## Constants

| | |
|---|---|
| Magnitude of electron charge | $e = 1.60 \times 10^{-19}\,\mathrm{C}$ |
| Coulomb's constant | $k = 8.99 \times 10^{9}\,\mathrm{N.m^2C^{-2}}$ |
| Permittivity of free space | $\epsilon_0 = \frac{1}{4\pi k}$ |
| | $\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2N^{-1}m^{-2}}$ |
| Permeability of free space | $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H.m^{-1}}$ |
| Mass of electron | $m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$ |

## Equations from 121

| | |
|---|---|
| Kinematics (1-dim) | $x = x_0 + v_0 t + at^2/2$ |
| | $v = v_0 x + at$ |
| | $v^2 = v_0^2 + 2a\Delta x$ |
| Kinetic energy | $K = \frac{1}{2}mv^2$ |
| Newton's 2nd law | $\vec{F}_{net} = m\vec{a}$ |
| Newton's 3rd law | $\vec{F}_{12} = -\vec{F}_{21}$ |

## Electrostatics

| | |
|---|---|
| Coulomb's Law | $\vec{F}_{12} = \frac{kq_1q_2}{r_{12}^2}\hat{r}_{12}$ |
| Electric field | $\vec{E} = \vec{F}/q$ |
| Dipole moment | $\vec{p} = q\vec{L}$ |
| Torque on a dipole | $\vec{\tau} = \vec{p} \times \vec{E}$ |
| Potential energy of a dipole | $U = -\vec{p} \cdot \vec{E}$ |
| Electric flux | $\phi = \int \vec{E} \cdot d\vec{A}$ |
| Electric flux for uniform field | $\phi = \lvert\vec{E}\rvert A \cos\theta$ |
| Gauss's law | $\phi_{net} = \oint \vec{E} \cdot d\vec{A} = Q_{enc}/\epsilon_0$ |
| Potential difference | $\Delta V = \frac{\Delta U}{q_0} = -\int_a^b \vec{E} \cdot d\vec{L}$ |
| Electric field from potential | $\vec{E} = -\vec{\nabla}V$ (magnitude = slope) |
| Pot. energy of point charges | $U = \sum_{\text{pairs}} kq_iq_j/r_{ij}$ |
| E from point charge | $\vec{E} = \frac{kq}{r^2}\hat{r}$ |
| E from system of charges | $\vec{E} = \sum_i \vec{E}_i$ |
| E from infinite line of charge | $E_R = 2k\lambda/R$ |
| E from infinite plane of charge | $E = \sigma/2\epsilon_0$ |
| E from thin spherical shell | $E_r = \begin{cases} \frac{Q}{4\pi\epsilon_0 r^2}, & \text{if } r > R \\ 0, & \text{if } r < R \end{cases}$ |
| E outside conductor | $E = \sigma/\epsilon_0$ (perp. to surface) |
| E inside conductor | $E = 0$ |
| V from point charge | $V = \frac{kq}{r}$ |
| V from system of point charges | $V = \sum_i \frac{kq_i}{r_i}$ |
| V from thin spherical shell | $V = \begin{cases} \frac{kQ}{r}, & \text{if } r > R \\ \frac{kQ}{R}, & \text{if } r < R \end{cases}$ |

## Capacitance

| | |
|---|---|
| Capacitance | $C = Q/V$ |
| Parallel plate capacitor | $C = \epsilon_0 A/d$ |
| Cylindrical capacitor | $C = \frac{2\pi\epsilon_0 L}{\ln\left({}^{R_2}/{}_{R_1}\right)}$ |
| Energy stored in a capacitor | $U = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$ |
| Energy density of an E field | $u_e = \frac{1}{2}\epsilon_0 E^2$ |
| Parallel capacitors | $C_{eq} = C_1 + C_2 + ...$ |
| Series capacitors | $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + ...$ |
| Electric field inside dielectric | $E = \frac{E_0}{\kappa}$ |
| Capacitance with dielectric | $C = \kappa C_0$ |

## Resistance and current

| | |
|---|---|
| Electric current | $I = dQ/dt$ |
| Current density | $J = I/A$ |
| Current microscopic view | $I = qn_eAv_d$ |
| Resistance | $R = V/I$ |
| Resistivity, $\rho$ | $R = \rho L/A$ |
| Power loss in resistor | $P = IV = \frac{V^2}{R} = I^2R$ |
| Series resistors | $R_{eq} = R_1 + R_2 + ...$ |
| Parallel resistors | $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ...$ |

| | |
|---|---|
| Power output of battery | $P = IV$ |
| Discharging a capacitor | $Q(t) = Q_0 e^{-t/\tau}$ |
| Charging a capacitor | $Q(t) = C\mathcal{E}(1 - e^{-t/\tau})$ |
| Time constant | $\tau = RC$ |
| Current in a capacitor | $I(t) = I_0 e^{-t/\tau}$ |

## Kirchhoff's laws for circuits

| | |
|---|---|
| Loop rule | $\sum_i \Delta V_i = 0$ |
| Junction rule | $\sum I_{\text{in}} = \sum I_{\text{out}}$ |