Formulary EE

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| **Charge and amounts of charge** | |
| Proton Charge symbol (“elementary charge”) |  |
| Electron charge symbol |  |
| Symbol for amounts of charge (aka “charge”)  Unit of amounts of charge  Relations | : constant amount of charge  : time variable charge |
| **Electric current** | |
| Amount of charge  passing through a cross-section  in the indicated direction during the time | Q  A |
| Electric current magnitude (aka current), mean value  Instantaneous electric current  Unit of the electric current  Relations |  |
| **Current direction** | |
| “real current (electron) direction”  “conventional direction of current” |  |
| **Current density** | |
| Cross sectional area |  |
| Current vertical through cross-sectional area |  |
| Current density, mean value: |  |
| time-dependant current density  Unit of current density  Example: Copper cables | about (no heating)  about (for higher Temps) |

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| **Power and energy** | | |
| Formula symbol for average power  Instantaneous power  Unit of Power | |  |
| Symbol for energy, from “work”   * E is reserved for electric field strength   Unit of energy | |  |
| **Voltage** | | | |
| Definition of voltage (aka electromotive force)  “ratio of the energy released to the amount of charge transported from **point A to point B**”  Symbol, mean value  Time variable voltage  Unit voltage  Relations | , (USA: | | |
| Nominal voltage = average voltage  = (Fully charged – allowable discharge)/2 | The nominal voltage allows the energy stored in a fully charged battery to be calculated, assuming a linear voltage decrease during discharge. | | |
| **Resistance and Conductance** | | | |
| Definition of electrical resistance  Unit of resistance |  | | |
| Definition of electrical conductance  Unit of conductance: |  | | |
| Resistor: const. ratio between voltage and current |  | | |
| **Specific Resistance, Specific Conductance** | | | |
| Specific resistance “rho”  use: calculate resistance of a wire based on its geometrical properties and  Unit |  | | |
| Specific conductance “sigma”  Unit |  | | |
| **Power** | | | |
| Average power |  | | |
| Instantaneous power |  | | |
| **Kirchhoff’s laws** | | | |
| Diagram  Description automatically generatedMesh rule The sum of all voltages in a mesh, taking into account the direction of the arrows, is 0. Justification: energy conservation | Diagram  Description automatically generatedNode rule The sum of all currents towards a node is equal to the sum of all currents flowing away from the node. Reason: the ideal node is a pure connecting element and therefore cannot store any charge. | | |
| **Systematic error correction** | | | |
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| **Ohmic Resistors** | | | |
| Series | | | |
| Diagram  Description automatically generated | | | |
| Parallel | | | |
| Diagram  Description automatically generated | | | |
| **Ohmic voltage divider** | **Ohmic current divider** | | |
| A picture containing diagram  Description automatically generated |  | | |

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| **Linear model for batteris and accumulators** |
| «**Linear voltage source**» = ideal voltage source + series resistance (“Internal resistance ”) |
| **Network Analysis** |
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| **Conditions for the method (Superposition Principle)** |
| * Linear network   + Allowed as used elements are resistors, linear sources, (capacitors, coils) * There is only one source in each partial solution * The current and voltage arrows on a particular one-port must point in the same direction in all partial solutions, preferably defined at the beginning. |

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| **Superposition Principle** |
| 1. all sources except 1 = 0 🡪 calculate currents & voltages 2. next source to value, all others = 0 🡪 calculate currents & voltages 3. add up partial solutions 4. Ideal voltage source with 0V = short circuit! 5. Set |
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| **Batteries in Parallel** | |
| Paralleling batteries results in higher available currents  Text  Description automatically generatedA picture containing text, clock  Description automatically generated |  |
| **Batteries in Series** | |
| Diagram, schematic  Description automatically generated | Paralleling similar batteries results double the voltage, whereas the short-circuit current stays the same |
| Exercise 4 – Task 1 | Solution |
| One of the first cars made by Tesla, the Tesla Roadster, used a battery bank consisting of 6831 batteries type 18650. Let us assume, all those batteries have an idle voltage of 3.7 V and an internal resistance of 100 mΩ. The batteries are connected as follows:  • Groups of 69 batteries are connected in parallel  • All these 99 groups are connected in series | Due to all batteries having the same idle voltage of 3.7 V and the same internal resistance of 100 mΩ, calculations are straightforward:   * A group of 69 batteries in parallel has an internal resistance of and an short circuit current of * All groups in series, i.e., the equivalent battery, has an internal resistance of and an idle voltage of . |
| **Temperature model for metal alloy resistors** | |
| Linear Temperature coefficient (in 1/Kelvin or 1/°C)  Quadratic Temperature coeff. (in 1/Kelvin2 or 1/°C2)  Resistance value at 20 °C  Δϑ Temperature increase  Rϑ Value of resistance at the temperature ϑ of the element (possibly ≠ ambient temperature), [ϑ] =°C | Polynomial description :  If β20 is not given, you can neglect it |
| **NTC temperature model** | |
| T Temperature in Kelvin  R Value of resistance at this temperature  R25 Nominal resistance at 25 °C  A1,B1,C1,D1 Coefficients (see datasheet) |  |

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| **Magnetic Force Between Conductors** | |
| depends on the material between the conductors, it is called “permeability” |  |
| **Permeability** | |
| Unit of permeability  Permeability of the vacuum  Permeability of any substance  Relative permeability |  |
| **Magnetic Field Strength** | |
| “Magnetic field strength B1” of a long straight current I1 at a distance r |  |
| **Magnetic field strength B** | **Magnetic field strength H** |
| also “magnetic flux density”, “magnetic induction”  Unit: | also “magnetic excitation”  Unit: |
| Relationship: | |
| **Application of Magnetic Field Strengths** | |
|  | For an angle |
| **Magnetic Field Vector** | |
| Definition  For force as a vector, a current vector and a magnetic field (strength) vector is needed, and the ordinary product is converted to a cross product: |  |
| **Magnetic Field Strength Inside a Coil** | |
| for current I,  Length ℓ,  diameter d,  Number of turns N, inside a coil |  |

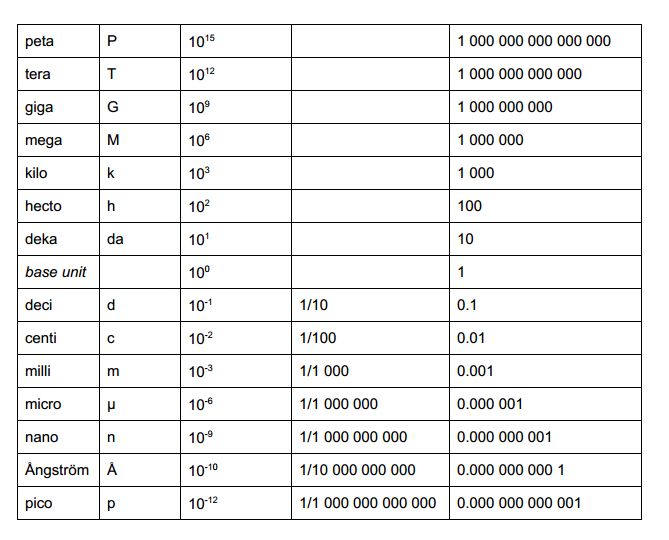
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| **Magnetic flux** | |
| A picture containing text, clock  Description automatically generatedUnit of magnetic flux  B homogeneous with inclination angle referred to a flat surface A |  |
| **Induced voltage** | |
| Diagram  Description automatically generated |  |
| **Linked flux** | |
| Linked flux “Psi” for coil with N turn with the flux per turn [Wb] |  |
| **Linked voltage** | |
| Diagram  Description automatically generatedMax voltage  P: number of poles, f: frequency |  |
| **Coil with iron core** | |
| Higher field strength |  |
| **Eddy current** | **Magnetic field of the eddy current** |
| Diagram  Description automatically generatedEddy current, ideal coil without resistance connected to an ohmic resistor R in an external magnetic field B(t), causing linked flux (t). | Eddy current causes a field in the coil  A picture containing text, metalware, kitchen appliance  Description automatically generatedField direction according to right-hand rule |
| **Self induction** | |
| Unit:  Self-induced voltage with inductance L |  |
| **Cylindrical coil** | |
| * Diagram, schematic    Description automatically generatedLength l * Diameter d * Windings N * Cross-sectional area A   **Energy** in the coil |  |
| **Toroidal coil for thin wire** | |
| * Diagram    Description automatically generatedd: Core diameter * r: Inner radius * R: Outer radius * N: windings |  |
| **Wire resistance** |  |
| **PM Motor torque** | |
| For a single loop, with current I, side length ℓ, lever arm r, magnetic field B, angle α between surface normal and magnetic field  With current I, A surface area, B magnetic field and N windings  Torque with many loops, without mechanical losses, with torque constant kM | Unit of torque  Unit of the torque constant |
| **PM Motor: Equivalent Circuit, Symbol** | |
| For the PMDC motor UBEMF= n /kn with speed constant kn and speed n, [n] = = rpm  Unit of the speed constant  Diagram  Description automatically generated |  |
| **Motor Power** | |
| Motor Power, voltage U at motor, current I through the motor |  |
| Mechanical Power (without mechanical losses) |  |
| Efficiency “eta” |  |
| Relationship between the torque kM· kn= 30 / π  constant and the speed constant when mechanical losses are neglectable |  |
| **Motor Characteristics of a PMDC Motor** | |
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| Idle speed [rpm] |  |
| Holding torque / stands still |  |

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| **Capacitance** | |
| Capacitance: Two capacitors connected in series have always the same charge!  N=nano, u=my=micro  Unit  Relations to the unit: |  |
| Charge  Charge when parallel |  |
| Instantaneous charge |  |
| Instantaneous current |  |
| Momentary voltage |  |
| **Energy** in a capacitor |  |
| **General formula** for capacitors in series  2 series capacitors (only for two cap.) |  |
| 2 Parallel capacitors |  |

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| **Dielectric strength** |  | |
| Dielectric strength  Unit  Flashover voltage  d: dielectric thickness  Maximum working voltage |  | |
| **Coulomb’s Law, Permittivity** | | |
| Attraction/repulsion force for two charged spheres at distance d (d >> sphere radius R)  Permittivity (permeability) of a material  Unit of permittivity |  | |
| Permittivity of the vacuum |  | |
| Dielectric constant (“epsilon r”) |  | |
| Flashover voltage |  | |
| **Capacitance Formulas** | | |
| Plate capacitor Distance d or thickness, area A  If two plates -> 2 windings -> multiplicate by 2 | |  |
| Spherical capacitor Outer radius ra, Inner: ri  Free standing sphere with radius r | |  |

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| **AC** | | Bei Mix von DC und AC -> DC berechnen -> î und Û berechnen und dann weiter |
| **Definitions about AC** | | |
| Amplitude Û (maximum value), angular frequency | |  |
| Frequency f | |  |
| Average power | |  |
| Instantaneous power | |  |
| **RMS value of a voltage 🡪 Amplitude** | | |
|  | |  |
| RMS voltage Û= Amplitude | |  |
| RMS current (meaning root-man-squared)  Î = Amplitude | |  |
| **Capacitors at alternating current** | | |
| Diagram  Description automatically generated |  | |
| **Ratio current/voltage at the capacitor** | | |
| "Impedance of the capacitor” (always positive, unit: Ω) |  | |
| **Coils at alternating current** | | |
| Diagram  Description automatically generated |  | |
| **Ratio current/voltage at the coil** | | |
|  |  | |
| **More AC quantities** | | |
| Admittance |  | |
| Capacitor reactance\*  Minus sign to distinguish capacitive/inductive (convention) |  | |
| Capacitor susceptance |  | |
| Coil reactance |  | |
| Coil susceptance |  | |
| Conductance |  | |

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| **AC Circuits and calculations series** | |
| Diagram  Description automatically generated | Text  Description automatically generated |
| Diagram, schematic  Description automatically generated | Text, letter  Description automatically generated |
| Diagram  Description automatically generated | Text, letter  Description automatically generated |
| **AC Circuits and calculations parallel** |  |
| Diagram, schematic  Description automatically generated | Text  Description automatically generated with medium confidence |
| Diagram, schematic  Description automatically generated | Text, letter  Description automatically generated |
| Diagram, schematic  Description automatically generated | Text, letter  Description automatically generated |

**Conversion Scale Areas**

Circle:

**Integration**

*Definition*

Eine Funktion heisst Stammfunktion von , falls **.**

Chart, histogram

Description automatically generatedBsp:

Bsp:

*Definition unbestimmtes Integral*

* Die Menge aller Stammfunktionen = unbestimmtes Integral von

1. 🡪 .

* Die Funktion = Integrand.

Beispiel: