B.E ECE/ETE - CONTINUOUS INTERNAL ASSESSMENT - I

ELECTRICAL ENGINEERING.

ANSWER KEY.

A1. Fill the blank, 1 weber = $\underline{10^8}$ lines of force.

A2. MAGNETIC FLUX DENSITY:

The flux per unit area (a) in a plane at right angles to the flux is known as flux density.

$$B = \frac{\phi}{a} \left(\frac{Wb}{m^2}\right)$$

MAGNETIC FIELD STRENGTH:

The force experienced by a unit N-Pole (i.e N Pole with 1 wb of Pole strength) when placed at a point in a magnetic field is known as magnetic field strength at that point.

A3. FLEMING'S LEFT HAND RULE:

The rule states that, "outstretch the three fingers of the left hand namely the first finger, middle finger and thumb such that they are mutually ⊥r to each other, now the first finger points the direction of magnetic field, the middle finger points the direction of current, the thumb gives the direction of force experienced by the conductor."

A4. $F = BIl\sin\theta$ where $\sin(\theta) = 1$ as $\theta = 90°$ [given] (1)

$B = 10\times10^{-3}\ Wb/m^2$

$l = 20cm = 0.2m$.

$I = 50A$

$$\boxed{F = 10\times10^{-3}\times0.2\times50 = 0.1N}$$ (1)

A5. Reluctance $= \frac{MMF}{Flux} = \frac{NI}{\phi}$ (AT/Wb)

A6. $I = 2A$

$N = 15$

$d = 10\,cm = 0.1\,m$

$H = \frac{NI}{2\pi d} = \frac{15 \times 2}{2 \times \pi \times 0.1} = 47.74\ AT/m$ (1) (1)

A7. Permeability of free space or Vacuum:

If the magnet is placed in a free space or vacuum or in air then the ratio of flux density B and magnetic field strength H is called permeability of free space or vacuum or air.

$$\boxed{\mu_0 = \frac{B}{H} = 4\pi \times 10^{-7}\ H/m}$$

A8.

Dynamically induced e.m.f	statically induced e.m.f.
E.M.F which is due to physical movement of coil, conductor w.r.to flux or movement of magnet w.r.to stationary coil is called Dynamically induced emf.	The ~~flux~~ change in flux lines w.r.to coil can be acheived without physically moving the coil or magnet is called statically induced e.m.f.

A9. LENZ'S LAW:

The direction of an induced e.m.f produced by the electromagnetic induction is such that it sets up a current which always opposes the cause that is responsible for inducing the e.m.f.

A10. Self Inductance $L = \frac{N\phi}{I}$ (1)

Mutual Inductance $M = \frac{N_2 \phi_2}{I_1}$ (1)

$M = \frac{K N_1 N_2}{S}$

B1)

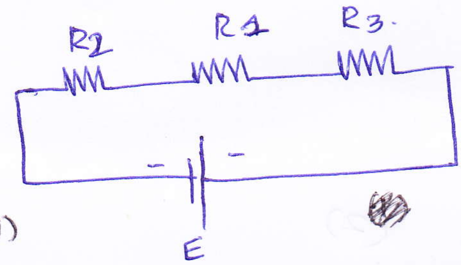
a)

(i) consider a circular ring made up of different materials of lengths l_1, l_2 and l_3 and with cross-sectional areas a_1, a_2 and a_3 with absolute permeabilities μ_1, μ_2 and μ_3 as shown below.

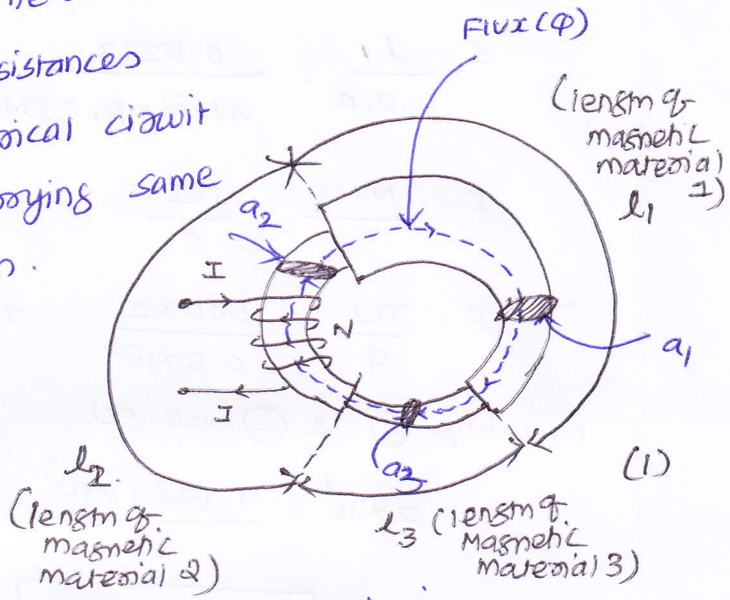
The Total MMF avalidble is $= NI$ (AT).

This flux 'φ' which is same thro' all the three elements of the circuit.

This is similar to three resistances connected in series in electrical circuit and connected to e.m.f carrying same current I thro' all of them.



(1)



(1)

The TOTal resistance of the electric circuit is $R_1 + R_2 + R_3$. lllly the total reluctance of the magnetic circuit is

$$\text{Total } S_T = S_1 + S_2 + S_3 = \frac{l_1}{\mu_1 a_1} + \frac{l_2}{\mu_2 a_2} + \frac{l_3}{\mu_3 a_3} \quad (1)$$

$$\text{Total } \varphi = \frac{\text{Total mmf}}{\text{Total reluctance}} = \frac{NI}{S_T}.$$

$$\varphi = \frac{NI}{(S_1+S_2+S_3)} \quad (1)$$

$$NI = (S_1+S_2+S_3)\varphi$$

$$\Rightarrow (MMM)_T = (MMF)_1 + (MMF)_2 + (MMF)_3 \quad (1)$$

$$= H_1 l_1 + H_2 l_2 + H_3 l_3.$$

$$\text{where } H_1 = \frac{B_1}{\mu_1}, \; H_2 = \frac{B_2}{\mu_2}; \; H_3 = \frac{B_3}{\mu_3}.$$

explaniations (1)

B1 a)

(ii) Given data:

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

$d = 20\ cm$

$N = 500$

$I = 2A$

$\phi = 0.5\ mWb$

NOW,

$l = \pi d = \pi\times20 = 62.8318 = 0.6283m$.

$S = \frac{l}{\mu_0\mu_r a} = \frac{0.6283}{4\pi\times10^{-7}\times\mu_r\times3\times10^{-4}} = \frac{1.6667\times10^{9}}{\mu_r}$ - (1) (1)

$f = \frac{MMF}{S} = \frac{NI}{S}$ (1)

$S = \frac{NI}{\phi} = \frac{500\times2}{0.5\times10^{-3}} = 2\times10^{6}\ AT/Wb$. - (2) (1)

Equating (1) & (2) we get

$2\times10^{6} = \frac{1.6667\times10^{9}}{\mu_r}$

$\Rightarrow \boxed{\mu_r = 833.334}$ (2)

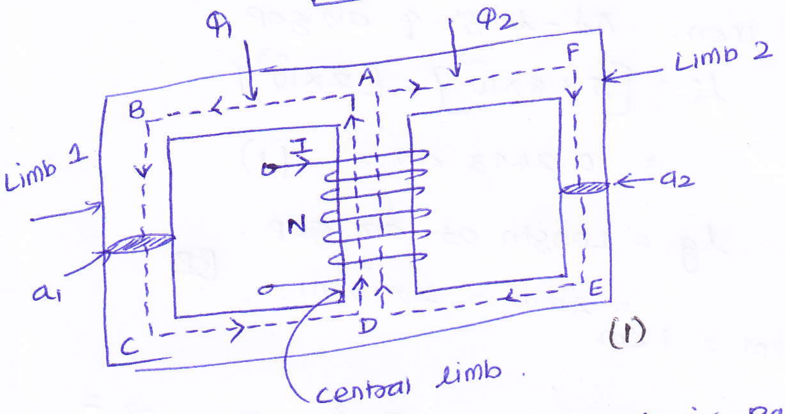
(iii) (4)

ELECTRIC CIRCUIT	MAGNETIC CIRCUIT:
(i) Path traced by the current is called Electric circuit	(i) Path traced by the magnetic flux is called magnetic circuit.
(ii) E.M.F. is the driving force	(ii) MMF is the driving force
(iii) There is current I in electric circuit measured in Amps	(iii) There is flux ϕ in the magnetic circuit measured in webers.
(iv) The flow of electrons decides the current	(iv) The flow of magnetic lines of force decides the flux.
(v) Resistance opposes flow of current	(v) Reluctance is opposed by magnetic path to the flux.
(vi) $R = \rho\left(\frac{l}{a}\right)$	(vi) $S = \frac{l}{\mu_0\mu_r a}$
(vii) $I = \frac{emf}{resistance}$	(vii) $I = \frac{mmf}{reluctance}$.
(viii) $\delta = \frac{I}{a}\ (A/m^2)$	(viii) $B = \frac{\phi}{a}\ (Wb/m^2)$

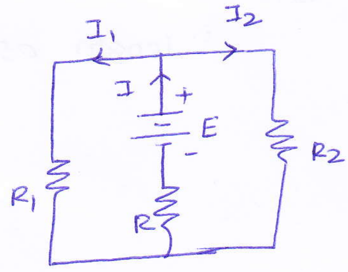
B1) b)

(i) consider a magnetic circuit shown in figure below At Point A the Total flux φ divides into two Parts φ_1 and φ_2.

$$\boxed{\varphi = \varphi_1 + \varphi_2}$$



(1)



(1)

The fluxes φ_1 and φ_2 have their Paths completed thro' ABCD and AFED respectively. This is $\parallel^r$ to division of current in case of Parallel connection of two resistances in an electric circuit as shown in figure above.

The mean length of Path ABCD = l_1 m
" " AFED = l_2 m.
The mean length of Path AD = l_c m (1)
The reluctance of Path ABCD = S_1
" AFED = S_2
" AD = S_c.

The Total mmf Produced = NI (AT)

$$\text{flux} = \frac{\text{mmf}}{\text{reluctance}}$$ explaniations (1).

$$\text{mmf} = \varphi \times S.$$

For Path ABCDA, $NI = \varphi_1 S_1 + \varphi S_c$ } (1)
For Path AFEDA, $NI = \varphi_2 S_2 + \varphi S_c$.

where $S_1 = \frac{l_1}{\mu_1 a_1}$, $S_2 = \frac{l_2}{\mu a_2}$ and $S_c = \frac{l_c}{\mu a_c}$

Generally $a_1 = a_2 = a_c$ = Area of cross section.

$\therefore$ for $\parallel^{el}$ circuit

$$\boxed{\text{Total mmf} = \text{mmf required by central limp} + \text{mmf required by any one of outer limbs}}$$ (1)

$NI = (NI)_{AD} + (NI)_{ABCD}$ (or) $(NI)_{AFED}$.

$NI = \phi S_c + [\phi_1 S_1$ or $\phi_2 S_2]$.

(ii) Given data

Diameter of ring $d = 8\,cm$

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

$$l_i = [\pi \times 8 \times 10^{-2}] - [2 \times 10^{-3}]$$

$$= 0.2493\ cm. \quad (1)$$

l_g = Length of air gap

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

diameter of iron = 1 cm.

$\therefore$ area of cross section $= a = \frac{\pi}{4} d^2 = \frac{\pi}{4}(1 \times 10^{-2})^2$

$$\boxed{a = 7.853 \times 10^{-5}\ m^2} \quad (1)$$

Area of cross section of air gap and ring is to be assumed same.

(i) Total mmf Produced $= NI = 400 \times 3.5 = 1400$ AT (1)

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

$$S_i = \frac{l_i}{\mu_0 \mu_r a} = \frac{0.2493}{4\pi \times 10^{-7} \times 900 \times 7.853 \times 10^{-5}}$$

$$= 2806947.615\ AT/Wb$$

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

$$= \frac{2 \times 10^{-3}}{4\pi \times 10^{-7} \times 7.853 \times 10^{-5}} = 20.2667 \times 10^{6}\ AT/Wb.$$

$$\boxed{S_T = 23.0737 \times 10^{6}\ AT/Wb} \quad (1)$$

(iii) $\phi = \frac{mmf}{reluctance} = \frac{NI}{S_T} = \frac{1400}{23.0737 \times 10^{6}}$. (1)

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

B1) b) (iii) FORCE EXPERIENCED BY THE CONDUCTOR:

The magnitude of the force experienced by the conductor depends on the following factors,

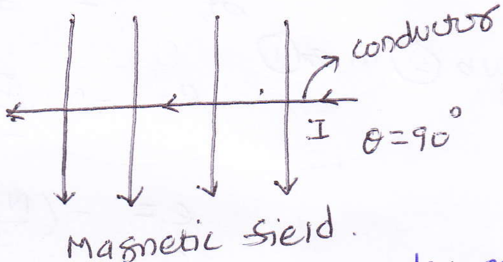
(i) Flux density (B) of the magnetic field in which the conductor is placed, measured in (Wb/m^2)

(ii) Magnitude of the current I passing through the conductor in Amperes. (1)

(iii) Active length l of the conductor in meters.

The active length of the conductor is that part of the conductor which is actually under the influence of magnetic field. If the conductor is at right angles to the magnetic field as shown in figure below then force F is given by,

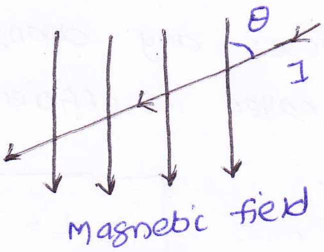
$$\boxed{F = BIl \text{ (Newtons)}}$$



(1)

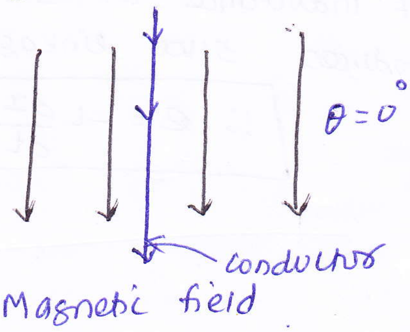
But if the conductor is not exactly at right angles, but inclined at angle θ degrees w.r.to axis of magnetic field as shown in figure below, Then force F is given by

$$\boxed{F = BIl \sin\theta \text{ (Newtons)}}$$



(1)

As shown in figure below, If conductor is kept along the lines of magnetic field then $\theta = 0°$ and as $\sin 0° = 0$, the force experienced by the conductor is also zero.



(1)

B2) a) (i) MAGNITUDE OF SELF INDUCED E.M.F

From Faraday's law of electromagnetic induction, self induced e.m.f can be expressed as.

$$e = -N\frac{d\phi}{dt} \quad --- ① \qquad (1)$$

The flux can be expressed as

$$\phi = \frac{\text{flux}}{\text{Ampere}} \times \text{Ampere} = \frac{\phi}{I} \times I \qquad (1)$$

Now for circuit, as long as permeability N is constant, ratio of flux to current (i.e B/H) remains constant.

$\therefore$ Rate of change of flux $= \frac{\phi}{I} \times$ rate of change of current.

$$\therefore \frac{d\phi}{dt} = \frac{\phi}{I}\cdot\frac{dI}{dt} \quad --- ② \qquad (1)$$

sub ② in ①

$$e = -N\cdot\frac{\phi}{I}\cdot\frac{dI}{dt}$$

$$e = -\left(\frac{N\phi}{I}\right)\cdot\frac{dI}{dt} \quad -- ③ \qquad (1)$$

The constant $\frac{N\phi}{I}$ in this expression is nothing but the quantitative measure of the property due to which coil opposes any change in current. So the constant $\frac{N\phi}{I}$ is called co-efficient of self inductance and denoted by 'L'.

$$\boxed{\therefore L = \frac{N\phi}{I}} \quad --- ④ \qquad (1)$$

It can be defined as flux linkages per ampere current in it. Its unit is henry (H).

A circuit possesses a self inductance of 1 H when a current of 1 A thro' it produces flux linkages of 1 Wb-turn in it.

$$\boxed{\therefore e = -L\frac{dI}{dt} \text{ volts}} \quad --- ⑤$$

(1)

B2) a)

(ii) Given data:

$N = 500$

$\phi = 50\,mWb = 50 \times 10^{-3}\ Wb$

$I = 25\ A$

$$L = \frac{N\phi}{I} = \frac{500 \times 50 \times 10^{-3}}{125} = 0.2\ H. \quad (1)$$

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

$$= \frac{0-125}{0.1} = \frac{-125}{0.1} = -1250\ A/sec. \quad (1)$$

$$e = -L\frac{dI}{dt} = -0.2 \times -1250 = 250\ volts. \quad (1)$$

This is positive because current is decreased. so this 'e' will try to oppose this decrease, means will try to increase current and will help the growth of the current. (1)

(iii) FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION:

Faradays First law:

Whenever the number of magnetic lines of force (flux) linking with a coil or circuit changes, an e.m.f gets induced in that coil or circuit. (2)

Faraday's second law:

The magnitude of induced e.m.f is directly proportional to the rate of change of flux linkages

$\boxed{\text{Flux linkages} = \text{Flux} \times \text{Number of turns of the coil.}}$ (2)

B2) b) (i) MAGNITUDE OF MUTUALLY INDUCED E.M.F.

Let

$N_1 \rightarrow$ No. of turns of coil A

$N_2 \rightarrow$ No. of turns of coil B.

$I_1 \rightarrow$ current flowing thro' coil A

$\phi_1 \rightarrow$ Flux produced due to current I_1 in wb.

$\phi_2 \rightarrow$ Flux linking with coil B. (1)

According to faraday's law, the induced e.m.f in coil B is

$$e_2 = -N_2 \frac{d\phi_2}{dt} \quad (1)$$

-ve sign indicates that this e.m.f will set up a current which will oppose the change of flux linking with it.

$$\text{Now,} \quad \phi_2 = \frac{\phi_2}{I_1} \times I_1 \quad (1)$$

If permeability of the surroundings is assumed constant then $\phi_2 \propto I_1$ and hence $\frac{\phi_2}{I_1}$ is constant.

$\therefore$ Rate of change of $\phi_2 = \frac{\phi_2}{I_1} \times$ Rate of change of current I_1. (1)

$$\therefore \frac{d\phi_2}{dt} = \frac{\phi_2}{I_1} \cdot \frac{dI_1}{dt}$$

$$\therefore e_2 = -N_2 \frac{\phi_2}{I_1} \cdot \frac{dI_1}{dt}$$

$$= -\left(\frac{N_2 \phi_2}{I_1}\right) \cdot \frac{dI_1}{dt} \quad (1)$$

Here $\frac{N_2\phi_2}{I_1}$ is called co-efficient of mutual inductance denoted by M.

$$\boxed{\therefore e_2 = -M \frac{dI_1}{dt} \text{ Volts}} \quad (1)$$

B2) b) (ii) co-efficient of coupling:

W.K.T $M = \frac{N_2 k_1 \phi_1}{I_1}$ --- ① and $M = \frac{N_1 k_2 \phi_2}{I_2}$ -- ② (1)

① × ② =>

$$M \times M = \frac{N_2 k_1 \phi_1}{I_1} \times \frac{N_2 k_2 \phi_2}{I_2}$$

$$M^2 = (k_1 k_2) \left[\frac{N_1 \phi_1}{I_1}\right]\left[\frac{N_2 \phi_2}{I_2}\right] \quad \text{-- ③} \quad (1)$$

But $\frac{N_1 \phi_1}{I_1}$ = self Inductance of coil 1 = L_1 --④

$\frac{N_2 \phi_2}{I_2}$ = self Inductance of coil 2 = L_2 -- ⑤ (1)

sub ④ and ⑤ in ③ we get,

$$M^2 = k_1 k_2 L_1 L_2$$

$$M = \sqrt{k_1 k_2}\sqrt{L_1 L_2}$$

$$= k\sqrt{L_1 L_2} \quad \text{where } k = \sqrt{k_1 k_2} \quad (1)$$

The k is called coefficient of coupling.

If entire flux produced by one coil links with other then $k = k_1 = k_2 = 1$ and maximum mutual inductance existing between coils is $M = k\sqrt{L_1 L_2}$.

It can be defined as the ratio of the actual mutual inductance present between the two coils to the maximum possible value of the mutual inductance.

The expression for k is

$$\boxed{k = \frac{M}{\sqrt{L_1 L_2}}} \quad (1)$$

⑥

B2) b) (iii) FACTORS AFFECTING SELF INDUCTANCE OF A COIL: (4)

(i) It is directly Proportional to the square of No. of turns of a coil. This means for same length, if the number of turns are more then self inductance of coil will be more (N)

(ii) It is directly Proportional to the cross-sectional area of the magnetic circuit (a)

(iii) It is inversely Proportional to the length of the magnetic circuit (l)

(iv) It is directly Proportional to the relative ~~(?)~~ Permeability of the core. so for iron and other magnetic material inductance is high as their relative Permeabilities are high. (μ_r)