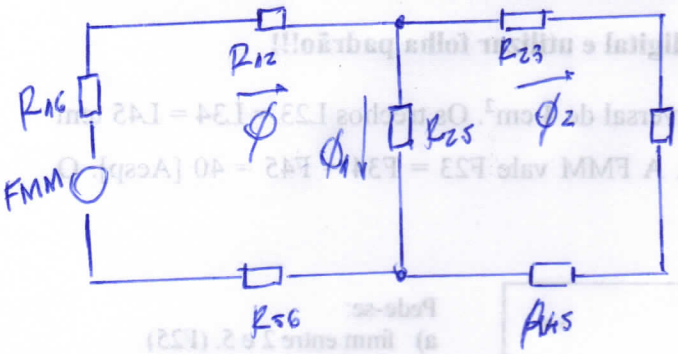
Soluções

① $S = 4cm^2$

$L_{23} = L_{34} = L_{45} = 20cm$

$F_{23} = F_{34} = F_{45} = 40 Aesp.$

Circuito equivalente (elétrico)



(a) FMM entre 2 e 5

$F_{25} = F_{23} + F_{34} + F_{45}$

$F_{25} = 40 + 40 + 40 = 120 Aesp.$

(b) $\Phi_{34} = \Phi_2$

$F_{34} = N.I = H.l_{34}$

$40 Aesp = H. 20 \times 10^{-2}$

$H = \frac{40}{20 \times 10^{-2}} = 200 \frac{Aesp}{m}$

↓ Curva de magnetização

$B = 0,18 \frac{Wb}{m^2}$

Logo: $B_{34} = \frac{\Phi_{34}}{S}$ $0,18 = \frac{\Phi_{34}}{4 \times 10^{-4}}$

$\Phi_{34} = 0,18 . 4 \times 10^{-4}$

$\Phi_{34} = 0,72 \times 10^{-4} Wb$

(c) $\Phi_1 = \Phi_{12} = \Phi_1 + \Phi_2$

$F_{25} = N.I = H.l_{25}$ $\rightarrow 20 \times 10^{-2}$

$120 = N.I = H_{25} . l_{25}$

$\frac{120}{20 \times 10^{-2}} = H_{25}$

$H_{25} = 600 \frac{Aesp}{m^2}$

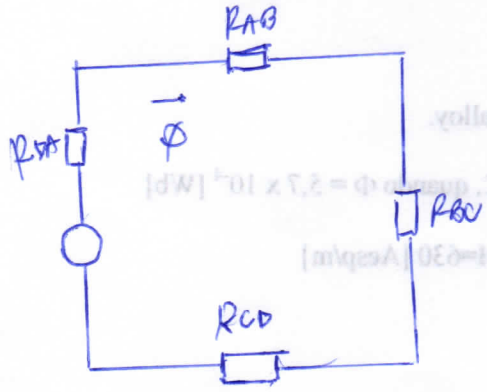
Curva de magnetização ↓

$B_{25} = \frac{\Phi_1}{S} \rightarrow 0,930 . 4 \times 10^{-4} = \Phi_1$

$\Phi_1 =$

$\Phi_T = 3,72 \times 10^{-4} + 0,72 \times 10^{-4}$ $\Phi_T = 4,44 \times 10^{-4} Wb$

② Circuito elétrico equivalente



(a) $\Phi = ?$

$l_{AB} = l_{CD} = 13cm$

$l_{BC} = l_{AD} = 12cm$

$A_{AB} = H_{CD} = 300 \frac{Aesp}{m}$

↓ Curva de magnetização

$B = 1,05 \frac{Wb}{m^2}$

$B = \frac{\Phi}{S} \Rightarrow 1,05 . (3 \times 10^{-2} . 2 \times 10^{-2}) = \Phi$

$\Phi = 6,3 \times 10^{-4} Wb$

(b) $H = \frac{B}{\mu}$ $\quad 300 = \frac{1,05}{\mu}$ $\quad \mu = 3,5 \times 10^{-3}$

$\mu = \mu_r \cdot \mu_0$

$\mu_r \cdot \frac{\mu}{\mu_0} = \frac{3,5 \times 10^{-3}}{4\pi \times 10^{-7}}$ $\quad \mu_r = 2785,2$

(c) Trecho BC = Trecho DA

$l_{BC} - l_{AD} = 12cm$

$B_{BC} = \frac{\phi_{BC}}{S}$

$B_{BC} = \frac{6,3 \times 10^{-4}}{3 \times 10^{-2} \cdot 2 \times 10^{-2}}$

$B_{BC} = 1,05 \frac{Wb}{m^2}$

$H = 725 \frac{Aesp}{m}$

$Fmm = \sum R \cdot \phi = \sum H l$

$N \cdot I = (725 \cdot 12 \times 10^{-2}) \cdot 2 + (300 \cdot 13 \times 10^{-2}) \cdot 2$

$I = \frac{252}{500} \simeq 0,5A$

(d) $\phi = 5,7 \times 10^{-4} Wb$ no trecho BC

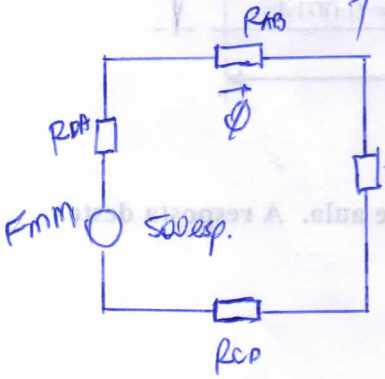
$H_{BC} = ?$

$B_{BC} = \frac{\phi}{S_{BC}} = \frac{5,7 \times 10^{-4}}{(3 \times 10^{-2}) \cdot (2 \times 10^{-2})}$

$B_{BC} = 0,95 \frac{Wb}{m^2}$

$H_{BC} = 630 \frac{Aesp}{m}$

(3) Circuito Elétrico Equivalente



Cast Iron

$\phi = 2 \times 10^{-4}$

$l_{TRECHOS} = l_{DA} + l_{AB} + l_{BC} + l_{CD}$

$l_{TRECHOS} = 20 + 20 + 20 + 20$

$= 80cm$

$S = (2,5 \cdot 2) \times 10^{-4} = 5 \times 10^{-4} m^2$

$B = \frac{\phi}{S}$

$B = \frac{2 \times 10^{-4}}{5 \times 10^{-4}} = 0,4 \frac{Wb}{m^2}$

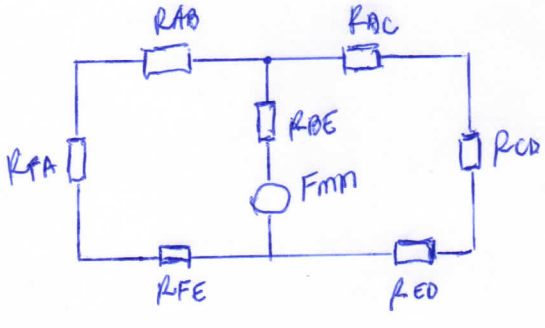
curva de magnetização

$H = 975 \frac{Aesp}{m}$

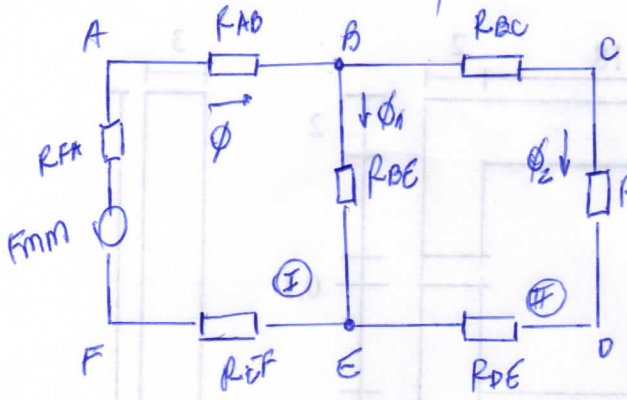
$Fmm = NI = \sum H \cdot l$

$I = \frac{975 \cdot 80 \times 10^{-2}}{500}$ $\quad \therefore I = 1,56A$

(6)



④ ⑤ Circuito Elétrico Equivalente



Malha (I)

$Fmm = R_{FA}.\phi + R_{AB}.\phi + R_{EF}.\phi + Fmm_{BE}$

$Fmm_{BE} = R_{BC}.\phi_2 + R_{CD}.\phi_2 + R_{DE}.\phi_2$

$\phi_2 = 0,0014$

$Fmm = H_{FA}.l_{FA} + H_{AB}.l_{AB} + H_{EF}.l_{EF} + Fmm_{BE}$

onde $Fmm_{BE} = H_{BC}.l_{BC} + H_{CD}.l_{CD} + H_{DE}.l_{DE}$

⑥ Análise dos trechos

Trecho BC

$l_{BC} = 17,5cm$

$S_{BC} = 0,06.5x10^{-2} = 3x10^{-3} m^2$

$B_{BC} = \frac{\phi_2}{S_{BC}} = \frac{0,0014}{3x10^{-3}} = 0,47$

$H_{BC} = 20 \frac{Aesp}{m}$

Trecho CD

$l_{CD} = 15cm$

$S_{CD} = 3x10^{-3} m^2$

$B_{CD} = 0,47$

$H_{CD} = 20 \frac{Aesp}{m}$

Trecho DE

$l_{DE} = 17,5cm$

$H_{DE} = 20 \frac{Aesp}{m}$

$Fmm_{BE} = 20.17,5x10^{-2} + 20.15x10^{-2} + 20.17,5x10^{-2}$

$Fmm_{BE} = 10 Aesp$

$10 = H_{BE}.15x10^{-2}$

$H_{DE} = \frac{10}{15x10^{-2}} = 66,7 \frac{Aesp}{m}$

$B = 1,25 \frac{Wb}{m^2}$

$\phi_1 = 1,25.(2x10^{-2} - 0,06)$

$\phi_1 = 1,5x10^{-3} Wb$

$\phi = \phi_1 + \phi_2$

$\phi = 1,5x10^{-3} + 0,0014$

$\phi = 2,9x10^{-3} Wb$

Trecho FA

$l_{FA} = 15cm$

$S_{FA} = 3x10^{-3} m^2$

$B_{FA} = \frac{\phi}{S_{FA}} = \frac{2,9x10^{-3}}{3x10^{-3}}$

$B_{FA} = 0,97 \frac{Wb}{m^2}$

$H_{FA} = 60 \frac{Aesp}{m}$

Trecho AB

$l_{AB} = 17,5cm$

$S_{AB} = 3x10^{-3}$

$H_{AB} = 60 \frac{Aesp}{m}$

Trecho EF

$l_{EF} = 17,5cm$

$S_{EF} = 3x10^{-3} m^2$

$H_{EF} = 60 \frac{Aesp}{m}$

$Fmm = H_{FA}.l_{FA} + H_{AB}.l_{AB} + H_{EF}.l_{EF} + Fmm_{BE}$

$Fmm = 60.15x10^{-2} + 60.17,5x10^{-2} + 60.17,5x10^{-2} + 10$

$\boxed{Fmm = 40 Aesp}$

(5) Trecho ABCD — Ferro fundido

$\ell = 20+20+20+20-0,1 = 79,9\times10^{-2}\ m$

$S = 3\times2 = 6\ cm^2 = 6\times10^{-4}\ m^2$

$B_{ABCD} = \frac{\Phi}{S} \Rightarrow B_{ABCD} = \frac{2\times10^{-4}}{6\times10^{-4}} = 0,33\ \frac{Wb}{m^2}$

Não se usa a curva de magnetização pois foi dada μ_{FE} →

$H_{ABCD} = \frac{780\ Aesp}{m}$

$B_{ABCD} = H_{ABCD}\cdot\mu_{FE}$

$H_{ABCD} = \frac{0,33}{2\times10^{-3}}$

$H_{ABCD} = 165\ \frac{Aesp}{m}$

Trecho entreferro

$\ell_E = 0,1\times10^{-2}\ cm$

$S_E = (2\times10^{-2}+0,1\times10^{-2})\cdot(3\times10^{-2}+0,1\times10^{-2})$

$S_E = 6,51\times10^{-4}\ m^2$

$B_E = \frac{\Phi}{S} \Rightarrow B_E = H_E\cdot\mu$

$B_E = \frac{2\times10^{-4}}{6,51\times10^{-4}}$

$B_E = 0,31\ \frac{Wb}{m^2}$

$\frac{0,31}{4\pi\times10^{-7}} = H_E$

$H_E = 244,477\times10^3\ \frac{Aesp}{m}$

ou

$H_E = 2,45\times10^5\ \frac{Aesp}{m}$

Lei de Ampère: $N\cdot I = H_{ABCD}\cdot\ell_{ABCD} + H_E\cdot\ell_E$

$500\cdot I = 165\cdot79,9\times10^{-2} + 2,45\times10^5\cdot0,1\times10^{-2}$

$I = 0,75\ A$