Department of Electrical Engineering
Indian Institute of Technology Bombay, Powai
EE111 : Introduction to Electrical Engineering
Solution to Assignment 5

1. $B = \phi/A = 0.0012/12.5 \times 10^{-4} = 0.96\text{Wb/m}^2$
   Corresponding $H = 140\text{AT/m}$; $l = 30$ cm
   Total ampere turns $= 140 \times 3 \times 10^{-1} = 42$ AT
   $F_1 + F_2 - F_3 = 42$, $F_1 = 100$, $F_2 = 300$, $F_3 = 358$

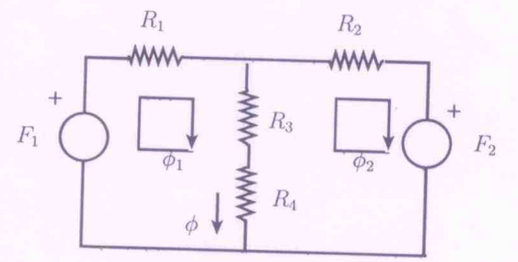

Figure 1: Solution 2

2. Reluctance of 40 cm core $= \frac{40\times10^{-2}}{4\pi\times10^{-7}\times4500\times30\times10^{-4}}$
   $R_1 = R_2 = 23.58 \times 10^3$
   Reluctance of the air gap $= \frac{1\times10^{-3}}{4\pi\times10^{-7}\times30\times10^{-4}}$
   $R_4 = 2.65 \times 10^5$
   Reluctance of the central limb $= \frac{(15-0.1)\times10^{-3}}{4\pi\times10^{-2}\times4500\times30\times10^{-4}}$
   $R_3 = 8.78 \times 10^3$
   MMF drop in the central limb $= \phi(2.65 \times 10^5 + 8.78 \times 10^3) = 1095.12$

From equivalent circuit,

$F_1 - \phi_1 R_1 - (\phi_1 - \phi_2)(R_3 + R_4) = 0$

$\phi_1(R_1 + R_3 + R_4) - \phi_2(R_3 + R_4) = F_1$

$-\phi_1(R_3 + R_4) + \phi_2(R_3 + R_4 + R_2) = -F_2$

$\phi_1 = 28.98$ mWb and $\phi_2 = 25$ mWb

$F_1 = \phi_1 R_1 + \phi(R_3 + R_4) = 1778$ AT

3. Reluctance of the airgap $= R_g = \frac{1\times10^{-3}}{4\pi\times10^{-7}\times2\times2.5\times10^{-4}} = 15.9 \times 10^5$

   AT required to create a flux of 0.25 mWb = 398 AT

   Length of the right limb $= L_{AB} = 2 \times 12 + 20 - 0.1 = 43.9$ cm

   Flux density in the right limb $= \frac{0.25\times10^{-3}}{2\times2.5\times10^{-4}} = 0.5\text{Wb/m}^2$

   Corresponding H from B-H curve = 220 AT/m

   AT required $F_{AB} = 220 \times 0.439 = 96$

   AT required for the right limb = 96 + 398 = 494 AT

   AT required to create a flux of 0.25 mWb in the airgap + in F_{AB} = AT in left limb

   Length of the left limb = 494/0.44 = 1125 AT/m

   Corresponding B = 1.38 Wb/m^2 (from B-H curve)

   ϕ in the left limb $= 1.38 \times 2 \times 2.5 \times 10^{-4} = 0.69$ mWb

   ϕ in the central limb $= 0.69 + 0.25 = 0.94$ mWb

   B in the central limb $= \frac{0.94}{4\times2.5\times10^{-4}} = 0.94$ T

   Required H = 450 AT/m

   AT required for the central limb $= 450 \times 20 \times 10^{-2} = 90$

   Total AT = 90 + 494 = 584 AT

   Coil current = 0.584 A

4. Mean length of the core ABCD = 2[20 - 2.5 + (20 - 5)] = 0.5 m

   Flux density in ABCD $= \frac{0.0014}{0.04\times0.05} = 0.7\text{Wb/m}^2$

   Corresponding H = 90 AT/m

   AT required for ABCD $= 90 \times 0.5 = 45$ AT

   AT for center leg = 45

   Mean core length of the center limb = 0.15 m

   $H = \frac{45}{0.15} = 300AT/m$, $B = 1.2\text{Wb/m}^2$

   $\phi = 1.2 \times 0.02 \times 0.04 = 9.6 \times 10^{-4}$ Wb

Total flux $= 9.6 \times 10^{-4} + 0.0014 = 2.36 \times 10^{-3}$ Wb

Corresponding $B = \frac{2.36\times10^{-3}}{0.05\times0.04} = 1.18 \text{Wb/m}^2$

H= 280 AT/m; Mean length of the core = 0.5m

AT $= 280 \times 0.5 + 45 = 190$

5. If the core is wound on the center leg, total flux in this leg is the sum of the flux in the right and the left leg.
   $\phi_c = 2 \times 0.0014 = 0.0028$ Wb (Since reluctance of both legs is the same)
   $B = \frac{0.0028}{0.02\times0.04} = 3.5 \text{Wb/m}^2$
   B is very high and therefore core of the center leg is highly saturated.
   The core losses are therefore very high.
   Also, from B-H curve, H will be found to be very high and so I^2R loss in the coil is high.
   So, it is not possible to estabish a flux of 0.0014 Wb in the right leg with this arrangement.

6. Hysteresis loss = Volume × Area of the loop × F
   1 cm $= 12$ AT/in $= \frac{12\times100}{2.54}$ AT/m $= 472.4$ AT/m
   1 cm $= 5 \times 10^3 \text{line/in}^2 = \frac{5\times10^3\times10^4}{1\times10^8\times(2.54)^2} = 0.0775 \text{Wb/m}^2$
   Volume $= 116.4 \times 10^{-6} \text{m}^3$
   Area $= 64.5 \times 472.4 \times 0.0775 = 2361.4$
   Loss $= 2361.4 \times 116.4 \times 10^{-6} \times 400 = 109$ W