Electron = $-1.602\ 19 \times 10^{-19}$ C = 9.11×10^{-31} kg
Proton = $1.602\ 19 \times 10^{-19}$ C = 1.67×10^{-27} kg
Neutron = 0 C = 1.67×10^{-27} kg
6.022×10^{23} atoms in one atomic mass unit
e is the elementary charge: $1.602\ 19 \times 10^{-19}$ C

Addition of Multiple Vectors:

$\vec{R} = \vec{A} + \vec{B} + \vec{C}$ Resultant = Sum of the vectors

$\vec{R}_x = \vec{A}_x + \vec{B}_x + \vec{C}_x$ *x*-component $A_x = A\cos\theta$

$\vec{R}_y = \vec{A}_y + \vec{B}_y + \vec{C}_y$ *y*-component $A_y = A\sin\theta$

$R = \sqrt{R_x^2 + R_y^2}$ Magnitude (length) of *R*

$\theta_R = \tan^{-1}\dfrac{R_y}{R_x}$ *or* $\tan\theta_R = \dfrac{R_y}{R_x}$ Angle of the resultant

ELECTRIC CHARGES AND FIELDS

Coulomb's Law: [Newtons *N*]

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

where: F = force on one charge by the other[*N*]
k = 8.99×10^9 [$N{\cdot}m^2/C^2$]
q_1 = charge [*C*]
q_2 = charge [*C*]
r = distance [*m*]

Electric Field: [Newtons/Coulomb or Volts/Meter]

$$E = k\frac{|q|}{r^2} = \frac{|F|}{|q|}$$

where: E = electric field [*N/C* or *V/m*]
k = 8.99×10^9 [$N{\cdot}m^2/C^2$]
q = charge [*C*]
r = distance [*m*]
F = force

Electric Field inside a spherical shell: [*N/C*]

$$E = \frac{kqr}{R^3}$$

E = electric field [*N/C*]
q = charge [C]
r = distance from center of sphere to the charge [*m*]
R = radius of the sphere [*m*]

Electric Field outside a spherical shell: [*N/C*]

$$E = \frac{kq}{r^2}$$

E = electric field [*N/C*]
q = charge [C]
r = distance from center of sphere to the charge [*m*]

Flux: the rate of flow (of an electric field) [$N{\cdot}m^2/C$]

$$\Phi = \oint \mathbf{E}\cdot d\mathbf{A} = \int E(\cos\theta)dA$$

$\mathbf{\Phi}$ is the rate of flow of an electric field [$N{\cdot}m^2/C$]
$\oint$ integral over a closed surface
$\mathbf{E}$ is the electric field vector [*N/C*]
$\mathbf{A}$ is the area vector [m^2] pointing outward normal to the surface.

$$\vec{F} = q\vec{E}$$

$$\vec{E} = k\int_Q \frac{dq}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\int_Q \frac{dq}{r^2}\hat{r}$$

Gauss' law: $\Phi_E = \oint_S \vec{E}\cdot d\vec{A} = \dfrac{Q_{enc}}{\varepsilon_0}$

Electric potential: $V = k\displaystyle\int_Q \frac{dq}{r} = \frac{1}{4\pi\varepsilon_0}\int_Q \frac{dq}{r}$ relative to $V = 0$ at $r \to \infty$

Relationship between $\vec{E}$ and V: $V_a - V_b = \displaystyle\int_a^b \vec{E}\cdot d\vec{l}$ $\quad E_i = -\dfrac{\partial V}{\partial x_i}$

Work done by the field in moving a charge q from a to b: $W_{ab} = U_a - U_b = q(V_a - V_b)$

Potential energy of a system of point charges: $U = \displaystyle\sum_{i<j}\frac{kQ_iQ_j}{r_{ij}}$

Work and Potential:

$$\Delta U = U_f - U_i = -W$$

$$U = -W_\infty$$

$$W = \mathbf{F} \cdot \mathbf{d} = Fd\cos\theta$$

$$W = q\int_i^f \mathbf{E} \cdot d\mathbf{s}$$

$$\Delta V = V_f - V_i = -\frac{W}{q}$$

$$V = -\int_i^f \mathbf{E} \cdot d\mathbf{s}$$

U = electric potential energy [J]
W = work done on a particle by a field [J]
W_∞ = work done on a particle brought from infinity (zero potential) to its present location [J]
$\mathbf{F}$ = is the force vector [N]
$\mathbf{d}$ = is the distance vector over which the force is applied[m]
F = is the force scalar [N]
d = is the distance scalar [m]
θ = is the angle between the force and distance vectors
$d\mathbf{s}$ = differential displacement of the charge [m]
V = volts [V]
q = charge [C]

Capacitors: $C = \dfrac{Q}{V}$

Capacitance of different capacitors (for air or vacuum, $K = 1$):

Capacitor	Capacitance
Parallel-plate capacitor with plate-area A and thickness d	$K\varepsilon_0 \dfrac{A}{d}$
Spherical capacitor of radii a and b	$K\varepsilon_0 \dfrac{4\pi ab}{b-a}$
Isolated sphere of radius a	$K\varepsilon_0\, 4\pi a$
Cylindrical capacitor of radii a and b, and length L	$K\varepsilon_0 \dfrac{2\pi L}{\ln(b/a)}$

Capacitor combinations:

Series connection: $\dfrac{1}{C_{eq}} = \sum_{i=1}^{N} \dfrac{1}{C_i}$ Parallel connection: $C_{eq} = \sum_{i=1}^{N} C_i$

Energy stored: $U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \dfrac{Q^2}{2C}$ Energy density: $u = \frac{1}{2}K\varepsilon_0 E^2$

Electric current and resistance: $I = \dfrac{dQ}{dt} = \int \vec{\boldsymbol{J}} \cdot d\vec{\boldsymbol{A}}$ $\quad \vec{\boldsymbol{J}} = nq\vec{\boldsymbol{v}}_d$ $\quad Q = \int I\, dt$

$$V = IR \qquad R = \rho\frac{L}{A} \qquad \rho_T = \rho_0\left[1 + \alpha\left(T - T_0\right)\right] \qquad P = IV = I^2R = \frac{V^2}{R}$$

Resistor combinations:

Series connection: $R_{eq} = \sum_{i=1}^{N} R_i$ Parallel connection: $\dfrac{1}{R_{eq}} = \sum_{i=1}^{N} \dfrac{1}{R_i}$

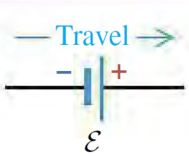
Kirchhoff's Rules

1. The sum of the currents entering a junctions is equal to the sum of the currents leaving the junction.
2. The sum of the potential differences across all the elements around a closed loop must be zero.

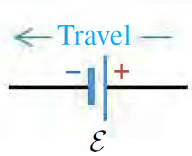
Kirchhoff's junction rule (valid at any junction): $\underbrace{\sum I}_{\text{The sum of the currents into any junction ...}} = 0$ ... equals zero.

Kirchhoff's loop rule (valid for any closed loop): $\underbrace{\sum V}_{\text{The sum of the potential differences around any loop ...}} = 0$ ... equals zero.

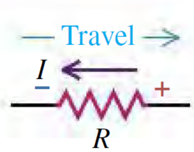
$+\mathcal{E}$: Travel direction from – to +:



$-\mathcal{E}$: Travel direction from + to –:



$+IR$: Travel *opposite to* current direction:



$-IR$: Travel *in* current direction: