14-16-44-47
(5.10)

МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ
имени М.В.ЛОМОНОСОВА

Вариант 3

Место проведения Москва
город

ПИСЬМЕННАЯ РАБОТА

Олимпиада школьников „Ломоносов"
наименование олимпиады

по Физике
профиль олимпиады

Тополевой Дарьи Олеговны
фамилия, имя, отчество участника (в родительном падеже)

выход 14:55
вход 14:58 Кон

Дата
«9» февраля 2024 года

Подпись участника

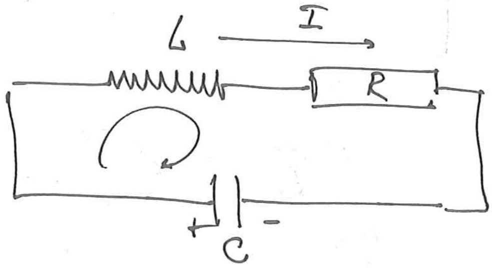
14-16-44-47 (5.10)

Чистовик

№ 5.4.3

R, C, U_c, Q

$L = ?$



Запишем второе правило Кирхгофа на контур: $-LI_м' = I_м R - U_c$

т.к. $I_{max} \Rightarrow I_м' = 0$

$\Rightarrow I_м R = U_c \quad \Rightarrow I_м = \frac{U_c}{R}$

за период $\Rightarrow$ от I_{max} до I_{max}

на резисторе:

$T = 2\pi\sqrt{LC}$ — период колебаний

$$Q = \left(\frac{I_м}{\sqrt{2}}\right)^2 \cdot RT =$$

$$= \frac{I_м^2}{2} \cdot R \cdot 2\pi\sqrt{LC} = \frac{U_c^2}{R^2} \cdot R \cdot \pi\sqrt{LC} = \frac{\pi U_c^2 \sqrt{LC}}{R}$$

$$Q^2 = \frac{\pi^2 U_c^4 LC}{R^2} \Rightarrow \pi^2 U_c^4 \cdot LC = Q^2 \cdot R^2 \Rightarrow$$

$$\Rightarrow \boxed{L = \frac{(QR)^2}{\pi^2 U_c^4 \cdot C}} = \frac{(31{,}4 \cdot 10^{-3} \cdot 0{,}4)^2}{(3{,}14)^2 \cdot 1^4 \cdot 40 \cdot 10^{-6}} =$$

$$= \frac{(3{,}14)^2 (10^{-4})^2 \cdot (0{,}4)^2}{(3{,}14)^2 \cdot 40 \cdot 10^{-6}} = \frac{10^{-8}}{10^{-6}} \cdot \frac{0{,}4 \cdot 0{,}4}{40} = \frac{10^{-2} \cdot 0{,}4 \cdot 0{,}4}{40} =$$

$$= \boxed{0{,}4 \cdot 10^{-4} \text{ Гн}}$$ ← Ответ

18

1	2	3	4	5	Σ
18	17	20	19	18	92

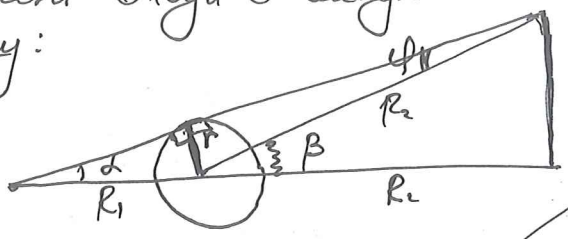
Потапин

девяносто два

№ 1.4.3. Чистовик

$M, r, G, R_1, R_2 \mid \tau = ?$

момент входа в "следующую" дугу:



$$\frac{\omega_1}{\omega_2} = \left(\frac{R_2}{R_1}\right)^{\frac{3}{2}}$$

II ЗН: $\frac{m_1 v_1^2}{R_1} = \frac{m_1 M G}{R_1^2}$

$v = \omega R$

$$\begin{cases} \omega_1 = \dfrac{v_1}{R_1} = \sqrt{\dfrac{MG}{R_1}} \cdot \dfrac{1}{R_1} = \sqrt{\dfrac{MG}{R_1^3}} \\ \omega_2 = \dfrac{v_2}{R_2} = \sqrt{\dfrac{MG}{R_2^3}} \end{cases} \qquad v_1 = \sqrt{\frac{MG}{R_1}}, \quad v_2 = \sqrt{\frac{MG}{R_2}}$$

$\frac{M}{G} = M$

$\frac{1}{C}$

$$\frac{\omega_1}{\omega_2} = \left(\frac{10^5 \cdot 10^3}{6{,}4 \cdot 10^4 \cdot 10^3}\right)^{\frac{3}{2}} = \left(\frac{100}{64}\right)^{\frac{3}{2}} \quad \left(\frac{\omega_1}{\omega_2}\right)^{\frac{2}{3}} = \frac{R_2}{R_1} = \frac{100}{64}$$

условие выхода: $\tau(\omega_1 - \omega_2) = 2\beta$

$\beta = \alpha + \varphi$

$2\beta = 2(\alpha + \beta)$

$$\left.\begin{aligned} \alpha \approx \frac{r}{R_1} \approx \sin\alpha \\ \varphi = \frac{r}{R_2} \approx \sin\varphi \end{aligned}\right\} \Rightarrow \beta = r\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\Rightarrow \tau(\omega_1 - \omega_2) = 2r\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\omega_1 = \left(\frac{R_2}{R_1}\right)^{\frac{3}{2}} \cdot \omega_2 \Rightarrow \omega_1 - \omega_2 = \omega_2\left(-1 + \left(\frac{R_2}{R_1}\right)^{\frac{3}{2}}\right)$$

$$\tau = \frac{2r\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}{\omega_1 - \omega_2} = \frac{2r\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}{\sqrt{MG}\left(\frac{1}{\sqrt{R_2^3}} - \frac{1}{\sqrt{R_1^3}}\right)} \Rightarrow$$

Ответ: $\tau = \dfrac{2r\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}{\sqrt{MG}\left(\frac{1}{\sqrt{R_2^3}} - \frac{1}{\sqrt{R_1^3}}\right)}$

Ответ: $2 \cdot 10^{-3}$ с

$\frac{1}{C} \cdot \alpha$

$(64)^{\frac{3}{3}}$

$\sqrt[3]{64^2} =$

$= \sqrt{8 \cdot 8 \cdot 8 \cdot 8}$

$\sqrt[3]{10 \cdot 10 \cdot 10 \cdot 10}$

$10\sqrt[3]{10}$

$8\sqrt[3]{8}$

Чистовик

$\ell \gg R$

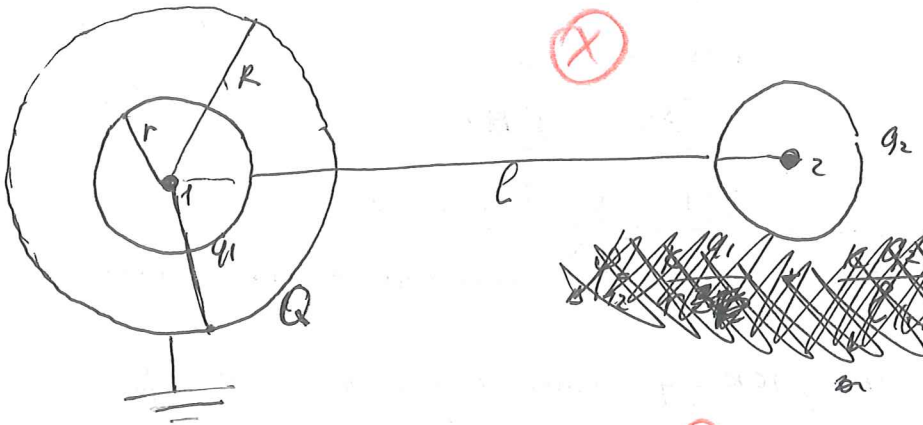
3.10.3

$r = 2$ см

$R = 3$ см

$q_1 = 6 \cdot 10^{-6}$ Кл

$q_2 = ?$



Т.к. заземлена, то $\varphi = 0$

$$\varphi_1 = \frac{kq_1}{r} + \frac{kQ}{R} \qquad \frac{q_1}{r} = -\frac{Q}{R}$$

$$\varphi_2 = \frac{kq_2}{r}$$

$\varphi_1 = \varphi_2$ (т.к. они соединены)

$$\frac{q_1}{r} + \frac{Q}{R} = \frac{q_2}{r} \qquad \frac{Q}{R} = \frac{1}{r}(q_2 - q_1)$$

φ на заземл. сфере $= 0 = \frac{kq_1}{R} + \frac{kQ}{R} + \frac{kq_2}{\ell}$ ($\ell \gg R$)

$$q_1 = -Q$$

$$-\frac{q_1}{R} = \frac{1}{r}(q_2 - q_1)$$

$$-\frac{q_1}{R} = \frac{q_2}{r} - \frac{q_1}{r} \qquad \frac{q_2}{r} = q_1\left(-\frac{1}{R} + \frac{1}{r}\right)$$

$\frac{1}{2} - \frac{1}{3} = \frac{3}{6} - \frac{2}{6} = \frac{1}{6}$

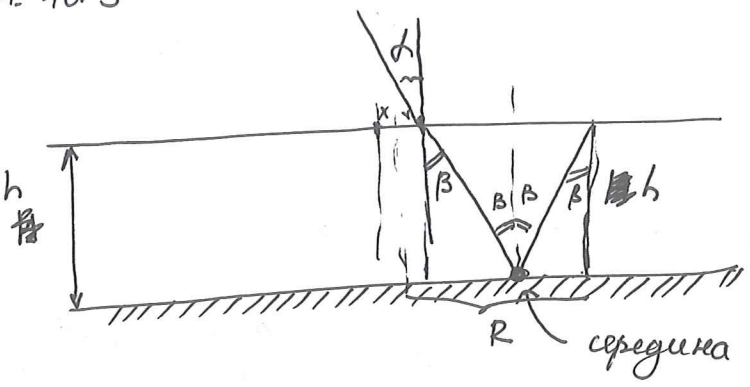
$$\boxed{q_2 = q_1\left(\frac{1}{r} - \frac{1}{R}\right)r} =$$

$$= 6 \cdot 10^{-6}\ \text{Кл} \cdot 2 \cdot 10^{-2}\ \text{м}\left(\frac{1}{2 \cdot 10^{-2}\ \text{м}} - \frac{1}{3 \cdot 10^{-2}\ \text{м}}\right) = 12 \cdot 10^{-6}\ \text{Кл} \cdot \left(\frac{1}{6}\right) =$$

Ответ $\longrightarrow = \boxed{2 \cdot 10^{-6}\ \text{Кл}}$ Ответ $\boxed{2 \cdot 10^{-6}\ \text{Кл}}$

Частовик

4. 10.3



$x \ll R$

$h = 4$ см

$R = 8$ см

$n = ?$

середина R, т.к. x - мало

по закону Снеллиуса: $\sin\alpha = n \sin\beta$

$$\sin\beta = \frac{\frac{R}{2}}{\sqrt{\frac{R^2}{4} + h^2}}$$

чтобы $\sin\beta$ - max,

$\sin\alpha$ - max $= 1 \Rightarrow \alpha = 90°$

тогда $R = R_{max}$

$\sin\alpha = 1$

$\Rightarrow 1 = n \cdot \sin\beta$

$$1 = \frac{n\frac{R}{2}}{\sqrt{\frac{R^2}{4} + h^2}} = \frac{\frac{Rn}{2}}{\frac{\sqrt{R^2 + 4h^2}}{2}} = \frac{Rn}{\sqrt{R^2 + 4h^2}}$$

$2 \times 16 \times 4 = 64$

$Rn = \sqrt{R^2 + 4h^2}$

$$\Rightarrow \boxed{n = \frac{\sqrt{R^2 + 4h^2}}{R}} = \frac{\sqrt{8^2 + 4 \cdot 4^2}}{8} =$$

$$= \frac{\sqrt{64 + 64}}{8} = \frac{\sqrt{2 \cdot 8^2}}{8} = \sqrt{2} \approx$$

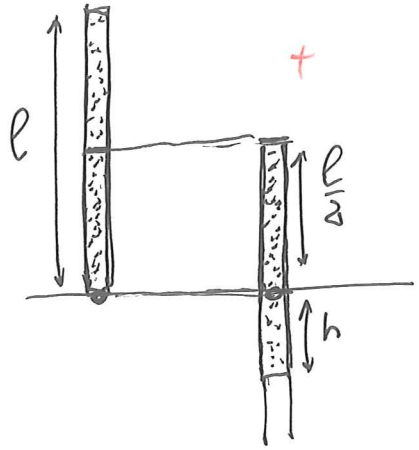
$\approx \boxed{1{,}7}$ - Ответ

14-16-44-47 (5.10)

№ 2.5.3 Чистовик

$h, \ell, P_{нп}, P_0, \rho_0$

$\ell = ?$



(1) $P_{г1} = P_0 - P_{нп}$ ($P_{нп} = const$, т.к. $T = const$)

(2) $P_0 + \rho_0 g h = P_{нп} + P_{г2}$

$$\frac{P_{г2}}{P_{г1}} = \frac{V_1}{V_2} = \frac{\ell S}{(\frac{\ell}{2} + h) S}$$

(3) $P_{г2} = P_{г1} \cdot \frac{\ell}{\frac{\ell}{2} + h}$

$$\begin{cases} P_{г1} = P_0 - P_{нп} \ (1) \\ P_0 + \rho_0 g h = P_{нп} + P_{г2} \ (2) \\ P_{г2} = P_{г1} \cdot \frac{\ell}{\frac{\ell}{2} + h} \ (3) \end{cases} \longrightarrow P_{г2} = P_0 - \rho_0 g h - P_{нп} \ (2)$$

$$P_{г1} \ell = P_{г2} \frac{\ell}{2} + P_{г2} h \ | \cdot 2$$

$$\ell (2P_{г1} - P_{г2}) = 2 P_{г2} h$$

$$(3) \ \ell = \frac{2 P_{г2} h}{2P_{г1} - P_{г2}} = \frac{2(P_0 - \rho_0 g h - P_{нп}) h}{2(P_0 - P_{нп}) - (P_0 - \rho_0 g h - P_{нп})} =$$

$$= \frac{2(P_0 - \rho_0 g h - P_{нп}) h}{2P_0 - 2P_{нп} - P_0 + \rho_0 g h + P_{нп}} = \boxed{\frac{2(P_0 - \rho_0 g h - P_{нп}) h}{P_0 - P_{нп} + \rho_0 g h}} =$$

$$= \frac{2(10^5 - 10^3 \cdot 10 \cdot 0{,}45 - 14{,}5 \cdot 10^3) \cdot 0{,}45}{10^5 - 14{,}5 \cdot 10^3 + 10^3 \cdot 10 \cdot 0{,}45} = \frac{0{,}9 \cdot 81}{90} =$$

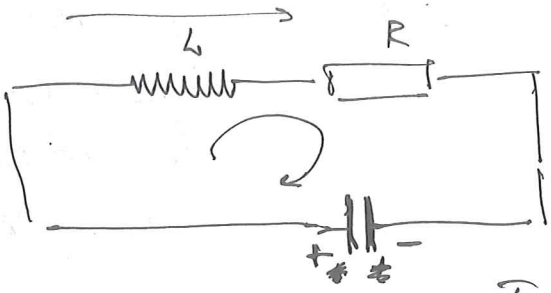
$$= \frac{8{,}1}{10} = 0{,}81 \text{ м} \approx \boxed{81 \text{ см}}$$

Ответ: 81 см

Черновик

$R = 0{,}4\ Ом$

$C = 40\ нФ$



$C = \frac{q}{U}$

$U = \frac{q}{C}$

$I_{max} \rightarrow U_C = 1\ В$

$Q = 3{,}4\ мкКл$

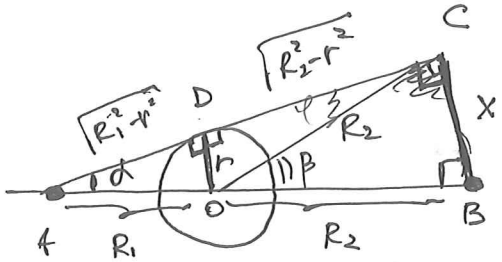
ЗСЭ:

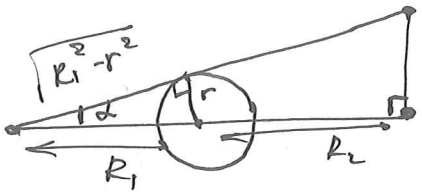
I_{max}

Закон Ома

$-LI' = IR - \left(\frac{q}{C}\right)$ U_C

$\boxed{IR = U_C}$

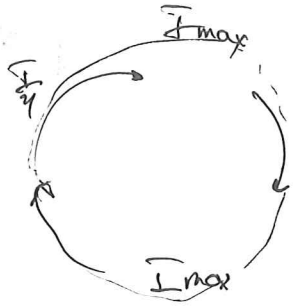




$\alpha = \frac{r}{R_1}$

$\beta = \frac{R_2}{R_2} \frac{Y}{X}$

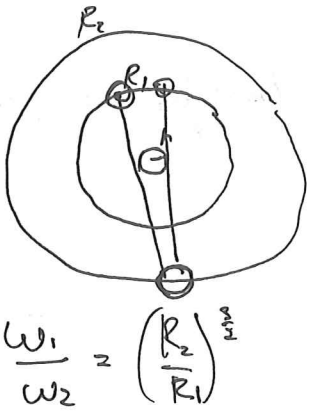
mg -



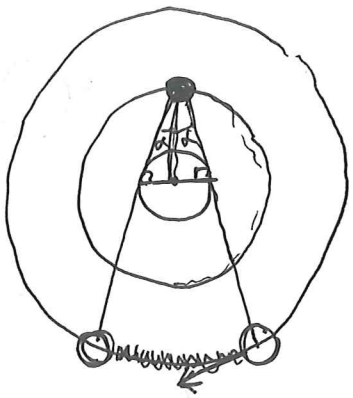
1.4.3

$R_1 = 6{,}4 \cdot 10^4\ км$ r, M, G

$R_2 = 10^5\ км$



$\frac{\omega_1}{\omega_2} = \left(\frac{R_2}{R_1}\right)^{\frac{3}{2}}$



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

$v_1 = \sqrt{\frac{GM}{R_1}}$

$v_2 = \sqrt{\frac{GM}{R_2}}$

т.к. $R_1 < R_2$, то $v_1 > v_2$

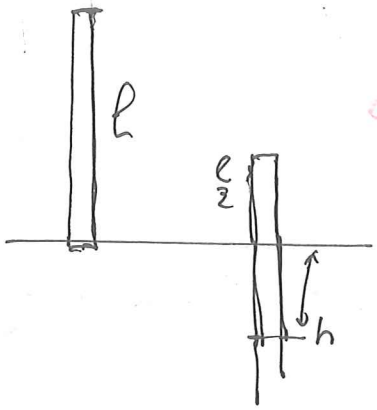
$a = \frac{v^2}{R} = \omega^2 R$ $\omega = \frac{v}{R}$

$v = \omega R$

$T = \frac{2\pi}{\omega} =$ $T_2 - T_1 = 2\pi\left(\frac{R_2}{v_2} - \frac{R_1}{v_1}\right)$

$= \frac{2\pi}{\frac{v}{R}} = \frac{2\pi R}{v}$ T

Черновик



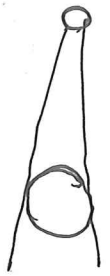
$l = ?$, h $T = const$

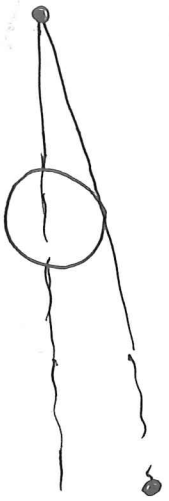
$P_{нас} = 14{,}5\ кПа$

$P_0 = 10^5\ Па$

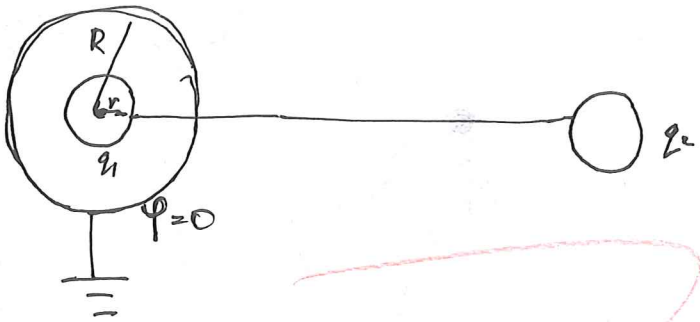
$\rho_0 = 10^3 \frac{кг}{м^3}$ | g

$P_{смеш} = P_с = P_б + P_{нп}$



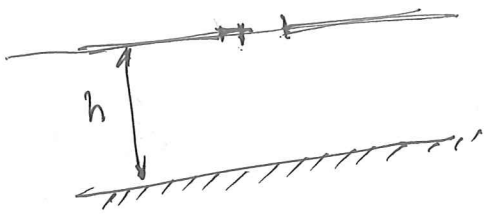


$q_1 + q_{20} = q_1 + q_2$

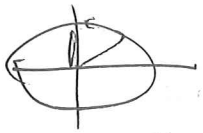


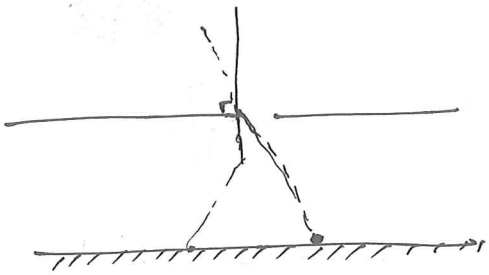
Подписывать лист-вкладыш запрещается! Писать на полях листа-вкладыша запрещается!

Черновик

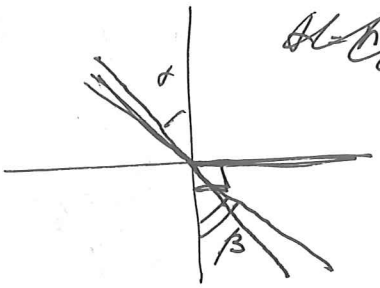


$n = ?$



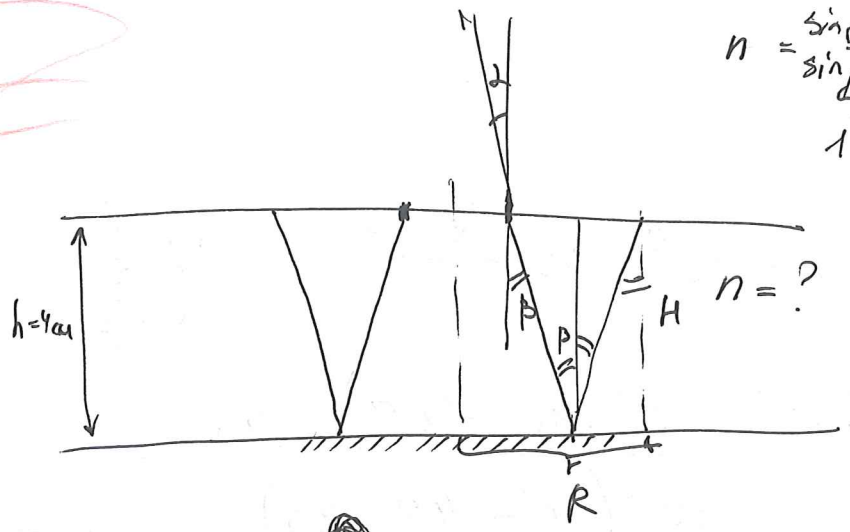


$\sin\alpha = n\sin\beta$

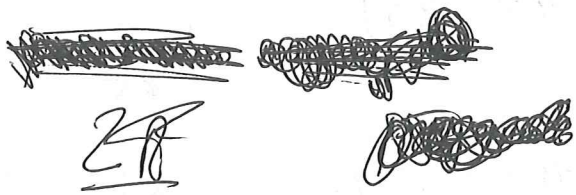


$n = \frac{\sin\alpha}{\sin\beta}$

1



$n = ?$



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

ω

Черновик

$P_{г1} = P_0 - P_{н.п}$

$P_{н.п} = const$

$P_0 + \rho g h = P_{н.п} + P_{г2}$

$\frac{P_{г2}}{P_{г1}} = \frac{V_1}{V_2}$

$P_{г2} = P_{г1} \cdot \frac{\ell}{\frac{\ell}{2} + h}$

$\left(\frac{1}{10^{12}(6,4)^7} - \frac{1}{10^8}\right) \cdot 6 \cdot 6,7 \cdot 10^{12} =$

$=$

$2(10^5 - 45 \cdot 10^3$

$\frac{2 \cdot 10^3 (10^2 - 4,5 - 14,5) \cdot 0,45}{10^3 (10^2 - 14,5 + 4,5)} =$

$= \frac{0,9 \cdot 10^3 (100 - 19)}{10^3 (100 - 10)} =$

$= 0,9.$

Человек

$$T = \frac{2r\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}{\sqrt{MG\left(\frac{1}{\sqrt{R_2^3}} - \frac{1}{\sqrt{R_1^3}}\right)}} = 2\sqrt{6{,}4\cdot 10^3 \cdot 10^3}\left(\frac{1}{6{,}4\cdot 10^4 \cdot 10^3}\right)$$

$$= \frac{2\cdot 6{,}4\cdot 10^3\cdot 10^3\left(\frac{1}{6{,}4\cdot 10^4\cdot 10^3} + \frac{1}{10^5\cdot 10^3}\right)}{\sqrt{6\cdot 10^{24}\cdot 6{,}7\cdot 10^{-11}}\left(\frac{1}{\sqrt{(6{,}4\cdot 10^4\cdot 10^3)^3}} - \frac{1}{\sqrt{(10^5\cdot 10^3)^3}}\right)} =$$

числитель:

$$10^3\cdot 12{,}8\left(\frac{1}{6{,}4\cdot 10^4} + \frac{1}{10^5}\right) = \frac{10^3}{10^8}\cdot 12{,}8\left(\frac{1}{6{,}4} + \frac{1}{100}\right) =$$

$$= 12{,}8\left(\frac{1}{64} + \frac{1}{100}\right) =$$

$$= \frac{12{,}8}{64} + \frac{12{,}8}{100} =$$

$$= \frac{6{,}4\cdot 2}{6{,}4\cdot 10^1} + 12{,}8\cdot 10^{-2} =$$

$$= \frac{2}{10} + 12{,}8\cdot 10^{-2}$$

$$= 0{,}2 + 0{,}128 =$$

$$= 0{,}328$$

$g = \frac{MG}{R}$

gR