ELECTRO TECHNOLOGY

Electric charge	$Q = I t$	Q	electric charge	C
		I	electric current	A
		t	time	s
Resistance in conductors	$R = \frac{\rho l}{A}$	R	resistance of conductor	Ω
		A	area of conductor	m^2
		l	length of conductor	m
		ρ	resistivity of material	$\Omega \cdot m$
Temperature effect on resistance	$R = R_1 \left[1 + \alpha_{T_1} (T_2 - T_1)\right]$	R	resistance at T	Ω
		R_1	resistance at T_1	Ω
		α_{T_1}	temperature coefficient at T_1	K^{-1}
		T_2	temperature (final)	K
		T_1	temperature (initial)	K
Conductance	$G = \frac{1}{R}$	G	conductance	S
		R	resistance	Ω
Conductivity	$\gamma = \frac{1}{\rho}$	γ	conductivity	S/m
		ρ	resistance	$\Omega \cdot m$
Ohm's Law	$V = R I$	V or E	voltage	V
		R	resistance	Ω
		I	electric current	A

Kirchhoff's laws

First law
(Current law)

$$\Sigma I = 0$$

$$I_1 + I_2 + \cdots + I_n = 0$$

Σ	summation (sum)	
I	sum of currents	A
I_1	current	A
I_2	current	A
I_n	current	A

The current flowing away from a junction point in a circuit is equal to the current flowing into the point.

Second law
(Voltage law)

$$\Sigma E + \Sigma V = 0$$

E	electro voltage	V
V	voltage	V

The sum of the potential or voltage drops taken around the circuit must be equal to the applied potential differences.

$$V = \Delta V_1 + \Delta V_2 + \cdots + \Delta V_n$$

V_1	voltage drop	V
V_2	voltage drop	V
V_n	voltage drop	V
V	total voltage	V

Circuit of resistances

Series circuits

$$R_T = R_1 + R_2 + R_3 + \cdots + R_n$$

R_T	total resistance	Ω
R_1	resistance in series	Ω
R_2	resistance in series	Ω
R_3	resistance in series	Ω
R_n	resistance in series	Ω

$$R_T = nR_1$$

R_1	equal resistances	Ω
n	number of equal resistances	1

Parallel circuits

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$$

R_T	resulting (total) resistance	Ω
R_1	resistance in parallel	Ω
R_2	resistance in parallel	Ω
R_3	resistance in parallel	Ω
R_n	resistance in parallel	Ω

	$R_T = \frac{R_1 \cdot R_2}{R_1 + R_2}$	R_T	total resistance of two resistances in parallel circuit	Ω
		R_1 R_2	two resistances in parallel circuit	Ω
	$G = G_1 + G_2 + G_3 + \cdots + G_n$	G	total conductance	S
		G_1 G_2 G_3 G_n	the various parts of conductance	S
Work, energy	$W = VIt = Pt$	W	work	J
		V	voltage	V
		I	electric current	A
		P	effect	W
		t	time	s
Effect	$P = VI = RI^2 = \frac{V^2}{R}$	P	effect	W
		R	resistance	Ω
Voltage loss in two-conductors	$V = \frac{I\,2\,l\,\rho}{A}$	V	loss of voltage	V
		I	electric current	A
		l	length	m
		ρ	resistance	Ω · m
		A	area	m^2
Effect loss in two-conductors	$P = \frac{I^2\,2\,l\,\rho}{A}$	P	loss of effect	W
Heat generated by electric work	$cm\Delta T = P\,t\,\eta$	c	specific heat capacity	J/kgK
		m	mass	kg
		ΔT	difference of temperature	K
		P	effect	W
		t	time	s
		η	efficiency	1

Electric batteries

Series circuit

$$I = \frac{E}{R_i + R_y} = \frac{e n_s}{r n_s + R_y}$$

I	electric current	A
E	total voltage for the complete battery	V
R_i	total inner resistance	Ω
R_y	external resistance	Ω
e	electro voltage per unit	V
n_s	number of units in series	1
r	inner resistance per unit	Ω

$$U = I R_y = e n_s - I r n_s$$

U	battery voltage	V

Parallel circuit

$$I = \frac{E}{R_i + R_y} = \frac{e}{\frac{r}{n_p} + R_y}$$

I	electric current	A
n_p	number of units in parallel	1

$$U = I R_y = e - I \frac{r}{n_p}$$

U	battery voltage	V

Series parallel circuit

$$I = \frac{E}{R_i + R_y} = \frac{e n_s}{\frac{r n_s}{n_p} + R_y}$$

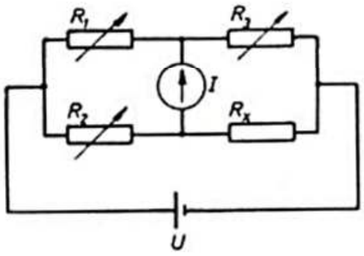
I	electric current	A

$$U = I R_y = e n_s - I \frac{r n_s}{n_p}$$

U	battery voltage	V

Wheatstone's bridge

$$\frac{R_1}{R_3} = \frac{R_2}{R_x}$$



R_1 R_2 R_3	controllable resistances	Ω
R_x	unknown resistance $I = 0$	Ω

Capacitors(condensers)

Capacitance of a capacitor

$$C = \frac{Q}{V} = \epsilon \frac{A}{l}$$

C	capacitance	F
Q	electric charge	C
V	voltage	V
ϵ	permitivity	F/m
A	area	m^2
l	distance	m

	$\epsilon = \epsilon_0 \epsilon_r$	ϵ_0	permitivity of void space	F/m
		ϵ_r	relative permittivity	1
Capacitors in series circuit	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_n}$	C	total capacitance	
		C_1 C_2 C_3 C_n	capacitance of the various capacitors	F
Capacitors in parallel circuit	$C = C_1 + C_2 + C_3 + \cdots + C_n$	C	total capacitance	F
Time constant	$\tau = RC$	τ	time constant	s
		R	resistance	Ω
		C	capacitance	F

ELECTROMAGNETISM

Magnetic flux	$\phi = BA$	ϕ	magnetic flux	Wb
		B	magnetic flux density	T
		A	area	m^2
Magnetic flux density	$B = \mu \frac{IN}{l}$	μ	permeability	H/m
		IN	magnetic force (ampere winding number)	A
		l	length of a conductor	m
	$\mu = \mu_0 \mu_r$	μ_0	void space permeability	H/m
		μ_r	relative permeability	1
	$B = \mu H$	H	strength of magnetic field	A/m
Strength of magnetic field	$H = \frac{IN}{l}$	H	strength of magnetic field	A/m

Ohm's law on magnetism	$\phi = \frac{IN}{R_m}$	ϕ	magnetic flux	Wb
		IN	magnetic force	A
		R_m	magnetic resistance (reluctance)	H^{-1}
Reluctance	$R_m = \frac{l}{\mu A}$	R_m	reluctance	H^{-1}
		l	length of conductor	m
		μ	absolute permeability	H/m
		A	area	m^2
Force on a current-carrying conductor in a magnetic field	$F = BIl$	F	force	N
		B	magnetic flux density	T
		I	electric current	A
		l	length of conductor	m
Faraday's law on inductance	$E = -N \frac{\Delta\phi}{\Delta t}$	E	electric voltage	V
		$\Delta\phi$	flux variation	Wb
		Δt	time variation	s
		N	number of windings/ turns	1
	$E = -L \frac{\Delta i}{\Delta t}$	Δi	current variation	A
		L	self induction	H
Self induction	$L = \frac{\Delta\phi}{\Delta i} N$	L	self induction	H
Self induction in a coil without iron	$L = \frac{\mu_0 N^2 A}{l}$	μ_0	permeability	H/m
		N	number of windings/ turns/loops	1
		A	area in section	m^2
		l	length of coil	m

ALTERNATING CURRENT (AC)

Periodic functions

$$f = \frac{1}{T}$$

f	frequency	Hz
T	time for one period	s

$$\omega = \frac{2\pi}{T} = 2\pi f$$

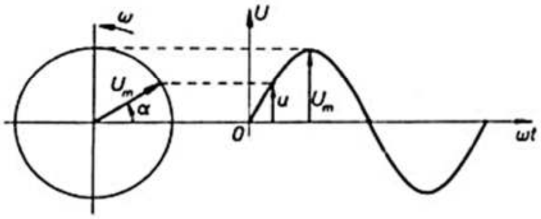
ω	velocity of angel	rad/s

$$\alpha = \omega t = 2\pi f t$$

α	angle	rad
ω	velocity of angel	rad/s
t	time	s

Momentary value of voltage

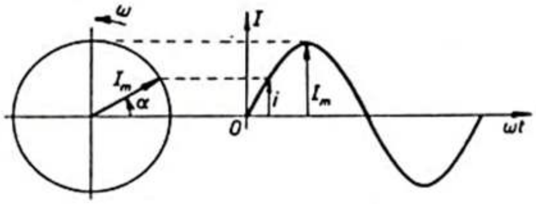
$$v = V_m \sin \alpha$$



v	momentary value of voltage	V
V_m	maximum value of voltage	V
α	angle	rad

Momentary value of current

$$I = I_m \sin a$$



I	momentary value of current	A
I_m	maximum value of voltage	
α	angel	rad

Mean value of voltage

$$V_{midl} = \frac{2}{\pi} V_m \approx 0{,}637\ V_m$$

V_{midl}	mean value of voltage	V
V_m	maximum value of voltage	V

Mean value of current

$$I_{midl} = \frac{2}{\pi} I_m \approx 0{,}637\ I_m$$

I_{midl}	mean value of current	A
I_m	maximum value of current	A

Effective value of voltage

$$V = \frac{V_m}{\sqrt{2}} \approx 0{,}707\ V_m$$

V	effective value of voltage	V
V_m	maximum value of voltage	V

Effective value of current

$$I = \frac{I_m}{\sqrt{2}} \approx 0{,}707\, I_m$$

I	effective value of current	A
I_m	maximum value of current	A

Inductive reactance

$$X_L = \omega L = 2\pi f L$$

X_L	inductive reactance	Ω
ω	angle velocity	s^{-1}
L	self induction	H
f	frequency	Hz

Capacitance reactance

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

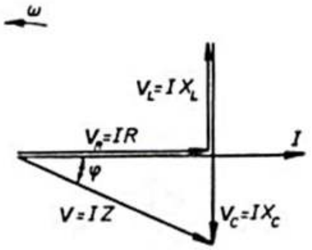
X_c	capacitance reactance	Ω

Resistance, inductive, and capacitance reactance in series

Voltage

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

V	total voltage	V
V_R	voltage on resistance	V
V_L	inductive drop of voltage	V
V_C	capacitive drop of voltage	V



Shifting of phase

$$\operatorname{tg}\varphi = \frac{X_L - X_C}{R} = \frac{X}{R}$$

φ	angel of phase	rad
X_L	inductive reactance	Ω
X_c	capacitance reactance	Ω
R	resistance	Ω
X	resulting reactance	Ω
Z	circuit impedance	Ω

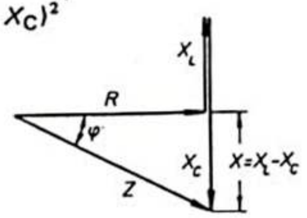
$$\sin\varphi = \frac{X}{Z}$$

$$\cos\varphi = \frac{R}{Z}$$

Impedance

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Z	circuit impedance	Ω



Electric current

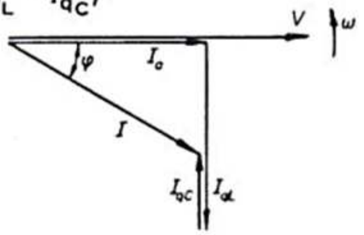
$$I = \frac{V}{Z}$$

I	electric current	A
V	voltage	V

Parallel circuits

Electric current

$$I = \sqrt{I_a^2 + (I_{q_L} - I_{q_C})^2}$$



I	resulting (total) current	A
I_o	current in resistance	A
I_{q_L}	current in inductive reactance	A
I_{q_C}	current in capacitive reactance	A

Impedance

$$\frac{1}{Z} = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

Z	circuit impedance	Ω
R	resistance	Ω
X_L	inductive reactance	Ω
X_c	capacitive reactance	Ω

Admittance

$$Y = \sqrt{G^2 + B^2}$$

Y	admittance	S
B	susceptance	S
G	conductance	S

$$Y = \frac{1}{Z}$$

$$B = \frac{1}{X}$$

$$G = \frac{1}{R}$$

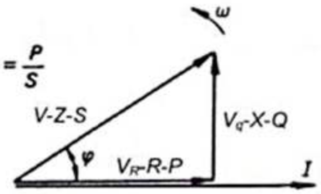
Voltage

$$V = IZ$$

V	voltage	V

Effect factor in series circuit

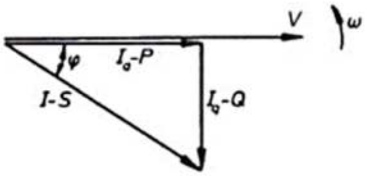
$$\cos\varphi = \frac{V_R}{V} = \frac{R}{Z} = \frac{P}{S}$$



$\cos\varphi$	effect factor	1
V_R	voltage over resistance	V
V	resulting (total) voltage	V
P	active effect	W
S	apparent effect	S

Effect factor in parallel circuit

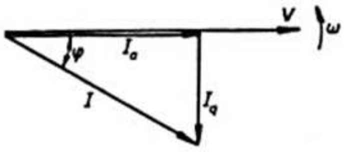
$$\cos\varphi = \frac{I_a}{I} = \frac{P}{S}$$

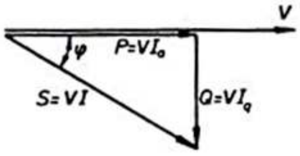


$\cos\varphi$	effect factor	1
Ia	current in resistance	A
I	resulting (total) current	A

Effect in circuits of alternating current

Active effect $P = VI \cos\varphi = I^2 R$





P	active effect	W
V	voltage	V
I	electric current	A
$\cos\varphi$	effect factor	1
R	resistance	Ω

Reactive effect $Q = VI \sin\varphi = I^2 X$

Q	reactive effect	VAr
X	reactance	Ω

Apparent effect $S = VI$

S	apparent effect	VA

Turnover of energy $W = Pt = VI \cos\varphi\, t$

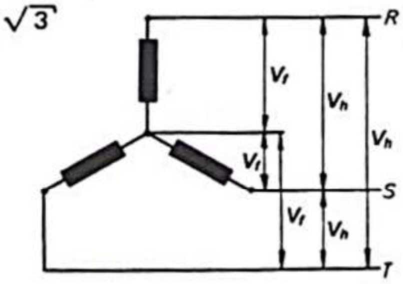
W	energy	J
P	active effect	W
t	time	s

Three-phase system

Star connection

Voltage $V_h = V_f \sqrt{3}$

Electric current $I_h = I_f$

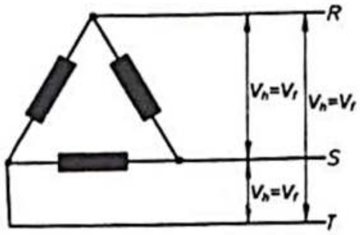


V_h	main voltage	V
V_f	phase voltage	V
I_h	main current	A
I_f	phase current	A

Triangular connection

Voltage $V_h = V_f$

Electric current $I_h = I_f \sqrt{3}$



V_h	main voltage	V
V_f	phase voltage	V
I_h	main current	A
I_f	phase current	A

Turnover of effect in the three-phase system

Active effect $P = \sqrt{3}\ V I \sin\varphi$

P	active effect	W
V	voltage	V
I	electric current	A
$\cos\varphi$	effect factor	1

Reactive effect $Q = \sqrt{3}\ V I \cos\varphi$

Q	reactive effect	VAr

Apparent effect $S = \sqrt{3}\ V I$

S	apparent effect	VA

Turnover of energy in the three-phase system $W = Pt = \sqrt{3}\, V I \cos\varphi\, t$

W	energy	J
P	active effect	W
t	time	s
V	voltage	V
I	electric current	A
$\cos\varphi$	effect factor	1

Transformers

Turnover one-phase transformer $\frac{I_2}{I_1} \approx \frac{V_1}{V_2} \approx \frac{N_1}{N_2}$

Turnover three-phase transformer $\frac{V_1}{V_2}$

Turnover of phase three-phase transformer $\frac{V_{1f}}{V_{2f}} \approx \frac{N_1}{N_2}$

I_1	primary current	A
I_2	secondary current	A
V_1	primary voltage	V
V_2	secondary voltage	V
N_1	number of turns on the primary part	1
N_2	number of turns on the secondary part	1
V_{1f}	primary phase voltage	V
V_{2f}	secondary phase voltage	V

Electric oscillation circuit

Frequency $f = \frac{1}{T} = \frac{1}{2\pi\sqrt{LC}}$

f	frequency	Hz
T	oscillation time	s
L	self inductance	H
C	capacitance	F

One-phase alternative current conductors

Voltage loss $V = \frac{2 I l \rho \cos\alpha}{A}$

V	loss of voltage	V
I	electric current	A
l	length	m
ρ	resistivity	$\Omega \cdot m$
$\cos\varphi$	effect factor	1
A	area in section	m^2

Loss of effect

$$P = \frac{2 l I^2 \rho}{A}$$

P	loss of effect	W

Three-phase alternative current conductors

Voltage loss

$$V = \frac{\sqrt{3}\, I l \rho \cos\varphi}{A}$$

V	loss of voltage	V
I	electric current	A
l	length	m
ρ	resistivity	$\Omega \cdot \mathrm{m}$
$\cos\varphi$	effect factor	1
A	area in section	m^2

Loss of effect

$$P = \frac{3 I^2 \rho l}{A}$$

P	loss of effect	W

ELECTRIC MOTORS

Induced voltages in DC motors

$$E = k_i \phi n$$

E	induced voltage	V
k_i	motor constant	1
ϕ	magnetic flux	Wb
n	rotation frequency	s^{-1}

Turning moment of DC motors

$$T = k_d \phi I_a$$

T	turning moment (torsion moment)	Nm
k_d	motor constant	1
I_a	rotor current	A

Turning moment of AC and DC motors

$$T = \frac{P}{\omega} = \frac{P}{2 \pi n_a}$$

T	turning moment (torsion moment)	Nm
P	effect	W
ω	angel velocity	rad/s
n_a	a synchronic velocity	s^{-1}

Induced voltage in AC motors

$$E = k_i \phi f$$

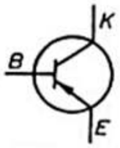
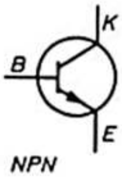
E	induced voltage	V
k_i	motor constant	1
f	frequency	Hz

Relationship between frequencies of rotation and electricity	$n = \frac{f}{p}$	n	frequency of rotation	s^{-1}
		f	electric frequency	Hz
		p	pair of poles	1
Synchronic motor	$n_s = \frac{f}{p}$	n_s	frequency of synchronic rotation	s^{-1}

A synchronic motor

Lagging/slowing	$s = \frac{n_s - n}{n_s}$	s	lagging/slowing (slip)	1
		n_s	frequency of synchronic rotation	s^{-1}
		n	rotation frequency of motor	s^{-1}
	$f_r = sf$	f_r	rotor frequency	Hz
		f	stator frequency	Hz

Transistor

Emitter current	$I_E = I_B + I_K$	 PNP	I_E	emitter current	A
			I_B	base current	A
			I_K	collector current	A
Amplifying factor	$F = \frac{\Delta I_K}{\Delta I_B}$	 NPN	F	emplifying factor for current with joint emitter	1