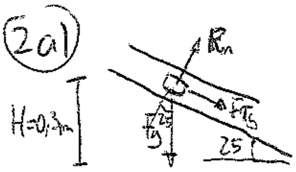
(2a)




$F_{tg} = \sin(25)\, F_g$ $\quad F_g = mg$

$F = ma \Rightarrow a = \frac{F}{m} = g\sin 25$

$x = \frac{1}{2} a t^2 = \frac{1}{2} g \sin(25)\, t^2$

$\Delta x \sin 25 = 0{,}3$

$\Delta x = \frac{0{,}3}{\sin 25}$

$\frac{0{,}3}{\sin 25} = \frac{1}{2} g \sin 25\, t^2$

$t = \sqrt{\frac{2\times 0{,}3}{g\sin^2 25}} = 0{,}585\,s$ $\quad v = at = 2{,}423\ m/s$

(b) $F = \mu R_n$, $\quad R_n = mg\cos 25$

$\ddot x = 0 \Rightarrow F = F_{gt}$

$\Leftrightarrow \cancel{m}g \sin 25 = \mu \cancel{m}g \cos 25 \quad \Leftrightarrow \mu = tg\,25 = 0{,}466$

(c) $V = mg\, r \sin 25$ $\quad$ 1 g.l. : r


$v = \frac{\partial r_k}{\partial q_j}\dot q_j + \frac{\partial r_k}{\partial t}$

$x = r\cos\omega t$

$y = r\sin\omega t$

$z = r\sin\theta$

$v_x = \dot r\cos\omega t - r\omega\sin\omega t$

$v_y = \dot r \sin\omega t + r\omega\cos\omega t$

$v_z = \dot r\sin\theta$

$v^2 = \dot r^2\cos^2\omega t + r^2\omega^2\sin^2\omega t + \dot r^2\sin^2\omega t + r\omega^2\cos^2\omega t - \cancel{r\omega\sin\omega t\,\dot r\cos\omega t} + \cancel{r\omega\sin\omega t}\, r\cos\omega t$

$v^2 = \dot r^2(\cos^2\omega t+\sin^2\omega t) + r^2\omega^2(\cos^2\omega t + \sin^2\omega t) + \dot r^2\sin^2\theta$

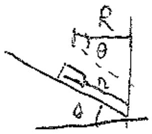
$L = T - V = \frac{1}{2} m(\dot r^2 + r^2\omega^2 + \dot r^2\sin^2\theta) + mgr\sin\theta$

$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot q}\right) = \frac{\partial L}{\partial q}$ $\quad \frac{d}{dt}(m\dot r + m\dot r\sin^2\theta) = mg\sin\theta + mr\omega^2$

$\Leftrightarrow m\ddot r + m\ddot r\sin^2\theta = mg\sin\theta + mr\omega^2$

$\Leftrightarrow \ddot r(1+\sin^2\theta) = r\omega^2 + g\sin\theta$

(d) $\ddot r = 0 \Rightarrow r\omega^2 + g\sin\theta = 0$

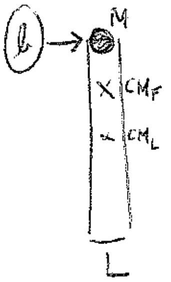



$\omega = \sqrt{\frac{g\sin\theta}{r}}$, Para $R = 0{,}1\,m$ : $r = R\cos\theta \Rightarrow \omega = \sqrt{\frac{g\sin\theta}{R\cos\theta}} = 6{,}436\ rad/s$

(3a) $F_{ext} = 0 \Rightarrow p = cte \Rightarrow v_{CM_i} = v_{CM_f}$

$$v_{CM_i} = \frac{v_M \times m_M}{m_M + m_L} = 5\ m/s$$

(b)




$$I^* = \overbrace{M\left(\frac{L}{4}\right)^2}^{M} + \left(\overbrace{\frac{1}{12}ML^2}^{L} + \overbrace{M\left(\frac{L}{4}\right)^2}^{\Delta x\, L_{CM}}\right) = \frac{10}{6}$$

$$\vec{L}_i = \vec{L}_f$$

$$\vec{L}_i = \vec{r} \times \vec{p} \Rightarrow L_i = Mv\frac{L}{4}$$

$$L_f = I^*\omega \Rightarrow \frac{10}{6}\omega = \frac{MvL}{4} \Leftrightarrow \omega = 3\ rad/s$$

(c) $E_{m_i} = \frac{1}{2}Mv^2 = 25\ J$

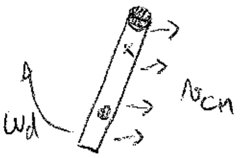
$$E_{m_f} = \frac{1}{2}M_{tot}v_{CM}^2 + \frac{1}{2}I^*\omega^2 = 12{,}5 + 7{,}5 = 20\ J$$

$$\Delta E_m = \overset{20-25}{\cancel{25-20}} = -5\ J$$

(d) A velocidade imediatamente a seguir à colisão é:

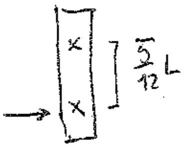
$v = \omega d + v_{CM}$

para um ponto a uma distância d do eixo de rotação (~~a~~=CM)




O ponto onde se sente o menor impacto é aquele onde $v$ logo após o impacto é zero:

$$v = 0 \Leftrightarrow \omega d = v_{CM} \Leftrightarrow d = \frac{v_{CM}}{\omega} = \frac{20}{12} \cdot \frac{5}{3} = \frac{5}{12}L$$



4a) $v = \sqrt{\frac{T}{\mu}} = 169 \text{ m/s}$

b) $\lambda_n = \frac{2L}{n}$ $\qquad f_n = \frac{v}{\lambda_n}$

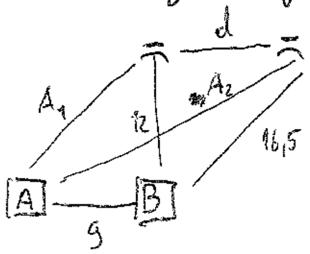
$$f_n = \frac{\sqrt{\frac{T}{\mu}}}{2L} n \quad \sim n\, 110{,}046 \text{ Hz}$$

c) 4ª Harmónica $= f_4 = 440{,}1845$ Hz

Batimento $= f_4 - f = 0{,}1845$ Hz

d) Fundamental : $f_1$

$$\lambda = \frac{v}{f} = \frac{330}{110} = 3 \text{ m}$$




$d = \sqrt{16{,}5^2 - 12^2} = 11{,}325 \text{m}$ $\qquad A_1 = 15 \text{m}$

$A_2^2 = 12^2 + (d+9)^2 \Rightarrow A_2 = 23{,}603 \text{m}$

Para A:

$\frac{A_1}{\lambda} = \frac{15}{3} = 5$

$\frac{A_2}{\lambda} = \frac{23{,}603}{3} = 7{,}86$

$\left(\frac{A_1}{\lambda} - \frac{A_2}{\lambda}\right)_{mod 1} = 0{,}86 \Rightarrow$ menos mal

Para B:

$\frac{B_1}{\lambda} = \frac{12}{3} = 4$

$\frac{B_2}{\lambda} = \frac{16{,}5}{3} = 5{,}5$

$\left(\frac{B_1}{\lambda} - \frac{B_2}{\lambda}\right)_{mod 1} = 0{,}5 \Rightarrow$ Os altifalantes estão em completa oposição de fase.

O espectador em A ouve melhor, dado que o espectador em B não ouve de todo.