Equations:

$|e|$ = 1.6 x 10^{-19} C

$$F_e = k_e \frac{|q_1||q_2|}{r^2}$$

k_e = 8.9876 x 10^9 N·m²/C² = $1/(4\pi\varepsilon_o)$

ε_o = 8.8542 x 10^{-12} C^2 / N·m^2

$$\vec{\mathbf{E}} \equiv \frac{\vec{\mathbf{F}}}{q_o}$$

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}_e}{q_o} = k_e \frac{q}{r^2}\hat{\mathbf{r}}$$

$\rho \equiv Q / V$ with units C/m³

$\sigma \equiv Q / A$ with units C/m²

$\lambda \equiv Q / \ell$ with units C/m

$$\vec{\mathbf{a}} = \frac{q\vec{\mathbf{E}}}{m}$$

$\Phi_E = EA$

$\Phi_E = EA \cos \vartheta$

$$\Phi_E = \lim_{\Delta A_i \to 0} \sum E_i \cdot \Delta A_i$$

$$\Phi_E = \int_{\text{surface}} \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}}$$

$E = k_e q / r^2$

$$\Phi_E = \frac{q}{\epsilon_0}$$

$$\boxed{\Phi_E = \oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{q_{\text{in}}}{\epsilon_0}}$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2} = \boxed{k_e \frac{Q}{r^2} \quad (\text{for } r > a)}$$

$$E = \frac{Q/\frac{4}{3}\pi a^3}{3(1/4\pi k_e)} r = \boxed{k_e \frac{Q}{a^3} r \quad (\text{for } r < a)}$$

$$E = \frac{\lambda}{2\pi\epsilon_0 r} = \boxed{2k_e \frac{\lambda}{r}}$$

$$E = \boxed{\frac{\sigma}{2\epsilon_0}}$$

$$E = \frac{\sigma}{\epsilon_0}$$

$$W_{\text{int}} = \vec{\mathbf{F}}_e \cdot d\vec{\mathbf{s}} = q\vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$$

$$\Delta U = -q \int_{Ⓐ}^{Ⓑ} \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$$

$$V = \frac{U}{q_o}$$

$W = \Delta U = q\,\Delta V$

$$\Delta V = -E \int_{Ⓐ}^{Ⓑ} ds$$

$$\boxed{\Delta V = -Ed}$$

$$\Delta U = q\Delta V = -q\vec{\mathbf{E}} \cdot \vec{\mathbf{s}}$$

$$V_B - V_A = k_e q\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

$$V = k_e \frac{q}{r}$$

$$U = k_e \frac{q_1 q_2}{r_{12}}$$

$$E_x = -\frac{dV}{dx}$$

$$C \equiv \frac{Q}{\Delta V}$$

$$C = \frac{Q}{\Delta V} = \frac{Q}{k_e Q/a} = \frac{a}{k_e} = 4\pi\epsilon_0 a$$

$$C = \frac{Q}{\Delta V} = \frac{Q}{Qd/\epsilon_0 A}$$

$$C = \frac{\epsilon_0 A}{d}$$

$$E = \frac{\lambda}{2\pi\epsilon_0 r} = 2k_e\frac{\lambda}{r}$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2} = k_e\frac{Q}{r^2} \quad (\text{for } r > a)$$

$$C_{eq} = C_1 + C_2 + C_3 + \ldots$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

$$U_E = \frac{Q^2}{2C} = \tfrac{1}{2}Q\,\Delta V = \tfrac{1}{2}C(\Delta V)^2$$

$$u_E = \tfrac{1}{2}\epsilon_0 E^2$$

$$U_0 = \frac{{Q_0}^2}{2C_0}$$

$$U = \frac{{Q_0}^2}{2C}$$

$$U = \frac{{Q_0}^2}{2\kappa C_0} = \frac{U_0}{\kappa}$$

$$U_E = -\vec{\mathbf{p}}\cdot\vec{\mathbf{E}}$$

$$I_{\text{avg}} = \frac{\Delta Q}{\Delta t} = nqv_d A$$

$$J \equiv I / A = nq\mathbf{v}_d$$

$$R = \rho\frac{\ell}{A}$$

$$\rho = \rho_0[1 + \alpha(T - T_0)]$$

$$R = R_o[1 + \alpha(T - T_o)]$$

$$\frac{dU}{dt} = \frac{d}{dt}(Q\,\Delta V) = \frac{dQ}{dt}\Delta V = I\,\Delta V$$

$$Q_{\max} = C\mathcal{E} \quad \text{(maximum charge)}$$

$$q(t) = C\mathcal{E}(1 - e^{-t/RC}) = Q_{\max}(1 - e^{-t/RC})$$

$$i(t) = \frac{\mathcal{E}}{R}e^{-t/RC}$$

$$\tau = RC$$

$$q(t) = Q_i e^{-t/RC}$$

$$i(t) = -\frac{Q_i}{RC} e^{-t/RC}$$

TABLE 23.1 *Charge and Mass of the Electron, Proton, and Neutron*

Particle	Charge (C)	Mass (kg)
Electron (e)	$-1.602\,176\,5 \times 10^{-19}$	$9.109\,4 \times 10^{-31}$
Proton (p)	$+1.602\,176\,5 \times 10^{-19}$	$1.672\,62 \times 10^{-27}$
Neutron (n)	0	$1.674\,93 \times 10^{-27}$

TABLE 26.1 *Approximate Dielectric Constants and Dielectric Strengths of Various Materials at Room Temperature*

Material	Dielectric Constant κ	Dielectric Strength[a] (10^6 V/m)
Air (dry)	1.000 59	3
Bakelite	4.9	24
Fused quartz	3.78	8
Mylar	3.2	7
Neoprene rubber	6.7	12
Nylon	3.4	14
Paper	3.7	16
Paraffin-impregnated paper	3.5	11
Polystyrene	2.56	24
Polyvinyl chloride	3.4	40
Porcelain	6	12
Pyrex glass	5.6	14
Silicone oil	2.5	15
Strontium titanate	233	8
Teflon	2.1	60
Vacuum	1.000 00	—
Water	80	—

[a]The dielectric strength equals the maximum electric field that can exist in a dielectric without electrical breakdown. These values depend strongly on the presence of impurities and flaws in the materials.

TABLE 27.2 *Resistivities and Temperature Coefficients of Resistivity for Various Materials*

Material	Resistivity[a] ($\Omega \cdot m$)	Temperature Coefficient[b] $\alpha[(°C)^{-1}]$
Silver	1.59×10^{-8}	3.8×10^{-3}
Copper	1.7×10^{-8}	3.9×10^{-3}
Gold	2.44×10^{-8}	3.4×10^{-3}
Aluminum	2.82×10^{-8}	3.9×10^{-3}
Tungsten	5.6×10^{-8}	4.5×10^{-3}
Iron	10×10^{-8}	5.0×10^{-3}
Platinum	11×10^{-8}	3.92×10^{-3}
Lead	22×10^{-8}	3.9×10^{-3}
Nichrome[c]	1.00×10^{-6}	0.4×10^{-3}
Carbon	3.5×10^{-5}	-0.5×10^{-3}
Germanium	0.46	-48×10^{-3}
Silicon[d]	2.3×10^{3}	-75×10^{-3}
Glass	10^{10} to 10^{14}	
Hard rubber	$\sim 10^{13}$	
Sulfur	10^{15}	
Quartz (fused)	75×10^{16}	

[a] All values at 20°C. All elements in this table are assumed to be free of impurities.

[b] See Section 27.4.

[c] A nickel–chromium alloy commonly used in heating elements. The resistivity of Nichrome varies with composition and ranges between 1.00×10^{-6} and 1.50×10^{-6} $\Omega \cdot m$.

[d] The resistivity of silicon is very sensitive to purity. The value can be changed by several orders of magnitude when it is doped with other atoms.