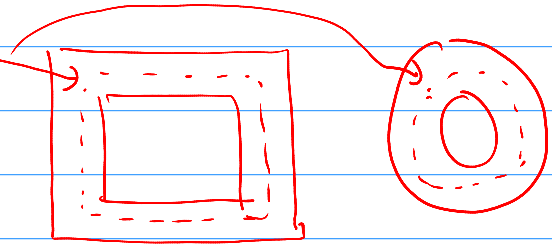
$$I_{avg} = \frac{2}{\pi} I_{max}$$

$$E_{avg} = \frac{2}{\pi} E_{max}$$

Formulas :

① $R_{el} = \dfrac{l}{\mu_0 \mu_r A}$, l = mean length of iron core $= \dfrac{l_{outer} + l_{inner}}{2}$



(dotted length)

② $mmf = NI$

③ $\phi = \dfrac{mmf}{R_{el}}$

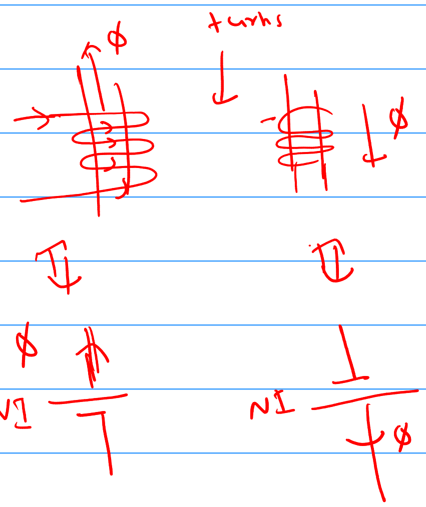
④ $B = \phi / A$ flux density

⑤ $H = \dfrac{NI}{l}$ mag field strength

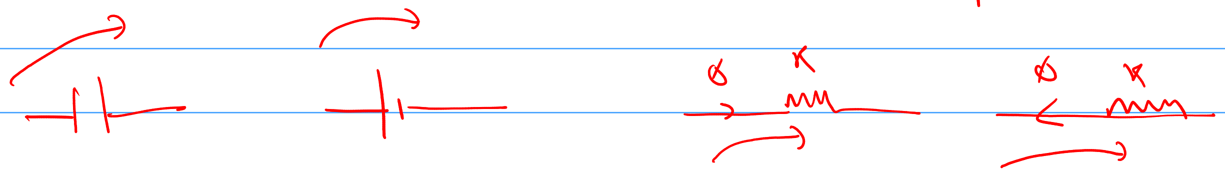
⑥ Self inductance $(L) = \dfrac{\phi}{I} = \dfrac{N^2 A \mu_0 \mu_r}{l}$

For air gap $\mu_r = \mu_g = 1$

Equivalent ckt of turns



KVL



$= +NI$ $\quad = -NI$ $\quad = -\phi \times R$ $\quad = \phi \times R$

ex: $NI - NI - \phi \times R + \phi \times R = 0$

flux linkage $= N\phi$

If leakage factor given

$\phi' =$ leakage factor $\times \phi$

$e = L\dfrac{di}{dt} = N\dfrac{d\phi}{dt}$

$= Blv$

$F = BIL$

In ring problems

mean length $(l) = 2\pi R$ ← mean radius is given

① A magnetic ckt with a single air gap is hown below.

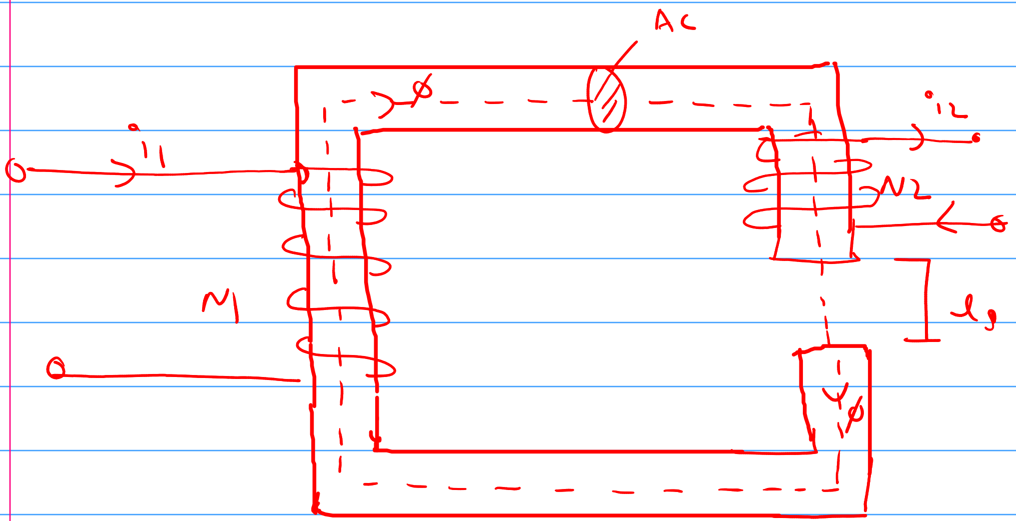
$A_c = 1.8 \times 10^{-3}\ m^2$, $\mu_r = 2000$

$l_c = 0.6\ m$

$l_g = 2.3 \times 10^{-3}\ m$

$N_1 = 83$ turns

$N_2 = 20$ turns

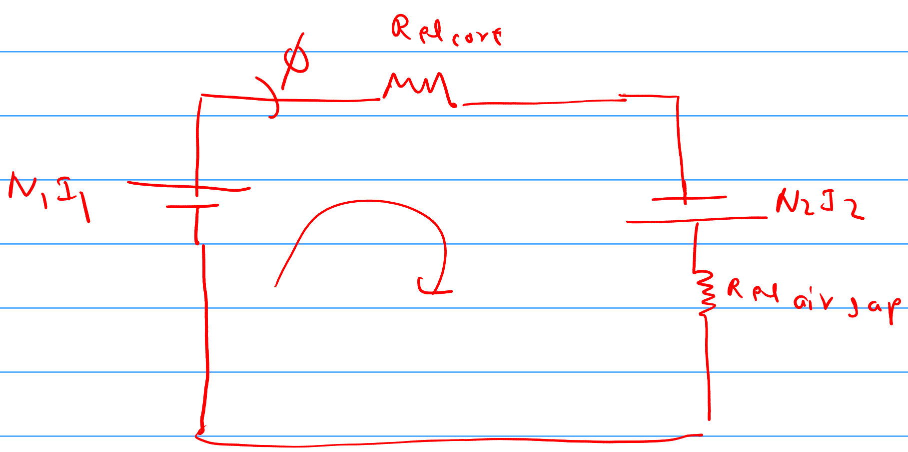


(i) calc rel of core and the gap with $i_1 = 1.5A$ and $i_2 = 1.25A$

(ii) calc total flux ϕ

Soln ÷

equivalent ckt



$$Rel_{core} = \frac{l_c}{\mu_0 \mu_r A_c} = \frac{0.6}{4\pi \times 10^{-7} \times 2000 \times 1.8 \times 10^{-3}}$$

$$= 132629.1172 \text{ A-turn/wb}$$

$$Rel\ gap = \frac{l_g}{\mu_0 \mu_g A_c} = \frac{l_g}{\mu_0 A_g} = \frac{2.3 \times 10^{-3}}{4\pi \times 10^{-7} \times 1.8 \times 10^{-3}}$$

$(\mu_r = \mu_g = 1)$

$$= 1016823.248 \text{ A-t/wb}$$

flux is flowing from upwards so upwards area

Now,

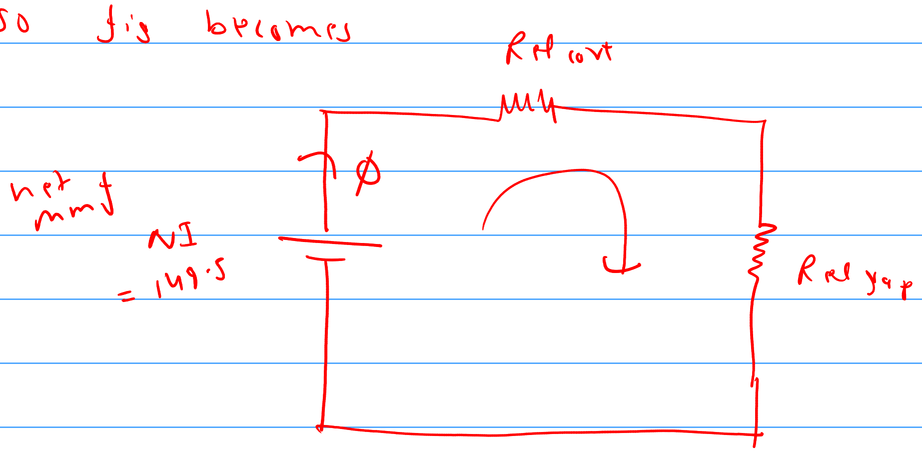
Since two ϕ are produce due to different coils then,

$mmf_1 = N_1 I_1 = 83 \times 1.5 = 124.5$ AT (↻)

$mmf_2 = N_2 I_2 = 20 \times 1.25 = 25$ AT (↻)

net mmf $= 124.5 + 25 = 149.5$ AT (↻)

So fig becomes



Using KVL

$$Mg.5 - R_{el\,core} \times \phi - R_{el\,gap} \times \phi = 0$$

or $$\phi = \frac{149.5}{R_{el\,core} + R_{el\,gap}} = \frac{149.5}{132629.1192 + 1016823.248}$$

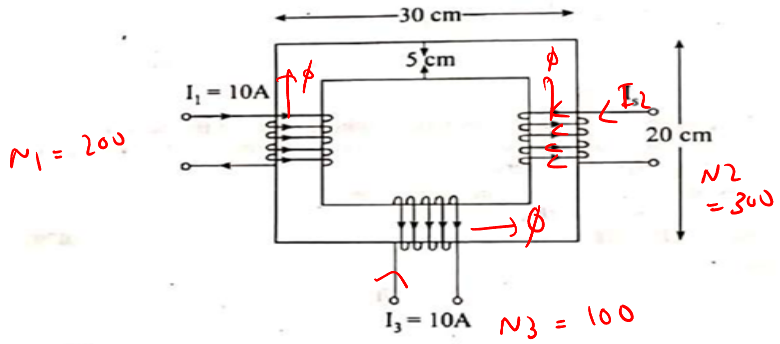
$$= 1.3 \times 10^{-4}\ wb$$

---

(2)

Calculate the magnetic flux in the core of the following magneti circuit and show the direction of magnetic flux in the core. Giver that cross-sectional area at the core is 25 sq. cm and $\mu_r = 4000$.

Solution:



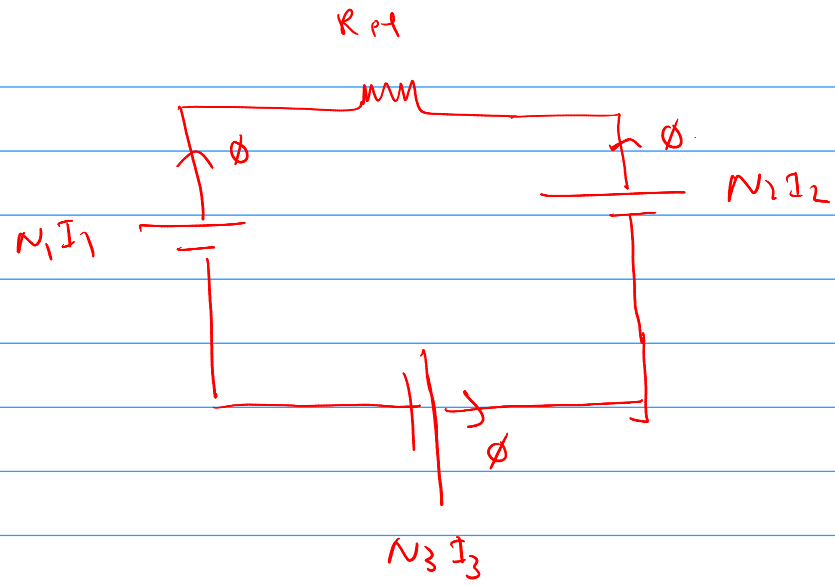
(hand → current
thumb → flux)
right hand

Soln :-

3 ϕ is produced here due to 3 coils so,

(Incomplete data in question, $N_1 = 200$, $N_2 = 300$, $N_3 = 100$, $I_1 = 10$, $I_2 = 15$, $I_3 = 10A$)

Equivalent ckt :



$mmf(1) = N_1 I_1 = 200 \times 10 = 2500$ AT (↷)

$mmf(2) = N_2 I_2 = 300 \times 15 = 4500$ AT (↶)

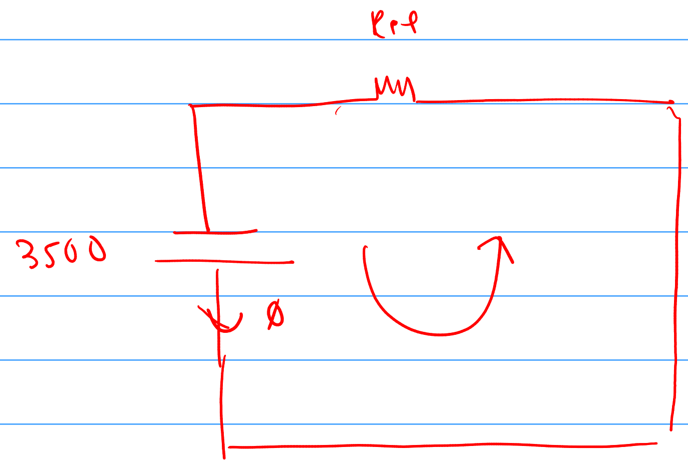
$mmf(3) = N_3 I_3 = 100 \times 10 = 1000$ AT (↶)

net mmf $= 2500 - 4500 - 1000$

$= -3500$ AT

$= 3500$ AT (↶)

Sq

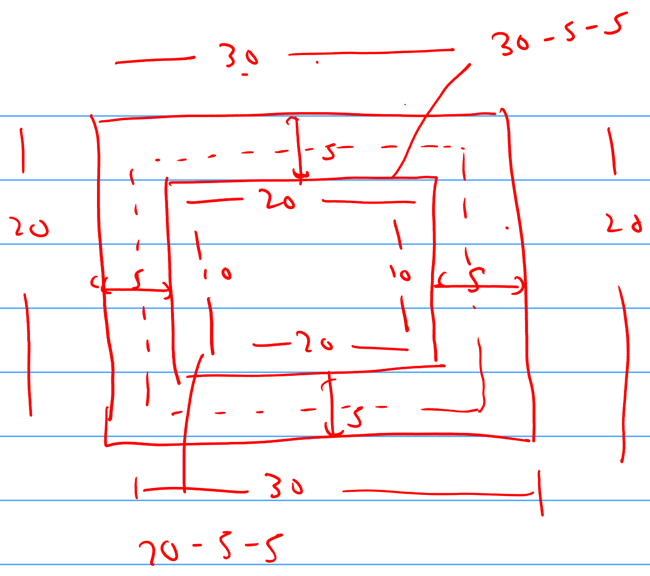


KVL

$3500 - \phi \times R_{et} = 0$

(core)

cm



or $\dfrac{3500}{R_{eq}} = \phi$

or $\phi = \dfrac{3500}{\left(\dfrac{l}{\mu_0 \mu_r A}\right)}$

$A = 25 \times 5 \times \text{cm}$

$= 25 \text{ cm}^2$

$= \dfrac{25}{100 \times 100} = 2.5 \times 10^{-3} \text{ m}^2$

$l_{mean} = \dfrac{l_{outer} + l_{inner}}{2}$

$= \dfrac{30+30+20+20+20+20+10+10}{2}$

$= 80 \text{ cm}$

$= 0.8 \text{ m}$

$\therefore \phi = \dfrac{3500}{\left(\dfrac{0.8}{4\pi \times 10^{-7} \times 4000 \times 2.5 \times 10^{-3}}\right)}$

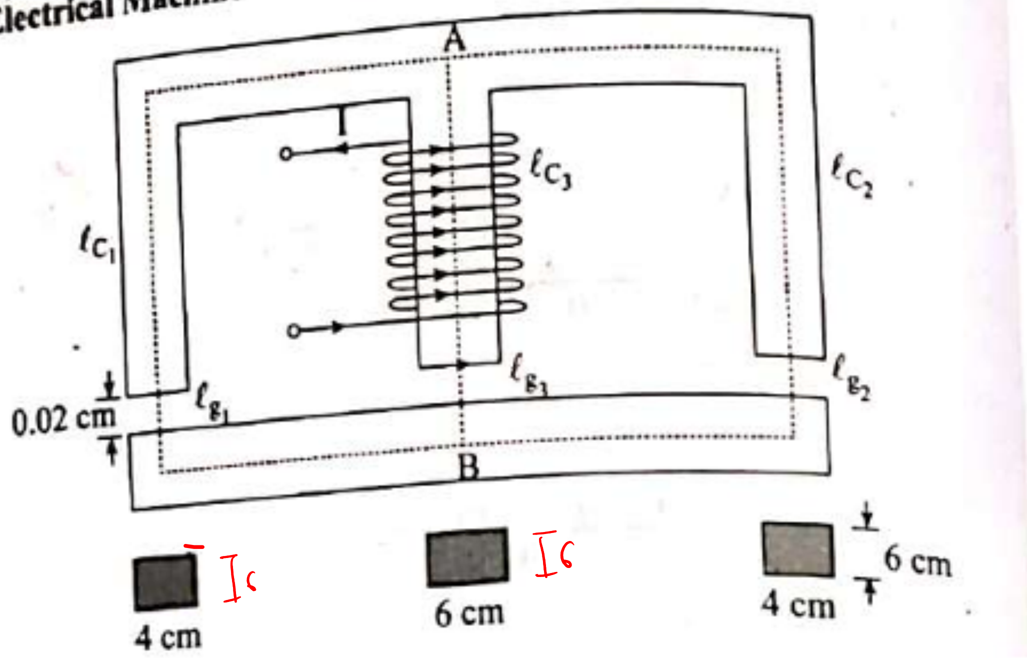
$= 0.054977 \text{ wb}$

The magnetic circuit of a cast steel core as shown in fig:3 has a the following dimension:

Mean length from A to B through either outer limb = 0.5 m

Mean length from A to B through central limb = 0.2 m

In the magnetic circuit, determine the mmf required to establish a flux of 0.75 mWb in the air gap of the central limb of the core. Take $\mu_r = 5000$ [2070]



Soln :-

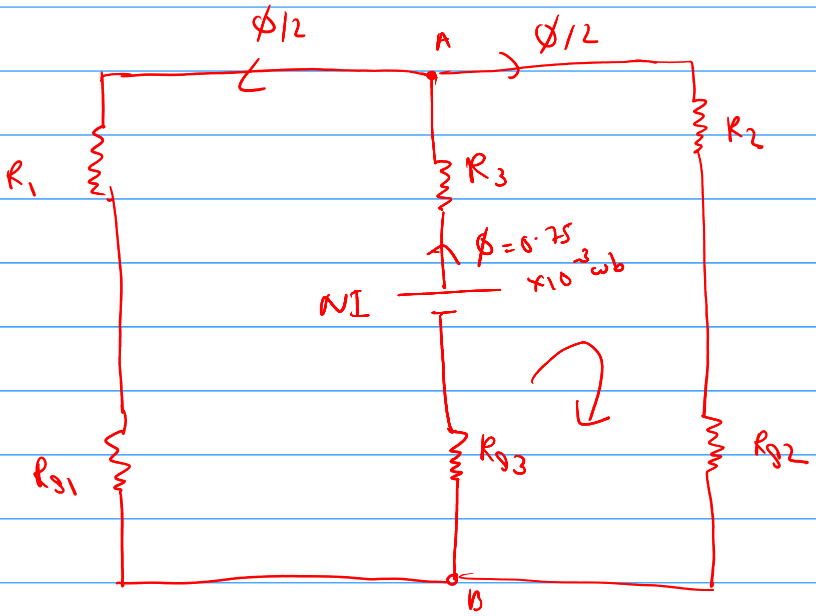
$\phi = 0.75 \times 10^{-3}$ wb, $l_{c1} = 0.5$m, $l_{c2} = 0.5$m, $l_{c3} = 0.2$m

$A_1 = 0.04 \times 0.06 = 2.4 \times 10^{-3}\ m^2$ $\quad A_2 = A_1 = 2.4 \times 10^{-3}\ m^2$

$A_3 = 0.06 \times 0.06 = 3.6 \times 10^{-3}\ m^2$

$l_{g1} = l_{g2} = l_{g3} = 0.02 \times 10^{-3}\ m$

equivalent ckt :



$A_1 = A_2$

So ϕ is divided in half

$$— (i)$$

oy $NI - \phi R_3 - \frac{\phi}{2} R_2 - \frac{\phi}{2} R_{g2} - \phi R_{g3} = 0$

Now,

$$R_3 = \frac{l_{c3}}{\mu_0 \mu_r A_3} = \frac{0.2}{4\pi \times 10^{-7} \times 3.6\times10^{-3} \times 5000} = 8841.941 \text{ AT/wb}$$

$$R_2 = \frac{l_{c2}}{\mu_0 \mu_r A_2} = \frac{0.5}{4\pi\times10^{-7} \times 5000 \times 2.4\times10^{-3}} = 33157.27981 \text{ AT/wb}$$

$$R_{g2} = \frac{l_{g2}}{\mu_0 A_2} = \frac{0.02\times10^{-2}}{\mu_0 \times 2.4\times10^{-3}} = 66314.55 \text{ AT/wb}$$

$(\mu_r = 1)$

$$R_{g3} = \frac{l_{g3}}{\mu_0 A_3} = \frac{0.02\times10^{-2}}{\mu_0 \times 3.6\times10^{-3}} = 44209.70641 \text{ AT/wb}$$

Using (i)

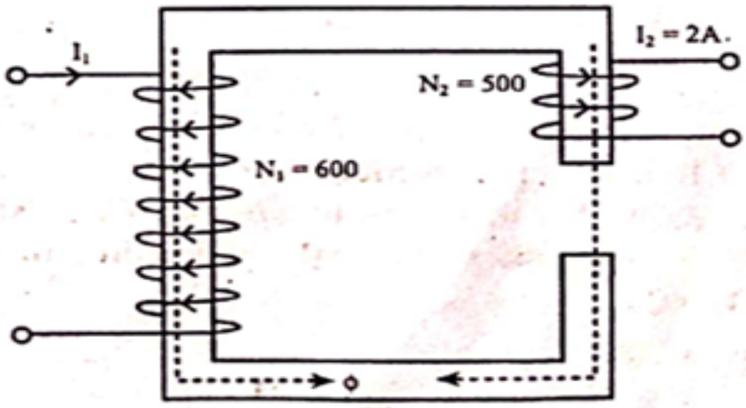
$$NI = \phi \left(R_3 + \frac{1}{2} R_2 + \frac{1}{2} R_{g2} + R_{g3} \right)$$

$$= 0.75\times10^{-3} \left(8841.94 + \frac{1}{2} \times 33157.27981 + \frac{1}{2} \times 66314.55 \right.$$

$$\left. + 44209.70641 \right)$$

$$= 77.0906 \text{ AT} \quad \#$$

0 For the magnetic circuit shown below, Calculate the value of current 'I' required to produce a magnetic flux density of 1.2 Tesla.



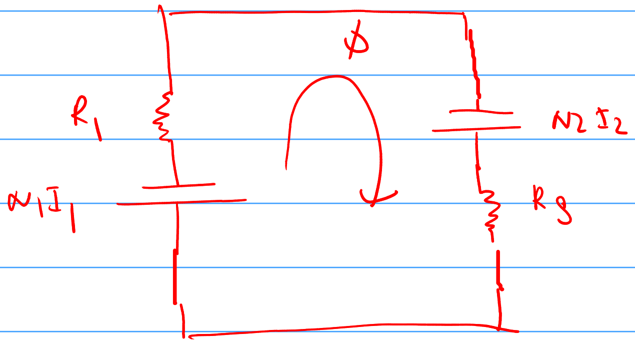
soln ÷

$A = 16\,cm^2$

$l_g = 0.06\,cm$

$l_c = 40\,cm$

$\mu_r = 6000$



$\phi = BA$

$= 1.2 \times 16 \times 10^{-4}$

$= 19.2 \times 10^{-4}$

$$R_1 = \frac{l_1}{\mu_0 \mu_r A_1} = \frac{40 \times 10^{-2}}{\mu_0 \times 6000 \times 16 \times 10^{-4}} = 33157.27\ AT/wb$$

$$R_g = \frac{l_g}{\mu_0 A_g} = \frac{0.06 \times 10^{-2}}{\mu_0 \times 16 \times 10^{-4}} = 298415.5183\ AT/wb$$

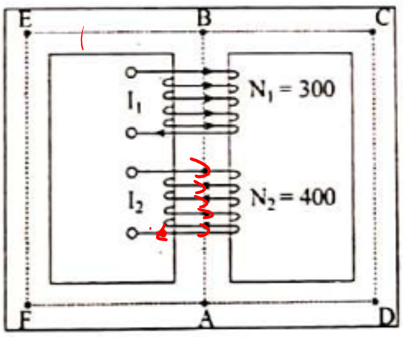
KVL

$$N_2 I_2 - \phi R_g - N_1 I_1 - \phi R_1 = 0$$

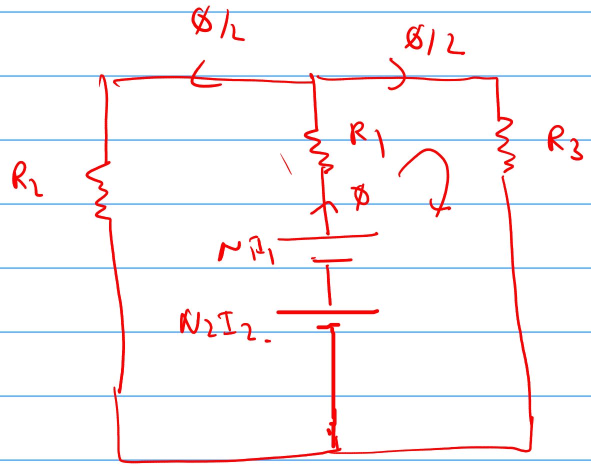
or $1000 - \phi \times 298415.5183 - 600 \times I_1 - \phi \times 33157.27 = 0$

$\therefore$ $I_1 = 0.6056\,A$ #

Magnetic circuit shown in figure below, find out the current to be passed through the coil B so that magnetic flux in CD section is 2mWb, Given $\mu_r = 1000$.
Given, $I_2 = 3A$, $A_1 = 6\ cm^2$, $A_2 = 3\ cm^2$
AB = CD = EF = 20 cm
BC = AD = BE = AF = 20 cm [2070]



soln :-



$A_2 = A_3$, ϕ is divided in $\phi/2$

$\phi/2 = 2\times10^{-3}\ wb$, $\phi = 4\times10^{-3}\ wb$

$l_1 = 20\times10^{-2}\ m$ $\quad l_3 = 60\times10^{-2}\ m$

$A_1 = 6\ cm^2$ $\quad A_2 = 3\times10^{-4}\ m^2$

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

Now,

$$N_1 I_1 - R_1 \times \phi - \frac{\phi}{2} \times R_3 + N_2 I_2 = 0$$

or,

$$300 \times I_1 + 400 \times 3 = 4 \times 10^{-3} \left(R_1 - \frac{R_3}{2} \right)$$

$$R_1 = \frac{l_1}{\mu_0 \mu_r A_1} = \frac{20 \times 10^{-2}}{4\pi \times 10^{-7} \times 1000 \times 6 \times 10^{-4}} = 265258.2385$$

$$R_3 = \frac{l_3}{\mu_0 \mu_r A_3} = \frac{60 \times 10^{-2}}{4\pi \times 10^{-7} \times 1000 \times 3 \times 10^{-4}} = 1591549.431$$

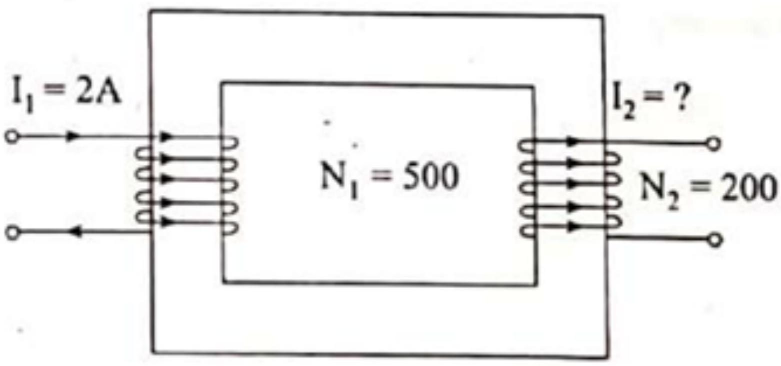
So

$$I_1 = -11.07\,A$$

$$\boxed{I = 11.07\,A}$$

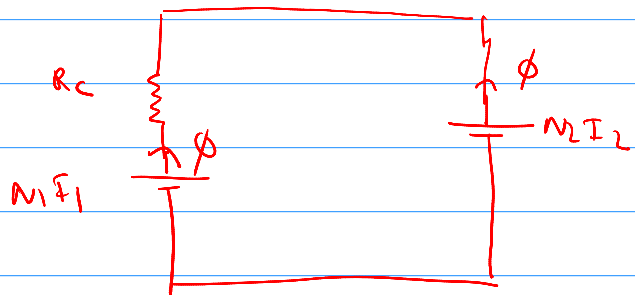
In figure given below, calculate value of I_2 required to establish a magnetic flux density of 1.2 Wb/m² in the core given, $\mu_r = 600$, the mean length of core 40 cm, area of core is 16 sq. cm.

ition:



Given

Soln ÷



$$mmf(1) = N_1 I_1 = 500 \times 2 = 1000 \text{ AT}$$

$$mmf(2) = N_2 I_2 = 200 I_2$$

$$\text{net } mmf = 1000 - 200 I_2$$

$$B = 1.2 \text{ wb/m}^2 \qquad \phi = BA = 1.2 \times 16 \times 10^{-4}$$

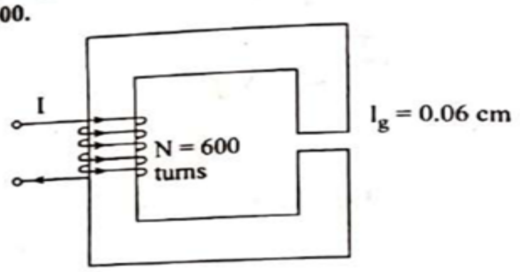
$$= 19.2 \times 10^{-4} \text{ wb}$$

$$\phi = \frac{mmf}{R_{eq}} = \frac{1000 - 200 I_2}{\frac{0.4}{\mu_0 \times 600 \times 16 \times 10^{-4}}}$$

$$19.2 \times 10^{-4} = \frac{1000 - 200 I_2}{\left(\frac{0.4}{\mu_0 \times 600 \times 16 \times 10^{-4}}\right)}$$

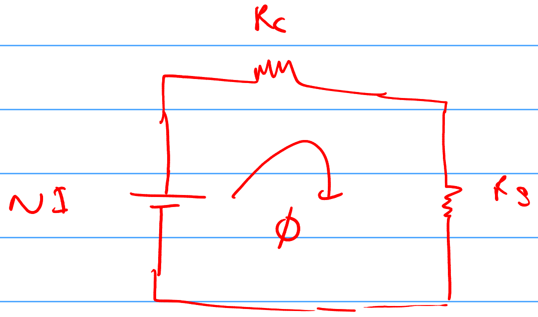
$$\therefore \quad I_2 = 1.82 \text{ A} \quad \#$$

For the magnetic circuit shown below calculate the value of current 'I' required to produce a magnetic flux density of 1.2 Tesla. Given that cross-sectional area of the core is 16 sq. mm, air gap length (ℓ_g) = 0.60 cm and length of core (ℓ_c) = 40 cm. Take $\mu_r = 6000$. [2075]



Soln ÷

$B = 1.2T$, $\phi = BA = 1.2 \times 16 \times 10^{-4}$
$= 19.2 \times 10^{-4}$ wb



Now,

$NI - R_c \times \phi - \phi \times R_g = 0$

or, $600 \times I = 19.2 \times 10^{-4} (R_c + R_g)$

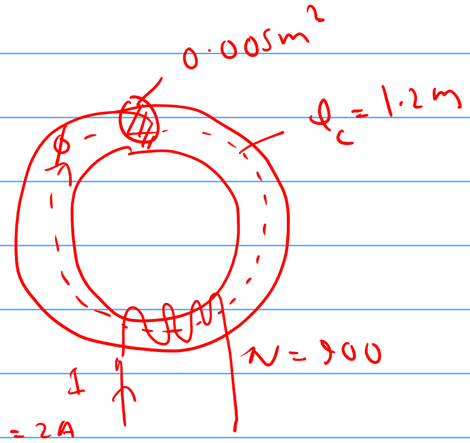
or, $600 \times I = 19.2 \times 10^{-4} \left(\dfrac{0.4}{\mu_0 \times 6000 \times 16 \times 10^{-4}} + \dfrac{0.6 \times 10^{-2}}{\mu_0 \times 16 \times 10^{-4}} \right)$

$\therefore$ $I = 9.65$ A #

An iron ring of mean length 1.2 m and cross sectional area of 0.005 m^2 is wound with a coil of 900 turns. If a current of 2 A in the coil produces a flux density of 1.2 T in the iron ring, calculate:

i) The mmf
ii) Total flux in the ring
iii) The magnetic field strength
iv) The relative permeability of iron at this flux density [2069]

Soln:



$B = 1.2T$, $I = 2A$, $N = 900$

$l_c = 1.2m$ $A_c = 0.005 m^2$

(i) $mmf = NI = 900 \times 2$

$= 1800 \, AT$

(ii) $\phi = BA_c = 1.2 \times 0.005 = 6 \times 10^{-3} wb$

(iv) mag field strength $(H) = \frac{NI}{l_c} = \frac{900 \times 2}{1.2} = 1500 \, AT/m$

(v) $\mu r = ?$

$$\phi = \frac{mmf}{Rel} = \frac{1800}{\left(\frac{l_c}{\mu_0 \mu_r A_c}\right)}$$

or, $$6 \times 10^{-3} = \frac{1800}{\left(\frac{1.2}{\mu_0 \times \mu_r \times 0.005}\right)}$$

$\therefore \mu r = 636.619$

An iron ring has a mean length of 1.5 m and cross-sectional area of 0.01 m^2. It has a radial air gap of 4mm. The ring is wound with 250 turns. What dc current would be needed in the coil to produce a flux of 0.8 weber in the air gap? Assume that μ_r=400 and leakage factor is 1.25.

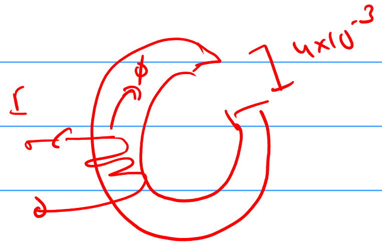
Soln:

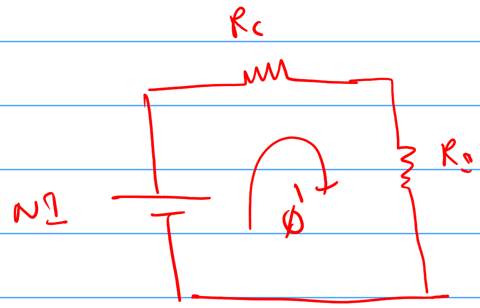
$l_c = 1.5m$, $A_c = 0.01 m^2$, $l_g = 4 \times 10^{-3} m$, $N = 250$

$I = ?$, $\phi = 0.8 wb$, $\mu_r = 400$, $leakage = 1.25$

So

new flux $\phi' = 1.25 \times 0.8 = 1 wb$





or $NI - \phi(R_c + R_g) = 0$

or $250 I = 1 \left(\frac{l_c}{\mu_0 \mu_r A_c} + \frac{l_g}{\mu_0 A_c} \right)$

or $250 I = \left(\frac{1.5}{\mu_0 \times 400 \times 0.01} + \frac{4 \times 10^{-3}}{\mu_0 \times 0.01} \right)$

$\therefore I = 2.46 \times 10^3 A$ #

A 30 cm long circular iron rod in bend into circular ring and 600 turns of winding are round on it. The diameter of the rod is 20mm and relative permeability of the iron is 40.00. A time varying current (i=5 sin314.16 t) is passes through the winding. Calculate the inductance of the coil and value of emf induced in the coil.

Soln ÷

$l = 30 \times 10^{-2} m$, $N = 600$, $\mu_r = 4000$, $d = 20 \times 10^{-3} m$

$i = 5 \sin 314.16 t$

$L = ?$ $e = ?$

Now,

$$A = \pi r^2 = \pi \frac{d^2}{4} = \frac{\pi \times (20 \times 10^{-3})^2}{4} = 3.14 \times 10^{-4} m^2$$

$$\text{Inductance } (L) = \frac{N^2 \mu_0 \mu_r A}{l} = \frac{600^2 \times \mu_0 \times 4000 \times 3.14 \times 10^{-4}}{30 \times 10^{-2}}$$

$$= 1.89496$$

$i = 5 \sin 314.16 t$

$$e = L \frac{di}{dt} = 1.89 \times \frac{d}{dt}(5 \sin 314.16 t)$$

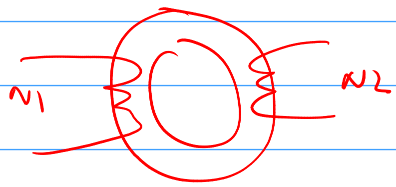
$$= 1.89 \times 5 \times 314.16 \cos 314.16°$$

$$= 2968.812 \cos 314.16°$$

$e_{peak} = 2968.812 V$

$\therefore\ e_{avg} = \frac{2}{\pi} \times 2968.812 = 1889.99\,V$

\# A circular iron core has a cross-sectional area of 5 sq cm and mean length of 15 cm. It has two coils A and B with 100 turns and 500 turns. The current in coil A is changed from 2m to 10A in 0.1 s. Calculate emf induced in coil B. $\mu_r = 3000$.



$A = 5 \times 10^{-4}\,m^2$

$l = 15 \times 10^{-2}\,m$

$N_1 = 100$, $N_2 = 500$

$\frac{di}{dt} = \frac{10}{0.1} = 100\,A/s$ $\quad \mu_r = 3000$

2 ko emf 2 ko kasari le garda nikalne so,

Now, $L = \frac{N^2 \mu_0 \mu_r A}{l} = \frac{500^2 \times \mu_0 \times 3000 \times 5 \times 10^{-4}}{15 \times 10^{-2}}$

$= 0.47$

$e = L\frac{di}{dt} = 0.47 \times 100 = 47.12\,V$ #

A wrought iron bar of 30 cm long and 2 cm diameter is bent into a circular shape as shown in fig:2. It is then wound with 600 turns of wire. Calculate the current required to produce a flux of 0.4 mWb in the magnetic circuit for the following cases:

i) With no air gap

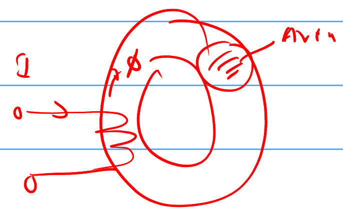
ii) With air gap of 1 mm, μ_r=4000 [2075]

Soln:

$l_c = 0.3\,m$, $A_c = \frac{\pi d^2}{4} = \frac{\pi}{4} \times 0.02^2 = 3.14 \times 10^{-4} m$

$N = 600$, $\phi = 0.4 \times 10^{-3}\,wb$

(i) no air gap



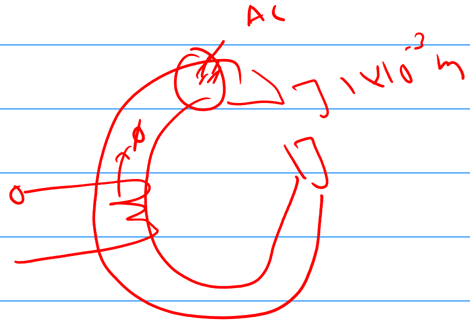
$$\phi = \frac{NI}{\frac{l_c}{\mu_0 \mu_r A_c}}$$

or, $\phi \times \frac{l_c}{\mu_0 \mu_r A_c} = NI$

or, $0.4 \times 10^{-3} \times \frac{0.3}{\mu_0 \times 4000 \times 3.14 \times 10^{-4}} = 600\,I$

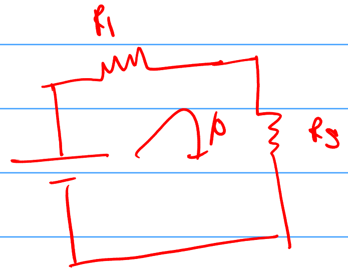
so, $I = 0.126\,A$

case II, air gap of $1 \times 10^{-3}\,m$



or $NI = \phi(R_1 + R_g)$

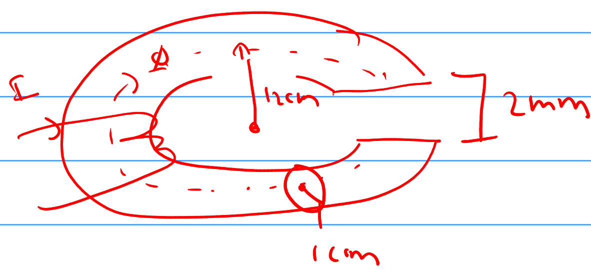
or $600I = 0.4\times10^{-3}\left(\frac{0.3}{\mu_0\times4000\times3.14\times10^{-4}} + \frac{1\times10^{-3}}{\mu_0\times3.14\times10^{-4}}\right)$ ($\mu_r = 1$ for air gap)



$\therefore$ $I = 1.816$ A #

A steel ring 12 cm mean radius and of circular cross section of 1 cm radius air gap = 2 mm. $N = 550$, $I = 3A$. Calculate B, $\mu_r = 80$.

solution,



$l_g = 2\times10^{-3}$ m

$A_c = \pi r^2 = \pi\times\left(\frac{1}{100}\right)^2$

$= 3.1415\times10^{-4}$ m^2

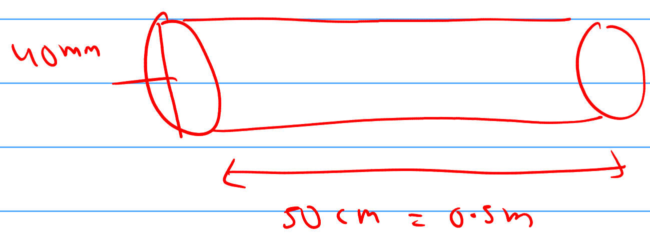
$l_c = 2\pi R$ mean radius $= 2\pi\times\frac{12}{100} = 0.7539$ m now $\phi = \frac{NI}{R_c + R_g} = \frac{550 \times 3}{\frac{1}{\mu_0 A_c}\left(\frac{l_c}{\mu_r} + l_g\right)}$

$$\phi = \frac{550 \times 3}{\frac{1}{\mu_0 \times 3.1415 \times 10^{-4}}\left(\frac{0.7538}{80} + 2 \times 10^{-3}\right)}$$

$$\phi = 5.701 \times 10^{-5}\ wb$$

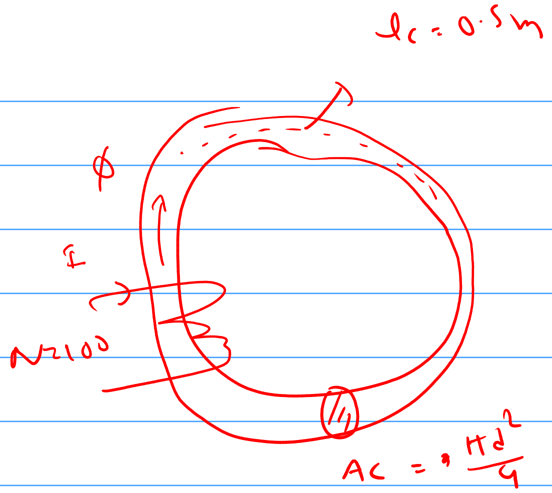
so, $B = \frac{\phi}{A_c} = 0.18\ wb/m^2 \,/\, T$

\# A 50 cm long iron rod is bent into circular ring and 100 turns of windings are wond on it. diameter of rod is 40mm, $\mu_r = 5000$. calculate inductance of coil. If a time varying current is passed through the coil whose mag changes from 2A to 10A in 5ms. Calculate average emf.



$$A_c = \frac{\pi d^2}{4} = \frac{\pi \times (40\times10^{-3})^2}{4}$$

$$= 1.2566 \times 10^{-3}\ m^2$$



$$L = \frac{N^2 \mu_0 \mu_r A_c}{l_c}$$

$$= \frac{100^2 \times 4\pi\times10^{-7} \times 5000 \times 1.2566\times10^{-3}}{0.5}$$

$$= 0.15790$$

$$e = L\frac{di}{dt} = 0.15 \times \frac{(10-2)}{5\times10^{-3}} = 240\,V \text{ (Peak)}$$

$$e_{avg} = \frac{2}{\pi}\times 240 = 152.78\,V \ \#$$