$L = T - V$ $\quad \frac{d}{dt}\left(\frac{\partial L}{\partial \dot q_j}\right) - \frac{\partial L}{\partial q_j} = 0 \quad j = 1,\dots,f$

$L = L(\vec q, \dot{\vec q}, t) \quad V = V(q_i)$

$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot q_j}\right) - \frac{\partial L}{\partial q_j} = \sum_{i=1}^{k} \lambda_i(t) a_{ij} \quad a_{ij} = \frac{\partial f_i}{\partial q_j}$ Lagrange

$\sum_{i=1}^{k} \lambda_i(t) a_{ij} = Z_j \quad p_j = \frac{\partial L}{\partial \dot q_j}$

$J[y] = \int_a^b \sqrt{1 + y'(x)^2}\, dx$ (Länge) $\quad J[y] = \int_a^b F\, dx$

$\frac{d}{d\epsilon} J(\epsilon)\Big|_{\epsilon=0} \Rightarrow \frac{\partial F(x, y, y')}{\partial y} - \frac{d}{dx}\left(\frac{\partial F}{\partial y'}\right) = 0$ WIRKUNG

$S[q(t)] = \int_{t_1}^{t_2} L(t, q(t), \dot q(t))\, dt \quad \exists$ jedes System

$J[y] = \int_a^b F dx \quad F = F(x, y(x), y'(x)) \Rightarrow \frac{\partial F}{\partial y'} y' - F = C$

$\nabla \times \vec E = -\frac{\partial B}{\partial t} \quad \nabla \cdot \vec E = \frac{\rho}{\epsilon} \quad \nabla \times \vec B = \mu\epsilon \frac{\partial E}{\partial t} + \vec j$

$\nabla \cdot \vec B = 0 \quad \vec B = \nabla \times \vec A \quad \vec E = -\nabla\varphi - \frac{\partial \vec A}{\partial t}$ MAXWELL LORENTZ

$V = q(\varphi - \vec A \dot{\vec r}) \quad F = q(\vec E + \vec v \times \vec B)$

$L = \frac{m}{2} |\dot{\vec r}|^2 - q(\varphi - \vec A \dot{\vec r})$

$L = -mc^2 \sqrt{1 - \frac{v^2}{c^2}} \quad E = \sum_i p_i \dot q_i - L$

$x_\mu = (ct, -x, -y, -z) \quad x^\mu = (ct, x, y, z)$ RELATIVISTIK

$K \frac{\partial^2 \varphi}{\partial x} - \rho \frac{\partial^2 \varphi}{\partial t} = 0 \quad v^2 = \frac{K}{\rho} \quad \varphi(x,t) = F(x) g(t)$

$\varphi_n(x,t) = \sum_{n=1}^{\infty} a_n \sin k_n x \cos \omega_n t + b_n \sin k_n x \sin \omega_n t$

$k_n = \frac{n\pi}{L} \quad a_n = \frac{2}{L} \int_0^L dx\, f(x) \sin k_n x$

$f(x) = \sum_{n=1}^{\infty} a_n \sin k_n x = \varphi(x, 0)$

$b_n = \frac{2}{\omega_n L} \int_0^L dx\, g(x) \sin k_n x \quad \int_0^L dx \sin k_n x \sin k_m x = \frac{L}{2}\delta_{m,n}$

$g(x) = \sum_{n=1}^{\infty} b_n \omega_n \sin k_n x = \dot\varphi(x, 0) \quad \varphi_x = \frac{\partial \varphi}{\partial x}$

L-Dichte: $h(t, x, \varphi, \varphi_x, \varphi_t) \quad \varphi_t = \frac{\partial \varphi}{\partial t}$ WELLENGLEICHUNG

$\frac{\partial}{\partial t} \frac{\partial h}{\partial \varphi_t} + \frac{\partial}{\partial x} \frac{\partial h}{\partial \varphi_x} - \frac{\partial h}{\partial \varphi} = 0 \quad \vec L = \vec r \times \vec p$

$\sum_j^{3N} a_{ij} dq_j + a_{it} dt = 0$ lösb.: $\frac{\partial a_{ij}}{\partial q_l} = \frac{\partial a_{il}}{\partial q_j} \quad \frac{\partial a_{ij}}{\partial t} = \frac{\partial a_{it}}{\partial q_j}$

ZWANGSBEDINGUNG

$\mathrm{div}\, \vec F = \nabla \cdot \vec F$ (Quellen) $\quad \nabla \times F = \mathrm{rot}\, F$

$D_z = \begin{pmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad D_y = \begin{pmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{pmatrix}$

$D_x = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{pmatrix}$

$\sum_{j=1}^{f} \frac{\partial L}{\partial \dot q_j}\left(\frac{\partial q_j}{\partial \epsilon}\right)\Big|_{\epsilon=0} - \frac{\partial F}{\partial \epsilon}\Big|_{\epsilon=0} = C$ NOETHER

$q_i = q_i + \epsilon \psi_i + O(\epsilon^2) \quad t' = t + \epsilon \phi + O(\epsilon^2)$

$\sum_{j=1}^{f} \left(\frac{\partial L}{\partial \dot q_j} \psi_j\right) + \left(L - \sum_{j=1}^{f} \frac{\partial L}{\partial \dot q_j} \dot q_j\right)\phi - \frac{\partial F}{\partial \epsilon}\Big|_{\epsilon=0} = C$

Isoperim.: $J[y(x)] = \int_a^b dx\, F(x, y, y')$; $g = g(x, y, t)$

$K[y(x)] = \int_a^b dx\, g = C \Rightarrow \frac{d}{dx}\left(\frac{\partial(F - \lambda g)}{\partial y'}\right) - \frac{\partial(F - \lambda g)}{\partial y} = 0$

Holonom:

$K[x, y, z, \lambda(t)] = \int_{t_1}^{t_2} dt\, \lambda(t) g(x, y, z) = 0 \quad \forall \lambda(t) \Rightarrow$

$\frac{d}{dt}\left(\frac{\partial F}{\partial \dot q_i}\right) - \frac{\partial F}{\partial q} + \lambda(t) \frac{\partial g}{\partial x} = 0$ NEBENBEDINGUNG

$p = f(x) \Rightarrow g(p) = f(x(p)) - p\, x(p)$

$\vec r' = (\vec r \cdot \vec n)\vec n + \cos\varphi(\vec r - (\vec r \cdot \vec n)\vec n) + \sin\varphi\, \vec r \times \vec n$

Punkt: $q_i = q_i(Q_1, \dots, Q_n, t)$ Eich.: $L' = L + \frac{d}{dt} F(q_1, \dots, q_n, t)$

$x_i = \sum_{k=1}^{3} (R_{ik} x_k') + v_i t + C_1$ aff. orth. $R_{ik} = R^{-1}_{ki}$ (Eich. <>)

$\left(\frac{d}{dt}\right)_I = \left(\frac{d}{dt}\right)_R + \vec\omega \times$ TRANSFORMATION (SYMM.)

$H(q_i, p_i, t) = \sum_{j=1}^{f} p_j \dot q_j(p_i, q_i, t) - L(q_i, \dot q_i(q_i, p_i, t))$

$\dot p_i = -\frac{\partial H}{\partial q_i} \quad \dot q_i = \frac{\partial H}{\partial p_i} \quad \frac{\partial H}{\partial t} = -\frac{\partial L}{\partial t}$ HAMILTON

---

virt. Verr. $\sum_{i=1}^{N} \vec Z_i \delta \vec r_i = 0 \quad \sum_{i=1}^{N} (m_i \ddot{\vec r}_i - \vec F_i)\delta \vec r_i = 0$ d'Alembert

gen. Kraft $\quad$ gen. Koord.

$Q_j = \sum_{i=1}^{N} \vec F_i \cdot \frac{\partial \vec r_i}{\partial q_j} \quad \sum_{i=1}^{N} \left[\frac{d}{dt} \frac{\partial T}{\partial \dot q_j} - \frac{\partial T}{\partial q_j} - Q_j\right]\delta q_j = 0$

$\dot{\vec r} = \dot r \hat e_r + r\dot\varphi \hat e_\varphi + \dot z \hat e_z = \dot r \hat e_r + r \dot\theta \hat e_\theta + r \sin\theta\, \dot\varphi\, \hat e_\varphi \quad \ddot{\vec r} = (\ddot r - r\dot\varphi^2)\hat e_r + (2\dot r \dot\varphi + r\ddot\varphi)\hat e_\varphi + \ddot z \hat e_z = (\ddot r - r\dot\theta^2 - r\sin^2\theta\, \dot\varphi^2)\hat e_r + (2\dot r\dot\theta + r\ddot\theta - r\sin\theta\cos\theta\,\dot\varphi^2)\hat e_\theta + ((r\ddot\varphi + 2\dot r\dot\varphi)\sin\theta + 2r\dot\varphi\dot\theta\cos\theta)\hat e_\varphi$ ZIV

Hamiltonsches Integralprinzip d. kleinsten Wirkung: S ist extremal; Galileisches ~~Integral~~Prinzip: Bew.gl. in allen Inertialsystemen gleich; d'Alembertsches Differenzialprinzip: virtuelle Verrückung $\delta t = 0$