Mehanika

Kinematika

$s = \int_{\mathbf{r}_0}^{\mathbf{r}} |\mathrm{d}\mathbf{r}|$
$\mathbf{v} = \frac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$
$\mathbf{a} = \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$

Enakomerno pospešeno gibanje
$v = v_0 + at$
$s = s_0 + v_0 t + \frac{1}{2}at^2$
$v^2 = v_0^2 + 2as$

Poševni met
$x = v_0 t \cos\beta$
$z = v_0 t \sin\beta - \frac{1}{2}gt^2$
$z = x\tan\beta - \frac{gx^2}{2v_0^2\cos^2\beta}$

$\boldsymbol{\omega} = \frac{\mathrm{d}\boldsymbol{\varphi}}{\mathrm{d}t}, \qquad \varphi = \frac{s}{r}$
$\boldsymbol{\alpha} = \frac{\mathrm{d}\boldsymbol{\omega}}{\mathrm{d}t}, \qquad \mathbf{v} = \boldsymbol{\omega} \times \mathbf{r}$
$a_r = \omega^2 r = \frac{v^2}{r}$

$R_{kriv} = \frac{v^2}{a_r} = \frac{\dot{r}^2}{\sqrt{a^2 - a_t^2}} = \frac{\dot{r}^2}{\sqrt{\ddot{r}^2 - a_t^2}}$

Dinamika

$\mathbf{F} = m\mathbf{a}$
$\rho = \frac{\mathrm{d}m}{\mathrm{d}V}$

$\mathbf{F} = k\mathbf{s}$ (Hookov zakon)
$\mathbf{M} = D\varphi$
$F_{tr} = k_{tr}F_\perp$
$F_{l,max} = k_l F_\perp$

$\mathbf{r}^* = \sum_i \frac{m_i \mathbf{r}_i}{m} = \int \frac{\mathbf{r}dm}{m} = \int \frac{\mathbf{r}dV}{V} = \iiint \frac{\mathbf{r}\,dx\,dy\,dz}{V}$
$\sum \mathbf{F}_{zun} = m\mathbf{a}^*$

$\mathbf{p} = \frac{\mathrm{d}\mathbf{F}}{\mathrm{d}S}$ (tlak)
$\mathbf{f} = \frac{\mathrm{d}\mathbf{F}}{\mathrm{d}V}$ (gostota sile)

$\mathbf{F}_s = -m\mathbf{a}_s$ (sistemska sila)
$\mathbf{F}_{\mathrm{cf}} = -m\omega \times (\omega \times \mathbf{r})$ (centrifugalna sila)
$\mathbf{F}_{\mathrm{Cor}} = -2m\omega \times \mathbf{v}$ (Coriolisova sila)

Gibalna količina

$\int \mathbf{F}dt = m\mathbf{v} - m\mathbf{v}_0 = \Delta\mathbf{G}$
$\mathbf{F} = \frac{\mathrm{d}\mathbf{G}}{\mathrm{d}t}$

Splošen trk v 1D ($v_2' = 0$)
$v_1 = \frac{1 - m_2/m_1}{1 + m_2/m_1}v_1' \qquad v_2 = \frac{2}{1 + m_2/m_1}v_1'$

$\phi_m = \frac{\mathrm{d}m}{\mathrm{d}t} = \rho\phi_V$
$\phi_V = \frac{\mathrm{d}V}{\mathrm{d}t} = S\frac{\mathrm{d}x}{\mathrm{d}t} = Sv$
$\mathbf{F} = \phi_m(\mathbf{v}_0 - \mathbf{v})$ (sila curka)

Energija

$A = \int \mathbf{F}\cdot\mathrm{d}\mathbf{s} = \int(\mathbf{F}\cdot\mathbf{v})\mathrm{d}t$
$P = \frac{\mathrm{d}A}{\mathrm{d}t} = \mathbf{F}\cdot\mathbf{v}$
$\Delta W_k = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 = \frac{1}{2}\frac{G^2}{m} - \frac{1}{2}\frac{G_0^2}{m}$
$\oint \mathbf{F}\cdot\mathrm{d}\mathbf{s} = 0 \implies$ konzervativna sila, lahko pripišemo potencialno energijo, delo sile je neodvisno od vmesne poti
$A' = \Delta W_k - A_{\mathrm{konz}} = \Delta W_k + \Delta W_p$
$\Delta W_{p,g} = mg\Delta h$
$\Delta W_{p,\mathrm{pr}} = \frac{1}{2}k(x^2 - x_0^2) = \frac{1}{2}D(\varphi^2 - \varphi_0^2)$

$A = \int \mathbf{F}\cdot\mathrm{d}\mathbf{s} = \int \mathbf{F}\cdot\mathrm{d}\mathbf{s}^* + \int \mathbf{F}\cdot\mathrm{d}\mathbf{s}'$ (premik težišča in premik prijemališča sile glede na težišče)

Vrtenje

$\mathbf{M} = \mathbf{r}\times\mathbf{F}$
$J = \int \mathrm{d}m\, r^2$
$J = J^* + md^2$ (Steinerjev izrek)
$\mathbf{M} = J\boldsymbol{\alpha}$

Vztrajnostni momenti nekaterih teles:
Homogena palica okoli težišča: $J = \frac{1}{12}ml^2$
Valj okoli težišča vzdolž višine: $J = \frac{1}{2}m(r_1^2 + r_2^2)$
Votla krogla okoli težišča: $J = \frac{2}{3}mr^2$
Polna krogla okoli težišča: $J = \frac{2}{5}mr^2$

$A = \int M\mathrm{d}\varphi$
$W_k = \frac{1}{2}mv^{*2} + \frac{1}{2}J^*\omega^2$ (samo za togo telo in ne za sistem)

$\boldsymbol{\Gamma} = J\boldsymbol{\omega}$ (2D)
$\boldsymbol{\Gamma} = \int \mathrm{d}\boldsymbol{\Gamma} = \int \mathbf{r}\times\mathrm{d}\mathbf{G} = \underline{\underline{J}}\boldsymbol{\omega}$

$$\underline{\underline{J}} = \begin{bmatrix} \int \mathrm{d}m\,(y^2+z^2) & -\int \mathrm{d}m\; xy & -\int \mathrm{d}m\; xz \\ -\int \mathrm{d}m\; yx & \int \mathrm{d}m\,(x^2+z^2) & -\int \mathrm{d}m\; yz \\ -\int \mathrm{d}m\; zx & -\int \mathrm{d}m\; zy & \int \mathrm{d}m\,(x^2+y^2) \end{bmatrix}$$

$\sum \mathbf{M}_{zun} = \frac{\mathrm{d}\boldsymbol{\Gamma}}{\mathrm{d}t}$
$\boldsymbol{\Gamma} = \boldsymbol{\Gamma}_0 + \boldsymbol{\Gamma}^* = m\mathbf{r}^*\times\mathbf{v}^* + \int \mathbf{r}'\times\mathbf{v}'dm$
$\mathbf{M}^* = \mathbf{r}'\times\mathbf{F} = \frac{\mathrm{d}\boldsymbol{\Gamma}^*}{\mathrm{d}t}$ (lastna vrtilna količina)
$\mathbf{M}_0 = \mathbf{r}^*\times\mathbf{F} = \frac{\mathrm{d}\boldsymbol{\Gamma}_0}{\mathrm{d}t}$ (tirna vrtilna količina)

$\mathbf{M}^* = \boldsymbol{\omega}_p \times \boldsymbol{\Gamma}^*$ (precesija)

Deformacije

$\frac{F_x}{S_x} = -E\frac{\Delta x}{x}$
$\frac{F_x}{S_y} = G\frac{\Delta x}{y}$
$\frac{F}{S} = -K\frac{\Delta V}{V}, \quad \chi^{-1} = K$
$\frac{\Delta y}{y} = \frac{\Delta z}{z} = -\mu\frac{\Delta x}{x}$

$K = \frac{E}{3(1-2\mu)}$
$G = \frac{E}{2(1+\mu)}$
$D = \frac{1}{2}\pi G\frac{r^4}{l}$
Območje sorazmernosti (*meja linearnosti*), območje prožnosti (*meja prožnosti*), območje plastičnosti (*meja natezne trdnosti*).

Gravitacija

$\mathbf{F}_g = \varkappa\frac{m_1 m_2}{(\mathbf{r}_2 - \mathbf{r}_1)^2}\frac{\mathbf{r}_2 - \mathbf{r}_1}{|\mathbf{r}_2 - \mathbf{r}_1|}$
$W_{p,g} = -\frac{\varkappa m_1 m_2}{r}$

Keplerjevi zakoni
1. Planet se giblje po elipsi s Soncem v središču.
2. Ploščinska hitrost planeta je konstantna.
3. $\frac{a^3}{T^2} = \frac{\varkappa(M+m)}{4\pi^2}$

Težnostni pospešek v okolici kroglastega telesa:
$r > r_0: \; g = g_0\frac{r_0^2}{r^2}$
$r < r_0: \; g = g_0\frac{r}{r_0}$

$W = \frac{1}{2}mv^2 - \frac{\varkappa Mm}{r} = \frac{1}{2}mv_0^2 - \frac{\varkappa Mm}{r_0}$
$W > 0 \implies$ telo se giblje po hiperboli.
$W = 0 \implies$ telo se giblje po paraboli.
$W < 0 \implies$ telo se giblje po elipsi.

Hidrostatika

$p = \frac{F}{S} = p_0 + \rho gh$
$\mathbf{F}_v = \int \mathbf{p}\,\mathrm{d}S = -m_t\mathbf{g}$
$pV = p_0 V_0$ (Boylov zakon za pline)
$\frac{\mathrm{d}V}{V} = -\chi\,\mathrm{d}p$
$F = \gamma b$
$W_{p,\mathrm{pov}} = \gamma S$
$\Delta p = \frac{2\gamma}{R}$ (kapljica)
$\Delta p = \frac{4\gamma}{R}$ (mehurček)
$h = \frac{2\gamma\cos\vartheta}{\rho gr}$ (kapilarni dvig v valjasti kapilari)

Hidrodinamika

$\mathrm{d}A = -p\,\mathrm{d}V$
$\frac{F_s}{S_s} = \eta\frac{\mathrm{d}v_x}{\mathrm{d}z}$
$\Phi_V = \int \mathbf{v}\cdot\mathrm{d}\mathbf{S}$
$v_s = \frac{\Phi_V}{S} = \frac{\int \mathbf{v}\cdot\mathrm{d}\mathbf{S}}{\int \mathrm{d}S}$ (srednja hitrost)
$\Phi_m = \Phi_{m0}$ (kontinuitetna enačba)
$p_0 + \frac{1}{2}\rho v_0^2 + \rho g z_0 \geq p + \frac{1}{2}\rho v^2 + \rho gz$

$p = p_0 + \frac{1}{2}\rho v_0^2$ (zastojni tlak)
$F_u = \frac{1}{2}c_u\rho v^2 S$ ($Re > 10^3$)
$F_u = cl\eta v$ ($Re < 0{,}5$)
$F_u = 6\pi R\eta v = \frac{24}{Re}\frac{1}{2}\rho v^2 S$ (Stokesov zakon za kroglo)
$Re = \frac{l\rho v}{\eta} = \frac{2R\rho v}{\eta}$

$v = v_0\left(1 - \frac{r^2}{R^2}\right), \quad v_0 = \frac{R^2(p_0 - p)}{4l\eta}$ (valjasta cev, $Re < 2300$)

$\Phi_V = v_s\pi R^2 = \frac{\pi R^4(p_0 - p)}{8l\eta}$ (Poiseuillov zakon)

Nihanje

$\omega_0 = \sqrt{k/m}$

$\omega_0 = \sqrt{g/l}$

$\omega_0 = \sqrt{D/J}$

$\omega_0 = \sqrt{mgd/J}$

$s = s_0 \cos(\omega t + \delta) = s_1 \cos \omega t + s_2 \sin \omega t$

$s_1 = s_0 \cos\delta, \quad s_2 = -s_0 \sin\delta$

$s = s_0 \cos\omega_1 t + s_0 \cos\omega_2 t =$
$= 2s_0 \cos\big(\frac{1}{2}(\omega_2 - \omega_1)t\big) \cos\big(\frac{1}{2}(\omega_2 + \omega_1)t\big) = 2s_0 \cos\frac{1}{2}\omega_u t \cos\omega t$

Dušeno nihanje

$W = W_0 e^{-2\beta t}, \quad F_u = -2\beta m v$

$\omega^2 = \omega_0^2 - \beta^2$

Podkritično dušenje ($\omega_0 > \beta$)

$s = s_0 e^{-\beta t}\cos(\omega t + \delta)$

$A = -\ln\frac{s(t+T)}{s(t)} = \beta T = \frac{2\pi\beta}{\omega}$

Kritično dušenje ($\omega_0 = \beta$)

$s = s_1 e^{-\beta t} + s_2 t e^{-\beta t}$

Nadkritično dušenje ($\omega_0 < \beta$)

$s = s_0 e^{-\beta t}\cosh(\omega t + \delta)$

Vsiljeno nihanje

$\ddot{x} + 2\beta\dot{x} + \omega_0^2 x = \omega_0^2 s_0 \cos\omega t$

$x = x_1 e^{-\beta t}\cos\left(\sqrt{\omega_0^2 - \beta^2}t - \delta'\right) + x_0\cos(\omega t - \delta)$

$w = \omega/\omega_0$

$\tan\delta = \frac{2\beta}{\omega_0}\frac{w}{1-w^2}$

$\frac{x_0}{s_0} = ((1-w^2)^2 + (\frac{2\beta}{\omega_0})^2 w^2)^{-\frac{1}{2}}$

$\overline{P} = \overline{\mathbf{F}\cdot\mathbf{v}} = \beta m \omega_0^2 s_0^2 \frac{w^2}{(1-w^2)^2 + (\frac{2\beta}{\omega_0})^2 w^2}$

$\omega_{1/2} = 2\beta, \overline{P}(\omega_0 + \frac{1}{2}\omega_{1/2}) = \overline{P}(\omega_0 - \frac{1}{2}\omega_{1/2}) = \frac{1}{2}\overline{P}_{max}$

Valovanje

$c = \sqrt{\frac{F}{\rho S}}$ (transverzalna motnja na napeti vrvici)

$c = \sqrt{\frac{E}{\rho}} = \sqrt{\frac{k}{m}}l$ (longitudinalna motnja v trdnini)

$c = \frac{1}{\sqrt{\chi\rho}} = \sqrt{\frac{\kappa p}{\rho}}$ (longitudinalna motnja v kapljevini in plinu)

$w = \frac{dW}{dV} = \rho v^2 \qquad w_k = w_p = \frac{1}{2}\rho v^2$ (transverzalna motnja)

Splošno

$w_k = \frac{1}{2}\rho v^2 = \frac{1}{2}\rho\left(\frac{\partial s}{\partial t}\right)^2$

$w_p = \frac{1}{2}c^2\rho\left(\frac{\partial s}{\partial x}\right)^2$

$\delta p = -c^2\rho\frac{\partial s}{\partial x}$

Valovanje v eni razsežnosti

$s = s_0\cos(kx - \omega t)$

$k = \frac{2\pi}{\lambda} = \frac{\omega}{c} \qquad \omega = 2\pi\nu \qquad c = \nu\lambda$

$w = \rho v^2 = \rho\omega^2 s_0^2 \sin^2(\omega t - kx)$

$\overline{w} = \frac{1}{2}\rho\omega^2 s_0^2$

$j = \frac{P}{S} = \frac{W}{St} = c\overline{w} = \frac{1}{2}c\rho\omega^2 s_0^2 = \frac{1}{2}\frac{(\delta p)_0^2}{\rho c}$

Interferenca

$s = s_1 + s_2 = s_0\cos(\omega t - kx) + s_0\cos(\omega t - kx + \delta) =$
$= 2s_0\cos\frac{1}{2}\delta\cos(\omega t - kx + \frac{1}{2}\delta) = S_0\cos(\omega t - kx + \Delta)$

Na prostem krajišču se valovanje odbije z enako fazo, na vpetem krajišču pa z nasprotno fazo.

Stoječe valovanje

$s = s_1\cos(\omega t - kx) + s_1\cos(\omega t + kx) = 2s_1\cos kx\cos\omega t$

$\nu_N = \frac{1}{2}(N+1)\frac{c}{l}$ (dve vpeti ali dve prosti krajišči)

$\nu_N = \frac{1}{4}(2N+1)\frac{c}{l}$ (eno vpeto in eno prosto krajišče)

$w = \frac{1}{2}\rho\omega^2 s_0^2(\sin^2 kx\sin^2\omega t + \cos^2 kx\cos^2\omega t)$

$\overline{w} = \frac{1}{4}\rho\omega^2 s_0^2$

Valovanje več razsežnostih

$\mathbf{k} = \frac{2\pi}{\lambda}\frac{\mathbf{c}}{c}$

$\mathbf{s} = \mathbf{s}_0(\mathbf{r})\cos(\mathbf{k}\cdot\mathbf{r} - \omega t)$ (ravni val)

$\mathbf{s} = \mathbf{s}_0(r)\cos(kr - \omega t)$ (krogelni val)

Interferenca

maksimumi: $a\sin\beta = n\lambda$ (daleč od izvira)

minimumi: $a\sin\beta = (2n+1)\frac{1}{2}\lambda$ (daleč od izvira)

Dopplerjev pojav

$\nu' = \nu\frac{1+v_s/c}{1-v_i/c}$

$\lambda' = \lambda\frac{1-v_i/c}{1+v_s/c}$

Disperzija je pojav, pri katerem je hitrost valovanja odvisna od valovne dolžine.

$c = \sqrt{\frac{g}{k} + \frac{\gamma k}{\rho}}$ (valovanje na vodni gladini v globoki vodi)

$c = \sqrt{gh}$ (valovanje na vodni gladini v plitvi vodi)

$c_g = \left(\frac{d\omega}{dk}\right)_{\omega_0} = c_f + k\left(\frac{dc}{dk}\right)_{\omega_0} = c_f - \lambda\left(\frac{dc}{d\lambda}\right)_{\lambda_0}$

Zvok

glasnost $= 10\log\frac{j}{j_0(\nu)}$[fon]

jakost neodvisna od frekvence: $10\log\frac{j}{j_0}$[dB]

Termodinamika

0. zakon termodinamike: Če sta v ravnovesju 1. in 2. sistem, ko sta med seboj v toplotnem stiku, a sta adiabatno izolirana od okolice, in če sta v ravnovesju 2. in 3. sistem, ko sta med seboj v toplotnem stiku, a sta adiabatno izolirana od okolice, sta v ravnovesju tudi 1. in 3. sistem.

Temperaturno raztezanje

$dl = \alpha l\, dT$

$dV = \beta V dT$

$\beta = 3\alpha$

$\frac{dV}{V} = -\chi_T dp + \beta_p dT$

Energijski zakon

1. zakon termodinamike:

W_n je funkcija stanja in $dW_n = đQ + đA$

$đA = -p\,dV$ (če so vsa vmesna stanja definirana)

$H = W_n + pV$ (entalpija - funkcija stanja)

$dH = đQ + V\,dp$

$(dW_n)_V = (dQ)_V = mc_V\,dT$

$(dH)_p = (dQ)_p = mc_p\,dT$

$\Delta H = (Q)_p = qm$ (poljuben fazni prehod)

$P = \frac{dQ}{dt}$

$\mathbf{j} = -\lambda\nabla T$ (prevajanje v 3 dimenzijah)

$j = -\lambda\frac{dT}{dx}$ (prevajanje v 1 dimenziji)

$P = -\Lambda S(T - T_0)$ (konvekcija)

Entropijski zakon

2. zakon termodinamike: S je funkcija stanja in $\Delta S \geq \int\frac{đQ}{T}$ (enakost pri reverzibilnih spremembah)

$S = k_B\ln w$ (w je število mikroskopskih stanj)

Clausius-Clapeyronova enačba

$\frac{dp_s}{p_s} = \frac{Mq_i(T)}{R}\frac{dT}{T^2}$

$p_s = p_{s0}e^{\frac{Mq_i}{R}\left(\frac{1}{T_0} - \frac{1}{T}\right)}$ (približek $q_i = konst.$)

$\frac{dp}{dT} = \frac{q_t}{T\left(\frac{1}{\rho_{\text{kaplj}}} - \frac{1}{\rho_{\text{trd}}}\right)}$

Toplotni stroji

$Q_{\text{dov}} = |A| + |Q_{\text{odv}}|$

$\eta = \frac{|A|}{Q_{\text{dov}}} = 1 - \frac{|Q_{odv}|}{Q_{dov}}$

$\eta_C = 1 - \frac{T_{\min}}{T_{\max}}$ (Carnotov stroj)

$\eta_C = \frac{Q_{\text{dov}}}{A} = \frac{T}{T_0 - T}$ (Carnotov hladilnik)

$\eta_C = \frac{Q_{\text{odv}}}{A} = \frac{T_0}{T_0 - T}$ (Carnotova toplotna črpalka)

Idealni plin

$pV = \frac{m}{M}RT$

$\rho = \frac{pM}{RT}$

$\beta_p = \frac{1}{T}$

$\chi_T = \frac{1}{p}$

$p = \sum p_{\text{parc}}$ (Daltonov zakon)

$W_n = mc_V T$ (vedno)

$H = mc_p T$ (vedno)

$\Delta S = mc_V\ln\frac{T}{T_0} + m\frac{R}{M}\ln\frac{V}{V_0}$ (vedno)

$\kappa = \frac{c_p}{c_V}$

$c_p - c_V = \frac{R}{M}$

$c_p = \frac{\kappa}{\kappa-1}\frac{R}{M}, \quad c_V = \frac{1}{\kappa-1}\frac{R}{M}$

Spremembe

	ΔW_n	A	Q
izohorna	$mc_V\Delta T$	0	$mc_V\Delta T$
izobarna	$mc_V\Delta T$	$-p\Delta V$	$\Delta H = mc_p\Delta T$
izotermna	0	$-p_0V_0\ln\frac{V}{V_0}$	$-A = p_0V_0\ln\frac{V}{V_0}$
izentropna	$mc_V\Delta T$	$mc_V\Delta T$	0

Pri izentropni (adiabatni) spremembi še dodatno:

$pV^\kappa = konst.$

$\chi_S = \frac{1}{\kappa p}$

Kinetična teorija plinov

$n = \frac{\mathrm{d}N}{\mathrm{d}V}$
$p = \frac{2}{N_p} n \langle W_k \rangle = \frac{1}{N_p} n m_1 \langle v^2 \rangle$
$W_n = N \langle W_k \rangle = \frac{N_p}{2} N k_B T$
$\langle l \rangle = \frac{1}{\sqrt{2}\pi d^2 n}$ (povprečna prosta pot)
$j_N = \frac{\mathrm{d}^2 N}{\mathrm{d}t \mathrm{d}S} = \frac{1}{4} n \langle v \rangle$
$j_D = D \frac{\partial n}{\partial x}, \quad D = \frac{1}{3} \langle v \rangle \langle l \rangle$ (difuzija)
$\frac{1}{N} \frac{\mathrm{d}^3 N}{\mathrm{d}v_x \mathrm{d}v_y \mathrm{d}v_z} = \left(\frac{m_1}{2\pi k_B T} \right)^{\frac{3}{2}} e^{-\frac{W_k}{k_B T}}$
$\frac{\mathrm{d}N}{N \mathrm{d}v} = 4\pi v^2 \left(\frac{m_1}{2\pi k_B T} \right)^{\frac{3}{2}} e^{-\frac{m v^2}{2 k_B T}}$

Elektrika

Električno polje

Naboj izoliranega sistema je konstanten.
Coulombov zakon: $\mathbf{F} = -\frac{e_1 e_2}{4\pi\varepsilon\varepsilon_0 (\mathbf{r}_1 - \mathbf{r}_2)^2} \frac{\mathbf{r}_1 - \mathbf{r}_2}{|\mathbf{r}_1 - \mathbf{r}_2|}$
$\sigma = \frac{\mathrm{d}e}{\mathrm{d}S}$
$\rho_e = \frac{\mathrm{d}e}{\mathrm{d}V}$

$\mathbf{F} = e\mathbf{E}$
$\mathbf{D} = \varepsilon\varepsilon_0 \mathbf{E}$
$\phi_e = \int \mathbf{D} \cdot \mathrm{d}\mathbf{S}$
Gaussov zakon: $\oint \mathbf{D} \cdot \mathrm{d}\mathbf{S} = e$

$\mathrm{d}V = -\mathbf{E} \cdot \mathrm{d}\mathbf{s}$
$\mathbf{E} = -\boldsymbol{\nabla} V$
$U(\mathbf{r}, \mathbf{r}_1) = V(\mathbf{r}) - V(\mathbf{r}_1)$
$\mathrm{d}A = U \mathrm{d}e$
$\oint \mathbf{E} \cdot \mathrm{d}\mathbf{s} = 0$
$W_{p,e} = eV$
$w_e = \frac{\mathrm{d}W_e}{\mathrm{d}V} = \frac{1}{2}\varepsilon\varepsilon_0 E^2 = \frac{1}{2} ED$

Električni dipol

$\mathbf{p}_e = e\mathbf{a}$
$W_p = -\mathbf{p}_e \cdot \mathbf{E}$
$\mathbf{M} = \mathbf{p}_e \times \mathbf{E}$
Dipol v izhodišču na premici z:
$E_x = \frac{3 p_e \sin\vartheta \cos\vartheta}{4\pi\varepsilon\varepsilon_0 r^3}, \quad E_y = 0, \quad E_z = \frac{p_e (3\cos^2\vartheta - 1)}{4\pi\varepsilon\varepsilon_0 r^3}$

Snov v električnem polju

V prevodniku v stacionarnem stanju ni električnega polja.
$P = n p_{e,1} = \frac{\mathrm{d}N}{\mathrm{d}V} p_{e,1}$ (polarizacija)
$e_p = PS$ (vezan naboj)
$P = (\varepsilon - 1)\varepsilon_0 E = \chi \varepsilon_0 E$

Električni tok

$I = \frac{\mathrm{d}e}{\mathrm{d}t}$
$j_e = \frac{\mathrm{d}I}{\mathrm{d}S}$
$\mathbf{j}_e = \rho_e \mathbf{v}$
$\mathbf{j}_e = \frac{\mathrm{d}\mathbf{D}}{\mathrm{d}t}$ (premikalni tok)
Prvi Kirchoffov izrek: $\sum I_{\mathrm{pri}} = \sum I_{\mathrm{od}}$ v razvejišču
Drugi Kirchoffov izrek: $\sum U_{\mathrm{gon}} = \sum U_{\mathrm{por}}$ v zanki

Ohmov zakon: $U = RI$
$R = \zeta \frac{l}{S}$
$\mathrm{d}\zeta = \alpha_\zeta \zeta \mathrm{d}T$
$\mathbf{E} = \zeta \mathbf{j}_e$
Zaporedno vezani uporniki: $R = \sum_i R_i$
Vzporedno vezani uporniki: $\frac{1}{R} = \sum_i \frac{1}{R_i}$
$P = UI = I^2 R = \frac{U^2}{R}$
$\frac{\mathrm{d}P}{\mathrm{d}V} = \zeta j_e^2$

Izmenični tok

$I = I_0 \cos\omega t = \mathrm{Re}(I_{0,\mathbb{C}} e^{i\omega t}) \qquad I_{ef} = \frac{1}{\sqrt{2}} I_0$
$U = U_0 \cos(\omega t + \delta) = \mathrm{Re}(U_{0,\mathbb{C}} e^{i\omega t}) \qquad U_{ef} = \frac{1}{\sqrt{2}} U_0$
$\overline{P} = \frac{1}{2} U_0 I_0 \cos\delta = U_{\mathrm{ef}} I_{\mathrm{ef}} \cos\delta$
Ohmov zakon za kompleksno impedanco: $U = ZI$
Zaporedno vezane komponente: $Z = \sum_i Z_i$
Vzporedno vezane komponente: $\frac{1}{Z} = \sum_i \frac{1}{Z_i}$
$Z_R = R$
$Z_C = \frac{1}{i\omega C}$ (kapacitanca)
$Z_L = i\omega L$ (induktanca)

Transformator

$U_1 = -L_{11} \frac{\mathrm{d}I_1}{\mathrm{d}t} - L_{12} \frac{\mathrm{d}I_2}{\mathrm{d}t}$
$U_2 = -L_{22} \frac{\mathrm{d}I_2}{\mathrm{d}t} - L_{21} \frac{\mathrm{d}I_1}{\mathrm{d}t}$
Obremenjen z uporom: $\frac{U_{\mathrm{ef},1}}{U_{\mathrm{ef},2}} = \frac{N_1}{N_2} = \frac{I_{\mathrm{ef},2}}{I_{\mathrm{ef},1}}$

Kondenzatorji

$e = CU$
$W_c = \frac{1}{2} C U^2 = \frac{1}{2} \frac{e^2}{C}$
Ploščati kondenzator: $C = \varepsilon\varepsilon_0 \frac{S}{l}$
Valjasti kondenzator: $C = 2\pi\varepsilon\varepsilon_0 \frac{l}{\ln(r_1/r_2)}$
Krogelni kondenzator: $C = 4\pi\varepsilon\varepsilon_0 \frac{r_1 r_2}{r_1 - r_2}$

Zaporedno vezani kondenzatorji: $\frac{1}{C} = \sum_i \frac{1}{C_i}$
Vzporedno vezani kondenzatorji: $C = \sum_i C_i$
Polnjenje kondenzatorja: $U_c = U_0 (1 - e^{-t/(RC)})$
Praznjenje kondenzatorja: $U_c = U_0 e^{-t/(RC)}$

Magnetizem

Magnetno polje

$\mathbf{F} = I\mathbf{l} \times \mathbf{B} = e\mathbf{v} \times \mathbf{B}$
$\mathbf{f} = \frac{\mathrm{d}\mathbf{F}}{\mathrm{d}V} = \mathbf{j}_e \times \mathbf{B}$

$\phi_m = \int \mathbf{B} \cdot \mathrm{d}\mathbf{S}$
$\oint \mathbf{B} \cdot \mathrm{d}\mathbf{S} = 0$ (ni magnetnih monopolov)

$\mathbf{B} = \mu\mu_0 \mathbf{H}$
Amperov zakon: $\oint \mathbf{H} \cdot \mathrm{d}\mathbf{s} = I + \frac{\partial}{\partial t} \int \mathbf{D} \cdot \mathrm{d}\mathbf{S} = I + \frac{\mathrm{d}\phi_e}{\mathrm{d}t}$
Biot-Savartov zakon: $\mathrm{d}\mathbf{H} = \frac{I}{4\pi} \frac{\mathrm{d}\mathbf{l} \times \mathbf{r}}{r^3} = \frac{\mathrm{d}e}{4\pi} \frac{\mathbf{v} \times \mathbf{r}}{r^3}$ ($\mathbf{r}$ ima smer od vodnik do neke točke)
$w_e = \frac{1}{2}\mu\mu_0 H^2 = \frac{1}{2} HB$

Magnetni dipol

$\mathbf{p}_m = I\mathbf{S}$
$\mathbf{M} = \mathbf{p}_m \times \mathbf{B}$
$W_p = -\mathbf{p}_m \cdot \mathbf{B}$

Snov v magnetnem polju

Paramagnetna snov: $\mu > 1$ (malo)
Diamagnetna snov: $\mu < 1$ (malo)
Feromagnetna snov: $\mu(H) = \frac{\mathrm{d}B}{\mu_0 \mathrm{d}H} \gg 1$
Diagram $B(H)$ za feromagnetne snovi je *histerezna krivulja.*
$M = n \langle p_{m,1} \rangle = \frac{\mathrm{d}N}{\mathrm{d}V} \langle p_{m,1} \rangle$
$I_M = Ml$
$M = (\mu - 1) \frac{B_0}{\mu_0} = \chi \frac{B_0}{\mu_0}$

Indukcija

Faradayev zakon: $\oint \mathbf{E} \cdot \mathrm{d}\mathbf{s} = -\frac{\partial}{\partial t} \int \mathbf{B} \cdot \mathrm{d}\mathbf{S}$
$U_i = \frac{\mathrm{d}\phi_m}{\mathrm{d}t}$
$U_i = \mathbf{v} \cdot (\mathbf{B} \times \mathbf{l})$
Gaussov zakon, zakon o magnetnem pretoku, Amperov zakon in Faradayev zakon so osnovni zakoni elektrodinamike ali Maxwellove enačbe.

Tuljava

$\phi_m = LI$
$U_i = -L \frac{\mathrm{d}I}{\mathrm{d}t}$
$W_m = \frac{1}{2} L I^2 = \frac{1}{2} \frac{\phi_m^2}{L}$
Dolga tuljava: $L = \frac{\mu_0 N^2 S}{l}$
Tanek toroid: $L = \frac{\mu_0 N^2 S}{2\pi r}$
Koaksialni vodnik: $L = \frac{\mu_0 l}{2\pi} \ln\left(\frac{r_1}{r_2} \right)$
Polnjenje tuljave: $I = I_0 (1 - e^{-tR/L})$
Praznjenje tuljave: $I = I_0 e^{-tR/L}$
Vzajemna induktivnost: $L_{ij} = \frac{\mu_0 N_i N_j S}{l}$

Nihajni krog

$\omega_0 = (LC)^{-\frac{1}{2}}$
$W = W_m + W_e = \frac{1}{2} L I_0^2 = \frac{1}{2} C U_0^2$

Dušeno nihanje

$\beta = \frac{R}{2L}$
$\omega_1 = \sqrt{\omega_0^2 - \beta^2}$
$I = I_0 e^{-\beta t} \cos\omega_1 t$

Vsiljeno nihanje

$w = \omega/\omega_0$
$\tan\delta = \frac{1 - \omega^2 LC}{\omega RC}$
$\frac{I_0}{U_0/\omega_0 L} = w / \sqrt{(1 - w^2)^2 + (\frac{2\beta w}{\omega_0})^2}$

Elektromagnetno valovanje

$c_0 = \sqrt{1/\varepsilon_0\mu_0}$
$\mathbf{E} = \mathbf{B} \times \mathbf{c}$
$w = w_e + w_m = 2w_{m0} = 2w_{e0} = \varepsilon_0 E^2 = \frac{B^2}{\mu_0}$
$j = wc = \varepsilon_0 c E^2$
$\mathbf{j} = \mathbf{E} \times \mathbf{H}$ (Poyntingov vektor)
$\overline{j} = \frac{1}{2}\varepsilon_0 c E_0^2 = \frac{1}{2}E_0 H_0$
Vpadanje valovanja na prevodno ploščo: $p = \overline{w}$

Točkasti izvor:
$E(r,t) = E_0(r)\sin(kr - \omega t)$
$E_0 \propto \frac{1}{r}$ $B_0 \propto \frac{1}{r}$
Polarizator: $j = j_0 \cos^2\vartheta$

Elektromagnetno valovanje v koaksialnem vodniku

$c = \sqrt{1/\varepsilon\varepsilon_0\mu_0} = c_0\sqrt{1/\varepsilon}$
$Z_0 = \frac{U}{I} = \frac{\ln(b/a)}{2\pi}\sqrt{\frac{\mu_0}{\varepsilon\varepsilon_0}}$
$\frac{\partial I}{\partial x} = -C_l \frac{\partial U}{\partial t} - \left(\frac{1}{R}\right)_l U$
$\frac{\partial U}{\partial x} = -L_l \frac{\partial I}{\partial t} - R_l I$
$U_{\text{odb}} = -U_{\text{vpd}} \frac{Z_0 - Z}{Z_0 + Z}$
$x = 0 : U = U_0 e^{-i\omega t}$, torej ima Z nasproten predznak kot ponavadi

Valovna optika

$n = \frac{c}{c_0}$
$R = \frac{j_o}{j_v} = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$
$T = \frac{j_p}{j_v} = \frac{4n_1 n_2}{(n_1+n_2)^2}$
Huyghensovo načelo: vsaka točka na valovni fronti je izvir točkastega valovanja.

Tanka plast in kristalne ravnine

$2nd\cos\beta = N\lambda$ (maksimumi)
$2nd\cos\beta = (N + \frac{1}{2})\lambda$ (minimumi)
Če je število obratov faze liho, se pogoja zamenjata.

Uklonska mrežica

$j = j_0 \frac{\sin^2(N\frac{ka}{2}\sin\alpha)}{\sin^2(\frac{ka}{2}\sin\alpha)} = j_0 \frac{\sin^2 N\delta_n}{\sin^2\delta_n}$
$a\sin\alpha = m\lambda$ (maksimumi)

Široka reža

$j = j_0 \frac{\sin^2(\frac{kb}{2}\sin\alpha)}{(\frac{kb}{2}\sin\alpha)^2} = j_0 \frac{\sin^2\delta}{\delta^2}$
$b\sin\alpha = m\lambda$ (minimumi)
N rež: $j = j_0 \frac{\sin^2 N\delta_n}{\sin^2\delta_n}\frac{\sin^2\delta}{\delta^2}$

Fotometrija

Prostorski kot: $\mathrm{d}\Omega = \frac{\mathrm{d}S}{r^2}$
Svetilnost: $I = \frac{\mathrm{d}P}{\mathrm{d}\Omega}$
Svetlost: $B_0 = \frac{I_0}{S}$

Absorpcija

$j = j_0 e^{-\mu z}$
$l_{1/2} = \frac{\ln 2}{\mu}$

Toplotno sevanje

$j_{\text{odp}} = a j_v$ $j_{\text{abs}} = (1-a) j_v$
$j^* = (1-a)\sigma T^4$
$\lambda_{\max} T = k_W$

Geometrijska optika

Odbojni zakon: odbojni kot je enak vpadnemu
Lomni zakon: $n_1 \sin\alpha = n_2\sin\beta$
Če $n_2 > n_1$, se ob odboju faza spremeni za π.
$\tan\alpha_{\text{Brew}} = \frac{n_2}{n_1}$
$\sin\alpha_{\text{tot}} = \frac{n_2}{n_1}$

Planparalelna plast: $d = h\frac{\sin(\alpha-\beta)}{\cos\beta}$

Zrcala

$f = \frac{1}{2}r$ (negativna pri konveksnem zrcalu)
$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$
$\frac{y'}{y} = \frac{b}{a}$ (povečava)
$\tan\alpha = \frac{y}{a}$ (zorni kot oddaljenega telesa)

Tanke leče

$\frac{1}{f} = (n-1)\left(\frac{1}{r} + \frac{1}{r'}\right)$ (negativna pri konkavi leči)
$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$
$\frac{y'}{y} = \frac{b}{a}$ (povečava)

Fizikalne konstante

$g = 9{,}81\,\frac{\mathrm{m}}{\mathrm{s}^2}$
$\varkappa = 6{,}67408 \cdot 10^{-11}\,\frac{\mathrm{m}^3}{\mathrm{kg\ s}^2}$

$r_Z = 6400$ km (polmer Zemlje)
$m_Z = 6 \cdot 10^{24}$ kg (masa Zemlje)
$m_S = 2 \cdot 10^{30}$ kg (masa Sonca)
$d_{ZS} = 1{,}5 \cdot 10^8$km (razdalja Zemlja - Sonce)
$d_{ZL} = 384\ 000$ km
$j_0 = 10^{-12}\ \frac{\mathrm{W}}{\mathrm{m}^2}$
$p_0 = 10^5$ Pa (tlak na gladini morja)
$c_{H_2O} = 4\ 200\ \frac{\mathrm{J}}{\mathrm{kg\ K}}$ (specifična toplota vode)
$q_t = 334\ \frac{\mathrm{kJ}}{\mathrm{kg}}$ (specifična talilna entalpija vode)
$q_i = 2\ 264\ \frac{\mathrm{kJ}}{\mathrm{kg}}$ (specifična izparilna entalpija vode)

$R = 8\ 310\ \frac{\mathrm{J}}{\mathrm{kmol\ K}}$
$N_A = 6{,}02 \cdot 10^{26}\ \frac{1}{\mathrm{kmol}}$
$k_B = \frac{R}{N_A} = 1{,}38 \cdot 10^{-23}\ \frac{\mathrm{J}}{\mathrm{K}}$

$M_{zrak} = 29\ \frac{\mathrm{kg}}{\mathrm{kmol}}$
$N_{p1} = 3,\quad N_{p2} = 5$ (prostorske stopnje)
$\kappa_1 = \frac{5}{3},\quad \kappa_2 = \frac{7}{5}$

$e_0 = 1{,}602 \cdot 10^{-19}$ As
$\varepsilon_0 = 8{,}85 \cdot 10^{-12}\ \frac{\mathrm{As}}{\mathrm{Vm}}$
$\mu_0 = 4\pi \cdot 10^{-7}\ \frac{\mathrm{Vs}}{\mathrm{Am}}$
$c_0 = 3{,}0 \cdot 10^8\ \frac{\mathrm{m}}{\mathrm{s}}$
$\sigma = 5{,}67 \cdot 10^{-8}\ \frac{\mathrm{W}}{\mathrm{m^2K^4}}$
$k_W = 2{,}90 \cdot 10^{-3}$ m · K

$u = 1{,}66 \cdot 10^{-27}$ kg $= 931{,}5\ \frac{\mathrm{MeV}}{\mathrm{c}^2}$
$m_e = 9{,}1 \cdot 10^{-31}$ kg $= 0{,}511\ \frac{\mathrm{MeV}}{\mathrm{c}^2}$
$m_p = 1{,}673 \cdot 10^{-27}$ kg $= 938{,}3\ \frac{\mathrm{MeV}}{\mathrm{c}^2} = 1{,}00728u$
$m_n = 1{,}675 \cdot 10^{-27}$ kg $= 939{,}6\ \frac{\mathrm{MeV}}{\mathrm{c}^2} = 1{,}00866u$

Trigonometrične identitete

$\sin^2\alpha + \cos^2\alpha = 1$
$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$
$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$
$\tan(\alpha \pm \beta) = \frac{\tan\alpha \pm \tan\beta}{1 \mp \tan\alpha\tan\beta}$
$\sin 2\alpha = 2\sin\alpha\cos\alpha$
$\cos 2\alpha = \cos^2\alpha - \sin^2\alpha = 2\cos^2\alpha - 1 = 1 - 2\sin^2\alpha$
$\sin\alpha + \sin\beta = 2\sin\frac{\alpha+\beta}{2}\cos\frac{\alpha-\beta}{2}$
$\sin\alpha - \sin\beta = 2\cos\frac{\alpha+\beta}{2}\sin\frac{\alpha-\beta}{2}$
$\cos\alpha + \cos\beta = 2\cos\frac{\alpha+\beta}{2}\cos\frac{\alpha-\beta}{2}$
$\cos\alpha - \cos\beta = -2\sin\frac{\alpha+\beta}{2}\sin\frac{\alpha-\beta}{2}$
$\tan\alpha \pm \tan\beta = \frac{\sin(\alpha\pm\beta)}{\cos\alpha\cos\beta}$

Diferencialne enačbe

$\ddot{x} = -\omega^2 x \implies \frac{1}{2}m\dot{x}^2 + \frac{1}{2}m\omega^2x^2 = W \implies$
$x = A\sin(\omega t) + B\cos(\omega t)$
$\ddot{x} = \omega^2 x \implies x = A\sinh(\omega t) + B\cosh(\omega t)$
$\frac{1}{c^2}\frac{\partial^2 s}{\partial t^2} = \frac{\partial^2 s}{\partial x^2} \implies s = A\cos(kx - \omega t + \delta)$

Koordinatni sistemi

$\mathbf{r} = x\hat{\mathbf{e}}_x + y\hat{\mathbf{e}}_y + z\hat{\mathbf{e}}_z$ (kartezični koordinatni sistem)
$\mathbf{r} = \rho\hat{\mathbf{e}}_\rho + \varphi\hat{\mathbf{e}}_\varphi + z\hat{\mathbf{e}}_z$ (cilindrični koordinatni)
$\mathbf{r} = r\hat{\mathbf{e}}_r + \varphi\hat{\mathbf{e}}_\varphi + \vartheta\hat{\mathbf{e}}_\vartheta$ (sferični koordinatni sistem)

$\rho = \sqrt{x^2+y^2}$ $\varphi = \arctan\frac{y}{x}$
$x = \rho\cos\varphi$ $y = \rho\sin\varphi$
$r = \sqrt{x^2+y^2+z^2}$ $\varphi = \arctan\frac{y}{x}$
$\vartheta = \arccos\frac{z}{\sqrt{x^2+y^2+z^2}}$
$x = r\sin\vartheta\cos\varphi$ $y = r\sin\vartheta\sin\varphi$ $z = r\cos\vartheta$