

Electrical Formulae

Electrical Quantities

Quantity	Symbol	Unit Name	Unit Symbol
Electromotive force	E, e*	Volt	V
Potential difference	V, v*	Volt	V
Current	I, i*	Ampere	A
Magnetic flux	Φ	Weber	Weber
Frequency	f	Hertz	Hz
Flux linkage	λ	Weber-turns	-
Resistance	R	Ohm	Ω
Inductance	L	Henry	H
Capacitance	C	Farad	F
Impedance	Z	Ohm	Ω
Reactance	X	Ohm	Ω
Power, dc, or active	P	Watt	W
Power, reactive	Q	Volt-ampere reactive	VA _r , var
Power, total or apparent	S	Volt-ampere	VA
Power factor angle	ϕ	-	$^{\circ}$, deg.
Angular velocity	ω	Radians per second	rads ⁻¹
Rotational velocity	n	Revolutions per second	s ⁻¹ , rev s ⁻¹
		Revolutions per minute	min ⁻¹ , rpm
Efficiency	η	-	
Number of pairs of poles	p	-	

* Capital and small letters designate rms and instantaneous value respectively.

AC Single-Phase

All quantities r.m.s. values:

$$V = I Z$$

$$\text{Total or apparent power in VA} = V_I = I^2 Z = V^2 / Z$$

$$\text{Active power in watts, } W = V_I \cos \phi$$

$$\text{Reactive power in VAR} = V_I \sin \phi$$

AC Three-Phase

(Assuming Balanced Symmetrical Waveform)

All quantities r.m.s values:

V_l = Line-to-line voltage

V_p = Phase voltage (line-to-neutral)

I_l = line current (wye)

I_p = Phase current (delta)

In a WYE connected circuit, $V_p = V_l / \sqrt{3}$, $V_l = \sqrt{3} V_p$, $I_l = I_p$

In a DELTA connected circuit: $I_p = I_l / \sqrt{3}$, $I_l = \sqrt{3} I_p$, $V_l =$

V_p

Total of apparent power in VA = $\sqrt{3} V_l I_l$

Active power in watts, $W = \sqrt{3} V_l I_l \cos \phi$

Reactive power in VAR = $\sqrt{3} V_l I_l \sin \phi$

Power factor (pf) = $\cos \phi$

$$= \text{Active power} / \text{Apparent power}$$

$$= W / \text{VAR}$$

Three-Phase Induction Motors

All quantities rms values:

$$\text{kW}_{\text{mech}} = \text{horsepower} \times 0.746$$

$$\text{kW}_{\text{elec}} = \sqrt{3} V_l I_l \cos \phi \text{ at rated speed and load}$$

where V_l = supply voltage I_l = rated full load current

$\cos \phi$ = rated full load power factor

$$\text{Efficiency, } \eta = (\text{kW}_{\text{mech}} / \text{kW}_{\text{elec}}) \times 100 \text{ per cent}$$

Phase current $I_p = I_l$ for wye connection

$$I_p = I_l / \sqrt{3} \text{ for delta connection}$$

Loads (phase values)

Resistance R, measured in Ohms (no energy storage)

Inductive reactance, $X_L = \omega L = 2\pi fL$ Ohms (stores energy)

Where f = frequency (Hz), L = Inductance (H)

Capacitive reactance, $X_C = 1/(\omega C) = 1/(2\pi fC)$

Where f = frequency (Hz), C = Capacitance (F)

Impedance

Impedance is the algebraic sum of the separate load values thus:

$$Z = \sqrt{R^2 + X_L^2} \text{ or } \sqrt{R^2 + X_C^2}$$

If R, X_L and X_C are present in series in the same circuit then X_L and X_C may be summated, treating X_C as negative, thus

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

Electrical Formulae

Ohms Law

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}} \quad \text{or} \quad \text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

$$\text{or} \quad \text{Volts} = \text{Amperes} \times \text{Ohms}$$

Power in DC Circuits

$$\text{Horsepower} = \frac{\text{Volts} \times \text{Amperes}}{746}$$

$$\text{Watts} = \text{Volts} \times \text{Amperes}$$

$$\text{Kilowatts} = \frac{\text{Volts} \times \text{Amperes}}{1,000}$$

$$\text{Kilowatts-Hours} = \frac{\text{Volts} \times \text{Amperes} \times \text{Hours}}{1,000}$$

Power in AC Circuits

Kilovolt-Amperes (KVA):

$$\text{kVA (1}\phi\text{)} = \frac{\text{Volts} \times \text{Amperes}}{1,000}$$

$$\text{kVA (3}\phi\text{)} = \frac{\text{Volts} \times \text{Amperes} \times 1.73}{1,000}$$

Kilowatts (Kw)

$$\text{kW (1}\phi\text{)} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}{1,000}$$

$$\text{kW (3}\phi\text{)} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.73}{1,000}$$

$$\text{Power Factor} = \frac{\text{Kilowatts}}{\text{Kilovolts} \times \text{Amperes}}$$

Other Useful Formulae

Three-Phase (3 ϕ) Circuits

$$\text{HP} = \frac{E \times I \times \sqrt{3} \times \text{Eff} \times \text{PF}}{746}$$

$$\text{Motor Amps} = \frac{\text{HP} \times 746}{E \times \sqrt{3} \times \text{Eff} \times \text{PF}}$$

$$\text{Motor Amps} = \frac{\text{kVA} \times 1000}{\sqrt{3} \times E}$$

$$\text{Motor Amps} = \frac{\text{kW} \times 1000}{\sqrt{3} \times E \times \text{PF}}$$

$$\text{Power Factor} = \frac{\text{kW} \times 1000}{E \times I \times \sqrt{3}}$$

$$\text{Kilowatt Hours} = \frac{E \times I \times \text{Hours} \times \sqrt{3} \times \text{PF}}{1000}$$

$$\text{Power (Watts)} = E \times I \times \sqrt{3} \times \text{PF}$$

Mechanical Variables

Material Densities

Materials	lb/in ³	gm/cm ³
Aluminum	0.096	2.66
Brass	0.299	8.3
Bronze	0.295	8.17
Copper	0.322	8.91
Hard Wood	0.029	0.8
Soft Wood	0.018	0.48
Plastic	0.04	1.11
Glass	0.079-0.090	2.2-2.5
Titanium	0.163	4.51
Paper	0.025-0.043	0.7-1.2
Polyvinyl chloride	0.047-0.050	1.3-1.4
Rubber	0.033-0.036	0.92-0.99
Silicone Rubber, without filler	0.043	1.2
Cast Iron, gray	0.274	7.6
Steel	0.28	7.75

Friction Coefficients

Materials	Ffr=μWL
Steel on Steel (greased)	~0.15
Plastic on Steel	~0.15-0.25
Copper on Steel	~0.30
Brass on Steel	~0.35
Aluminum on Steel	~0.45
Steel on Steel	~0.58
Mechanism	μ
Ball Bushings	<0.001
Linear Bearings	<0.001
Dove-tail Slides	~0.2++
Gibb Ways	~0.5++

Mechanism Efficiencies

Acme screw with brass nut	~0.35-0.65
Acme screw with plastic nut	~0.50-0.85
Ballscrew	~0.85-0.95
Chain and Sprocket	~0.95-0.98
Preloaded Ballscrew	~0.75-0.85
Spur or Bevel gears	~0.90
Timing Belts	~0.96-0.98
Worm Gears	~0.45-0.85
Helical Gear (1 reduction)	~0.92