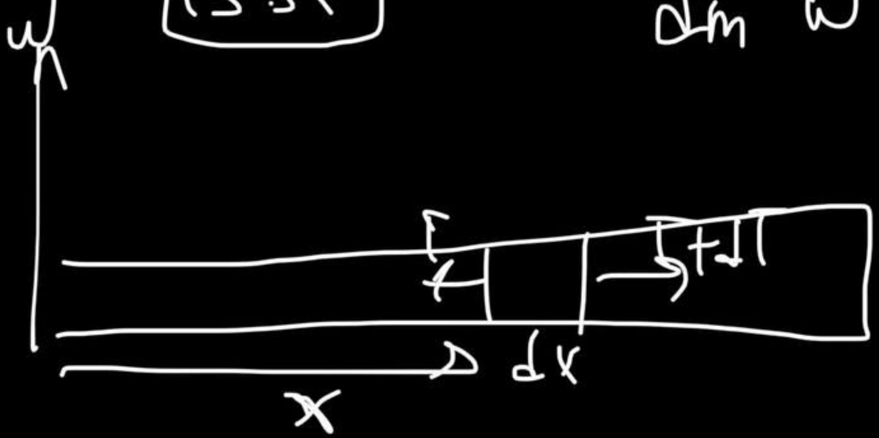
13.35



$$dm\,\omega^2 x = -dT$$

$$\rho S \omega^2 x\,dx = -dT$$

$$\int$$

$$\frac{1}{2}\rho S \omega^2 (l^2 - x^2) = T$$

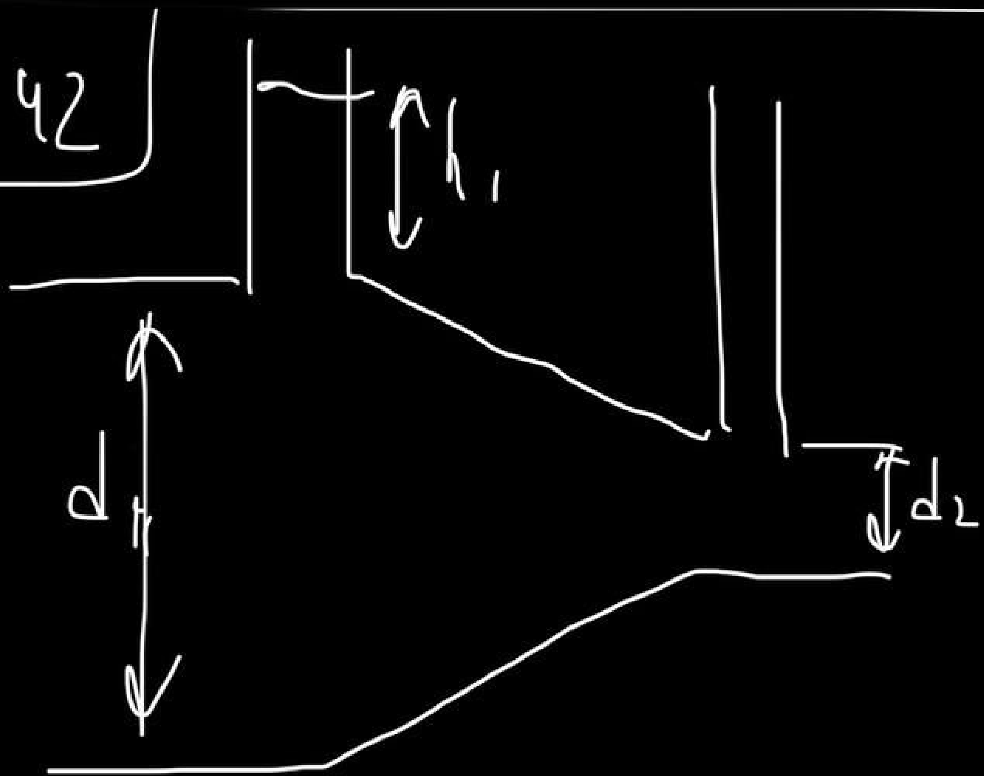
$$\frac{T}{S} = \frac{dl}{dx} E$$

$$\Delta l = \frac{\rho \omega^2}{2E}\int_0^l (l^2 - x^2)\,dx = \frac{\rho \omega^2 l^3}{3E}$$

$$\omega = \frac{2v}{l}$$

$$\boxed{\frac{\Delta l}{l} = \frac{4}{3}\left(\frac{v}{v_{зв}}\right)^2}$$

14.42



$$\rho_1 v_1 S_1 = \rho_2 v_2 S_2$$

$$-p_1 S_1 v_1 t + p_2 S_2 v_2 t =$$

$$= \rho_1 v_1 t S_1 (h_1 - h_2) g + \frac{dm}{2}(v_2^2 - v_1^2)$$

$$-\frac{p_1}{\rho_1} + \frac{p_2}{\rho_1} = g(h_1 - h_2) + \frac{v_1^2 - v_2^2}{2}$$

$$\frac{p_1}{\rho_1} + g h_1 + \frac{v_1^2}{2} = \text{const.}$$

$$Q = vS + \dot{v} S t + v t \dot{S}$$

$$Q = v_1 S_1 = v_2 S_2$$

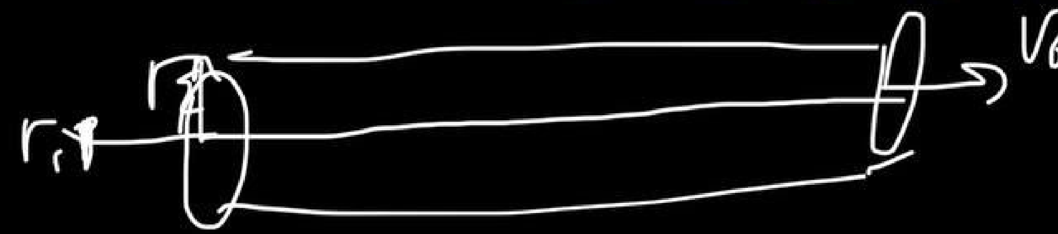
$$\frac{\Delta p}{\rho} = \frac{1}{2}(v_1^2 - v_2^2)$$

$$g h_1 = \frac{1}{2} Q^2 \left(\frac{16}{\pi^2 d_2^4} - \frac{16}{\pi^2 d_1^4} \right)$$

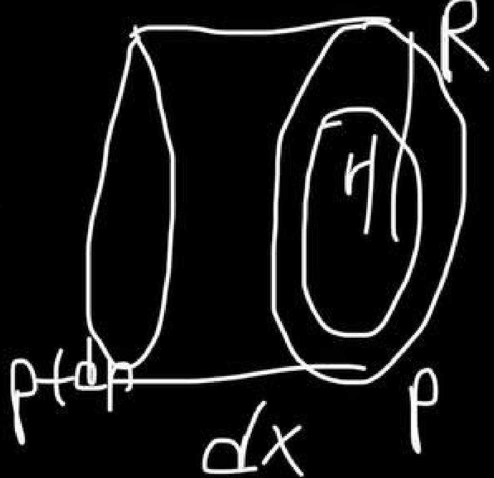
$$\left(\frac{g h_1 \pi^2}{8 Q^2} + \frac{1}{d_1^4} \right)^{-\frac{1}{4}} = d_2$$

$$\boxed{d_2 = \left(\frac{d_1^4}{1 + \frac{g h_1 \pi^2 d_1^4}{8 Q^2}} \right)^{1/4} \qquad d_2 = 5 \text{ cm}}$$

$\boxed{4.21}$



$$\eta = 0{,}01 \text{ П} \; ; \quad \tau = \eta \frac{\partial v}{\partial r}$$



$$f = 2\pi r \tau =$$

$$= -2\pi r \frac{dv}{dr} \eta$$

$$-f \frac{dr}{r} = 2\pi \eta \, dv$$

$$f \ln\left(\frac{r_2}{r_1}\right) = 2\pi \eta v_0$$

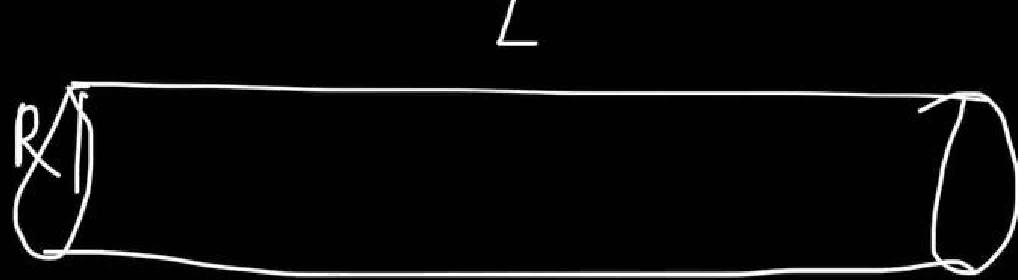
$$\boxed{f = \frac{2\pi\eta v_0}{\ln\left(\frac{r_2}{r_1}\right)} = 0{,}27 \, \frac{\text{дин}}{\text{см}}}$$

$$f \ln \frac{r_2}{r} = 2\pi \eta v$$

$$v(r) = v_0 \frac{\ln \frac{r_2}{r}}{\ln r_2}$$

$$\boxed{v(r) = v_0 \frac{\ln\frac{r_2}{r}}{\ln\frac{r_2}{r_1}}}$$

14.96)



$$Re = 2000, \quad \eta = 10^{-3}\ \text{Па}\cdot\text{с}$$

$$Re = \frac{\rho \langle v \rangle R}{\eta}$$

$$\tau = \eta \frac{dv}{dr}$$

$$\pi r^2 \Delta p = -2\pi r \eta \frac{dv}{dr} \Delta x$$

$$r\,dr\,\Delta p = -2\eta\, dv\, L$$

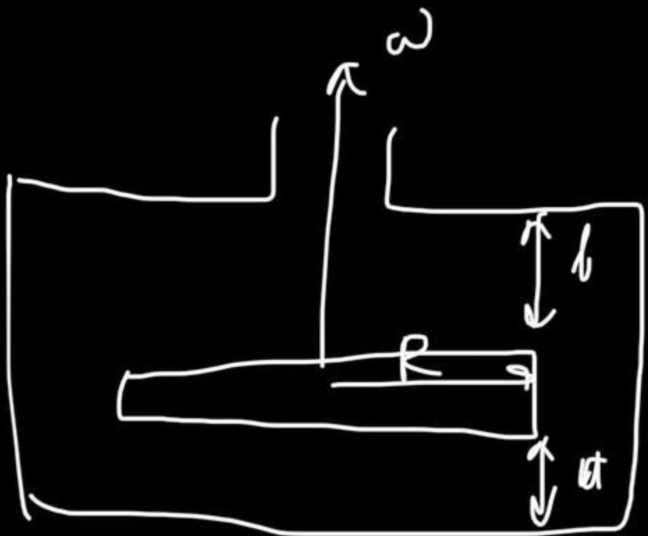
$$\frac{1}{2}(R^2 - r^2)\Delta p = 2\eta L v$$

$$\langle v \rangle = \frac{\Delta p}{4\eta L}\frac{1}{R}\frac{2}{3}R^3 = \frac{\Delta p R^2}{6\eta L}$$

$$Re = \rho\frac{R}{\eta}\frac{\Delta p R^2}{6\eta L}$$

$$\boxed{\frac{\Delta p}{L} = \frac{6\, Re\, \eta^2}{\rho R^3}}$$

14.29



$$dN = \frac{dA}{dt} = \frac{F_{T} d s}{dt} = \frac{\tau \, ds \, ds' \, dr}{dt}$$

$$dN = \eta \frac{dv}{dy} ds \, \omega r^{dr} = \eta \omega \frac{dr}{dy} r \, dr \, ds$$

$$\cancel{v_1(y) = v_0\left(1 - \frac{y}{b}\right), \quad v_1' = \frac{\omega r}{b}}$$

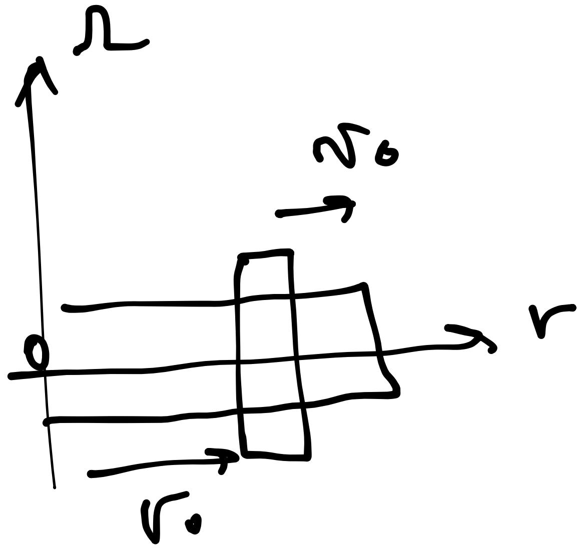
$$v_2(y) = v_0\left(1 - \frac{y}{a}\right), \quad v_2' = \frac{\omega r}{a}$$

$$N = \eta \omega^2 \int r^2 \left(\frac{1}{a} + \frac{1}{b}\right) dr \, ds =$$

$$= 2\pi \eta \omega^2 \frac{a+b}{ab} \int r^3 dr =$$

$$= \boxed{\frac{\pi}{2} \eta \omega^2 \frac{a+b}{ab} R^4 \simeq 76 \text{ Вт}}$$

12.48



$$m\ddot{r} = m\Omega^2 r - F_{тр}$$

$$F_{тр} = kF_{к} = 2km\Omega\dot{r}$$

$$\dot{r} = \frac{v_0 r}{r_0} \Rightarrow r = r_0 e^{\frac{v_0 t}{r_0}}$$

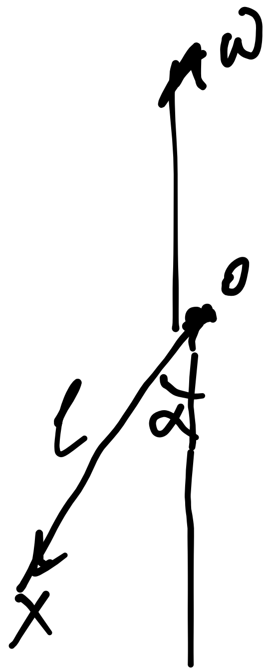
$$\ddot{r} = \frac{v_0^2}{r_0^2} r$$

$$2k\Omega\frac{v_0}{r_0} = \Omega^2 - \frac{v_0^2}{r_0^2}$$

$$k = \frac{1}{2}\left[\frac{\Omega r_0}{v_0} - \frac{v_0}{\Omega r_0}\right]$$

т.е. $\boxed{\Omega r_0 > v_0}$

12.82



$$\langle M\rangle_{\text{тяж}} = \langle M_{\text{ин}}\rangle$$

$$\frac{1}{l}\int_0^l g\,dm(x)\,x\sin\alpha =$$

$$= \frac{1}{2} mgl\sin\alpha$$

$$\frac{1}{l}\int_0^l \frac{m\,dx}{l}\,\omega^2 x\sin\alpha\; x\cos\alpha =$$

$$= \frac{1}{3} m\omega^2 l^2 \sin\alpha\cos\alpha$$

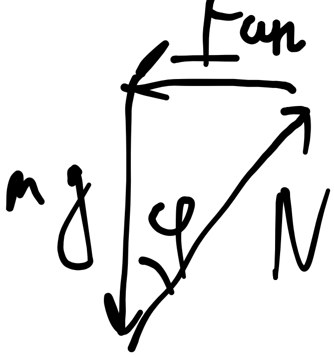
$$\cos\alpha = \frac{3}{2}\frac{g}{l\omega^2} = 0.87$$

$$\Rightarrow \boxed{\alpha \simeq 29^\circ}$$

$$N = \sqrt{(mg)^2 + F_{an}^2} =$$

$$= \sqrt{(mg)^2 + \left(\frac{1}{2} m\omega^2 l \sin\alpha\right)^2} =$$

$$= mg\sqrt{1 + \frac{1}{4}\left(\frac{\omega^2 l}{g}\right)^2 \sin^2\alpha} \simeq \boxed{1{,}1\, mg}$$



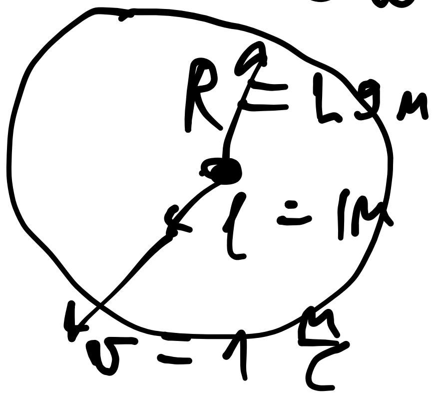
$$\operatorname{tg}\varphi = \frac{\frac{1}{2} m\omega^2 l \sin\alpha}{mg} =$$

$$= \frac{1}{2}\frac{\omega^2 l}{g}\sin\alpha = 0{,}41$$

$$\boxed{\varphi \simeq 22^\circ}$$

12.86

$\omega = 1\ c^{-1}$



$K = 1\ \frac{Н}{м}$

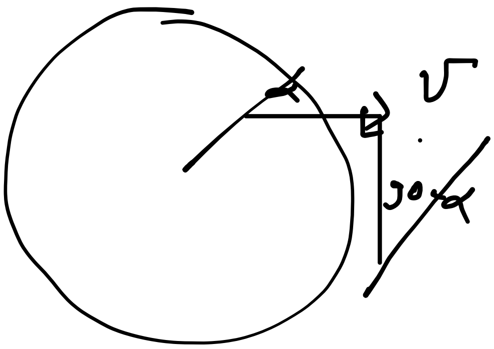
$m = 1\ кг$

$$Kl = m\omega^2 l\ ,\quad k = m\omega^2$$

Перейдём в СО карусели

$$m\ddot{\bar r} = m\omega^2 \bar r + 2m[\bar\omega \times \dot{\bar r}] - K\bar r$$

$\bar r = (r\cos\varphi, r\sin\varphi)$



$\dot{\bar r} = (\dot r\cos\varphi - r\sin\varphi\,\dot\varphi,\ \dot r\sin\varphi + r\cos\varphi\,\dot\varphi)$

$$\begin{vmatrix} i & j & k \\ 0 & 0 & \omega \\ \dot{\bar r}_x & \dot{\bar r}_y & 0 \end{vmatrix} =$$

$$= \begin{pmatrix} -\omega(\dot r \sin\varphi + r\cos\varphi\, \dot\varphi) \\ \omega(\dot r\cos\varphi - r\sin\varphi\, \dot\varphi) \\ 0 \end{pmatrix} =$$

$$= -\omega \langle -\dot{\bar r}_y , \dot{\bar r}_x \rangle = \bar A$$

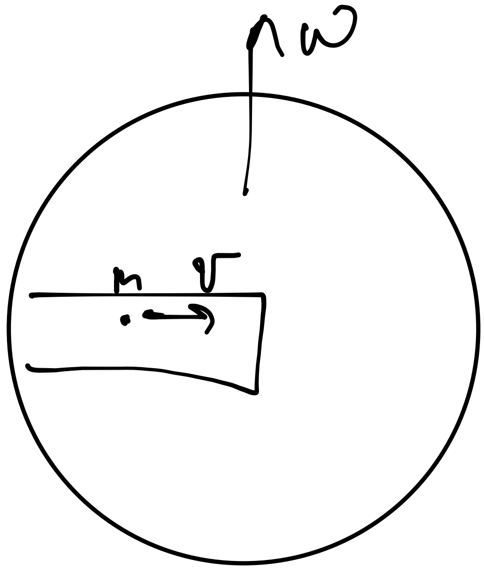
$$(\bar F_k)_r = (\bar A, \bar r) / |\bar r| = 0$$

$$m\ddot r = m\omega^2 r - kr = 0$$

$$r = v_0 t + r_0$$

$\Rightarrow$ $\boxed{\text{соскочит}}$

12.70



Перейдём в СО Земли

$$F_k = 2m\omega v = m a_\perp$$

$$m\ddot{r} = \frac{-GmM\left(\frac{r}{R}\right)^3}{r^2} = \frac{-GmMr}{R^3}$$

$$\ddot{r} = \frac{-GM}{R^3} r = kr$$

$$\frac{dv}{dt} = \frac{dv}{dr} v = -kr$$

$$v\,dv = -k r\,dr$$

$$\frac{v^2}{2} = \frac{k}{2}(-r^2 + R^2)$$

$$\frac{dr}{dt} = \sqrt{k(-r^2 + R^2)}$$

$$\frac{dr}{\sqrt{R^2-r^2}} = \sqrt{k}\, t$$

$$\sin^{-1}\frac{r}{R} - \frac{\pi}{2} = \sqrt{k}\, t$$

$$r = R\cos\sqrt{k}\, t$$

$$v = \dot{r} = -R\sqrt{k}\sin\sqrt{k}\, t$$

$$2\omega v = a_\perp = \ddot{r}_\perp$$

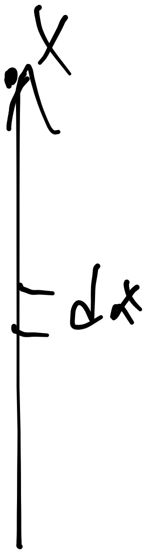
$$v_\perp = 2\omega R\left(1-\cos\sqrt{k}\, t\right)$$

$$r_\perp = 2\omega R t - \frac{2\omega R}{\sqrt{k}}\sin(\sqrt{k}\, t)$$

$$r_\perp^{max} = \omega R\left(\frac{\pi}{\sqrt{k}} - \frac{2}{\sqrt{k}}\right) =$$

$$= \frac{\omega R(\pi-2)\sqrt{R}}{\sqrt{\frac{GM}{R^2}}} = \boxed{\omega R(\pi-2)\sqrt{\frac{R}{g}}}$$

13.36



$$\sigma = \varepsilon E$$

$$\frac{\langle g \rangle m(x)}{S} = \frac{dl}{dx} E$$

$$\langle g \rangle \rho x \, dx = E \, dl$$

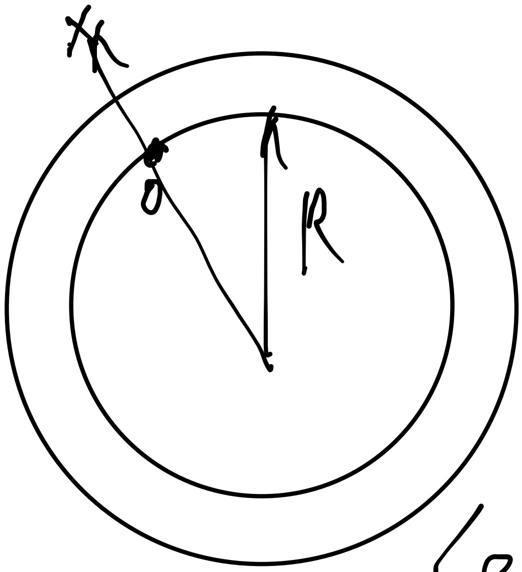
$$g = \frac{GM(x)}{x^2} = g_0 \frac{x}{R}$$

$$\langle g \rangle = \frac{1}{2} g$$

$$\frac{g_0 \rho}{2RE} x^2 dx = dl$$

$$\Delta l = \frac{g_0 \rho R^2}{6E} \simeq \boxed{115 \text{ m}}$$

13.49



$$\frac{m(x)\,\omega^2(x+R)}{S} =$$

$$= \frac{dl}{dx}E$$

$$\rho(x_0 - x)\,\omega^2(x+R) \to$$

$$= \rho\omega^2 \frac{1}{x}\int_0^x \left(-x^2 - (R-x_0)x + x_0R\right)dx =$$

$$= \frac{\rho\omega^2}{x}\left(-\frac{1}{3}x^3 - \frac{1}{2}x^2(R-x_0) + x_0Rx\right) =$$

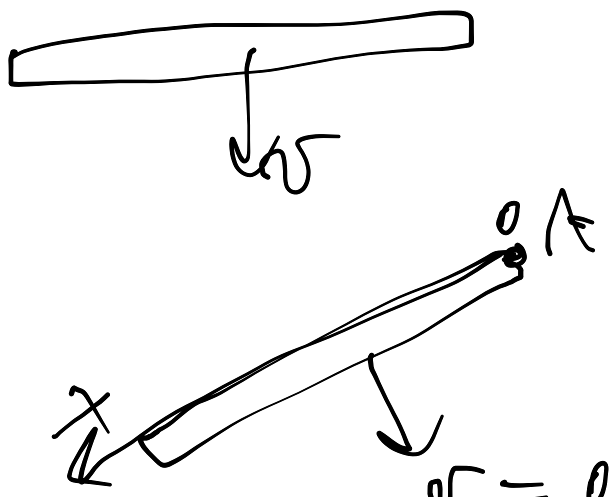
$$= \rho\omega^2\left(Rx_0 - \frac{1}{3}x^2 - \frac{x}{2}(R-x_0)\right) =$$

$$= E\frac{dl}{dx}$$

$$\Delta l = \frac{\rho\omega^2}{E}\left(Rx_0^2 - \frac{1}{9}x_0^3 - \frac{1}{4}x_0^2(R-x_0)\right) =$$

$$= \frac{\rho\omega^2}{E}\left(\frac{3}{4}Rx_0^2 + \frac{5}{36}x_0^3\right)$$

13.35



$v = 0{,}002\, v_{зв} = k\, v_{зв}$

$$\omega = \frac{2v}{l}$$

$$\langle \underbrace{m(x)\,\omega^2 x}_{S} \rangle = \frac{dl}{dx} E$$

$$\frac{1}{x}\int_0^x \rho\omega^2 x(l-x)\,dx =$$

$$= \frac{\rho\omega^2}{x}\left(\frac{1}{2}x^2 l - \frac{1}{3}x^3\right) = \rho\omega^2\left(\frac{xl}{2} - \frac{x^2}{3}\right)$$

$$\int_0^l \rho\omega^2\left(\frac{xl}{2} - \frac{x^2}{3}\right)dx = E\Delta l$$

$$\rho\omega^2 l^3\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5}{36}\rho\,\frac{4v^2}{l^2}\,l^3 =$$

$$= \frac{5}{9}\rho v^2 l = E\Delta l$$

10.78. $$\frac{J\dot{\alpha}^2}{2} + 3mgh_c\frac{\alpha^2}{2} = c$$

$$\ddot{\alpha} + \frac{3mgh_c}{J}\alpha = 0$$

$$T = 2\pi\sqrt{\frac{J}{3mgh_c}}$$

$$h_c = \frac{a\sqrt{2}}{2} = \frac{a}{\sqrt{2}}$$

$$J_1 = mh_c^2 + 2\cdot\frac{ma^2}{12} = m\left(h_c^2 + \frac{a^2}{6}\right)$$

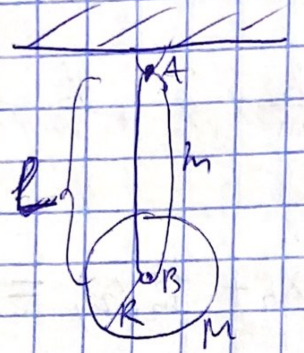
$$J_2 = J_3 = mh_c^2 + \frac{ma^2}{12}$$

$$J = J_1 + J_2 + J_3 = m\left(3h_c^2 + \frac{a^2}{3}\right) = ma^2\left(\frac{3}{2} + \frac{1}{3}\right) =$$

$$= \frac{11}{6}ma^2$$

$$T = 2\pi\sqrt{\frac{11a\sqrt{2}}{18g}} = \boxed{2\pi\sqrt{\frac{11a}{9g\sqrt{2}}}}$$

10.43



$$r_c = \frac{m\frac{l}{2} + Ml}{m+M}$$

$$J_{ст} = \frac{ml^2}{12} + m\frac{l^2}{4} = \frac{ml^2}{3}$$

$$J_g = \cancel{\frac{MR^2}{2}} + Ml^2$$

$$J = \frac{ml^2}{3} + \cancel{\frac{MR^2}{2}} + Ml^2$$

$$T = 2\pi\sqrt{\frac{\frac{ml^2}{3} + Ml^2 + \cancel{\frac{MR^2}{2}}}{(m+M)\,g\,r_c}} =$$

$$= \boxed{2\pi\sqrt{\frac{m+3M}{m+2M}\cdot\frac{2}{3}\,\frac{l}{g}}}$$

10.53

$$\frac{J\dot{\alpha}^2}{2} + \frac{f\alpha^2}{2} = C$$

$$\ddot{\alpha} + \frac{f}{J}\alpha = 0$$

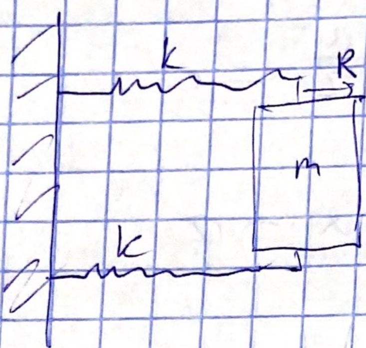
$$T \sim \frac{1}{\sqrt{f}}$$

$$\frac{1}{f_0} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$T^2 = T_1^2 + T_2^2$$

$$\boxed{T = \sqrt{T_1^2 + T_2^2}}$$

10.34



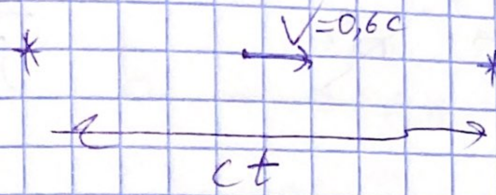
$$J = J_c + mR^2$$

$$\frac{J\dot{\alpha}^2}{2} + \frac{2k(\alpha R)^2}{2} = C$$

$$T = 2\pi\sqrt{\frac{J}{2kR^2}} =$$

$$= \boxed{\frac{2\pi}{R}\sqrt{\frac{J_c + mR^2}{2k}}}$$

8.7.



$$t_1 = \frac{ct/2}{c-V}$$

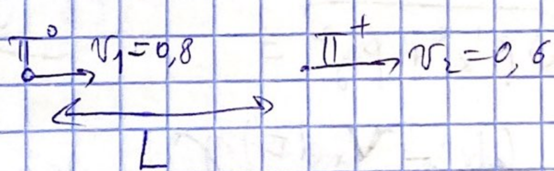
$$t_2 = \frac{ct/2}{c+V}$$

$$\Delta t = \frac{ct}{2}\,\frac{2V}{c^2-V^2} = t\cdot\frac{\beta}{1-\beta^2} = t\beta\gamma^2$$

$$\Delta t' = \frac{\Delta t}{\gamma} = t\beta\gamma = 2\,\text{мес}\cdot\frac{0,6}{\sqrt{1-0,6^2}} = 2\,\text{мес}\cdot\frac{0,6}{0,8} =$$

$$= \frac{3}{4}t = \boxed{1,5\ \text{мес}}$$

8.98.



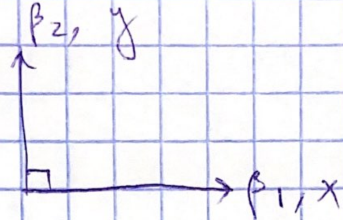
$$v_{отн} = \frac{v_1 - v_2}{1 - \frac{v_1 v_2}{c^2}} = \frac{0,2}{1-0,48} = \frac{0,20}{0,52} = \frac{5}{13}$$

$$L_1 = L\sqrt{1-\frac{v_{отн}^2}{c^2}}\ ; \quad t = \frac{L_1}{v_{отн}} = \frac{6\,\text{нм}\cdot\frac{12}{13}}{\frac{5}{13}c} =$$

$$= \frac{6\cdot 12\cdot 10^{-9}}{5\cdot 3\cdot 10^{8}} = 4,8\cdot 10^{-17}\,\text{с} < 8,7\cdot 10^{-17}\,\text{с}$$

$$\tau'_{\pi^+} = \tau_2\,\gamma_{отн} > 2,6\cdot 10^{-8}\,\text{с}.$$ Ответ: $\boxed{\text{успеет}}$

8.89.



Перейдем в СО 1:

$$dx_2' = \gamma\left(\cancel{dx_2}^{=0} - \cancel{\beta}\, v_1\, dt_2\right) = -\gamma v_1 dt_2$$

$$dy_2' = dy_2$$

$$dt_2' = \gamma\left(dt_2 - \frac{v_1 \cancel{dx_2}^{=0}}{c^2}\right) = \gamma dt_2$$

$$v_{2y}' = \frac{1}{\gamma} v_{2y} = v_2\sqrt{1-\beta_1^2}$$

$$v_{2x}' = -v_1$$

$$\beta' = \sqrt{\beta_1^2 + \beta_2^2(1-\beta_1^2)} = \sqrt{\beta_1^2+\beta_2^2-\beta_1^2\beta_2^2} =$$

$$= 0,89$$

$\boxed{11}$

8.44 ЗСЭ: $m_\pi c^2 = m_\mu c^2 + K_\mu + K_\nu$

$$\Rightarrow K_\nu = -K_\mu + c^2(m_\pi - m_\mu)$$

ЗСИ: $\bar{0} = \bar{p}_1 + \bar{p}_2 \Rightarrow |p_1| = |p_2|$

$$E = mc^2 + K$$

$$E^2 = p^2c^2 + m^2c^4$$

$$p_1 = p_2 \Rightarrow E_\mu^2 - m_\mu^2 c^4 = E_\nu^2$$

$$(m_\mu c^2 + K_\mu)^2 - m_\mu^2 c^4 = K_\nu^2$$

$$K_\mu^2 + 2K_\mu m_\mu c^2 = K_\nu^2$$

$$\cancel{K_\mu^2} + 2K_\mu \cancel{m_\mu} c^2 = \cancel{K_\mu^2} - 2K_\mu c^2(m_\pi - \cancel{m_\mu}) + c^4(m_\pi - m_\mu)^2$$

$$K_\mu = \frac{(m_\pi - m_\mu)^2 c^4}{2 m_\pi c^2} = \frac{(\varepsilon_{0\pi} - \varepsilon_{0\mu})^2}{2\varepsilon_{0\pi}} =$$

$$= 4,12 \text{ МэВ} \approx \boxed{4 \text{ МэВ}}$$

$$K_\nu = \frac{(m_\pi^2 - m_\mu^2)c^4}{2 m_\pi c^2} = \frac{\varepsilon_{0\pi}^2 - \varepsilon_{0\mu}^2}{2\varepsilon_{0\pi}} \approx \boxed{30 \text{ МэВ}}$$

8.57 $\quad K^+ \rightarrow \pi^+ + \pi^0$

$\pi^0 \rightarrow \gamma + e^+ + e^-$

ЗСЭ: $\quad m_K c^2 = m_{\pi^+} c^2 + m_{\pi^0} c^2 +$
$+ K_{\pi^+} + K_{\pi^0}$

ЗСИ: $\quad |\bar{p}_{\pi^+}| = |\bar{p}_{\pi^0}|$

$$(m_{\pi^+} c^2 + K_{\pi^+})^2 - m_{\pi^+} c^2 =$$

$$= (m_{\pi^0} c^2 + K_{\pi^0})^2 - m_{\pi^0} c^2$$

$$K_{\pi^+}^2 + 2 K_{\pi^+} m_{\pi^+} c^2 =$$
$$= K_{\pi^0}^2 + 2 K_{\pi^0} m_{\pi^0} c^2$$

$$K_{\pi^0} = K_{\pi^+} + \Delta K_\pi$$

$$2 K_{\pi^+} \Delta K_\pi + 2 \Delta K_\pi m_{\pi^0} c^2 = 2 K_{\pi^+} (\Delta \mathcal{E}_{0\pi})$$

$$\Delta K_\pi = \frac{K_{\pi^+}}{K_{\pi^+} + \mathcal{E}_{0\pi^0}} \Delta \mathcal{E}_{0\pi}$$

$$c^2 (m_K - m_{\pi^+} - m_{\pi^0}) = K_{\pi^+} \left(2 + \frac{\Delta \mathcal{E}_{0\pi}}{K_{\pi^+} + \mathcal{E}_{0\pi^0}} \right)$$

$\Delta \mathcal{E}_{0\pi} \rightarrow 0 \qquad K_\pi = \frac{1}{2} c^2 (m_K - m_{\pi^+} - m_{\pi^0}) \simeq 94{,}5$ МэВ

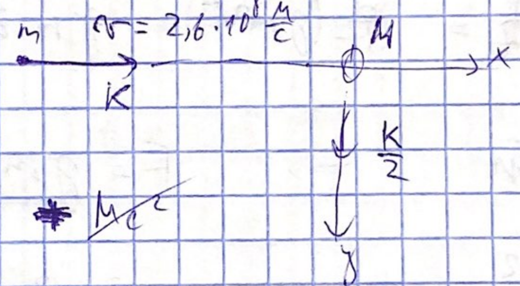
$$p = \frac{1}{c}\sqrt{K_\pi^2 + 2K_\pi m_\pi c^2} = \frac{187\ \text{МэВ}}{c}$$

$$\cancel{p=}\quad \beta = \frac{pc}{E} = \frac{187}{94{,}5+135} = 0{,}81$$

$$\gamma = 1{,}7$$

$$\tau_0 = \frac{l}{\beta c \gamma} \approx \boxed{9\cdot 10^{-16}\ \text{с}}$$

8.105



3СЭ: $\cancel{mc^2} + K + \cancel{Mc^2}$

$$= \cancel{Mc^2} + \cancel{mc^2} + \frac{K}{2} + K_M$$

$$K_M = \frac{K}{2}$$

$$\bar{p}_1 = \bar{p}_1' + \bar{p}_2'$$

$$p'_{2x} = p_{1x}, \quad p'_{2y} = p'_{1y}$$

$$K_M^2 + 2K_M Mc^2 = p_{1x}^2 c^2 + p_{1y}'^2 c^2 =$$

$$= K^2 + 2Kmc^2 + \left(\frac{K}{2}\right)^2 + Kmc^2$$

$$Mc^2 = K + 3mc^2 = (\gamma + 2)mc^2$$

$$M = (\gamma + 2)m$$

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{2,6}{3}\right)^2}} = 2$$

$$M = 4m \Rightarrow \boxed{\alpha\text{ - частица}}$$

1.4

$e_0 \xrightarrow{F}$

ЗСЭ.

$$\cancel{\mathcal{E}_0} + A_F = \cancel{\mathcal{E}_0} + K$$

$$A_F = F \cdot s = K = \mathcal{E}_0$$

$$s = \frac{\mathcal{E}_0}{F} \approx \boxed{0{,}51\ \text{м}}$$

$$Ft = p = \frac{1}{c}\sqrt{K(K+2\mathcal{E}_0)} = \sqrt{3}\,\frac{\mathcal{E}_0}{c}$$

$$t = \sqrt{3}\,\frac{\mathcal{E}_0}{Fc} = \sqrt{3}\,\frac{s}{c} \approx \boxed{3\ \text{нс}}$$