Equations

Point Charge

$$\vec{\mathbf{F}}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^2}\,\hat{\mathbf{r}}_{12}$$

$$\vec{\mathbf{E}}_{12} = \frac{\vec{\mathbf{F}}_{12}}{q_{\text{test}}} = \frac{1}{4\pi\epsilon_0}\frac{q}{r_{12}^2}\,\hat{\mathbf{r}}_{12}$$

Area

$A = 4\pi r^2$ (sphere)

$A = 2\pi r l$ (cylinder)

$A = l^2 + l^2$ (two sided sheet)

$$\Phi = \oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \oint \vec{\mathbf{E}} \cdot \hat{\mathbf{n}} dA = \frac{Q_{\text{encl}}}{\epsilon_0}$$

$\Phi = E\,A$ (some cases)

$$(V_b - V_a) = -\int_a^b \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$$

$$E_x = -\frac{\partial V}{\partial x},\ E_y = -\frac{\partial V}{\partial y},\ E_z = -\frac{\partial V}{\partial z}$$

$$\vec{\mathbf{F}}_{\text{net}} = \sum_i \vec{\mathbf{F}}_i \qquad \vec{\mathbf{E}}_{\text{net}} = \sum_i \vec{\mathbf{E}}_i \qquad V_{\text{net}} = \sum_i V_i$$

$$\vec{\mathbf{F}} = m\,\vec{\mathbf{a}} \qquad x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 \qquad v_x = v_{0x} + a_x t$$

$$-\Delta U = W = \int \vec{\mathbf{F}} \cdot d\vec{\mathbf{s}} \qquad KE = \frac{1}{2}mv^2$$

Constants

$$\epsilon_0 = 8.85 \times 10^{-12}\,\frac{\text{F}}{\text{m}} \text{ or } \frac{\text{C}^2}{\text{Nm}^2}$$

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^{9}\,\frac{\text{m}}{\text{F}} \text{ or } \frac{\text{Nm}^2}{\text{C}^2}$$

$e = 1.60 \times 10^{-19}\,\text{C}$

$m_{\text{proton}} = 1.67 \times 10^{-27}\,\text{kg}$

$m_{\text{electron}} = 9.11 \times 10^{-31}\,\text{kg}$

Equations

$$C = \frac{\epsilon_0 A}{d}\ Parallel\ Plate, \quad C = \frac{2\pi\epsilon_0 L}{ln(b/a)}\ Cylindrical, \quad C = 4\pi\epsilon_0\frac{ab}{a-b}\ Spherical$$

$$Q = CV, \qquad U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}, \qquad C = \kappa C_0, \quad E = \frac{E_0}{\kappa}, \quad \epsilon = \kappa\epsilon_0$$

$$I = \frac{dq}{dt}, \quad I = \int \overrightarrow{J} \cdot d\overrightarrow{A}, \quad V = IR, \quad R = \frac{\rho l}{A}, \quad \rho = \frac{1}{\sigma} \quad \rho = \frac{m}{e^2 n\tau}, \quad P = IV$$

$$R = R_1 + R_2 + R_3 ... \ , \qquad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

$$(charging) \quad Q = Q_0(1 - e^{-\frac{t}{RC}}), \quad \tau = RC, \quad I = \frac{V}{R}e^{-\frac{t}{RC}}$$

$$(discharging) \quad Q = Q_0 e^{-\frac{t}{RC}}, \quad I = -\frac{Q_0}{RC}e^{-\frac{t}{RC}}, \qquad KE = \frac{1}{2}mv^2$$

$$\overrightarrow{F} = q\overrightarrow{v} \times \overrightarrow{B}, \quad qvB = \frac{mv^2}{r}, \quad \omega = 2\pi f, \quad \omega = \frac{v}{r}$$

$$\overrightarrow{F} = I\overrightarrow{l} \times \overrightarrow{B}, \quad d\overrightarrow{F} = Id\overrightarrow{l} \times \overrightarrow{B}, \quad \overrightarrow{\tau} = \overrightarrow{\mu} \times \overrightarrow{B}, \quad \overrightarrow{\tau} = \overrightarrow{r} \times \overrightarrow{F}$$

$$d\overrightarrow{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{Id\overrightarrow{l} \times \hat{r}}{r^2}, \quad \overrightarrow{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{q\overrightarrow{v} \times \hat{r}}{r^2}, \qquad \oint \overrightarrow{B} \cdot \overrightarrow{ds} = \mu_0 I_{enclosed}$$

$$B = \frac{\mu_0 I}{2\pi r} \quad (infinite\ wire)$$

$$B = \frac{\mu_0 I}{2R}\ (center\ of\ whole\ loop), \quad B = \mu_0 nI\ (solenoid), \quad B = \frac{\mu_0 NI}{2\pi r}\ (toroid)$$

$$\overrightarrow{E} = \overrightarrow{F}/q_{test} = \frac{1}{4\pi\epsilon_0}\frac{q}{r_{12}^2}\ \hat{r}_{12}, \quad \Phi = \oint \overrightarrow{E} \cdot d\overrightarrow{A} = \oint \overrightarrow{E} \cdot \hat{n}dA = \frac{q_{enclosed}}{\epsilon_0}$$

Constants

$\mu_0 = 4\pi \times 10^{-7}\ \frac{Tm}{A}$

$\epsilon_0 = 8.85 \times 10^{-12}\ \frac{C^2}{Nm^2}$

$c = 3.0 \times 10^8\ m/s$

$g = 9.8\ m/s^2$

$e = 1.60 \times 10^{-19}\ C$

$M_{proton} = 1.67 \times 10^{-27}\ kg$

Equations

$$I = \frac{dq}{dt}, \quad I = \int \overrightarrow{J} \cdot d\overrightarrow{A}, \quad V = IR, \quad P = IV, \quad \overrightarrow{F} = m\overrightarrow{a}$$

$$\phi_B = \int \overrightarrow{B} \cdot d\overrightarrow{A}, \quad \varepsilon = -\frac{d\phi_B}{dt}, \quad \phi_B = BA\ (sometimes), \quad \varepsilon = -L\frac{dI}{dt}$$

$$(Increasing) \quad I = I_0(1 - e^{-t/\tau}), \quad \tau = L/R, \quad (decreasing) \quad I = I_0 e^{-t/\tau}$$

$$\overrightarrow{F} = I\overrightarrow{l} \times \overrightarrow{B}, \quad d\overrightarrow{F} = I\overrightarrow{dl} \times \overrightarrow{B}, \quad \phi_E = \int \overrightarrow{E} \cdot d\overrightarrow{A}$$

$$\oint \overrightarrow{E} \cdot \overrightarrow{ds} = -\frac{d\phi_B}{dt}, \quad \oint \overrightarrow{B} \cdot \overrightarrow{ds} = \mu_0\epsilon_0\frac{d\phi_E}{dt} + \mu_0 I_{enclosed}, \quad I_{Displacement} = \epsilon_0\frac{d\phi_E}{dt}$$

$$B = \mu_0 n I \quad (solenoid), \quad L = \mu_0 n^2 A l \quad (solenoid)$$

$$U_L = (1/2)\ LI^2, \quad U_C = (1/2)\ CV^2, \quad u_B = B^2/(2\mu_0), \quad u_E = \epsilon_0 E^2/2$$

$$X_C = 1/(wC),\ X_L = wL,\ Z = \sqrt{R^2 + (X_L - X_C)^2},\ tan(\phi) = \frac{wL - 1/(wC)}{R}$$

$$P_{avg} = 0.5 V_{max} I_{max} cos(\phi), \quad V = IZ, \quad V_C = IX_C, \quad V_L = IX_L, \quad cos(\phi) = \frac{R}{Z}$$

Constants

$$\mu_0 = 4\pi \times 10^{-7}\ \frac{Tm}{A}, \quad \epsilon_0 = 8.85 \times 10^{-12}\ \frac{C^2}{Nm^2}, \quad c = 3.0 \times 10^8\ m/s, \quad g = 9.8\ m/s^2$$

Equations

$$U_L = (1/2)\ LI^2, \quad U_C = (1/2)\ CV^2, \quad u_B = B^2/(2\mu_0), \quad u_E = \epsilon_0 E^2/2$$

$$c = E/B, \quad Pressure = S/c, \quad \overrightarrow{S} = (1/\mu_0)\ \overrightarrow{E} \times \overrightarrow{B}, \quad S_{av} = E_{max}B_{max}/(2\mu_0)$$

$$\overrightarrow{E} = \overrightarrow{E_0} \sin(kx - \omega t), \quad k = 2\pi/\lambda, \quad \omega = 2\pi f, \quad c_{vacuum} = \lambda f = 1/\sqrt{\epsilon_0 \mu_0}$$

$$n_a \sin\theta_a = n_b \sin\theta_b, \quad \sin\theta_c = \frac{n_b}{n_a}, \quad \tan\theta_p = \frac{n_b}{n_a}, \quad n = \frac{c}{v}, \quad n_a\lambda_a = n_b\lambda_b$$

$$E = E_0 \cos\theta_{polarizer}, \quad I = I_0 \cos^2\theta_{polarizer}, \quad \theta_{polarizer} = \theta_E - \theta_{axis}^{transmission}$$

$$I_{unpolarized} \rightarrow I_{unpolarized}/2, \quad Work = \int \overrightarrow{F} \cdot d\overrightarrow{l} = Fl, \quad Power = \frac{dW}{dt} = Fv$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}\ , \quad M = -\frac{s'}{s} = \frac{h'}{h}, \quad M_{overall} = M_1 \cdot M_2 \cdot M_3 ...$$

$$|f| = |R/2|\ (mirror), \quad \frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}, \quad \frac{1}{f} = (n-1)(\frac{1}{R_1} - \frac{1}{R_2})$$

$$d\sin(\theta) = m\lambda \quad Double\ slit, \qquad 2d\sin(\theta) = m\lambda \quad Bragg$$

$$a\sin(\theta) = m\lambda \quad Single\ slit, \quad \theta_{res} = \frac{\lambda}{a}\ \ (slit), \quad \theta_{res} = 1.22\ \frac{\lambda}{D}\ \ (hole)$$

$$d\sin(\theta) = m\lambda\ \ Diffraction\ grating, \quad Resolving\ Power,\ R = mN = \frac{\lambda}{\Delta\lambda}$$

$$\phi = 0, 2\pi, 4\pi, 6\pi ... \quad Constructive\ Interference \quad \Delta x = 0,\ \lambda,\ 2\lambda,\ 3\lambda ...$$

$$\phi = \pi, 3\pi, 5\pi ... \quad Destructive\ Interference \quad \Delta x = \lambda/2,\ 3\lambda/2,\ 5\lambda/2 ...$$

$$\phi = K_n \Delta x, \quad K_n = \frac{2\pi}{\lambda/n}, \qquad \phi = \pi \quad (if\ n_1 < n_2)\ \ \Delta x = \lambda/2$$

Constants

$$\mu_0 = 4\pi \times 10^{-7}\ \frac{Tm}{A}, \quad \epsilon_0 = 8.85 \times 10^{-12}\ \frac{C^2}{Nm^2}, \quad c = 3.0 \times 10^8\ m/s, \quad g = 9.8\ m/s^2$$

Equations

$$\gamma = 1/\sqrt{1-(v^2/c^2)}, \quad \beta = v/c, \quad \Delta t = \gamma \Delta t_0, \quad L_0 = \gamma L$$

$$f = \sqrt{(c+v)/(c-v)} f_0, \quad u = (u' + v)/(1 + u'v/c^2)$$

$$E = KE + mc^2, \quad E^2 = p^2c^2 + m^2c^4, \quad E = \gamma mc^2, \quad \beta = pc/E$$

$$\lambda_{max} T = 0.2898 \times 10^{-2}\ m\ K, \quad E = hc/\lambda\ (photons!)$$

$$KE_{max} = E_{photon} - \Phi, \quad KE_{max} = eV_{stop}, \quad E_{threshold} = \Phi\ (Work\ Function)$$

$$\lambda_{scattered} - \lambda_{incident} = (h/(m_e c))(1 - \cos(\theta)), \quad KE = p^2/(2m)$$

$$\Delta x \Delta p_x \geq \frac{h}{4\pi}, \quad \Delta E \Delta t \geq \frac{h}{4\pi}, \quad \lambda = \frac{h}{p} = \frac{h}{mv}(DeBroglie), \quad L = \frac{nh}{2\pi}(Bohr)$$

$$E_n = -\frac{Ke^2}{2a_o}\frac{1}{n^2}, \quad a_o = \frac{h^2}{(2\pi)^2 m_e K e^2}, \quad E_n = -\frac{13.6eV}{n^2}, \quad \frac{1}{\lambda} = \frac{13.6eV}{hc}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$1/(2m)(h/2\pi)^2 \partial^2 \Psi(x)/\partial x^2 + U(x)\Psi(x) = E\Psi(x)$$

$$(Infinite\ Square\ Well) \quad \lambda_n = 2L/n, \quad E_n = h^2 n^2/(8mL^2)$$

$$(Tunnelling) \quad T = Ge^{-2\kappa L}, \quad G = 16(E/U_0)(1 - (E/U_0)), \quad \kappa = 2\pi\sqrt{2m(U_0 - E)}/h$$

$$r = r_o A^{1/3}, \quad A = Z + N, \quad {}^{A}_{Z}X, \quad E_{bind} = [Z \cdot M(H) + N \cdot M_n - M({}^{A}_{Z}X)]$$

$$\frac{dN}{dt} = -\lambda N, \quad R = \lambda N, \quad N = N_o e^{-\lambda t}, \quad R = R_o e^{-\lambda t}, \quad T_{1/2} = \ln(2)/\lambda$$

Useful Masses of Particles and Isotopes(Example!!!!)

Quantity	Mass (u)	Quantity	Mass (u)
proton	1.007276	${}^{12}_{6}C$	12.000000
neutron	1.008665	${}^{94}_{40}Zr$	93.906450
electron	5.486×10^{-4}	${}^{140}_{58}Ce$	139.90532
${}^{1}_{1}H$	1.007825	${}^{236}_{92}U$	236.045637

Constants

$h = 6.626 \times 10^{-34} J\ s$

$M_{electron} = 9.11 \times 10^{-31}\ kg$

$m_e\ c^2 = 0.511 \times 10^6\ eV$

$a_o = 0.0528\ nm$

$1Ci = 3.7 \times 10^{10}\ decays/s$

$hc = 1239.8\ eV\ nm$

$1\ eV = 1.6022 \times 10^{-19} J$

$1u = 931.494\ MeV/c^2$

$1Bq = 1\ decay/s$