ELEC 343, Assignment 4, Stepper Motors:
Do Study Problem: SP9.2-2, SP9.3-1, SP9.3-2, SP9.4-2, and SP9.6-1
Textbook Chapter 9 Problem(s): 1, 2, 5, and 8.

SP9.2-2. (a) From (8.2-1), $TP = \frac{2\pi}{RT} = \frac{2\pi}{2} = \pi = 180^\circ$

(b) From (8.2-3), $SL = \frac{2\pi}{RT\,N} = \frac{2\pi}{(2)(2)} = \frac{\pi}{2} = 90^\circ$

(c) The rotor could rotate in either direction.

SP9.3-1. From (8.3-27) with T_e and $i_{cs} = 0$,

$$\sin(\frac{2\pi}{TP}\theta_{rm}) + \sin[\frac{2\pi}{TP}(\theta_{rm} \pm \frac{TP}{3})] = 0$$

Therefore, $\theta_{rm} = -\theta_{rm} \mp \frac{TP}{S}$

from which $\theta_{rm} = \pm\frac{TP}{(2)(3)} = \pm\frac{TP}{6}$

SP9.4-2.

$T_L = 0$ therefore from (8.3-2) with $i_{as} = I$, $i_{cs} = 0$ and $\theta_{rm} = -\frac{SL}{3}$,

$$0 = I^2 \sin[RT(-\frac{SL}{3})] + i_{bs}^2 \sin[RT(-\frac{SL}{3} + SL)]$$

$$I^2 \sin[(RT)(\frac{SL}{3})] = i_{bs}^2 \sin[(RT)(\frac{2}{3})(SL)]$$

$$i_{bs}^2 = I^2 \frac{\sin[\frac{(RT)(SL)}{3}]}{\sin[\frac{2(RT)(SL)}{3}]} = I^2 \frac{\sin[\frac{(4)(30^\circ)}{3}]}{\sin[\frac{2(4)(30^\circ)}{3}]} = I^2\,\frac{\sin 40^\circ}{\sin 80^\circ}$$

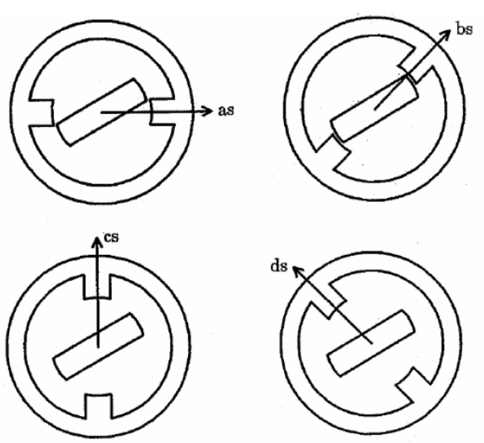
$i_{bs} = 0.81\ I$

SP9.6-1. The step length from (9.6-2) is

$$SL = \frac{\pi}{RT\,N} = \frac{180}{(5)(2)} = 18^\circ$$

Initially $\theta_{rm} = 0$. With $i_{as} = 0$ and $i_{bs} = I$, the rotor advances a step length thus, $\theta_{rm} = 18^\circ$. With $i_{as} = -I$ and $i_{bs} = I$ the rotor advances one half a step length, thus $\theta_{rm} = 18 + 9 = 27^\circ$.

1.



From (9.2-1), $TP = \frac{2\pi}{RT} = \frac{2\pi}{2} = \pi$

From (9.2-3), $SL = \frac{TP}{N} = \frac{\pi}{5} = 36^\circ$

The excitation sequence for ccw rotation is as, bs, cs, ds, as,... .

2. $L_{asas} = L_{ls} + L_A + L_B \cos(RT\,\theta_{rm})$

$L_{bsbs} = L_{ls} + L_A + L_B \cos[RT\,(\theta_{rm} - SL)]$

$L_{cscs} = L_{ls} + L_A + L_B \cos[RT\,(\theta_{rm} - 2\,SL)]$

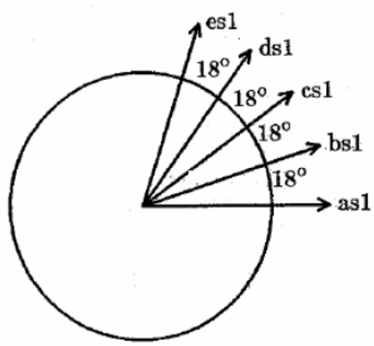
$L_{dsds} = L_{ls} + L_A + L_B \cos[RT\,(\theta_{rm} - 3\,SL)]$

$$W_c = \frac{1}{2} L_{asas}\, i_{as}^2 + \frac{1}{2} L_{bsbs}\, i_{bs}^2 + \frac{1}{2} L_{cscs}\, i_{cs}^2 + \frac{1}{2} L_{dsds}\, i_{ds}^2$$

$$T_e = \frac{\partial W_c}{\partial \theta_{rm}} = -\frac{RT}{2} L_B \Big\{ i_{as}^2 \sin(RT\,\theta_{rm}) + i_{bs}^2 \sin[RT\,(\theta_{rm} - SL)] + i_{cs}^2 \sin[RT\,(\theta_{rm} - 2\,SL)] + i_{ds}^2 \sin[RT\,(\theta_{rm} - 3\,SL)] \Big\}$$

5. $P = 4$, $N = 5$, and $RT = 8$

$$SL = \frac{2\pi}{RT\,N} = \frac{2\pi}{(8)(5)} = 0.05\,\pi = 9°$$



With the axes as shown,
an as, bs, cs, ds, es, as, bs excitation
sequence produces cw rotation.

The self-inductances are

$L_{asas} = L_{ls} + L_A + L_B \cos 8\theta_{rm}$

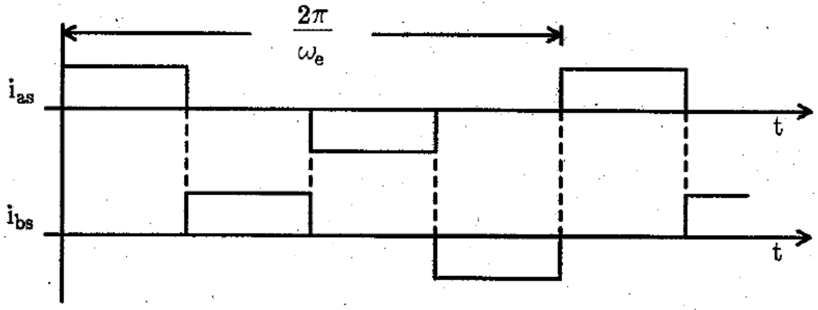
$L_{bsbs} = L_{ls} + L_A + L_B \cos 8(\theta_{rm} + SL)$

$L_{cscs} = L_{ls} + L_A + L_B \cos 8(\theta_{rm} + 2\,SL)$

$L_{dsds} = L_{ls} + L_A + L_B \cos 8(\theta_{rm} + 3\,SL)$

$L_{eses} = L_{ls} + L_A + L_B \cos 8(\theta_{rm} + 4\,SL)$

8.



$$\frac{2\pi}{\omega_e} = 4T_s\text{, thus } \omega_e = \frac{2\pi}{4T_s} = \frac{\pi}{2} f_s.$$

Thus, $f_s = \frac{2}{\pi}\,\omega_e \qquad \omega_{rm} = SL\,f_s = \frac{\pi}{RT\,N} f_s$

For $N = 2$, $\omega_{rm} = \frac{\pi}{RT\,2}\,\frac{2}{\pi}\,\omega_e = \frac{\omega_e}{RT}$