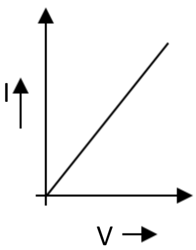
BASIC ELECTRICAL ENGINEERING :

MODULE - 1

I . DC CIRCUITS :

Syllabus : *Ohm's law, Kirchhoff's laws, analysis of series, parallel & series parallel circuits excited by independent voltage sources, power & energy, examples.*

Ohm's law : " The potential difference between the two ends of a conductor is directly proportional to the current flowing through it, provided its tempe ature & other parameters remain unchanged ".



$$\boxed{\begin{array}{c} V \propto I \\ V=RI \end{array}}$$

R - Constant of p opo tionality called Resistance
V - voltage in volts
I - current n Amps
R - res stance in Ohms (Ω)

<u>Limitations of Ohm's law :</u>

- It is not applicable to <u>non-metallic conductors</u> like silicon carbide. Their v-i relationship is given by ,

  [$V= K I^m$] - Here the relation between V & I is <u>non linear</u>. ($m< 1$)
- It is not applicable to <u>non-linear devices</u> like <u>diodes</u>.
- It is not applicable to <u>'arc lamps'</u>, because arc produced exhibits non-linear characteristics.

<u>Kirchhoff's laws</u> :-

I. <u>Kirchhoff's current law</u> [KCL] -

" Algebraic sum of all currents meeting at a node is zero in any electric circuit"

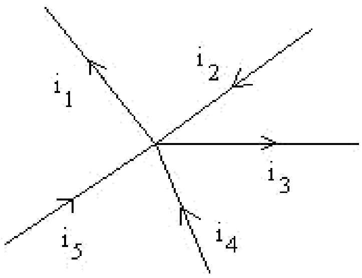
OR

" Sum of all currents entering a node is equal to sum of all currents leaving a node in any electrical circuit."

KCL is illustrated below .

Convention

Current flowing **out** of a node is considered positive (+ve)
Current flowing **into** a node is considered negative (- ve)



$$\boxed{i_1 - i_2 + i_3 - i_4 - i_5 = 0}$$

or

$$\boxed{i_1 + i_3 = i_2 + i_4 + i_5}$$

II. Kirchhoff's voltage law [KV] -

" In any electrical circuit, the algebraic sum of voltage drops of all branches & emf's is zero."

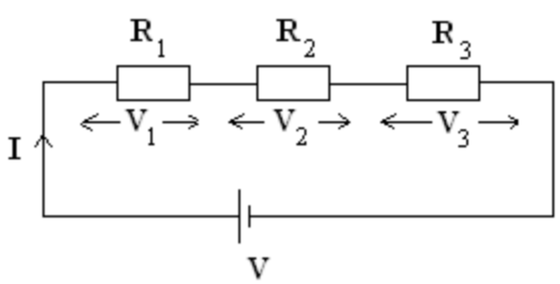
or

" In any electrical network, the algebraic sum of voltage drops of all branches and emf's forming a closed loop is zero."

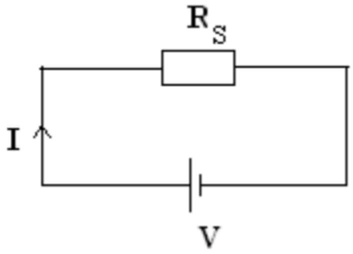
Series , parallel , series-parallel combination circuits:-

Resistances in series :-

Series circuit



Equivalent circuit

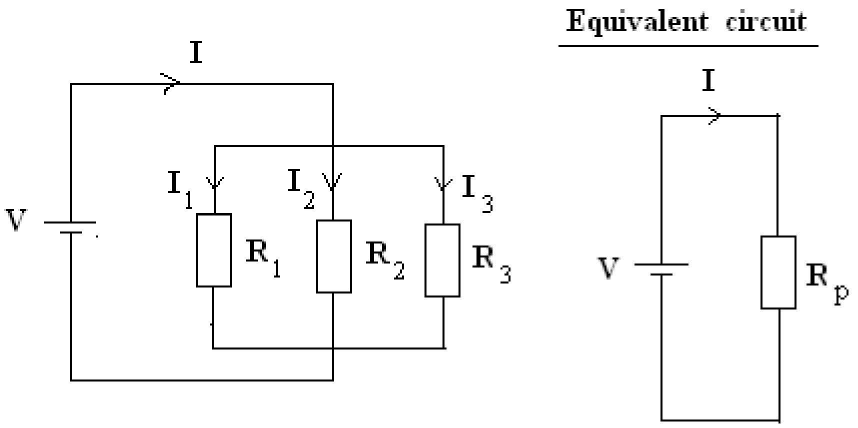


$$V = V_1+V_2+V_3$$

$$IR_s = IR_1 + IR_2 + IR_3$$

$$\boxed{R_s = R_1 + R_2 + R_3}$$

Resistances in parallel :-



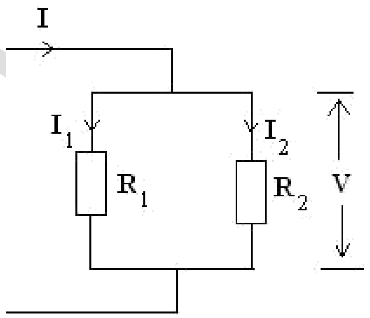
$$I = I_1 + I_2 + I_3$$

$$V/R_p = V/R_1 + V/R_2 + V/R_3$$

$$\boxed{1/R_p = 1/R_1 + 1/R_2 + 1/R_3}$$

Current divider rule and voltage divider rule **:**

a) Current divider rule **:**



$V = I_1R_1 = I_2R_2$

$I_2 = (I_1 R_1 / R_2)$...... (1)

$\boxed{I = I_1 + I_2}$ as per KCL

$I = I_1 + (I_1 R_1 / R_2)$...... from (1)

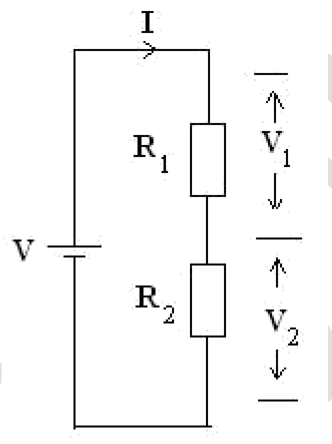
$$I = I_1 \frac{(R_1 + R_2)}{R_2}$$

$$I_1 = \frac{I R_2}{(R_1 + R_2)}$$

In general it can be expressed as follows :

Current through R_1 = $\dfrac{\text{Main current x opposite esistance}}{\text{Sum of resistances}}$

b) Voltage divider rule :



$I = V / (R_1 + R_2)$

$$\boxed{V_1 = I R_1 = [\, V R_1 / (R_1 + R_2)]}$$

In general it can be expressed as follows :

$$\text{Voltage across } R_1 = \frac{\text{Main voltage x same resistance}}{\text{Sum of resistances}}$$

II . ELECTROMAGNETISM & ELECTROMAGNETIC INDUCTION :

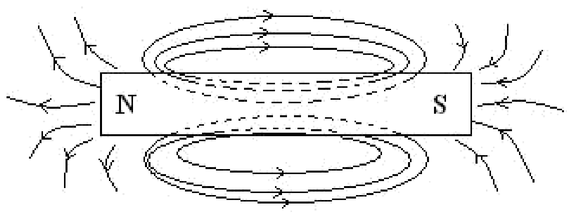
Syllabus **:** *Review of field around a conductor & coil, magnetic flux & flux density, mmf , magnetic field intensity, reluctance & permeability, definition of magnetic circuit & analogy between electric & magnetic circuit.*

- Definition of electromagnetic induction, faradays laws, Fleming's right hand rule, Lenz's law, statically & dynamically induced emf. Self inductance, mutual inductance and coefficient of coupling. Energy stored in magnetic field. Force on current carrying conductor placed in a magnetic field, Fleming's left hand rule.

Basic definitions **:**

1. Magnetic field :-

The space around a magnet in which the magnetic effects are felt is known as magnetic field.



2. Magnetic flux :- [Ø]

The magnetic lines of force originate from north pole N & go into south pole S. The entire magnetic lines of force representing a magnetic field is magnetic flux. It is expressed in [WB] . It is analogous to **current** .

3. Magnetic flux density:- [B]

The magnetic flux per unit area, area being normal to lines of flux is flux density. It is expressed in (Wb/m$^{2)}$ or Tesla (T) .

4. Magneto motive force (mmf) :-

mmf is the force that drives flux through a magnetic ci cuit. Or it c n also be defined as the force required to drive flux through a magnetic ci cuit. It is n logous to **emf** . It is expressed in [AT].

5. Magnetic field intensity / Magnetising force/ Magnetic field strength**:-**

It is defined as number of ampere turns produced per unit length or it can also be defined as the force experienced by unit N pole placed at that point

$$[\, H= NI / l \,] \ \ AT/m$$

6. Reluctance:-

Opposition offered to the production of magnetic flux. Or it can also be defined as opposition offered to the passage of magnetic flux through a material.

It is expressed in (AT/Wb)

It is analogous to resistance. It is given by ,

$$[S = l / \mu_0 \mu_r A]$$

l - length of magnetic material or circuit

A- area of cross section

μ_0 - permeability of free space

μ_r - relative permeability

7. Permeability:-

It is the property of a magnetic material by virtue of which magnetic flux can be easily created in it. It is analogous to conductance.

a) Absolute permeability (μ) [μ=B/H]

b) Relative permeability (μ_r) [$\mu_r = B / B_0$] B_0 - flux induced in f ee space

8. Magnetic circuit:-

Path followed by magnetic flux is magnetic circuit .

Mean circumference of the ring is taken as length of magnetic circuit. ($l = \pi d$)

Analogy Between Electric & Magnetic Circuits :

Magnetic Circuit	Electric Circuit
1. mmf creates magnetic flux. (At)	Emf drives current (V)
2. Reluctance is opposition offered magnetic flux.	Resistance is opposition to offered to flow of current
3. Magnetic flux Ø (Wb)	Electric Current I, (A)
4. Permeability µ (Tm/A)	Conductivity (S/m)
5. Permeance, G (Wb/A)	Conductance, G (S)
6. Flux density B (Wb/m^2) or T	Current density (A/m^2) J
7. Magnetic field intensity H (At/m)	Electric field intensity E (V/m)

Differences Between Magnetic Circuit And Electric Circuit

Magnetic circuit	Electric circuit
1. Once set up, no energy is required to maintain it .	Energy must be continuously supplied to maintain current flow.
2. It stores energy	It dissip tes energy in the form of he t.
3. Saturation exists in magnetic circuits (B.H curve)	The e is no concept of saturation in electric circuit

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ELECTROMAGNETIC INDUCTION :

Faraday's laws of electromagnetic induction -

I law :- Whenever magnetic flux linking a coil changes, emf is induced.

or

Whenever there is a relative motion between flux & conductor emf is induced in that conductor.

II law:- The magnitude of induced emf is equal to rate of change of flux linking the coil.

$$[e = d\text{Ø} / dt]$$

For a coil with 'N' turns, (emf is induced in each turn)

Total emf induced is given by -

$$\boxed{e = N\, d\text{Ø}/dt}$$

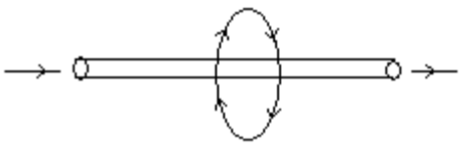
Lenz's law-

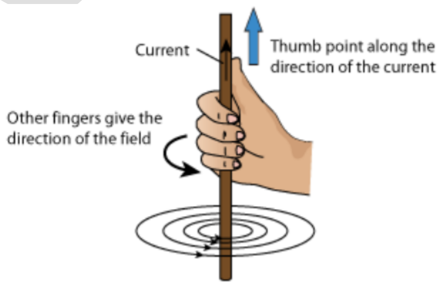
The direction of induced emf is such that it opposes the c use producing it.

$$\boxed{e\ e= =- -NN\ d\text{Ø}/dt/dt}$$

Property of electromagnetism **:**

" Every current carrying conductor produces ts own flux around it " . The direction of the flux is given by Right hand thumb rule.





Right hand thumb rule :

When a conductor is held in the palm - **Thumb** points towards direction of current
Curled fingers represent direction of flux

Types of induced emf :

1. Dynamically induced emf -

Emf induced due to the relative motion between flux & conductor is called dynamically induced emf .

Example - Generators

2. Statically induced emf -

Emf induced in the coil when the varying flux links with itself is called statically induced emf and is called so because it involves no moving parts .(flux and conductor remain stationary)

a) Self induced emf - Current is passed through a coil, flux develops around it. When the current is varied flux varies which links with coil and emf is induced.

b) Mutually induced emf - Emf induced when varying flux in a coil links with the neighbouring coil and induces emf in neighbouring coil .

Example - transformer

Self inductance :

The ability of a coil to induce emf in tself (y changing current flowing through it) is self inductance.

Or

When current is increased through a coil, it is opposed by instantaneous production of emf (self induced / counter emf) or when current is decreased , it is also opposed by self induced emf [delayed]. This property of coil due to which it opposes an increase or decrease of current through it, is called self inductance.

Self inductance is measured in terms of co efficient of self induction.

$$e = -N\frac{d\phi}{dt} = \frac{-N\,d\phi}{di} \times \frac{di}{dt}$$

$$\boxed{e = -L\frac{di}{dt}}$$

where L is the self inductance (coefficient of self induction) given by ,

$$\boxed{L = N\,d\phi/di}$$

Since Ø α I , dØ/di can be replaced by Ø/i

$$\boxed{L = N\,Ø/i}$$

When flux is expressed in terms of the ratio of mmf & reluctance , L is given by ,

$$\boxed{L = N^2\,\mu A / l}$$

Energy stored in an inductor:-

When current through an inductor is increased from 0 to I in time 't', n emf 'e' is induced in the coil.

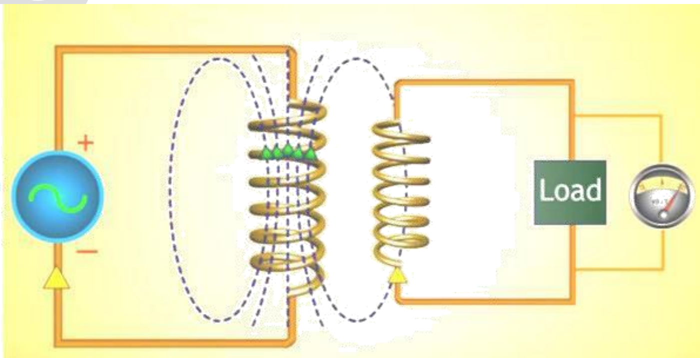
Work done to overcome the opposition due to induced emf for an increase in current is given by

Total energy W absorbed is given by-

$$W = \int e\,i\,dt = \int (di/dt)\,i\,dt = \int Li\,di = L\,i^2\;/\;2 = (1/2)\,LI^2$$

Mutual inductance :

The ability of a coil to induce emf in the neighbouring coil by induction due to change in current in 1st coil .



Consider two coils having turns N_1 & N_2 respectively as shown above .

Let V_1 be the applied voltage in coil1 .

I_1 be the current flowing in coil1 due to V_1

Flux $Ø_1$ is produced in coil 1 due to I_1

emf is induced in coil 1 given by ,

$$\boxed{e_1 = - N_1\, dØ_1/dt}$$

Part of the flux $Ø_1$ which is $Ø_{12}$ links with both coils 1 & 2 . emf induced in coil 2 is given by ,

$$\boxed{e_{12} = - N_2\, dØ_{12}/dt}$$

$$\boxed{e_{12} = - N_2\, (dØ_{12}/di_1) \times (di_1/dt)}$$

$$\boxed{e_{12} = - M_{12}\, di_1/dt}$$

where M_{12} is the mutual inductance given by , $\boxed{M_{12} = N_2\, dØ_{12}/di_1}$

<u>Coefficient Of Coupling</u> :- [Relation between L_1 , L_2 & M]

It is a measure of proximity between two coils . It gives an idea about what portion of flux produced links with other coil.

Consider two magnetically coupled coils A & B with turns N_1 & N_2.

<u>Coil A is energized by a.c. supply</u>

<u>Coil B is energized by a.c. supply</u>

Fleming's rules :

Force on current carrying conductor placed in a magnetic field -

" Whenever a current carrying conductor is placed in a magnetic field it expe iences a force."

Direction given by Flemings left hand rule

Thumb represents di ection of motion (force)

forefinger represents di ection of flux

second finger represents direction of current carrying conductor

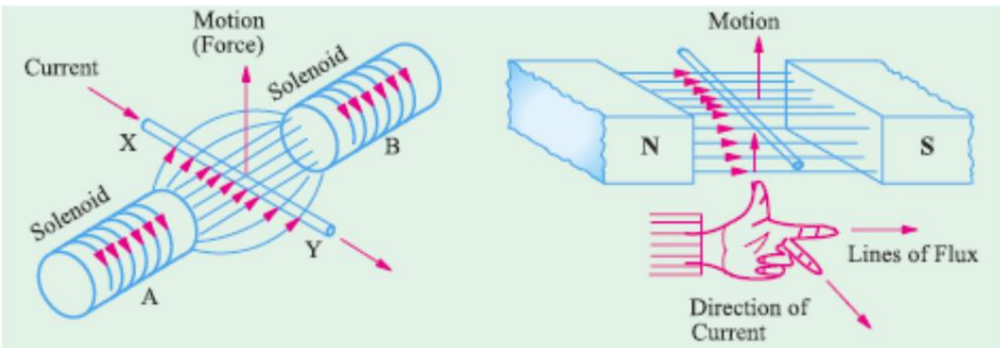
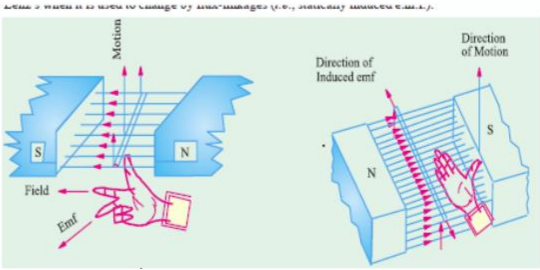


Fig. 6.8 Fig. 6.9



QUESTION BANK :

1(a) D.C CIRCUITS

1. State and explain Kirchhoff's laws as applied to DC Circuits.(Jan 2014,6M)
2. What are the advantages of parallel circuit over series circuit?(Jan 2010,5M)
3. State and explain Ohm's law & state its limitation.(Jan 2013,6M)
4. A resistance R is connected in series with a parallel circuit comprising two resistances of 12Ω & 8Ω respectively. The total power dissipation in the circuit is 70W when the applied voltage is 20V. Calculate R.(June 2014,6M)
5. The total power consumed by the network shown in the figu e (a) is 16W. Find the value of R & the total current. (Jan 2013,6M)
6. Obtain the potential difference V_{xy} in the circuit shown in figure (b).(Jan 2012,6M),(Jan 2015,8M)(June 2015,8M)
7. Find the currents in all the resistors of the netwo k shown in the figure (c). Also the voltage across AB.(June 2013,6M)(Jan 2015,6M)
8. A current of 20A flows through two ammeters A & B in series. The potential difference across A is 0.2V & across B is 0.3V. F nd how the same current will divide between A & B when they are in parallel.(Jan 2012,6M)(June 2014,6M)(Jan 2015,6M)
9. A circuit consists of two parallel resistors having resistances of 20Ω & 30Ω respectively, connected in series with a 15Ω resistor. If the current through 15Ω resistor is 3A find, (a) the currents in 20Ω & 30Ω resistors, (b) the voltage across whole circuit, & (c) the total power consumed in allresistor.(Jan 2009,6M)(June 2010,6M)
10. Using Kirchhoff's laws, determine R_1, R_2, I_1,I_2& I_3 in the circuit shown in figure (d).(Jan 2012,6M)
11. For the network shown in figure (e), calculate the currents I_x&I_y.(Jan 2013,6M)
12. Three 60W, 120V light bulbs are connected across a 120V power line as shown in the figure (f). Find (a) the voltage across each bulb & (b) the total power dissipated in the three bulbs.(Jan 2011,6M)(June 2012,6M)(June 2013,6M)
13. For the circuit shown in figure (g), find the current supplied by each battery and power dissipated in 1Ω resistor.(Jan 2015,5M)

14. In the parallel arrangements of resistors shown in the figure (h), the current flowing in the 8Ω resistor is 2.5A. Find the current in other resistors, resistor X and the equivalent resistance.

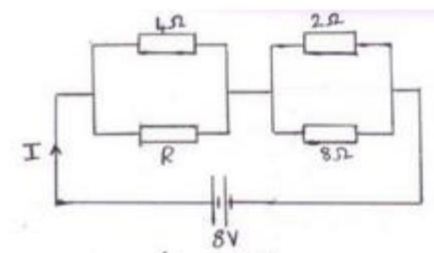


figure (a)

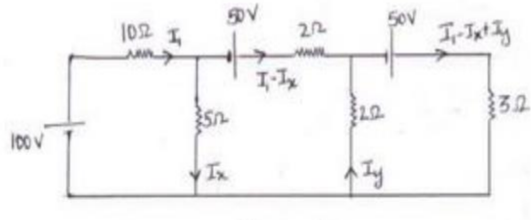


figure (e)

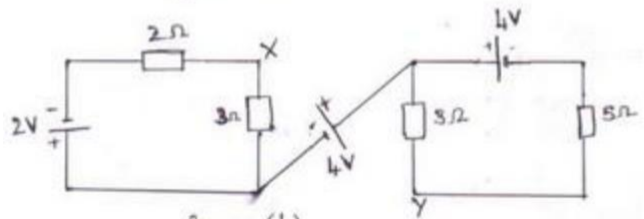


figure (b)

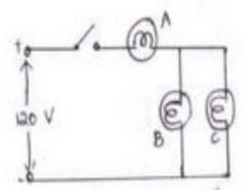


figure (f)

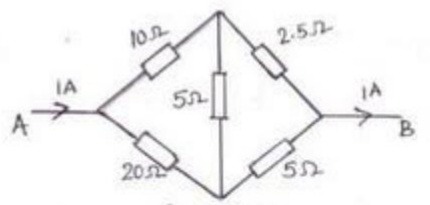


figure (c)

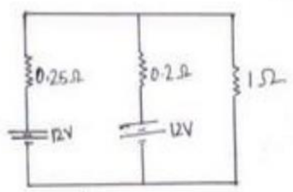


figure (g)

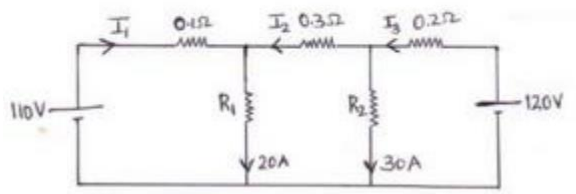


figure (d)

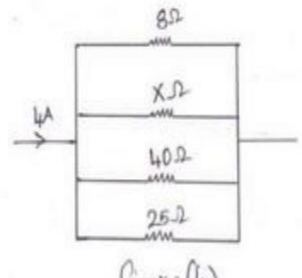


figure (h)

1(b) ELECTROMAGNETISM

1. With examples, clearly differentiate between statically induced emf & dynamically induced emf.(Jan 2013,6M)(June 2014,5M)
2. Explain Fleming's rules & their use in electromagnetism.(Jan 2015,6M)
3. Prove that the co-efficient of mutual inductance between two coils of self-inductances L_1 and L_2 is given by M= k (L_1L_2), where k is the co-efficient of coupling between the two coils.(Jan 2011,7M)(June 2014,8M)(June 2015,6M)

4. What is meant by electromagnetic induction? State and explain Faraday's laws of electromagnetic induction.(Jan 2015,5M)(June 2009,7M)
5. Derive an expression for energy stored in the magnetic field.(Jan 2010,5M)(June 2013,5M)(Jan 2015,5M)(June 2014,4M)(Jan 2014,5M)
6. What are the factors on which the inductance of the coil depends? Derive the necessary expression for calculating the inductance.(June 2014,6M)(June 2013,6M)
7. A coil A of 1200 turns & another coil B of 800 turns lie near each other so that 60% of the flux produced in one coil links with the other. It is found that a current of 5A in coil A produces flux of 0.25mWb, while the same current in coil B p oduces a flux of 0.15mWb. Determine the mutual inductance & coefficient of coupling between the coils.(Jan 2013,8M)(June 2015,8M)(Jan 2012,8M)(June 2014,8M)
8. A coil consists of 600 turns & a current of 10A in the coil gives rise to a magnetic flux of 1mWb. Calculate self-inductance, the emf induced & the ene gy stored when the current is reversed in 0.01 second.(Jan 2015,4M)(June 2014,4M)(Jan 2013,6M)
9. A coil of resistance 150Ω is placed in a magnetic field of 0.1mWb. The coil has 500 turns & a galvanometer of 450Ω is connected n ser es w th it. The coil is moved in 0.1second from the given field to another field of 0.3mWb. F nd the average induced emf & the average current through the coil.(Jan 2011,5M)(June 2012,5M)(Jan 2013,7M)
10. A solenoid 1m in length & 10cm in diameter has 5000 turns. Calculate the inductance & energy stored in the magnetic field when a current of 2A flows in a solenoid.(Jan 2013,5M)(Jan 2015,5M)(June 2013,6M)(Jan 2010,6M)
11. A coil of 750 turns & a current of 10A gives rise to a magnetic flux of 1200μWb. Determine the inductance of the coil & the average emf induced in the coil when this current is reversed in 0.01 second.(June 2015,8M)(June 2013,7M)(Jan 2012,8M)
12. Two identical coils of 1200 turns each, are placed side by side such that 60% of flux produced by one coil links with the other. A current of 10A in the first coil sets up a flux of 0.12mWb. If the current in the first coil changes from +10A to -10A in 20msec, find the self-inductances of the coil & the emfs' induced in both the coils.(Jan 2015,8M)
13. Coils A& B in a magnetic circuit has 600 & 500 turns respectively. A current of 8A in coil A produces a flux of 0.04 Wb. If the coefficient of coupling is 0.2, calculate: (a) self inductance of coil A with coil B open circuited. (b)flux linkage with coil B. (c)the average emf induced in coil B when flux with it changes from 0 to full value in 0.02sec. (d)mutual inductance.
14. Two coils having 1000 turns & 1600 turns respectively are placed close to each other such that 60% of the flux produced by one coil. If a current of 10A flowing in the first coil

produces a flux of 0.5mWb. Find the inductance of the second coil. (June 2014,8M)(Jan 2012,7M)(Jan 2011,8M)

15. An air cored solenoid with length 30cm & internal diameter 1.5cm has a coil of 900 turns wound on it. Estimate its inductance & amount of energy stored in it when the current through the coil rises from 0A to 5A.(Jan 2013,8M)(June 2015,7M)