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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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Preface to the 2nd English edition

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, AFCI, 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, micromotors, 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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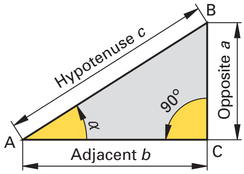
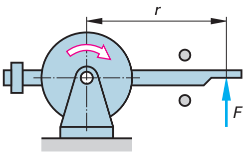
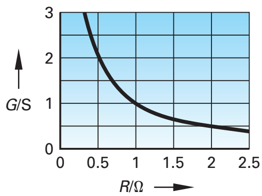
Section M: Mathematics, Physics, Theory of Circuits, Components

Mathematics

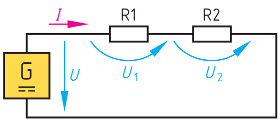


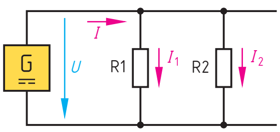
Physics





Circuit theory





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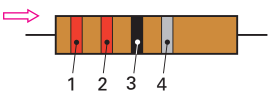
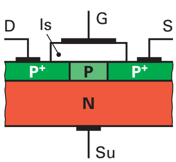




Symbols in this Book

Lower-case letters

Symbol	Meaning
a	acceleration
c	1. spec. heat capacity 2. electrochemical equivalent 3. propagation velocity of waves 4. coefficient
d	1. diameter 2. distance 3. dissipation factor 4. duty cycle
e	elementary charge
f	1. frequency 2. filter factor
g	1. gravitational acceleration, position
h	height
i	time-controlled current
l	1. length 2. spacing
m	1. mass 2. number of strands
n	1. speed, number of revolutions 2. integer 1, 2, 3, ... 3. refractive index
o	overdrive factor
p	1. number of pole pairs 2. pressure 3. percentage rate
q	1. quantity 2. shunt current ratio
r	1. radius 2. rate 3. differential resistance
s	1. section, strength 2. normalized slip 3. correction
t	1. time 2. transformation ratio
v	1. velocity 2. time-controlled voltage
w	1. width 2. energy density 3. command variable
x	controlled variable
y	correcting variable
z	integer, e.g. number of teeth of a gear

Upper-case letters

Symbol	Meaning
A	1. area, 2. cross section 3. attenuation constant 4. apparent power 5. amplification factor 6. phase of three-phase system
B	1. magn. flux density 2. current gain 3. number base 4. phase of three-phase system
C	1. capacitance 2. thermal capacity 3. constant 4. coupling factor 5. phase of three-phase system
D	1. electric flux density 2. damping factor 3. deflection coefficient
E	1. electric field strength 2. illuminance
F	1. force, 2. factor, 3. fault
G	1. conductance 2. amplification factor 3. gravitational force
H	magnetic field strength
I	1. electric current 2. light intensity
J	1. current density 2. mass moment of inertia
L	1. level 2. inductance
M	1. moment of force 2. memory capacity
N	number of turns
P	1. active or effective power 2. process value in controller circuits, often also PV
Q	1. electric charge 2. heat 3. reactive power 4. resonant circuit quality
R	1. active resistance 2. spring rate 3. rigidity
S	1. susceptance 2. steepness 3. slip (absolute) 4. transmission quantity 5. set value in controller circuits, often also SV
T	1. cycle time 2. transmission factor 3. temperature in K 4. torque
U	voltage
V	volume
W	1. energy 2. work
X	reactance
Y	admittance
Z	1. impedance 2. wave impedance 3. oscillation impedance

Lower-case Greek letters

Symbol	Meaning
α (alpha)	1. angle 2. temperature coefficient 3. triggering angle
β (beta)	1. angle 2. short-circuit current amplification factor
γ (gamma)	1. angle 2. conductivity
δ (delta)	angle for losses
ε_0	electric field constant
ε (epsilon)	permittivity
ζ (zeta)	work ratio, utilisation ratio
η (eta)	efficiency
$\varkappa$ (kappa)	conductivity (optional symbol)
ϑ (theta)	temperature in °C
λ (lambda)	wavelength
μ (mu)	1. permeability 2. friction coefficient
μ_0	magnetic field constant
π (pi)	number 3.1415926...
ϱ (rho)	1. specific resistance 2. density
σ (sigma)	1. leakage factor 2. stress
τ (tau)	time constant
φ (phi)	angle, particularly phase-shift angle
ω (omega)	1. angular velocity 2. angular frequency

Upper-case Greek letters

Symbol	Meaning
Δ (Delta)	difference
Θ (Theta)	current linkage, (phase-shift angle in NA)
Φ (Phi)	1. magnetic flux 2. luminous flux
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

Numerals, symbols

Subscript, sign	Meaning
0	1. idle 2. vacuum 3. reference variable
1	1. input 2. order, sequence
2	1. output 2. order, sequence
3, 4, …	order, sequence
^, e.g. $\hat{u}$	peak value
ˇ, e.g. $\check{u}$	minimum value
^ˇ, e.g. $\hat{\check{u}}$	1. peak-to-peak value 2. oscillation width
', e.g. u'	1. related to 2. note 3. derivation
△	delta connection
Y	star connection

Lower-case letters

Subscript	Meaning
a	1. armature, 2. ambient, 3. actual
ab	absorbed
adm	admissible
del	delivered
amb	ambient air …
b	1. bit 2. brake …
c	1. cut-off, 2. crest, 3. comparison 4. centripetal…
d	1. referring to DC 2. duration, 3. digit 4. damping, 5. direction 6. desired 7. derivation, derived
e	1. exterior, 2. effective, 3. error
eff	effective value
f	1. frequency 2. fall …
h	high, upper
i	1. inner, internal 2. induced, 3. current 4. ideal, 5. intermediate 6. impulse
in	input
j	junction
k	kinetic
l	1. low, lower, 2. loss
m	1. magnetic 2. mean value 3. measuring, measured
max	maximum
mec	mechanical
min	minimum
n	1. nominal, 2. normal 3. noise
o	oscillator
off	switch off, turn off
out	output
p	1. parallel, 2. pause 3. pulse, 4. potential 5. pressure, 6. pre-
per	permissible
q	quality
r	1. reactive quantity 2. relative, related to 3. rise, 4. resonance 5. remanence, retentivity 6. reception
s	1. screen… 2. signal… 3. specific
sh	short circuit
st	step
t	1. test, 2. transverse 3. time
th	thermal, heat …
tot	total
v	1. voltage 2. visual
w	1. command variable 2. wind… 3. wave …
x	1. unknown variable 2. in x-direction
y	1. correcting variable 2. in y-direction
z	zigzag connection

Upper-case letters

Subscript	Meaning
A	1. ammeter 2. aerial 3. armature, 4. anode 5. acceleration, 6. area 7. amplifyer, amplifying
B	1. base 2. building
C	1. collector, 2. capacitive 3. clock pulse, 4. coercitive 5. cluster, 6. channel 7. maximum (max) contact voltage 8. carrier
D	1. drain, 2. data, 3. discharge
E	1. emitter 2. environment 3. earth
F	1. forward, 2. fault 3. (negative) feedback
G	gate
H	1. hysteresis 2. Hall, 3. height 4. heat sink
K	cathode
L	1. inductive 2. load 3. left 4. Lorentz 5. loop
N	nominal, rated
O	1. operation, 2. operational earthing (network)
P	positive feedback
R	1. reverse, reward 2. active resistance 3. right 4. regular 5. red
S	1. source, 2. saddle … 3. smoothing 4. switching 5. sluice … 6. sector 7. system earthing 8. scanning
T	1. transformer … 2. transverse 3. track 4. test …
V	voltage meter
W	weight
X	at the x-port
Y	1. at the y-port 2. star connection
Z	Zener …

Lower-case Greek letters

Subscript	Meaning
α (alpha)	in direction of the angle α
σ (sigma)	leakage
φ (phi)	phase-shift related

Upper-case Greek letters

Subscript	Meaning
Δ (Delta)	1. referring to a difference 2. configuration of a three-phase system

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.

International Formula Symbols

cf. DIN EN 60027-4: 3-08

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	
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	$\hat{I}_k$	$\hat{I}_{SC}$	Ampere, A
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	
Nominal voltage	U_n	Not applicable		Volt, V
Induced voltage	U_i	U_g	Not applicable	
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}		
Input power	P_1 or P_i	P_{in}		
Output power	P_2 or P_o	P_{out}		Watt, W
Mechanical power	P	P_{mec}	Not applicable	
Dissipation	P_v	P_t		
Power factor (P.F.)	cos φ	λ (lambda)		One (no unit)
Active factor	–	cos φ		
Moments of force, torques				
Torque, moment of force	M	T	M	
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	Newton meter, Nm
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
Length, area, volume, angle		
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
area	square metre	m^2
volume	cubic metre (litre)	m^3 $1\ l = 1\ dm^3 = 1/1000\ m^3$
angle (plane) (see page 20)	radian (degree)	rad $1° = \frac{\pi}{180}$ rad
solid angle	steradian	sr
Time, frequency, velocity, acceleration		
time	second (minute) (hour) (day)	s 1 min = 60 s 1 h = 60 min = 3,600 s 1 d = 24 h
frequency	hertz	1Hz = 1/s
rotational speed- rotational frequency	per second (per minute)	1/s = 60/min
angular frequency	per second	1/s
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
angular velocity	radians per second	rad/s
acceleration	–	m/s^2
Mechanics		
mass	kilogram (carat) (tonne)	kg 1 Kt = 0.2 g 1 t = 1,000 kg
density	–	kg/m^3, kg/dm^3
moment of inertia	–	$kg \cdot m^2$
force	newton	1 N $= 1\ kg \cdot m/s^2$
moment of force, torque	–	Nm
impulse	newton sec.	1 Ns $= 1\ kg \cdot m/s$
pressure	pascal (bar)	1 Pa $= 1\ N/m^2$ 1 bar = 0.1 MPa $= 10\ N/cm^2$
surface pressure, rigidity, modulus of elasticity	–	N/mm^2
work, energy	joule (electron volt)	1 J = 1 Nm = 1 Ws 1 eV = 0.1602 aJ
power	watt	1 W = 1 J/s = 1 Nm/s

Quantity	SI unit (other unit)	Unit symbol, unit equation
Electricity		
electric charge, electric flux	coulomb	1 C $= 1\ A \cdot 1\ s$ = 1 As
electric charge density, electric flux density	coulombs per square metre	C/m^2
space charge density	coulombs per cubic metre	C/m^3
electr. voltage, electr. potential	volt	1 V = 1 J/C
electr. field strength	volts per metre	1 V/m = 1 N/C
electr. capacitance	farad	1 F = 1 As/V = 1 C/V
current loading	amperes per metre	A/m
permittivity, dielectric constant	farads per metre	1 F/m = 1 C/(Vm)
electric current	ampere	1 A = 1 C/s
electric current density	amperes per m^2	A/m^2
electric resistance, active resistance, reactance, impedance	ohm	1 Ω = 1 V/A
electric conductance, susceptance, admittance	siemens	1 S $= \frac{1}{1\ \Omega}$
specific electric resistance	ohmmetre	1 Ωm = 100 Ωcm $1\ \Omega mm^2/m = 1 \mu\Omega m$
electric conductivity	siemens per metre	$1\ Sm/mm^2$ = 1 MS/m
power	watt	1 W $= 1\ V \cdot 1\ A$
reactive power	(var)	1 var $= 1\ V \cdot 1\ A$
apparent power	(VA)	1 VA $= 1\ V \cdot 1\ A$
inductance	henry	1 H = 1 Vs/A
work, energy	joule (watt-hour) (electron volt)	1 J = 1 Ws 1 Wh = 3.6 kNm 1 eV = 0.1602 aJ
Magnetism		
current linkage	ampere	A
magnetic field strength	amperes per metre	A/m
magnetic flux	weber	1 Wb $= 1\ T \cdot 1\ m^2$ = 1 Vs
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

Quantity	SI unit (other unit)	Unit symbol, unit equation
Electromagnetic radiation (except light)		
radiant energy	joule	1 J = 1 Nm = 1 Ws
radiant power	watt	1 W = 1 J/s
radiant intensity	watt/sterad.	W/sr
radiant intensity	–	W/(sr · m^2)
irradiance	–	W/m^2
Light, optics		
light intensity	candela	cd
luminance	candelas per m^2	cd/m^2
luminous flux	lumen	lm
luminous efficacy	lumens per watt	lm/W
illuminance	lux	1 lx = 1 lm/m^2
optical power of lenses	– (dioptre)	1/m 1 dpt = 1/m
Heat		
centigrade temperature	degree centigrade	°C
thermodynamic temperature	kelvin	K (0 K ≙ – 273.15 °C)
temperature difference	kelvin	K
heat, inner energy	joule	1 J = 1 Ws
heat flow	watt	1 W = 1 J/s
thermal resistance (of components)	kelvins per watt	K/W
thermal conductivity	–	W/(K · m)
heat transfer coefficient	–	W/(K · m^2)
thermal capacity, entropy	joules per kelvin	J/K
specific thermal capacity	–	J/(kg · K)
Chemistry, molecular physics		
quantity of substance	mol(e)	mol
concentration of quantity of sub-stance	–	mol/m^3
molar volume	–	m^3/mol
molality	–	mol/kg
molar mass	–	kg/mol
molar thermal capacity	–	J/(mol · K)
diffusion coefficient	–	m^2/s

Quantity	SI unit (other unit)	Unit symbol, unit equation
Nuclear reaction, ionising radiation		
activity of a radioactive substance	bequerel	1 Bq = 1/s
absorbed dose	gray	1 Gy = 1 J/kg
absorbed dose rate	grays per second	Gy/s
dose equivalent	sievert	1 Sv = 1 J/kg
dose equivalent rate	sieverts per second	1 Sv/s = 1 J/(kg · s)
ion dose	coulombs per kilogram	C/kg
ion dose rate	amperes per kilogram	1 A/kg = 1 C/(kg · s)
Acoustics		
sound pressure	pascal	1 Pa = 1 N/m^2
sound particle velocity	metres per second	m/s
sound velocity (propagation velocity)	metres per second	m/s
volume velocity	–	1 m^3/s = 1 m^2 · 1 m/s
sound intensity	–	W/m^2
specific sound impedance	–	Pa · s/m
acoustic impedance	–	Pa · s/m^3
mechanical impedance	–	N · s/m
equivalent absorption area	square metre	m^2
Other disciplines		
distance in astronomy	(astronomical unit) parsec	1 AU = 149.6 Gm 1 pc = 30.857 Pm
velocity of light	km/s	$c = 3 \times 10^8$ m/s ≈ 300,000 km/s
light year l.y.	km	1 l.y. = 9.461 · 10^{12} km
mass in nuclear physics	(nuclear mass unit)	1 u = 1.66 · 10^{-27} kg
mass per unit length of textile fibres and threads	tex	1 tex = 1 g/kg
area of plots of land	are hectare	1 a = 100 m^2 1 ha = 100 a

Mathematical Symbols

Symbol	Meaning	Example
General symbols		
$\ldots n$	and so on until *n*	$k = 1, 2, 3, \ldots, n$
$\ldots$	and so on until infinity	$n = 1, 2, 3, \ldots$ $\sqrt{2} = 1.41421 \ldots$
Boolean algebra		
$\neg a$, $\bar{a}$	NOT *a*	$\overline{a \wedge b} = \neg (a \wedge b)$
$\wedge$	AND	$a \wedge b$ or $\wedge (a, b)$
$\vee$	OR	$a \vee b$ or $\vee (a, b)$
$\bar{\wedge}$	NOT AND (NAND)	$a \mathbin{\bar{\wedge}} b = \overline{a \wedge b}$
$\bar{\vee}$	NOT OR (NOR)	$a \mathbin{\bar{\vee}} b = \overline{a \vee b}$
Set theory		
$\in$	element of	$a \in M$: *a* is element of *M*
$\subset$	subset	$M_1 \subset M_2$: M_1 is subset of M_2
$\cup$	union of sets	$\{1, 2\} \cup \{3, 4\} =$ $= \{1, 2, 3, 4\}$
$\Rightarrow$	from this follows that	$a \cdot b = c \Rightarrow a = c/b$
Arithmetic		
$=$	equal to	$P = U \cdot I$
$\neq$	not equal, unequal	$4 \neq 5$
$\sim$	proportional	$u \sim r$
$\approx$	approximately	$\pi \approx 3.14$
$\triangleq$	corresponds to	1 cm $\triangleq$ 20 N
$<$	less than	$2 < 3$
$>$	greater than	$5 > 2$
$\leq$	less than or equal to	$a \leq 10$
$\geq$	greater than or equal to	$n \geq 7$
$\ll$	considerably less than	$R \ll 100\ \mathrm{k\Omega}$
$\gg$	considerably greater than	$R_x \gg R_n$
$\cdot$, $\times$	times, multiplied	$a \cdot b = ab$, $12 \times 3 = 36$
—, /, :	divided by	$\frac{7}{2} = 7/2 = 7 : 2$
%	per cent	$1\,\% = 10^{-2}$, $50\,\% = 0.5$
‰	per thousand, per mil	$1\,‰ = 10^{-3}$, $8\,‰ = 0.8\,\%$
( ), [ ], { }	round, squared, curly, pointed brackets	$[a\,(b - c) + d\,]^2$
$\lvert z \rvert$	amount of *z*	$\lvert 4 \rvert = 4$, $\lvert -7 \rvert = 7$
$n!$	*n* factorial	$n! = 1 \cdot 2 \cdot 3 \cdot \ldots \cdot n$, $3! = 6$
Σ	sum	$\Sigma I = I_1 + I_2 + I_3 + \ldots$
Π	product	$\Pi k = k_1 \cdot k_2 \cdot k_3 \cdot \ldots$
$\sqrt{\ }$	square root of	$\sqrt{16} = 4$
$\sqrt[n]{\ }$	n_{th} root of	$\sqrt[3]{8} = 2$
π	pi	$\pi = 3.14159\ldots$

Symbol	Meaning	Example
∞	infinite	$n = 1, 2, 3, \ldots, \infty$
$\rightarrow$	versus, approaches, exceeds	$x \rightarrow a$, *x* approaches the value *a*
$f(x)$	function of *x*	$f(I) = I^2 \cdot R$
i or j	imaginary unit	$\mathrm{i}^2 = \mathrm{j}^2 = -1$
$\underline{Z}$	complex quantity Z	$\underline{Z} = R + \mathrm{j}X$
Geometry, vectors		
$\parallel$	parallel	$g_1 \parallel g_2$, R1 $\parallel$ R2
$\uparrow\uparrow$	parallel in the same dir.	$g \uparrow\uparrow h$
$\uparrow\downarrow$	parallel in opposite dir.	$g_1 \uparrow\downarrow g_2$
$\perp$	orthogonal, perpendicular	$g \perp h$
$\triangle$	triangle	$\triangle$ ABC
$\cong$	congruent	$\triangle \mathrm{ABC} \cong \triangle \mathrm{DEF}$
$\sim$	similar	$\triangle \mathrm{P_1P_2P_3} \sim \triangle \mathrm{ABC}$
$\sphericalangle$	angle	$\sphericalangle \mathrm{ABC} = \sphericalangle (\overline{\mathrm{BA}}, \overline{\mathrm{BC}})$, $\sphericalangle (\vec{a}, \vec{b})$
$\overline{\mathrm{AB}}$	line segment AB	$\overline{\mathrm{P_1P_2}}$
$\overset{\frown}{\mathrm{AB}}$	arc AB	$\overset{\frown}{\mathrm{AB}} = \sphericalangle \gamma$
$\vec{A}$, $\vec{B}$	vector *A*, vector *B*	$\vec{C} = \vec{A} + \vec{B}$
$\lvert \vec{A} \rvert$	absolute value of vector *A*	$\lvert \vec{F} \rvert = 50$ N
Differentiation, integration		
Δ	difference	$\Delta U = U_2 - U_1$
y'	*y* prime	y' is the first derivation of *y*, first derivative
$\frac{\mathrm{d}y}{\mathrm{d}x}$	d*y* by d*x* or d*y* over d*x*	quotient $y' = \mathrm{d}y/\mathrm{d}x$
$\int$	integral	$\int \mathrm{f}(x)\,\mathrm{d}x$, $\int_a^b \mathrm{f}(x)\,\mathrm{d}x$
Exponents, logarithms		
a^x	*a* to the power of *x*	5^3, 10^x
exp	exponential function	$\exp x = \mathrm{e}^x$, with $\mathrm{e} = 2.718\ldots$
log	general logarithm	
$\log_a$	logarithm to the basis a	$\log_3 9 = 2$
lg	common logarithm	$\lg 2 = 0.30103\ldots$
lb	dyadic logarithm	$\mathrm{lb}\ 8 = 3$
ln	natural logarithm	$\ln 10 = 2.3025\ldots$
Trigonometry		
sin	sine	$\sin \alpha$
cos	cosine	$\sin^2 \alpha + \cos^2 \alpha =$ $= (\sin \alpha)^2 + (\cos \alpha)^2 = 1$
tan	tangent	$\tan \alpha = \sin \alpha / \cos \alpha$
cot	cotangent	$\cot \alpha = 1/\tan \alpha$
arcsin	arc sine	$\sin \alpha = x \Rightarrow \arcsin x = \alpha$
arccos	arc cosine	$\cos \alpha = x \Rightarrow \arccos x = \alpha$
arctan	arc tangent	$\tan \alpha = x \Rightarrow \arctan x = \alpha$
arccot	arc cotangent	$\cot \alpha = x \Rightarrow \operatorname{arccot} x = \alpha$

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.

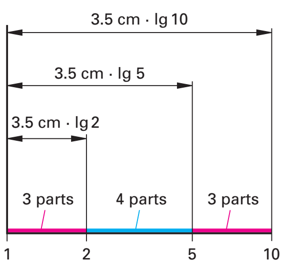
Value	1/128	1/64	1/32	1/16	1/8	1/4	1/2	1	2	4	8	16	32	64	128
Powers of two	2^{-7}	2^{-6}	2^{-5}	2^{-4}	2^{-3}	2^{-2}	2^{-1}	2^{0}	2^{1}	2^{2}	2^{3}	2^{4}	2^{5}	2^{6}	2^{7}

Metric prefixes / Binary prefixes

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	–	–	–	For large
z	Zepto	10^{-21}	h	hecto	10^{2}	–	–	–	mass storage
a	atto	10^{-18}	k	kilo	10^{3}	Ki	kibi	2^{10}	units, often
f	femto	10^{-15}	M	mega	10^{6}	Mi	mebi	2^{20}	the meaning
p	pico	10^{-12}	G	giga	10^{9}	Gi	gibi	2^{30}	of the
n	nano	10^{-9}	T	tera	10^{12}	Ti	tibi	2^{40}	physical
µ	micro	10^{-6}	P	peta	10^{15}	Pi	pebi	2^{50}	quantities
m	milli	10^{-3}	E	exa	10^{18}	Ei	exbi	2^{60}	applies
c	centi	10^{-2}	Z	zetta	10^{21}	Zi	zebi	2^{70}	(decimal
d	deci	10^{-1}	Y	yobi	10^{24}	Yi	yobi	2^{80}	prefixes).

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.

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

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

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

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

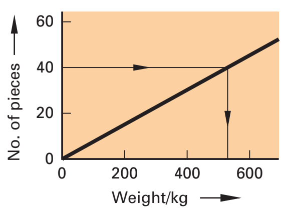
$$\log_a \sqrt[n]{c} = \frac{1}{n}\log_a c \quad (4)$$

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

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

$$\mathrm{lb}\, x = \lg x / \lg 2 \quad (7)$$

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)	 S_1, S_2 quantities referring to transmission
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 mW/250 mW = **2** b) A = 10 lg (500 mW/250 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 gain ratio? a) $V = U_2/U_1$ = 5 V/3 mV = **1,667** b) $G = 20\ \lg\ (U_1/U_2)$ = 20 lg (5 V/3 mV) = **64.4 dB**

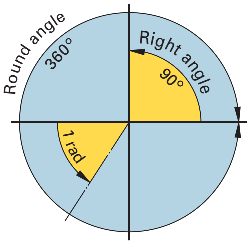
Level in dB(*) (* place holder for additional specifications)

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 μV) or dBm = dB (1 mV) Sound-pressure level Lp actually identified by dB (20 μN/m²)	**Power level** $L_P = 10\ \lg\ (P/1\ mW)$ (12) **Voltage level** $L_U = 20\ \lg\ (U/1\ \mu V)$ (13) **Sound-pressure level** $L_P = 20\ \lg\ (p/20\ \mu N/m^2)$ (14)	The agreed reference values are 1 mW for L_P, 1mV for L_U and 20 μN/m² for L_P. **Example 3:** An aerial has an output of 80 mV. L_U = ? L_U = 20 lg (*U*/1 mV) = **38 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

Figures	Explications	Notes, formulas

Angles



Angle dimensions

The units referring to angles are degree, centesimal degree and radian.

The *round angle* 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.

$$\alpha_r = \alpha° \cdot \frac{\pi}{180°} \quad (1)$$

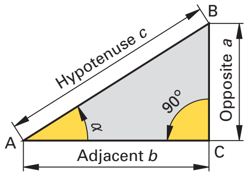
$$1 \text{ rad} = \frac{360°}{2\pi} = 57.296°$$

Important angles

Round angle	Straight angle	Right angle
360°	180°	90°
$2 \cdot \pi$ rad	π rad	$\frac{\pi}{2}$ rad
400 gon	200 gon	100 gon

Still customary in survey engineering: 1 gon = (π/200) rad

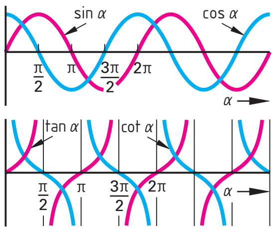
Angle functions



Right-angled triangle

The longest side (c) of the right-angled triangle is referred to as the *hypotenuse*. 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 *catheti* or simply *legs* of the triangle. The leg (a) opposite the acute angle α is the *opposite*. The leg contiguous to the angle α is the adjacent (b).

An angle in a right-angled triangle can be defined by its angle degrees or as a *ratio of two triangle sides*. 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 *angle functions* (function = dependence) or trigonometric functions.



Trigonometric functions

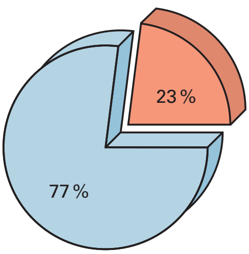
$$\text{Sine} = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \sin\alpha = \frac{a}{c} \quad (2)$$

$$\text{Cosine} = \frac{\text{adjacent}}{\text{hypotenuse}} \qquad \cos\alpha = \frac{b}{c} \quad (3)$$

$$\text{Tangent} = \frac{\text{opposite}}{\text{adjacent}} \qquad \tan\alpha = \frac{a}{b} \quad (4)$$

$$\text{Cotangent} = \frac{\text{adjacent}}{\text{opposite}} \qquad \cot\alpha = \frac{b}{a} \quad (5)$$

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 € is equal to **69 €**
(23% = percentage; 300 € = basic value; 69 € = percentage amount)

$$\text{percentage} = \frac{100 \cdot \text{percentage amount}}{\text{basic value}} \quad (8)$$

Percentage calculation

$$p = \frac{P \cdot 100\%}{B} \quad (6)$$

Calculation of interest

$$I = \frac{C_0 \cdot p \cdot n}{100\%} \quad (7)$$

Calculation of compound interest

$$C_n = C_0 \cdot \left(1 + \frac{p}{100\%}\right)^n \quad (9)$$

a, b, c	legs of a right-angled triangle	I	interest per year	α, β, γ	angles in a triangle
B	basic amount	n	term in years	$\alpha°$	degrees of an angle
C_0	starting capital	P	percentage amount	α_r	radian of an angle
C_n	capital after n years	p	percentage in %, interest rate in %		