec{B}$ $ \vec{F} = 50 \text{ N}$
Set theory					
Arithmetic					
$=$ \neq \sim \approx \cong $<$ $>$ \leq \geq \ll \gg \cdot, \times $-, /, :$ $\%$ ‰ $(), [], \{ }$ $ z $ $n!$ Σ Π $\sqrt{\quad}$ $\sqrt[n]{\quad}$ π	equal to not equal, unequal proportional approximately corresponds to less than greater than less than or equal to greater than or equal to considerably less than considerably greater than times, multiplied divided by per cent per thousand, per mil round, squared, curly, pointed brackets amount of z n factorial sum product square root of n th root of pi	$P = U \cdot I$ $4 \neq 5$ $u \sim r$ $\pi \approx 3.14$ $1 \text{ cm} \cong 20 \text{ N}$ $2 < 3$ $5 > 2$ $a \leq 10$ $n \geq 7$ $R \ll 100 \text{ k}\Omega$ $R_x \gg R_n$ $a \cdot b = ab$, $12 \times 3 = 36$ $\frac{7}{2} = 7/2 = 7 : 2$ $1\% = 10^{-2}$, $50\% = 0.5$ $1\text{‰} = 10^{-3}$, $8\text{‰} = 0.8\%$ $[a(b - c) + d]^2$ $ 4 = 4$, $ -7 = 7$ $n! = 1 \cdot 2 \cdot 3 \cdot \dots \cdot n$, $3! = 6$ $\Sigma I = I_1 + I_2 + I_3 + \dots$ $\Pi k = k_1 \cdot k_2 \cdot k_3 \cdot \dots$ $\sqrt{16} = 4$ $\sqrt[3]{8} = 2$ $\pi = 3.14159 \dots$	Differentiation, integration		
Δ y' $\frac{dy}{dx}$ \int	difference y prime dy by dx or dy over dx integral	$\Delta U = U_2 - U_1$ y' is the first derivation of y , first derivative quotient $y' = dy/dx$ $\int f(x) dx$, $\int_a^b f(x) dx$	Exponents, logarithms		
a^x exp log \log_a lg lb ln	a to the power of x exponential function general logarithm logarithm to the basis a common logarithm dyadic logarithm natural logarithm	5^3 , 10^x $\exp x = e^x$, with $e = 2.718 \dots$ $\log_3 9 = 2$ $\lg 2 = 0.30103 \dots$ $\text{lb } 8 = 3$ $\ln 10 = 2.3025 \dots$	Trigonometry		
sin cos tan cot arcsin arccos arctan arccot	sine cosine tangent cotangent arc sine arc cosine arc tangent arc cotangent	$\sin \alpha$ $\sin^2 \alpha + \cos^2 \alpha = 1$ $= (\sin \alpha)^2 + (\cos \alpha)^2 = 1$ $\tan \alpha = \sin \alpha / \cos \alpha$ $\cot \alpha = 1 / \tan \alpha$ $\sin \alpha = x \Rightarrow \arcsin x = \alpha$ $\cos \alpha = x \Rightarrow \arccos x = \alpha$ $\tan \alpha = x \Rightarrow \arctan x = \alpha$ $\cot \alpha = x \Rightarrow \text{arccot } x = \alpha$			

Exponents, Unit Prefixes, Logarithms, Calculations According to the Rule of Three

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

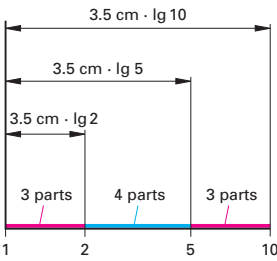
Metric prefixes

Binary prefixes

Prefix symbol	Prefix	Meaning (factor)	Prefix symbol	Prefix	Meaning (factor)	Prefix symbol	Prefix	Meaning (factor)
y	Yokto	10^{-24}	da	deca	10	-	-	-
z	Zepto	10^{-21}	h	hecto	10^2	-	-	-
a	atto	10^{-18}	k	kilo	10^3	Ki	kibi	2^{10}
f	femto	10^{-15}	M	mega	10^6	Mi	mebi	2^{20}
p	pico	10^{-12}	G	giga	10^9	Gi	gibi	2^{30}
n	nano	10^{-9}	T	tera	10^{12}	Ti	tibi	2^{40}
μ	micro	10^{-6}	P	peta	10^{15}	Pi	pebi	2^{50}
m	milli	10^{-3}	E	exa	10^{18}	Ei	exbi	2^{60}
c	centi	10^{-2}	Z	zetta	10^{21}	Zi	zebi	2^{70}
d	deci	10^{-1}	Y	yobi	10^{24}	Yi	yobi	2^{80}

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

Logarithms



Logarithmic sectioning

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.

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

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

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

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

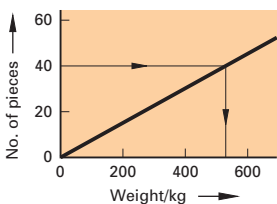
$$\log_a \sqrt[n]{c} = \frac{1}{n} \log_a c \quad 4$$

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

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

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

Calculation according to the rule of three

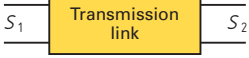


Calculation acc. to the rule of three of a proportional relation

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

Logarithmic Unit Decibel

Logarithmic unit decibel

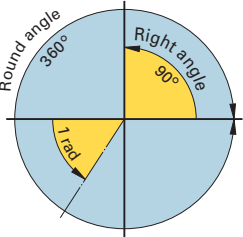
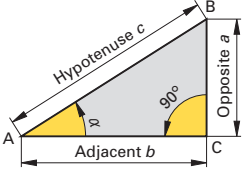
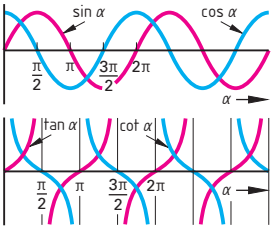
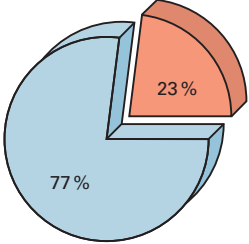
Term, definition	Formula, note	Comments, example
Transmission factor T Gain factor V Attenuation factor D	Increase > 1 and decrease < 1 : $T = V = S_2/S_1$ 1 $D = S_1/S_2$ 2	 <p style="text-align: center;">S_1 Transmission link S_2</p> <p>S_1, S_2 quantities referring to transmission</p>
Power-related measures Gain ratio G Attenuation ratio A In order to identify the value as a logarithmic quantity, dB is added instead of a unit, 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 (one tenth of a bel, 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 are a) the attenuation factor D and b) the attenuation ratio A ? a) $D = S_1/S_2 = 500 \text{ mW}/250 \text{ mW} = 2$ b) $A = 10 \lg (500 \text{ mW}/250 \text{ mW}) = 3.01 \text{ dB}$
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 gain ratio? a) $V = U_2/U_1 = 5 \text{ V}/3 \text{ mV} = 1,667$ b) $G = 20 \lg (U_1/U_2) = 20 \lg (5 \text{ V}/3 \text{ mV}) = 64.4 \text{ dB}$

Level in dB(*) (* place holder 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 dBm = dB (1 mV) 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 $L_p = 20 \lg (p/20 \mu\text{N/m}^2)$ 14	The agreed reference values are 1 mW for L_p , 1mV for L_U and 20 μ N/m ² for L_p . Example 3: An aerial has an output of 80 mV. $L_U = ?$ $L_U = 20 \lg (U/1 \text{ mV}) = 38 \text{ dBm}$
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 loudness 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 link

Angles, Trigonometric Functions, Percentage Calculation

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Figures	Explanations	Notes, formulas												
Angles														
 <p>Angle dimensions</p>	<p>The units referring to angles are degree, centesimal degree and radian.</p> <p>The <i>round angle</i> has</p> <ol style="list-style-type: none"> 360° (degrees) 400 gon (centesimal degrees) 2π rad (radian) <p>The unit radian corresponds to the proportion of the circular arc length to the radius in a circle.</p> $\alpha_r = \alpha^\circ \cdot \frac{\pi}{180^\circ}$ <p>1 rad = $\frac{360^\circ}{2\pi} = 57.296^\circ$</p>	<p>Important angles</p> <table border="1"> <thead> <tr> <th>Round angle</th> <th>Straight angle</th> <th>Right angle</th> </tr> </thead> <tbody> <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> </tbody> </table> <p>Still customary in survey engineering: 1 gon = (π/200) rad</p>	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°												
2 · π rad	π rad	$\frac{\pi}{2}$ rad												
400 gon	200 gon	100 gon												
Angle functions														
 <p>Right-angled triangle</p>	<p>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> or simply <i>legs</i> of the triangle. The leg (a) opposite the acute angle α is the <i>opposite</i>. The leg contiguous to the angle α is the <i>adjacent</i> (b).</p>	<p>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.</p>												
 <p>Trigonometric functions</p>	<p>Sine = $\frac{\text{opposite}}{\text{hypotenuse}}$</p> <p>Cosine = $\frac{\text{adjacent}}{\text{hypotenuse}}$</p> <p>Tangent = $\frac{\text{opposite}}{\text{adjacent}}$</p> <p>Cotangent = $\frac{\text{adjacent}}{\text{opposite}}$</p>	$\sin \alpha = \frac{a}{c}$ $\cos \alpha = \frac{b}{c}$ $\tan \alpha = \frac{a}{b}$ $\cot \alpha = \frac{b}{a}$												
Percentage calculation														
	<p>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).</p> <p>23% of 300 € is equal to 69 €</p> <p>percentage = $\frac{100 \cdot \text{percentage amount}}{\text{basic value}}$</p>	<p>Percentage calculation</p> $p = \frac{P \cdot 100\%}{B}$ <p>Calculation of interest</p> $I = \frac{C_0 \cdot p \cdot n}{100\%}$ <p>Calculation of compound interest</p> $C_n = C_0 \cdot \left(1 + \frac{p}{100\%}\right)^n$												
<p>a, b, c legs of a right-angled triangle</p> <p>B basic amount</p> <p>C₀ starting capital</p> <p>C_n capital after n years</p>	<p>I interest per year</p> <p>n term in years</p> <p>P percentage amount</p> <p>p percentage in %, interest rate in %</p>	<p>α, β, γ angles in a triangle</p> <p>α° degrees of an angle</p> <p>α_r radian of an angle</p>												