10/11/21

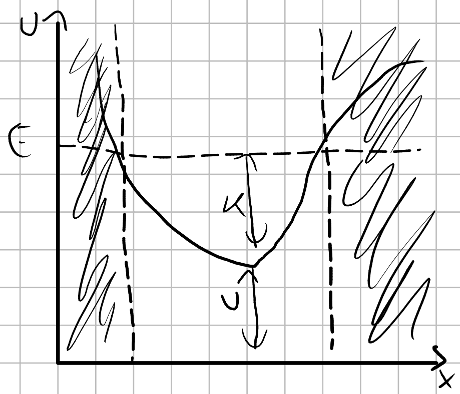
$dW = \vec{F}\cdot d\vec{s} = -dU$

$F_x\,dx + F_y\,dy + F_z\,dz = -dU$

$F_x = -\frac{\partial U(x,y,z)}{\partial x}$

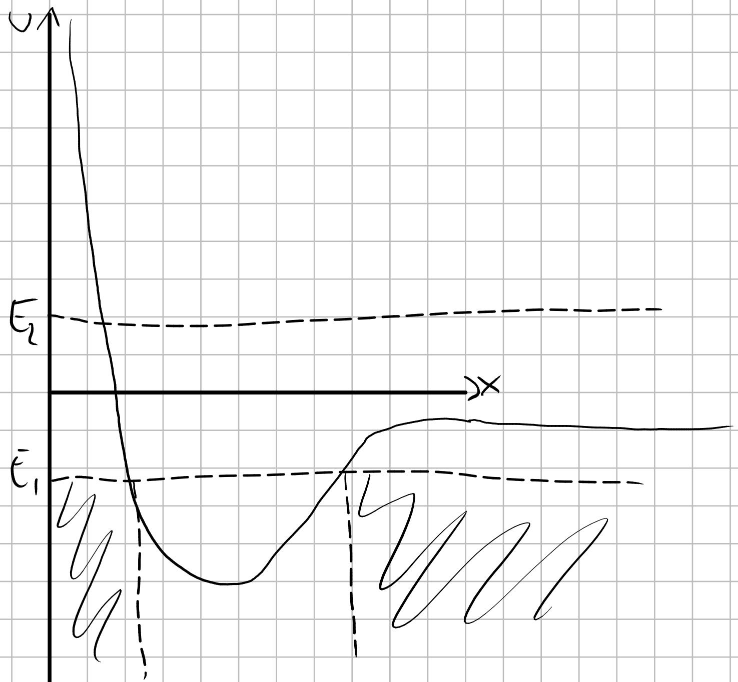
$F_y = -\frac{\partial U}{\partial y}$

$F_z = -\frac{\partial U}{\partial z}$



$E = K(x) + U(x)$

$K(x) = E - U(x) \geq 0 \qquad E \geq U(x)$

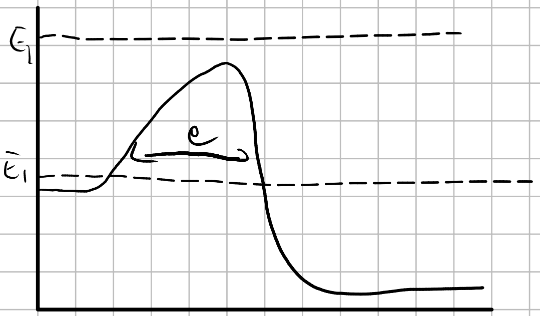


$E > U(x)$

Velocità di fuga della terra

$E = K + U = \frac{1}{2} m v^2 - G\frac{mM}{r} \qquad E_0 = E_\infty$

$E_\infty = 0 \qquad \frac{1}{2}\cancel{m} v^2 - G\frac{\cancel{m} M}{r} = 0 \qquad v^2 = 2\frac{GM}{r}$



$E_2 > U$

$E_1 < U$

Quantità di moto

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

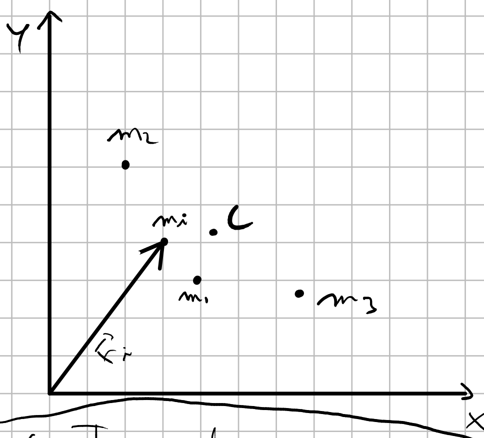
$$\sum \vec{F} = m\vec{a} = m\frac{d\vec{v}}{dt} = \frac{d(m\vec{v})}{dt} = \frac{d\vec{p}}{dt}$$ II° legge della din.

Teorema dell'impulso

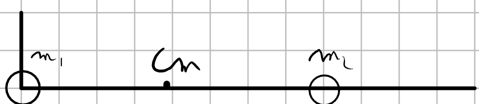
$\vec{F}_{tot} = \frac{d\vec{p}}{dt}$ $\qquad \vec{F}_{tot}\,dt = d\vec{p}$

$$\underbrace{\vec{J}}_{\text{impulso}} = \int_0^t \vec{F}\,dt = \int_{\vec{p}_0}^{\vec{p}_F} d\vec{p} = \vec{p}_F - \vec{p}_0 \Rightarrow \vec{J} = \Delta\vec{p}$$

Sistema discreto di punti materiali

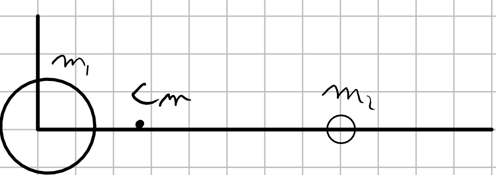


Centro di massa:



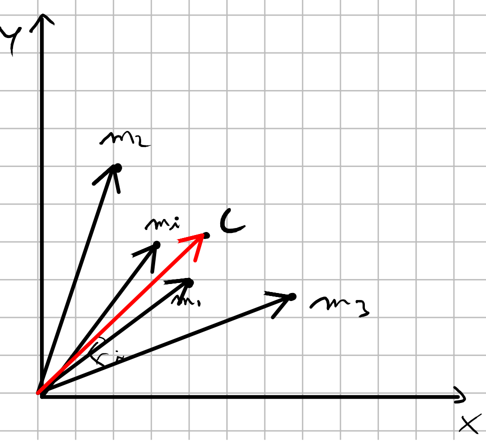
$m_1 = m_2 = m$

$x_{cm} = \frac{\cancel{m}\, x_2}{2\cancel{m}}$



$m_1 > m_2$

$x_{cm} \simeq \frac{m_2 x_2}{m_1}$

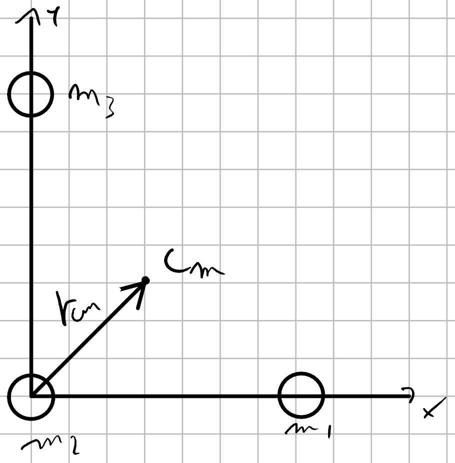


$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 \dots}{m_1 + m_2 \dots}$$

$$x_{cm} = \frac{\sum_{i=1}^{N} m_i x_i}{M_{tot}}$$

$$y_{cm} = \frac{\sum_{i=1}^{N} m_i y_i}{M_{tot}}$$

$$\vec{r}_{cm} = x_{cm}\hat{\imath} + y_{cm}\hat{\jmath} = \frac{\sum_{i=1}^{N} m_i \vec{r}_i}{M_{tot}}$$



$m_1 = 2\,kg$ $(0,0)$

$m_2 = 6\,kg$ $(4,0)$

$m_3 = 4\,kg$ $(0,3)$

$$x_{cm} = \frac{24\,kg\,m}{12\,kg} = 2\,m$$

$$y_{cm} = \frac{12\,kg\,m}{12\,kg} = 1\,m$$

Cambiando sistema di riferimento, $\vec{r}_{cm} = \vec{r}\,'_{cm} + \vec{OO'}$

$$M\vec{r}_{cm} = \sum_{i=1}^{N} m_i r_i \qquad M\frac{dr_{cm}}{dt} = \sum_{i=1}^{N} m_i \frac{dr_i}{dt} \qquad M\vec{v}_{cm} = \sum_{i=1}^{N} m_i \vec{v}_i$$

$\vec{P}$ = quantità di moto del sistema $= \sum_{i=1}^{N} m_i v_i = M\vec{v}_{cm}$

$$M\frac{d\vec{v}_{cm}}{dt} = \sum_{i=1}^{N} m_i \frac{d\vec{v}}{dt} \qquad M\vec{a}_{cm} = \sum_{i=1}^{N} m_i \vec{a}_i$$

$$M\vec{a}_{cm} = \sum_{i=1}^{N} \vec{F}_i^{tot} \qquad \vec{F}_i^{tot} = \vec{F}_i^{ext} + \sum_{i=1}^{N-1} \vec{F}_i^{int} = m_i a_i$$

Teorema del centro di massa:

$$\sum \vec{F}_{ext} = M\vec{a}_{cm}$$

$$\vec{F}_{ext} = M\frac{d\vec{v}_{cm}}{dt} = \frac{d\vec{P}}{dt}$$

I equazione cardinale della meccanica

$$F_x^{ext} = 0 \qquad \frac{d\vec{P}_x}{dt} = 0 \qquad P_x = k$$

$$F_y^{ext} = 0 \qquad \frac{dP_y}{dt} = 0 \qquad P_y = k$$

$$\vec{F}_{ext} = 0 \Rightarrow P = k$$

II° legge della conservazione della quantità di moto di tutto il sistema

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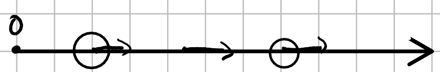

$m_1 = m_2 = m$

$$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} = \frac{x_1 + x_2}{2}$$

$$V_{cm} = \frac{m_1V_1 + m_2V_2}{m_1 + m_2} = \frac{\cancel{2m}V}{\cancel{2m}}$$ se $V_2 = 0$, $V_1 = V$

$$V_{cm} = \frac{mV - mV}{2m} = 0$$ se $V_1 = V$, $V_2 = -V$

Moto di un sistema di punti con forza peso

$$M\vec{a}_{cm} = \sum_{i=1}^{N} m_i \vec{a}_i = \sum_{i=1}^{N} m_i \vec{g} = M\vec{g} \Rightarrow \vec{a}_{cm} = \vec{g}$$

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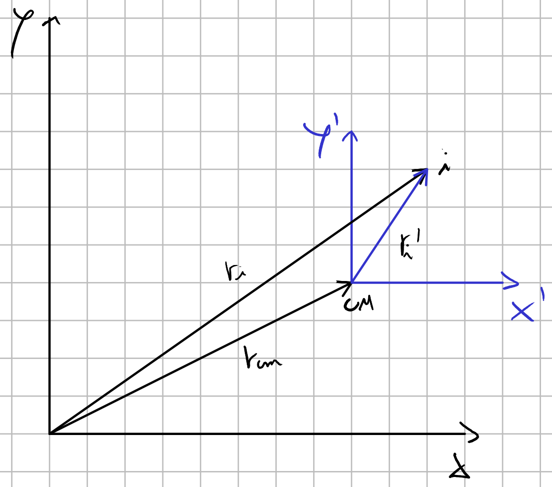


$$\vec{r}_i = \vec{r}_{cm} + \vec{r}_i'$$
$$\vec{v}_i = \vec{v}_{CM} + \vec{v}_i'$$
$$\vec{a}_i = \vec{a}_{CM} + \vec{a}_i'$$

$$M\vec{r}_{CM}' = \sum_{i=1}^{N} m_i \vec{r}_i' = 0$$

$$M\vec{v}_{CM}' = \sum_{i=1}^{N} m_i \vec{v}_i' = 0$$

$$K = \sum_{i=1}^{N} K_i = \sum_{i=1}^{N} 1/2\, m_i v_i^2 = \sum_{i=1}^{N} 1/2\, m_i (\vec{v}_i \cdot \vec{v}_i) = \sum_{i=1}^{N} 1/2\, m_i \left(\vec{v}_{CM} + \vec{v}_i'\right)\left(\vec{v}_{CM} + \vec{v}_i'\right)$$

$$K = 1/2 \sum_{i=1}^{N} m_i \left(v_{CM}^2 + 2\vec{v}_{CM}\vec{v}_i' + \vec{v}_i'^2\right) = 1/2 \sum_{i=1}^{N} m_i v_{CM}^2 + \sum_{i=1}^{N} m_i \vec{v}_i' \vec{v}_{CM} + 1/2 \sum_{i=1}^{N} m_i v_i'^2$$

NON COMPLETO

Teorema dell'energia cinetica

$$\vec{F}_i = \vec{F}_i^{ext} + \vec{F}_i^{int}$$

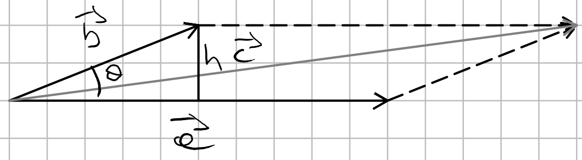
$$dW_i = \vec{F}_i \cdot d\vec{s}_i = \left(\vec{F}_i^{ext} + \vec{F}_i^{int}\right) \cdot d\vec{s}_i$$

$$dW_i = \vec{F}_i^{ext} \cdot d\vec{s}_i + \vec{F}_i^{int} \cdot d\vec{s}_i = dW_i^{ext} + dW_i^{int}$$

$$dW = \sum_{i=1}^{N} dW_i \Rightarrow W = \sum_{i=1}^{N} W_i^{ext} + \sum_{i=1}^{N} W_i^{int} = K_f - K_i \Rightarrow dW_i = dK_i \Rightarrow$$

$$\Rightarrow W_i = \Delta K_i = \quad W^{int} = -\Delta U^{int}, \quad W^{ext} = -\Delta U^{ext} \qquad W^{ext} + W^{int} = -\Delta U^{ext} - \Delta U^{int} = \Delta K \Rightarrow$$

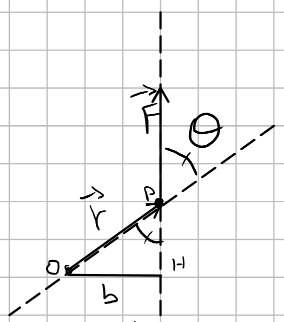
$$\Rightarrow \Delta E = W^{int} \,/\, \Delta E = 0$$



$c = ab \operatorname{sen}\theta$

$$c = |\vec a \times \vec b| = \begin{vmatrix} \hat i & \hat j & \hat k \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

Momento di una forza



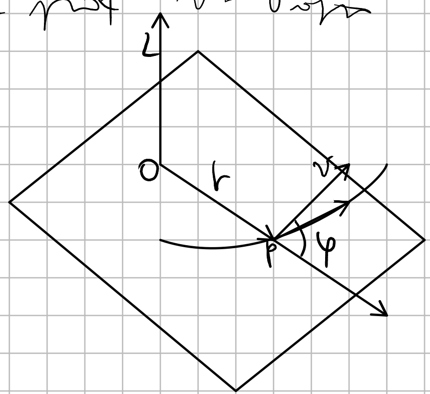
$b = r \operatorname{sen}\theta$

b = braccio è la distanza della linea di applicazione della forza

$r = \overrightarrow{OP}$

$M = bF = r \operatorname{sen}\theta \, F$

La prof va troppo veloce per fare grafici esatti.



$\vec L_0 = \vec r \times m\vec v = \vec r \times \vec p$ ← momento d'inerzia, credo

$L_0 = r m v \operatorname{sen}\varphi$

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Sistemi di punti materiali

$\vec P = \sum_{i=1}^{N} m_i \vec v_i = \sum_{i=1}^{N} \vec p_i = P = m \vec v_{cm}$

$K = \sum_{i=1}^{N} 1/2\, m_i v_i^2$

$\vec L = \sum_{i=1}^{N} \vec r_i \times m_i \vec v_i = \sum_{i=1}^{N} \vec L_i$

$$\frac{dL}{dt} = -\vec v_0 \times M \vec v_{cm} + \sum_{i=1}^{N} \vec\tau_i^{\,ext} + \sum_{i=1}^{N} \tau_i^{\,int}$$

$$\frac{dL}{dt} = -\vec v_0 \times M \vec v_{cm} + \vec\tau^{\,ext}$$ → II° legge cardinale della meccanica

① polo O è fisso
② $O \equiv CM$
③ $\vec{v}_O \parallel \vec{v}_{CM}$
⑤ $\vec{v}_{CM} = 0$

$$\boxed{\frac{dL}{dt} = \vec{\tau}^{ext}}$$

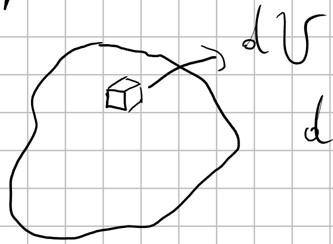
Sistema discreto di punti

m_3

m_i

m_2

Corpo esteso



$dm = \rho \, dV$

$\rho \to$ densità volumetrica

$\rho(x,y,z)$

$\rho = k$ corpo omogeneo

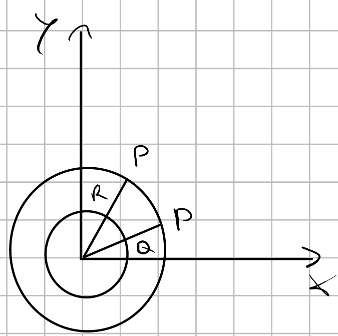
3D: $m = \int_V \rho \, dV = \underbrace{\rho \int_V dV = \rho V}_{\rho = k}$

2D: $\sigma \equiv$ densità superficiale $= kg/m^2$ disco

$dm = \sigma \, dS \qquad m = \int_S \sigma \, dS = \sigma \int_S dS = \sigma S$ ($\sigma \to k$)

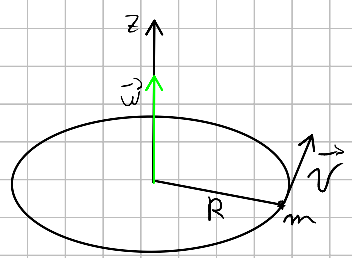
1D: λ densità lineare kg/m filo

$d = \lambda \, dl \qquad m = \int_l \lambda \, dl = \lambda \int_l dl = \lambda L$ ($\lambda \to k$)



$\omega = \frac{d\theta}{dt}$

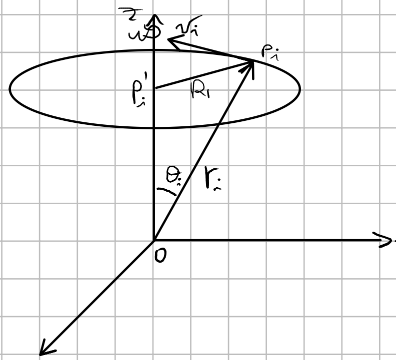
$ds = r \, d\theta$



$\vec{v} = \vec{\omega} \times \vec{r}$

$$\frac{d\vec{v}}{dt} = \frac{d(\vec{\omega} \times \vec{r})}{dt} = \frac{d\vec{\omega}}{dt} \times \vec{r} + \vec{\omega} \times \frac{d\vec{r}}{dt} = \underset{a_T}{\vec{\alpha} \times \vec{r}} + \underset{a_C}{\vec{\omega} \times \vec{v}}$$

Energia cinetica di rotazione



$K_i = 1/2\, m_i v_i^2 \qquad V_i = \omega R_i$

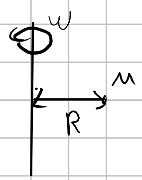
$K_i = 1/2\, m_i \omega^2 R_i^2 = 1/2\,(m_i R_i^2)\,\omega^2$

$K = \sum_{i=1}^{N} K_i = \sum_{i=1}^{N} 1/2\, \omega^2$

APPUNTI INCOMPLETI

Corpo discreto

$I_z = M R^2$



$I = \sum_{i=1}^{N} m_i R_i^2$

Corpo continuo

$I = \int R^2\, dm = \int_0^L x^2 \lambda\, dx = \lambda \int_0^L x^2 dx = \lambda/3\, L^3 = 1/3\, M L^3$

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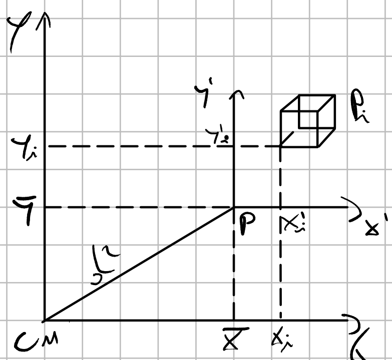


$x_i = \bar X + x_i' \qquad x_i' = x_i - \bar X$

$y_i = \bar Y + y_i' \qquad y_i' = y_i - \bar Y$

$z_i = z_i' \qquad z_i' = z_i$

$I_{cm} = \sum_i m_i (x_i^2 + y_i^2) = \sum_i m_i r_i^2$

$I_p = \sum_i m_i (x_i'^2 + y_i'^2) = \sum_i m\, r_i'^2$

$I_p = \sum_i m_i [(x_i - \bar x)^2 + (y_i - \bar y)^2] = \sum_i m_i [x_i^2 - 2 x_i \bar x + \bar x^2 + y_i^2 - 2 y_i \bar y + \bar y^2] =$

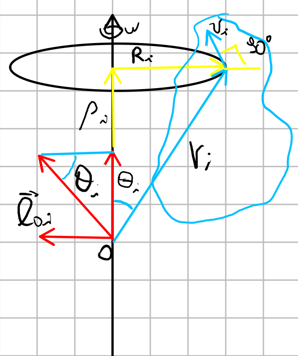
$= \sum_i m_i (x_i^2 + y_i^2) + \sum_i m_i (\bar x^2 + \bar y^2) \cancel{+2 \sum_i m_i x_i \bar x} \cancel{- 2 \sum_i m_i y_i \bar y}$

$\sum_i m_i x_i = M x_{cm} = 0$

$\sum_i m_i y_i = M y_{cm} = 0$

$I_p = \sum_i m_i (x_i^2 + y_i^2) + \sum_i m_i d^2$

$\boxed{I_p = I_{cm} + M d^2}$



$\vec r_i = \vec \rho_i + \vec R_i$

$\vec L_{0i} = \vec r_i \times m_i \vec v_i$

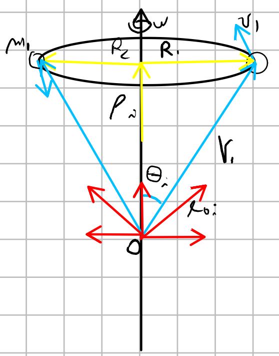
$\vec L = \sum_i \vec L_i = \sum_i \vec r_i \times m_i \vec v_i$

$\vec L = \sum (\vec \rho_i + \vec R_i) \times m_i \vec v_i = \sum_i \vec \rho_i \times m_i \vec v_i + \sum_i \vec R_i \times m_i \vec v_i$

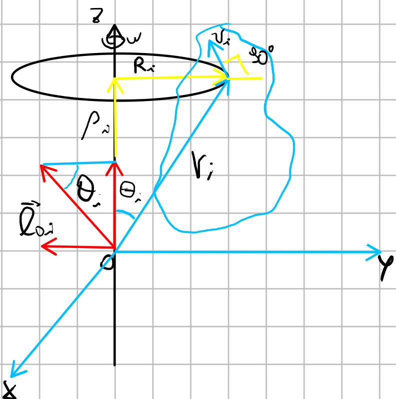
$\vec L = \vec L_1 + \vec L_2 = \vec L_1 + L_z \hat k$

$$L_z = \sum_i \vec{R}_i \times m_i \vec{v}_i = \sum_i R_i m_i v_i \sin 90° = \sum_i R_i m_i \omega R_i \hat{k} = \sum_i m_i R_i^2 \omega \hat{k}$$

$$v_i = \omega R_i \Rightarrow \boxed{L_z = I_z \omega}$$



polo o fisso,



$$\vec{\tau} = \frac{d\vec{L}}{dt} \qquad \vec{\tau} = \sum_i \vec{\tau}_i$$

$$\vec{\tau}_i = \vec{r}_i \times \vec{F}_i$$

$$\vec{r}_i = \vec{\rho}_i + \vec{R}_i$$

$$\vec{\tau}_i = (\vec{\rho}_i + \vec{R}_i) \times \vec{F}_i$$

$$\vec{\tau}_i = \underbrace{\vec{\rho}_i \times \vec{F}_i}_{\tau_{i\perp}} + \underbrace{\vec{R}_i \times \vec{F}_i}_{\tau_{iz}} \qquad (\vec{\rho}_i \times \vec{F}_i)_z = 0$$

$$\vec{F}_i = \vec{F}_{iz} + \vec{F}_{i\perp}$$

$$\tau_{iz} = \vec{R}_i \times (\vec{F}_{iz} + \vec{F}_{i\perp}) = \underbrace{\vec{R}_i \times \vec{F}_{iz}}_{\text{non ha comp } z} + \vec{R}_i \times \vec{F}_{i\perp}$$

$$\tau_{iz} = \vec{R}_i \times \vec{F}_{i\perp}$$

$$\vec{F}_{i\perp} = \vec{F}_{it} + \vec{F}_{ir}$$

$$\tau_{iz} = \vec{R}_i \times (\vec{F}_{it} + \vec{F}_{ir})$$

$$\tau_{iz}$$

$$\tau_{z} = \sum_i \tau_{iz} = \sum_i R_i F_{it}$$

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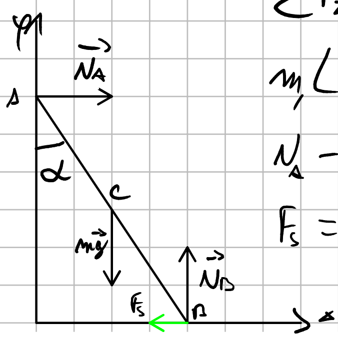
STATICA

$$\sum \vec{F} = 0 \quad \begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \\ \sum F_z = 0 \end{cases} \qquad \sum \vec{\tau}^{\,ext} = 0 \;\Downarrow\; \forall \text{ polo}$$



$m, L \qquad \mu_s = ?$

$N_A - F_s = 0 \qquad N_B - mg = 0$

$F_s = -N_A \qquad N_B = mg$

$\tau_z = 0$ Polo z $\quad -N_A L \cos\alpha + mg \frac{L}{2} \operatorname{sen}\alpha = 0$

$$N_A = \frac{mg}{2} \operatorname{tg}\alpha$$

$$F_S = \frac{\cancel{mg}}{2} \operatorname{tg}\alpha \leq \mu_s N_B = \mu_s \cancel{mg} \Rightarrow \mu_s \geq \frac{\operatorname{tg}\alpha}{2}$$

moto della ruota:

$$s = R\theta$$

$$v_{cm} = \frac{ds}{dt} = \frac{d(R\theta)}{dt} = R\frac{d\theta}{dt} = R\omega$$

$$K = \frac{1}{2} I_P \omega^2 = \frac{1}{2}\left(I_{cm} + mR^2\right)\omega^2 = \frac{1}{2} I_{cm}\omega^2 + \frac{1}{2} m$$ NON COMPLETO

$$\vec{F}^{ext} = \frac{dp}{dt} = M\vec{a}_{cm}$$

x: $F - F_s = M\vec{a}_{cm}$

y: $N - Mg = 0$

$$\vec{\tau} = \frac{d\vec{L}}{dt} \qquad cm \qquad \vec{\tau}_z = I_{cm}\alpha$$

$\tau_{peso}, \tau_F = 0$ braccio nullo

$\tau_N = 0 \qquad b \parallel N$

$F_S R = I_{cm}\alpha \qquad a_{cm} = \alpha R$ moto di puro rotolamento

$$F_s = I_{cm}\alpha = \frac{I_{cm} a_{cm}}{R^2}$$

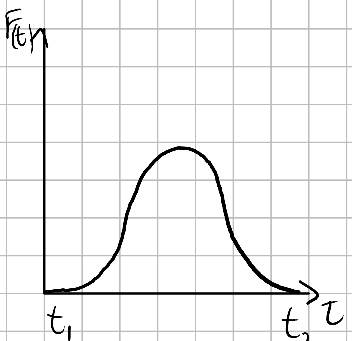
$$F - \frac{I_{cm} a_{cm}}{R^2} = M a_{cm} \qquad F = \left(M + \frac{I_{cm}}{R^2}\right) a_{cm}$$

$$a_{cm} = \frac{F}{M + \frac{I_{cm}}{R^2}} \qquad \alpha = \frac{a_{cm}}{R} \qquad F_s = \frac{I_{cm}\alpha}{R} = \frac{I_{cm}}{R^2}\frac{F}{M + \frac{I_{cm}}{R^2}} \leq \mu_s N$$

$$\frac{I_{cm}}{R^2}\frac{F}{M + \frac{I_{cm}}{R^2}} \leq \mu_s Mg \qquad \frac{I_{cm} F}{MR^2 + I_{cm}} \leq \mu_s Mg$$

$$F \leq \mu_s Mg$$

01/12/21



$I = \int_{t_1}^{t_2} F\,dt = \Delta \vec{P}$

F^{int} e F^{ext}

$\downarrow$

impulsive

F^{ext} trascurabili, $F^{ext} = 0$

$\vec{P} = k$, $\vec{L} = k$

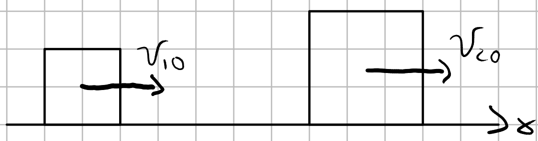
$\vec{P}_0 = \vec{P}_f$, $\vec{L}_0 = \vec{L}_f$

$\downarrow$

in assenza di vincoli

conservazione di E meccanica se F^{int} sono conservative

Urti tra due punti materiali



sistema $m_1 + m_2$

F^{int} impulsive

$P_0 = P_f$ $\boxed{m_1 v_{10} + m_2 v_{20} = m_1 v_{1f} + m_2 v_{2f}}$ ①

urto elastico $K_0 = K_f \rightarrow \frac{1}{2} m_1 v_{10}^2 + \frac{1}{2} m_2 v_{20}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2 \Rightarrow$

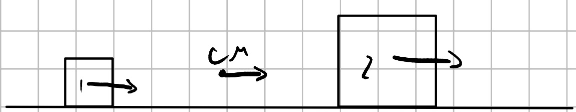
$\Rightarrow m_2 (v_{2f}^2 - v_{20}^2) = -m_1 (v_{1f}^2 - v_{10}^2)$ ②

dalla ① $m_2 (v_{2f} - v_{20}) = -m_1 (v_{1f} - v_{10})$

e ② $\cancel{m_2 (v_{2f} - v_{20})} (v_{2f} + v_{20}) = \cancel{-m_1 (v_{1f} - v_{10})} (v_{1f} + v_{10}) \Rightarrow$

$\Rightarrow \boxed{v_{2f} - v_{1f} = -(v_{20} - v_{10})}$

Urti elastici nel sistema di CM



$v_{CM} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$

$P_{10} = m_1 u_1$ $P_{20} = m_2 u_2$

u_1, u_2 velocità nel sistema con origine CM

$K_{10} = \frac{1}{2} m_1 u_{10}^2 = \frac{P_{10}^2}{2 m_1}$ $K_2^0 = \frac{P_{20}^2}{2 m_2}$

urto elastico

$$\frac{P_{1o}^2}{2m_1}+\frac{P_{2o}^2}{2m_2}=\frac{P_{1f}^2}{2m_1}+\frac{P_{2f}^2}{2m_2}$$

nel sistema con origine in CM $v_{cm}=0$

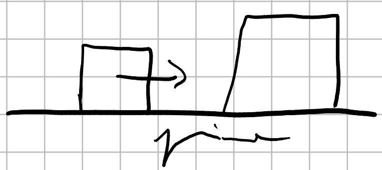
$m_1v_1+m_2v_2=(m_1+m_2)v_{cm}=0 \equiv m_1v_1+m_2v_2=0$

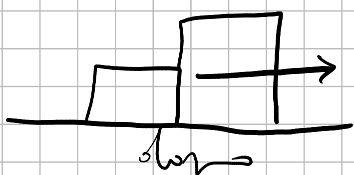
$P_{1o}=-P_{2o}$, $P_{1f}=-P_{2f}$ $\Rightarrow P_{1o}^2/2\,(1/m_1+1/m_2)=P_{1f}^2/2\,(1/m_1+1/m_2) \Rightarrow$

$\Rightarrow P_{1o}^2=P_{1f}^2 \Rightarrow P_{1o}=\pm P_{1f}$ $\boxed{P_{1o}=-P_{1f}}$

$\cancel{P_{1o}=P_{1f}}$ $\leftarrow$ NON HA SENSO

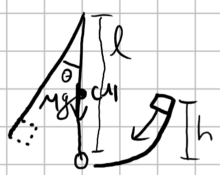
Urto completamente anelastico





Urto tra punti materiali e corpi rigidi

sistema vincolato



$mgh=\frac{1}{2}mv_0^2$ $\quad v_0=\sqrt{2gh}$

$I=\Delta P=P_f-P_0$ solo su x

$I=Mv_{cm}+mv-mv_0$

$L_{zo}=L_{zf}$ $\quad mlv_0=\left(\frac{1}{3}Ml^2+ml^2\right)\omega$

$$\omega=\frac{mlv_0}{\frac{1}{3}Ml^2+ml^2}$$

$I=M\omega/2+m\omega l-mv_0=(M/2+m)l\omega-mv_0$

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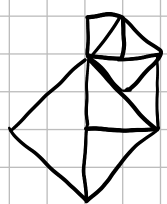
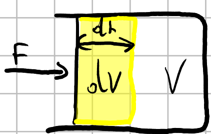
DINAMICA DEI FLUIDI

$dm=\rho\, dV$

$p=\frac{dF}{dS}$ superficie $\quad F_s=p\,dS$



LAVORO



$W=\int^{B}\vec{F}\cdot d\vec{s}$ $\rightarrow p\,dS$

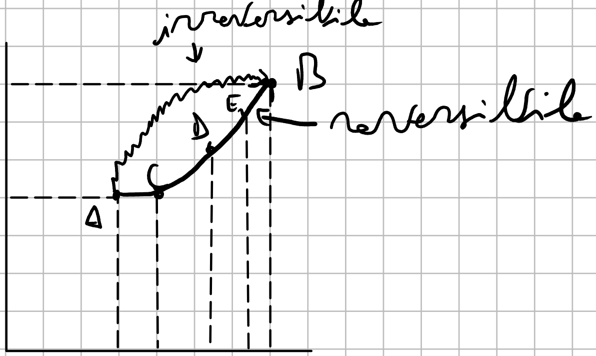
$dW=\vec{F}\cdot d\vec{s}=F\,dh=p$

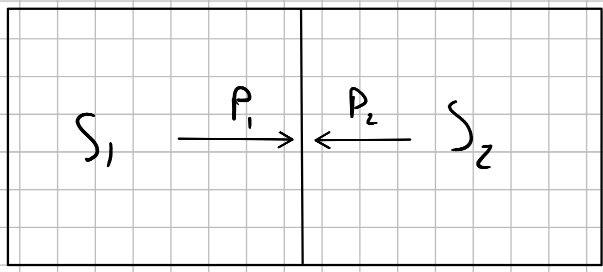
NON COMPLETO

LEGGE DI STEVINO: $\boxed{P_2=P_1+\rho g h}$

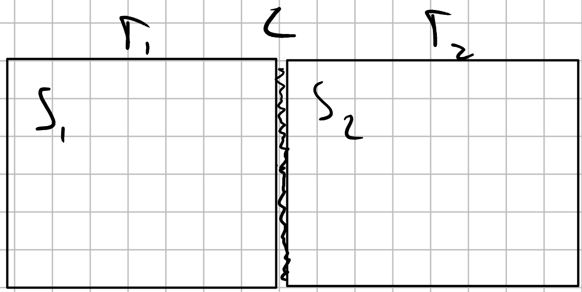
10/12/21

Termodinamica



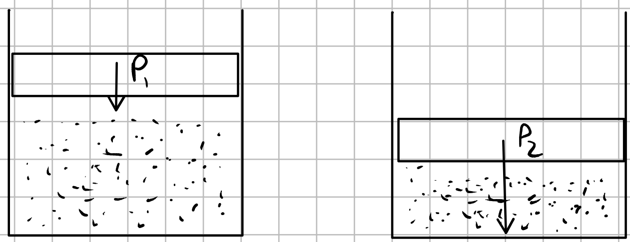


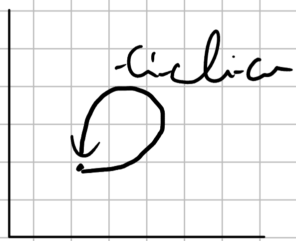
equilibrio se $P_1 = P_2$



equilibrio termico quando $T_1 = T_2$

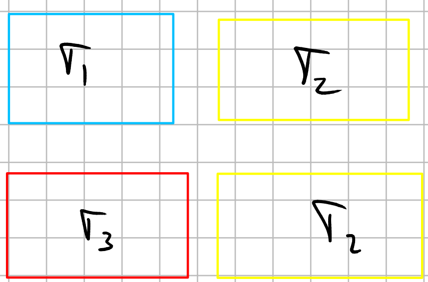
$T_1 < T_{eq} < T_2$





Trasformazione spontanea → irreversibile

adiabatica se non ci sono scambi di calore con l'esterno



$$\left.\begin{aligned} T_1 &= T_2 \\ T_3 &= T_2 \end{aligned}\right\} T_1 = T_3$$

Temperatura e calore

$Q \propto \Delta T$ $\qquad Q = C \Delta T$ $\qquad C =$ capacità termica

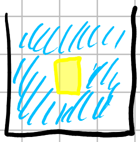
$C = m\underset{\text{calore specifico}}{c}$ $\qquad C = \underset{\text{numero di moli}}{n}c$ $\qquad Q = mc(T_f - T_i)$

Calore = quantità di energia che l'acqua ha bisogno per aumentare la temperatura di 1°C

$m_1 = 600\,g$ $\quad T_1 = 100°C$ $\quad c_{Al} = \dots$

$m_{Al} = 200\,g$ $\quad T_2 = 17,\dots °C$ $\quad c_{H_2O} = \dots$

$m_{H_2O} = 500\,g$ $\quad T_{eq} = 20°C$ $\quad c_1 = ?$



$$Q_1 + Q_2 = 0$$

$$Q_1 = m_1 c_1 (T_{eq} - T_1)$$

$$Q_2 = m_{Al} c_{Al} (T_{eq} - T_2) + m_{H_2O} c_{H_2O} (T_{eq} + T_2)$$

$$m_1 \underbrace{c_1}_{\text{easy}} (T_{eq} - T_1) + m_{Al} c_{Al} + m_{H_2O} c_{H_2O} (T_{eq} + T_2) = 0$$

Transizioni di fase

solido ⇄ liquido $\quad$ fusione $Q > 0$ / solidificazione $Q < 0$ $\quad$ ghiaccio ⇄ acqua

liquido ⇄ gas $\quad$ evaporazione $Q > 0$ / condensazione $Q < 0$ $\quad$ H_2O ⇄ vapore

solido → gas $\quad$ sublimazione $\quad Q = m\underbrace{\lambda}_{\text{calore latente}}$

ES.

$P = 1\,atm$ $\quad gh = $ ghiaccio

$m = 1\,kg$

$T_0 = -20°C$

$$Q_1 = m_{gh} c_{gh} (0°C + 20°C) = 41\,kJ > 0$$

$$Q_2 = m_{gh} \lambda_{fusione} = 333\,kJ > 0$$

$$Q_3 = m_{H_2O} c_{H_2O} (100°C - 0°C) = 418\,kJ > 0$$

$$Q_4 = m_{H_2O} \lambda_{evaporazione} = 2260\,kJ > 0$$

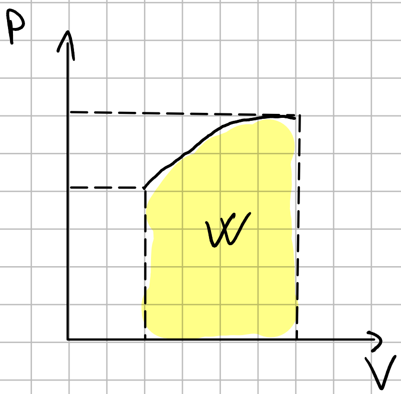
$$Q_{TOT} = \Sigma Q$$

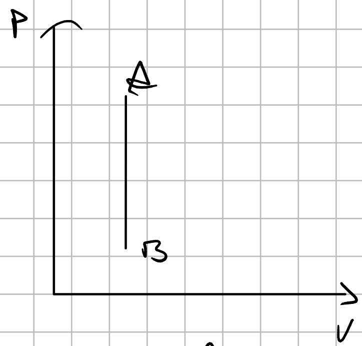
Lavoro

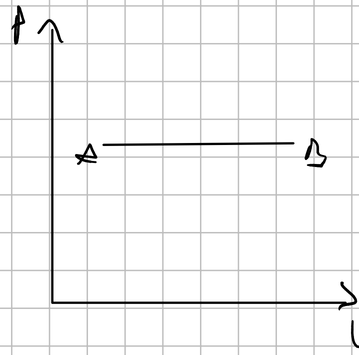
$dW = P\,dV$ >0 lavoro **fatto** dal sistema
<0 lavoro **subito** dal sistema

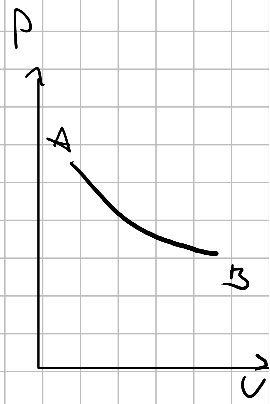
$dW > 0$ $dV > 0$, $V_f > V_0$ espansione

$dW < 0$ $dV < 0$, $V_f < V_0$ compressione









isocora

$dW = P\,dV$

$dV = 0$

$dW = 0$

$W = 0$

isobara

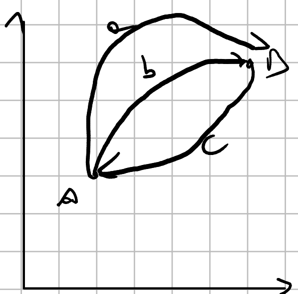
$W = \int P\,dV =$

$= P\int_{V_A}^{V_B} dV$

$W = P_A(V_B - V_A)$ >0 espansione
<0 compressione

I principio termodinamica: $Q = W$ (considerando tutto il ciclo di trasformazione)

sorgente di calore = serbatoio che non cambia la sua temperatura



$(Q - W)_a = (Q - W)_b$

$\boxed{Q - W = U(B) - U(A) = U}$ estensione dell'energia

$\delta Q - \delta W = dU$ se la trasformazione è ciclica $\delta Q - \delta W = 0$

↑ dipende ↑ dipende ↑ non dipende

Trasformazione ciclica:

$\oint \delta Q - \delta W = 0 = \Delta U = 0$ $U(B) = U(A)$

Trasformazione adiabatica:

$Q - W = U(B) - U(A)$

$Q = 0$ $-W = U(B) - U(A)$

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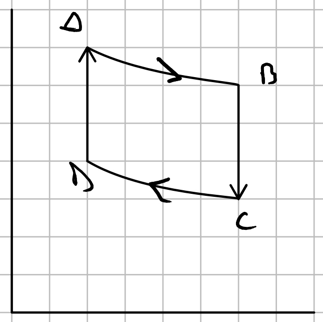

$Q_{AB} = Q_{BC} = 0$