Permeability constant: $\mu_0 = 1.26 \times 10^{-6}$
Permittivity of free space: $\epsilon_0 = 8.854 \times 10^{-12}$
Elementary charge: $e = 1.602 \cdot 10^{-19}$
Proton mass: $1.673 \cdot 10^{-27}$
Electron mass: $9.11 \cdot 10^{-31}$

$$\Delta V = -E_s \Delta s$$

$$W = Q \times V$$

$$C = \frac{Q}{\Delta V_C} = \text{ with units F or farad}$$

$$C = \frac{\epsilon_0 A}{d} \quad \text{(parallel-plate capacitor)}$$

$$Q = \frac{\epsilon_0 A}{d} \Delta V_C \quad \text{(parallel-plate capacitor)}$$

$$C_{\text{eq}} = C_1 + C_2 + C_3 + \cdots \quad \text{(parallel capacitors)}$$

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \quad \text{(sequential capacitors)}$$

$$C = \kappa C_0$$

Wires in series have the same current

$$i_e = n_e A v_d$$

$$I = n \times A \times e \times v_d$$

where n is electron density and e is elementary charge

Metal	Electron density (m^{-3})
Aluminum	18×10^{28}
Iron	17×10^{28}
Copper	8.5×10^{28}
Gold	5.9×10^{28}
Silver	5.8×10^{28}

$$I = \frac{dQ}{dt} \text{ with units A or ampere or C/s}$$

$$\text{Current density: } J = \frac{I}{A} = n_e e v_d$$

$$I = JA = \sigma AE$$

Metal	Resistivity	Conductivity
Aluminum	2.8×10^{-8}	3.5×10^{7}
Iron	9.7×10^{-8}	1.0×10^{7}
Copper	1.7×10^{-8}	6.0×10^{7}
Gold	2.4×10^{-8}	4.1×10^{7}
Silver	1.6×10^{-8}	6.2×10^{7}

Resistivity, $\rho = 1/\sigma$, is the inverse of the conductivity.

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

$$I = \frac{A}{\rho L} \Delta V$$

$$\Delta V = IR$$

$$R_{\text{eq}} = R_1 + R_2 + R_3 + \cdots \quad \text{(sequential resistors)}$$

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \quad \text{(parallel resistors)}$$

If one branch in a parallel circuit is opened, the current through the other stays the same

$$P = \Delta V_R \times I = I^2 \times R = \frac{(\Delta V_R)^2}{R}$$

$$\tau = RC$$

$$Q = Q_0 e^{-t/\tau}$$

$$\Delta V_C = \Delta V_0 e^{-t/\tau}$$

Right-hand rule for wire

1. Thumb is in direction of current
2. If from wire, fingers are curled around the wire
3. Fingers point in the direction of magnetic field

Right-hand rule for magnetic field

1. Thumb is in direction of force
2. Palm is facing the magnetic field
3. Fingers point in the direction of motion

$$\oint B \cdot dl = Bl = \frac{mu_0 I}{2\pi r} \times 2\pi r = \mu_0 I_{\text{enc}}$$

$$\Phi_b = BA \cos\theta$$

$$F_B = qv \times B = IL \times B$$

$$\vec{B}_{\text{point charge}} = \left(\frac{\mu_0}{4\pi} \frac{qv \sin\theta}{r^2}, \text{direction given by the right-hand rule} \right)$$

1. An infinite wire: $B = \frac{\mu_0}{2\pi} \frac{I}{r}$ if **outside** of the wire and $B = \frac{\mu_0}{2\pi} \frac{Ir}{R^2}$ if **inside** the wire where r is the distance from the center and R is the radius of the wire
2. A current loop: $B_{\text{center}} = \frac{\mu_0}{2} \frac{NI}{R}$
3. A solenoid: $B = \mu_0 n I \quad$ (where $n = N/L$)

$$\vec{B}_{\text{current segment}} = \frac{\mu_0}{4\pi} \frac{I \Delta \vec{s} \times \hat{r}}{r^2}$$

(magnetic field of a very short segment of current)

Magnetic dipole moment $\vec{m} = (AI$, from the south pole to the north pole)

$$\vec{B}_{\text{dipole}} = \frac{\mu_0}{2\pi} \frac{\vec{m}}{z^3} \quad \text{(on the axis of a magnetic dipole)}$$

$$A \times B = (A_y B_z - A_z B_y)\mathbf{i} + (A_z B_x - A_x B_z)\mathbf{j} + (A_x B_y - A_y B_x)\mathbf{k}$$