

Introduction to Physics I

For Biologists, Geoscientists, & Pharmaceutical Scientists

Reibungskoeffizienten

Oberflächen	Haftreibung	Gleitreibung	
	trocken	trocken	geölt
Stahl / Stahl	0.74	0.57	0.01
Stahl / Eis	0.027	0.014	
Holz / Stein	0.7	0.3	
Stahl / Bremsbeläge		0.6	0.3
Stahl / Glas	0.6	0.1	
Teflon / Teflon	0.04	0.02	
Gummi / Asphalt	0.8 - 1.1	0.7 - 0.9	0.2 - 0.5

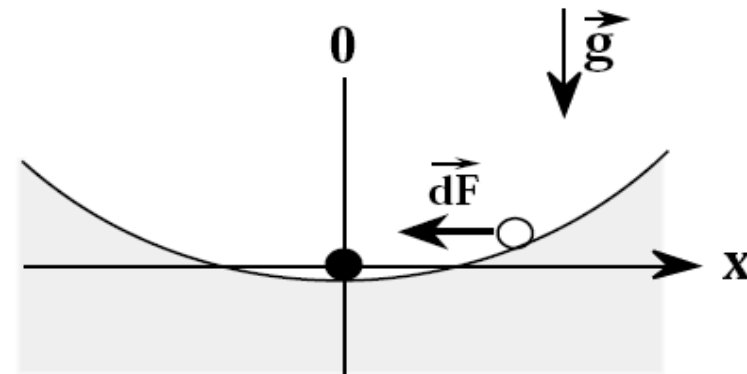
103-12

3. Dynamik

3 Arten von Gleichgewicht

1. Stabiles Gleichgewicht

Modell

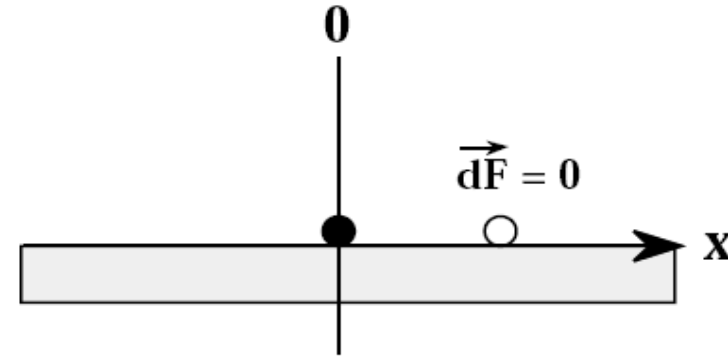


Gleichgewichtslage $x = 0$

Auslenkung um dx bewirkt eine rücktreibende Kraft \vec{F}

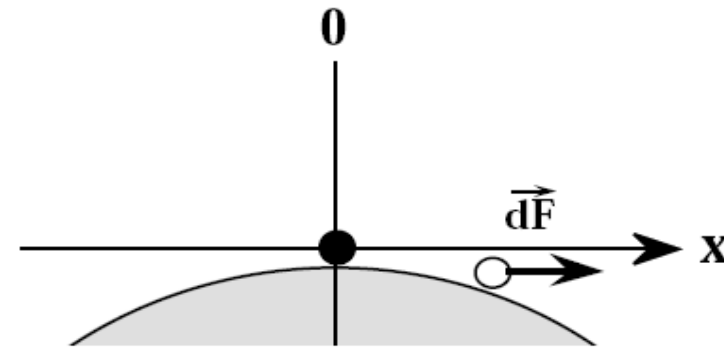
$$dF = -\alpha dx$$

2. indifferentes Gleichgewicht



es existieren unendlich viele Gleichgewichtslagen. Eine Auslenkung um Δx bewirkt keine Kraftwirkung.

3. labiles Gleichgewicht



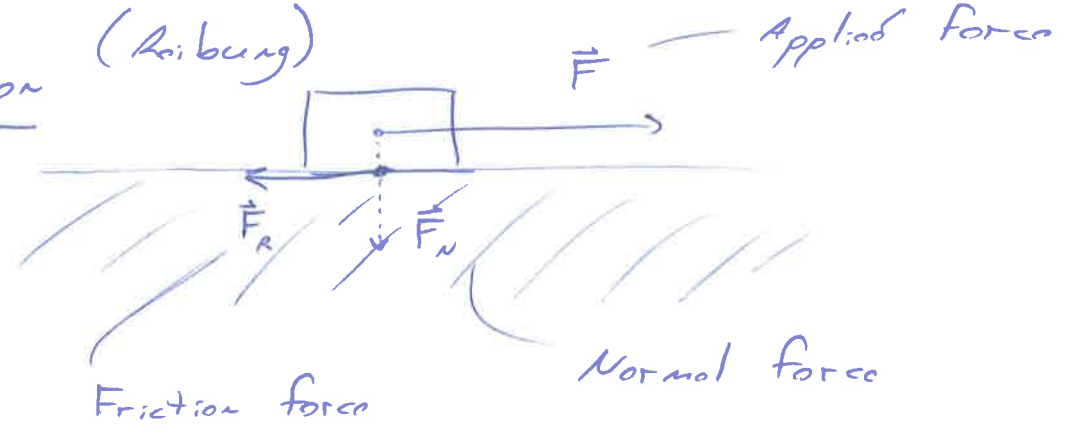
Gleichgewichtslage $x = 0$

Auslenkung um dx bewirkt eine Kraft in Richtung dx : $dF = \alpha dx$

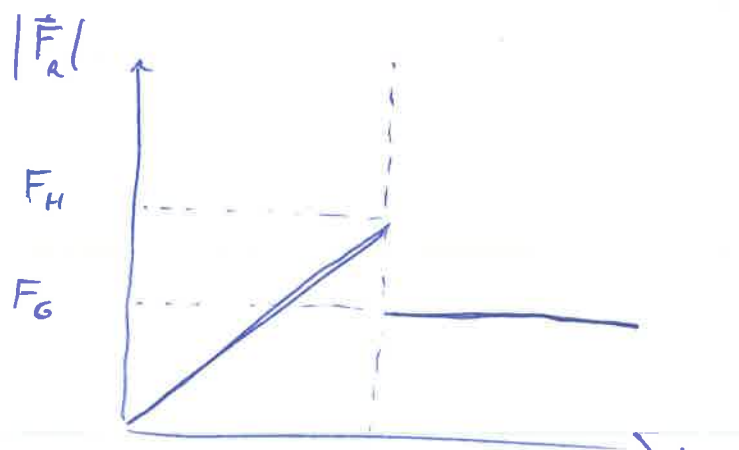
Neben diesen drei Gleichgewichtsarten existiert noch das metastabile Gleichgewicht.

Friction

(Reibung)



- Friction force acts opposite to direction of motion or applied force.
- Friction force acts at interface between object & surface.



$F_H \rightarrow$ Force of static friction

$F_G \rightarrow$ Force of dynamic friction

Object does not move

Object accelerates

Static

Dynamic

$$F_H = \mu_H |\vec{F}_N|$$

$$F_G = \mu_G |\vec{F}_N|$$

In general:

$$\mu_G < \mu_H$$

Static case:

$$|\vec{F}_R| = |\vec{F}| \quad \text{for} \quad |\vec{F}| \leq \mu_H |\vec{F}_N|$$

Dynamic case:

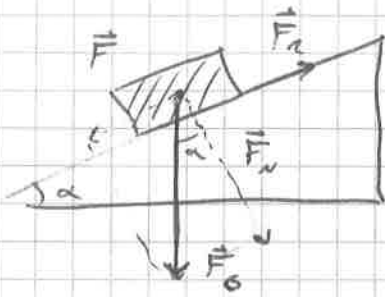
$$|\vec{F}_R| = \mu_G |\vec{F}_N|$$

$|\vec{F}_f|$ depends on :

- material (object & surface)
- normal force $|\vec{F}_n|$
- For static friction, on applied force $|\vec{F}|$

does not depend on :

- contact area A .



Gleichgewicht: $|\vec{F}_R| = |\vec{F}|$

Begint zu rutschen:

$$|\vec{F}| \geq |\vec{F}_{R, \max}|$$

$$mg \sin \alpha \geq \mu_h |\vec{F}_N|$$

$$mg \sin \alpha \geq \mu_h mg \cos \alpha$$

$$\frac{\sin \alpha}{\cos \alpha} \geq \mu_h$$

$$\tan \alpha \geq \mu_h$$

Grenzbedingung

$$\mu_h = \tan \alpha$$

Gleichförmiges Rutschen:

$$|\vec{F}| = |\vec{F}_R|$$

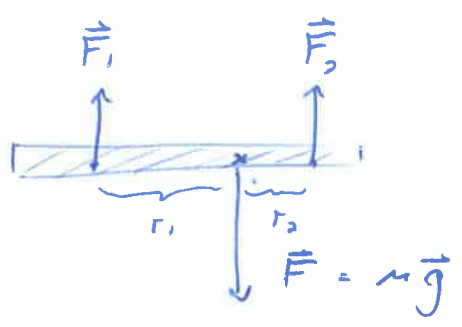
$$mg \sin \alpha = \mu_g |\vec{F}_N|$$

$$mg \sin \alpha = \mu_g mg \cos \alpha$$

$$\mu_g = \frac{\sin \alpha}{\cos \alpha} = \tan \alpha$$

$|\vec{F}_{\text{exp}}|$

4
Exp



Forces: $\vec{F}_1 + \vec{F}_2 - \vec{F}_3 = 0$

$F_1 + F_2 = mg$

Torques: $\vec{M}_1 + \vec{M}_2 = 0$

$-r_1 F_1 + r_2 F_2 = 0$

$r_1 F_1 = r_2 F_2$

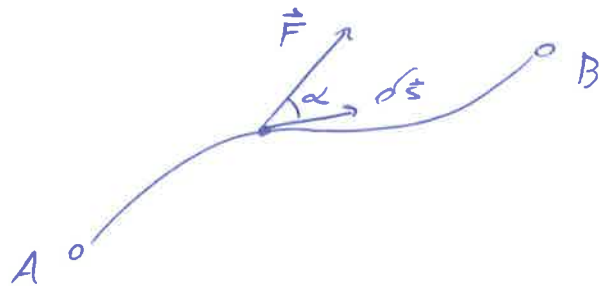
For $r_1 > r_2$

$\hookrightarrow F_1 < F_2$

If $F_1 < F_2$ then the friction against finger 1 is smaller than against finger 2. Then finger 1 slides more easily. This will bring finger 1 closer to the center of mass until $r_1 \leq r_2$. Then finger 2 will slide more easily... ultimately the two fingers will meet at the center of mass.

Work (Arbeit)

$$dW = \vec{F} \cdot d\vec{s} = |\vec{F}| |d\vec{s}| \cos \alpha$$



$$W = \int_A^B dW = \int_A^B \vec{F} \cdot d\vec{s}$$

$$W = \int_A^B \vec{F} \cdot d\vec{s}$$

W is a scalar
quantifying the work
done along the path
from A to B.

The units of work are $[N \cdot m]$

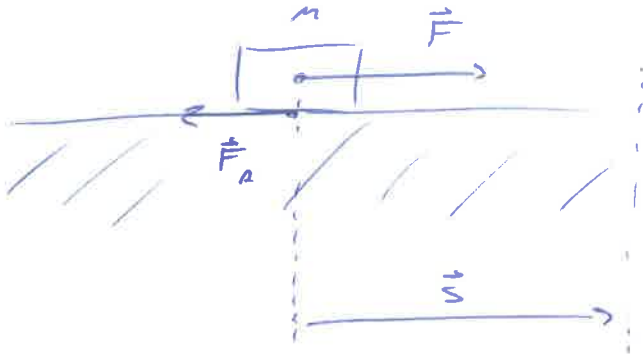
$$\downarrow$$

$$[kg \frac{m}{s^2} \cdot m]$$

$$\downarrow$$

$$[J] \leftarrow \text{definition}$$

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Work to move a sliding object :



$$W = \int \vec{F} \cdot d\vec{s} = \int \vec{F}_r \cdot d\vec{s} = \int \mu_0 \vec{F}_N \cdot d\vec{s}$$

> for constant velocity motion, $|\vec{F}| = |\vec{F}_r| = \text{constant}$ and $\vec{F} \parallel \vec{s}$

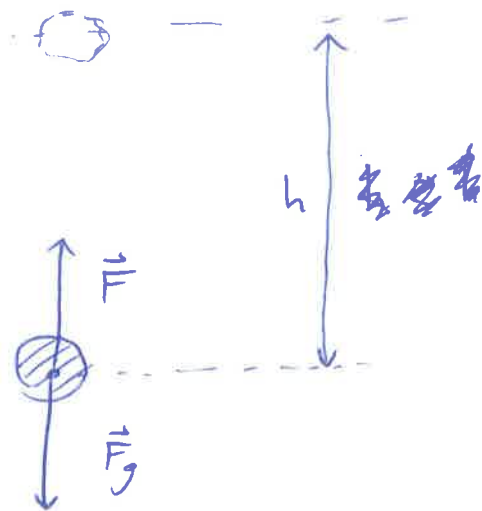
$$\therefore W = \int \mu_0 F_N ds = \mu_0 F_N s = \mu_0 m g s$$

$$W = \mu_0 m g s$$

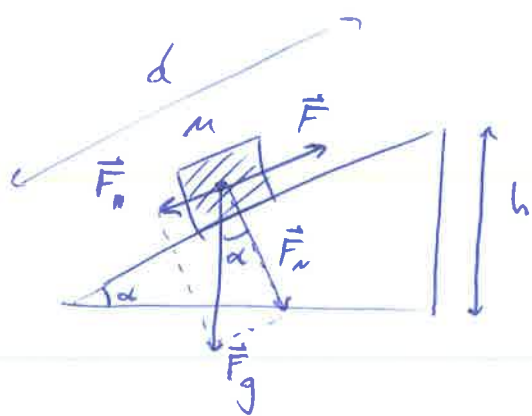
Work to lift a mass:

$$W = \int \vec{F} \cdot d\vec{s} = \int_0^h mg ds = mgh$$

\vec{F} must be equal & opposite to \vec{F}_g and \parallel to \vec{s} .



$$|W = mgh|$$



$$|\vec{F}_g| = mg$$

$$|\vec{F}_{g\parallel}| = mg \sin \alpha$$

$$|\vec{F}_{g\perp}| = mg \cos \alpha$$

$$W = \int \vec{F} \cdot d\vec{s} = \int_0^d |\vec{F}_{\parallel}| ds = |\vec{F}_{\parallel}| d$$

must be equal & opposite to $\vec{F}_{g\parallel}$ and \parallel to $d\vec{s}$.

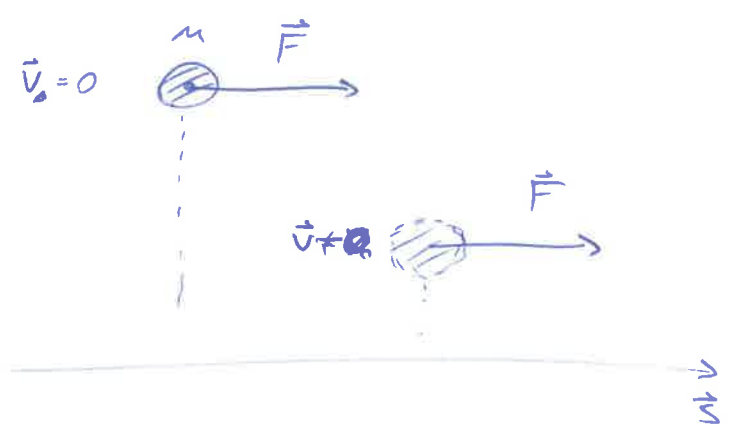
$$W = (mg \sin \alpha) d = mg \underbrace{(d \sin \alpha)}_h = mgh$$

$$|W = mgh|$$

Work accelerating an Object

$$W = \int \vec{F} \cdot d\vec{s}$$

$$\vec{F} \parallel d\vec{s}$$



$$W = \int F ds$$

$$ds = v dt$$

$$F = m \frac{dv}{dt}$$

$$W = \int m \frac{dv}{dt} v dt = m \int v \frac{dv}{dt} dt = m \int_0^{v_f} v dv$$

$$\boxed{W = \frac{1}{2} m v_f^2}$$

← Work accelerating to velocity v_f from ~~rest~~ rest

If initial velocity is v_0 and final velocity v_f , then

$$W = m \int_{v_0}^{v_f} v dv = \frac{1}{2} m (v_f^2 - v_0^2)$$

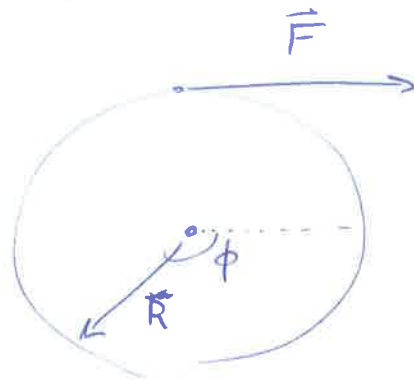
$$W = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_0^2$$

Exp

Work Rotating an object:

$$W = \int \vec{F} \cdot d\vec{s}$$

$$\vec{F} \parallel d\vec{s}$$



$$W = \int F ds$$

$$\left. \begin{aligned} ds &= R d\phi \\ d\phi &= \omega dt \end{aligned} \right\} ds = R\omega dt$$

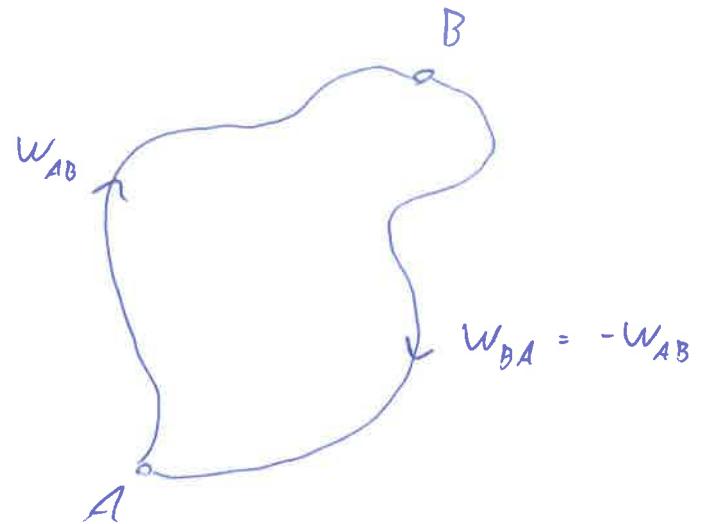
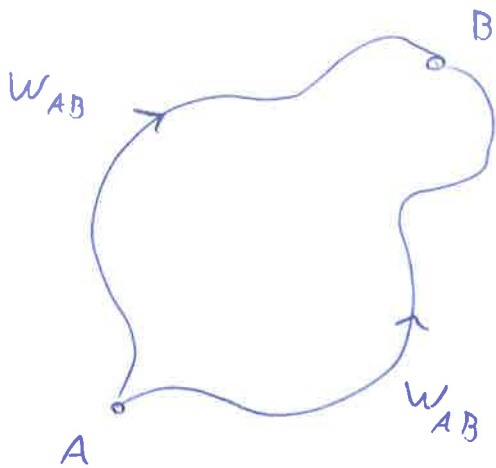
$$F = \frac{|\dot{L}|}{R} = \frac{1}{R} \left| \frac{dL}{dt} \right| = \frac{1}{R} \frac{d}{dt} (J\omega)$$

$$F = \frac{J}{R} \frac{d\omega}{dt}$$

$$W = \int \frac{J}{R} \frac{d\omega}{dt} R\omega dt = J \int_0^{\omega} \omega d\omega = \frac{1}{2} J \omega^2$$

$$\boxed{W = \frac{1}{2} J \omega^2}$$

Conservative Forces



$$W_{AB} = \int_A^B \vec{F} \cdot d\vec{s}$$

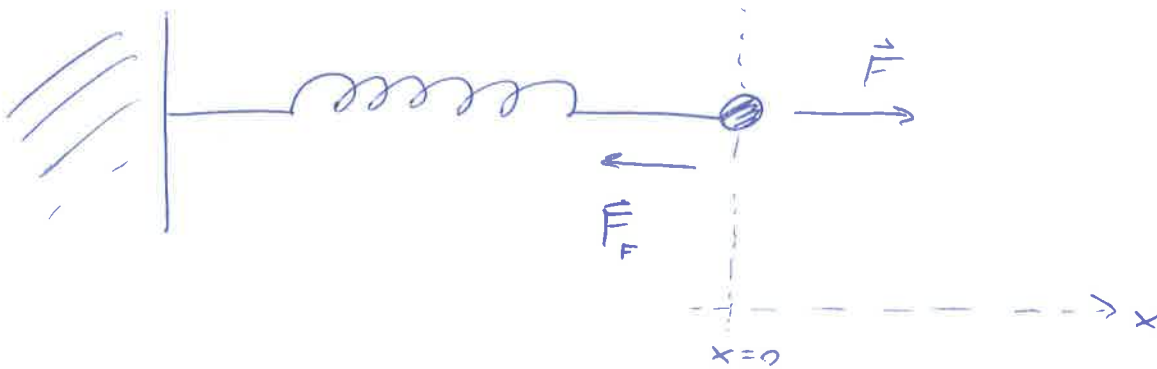
Work does not depend on path taken for conservative forces \vec{F} .

$$\therefore W_{BA} = \int_B^A \vec{F} \cdot d\vec{s} = - \int_A^B \vec{F} \cdot d\vec{s} = -W_{AB}$$

$$W_{ABC} = W_{AB} + W_{BA} = W_{AB} - W_{AB} = 0$$

$$W_{ABC} = 0$$

Work deforming a Spring



Hooke's Law : $\vec{F}_F = -D\vec{x}$

$$W = \int \vec{F} \cdot d\vec{x} = \int D\vec{x} \cdot d\vec{x} = \int_0^x D x dx$$

must be equal & opposite ~~to~~ to spring force \vec{F}_F .

$$W = \frac{1}{2} D x^2$$

Exp