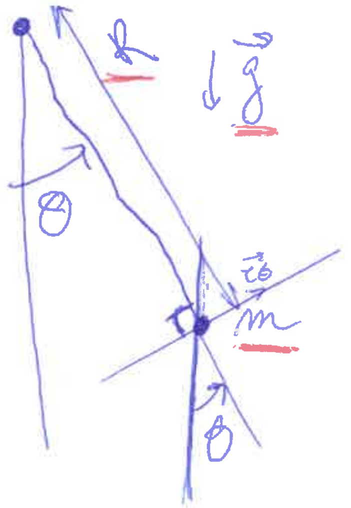

1

$$\frac{d}{dt}(m\vec{v}) = \vec{T} + m\vec{g} \leftarrow \text{Newton 2nd law}$$

$$\frac{d}{dt}\vec{v} = \frac{1}{m}\vec{T} + \vec{g}$$

$$\vec{e}_\theta \cdot \frac{d}{dt}\vec{v} = -g\sin\theta \leftarrow \text{geometry}$$

$$r\ddot{\theta} + 2\dot{r}\dot{\theta} = -g\sin\theta \leftarrow \text{differential equations}$$

$r = R = cte \Rightarrow$

$$R\ddot{\theta} + g\sin\theta = 0$$

$$\ddot{\theta} + \frac{g}{R}\cdot\sin\theta = 0$$

$\sin\theta \approx \theta \Rightarrow$

$$\ddot{\theta} + \omega_0^2\theta = 0 \qquad \omega_0^2 = \frac{g}{R}$$

solution $\Rightarrow$ $\theta(t) = \underline{\theta_0}\cos(\omega_0 t)$ if $\theta = \theta_0$ at $t = 0$ and no speed

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Maximum speed: $v_{max} = R\theta_0 \cancel{\max(\ldots\sin(\omega_0 t))}$

$$= \omega_0\theta_0 R = \sqrt{\frac{g}{R}}\cdot R\theta_0$$

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analytic solution

$$\ddot{\theta} + \omega_0^2\sin(\theta) = 0$$

$$\frac{d}{dt}\left(\frac{1}{2}(\dot{\theta})^2 + \omega_0^2\left[-\cos(\theta)\right]\right) = 0$$

$$\cancel{\frac{1}{2}(\dot{\theta}_0)^2} + \omega_0^2\left[-\cos(\theta_0)\right] = \frac{1}{2}\dot{\theta}^2 + \omega_0^2\left[-\cos(\theta)\right]$$

$$\dot{\theta}^2 = 2\omega_0^2\left(\cos(\theta) - \cos(\theta_0)\right) \hookrightarrow \frac{d\theta}{\sqrt{2\omega_0^2(\cos\theta - \cos\theta_0)}} = \pm dt$$

Dimensional analysis:

θ_0 , g , m , R , ~~θ_0~~ | V_{max}

$[\theta_0] = 1$

$[g] = L T^{-2}$

$[m] = M$ ← dimensionless analysis quick reminder

$[R] = L$

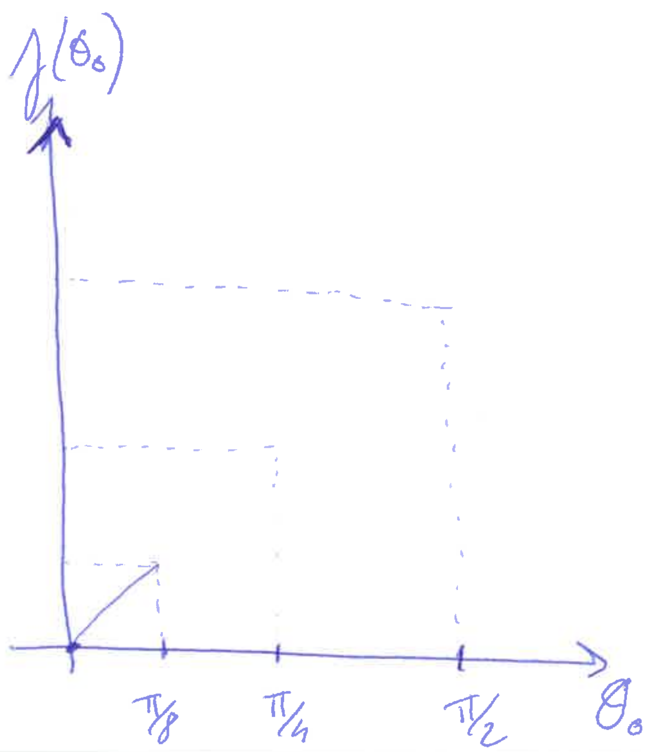
$[V_{max}] = L T^{-1}$

$\tau = g^{-1/2} R^{1/2} = \sqrt{\frac{R}{g}}$, $\lambda = R$

dimensionless : θ_0

$$V_{max} = f_1(\theta_0) \cdot \frac{\lambda}{\tau} = f_1(\theta_0) \cdot \sqrt{\frac{g}{R}} \cdot R = f_1(\theta_0)\, g^{1/2} R^{1/2}$$

$$V_{MAX} \cdot (gR)^{-1/2} = f_1(\theta_0)$$



Friction:

$$\vec{F}_1 = -C_1\,\vec{v} \Longrightarrow [C_1] = M T^{-1}$$

3

$$\vec{F}_2 = -C_2 \|\vec{v}\|^2 \cdot \vec{u}_v \Longrightarrow [C_2] = ML$$

dimensionless number: $\alpha_1 = C_1 \frac{\tau}{m}$; $\alpha_2 = C_2 \frac{1}{R}$

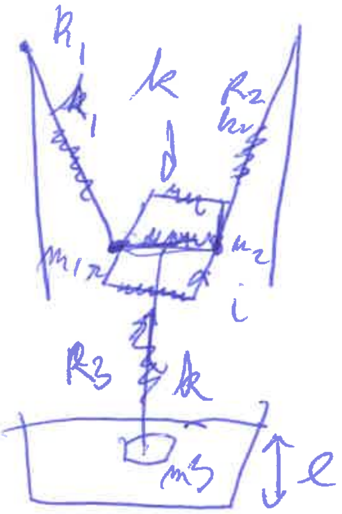
$$\cancel{\Longrightarrow V_{max} = f_1(\theta_0)\, g^{1/2} R^{1/2} \cdot f_2}$$

$$V_{MAX} = g^{1/2} R^{1/2} f_2(\theta_0, \alpha_1, \alpha_2) \Longrightarrow \frac{V_{max}}{\sqrt{gR}} = f_2(\theta_0, \alpha_1, \alpha_2)$$

Calibration table:

θ_0	α_1	α_2	$\frac{V_{MAX}}{\sqrt{gR}}$

input   output



dg $\uparrow B$ T

other part of space where Newton laws don't apply

$\boxed{4}$ *

m_i, R_i, k_i, i, B, g, T, l, r $\boxed{4}$ $\frac{d\,m_i(\theta)_{uv}}{dT} = \varepsilon F$

$3 \times 3 + 6 = 15$

$\boxed{1}$ modelling analytic : impossible too many nonlinear coupling and equation.

$\boxed{2}$ model numeric : impossible physics is different

$\boxed{3}$ calibration table : still possible.

$\boxed{2}$* : Electro-mag and elasticity and gravity are still the same so their insight can still be used.

How to save data:

use CSV format. Can be read by anyone.

eg:

var_1, var_2, var_3, var_4, target
val_1_1, val_2_1, val_3_1, val_4_1, val_t_1
⋮
val_1_N, val_2_N, val_3_N, val_4_N, val_t_N

⚠ do not use excel or ~~compile~~ software specific

easy to read for pandas:

pd.read_csv("filename.csv")

"physics or stamp collecting"

sometimes we are stuck with stamp collecting

Finding a value:

* temperature , density

temperature	density
0	999,82
1	999,89
2	999,94
⋮	⋮
100	958,05