Basic formula 22/2/19

Basic units

Base quantity	**SI Base unit** (System International)	**SI base unit abbreviation**
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Electrical units

Base quantity	**SI Base unit** (Measured in)	**Definition**	**SI base unit abbreviation**	**Symbol** (in formula)
Electric current	Ampere	1 Ampere is 1 coulomb for 1 second	A	I
Voltage	Volt	1 Volt is required to drive 1 Ampere to produce 1 Watt of energy	V	V
Potential difference	Volt		p.d.	V
Electromotive force	Volt		e.m.f.	E
Resistance	Ohm	1 Ohm allows a current of 1 ampere given 1 Volt	Ω	R
Impedance	Ohm	Resistance including reactance	Ω	Z
Resistivity	Ohms per meter (μΩ/mm)		Ω/m	ρ (row)
Charge	Coulomb	1 coulomb is 1 ampere for 1 second (one coulomb equals the charge of roughly 6.242×10^{18} electrons)	C	Q
Electrical energy	Joule (kWh)(unit)	1 watt per second (1 amp flows through 1 Ohm for 1 second)	J	E
Power	Watt	1 Watt is 1 Joule per 1 second	W	P
Capacitance	Farad	1 farad is where 1 volt maintains 1 coulomb of charge	F	C
Capacitive reactance	Ohm		Ω	Xc
Inductance	Henry	1 henry is produced by an emf of 1Volt by a changing current of 1 amp per second	H	L
Inductive reactance	Ohm		Ω	Xl
Magnetic flux density inductance/field	Tesla	Number of lines of force /m^2	T	ß
Magnetic flux (quantity)	Weber	Number of lines of force (flux)	Wb	Φ

Base quantity	SI Unit (measured in)	Definition	SI Base Unit abbreviation	Symbol (In formula)
Mutual inductance	Henry	1 henry exists between two coils when a uniform varying current of 1 ampere/second in one coil produces an emf of 1 volt in the other.	H	M
Frequency	Hertz	Cycles per second	Hz	f
Temperature coefficient	Ohms /ohm/^{0}C	Change in resistance per degree C		A
Cross sectional area	Milli metres^2		mm^2	Csa

SI unit prefixes

Multiplier	**Name**	**Symbol prefix**	**As a power of 10**	
1 000,000,000,000.	Tera	T	1 X 10^{12}	One million million (US trillion)
1 000,000,000.	Giga	G	1 X 10^9	One thousand million (US billion)
1 000,000.	Mega	M	1 X 10^6	One million
1 000.	Kilo	K	1 X 10^3	One thousand
10.	Deca		1 X 10^1	Ten
1	Unit		1 X 10^0	any number to the power of ^{0} = itself. Eg 3 x 10^0 = 3
0.1	Deci	D	1 X 10^{-1}	One tenth
0.01	Centi	C	1 X 10^{-2}	One hundredth
0.001	Milli	M	1 X 10^{-3}	One thousandth
0.000 001	Micro	µ	1 X 10^{-6}	One millionth
0.000 000 001	Nano	N	1 X 10^{-9}	One thousand millionth
0.000 000 000 001	Pico	P	1 X 10^{-12}	One million millionth

Conversions

Temperature - 0°C = 32°f. T(°F) = T(°C) × 1.8 + 32.

Kelvin – 0 Kelvin = -459.67°f = -273.15°C

Power - KW, 1 hp = 0.735KW

Weight – 1 Kg = 2.2 ponds = 0.57 stone = 35.27 ounces

Distance – 1 mile = 0.621 KM

Volume – 1 pint = 0.568 ltrs

1 gallon = 4.54 ltrs

Energy – 1 joule = 0.239 gram calories

Pressure – 1 bar = 14.5 psi

LAWS and THEOREMS

Many of the recognised Laws and theorems seem similar because they are progressions from previous observations by other scientists.

Faraday's law of induction - The magnitude of induced emf (voltage) in a conductor is equal to the rate of change of flux linkages with the coil. The flux linkage is the product of the number of turns and the flux associated with the coil.

Eg. In a motor the rotating magnetic field induces a current in the rotor cage proportional to the difference in speed.

Lenz's - The direction of current induced in a conductor by a changing magnetic field due to Faraday's law of induction will be such that it will create a field that opposes the change that produced it, eg a magnet falling down a copper pipe, damping effect.

Eg. Back emf in transformers and motors

Fleming – right hand generator rule, left hand motor rule.

Eg used to calculate current and motion direction in motors and generators

Maxwell's Theorem – If a right handed cork screw is assumed to be held along the conductor, and screw is rotated such that it moves in the direction of the current, direction of magnetic field is same as that of the rotation of screw. It is also known as **Maxwell's corkscrew rule** or Right handed **corkscrew rule**.30 Jan 2016

Eg. Used to determine the direction of current when moved in a magnetic field, or the direction of magnetic field when current passes down a wire.

Kirchhoff's – 1st and 2nd law

Current Law or KCL, states that the "*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, $I_{(exiting)} + I_{(entering)} = 0$. This idea by Kirchhoff is commonly known as the **Conservation of Charge**.

$\sum I_i = 0$

Eg. Used in RCDs

Voltage Law or KVL, states that "*in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop*" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the **Conservation of Energy**.

$\sum V_i = 0$

Eg. Assumed for general distribution to accessories in parallel connected systems (230V at each light), and used in electronics, in series connected systems (potential dividers).

Thevenin's Theorem - states that "*Any linear circuit containing several voltages and resistances can be replaced by just one single voltage in series with a single resistance connected across the load*". In other words, it is possible to simplify any electrical circuit, no matter how complex, to an equivalent two-terminal circuit with just a single constant voltage source in series with a resistance (or impedance) connected to a load.

Eg. A method of simplifying any linear complex circuit in order to calculate current, voltage or resistance at any point.

Norton's Theorem - *Any linear circuit containing several energy sources and resistances can be replaced by a single Constant Current generator in parallel with a Single Resistor*.

Eg. A method of simplifying any linear complex circuit in order to calculate current, voltage or resistance at any point.

Lorentz's Law – deals with the inadequacy of Faraday's Law of induction under certain conditions, and addresses the result of the combination of electric and magnetic force on a point charge due to electromagnetic fields.

Eg. In a motor the current created in the conductors of the cage within a magnetic field experience a force (motion) proportional to the current and magnetic field.

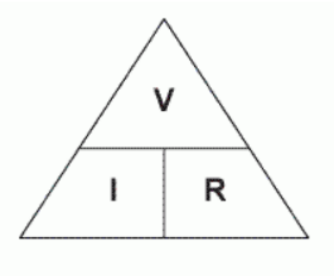
Ampere's Laws

Force Law: states that for any closed loop path, the sum of the length elements times the magnetic field in the direction of the length element is equal to the permeability times the electric current enclosed in the loop.

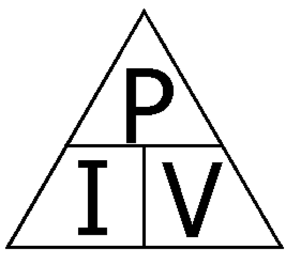
Circuital Law: The line integral of the magnetic field around some closed loop is equal to the times the algebraic sum of the currents which pass through the loop.

Eg. When a wire is coiled the magnetic field is amplified in proportion to the number of turns

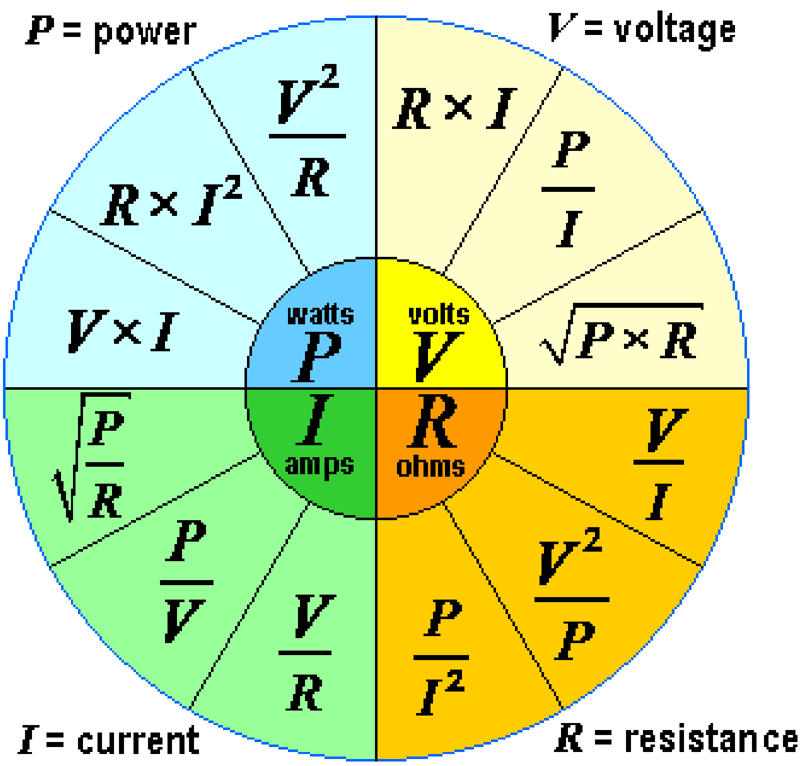
Ohms Law



Voltage Triangle Formula



Power Triangle Formula



<u>Coulomb's law formula</u>

Coulomb's law calculates the electric force *F* in newtons (N) between two electric charges $q_1$and q_2 in coulombs (C)
with a distance of *r* in meters (m):

$$F = k\frac{q_1 \cdot q_2}{r^2}$$

Common formula

Circle circumference = 2πr

Circle area = πr^2

Sphere volume = $\frac{4}{3\pi r^3}$

Sphere surface area = $4\pi r^2$

Pythagoras $Hy^2 = Adj^2 + Opp^2$

SOH CAH TOA

Gradient = change in Y (Δy) / change in X (Δx)

Mechanics

Mechanical advantage = $\frac{Load}{Effort}$

Speed =$\frac{distance}{time}$

Velocity Ratio =$\frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load}$

Force (N) = Mass (kg) x Acceleration (m/s^2)

(acceleration due to gravity = $9.81 m/s^2$)

Work done (J) = Force (N) x distance (m)

Efficiency = $\frac{output}{input}$

Torque= force x radius

Resistance

R = $\frac{\rho \times L}{A}$

$\frac{1}{rt} = \frac{1}{r1} + \frac{1}{r2} + \frac{1}{r3} + \frac{1}{r4}$ (parallel)

Do a strait calculation 1 /r1 etc then add them up, then invert the answer and divide 1/by the total added (Be careful of over complicated calculators).

Or product (x) over sum (+)

Eg. 100Ω, 10Ω, 150Ω in parallel

(100 x 10 / 100 + 10) = 9.09

(9.09 x 150 / 9.09 + 150) = 8.5Ω

Resistance of copper is 17.8µΩ per mm

Internal resistance of battery r = $\frac{E-IR}{I}$ or $\frac{E-V}{I}$

E = emf (open terminal V of battery)

I = load current of circuit through external resistor

R = value of external resistor

V = pd across external resistor or battery terminals on load

Or Gradient of curve of terminal voltage against current

Amperes

1 Amp = 1 coulomb of electrons per second

1 coulomb = 6,240,000,000,000,000,000 electrons

Volts

The amount of joules of work to push 1 coulomb along a circuit

1 volt = 1 joule / coulomb

Energy

E = Power x time

1 Joule = 1 Watt for 1 second

1KW hr = 3.6 x 10^6Joules

Power

Horse power1hp = 0.735KW

Power = $\frac{work\ done\ (W)}{time\ taken\ to\ do\ that\ work\ (t)}$

Power = $\frac{Energy\ (E)}{time\ taken\ to\ do\ that\ work\ (t)}$

Killowatts to Volt ampere

VA = (KW / Power factor) x 1000

Electrical power

The power taken by a circuit (single or three phase) is measured in watts W (or kW). The product of the voltage and current is the apparent power and measured in VA (or kVA) . The relationship between kVA and kW is the power factor (pf or cosϴ):

Power = I x V

Power = I^2 x R

Power = $\frac{V^2}{R}$

3 phase power = √3 x VL x IL x cos ϴ

IL = $\frac{P\ (W)}{\sqrt{3}x\ VL\ x\ cos\theta}$

Power factor (cosΘ) = $\frac{true\ power\ kW}{apparent\ power\ kVA}$

Power is charged at kva (hypotenuse)

1KW hr = 3.6 x 10^6Joules

Power factor (cosΘ)= $\frac{R}{Z}$=$\frac{Vr}{Vt}$=$\frac{KW}{KVA}$

KVA = $\frac{I\ x\ V}{1000}$

Power triangle

Real *or* ***true*** *or* ***active*** *power (K Watts) P=V x I x cosΘ (adjacent), the same as KW = pf x KVA*

Reactive *power (Kvar) Q=V x I x sinΘ (opposite), the same as Kvar = $\sqrt{KVA^2 - KW^2}$*

Apparent *power (KVA) S = V x I (hypotenuse), the same as KVA = KW / pf*

(Power is charged at kva (hypotenuse))

(power used by an appliance is true (adjacent))

(reactive power is unused waste (opposite))

Power factor *(pf) = KW / KVAR + KW*

Mechanical power output =2π*nT*

Magnetism

Inductance $L = \frac{N\Phi}{I}$ (henry's) where N is the number of turns, Φ is the flux, I is the current

Magnetic flux *Φ (webers) = flux density* (β) *x area*

Flux density β (tesla) = $\frac{flux\ \Phi\ (webers)}{csa\ (m^2)}$

Rotation of magnetic field **=** screw rule

Fleming's **left-hand** motor rule

Fleming's **right hand** generator rule

Force (F) = β I L   Flux density x current x length

Induced emf = flux density x speed of cutting flux x length of conductor (E = β x *v* x *l*)

Also $E = -\frac{\Phi 2 - \Phi 1}{t} \text{ x N volts}$ (the – sign indicates that the emf is a back emf and opposes the rate of change of current

Self inductance $E = \frac{-L(I2 - I1)}{t}$ volts

Mutual inductance $M = \frac{(\Phi 2 - \Phi 1)}{(I2 - I1)} \text{ x N}$ *henry's*

Faraday's law – whenever a conductor cuts through magnetic field lines an 'emf' is induced across it's ends.

Lorentz equation for force – *F = q (E + u x B) newtons.*

where q = charge, E = field strength, u = velocity (m/s), B = flux density.

Three Phase

Delta - VL = Vp   IL = √3 x Ip

- $Ip = \frac{Il}{\sqrt{3}}$
- $IL = \frac{Kw}{\sqrt{3}\ x\ Vlx\ \text{Cos}\ \emptyset}$

Star - IL = Ip   VL = √3 x Vp

- $Vp = \frac{Vl}{\sqrt{3}}$
- $IL = Ip = \frac{Vp}{Rp\ (winding\ resistance)}$

3 phase power = √3 x VL x IL x cosΘ (common to both star and delta)

$$IL = \frac{Kw}{\sqrt{3}\ x\ Vlx\ \text{Cos}\ \emptyset}$$

Motors

3 phase Synchronous motor speed $n = \frac{120\ x\ frequency}{pairs\ of\ poles}$

Back emf (E) = V – Ia x Ra

(Ia-armature current x Ra-armature resistance)

Torque (T) = $\frac{EIa}{2\pi n}$(armature power o/p divided by $2\pi\ x\ speed$)

Voltage across windings in STAR = $\frac{1}{1.732}$ x supply voltage

Voltage across windings in DELTA = supply voltage

For correct fuse ratings of motors see manufactures data

Impedance

$Z^2 = R^2 + X^2$

Impedance triangle

Z is the hypotenuse

R is the adjacent

X is the opposite

Z = $\sqrt{R^2 + X^2}$

Reactance

Inductive (Xl) = 2π x f x L (Ω)

Capacitive (Xc) = $\frac{1}{2\pi\ x\ f\ x\ C}$(Ω)

Transformers

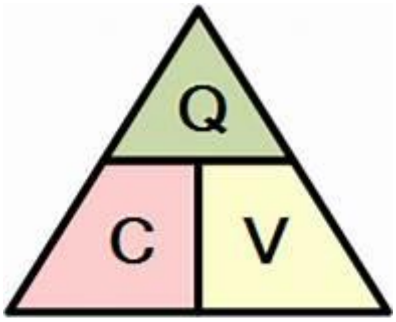
$\frac{Ep}{Es} = \frac{Np}{Ns} = \frac{Is}{Ip}$

Back emf = applied V – (Ip x Rp)

Capacitance

Charge Q = Capacitance x voltage **Capacitance** **C = Q/V**

Inversely proportional to dielectric thickness **Proportional to area of plate**

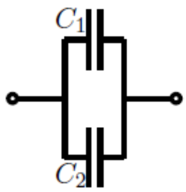
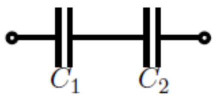


Capacitance Triangle Formula

Where Q=charge in coulombs C=capacitance in farads V=voltage

Capacitors in series reduce overall capacitance $\frac{1}{ct} = \frac{1}{c1} + \frac{1}{c2} + \frac{1}{c3} + \frac{1}{c4}$

Capacitors in parallel increase overall capacitance *ct = c1 + c2 + c3 + c4*

PARALLEL		$C_p = C_1 + C_2$
SERIES		$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$

Converting Amps to kVA (3 phase unity power factor)

kVA = $\frac{3\ x\ nominal\ line\ to\ neutral\ voltage\ (Uo) x\ line\ current}{1000}$

kVA = $\frac{\sqrt{3}\ x\ nominal\ line\ to\ line\ voltage\ (Uo) x\ line\ current}{1000}$

Converting kVA to Amps (3 phase unity power factor

Current = $\frac{kVA\ x\ 1000}{3\ x\ nominal\ V}$

Current = $\frac{kVA\ x\ 1000}{\sqrt{3}\ x\ line\ V}$

Frequency *f*

f = 1/T cycles per second in Hertz (Hz)

T = 1/f cycle duration (period) in seconds (s)

ʎ = c/f wave length in metres (m)

c = ʎ x f wave speed in metres per seconds (m/s

Peak, RMS and average voltage (AC)

Peak to peak V = RMS V x 2.828 *(for 240V = 679V)*

Peak V = RMS V x 1.42 (√2) *(for 240V = 341V)*

RMS V = V peak x 1/√2 (0.707)

DC

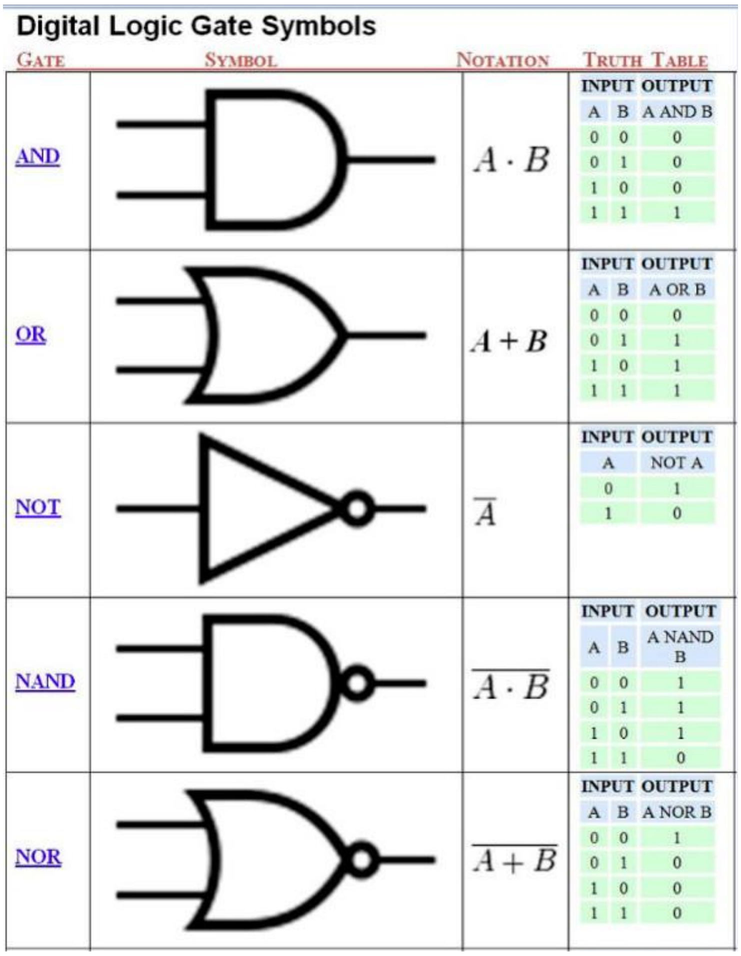
Peak V = average V x π /2 (or1.57)

Average VDC of a sign wave = 2 x Vpeak / π   or   0.637 x Vpeak

Vavg = Vpeak / π   for half wave rectifier

Vavg = 2V x peak / π pi for full wave

Degrees to radians – degrees x π / 180



Digital Logic Gate Symbols

Gate	Symbol	Notation	Truth Table
AND		$A \cdot B$	see below
OR		$A + B$	see below
NOT		$\overline{A}$	see below
NAND		$\overline{A \cdot B}$	see below
NOR		$\overline{A + B}$	see below

AND

INPUT		OUTPUT
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

OR

INPUT		OUTPUT
A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

NOT

INPUT	OUTPUT
A	NOT A
0	1
1	0

NAND

INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

NOR

INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

Device Type	Logic 0	Logic 1
TTL	0 to 0.8v	2.0 to 5v (V_{CC})
CMOS	0 to 1.5v	3.0 to 18v (V_{DD})