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МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ
имени М.В.ЛОМОНОСОВА

Вариант 1

Место проведения Москва
город

ПИСЬМЕННАЯ РАБОТА

Олимпиада школьников Олимпиада Ломоносов
наменование олимпиады

по Физике
профиль олимпиады

Ермакова Глеба Андреевича
фамилия, имя, отчество участника (в родительном падеже)

Дата

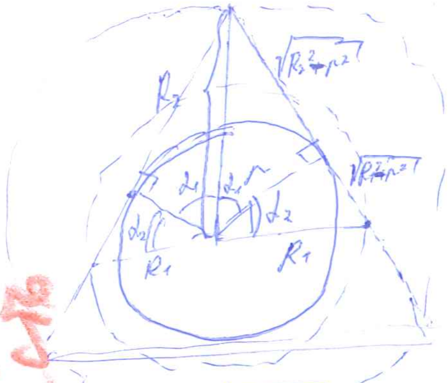
«9» февраля 2024 года

Подпись участника

23-43-74-03
(3.11)

чистовик

1.4.1



$$\begin{cases} m_1 a_1 = G\frac{m_1 M}{R_1^2} \\ m_2 a_2 = G\frac{m_2 M}{R_2^2} \end{cases}$$

$mg = G\frac{mM}{r^2}$

$GM = gr^2$

$\omega_1^2 \cdot R_1 = G\frac{M}{R_1^2}$

$\omega_1^2 = \frac{gr^2}{R_1^3}$

$\omega_2^2 = \frac{gr^2}{R_2^3}$

т.к. $R_2 > R_1 \Rightarrow$
$\Rightarrow \omega_2 < \omega_1$

$\sin\alpha_1 = \frac{\sqrt{R_2^2+r^2}}{R_2}$

$\sin\alpha_2 = \frac{\sqrt{R_1^2+r^2}}{R_1}$

~~$\alpha_1 \approx \frac{\sqrt{R_2^2+r^2}}{R_2}$~~

~~$\alpha_2 \approx \frac{\sqrt{R_1^2+r^2}}{R_1}$~~

$\cos\alpha_1 = \frac{r}{R_2}$

$\cos\alpha_2 = \frac{r}{R_1}$

2

$\alpha_0 = 2(\alpha_1+\alpha_2)$ – общий угол при котором не будет слепая зона

$\omega_{отн} = \omega_1 - \omega_2 = \sqrt{\frac{gr^2}{R_1^3}} - \sqrt{\frac{gr^2}{R_2^3}} =$

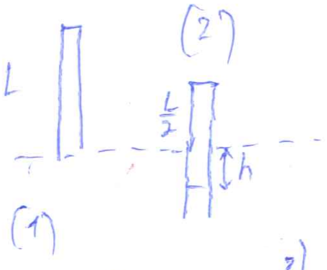
$= \frac{r}{R_1}\sqrt{\frac{g}{R_1}} - \frac{r}{R_2}\sqrt{\frac{g}{R_2}} = \sqrt{g}\,r\left(\sqrt{\frac{1}{R_1^3}} - \sqrt{\frac{1}{R_2^3}}\right)$

$T = \frac{2\pi}{\omega_{отн}}$

~~$\tau = \frac{2\pi - \alpha_0}{2\pi}T = \frac{2\pi - \alpha_0}{\omega_{отн}} = \frac{2\pi - 2\left(\frac{\sqrt{R_2^2+r^2}}{R_2} + \frac{\sqrt{R_1^2+r^2}}{R_1}\right)}{\sqrt{g}\,r\left(\sqrt{\frac{1}{R_1^3}} - \sqrt{\frac{1}{R_2^3}}\right)} =$~~

~~$2\pi - 2\left(\frac{\sqrt{10^{10}+r^2}}{10^5}\right)$~~

2.5-1



1) $p_0 = p_в + p_{н.п.}$ V ; $p_в = p_0 - p_{н.п.}$ V

$p_в \cdot L \cdot S = p_{в1} \cdot (L-h) S$

$p_{в1} = \frac{p_в \cdot L}{L-h}$

V

т.к. $T = const \Rightarrow$
$\Rightarrow p_{н.п1} = p_{н.п2}$

2) $p_{в1} + p_{н.п} = p_0 + h\rho_0 g$

$\frac{L \cdot p_в}{L-h} + p_{н.п.} = p_0 + h\rho_0 g$

$\frac{L(p_0 - p_{н.п})}{L-h} + p_{н.п.} = p_0 + h\rho_0 g$

$p_{н.п}\left(1 - \frac{L}{L-h}\right) = p_0\left(1 - \frac{L}{L-h}\right) + h\rho_0 g$

$p_{н.п}\left(\frac{-h}{L-h}\right) = p_0\left(\frac{-h}{L-h}\right) + h\rho_0 g \quad | : h$

$\frac{p_{н.п}}{L-h} = \frac{p_0}{L-h} - \rho_0 g$

$p_{н.п.} = p_0 - \rho_0 g(L-h) = 10^5 - 1000 \cdot 10(1-0{,}45) = 10^4(10-0{,}55) =$
$= 10^4 \cdot 9{,}45$ Па   Ответ: $9{,}45 \cdot 10^4$ Па

№	1	2	3	4	5	Σ
балл	18	14	18	20	16	86
	Молоков А.Б.	Калин. П.г.	Ежимова Ж.	Плакина [illegible]	Соколова Ю.Т.	

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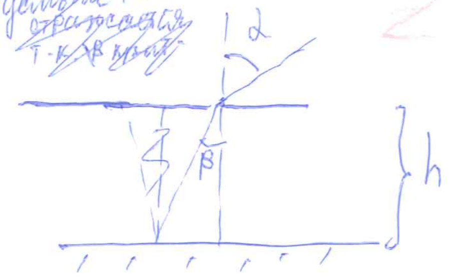
4.10.1 Чистовик

детали не отражаются т.к. в воде



~~$\alpha = n \cdot \beta$~~

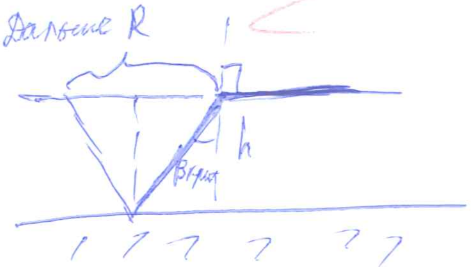
$$\sin\alpha = n \cdot \sin\beta$$

для максимального радиуса нужен макс β, это достигается при β критическом, где $\sin\alpha = 1$ (+)

$$\sin\beta = \frac{1}{n}$$ (+)

~~$R = 2h \cdot tg\beta =$~~

Дальше R



~~$tg\beta$~~ $\cos\beta = \sqrt{1 - \frac{1}{n^2}} = \sqrt{\frac{n^2-1}{n}} = \frac{\sqrt{n^2-1}}{n}$

$$tg\beta = \frac{1}{\sqrt{n^2-1}}$$

20б

$R = 2h \cdot tg\beta = \frac{2h}{\sqrt{n^2-1}} = \frac{2 \cdot 5 \cdot 10^{-2}}{\sqrt{\frac{3}{4}}} = \boxed{4 \cdot \sqrt{5} \cdot 10^{-2} м}$, если углы не малы. (+)

~~$R = 2h \cdot tg\beta \approx 2h \sin\beta \approx 2h\beta \approx \frac{2h}{n} = \frac{2 \cdot 5 \cdot 10^{-2} \cdot 2}{3} = \frac{4 \cdot 5}{3} \cdot 10^{-2} \approx \boxed{6{,}(6) \cdot 10^{-2}} м$, если углы принимаем малыми~~

~~$\sqrt{\frac{9}{4} - 1} = \sqrt{\frac{5}{4}}$~~

$tg\beta \approx \sin\beta \approx \beta$ если углы малы

20 | 3
18 | 6,666
20

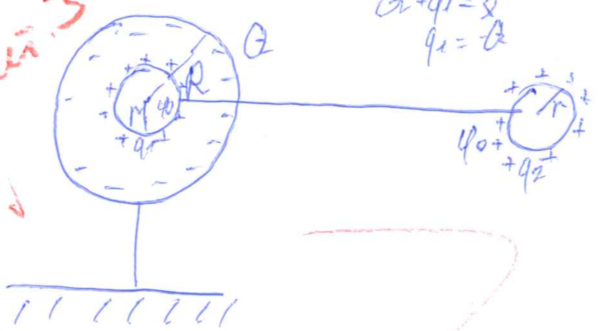
3.10.1

$Q = q_1$

$Q + q_1 = 0$

$q_1 = -Q$

(-) крит 3



$$\varphi_0 = \frac{kq_1}{r} - \frac{kq_1}{R}$$

$$\frac{kq_1}{r} - \frac{kq_1}{R} = \frac{kq_2}{r}$$

~~kq_1~~ $q_1 R - q_1 r = q_2 R$ ✓

$$R = \frac{q_1 r}{q_1 - q_2} = \frac{6 \cdot 10^{-10} \cdot 2 \cdot 10^{-2}}{(6-2) \cdot 10^{-10}} =$$

$= 3 \cdot 10^{-2}$ м ✓

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чистовик

5.4.1

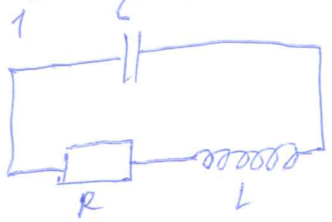
Дано:

$L = 0{,}3$ Гн

$C = 30$ мкФ

$R = 1$ Ом

$U = 2$ В



$$Z = \sqrt{\left(\frac{1}{\omega C} - \omega L\right)^2 + R^2}$$

$$I_{max} = \frac{U}{\left(\frac{1}{\omega C}\right)} = U \cdot \omega \cdot C$$

$T = 2\pi\sqrt{LC} =$ (+)

$\omega = \frac{2\pi}{T} = \frac{1}{\sqrt{LC}}$

$U_{эф} = I_{эф} R$

$I_{эф} = \frac{U_{эф}}{R}$

⊖ крит. 2

$$\Delta Q = \frac{U_{эф}^2}{R} \cdot t = \frac{U^2}{2R} \cdot t = \frac{U^2}{2R} \cdot 2\pi\sqrt{LC} = \frac{U^2}{R} \cdot \pi\sqrt{LC} =$$ (+)

$$= \frac{4}{1} \cdot 3{,}14\sqrt{0{,}3 \cdot 30 \cdot 10^{-6}} = 4 \cdot 3{,}14\sqrt{9 \cdot 10^{-6}} = 4 \cdot 3{,}14 \cdot 3 \cdot 10^{-3} =$$

$$= 37{,}68 \cdot 10^{-3}\ Дж = 37{,}68\ мДж$$

~~×12~~

$$\begin{array}{r} \times\ 3{,}14 \\ 12 \\ \hline 628 \\ 314\ \ \\ \hline 37{,}68 \end{array}$$

Ответ: 37,68

1.4.1

продолжение

$$t = \frac{2\pi - 2\left(\frac{\sqrt{R_1^2 + r^2}}{R_1} + \frac{\sqrt{R_2^2 + r^2}}{R_2}\right)}{\sqrt{g} \cdot r\left(\sqrt{\frac{1}{R_1^3}} - \frac{1}{\sqrt{R_2^3}}\right)} = \frac{2\pi - 2\left(\frac{\sqrt{R_1^2 + r^2}}{R_1} + \frac{\sqrt{R_2^2 + r^2}}{R_2}\right)}{\sqrt{g} \cdot r\left(\frac{\sqrt{R_2^3} - \sqrt{R_1^3}}{\sqrt{R_1^3 \cdot R_2^3}}\right)} =$$

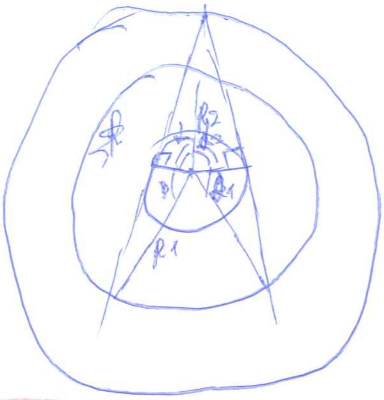
$$= \frac{R_1 R_2 \cdot 2\pi - 2\left(R_2\sqrt{R_1^2 + r^2} + R_1\sqrt{R_2^2 + r^2}\right)}{\sqrt{g}\, r \cdot \left(\frac{R_2\sqrt{R_2} - R_1\sqrt{R_1}}{\sqrt{R_1 R_2}}\right)} =$$

$$= \frac{\sqrt{R_1^3 R_2^3} \cdot 2\pi}{\sqrt{g}\, r \cdot (R_2\sqrt{R_2} - R_1\sqrt{R_1})} - \frac{2\sqrt{R_1 R_2}\left(R_2\sqrt{R_1^2 + r^2} + R_1\sqrt{R_2^2 + r^2}\right)}{R_2\sqrt{R_2} - R_1\sqrt{R_1}}$$

Подписывать лист-вкладыш запрещается! Писать на полях листа-вкладыша запрещается!

Чистовик

1.4.1.



$$\omega_{отн} = \sqrt{\frac{g r^2}{R_1^3}} - \sqrt{\frac{g r^2}{R_2^3}}$$

$$\omega^2 R_1 = \frac{GM}{R_1^2}$$

$$\omega_1 = \sqrt{\frac{g r^2}{R_1^3}}$$

$$\omega_2 = \sqrt{\frac{g r^2}{R_2^3}}$$

$$\alpha_1 = \arccos\frac{r}{R_1}$$

$$\alpha_2 = \arccos\frac{r}{R_2}$$

$$\alpha_0 = 2(\alpha_1+\alpha_2) \qquad \arccos x + \arcsin x = \frac{\pi}{2}$$

$$\tau = \frac{2\pi - 2(\alpha_1+\alpha_2)}{\omega_{отн}} = \frac{2\left(\pi - \arccos\frac{r}{R_1} - \arccos\frac{r}{R_2}\right)}{r\left(\sqrt{\frac{g}{R_1^3}} - \sqrt{\frac{g}{R_2^3}}\right)} =$$

$$= \frac{2\left(\arcsin\frac{r}{R_1} + \arcsin\frac{r}{R_2}\right)}{r\left(\sqrt{\frac{g}{R_1^3}} - \sqrt{\frac{g}{R_2^3}}\right)} = \frac{2\left(\frac{r}{R_1}+\frac{r}{R_2}\right)}{r\left(\sqrt{\frac{g}{R_1^3}} - \sqrt{\frac{g}{R_2^3}}\right)} =$$

$$= \frac{2(R_1+R_2)}{R_1R_2\left(\sqrt{\frac{g}{R_1^3}} - \sqrt{\frac{g}{R_2^3}}\right)} = \frac{2\cdot 16{,}4\cdot 10^4}{64\cdot 10^8\left(\sqrt{\frac{g}{6{,}4^3\cdot 10^{12}}} - \sqrt{\frac{g}{10^{15}}}\right)} =$$

$$= \frac{2\cdot 16{,}4}{64\cdot 10^4\cdot 3\left(\frac{1}{\sqrt{64^3\cdot 10^{-3}\cdot 10^{12}}} - \frac{1}{10^{4}\sqrt{10}}\right)} =$$

$$= \frac{2\cdot 16{,}4}{64\cdot 10^4\cdot 3\left(\frac{1}{8^3\cdot 10^4\cdot \sqrt{10}} - \frac{1}{10^7\sqrt{10}}\right)} =$$

$$= \frac{2\cdot 16{,}4}{64\cdot 3}\left(\frac{1}{8^3\cdot\sqrt{10}} - \frac{1}{10^3\cdot\sqrt{10}}\right) = \frac{16{,}4}{32\cdot 3\cdot\sqrt{10}}\left(\frac{1}{8^3} - \frac{1}{10^3}\right) =$$

$$= \frac{4{,}1}{8\cdot 3\cdot\sqrt{10}}\left(\frac{1000-512}{512\cdot 10^3}\right) = \frac{4{,}1\cdot 488}{8\cdot 3\sqrt{10}\cdot 512\cdot 10^3} =$$

$$= \frac{4{,}1\cdot 61}{3\sqrt{10}\cdot 512\cdot 10^3} = \frac{250{,}1}{3\sqrt{10}\cdot 512\cdot 10^3} =$$

$$= \frac{2501}{3\sqrt{10}\cdot 512\cdot 10^4} = \boxed{\frac{2501}{3\cdot 512\cdot 10^{4{,}5}}}\ c$$

$$\begin{array}{r} 61 \\ \times\ 41 \\ \hline 61 \\ 244\ \\ \hline 2501 \end{array} \qquad \begin{array}{r} 64 \\ \times\ 8 \\ \hline 512 \end{array}$$

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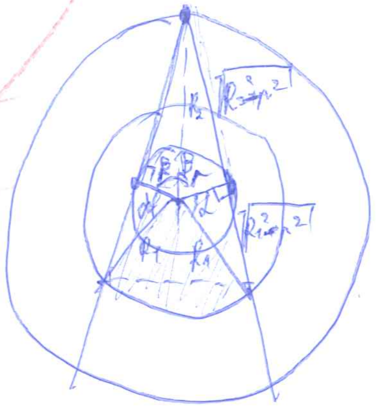
Чистовик
1.4.1

$$= \frac{2(R_1+R_2)}{R_1R_2\left(\sqrt{\frac{g}{R_1^3}}-\sqrt{\frac{g}{R_2^3}}\right)} = \frac{2\cdot 16{,}4\cdot 10^7}{64\cdot 10^{14}\cdot\sqrt{10}\left(\frac{1}{\sqrt{64\cdot 10^{-3}\cdot 10^{21}}}-\frac{1}{\sqrt{10^{24}}}\right)}$$

$$= \frac{16{,}4}{32\cdot 10^7\cdot\sqrt{10}\left(\frac{1}{8\cdot 10^9}-\frac{1}{10^{12}}\right)} = \frac{4{,}1}{8\cdot 10^7\cdot\sqrt{10}\left(\frac{10^{12}-8\cdot 10^9}{8\cdot 10^{21}}\right)}$$

Подписывать лист-вкладыш запрещается! Писать на полях листа-вкладыша запрещается!

Черновик



R_1 $\frac{\omega_1}{\omega_2} = \sqrt{\frac{R_2^3}{R_1^3}}$

$\omega_{отн} = \frac{2\pi}{T}$; $T = \frac{2\pi}{\omega_{отн}}$

$\sin\alpha = \frac{\sqrt{R_1^2 + r^2}}{R_1^2}$

$\sin\beta = \frac{\sqrt{R_2^2 + r^2}}{R_2^2}$

$mg = \frac{GMm}{r^2}$

$gr^2 = GM$

$r^2 = \frac{GM}{g}$

$2(\alpha + \beta)$

$mg = \frac{GM}{r^2}$

$g = \frac{GM}{r^2}$

$\cos\alpha = \frac{r}{R}$

$\arccos\alpha + \arcsin\alpha = \frac{\pi}{2}$

~~arccos~~

$\omega_1^2 R_1 = \frac{GM}{R_1^2}$

$\omega_1^2 = \frac{GM}{R_1^3} = \frac{gr^2}{R_1^3}$

$\alpha = \arccos\frac{r}{R_1}$

$\beta = \arccos\frac{r}{R_2}$

$\sin 60 = \frac{1}{2}$

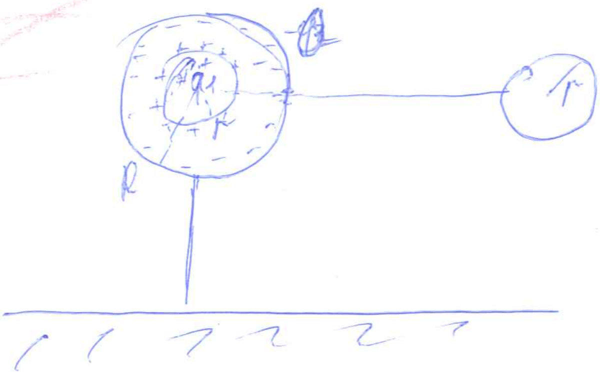
$60 = \arcsin\frac{1}{2}$

$2(\alpha + \beta) = \arccos\frac{r}{R_2} + \arccos\frac{r}{R_1}$

$2\pi - \arccos\frac{r}{R_2} - \arccos\frac{r}{R_1}$

$\arcsin\frac{1}{2} + \arccos\frac{1}{2} =$

Черновик



$Q + q_1 = 0$

$Q = -q_1$

$\varphi_0 = \frac{kq_1}{r} - \frac{kq_1}{R}$

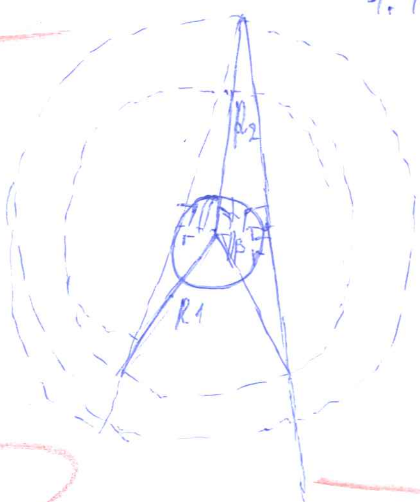
$\frac{kq_1}{r} - \frac{kq_1}{R} = \frac{kq_2}{r}$

$q_1 R - q_1 r = q_2 R$

$R = \frac{q_1 r}{q_1 - q_2} = \frac{6 \cdot 10^{-10} \cdot 2 \cdot 10^{-2}}{4 \cdot 10^{-10}} =$

$= 3 \cdot 10^{-2}$

1.4.1



$\omega_1 = \sqrt{\frac{gr^2}{R_1^3}}$

$\omega_2 = \sqrt{\frac{gr^2}{R_2^3}}$

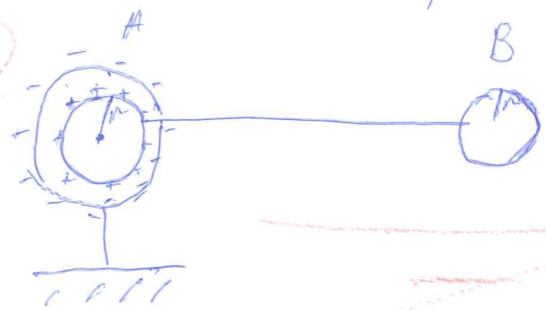
$\frac{\omega_1}{\omega_2} = \sqrt{\frac{R_2^3}{R_1^3}}$

$L =$

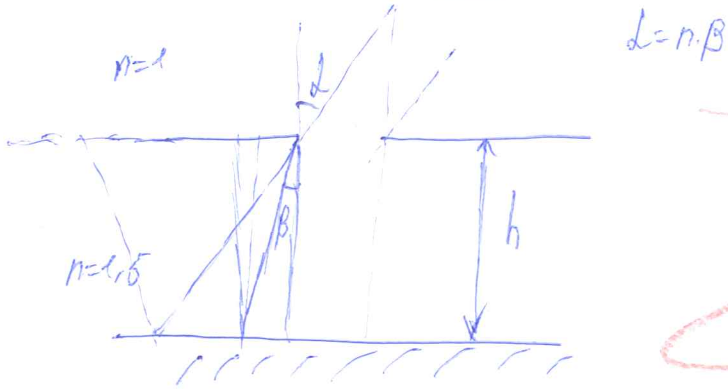
$2h \cdot tg\beta = 2h \cdot \sin\beta = \frac{2h}{n} = \frac{2 \cdot 5 \cdot 10^{-2}}{1{,}5} = \frac{4 \cdot 5}{3} \cdot 10^{-2} =$

$= 6(666) \cdot 10^{-2}$

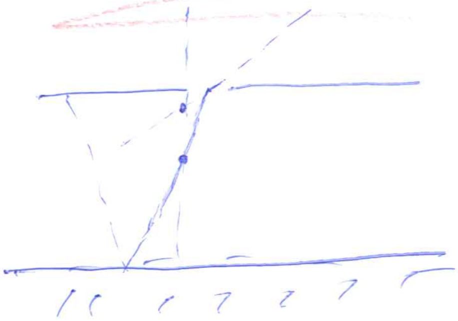
черновик

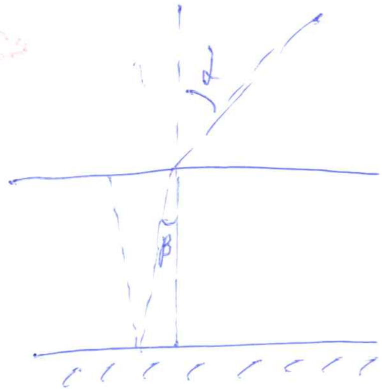


$\varphi_A = \varphi_B$



$\alpha = n \cdot \beta$





$\alpha = \beta n$

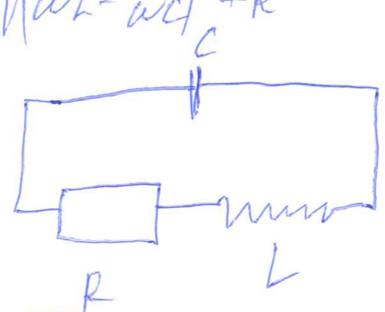
$\beta_{кр} = \frac{1}{n}$

5-4-1

$Z = \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}$

$I = \frac{U}{Z}$; $q = q_{max} \cdot \cos(\omega t + \varphi_0)$

$I_{\cancel{max}} = I$

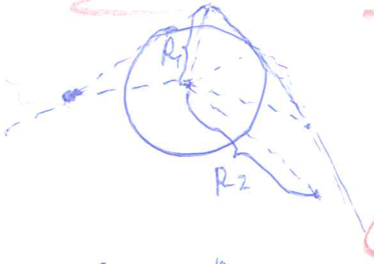


$I_{max} = \frac{U}{\left(\frac{1}{\omega C}\right)} = U \omega C$

$T = 2\pi\sqrt{LC}$

Подписывать лист-вкладыш запрещается! Писать на полях листа-вкладыша запрещается!

Черновик



$$a_1 m_1 = G\frac{m_1 M}{R_1^2}$$

$$mg = \frac{GmM}{r^2}$$

$$\frac{v_1^2}{R_1}\cdot m_1 = G\frac{m_1 M}{R_1^2}$$

$$g = \frac{GM}{r^2}$$

$$v_1^2 = \frac{GM}{R_1} = \frac{gr^2}{R_1}$$

$$GM = gr^2$$

$v_1 = w_1 R_1$

$$v_2^2 = \frac{GM}{R_2} = \frac{gr^2}{R_2}$$

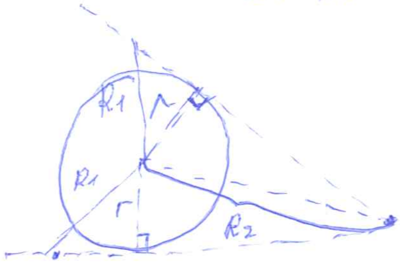
$w_2 < w_1$

$$w_1^2\cdot R_1^2 = \frac{gr^2}{R_1}$$

$$w_2^2\cdot R_2^2 = \frac{gr^2}{R_2}$$

$$w_1 = \sqrt{\frac{gr^2}{R_1^3}}$$

$$w_2 = \sqrt{\frac{gr^2}{R_2^3}}$$

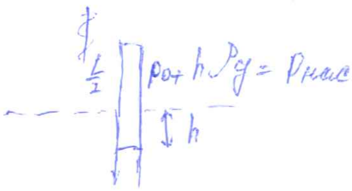


$$\frac{w_1}{w_2} = \sqrt{\frac{R_2^3}{R_1^3}}$$

$$w_1 = \sqrt{\frac{R_2^3}{R_1^3}}\, w_2$$

$$w_{отн} = w_1 - w_2 = \left(\sqrt{\frac{R_2^3}{R_1^3}} - 1\right) w_2$$

2.5.1



$$p_{нас}\cdot S = p_0\cdot S + h\rho_0 g\cdot S$$

$$p_в + p_{нас} = p_0 + h\rho_0 g$$

$\cancel{p_0 L S = \nu R T_0}$

$$p_{нас}\cdot(L-h)\cdot S = \nu_1 R T_0$$

$$\frac{p_в\cdot L}{L-h} + p_{нас} = p_0 + h\rho_0 g$$

$$p_0 = p_{н.п.} + p_в$$

$$\frac{(p_0 - p_{н.п.})L}{L-h} + p_{н.п.} = p_0 + h\rho_0 g$$

$\cancel{p_в V_0}$ $p_в\cdot L\cdot S = \nu_в\cdot R\cdot T_0$

$\cancel{p_в\cdot L\cdot S = p_{в1}}$

$$p_{н.п.} - \frac{p_{н.п.}L}{L-h} = p_0 - \frac{p_0 L}{L-h} + h\rho_0 g$$

$$(p_{н.п.} + p_в)\cdot L\cdot S = (p_{н.п.} + p_{в1})(L-h)\cdot S$$

$$p_{н.п.}\left(\frac{-h}{L-h}\right) = p_0\frac{-h}{L-h} + h\rho_0 g$$

$$p_в\cdot L = p_{в1}(L-h)$$

$$p_{в1} = \frac{p_в\cdot L}{L-h}$$

$$p_{н.п.} = \frac{\frac{p_0 h}{L-h} - h\rho_0 g}{\left(\frac{h}{L-h}\right)} = \frac{p_0 h - h\rho_0 g(L-h)}{h}$$

$$= p_0 - \rho_0 g(L-h)$$