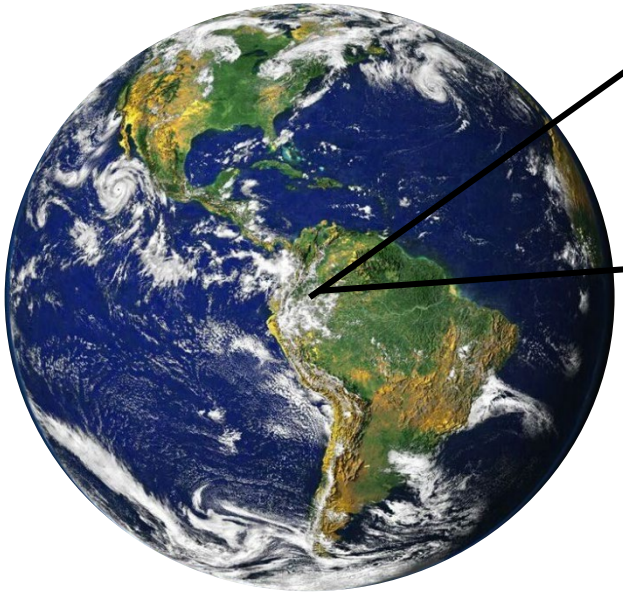
Força a distància: llei de gravitació universal

[vàlida a la Terra i al cel]

$$\vec{F} = G\frac{m_1 m_2}{|\vec{r}_{12}|^2}\hat{r}_{12}$$

$$G = 6{,}67384 \cdot 10^{-11}\,\frac{\mathrm{Nm}^2}{\mathrm{Kg}^2}$$



$\vec{r}_{12}$

$\vec{r}_{12}$

$$\vec{F} = G\frac{M_T m}{|\vec{r}_{12}|^2}\hat{r}_{12}$$

$$M_T = 5{,}98 \cdot 10^{24} Kg \quad R_T \approx 6400\ \mathrm{Km}$$

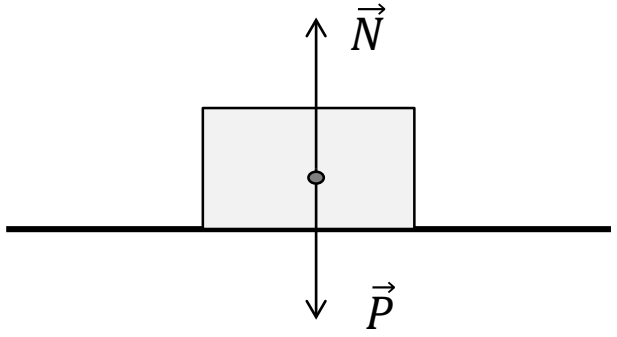
$$|\vec{F}| = mg \Rightarrow g = G\frac{M_T}{{R_T}^2} \approx 9{,}8\ {}^{\mathrm{m}}/_{\mathrm{s}^2}$$

Tots els cossos a la mateixa distància del centre de la Terra cauen amb la mateixa acceleració

$$|\vec{F}_{12}| = |\vec{F}_{21}| \Rightarrow M_T a_T = mg \Longrightarrow a_T = \frac{m}{M_T}g$$

Forces de contacte

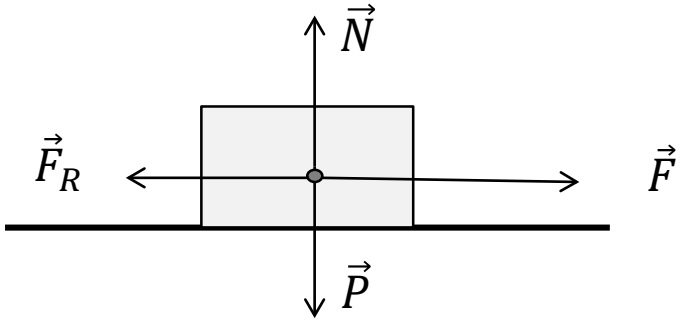
- ***Normals*** a la superfície de contacte



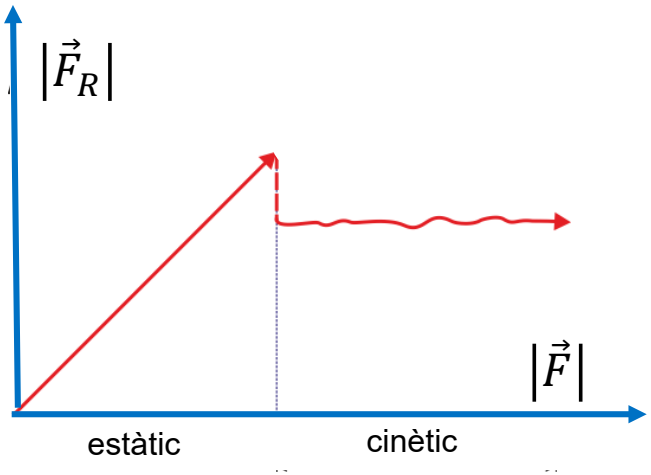
- ***Tangencials*** a la superficie de contacte: fregament

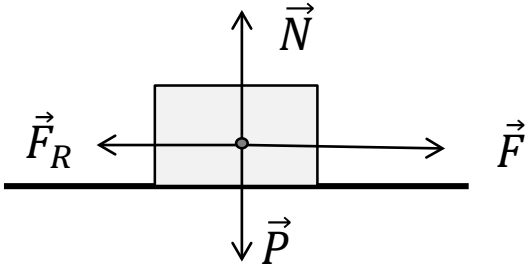
$$\left|\vec{F}_R\right| = \mu\left|\vec{N}\right|$$

- Són proporcionals a la força normal
- μ depèn del material



Fregament estàtic i cinètic

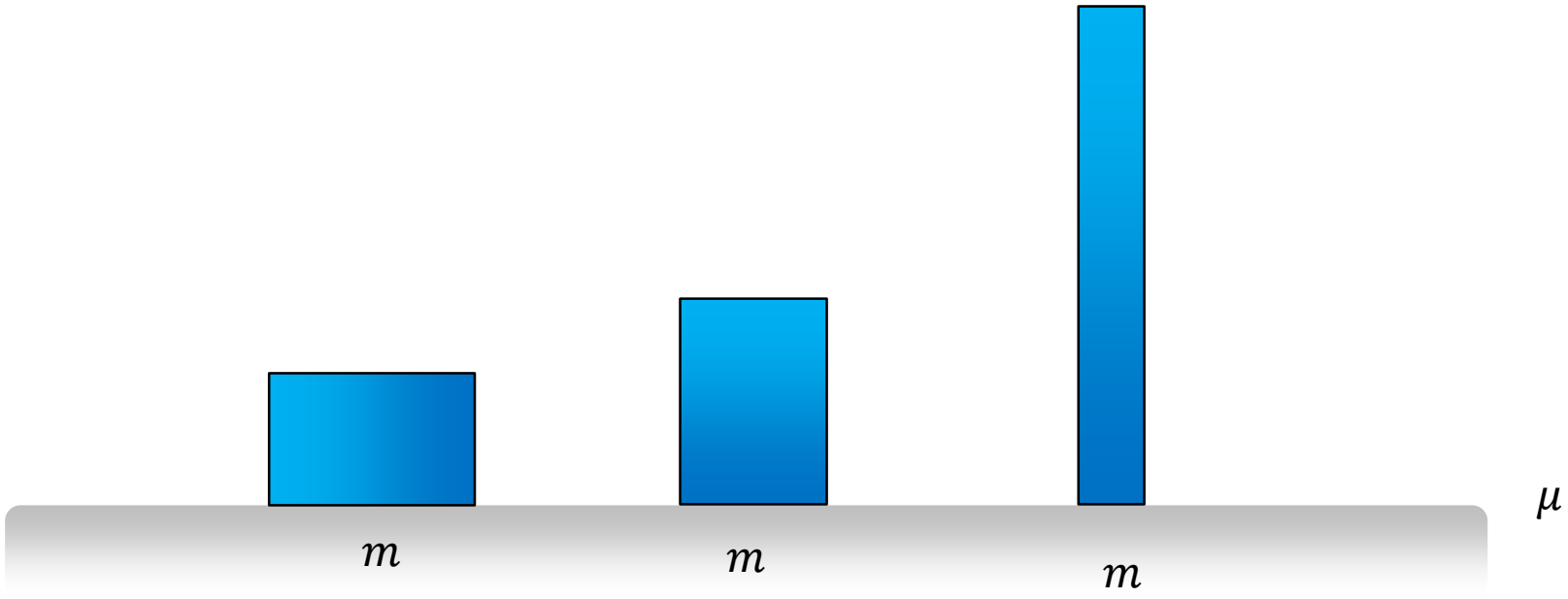




Material	μ_e	μ_c
Acer sobre acer	0,7	0,6
Llautó sobre acer	0,5	0,4
Cobre sobre ferro forjat	1,1	0,3
Vidre sobre vidre	0,9	0,4
Teflon sobre teflon	0,04	0,04
Teflon sobre acer	0,04	0,04
Cautxú sobre formigó (sec)	1,0	0,80
Cautxú sobre formigó (humit)	0,3	0,25
Esquí encerat sobre neu (0ºC)	0,1	0,05

Si $F < F_R$ el cos no es comença a moure

Mesura del fregament estàtic

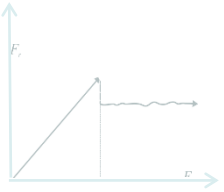


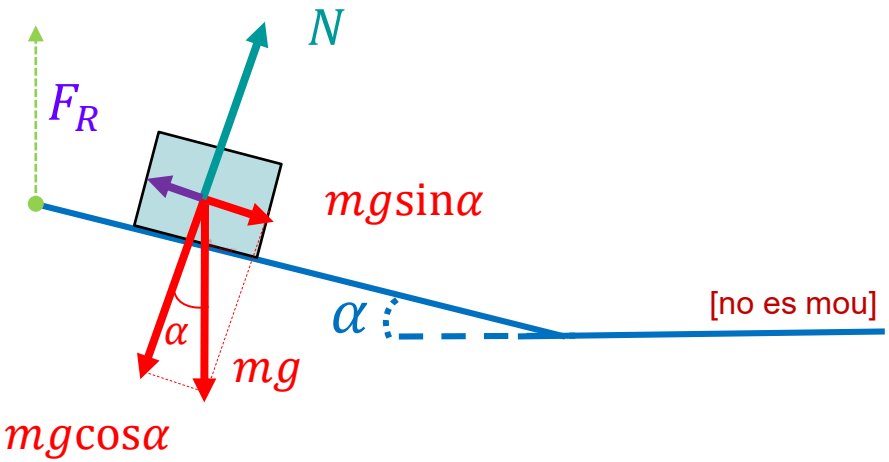
Depèn de la massa, no de l'àrea

$$F_R = \mu m g$$

[en moviment!]

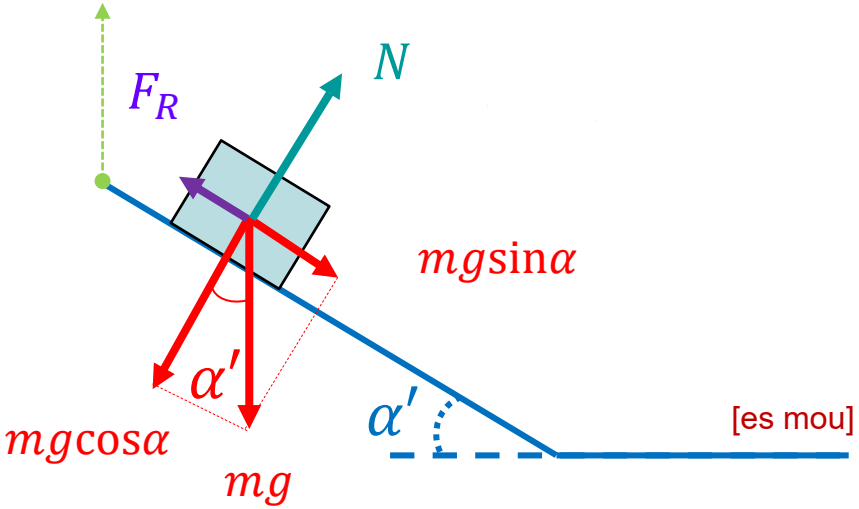
Mesura del fregament estàtic





$$N = mg\cos\alpha$$

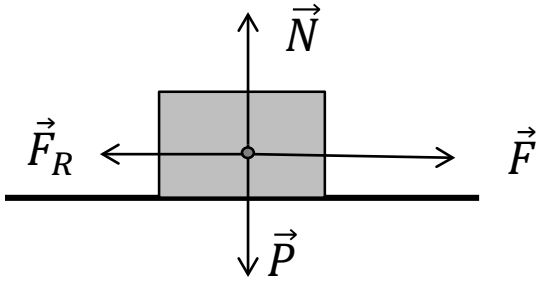
$$mg\sin\alpha = F_R \neq \mu_e mg\cos\alpha$$



$$mg\sin\alpha' = F_R = \mu_e mg\cos\alpha'$$

$$\mu_e = \tan\alpha'$$

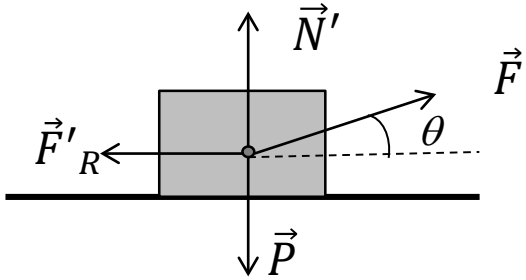
Equilibri de forces



Eje Y: $|\vec{P}| = |\vec{N}| = mg$

Eje X: $|\vec{F}| - |\vec{F}_R| = |\vec{F}| - \mu_c mg = ma$

[*estan en moviment*]

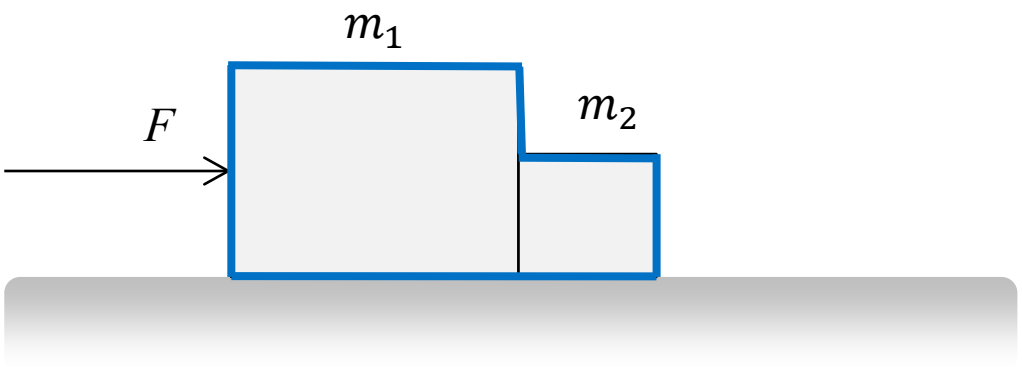


Eje Y: $|\vec{P}| = |\vec{N}'| + |\vec{F}|\sin\theta = mg$

Eje X: $|\vec{F}|\cos\theta - |\vec{F}'_R| = |\vec{F}|\cos\theta - \mu_c\left(mg - |\vec{F}|\sin\theta\right) = ma'$

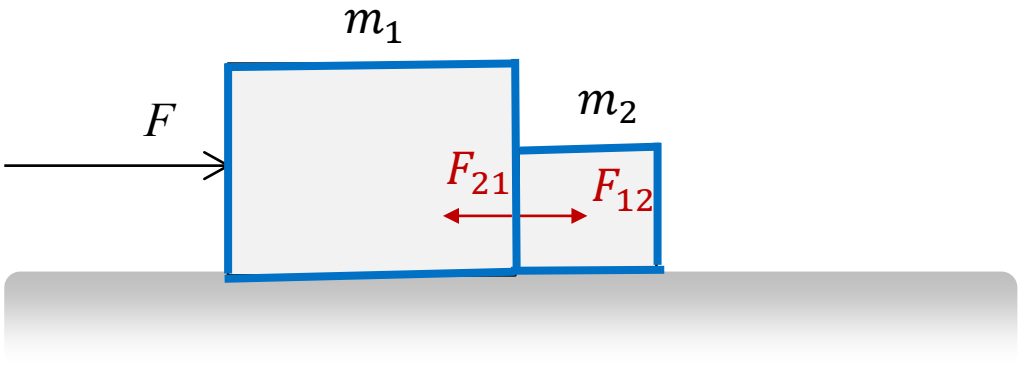
$$\Rightarrow \quad |\vec{N}|' < |\vec{N}|$$

Forces internes



$$F = (m_1 + m_2)a$$

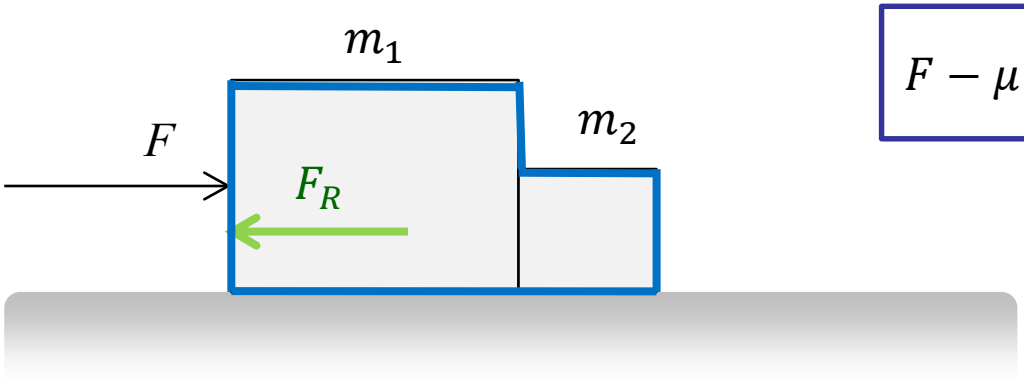
$\mu = 0$



$$F - F_{21} = m_1 a$$
$$F_{12} = m_2 a$$

$\mu = 0$

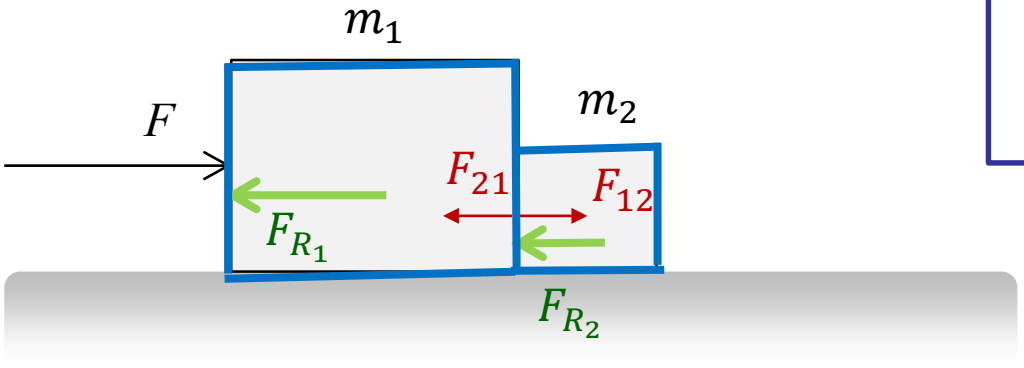
Forces internes (II)



$$F - \mu(m_1 + m_2)g = (m_1 + m_2)a'$$

$\mu \neq 0 \ \ (\mu_1 = \mu_2)$

$[a \neq a' \ ; \ F_{12} = F'_{12}]$

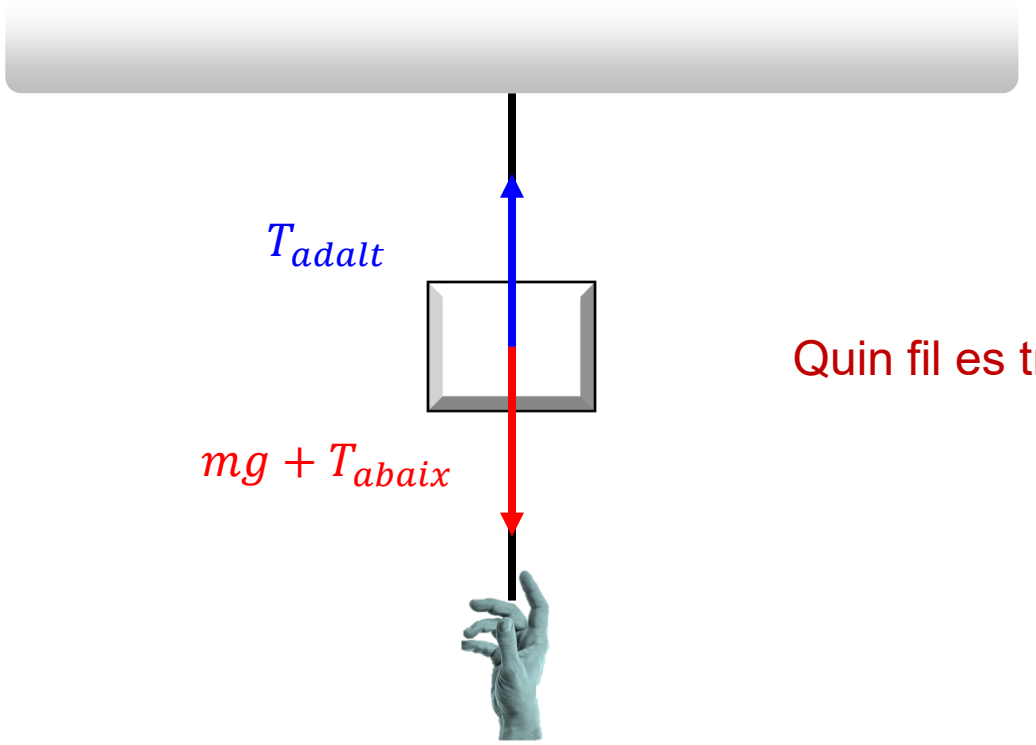


$$F - \mu m_1 g - F_{21} = m_1 a'$$

$$F_{12} - \mu m_2 g = m_2 a'$$

$\mu \neq 0 \ \ (\mu_1 = \mu_2)$

Forces internes (III)



Quin fil es trencarà?

Politges i cordes

$$T_1 - T_2 = m_c a$$

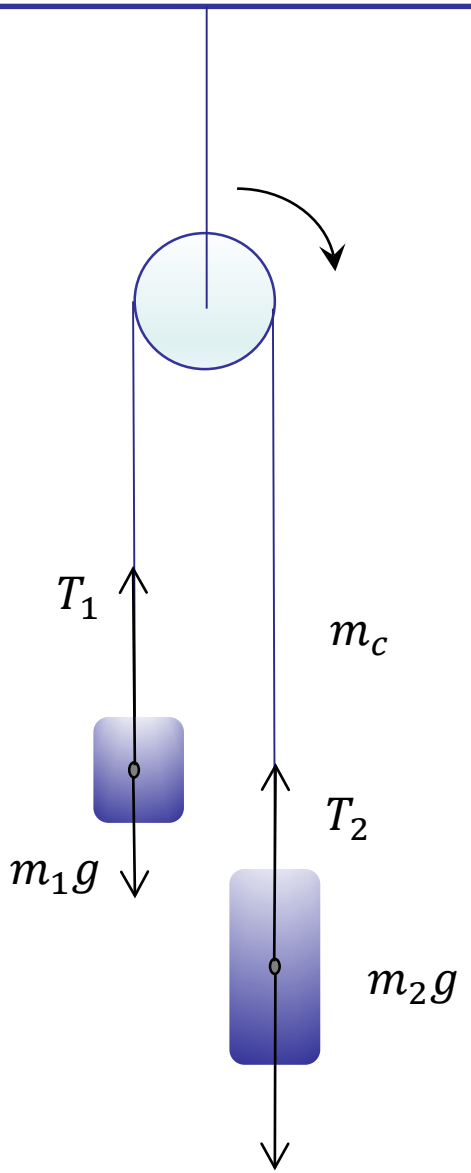
$$m_c \approx 0 \quad \Rightarrow \quad T_1 \approx T_2 \equiv T$$

$$T - m_1 g = m_1 a$$

$$m_2 g - T = m_2 a$$

$$\Downarrow$$

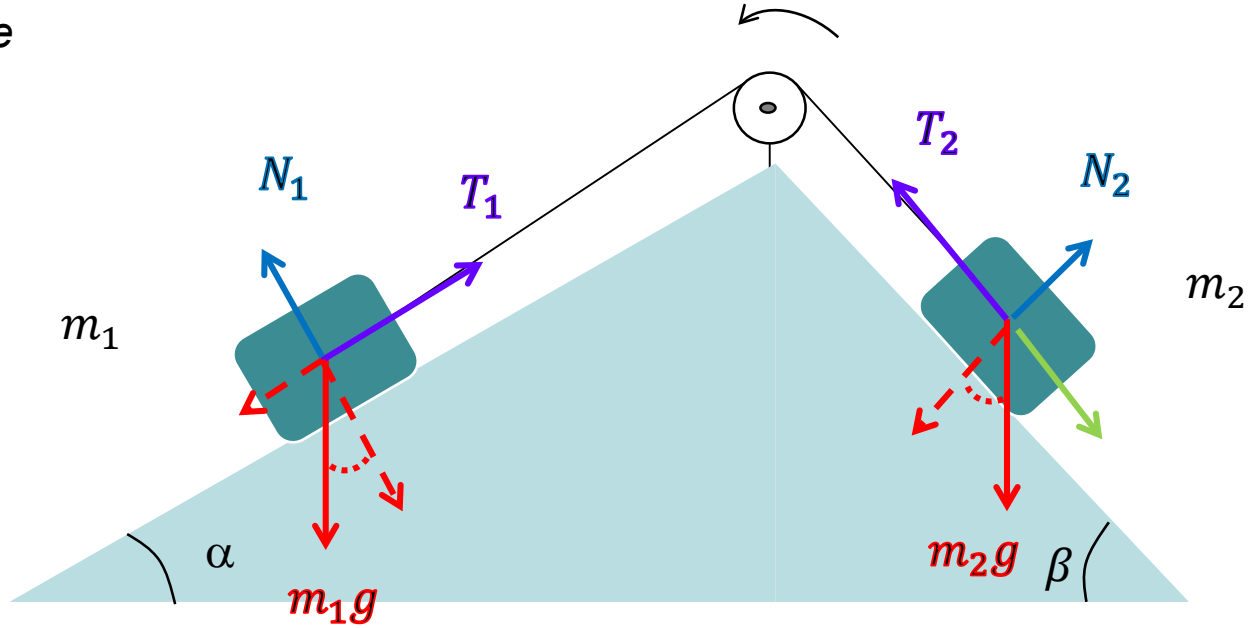
$$a = \frac{(m_2 - m_1)}{m_2 + m_1} g$$



Si la massa de la corda és negligible

$T_1 \cong T_2$

$\mu = 0$



$N_1 = m_1 g \cos\alpha$

$m_1 g \sin\alpha - T = m_1 a$

$N_2 = m_2 g \cos\beta$

$T - m_2 g \sin\beta = m_2 a$

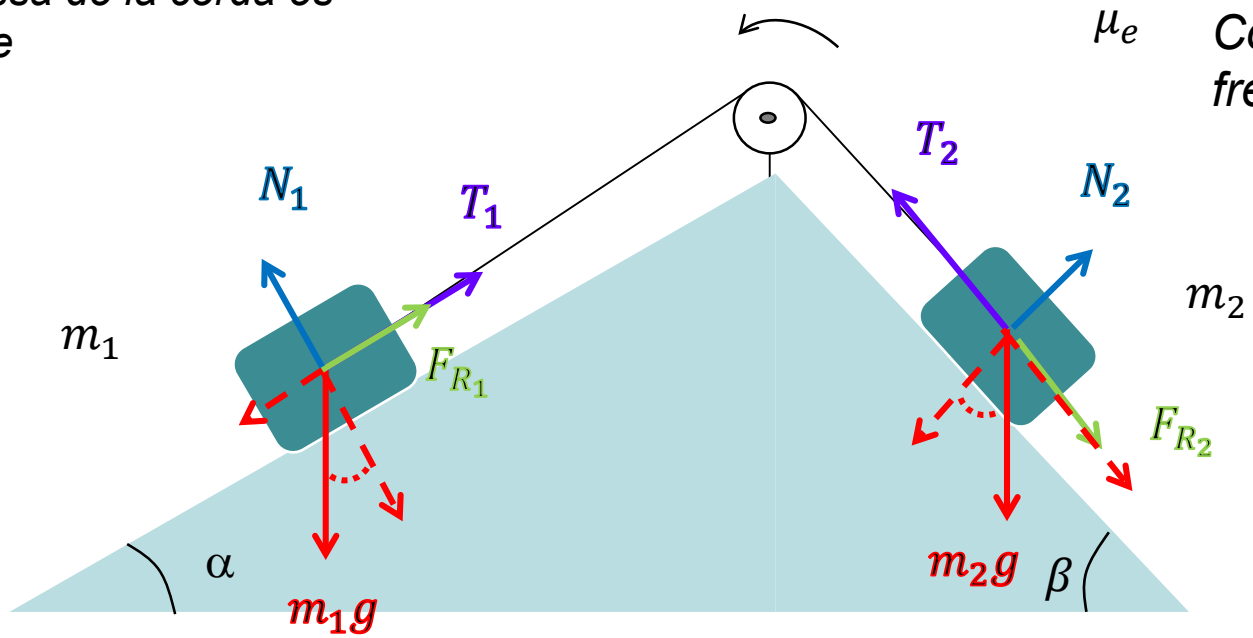
$$a = \frac{m_1 \sin\alpha - m_2 \sin\beta}{m_1 + m_2} g$$

- *Si es major que zero es mou*
- *Si es zero no es mou*
- *Si es menor que zero es mou en sentit contrari*

Si la massa de la corda és negligible

$T_1 \cong T_2$

μ_e *Coeficient de fregament estàtic*



$N_1 = m_1 g\cos\alpha$

$m_1 g\sin\alpha - F_{R_1} - T = m_1 a$

$F_{R_1} = \mu_e N_1 = \mu_e m_1 g\cos\alpha$

$m_1 g\sin\alpha - \mu_e m_1 g\cos\alpha - T = m_1 a$

$N_2 = m_2 g\cos\beta$

$T - m_2 g\sin\beta - F_{R_2} = m_2 a$

$F_{R_2} = \mu_e N_2 = \mu_e m_2 g\cos\alpha$

$T - m_2 g\sin\beta - \mu_e m_2 g\cos\beta = m_2 a$

$$a = \frac{m_1\sin\alpha - m_2\sin\beta - \mu_e(m_1\cos\alpha + m_2\cos\alpha)}{m_1 + m_2} g$$

- *Si es major que zero es mou*
- *Si es zero no es mou*
- *Si es menor que zero cal repetir els càlculs en l'altre sentit de gir*