$$\boxed{\begin{aligned}\vec v &= \dot{\vec r}\\ \vec a &= \dot{\vec v} = \ddot{\vec r}\end{aligned}}$$

Kinematik

reine Raum-Zeit Lehre. Keine Kräfte. Keine Massen

x, y, z, t

$$\ddot{\vec r} = \ddot{\vec r}(\vec r) \quad \text{N}$$

schwache Äquivalenzprinzip

$$-kx = \vec F = m_t \vec a = m_t \ddot x$$

$$\ddot x = -\frac{k}{m} x$$

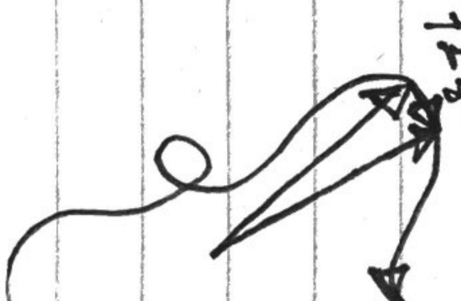
$$m_s = m_t$$

$$\ddot x = -x$$

Aufgabe Mechanik: finde $\vec r(t)$ aus $\ddot{\vec r}(t)$

L

mittels DGL $\ddot{\vec r} = \ddot{\vec r}(\vec r, \dot{\vec r}, \dddot{\vec r})$ jerk



vgl. QM: bestimme $|\Psi|^2 dx$ aus $H\Psi = \frac{i}{\hbar}\dot\Psi$ Schrödinger-glg

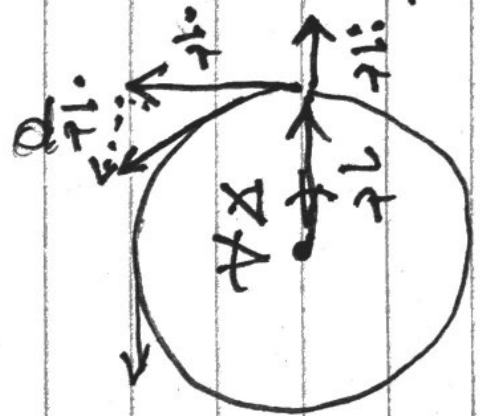
$$\dot{\vec r} = \frac{\vec r(t+dt) - \vec r(t)}{dt}$$

$\dot{\vec r}$ tangent an $\vec r$

$\ddot{\vec r}$ tangent an $\dot{\vec r}$

$\Rightarrow$ $\ddot{\vec r}$ tangent $\vec r$

nach Def „ $\ddot{}$ "



Galileitransformation

$$t' = t$$

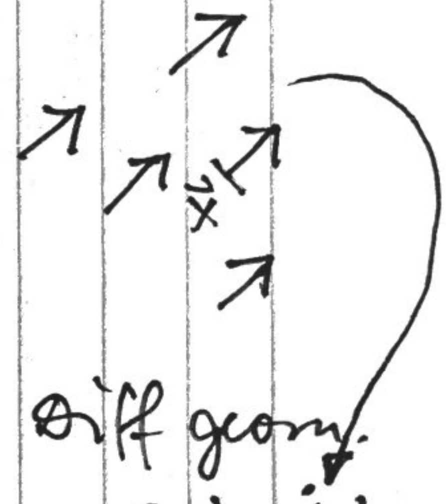
$$\vec r\,' = \vec r + \vec U t$$

Konstante (Richtung & Betrag)

$$\dot{\vec r}\,' = \dot{\vec r} + \vec U$$

$$\ddot{\vec r}\,' = \ddot{\vec r}$$

Relativgeschw.



Diff geom.

Vektor $(\vec X, \dot{\vec X})$

Satz Die Newtonsche Mechanik ist galileiinvariant

$$m\vec{a} = \vec{F}$$

$$\wr$$

nach Galileitrafo

besser: kovariant

nicht nur $m'\vec{a}' = \vec{F}'$ z.B. $m\Lambda\vec{a} = \Lambda\vec{F}$

(würde schon reichen)

sondern sogar $m\vec{a} = \vec{F}$

Abstand

$$\Delta\vec{r}' = \vec{r}_1' - \vec{r}_0'$$

$$= \vec{r}_1 + \vec{u}t - (\vec{r}_0 + \vec{u}t)$$

$$= \vec{r}_1 - \vec{r}_0 = \Delta\vec{r}$$

Beweis $\vec{a}' = \ddot{\vec{r}}' = \ddot{\vec{r}} = \vec{a}$

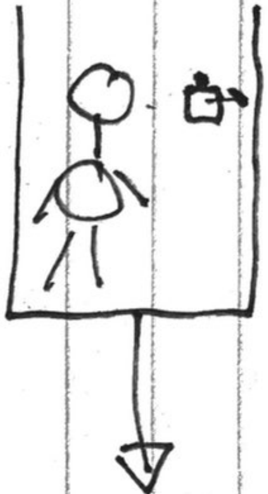
$$m' = m$$

$$\vec{F}' \overset{?}{=} \vec{F}$$

ja!! denn alle bekannten Kräfte hängen offenbar nur vom Abstand ab

$\cancel{\Delta\vec{r}}$

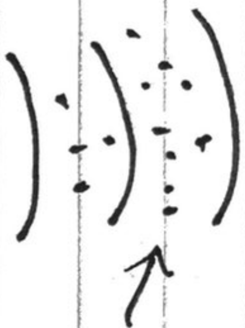
Inertialsysteme



Galilei-Prinzip:

Für kräftefreie Körper

ist $\vec{v} = \text{const}$



$$\frac{4\pi \cancel{r^2}\, dr}{\cancel{r^2}}$$

Inertialsystem:

Im Inert.-syst. ist $\vec{v} = \text{const}$,

wenn empirische Kräfte verschwinden

- Federn
- Gravitation?
- thermischer Druck
- Lichtdruck

nichtempirisch

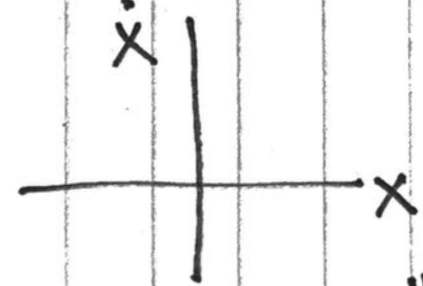
- Zentrifugal
- Coriolis
- Quelle

ergo

Im Inertialsystemen gibt es keine

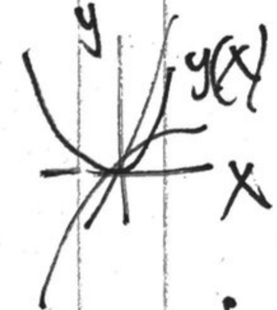
Inertialkräfte = Trägheitskräfte = nicht empirische K.

Phasenraum — Poincaré & Boltzmann



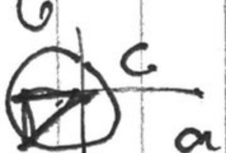
Hook $\ddot{x} = -x$ (am $\vec{F} = -k\Delta\vec{r}$)

$x + \ddot{x} = 0$ $\qquad \ddot{x} = \frac{d^2x}{dt^2} \neq \cancel{\frac{dx^2}{dt^2}}$



$a^2 + b^2 = c^2$ $\qquad x\dot{x} + \dot{x}\ddot{x} = 0$

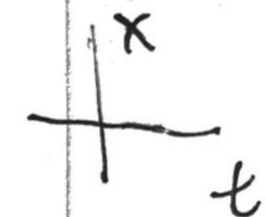
$y\dot{y}$



$\frac{d\boxed{\frac{x^2}{2}}}{dx}\;\frac{dx}{dt}$

$\qquad = \qquad =$

$\quad x \qquad \dot{x}$

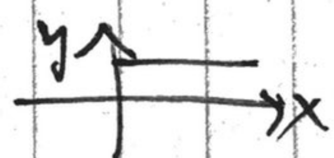


$\overset{\cdot}{\overbrace{\frac{1}{2}x^2}} + \overset{\cdot}{\overbrace{\frac{1}{2}\dot{x}^2}} = 0$

$= \frac{d}{dt}(\dot{x}\dot{x})$ $\quad \frac{dx}{dt}$

$\frac{d}{dt}\left(\frac{1}{2}x^2 + \frac{1}{2}\dot{x}^2\right) = 0$

$\frac{1}{2}k x^2 + \frac{1}{2}m\dot{x}^2 = E_t$

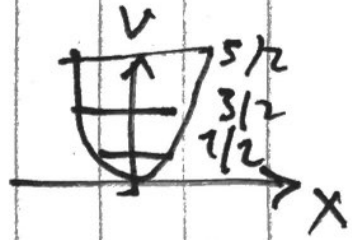


$\dot{x}^2 = \dot{x}\dot{x}$

$\dot{\overline{x^2}} = \frac{d}{dt}x^2$

Erstes Integral d. Bewegung $\qquad y = \text{const} \rightarrow dy/dx = 0$

$$F_H = -\frac{dV_H}{dx} = -kx \to V_H = \frac{1}{2}kx^2$$

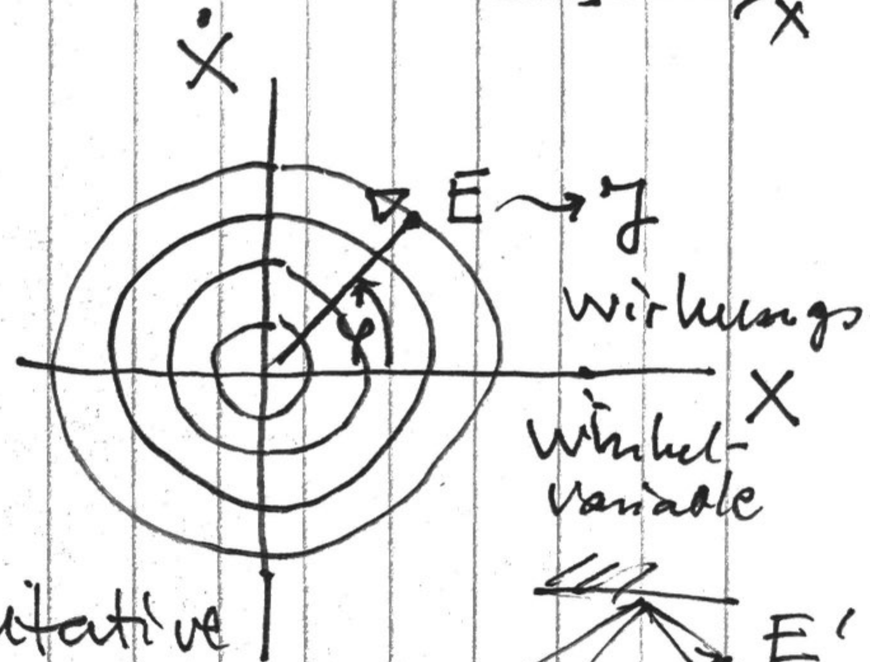


$$V + T = E$$

pot   kin   tot.

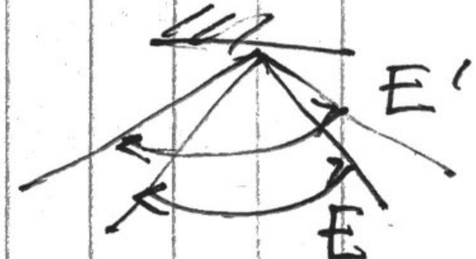
en.   en.   en.

$$\frac{1}{2}kx^2 + \frac{1}{2}m\dot{x}^2 = 2E$$



Topologie

„qualitative Dynamik“



nicht kreuzen

für freien Falls