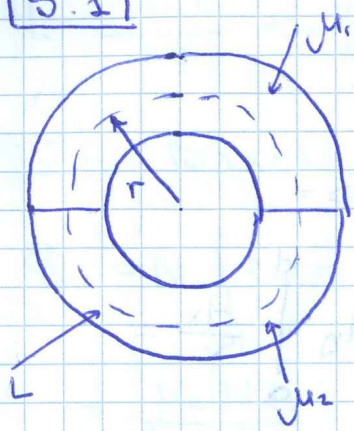
3.1



$$H_1 = \frac{B(r)}{\mu_0 \mu_1}$$

$$H_2 = \frac{B(r)}{\mu_0 \mu_2}$$

$$\oint H dl = H_1 \pi r + H_2 \pi r = NI =$$

$$= \frac{B(r)}{\mu_0} \pi r \left(\frac{1}{\mu_1} + \frac{1}{\mu_2}\right) = \frac{B(r)}{\mu_0} \frac{\mu_1 + \mu_2}{\mu_1 \mu_2} \pi r$$

$$B(r) = \frac{\mu_0 \mu_1 \mu_2 NI}{B(r) \pi r (\mu_1 + \mu_2)}$$

$$\Phi = N \int_{S_i} B dS = \frac{\mu_0 \mu_1 \mu_2 N^2 I}{\pi(\mu_1 + \mu_2)} \int_S \frac{dS}{r} =$$

$$= \frac{\mu_0 \mu_1 \mu_2 N^2 I}{\pi(\mu_1 + \mu_2)} \int_0^h dz \int_{R_1}^{R_2} \frac{dr}{r} = \frac{\mu_0 \mu_1 \mu_2 N^2 I}{\pi(\mu_1 + \mu_2)} h \ln \frac{R_1}{R_2}$$

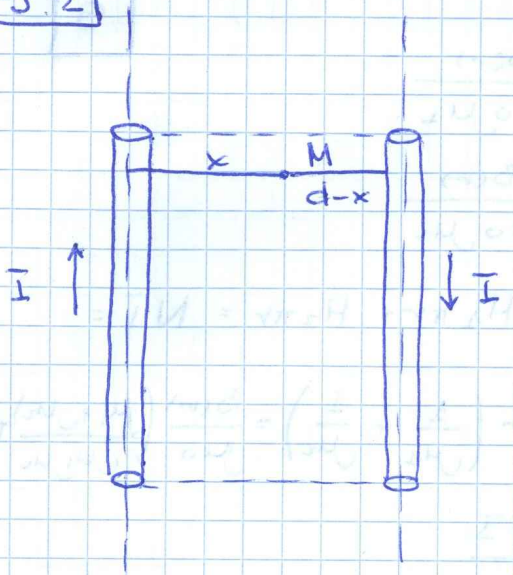
$$\Phi = LI \Rightarrow L = \frac{\mu_0 \mu_1 \mu_2 N^2 h}{\pi(\mu_1 + \mu_2)} \ln \frac{R_2}{R_1} =$$

$$= \frac{4\pi \cdot 10^{-7} \text{ Н/А}^2 \cdot 400 \cdot 100 \cdot 400^2}{\pi(400 + 100)} 6 \cdot 10^{-2} \text{м} \ln \frac{10,8}{4} =$$

$$= 0,3 \text{ Гн}$$

Решение не согласуется с действительностью :C

9.2



$$B_1 = \frac{\mu_0 I}{2\pi x}$$

$$\Phi_1 = \int_S B_1 \, dS =$$

$$= \frac{\mu_0 I}{2\pi} \int_0^{\ell} d\ell \int_a^d \frac{dx}{x} =$$

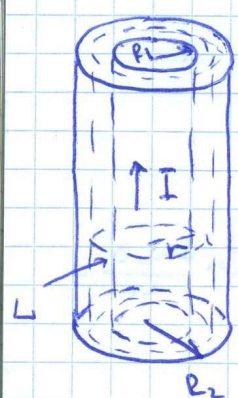
$$= \frac{\mu_0 I \ell}{2\pi} \ln \frac{d}{a} = \Phi_2$$

$$\Phi = \Phi_1 + \Phi_2 = \frac{\mu_0 I \ell}{\pi} \ln \frac{d}{a}$$

$$\Phi = IL \Rightarrow L = \frac{\mu_0 \ell}{\pi} \ln \frac{d}{a} =$$

$$= \frac{4\pi \cdot 10^{-7} \, Н/А^2 \cdot 1 м}{\pi} \ln \frac{100}{0.5} = 1{,}2 \cdot 10^{-6} \, Гн$$

9.3



$$\oint_L H \, dl = 2\pi r \frac{B}{\mu\mu_0} = I \qquad \mu = 1$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\Phi = \int_S B \, dS = \frac{\mu_0 I}{2\pi} \int_0^{\ell} dz \int_{R_1}^{R_2} \frac{dr}{r} =$$

$$= \frac{\mu_0 I}{2\pi} \ell \cdot \ln \frac{R_2}{R_1} \Rightarrow L = \frac{\mu_0 \ell}{2\pi} \ln \frac{R_2}{R_1}$$

$$L = \frac{\mu_0 \ell}{2\pi} \ln\frac{R_2}{R_1} = \frac{4\pi \cdot 10^{-7}\ \text{Н/А}^2 \cdot 1\text{м}}{2\pi} \ln\frac{100}{0.5} = 0{,}6\ \text{мкГн}$$

9.5 $B_1(r) = \dfrac{\mu_0 I_1}{2\pi r}$ (провод)

$$\Phi_2 = N\int_{S_i} B_1(r)\,dS = N\cdot\frac{\mu_0 I_1}{2\pi}\int_0^h dz\int_{R_1}^{R_2}\frac{dr}{r} =$$

$$= \frac{\mu_0 N I_1}{2\pi} h \ln\frac{R_2}{R_1}$$

$$L_{12} = \frac{\Phi_2}{I_1} = \frac{\mu_0 N h}{2\pi}\ln\frac{R_2}{R_1} = \frac{4\pi\cdot 10^{-7}\ \text{Н/А}^2 \cdot 500 \cdot 6\cdot 10^{-2}\text{м}}{2\pi}\ln\frac{10{,}8}{4}$$

$$= 6\ \text{мГн}$$

9.6

$$\oint_L H e l\,\ell = \frac{B_1}{\mu\mu_0} e = n\cdot\ell\cdot I_1$$

$$\Rightarrow B_1 = \mu\mu_0 n I_1 \quad \text{(внут. катушка)}$$

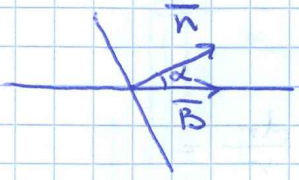
$$\Phi_2 = N\int_{S_i} B_1\,dS = \{\text{поток через (2)} = \text{поток через (1)}\} =$$

$$= N\,\mu\mu_0 n I_1 S$$

$$L_{12} = \frac{\Phi_2}{I_1} = \mu\mu_0 n N S = 4\pi\cdot 10^{-7}\ \text{Н/А}^2 \cdot 10^3\,\frac{1}{\text{м}}\,20\cdot 10\cdot 10^{-4}\,\text{м}^2 =$$

$$= 25\ \text{мкГн}.$$

9.8 $B_1 = \mu\mu_0 n I_1$ (для соленоида)

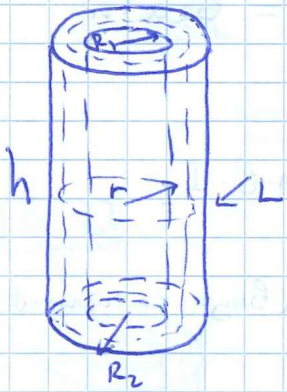


$$\Phi_2 = N \int_{S_1} B_1 \, dS =$$

$$= N \cdot \mu\mu_0 n I_1 \cdot S \cdot \cos\alpha \quad (\mu = 1)$$

$$L_{12} = \frac{\Phi_2}{I_1} = \mu\mu_0 n N S \cos\alpha \quad (\mu = 1)$$

9.10



$$\oint_L H \, dl = H \cdot 2\pi r = I \Rightarrow H = \frac{I}{2\pi r}$$

$r \in [R_1, R_2]$

$$B = \mu\mu_0 H = \frac{\mu\mu_0 I}{2\pi r}$$

$$w_M = \frac{1}{2} BH = \frac{1}{2} \cdot \frac{\mu\mu_0 I^2}{4\pi^2 r^2}$$

$$W = \int_V w_M \, dV = \int_0^h dz \int_0^{2\pi} d\varphi \int_{R_1}^{R_2} r \, dr \left[\frac{1}{2} \frac{\mu\mu_0 I^2}{4\pi^2 r^2} \right] =$$

$$= h \cdot 2\pi \cdot \frac{1}{2} \mu\mu_0 I^2 \frac{1}{4\pi^2} \ln \frac{R_2}{R_1} =$$

$$= \frac{\mu\mu_0 I^2 h}{4\pi} \ln \frac{R_2}{R_1} = \int \Leftarrow 0{,}62 \text{ Дж}$$

$$= \frac{1000 \cdot 4\pi \cdot 10^{-7} \text{ Н/А}^2 \cdot 100^2 \text{ А}^2 \cdot 0{,}2 \text{ м}}{4\pi} \ln \frac{60}{3} \Leftarrow$$

5.11

$$\oint H dl = H \cdot 2\pi r = NI \Rightarrow H = \frac{NI}{2\pi r}$$

$$B = \mu\mu_0 H = \frac{\mu\mu_0 NI}{2\pi r}$$

$$w_M = \frac{1}{2} BH = \frac{1}{2} \frac{\mu\mu_0 N^2 I^2}{4\pi^2 r^2}$$

$$W = \int_V w_M dV = \int_0^h dz \int_0^{2\pi} d\varphi \int_{R_1}^{R_2} r dr \cdot \frac{1}{2} \frac{\mu\mu_0 N^2 I^2}{4\pi^2 r^2} =$$

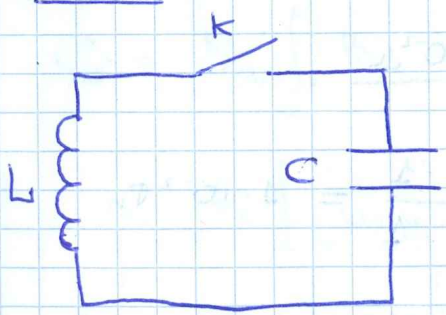
$$= h \cdot 2\pi \cdot \frac{1}{2} \frac{\mu\mu_0 N^2 I^2}{4\pi^2} \ln \frac{R_2}{R_1} =$$

$$= \frac{\mu\mu_0 N^2 I^2 h}{4\pi} \ln \frac{R_2}{R_1} =$$

$$= \frac{500 \cdot 4\pi \cdot 10^{-7} \frac{Н}{А^2} \cdot 100^2 \cdot 10^2 А^2 \cdot 3 \cdot 10^{-2} м}{4\pi} \cdot \ln \frac{5{,}4}{2} =$$

$$= 0{,}15 Дж$$

5.13



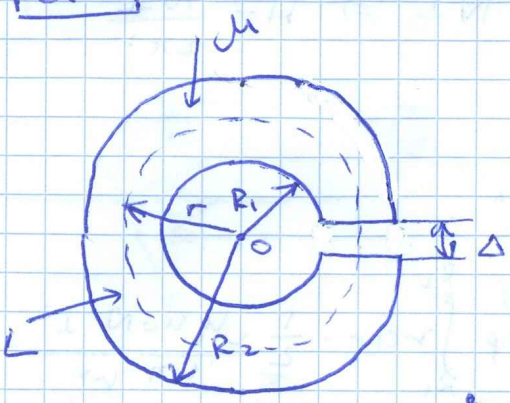
Вся энергия конденсатора должна перейти в энергию катушки.

$$\frac{CU_0^2}{2} = \frac{LI_{max}^2}{2}$$

$$I_{max} = U_0 \sqrt{\frac{C}{L}} =$$

$$= 12 В \cdot \sqrt{\frac{1 \cdot 10^{-6} Ф}{10 \cdot 10^{-3} Гн}} = 0.12 А$$

9.7



$$\oint_L H\,dl = H_1(2\pi r - \Delta) + H_2\Delta =$$

$$= \frac{B(r)}{\mu\mu_0}(2\pi r - \Delta) + \frac{B(r)}{\mu_0}\Delta =$$

$$= NI$$

$$B(r) = \frac{\mu\mu_0 NI}{2\pi r - \Delta + \mu\Delta}$$

$$\Phi = N\int_{S_i} B(r)\,dS = N\cdot\mu\mu_0 NI\cdot\int_0^h dz\cdot\int_{R_1}^{R_2}\frac{dr}{2\pi r - \Delta + \mu\Delta} =$$

$$= \frac{\mu\mu_0 N^2 I h}{2\pi}\ln\frac{2\pi R_2 + (\mu-1)\Delta}{2\pi R_1 + (\mu-1)\Delta}$$

$$\Phi = LI \Rightarrow L = \frac{\mu\mu_0 N^2 h}{2\pi}\ln\frac{2\pi R_2 + (\mu-1)\Delta}{2\pi R_2 + (\mu-1)\Delta} =$$

$$= \frac{200\cdot 4\pi\cdot 10^{-7}\ H/A^2\cdot 200^2\cdot 3\cdot 10^{-2}\ m}{2\pi}\cdot$$

$$\cdot\ln\frac{2\pi\cdot 54 + (200-1)\cdot 1}{2\pi\cdot 20 + (200-1)\cdot 1} = 1\cdot 10^{-2}\ H_n.$$

3.4

$$\begin{cases} \Phi = LI = \Phi_1 + \Phi_2 \\ \Phi_1 = L_1 I \\ \Phi_2 = L_2 I \end{cases} \Rightarrow L = L_1 + L_2.$$

Пусть L_0 – индуктивность одного витка.

$$\begin{cases} L_1 = N_1 L_0 \\ L_2 = N_2 L_0 \\ L = N L_0 = (N_1 + N_2) L_0 \end{cases} \Rightarrow N = N_1 \left(1 + \frac{L_2}{L_1}\right)$$

3.1 (видимо, правильное решение)

$$\oint H_1 dl = H_1 \cdot \pi r = \frac{N}{2} I \Rightarrow B_1 = \mu_1 \mu_0 \frac{NI}{2\pi r}$$

аналогично для $B_2 = \mu_2 \mu_0 \frac{NI}{2\pi r}$

$$\Phi = N/2 \int_{S_1} B_1 dS + N/2 \int_{S_1} B_2 dS =$$

$$= N/2 \left[\mu_1 \mu_0 \frac{NI}{2\pi} \int_0^h dz \int_{R_1}^{R_2} \frac{dr}{r} + \mu_2 \mu_0 \frac{NI}{2\pi} \int_0^h dz \int_{R_1}^{R_2} \frac{dr}{r} \right] =$$

$$= \frac{\mu_0 (\mu_1 + \mu_2) N^2 I}{4\pi} h \ln \frac{R_2}{R_1}$$

$$\Phi = LI \Rightarrow L = \frac{\mu_0 (\mu_1 + \mu_2) N^2 h}{4\pi} \ln \frac{R_2}{R_1} = 0{,}47 \text{ Гн}$$

3.12 1) $B_2 = \mu_0 n I \qquad H_2 = nI$

$$\Phi_2 = \int_S B_2 dS = n\ell \int_{S_1} B_2 dS = \mu_0 n^2 I \ell S_2$$

$$W_2 = \frac{\Phi_2 I}{2} = \frac{\mu_0 n^2 I^2 \ell}{2} S_2$$

2) $B_1 = \frac{\mu_0 I}{2\pi r} \qquad H_1 = \frac{I}{2\pi r}$

$$w_m = \frac{1}{2} B_1 H_1 = \frac{1}{2} \frac{\mu_0 I^2}{4\pi^2 r^2}$$

$$W_1 = \int_{V_0} w_m dV = \int_0^\ell dz \int_0^{2\pi} d\varphi \int_{R_1}^{R_2} \frac{r\,dr}{r^2} \frac{1}{2} \frac{\mu_0 I^2}{4\pi^2} =$$

$$= \frac{\mu_0 I^2}{4\pi^2} \cdot \frac{1}{2} 2\pi \ell \ln \frac{R_2}{R_1} =$$

$$= \frac{1}{2} \frac{\mu_0 I^2}{4\pi} \ell \ln \frac{S_2}{S_1}$$

3) $$\frac{W_2}{W_1} = \frac{4\pi S_2 n^2}{\ln S_2/S_1} \approx 2700$$

3.15 2) $B = \mu_0 n I \qquad \Phi = N \int_{S_1} B dS = \mu_0 n N I S$

$$IL = \Phi \Rightarrow L = \mu_0 n N S = \mu_0 \frac{N^2}{\ell} S$$

$$L_1 = L_0 = \mu_0 \frac{N^2}{\ell_0} S_0 \Rightarrow L_2 = \mu_0 \frac{N^2}{\ell_0} \beta \frac{S_0}{\beta^2} = \frac{L_0}{\beta}$$

2) $B_1 = \mu_0 n I_1 \qquad n = \frac{N}{\ell_0}$

$$\Phi_2 = N \int_{S_i} B_1 \, dS = N \mu_0 n I_1 S_2 = N \mu_0 n I_1 \frac{S_0}{\beta^2}$$

$$L_{12} = \frac{\Phi_2}{I_1} = \mu_0 n N \frac{S_0}{\beta^2} = \mu_0 \frac{N^2}{\ell_0} \frac{S_0}{\beta^2} = \frac{L_0}{\beta^2}$$

3) $$W = \frac{1}{2} L I^2 = \frac{1}{2} L_1 I^2 + L_{12} I^2 + \frac{1}{2} L_2 I^2$$

$$L = L_1 + 2L_{12} + L_2 =$$

$$= L_0 \left[1 + \frac{1}{\beta} + \frac{2}{\beta^2} \right]$$

9.14 Вдвинем соленоид (2) в соленоид (1) на Δx.

Тогда поток изменится на $\Delta\Phi$:

$$\begin{cases} \Delta\Phi = (B_2 - B_1) \cdot S \cdot \underbrace{n_1 \Delta x}_{\Delta N} \\ B_2 = \mu_0 n_1 I_1 + \mu_0 n_2 I_2 \quad - \text{внутри (2) и (1)} \\ B_1 = \mu_0 n_2 I_1 \quad - \text{внутри (2) вдали от (1)} \end{cases}$$

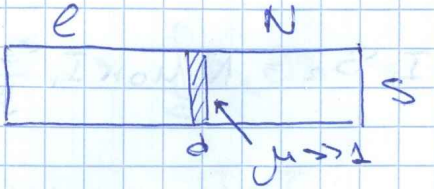
$$\Rightarrow \Delta\Phi = \mu_0 n_2 I_2 \cdot S \cdot n_1 \Delta x$$

$$F = \frac{\Delta A}{\Delta x} = \frac{\Delta\Phi I_1}{\Delta x} = \mu_0 n_1 n_2 I_1 I_2 S = \mu_0 n_1 n_2 I_1 I_2 \pi r^2 =$$

$$= 4\pi \cdot 10^{-7} \, \text{Н/А}^2 \cdot 10^3 \, \frac{1}{\text{м}} \cdot 10^3 \, \frac{1}{\text{м}} \cdot 2\,\text{А} \cdot 5\,\text{А} \cdot \pi \cdot 1^2 \cdot 10^{-4} \, \text{м}^2 =$$

$$= 40 \, \text{Н}$$

9.9



$n = \frac{N}{l}$ $\quad d \ll l$

$$\begin{cases} B_1 = \mu_0 n J \\ B_2 = \mu \mu_0 n J \end{cases} \Rightarrow \begin{cases} \Phi_1 = \mu_0 n J \cdot S \frac{l-d}{l} N \\ \Phi_2 = \mu \mu_0 n J \cdot S \cdot \frac{d}{l} N \end{cases}$$

$$L = \frac{\Phi_1 + \Phi_2}{J} = \frac{\mu_0 n \cancel{J} S N}{\cancel{J} l} (l - d + \mu d) =$$

$$= \mu_0 S \cdot \frac{N^2}{l^2} (l - d + \mu d) \approx$$

$$\approx \frac{\mu_0 S N^2}{l}$$