

Problem 3.1

$$a) \quad L = \frac{N^2}{R} \quad R = \frac{2g_0}{\mu_0 A} + R_c \rightarrow 0$$

$$\therefore L_1 = \frac{N_1^2 \mu_0 A}{2g_0} \quad L_2 = \frac{N_2^2 \mu_0 A}{2g_0}$$

$$b) \quad M^2 = L_1 L_2 \Rightarrow M = \frac{N_1 N_2 \mu_0 A}{2g_0}$$

$$\begin{aligned} c) \quad W_m' &= \frac{1}{2} L_1 i_1^2 + \frac{1}{2} L_2 i_2^2 + M i_1 i_2 \\ &= \frac{1}{2} \frac{N_1^2 \mu_0 A}{2g_0} i_1^2 + \frac{1}{2} \frac{N_2^2 \mu_0 A}{2g_0} i_2^2 + \frac{N_1 N_2 \mu_0 A}{2g_0} i_1 i_2 \\ &= \frac{\mu_0 A}{4g_0} (N_1^2 i_1^2 + N_2^2 i_2^2 + 2N_1 N_2 i_1 i_2) \\ &= \frac{\mu_0 A}{4g_0} (N_1 i_1 + N_2 i_2)^2 \end{aligned}$$

$$d) \quad F = \left. \frac{\partial W_m'}{\partial x} \right|_{i \text{ const}} = - \frac{\mu_0 A}{4g_0^2} (N_1 i_1 + N_2 i_2)^2$$

Problem 3.2

$$a) \quad a \rightarrow d \rightarrow c \rightarrow b$$

$$b) \quad m=4 \quad N_r=6 \quad S=mN_r=24$$

$$f_s = \frac{1}{0.1 \text{ ms}} = 10^4 \text{ step/s} \quad n = 60 \frac{f_s}{S} = 60 \frac{10^4}{24} = 25000 \text{ rpm.}$$

$$c) \quad a \rightarrow ab \rightarrow b \rightarrow bc \rightarrow c \rightarrow cd \rightarrow d \rightarrow ad$$

$$S' = 48$$

$$n' = 12500 \text{ rpm.}$$

problem 3.3.

a) $A \rightarrow B \rightarrow C \rightarrow D$

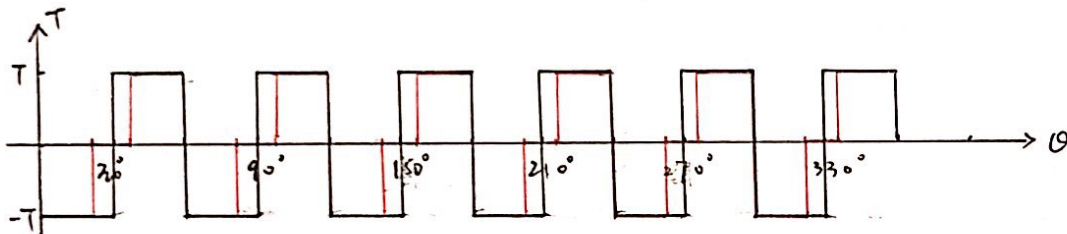
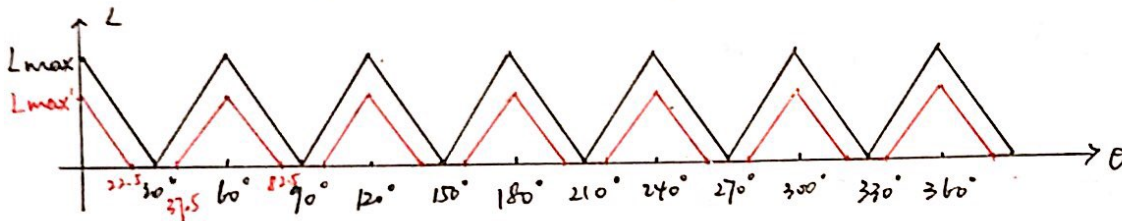
b) $f = 2/\text{ms} = 2000 \text{ Hz}$. $S = m N_r = 4 \times 6 = 24 \text{ steps/rev.}$

$$n = \frac{f}{S} 60 = \frac{2000}{24} 60 = 5000 \text{ rpm.}$$

c) $R = \frac{L}{\mu A} = \frac{2g}{\mu_0 r d \theta}$

$$L_{\text{max}} = \frac{N^2}{R} = \frac{N^2 \mu_0 r d \theta}{2g} = \frac{100^2 \times 4\pi \times 10^{-7} \times 0.06 \times 0.1 \times \frac{\pi}{6}}{2 \times 10^{-3}} = 19.7 \text{ mH}$$

$$T = \frac{1}{2} I^2 \frac{L_{\text{max}}}{\theta} = \frac{1}{2} \times 1^2 \times \frac{19.7 \times 10^{-3}}{\pi/6} = 0.0188 \text{ Nm}$$



d) $L_{\text{max}}' = \frac{N^2 \mu_0 r d \theta'}{2g} = 14.8 \text{ mH}$

$$T = \frac{1}{2} I^2 \frac{L_{\text{max}}'}{\theta'} = 0.188 \text{ Nm}$$

plot see red lines.