Physics 121 (Physics 2) Formulas, page 1 of 2

Area of circle = πr^2 Circumference of circle = $2\pi r$ 1 meter = 1000 mm = 100 cm 1 kg = 1000 g
Surface area of sphere = $4\pi r^2$ Volume of sphere = $(4/3)\pi r^3$, 1 μC = 10^{-6} C 1 nC = 10^{-9} C
$1/4\pi\varepsilon_o = k_e = 9 \times 10^9$ N-m^2/C^2, $\varepsilon_o = 8.85 \times 10^{-12}$ C^2/N-m^2, $\mu_o = 4\pi \times 10^{-7}$ T-m/A
e = 1.60×10^{-19} C, $m_{electron} = 9.11 \times 10^{-31}$ kg, $m_{proton} = 1.67 \times 10^{-27}$ kg, 1 electron volt (eV) = 1.60×10^{-19} J.

Point charges: $\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$ $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}$ where $\hat{r}$ is a unit vector $k_e \equiv \frac{1}{4\pi\varepsilon_0} = 9\text{x}10^9$

Superposition: contributions to the field or force from point charges add as vectors at a point of interest $\vec{F}_{net\ on\ 1} = \sum_{i=2}^{n}\vec{F}_{1,i} = \vec{F}_{1,2} + \vec{F}_{1,3} + \vec{F}_{1,4+.....}$

Shell Theorem (spheres only): mimics point charge outside; inside **E** or **F** is zero

E = force per unit test charge at a point **F** = q**E** F_{net} = m**a**

Dipole moment: **p** = q**d** τ_{dipole} = **p**X**E** U_{dipole} = -**p**.**E** $E_{on\ dipole\ axis} \approx +\frac{p}{2\pi\varepsilon_0}\frac{1}{z^3}$ for large z

For continuous charge distributions: $\vec{E} = \int_{dist} k_e \frac{dq}{r^2}\hat{r}$ and $V = \int_{dist} k_e \frac{dq}{r}$ (integrate over the distribution)

σ = surface charge density $E_{cond\ sheet} = \sigma/\varepsilon_o$ $E_{non\text{-}cond\ sheet} = \sigma/2\varepsilon_o$
λ = linear charge density $E_{infinite\ line} = \lambda/2\pi\varepsilon_o r$ $E_{finite\ line} = \lambda\sin(\theta_0)/2\pi\varepsilon_o d$ $E_{arc} = \lambda\sin(\theta_0)/2\pi\varepsilon_o R$
$d\Phi_E$ = **E . n**dA = EAcos(ϕ) Φ_E = electric flux = $q_{enc}/\varepsilon_o = \oint$ **E . dA** over a Gaussian surface

$\Delta V = \Delta U/q = -\oint E\cos\theta\, ds = -\oint$ **E . ds** $\Delta U_{el} = q\Delta V$ $V = k_e Q/r$ $U = k_e Qq/r$ $V = -E\,\Delta x$

$E_x = -\partial V/\partial x$ $E_y = -\partial V/\partial y$ $E_z = -\partial V/\partial z$ Q = CV Electrostatic PE: $U_{el} = Q^2/2C = CV^2/2$

$\Delta W_{nc} = \Delta E_{mech} = \Delta K + \Delta U$ $C_{parallel} = \Sigma C_i$ $1/C_{series} = \Sigma(1/C_i)$ $C_{series} = C_1C_2/(C_1+C_2)$
$C_{parallel\ plates} = \kappa\varepsilon_o A/d$ $C_{sphere} = 4\pi\varepsilon_o R$ Dielectric constant: $C_{die;} = \kappa C_{vac}$ $\kappa >= 1$

$q = \oint i\,dt = i\Delta t$ dq = idt i = dq/dt $i = \oint \mathbf{J}\bullet d^2\mathbf{A} = J\Delta A$ $J = qnv_{drift}$ $J = \sigma E$ $\sigma = 1/\rho$

R = V / i V = iR R = ρL/A $\rho = \rho_0(1 + \alpha(T - T_0))$ Ohms Law: R independent of V

$R_{series} = \Sigma R_i$ $1/R_{parallel} = \Sigma 1/R_i$ $R_{para} = R_1R_2/(R_1 + R_2)$ $P = dU_{el}/dt = iV$ $P_{resistor} = i^2R = V^2/R$

Junction rule: $\Sigma i_{in} = \Sigma i_{out}$ Loop rule: $\Sigma\,\Delta V_i = 0$ around any closed circuit path. ΔV = -iR when following assumed current, +iR otherwise. Count EMF positive when crossing from – to +, negative otherwise.

RC Circuits: RC = time constant for circuit
charging: $i(t) = (V/R)e^{-t/RC}$ $Q(t) = CV_{cap}(t) = CV_\infty(1 - e^{-t/RC})$
discharging: $i(t) = (Q_o/RC)e^{-t/RC}$ $Q(t) = Q_o e^{-t/RC}$

F_m = q **v**x**B** F_e = q**E** F_m = i **L**x**B** τ = μx**B** U = -μ . **B** |μ| = NiA normal to loop = magnetic dipole moment. Cyclotron motion : r = mv/(qB) period = 2πm/(qB) ω = qB/m f = $\omega/2\pi$ = 1/period

Biot Savart: $d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,d\vec{s}\times\hat{r}}{r^2}$ where d**B** is in the direction of $d\vec{s}\times\hat{r}$ $\mu_o = 4\pi \times 10^{-7}$ T-m/A

$F/L = \mu_o i_1 i_2/2\pi d$ (2 parallel, straight wires) $B_{arc} = \mu_o i\phi/4\pi R$ $B_{circle} = \mu_o i/2R$ $B_{solenoid} = \mu_0 in$

$B_{infinite\ wire} = \frac{\mu_0 i}{2\pi r}$ $B_{wire} = \frac{\mu_0 i}{4\pi r}[\sin(\theta_1) - \sin(\theta_2)]$ For symmetric point : $B_{wire} = \frac{\mu_0 i}{2\pi r}\sin(\theta)$

Amperes law: $\oint \vec{B}\cdot d\vec{s} = \mu_0 i_{enclosed}$ for a closed "Amperian" loop $B_{current\ ring} \approx +\frac{\mu_0}{2\pi_0}\frac{\vec{\mu}}{z^3}$ for large z

Physics 121 (Physics 2) Formulas, page 2 of 2

Magnetic flux: $d\Phi_B = \mathbf{B.dA}$ $\Phi_B = \oint \mathbf{B.dA}$ $\Phi_B = BA\cos(\theta)$ $\Phi_B = 0$ over every *Gaussian* surface

Faraday's Law: $$\mathcal{E}_{ind} = -\frac{N d\Phi_B}{dt} = \oint_{loop} \mathbf{E}_{ind} \circ d\vec{s}$$

Lenz's Law: induced flux, current, & emf oppose the change in Φ_B

$\mathcal{E}_{ind} = BLv$ (slidewire) $\mathcal{E}_{ind} = NAB\omega \sin(\omega t)$ (rotating coil)

$\mathcal{E}_{self\text{-}induced} = -L\, di/dt$ $L = N\Phi_B / i$ Magnetic energy: $U_B = Li^2 / 2$

LR circuits: L/R= inductive time constant $=\tau_L$

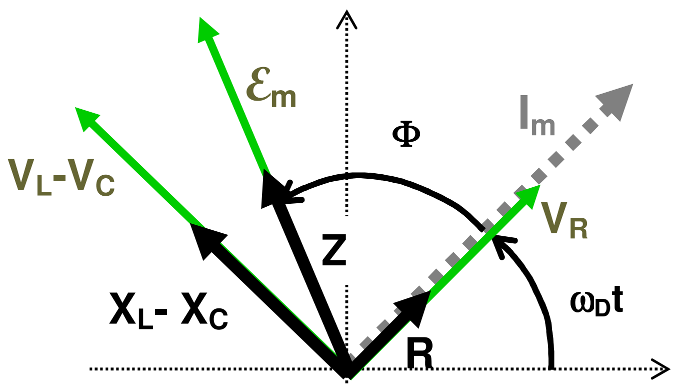
growth phase: $V_L(t) = \mathcal{E}\, e^{-Rt/L}$ $i(t) = i_{infinity}(1 - e^{-Rt/L})$ $i_{infinity} = \mathcal{E} / R$

Decay phase : $V_L(t) = -i_o R\, e^{-Rt/L}$ $i(t) = i_o\, e^{-Rt/L}$ $i_0 = \mathcal{E} / R$

LC circuit, no damping: Resonance at $\omega_{res} = 1 / \sqrt{LC}$

LCR circuit with damping: $Q(t) = Q_0 e^{-Rt/2L} \cos(\omega' t + \phi)$ $Q_0 \equiv C\mathcal{E}$ $\omega' \equiv \left[\omega_0^2 - (R/2L)^2\right]^{1/2}$

For LCR circuit driven at $\omega_d = 2\pi f$:



$i(t) = I_{max}\cos(\omega_D t - \Phi)$ $\mathcal{E}(t) = \mathcal{E}_{max}\cos(\omega_D t + \Phi)$

Reactances: $X_C = 1 / \omega_d C$ $X_L = \omega_d L$

Voltage across inductance leads the current by 90°

Voltage across capacitance lags the current by 90°

Impedance, series branch: $|Z| \equiv \sqrt{R^2 + (X_L - X_C)^2}$

Resonance occurs at $\omega_d = \omega_{res} = 1 / \sqrt{LC}$

Phase angle Φ: $\tan(\Phi) = (X_L - X_C) / R$

The power factor = $\cos(\Phi)$. $\cos(\Phi) = R / |Z|$ $P_{avg} = I_{rms}\mathcal{E}_{rms}\cos(\Phi) = I^2_{rms}R$

$I_{rms} = I_{max} / \sqrt{2}$ $\mathcal{E}_{rms} = \mathcal{E}_{max} / \sqrt{2}$ $I_{rms} = \mathcal{E}_{rms} / |Z|$ $I_m \equiv \dfrac{\mathcal{E}_m}{|Z|}$ $I_{rms} \equiv \dfrac{\mathcal{E}_{rms}}{|Z|}$

Transformers: $V_s / V_p = N_s / N_p = I_p / I_s$

Prefixes: n (nano) = 10^{-9} , μ (micro) = 10^{-6} , m (milli) = 10^{-3}, M (Mega) = 10^{+6}

Useful Derivatives: $\frac{d}{dt}\sin(\omega t) = \omega\cos(\omega t)$ $\frac{d}{dt}\cos(\omega t) = -\omega\sin(\omega t)$ $\frac{d}{dx}e^{\alpha x} = \alpha e^{\alpha x}$ $\frac{d}{dx}Ax^N = ANx^{N-1}$

Useful Integrals: $\int x^n dx = x^{n+1} / n+1$ $\int e^{\pm\alpha x} dx = \pm e^{\alpha x} / \alpha$

$\int dx / (a^2 + x^2) = (1/a)\tan^{-1}(x/a)$ $\int dx / (a^2 + x^2)^{3/2} = x / (a^2\sqrt{a^2 + x^2})$ $\int x\, dx / (a^2 + x^2)^{3/2} = -1 / \sqrt{a^2 + x^2}$

$\int dx/(a - x)^2 = 1/(a - x)$ $\int dx / (x^2 + a^2)^{1/2} = \ln(x + (x^2 + a^2)^{1/2})$ $\int dx/(a + x)^2 = -1/(a + x)$

$\int x dx / (x^2 + a^2)^{1/2} = (x^2 + a^2)^{1/2}$ $\int (dx/(a - x) = \ln(|a - x|)$ $\int (dx/(x + a) = \ln(|x + a|)$

Physics 1: $v = v_o + at$ $x - x_o = v_o t + ½at^2$ $v^2 = v_o^2 + 2a(x - x_o)$ $x - x_o = ½(v + v_o)t$

$a_{centripetal} = v^2 / r$ $\underline{F}_{net} = m\underline{a} = d\underline{p}/dt$ $\tau_{net} = I\alpha = d\underline{L}/dt$ $\underline{\tau} = \underline{r} \times \underline{F}$ $\underline{L} = \underline{r} \times \underline{p}$

Vectors: Components: $a_x = a\cdot\cos(\theta)$ $a_y = a\cdot\sin(\theta)$ $a = a_x\mathbf{i} + a_y\mathbf{j}$

$|a| =$ sqrt $[a_x^2 + a_y^2]$ $\theta = \tan^{-1}(a_y/a_x)$ Addition: $\mathbf{a} + \mathbf{b} = \mathbf{c}$ implies $c_x = a_x + b_x$, $c_y = a_y + b_y$

Dot product: $\mathbf{a}\cdot\mathbf{b} = a\cdot b\cdot\cos(\phi) = a_x b_x + a_y b_y + a_z b_z$ unit vectors: $\mathbf{i}\cdot\mathbf{i} = \mathbf{j}\cdot\mathbf{j} = \mathbf{k}\cdot\mathbf{k} = 1$; $\mathbf{i}\cdot\mathbf{j} = \mathbf{i}\cdot\mathbf{k} = \mathbf{j}\cdot\mathbf{k} = 0$

Cross product: $|\mathbf{a} \times \mathbf{b}| = a\cdot b\cdot\sin(\phi)$; $\mathbf{c} = \mathbf{a} \times \mathbf{b} = (a_y\cdot b_z - a_z\cdot b_y)\cdot\mathbf{i} + (a_z\cdot b_x - a_x\cdot b_z)\cdot\mathbf{j} + (a_x\cdot b_y - a_y\cdot b_x)\cdot\mathbf{k}$

$\mathbf{a} \times \mathbf{b} = -\mathbf{b} \times \mathbf{a}$, $\mathbf{a} \times \mathbf{a} = \mathbf{0}$ always; $\mathbf{c} = \mathbf{a} \times \mathbf{b}$ is perpendicular to **a-b** plane; if **a** || **b** then $|\mathbf{a} \times \mathbf{b}| = 0$

$\mathbf{i} \times \mathbf{i} = \mathbf{j} \times \mathbf{j} = \mathbf{k} \times \mathbf{k} = 0$, $\mathbf{i} \times \mathbf{j} = \mathbf{k}$ $\mathbf{j} \times \mathbf{k} = \mathbf{i}$ $\mathbf{k} \times \mathbf{i} = \mathbf{j}$