

## SI units and simple mechanical and AC electrical formulae

### SI units

The international system of units based on:

Parameter	SI units	Abbreviation
Distance	metres	m
Mass	kilograms	kg
Time	seconds	s

Many other SI units are named after historical scientists or engineers. So we have:

Parameter	Usual symbol in formulae	SI units	Abbreviation	Named after
Electrical current	I	amps	A	Ampere
Electrical 'pressure' or potential difference	V	volts	V	Volta
Electrical resistance	R	ohms	$\Omega$	Ohm
Electrical charge		coulombs	C	de Coulomb
Power	P	watts	W	Watt
Frequency	f	hertz	Hz	Hertz
Force		newtons	N	Newton
Mechanical pressure		pascals	Pa	Pascal
Energy		joules	J	Joule
Thermodynamic temperature	T	kelvin	K	Kelvin
			(Note: There is no °)	
Electrical inductance	L	henry	H	Henry
Electrical capacitance	C	farad	F	Faraday
Magnetic flux		weber	Wb	Weber
Magnetic flux density		tesla	T	Tesla

Also:

Parameter	SI units	Abbreviation
Angle	radians	rad
Luminous intensity	candela	cd
Luminous flux	lumens	lm

Note: All the name-related units are represented by CAPITAL roman letters or abbreviations (Ohms is an exception!), and the rest are represented by lower-case roman letters or abbreviations.

Prefixes are applied to SI units to create new units, which are multiples or sub-multiples of the basic SI units. Common prefixes are:

tera (T)	– $10^{12}$ times (1,000,000,000,000).
giga (G)	– $10^9$ times (1,000,000,000).
mega (M)	– $10^6$ times (1,000,000).
kilo (k)	– $10^3$ times (1,000).
hecto (h)	– $10^2$ times (100). (Non-preferred.)
deca (da)	– 10 times (10). (Non-preferred.)
deci (d)	– $10^{-1}$ times (1/10). (Non-preferred.)
centi (c)	– $10^{-2}$ times (1/100). (Non-preferred.)
milli (m)	– $10^{-3}$ times (1/1,000).
micro ( $\mu$ )	– $10^{-6}$ times (1/1,000,000).
nano (n)	– $10^{-9}$ times (1/1,000,000,000).
pico (p)	– $10^{-12}$ times (1/1,000,000,000,000).

The preferred multiples are in steps of 1000. However, some non-preferred units remain in use, particularly in mainland Europe, for example cm.

The typeface case of the prefix is also vitally important, otherwise mega (M) and milli (m) would be confused, for example.

Only one prefix can be used. The fundamental SI unit of mass, the kg, is already a multiple, and so, for example, a thousandth of a kilogram is a g, not a mkg!

SI units are not spaced from the number. For example, 400 Volts is written ‘400V’, not ‘400 V’.

There are a number of ‘metric’ units in use, which are not part of the SI system, but have simple relationships with them. For example:

tonne (t)	= 1Mg (or 1,000kg)
litre (l)	= $10^{-3}\text{m}^3$
cubic centimetre (cc)	= $10^{-6}\text{m}^3$ (or 1 ml)
degree Celsius ( $^{\circ}\text{C}$ )	= K – 273.15
minute (min)	= 60s
hour (h)	= 3,600s
bar (bar)	= $10\text{kN/m}^2$
kilowatt hour (kWh)	= 3.6MJ
are (a)	= $100\text{m}^2$ (an area 10m x 10m)
hectare (ha)	= $10,000\text{m}^2$ (an area 100m x 100m!)

## Mechanical Formulae

### ***Distance, velocity and acceleration***

velocity, $u$ or $v$	= distance, $s$ per unit time, $t$ ( $m\ s^{-1}$ )
acceleration $a$	= rate of change of velocity ( $m\ s^{-2}$ )
so, $s$	= $ut + \frac{1}{2} a t^2$
$v$	= $u + at$
$v^2$	= $u^2 + 2as$
$a$	= $(v - u) / t$
etc	

### ***Newton's Laws***

force (N)	= mass x acceleration. So $N = kg\ m\ s^{-2}$
power (W)	= force x velocity. So $W = N\ m\ s^{-1}$ , or $kg\ m^2\ s^{-3}$
work done, or energy (J)	= force x distance. So $J = N\ m$ , or $kg\ m^2\ s^{-2}$
or	= power x time. So $J = W\ s$ , or $kg\ m^2\ s^{-2}$ (again!)

Weight, the downward force due to a mass on the Earth's surface, is commonly expressed in kg, although this is not strictly speaking correct in the SI system.

The acceleration due to gravity on the surface of the Earth is usually taken as  $9.81ms^{-2}$ . So the relationship between 'weight' and mass is:

$$\text{weight (N)} = 9.81 \times \text{mass (kg)}.$$

### ***Pressure***

pressure (Pa)	= force per unit area. So $Pa = N\ m^{-2}$
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### ***Torque***

Measured in Newton-metres (Nm).

Note that this is not the same as joules (J), since in this case the force and distance are not in the same direction, but are at right angles to each other.

## Electrical Formulae

### ***Ohm's Law***

The basic relationships are:

$$\text{volts} = \text{amps} \times \text{ohms}$$

$$\text{watts} = \text{volts} \times \text{amps}$$

Capacitive impedance ( $X_C$ ) is measured in ohms

$$X_C = 1 / (2 \pi f C), \text{ when } f \text{ in frequency in Hz and } C \text{ is capacitance in farads}$$

Inductive impedance ( $X_L$ ) is measured in ohms

$$X_L = 2 \pi f L, \text{ when } f \text{ in frequency in Hz and } L \text{ is inductance in henrys}$$

all the other relationships can be derived from these formulae

### ***Resistive load***

We usually measure this in kW.

Ohm's law for a simple resistive load gives

$$\text{amps} = \text{volts} / \text{ohms}$$

$$\text{kW} = \text{amps} \times \text{volts} / 1000$$

$$\text{kW} = \text{volts}^2 / (1000 \times \text{ohms})$$

$$\text{kW} = \text{amps}^2 \times \text{ohms} / 1000$$

### ***Inductive load***

We usually measure this in 'kiloVoltAmps (reactive)' or kVA<sub>r</sub>.

The inductive impedance (or resistance) is given in  $\Omega$ ,  $X_L = 2\pi \times \text{Hz} \times \text{H}$

$$\text{amps} = \text{volts} / (2\pi \times \text{hertz} \times \text{henrys})$$

$$\text{kVA}_r = \text{amps} \times \text{volts} / 1000$$

$$\text{kVA}_r = \text{volts}^2 / (1000 \times 2\pi \times \text{hertz} \times \text{henrys})$$

### ***Power factor***

Power factor (pf) =  $\text{Cos } \emptyset = \text{kW} / \text{kVA}$ . This is the definition of 'Power factor'.

$$\text{kW} = \text{kVA} \times \text{pf}$$

$$\text{kVA}_r = \text{kVA} \times \sqrt{(1-\text{pf}^2)}$$

### ***Variation of electrical load with Voltage and frequency***

If a resistive load is rated at kW<sub>1</sub> at V<sub>1</sub>, then the load at V<sub>2</sub> is:

$$\text{kW}_2 = \text{kW}_1 \times (V_2 / V_1)^2$$

If an inductive load is rated at kVA<sub>r1</sub> at V<sub>1</sub> and Hz<sub>1</sub>, then the load at V<sub>2</sub> and Hz<sub>2</sub> is:

$$\text{kVA}_{r2} = \text{kVA}_{r1} \times (V_2 / V_1)^2 \times (\text{Hz}_1 / \text{Hz}_2)$$