4/03/18

Solved Problems

Unit - I

II nd year EEE.

Magnetic Circuits and Magnetic Materials

1.) An iron ring of circular cross sectional area of 3.0 cm^2 and mean diameter of 20 cm is wound with 500 turns of wire and carries a current of 2.09 A to produce the magnetic flux of 0.5 m Wb in the ring. Determine the permeability of the material.

Solution:-

Given:-

$a = 3cm^2 = 3\times10^{-4} m^2$

$d = 20 cm$

$N = 500$

$I = 2A$

$\phi = 0.5 \ m Wb$

$l = \pi \times d$

$= \pi \times 20 = 62.8318 cm$

$= 0.628318 m$

$$S = \frac{l}{\mu_0 \mu_r a} = \frac{0.628313}{4\pi\times10^{-7} \times \mu_r \times 3\times10^{-4}} = \frac{1.6667\times10}{\mu_r}$$

(1) → (

$$\phi = \frac{m.m.f}{S} = \frac{NI}{S}$$

$$S = \frac{NI}{\phi} = \frac{500 \times 2}{0.5 \times 10^{-3}}$$

$$= 2 \times 10^{6} \text{ AT/Wb.} \longrightarrow (2)$$

On equating (1) & (2)

$$2 \times 10^{6} = \frac{1.6667 \times 10^{9}}{\mu_r}$$

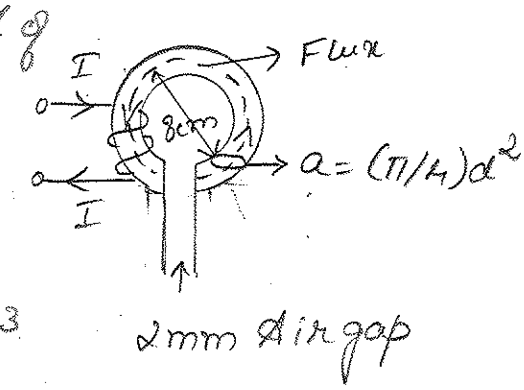
$$\mu_r = \frac{1.6667 \times 10^{9}}{2 \times 10^{6}} = 833.35$$

2. An iron ring 9cm. mean diameter is made up of round iron of diameter 1cm and permeablity of 900, has an air gap of 2mm wide. It consist of winding with 400 turns carrying a current of 3.5A. Determine (i) mmf ii) Total reluctance iii) The flux iv) Flux density in ring.

Solution:-

Diameter of ring $d = 8cm$

Length of iron $= \pi d -$ length of air gap



$l_i = \pi \times (8 \times 10^{-2}) - 2 \times 10^{-3}$

$= 0.2493\ m$

$l_g =$ length of air gap $= 2mm = 2 \times 10^{-3} m$

Diameter of iron $= 1cm$

$\therefore$ Area of cross section of airgap and ring is to be assumed same.

(i) Total m.m.f produced $= NI = 400 \times 3.4$

$= 1400$ AT (ampere turn)

(ii) Total reluctance $S_T = S_i + S_g$

$$S_i = \frac{l_i}{\mu_0 \mu_r a} \quad [\mu_r = 900] \text{ given.}$$

$$= \frac{0.2493}{4\pi \times 10^{-7} \times 900 \times 7.853 \times 10^{-5}}$$

$= 2806947.615$ AT/wb.

$$S_g = \frac{l_g}{\mu_0 a} \quad [\mu_r = 1]$$

$$S_g = \frac{2 \times 10^{-3}}{4\pi \times 10^{-7} \times 7.853 \times 10^{-5}}$$

$$= 20.2667 \times 10^{6} \text{ AT/Wb}$$

$$S_T = 2806947.615 + 20.2667 \times 10^{6}$$

$$= 23.0737 \times 10^{6} \text{ AT/Wb}$$

iii) $$\varphi = \frac{mmf}{\text{Reluctance}} = \frac{NI}{S_T} = \frac{1400}{23.0737 \times 10^{6}}$$

$$= 6.067 \times 10^{-5} \text{ Wb}$$

iv) $$\text{Flux density} = \frac{\varphi}{a} = \frac{6.067 \times 10^{-5}}{7.853 \times 10^{-5}}$$

$$= 0.7725 \text{ Wb/m}^2$$

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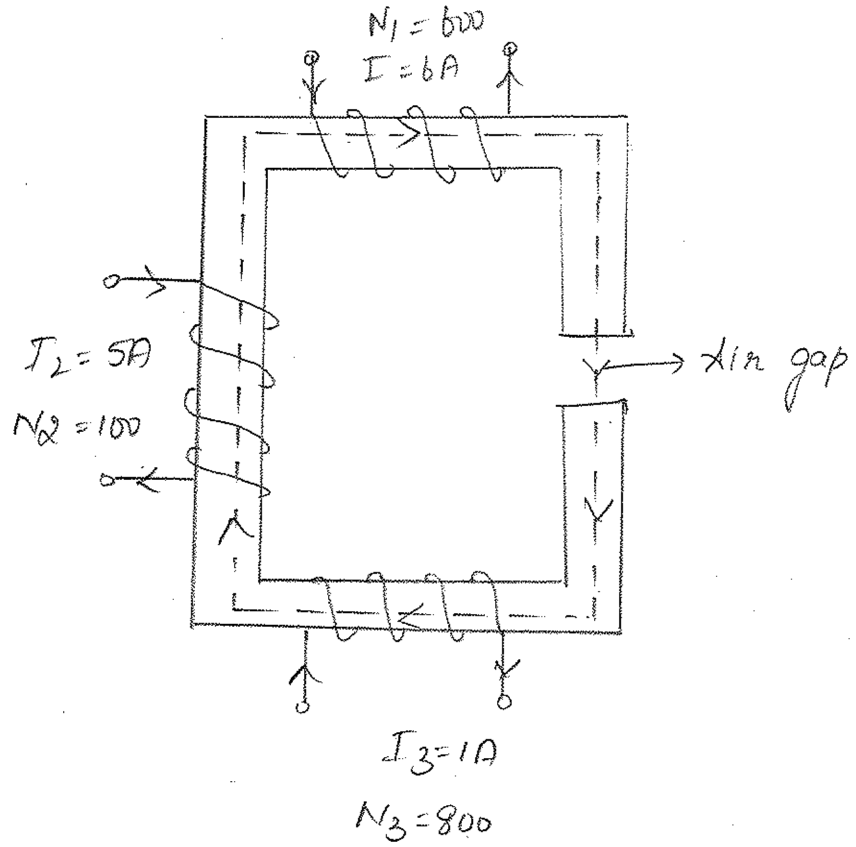
3. A magnetic circuit is excited by three coils as shown. Calculate the flux produced in the air gap. The material used for core is iron having relative permeability of 800. The length of the magnetic circuit is 100 cm with an air gap of 2 mm in it. The core has uniform cross-section of 6 cm^2.

[Dec-02 Marks-8]



Solution :-

Given :-

$N_1 = 600 \quad I_1 = 6A$

$N_2 = 100 \quad I_2 = 5A$

$N_3 = 800 \quad I_3 = 1A$

$l_T = 100\,cm = 1m$

$l_i = l_T - l_g = 1m - 2 \times 10^{-3} = 0.998\,m$

$l_g = 2 \times 10^{-3}\,m, \; \mu_r = 800, \; a = 6\,cm^2 = 6 \times 10^{-4}\,m^2$

Total reluctance :- $S = S_i + S_g$

$$S_i = \frac{l_i}{\mu_0 \mu_r a} = \frac{0.998}{4\pi \times 10^{-7} \times 800 \times 6 \times 10^{-4}}$$

$$= 1654548.263 \text{ AT/Wb}$$

$$S_g = \frac{l_g}{\mu_0 a} = \frac{2\times10^{-3}}{4\pi\times10^{-7}\times6\times10^{-4}} = 2652582.385\ AT/Wb$$

$$S = 1654548.263 + 2652582.385$$

$$= 4307130.648\ AT/Wb$$

$$\text{Net mmf} = (N_1 I_1) + (N_2 I_2) - (N_3 I_3)$$

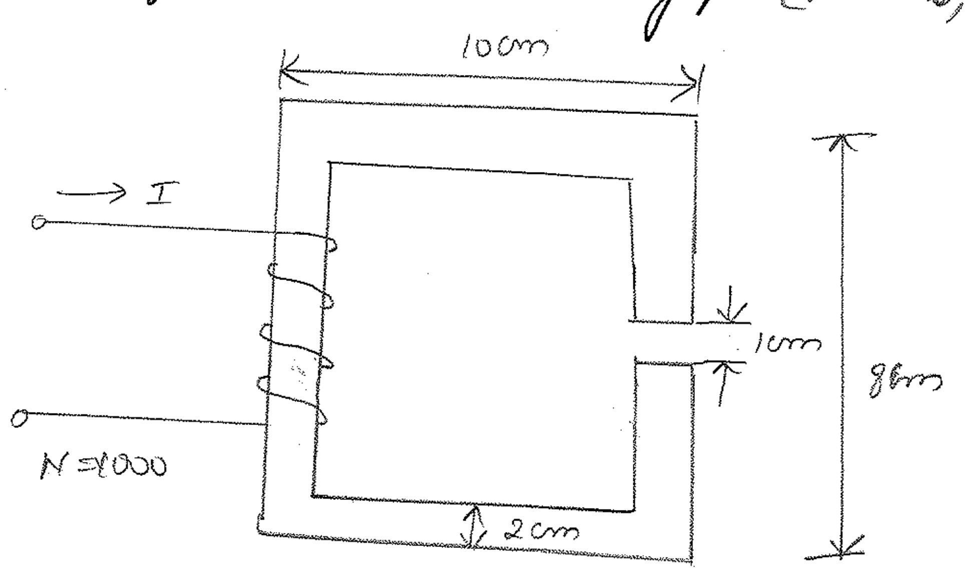
$$= (600\times6) + (100\times5) - (1\times800)$$

$$NI = 3300\ AT$$

$$\varphi = \frac{\text{mmf}}{\text{Reluctance}} = \frac{NI}{S} = \frac{3300}{4307130.648}$$

Flux in air gap $\varphi = 0.7661$ mWb.

4. For the given magnetic circuit determine the current required to establish a flux density of 0.5 T in the air gap. [Dec-10, Marks-12]



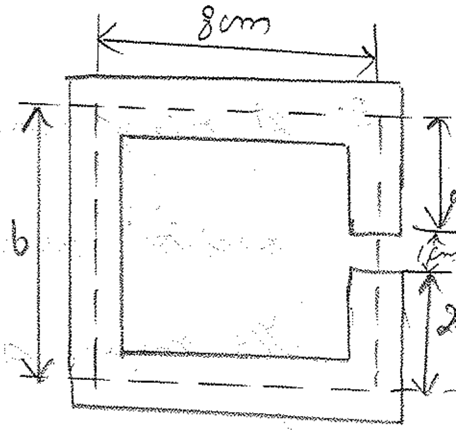
Iron core :- thickness - 2cm ; μ core = $5000\mu_0$

Solution :-

Given :-

$N = 1000,\ B = 0.5\,T,\ a = 2 \times 2 = 4\,cm^2$

$l_g = 1\,cm$



l_i = length of iron path

$= 8 + 8 + 6 + 5$

$= 27\,cm$

$\mu_{core} = 5000\mu_0 \quad [\mu_r = 5000]$

$\phi = B \times a = 0.5 \times 4 \times 10^{-4}$

$= 0.2\,mWb$

$$S_i = \frac{l_i}{\mu_0 \mu_r a}$$

$$= \frac{27 \times 10^{-2}}{5000 \times 4\pi \times 10^{-7} \times 4 \times 10^{-4}}$$

$= 107.4295 \times 10^3$ AT/Wb.

$$S_g = \frac{l_g}{\mu_0 a} = \frac{1 \times 10^{-2}}{4\pi \times 10^{-7} \times 4 \times 10^{-4}}$$

$= 19.8943 \times 10^6$ AT/Wb

$S_T = S_i + S_g = 20.00173 \times 10^6$ AT/Wb

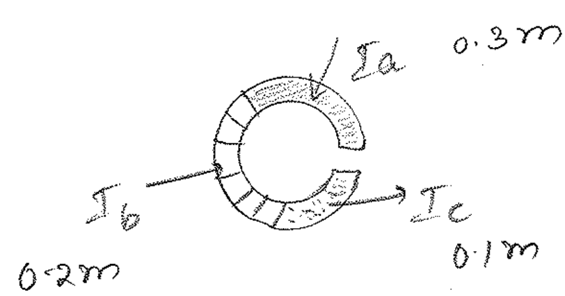
$$\phi = \frac{mmf}{S_T} \Rightarrow 0.2 \times 10^{-3} = \frac{NI}{20.00173 \times 10^{6}}$$

$$I = \frac{0.2 \times 10^{-3} \times 20.00173 \times 10^{6}}{1000} = 4A$$

5. A ring composed of three sections. The cross section area is $0.001\ m^2$ for each section. The mean arc length are $l_a = 0.3m$, $l_b = 0.2m$, $l_c = 0.1\ m$, an air gap length of 0.1 mm is cut in the ring, μ_r for section a, b and c are 5000, 1000 and 10000 respectively. Flux in the air gap is 7.5×10^{-4} Wb. Find i) mmf ii) Exciting current if the coil has 100 turns (iii) Reluctance of the section.

[Dec-11, Marks 8-16]

Solution :-



$a = 0.001\ m^2$

$N = 100$

Reluctance for the Section

$$S_a = \frac{l_a}{\mu_0 \mu_r a} = \frac{0.3}{4\pi \times 10^{-7} \times 5000 \times 0.001}$$

$$= 47746.4829 \ AT/wb$$

$$S_b = \frac{l_b}{\mu_0 \mu_r a} = \frac{0.1}{4\pi \times 10^{-7} \times 10000 \times 0.001}$$

~~7957.7471 AT/wb~~

$$= 7957.7471 \ AT/wb$$

$$S_c = \frac{l_c}{\mu_0 \mu_r a} = \frac{0.2}{4\pi \times 10^{-7} \times 1000 \times 0.001}$$

~~7987.7471 AT/wb~~

$$= 159154.9431 \ AT/wb$$

$$S_g = \frac{l_g}{\mu_0 a} = \frac{0.1 \times 10^{-3}}{4\pi \times 10^{-7} \times 0.001}$$

$$= 79577.4715 \ AT/wb$$

Total reluctance:-

$$S_T = S_a + S_b + S_c + S_g$$

$$= 294.4366 \times 10^3 \ AT/wb$$

$$\phi = \frac{mmf}{S_T} \ (ie) \ 7.5 \times 10^{-4} = \frac{mmf}{294.4366 \times 10^3}$$

$$mmf = 220.8275 \ AT$$

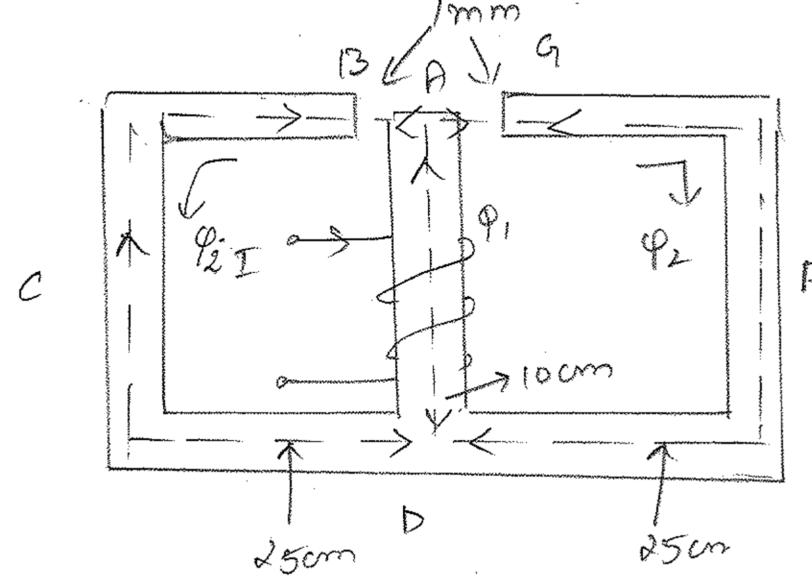
$mmf = NI$

$$I = \frac{220.8275}{N} = \frac{220.8275}{100}$$

$$= 2.2082\ A$$

6. The magnetic circuit is constructed of wrough iron. The cross-section of the centre limb is $8 cm^2$ and of each other limb, $5 cm^2$. If the coil on centre limb is wound with 1000 turns, calculate the exciting current required to set up a flux of 1.2 mWb in the centre limb. Width of each air gap is 1 mm. Points on the B/H curve of wrought iron are as follows:-

B in tesla :-	1.2	1.35	1.5
H in AT/m :-	625	1100	2000



Solution:-

Given:-

l_c = length of centre limb $= 10cm = 0.1m$

$a_c = 8cm^2 = 8\times10^{-4}\,m^2$

$\varphi_c = 1.2\,m\,Wb = 1.2\times10^{-3}\,Wb$

l_i = length of iron path of side limb

$= 25cm$

$= 0.25$ [on each side]

l_g = length of air gap $= 1mm = 1\times10^{-3}m$

$a_i = 5cm^2 = 5\times10^{-4}\,cm^2$

Flux in side limbs $= \frac{1.2}{2} = 0.6\,mWb$

Flux density in central limb is,

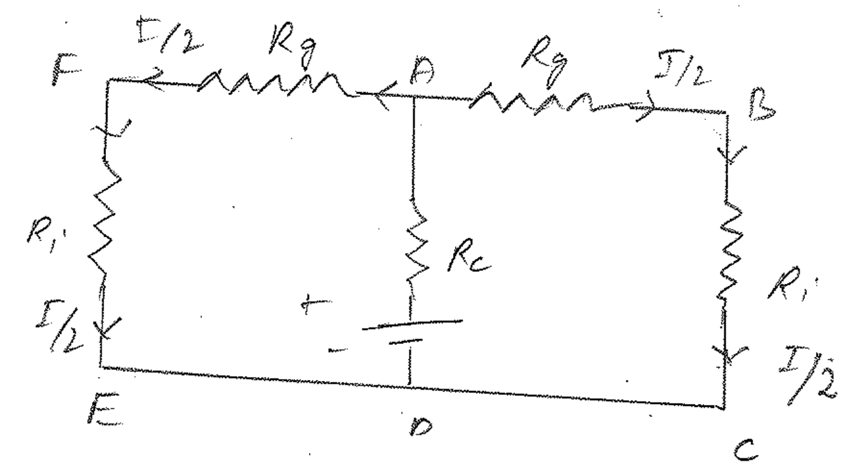
$$B_c = \frac{\varphi_c}{a_c} = \frac{1.2\times10^{-2}}{8\times10^{-4}} = 1.5\ \text{Tesla}$$

Flux density in air gap is,

$$B_g = \frac{\varphi_i}{a_i} = \frac{0.6\times10^{-3}}{5\times10^{-4}} = 1.2\ Wb/m^2$$

Flux density in side limb is,

$$B_i = \frac{\varphi_i}{a_i} = \frac{0.6\times10^{-3}}{5\times10^{-4}} = 1.2\ Wb/m^2$$



Applying KVL for ABCD,

$$E - IR_c - \frac{I}{2} R_g - \frac{I}{2} R_i = 0$$

$$E = IR_c + \frac{I}{2} R_g + \frac{I}{2} R_i$$

Apply Kirchoff's mmf law,

$$mmf = H_c l_c + H_g l_g + H_i l_i$$

- $H_c l_c$ → Centre limb
- $H_g l_g$ → air gap
- $H_i l_i$ → iron path on one side.

(i) Centre limb : $B_c = 1.5$ Tesla

$$H_c = 2000$$

$$H_c l_c = 2000 \times 0.1$$

$$= 200 \text{ AT}$$

(ii) Side limb:

$$B_i = 1.2 \text{ Tesla}$$

$$H_i = 625$$

$$H_i l_i = 625 \times 0.25$$

$$= 156.25 \text{ AT}$$

(iii) Air gap:

$$B_g = \mu_0 H_g$$

$$H_g = \frac{B_g}{\mu_0} = \frac{1.2}{4\pi \times 10^{-7}}$$

$$= 954929.65 \text{ AT}$$

$$H_g l_g = 954929.65 \times (1 \times 10^{-3})$$

$$= 954.9296 \text{ AT}$$

Total mmf = $H_c l_c + H_i l_i + H_g l_g$

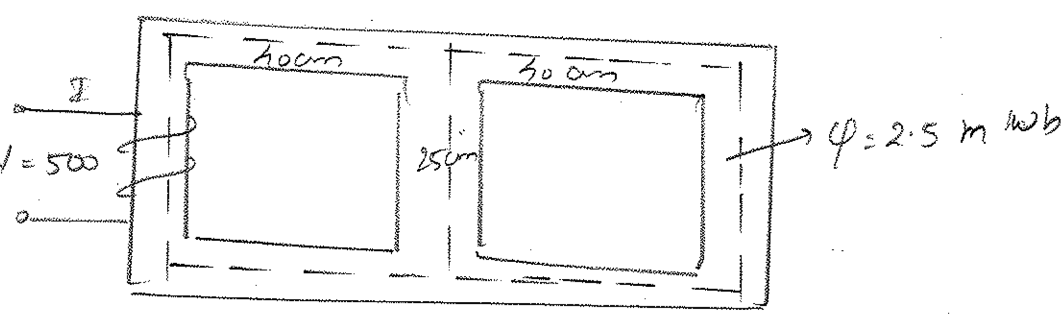
$$NI = 200 + 156.25 + 954.9296$$

$$= 1311.77 \text{ AT}$$

Current $I = \frac{1311.17}{\text{No. of turns}} = \frac{1311.77}{1000}$

$$= 1.31 \text{ A}$$

7: A Cast steel structure is made of a rod of square section 2.5 cm × 2.5 cm as shown. What is the current that should be passed in a 500 turn coil on the left limb so that a flux of 2.5 mWb is made to pass in the right limb. Assume permeability as 750 and neglect leakage.



Solution:-

Given:

S_1 = Reluctance of Centre limb

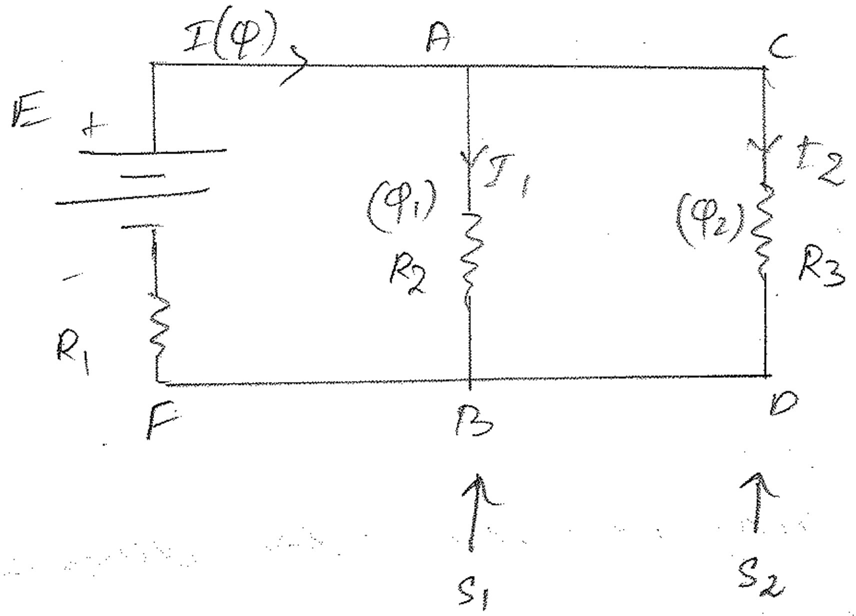
S_2 = Reluctance of right side

$$S_1 = \frac{l_1}{\mu_0 \mu_r a_1} = \frac{25 \times 10^{-2}}{4\pi \times 10^{-7} \times 750 \times 2.5 \times 2.5 \times 10^{-4}}$$

$$= 424.413 \times 10^{3} \text{ AT/Wb}$$

$$S_2 = \frac{l_2}{\mu_0 \mu_r a_2} = \frac{40 \times 10^{-2}}{4\pi \times 10^{-7} \times 750 \times 2.5 \times 2.5 \times 10^{-4}}$$

$$= 679.061 \times 10^{3} \text{ AT/Wb}$$



For AB,

$$\text{mmf} = \varphi_1 S_1 = \varphi_2 S_2$$

$$\varphi_2 = 2.5\ \text{mWb}$$

$$\varphi_1 = \frac{\varphi_2 S_2}{S_1} = \frac{2.5 \times 10^{-3} \times 679.061 \times 10^{3}}{424.413 \times 10^{3}}$$

$$= 4\ \text{mWb}$$

$$\varphi = \varphi_1 + \varphi_2 = 2.5 + 4$$

$$= 6.5\ \text{mWb.}$$

$$S_{AEFB} = S_2 = 679.061 \times 10^{3}\ \text{AT/Wb}$$

$$\text{mmf of } AEFB = S_{AEFB} \times \varphi$$

$$= 679.061 \times 10^{3} \times 6.5 \times 10^{-3}$$

$$= 4413.8965\ \text{AT}$$

$$\text{Total mmf} = 4413.8965 + \varphi_1 S_1$$

$$= 4413.8965 + 4 \times 10^{-3} \times 424.413 \times 10^{3}$$

$$= 6111.548\ \text{AT}$$

NI = total mmf

$$I = \frac{6111.548}{500}$$

$$I = 12.223\ A$$

Q. The magnetic circuit has dimensions:

$A_C = 4 \times 4\ cm^2$, $l_g = 0.06 cm$, $l_c = 40 cm$, $N = 600$ turns. Assume the value of $\mu_r = 6000$ for iron. Find the exciting current for $B_C = 1.2 T$ & the corresponding flux & flux linkage [May-13, Marks 16]

Solution:-

$B_C = 1.2 T$, $A_C = 4 \times 4 = 16\ cm^2$

$l_g = 0.06 cm$, $l_c = 40 cm$, $N = 600$

$\mu_r = 6000$ $\phi = B_C A_C = 1.2 \times 16 \times 10^{-4}$

$[\phi = 1.92 \times 10^{-3} Wb.] \rightarrow$ Flux.

$$S_T = S_c + S_g$$

$$= \frac{l_c}{\mu_0 \mu_r A_c} + \frac{l_g}{\mu_0 \mu_r A_c} \quad [\mu_r = 1]$$

$$= \frac{40 \times 10^{-2}}{4\pi \times 10^{-7} \times 6000 \times 16 \times 10^{-4}} + \frac{0.06 \times 10^{-2}}{4\pi \times 10^{-7} \times 16 \times 10^{-4}}$$

$$= 331.5727 \times 10^{3}\ AT/Wb$$

$\varphi = \frac{NI}{S_T}$

$1.92 \times 10^{-3} = \frac{600\,I}{331.5727 \times 10^{3}}$

$I = 1.061\ A$

Flux linkage $= N\varphi$

$= 600 \times 1.92 \times 10^{-3}$

$= 1.152$ Wb-turn.

9. A steel ring has a mean diameter of 20 cm a cross section of 25 cm² and a radial air-gap of 0.8 mm cut across it. When excited by a current of 1A through a coil of turns 1000 wound on the ring core, it produces an air gap flux of 1 mWb. Neglecting leakage and fringing.

Calculate :-

(i) Relative permeability of steel

(ii) Total reluctance of magnetic circuit.

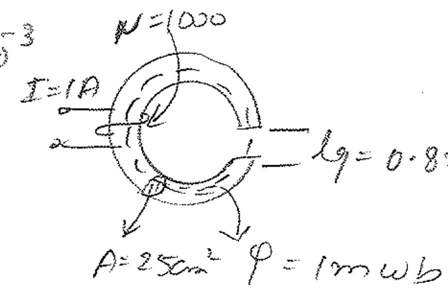
[Dec-13, Marks-10]

Solution :-

d = diameter = 20cm

$l_i = \pi \times d - l_g = \pi \times 0.2 - 0.8\times10^{-3}$

$= 0.6275$ m



(i) $S_i = \dfrac{l_i}{\mu_0 \mu_r A}$ $\qquad S_g = \dfrac{l_g}{\mu_0 A}$

$S_T = S_i + S_g$

$= \dfrac{1}{\mu_0 A}\left[\dfrac{l_i}{\mu_r} + l_g\right]$

$S_T = \dfrac{\left[\dfrac{0.6275}{\mu_r} + 0.8\times10^{-3}\right]}{4\pi\times10^{-7}\times25\times10^{-4}}$

$S_T = \dfrac{mmf}{\varphi} = \dfrac{NI}{\varphi} = \dfrac{1000\times1}{1\times10^{-3}} = 1\times10^{6}$ AT/wb

$1\times10^{6} = \left[\dfrac{\dfrac{0.6275}{\mu_r} + 0.8\times10^{-3}}{4\pi\times10^{-7}\times25\times10^{-4}}\right]$

$\mu_r = 267.98$

$\mu_r \approx 268$

$S_T = \dfrac{1}{4\pi\times10^{-7}\times25\times10^{-4}}\left[\dfrac{0.6275}{268} + 0.8\times10^{-3}\right]$

$= 1\times10^{6}$ AT/Wb

10.) A cast iron ring of 40cm mean length and circular cross section of 5cm diameter is wound with a coil. The coil carries a current of 3A and produces a flux of 3 mWb in the airgap. The length of the air gap is 2mm. The relative permeability of the cast iron is 800. The leakage coefficient is 1.2. Calculate no. of turns of the coil

Given:

$l_t = 40\text{ cm} = 0.4\text{ m}$

$l_g = 2 \times 10^{-3}\text{ m}$

$l_i = l_t - l_{gap} = 0.4 - 2 \times 10^{-3}$

$= 0.398\text{ m}$

$I = 3A, \quad \phi_g = 2 \times 10^{-3}\text{ Wb}$

$\mu_r = 800, \quad \lambda = 1.2$

$\lambda = \dfrac{\phi_T}{\phi_g}$

$1.2 = \dfrac{\phi_T}{2 \times 10^{-3}}$

$\phi_T = 2.4 \times 10^{-3}\text{ Wb}$

Solution :-

$$S_i = \frac{l_i}{\mu_0 \mu_{ri} a}$$

$$a = \frac{\pi}{4} d^2 = \frac{\pi}{4}(5)^2$$

$$= 19.6349\,cm^2$$

$$= 19.634 \times 10^{-4}\,m^2$$

$$S_i = \frac{0.398}{4\pi \times 10^{-7} \times 800 \times 19.63 \times 10^{-4}}$$

$$= 201629.16\ AT/wb.$$

$$\varphi_T = \frac{mmf}{Reluctance} = \frac{NI}{S_i}$$

$$2.4 \times 10^{-3} = \frac{NI}{201629.16}$$

NI for iron part = 483.909 AT

Reluctance of air gap $S_g = \frac{l_g}{\mu_0 a}$

$$= \frac{2 \times 10^{-3}}{4\pi \times 10^{-7} \times 19.634 \times 10^{-4}}$$

$$= 810608.86\ AT/wb$$

$$\varphi_g = \frac{mmf}{S_g} \Rightarrow 2 \times 10^{-7} = \frac{NI}{810608.86}$$

$$NI = 1621.2177\ AT$$

Total mmf required = $(NI)_{iron} + (NI)_{air\,gap}$

$= 483.909 + 1621.2177$

$NI = 2105.1267$

$N \times 3 = 2105.1267$

$N = \frac{2105.1267}{3}$

$N = 701.7$

$\Rightarrow 702$ turns

11.) A conductor of 2m length moves with a uniform velocity of 1.27 m/sec under a magnetic field having a flux density of 1.2 wb/m 2 (Tesla). Calculate magnitude of induced emf if conductor moves,

i) At right angles to axis of field

ii) At an angle of 60° to the direction of field

Solution:-

(i) Magnitude of induced emf.

$e = Blv$ for $\theta = 90°$

$e = 1.2 \times 1.27 \times 2 = 3.048$ V.

(ii) $e = Blv \sin\theta$ when $\theta = 60°$

$e = 1.2 \times 2 \times 1.27 \times \sin 60 = 2.6397$ V

12: A coil caries 200 turns gives rise a flux of 500 μ Wb when carrying a certain current. If this current is reversed in $\frac{1}{10}$ th of a second. Find the average emf induced in the coil.

Solution:

The magnetude of induced emf is,

$$= \frac{N\,d\varphi}{dt}$$

$$d\varphi = \varphi_2 - \varphi_1$$

$$= -500 \times 10^{-6} - (+500 \times 10^{-6})$$

$$= -1 \times 10^{-3}$$

$$dt = 0.1 \text{ sec}$$

$$\text{Average emf} = \frac{-N\,d\varphi}{dt}$$

$$= -200 \frac{(-1 \times 10^{-3})}{0.1}$$

$$= 2V$$

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13. If a coil has 500 turns linked to a flux of 50 mWb, when carrying a current of 125 A, calculate inductance of the coil, If this current is reduced to zero uniformly in 0.1 sec. Calculate self induced emf in co

Solution:

$$L = \frac{N\varphi}{I}$$

$N = 500$

$\varphi = 50\ mWb$

$I = 25A$

$$= \frac{500 \times 50 \times 10^{-3}}{25}$$

$= 0.2\ H$

$$e = -L\frac{dI}{dt}$$

$$= -L\left[\frac{\text{Final value of } I - \text{Initial value of } I}{\text{Time}}\right]$$

$$= -0.2 \times \left(\frac{0-125}{0.1}\right)$$

$= 250V.$

14. An electric conductor of effective length of 0.3 metre is made to move with a constant velocity of 5 metre per second perpendicular to a magnetic field of uniform flux density 0.5 tesla. Find the emf induced in it. If this emf is used to supply a current of 25A, find the force on the conductor. & state its direction w.r.t motion of conductor, ignoring friction

Find the power required to keep the conductor moving.

Solution:

$l = 0.3\,m$

$v = 5\,m/s$

$B = 0.5\,T$

$e = Blv$

$= 0.3 \times 5 \times 0.5 = 0.75\,V$

$I = 25\,A$

$F = BlI = 0.5 \times 0.3 \times 25$

$= 3.75\,N$

$P = e \times I = 0.75 \times 25$

$= 2.8125\,W$

15\. A coil is wound uniformly on an iron core. The relative permeability of the iron is 1400. The length of the magnetic circuit is 70cm. The cross-sectional area of the core is $5\,cm^2$. The coil has 1000 turns. calculate,

i) Reluctance of magnetic circuit
ii) Inductance of coil in henries
iii) E.M.F induced in coil if a current of 10A is uniformly reversed in 0.2 seconds.

Solution :-

$\mu_r = 1400$, $L = 70cm = 0.7m$, $N = 1000$

$A = 5cm^2 = 5 \times 10^{-4} m^2$, $\mu_0 = 4\pi \times 10^{-7}$

(i) $$S = \frac{l}{\mu_0 \mu_r a} = \frac{0.7}{4\pi \times 10^{-7} \times 1400 \times 5 \times 10^{-4}}$$

$$= 7.957 \times 10^{5} \ AT/wb$$

(ii) $$L = \frac{N^2}{S} = \frac{(1000)^2}{7.957 \times 10^5} = 1.2566 \ H$$

(iii) A current of +10 A is made −10A in 0.2 sec

$$\frac{dI}{dt} = \frac{-10-10}{0.2} = -100$$

$$e = -L\frac{dI}{dt} = -1.2566 \times (-100)$$

$$= 125.66 \ V$$

16. Two coils A and B are kept in parallel planes, such that 70% of the flux produced by coil A links with coil B. Coil A has 10,000 turns. Coil B has 12000 turns. A current of 4A in coil A produces a flux of 0.04 mwb while a current of 4A in coil B produces a flux of 0.08 mwb. Calculate, i) Self inductance (L_A and L_B) ii) Mutual inductance M iii) Coupling Coefficient.

Solution :-

Given values :-

$N_A = 1000$

$N_B = 12000$

$\phi_B = 0.7\phi_A$

$k_A = \frac{\phi_B}{\phi_A} = 0.7$

$\phi_A = 0.04 \times 10^{-3}$ wb for $I_A = 4A$

$\phi_B = 0.08 \times 10^{-3}$ wb for $I_B = 4A$

(i) Self inductance $L_A = \frac{N_A \phi_A}{I_A}$

$= \frac{10,000 \times 0.04 \times 10^{-3}}{4}$

$= 0.1 H$

$L_B = \frac{N_B \phi_B}{I_B} = \frac{12000 \times 0.08 \times 10^{-3}}{4}$

$= 0.24 H$

(ii) Mutual Inductance $M = \frac{N_B \phi_B}{I_A}$

$= \frac{N_B k_A \phi_A}{I_A}$

$= \frac{12000 \times 0.7 \times 0.04 \times 10^{-3}}{4}$

$= 0.084 H$

(iii) Coefficient of coupling $k = \frac{M}{\sqrt{L_A L_B}}$

$$= \frac{0.084}{\sqrt{0.1 \times 0.24}}$$

$$= 0.5422$$

17. Two coil A and B are wound on same iron core. There are 600 turns on B. The current of 4 amps through coil A produces a flux of 500×10^{-6} Wb in the core. If this current is reversed in 0.02 second calculate average emf induced in coil A and B. [DEC-12 Marks-8]

Solution:-

$N_A = 600$, $N_B = 3600$, $I_A = 4A$, $\phi = 500 \times 10^{-6}$

$$L_A = \frac{N_A \phi}{I_A} = \frac{600 \times 500 \times 10^{-6}}{4} = 0.075 \text{ H}$$

$$M = \frac{N_B \phi}{I_A} = \frac{3600 \times 500 \times 10^{-6}}{4} = 0.45 \text{ H}$$

$$e_A = -L_A \frac{dI_A}{dt} \quad \& \quad e_B = -M \frac{dI_A}{dt}$$

$$\frac{dI_A}{dt} = \frac{-4 - (4)}{0.02} = -400 \text{ A/s}$$

(Current reversed)

$$e_A = -0.075 \times (-400) = 30V$$

$$e_B = -0.45 \times (-400) = 180V$$

18. Two coil A and B, have self inductance of 120μH and 300 μH respectively. A current of 1A through coil 'A' produces flux linkage of 100 μ wb turns in coil 'B'. Calculate

(i) Mutual inductance between the coil

(ii) Average emf induced in coil 'B' if current of 1A in coil 'A' is reversed at a uniform rate in 0.1 sec. Also find coefficient of coupling.

Solution :-

$$L_A = 120\mu H, \; L_B = 300\mu H$$

$I_A = 1A$ produces $N_B \phi_B = 100\mu wb$

i) $M = \dfrac{N_B \phi_B}{I_A} = \dfrac{100 \times 10^{-6}}{1} = 100\mu H$ (mutual inductance)

ii) $e_B = -M \dfrac{dI_A}{dt}$

The current in coil A is reversed i.e it is

$-1A$ in 0.1 sec

$$\Delta I = (\text{New value} - \text{Original value})$$

$$= (-1-1) = -2A$$

$$\Delta t = 0.1 \text{ sec}$$

$$\frac{dI_A}{dt} = \frac{\Delta I}{\Delta t} = \frac{-2}{0.1} = -20 \text{ A/sec}$$

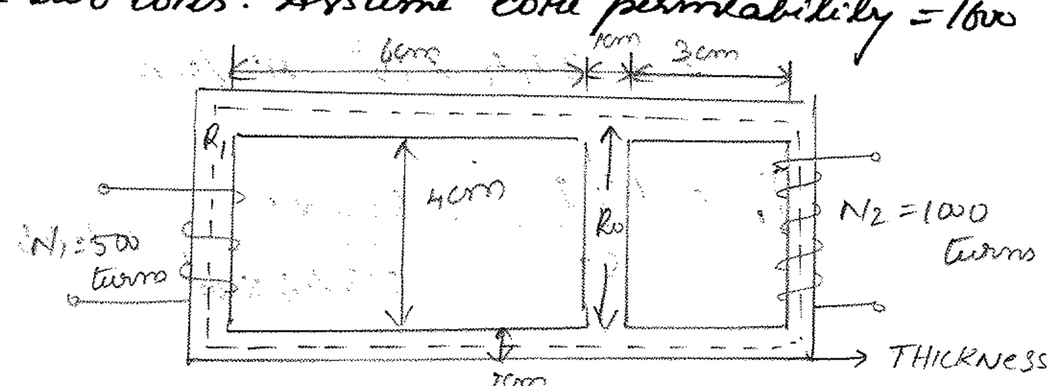
$$e_B = -100 \times 10^{-6} \times (-20)$$

$$= 2mV$$

$$K = \frac{M}{\sqrt{L_A L_B}} = \frac{100 \times 10^{-6}}{\sqrt{120 \times 10^{-6} \times 300 \times 10^{-6}}}$$

$$= 0.527$$ [Coefficient of coupling]

A. For the magnetic circuit as shown below find the self and mutual inductance between the two coils. Assume core permeability = 1600



Solution :-

Length $R_1 = (6+0.5+1) \times 2 + (4+1+1) = 21\,cm$

Length $R_2 = (3+0.5+1) \times 2 + (4+1+1) = 15\,cm$

Length $R_0 = 4+1+1 = 6\,cm$, a = area of c/s $= 4\,cm^2$

$$S_1 = \frac{R_1}{\mu_0 \mu_r a} = \frac{21 \times 10^{-2}}{4\pi \times 10^{-7} \times 1600 \times 4 \times 10^{-4}}$$

$$= 0.2612 \times 10^6 \; AT/wb$$

$$S_2 = \frac{R_2}{\mu_0 \mu_r a} = \frac{15 \times 10^{-2}}{4\pi \times 10^{-7} \times 1600 \times 4 \times 10^{-4}}$$

$$= 0.1866 \times 10^6 \; AT/wb$$

$$S_3 = \frac{R_0}{\mu_0 \mu_r a} = \frac{6 \times 10^{-2}}{4\pi \times 10^{-7} \times 1600 \times 2 \times 10^{-4}}$$

$$= 0.149 \times 10^6 \; AT/wb$$

(i) Let coil 1 is excited with $I = 1A$

$$S_T = S_1 + [S_0 \parallel S_2] = \{0.2612 + [0.1866 \parallel 0.149]\} \times 10^6$$

$$= 0.344 \times 10^6 \; AT/wb$$

$$\phi_1 = \frac{N_1 I}{S_T} = \frac{500 \times 1}{0.344 \times 10^6} = 1.4535 \times 10^{-3}\; wb$$

$$\varphi_{21} = \varphi_1 \times \frac{S_0}{(S_0 + S_2)}$$

$$= \frac{1.4535 \times 10^{-3} \times 0.149 \times 10^6}{[0.149 + 0.1866] \times 10^6}$$

$$= 0.6453 \text{ m Wb}$$

$$L_{11} = \frac{N_1 \varphi_1}{I} = \frac{500 \times 1.4535 \times 10^{-3}}{1}$$

$$= 0.7267 \text{ H}$$

$$M_{21} = \frac{N_2 \varphi_{21}}{I} = \frac{1000 \times 0.6453 \times 10^{-3}}{1}$$

$$= 0.645 \text{ H}$$

(ii) Let coil 2 is excited with $I = 1A$

$$S_T = S_2 + [S_0 \parallel S_1]$$

$$= \left\{ 0.1866 + \left[\frac{0.149 \times 0.2612}{0.149 + 0.2612} \right] \right\} \times 10^6$$

$$= 0.2814 \times 10^6 \text{ AT/Wb}$$

$$\varphi_2 = \frac{N_2 \cdot I}{S_T} = \frac{1000 \times 1}{0.2814 \times 10^6}$$

$$= 3.5526 \times 10^{-3} \text{ Wb}$$

$$L_{22} = \frac{N_2 \varphi_2}{I} = \frac{1000 \times 3.5526 \times 10^{-3}}{1}$$

$$= 3.552 \text{ H}$$

$$M_{21} = M_{12} = 0.645 \text{ H}$$

20. [The direction of \ such.]

Calculate the force experienced by the conductor of 20 cm long, carrying 50 amperes, placed at right angles to the lines of force of flux density 10×10^{-3} wb/m

<u>Solution:</u>

Given: $F = BIl \sin\theta$

where $\sin(\theta) = 1$. $[\theta = 90^\circ]$

B = Flux density $= 10 \times 10^{-3}$ wb/m^2

l – Active length = 20 cm = 0.2 m

I – Current = 50 A

$F = 10 \times 10^{-3} \times 50 \times 0.2$

$= 0.1$ N.

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21. A coil is wound on an iron core to form a solenoid. A certain current is passed through the coil which is producing a flux of 40 μwb. The length of magnetic circuit is 75 cm, while its cross-sectional area is 3 cm^2. Calculate the energy stored in the circuit. Assume relative permitivity of iron as 1500.

Solution:

$l = 75\,cm = 0.75\,m$

$a = 3\,cm^2 = 3\times10^{-4}\,m^2$

$\phi = 40\,\mu Wb = 40\times10^{-6}\,Wb$, $\mu_r = 1500$

$$B = \frac{\phi}{a} = \frac{40\times10^{-6}}{3\times10^{-4}} = 0.133\ Wb/m^2$$

Energy stored per unit volume,

$$\frac{1}{2}\frac{B^2}{\mu} = \frac{1}{2}\frac{B^2}{\mu_0\mu_r} = \frac{1}{2}\frac{(0.133)^2}{4\times\pi\times10^{-7}\times1500}$$

$$= 4.7157\ J/m^3$$

Total energy stored = Energy per unit volume $\times$ Volume

$$= E\times(a\times l)$$

$$= 4.7157\times(3\times10^{-4}\times0.75)$$

$$= 0.00106\ \text{joules.}$$

Q2. In the magnetic circuit considered if $\mu_r = 2000$ then determine,

a) Energy stored in the core and air gap if exciting current is 5A.

b) Exciting current to produce a sinusoidally varying flux of $0.5 \sin 314t$:

c) Inductance of the coil.

<u>Solution</u> :

$\mu_r = 2500$

$a_c = 20 \times 10^{-4}\ m^2$, $l_c = 55 \times 10^{-2}\ m$, $a_g = 20.91 \times 10^{-4}\ m^2$

$l_g = 0.1 \times 10^{-2}\ m$.

$$S_c = \frac{l_c}{\mu_0 \mu_r a_c} = 87.535 \times 10^3 \ AT/Wb$$

$$S_g = \frac{l_g}{\mu_0 a_g} = 380.571 \times 10^3 \ AT/Wb$$

$$S_T = S_c + S_g$$

$$= 468.1065 \times 10^3 \ AT/Wb$$

(c) New current, $I = 5A$

$$\phi = \frac{NI}{S_T} = \frac{200 \times 5}{468.1065 \times 10^3} = 2.1362 \times 10^{-3}\ Wb$$

$$\text{Energy / unit volume} = \frac{1}{2} \frac{B^2}{\mu}$$

$$\therefore \text{Energy stored in core} = \frac{1}{2} \frac{B_c^2}{\mu_0 \mu_r} \times a_c l_c$$

$$B_c = \frac{\phi_c}{a_c}$$

$$= \frac{1}{2}\left[\frac{\varphi_c}{a_c}\right]^2 \times \frac{1}{\mu_0 \mu_r} \times a_c l_c$$

$$= \frac{\varphi_c^2 \, l_c}{2 \mu_0 \mu_r \, a_c}$$

$$= \frac{(2.1362 \times 10^{-3})^2 \times 55 \times 10^{-2}}{2 \times 4\pi \times 10^{-7} \times 2500 \times 20 \times 10^{-4}}$$

$$= 0.2 \, J$$

Energy stored in air gap $= \frac{1}{2} \frac{B_g^2}{\mu_0} \times a_g l_g$

$$B_g = \frac{\varphi_g}{a_g}$$

$$= \frac{1}{2} \times \left[\frac{\varphi_g}{a_g}\right]^2 \times \frac{1}{\mu_0} \times a_g l_g$$

$$= \frac{1}{2} \frac{\varphi_g^2 \, l_g}{\mu_0 \, a_g}$$

$$= \frac{1}{2} \times \frac{(2.1362 \times 10^{-3})^2 \times 0.1 \times 10^{-2}}{4\pi \times 10^{-7} \times 20.91 \times 10^{-4}}$$

$$= \underline{0.8683 \, J}$$

b) $\varphi = \varphi_m \sin \omega t$ $\qquad \varphi_m = 0.5 \, Wb$

$$\varphi_m = \frac{N I_m}{S_T} \qquad 0.5 = \frac{200 \times I_m}{468.1065 \times 10^3}$$

$I_m = 1.1702$

$i = I_m \sin \omega t = 1.1702 \sin 314t$ A

c) $L = \frac{N^2}{S_T} = \frac{(200)^2}{468.1065 \times 10^3}$

$= 0.0855$ H.

23.) The field winding of dc electromagnets is wound with 800 turns and has a resistance of 40Ω when exciting voltage is 230 volts, magnetic flux around the coil is 0.004 Wb. Calculate self inductance and energy stored in magnetic field.

Solution:

$N = 800$; $R = 40\Omega$, $V = 230$ V, $\varphi = 0.004$ Wb

$I = \frac{V}{R} = \frac{230}{40} = 5.75$ A

$L = \frac{N\varphi}{I} = \frac{800 \times 0.004}{5.75} = 0.5565$ H

$E = \frac{1}{2} L I^2 = \frac{1}{2} \times 0.5565 \times (5.75)^2$

$= 9.199$ J.

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