
Useful Constants:Acceleration due to gravity: $g = 9.80 \text{ m/s}^2$ Basic unit of charge: $e = 1.6 \times 10^{-19} \text{ C}$ Mass of electron: $m_e = 9.11 \times 10^{-31} \text{ kg}$ Mass of proton/neutron: $m_p = 1.67 \times 10^{-27} \text{ kg}$ Coulomb constant: $k = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2$ Permittivity of free space: $\epsilon_0 = 1/(4\pi k) = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$ Permeability of free space: $\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A}$ Speed of light in a vacuum: $c = 3 \times 10^8 \text{ m/s}$ Planck's Constant: $h = 6.626 \times 10^{-34} \text{ Js}$ eV to joule conversion: $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$ kilowatt-hour to joule conversion: $1 \text{ kW}\cdot\text{hr} = 3.6 \times 10^6 \text{ J}$ Atomic Mass Unit: $1 \text{ u} = 1.66054 \times 10^{-27} \text{ kg} = 931.5 \text{ MeV}/c^2$

Vector Concepts:Unit Vector: $\hat{r} = \frac{\vec{r}}{r}$ Gradient: $\vec{\nabla} = \frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial z}\hat{z}$ Dot Product: $\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos \theta$ Dot Product: $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$

Cross Product:

$$|\vec{A} \times \vec{B}| = |\vec{A}||\vec{B}| \sin \theta$$

$$\vec{A} \times \vec{B} = (A_y B_z - A_z B_y)\hat{x} - (A_x B_z - A_z B_x)\hat{y} + (A_x B_y - A_y B_x)\hat{z}$$

Sample Indefinite Integrals:

$$\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln(x + \sqrt{x^2 \pm a^2}) + c$$

$$\int \frac{xdx}{(x^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}} + c$$

$$\int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{x}{a^2 \sqrt{x^2 + a^2}} + c$$

$$\int x^n dx = \frac{x^{n+1}}{n+1} + c (n \neq -1)$$

$$\int \frac{dx}{x} = \ln(x) + c$$

$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a} \arctan \frac{x}{a} + c$$

$$\int \frac{dx}{\sqrt{a^2 - x^2}} = \arcsin \frac{x}{a} + c$$

SI Prefixes:T= $\times 10^{12}$, G= $\times 10^9$, M= $\times 10^6$, k= $\times 10^3$ c= $\times 10^{-2}$, m= $\times 10^{-3}$ μ = $\times 10^{-6}$, n= $\times 10^{-9}$, p= $\times 10^{-12}$, f= $\times 10^{-15}$

Useful integral relationships:Spherical: $dV = 4\pi r^2 dr$ Cylindrical (with constant r): $dV = \pi r^2 dz$ Cylindrical (with constant z): $dV = z 2\pi r dr$ Cylindrical (with constant r): $dA = 2\pi r dz$ Cylindrical (with constant z): $dA = 2\pi r dr$

Geometry:Surface Area of a Sphere: $A = 4\pi r^2$ Volume of a Sphere: $V = \frac{4}{3}\pi r^3$ Area of curved region of a cylinder: $A = 2\pi r h$ Volume of a cylinder: $V = \pi r^2 h$

Physics 1 Concepts:Work: $W = \int \vec{F} \cdot d\vec{\ell}$

Potential Energy of conservative force:

 $W_{cons} = -\Delta U$ Kinetic Energy: $K = \frac{1}{2}mv^2$ Momentum: $\vec{p} = m\vec{v}$

Chapter 21:

Coulomb's Law [N]: $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$

Force due to an electric field [N]: $\vec{F} = q\vec{E}$

E Field due to a pt. charge [N/C]: $\vec{E} = \frac{kq}{r^2}\hat{r}$

E Field due to a continuous charge dist. [N/C]:

$$\vec{E} = \int \frac{k dq}{r^2} \hat{r}$$

Electric dipole moment [Cm]: $\vec{p} = q\vec{d}$

Torque on an electric dipole [Nm]: $\vec{\tau} = \vec{p} \times \vec{E}$

Electric pot. energy stored in electric dipole [J]:

$$U = -\vec{p} \cdot \vec{E}$$

Chapter 22:

Electric Flux [Vm or Nm²/C]: $\Phi_E = \int \vec{E} \cdot d\vec{A}$

Electric Flux when E and θ are const.

on the surface: $\Phi_E = EA \cos \theta$

Gauss's Law (vacuum): $\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{encl}}}{\epsilon_0}$

Chapter 23: The below equations generally but not always assume that $V(\infty) = 0$ and/or $U(\infty) = 0$.

Elec. pot. energy between 2 pt charges [J]:

$$U = \frac{kq_1q_2}{r}$$

Elec. pot. difference btw. two locations [V or J/C]:

$$\Delta V = \frac{\Delta U}{q} \text{ (or often) } V = \frac{U}{q}$$

Electric potential due to a point charge [V]:

$$V = \frac{kq}{r}$$

Electric potential due to a charge dist. [V]:

$$V = \int \frac{k dq}{r}$$

Relating \vec{E} and V : $\vec{E} = -\vec{\nabla}V$

$$\Delta V = V_b - V_a = - \int_a^b \vec{E} \cdot d\vec{l}$$

Chapter 24:

Capacitance [F]: $Q = CV$

Capacitance for Parallel Plates [F]: $C = \frac{\kappa\epsilon_0 A}{d}$

Energy stored in a capacitor [J]: $U = \frac{1}{2}CV^2$

E field energy density [J/m³]: $u_E = \frac{1}{2}\kappa\epsilon_0 E^2$

Definition of Dielectric Constant: $C = \kappa C_0$

Eff. Cap. (series) [F]: $\frac{1}{C_{\text{eff}}} = \sum_i \frac{1}{C_i}$

Eff. Cap. (parallel) [F]: $C_{\text{eff}} = \sum_i C_i$

Chapters 25 and 26:

Electric Current [A]: $I = \frac{dq}{dt}$

I from current density [A]: $I = \int \vec{j} \cdot d\vec{A}$

j of uniform current [A/m²]: $|\vec{j}| = \frac{I}{A}$

j for charges in motion [A/m²]: $\vec{j} = nq\vec{v}_d$

Ohm's Law: $\vec{E} = \rho\vec{j}$

Ohm's Law: $\Delta V = IR$ (or often just) $V = IR$

Resistivity and conductivity: $\rho = \frac{1}{\sigma}$

Resistance of a wire [Ω]: $R = \frac{\rho\ell}{A}$

Resistance of an object [Ω]: $R = \int \frac{\rho(x)dx}{A(x)}$

Power in a circuit element [W]:

$P = I\Delta V$ (or often) $P = IV$

Eff. Res. (series) [Ω]: $R_{\text{eff}} = \sum_i R_i$

Eff. Res. (parallel) [Ω]: $\frac{1}{R_{\text{eff}}} = \sum_i \frac{1}{R_i}$

Time constant for an RC -circuit [s]: $\tau = RC$

Charge on a charging capacitor [C]:

$$q(t) = q_{\text{max}}(1 - e^{-t/\tau})$$

Charge on a discharging capacitor [C]:

$$q(t) = q_0 e^{-t/\tau}$$

Current in an RC -circuit [A]: $I(t) = I_0 e^{-t/\tau}$

Chapter 27:

Mag. Force on a moving q [N]: $\vec{F} = q\vec{v} \times \vec{B}$

Mag. Force on a current-carrying conductor [N]:

$$\vec{F} = I \int d\vec{\ell} \times \vec{B}$$

R of q 's path in a B field [m]: $R = \frac{mv}{|q|B}$

Magnetic Dipole Moment [Am²]: $\vec{\mu} = I\vec{A}$

Torque on current loops [Nm]: $\vec{\tau} = N\vec{\mu} \times \vec{B}$

Mag. pot. energy in a magnetic dipole [J]:

$$U = -N\vec{\mu} \cdot \vec{B}$$

Chapter 28:

Biot-Savart Law (2 forms):

B made by a moving charge [T]: $\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$

B made by any current [T]: $\vec{B} = \int \frac{\mu_0}{4\pi} \frac{I d\vec{\ell} \times \hat{r}}{r^2}$

B made by a long straight wire in a vacuum [T]:

$$B = \frac{\mu_0 I}{2\pi r}$$

B made by N loops, w/ radius R , on the axis,

z from the center (vacuum) [T]: $B = \frac{N\mu_0 I R^2}{2(z^2 + R^2)^{3/2}}$

B made inside a solenoid: $B = \mu_0 K_m \frac{N}{\ell} I$

Chapter 29:

Magnetic Flux [Wb]: $\Phi_B = \int \vec{B} \cdot d\vec{A}$

Magnetic Flux when B and θ are const.

on the surface: $\Phi_B = BA \cos \theta$

Faraday's Law [V]: $\mathcal{E} = -N \frac{d\Phi_B}{dt}$

Motional emf [V]: $\mathcal{E} = \int (\vec{v} \times \vec{B}) \cdot d\vec{\ell}$

Induced E Fields: $\oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$

Displacement current [A]: $i_d = \epsilon_0 \frac{d\Phi_E}{dt}$

General Ampere's Law: $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 (I_{\text{encl}} + i_d)$

Chapter 30:

emf and Mutual Inductance:

$$\mathcal{E}_1 = -M \frac{di_2}{dt}, \mathcal{E}_2 = -M \frac{di_1}{dt}$$

Mut. Inductance [H]: $M = \frac{N_2 \Phi_{B,2}}{i_1} = \frac{N_1 \Phi_{B,1}}{i_2}$

emf and Self Inductance: $\mathcal{E} = -L \frac{di}{dt}$

Self Inductance [H]: $L = \frac{N\Phi_B}{i}$

Inductance of a Solenoid [H]: $L = \frac{\mu_0 N^2 A}{\ell}$

Magnetic energy stored in an inductor [J]:

$$U = \frac{1}{2} LI^2$$

B field energy density [J/m³]: $u_B = \frac{1}{2\mu_0} B^2$

Time Constant in an RL -Circuit [s]: $\tau = L/R$

Current growth in an RL -Circuit [A]:

$$i(t) = I_{\text{max}}(1 - e^{-t/\tau})$$

Current decay in an RL -Circuit [A]:

$$i(t) = I_0 e^{-t/\tau}$$

Angular frequency of the oscillation

in an LC -Circuit [rad/s]: $\omega = \frac{1}{\sqrt{LC}}$

q on a capacitor in an ideal LC -Circuit [C]:

$$q(t) = q_{\text{max}} \cos(\omega t + \phi)$$

Chapter 32:

Wave speed [m/s]: $v = f\lambda$

Wave number [1/m]: $k = \frac{2\pi}{\lambda}$

E - B relationship: $E = cB$

Speed of light (vacuum): $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$

Speed of light (medium): $v = \frac{c}{\sqrt{\kappa K_m}}$

Poynting Vector [W/m²]: $\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$

Intensity of a wave in vacuum [W/m²]:

$$I = S_{\text{av}} = \frac{1}{2} uc = \frac{P}{A}$$

Total EM energy density [J/m³]: $u = u_E + u_B$