

UEECD0046 & UEECD0044 FORMULA SHEET

BASIC ELECTRICAL CONCEPTS

Charge

Q = charge in coulombs (C)

I = current in amperes (A)

t = time in seconds (s)

$$Q = I t$$

$$I = Q / t$$

$$t = Q / I$$

Speed

Velocity

Angular velocity

One radian = 57.3°

Radians per revolution = 360 / 57.3° = 6.28 (or 2 x π)

Revolution per second = rpm / 60, e.g. 420 / 60 = 7 rps

$$\text{Speed (kmh}^{-1}\text{)} = \text{distance (km)} / \text{time (hrs)}$$

$$\text{Velocity (m/s}^{-1}\text{)} = \text{displacement (m)} / \text{time (s)}$$

$$\text{Radian/s} = (\text{radian} \times \text{rps}) / \pi$$

Acceleration

Pressure

$$\text{Acceleration} = \Delta \text{ velocity (ms}^{-1}\text{)} / \Delta \text{ time (s)}$$

$$P = \text{force (N)} / \text{area (sq metres)}$$

$$(\text{Force} = \text{mass} \times \text{acceleration})$$

BASIC ELECTRICAL CIRCUITS

Common prefixes

Atto (a)	=	Unit x 10 ⁻¹⁸	(Unit x 0.000 000 000 000 000 001)
Femto (f)	=	Unit x 10 ⁻¹⁵	(Unit x 0.000 000 000 000 001)
Pico (p)	=	Unit x 10 ⁻¹²	(Unit x 0.000 000 000 001)
Nano (n)	=	Unit x 10 ⁻⁹	(Unit x 0.000 000 001)
Micro (μ)	=	Unit x 10 ⁻⁶	(Unit x 0.000 001)
Milli (m)	=	Unit x 10 ⁻³	(Unit x 0.001)
Unit	=	Unit x 10 ⁰	(Unit x 1)
Kilo (k)	=	Unit x 10 ³	(Unit x 1 000)
Mega (M)	=	Unit x 10 ⁶	(Unit x 1 000 000)
Giga (G)	=	Unit x 10 ⁹	(Unit x 1 000 000 000)
Tera (T)	=	Unit x 10 ¹²	(Unit x 1 000 000 000 000)
Peta (P)	=	Unit x 10 ¹⁵	(Unit x 1 000 000 000 000 000)
Exa (E)	=	Unit x 10 ¹⁸	(Unit x 1 000 000 000 000 000 000)

OHMS LAW & ELECTRICAL POWER

Ohm's Law and power

V = voltage in volts (V)

I = current in amperes (A)

R = resistance in ohms (Ω)

P = power in watts (W)

$$V = RI$$

$$I = V / R$$

$$R = V / I$$

$$P = VI$$

$$V = P / I$$

$$I = P / V$$

$$R = V^2 / P$$

$$P = I^2 R$$

$$V = \sqrt{(PR)}$$

$$I = \sqrt{(P / R)}$$

$$R = P / I^2$$

$$P = V^2 / R$$

FORCE, POWER, WORK AND ENERGY

Force (N)

F = force in newtons (N)

m = mass in kilograms (kg)

a = acceleration in metres per second per second (ms^{-2})

$$F = m a$$

$$m = F / a$$

$$a = F / m$$

Torque

T = torque in newton metres (Nm)

F = force in newtons (N)

r = radius in metres (m)

$$\text{Torque} = F r \sin \Theta$$

$$F = \text{Torque} / r \sin \Theta$$

$$r = \text{Torque} / F \sin \Theta$$

Work (J)

Work = work done in Joules (J)

Force = force used in newtons (N)

Distance = distance in metres (m)

$$J = N m$$

$$N = J / m$$

$$m = J / N$$

Gravity

Weight (kg)

$$\text{Gravity} = 9.81 \text{ m} / \text{s}^2$$

$$\text{Weight (kg)} = \text{mass} \times \text{force due to gravity (N)}$$

Potential energy (kJ)

kJ = potential energy in kilojoules (kJ)

m = mass in kilograms (kg)

g = force of gravity in metres per second squared (m/s^2)

h = height in metres (m)

$$\text{kJ} = m g h$$

$$m = \text{kJ} / (g h)$$

$$g = \text{kJ} / (m h)$$

$$h = \text{kJ} / (m g)$$

Power

Power = power in watts (W)

Work = work done in joules (J)

Time = time in seconds (s)

$$W = J / t$$

$$J = W t$$

$$t = J / W$$

Mechanical power

P = mechanical power in watts (W)

N = speed of rotation in revs per minute (rpm)

T = torque in newton-metres (Nm)

$$P = (2 \pi N T) / 60$$

$$N = (P 60) / (2 \pi T)$$

$$T = (P 60) / (2 \pi N)$$

Electrical energy (J)

J = Electrical energy in joules (j)

P = power in watts (W)

t = time in seconds(s)

$$J = P t$$

$$\text{Or } J = V \times I \times t$$

$$P = J / t$$

$$t = J / P$$

$$\text{Joules} = (W \times \text{hour}) / 1000 = \text{kWh}$$

EMF SOURCES ENERGY SOURCES & CONVERSION ELECTRICAL ENERGY

Machine efficiency

η % = efficiency percentage (%)

P_{out} = output power in watts (W)

P_{in} = input power in watts (W)

$P_{in} = P_{out} + \text{Losses}$

$P_{out} = P_{in} - \text{Losses}$

Therefore;

Or

$$\eta \% = (P_{out} / P_{in}) \times 100$$

$$P_{out} = \eta \% \times P_{in}$$

$$P_{in} = P_{out} / \eta \%$$

$$\text{Losses} = P_{in} - P_{out}$$

$$\eta \% = ((P_{in} - \text{Losses}) / P_{in}) \times 100$$

$$\eta \% = (P_{out} / (P_{out} + \text{Losses})) \times 100$$

Torque

T = force in newtons (N)

F = force in newtons or kilograms (N) or (kg)

r = radius between conductor and pivot point (m)

$$T = F r$$

$$F = T / r$$

$$r = T / F$$

Torque

T = torque in newton metres (Nm)

P = power output in watts (W)

N = speed of rotation in revs per minute (rpm)

$$T = (P / 60) / (2 \pi N)$$

$$P = (2 \pi N T) / 60$$

$$N = (P / 60) / (2 \pi T)$$

SERIES CIRCUITS

Resistance (Ω)

Current(A)

Voltage (V)

Power(W)

Capacitance (F)

$$R_T = R_1 + R_2 + R_3$$

$$I_S = I_1 = I_2 = I_3$$

$$V_S = V_1 + V_2 + V_3$$

$$P_T = P_1 + P_2 + P_3$$

$$C_T = 1 / ((1/C_1) + (1/C_2) + (1/C_3))$$

PARALLEL CIRCUITS

Equal resistances (Ω)

Product / sum resistance method (Ω)

Reciprocal method of resistance (Ω)

Current (A)

Voltage (V)

Power (W)

Capacitance (F)

$$R_T = R / n \text{ of parallel paths}$$

$$R_T = (R_1 \times R_2) / (R_1 + R_2)$$

$$R_T = 1 / ((1 / R_1) + (1 / R_2) + (1 / R_3))$$

$$I_T = I_1 + I_2 + I_3$$

$$V_S = V_1 = V_2 = V_3$$

$$P_T = P_1 + P_2 + P_3$$

$$C_T = C_1 + C_2 + C_3$$

Unknown resistance value

Or

$$1 / R_2 = 1 / R_T - 1 / R_1$$

$$1 / R_3 = 1 / R_T - (1 / R_1 + 1 / R_2)$$

Conductance (S)

G = conductance in siemens (S)

R = resistance in ohms (Ω)

$$G = 1 / R$$

$$R = 1 / G$$

Reciprocal method of conductance (Siemens)

$$G_T = 1 / ((1 / R_1) + (1 / R_2) + (1 / R_3))$$

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FACTORS AFFECTING RESISTANCE

Resistance of a conductor directly proportional to length

$$\frac{R_1}{R_2} = \frac{L_1}{L_2} \quad \text{in Ohms}$$

Where R_1 is the resistance of conductor with length L_1

And R_2 is the resistance of the same length but having length L_2

Therefore;

$$R_2 = R_1 L_2 / L_1$$

Resistance of a conductor is inversely proportional to CSA

$$\frac{R_1}{R_2} = \frac{A_2}{A_1} \quad \text{in Ohms}$$

Where R_1 is the resistance for a given length of conductor with a CSA of A_1 square unit

And R_2 is the resistance of the same length but with a CSA of A_2 square unit

Therefore;

$$R_2 = R_1 \times A_1 / A_2$$

Resistance of a conductor is inversely proportional to the square of its diameter

$$\frac{R_1}{R_2} = \frac{d_2^2}{d_1^2} \quad \text{in Ohms}$$

Where R_1 is the resistance for a given length of conductor with a diameter d_1

And R_2 is the resistance of the same length but with a diameter d_2

Therefore;

$$R_2 = R_1 (d_1 / d_2)^2$$

Combining the three equations

$$R_2 = (R_1 A_1 L_2) / (A_2 L_1) \quad \text{in Ohms}$$

Where R_1 is the resistance of a conductor having length L_1 units, and CSA A_1 square units

And R_2 is the resistance of the same conductor but having length L_2 units, and CSA A_2 square units

Resistivity

R = resistance in ohms (Ω)

ρ = resistivity in ohm-metres (Ωm)

L = length in metres (m)

A = cross-sectional area in square meters (m^2)

$$R = (\rho L) / A$$

$$\rho = (R A) / L$$

$$L = (R A) / \rho$$

$$A = (\rho L) / R$$

Cross section area of a conductor

A = cross-sectional area of a circular conductor in mm^2

d = diameter of wire in mm

$$A = \pi \times d^2 / 4 \quad \text{in } mm^2$$

Resistance with variation of temperature

R_h = final hot resistance in ohms

R_c = initial cold resistance in ohms

α = temperature coefficient of resistance in $^{\circ}C$

T = final temperature in $^{\circ}C$

T_{ref} = reference temperature that α is specified at for the conductor itself

$\Delta \vartheta$ = temperature change (same as $T - T_{ref}$)

$$R_h = R_c (1 + \alpha (T - T_{ref}))$$

$$\Delta \vartheta = R_h - R_c / \alpha \times R_c$$

ΔR = change of resistance in ohms

$$\Delta R = \alpha \times R_c \times \Delta \vartheta$$

Resistor Tolerance

To calculate the acceptable value of a resistor with a tolerance; say 200Ω tolerance 5%

Tolerance in Ohms is : tolerance % x resistor value / 100 $5 \times 200 / 100 = 10\Omega$

Lowest acceptable value: resistor value MINUS tolerance. $200\Omega - 10\Omega = 190\Omega$

Highest acceptable value: resistor value PLUS tolerance. $200\Omega + 10\Omega = 210\Omega$

Therefore acceptable resistor range is 190Ω to 210Ω

OR:

Lowest acceptable value: (100% – tolerance %) x resistor value $95\% \times 200\Omega = 190\Omega$

Highest acceptable value: (100% + tolerance %) x resistor value $105\% \times 200\Omega = 210\Omega$

Therefore acceptable resistor range is 190Ω to 210Ω

EFFECTS OF METERS IN A CIRCUIT

Voltmeter (high resistor in series)

$$R_T = (V / I) - R_{\text{Meter}},$$

$$I_{\text{Total}} = I_{\text{Resistor}} = I_{\text{Meter}},$$

$$R_T = R_{\text{Resistor}} + R_{\text{Meter}}$$

For 50 μA , 2000 Ω meter

Measuring on 250 V scale

$$R_T = 250 / .000050 = 5 \text{ M } \Omega - 2000 \Omega = 4.8 \text{ M } \Omega$$

Measuring on 100 V scale

$$R_T = 100 / .000050 = 2 \text{ M } \Omega - 2000 \Omega = 1.8 \text{ M } \Omega$$

Ammeter (low resistor in parallel)

$$V = I_{\text{Meter}} \times R_{\text{Meter}}$$

$$I_{\text{Shunt}} = I_{\text{Scale}} - I_{\text{Meter}}$$

$$R_T = V / I_{\text{Shunt}}$$

For 50 μA , 5000 Ω meter

$$V = 0.000050 \times 5000 = 0.25 \text{ V}$$

Measuring on 10 A scale

$$I_{\text{Shunt}} = 10 - 0.000050 = 9.99995 \text{ A}$$

Resistance of the shunt

$$R_{\text{Shunt}} = 0.25 / 9.99995 \text{ A} = 25 \text{ m}\Omega$$

Measuring on 100 mA scale

$$I_{\text{Shunt}} = 0.100 - 0.000050 = 0.09995 \text{ A}$$

Resistance of the shunt

$$R_{\text{Shunt}} = 0.25 / 0.09995 \text{ A} = 2.5 \Omega$$

CAPACITANCE AND CAPACITORS

Capacitance

C = capacitance in farads (F)

$$C = Q / V$$

Q = electric charge in coulombs (C)

$$Q = C V \quad \text{Or} \quad Q = I t$$

V = voltage in volts (V)

$$V = Q / C$$

Capacitance in series (F)

$$C_T = 1 / ((1/C_1) + (1/C_2) + (1/C_3))$$

Capacitance in parallel(F)

$$C_T = C_1 + C_2 + C_3$$

Energy stored in a capacitor

W = energy in joules (J)

$$W = (C V^2) / 2$$

C = capacitance in farads (F)

$$C = 2W / V^2$$

V = voltage across the plates in volts (V)

$$V = \sqrt{2W / C}$$

Capacitive time constant (t)

τ = time constant in seconds (s)

$$\tau = C \times R$$

C = capacitance in farads (F)

$$C = \tau / R$$

R = resistance in ohms (Ω)

$$R = \tau / C$$

Full charge

$$\text{Full charge} = 5 \times \tau$$

Voltage

$$V = I R$$

Instantaneous voltage

$$V_{\text{inst}} = V \times \text{Universal time charge value}$$

Maximum current

$$I = V / R$$

Instantaneous current

$$I_{\text{inst}} = (V / R) \times \text{Universal time charge value}$$

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Universal Time Constant Chart

