Electricity, Magnetism, Light

Series 30- Inductance

Solutions to Homework #10

Prob. #3

The magnetic field inside the outer solenoid is

$$B = \mu_0 n_1 I_1$$

The magnetic flux linked with the inner solenoid is

$$\Phi_{21} = \mu_0 n_1 I_1 A_2$$

The mutual inductance with the N_2 turns of the inner solenoid is

$$M_{21} = \frac{N_2 \Phi_{21}}{I_1} = n_2 \ell \mu_0 n_1 A_2$$

Per unit length it's $M_{21}/\ell = \mu_0 n_1 n_2 \pi r_2^2$

Prob #5

$$\Phi_B = \int \vec{B} \cdot d\vec{s} = \int_{\ell_1}^{\ell_2} \frac{\mu_0 I}{2\pi r} w\, dr = \frac{\mu_0 I w}{2\pi} \ln\left(\frac{\ell_2}{\ell_1}\right)$$

The mutual inductance is

$$M = \frac{\Phi_B}{I} = \frac{\mu_0 w}{2\pi} \ln\left(\frac{\ell_2}{\ell_1}\right)$$

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Prob # 16

$$\oint \bar{B} \cdot d\bar{\ell} = \mu_0 I_{enc}$$

$$B \cdot 2\pi r = \mu_0 N I \quad \text{gives} \quad B = \frac{\mu_0 N I}{2\pi r}$$

$$\Phi_B = \int \bar{B} \cdot d\bar{s} = \int_{r_1}^{r_2} \frac{\mu_0 N I h}{2\pi r} dr = \frac{\mu_0 N I h}{2\pi} \ln\left(\frac{r_2}{r_1}\right)$$

The flux through the entire toroidal winding is N times this, so the self-inductance is

$$L = \frac{N\Phi_B}{I} = \frac{\mu_0 N^2 h}{2\pi} \ln\left(\frac{r_2}{r_1}\right)$$

Prob # 23

The magnetic field is $B = \frac{\mu_0 I}{2\pi r}$

The electron density of the field is

$$u = \frac{1}{2} \frac{B^2}{\mu_0} = \frac{\mu_0 I^2}{8\pi^2 r^2}$$

$$\frac{U}{\ell} = \int \frac{u}{\ell} dV = \int_{r_1}^{r_2} \frac{\mu_0 I^2}{8\pi^2 r^2 \ell} 2\pi r \ell dr = \frac{\mu_0 I^2}{4\pi} \ln\left(\frac{r_2}{r_1}\right)$$