$\vec F_c = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat e_r$ | $\vec F_c = q\vec E$ | $\vec E = \vec v\times\vec B$

$\vec F_c = \frac{q}{4\pi\epsilon_0}\int_V \frac{\rho(\vec r')}{|\vec r-\vec r'|^2}\frac{(\vec r-\vec r')}{|\vec r-\vec r'|}\, d^3r'$

$\vec E = \lim_{q\to 0}\frac{\vec F_c}{q}$ | Feldl. ⊕ → ⊖; Leiter: Linien ⊥ Oberfl.; im Innern eines Leiters: $\vec E=\vec 0$

$d\phi_{el} = \vec E\, d\vec A = \vec E\vec n\, dA$ | $\phi_{el}=\int_A \vec E\, d\vec A = \frac{Q_{innen}}{\epsilon_0}$ Gauß'sches Ges.

$\vec\nabla\cdot\vec E(\vec r) = \frac{\rho(\vec r)}{\epsilon_0}$ | $\vec E_{lokal} = \frac{\sigma}{\epsilon_0}\vec n$ | $\vec\nabla\times\vec E=0$

$dW = -\vec F_c\, d\vec s = -q\vec E\, d\vec s$ | $W=-q\int_{r_1}^{r_2}\vec E(\vec r')\,d\vec s$ | $\vec E(\vec r) = \frac{\sigma}{2\epsilon_0}$ hom. gel. Platte

Kugel: $(r\geq R)$ $\vec E(\vec r) = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat e_r$

$d\varphi = -\vec E\, d\vec s$ | $\varphi(\vec r) = -\int_{r_1}^{r_2}\vec E(\vec r')\,d\vec s'$ | $\varphi(\infty)=0$

$dE_{pot} = -q\vec E\, d\vec s$ | $E = -\vec\nabla\varphi$ | $W=qU$

$U=\varphi_2-\varphi_1$ | $\varphi(\vec r) = \frac{1}{4\pi\epsilon_0}\int_V\frac{\rho(\vec r')}{|\vec r-\vec r'|}\,d^3r'$ | Äquipot.-fläche: $\vec E\perp\vec n$

Poisson: $\vec\nabla\vec E(\vec r) = -\vec\nabla^2\varphi(\vec r) = \rho(\vec r)/\epsilon_0$

Kugel: $r\geq R$ $\varphi(\vec r) = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$; $r<R$: $\varphi(r)=\frac{q}{4\pi\epsilon_0 R}$

$C=Q/U$ | P: $C=\sum_i C_i$ | R: $\frac1C=\sum_i\frac1{C_i}$ | Plattenkond.: $C=\epsilon_0\frac{A}{d}$

$W_{el} = \frac12\frac{Q^2}{C}=\frac12 QU=\frac12 CU^2$ | $w_{el}=\frac{W_{el}}{V_{el}}=\frac{\epsilon_0}{2}E^2$

Metallplatte: $C_L = \epsilon_0\frac{A}{d-d_L} = \frac{d}{d-d_L}C$ (Plattenkond.) | Kugel $4\pi\epsilon_0 r_K$

$|\vec E| = \frac{\sigma}{\epsilon_0}=\frac{Q}{\epsilon_0 A}$ | $U=d|\vec E|$ | Diel: $C_D=\epsilon C \Rightarrow W_{el}=\epsilon/2\,\epsilon_0 E^2$

Dipol: $\vec p = q\vec l = \alpha\vec E$ | $\vec P = \frac1V\sum_i\vec p_i$ | $\vec E_{ind} = -\frac{\vec P}{\epsilon_0}$

$|\vec P| = \sigma = \frac{Q_{ind}}{A}$ | $M=\vec p\times\vec E$ | $E_{pot} = -\vec p\vec E$

el. Verschieb. $\vec D = \epsilon_0\vec E+\vec P = \epsilon\epsilon_0\vec E$ | $\vec F = (\vec p\vec\nabla)\vec E_{inh}$

el. Suszeptibilität: $\vec P = \chi_{el}\epsilon_0\vec E$ | $\vec P = \frac NV\alpha\vec E = \frac1V\sum_i\vec p_i$

$\chi_{el} = \epsilon-1 = \frac NV\frac{\alpha}{\epsilon_0}$ | $I=\dot Q$ | ⊕ → ⊖ | $\vec j = I/A$ | $I=\int_A\vec j\, d\vec A$

$I = nqAv_d$ | $n=\frac{dN}{dV}$ | $\vec j = nq\vec v_d$ | $U=RI$ | $P=UI$

$R=\rho\frac{l}{A}$ | $\sigma=\frac1\rho$ | $\vec j=\sigma\vec E$ | $dP_{el} = \vec j\vec E\, dV = \sigma\vec E^2\, dV$

$P=\int_V\vec j\vec E\, dV$ | R: $R=\sum_i R_i$ | P: $\frac1R=\sum_i\frac1{R_i}$

mittl. Stoßz. $\tau = \frac{\lambda}{v_R}$ | $v_d = -\frac12\frac{e\vec E}{m_e}\tau$ | $v_R = \sqrt{\frac{8}{\pi}\frac{k_BT}{m_e}}$

Leitf. $\sigma = \frac12\frac{ne^2\tau}{m_e}$ | spez. Wid. $\rho = \frac{2m_e}{ne^2\tau}$ | Beweglk. $\mu = |\vec v_d|/|\vec E|$

$\mu = e\tau/(2m_e)$ | $\sigma = ne\mu$ | Spannungsabfall: Spann. in $\vec I$

Laden Kond. $\dot Q + \frac{1}{RC}Q - \frac1R U_0 = 0$ | $Q_0 = CU_0$ | $\tau=RC$

$Q = Q_0(1-e^{-t/\tau})$ | $U_c(t) = Q(t)/C$ | $I=\dot Q = I_0 e^{-t/\tau}$

$I_0 = U_0/R$

$1C = 1As$ | $e=1{,}602\cdot10^{-19}\,C$ | $[B]=1T=\frac{Vs}{m^2}$

$[E]=1\frac Vm$ | $\epsilon_0 = 8{,}85\cdot10^{-12}\frac{As}{Vm}$

$[\phi_{el}] = 1Vm$ | $[I]=1A=\frac Cs$ | $[H]=1A/m$

$[\varphi]=1V=\frac WA$ | $[j]=1\frac{A}{m^2}$ | $\mu_0 = 4\pi\cdot10^{-7}\frac{Vs}{Am}$

$[C]=1F=As/V$ | $[R]=1\frac VA$ | $[A_H]=1\frac{m^3}{C}$

$[\alpha]=1Asm^2/V$ | $[\rho]=1\Omega m$ | $[\phi_m]=1Wb=Vs$

$[\mu]=1m^2/Vs$ | $[L]=1H=Vs/A$

$[M]=1VAs$

$[D]=As/m^2=[P]$ | $\vec B = S\to N$

Entladen Kond. $Q=Q_0e^{-t/RC}$; $U_c = Q/C = U_0e^{-t/RC}$

$U_0=Q_0/C$ | $I=\dot Q = -I_0e^{-t/RC}$ | $I_0 = Q_0/RC$

$\vec B=\mu_0\vec H$ | $\epsilon_0\mu_0=\frac1{c^2}$ | Strom: $\vec F_L = I\vec l\times\vec B$ | $T=\frac{2\pi}{\omega}$

Ladung: $\vec F_L = q\vec v\times\vec B$ | $\omega_c = qB/m$ | $r_c = \frac{v}{\omega_c}$ | $E=v_dB$

$U_H = bv_dB = R_HI$ | $R_H = B/nqd$ | $A_H = 1/nq$ | $|A| = \frac{\mu}{\sigma}$

gerad. Leiter: $|B| = I\mu_0/2\pi r$ | $F=\mu_0I_1I_2\,l/2\pi d$ | $F$: ↑↑ ↑↓

Ampère: $\oint_S\vec B\, d\vec s = \mu_0 I_{innen}$ | $\vec\nabla\times\vec B=\mu_0\vec j$

Biot-Savart: $\vec B = \frac{\mu_0 I}{4\pi}\int_{Leiter}\frac{d\vec l\times(\vec r-\vec r')}{|\vec r-\vec r'|^3} = \frac{\mu_0}{4\pi}\int_V dV\frac{\vec j(\vec r')\times(\vec r-\vec r')}{|\vec r-\vec r'|^3}$

zyl. Leiter: $B(\vec r) = \mu_0\frac{I}{2\pi R^2}r$ $(r<R)$ | $B=\mu_0 I/2\pi r$ $r\geq R$

kreisf. Schleife: $B(z) = \frac{\mu_0 I}{2}\frac{R^2}{(R^2+z^2)^{3/2}}$ | lange Spule $B=\mu_0\frac NlI$

$\oint\vec B(\vec r)\,d\vec A = 0$ | $\vec\nabla B(\vec r)=0$ | $B(\vec r) = \vec\nabla\times\vec A_m(\vec r)$

Coulomb-Eich. $\vec\nabla\vec A_m(\vec r)=0$ | Ampère: $\vec\nabla\times[\vec\nabla\times\vec A_m(\vec r)] = \mu_0\vec j(\vec r)$

Ampère in C: $\Delta\vec A_m(\vec r) = -\mu_0\vec j(\vec r)$ | $\vec A_m(\vec r) = \frac{\mu_0}{4\pi}\int_V dV\frac{\vec j(\vec r')}{|\vec r-\vec r'|}$

$\phi_m = \oint_{S_A}\vec A_m(\vec r)\,d\vec s = \int_A\vec B\, d\vec A$ | $U_{ind} = \oint_{S_A}\vec E\, d\vec s = -\dot\phi_m$

$\vec\nabla\times\vec E = -\frac{\partial B}{\partial t}$ | Generator: $U_{ind} = \omega NBA\sin\omega t$

$\phi_m = LI$ | $L=\mu_0\frac{N^2A}{l}$ (lange Spule) | $W_{mag} = \frac12 LI^2 = \frac12\vec\mu_m\vec B$

$w_{mag} = \frac{W_{mag}}{V} = \frac{1}{2\mu_0}\vec B^2 = \frac12\vec B\vec H$ | Laden: $I_0 = U_0/R$; $\tau = L/R$

$I=I_0(1-e^{-t/\tau})$; $U=-U_0e^{-t/\tau}$ | Entladen: | $X_c = 1/\omega C$

$I=I_0e^{-t/\tau}$; $U=U_0e^{-t/\tau}$ | $P=U_{eff}I_{eff}$ | $I=I_0\cos(\omega t+\delta+\frac\pi2)$

$\hat U = U_0e^{i(\omega t+\delta)}$ | $Z=R+iX$ | $X_L=\omega L$ | $I=I_0\cos(\omega t+\delta-\frac\pi2)$

$\hat U = Z\hat I$ | $Z_C = -i\frac1{\omega C} = \frac{1}{i\omega C}$ | $Z_L = i\omega L$ | Trafo: $\frac{U_2}{U_1} = \frac{N_2}{N_1}$

$\vec B = \vec B_0+\mu_0\vec M = \mu_r\vec B_0$ | kurzg.: $I_2/I_1 = N_1/N_2$

LCR-Kreis (R=0) | $I=I_0\sin\omega_0 t$ | $I_0 = \omega_0 Q_0$ | $\omega_0 = \frac{1}{\sqrt{LC}}$

$E = \frac1{2C}Q_0^2$ | $U_c = U_0\cos\omega_0 t$ | $U_0 = Q_0/C$ | $R>0$

$\ddot Q + R(C\dot Q + LC\ddot Q) = 0$ | $Q = Q_0e^{-t/\tau}\cos(\omega t+\delta)$ | $\tau = \frac{2L}{R}$

$\omega_0>\tau^{-1}$ schwach; $\omega_0 = \frac1\tau$ krit.

Maxwell: $\vec\nabla\vec E = 0$ | $\vec\nabla\times\vec E = -\frac{\partial}{\partial t}\vec B$ | $\vec\nabla\vec B=0$ | $\vec\nabla\times\vec B = \mu_0\epsilon_0\frac{\partial}{\partial t}\vec E$

Versch. Strom: $I_V = \epsilon_0\int\frac{\partial}{\partial t}\vec E\, d\vec A$ | $\vec j_V = \epsilon_0\frac{\partial}{\partial t}\vec E$ | $\vec j_{maxw.} = \vec j + \vec j_V$

$w_{em} = \epsilon_0\vec E^2 = \frac1{\mu_0}\vec B^2 = \frac{1}{\mu_0 c}|\vec E||\vec B|$ | $c=\omega/k = f\lambda$

$\Delta(\vec E/\vec B) = \mu_0\epsilon_0\frac{\partial^2}{\partial t^2}(\vec B/\vec E)$ | $\vec E\perp\vec B$; $\vec E\perp\vec k$; $\vec B\perp\vec k$

$E = E_0\cos(\vec k\vec r-\omega t+\delta)$

$B=B_0\cos(\dots)$

$\vec{\mu}_L = -\frac{e\hbar}{2m_e}\vec{L}$ | $\mu_B = \frac{e\hbar}{2m_e}$ | $\vec{\mu}_S = -\mu_B g_0 \vec{S}$ | $g_0 \approx 2$

Dreh-Imp. $\vec{J} = \vec{L} + \vec{S}$ | $\vec{\mu}_J = \vec{\mu}_L + \vec{\mu}_S$ | $\vec{M} = \frac{1}{V}\sum_i \vec{\mu}_i$

$\vec{B} = \vec{B}_0 + \mu_0 \vec{M}$ | $\vec{M} = \frac{1}{\mu_0}\chi_m \vec{B}_0$ | ~~$\vec{M} = \frac{1}{\mu_0}\chi_m \vec{B}_0$~~

Perm. $\mu_r = \vec{B} = \mu_r \vec{B}_0$ | $\chi_m = \mu_r - 1$

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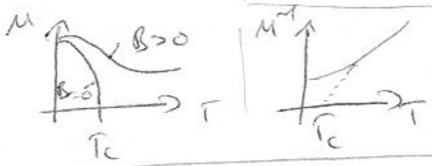
unterhalb v. $T_c$ auch bei $B_0 = 0$ | Ordnung (T > $T_c$: Para.)

Ferro: $\chi_f >> 0$ | $\chi_f = \chi_f(B_0, T) = \frac{C}{T - T_c}$ | C = Curie-Konst.




↑↑↑↑

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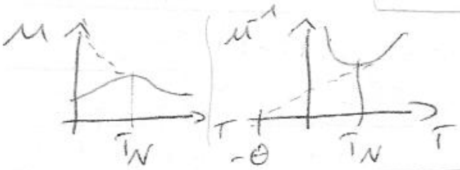
Antiferro: $T_N$ = Néel-T. | $\chi_{af} = \frac{C}{T + \Theta}$

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Ferri:


↑↓↑↓↑↓↑↓

$\chi_{ferri} = \frac{C}{T - T_c}$

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Diamag. bei allen (wird überdeckt)

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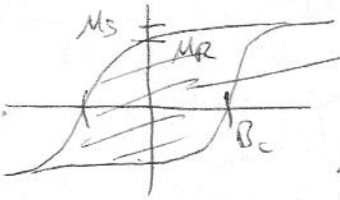


Ummag. $E \oint M(B_0)\, dB_0$

$M_S$ = Sättigung

$M_r$ = rem. Mag. (≙ Fläche)

$B_c$ = Koerzitivf. (≙ Resistenz)

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$\vec{\mu}_m = I\vec{A}$, $\vec{M} = \vec{\mu}_m \times \vec{B}$ (eine Leiterschleife)

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$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$ Poynting-Vektor $I = |\vec{S}| = c w_{em} = c\varepsilon_0 \vec{E}^2$

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$U = U_0 \cos(\omega t + \delta)$ $\omega = 2\pi\nu = \frac{2\pi}{T}$ $f = \frac{\omega}{2\pi}$

$U_{eff} = \sqrt{\frac{1}{T}\int_0^T U^2(t)\,dt}$ analog $I_{eff}$

bei sin: $U_{eff} = \frac{1}{\sqrt{2}}U_0$ $I_{eff} = \frac{1}{\sqrt{2}} I_0$