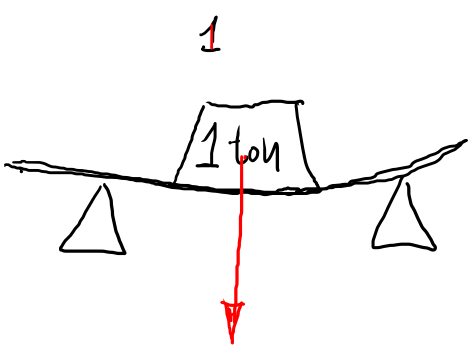
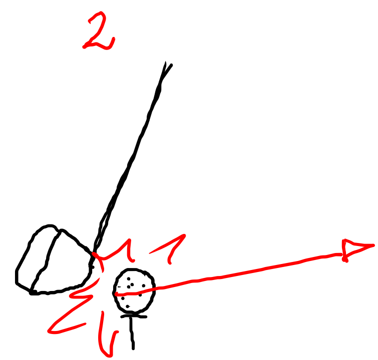
DINAMICA

FORZE (VETTORI)

1. DEFORMAZIONE su un corpo vincolato
2. MOVIMENTO su un corpo libero

1. allungamento di una molla (dinamometro)
2. accelerazione di una massa





FORZE FONDAMENTALI IN NATURA

GUT

Forza gravitazionale (Newton, 1686)
Forza elettrica
Forza magnetica
Forza nucleare debole
Forza nucleare forte

forza elettromagnetica (Maxwell, 1865)

forza elettrodebole

SUSY

I PRINCIPI DELLA DINAMICA
(Leggi di Newton)

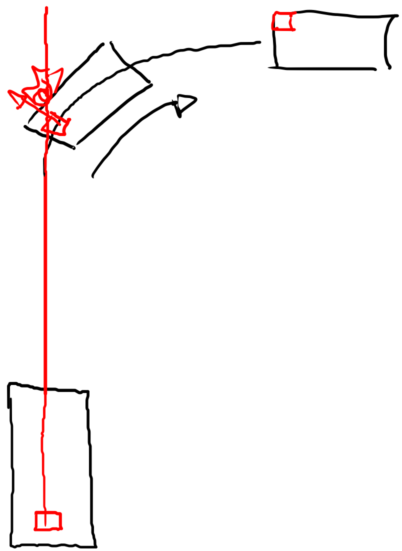
I) Legge di Inerzia

$$F_{est} = 0 \Rightarrow \begin{cases} \text{quiete} \\ \text{moto rettilineo uniforme} \end{cases}$$

sistema di riferimento è INERZIALE

$\Updownarrow$

vale la legge d'inerzia



II PRINCIPIO

In un sistema inerziale $\vec{F} = m\vec{a}$ $\qquad \vec{a} = \frac{\vec{F}}{m}$

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

risultante delle forze,
ovvero la somma di <u>tutte</u> le forze

MKS $\quad 1\,N = 1\,kg \cdot 1\,\frac{m}{s^2} = 1\,\frac{kg\,m}{s^2}$

cgs $\quad 1$ dyne $= 1\,g \cdot 1\,\frac{cm}{s^2} = 10^{-3}\,kg \cdot \frac{10^{-2}\,m}{s^2} = 10^{-5}\,N$

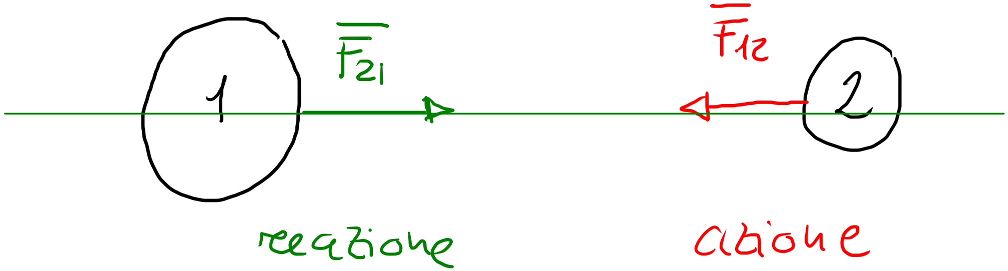
dina

III PRINCIPIO
(Azione e Reazione)

Dati due corpi, 1 e 2
se 1 esercita $\vec{F}_{12}$ su 2 allora
2 esercita $\vec{F}_{21}$ su 1 e $\vec{F}_{21} = -\vec{F}_{12}$

(inoltre $\vec{F}_{21}$ ed $\vec{F}_{12}$ hanno la stessa retta di applicazione)

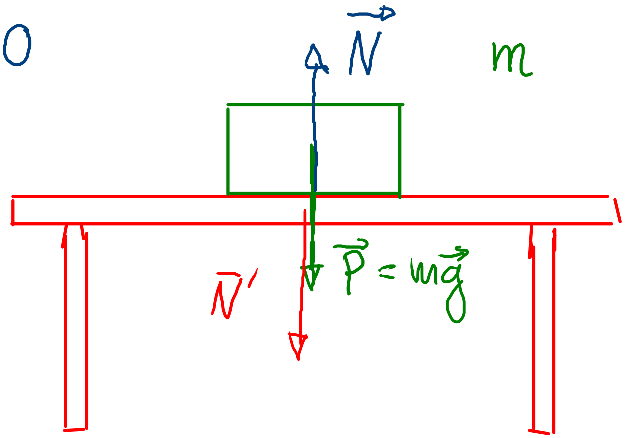
il corpo 1 attira verso di sè il corpo 2



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

$$\sum \vec{F} = 0$$

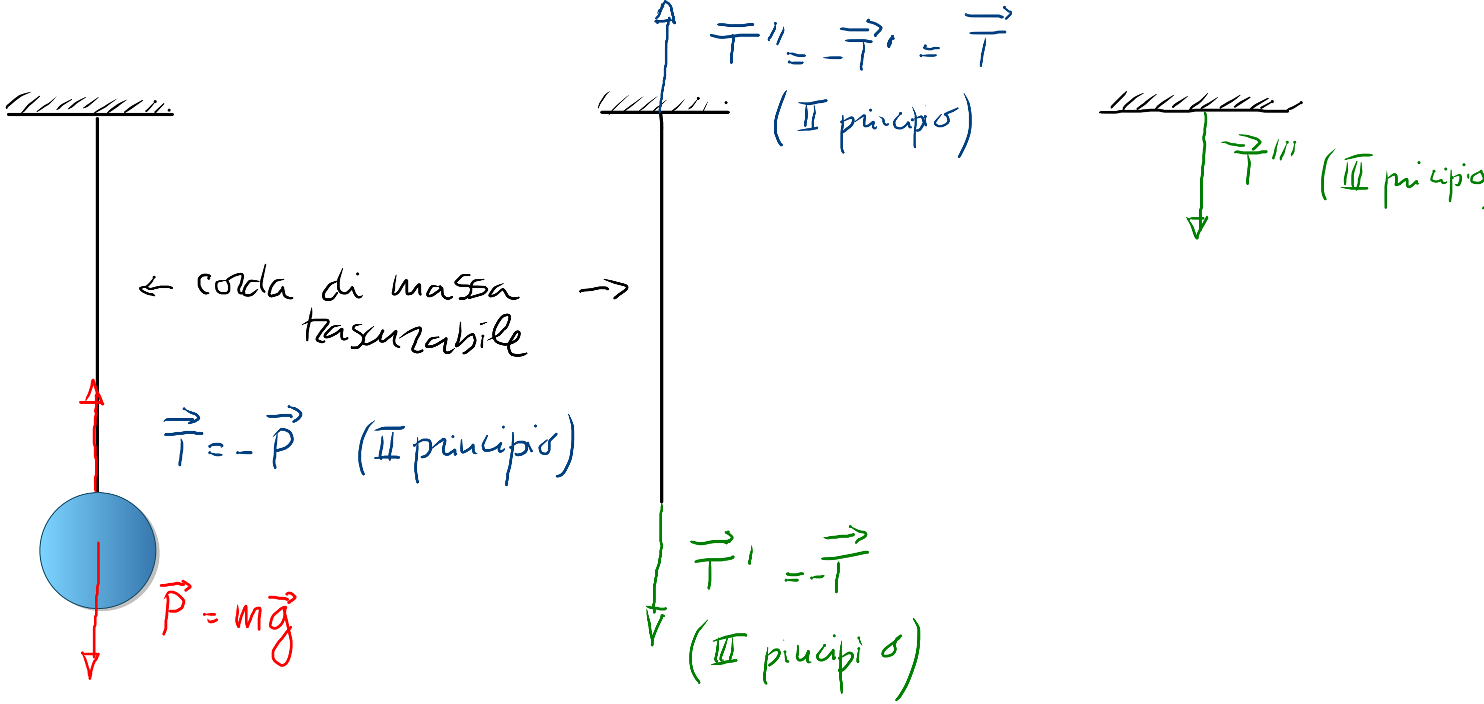
$$\sum \vec{F} = \vec{P} + \vec{N} = 0$$



$\vec{N} = -\vec{P}$ II principio

$\vec{N}' = -\vec{N}$ III principio

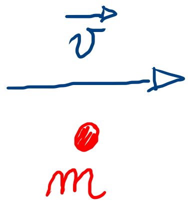
$\vec{N}' = \vec{P}$



$$\vec{P} = \vec{T}' = \vec{T}''' = -\vec{T} = -\vec{T}''$$

$$\vec{T} = \vec{T}''$$

QUANTITÀ DI MOTO ($\vec{q}$)



$$\vec{q} = m\vec{v}$$

unità: $\quad Kg\,\dfrac{m}{s}$

FORMULAZIONE DEL II PRINCIPIO UTILIZZANDO $\vec{q}$

$$\vec{F} = m\vec{a} \qquad\qquad \vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{F} = m\frac{d\vec{v}}{dt} = \frac{d}{dt}(m\vec{v}) = \frac{d\vec{q}}{dt}$$

$$\boxed{\vec{F} = \frac{d\vec{q}}{dt}}$$

PRINCIPIO DI CONSERVAZIONE DELLA Q. di Moto

Sistema ad N corpi $\quad 1, 2, \dots, N$

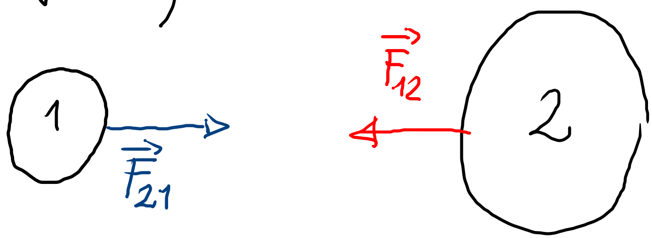
$\qquad\qquad\qquad\qquad\quad \vec{q}_1, \vec{q}_2, \dots, \vec{q}_N$

$$\Sigma \vec{F}_{ext} = 0 \quad \Rightarrow \quad \sum_{i=1}^{N} \vec{q}_i = \text{costante}$$

(non dipende dal tempo)

DIM. (nel caso $N = 2$)

$$\vec{F}_{21} = m_1 \vec{a}_1 \overset{!}{=} \frac{d}{dt}\vec{q}_1$$



$$\vec{F}_{12} = m_2 \vec{a}_2 \overset{!}{=} \frac{d}{dt}\vec{q}_2$$

$$\vec{F}_{21} = -\vec{F}_{12} \qquad \text{(III principio)}$$

$$= \vec{F}_{12} + \vec{F}_{21} = 0$$

$$\overset{!}{=} \frac{d}{dt}\vec{q}_2 + \frac{d}{dt}\vec{q}_1 = \frac{d}{dt}(\vec{q}_2 + \vec{q}_1) = \frac{d}{dt}\left(\Sigma_i \vec{q}_i\right) = 0 \Leftrightarrow \Sigma_i \vec{q}_i$$

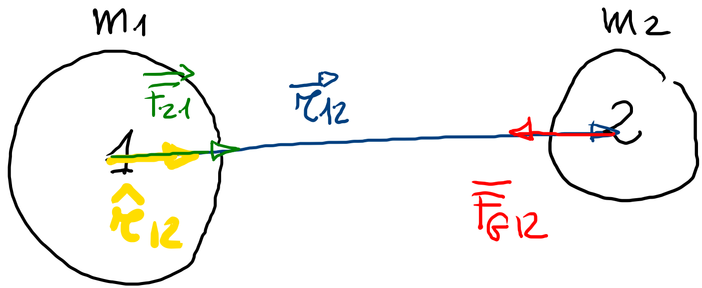
è costante

FORZA PESO

$$\vec{P} = m\vec{g} \qquad g = 9{,}8 \ \frac{m}{s^2}$$

FORZA GRAVITAZIONALE

$$\boxed{\vec{F}_{G12} = -G\,\frac{m_1 \cdot m_2}{|\vec{r}_{12}|^2}\,\hat{r}_{12}}$$

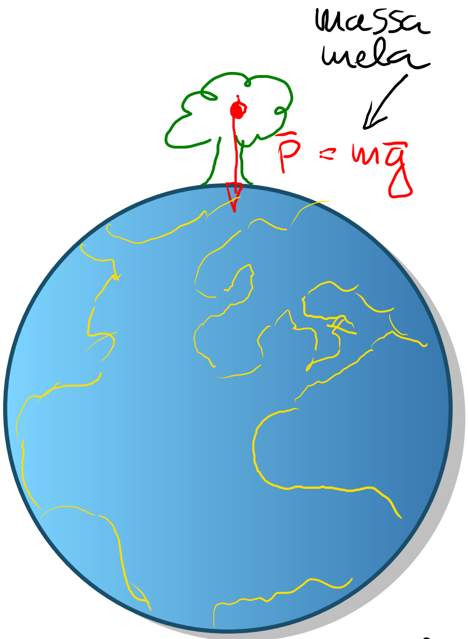


$$G = 6{,}67 \cdot 10^{-11} \ \frac{N\,m^2}{Kg^2}$$

$$\hat{r}_{12} = \frac{\vec{r}_{12}}{|\vec{r}_{12}|}$$

$$\vec{F}_{G21} = -\vec{F}_{G12}$$

(esiste per il III principio)



$M_T = 5{,}97 \cdot 10^{24}$ kg

$R_T = 6{,}37 \cdot 10^{6}$ m

massa mela

$$\vec{F}_{GTM} = -G\,\frac{M_T\, m}{R_T^{\,2}}\;\hat{R}_T$$

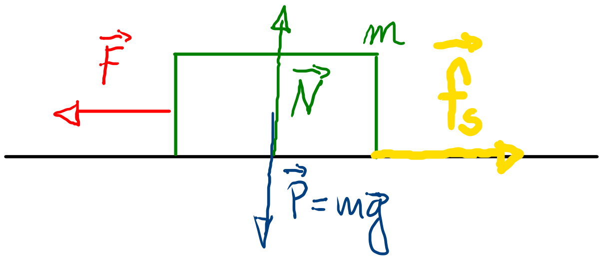
direzione & verso OK

$$|\vec{P}| = |\vec{F}_{GTM}|$$

$$\cancel{m}g = G\,\frac{M_T\,\cancel{m}}{R_T^{\,2}} = \frac{6{,}67\cdot 10^{-11}\,\frac{N\cancel{m^2}}{kg^{\cancel{2}}}\cdot 5{,}97\cdot 10^{24}\,\cancel{kg}}{(6{,}37\cdot 10^{6}\,\cancel{m})^2}$$

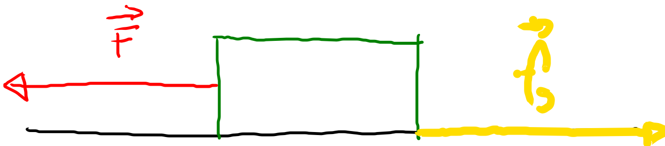
$$\left(\frac{6{,}67\cdot 5{,}97}{6{,}37^2}\right)10\cdot\frac{N}{kg}\left(=\frac{m}{s^2}\right) =$$

FORZA D'ATTRITO STATICO

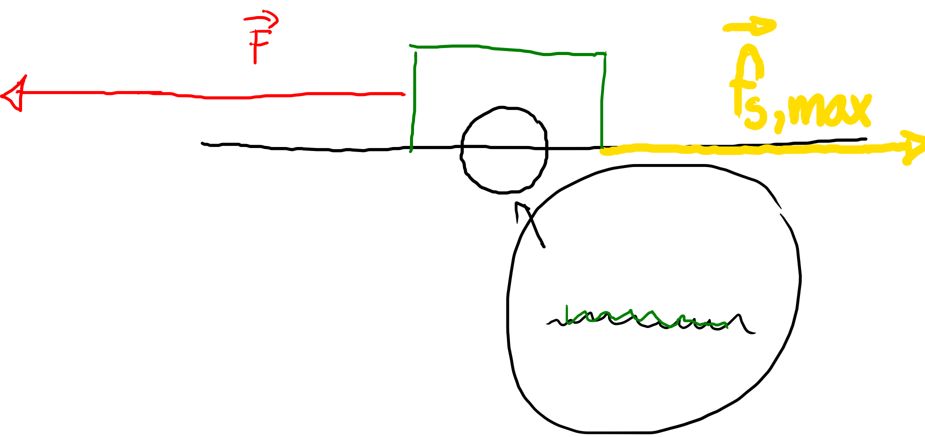


$$\vec{N} + \vec{P} = 0$$

$$\vec{F} + \vec{f}_s = 0$$



$$\vec{F} + \vec{f}_s = 0$$

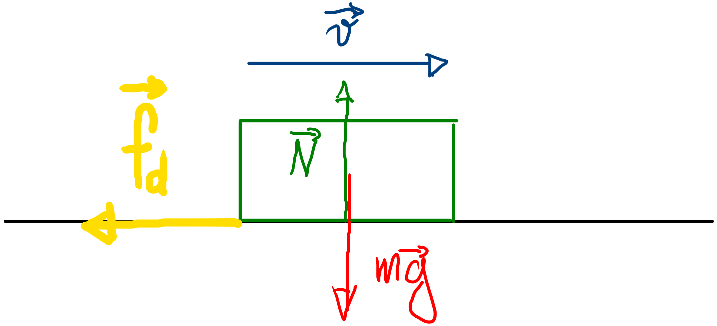


$$|\vec{F}| > |\vec{f}_{s,max}|$$

$$|\vec{f}_{s,max}| = \mu_s \cdot |\vec{N}|$$

materiali

FORZA D'ATTRITO DINAMICO



$$\vec{N} = m\vec{g}$$

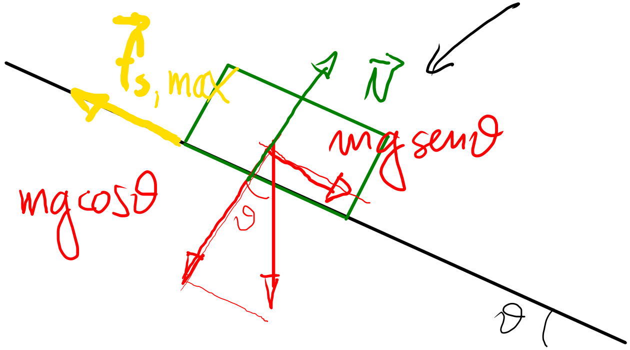
$$|\vec{f}_d| = \mu_d \cdot |\vec{N}|$$

materiali

μ_s e $\mu_d < 1$

$\mu_d < \mu_s$

non si muove!



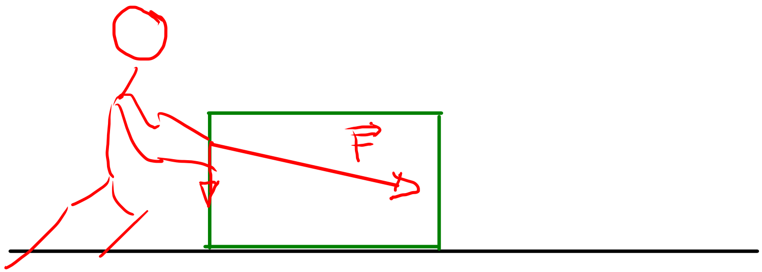
$$|\vec{N}| = mg\cos\vartheta$$

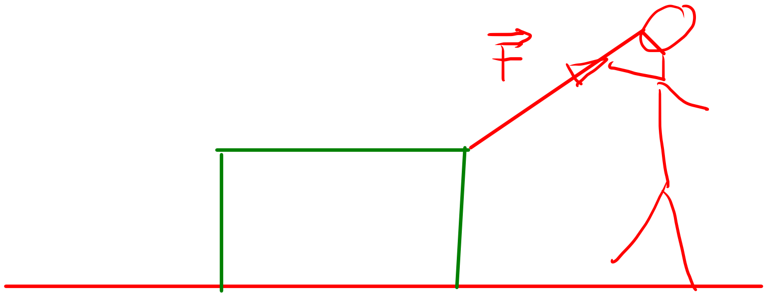
$$|\vec{f}_{s,max}| \stackrel{def}{=} \mu_s |\vec{N}| = \mu_s mg\cos\vartheta$$

$$|\vec{f}_{s,max}| = mg\,sen\vartheta$$

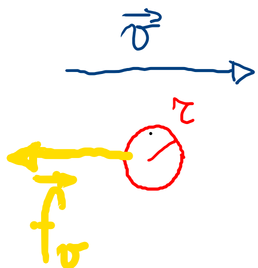
$$\cancel{mg}\,sen\vartheta = \mu_s \cancel{mg}\cos\vartheta$$

$$\mu_s = \frac{sen\vartheta}{\cos\vartheta} = tg\vartheta$$


$\vec{F}$


$\vec{F}$

ATTRITO VISCOSO



Stokes: $\vec{f}_v = -6\pi r \eta \vec{v}$

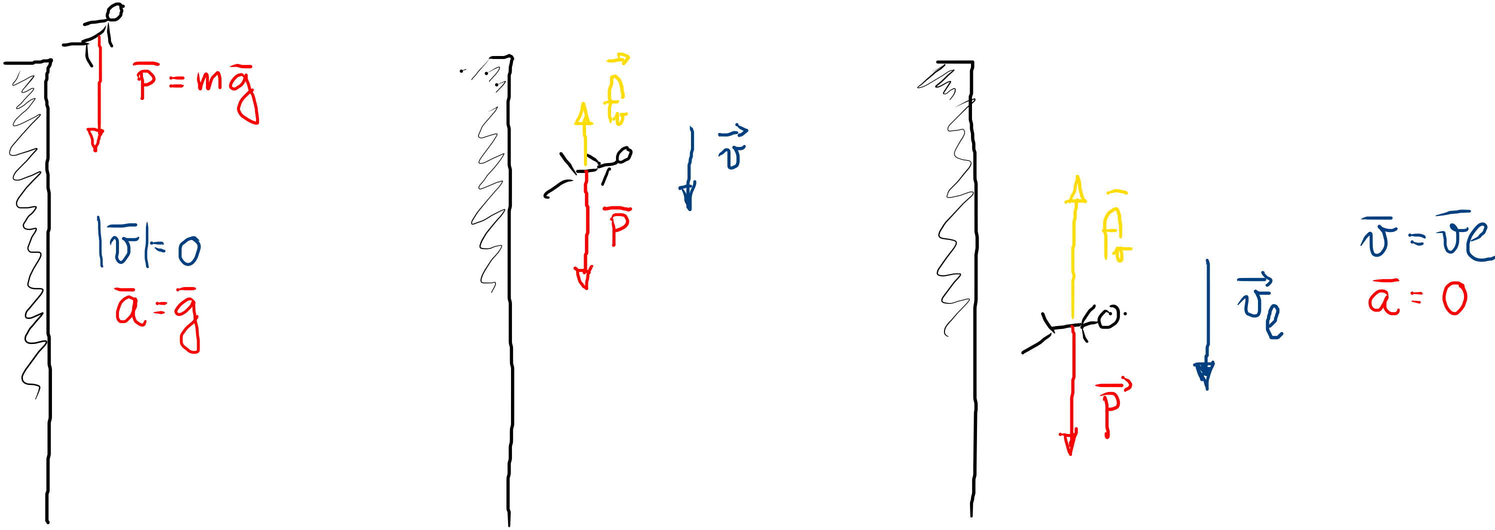
viscosità del fluido

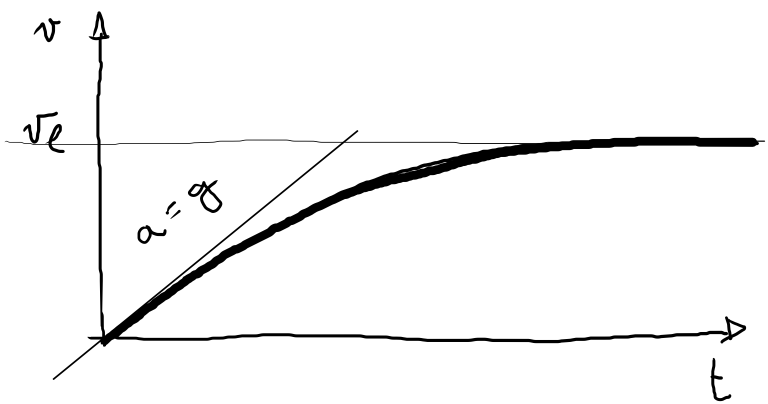
$$[\eta] = \frac{[M][\cancel{L}][T^{\cancel{-2}\,-1}]}{[L][\cancel{L}][\cancel{T^{-1}}]} = [M][L^{-1}][T^{-1}]$$

in c.g.s $\Rightarrow \dfrac{g}{cm \cdot s} =$ poise (Poiseuille)

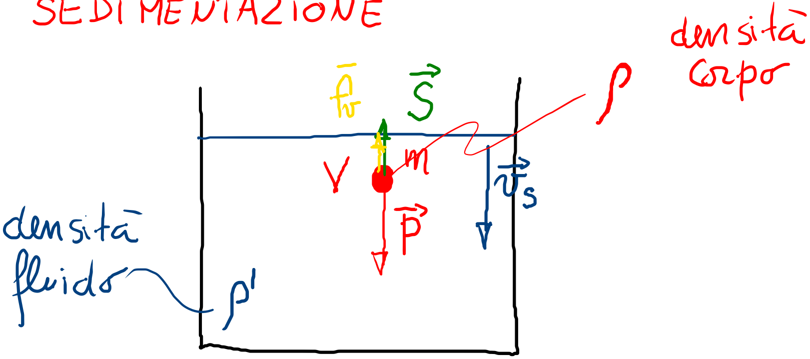
$$SI \Rightarrow \frac{kg}{m \cdot s} = \frac{10^3\, g}{10^2\, cm \cdot s} = 10 \text{ poise} = 1 \text{ decapoise}$$

BASE JUMPING





SEDIMENTAZIONE



$$\rho = \frac{m}{V} \qquad \frac{kg}{m^3} \qquad \frac{g}{cm^3}$$

$$\rho_{H_2O} = 1\,\frac{g}{cm^3} = \frac{10^{-3}\,kg}{(10^{-2}\,m)^3} = \frac{10^{-3}\,kg}{10^{-6}\,m^3} = 10^3\,\frac{kg}{m^3}$$

Raggiunta $\vec{v}_s$, velocità di sedimentazione

$$\Sigma\vec{F} = \vec{P} + \vec{S} + \vec{f}_v = 0$$ vettori

$$|\vec{P}| - |\vec{S}| - |\vec{f}_v| = 0$$ moduli

$$(*) \quad P - S - f_v = 0$$ moduli in notazione PIGRA

$$S = \rho' V g$$

$$P = mg = \rho V g$$

$$f_v = 6\pi r \eta v_s$$

* $P - S - f_v = 0$

$$\rho V g - \rho' V g - 6\pi r \eta v_s = 0$$

$$V = \frac{4}{3}\pi r^3$$

$$v_s = \frac{\rho V g - \rho' V g}{6\pi r \eta} = \frac{V g(\rho - \rho')}{6\pi r \eta}$$

$$= \frac{{}^{2}\cancel{4}\,\cancel{\pi}\, r^{\cancel{3}\,2}\, g(\rho-\rho')}{3 \cdot {}_{3}\cancel{6}\,\cancel{\pi}\,\cancel{r}\,\eta} = \frac{2}{9}\,\frac{r^2(\rho-\rho')}{\eta}\,g$$

VES : velocità di eritro-sedimentazione

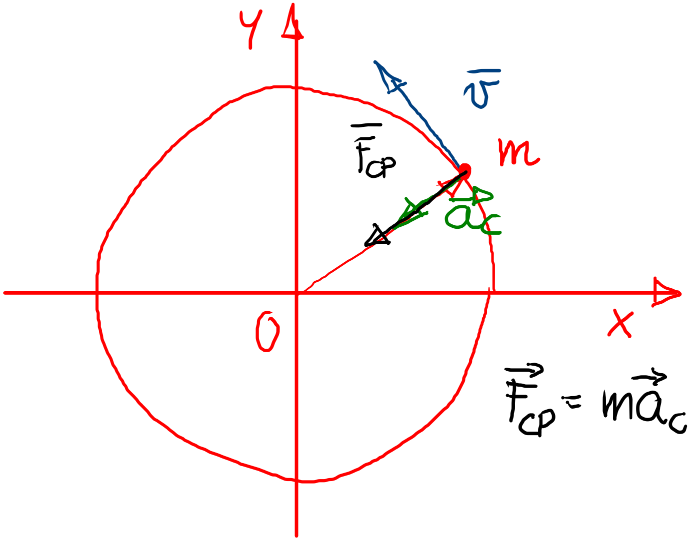
VES $\leq$ 7 mm/h OK

$>$ 15 mm/h ?

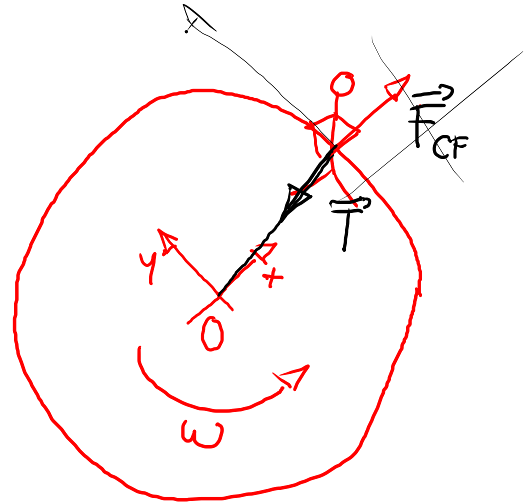
centrifuga: $g \longrightarrow \omega^2 R$ ω velocità angolo

$\sim 10^4 - 10^6\, g$

FORZA CENTRIPETA / CENTRIFUGA



$$\vec{F}_{CP} = m\vec{a}_c$$



$$|\vec{v}| = \text{cost.} = \omega R$$

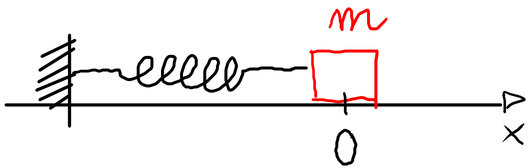
$$|\vec{a}| = \text{cost.} = \frac{v^2}{R} = \omega^2 R$$

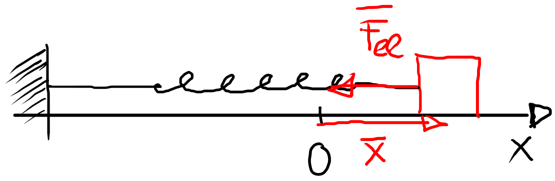
$$\omega = 2\pi\nu = \frac{2\pi}{T}$$

T è il periodo

$$\vec{T} + \vec{F}_{CF} = 0$$

FORZA ELASTICA





costante elastica

$$\boxed{\vec{F} = -K\vec{x}}$$

legge di Hooke

$$[K] = \frac{N}{m} \qquad K \sim 10^3 \frac{N}{m}$$

$$\begin{cases} F = -Kx \\ F = ma \end{cases}$$

moto armonico

$$ma = -Kx$$

$$a = -\frac{K}{m}x \quad \longleftrightarrow \quad a = -\omega^2 x$$

$$\boxed{\omega^2 = \frac{K}{m}} \qquad \omega = \sqrt{\frac{K}{m}}$$

$$\boxed{\omega = \frac{2\pi}{T}} \qquad T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{K}}$$