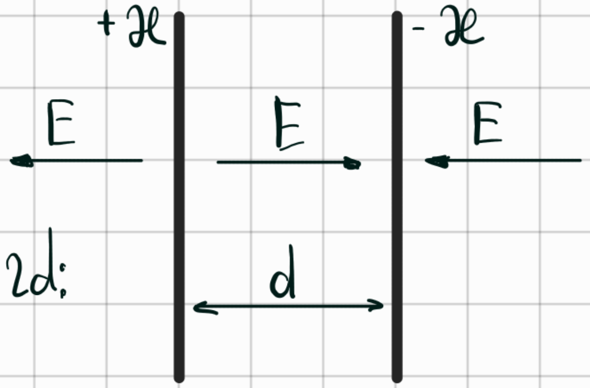
Неделя 1.

I

№1.14

2d:



3d:

1) $E(r)$ для одного провода:

th. Гаусса: $E(r)\cdot \cancel{2\pi} r\cdot \cancel{l} = \overset{2}{\cancel{4\pi}}\cdot \cancel{l}\cdot \varkappa \Rightarrow$

$$\Rightarrow E(r) = \frac{2\varkappa}{r}$$

2) $\vec{E}(h) = \vec{E}_+(h) + \vec{E}_-(r)$

$$\cos\theta = \frac{d/2}{\sqrt{d^2/4 + h^2}} = \frac{d}{\sqrt{4h^2+d^2}}$$

$$E^2(h) = 2E^2 - 2E^2\cos(2\theta) = 2E^2(1+\cos(2\theta)) \Rightarrow$$

$$\boxed{E(h) = 2E\cos\theta = \frac{8\varkappa d}{4h^2+d^2}}$$

№1.21

$E = const$ – по радиусу

$\rho = \rho(r) = ?$

1) th. Гаусса через ~:

$$E(r+dr)\,4\pi(r+dr)^2 - E(r)\cdot 4\pi r^2 = 4\pi\, 4\pi r^2 dr\, \rho(r)$$

$$\cancel{4\pi} E\cdot 2\cancel{r}\cancel{dr} = \cancel{4\pi} r^{\cancel{2}} \cancel{dr}\,\rho(r)\cdot 4\pi \Rightarrow \rho(r) = \frac{E}{2\pi r}$$

T1

$F = ?$

$q_{max} = ?$

1) $W = (\vec{p}, \vec{E}) \Rightarrow F = (\vec{p}, \nabla)\vec{E}$

$$F = \left(\vec{p}_1, \frac{\partial \vec{E}_2}{\partial x} + \frac{\partial \vec{E}_2}{\partial y}\right) = $$

$$= p_{1x}\frac{\partial \vec{E}_2}{\partial x} + p_{1y}\frac{\partial \vec{E}_2}{\partial y}$$

2) $$\vec{E}_2 = \frac{3(\vec{p}_2, \vec{r})\vec{r}}{r^5} - \frac{\vec{p}_2}{r^3} = \begin{pmatrix} \frac{3(p_{2x}x + p_{2y}y)x}{r^5} - \frac{p_{2x}}{r^3} \\ \frac{3(p_{2x}x + p_{2y}y)y}{r^5} - \frac{p_{2y}}{r^3} \end{pmatrix}$$

$$\frac{\partial E_{2x}}{\partial x} = -\frac{6p_{2x}}{r^4} \qquad \frac{\partial E_{2x}}{\partial y} = \frac{3p_{2y}}{r^4}$$

$$\frac{\partial E_{2y}}{\partial x} = 0 \qquad \frac{\partial E_{2y}}{\partial y} = \frac{3p_{2x}}{r^4}$$

$$\Rightarrow F_x = -6\frac{p_{1x}p_{2x}}{r^4} + 3\frac{p_{1y}p_{2y}}{r^4}$$

$$\Rightarrow F_y = \frac{3p_{1x}p_{2y}}{r^4} + 3\frac{p_{1y}p_{2x}}{r^4}$$

3) а) $\alpha_1 = \alpha_2 = 0$

$F_x = -6\frac{p^2}{r^4}$; $F_y = 0$

$\frac{p^2}{r^4} = 2{,}2 \cdot 10^{-15}$ Н

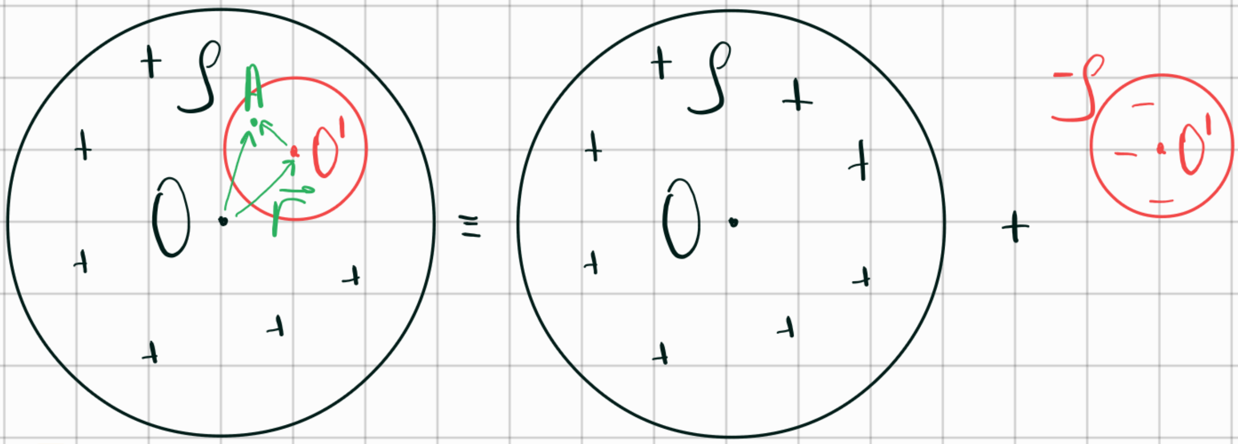
б) $\alpha_1 = \frac{\pi}{2}$; $\alpha_2 = \pm\frac{\pi}{2}$

$F_x = \pm\frac{3p^2}{r^4}$; $F_y = 0$

в) $\alpha_1 = 0$; $\alpha_2 = \pm\frac{\pi}{2}$

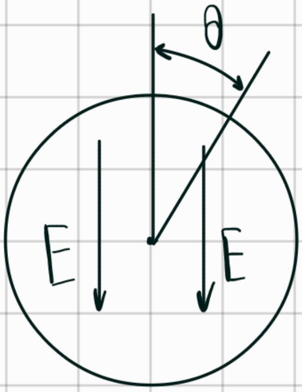
$F_x = 0$; $F_y = \pm\frac{3p^2}{r^4}$

№1.22



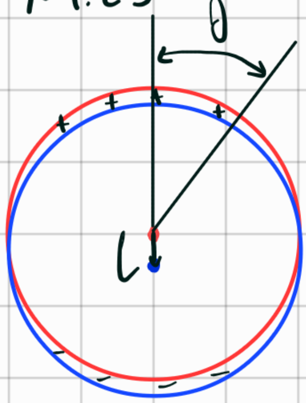
$$\vec{E} = \vec{E}_0 + \vec{E}_{0'} = \frac{4\pi}{3}\left(\rho\vec{OA} - \rho\vec{O'A}\right) = \frac{4\pi\rho}{3}\left(\vec{OA} + \vec{AO'}\right) = \boxed{\frac{4\pi\rho}{3}\vec{r}}$$

№1.23



$\sigma(\theta) = ?$

1)



$$\sigma(\theta) = \rho l \cos\theta$$

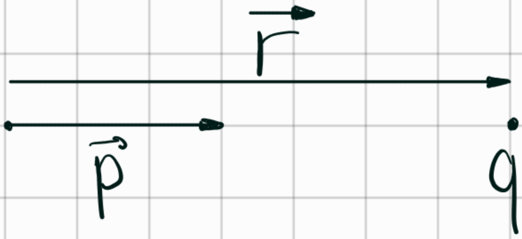
2) $$4\pi R^2 E = \frac{4}{3}\pi R^3 \rho \cdot 4\pi \Rightarrow$$

$$\Rightarrow \vec{E} = \frac{4\pi\rho}{3}\vec{R}$$

$$\vec{E} = \vec{E}_+ + \vec{E}_- = \frac{4\pi\rho}{3}\vec{l}$$

3) $$\sigma(\theta) = \frac{3E}{4\pi l} l\cos\theta \Rightarrow \boxed{\sigma(\theta) = \frac{3E}{4\pi}\cos\theta}$$

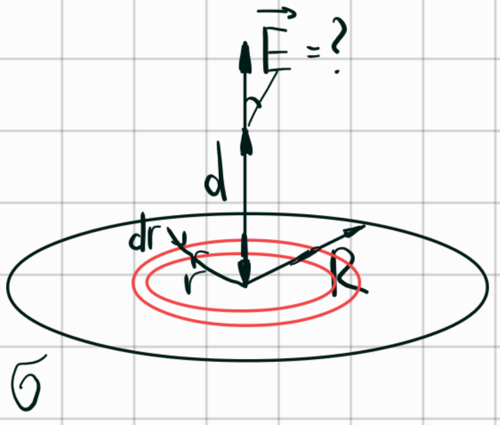
№1.7



1) $$\vec{E} = \frac{3(\vec{p},\vec{r})\vec{r}}{r^5} - \frac{\vec{p}}{r^3} = \frac{2\vec{p}}{r^3}$$

2) $$\vec{F} = q\vec{E} = \frac{2q}{r^3}\vec{p}$$

№1.10

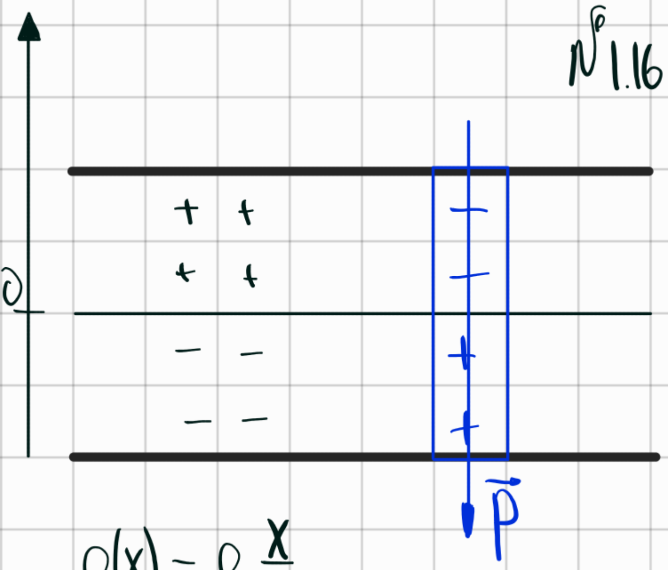


1) $d\vec{E} = \frac{2\pi r\,dr\,\sigma}{r^2+d^2}\cdot\frac{d}{\sqrt{r^2+d^2}}$

$$E = 2\pi d\sigma\int_0^R \frac{d(r^2+d^2)}{(r^2+d^2)^{3/2}} = -2\pi d\sigma\left[\frac{1}{\sqrt{R^2+d^2}}-\frac{1}{d}\right]=$$

$$E = 2\pi\sigma\left(1-\frac{d}{\sqrt{R^2+d^2}}\right)$$

№1.16



$$\rho(x) = \rho_0\frac{x}{d}$$

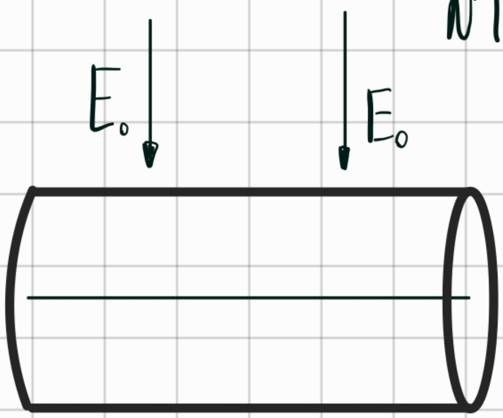
1) $m\ddot{x} = -p\frac{dE}{dx} = -4\pi\rho_0 p\frac{x}{d}$

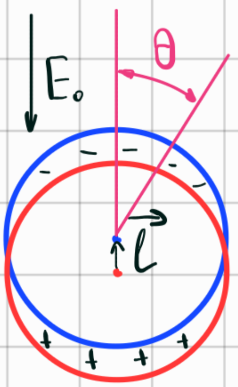
2) $\mathrm{div}\,\vec{E} = 4\pi\rho \Rightarrow \frac{dE}{dx} = 4\pi\rho$

3) $m\ddot{x} + \frac{4\pi p\rho_0}{d}x = 0$

$$T = 2\pi\sqrt{\frac{md}{4\pi p\rho_0}}$$

№1.24





$\boxed{r<R}$

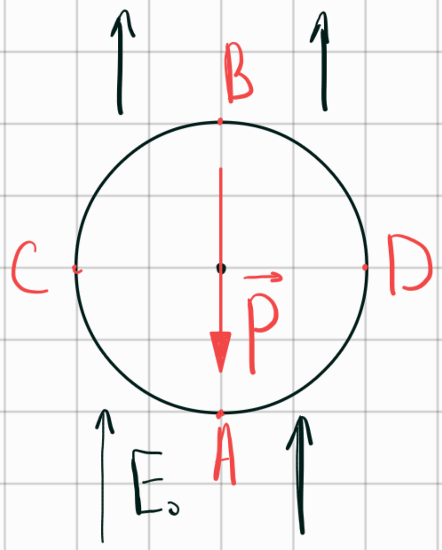
1) $\vec{E}(r) = \frac{4\pi\rho\pi r^2 l}{2\pi r\cdot d} = 2\pi\rho\vec{r}$

2) $\vec{E}_\Sigma = 2\pi\rho\vec{l}$

3) $\sigma(\theta) = \rho l\cos\theta$

$$\sigma(\theta) = \frac{E_0}{2\pi l}l\cos\theta = \frac{E_0}{2\pi}\cos\theta$$

№1.26



1) $\vec p = -R^3 \vec E$

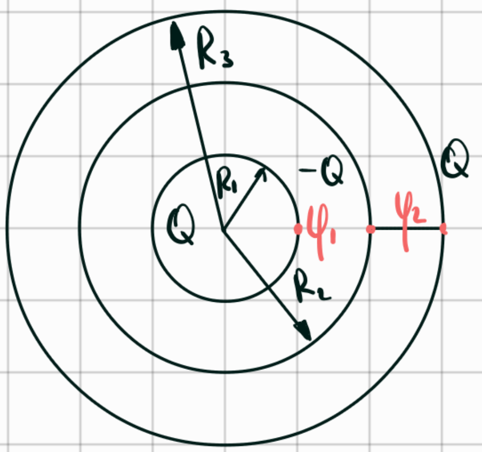
2) $\vec E = \cancel{\vec E_0} + \frac{3(\vec p \vec R)\vec R}{R^5} - \cancel{\frac{\vec p}{R^3}}$

$\vec E = 3E_0\cos\theta \cdot \left(\frac{\vec R}{R}\right)$

• $|E_A| = 3E_0$ • $|E_C| = |E_D| = 0$

• $|E_B| = 3E_0$

№2.3

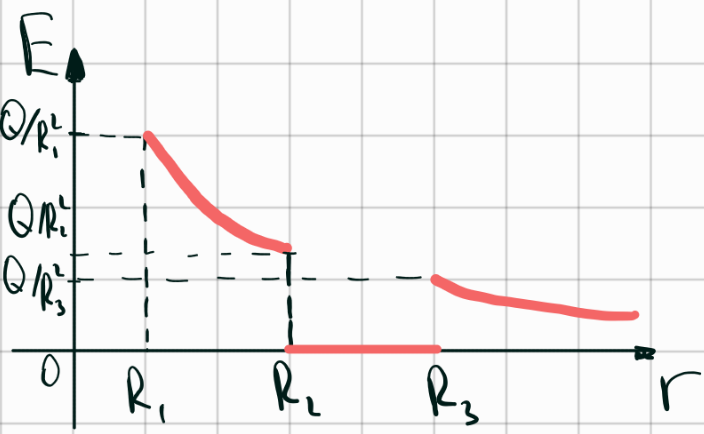


1) Из т. Гаусса:

• $E(r) = \frac{Q}{r^2}$, $R_1 \le r < R_2$

• $E(r) = 0$, $R_2 \le r < R_3$

• $E(r) = \frac{Q}{r^2}$, $R_3 \le r < \infty$

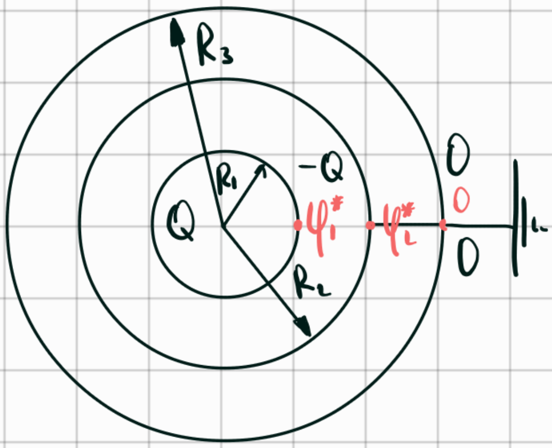


2) $\varphi_1 = \int_{R_1}^{R_2} \frac{Q}{r^2}dr + \int_{R_2}^{R_3} 0\,dr + \int_{R_3}^{\infty} \frac{Q}{r^2}dr \Rightarrow$

$\varphi_1 = Q\left(-\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_3}\right)$

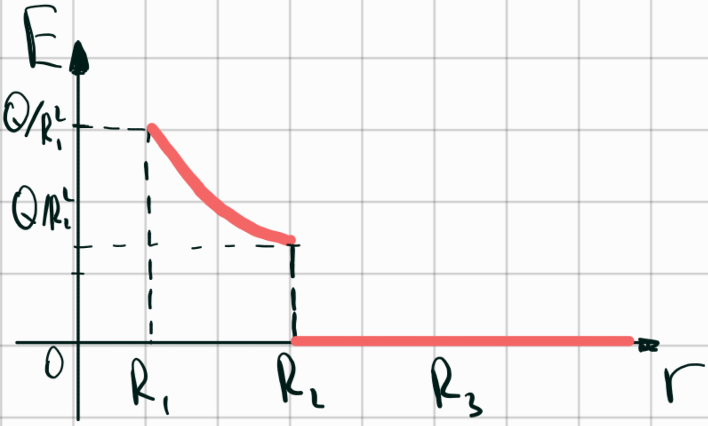
$\varphi_2 = \int_{R_3}^{\infty} \frac{Q}{r^2}dr = \frac{Q}{R_3}$

3) Заземлим внеш. шар, тогда

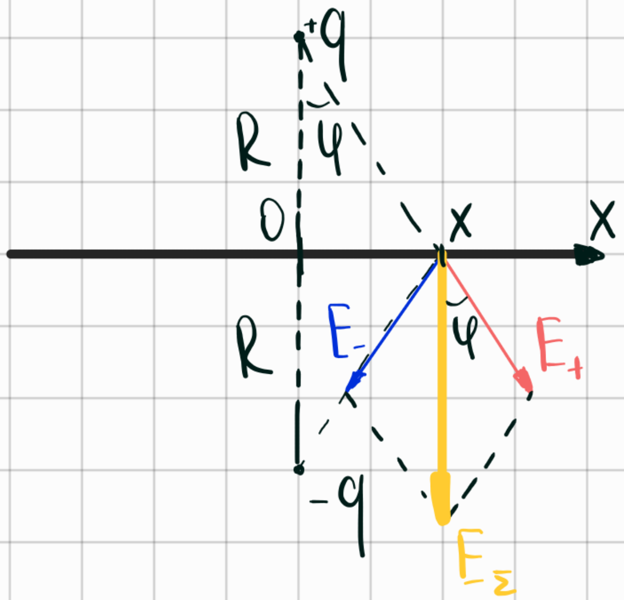


$$\varphi_1^* = \int_{R_1}^{R_2} \frac{Q}{r^2} dr = Q\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{R_2 - R_1}{R_2 R_1} Q$$

$\varphi_2^* = 0$ - очев



№2.11



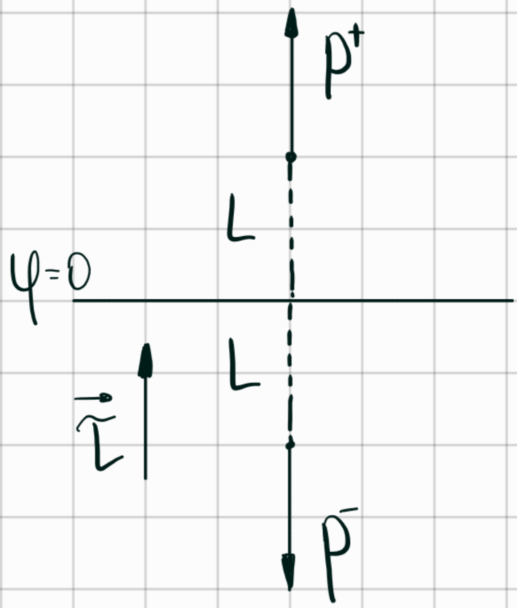
1) $E_\Sigma = 2E_\pm \cos\varphi = 2\frac{q}{x^2+R^2} \cdot \frac{R}{\sqrt{x^2+R^2}}$

2) По т. Гаусса:

$$E_\Sigma S = 4\pi\sigma S \Rightarrow \sigma = \frac{E_\Sigma}{4\pi}$$

$$\sigma = \frac{1}{2\pi} \frac{qR}{(R^2+x^2)^{3/2}}$$

№2.15



1) $W = (\vec{p}^{+}, \vec{E}^{-}) \Rightarrow F = \left(\vec{p}^{+}, \frac{\partial \vec{E}^{-}}{\partial x}\right)$

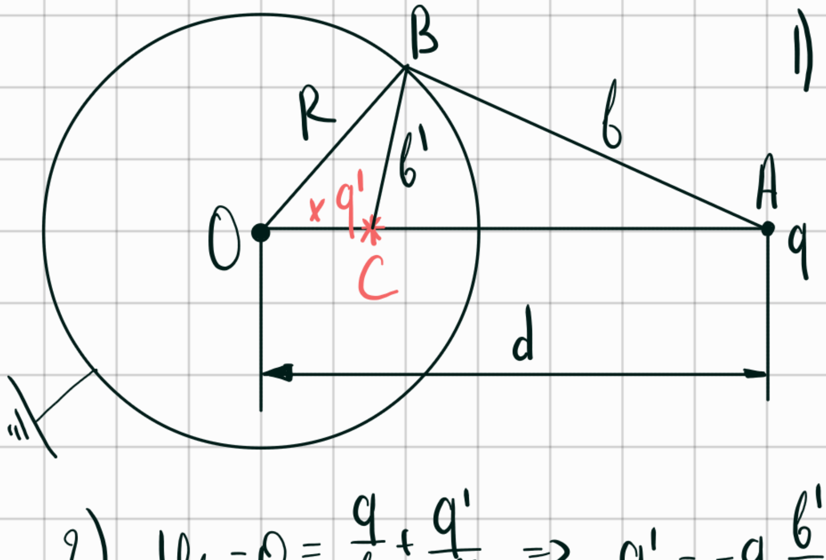
2) $\vec{E}^{-} = \frac{3(\vec{p}\cdot\vec{r})}{r^5}\vec{r} - \frac{\vec{p}}{r^3} = \frac{-3\cdot p\cdot r^2}{r^5}\vec{\iota} + \frac{p}{r^3}\vec{\iota} = \frac{2\vec{p}}{r^3}$

$F = p\cdot\frac{-6p}{r^4} = \frac{-6p^2}{r^4} \approx -0{,}54$ дин

3) $A = \int_L^{2L} F\,dx = -6p^2\int_L^{2L}\frac{dx}{r^4} = \left| r = 2x \right| \Rightarrow$

$A = -6p^2\int_L^{2L}\frac{dx}{16x^4} = \frac{p^2}{8}\cdot\left(-\frac{7}{8L^2}\right) = -\frac{7}{64}\frac{p^2}{L^2} \approx -0{,}167p$

№2.20 (Овчинкин)



1) Поставим q' в т. C так, что $\Delta OBC \sim \Delta OAB$:

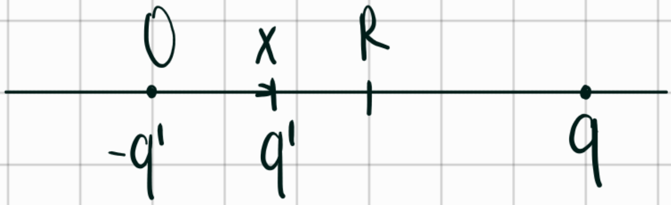
$\frac{b'}{b} = \frac{R}{d}$

2) $\varphi_B = 0 = \frac{q}{b} + \frac{q'}{b'} \Rightarrow q' = -q\frac{b'}{b} = -q\frac{R}{d}$;

$\frac{d}{R} = \frac{R}{x} \Rightarrow x = R^2 d$

3) $F = \frac{qq'}{(d-x)^2} = -\frac{q^2Rd}{(d^2-R^2)^2}$

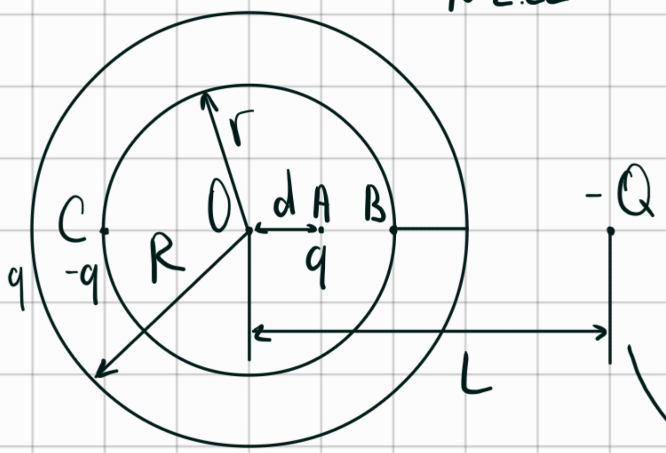
4) Если сфер изол., то скомпенсируем q' с $-q'$



$$F = -\frac{q'q}{(d-x)^2} + \frac{q'q}{d^2} = q^2\frac{R}{d}\frac{1}{(d-x)^2} - q^2\frac{R}{d}\frac{1}{d^2} = q^2\frac{R}{d}\left(\frac{1}{(d-x)^2} - \frac{1}{d^2}\right) \Rightarrow$$

$$F = q^2\left(\frac{Rd}{(d^2-R^2)^2} - \frac{R}{d^3}\right)$$

№2.22



2) Метод изображений:

Известно: $L = \frac{R^2}{d}$; $Q = q\frac{d}{r}$

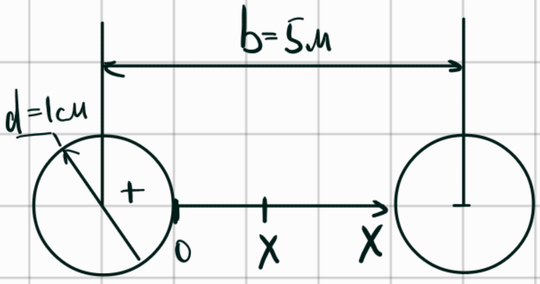
$$E_B = \frac{q}{(r-d)^2} + \frac{q\frac{d}{r}}{(L-r)^2} = \frac{q(1+\frac{d}{r})}{(r-d)^2}$$

Аналогично: $E_C = \frac{q(1-\frac{d}{r})}{(r+d)^2}$

1) Из т. Гаусса для $r<x<R$ очев., что на внеш. часть сферы не действ. $E \Rightarrow$

$\Rightarrow 4\pi R^2 \sigma_{вн} = q \Rightarrow \sigma_{внеш} = \frac{q}{4\pi R^2}$; $\varphi_{внеш} = \frac{q}{R}$

$№2.48$



1) $$E(x) = \frac{2æ}{x} + \frac{2æ}{b-x}$$

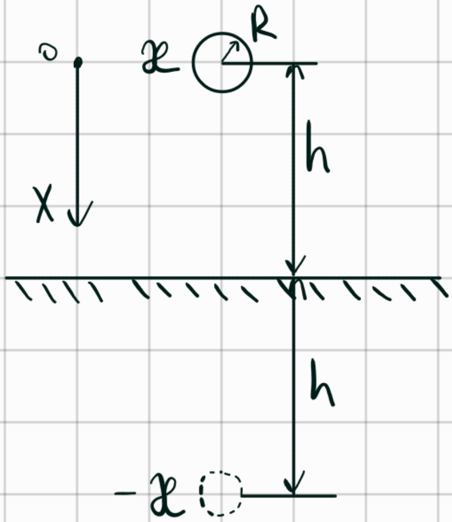
$$E(x) = E_{max} \Leftrightarrow x = \left[\begin{array}{l} \frac{d}{2} \\ b-\frac{d}{2} \end{array}\right.$$

$$\Rightarrow E(x_{max}) = \frac{4æb}{d(b-\frac{d}{2})} \Rightarrow æ = \frac{E_{max}d(b-\frac{d}{2})}{4b}$$

2) $$\Delta\varphi = \int_{d/2}^{b-d/2} 2æ\left(\frac{1}{x}+\frac{1}{b-x}\right)dx =$$

$$= 2æ\left[\ln\frac{x}{b-x}\Big|_{d/2}^{b-d/2}\right] = \frac{E_{max}d(b-\frac{d}{2})}{b}\ln\left(\frac{2b}{d}-1\right)$$

T_2



1) Метод изображений:

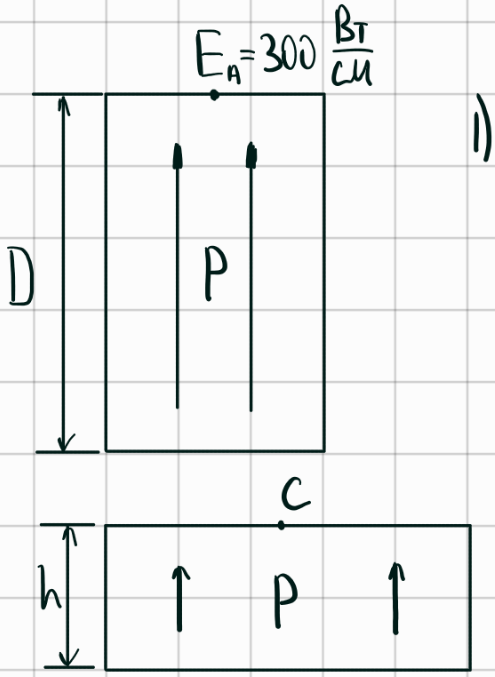
$$E_0 = \frac{4æ}{h} \Rightarrow æ = \frac{1}{4}E_0h$$

2) $$d\varphi = -\mathrm{grad}\,\vec{E} = \frac{\partial E}{\partial x} = \frac{d}{dx}\frac{2æ}{x} = -\frac{2æ}{x^2}$$

$$\Delta\varphi = \int_R^h E(x)dx = 2æ\int_R^h\left[\frac{1}{x}+\frac{1}{2h-x}\right]dx =$$

$$= 2æ\ln\frac{2h-R}{R} \simeq 2æ\ln\frac{2h}{R} = \frac{1}{2}E_0h\cdot\ln\frac{2h}{R} \simeq 10\text{ кВ}$$

№3.8

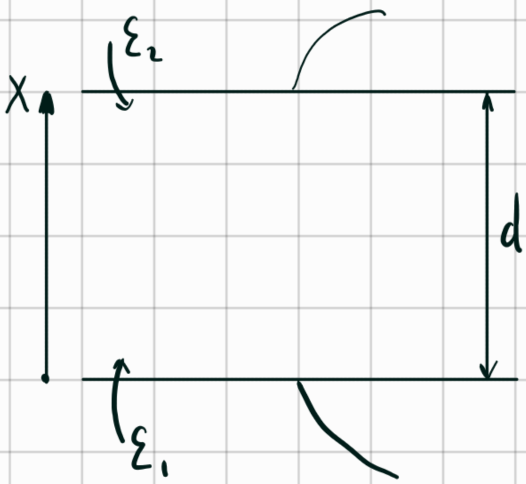


1) Т. Гаусса: $E_A = 2\pi\sigma_A = 2\pi PD$

$E_c = 4\pi\sigma_c = 4\pi Ph$ – т.к. $h \ll D$, учитываем обе стороны

2) $\frac{E_c}{E_A} = \frac{2h}{D} \Rightarrow E_c = E_A\frac{2h}{D} = 12\ \frac{В}{см}$

№3.26



1) $\varepsilon(x) = \varepsilon_1 + (\varepsilon_2 - \varepsilon_1)\frac{x}{d}$

2) Т. Гаусса: $DS = 4\pi q \Rightarrow D = 4\pi\sigma$

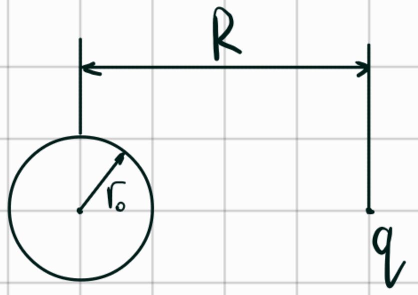
$D = 4\pi\frac{q}{S} = const$

3) $E(x) = \frac{D}{\varepsilon} = \frac{4\pi q}{S[\varepsilon_1 + (\varepsilon_2 - \varepsilon_1)\frac{x}{d}]}$

$U = \int_0^d E(x)dx = \frac{4\pi q}{S}\int_0^d \frac{d}{\varepsilon_1 d + \Delta\varepsilon x} = \frac{4\pi q d}{(\varepsilon_2 - \varepsilon_1)S}\ln\frac{\varepsilon_2}{\varepsilon_1}$

4) $C = \frac{q}{U} \Rightarrow$ $\boxed{C = \frac{(\varepsilon_2 - \varepsilon_1)S}{4\pi q d \ln\frac{\varepsilon_2}{\varepsilon_1}}}$

№3.39

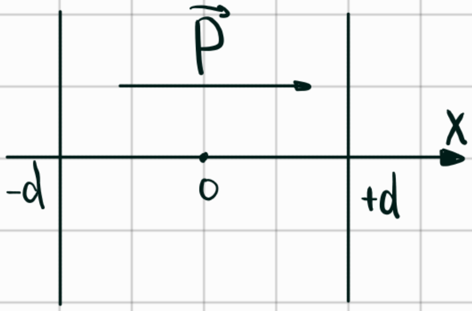


1) $p = r_0^3 \dfrac{\varepsilon-1}{\varepsilon+2} E_0 = r_0^3 \dfrac{\varepsilon-1}{\varepsilon+2} \cdot \dfrac{q}{R^2}$

2) $F = p \dfrac{\partial E}{\partial x} = r_0^3 \dfrac{\varepsilon-1}{\varepsilon+2} \dfrac{q}{R^2} \dfrac{-q}{R^3} \Rightarrow$

$$F \simeq -\frac{2}{3} \frac{q^2 r_0^3}{R^5} (\varepsilon - 1)$$

T3



$\vec{P}(x) = \vec{P}_0 \left(1 + \dfrac{x^2}{d^2}\right)$

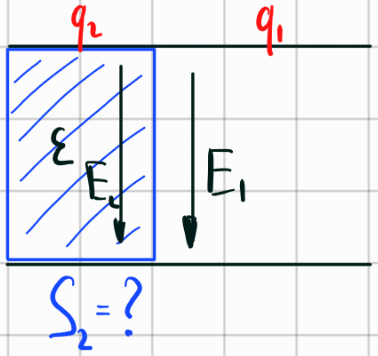
1) $D = 4\pi \dfrac{q}{S} = 0 = E + 4\pi P$

2) $\vec{E} = -4\pi \vec{P}$

$$U = -4\pi \int_{-d}^{d} P\,dx = -4\pi P_0 \int_{-d}^{d} \left(1 + \frac{x^2}{d^2}\right) dx = -\frac{32}{3} \pi P_0 d$$

№3.30

$S_1 = 1\,м^2$



1) До введения: $E = 4\pi \frac{q}{S}$

После: $E_1 = E_2$ (гран. усл.)

$$E_1 = E_2 = \frac{D_2}{\varepsilon} = D_1$$

2) $q_1 + q_2 = q_0$

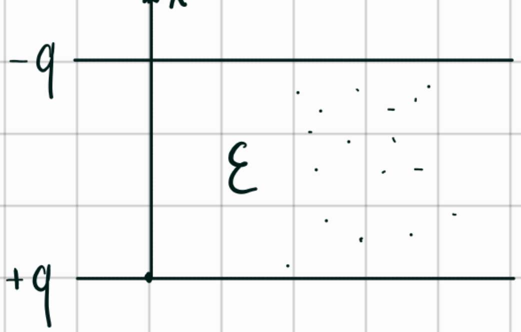
$$D_1 = 4\pi \frac{q_0 - q_2}{S - S_2}$$

$$D_2 = 4\pi \frac{q_2}{S_2} = \varepsilon \cdot 4\pi \frac{q_0 - q_2}{S - S_2} \Rightarrow q_1 = q \frac{S_1 - S_2}{S_1 - S_2 + \varepsilon S_2}$$

3) $$D_2 = n \cdot E_0 = n \cdot 4\pi \frac{q}{S} = 4\pi \cdot \frac{\varepsilon}{\cancel{S_1 - S_2}} \cdot \frac{\cancel{S_1 - S_2}}{S_1 - S_2 + \varepsilon S_2}$$

$$\frac{n}{S_1} = \frac{\varepsilon}{S_1 - S_2 + \varepsilon S_2} = \frac{\varepsilon}{S_1 + (\varepsilon - 1) S_2} \Rightarrow S_2 = \frac{\varepsilon - n}{\varepsilon - 1} \frac{S_1}{n} = 200\ см^2$$

T4



$$\varepsilon(x) = \frac{2}{1 + \frac{x}{h}}$$

$\rho_{пол} = ?$ $C = ?$

1) $D = 4\pi \frac{q}{S} = const$

$$E = E(x) = \frac{D}{\varepsilon(x)} = \frac{1}{2}\left(1 + \frac{x}{h}\right) \cdot 4\pi \frac{q}{S} = 2\pi \left(1 + \frac{x}{h}\right) \frac{q}{S}$$

2) $$U = \int_0^h E(x)\,dx = \frac{2\pi q}{S} \int_0^h \left(1 + \frac{x}{h}\right) dx = \frac{2\pi q}{S} \frac{3h}{2} = \frac{3\pi q h}{S}$$

$$C = \frac{q}{U} = \frac{S}{3\pi h}$$

3) $$P = \frac{D - E}{4\pi} = \frac{q}{S} - \frac{q}{S}\cdot\frac{1}{2}\left(1 + \frac{x}{h}\right) = \frac{q}{2S}\left(1 - \frac{x}{h}\right)$$

$$\operatorname{div}\vec{P} = -\rho_{пол} \Rightarrow \rho_{пол} = \frac{q}{2Sh}$$

T1'

$$W = -(\vec{p}_1, \vec{E}_{21})$$

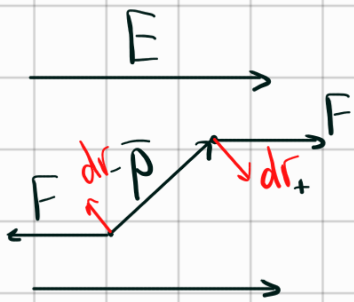
$$\vec{E}_{21} = \frac{3(\vec{p}_2, \vec{r}_{21})\vec{r}_{21}}{R^5} - \frac{\vec{p}_2}{R^3}$$

$$\Rightarrow W = -\frac{3(\vec{p}_2, \vec{r})(\vec{r}, \vec{p}_1)}{r^5} + \frac{(\vec{p}_1, \vec{p}_2)}{r^3} =$$

$$= -\frac{3}{r^5} p_1 p_2 r^2 \cos\theta_1 \cos\theta_2 + \frac{p_1 p_2}{r^3}\cos(\theta_1 - \theta_2) \Rightarrow$$

$$W = -\frac{p_1 p_2}{r^3}\left[3\cos\theta_1\cos\theta_2 - \cos(\theta_1 - \theta_2)\right]$$

№1.5



1) $$dW = -q\vec{E}d\vec{r}_+ + q\vec{E}d\vec{r}_- = \vec{E}q\,d(\vec{r}_+ - \vec{r}_-) = -\vec{E}\cdot d\vec{p} \Rightarrow$$

$$\Rightarrow W = -(\vec{p}, \vec{E})$$

2) $$\vec{P} = \alpha\vec{E}: \quad dW = -\vec{E}d\vec{p} = -E\,dp = -\alpha E\,dE \Rightarrow W = -\frac{\vec{p}\vec{E}}{2}$$

№3.44

$W = mc^2$

$R = ?$

I) $\rho_з = const$

II) заряд на поверхности

I 1) 

$$w = \frac{E^2}{8\pi}$$

$$E \cdot S = 4\pi V \frac{q}{V_0} \Rightarrow E \cdot \cancel{4\pi} r^{\cancel{2}} = \cancel{4\pi} \cdot \cancel{\tfrac{4}{3}} \pi r^{\cancel{3}} \cdot \frac{q}{\cancel{\tfrac{4}{3}} \pi R^3}$$

$$E(r) = \frac{q}{R^3} r$$

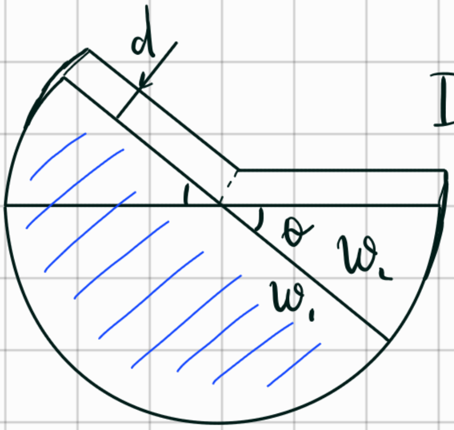
2) $$W_{внутр} = \int_0^R w \cdot 4\pi r^2 dr = \frac{q^2}{2R^6} \int_0^R r^4 dr = \frac{q^2}{2R^6} \cdot \frac{R^5}{5} = \frac{q^2}{10R}$$

$$W_{внеш} = \int_R^\infty w\, 4\pi r^2 dr = \frac{q^2}{2} \int_R^\infty \frac{dr}{r^2} = \frac{q^2}{2R}$$

$$W = \frac{3}{5} \frac{q^2}{R} = mc^2 \Rightarrow R = \frac{3q^2}{5mc^2} \approx 1{,}7 \cdot 10^{-13} см$$

II 1) аналогично $W_{внеш} = \frac{q^2}{2R}$, $W_{внутр} = 0$ $\Rightarrow W = \frac{1}{2} \frac{q^2}{R} \Rightarrow R = \frac{q^2}{2mc^2} \approx 1{,}4 \cdot 10^{-13} см$

№3.67/68



I 1) $$P = w_2 - w_1 = \frac{1}{8\pi}\left[\varepsilon E^2 - E^2\right] = \frac{E^2}{8\pi}(\varepsilon - 1)$$

2) $$M = \int_0^R P S\, r\, dr = P \cdot d \cdot \frac{R^2}{2} \Rightarrow$$

$$M = \frac{E^2}{16\pi} R^2 d (\varepsilon - 1) = \frac{V^2 R^2}{16\pi d}(\varepsilon - 1)$$

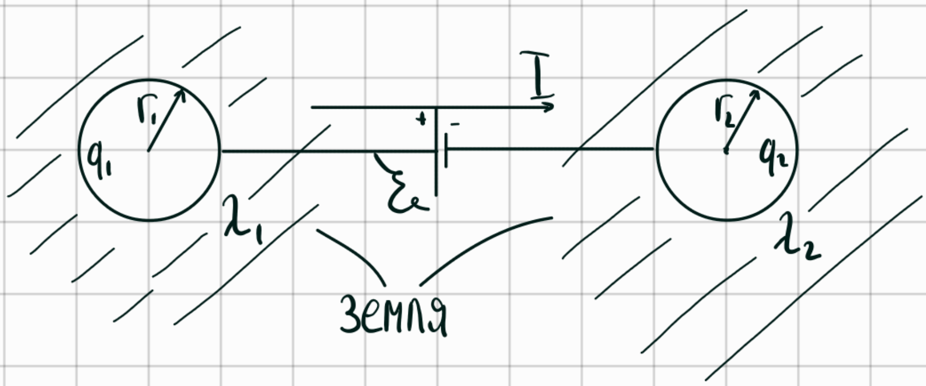
II 1) $D_1 = 4\pi \frac{q_1}{S_1}$ $\quad E_1 = \frac{D_1}{\varepsilon} = \frac{4\pi}{\varepsilon} \frac{q_1}{S_1} = 4\pi \frac{q_2}{S_2} = E_2 \Rightarrow \frac{q_1}{S_1} = \frac{q_2}{S_2} \varepsilon$

$D_2 = 4\pi \frac{q_2}{S_2}$

$$\Delta W = 2\pi\left[\frac{q_1^2}{S_1^2\varepsilon} - \frac{q_2^2}{S_2^2}\right] = 2\pi\frac{q_2^2}{S_2^2}(\varepsilon-1) = \frac{E_2^2}{8\pi}(\varepsilon-1)$$ – аналогично =>

=> ответ такой же

№4.36



1) $I = j(r)\cdot 4\pi r^2 \Rightarrow j(r) = \frac{I}{4\pi r^2} = \lambda E \Rightarrow E(r) = \frac{I}{4\pi r^2\lambda}$, $I = \text{const}$

2) $U = \varphi_1 - \varphi_2 = \frac{I}{4\pi}\left(\frac{1}{\lambda_1 r_1} + \frac{1}{\lambda_2 r_2}\right) \Rightarrow R = \frac{1}{4\pi}\left(\frac{1}{\lambda_1 r_1} + \frac{1}{\lambda_2 r_2}\right)$

$$\varphi_1 = \int_{r_1}^{\infty}\frac{I}{4\pi r^2\lambda_1}dr$$

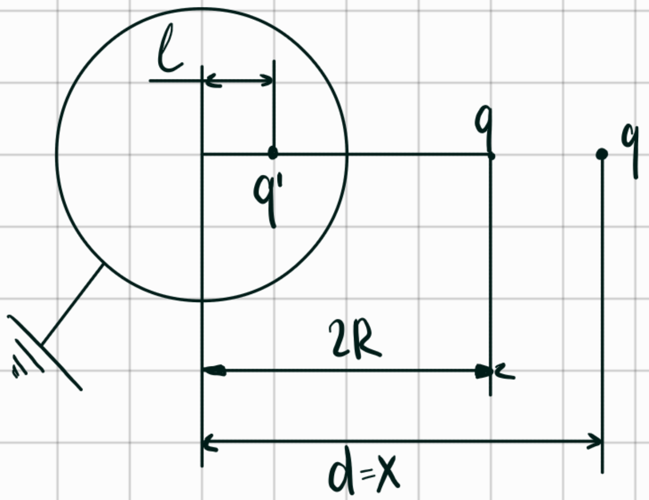
$$\varphi_2 = -\int_{r_2}^{\infty}\frac{I}{4\pi r^2\lambda_2}dr$$

3) $I = \frac{\mathcal{E}_e}{R} = \frac{4\pi}{\frac{1}{\lambda_1 r_1} + \frac{1}{\lambda_2 r_2}}\mathcal{E}_e = \frac{4\pi\mathcal{E}_e\lambda_1 r_1\lambda_2 r_2}{\lambda_1 r_1 + \lambda_2 r_2}$

4) $E = \frac{q}{r^2} = \frac{I}{4\pi r^2\lambda} \Rightarrow q_1 = \frac{\mathcal{E}_e r_1 r_2\lambda_2}{\lambda_1 r_1 + \lambda_2 r_2} = \frac{\mathcal{E}_e r_2}{\frac{\lambda_1}{\lambda_2} + \frac{r_2}{r_1}}$

$$q_2 = \frac{\mathcal{E}_e r_1}{\frac{\lambda_2}{\lambda_1} + \frac{r_1}{r_2}}$$

T5



1) $q' = -q\frac{R}{d}$ – изображ

$l = \frac{R^2}{d}$

2) $F = \frac{qq'}{(x-l)^2} = -\frac{q^2Rx}{(x^2-R^3)^2}$

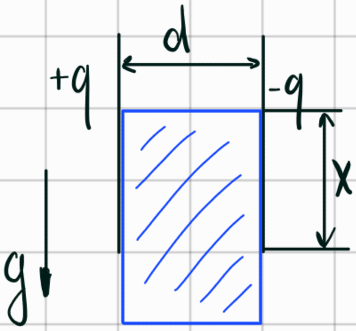
3) $A = \int\limits_{2R}^{4R} F dx = -q^2R\int\limits_{2R}^{4R}\frac{x\,dx}{(x^2-R^3)^2} =$

$= -\frac{q^2R}{2}\int\limits_{2R}^{4R}\frac{d(x^2-R^3)}{(x^2-R^3)^2} = -\frac{2}{15}\frac{q^2}{R} \Rightarrow A_{внеш} = \frac{2}{15}\frac{q^2}{R}$

4) $\Delta W = W_2 - W_1 = \frac{4q^2}{15R}$

5) ЗСЭ: $A_{внеш} = \Delta W + \Delta W_{инд} \Rightarrow \Delta W_{инд} = -\frac{2q^2}{15R}$

№3.73

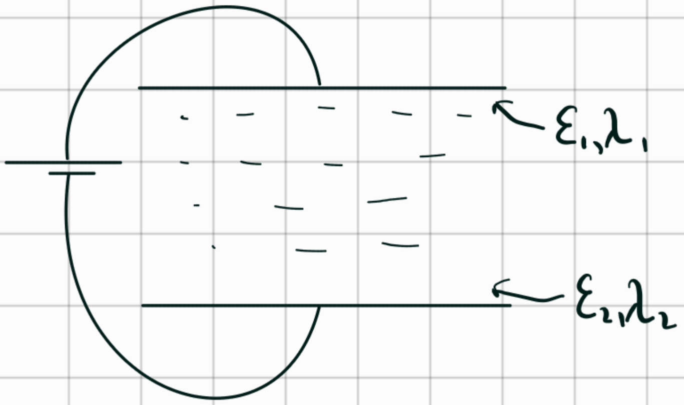


1) $C(x) = \frac{\varepsilon x a}{4\pi d} + \frac{(a-x)a}{4\pi d} = \frac{1}{4\pi d}\left[xa(\varepsilon-1) + a^2\right]$

2) $W(x) = \frac{q^2}{2C(x)} + mgx = \frac{2\pi d q^2}{xa(\varepsilon-1)+a^2} + mgx$

3) $\frac{\partial W(x)}{\partial x} = -\frac{2\pi d q^2 a(\varepsilon-1)}{(xa(\varepsilon-1)+a^2)^2} + mg = 0 \Rightarrow x = \frac{1}{\varepsilon-1}\left[\sqrt{\frac{2\pi d q^2(\varepsilon-1)}{mga}} - a\right]$

№4.23



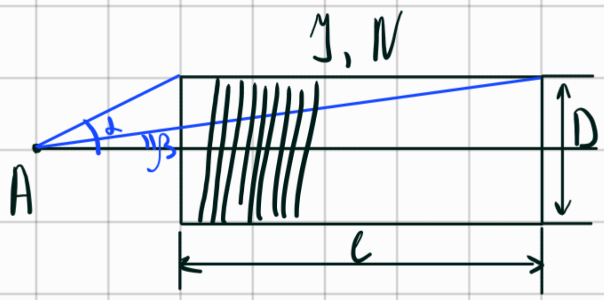
1) $j = \frac{I}{S} = \lambda E; \quad D = \varepsilon E = \varepsilon \frac{I}{S\lambda}$

2) $\operatorname{div} D = \frac{\partial D}{\partial x} = 4\pi\rho \Rightarrow$

$\Rightarrow \rho = \frac{I}{4\pi S} \cdot \frac{\partial\left(\frac{\varepsilon}{\lambda}\right)}{\partial x}$

3) $q = \int_0^d \rho S\, dx = \frac{I}{4\pi} \int_0^d \frac{\partial\left(\frac{\varepsilon}{\lambda}\right)}{\partial x} dx = \frac{I}{4\pi}\left(\frac{\varepsilon_2}{\lambda_2} - \frac{\varepsilon_1}{\lambda_1}\right) \simeq 79$ СГСЭ

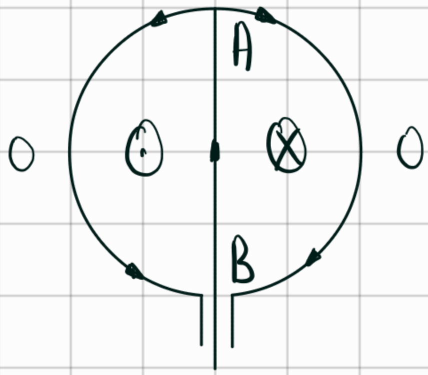
№5.5



$dB = \frac{i}{c} d\Omega, \quad i = \frac{JN}{l} \Rightarrow dB = \frac{JN}{cl} d\Omega$

$B = \frac{JN}{cl}(\Omega_\beta - \Omega_\alpha) = \frac{JN}{cl}(\cos\beta - \cos\alpha)$

№5.10

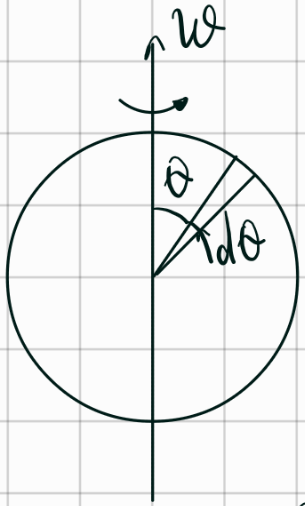


1) вне сферы очев $B=0$

2) внутри: т. о циркуляции:

$$B_0 \cdot 2\pi R = \frac{4\pi}{c} I \Rightarrow B = \frac{2I}{cR}$$

№5.17



I 1) q по объёму:

$$d\mathfrak{m} = \frac{\delta J}{c} S, \quad \delta J = \frac{dq}{t} = \frac{\sigma \cdot \cancel{2\pi} R\sin\theta \cdot R\,d\theta}{\cancel{2\pi}}\,\omega \Rightarrow$$

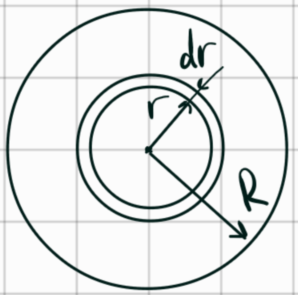
$$\Rightarrow \delta J = \sigma \omega R^2\, d(\cos\theta),$$

$$\sigma = \frac{q}{4\pi R^2} \Rightarrow \delta J = \frac{q\omega}{4\pi}\sin\theta\, d\theta$$

$$d\mathfrak{m} = R^2\frac{q\omega}{4c}\sin^3\theta\, d\theta \Rightarrow \mathfrak{m} = R^2\frac{q\omega}{4c}\int_0^\pi \sin^3\theta\, d\theta = R^2\frac{q\omega}{3c} \Rightarrow$$

$$\Rightarrow B = \frac{qR^2}{3c}\left[\frac{3(\vec\omega\vec r)\vec r}{r^5} - \frac{\omega}{r^3}\right]$$

II

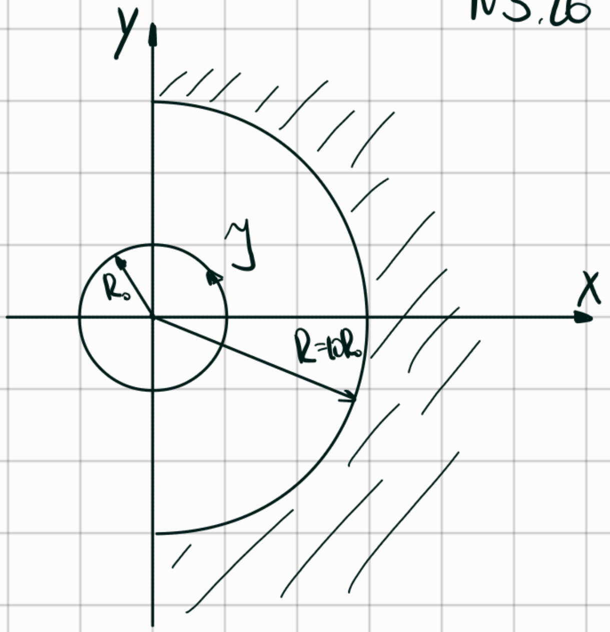


$$d\mathfrak{m}(r) = r^2\frac{dq\,\omega}{3c}, \quad dq = 3\frac{4\pi r^2 dr}{4\pi R^3} q = 3\frac{r^2 dr}{R^3} q$$

$$d\mathfrak{m}(r) = r^2 \cdot \cancel{3}\frac{r^2 dr}{R^3} q \cdot \frac{\omega}{\cancel{3}c} = \frac{r^4 dr}{R^3}\frac{\omega}{c}$$

$$\mathfrak{m}(r) = \int_0^R d\mathfrak{m}(r)\, dr = \frac{\omega q R^2}{5c} \Rightarrow B = \frac{qR^2}{5c}\left[\frac{3(\vec\omega\vec r)\vec r}{r^5} - \frac{\omega}{r^3}\right]$$

№5.26

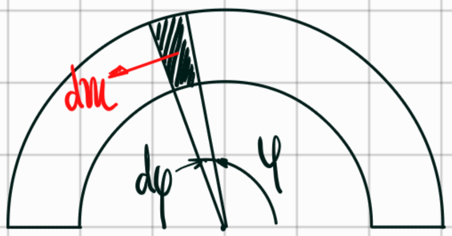


1) $\mathcal{M} = \frac{\mathcal{J}}{c}\cdot \pi R_0^2$

2) $B(r) = -\frac{\mathcal{M}}{r^3} = -\frac{\mathcal{J}}{c}\pi R_0^2 \frac{1}{r^3}$

$$\varphi = \int_R^\infty |B(r)|\cdot \pi r\,dr = \frac{\mathcal{J}\pi^2 R_0^2}{cR} = \frac{\mathcal{J}\pi^2 R_0}{10c}$$

№5.12

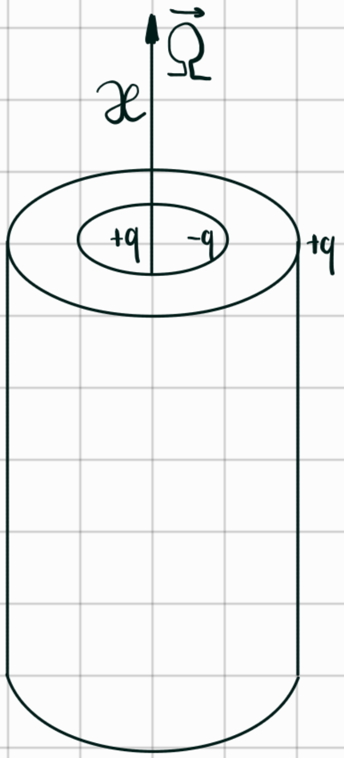


1) $d\mathcal{M} = \frac{dJ}{c}S = \frac{iR\,d\varphi}{c}S$

$dB = \frac{d\mathcal{M}}{R^3} = \frac{i\,d\varphi\,S}{cR^2}$

$$B = \frac{iS}{cR^2}\int_0^\pi \sin\varphi\,d\varphi = \frac{2iS}{cR^2} = \frac{2\pi i}{c}\left(\frac{r}{R}\right)^2$$

№5.14



I Метал. немагн. цилиндр:

1) $E = \frac{2\varkappa}{R} = 4\pi\sigma \Rightarrow \sigma = \frac{\varkappa}{2\pi R}$

2) $i = \sigma\Omega R = \frac{\varkappa\Omega}{2\pi}$

3) $B = \frac{4\pi}{c}i = \frac{2\varkappa\Omega}{c} \simeq 0{,}67\cdot 10^{-7}$ Гс в металле

$B = 0$ снаружи

II Диэлектрик $\varepsilon=3$

1) $\sigma_{пол} = P_n = P$

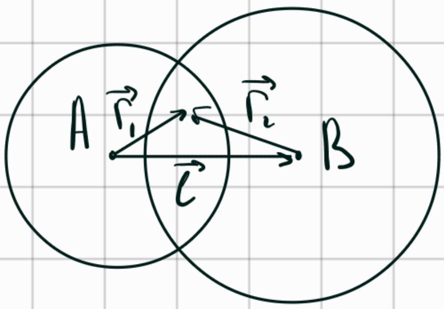
2) На внеш R: $D = \frac{2\varkappa}{R}$

$$D = E + 4\pi P \Rightarrow P = \frac{1}{4\pi}\left(D - \frac{D}{\varepsilon}\right) = \frac{\varkappa(\varepsilon-1)}{2\pi\varepsilon R} = \sigma_{пол}$$

3) Аналог: $B = \frac{4\pi}{c}\cdot\sigma_{пол}\Omega R = \frac{2\varkappa(\varepsilon-1)\Omega}{c\varepsilon} \approx 0{,}44\cdot10^{-7}$ Гс

$B = 0$ в воздухе

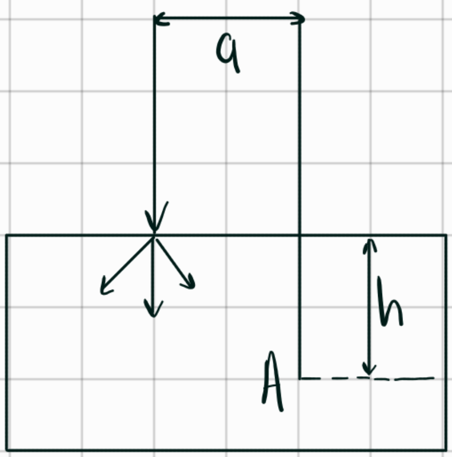
№5.23



$$\left.\begin{aligned}\vec{B}_1 &= \frac{2\pi}{c}[\vec{j}\times\vec{r}_1]\\ \vec{B}_2 &= -\frac{2\pi}{c}[\vec{j}\times\vec{r}_2]\end{aligned}\right| \Rightarrow \vec{B} = \frac{2\pi}{c}[\vec{j},\vec{l}]$$

$$B = \frac{2\pi}{c}jl$$

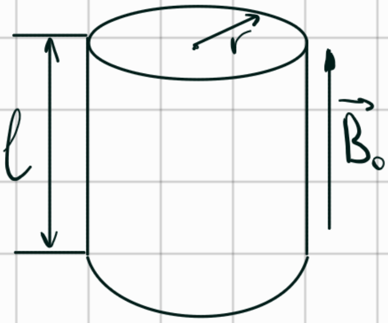
T7



$$B\cdot 2\pi a = \frac{4\pi}{c}I_k = \frac{4\pi}{c}I\cdot\frac{\Omega}{2\pi} = \frac{4\pi}{c}I(1-\cos\alpha) \Rightarrow$$

$$\Rightarrow B = \frac{2I}{ca}\left(1 - \frac{h}{\sqrt{h^2+a^2}}\right) = \frac{I}{ca}$$

№6.7.



1) $B=\mu B_0, \quad H=B_0$

$B=H+4\pi I \Rightarrow B_0(\mu-1)=4\pi I \Rightarrow I=B_0\frac{\mu-1}{4\pi}$

2) $B_m = I\cdot\Omega = I(4\pi-2\Omega') =$

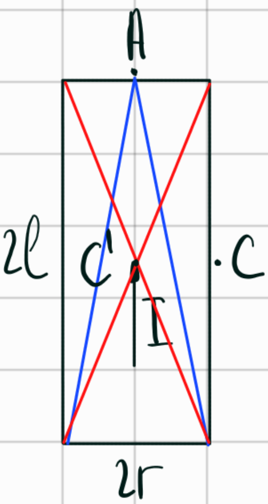
$\Omega' = 2\pi(1-\cos\theta) = 2\pi\left(1-\frac{1}{\sqrt{1+\left(\frac{2r}{l}\right)^2}}\right)\approx \frac{4\pi r^2}{l^2}$

$= 4\pi I\left(1-2\left(\frac{r}{l}\right)^2\right) = B_0(\mu-1)\left(1-2\left(\frac{r}{l}\right)^2\right)$

3) $\Delta B = B_0(\mu-1)\,2\left(\frac{r}{l}\right)^2$

$\Delta B \le \frac{1}{100}B \Rightarrow l \ge 10r\sqrt{\frac{(\mu-1)r}{\mu}}$

№6.5



1) $B_A = \frac{i}{c}\Omega = I(2\pi-\Omega_0) \approx 2\pi I$

$\Omega_0 = 2\pi(1-\cos\theta) = \ldots = \frac{\pi}{4}\left(\frac{r}{l}\right)^2 \approx 0$

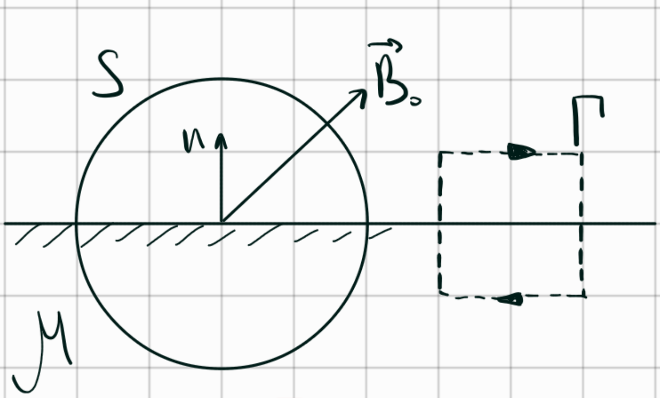
2) $B_{C'} = B_C = \frac{i}{c}\Omega = I(4\pi-2\Omega_0)$

$\Omega_0 = \ldots = \frac{\pi r^2}{l^2}$

$B_C = 2\pi I\left[2-\left(\frac{r}{l}\right)^2\right]$

$H_C = B_C - 4\pi I = -2\pi I\left(\frac{r}{l}\right)^2 \Rightarrow \frac{B_A}{B_C} = -\left(\frac{l}{r}\right)^2$

№6.9



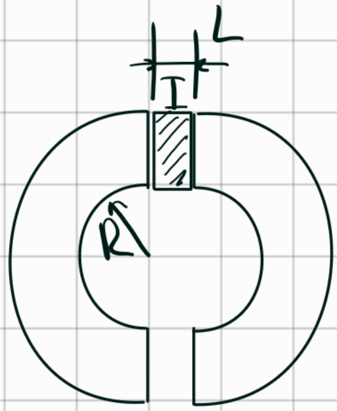
1) $H_0 = H = B_0 \Rightarrow H_{0\tau} = H_\tau = B_0 \sin\theta$

$B_{0n} = B_n$; $B = \mu B_0$

2) $\oint\limits_\Gamma \vec{B} d\vec{l} = B_0 \sin\theta \cdot l - \mu B_0 \sin\theta\, l = B_0 \sin\theta\, l\,(1-\mu)$

3) $\oint\limits_S \vec{H} d\vec{S} = B_0 \cos\theta \cdot \pi R^2 - \frac{B_0}{\mu} \cos\theta\, \pi R^2 = B_0 \cos\theta\, \pi R^2 \frac{\mu - 1}{\mu}$

№6.18



1) $B_{маг} = B_{сер} = B_{заз} = B$

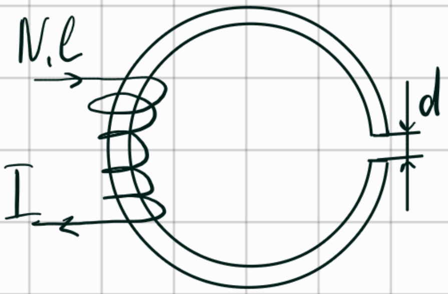
2) $H_{маг} = B - 4\pi I$

$H_{сер} = \frac{B}{\mu}$

$H_{заз} = B_{заз}$

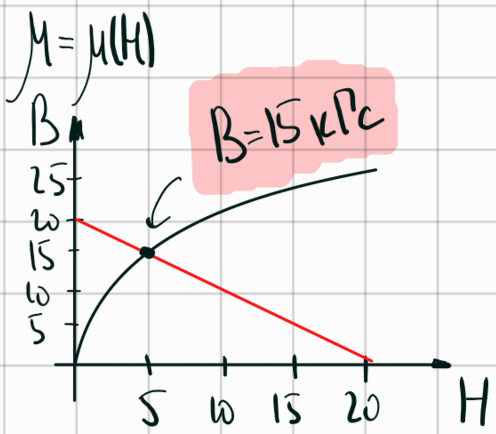
3) $\oint \vec{H} d\vec{l} = 0 = (B - 4\pi I)L + \frac{B}{\mu} 2\pi R + BL = 0 \Rightarrow B = \frac{2\pi I L}{L + \frac{\pi R}{\mu}}$

№6.17



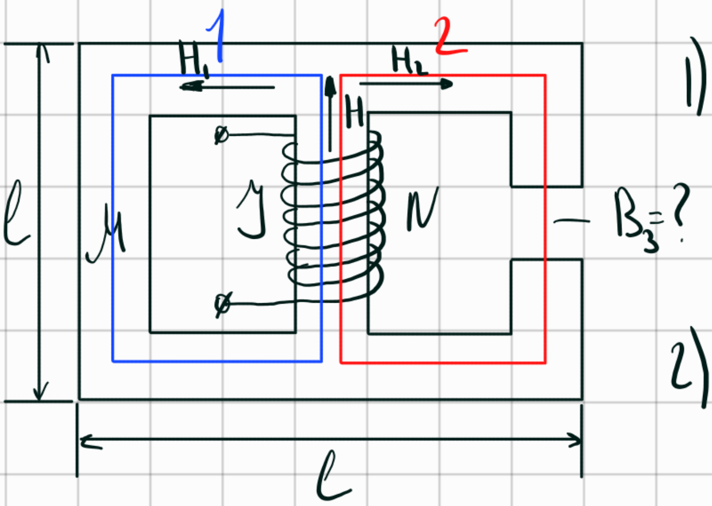
1) $\oint H dl = Bd + Hl = \frac{4\pi}{c} NJ \simeq 2010$ Гс·см

$$B = 20\cdot10^3 - H\cdot10^3$$



$B_{заз} = ?$

№6.12



1) $H = H_1 + H_2$

$B_2 = B_{заз} = H_{заз} = \mu H_2 \Rightarrow H_2 = \frac{B_{заз}}{\mu}$

2) $\oint_2 \vec{H} d\vec{l} = H\cdot l + H_2(2l-d) + B_{заз}\cdot d = \frac{4\pi}{c} IN$

$\oint_1 \vec{H} d\vec{l} = H\cdot l + H_1\cdot 2l = \frac{4\pi}{c} IN$

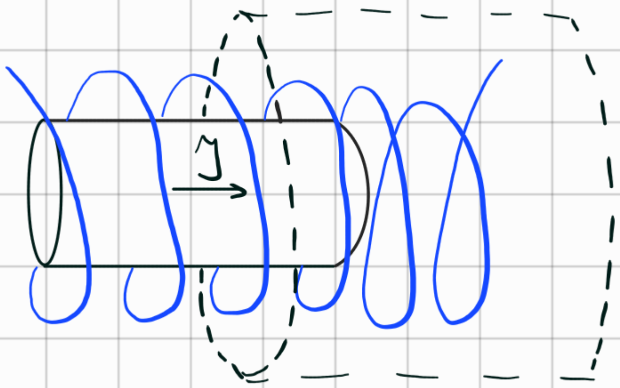
3) $\cancel{Hl} + \frac{B_{заз}}{\mu}(2l-d) + B_{заз} d = \cancel{Hl} + H_1\cdot 2l$

$$H_1 = \frac{B_{заз}}{\mu}\left(1 + \frac{d(\mu-1)}{2l}\right) \Rightarrow H = \frac{B_{заз}}{\mu}\left(2 + \frac{d(\mu-1)}{2l}\right)$$

4) $\frac{B_{заз}}{\mu}\left(2+\frac{d(\mu-1)}{2\ell}\right)\ell+\frac{B_{заз}}{\mu}\left(1+\frac{d(\mu-1)}{2\ell}\right)=\frac{4\pi}{c}IN \Rightarrow$

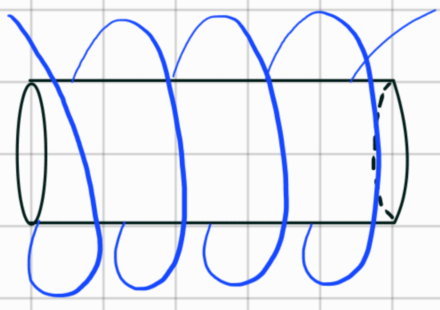
$$\Rightarrow B_{зaз}=\frac{\pi I N \mu}{c\ell\left(1+\frac{3}{8}d(\mu-1)\right)}$$

№6.52.



1) $\oint_S \vec{H}d\vec{S}=\oint_S \vec{H}dS-\oint_S \vec{B}d\vec{S}^{\,=0}=\int_\sigma (H-B)d\sigma=\int_\sigma -4\pi I\,d\sigma=-4\pi I\sigma$

T8



$B(H)=H+4\pi I$

1) $H(J_0)=\frac{1}{2}H_н \Rightarrow H(3J_0)=\frac{3}{2}H_н$

$B(J_0)=B_1$

$B(3J_0)=2{,}1B_1$

2) „$tg\,\xi$" $=\varkappa=\frac{I_н}{H_н}$

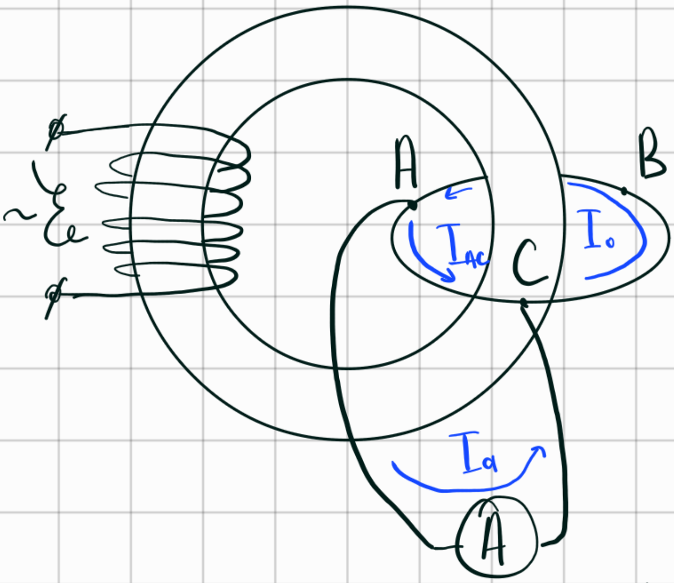
$\mu=1+4\pi\varkappa$

3) $B_1 = \frac{H_H}{2} + 4\pi\frac{\varkappa H_H}{2} = \frac{H_H}{2}\mu$

$$B_2 = \mu\cdot\frac{3}{2}H_H + 4\pi\cdot\varkappa H_H = \frac{H_H}{2}(3+8\pi\varkappa) = \frac{H_H}{2}(2\mu+1)$$

4) $B_2 = \frac{1}{\cancel{2}}\cancel{H_H}(2\mu+1) = 2{,}1\cdot\frac{\cancel{H_H}}{\cancel{2}}\mu \Rightarrow \mu = 10$

№10.1



1) Фарадей: $\mathcal{E}_{кат} = -\frac{1}{c}\cdot\frac{d\Phi}{dt}\cdot n$

$$\mathcal{E}_e = -\frac{1}{c}\frac{d\Phi}{dt} = \frac{\mathcal{E}_{кат}}{n}$$

2) $R_{общ} = \left(\frac{1}{3}R \parallel r\right) + \frac{2}{3}R = \frac{1}{\frac{3}{R}+\frac{1}{r}} + \frac{2}{3}R =$

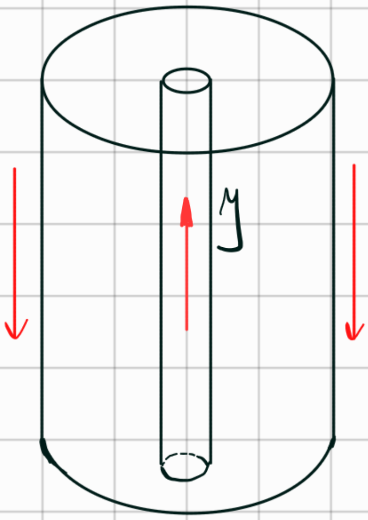
$$= \frac{3Rr}{3(3r+R)} + \frac{2R(3r+R)}{3(3r+R)} = \frac{R(9r+2R)}{3(3r+R)}$$

3) $I = \frac{\mathcal{E}_e}{R_{общ}} = \frac{\mathcal{E}_e}{R}\cdot\frac{3(3r+R)}{9r+2R}$

$$I_a = \frac{I\cdot(R/3 \parallel r)}{r} = \frac{3}{n}\cdot\frac{\mathcal{E}_{кат}}{9r+2R}$$

4) 2 случай: $\mathcal{E}_e \to 2\mathcal{E}_e \Rightarrow I_a' = 2I_a$

№5.28



1) Т. о циркуляции:

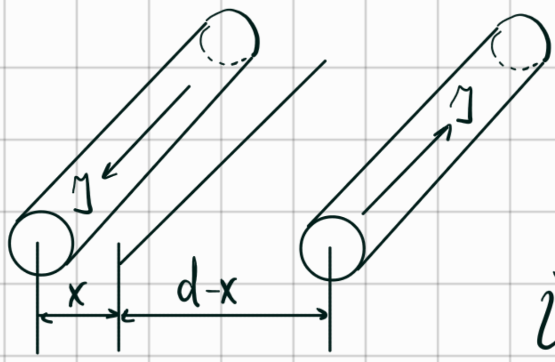
$$B \cdot 2\pi r = \frac{4\pi}{c} \cdot J \Rightarrow B = \frac{2J}{cr}$$

2) $d\Phi = B(r) \cdot l\,dr$

$$\Phi = \int_a^b \frac{2J}{cr} l\,dr = \frac{2Jl}{c} \ln\frac{b}{a} = \frac{I}{c} L \Rightarrow$$

$$\Rightarrow L = 2l \ln\frac{b}{a} \approx 240 \text{ см}$$

№5.29



1) $B(r) = \frac{2J}{cr}$

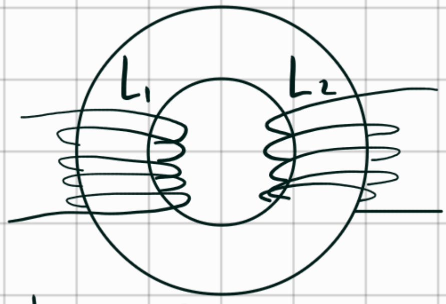
$$d\Phi = B(x) \cdot l\,dx$$

2) $$\Phi = l \int_r^{d-r} \left[\frac{2J}{cr} dr + \frac{2J}{c(d-r)} dr\right] =$$

$$= \frac{2Jl}{c}\left[\ln\frac{d-r}{r} + \ln\frac{d-r}{r}\right] = \frac{4Jl}{c} \ln\frac{d-r}{r}$$

3) $\Phi = \frac{J}{c} L \Rightarrow L_l = \frac{L}{l} = 4 \ln\frac{d-r}{r} \approx 8{,}79 \frac{\text{см}}{\text{см}}$

№5.30



1) Ток только через L_1:

$$\Phi = \frac{\Phi_1}{N_1} = \frac{\Phi_{21}}{N_2}$$

только через L_2:

$$\Phi = \frac{\Phi_2}{N_2} = \frac{\Phi_{12}}{N_1}$$

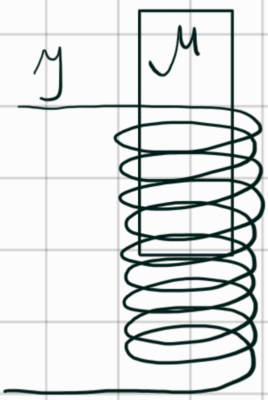
$L_1 = 0{,}5$ Гн
$L_2 = 0{,}7$ Гн
$M = ?$

2) $\Phi_1 = \frac{1}{c} L_1 J$; $\Phi_{21} = \frac{1}{c} M J$ =>

$$\Rightarrow \frac{L_1}{N_1} = \frac{M}{N_2} \Rightarrow M = L_2 \frac{N_1}{N_2} = L_1 \frac{N_2}{N_1} \Rightarrow$$

3) $\Rightarrow \frac{L_2}{L_1} = \frac{N_2^2}{N_1^2} \Rightarrow$ $M = \sqrt{L_1 L_2} = 0{,}59$ Гн

№7.58.

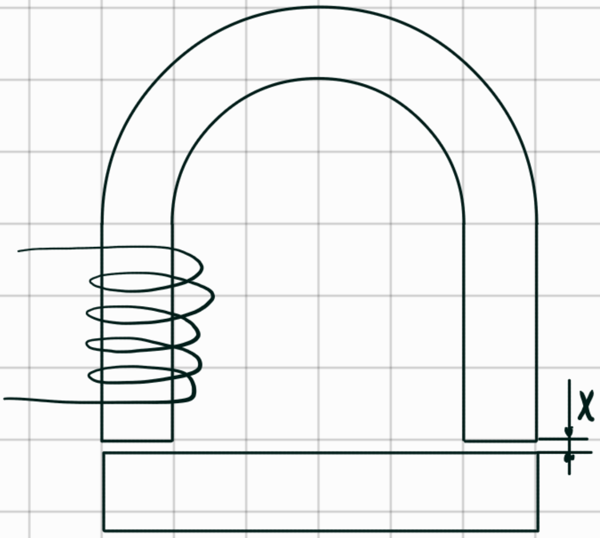


1) $w_{ст} = \frac{B^2}{8\pi\mu}$; $w_в = \frac{B^2}{8\pi}$

$$f = (w_в - w_{ст}) \Rightarrow F = (w_в - w_{ст}) \cdot S$$

2) $F = \frac{B^2 S}{8\pi}\left(1 - \frac{1}{\mu}\right) \overset{\text{общ. вид}}{=\!=} \frac{B^2 S}{8\pi}\left(\frac{1}{\mu_{ср}} - \frac{1}{\mu_{ст}}\right)$

№7.64



$\mu = 200$
$N = 200$
$J = 2A$

$F = ?$

1) $l_0 = (\pi \cdot 7{,}5 + 20 + 15 + 5)\,см \approx 64см$

2) $\oint\limits_{\square} B\,dl = \frac{B}{\mu} l_0 + B \cdot 2x = \frac{4\pi}{c} \cdot JN \Rightarrow$

$\Rightarrow B = \dfrac{\frac{4\pi}{c} NJ}{l/\mu + 2x} \quad \left(x \ll \frac{l}{\mu}\right)$

3) Из прошлой задачи:
(·2, т.к. 3 среды)

$$F = 2 \cdot \frac{B^2 S}{8\pi}\left(1 - \frac{1}{\mu}\right) = \frac{4\pi N^2 J^2 \mu^2 S}{c^2 l^2} \quad (x = 0)$$

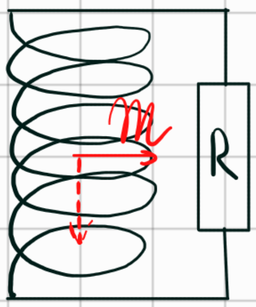
№6.50

1) $L = L_1 + L_2 + 2M, \quad M_0 = \sqrt{L_1 L_2} \approx 0{,}24\ Гн$

$M = \frac{1}{2}(L - L_1 - L_2) = 0{,}20\,Гн$

2) $\alpha = \dfrac{\Phi_{пот}}{\Phi_0} = 1 - \dfrac{M}{M_0} \approx 16\%$

№ 7.88



1) $I = \frac{\mathcal{E}}{R} = -\frac{1}{cR}\frac{d\Phi}{dt} = -\frac{1}{cR}\cdot\frac{dBS}{dt} \approx -\frac{1}{cR}\frac{\Delta BS}{\Delta t}$

2) $\mathfrak{M} = \frac{S}{c} i$

$$\Delta B \approx \frac{4\pi}{c} n i = 4\pi n \frac{\mathfrak{M}}{S}$$

3) $q = I\Delta t = -\frac{1}{cR}\Delta BS = -\frac{1}{cR}\cdot 4\pi n\cdot\mathfrak{M} = \frac{4\pi n\mathfrak{M}}{cR}$