Introduction to Physics I

For Biologists, Geoscientists, & Pharmaceutical Scientists

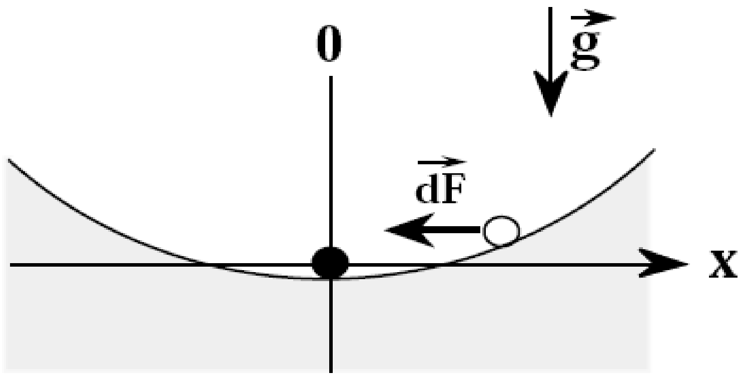
Reibungskoeffizienten

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

3 Arten von Gleichgewicht

1. Stabiles Gleichgewicht

Modell

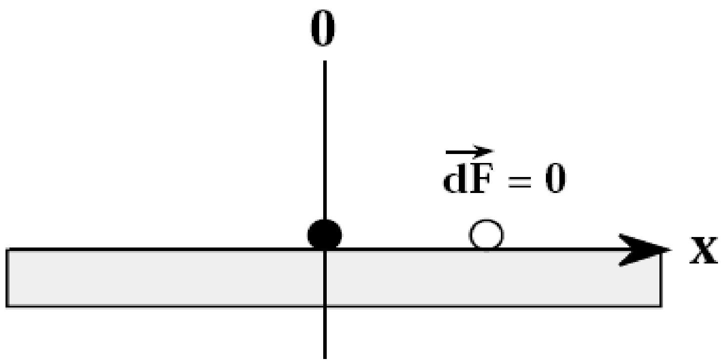


Gleichgewichtslage $x = 0$

Auslenkung um dx bewirkt eine rücktreibende Kraft $\vec{F}$
$dF = -\alpha\, dx$

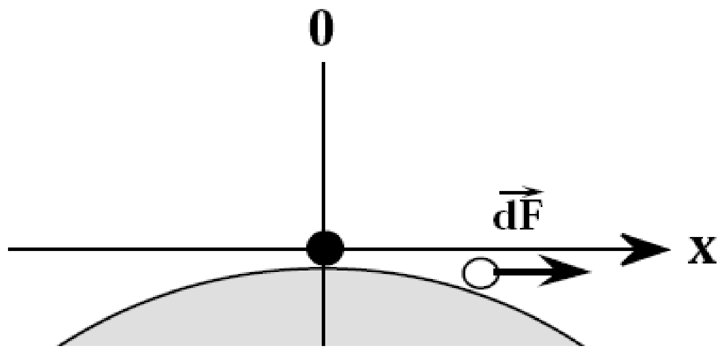
3 Arten von Gleichgewicht

2. indifferentes Gleichgewicht



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

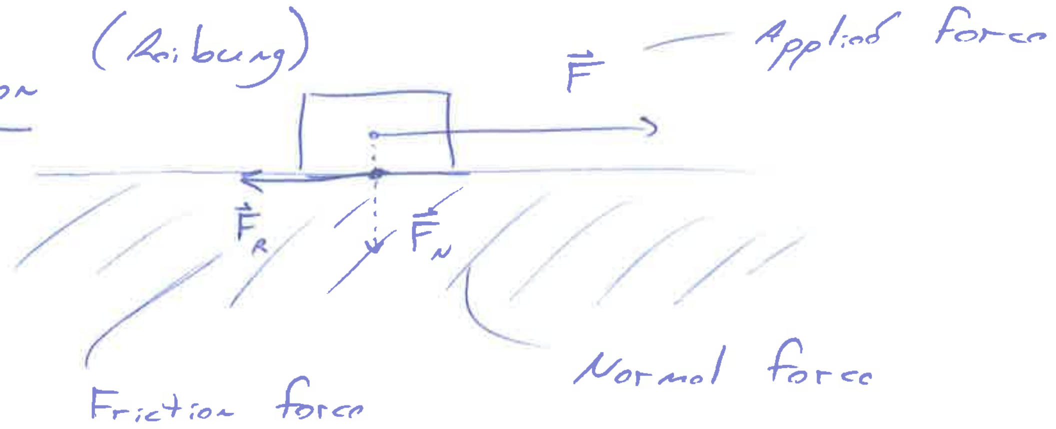
3. labiles Gleichgewicht



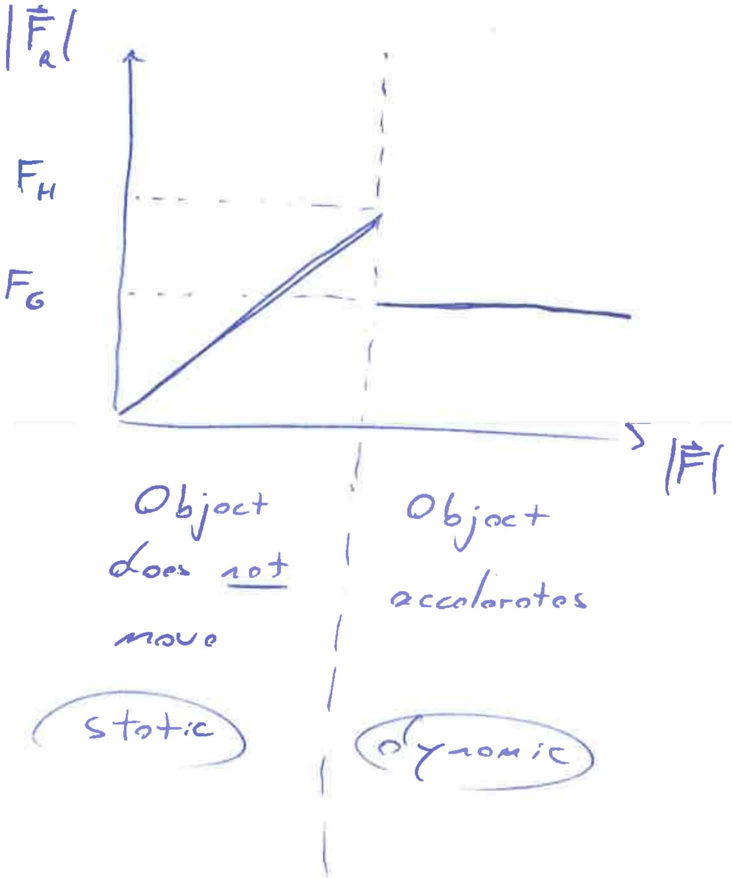
Gleichgewichtslage $x = 0$
Auslenkung um dx bewirkt eine Kraft in Richtung dx: $dF = \alpha\, dx$

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

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

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

In general:

$$\mu_G < \mu_H$$

Static case: $\quad |\vec{F}_R| = |\vec{F}| \quad$ for $\quad |\vec{F}| \leq \mu_H |\vec{F}_N|$

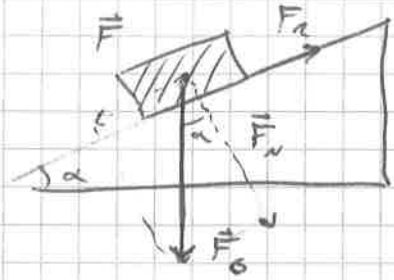
Dynamic case: $\quad |\vec{F}_R| = \mu_G |\vec{F}_N|$

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

Beginnt zu rutschen:

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

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

$$\cancel{mg}\sin\alpha \geq \mu_h \cancel{mg}\cos\alpha$$

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

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

Grenzbedingung $\longrightarrow$ $\mu_h = \tan\alpha$

Gleichförmiges Rutschen:

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

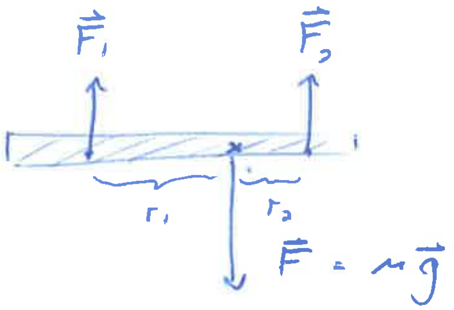
$$mg\sin\alpha = \mu_g |\vec{F}_N|$$

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

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

$\boxed{\text{Exp}}$

4 $\boxed{\text{Exp}}$



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

$$\boxed{F_1 + F_2 = mg}$$

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

$$-r_1 F_1 + r_2 F_2 = 0$$

$$r_1 F_1 = r_2 F_2$$

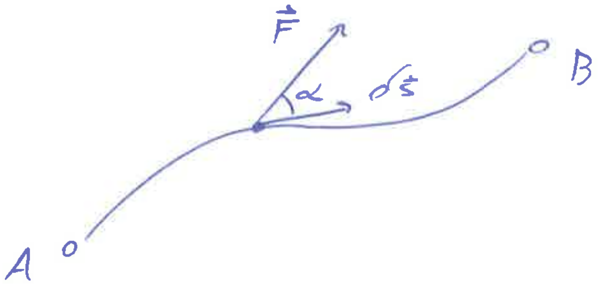
$\therefore$ For $r_1 > r_2$

$\hookrightarrow F_1 < F_2$

If $F_1 < F_2$ then the friction against finger 1 is smaller than against finger 2. There 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)

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



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

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

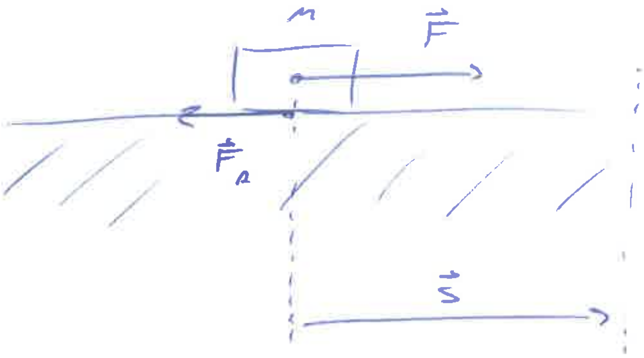
W is a scalar quantifying the work done along the path from A to B.

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

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

$$[J]$$ ← definition

Work to move a sliding object:



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

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

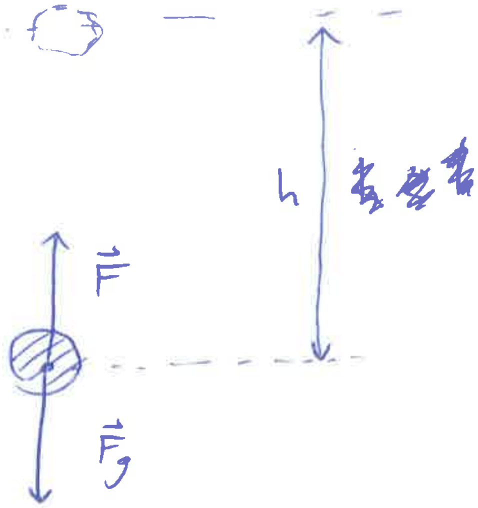
$$\therefore \quad W = \int \mu_G F_N \, ds = \mu_G F_N s = \mu_G m g s$$

$$W = \mu_G m g s$$

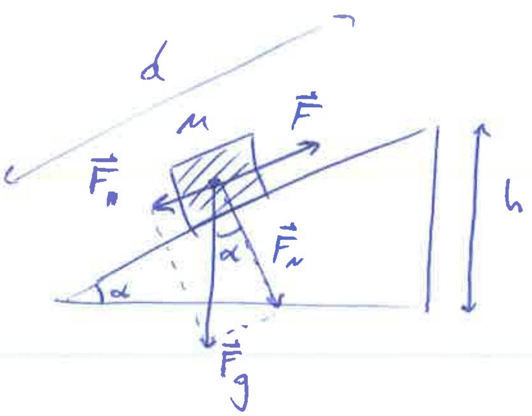
Work to lift a mass:

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

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



$$\boxed{W = mgh}$$



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

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

$$|\vec{F}_N| = mg \cos\alpha$$

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

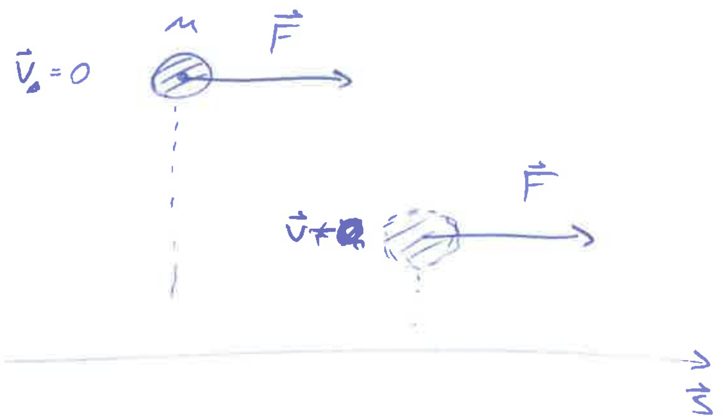
must be equal & opposite to $\vec{F}_\parallel$ and $\parallel$ to $d\vec{s}$.

$$W = (mg \sin\alpha) \, d = mg \underbrace{(d \sin\alpha)}_{h} = mgh$$

$$\boxed{W = mgh}$$

Work accelerating an Object

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



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

$\therefore$

$$W = \int F\, ds \qquad ds = v\, dt$$

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

$$W = \int m \frac{dv}{dt} v\, dt = m \int v \frac{dv}{dt} dt = m \int_0^{v_1} v\, dv$$

$$\boxed{W = \frac{1}{2} m v_1^2}$$

$\leftarrow$ Work accelerating to velocity v_1 from rest

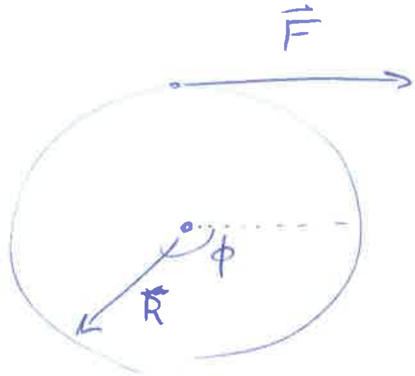
If initial velocity is v_0 and final velocity v_1, then

$$W = m \int_{v_0}^{v_1} v\, dv = \frac{1}{2} m \left(v_1^2 - v_0^2\right)$$

$$W = \frac{1}{2} m v_1^2 - \frac{1}{2} m v_0^2$$

$\boxed{\text{Exp}}$

Work Rotating an object:



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

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

$$W = \int F\, ds$$

$$\left.\begin{array}{l} ds = R\, d\phi \\ d\phi = \omega\, dt \end{array}\right\} \; ds = R\omega\, dt$$

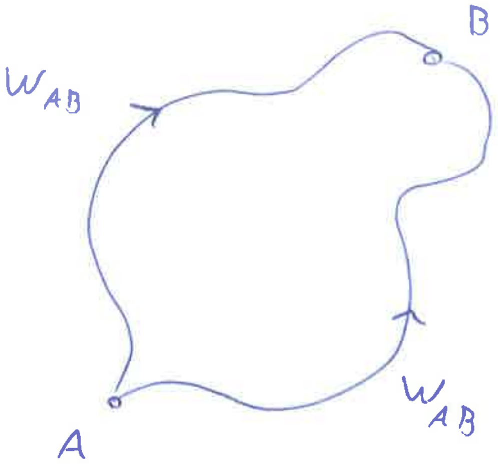
$$F = \frac{|\vec{M}|}{R} = \frac{1}{R}\left|\frac{d\vec{L}}{dt}\right| = \frac{1}{R}\frac{d}{dt}(J\omega)$$

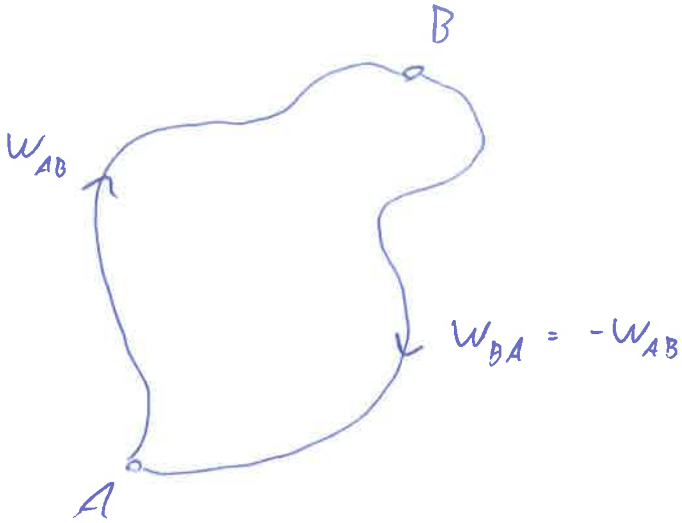
$$F = \frac{J}{R}\frac{d\omega}{dt}$$

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

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

Conservative Forces





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

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

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

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

$$W_{ABC} = 0$$

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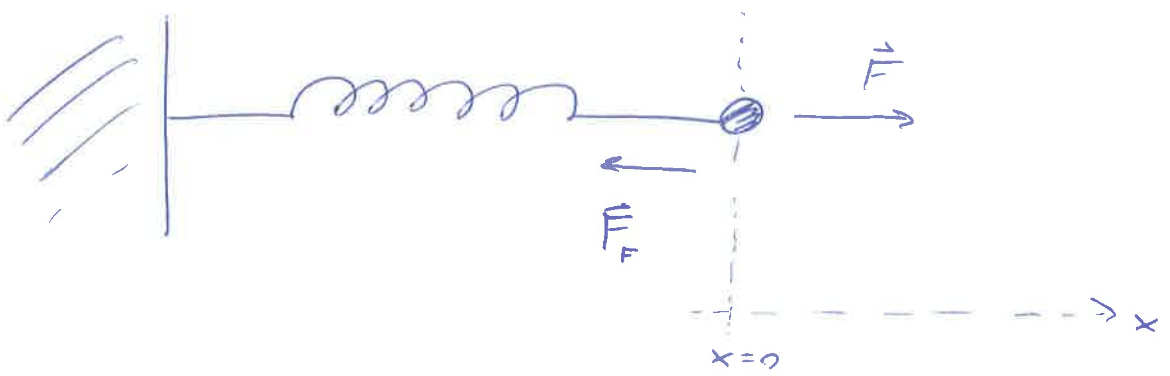
Work deforming a Spring



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 spring force $\vec{F}_F$.

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

Expl