Prefixes
a = 10\(^{-18}\), f = 10\(^{-15}\), p = 10\(^{-12}\), n = 10\(^{-9}\), \(\mu = 10^{-6}\), m = 10\(^{-3}\), c = 10\(^{-2}\), k = 10\(^{3}\), M = 10\(^{6}\), G = 10\(^{9}\), T = 10\(^{12}\), P = 10\(^{15}\)

Physical Constants

\[ k = \frac{1}{4\pi\varepsilon_0} = 8.988 \text{ GNM}^2/\text{C}^2 \text{ (Coulomb's Law)} \]
\[ e = 1.602 \times 10^{-19} \text{ C (proton charge)} \]
\[ m_e = 9.11 \times 10^{-31} \text{ kg (electron mass)} \]
\[ \varepsilon_0 = 1/4\pi k = 8.854 \text{ pF/m (permittivity of space)} \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T.m/A (permeability of space)} \]
\[ m_p = 1.67 \times 10^{-27} \text{ kg (proton mass)} \]

Units

\[ N_A = 6.02 \times 10^{23}/\text{mole (Avogadro's #)} \]
\[ 1.0 \text{ eV} = 1.602 \times 10^{-19} \text{ J (electron-volt)} \]
\[ 1 \text{ F} = 1 \text{ C/V} = 1 \text{ farad} = 1 \text{ C}^2/\text{J} \]
\[ 1 \text{ A} = 1 \text{ C/s} = 1 \text{ ampere} = 1 \text{ coulomb/second} \]
\[ 1 \text{ T} = 1 \text{ N/A.m} = 1 \text{ tesla} = 1 \text{ newton/ampere-meter} \]

Chapter 16 Equations

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

Electric Force:
\[ F = k\frac{Q_1Q_2}{r^2}, \quad k = 8.988 \times 10^9 \text{ N.m}^2/\text{C}^2, \quad F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}, \quad \varepsilon_0 = \frac{1}{4\pi} = 8.854 \text{ pF/m.} \]
\[ \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots \text{ superposition of forces.} \]

Electric Field:
\[ \vec{E} = \frac{\vec{F}}{q}, \quad q = \text{test charge}. \quad \text{Or: } \vec{F} = q\vec{E}. \]
\[ |\vec{E}| = E = k\frac{Q}{r^2} = \frac{Q}{4\pi\varepsilon_0 r^2}, \text{ due to point charge. Negative } Q \text{ makes inward } \vec{E}, \text{ positive } Q \text{ makes outward } \vec{E}. \]
\[ \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots \text{ superposition of many electric fields.} \]
\[ E = k\frac{Q}{r^2} = \text{electric field around a point charge or outside a spherical charge distribution.} \]

Chapter 17 Equations

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

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

Capacitance:
\[ Q = CV, \quad C = k\varepsilon_0 \frac{A}{d} = \text{capacitor equations.} \]
\[ U = \frac{1}{2}qV = \frac{1}{2}CV^2 = \frac{1}{2} \frac{Q^2}{C} = \text{stored energy.} \]
\[ E = \frac{Q/A}{\varepsilon_0} = \text{electric field strength very near a charged conductor.} \]
Chapter 18 Equations

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

Alternating current:
\[ V = V_0 \sin 2\pi ft = \text{time-dependent AC voltage.} \]
\[ V_{\text{rms}} = \sqrt{\frac{1}{T} \int_{-T/2}^{T/2} V^2(t) \, dt} = \text{root-mean-square voltage.} \]
\[ I = I_0 \sin 2\pi ft = \text{time-dependent AC current.} \]
\[ I_{\text{rms}} = \sqrt{\frac{1}{T} \int_{-T/2}^{T/2} I^2(t) \, dt} = \text{root-mean-square current.} \]
\[ \overline{P} = \frac{1}{2} I_0^2R = \frac{1}{2} V_0^2/R = \frac{1}{2} I_0V_0 = \text{average power.} \]
\[ \overline{P} = I_{\text{rms}}^2R = V_{\text{rms}}^2/R = I_{\text{rms}}V_{\text{rms}} = \text{average power.} \]

Chapter 19 Equations

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

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

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

Chapter 20 Equations

Magnetic forces, torque
\[ F = lBI \sin \theta \quad \text{(on a current)} \]
\[ F/qvB = \frac{lI}{q \times \sigma^2} \quad \text{(between currents)} \]
\[ \tau = NBAI \sin \theta \quad \text{(torque on a coil)} \]
\[ F = qvB = mv^2/r \quad \text{(during cyclotron motion)} \]
\[ v = \omega r = 2\pi f r = 2\pi r/T \quad \text{(circular motion)} \]

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

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

Chapter 21 Equations

Faraday’s Induced EMF
\[ \Phi_B = BA \cos \theta \quad \text{(magnetic flux)} \]
\[ \mathcal{E} = Blv \quad \text{(moving conductor)} \]
\[ \mathcal{E} = -N \frac{\Delta \Phi_B}{\Delta t} \quad \text{(induced emf)} \]
\[ V - \mathcal{E} = IR \quad \text{(motor’s counter-emf)} \]
\[ \mathcal{E}_1 = -M \frac{\Delta \phi}{\Delta t} \quad \text{(mutual inductance emf)} \]
\[ V_{S}/V_{P} = N_{S}/N_{P} \quad \text{(transformer equation)} \]
\[ I_{P}V_{P} = I_{S}V_{S} \quad \text{(power in = power out)} \]

AC Circuits, Inductors, Capacitors, Reactance
\[ \mathcal{E} = -L \frac{\Delta I}{\Delta t} \quad \text{(self-inductance emf)} \]
\[ X_L = 2\pi fL = \omega L \quad \text{(inductive reactance)} \]
\[ X_C = 1/(2\pi fC) = 1/(\omega C) \quad \text{(capacitive reactance)} \]
\[ Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \text{(series RLC impedance)} \]
\[ \omega_0 = 1/\sqrt{LC}, \quad f_0 = \frac{\omega_0}{2\pi} \quad \text{(LC resonance)} \]
\[ \frac{\omega_0}{L} \quad \text{f0} = \frac{\omega}{2\pi} \quad \text{(LC resonance)} \]
\[ \tan \phi = (X_L - X_C)/R \quad \text{(series RLC phase)} \]
\[ \overline{P} = I_{\text{rms}}V_{\text{rms}} \cos \phi \quad \text{(AC average power)} \]
\[ \overline{P} = I_{\text{rms}}V_{\text{rms}} \cos \phi = I_{\text{rms}}^2R \quad \text{(series RLC)} \]