Physical Constants

\[ k = \frac{1}{4\pi\epsilon_0} = 8.988 \text{ GNm}^2/\text{C}^2 \] (Coulomb’s Law)
\[ e = 1.602 \times 10^{-19} \text{ C} \] (proton charge)
\[ m_e = 9.11 \times 10^{-31} \text{ kg} \] (electron mass)
\[ \epsilon_0 = 1/4\pi k = 8.854 \text{ pF/m} \] (permittivity of space)
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A} \] (permeability of space)
\[ m_p = 1.67 \times 10^{-27} \text{ kg} \] (proton mass)

Units

\[ N_A = 6.02 \times 10^{23}/\text{mole} \] (Avogadro’s #)
\[ 1.0 \text{ eV} = 1.602 \times 10^{-19} \text{ J} \] (electron-volt)
\[ 1 \text{ F} = 1 \text{ C/V} = 1 \text{ farad} = 1 \text{ C} \]
\[ 1 \text{ V} = 1 \text{ J/C} = 1 \text{ joule/coulomb} \]
\[ 1 \text{ A} = 1 \text{ C/s} = 1 \text{ ampere} = 1 \text{ coulomb/second} \]
\[ 1 \text{ T} = 1 \text{ N/A} \cdot \text{m} = 1 \text{ tesla} = 1 \text{ newton/ampere-meter} \]

OpenStax Chapter 18 Equations

Charges:
\[ Q = \pm Ne, \quad \Delta Q_1 + \Delta Q_2 = 0, \quad e = 1.602 \times 10^{-19} \text{ C} \]

Electric Force:
\[ F = k\frac{Q_1Q_2}{r^2}, \quad k = 8.988 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2, \quad F = \frac{Q_1Q_2}{4\pi \epsilon_0 r^2}, \quad \epsilon_0 = \frac{1}{4\pi k} = 8.854 \text{ pF/m} \]
\[ \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots \text{ superposition of forces.} \]

Electric Field:
\[ \vec{E} = \frac{\vec{F}}{q}, \quad q = \text{ test charge.} \quad \text{Or: } \vec{E} = q\vec{E}. \]
\[ |\vec{E}| = E = k\frac{Q}{r^2} = \frac{Q}{4\pi \epsilon_0 r^2}, \text{ due to point charge. Negative } Q \text{ makes inward } \vec{E}, \text{ positive } Q \text{ makes outward } \vec{E}. \]
\[ \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots \text{ superposition of many electric fields.} \]
\[ E = k\frac{Q}{r^2} \] = electric field around a point charge or outside a spherical charge distribution.

OpenStax Chapter 19 Equations

Potential Energy and Work:
\[ W_{ba} = F_E d \cos \theta = \text{ work done by electric force } F_E \text{ on test charge, in displacement } d \text{ from } a \text{ to } b. \]
\[ W_{ba} = -q\Delta V = -q(V_b - V_a) = \text{ work done by electric force on a test charge, moved from } a \text{ to } b. \]
\[ \Delta \text{PE} = q\Delta V = q(V_b - V_a) = \text{ change in electric potential energy of the system. Also: } \Delta \text{PE} = -W_{ba}. \]

Potential:
\[ \Delta V = \frac{\Delta \text{PE}}{q} = \text{ definition of change in electric potential.} \]
\[ \Delta V = Ed = \text{ potential change in a uniform electric field.} \]
\[ V = k\frac{Q}{r} = \text{ potential produced by a point charge or outside a spherical charge distribution.} \]
\[ \text{PE} = qV = \text{ potential energy for a test charge at a point in a field.} \]
\[ \text{PE} = k\frac{Q_1Q_2}{r_{12}} = \text{ potential energy of a pair of charges.} \]

Capacitance:
\[ Q = CV, \quad C = K\epsilon_0 \frac{A}{\pi} = \text{ capacitor equations.} \]
\[ U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \text{ stored energy.} \]
\[ E = \frac{Q}{\epsilon_0} \] = electric field strength very near a charged conductor.
OpenStax Chapter 20 Equations

Electric current and power:

\[ I = \frac{\Delta Q}{\Delta t}, \quad \Delta Q = I \Delta t \quad \text{current definition.} \]
\[ V = IR, \quad I = V/R \quad \text{Ohm’s law.} \]
\[ R = \rho L/A \quad \text{calculation of resistance.} \]
\[ \rho = \rho_0[1 + \alpha(T - T_0)] \quad \text{resistivity changes.} \]
\[ P = IV, \quad P = I^2R, \quad P = V^2/R. \]

Alternating current:

\[ V = V_0 \sin(2\pi ft) = \text{time-dependent AC voltage.} \]
\[ V_{\text{rms}} = \sqrt{\overline{V^2}} = V_0/\sqrt{2} = \text{root-mean-square voltage.} \]
\[ I_{\text{rms}} = \sqrt{\overline{I^2}} = I_0/\sqrt{2} = \text{root-mean-square current.} \]
\[ \mathcal{P} = \frac{1}{2} I_0 V_0 = \frac{1}{2} I_{\text{rms}}^2 R = \frac{1}{2} V_{\text{rms}}^2/R = \text{average power.} \]

AC power:

\[ \mathcal{P} = \mathcal{P}_{\text{rms}}V_{\text{rms}} = I_{\text{rms}}^2 R = V_{\text{rms}}^2 / R = \text{average power.} \]

OpenStax Chapter 21 Equations

Resistor Combinations

\[ R_{\text{eq}} = R_1 + R_2 + R_3 + ... \quad \text{(series)} \]
\[ \frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... \quad \text{(parallel)} \]

Real batteries

\[ V_{ab} = \mathcal{E} - \mathcal{I} \mathcal{R} \quad \text{(terminal voltage)} \]
\[ V_{ab} = \mathcal{I} \mathcal{R} \quad \text{(connected to load \( R \))} \]

Kirchhoff’s Rules

\[ \sum \Delta V = 0 \quad \text{(loop rule, energy conservation)} \]
\[ \sum \mathcal{I} = 0 \quad \text{(node rule, charge conservation)} \]

OpenStax Chapter 22 Equations

Magnetic forces, torque

\[ F = nB \sin \theta \quad \text{(on a current)} \]
\[ F = qvB \sin \theta \quad \text{(on a moving charge)} \]
\[ F/l = \mu_0 \frac{I_3 l_2}{2\pi} \quad \text{(between currents)} \]
\[ F = qvB = mv^2/r \quad \text{(during cyclotron motion)} \]
\[ \tau = NBAI \sin \theta \quad \text{(torque on a coil)} \]
\[ v = \omega r = 2\pi vr = 2\pi r/T \quad \text{(circular motion)} \]

Magnetic Fields

\[ B = \frac{I_0 l}{2\pi} \quad \text{(due to long straight wire)} \]
\[ B = \mu_0 I_0 N/l \quad \text{(inside a solenoid)} \]

Right Hand Rules

\[ \text{Force (thumb) = [\text{I (4 fingers)] \times [magnetic field (palm)]} \quad \text{(force on a current)} \]
\[ \text{Force (thumb) = [qv (4 fingers)] \times [magnetic field (palm)]} \quad \text{(force on a moving charge)} \]
\[ \text{Current (thumb) \leftrightarrow [magnetic field (4 fingers)]} \quad \text{(magnetic field around a wire)} \]
\[ \text{Current (4 fingers) \leftrightarrow [magnetic field (thumb)]} \quad \text{(magnetic field inside a current loop)} \]

OpenStax Chapter 23 Equations

Faraday’s Induced EMF

\[ \Phi_B = B A \cos \theta \quad \text{(magnetic flux)} \]
\[ \mathcal{E} = Blv \quad \text{(moving conductor)} \]
\[ V = \mathcal{E} + \mathcal{I} \mathcal{R} \quad \text{(motor’s back-emf)} \]
\[ V_S/V_P = N_S/N_P \quad \text{(transformer equation)} \]
\[ \mathcal{I}_P \mathcal{V}_P = \mathcal{I}_S \mathcal{V}_S \quad \text{(power in = power out)} \]

AC Circuits, Inductors, Capacitors, Reactance

\[ \mathcal{E} = -L \frac{\Delta I}{\Delta t} \quad \text{(self-inductance emf)} \]
\[ X_L = 2\pi f L = \omega L \quad \text{(inductive reactance)} \]
\[ X_C = 1/(2\pi f C) = 1/\omega C \quad \text{(capacitive reactance)} \]
\[ Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \text{(series RLC impedance)} \]
\[ \omega_0 = 1/\sqrt{LC}, \quad f_0 = \frac{\omega_0}{2\pi} \quad \text{(LC resonance)} \]
\[ \mathcal{P} = I_{\text{rms}} V_{\text{rms}} \cos \phi \quad \text{(AC average power)} \]
\[ U = \frac{1}{2} LI^2 \quad \text{(stored magnetic energy)} \]
\[ V_L = I X_L \quad \text{(inductor voltage)} \]
\[ V_C = I X_C \quad \text{(capacitor voltage)} \]
\[ V_{\text{gen}} = I Z = \sqrt{V_L^2 + (V_L - V_C)^2} \quad \text{(series RLC)} \]
\[ V_{\text{gen}} = I Z = \sqrt{V_L^2 + (V_L - V_C)^2} \quad \text{(series RLC)} \]
\[ \tan \phi = (X_L - X_C)/R \quad \text{(series RLC phase)} \]
\[ \mathcal{P} = I_{\text{rms}} V_{\text{rms}} \cos \phi = I_{\text{rms}}^2 R \quad \text{(series RLC)} \]