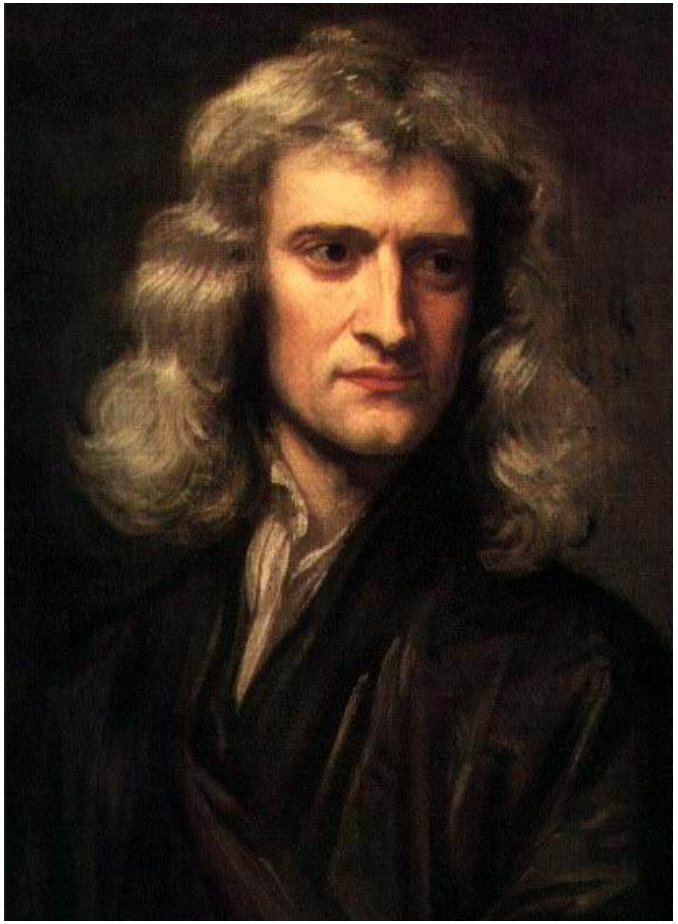
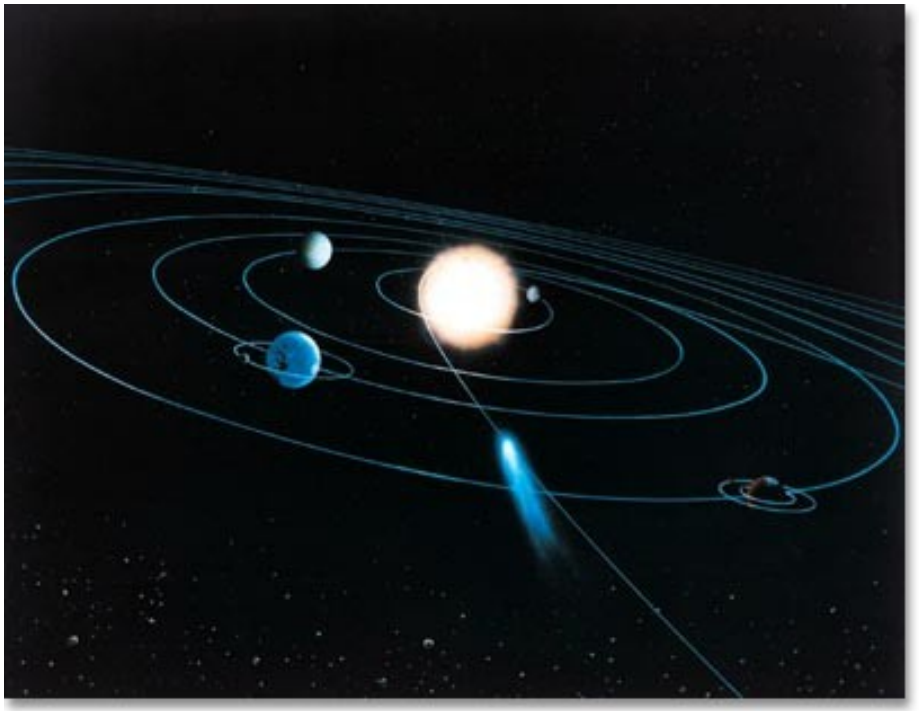
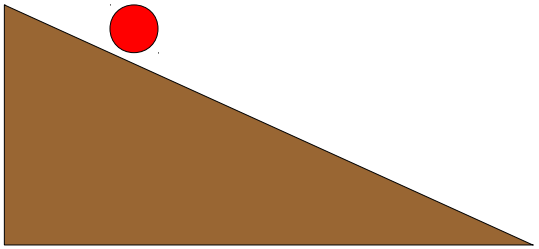
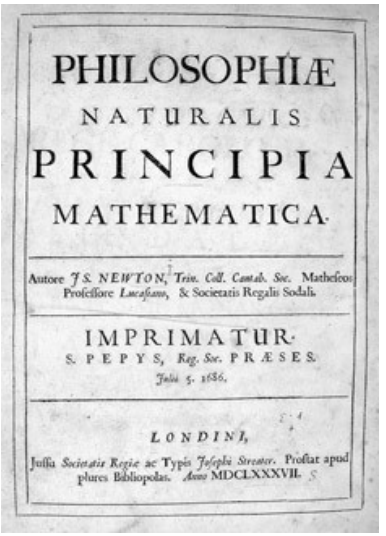
As Leis de Newton





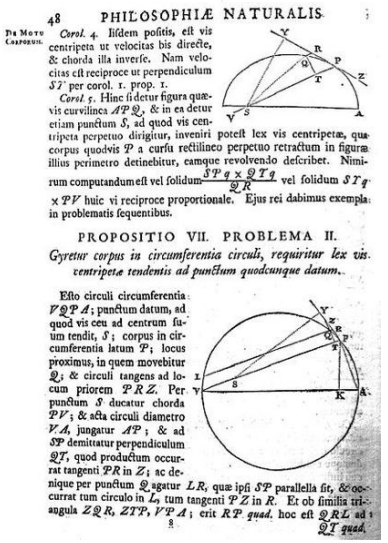



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *Is. NEWTON*, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Justu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.


48 PHILOSOPHIÆ NATURALIS

De Motu Corporum.

Corol. 4. Iisdem positis, est vis centripeta ut velocitas bis directe, & chorda illa inverse. Nam velocitas est reciproce ut perpendiculum ST per corol. 1. prop. 1.

Corol. 5. Hinc si detur figura quævis curvilinea APQ, & in ea detur etiam punctum S, ad quod vis centripeta perpetuo dirigitur, inveniri potest lex vis centripetæ, qua corpus quodvis P a cursu rectilineo perpetuo retractum in figuræ illius perimetro detinebitur, eamque revolvendo describet. Nimirum computandum est vel solidum $\frac{SPq \times QTq}{QR}$ vel solidum $STq \times PV$ huic vi reciproce proportionale. Ejus rei dabimus exempla in problematis sequentibus.

PROPOSITIO VII. PROBLEMA II.

Gyretur corpus in circumferentia circuli, requiritur lex vis centripetæ tendentis ad punctum quodcunque datum.

Esto circuli circumferentia $VQPA$; punctum datum, ad quod vis ceu ad centrum fuum tendit, S; corpus in circumferentia latum P; locus proximus, in quem movebitur Q; & circuli tangens ad locum priorem PRZ. Per punctum S ducatur chorda PV; & acta circuli diametro VA, jungatur AP; & ad SP demittatur perpendiculum QT, quod productum occurrat tangenti PR in Z; ac denique per punctum Q agatur LR, quæ ipfi SP parallella fit, & occurrat tum circulo in L, tum tangenti PZ in R. Et ob fimilia triangula ZQR, ZTP, VPA; erit RP quad. hoc eft QRL ad QT quad.

Espaço – homogêneo e isotrópico
Tempo – uniforme

Corpo material no espaço

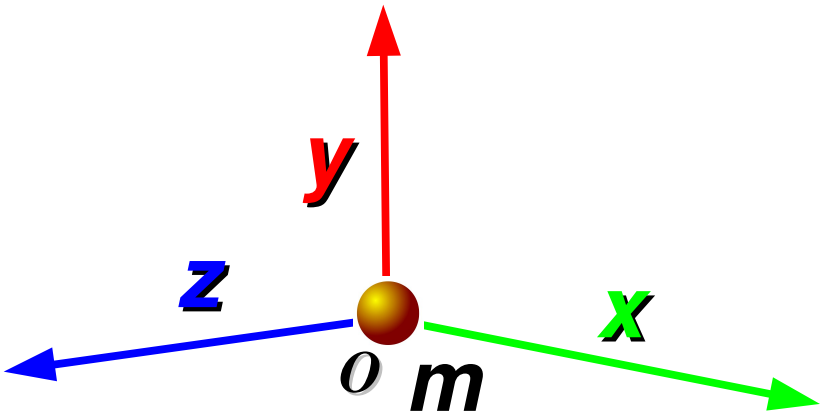
m

Massa *m* (quantidade de matéria)

Exemplo 1: planeta;
Exemplo 2: partícula de poeira

1ª Lei

$$\vec{F} = 0 \Rightarrow \vec{v}(t) = \vec{v}_0$$



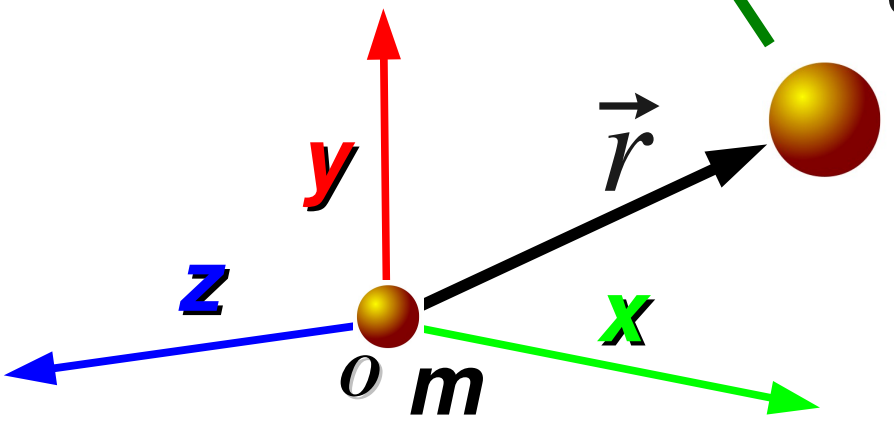
Corpo material na ausência de forças

Sistema de coordenadas inercial

1ª Lei

$$\vec{F} = 0 \Rightarrow \vec{v}(t) = \vec{v}_0$$

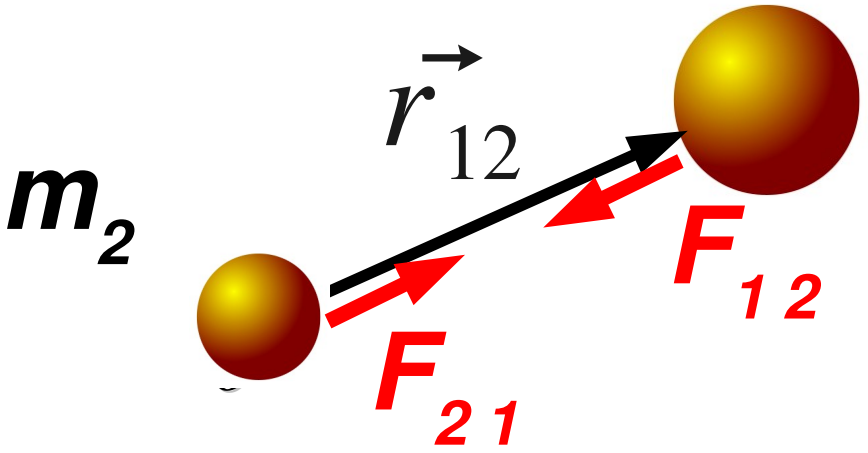
$$\vec{v} = \frac{d\vec{r}}{dt} = \vec{v}_0 \, (const.)$$



Corpos não-interagentes

Equivalência entre refs. inerciais

Forças - Interação



Obs.: F_{12} (1- sofre; 2- exerce)

$$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2 = -\vec{r}_{21}$$

2ª Lei

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

3ª Lei

$$\vec{F}_{12} = -\vec{F}_{21}$$

4ª Lei

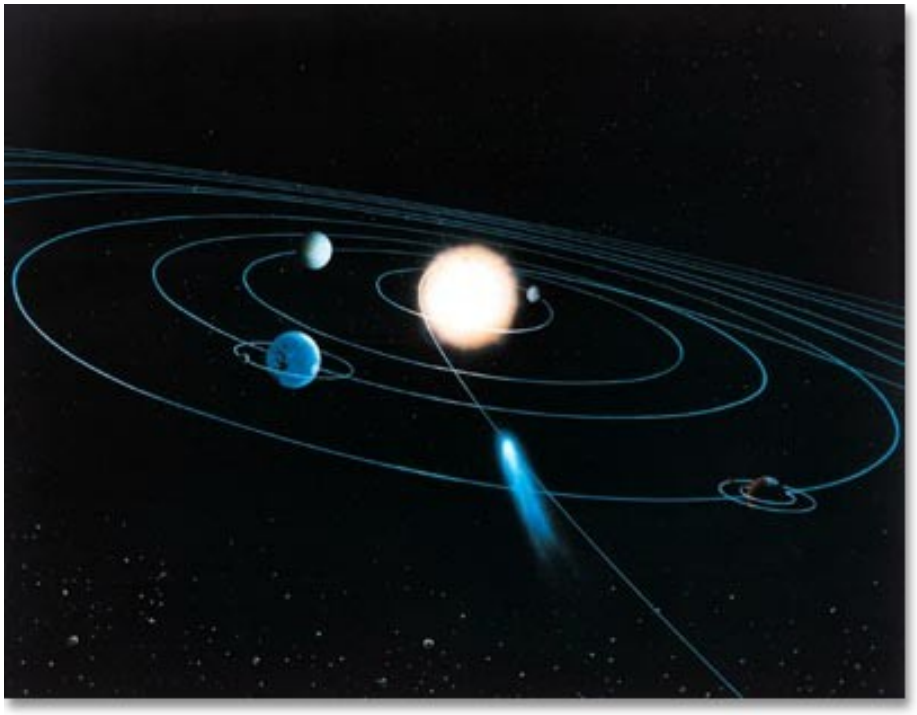
$$\vec{F}_{12} = -G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$$

Gravitação

OBS.: $\hat{r}_{12} = \dfrac{\vec{r}_{12}}{r_{12}}$

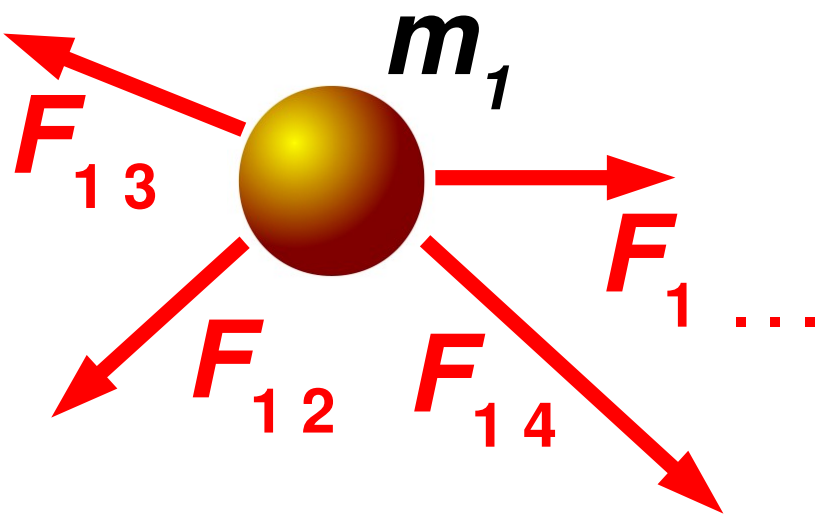
Sitema Planetário

Leis de Kepler



Gravitação Universal

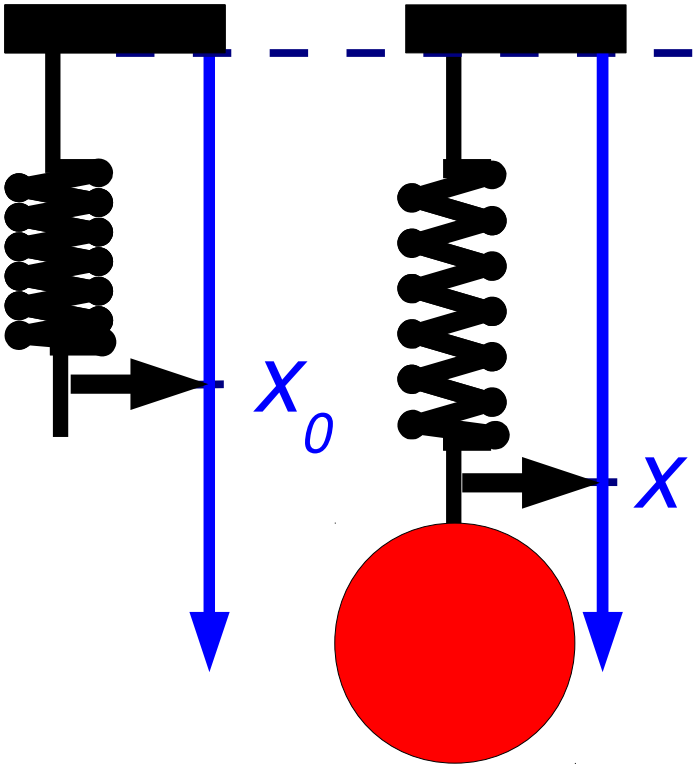
Força resultante



$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \ldots = \sum_{i=2}^{N} \vec{F}_{1i}$$

Soma vetorial

Dinamômetro (medida de forças)



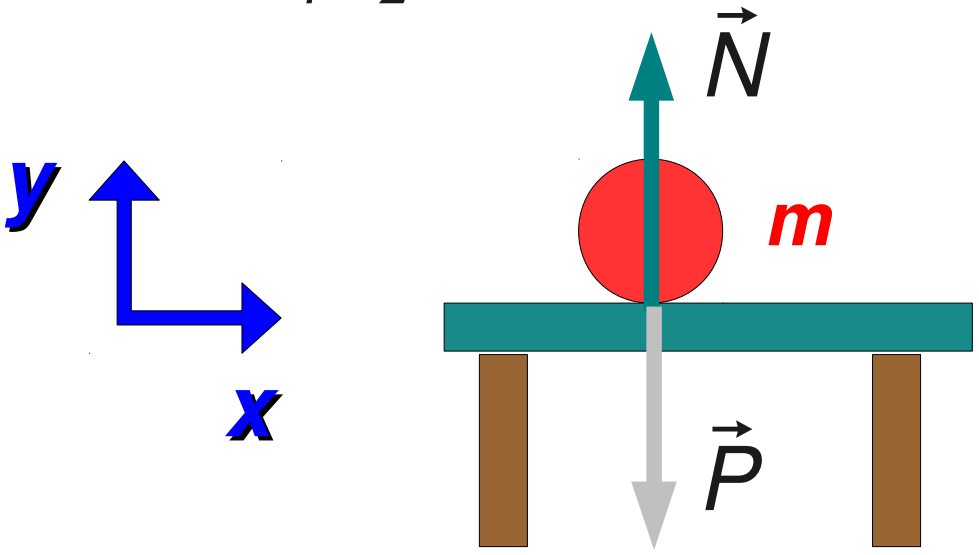
Lei de Hooke

$$F_x = -k(x - x_0)$$

$$P = -F_x$$

Equilíbrio de forças

$$\vec{F}_R = \sum_{i=2}^{N} \vec{F}_i = 0$$



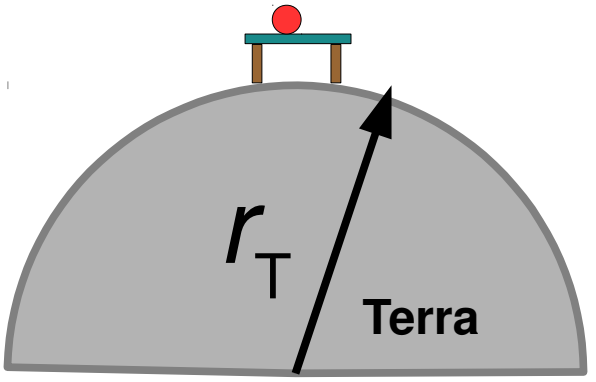
$$\vec{F}_R = \vec{N} + \vec{P} = 0$$

Normal:

$$\vec{N} = -\vec{P} = mg\,\hat{y}$$

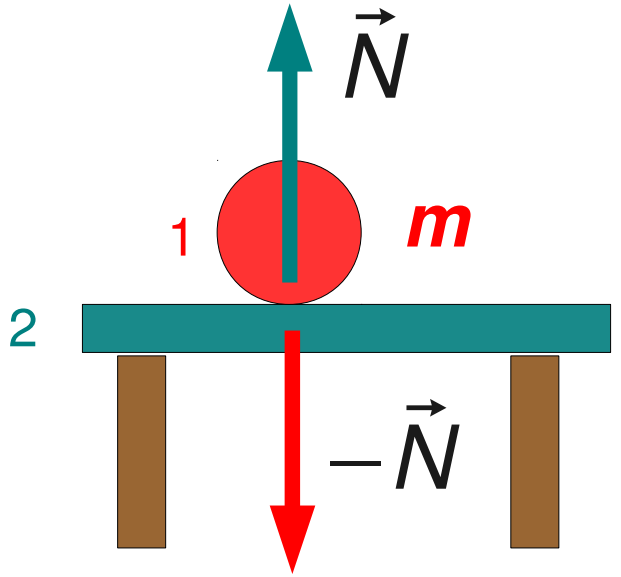
Peso:

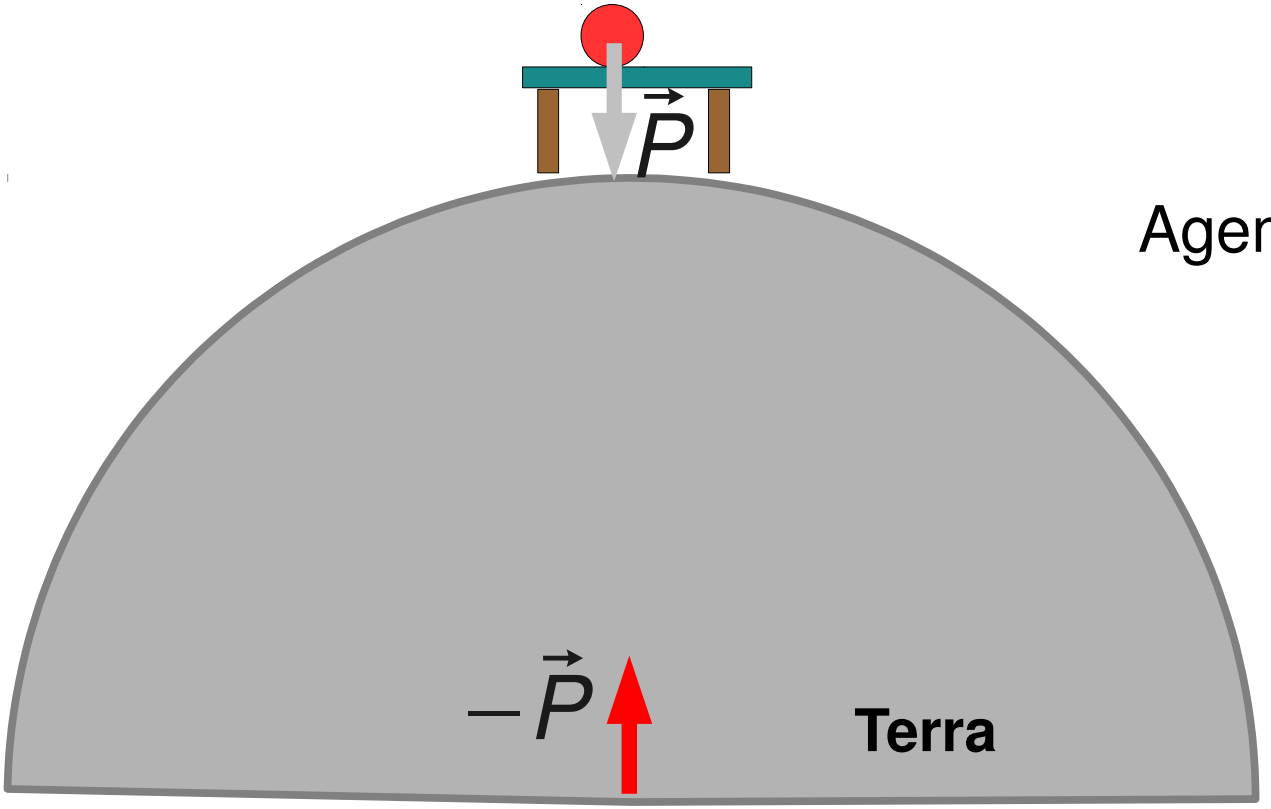
$$\vec{P} = -m\left(G\frac{m_T}{r_T^2}\right)\hat{y} = -mg\,\hat{y}$$



Ação e reação

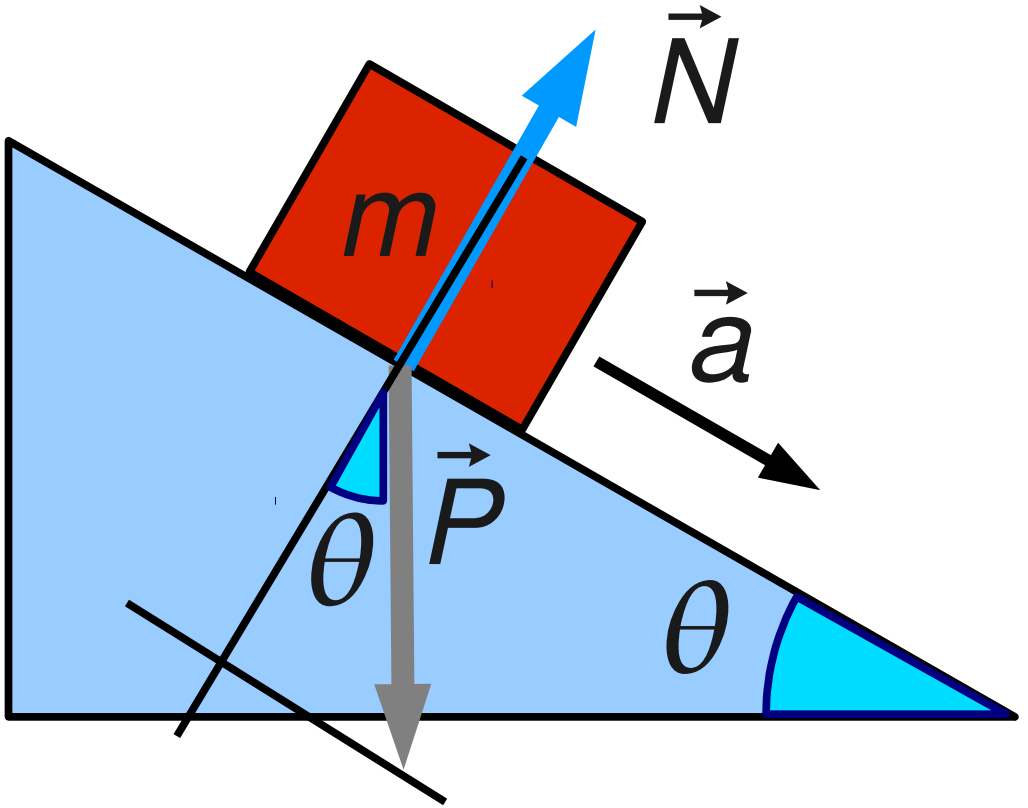
$$\vec{F}_{12} = -\vec{F}_{21}$$





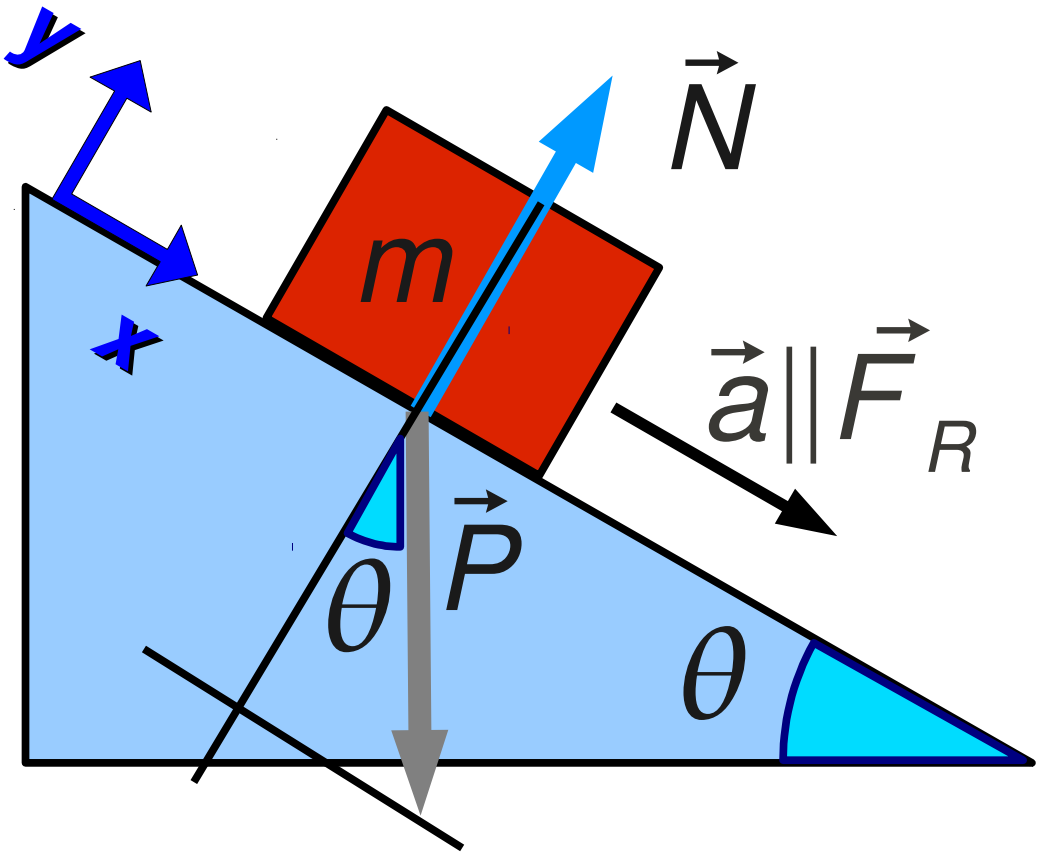
Agem em corpos diferentes

Plano Inclinado (sem atrito): $\vec{a}$?



Plano Inclinado (sem atrito): $\vec{a}$?

Sistema de coordenadas



$$\vec{F}_R = \vec{P} + \vec{N}$$

$$\vec{N} = N\,\hat{y}$$

$$\vec{F}_R \perp \hat{y} \quad (F_{Ry} = 0)$$

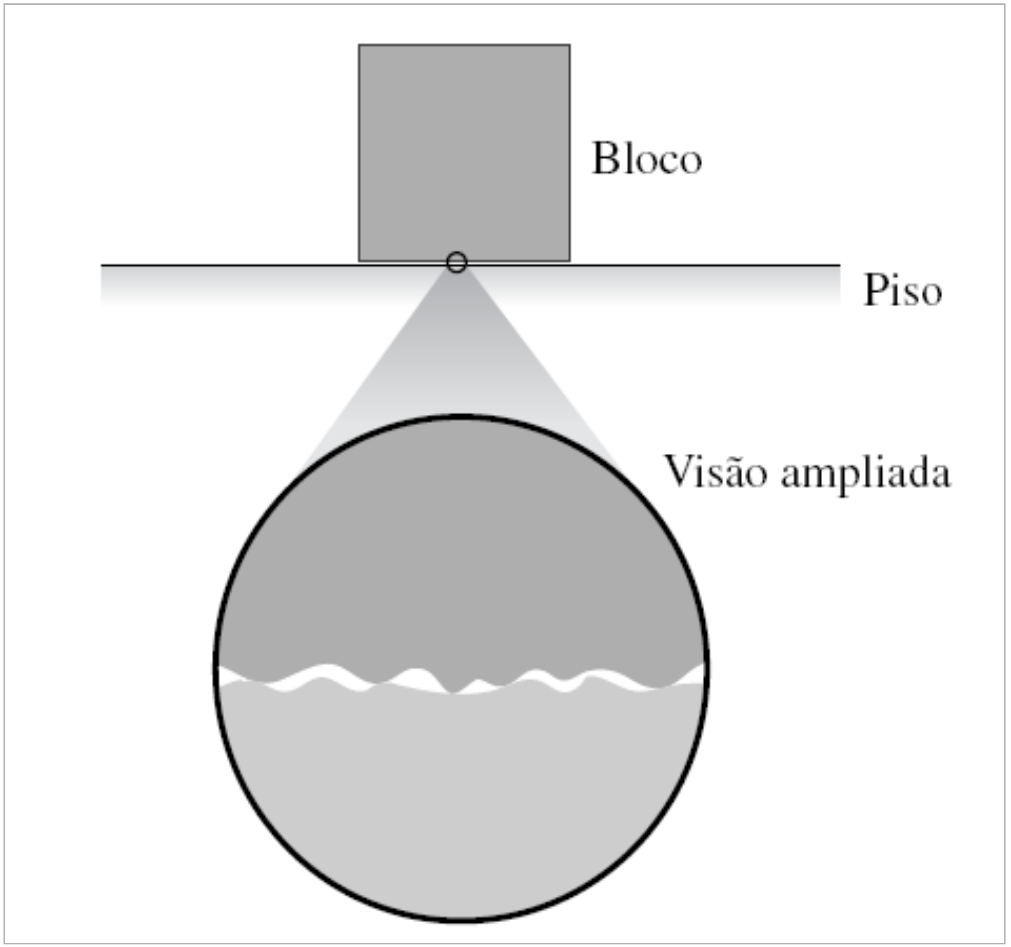
$$\vec{F}_R = F_R\,\hat{x} = P_x\,\hat{x}$$

$$P = mg \qquad P_x = mg\,\mathrm{sen}\,\theta$$

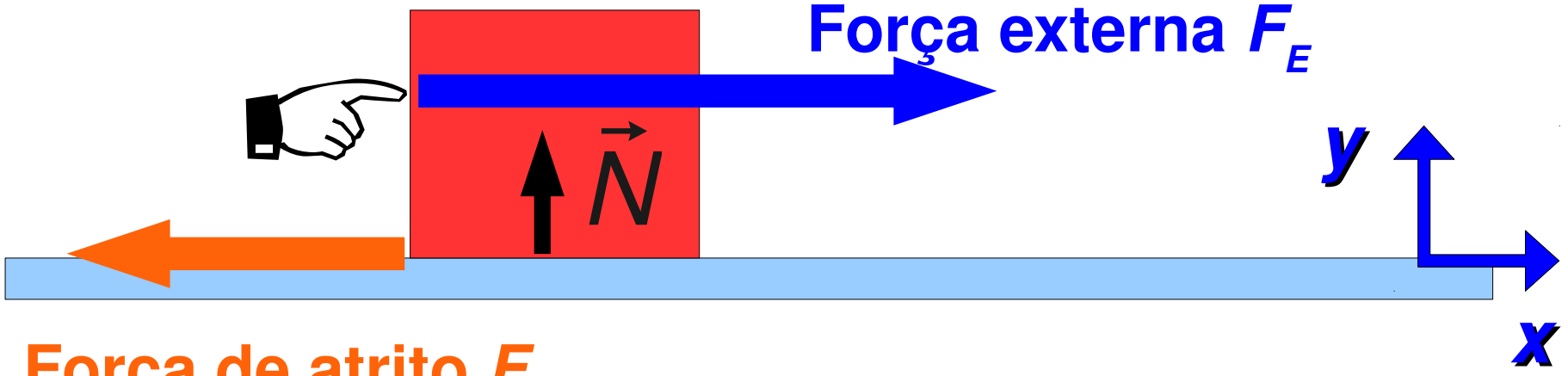
$$\vec{F}_R = mg\,\mathrm{sen}\,\theta\,\hat{x} = m\vec{a}$$

$$\boxed{\vec{a} = g\,\mathrm{sen}\,\theta\,\hat{x}}$$

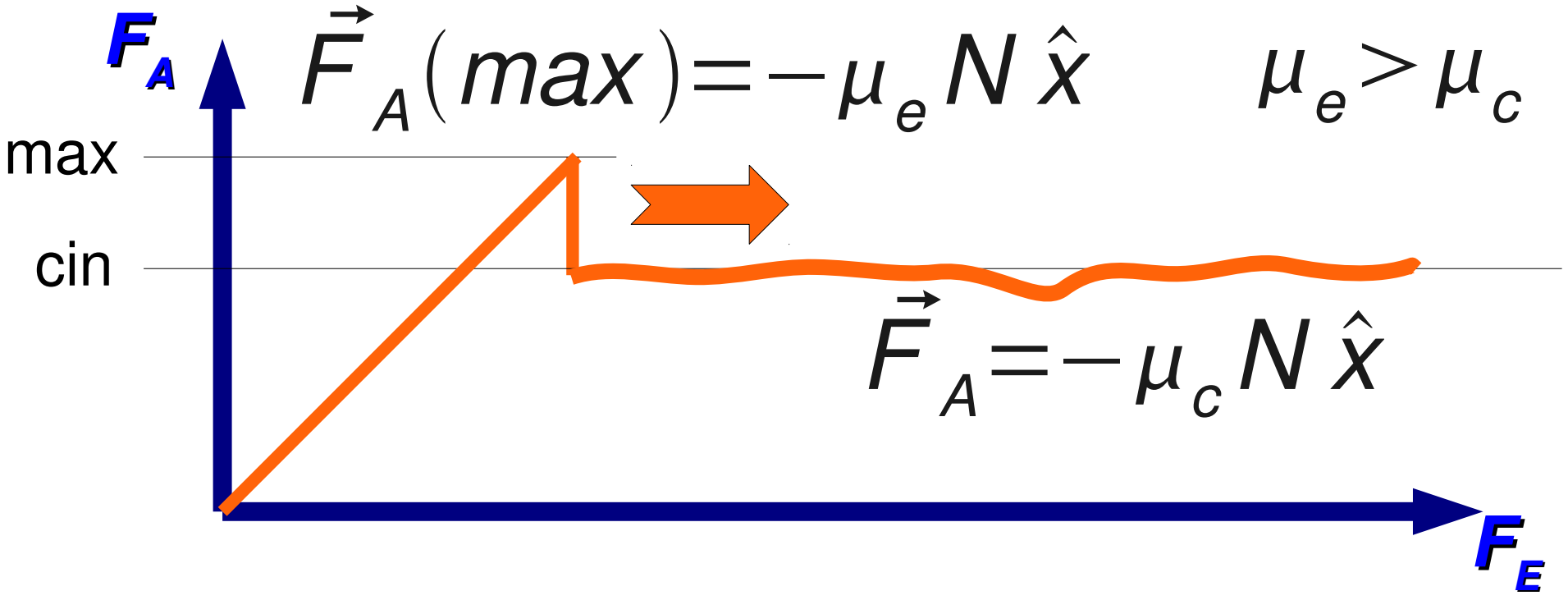
Atrito



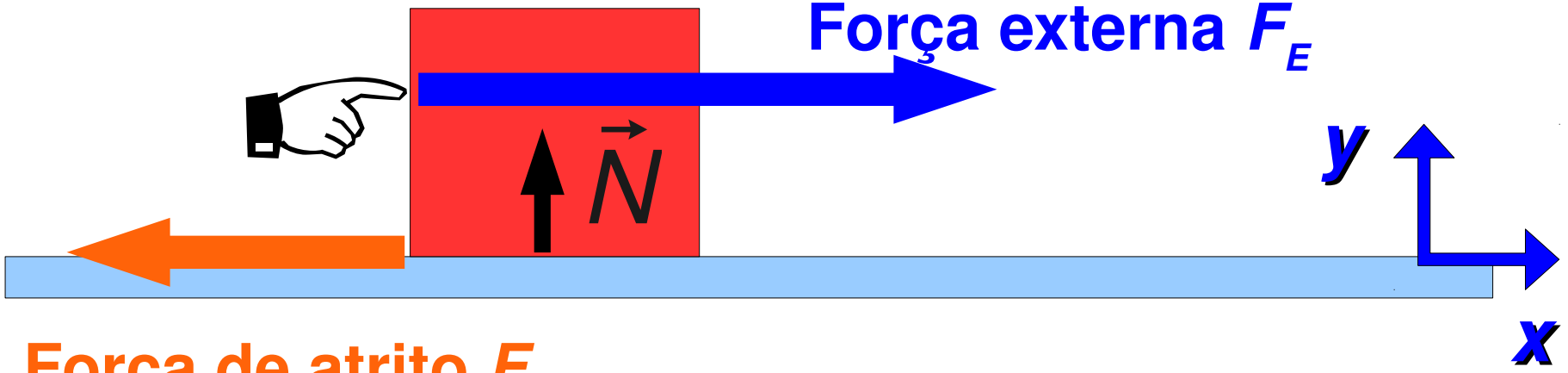
Atrito estático e cinético



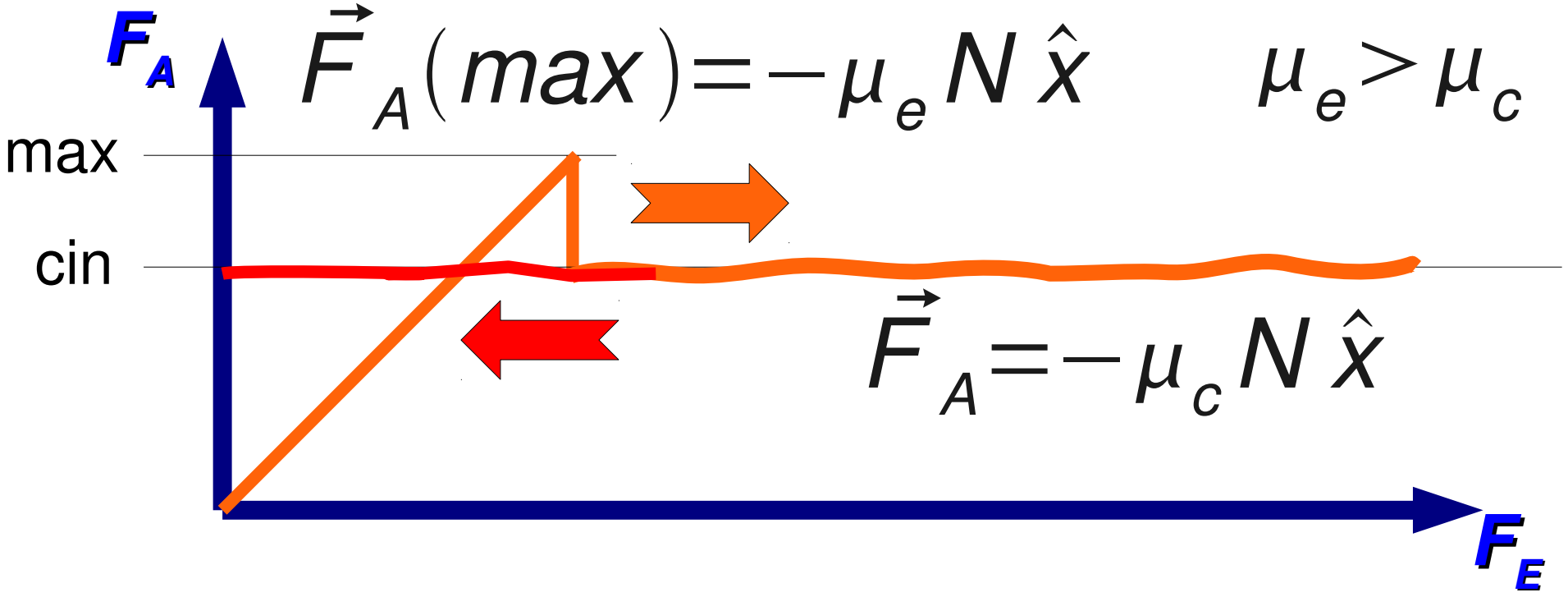
Força de atrito F_A



Atrito estático e cinético



Força de atrito F_A



Plano Inclinado com atrito cinético

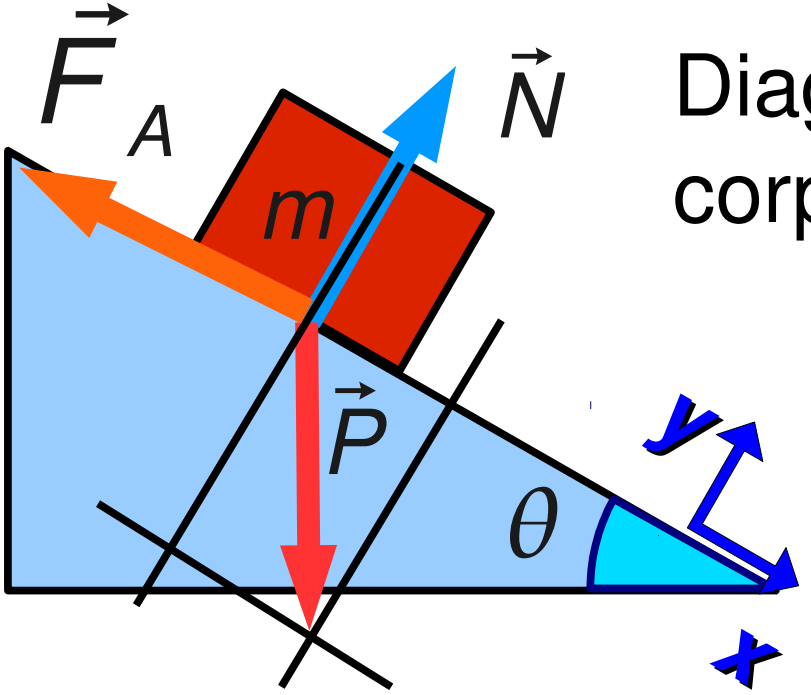


Diagrama de corpo livre

$$P = mg$$

$$P_x = P \sin\theta$$

$$P_y = -P \cos\theta$$

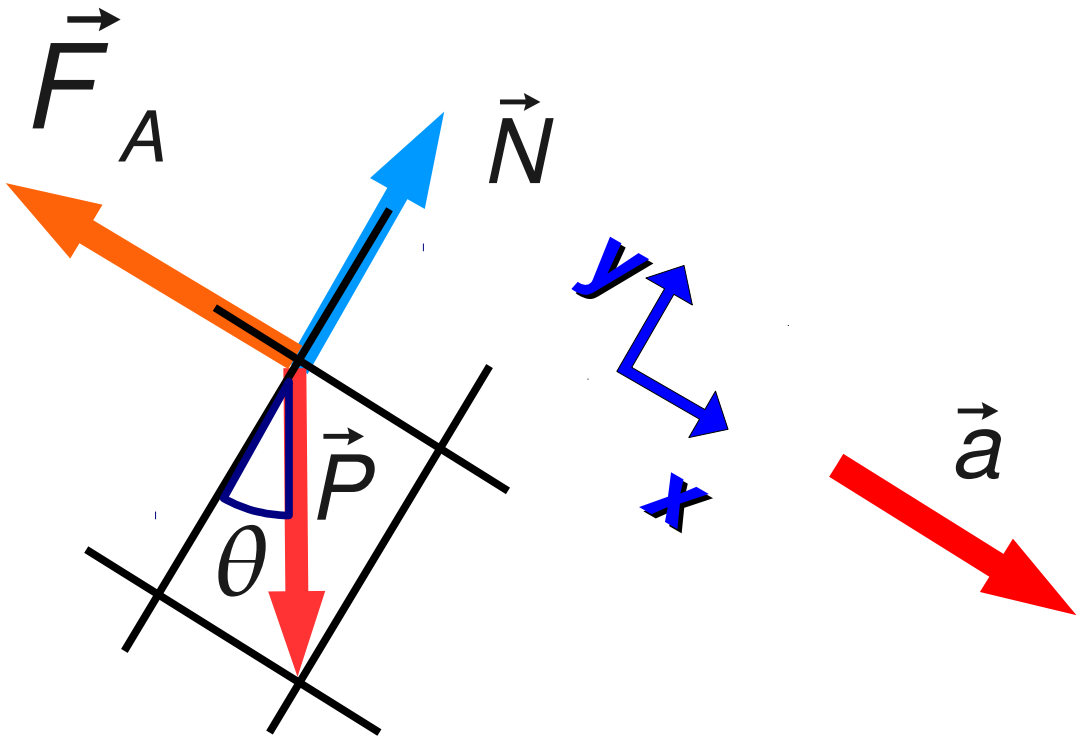
$$\vec{F}_R = \vec{P} + \vec{N} + \vec{F}_A$$

$$\vec{F}_A = -\mu_c N \hat{x} \qquad \vec{F}_R \perp \hat{y} \quad \Rightarrow N = P\cos\theta$$

$$\vec{F}_R = \left(P \operatorname{sen}\theta - \mu_c N\right)\hat{x} = m\vec{a}$$

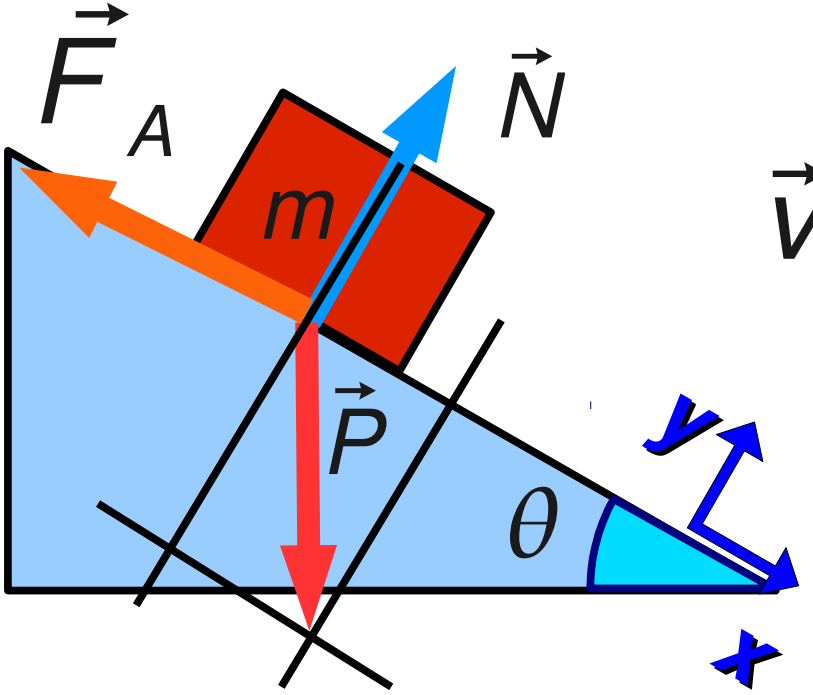
$$g\left(\operatorname{sen}\theta - \mu_c \cos\theta\right)\hat{x} = \vec{a}$$

Diagrama de corpo livre



$$\vec{F}_R = \sum_i \vec{F}_i = m\vec{a}$$

Plano Inclinado com atrito estático



$$P = mg$$

$$\vec{v} = 0 \qquad P_x = P \sin\theta$$

$$P_y = -P \cos\theta$$

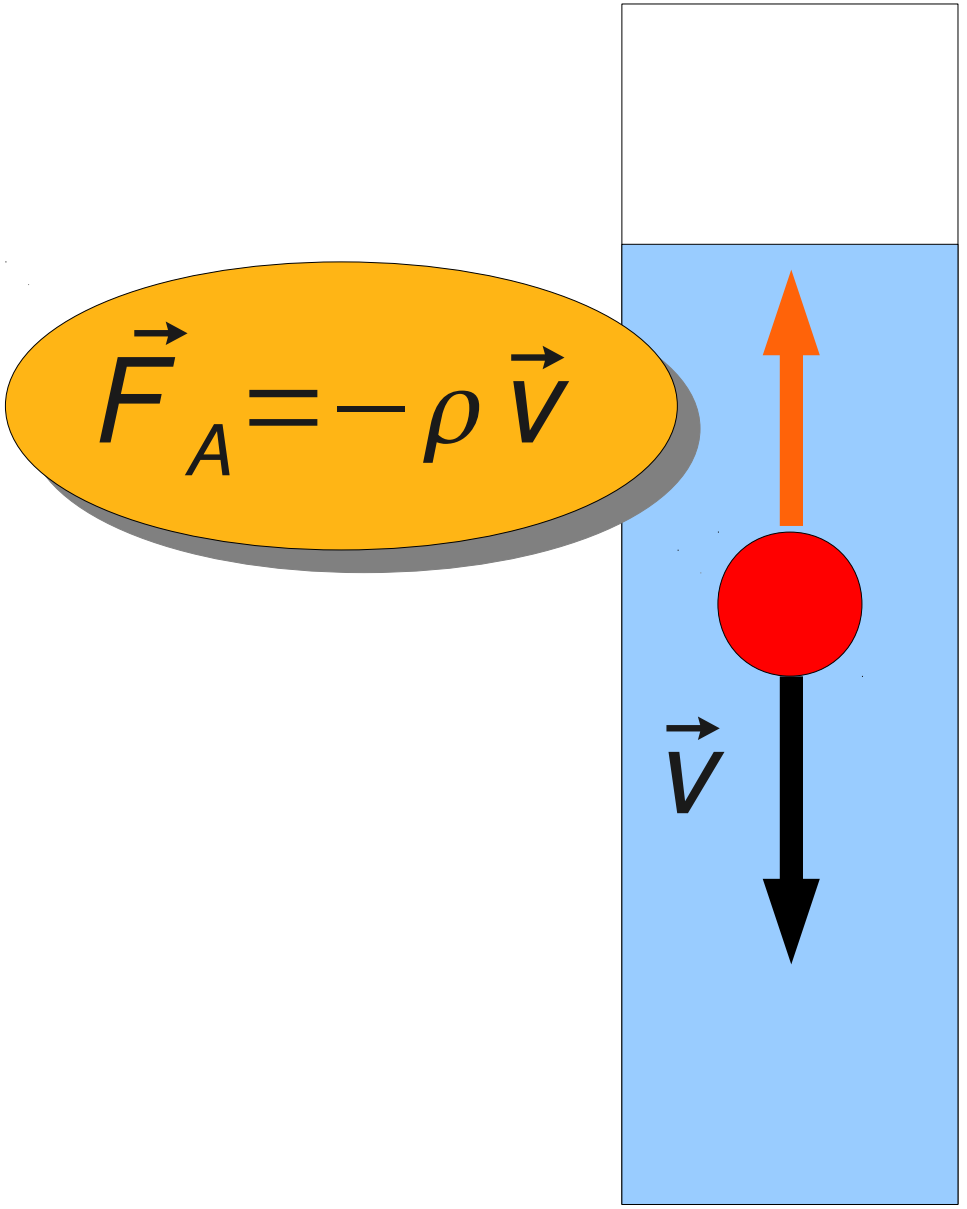
$$\vec{F}_R = \vec{P} + \vec{N} + \vec{F}_A$$

$$\vec{F}_R = 0 \qquad \underline{\textbf{Se}} \quad F_A < \mu_e N = F_A(max)$$

$$\vec{a} = 0 \qquad \vec{F}_A = -P\,sen\,\theta\,\hat{x} \qquad N = P\cos\theta$$

$$\Rightarrow tg\,\theta < \mu_e$$ **Senão –> caso cinético**

Atrito viscoso



$$\vec{F}_R = \vec{P} + \vec{E} - \rho\,\vec{v} = m\,\vec{a}$$

Empuxo:

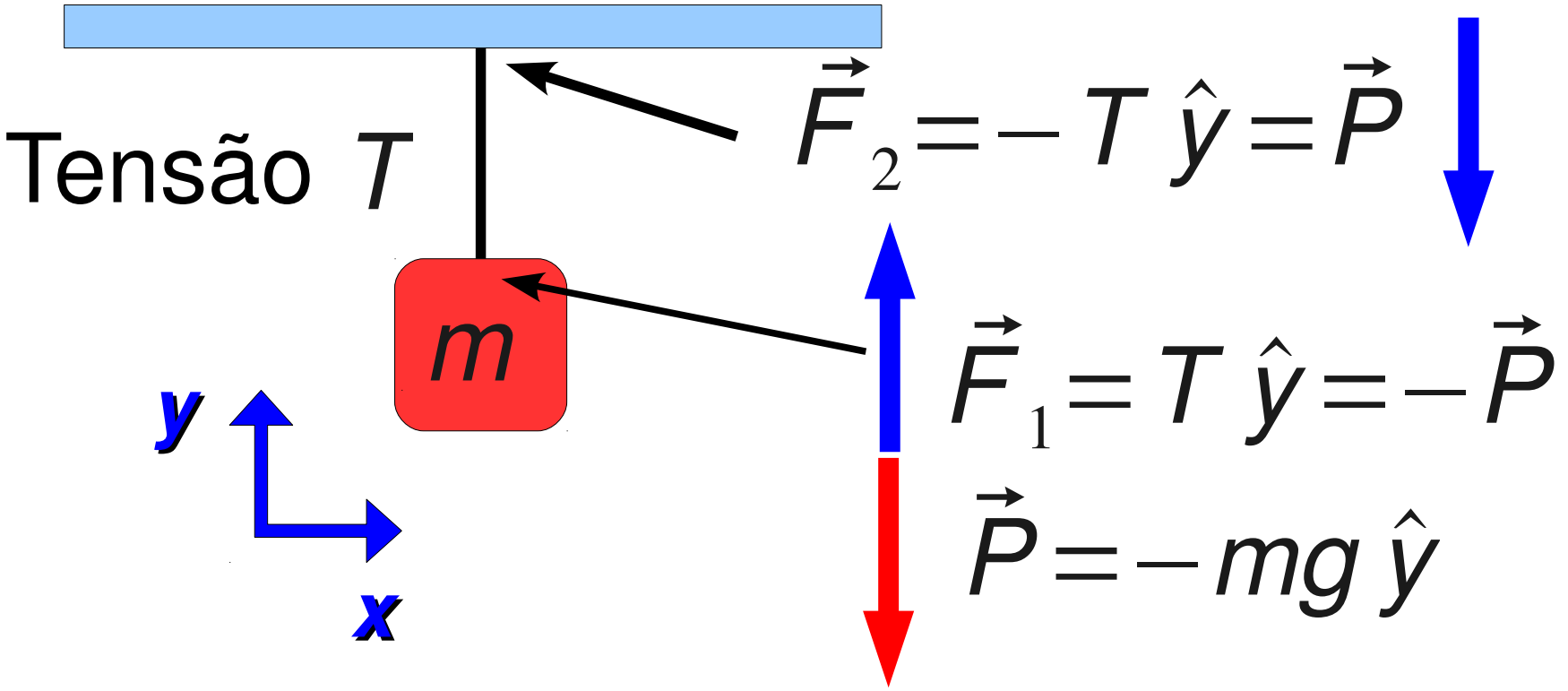
$$\vec{E} = -d_{\text{líq.}} \cdot V_{\text{desl.}}\,\vec{g}$$

$\vec{g}$ ↓

$$\vec{P} = m\,\vec{g}$$

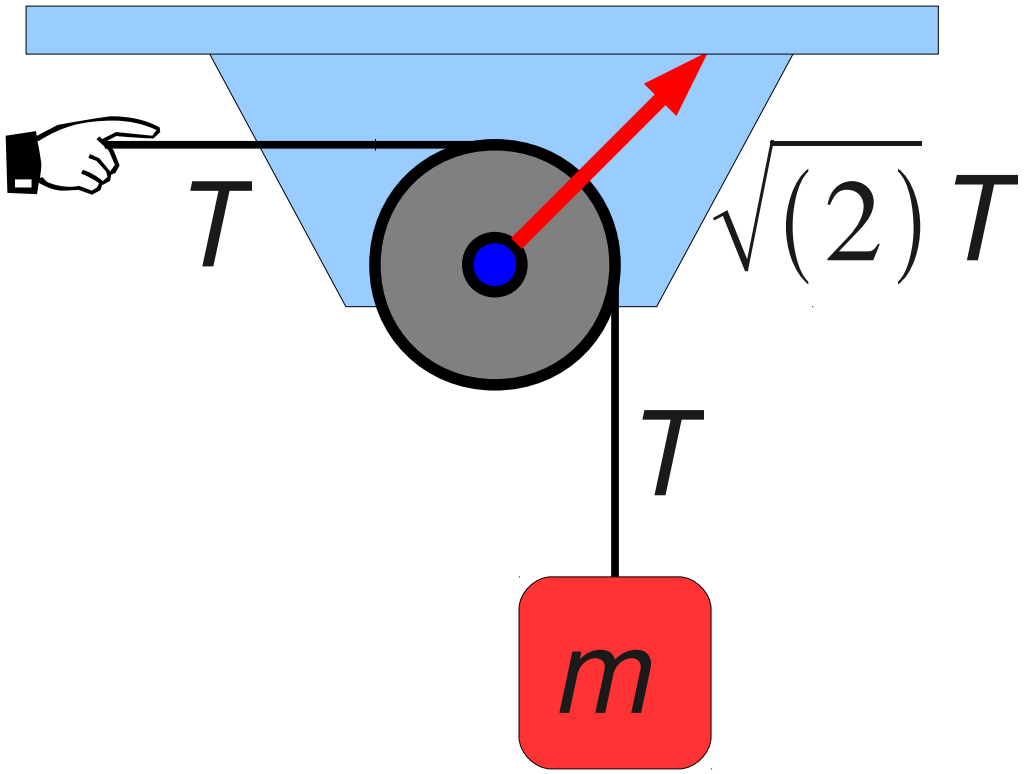
Outras idealizações

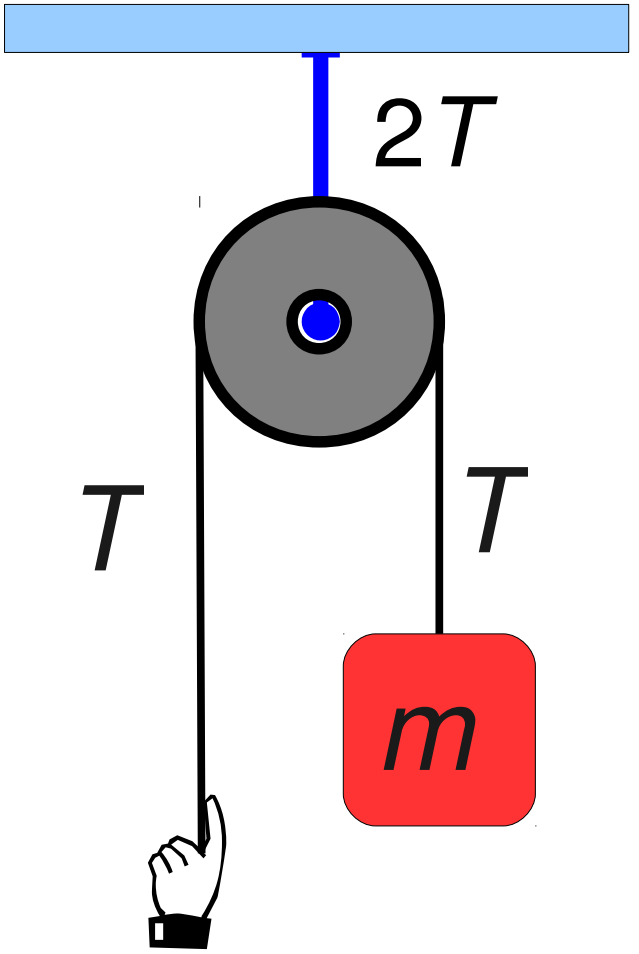
Fio (ou corda) inextensível e de massa desprezível



Outras idealizações

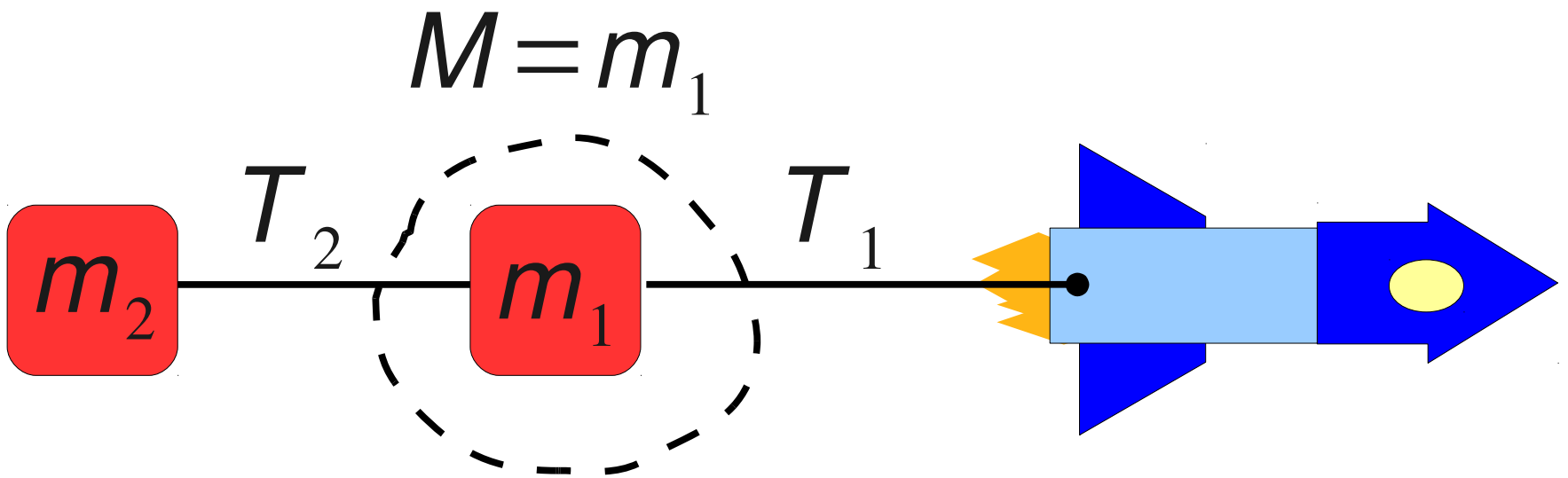
Polia de massa desprezível e sem atrito





Outras idealizações

Corpo de massa M - Dado T_1, a = ?

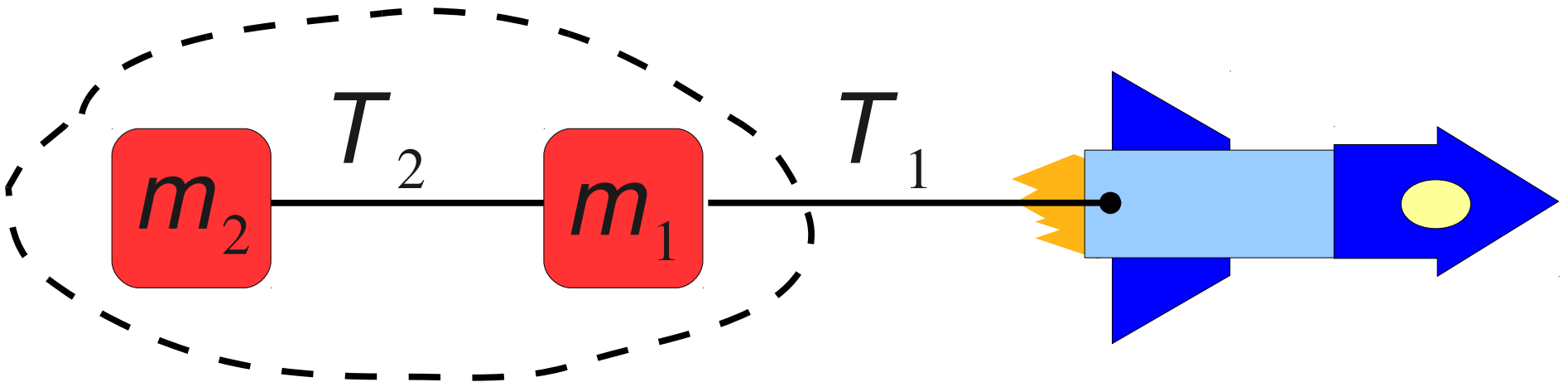


$$m_1 a = T_1 - T_2 = T_1 - m_2 a \Rightarrow a = \frac{T_1}{(m_1 + m_2)}$$

Outras idealizações

Corpo de massa M - Dado T_1, a = ?

$$M = m_1 + m_2$$



$$a = \frac{T_1}{M} = \frac{T_1}{(m_1 + m_2)}$$

$$T_2 = m_2 a$$

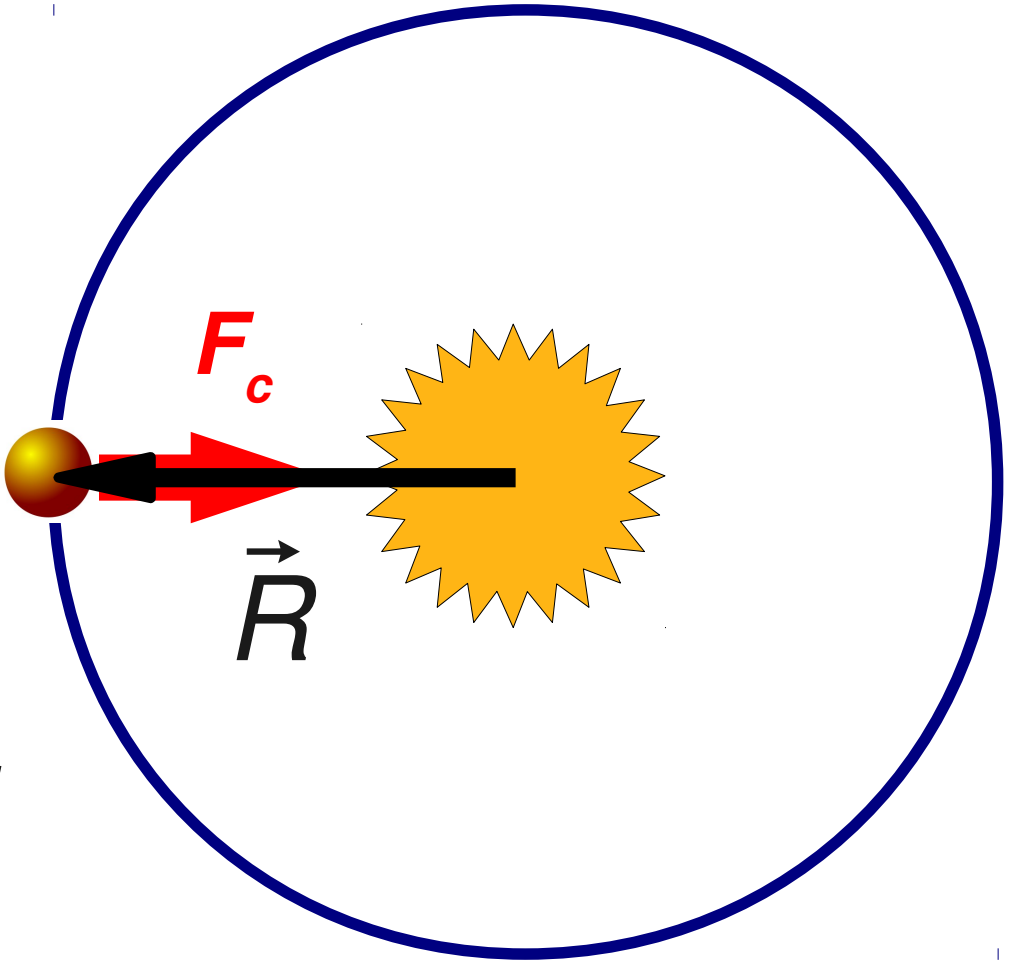
Movimento circular

$$F_c = m a_c = m \frac{v^2}{R} = m \omega^2 R$$

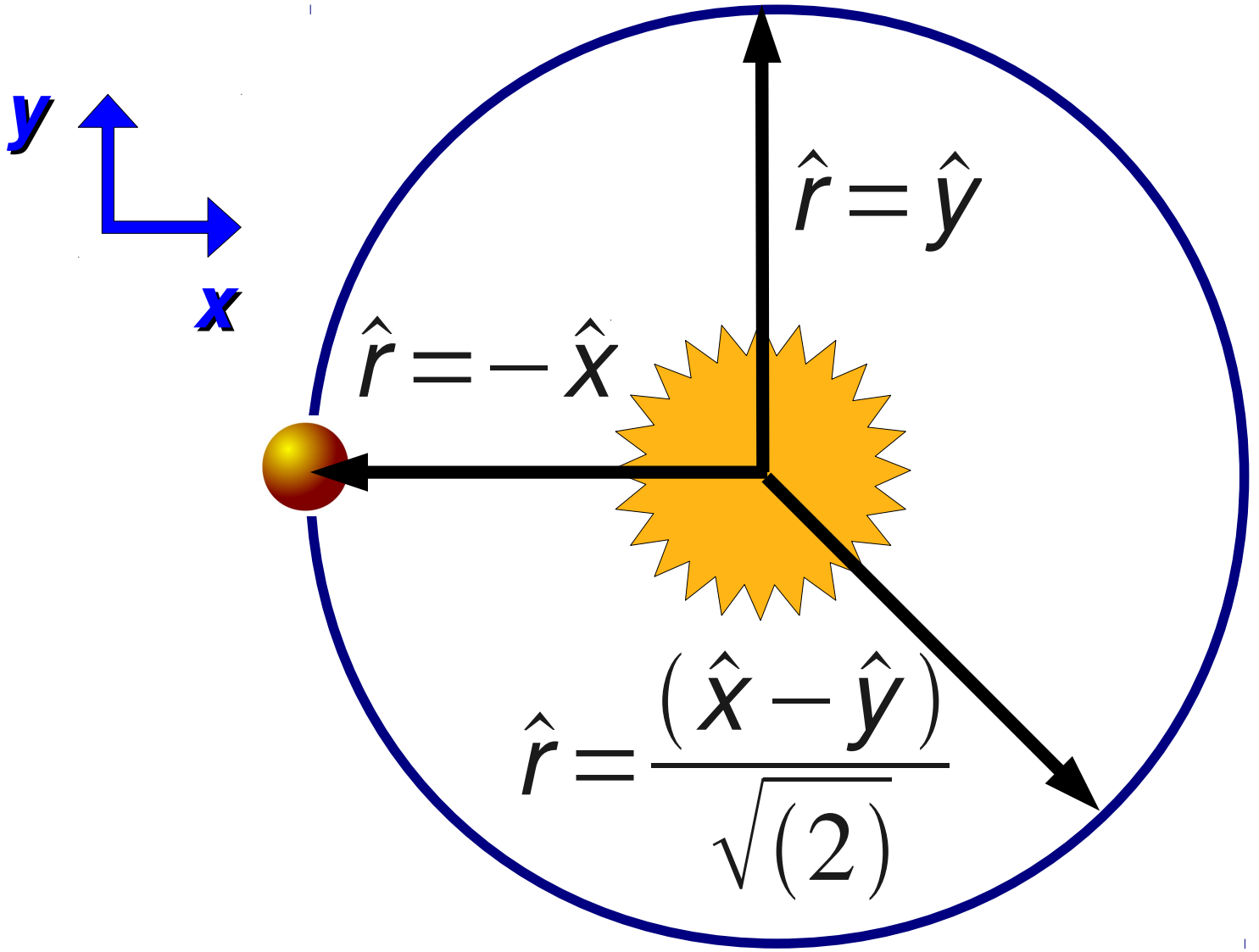
$$\vec{a}_c = -a_c \hat{r}$$

$$\hat{r} = \frac{\vec{R}}{R}$$ Versor radial

$$\vec{F}_c = -F_c \hat{r}$$



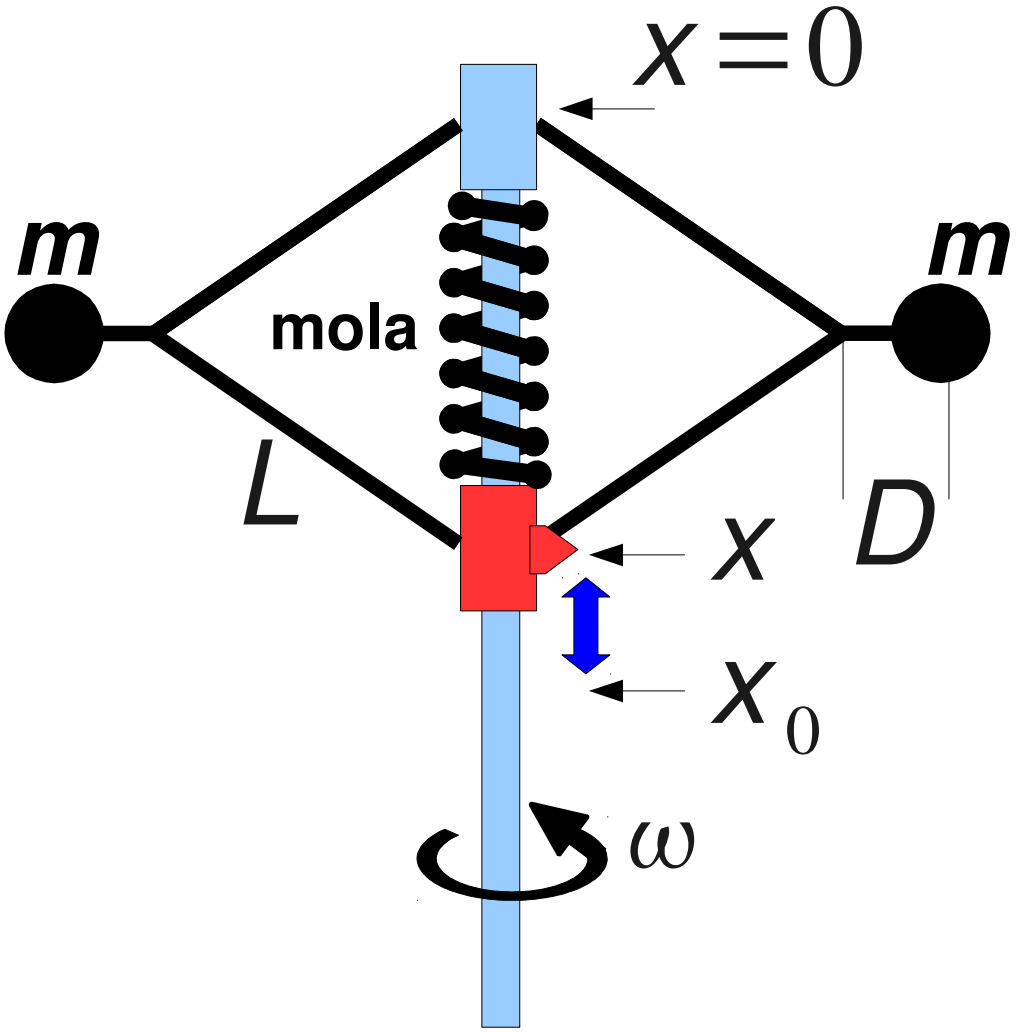
Versor radial - exemplos



Medidor de velocidade angular

Semelhante ao regulador de Watt:

$\omega(x)=?$



Obs: Desprezando a gravidade – boa aprox. quando

$$a_c = R\omega^2 \gg g$$

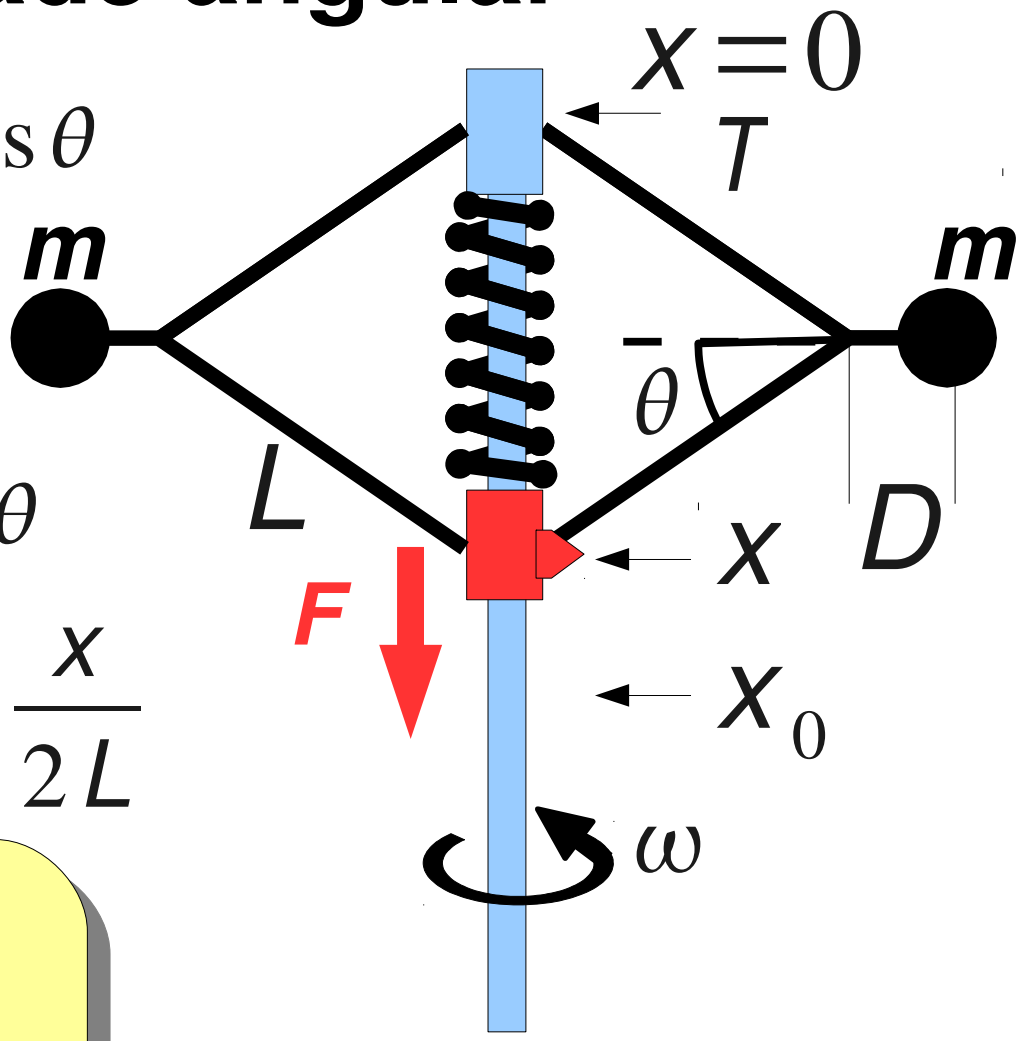
Medidor de velocidade angular

$$m\omega^2(L\cos\theta+D)=2T\cos\theta$$

$$F=2T\sin\theta$$

$$F=m\omega^2(L+D/\cos\theta)\sin\theta$$

$$F=-k(x-x_0) \qquad \sin\theta=\frac{x}{2L}$$



$$\omega=\sqrt{\frac{2Lk(x_0/x-1)}{m\left(L+D/\sqrt{1-\left(\frac{x}{2l}\right)^2}\right)}}$$

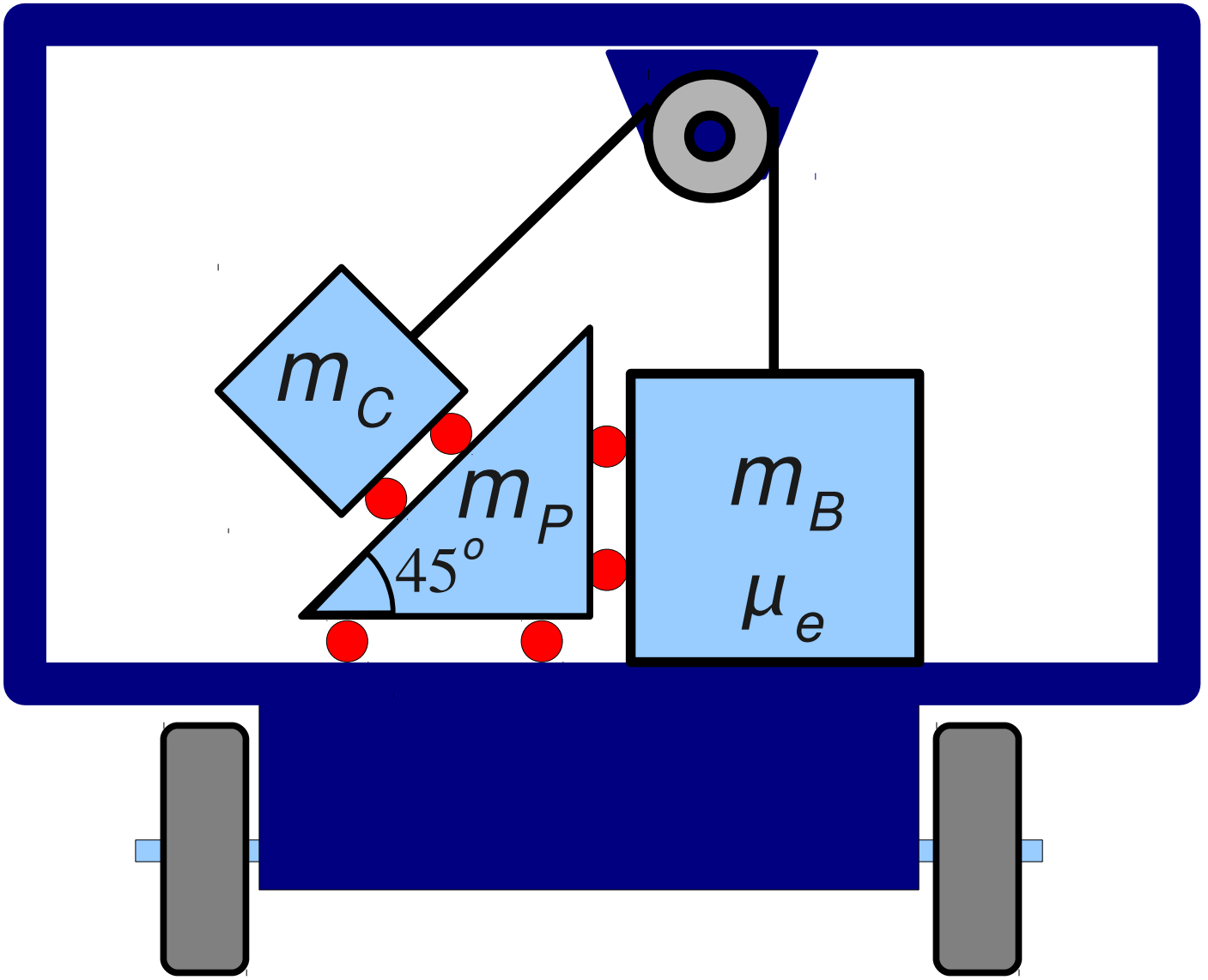
Verificar aprox. de *g* despr.:

$$a_c=(L\cos\theta+D)\omega^2\gg g$$

“Exercício”

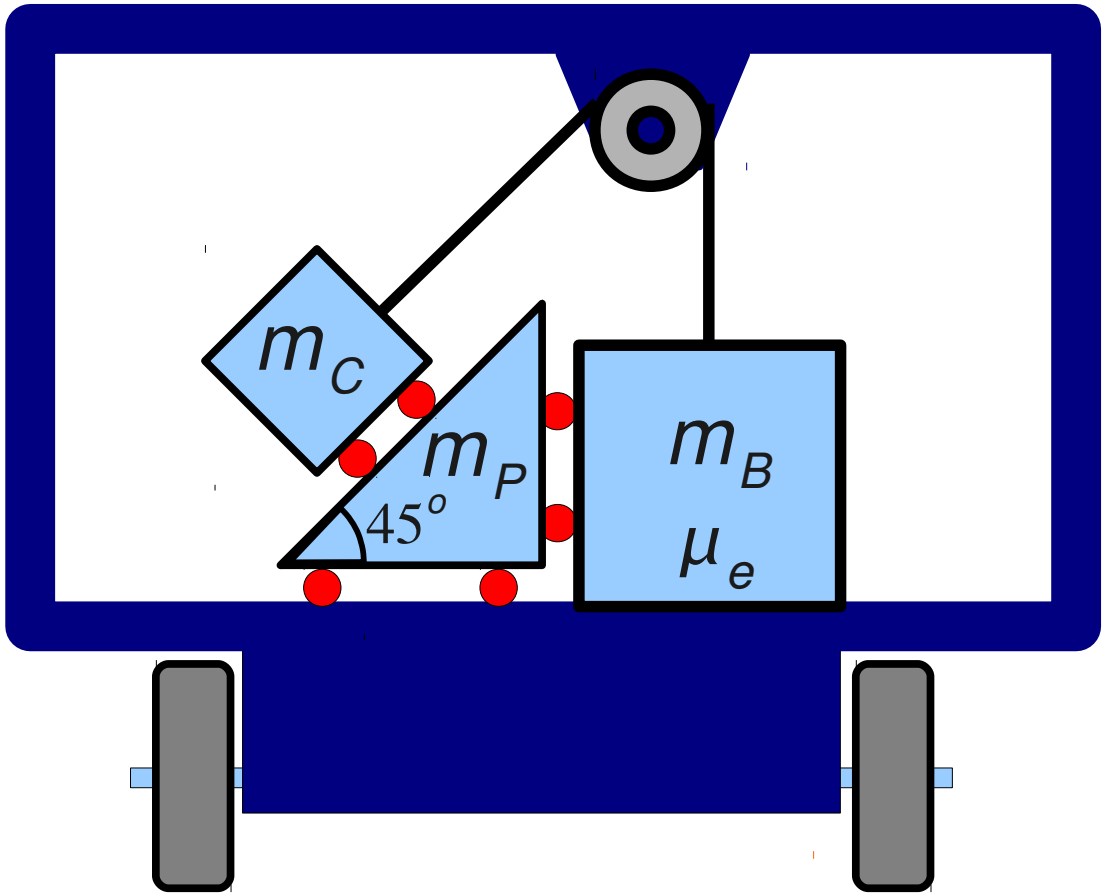
Vagão c/ objetos em equilíbrio. m_c (máx.) = ?

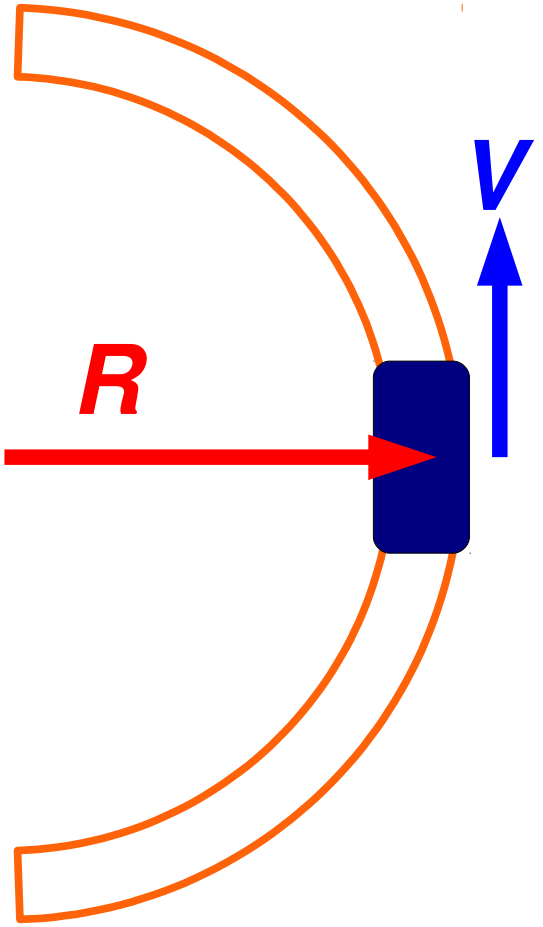
Parado.



“Exercício”

Vagão c/ objetos em equilíbrio. m_C (máx.) = ?





Em movimento, na curva de raio *R* com vel. *V.*