

Mécanique du point

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I - Cinématique du point

Exercice 1: Un conducteur prudent

1) a) $a = \frac{dv}{dt} \Leftrightarrow v = \int a \cdot dt = a \cdot t$

AN: $24 = 2 \cdot t \Leftrightarrow t = 12 \text{ s}$

b) $d = \int v \cdot dt = \frac{1}{2} a t^2$

AN: $d = \frac{1}{2} \cdot 2 \cdot 12^2 = 144 \text{ m}$

2) En file: $d = v \cdot t \Rightarrow d = 288 \text{ m}$
En insertion: $d = 144 \text{ m}$ } Par $t = 12 \text{ s}$

IP faut donc $288 - 144 + 20 = 164 \text{ m}$ de distance

Exercice 2: Mouvement circulaire uniforme

1) Base polaire:

$$\begin{aligned}\vec{v} &= \dot{r} \vec{e}_r + r \dot{\varphi} \vec{e}_\varphi = R \omega \\ \vec{a} &= \ddot{r} \vec{e}_r + \dot{r} \dot{\vec{e}}_r + (r \ddot{\varphi} + \dot{r} \dot{\varphi}) \vec{e}_\varphi + r \dot{\varphi} \dot{\vec{e}}_\varphi \\ &= (\ddot{r} - r \dot{\varphi}^2) \vec{e}_r + (r \ddot{\varphi} + 2 \dot{r} \dot{\varphi}) \vec{e}_\varphi \\ &= -R \omega^2 \vec{e}_r\end{aligned}$$

Dans le repère de Frenet: $\vec{a} = \frac{dv}{dt} \vec{t} + \frac{v^2}{R} \vec{n}$

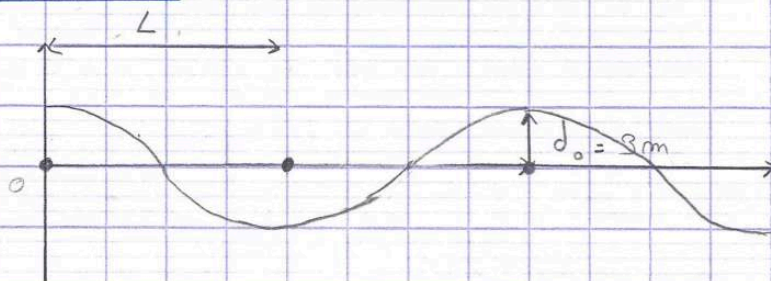
2) a) $\omega = \frac{\text{mbR tours} \times 2\pi}{\Delta t} = 6\pi$

$v = 6,60 \text{ m.s}^{-1}, a = 124,36 \text{ m.s}^{-2}$

b) $\omega = \int \dot{\omega} dt$
 $\frac{d\omega}{dt} = \dot{\omega}$

AN: $\frac{6\pi}{s} = \dot{\omega}$

Exercice 3 Test de stabilité d'une voiture



1) Équation de la forme $y = A \cos Bx$

$$y(x=0) = A = d_0$$

$$y(x=L) = A \cos BL = -d_0$$

$$\Rightarrow \cos BL = -1$$

$$\Rightarrow BL = \pi$$

donc $y = d_0 \cos\left(\frac{\pi}{L} x\right)$

2) $v_y = \frac{dy(x)}{dt} = \frac{dy(x)}{dx} \frac{dx}{dt} = \left(-\frac{\pi}{L} d_0 \sin\left(\frac{\pi}{L} x\right) \right) \dot{x}$

$$v_x = \dot{x} = v_0$$

3) $a_y = \frac{dv_y(x)}{dt} = \frac{dv_y(x)}{dx} \frac{dx}{dt} =$

$$-\frac{\pi^2}{L^2} d_0 \cos\left(\frac{\pi}{L} x\right) v_0^2$$

$$a_x = 0$$

4) $\|\vec{a}_y\| = \frac{\pi^2}{L^2} d_0 \left| \cos\left(\frac{\pi}{L} x\right) \right| v_0^2$

L'accélération est maximale en $0[L]$

5) IP faut que $\|\vec{a}_{\max}\| \leq 0,7g$

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$$6,87 > \frac{\pi^2}{L^2} d_0 \left| \cos \frac{\pi}{L} \right| v_0^2$$

$$6,87 > \frac{\pi^2}{L^2} d_0 v_0^2$$

$$\frac{\pi^2 d_0 v_0^2}{6,87} < L^2$$

$$L > \underline{28,8 \text{ m}}$$

6) Le mouvement n'est pas uniforme car $\vec{v} \neq \text{cte}$

Exercice 4: Mouvement hélicoïdal

1)
$$\vec{OM} = x\vec{e}_x + y\vec{e}_y + z\vec{e}_z$$
$$= r\cos\varphi\vec{e}_x + r\sin\varphi\vec{e}_y + h\varphi\vec{e}_z$$

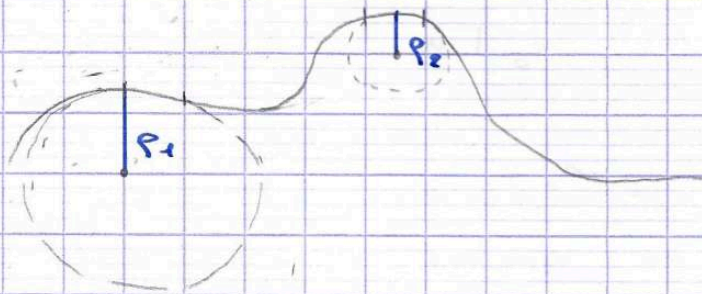
$$\begin{aligned}\vec{v} &= \frac{d\vec{OM}}{d\varphi} \frac{d\varphi}{dt} + \frac{d\vec{OM}}{d\varphi} \frac{d\varphi}{dt} + \frac{d\vec{OM}}{dz} \frac{dz}{dt} \\ &= (\cos\varphi\vec{e}_x + \sin\varphi\vec{e}_y)\dot{\varphi} + (-r\sin\varphi\vec{e}_x + r\cos\varphi\vec{e}_y + h\vec{e}_z)\dot{\varphi} \\ &= \dot{\varphi}\vec{e}_\varphi + r\dot{\varphi}\vec{e}_\varphi + h\dot{\varphi}\vec{e}_z \\ &= \omega(r\vec{e}_\varphi + h\vec{e}_z)\end{aligned}$$

$$\|\vec{v}\| = \omega\sqrt{r^2 + h^2}$$

$$\begin{aligned}\vec{a} &= (\dot{\omega}r + \omega\dot{r})\vec{e}_\varphi - \omega^2 r\vec{e}_\varphi + (\dot{\omega}h + \omega\dot{h})\vec{e}_z \\ &= \dot{\omega}r\vec{e}_\varphi - \omega^2 r\vec{e}_\varphi + \dot{\omega}h\vec{e}_z\end{aligned}$$

$$\|\vec{a}\| = \sqrt{\dot{\omega}^2 r^2 + \omega^4 r^2 + \dot{\omega}^2 h^2}$$

Rayon de courbure:



p : Rayon de courbure

$$\omega = cfe$$

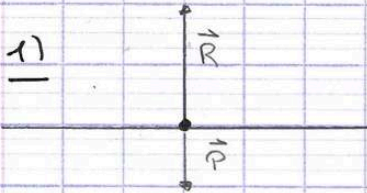
$$\dot{\omega} = 0$$

$$\begin{aligned} \vec{a} &= \dot{\omega} \vec{t} + \frac{v^2}{R} \vec{n} \\ &= \frac{v^2}{R} \vec{n} \end{aligned}$$

$$= \frac{\omega^2 (p^2 + h^2)}{R} \vec{n}$$

II - Dynamique du point

Exercice 5: Forces exercées par des ressorts



PFD: $\sum \vec{F} = m \cdot \vec{a}$

$$\vec{P} + \vec{R} = m \cdot \vec{a}$$

$$\text{soit } \vec{a} = -3g$$

$$\vec{P} = mg$$

$$\text{donc } \vec{R} = -4m \cdot g$$

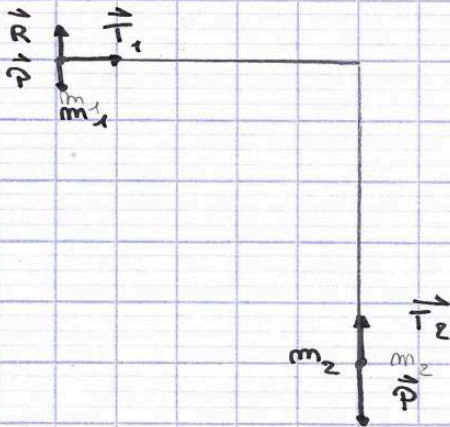
2) $v^2 - v_0^2 = 2a_0(x - x_0)$

$$v^2 = 2a_0 x$$

$$a_0 = \frac{v^2}{2x} \Rightarrow a_0 = \underline{400 \text{ m.s}^{-2}}$$

$$\vec{F} = \vec{P} = m \cdot \vec{a} = \underline{68 \text{ N}}$$

Exercice 6: Mouvement de deux blocs.



Système 1:

$$\vec{P} + \vec{R} + \vec{T} = m \cdot \vec{a}$$

$$m \cdot g \cdot \vec{e}_y - R \vec{e}_y + T_1 \vec{e}_x = m_1 a_1 \vec{e}_x$$

$$\begin{cases} R = m \cdot g \\ T_1 = m_1 a_1 \end{cases}$$

Système 2

$$\vec{P} + \vec{T} = m \cdot \vec{a}$$

$$m \cdot g \vec{e}_z - T_2 \vec{e}_z = m \cdot a \vec{e}_z$$

$$m_2 a_2 = m_2 g - T_2$$

$$\text{or } a_1 = a_2 = a$$

$$T_1 = T_2 = T$$

donc

$$m_1 a = m_2 g - m_2 a$$

$$a = \frac{m_2 g}{m_1 + m_2}$$

$$= \underline{3,27 \text{ m.s}^{-2}}$$

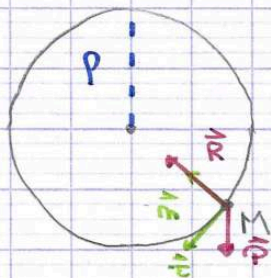
$$T = \underline{65,4 \text{ N}}$$

2) $x = \int \int a dt$

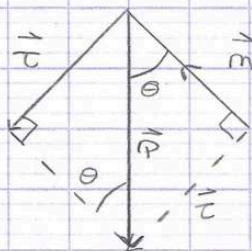
$$= \frac{1}{2} a t^2$$

$$= \underline{6,54 \text{ m}} \quad \text{pour } t = 2 \text{ s}$$

Exercice 7: Le guide circulaire



a) PFD: $\vec{P} + \vec{R} = m \cdot \vec{a}$



$$\vec{P} = 3 \sin \theta mg \vec{e}_r$$

$$= 3 \sin \theta mg \vec{e}_r$$

$$\vec{R} = R \vec{e}_\theta$$

$$3 \sin \theta mg \vec{e}_r - 3 \sin \theta mg \vec{e}_r + R \vec{e}_\theta = m \left(\frac{dv}{dt} \vec{e}_r + \frac{v^2}{\rho} \vec{e}_\theta \right)$$

donc

$$\begin{cases} 3 \sin \theta mg = m \frac{dv}{dt} & (r) \\ R - 3 \sin \theta mg = m \frac{v^2}{\rho} & (\theta) \end{cases}$$

ou $v = \rho \dot{\theta}$

$$\begin{cases} \rho \ddot{\theta} = 3 \sin \theta g \\ \rho \dot{\theta}^2 = R - 3 \sin \theta mg \end{cases}$$

b) TMC: $\Sigma \vec{M}_O = \frac{d\vec{\sigma}_O}{dt}$

$$\vec{M}_O(R) = \vec{OM} \wedge \vec{R} = -\rho \vec{e}_\theta \wedge R \vec{e}_\theta = \vec{0}$$

$$\vec{M}_O(P) = \vec{OM} \wedge \vec{P} = -\rho \vec{e}_\theta \wedge 3 \sin \theta mg \vec{e}_r = 3 \sin \theta mg \rho \vec{e}_\theta$$

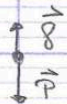
$$\vec{\sigma}_O = \vec{OM} \wedge m \vec{v} = -\rho \vec{e}_\theta \wedge m \dot{\theta} \vec{e}_\theta = \rho^2 m \dot{\theta} \vec{e}_\theta$$

$$M_o(\ddot{\vec{R}}) + M_o(\ddot{\vec{P}}) = P^e_m \ddot{\vec{b}}$$

$$2 \sin \theta g P_m = \ddot{\vec{P}}^e_m$$

$$P \ddot{\theta} = 2 \sin \theta g$$

Exercice 8 : Mouvement vertical d'une goutte d'eau



1) a)

$$\text{PFD: } \Sigma \vec{F} = m \cdot \vec{a}$$

$$m_o g \vec{e}_z - \alpha m_o v \vec{e}_z = m_o \cdot a \vec{e}_z$$

$$= m_o \cdot \frac{dv}{dt} \vec{e}_z$$

$$\text{donc } \dot{v} = g - \alpha v$$

$$v = v_p \text{ quand } a = \dot{v} = 0$$

$$g - \alpha v_p = 0$$

$$\alpha v_p = g$$

$$v_p = \frac{g}{\alpha}$$

$$v_p = \frac{1}{4} \text{ m.s}^{-1}$$

$$\text{b) } y' = g - \alpha y$$

$$y' + \alpha y = g$$

$$y_H = C \cdot e^{-\alpha x}$$

$$y_0 = C$$

$$C(x) = g e^{\alpha x}$$

$$C(x) = \frac{g}{\alpha} e^{\alpha x}$$

$$y_p = \frac{g}{\alpha}$$

$$v = v_p + e^{-\alpha t} \cdot (-v_p)$$

$$\text{à } t=0, v=0 \text{ donc}$$

$$C = -v_p$$

$$\text{c) On cherche } \frac{v_p - v(T)}{v_p} = \frac{1}{1000}$$

$$v(T) = v_p - \frac{v_p}{1000}$$

$$\frac{v_p}{1000} + e^{-\alpha t} \cdot (-v_p) = v_p - \frac{v_p}{1000}$$

$$-\alpha t = P_m \left(\frac{1}{1000} \right), \quad t = \frac{P_m (1/1000)}{-\alpha}$$

$$t = 0,173$$

$$2) \quad \rho = \frac{m}{\frac{4}{3}\pi R^3} \Leftrightarrow \frac{4}{3}\pi R^3 \rho = m$$

$$a) \quad \frac{dm}{dt} = \frac{dm}{dR} \frac{dR}{dt} = \underline{4\pi R^2 \rho \cdot R_0 b}$$

$$b) \quad \text{PFD: } \Sigma \vec{F} = \frac{dm}{dt} \vec{v} + m \frac{d\vec{v}}{dt}$$

$$m \cdot g = (4\pi R^2 \rho R_0 b) v + m \dot{v}$$

$$g = \frac{3R_0 b}{R} v + \dot{v}$$

$$c) \quad \dot{v} + \frac{3R_0 b}{R} v = g \Leftrightarrow \dot{v} + \frac{3}{R} v = \frac{g}{R_0 b}$$

$$v_H = C \cdot e^{\int -\frac{3}{R} dR} = C \cdot R^{-3}$$

$$v_0 = R$$

$$C(R) = \frac{g}{R_0 b} R^3$$

$$C(R) = \frac{gR^4}{4R_0 b}$$

$$v_p = \frac{gR}{4R_0 b}$$

$$v = C \cdot R^{-3} + \frac{gR}{4R_0 b}$$

$$\text{à } t=0, v=v_p,$$

$$R=R_0 \text{ donc}$$

$$v_p = C \cdot R_0^{-3} + \frac{g}{4b}$$

$$\text{donc } C = \left(v_p - \frac{g}{4b}\right) R_0^3$$

$$\text{Ainsi: } v = \left(v_p - \frac{g}{4b}\right) R_0^3 R^{-3} + \frac{gR}{4bR_0}$$

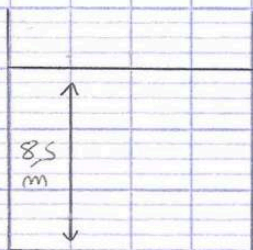
$$v(t) = \left(v_p - \frac{g}{4b}\right) (1+bt)^3 + \frac{g(1+bt)}{4b}$$

$$d) \quad a = \frac{dv}{dt} = \frac{-3b(v_p - \frac{g}{4b})}{(1+bt)^4} + \frac{g}{4}$$

$$\text{P.L.M. } a = \frac{g}{4}$$

III - Travail et énergie

Exercice 9 : Intérêt des aires maximales



$$S = 23 \text{ km}^2$$

$$d\vec{L}_p = dm \, g \, z$$

$$\delta W = -dm \, g \, z$$

$$= -\rho \, S \, g \, z \, dz$$

$$W = -\frac{1}{2} \rho \, S \, g \, z^2$$

$$\begin{aligned} \delta W &= \vec{g} \, d\vec{R} = \vec{g} \cdot \vec{v} \, dt \\ &= -d\vec{L}_p \end{aligned}$$

On décompose en tranches élémentaire de hauteur z et d'épaisseur dz , de masse dm

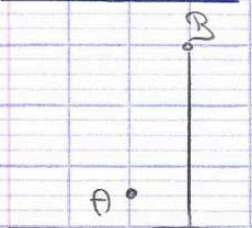
$$dm = \rho \, dV$$

$$dV = S \, dz$$

$$dm = \rho \, S \, dz$$

$$\text{AN: } W = \left[-\frac{1}{2} \rho \, S \, g \, z^2 \right]_{8,5}^0 = \underline{\underline{8,15 \cdot 10^{12} \text{ J}}}$$

Exercice 10 : Saut à la perche



$$\vec{L}_m(A) = \vec{L}_c(A) + \vec{L}_c(B) \quad (1)$$

$$= \frac{1}{2} m v^2 + m g z$$

$$\vec{L}_m(B) = m g h \quad (2)$$

La seule force étant conservative il y a conservation de l'énergie mécanique donc (1) = (2)

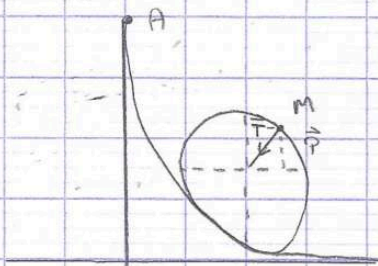
$$\frac{1}{2} m v^2 + m g z = m g h$$

$$h = \frac{1}{2g} v^2 + z$$

$$h = \underline{\underline{6,09 \text{ m}}}$$

Exercice 11 : Le Pooping

Repère de Frenet



$$\text{PFI} (M) : \Sigma \vec{F} = m \cdot \vec{a}$$

$$\vec{T} + \vec{P} = m \cdot \vec{a}$$

$$T \cdot \vec{m} + mg(-\sin \theta \vec{m} + \cos \theta \vec{e}) = m \left(\frac{dv}{dt} \vec{e} + \frac{v^2}{R} \vec{m} \right)$$

$$\begin{cases} T + \sin \theta mg = \frac{v^2}{R} m & (m) \\ \cos \theta g = \frac{dv}{dt} & (v) \end{cases}$$

$$\text{donc } T = \frac{v^2}{R} m - \sin \theta mg \quad \text{avec } z$$

Il y a conservation de l'énergie mécanique, T est une force conservative, T est perpendiculaire.

$$E_m(A) = E_m(M)$$

$$mgh = \frac{1}{2} mv^2 + mgz \quad \text{avec } z = R + R \sin \theta$$

$$v^2 = 2g(h - z)$$

$$v^2 = 2g(h - R - R \sin \theta)$$

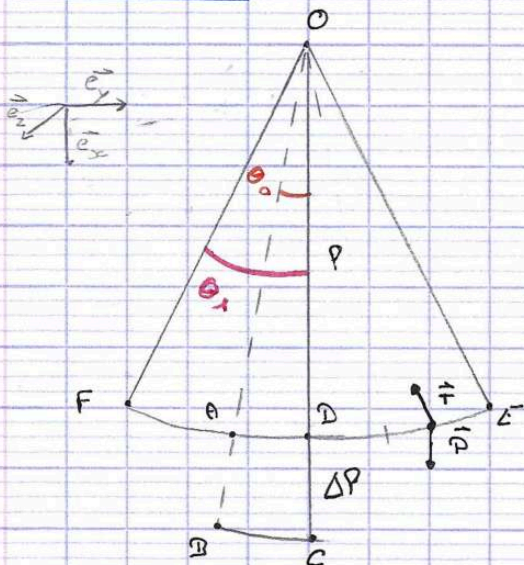
$$\text{donc } T = \frac{2g(h - R - R \sin \theta)}{R} m - \sin \theta mg$$

$$= mg \left(\frac{2h}{R} - 2 - \sin \theta \right)$$

$$\text{en } \theta = \frac{\pi}{2} : T_m = mg \left(\frac{2h}{R} - 5 \right) \geq 0$$

$$h \geq \frac{5}{2} R$$

Exercice 12: Mouvement de la balançoire



$$1) \vec{\Omega}_O^1(C) = \vec{\Omega}_O^1(D)$$

$$\begin{aligned} \vec{\Omega}_O^1(C) &= \vec{OC} \wedge \vec{mv} \\ &= (P + \Delta P) \vec{e}_x \wedge mv_c \vec{e}_y \\ &= \underline{(P + \Delta P) mv_c \vec{e}_z} \end{aligned}$$

$$\begin{aligned} \vec{\Omega}_O^1(D) &= \vec{OD} \wedge \vec{mv} \\ &= P \vec{e}_x \wedge mv_D \vec{e}_y \\ &= \underline{P mv_D \vec{e}_z} \end{aligned}$$

donc $v_D P m = (P + \Delta P) m v_c$

$$v_D = \frac{P + \Delta P}{P} v_c > v_c$$

$$\frac{P + \Delta P}{P} > 1$$

Ainsi, P gagne de la vitesse

$$2) \vec{L}_m^1(A) = \vec{L}_m^1(C)$$

$$mgz_A = \frac{1}{2} m v^2 \quad \text{avec} \quad z_A = R - R \cos \theta$$

$$v^2 = 2g(R - R \cos \theta)$$

$$v_c^2 = 2g(P + \Delta P)(1 - \cos \theta_0)$$

$$v_D^2 = 2gP(1 - \cos \theta_1) = \left(\frac{P + \Delta P}{P}\right)^2 v_c^2$$

$$\begin{aligned} 2gP(1 - \cos \theta_1) &= \left(\frac{P + \Delta P}{P}\right)^2 2g(P + \Delta P)(1 - \cos \theta_0) \\ \frac{\sin \theta_1/2}{\sin \theta_0/2} &= \left(\frac{P + \Delta P}{P}\right)^{3/2} \end{aligned}$$

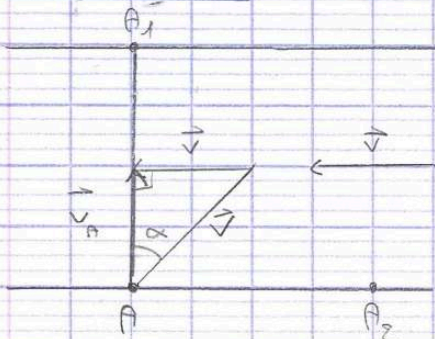
$$\begin{aligned} 3) \theta_0 &= \varepsilon, \quad \sin \theta \xrightarrow{\theta \rightarrow 0} \theta, \quad \sin \frac{\theta_0}{2} = \frac{\varepsilon}{2} \\ \sin \frac{\theta_1}{2} &= \sin \frac{\theta_0}{2} \cdot R = R \frac{\varepsilon}{2} \\ \sin \frac{\theta_2}{2} &= R^2 \frac{\varepsilon}{2} \\ \sin \frac{\theta_n}{2} &= R^n \frac{\varepsilon}{2} \end{aligned}$$

Horizontal si $\theta_n \geq \frac{\pi}{2} \Leftrightarrow \frac{\theta_n}{2} \geq \frac{\pi}{4} \Leftrightarrow \sin \frac{\theta_n}{2} \geq \frac{\sqrt{2}}{2}$

$$n \geq \frac{\frac{1}{2} P m \varepsilon - P m \varepsilon}{P m R}$$

IV - Changement de référentiel

Exercice 13: Problème du magneur



(R): la berge

(R'): l'eau

$\vec{v} = \vec{v}_e$ = vitesse de l'eau R/R

$\vec{V} = \vec{V}_R$ = vitesse magneur / eau
/ R'

$\vec{v}_a = \vec{v}_e + \vec{V}_R$ vitesse magneur / berge
/ R

1)

Trajet AA_1A :

$$t_1 = \frac{2d}{v_a}$$

$$v_a^2 = V^2 - v^2$$

donnée

$$t_1, t_2 = t_1' + t_1'' = 2t_1'$$

pythagore

$$t_1 = \frac{2d}{\sqrt{V^2 - v^2}}$$

$$\frac{t_2}{t_1} > 1 \text{ donc } t_2 > t_1$$

Trajet AA_2A :

$$t_2 = t_2' + t_2''$$

$$t_2' = \frac{d}{V-v}$$

$$t_2 = \frac{2dV}{V^2 - v^2}$$

$$t_2'' = \frac{d}{V+v}$$

2) $t_2 = 2t_1 = 7 \text{ min}$

$$\sin \alpha = \frac{v}{V}$$

$$\frac{1}{\sqrt{1 - \frac{v^2}{V^2}}} = 2 \Rightarrow 1 - \frac{v^2}{V^2} = \frac{1}{4} \Rightarrow \frac{v}{V} = \frac{\sqrt{3}}{2} \Rightarrow \alpha = \frac{\pi}{3}$$

$$t_0 = \frac{2d}{v}, \quad t_z = \frac{2dv}{v^2 - v} = \frac{2d}{v} \cdot \frac{1}{\sqrt{1 - \frac{v^2}{v^2}}}$$

$$t_x = \frac{t_0}{\sqrt{1 - \frac{v^2}{v^2}}}$$

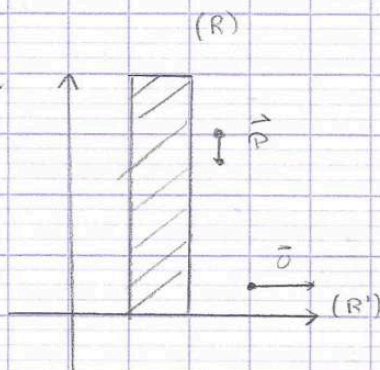
avec $\frac{v^2}{v^2} = \frac{3}{4}$, $t_x = \frac{t_0}{\sqrt{1 - \frac{3}{4}}} = 2t_0$

$$\begin{cases} t_0 = \frac{2}{4} \text{ min} \\ t_x = \frac{2}{2} \text{ min} \\ t_z = \frac{2}{2} \text{ min} \end{cases}$$

Exercice 14: chute d'un objet dans différents référentiels

1) La masse va tomber en bas du mat

2) a)



dans (R)

$$\vec{P} = m\vec{g} = m\vec{a} \Rightarrow \vec{a} = \vec{g}$$

$$\begin{cases} a_x = 0 \\ a_y = -g \end{cases} \Leftrightarrow \begin{cases} v_x = 0 \\ v_y = -gt + v_{y0} \end{cases}$$

à $t=0$ la masse est au repos

donc $v_x = v_y = 0$

$$c_x = c_y = 0$$

$$\begin{cases} x = d_x \\ y = -\frac{1}{2}gt^2 + d_y \end{cases}$$

à $t=0$ $d_x = 0$

$d_y = h$

$$\rightarrow y = -\frac{1}{2}gt^2 + h$$

dans (R'), référentiel galiléen on a encore $\vec{a}' = \vec{g}$

$$\vec{v}_a = \vec{v}_R + \vec{v}_e \Leftrightarrow \vec{v} = \vec{v}' + \vec{u} \Leftrightarrow \vec{v}' = \vec{v} - \vec{u}$$

$$\begin{cases} v'_x = -u \\ v'_y = v_y = -gt \end{cases} \Leftrightarrow \begin{cases} x' = -ut + R_1 \\ y' = -\frac{1}{2}gt^2 + R_2 \end{cases}$$

$R_1 = 0, R_2 = h$

$$\begin{aligned} \underline{b)} \quad \vec{a}' &= \vec{a} - \vec{a}_e \\ &= -g \vec{e}_y - a_e \vec{e}_x \end{aligned}$$

$$\Rightarrow \begin{cases} a'_x = -a_e \\ a'_y = -g \end{cases}$$

$$\Rightarrow \begin{cases} v'_x = -a_e t \\ v'_y = -gt \end{cases}$$

$$\Rightarrow \begin{cases} x' = -\frac{1}{2} g a_e t^2 \\ y' = -\frac{1}{2} g t^2 + h \end{cases}$$

$$y' = \frac{g}{a_e} x' + h$$

mouvement rectiligne

Exercice 16 Référentiel terrestre non galiléen (R)

$$\begin{aligned} \underline{1)} \quad \vec{g} + \vec{g}_{ie} + \vec{g}_{ic} &= m \cdot \vec{a}_R \\ \vec{g} - m \vec{a}_e - m \vec{a}_c &= m \cdot \vec{a}_R \\ m \vec{g} - 2m \vec{\omega} \wedge \vec{v}_R &= m \cdot \vec{a}_R \\ \vec{g} - 2\vec{\omega} \wedge \vec{v}_R &= \vec{a}_R \end{aligned}$$

$$\begin{aligned} \underline{2)} \quad \vec{g} &= -g \vec{e}_z \\ \vec{\omega} &= \omega \cos \lambda \vec{e}_y + \omega \sin \lambda \vec{e}_z \\ \vec{v} &= \dot{x} \vec{e}_x + \dot{y} \vec{e}_y + \dot{z} \vec{e}_z \\ \vec{\omega} \wedge \vec{v} &= (\dot{z} \omega \cos \lambda - \dot{y} \omega \sin \lambda) \vec{e}_x + \dot{x} \omega \sin \lambda \vec{e}_y - \dot{x} \omega \cos \lambda \vec{e}_z \end{aligned}$$

$$\begin{aligned} \vec{a}_x &= -2\omega (\cos \lambda \dot{z} - \sin \lambda \dot{y}) \\ \vec{a}_y &= -2\omega \dot{x} \sin \lambda \\ \vec{a}_z &= -g + 2\omega \dot{x} \cos \lambda \end{aligned}$$

$$\begin{aligned} \underline{3)} \quad \dot{y} &= -2\omega x \sin \lambda + c_1, \quad c_1 = 0 \\ \dot{z} &= -gt + 2\omega x \cos \lambda + c_2, \quad c_2 = 0 \end{aligned}$$

$$\begin{aligned} \underline{4)} \quad \ddot{x} &= -2\omega (-gt \cos \lambda + 2\omega x \cos \lambda + 2\omega x \sin^2 \lambda) \\ &= +2\omega g t \cos \lambda - 4\omega^2 x \end{aligned}$$

5) $\omega = \frac{2\pi}{T} = 7,3 \cdot 10^{-5} \text{ rad.s}^{-1}$
avec $T \approx 24 \text{ h}$.

$$\omega^2 \ll \omega$$

$$\ddot{x} \approx 2\omega g t \cos \lambda$$

6) $\dot{x} = +\omega g t^2 \cos \lambda$

$$x = \frac{1}{3} \omega g t^3 \cos \lambda + \text{cte}$$

$$\dot{y} = -\frac{2}{3} \omega^2 g t^3 \cdot \frac{\sin(2\lambda)}{2}$$

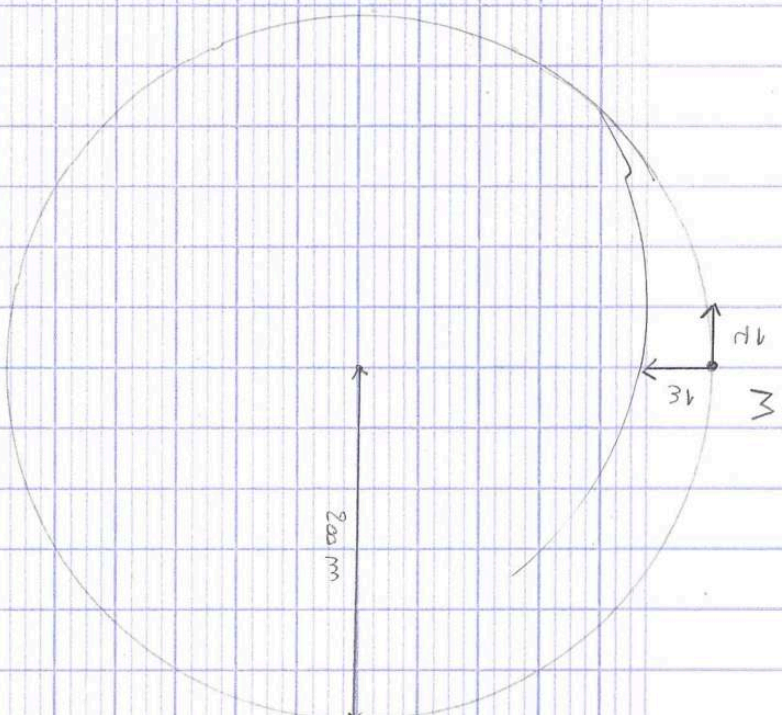
$$y = -\frac{1}{12} \omega^2 g t^4 \sin 2\lambda$$

$$\dot{z} = -g t + \frac{2}{3} \omega^2 g t^3 \cos^2 \lambda$$

$$z = -\frac{1}{2} g t^2 + \frac{1}{6} \omega^2 g t^4 \cos^2 \lambda + h$$

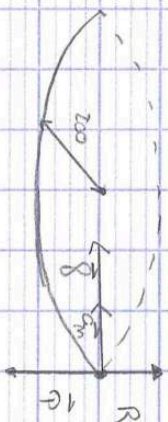
7) Déviation vers Est > Déviation vers Sud
4,3 cm 7 μm

Plot



$$a_m = \frac{v^2}{R}$$

$$a_c = \frac{dv}{dt}$$

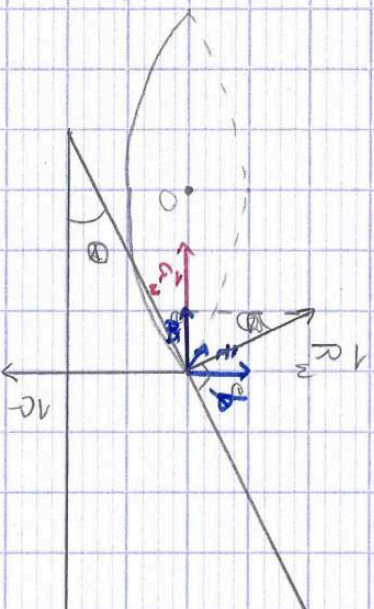


$$\sum F_{ext} = m \cdot a \Rightarrow \vec{P} + \vec{R}_N + \vec{f} = m \cdot \vec{a}$$

$$\sum F_{ext} = m \cdot a_N \Rightarrow \vec{f} = m \cdot a_N \Rightarrow \vec{f} = m \cdot \frac{v^2}{R}$$

$$Si \quad m \approx 1000 \text{ kg}, \quad f \approx 4500 \text{ N}$$

Relevé



$$\sum F = m \cdot a \Rightarrow \vec{P} + \vec{R}_N = m \cdot \vec{a}$$

$$\begin{cases} R_N \sin \theta = m \cdot \frac{v^2}{R} \\ R_N \cos \theta = mg \end{cases} \quad (h)$$

$$\frac{mg}{\sin \theta} = m \cdot \frac{v^2}{R}$$

$$\Leftrightarrow v^2 = Rg \tan \theta$$

$$\Leftrightarrow \tan \theta = \frac{v^2}{Rg} \Rightarrow \theta = 23,27^\circ$$