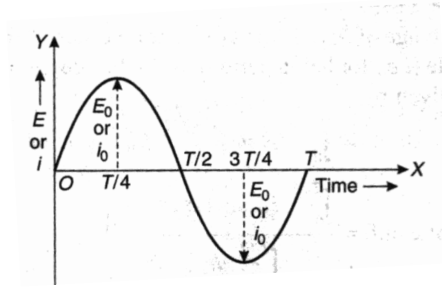
ALTERNATING CURRENTS AND ELECTROMAGNETIC WAVES

Alternating current: An alternating current is an electric current which changes in both magnitude and direction with the time. It increases from zero to maximum in one direction and then falls to zero and becomes maximum in opposite direction and then again falls to zero as shown in the fig.



Voltage and current is represented by

Instantaneous current $i=i_o \text{ Sin } \omega t$

Instantaneous voltage $E=E_o \text{ Sin } \omega t$

Here i_o= Maximum current

E_o = Maximum voltage

Average value of A.C during complete cycle: $i_{ave} = \frac{\int_0^T i_0 \text{ Sin } \omega t \, dt}{\int_0^T dt} = 0$

Average value of A.C voltage half cycle: $E_{ave} = \frac{\int_0^{T/2} E_0 \text{ Sin } \omega t \, dt}{\int_0^{T/2} dt} = \frac{2}{T}\int_0^{T/2} E_0 \text{ Sin } \omega t \, dt = \frac{2E_0}{\pi}$

$$i_{ave} = \frac{2i_0}{\pi}$$

RMS value of current: $i_{rms}=0.707\ i_o$

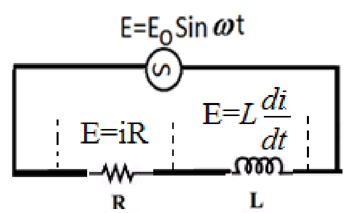
Erms=$\frac{E_0}{\sqrt{2}} = 0.707\ E_o$

1. Ac cycle: One complete cycle consisting of all positive and negative values of an AC quantity is known as AC cycle.
2. Time period:- The time required for one complete cycle is known is time period.
3. Frequency: - The number of complete cycles per second is known as frequency (n) or (f).
   The reciprocal of time period is called frequency f or n.

$$f=1/T$$

Kilohertz (KHz) $=10^3$, Mega hertz (MHz) $=10^6$, Giga hertz (GHz) $= 10^9$

Relation between current and voltage in LR circuit: Let us consider a circuit containing non inductive resistance R and inductance L in series connected to a source of alternating emf
$E=E_o \text{ Sin } \omega t$ as shown in the figure.
According to Kirchhoff's law.



L R - CIRCUIT

$$E_o \text{Sin } \omega t = iR + L\frac{di}{dt} ------(1)$$

Let $i = i_o \text{ Sin } (\omega t - \emptyset)$ be the solution of the above eqn.

Then $\frac{di}{dt} = i_o\omega \text{ Cos } (\omega t - \emptyset)$

Substituting the above values in eqn. (1) we get

$$E_o\text{Sin } \omega t = R\, i_o \text{ Sin } (\omega t - \emptyset) + L\, i_o\omega \text{ Cos } (\omega t - \emptyset)$$

$$E_o\text{Sin}[(\omega t - \emptyset) + \emptyset] = R\, i_o \text{ Sin } (\omega t - \emptyset) + L\, i_o\omega \text{ Cos } (\omega t - \emptyset)$$

$$E_o\text{Sin } (\omega t - \emptyset) \text{ Cos } \emptyset + E_o\text{Cos } (\omega t - \emptyset)\text{Sin } \emptyset = R\, i_o \text{ Sin } (\omega t - \emptyset) + L\, i_o\omega \text{ Cos } (\omega t - \emptyset)$$

Comparing the coefficients of $\text{Sin } (\omega t - \emptyset)$ *and* $\text{Cos } (\omega t - \emptyset)$ we get

$$E_o \text{ Cos } \emptyset = R\, i_o ------(2)$$

$$E_o \text{Sin}\,\emptyset = L\, i_o \omega \ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Squaring and adding eqns. (2) and (3) we get

$$E_o^2 = R^2\, {i_o}^2 + L^2\, {i_o}^2 \omega^2$$

$$\therefore\ {i_o}^2 (R^2\ + L^2\omega^2) = E_o^2$$

$$\therefore\ {i_o}^2 = \frac{E_o^2}{(R^2\ + L^2\omega^2)}$$

$$\therefore i_0 = \frac{E_o}{\sqrt{(R^2\ + L^2\omega^2)}}$$

$$\therefore i = \frac{E_o}{\sqrt{(R^2 + L^2\omega^2)}} \text{Sin}\,(\omega t - \emptyset)$$

Dividing eqn. 3 by eqn. 2 we get

$$Tan\,\emptyset = \frac{L\, i_o \omega}{R\, i_o} = \frac{L\omega}{R}$$

$\therefore$ The current lags in phase behind the EMF by an angle given by

$$\emptyset = Tan^{-1}\left(\frac{L\omega}{R}\right) = Tan^{-1}\left(\frac{X_L}{R}\right)$$

Impedance of the circuit $\quad Z = \frac{E_o}{i_o} = \sqrt{(R^2\ + L^2\omega^2)}$

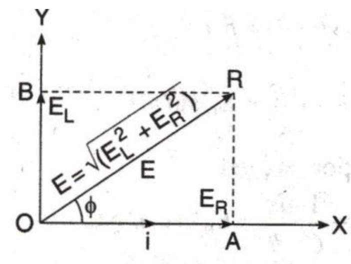
$$Z = \sqrt{\left(R^2\ + {X_L}^2\right)}$$

Where X_L = inductive reactance

Vector diagram: The impedance and phase value can also be determined by vector diagram. The voltage across resistance always remains in phase with the current but the voltage across inductance lead over current 90^0. Let E_R *and* E_L be the magnitudes of the voltages across the resistance and inductance respectively. Here the current i is the same in R and inductance L respectively.

Hence

$E_R = iR$ *and* $E_L = i\omega L$



So E_R may be represented along current line while E_L at 90^0 to E_R as shown in the fig. In the fig **OA** represents the magnitude and direction of voltage across R while **OB** represents the magnitude and direction of voltage across L. By the law of parallelogram of vector addition the diagonal **OR** represents the resultant voltage across the inductance and resistance in series.

Hence $\quad E^2 = E_L^2 + E_R^2$

$$(iZ)^2 = (i\omega L)^2 + (iR)^2$$

$$\therefore Z^2 = (\omega L)^2 + R^2$$

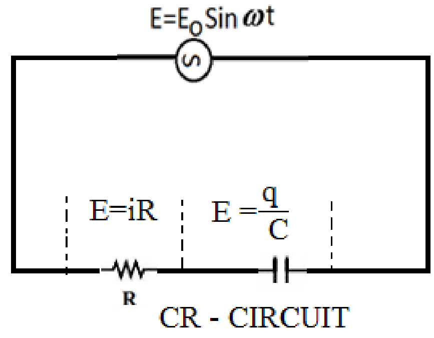
$$\therefore Z = \sqrt{(\omega L)^2 + R^2}$$

$$Tan\,\emptyset = \frac{E_L}{E_R} = \frac{\omega L}{R}$$

$$\therefore \emptyset = Tan^{-1}\left(\frac{\omega L}{R}\right)$$

Relation between current and voltage in CR circuit: Let us consider a circuit containing non inductive resistance R and capacitor C in series connected to a source of alternating emf $E=E_o \sin \omega t$ as shown in the figure.

According to Kirchhoff's law



$$E_o \text{Sin } \omega t = iR + \frac{q}{C}$$

Differentiating the above equation with respect to t we get

$$E_o \omega \text{Cos } \omega t = R\frac{di}{dt} + \frac{1}{C}\frac{dq}{dt} = R\frac{di}{dt} + \frac{1}{C}.i \text{ ------}(1)$$

Let $i = i_o \text{Sin } (\omega t - \emptyset)$ be the solution of the above eqn.

Then $\frac{di}{dt} = i_o \omega \text{ Cos } (\omega t - \emptyset)$

Substituting the above values in eqn. (1) we get

$$E_o \omega \text{Cos } \omega t = R\, i_o \omega \text{ Cos}(\omega t - \emptyset) + \frac{i_o}{C}\text{Sin } (\omega t - \emptyset)$$

$$E_o \omega \text{Cos}[(\omega t - \emptyset) + \emptyset] = R\, i_o \omega \text{ Cos}(\omega t - \emptyset) + \frac{i_o}{C}\text{Sin } (\omega t - \emptyset)$$

$$E_o \omega \text{Cos } (\omega t - \emptyset) \text{ Cos } \emptyset - E_o \omega \text{Sin } (\omega t - \emptyset) \text{Sin } \emptyset = R\, i_o \omega \text{ Cos}(\omega t - \emptyset) + \frac{i_o}{C}\text{Sin } (\omega t - \emptyset)$$

Comparing the coefficients of $\text{Sin } (\omega t - \emptyset)$ *and* $\text{Cos } (\omega t - \emptyset)$ we get

$$E_o \omega \text{Cos } \emptyset = R\, \omega i_o \text{ ------}(2)$$

$$-E_o \omega \text{Sin } \emptyset = \frac{i_o}{C} \ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Squaring and adding eqns. (2) and (3) we get

$$E_o^2 \omega^2 = R^2\, i_o^{\,2} \omega^2 + \frac{i_o^{\,2}}{C^2}$$

$$\therefore E_o^2 \omega^2 = i_o^{\,2}\left(R^2\, \omega^2 + \frac{1}{C^2}\right)$$

$$\therefore i_o^{\,2} = \frac{E_o^2}{\left(R^2 + \frac{1}{\omega^2 C^2}\right)}$$

$$\therefore i_0 = \frac{E_o}{\sqrt{\left(R^2 + \frac{1}{\omega^2 C^2}\right)}}$$

$$\therefore i = \frac{E_o}{\sqrt{\left(R^2 + \frac{1}{\omega^2 C^2}\right)}} \text{Sin } (\omega t - \emptyset)$$

Dividing eqn. 3 by eqn. 2 we get

$$Tan\ \emptyset = \frac{1}{R\, C\omega}$$

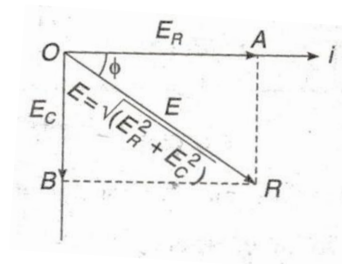
$\therefore$ The current leads the EMF by an angle given by

$$\emptyset = Tan^{-1}\left(\frac{1}{R\,C\omega}\right) = Tan^{-1}\left(\frac{1/\omega C}{R}\right) Tan^{-1}\left(\frac{X_C}{R}\right)$$

Impedance of the circuit $Z = \frac{E_0}{i_0} = \sqrt{\left(R^2 + \frac{1}{\omega^2 C^2}\right)}$

$$Z = \sqrt{\left(R^2 + {X_C}^2\right)}$$

Where X_C = Capacitive reactance



<u>Vector diagram</u>: The impedance and phase value can also be determined by vector diagram. The voltage across resistance always remains in phase with the current but the voltage across inductance lags behind by 90^0. Let E_R *and* E_C be the magnitudes of the voltages across the resistance and capacitance respectively. Here the current i is the same in R and capacitance C respectively.

Hence

$E_R = iR$ *and* $E_C = \frac{i}{\omega C}$

So E_R may be represented along current line while E_c at 90^0 to E_R as shown in the fig. In the fig **OA** represents the magnitude and direction of voltage across R while **OB** represents the magnitude and direction of voltage across C. By the law of parallelogram of vector addition the diagonal **OR** represents the resultant voltage across the capacitance C and resistance R in series.

Hence $E^2 = E_C^2 + E_R^2$

$$(iZ)^2 = \left(\frac{i}{\omega C}\right)^2 + (iR)^2$$

$$\therefore Z^2 = \left(\frac{1}{\omega C}\right)^2 + R^2$$

$$\therefore Z = \sqrt{\left(\frac{1}{\omega C}\right)^2 + R^2}$$

$$Tan\,\emptyset = \frac{E_C}{E_R} = \frac{1}{\omega CR}$$

$$\therefore \emptyset = Tan^{-1}\left(\frac{1}{\omega CR}\right)$$

<u>LCR series resonant circuit</u>:

<u>RESONANCE:</u> When the frequency of an applied emf is equal to the natural frequency of the circuit, the current or voltage in the circuit increases to maximum .This phenomenon is called resonance.

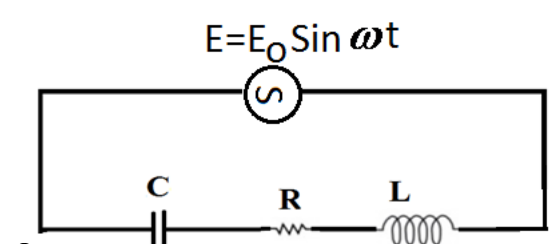
<u>LCR SERIES RESONANCE CIRCUIT:</u>

Let us consider resistance 'R', inductance 'L' and capacitance 'C' are connected to an AC source in series as shown in figure.

The impedance of the circuit

$Z = R + X_L + X_C$

$Z = R + j\omega L + \frac{1}{j\omega c}$



LCR - CIRCUIT

$$Z = R + j\omega L + \frac{j}{j^2 \omega C}$$

$$Z = R + j\left(\omega L - \frac{1}{\omega c}\right)$$

At resonance, the reactive component is zero i.e., at $\omega = \omega_o$

i.e., $$\omega_0 L = \frac{1}{\omega_0 c}$$

$$\omega_o^2 = 1/LC$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$2\pi f_0 = \frac{1}{\sqrt{LC}}$$

Resonant frequency $f_o = \frac{1}{2\pi\sqrt{LC}}$

At resonance impedance $|Z| = R$, while at any other frequency, the magnitude of impedance

$$|Z| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

At resonance $|Z| = R$ and at all other frequencies $|Z| > R$.

At resonance maximum current $I_o = \frac{E}{R}$

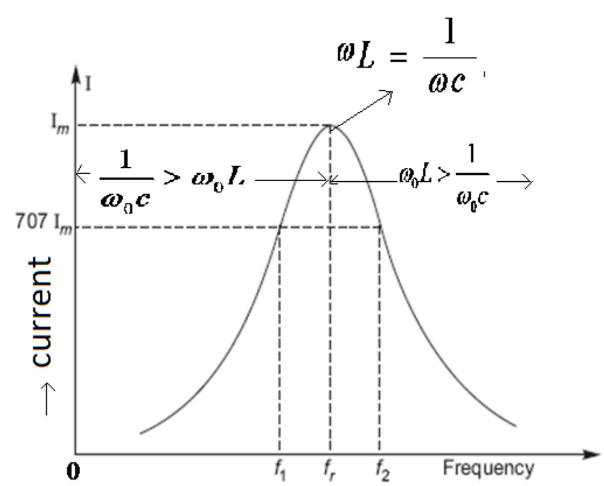
Series resonant circuit has minimum impedance at resonance; hence current through the circuit becomes maximum. Hence it is called Acceptor circuit.

The variation of current I with frequency is shown in the figure.

Case (i): At frequency lower than the resonant frequency, $\frac{1}{\omega_0 c} > \omega_0 L$ and the circuit is capacitive.

Case (ii): At frequency higher than the resonant frequency, $\omega_0 L > \frac{1}{\omega_0 c}$ and the circuit is inductive.

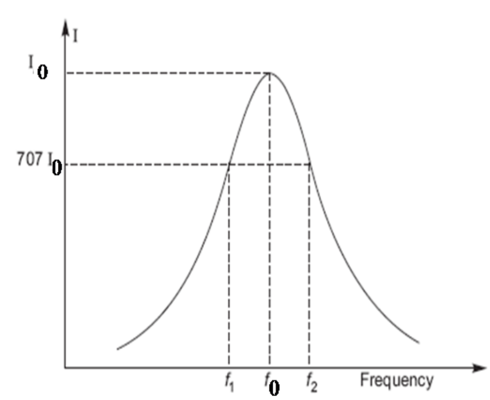
Case (iii): At resonant frequency, $\omega_0 L = \frac{1}{\omega_0 c}$ and the circuit is purely resistive.



<u>Band width, Sharpness of resonance and Q-factor:</u> It is a measure of the efficiency of energy stored in an inductor or capacitor when a.c is applied.

From the figure, $Q - factor = \frac{f_0}{f_2 - f_1} = \frac{Resonant \quad Frequency}{Band \quad width}$

OR



LCR SERIES RESONANCE CURVE

$$Q = 2\pi \frac{energy\ stored}{energy\ loss\ per\ period}$$

Def: This is defined as 2π times the ratio of the energy stored to the average energy loss per period.

Band width : The difference of two half power frequencies (f_2-f_1) is called Band width .

Therefore Band width $B.W. = \Delta f = f_2 - f_1$

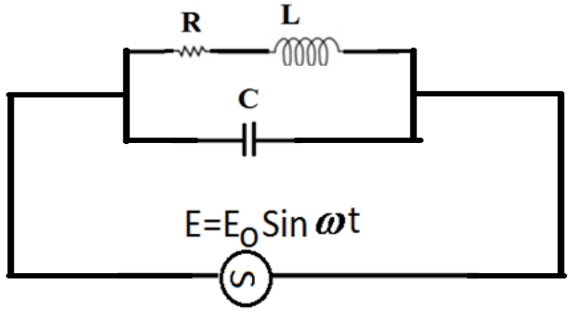
Sharpness of resonance is defined as the ratio of band width of the circuit to the resonance frequency.

Sharpness of resonance = $\frac{f_2 - f_1}{f_0}$

$\therefore Q = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$ [Because $\omega_0 = \frac{1}{\sqrt{LC}}$]

<u>LCR parallel resonance circuit</u>:

A parallel resonant LCR circuit is shown in the figure. An A.C. source is connected across this parallel arrangement of LR and C.



PARALLEL LCR - CIRCUIT

The combined impedance z of the two branches is_given by

$$\frac{1}{Z} = \frac{1}{R + j\omega L} + \frac{1}{1/\,j\omega C}$$

$$\frac{1}{Z} = \frac{1}{R + j\omega L} + j\omega C$$

$$\frac{1}{Z} = \frac{R - j\omega L}{(R + j\omega L)(R - j\omega L)} + j\omega C$$

$$\frac{1}{Z} = \frac{R - j\omega L}{(R^2 + \omega^2 L^2)} + j\omega C$$

$$\frac{1}{Z} = \frac{R}{(R^2 + \omega^2 L^2)} + j\omega\left(C - \frac{L}{(R^2 + \omega^2 L^2)}\right) ....(1)$$

At resonance the reactive component is zero, $\omega = \omega_o$

$$\therefore \quad j\omega_0\left(C - \frac{L}{R^2 + \omega^2 L^2}\right) = 0$$

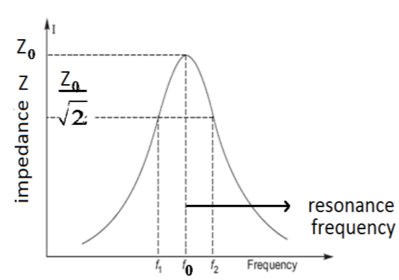
$$here, \quad j\omega_0 \neq 0$$

$$\therefore C - \frac{L}{R^2 + \omega^2 L^2} = 0$$

$$\Rightarrow C = \frac{L}{R^2 + \omega^2 L^2}$$

$$\Rightarrow \frac{L}{C} = R^2 + \omega^2 L^2 ....(2)$$

On dividing with L^2 both sides, we get



LCR SERIES RESONANCE CURVE

figure 2

$$\Rightarrow 2\pi f_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$\therefore f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \quad \text{.............(3)}$$

if R is small, then $\frac{R^2}{L^2}$ is very small, i.e., it can be neglected

Therefore, Resonance frequency

$$\therefore f_0 = \frac{1}{2\pi\sqrt{LC}} \quad \text{.............(4)}$$

From equation (1), the impedance at resonance frequency ($\omega = \omega_o$)

$$\frac{1}{Z} = \frac{R}{R^2 + \omega_0^2 L^2}$$

Substituting equation (2) in the above equation, we get

$$\frac{1}{Z} = \frac{R}{L/C} = \frac{RC}{L}$$

Therefore impedance at resonance $Z = \frac{L}{RC}$

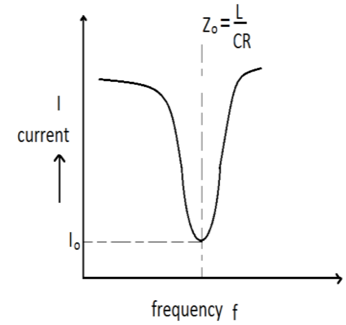


FIGURE 3

The variation of impedance Z and current I with frequency in LCR parallel circuit are shown in figure 2 and figure 3.

Parallel resonant circuit has maximum impedance at resonance; hence current through the circuit becomes minimum. Hence it is called rejecter circuit.

DIGITAL PRINCIPLES

SIGNAL:

Any variation that can be transferred through the space is known as signal. This variation may be visual, audible, electrical etc.

ANALOG SIGNALS:

The variation of pressure due to sound is converted into electrical signals by means of a microphone. This kind of signals is called analog signals.

DIGITAL SIGNAL:

The signals which are confined to a limited number of discrete levels of current or voltage is known as digital signal. Usually these signals are binary coded as 0 or 1. These binary codes correspond to the off or on conditions. By using transistor or other electronic devices we obtained this condition.

BINARY SYSTEM:

A system which has two digits 0 and 1 is known as binary system.

EXPRESSING A DECIMAL NUMBER IN THE BINARY SYSTEM:

2	11	
2	5 reminder	1
2	2	1
2	1	0
	0	1

$(11)_{10} = (1011)_2$

EXPRESSING A DECIMAL FRACTION IN THE BINARY SYSTEM:

$(0.625)_{10} = (0.101)_2$

	0.625	
multiplied by 2	2	
carry 1	1.250	
	2	
carry 0	0.500	
	2	
carry 1	1.000	

MSB= most significant bit

LSB = least significant bit

CONVERSION OF A MIXED NUMBER IN DECIMAL SYSTEM INTO BINARY SYSTEM:To convert a mixed number in the decimal system into binary system we have to simply take the integer part and fractional part separately and convert each part in to its equivalent binary part. Then we have to combine the two binary equivalents.

Ex: $(11.625)_{10}=(1011.101)_2$

CONVERSION OF AN INTEGER IN BINARY SYSTEM INTO DECIMAL SYSTEM:

Ex: $(11110011)_2 = (253)_{10}$

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
=128	64	32	16	8	4	2	1

Ans :

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	1	1	0	0	1	1

1*128 + 1*64 + 1*32 + 1*16 + 0*8 + 0*4 + 1*2 + 1*1 = **253**

CONVERSION OF A FRACTION IN BINARY SYSTEM INTO DECIMAL SYSTEM:

Ex: $(10.1011)_2 = (2.6875)_{10}$

Ans :

2^1	2^0		2^{-1}	2^{-2}	2^{-3}	2^{-4}
1	0	.	1	0	1	1

$= 2 + 0 + 0.5 + 0.0 + 0.125 + 0.0625 = 2.6875$

BINARY ADDITION:

binary	decimal
10101	21
+ 11001	+ 25
101110	= 46

BINARY SUBTRACTION:

binary	decimal
11001	25
− 10101	+ 21
100	= 4

WHY BINARY NUMBER IS NEEDED?

In digital circuits we use the supply voltage of the order of few volts. If we use decimal system then we have 10 voltage levels. Hence it will become crowded. This will lead to mis- interpretation of voltage levels. If we use binary system there will be only two voltage levels which are represented by 0 and 1. There is no mis-interpretation of data. Another important advantage with binary number is that we have devices which exhibit two well defined states. For example diode conducts heavily during forward bias and does not conduct in reverse bias. These two states on and off states are represented by1 and 0. Hence binary system is needed in digital circuits.

ONE'S COMPLEMENT SUBTRACTION:

One's complement of a binary number is obtained by changing 0 to 1 and 1 to 0. For example one's complement of $(1101)_2 = (0010)_2$

TWO'S COMPLEMENT:

The two's complement of binary number is obtained by adding 1 to its one's complement.

EXAMPLE: two's complement of $(1011)_2$ is $(0101)_2$

EXPLANATION: one's complement of $(1011)_2$ is $(0100)_2$

By adding 1 to one's complement is $1+0100 = (0101)_2$

ONE'S COMPLEMENTAL SUBTRACTION:

EXAMPLE : (1) subtract $(101)_2$ from $(111)_2$

STEPS:

(1) we find the one's complement of the subtrahend number
(2) Now we add this one's complement to the minuend.
(3) If there is a 1 carry in the most significant position of the result obtained by step (2), then this carry is removed and perform the end- around carry of the last 1.
(4) If there is no end around carry then the answer is recompleted and a –ve sign is attached to it to get the final answer.
(5) Ex 1:

```
      111   minuend
      010   one's complement of 101
     ----
  [1] 001
        1   add carry
     ----
      010   final result
```

(6) Ex (2):

```
                 1010   minuend
                 0010   one's complement of 1101
                 ----
                 1100   no carry
                 0011   re complement
                 ----
add -ve sign    -0011   final result
```

TWO'S COMPLEMENTAL SUBTRACTION:

STEPS:

(1) Change all 0 to 1 and 1 to 0 of subtrahend to get one's complemented and then adds 1 to get two's complement.
(2) Now we add the 2's complement to menu-end.
(3) If there is a carry in the result, it is dropped.
(4) If carry is one, then the answer is +ve and needs no re-completing.
(5) If there is no carry, we re-complement the result and attach a –ve sign to it.

Ex 1: Using 2's complement, subtract $(100111)_2$ from $(110011)_2$

```
 011000   1's complement of 100111
      1   Addone
-----------
 011001
-----------
-----------
 110011   minuend
 011001   2's complement
-----------
[1] 001100
 └────────→ discard carry
```

final result 001100

Ex 1: Using 2's complement, subtract $(1101)_2$ from $(1010)_2$

```
               0010    1's complement of 1101
                  1    Add one
              -----------
               0011    2's complement
               1010    minuend
              -----------
               1101
                  1    subtract 1
              -----------
               1100
               0011    re complement
add -ve sign  -0011    final result
```

final result 0011

LOGIC GATES:

Circuits which are used to process digital signals are called logic gates. Gate is a digital circuit with one or more input voltages but only one output voltage. The most basic gates are AND, OR and NOT gates. By connecting these gates in different ways, we can build circuits that can perform arithmetic and other functions. Logic gates are of two types. They are combinational and sequential. In combinational gates, the output at any instant depends upon the inputs at that instant. In sequential gates, the output at any instant depends upon the order or sequence in which the inputs are applied.

OR GATE:

Or gate has two or more inputs but only one output. According to Boolean algebra OR gate performs logic addition. If A, B are the inputs then the output of the OR gate is X=A+B. the symbolic representation of a two input OR gate is shown in the fig (1) and fig (2) shows the electrical equivalent circuit.

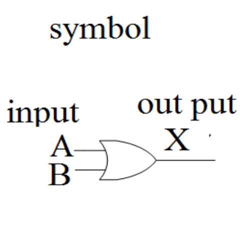


fig 1

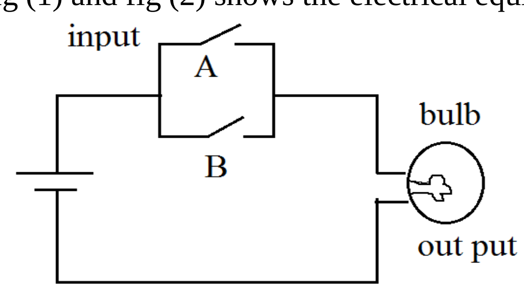


fig 2

truth table

A	B	X= A+ B
0	0	0
0	1	1
1	0	1
1	1	1

DEFINITION:

The output of an OR gate is one [on] if any one of the input is one [on]. Otherwise it is zero.

AND GATE:

The AND gate is a circuit which provides an output when all the inputs are simultaneously present. The symbolic representation of two input AND gate is shown in the fig (3) and fig (4) represents electrical equivalent circuit. If A, B are the inputs then the output of AND gate performs logic multiplication.

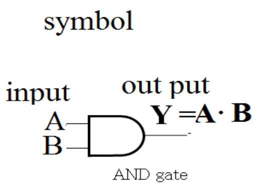


fig 3

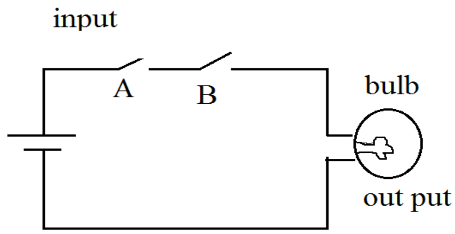


fig 4

truth table

AND		
A	B	Y =A· B
0	0	0
0	1	0
1	0	0
1	1	1

DEF:

The output of AND gate is one [on] if all the input is one [on] otherwise it is zero.

NOT GATE:

It has one input and one output. It inverts the polarity of the input. Thus an output present when there is no input or vice-versa. This gate is also called as inverter gate. If A is the input then the output of the NOT gate is $Y=\overline{A}$ .Fig (5) shows the symbolic representation of NOT gate and fig (6) shows the electrical equivalent circuit.

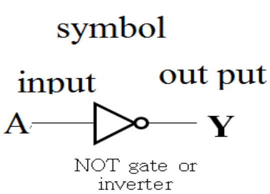


fig 5

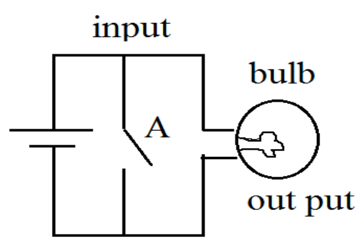


fig 6

truth table

NOT	
A	$Y = \overline{A}$
0	1
1	0

NOR GATE:

The negation following OR gate is called NOT-OR gate or NOR gate. Therefore NOR gate gives output only when all the inputs are zero. If A, B are the inputs of the NOR gate then the output is $Y=\overline{A+B}$. So it is the circuit combination in which a not circuit follows an OR gate. The symbolic representation of NOR gate is shown in the fig (7) and fig (8) shows the electrical equivalent circuit.

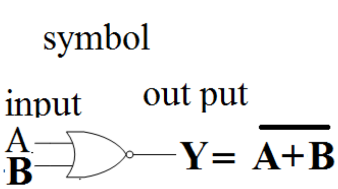


fig 7

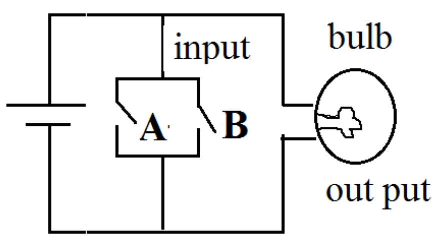


fig 8

truth table

A	B	A+B	$\overline{A+B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

NAND GATE:

It is the combination of AND gate and a NOT gate. If A, B are the inputs then the output of NAND gate is $\overline{A\cdot B}$. Fig (9) shows the symbolic representation of NAND gate and fig (10) shows the electrical equivalent circuit.

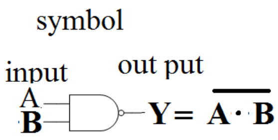


fig 9

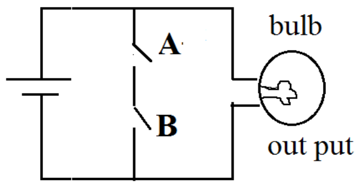


fig 10

truth table

A	B	$A \cdot B$	$\overline{A \cdot B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

FIG

<u>EXCLUSIVE OR GATE (OR) XOR GATE:</u>This gate gives an output when two inputs are different. If A, B are the inputs, then the output of the XOR gate is $Y=A.\overline{B}+B.\overline{A}$ Fig (11) shows the symbolic representation of XOR gate and fig(12)shows its electrical equivalent circuit.

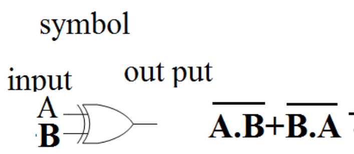


fig 11

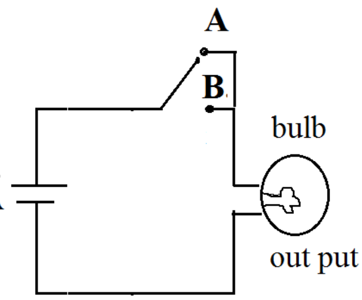


fig 12

truth table

A	B	$Y=A.\overline{B}+B.\overline{A}$
0	0	0
0	1	1
1	0	1
1	1	0

<u>Why NAND is called universal gates.</u>

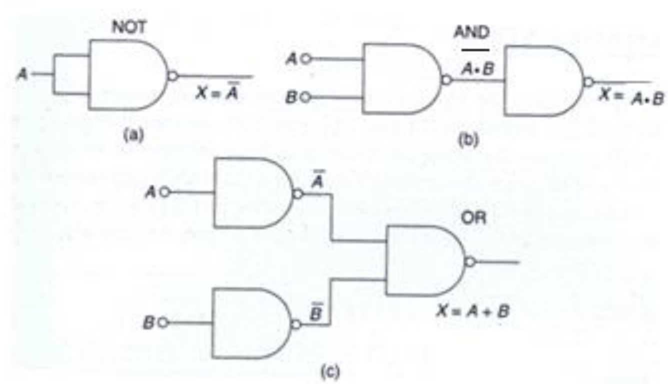
<u>NAND gate as universal gate</u>: Any basic logic gates are constructed by using only NAND as shown in the figure. Hence NAND gate is called as universal gate.

By connecting all the input of NAND gate together we get NOT gate.

By connecting two NAND gate as shown in fig.b we get AND gate.

By connecting three NAND gate as shown in fig.c we get OR gate.

Hence NAND gate is called as universal gate.



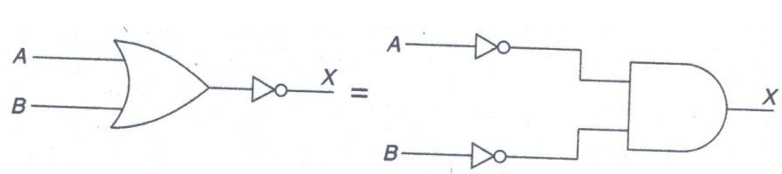
<u>DE-MORGANS LAW:</u>

<u>1st LAW:</u>

De-morgan's first law states that the complement of the sum is equal to the product of the complements. i.e.

$$\overline{A+B}=\overline{A}\,\overline{B}$$

<u>PROOF:</u>



Let us consider the first part of the de-Morgan's law

$$\overline{A+B}=\overline{A}\,\overline{B}$$

(1) Let us consider A=0 and B=0

$$\overline{A+B}=\overline{0+0}=\overline{0}=1$$

$$\overline{A}\,\overline{B}=\overline{0}.\overline{0}=1.1=1$$

Therefore LHS=RHS

(2)Let us consider A=1 and B=0

$\overline{A+B}=\overline{1+0}=\overline{1}=0$

$\overline{A}.\overline{B}=\overline{1}.\overline{0}=0.1=0$

∴LHS=RHS

The same proof holds good for A=0 and B=1

(3) Let us consider A=1 and B=1

$\overline{A+B}=\overline{1+1}=\overline{1}=0$

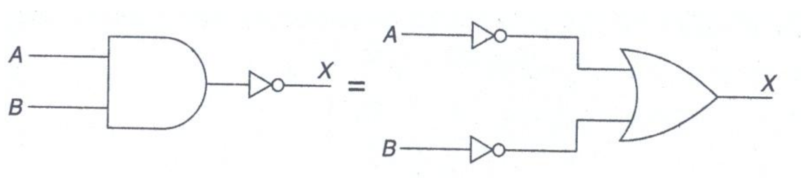
$\overline{A}.\overline{B}=\overline{1}.\overline{1}=0.0=0$

∴LHS = RHS

Thus the theorem is proved for all possible values of A and B. hence the theorem is proved.

SECOND THEOREM:

The complement of the product of two or more variables is equal to the sum of the complements of the variables.



i.e. $\overline{A.B}=\overline{A}+\overline{B}$

PROOF:(1) Let us consider A=0 and B=0

$\overline{A.B}=\overline{0.0}=\overline{0}=1$

$\overline{A}+\overline{B}=\overline{0}+\overline{0}=1+1=1$

∴LHS = RHS

(2) Let us consider A=1 and B=0

$\overline{A.B}=\overline{1.0}=\overline{0}=1$

$\overline{A}+\overline{B}=\overline{1}+\overline{0}=0+1=1$

∴ LHS = RHS

The same proof holds good for A=0 and B=1

(3) Let us consider A=1 and B=1

Then $\overline{A.B}=\overline{1.1}=\overline{1}=0$

$\overline{A}+\overline{B}=\overline{1}+\overline{1}=0+0=0$

∴LHS = RHS

Thus the theorem is proved for all possible values of A and B. hence the theorem is proved.

HALF ADDER:

It is an electronic circuit that adds two single bits to produce a sum, and a carry to be used in the next higher position. The circuit is called a half-adder because; it can't accept a carry in from previous addition. In order to achieve a carry in from previous addition ,we have to construct a 3 input adder which is called full-adder fig(13) shows the symbol of half-adder and fig(14) shows the combination of AND and XOR gates.

Truth table

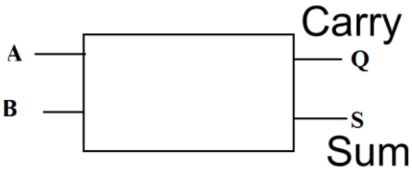


FIG 13

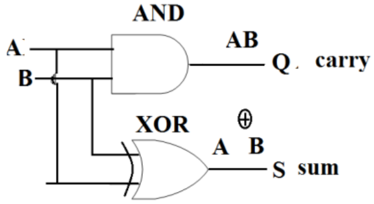


FIG 14

A	B	sum	carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

FULL-ADDER:

It is an electronic circuit that adds three bits, two bits to be added and a carry bit from previous addition resulting in a sum and a carry. It consists of two half-adders and one OR gate are cascaded as shown in the fig (15) and fig (16) shows its symbol

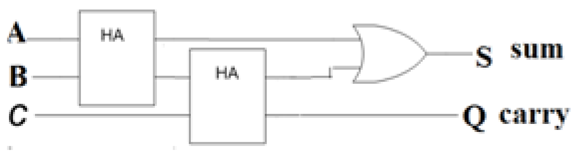


FIG 15

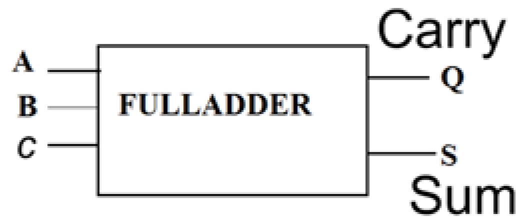


FIG 16

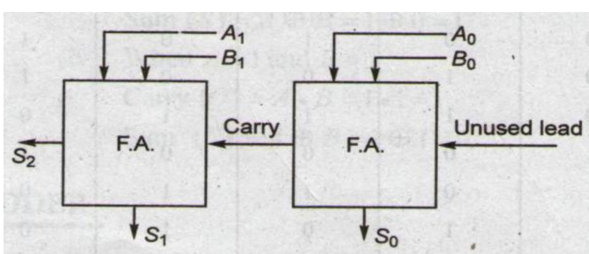
Here input C is referred to the carry in and output carry Q is referred as the carry out.

Truth table

A	B	carryQ'	Sum(s)	Carry(Q)
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
1	0	0	1	0
1	1	0	0	1
1	0	1	0	1
0	1	1	0	1
1	1	1	1	1

Parallel Binary adder:

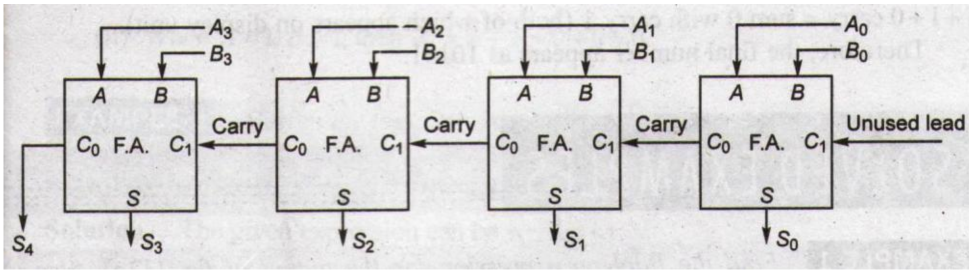
A single full adder is capable of adding two one-bit numbers and an input CARRY. For adding binary numbers with more than one bit, additional full adders are required. The CARRY output of each adder is connected to the CARRY input of the next higher order adder as shown in the figure (1)



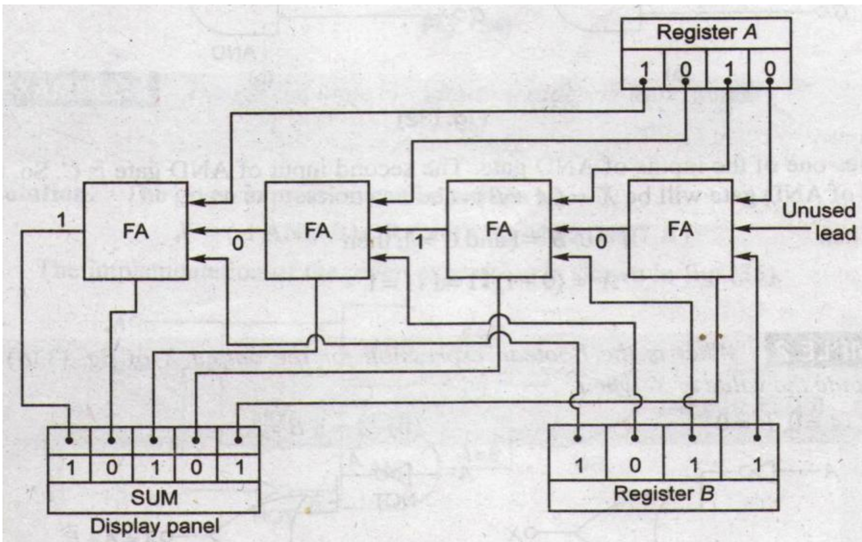
Four- bit parallel adder:

Circuit diagram of four-bit binary parallel adder is shown in fig(2). consider two four bit binary numbers whose bits in the order of decreasing value are respectively A_3, A_2, A_1, A_0 and B_3, B_2, B_1, B_0.Their sum

Is S_4,S_3,S_2,S_1, and S_0



The full-adder circuit in each position has three inputs: an A bit and a B bit and a C_1(CARRY IN) bit and it produces two outputs: a SUM bit and a CARRY OUT bit. For example, full adder FA_0 has inputsA_0B_0 and C_1 and it produces output S_0 and C1 . The procedure is repeated for other full adders.



Operation

The actual operation may be understood with the help of fig(3).

Suppose we want to add the following four bit numbers

```
  1010
 +1011
  -------
 10101
 ---------
```

The first adder performs 0+1 binary addition. This gives a sum of 1 and a carry of 0. The two bits 0 and 1 are supplied from two registers A and B simultaneously. The sum 1 appears on the display panel and carry 0 is passed to the next full adder.

The second adder 1+1+1+0 carry=1 with carry0.the fourth adder adds 1+1+0carry=sum0 with carry1

Therefore, the final number appears10101

The first adder performs 0+1 binary addition. This gives a sum of 1 and a carry of 0. The two bits 0 and 1 are supplied from two registers A and B simultaneously. The sum1 appears on the display panel and carry 0 is passed to the next full adder.

The second adder 1+1+0 carry = sum 0 with carry 1.

The third adder performs 0+0+1 carry = 1 with carry 0. The fourth adder adds 1+1+0 carry= sum 0 with carry 1(both of which appears on display unit).

Therefore, the final number appears as 10101.

BASIC ELECTRONICS

INTRODUCTION:

Materials are classified into three categories on the basis of conduction of electricity. They are

(1) CONDUCTOR:

The material which allows electricity freely is known as conductor.

Ex:Cu,Fe,..etc Resistivity $\rho=10^{-2}$to 10^{-8} Ωm

(2) INSULATOR:

The material which does not allows electricity is known as insulator.

ExGlass,rubber,...etc Resistivity $\rho=10^{11}$to 10^{19} Ωm

(3) SEMICONDUCTOR:

The material which allows electricity partially is known as semi-conductor.

Ex:Si,Ge..etc Resistivity $\rho=10^{-5}$to 10^{6} Ωm

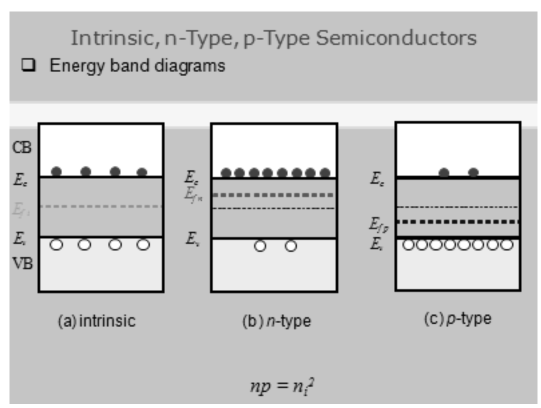
VALENCE BAND, CONDUCTION BAND AND FORBIDDEN ENERGY GAP:

VALENCE BAND: The electrons in the outermost shell are called valence electrons. The band formed by a series of energy levels containing the valence electrons is known as valence band.

Def: A band which is occupied by the valence electrons is known as valence band.

CONDUCTION BAND:

In some materials like metals valence electrons are loosely attached to the nucleus. Even at ordinary temperature, some electrons leave the valence band. These are called free electrons. These are responsible for the conduction of current. The band occupied by these electrons is known as conduction band. Insulators have empty conduction band.



FORBIDDEN ENERGY GAP:

- The separation between conduction band and valence band is known as forbidden energy gap. There is no allowed energy state in this band .Hence no electrons can stay in the forbidden energy gap.
- **Fermi level**: The highest occupied energy level of electron at absolute zero is called Fermi level. In semiconductors due to interaction between the periodic potential and electrons, the Fermi level moves into the forbidden energy gap. This is an energy level in the energy gap that represents the point where the probability of finding an electron is = 0.5 .

  Hence Fermi level lies in the middle of the band gap

- Fermi level is the energy that corresponds to the centre of gravity of the conduction electrons and holes weighted according to their energies.
- In the case of N-type semiconductor it has more conduction electrons; hence the Fermi level shifts towards the conduction band.
- In the case of P-type semiconductor it has more conduction holes; hence the Fermi level shifts towards the valance band.

Drift current: Before applying an electric field to a semiconductor the charge carriers are in random motion. An electric field is applied to a semiconductor, then the free electrons move from negative to positive terminal with a steady velocity. They constitute a current called drift current.

The drift velocity of charge carrier's v is given by

$v=\mu E$

Where μ= mobility of charge carriers.

Diffusion current : In a semiconductor the charge carriers flow from highly doped area to lightly doped area in a non uniformly doped semiconductor. This current is known as diffusion current

INTRINSIC SEMI-CONDUCTORS:

A pure semiconductor without any contaminated material is known as intrinsic semiconductor.

In the case of silicon, it has four valence electrons. Every Si atom tends to share one of its four valence electrons with each other of its four nearest neighbor atoms. These shared electron pairs are referred as forming a covalent bond.

EXTRINSIC SEMICONDUCTOR:

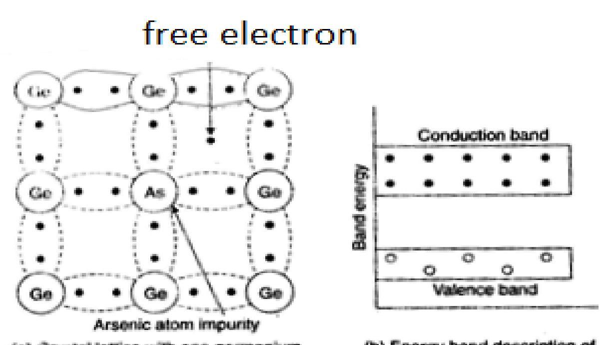
To increase the electrical conductivity, certain impurity atoms are added to the pure semiconductor (one atom per million). This process is known as doping. The impurity elements are called dopants. This type of semiconductor is known as extrinsic semiconductor.

Def: A doped semiconductor is known as extrinsic conductor. They are divided in to two classes. They are (1) N-type semiconductor (2) P-type semiconductor.

(1) N-TYPE SEMICONDUCTOR:

Pentavalent material like Arsenic is added as impurity to a (quadruvalent element) pure semiconductor like germanium during the process of crystallization, the resulting semiconductor is known as N -type semiconductor.

Of the five valence electrons of Arsenic four will form covalent bonds with four electrons of four neighboring Ge atoms. The fifth valence electron has no chance to form covalent bond. Hence these electrons become free and take part in conduction.



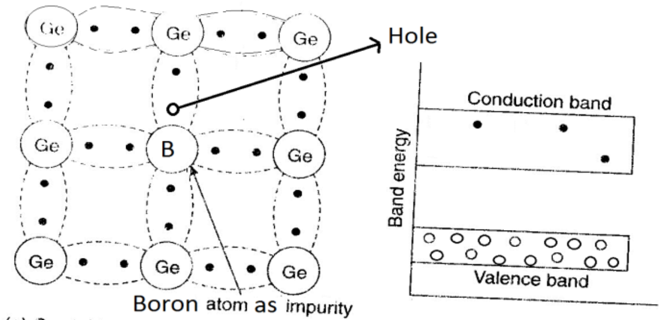
(a) Crystal lattice with one germanium atom displaced by arsenic atom.
(b) Energy band description of N-type semi-conductor

Hence each impurity atom donates one electron to the conduction band. So, a pentavalent impurity is called a donor impurity.

As the no: of free electrons are very large, the chance of their recombination with holes also increases. Therefore the net concentration of the holes in the N-type semiconductor will become much less than the values in an intrinsic semiconductor. Hence in N-type semiconductors majority charge carriers are electrons and minority charge carriers are holes. As impurity atom donates one electron to the conduction band it becomes +vely charged and it cannot move. This ion is known as immovable ion.

(2) P-TYPE SEMICONDUCTOR:

Trivalent material like Boron is added as impurity to a pure semiconductor (quadruvalent element) like Ge then P-type semiconductor is formed. Three valence electrons of Boron will form covalent bonds with electrons of the three neighboring Ge atoms. In the fourth covalent bond, only Ge atom contributes one valence electron and there is a deficiency of one electron. This is called hole. The Boron atom accepts an electron to fill the incomplete bond and hence this type of trivalent impurity is known as acceptor impurity.



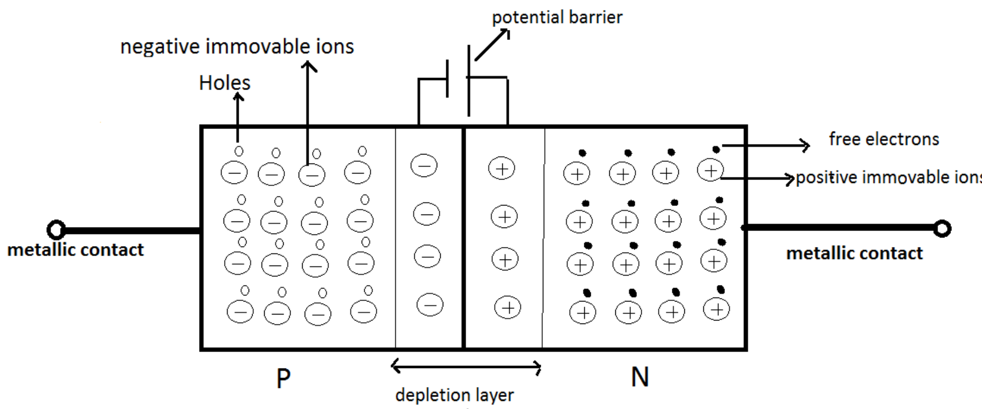
(a) Crystal lattice with one germanium atom displaced by Boron atom.

(b) Energy band description of P -type semi-conductor

In P-type semiconductor majority charge carriers are holes and minority charge carriers are electrons.
If the doping concentration is high then width of the depletion layer is small .If the doping concentration is light then width of the depletion layer is big.

P-N JUNCTION DIODE: It is a two terminal semiconductor diode with metallic contacts provided at the ends for the application of an external voltage.

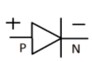
A P-N junction is formed from a single piece of a semi conducting material like Ge by special fabrication techniques such that one half will be P-type and the other half N-type. The plane dividing the two regions is called the PN- junction.



As P-type material has high concentration of holes and N-type has high concentration of electrons and there is a tendency of holes to diffuse over to N-side and electrons to P-side. The process is known as diffusion. So due to diffusion some of the holes from P-side cross over to N-side where they combine with electrons and become neutral. Similarly, some of the electrons from N-side cross over to P-side where they combine with holes and become neutral. This neutralized region is known as depletion layer. The diffusion of holes and electrons continues till a potential barrier is developed in depletion layer. This potential barrier (0.1 to 0.3V) prevents further diffusion.

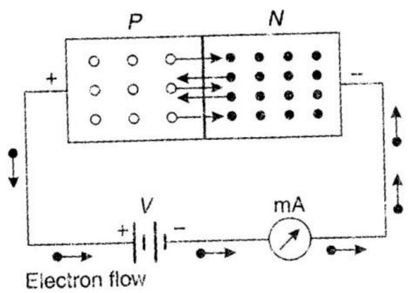
JUNCTION VOLTAGE (OR) BARRIER POTENTIAL:

When the depletion layer is formed there are negative immovable ions in P-type and positive immovable ions in N-type as shown in the fig. Hence voltage is established across the junction. This voltage is known as junction voltage.

DIODE SYMBOL: 

WORKING OF P-N JUNCTION DIODE:

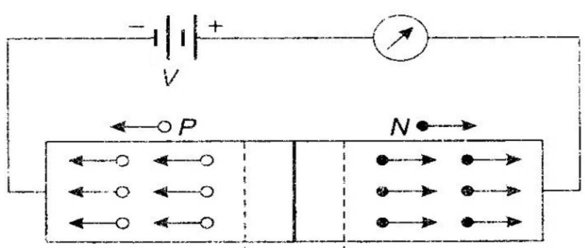
(1)FORWARD BIAS: When an external voltage is applied to the P-N junction in such a direction that it cancels the potential barrier and permits the current flow is known as forward bias. Hence +ve terminal of battery is connected to P-type semiconductor and –ve terminal of the battery is connected N- type semiconductor as shown in the fig.



When the forward voltage is applied the potential barrier [0.3 V for Ge and 0.7 V for Si] across the junction is completely eliminated.

When forward voltage is applied, holes from P-type are repelled by the +ve polarity of the battery and electrons from N-type are repelled by the –ve polarity of the battery towards the junction. Here battery potential should be higher than the potential barrier to cross the junction. When an electron-hole combination takes place near the junction, a covalent bond near the positive terminal of the battery breaks down. Hence an electron-hole pair is generated and the electron enters the +ve terminal of the battery and the hole moves towards the junction. Hence high forward current is established.

(2)REVERSE BIAS:



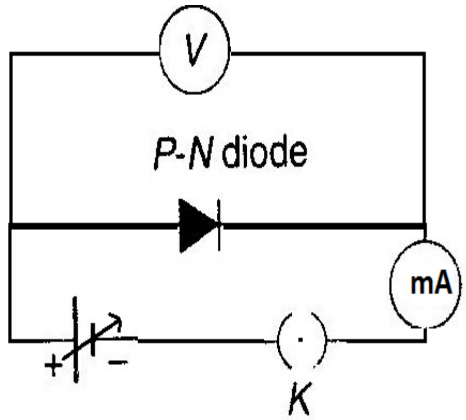
When an external voltage is applied to P-N junction in such a direction that it increases the potential barrier then it is known as reverse bias. For reverse bias +ve terminal of the battery is connected to N-type and –ve terminal of the battery is connected to P-type semiconductor. The applied reverse voltage establishes an electric field which acts in the same direction of potential barrier. Therefore, junction voltage is increased and hence it prevents the flow of charge carriers. Hence high resistance path is established. Reverse voltage attracts the charge carriers from the junction. Hence potential barrier is increased.

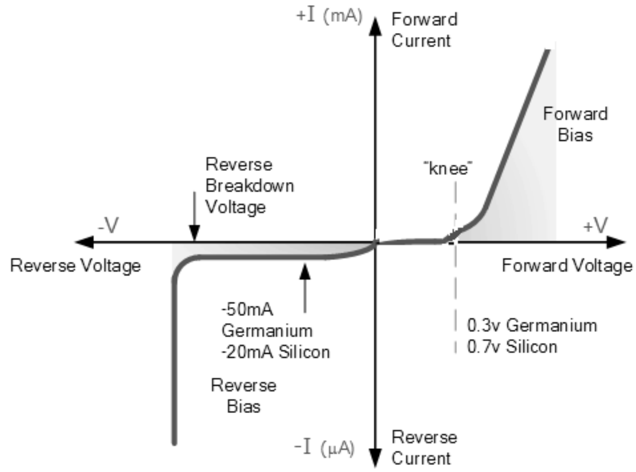
From the above discussion it is clear that, the P-N junction acts as an insulator in the case of reverse bias and act as a conductor in the case of forward bias. Hence it is used for converting A.C into D.C

V-I CHARACTERISTICS OF P-N JUNCTION DIODE:

A graph which represents voltage on X-axis and current on Y-axis is known as characteristics of a P-N junction diode.

Forward bias characteristics: The experimental arrangement is as shown in the figure. The diode is connected in the forward bias. Rheostat R_h is used to vary the applied





voltage, milli ammeter is used to measure the diode current and voltmeter is used to measure the voltage across the diode. By increasing the forward voltage from 0.1v to 1.2v the diode current I is noted. The graph is drawn by taking V values on X-axis and I values on Y-axis. The graph is as shown in the figure.

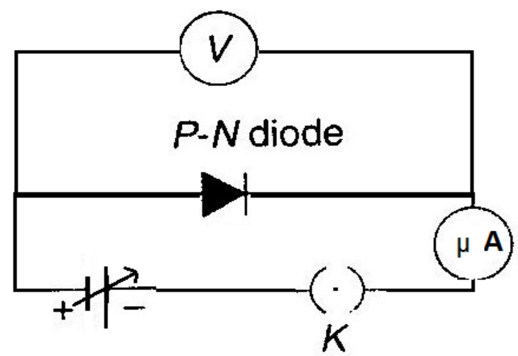
From the graph we observed that the diode current is quite small up to a point A [0.7v for Si and 0.3v for Ge]. This is because of the barrier potential is to be overcome first. After the voltage reaches the point A, there is a sharp increase in current even for a slight increase in voltage. The point A is known as "cut in voltage" or "knee voltage".

Dynamic resistance $r_d = \frac{\Delta V}{\Delta I}$

REVERSE BIAS CHARACTERISTICS:

The experimental arrangement is as shown in the fig.

The reverse voltage is increased from 2v to 30v in steps of2v. The diode current is noted in μ.A. A graph is drawn by taking reverse voltage V_r on X-axis and the reverse current $I_r$on Y-axis. The graph is shown in the fig. From the graph it is clear that the small reverse current is almost constant up to certain voltage called "breakdown voltage" V_b is reached. When V_b reaches, the reverse current increases abruptly for a small increase in voltage. This can be explained as follows:



(1) Up to V_b the small reverse current is independent of applied voltage. This is because of the drift of minority carriers.

(2) After V_b the reverse current increases abruptly because the crystal structure gets break down. This can be explained by two mechanisms.

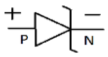
(a)ZENER BREAKDOWN: Zener break down takes place in very thin junction. When a small reverse voltage is applied a very strong electric field (10^7V/m) is set up across the thin depletion layer. With increase of reverse voltage, the electric field at the junction increase and this high electric field break down the covalent bonds. Hence electron hole-pairs are generated. This breakdown mechanism is called Zener breakdown. Zener current is independent of the applied voltage.

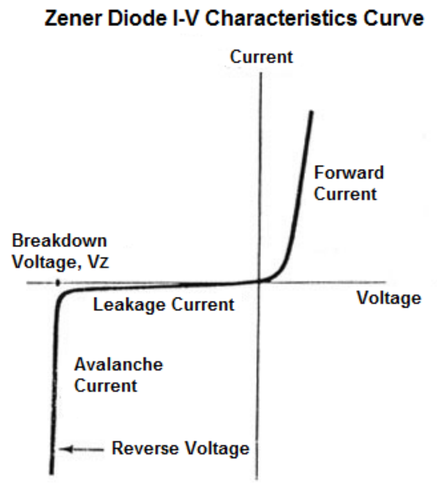
(b)AVALANCHE BREAKDOWN: This type of break down takes place in thick depletion region. In this case the electric field across the junction is not so strong. Here the minority charge carriers accelerated by the field collide with the semiconductor atoms in the depletion region. Due to the collision with valance electrons, covalent bonds are broken and electron hole pairs are generated. They in turn breakdown the covalent bonds. There are more charge carriers are generated. These charge carriers are accelerated by the electric field and break more covalent bonds. And this process continues as a chain reaction. A large number of charge carriers are generated as an avalanche and hence this break down is known as Avalanche breakdown.

ZENER DIODE:

A properly doped P-N junction diode which has sharp break down voltage when operated in the reverse bias condition is known as Zener diode.

The break down voltage of a junction diode depends on the amount of doping. If the doping is heavy the depletion layer will be thin. Consequently, the breakdown occurs at lower reverse voltage where as a lightly doped diode has a higher break down voltage.

Symbol: 



Working: In the case of forward bias it acts as an ordinary P-N junction diode.

When a reverse voltage is increased from zero to a critical value called zener voltage, the current remains very small value. After the zener voltage, the electric field becomes strong enough to remove electrons from covalent bond and hence electron hole pair is generated. The generated electron hole pair increases the reverse current without change in voltage. The V-I characteristics is shown in the figure. Zener diodes with different breakdown voltages can be obtained by changing the doping concentration.

PROPERTIES OF ZENER DIODE:

(1) It has sharp break down voltage when it is operated in reverse bias. Hence it is used as voltage regulator.

(2) In the case of forward bias it acts as an ordinary P-N junction diode.

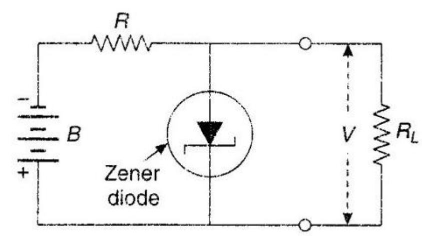
(3) By changing doping concentration, zener diode with different voltages can be designed.

(4) They have high thermal stability.

(5) At zener voltage, the diode voltage remains constant over a wide range of currents.

ZENER DIODE AS VOLTAGE REGULATOR:

A device which gives constant output voltage even though the input voltage changes is known as voltage regulator. Zener diode can use as a voltage regulator by operating in the break down region in reverse bias condition.



The circuit diagram is as shown in the figure. The resistance R is used to limiting the current through the Zener diode. The zener diode will not conduct as long as the voltage across the load resistance R_L is less than the zener breakdown voltage. As the input voltage V_{in} increased, the voltage across R_L becomes greater than the zener break down voltage V_z. Hence the reverse biased zener diode now operates in the breakdown region.

From the Kirchhoff's first law $I=I_Z + I_L$------------------ (1)

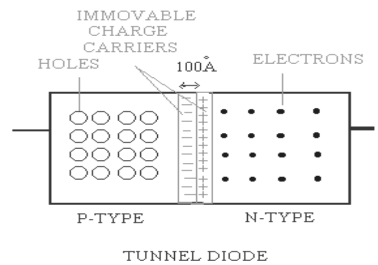
Let us suppose that the load resistance R_L reduces. As a result load current I_L increases. But from eq. (1) as I_L increases I_Z will decrease by the same amount and I is the same. Hence P.D across R_L remains constant. Therefore output voltage is constant.

Now, let us consider the variations in the input voltage V_{in} when the input voltage increases, the zener diode passes a large current through it so that there is an additional voltage drop across the resistance R. Hence the change in the output voltage V_o will be far less, compared to changes in the input voltage V_{in}.

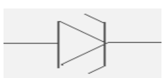
AN IDEAL DIODE :

A diode which act as a perfect conductor in forward bias [$R_F = 0$] and acts as a perfect insulator in reverse bias [$R_R = \infty$] is known as an ideal diode.

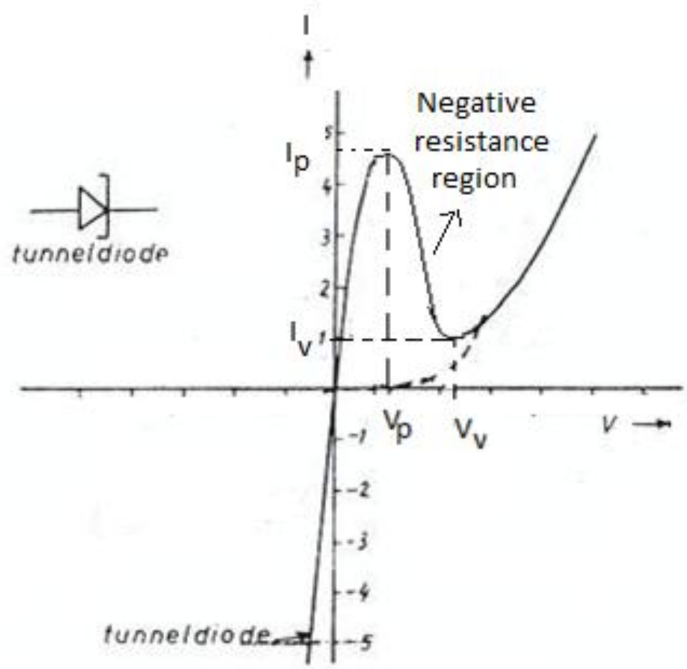
Tunnel diode: In ordinary diode the doping concentration is $1:10^8$. It's depletion layer is of the order of 5μm.If the doping concentration is greatly increased up to 1:10 then depletion layer is of the order of 100˚A and the device properties are completely changed such a diode is known as "Tunnel diode or Esaki diode"(1958). It utilizes the phenomenon of tunneling of electrons through the potential barrier.



Construction: It is heavily doped P-N junction diode. This heavily doping reduces the width of the depletion layer(100˚A). The electric field at the junction is very high. For a small reverse voltage ,electrons are capable of tunneling through one side of the junction to the other side. Even less than 0.5V of forward bias. It is made from Ga or GaAs.

Symbol: 

Working:when Reverse bias voltage is applied to a tunnel diode ,it conducts and there is no region of high reverse resisrance. As soon as forward bias is applied the tunnel diode passes current which quickly reaches to peak value I_p at a low voltage V_p. As the forward voltage is increased diode current starts decreasing and achieves a minimum value I_v for a vally voltage V_v. as the forward voltage is further increased beyond Vv the current increases again as in the case of P-N diode. Total current is the sum of two different mechanisms.



APPLICATIONS:1) It is used as an amplifier, an oscillator, or a relaxation oscillator

2)Since tunneling mechanism takes place at the speed of light ,it is used as switching device in computers.

3)It is used as a micro wave oscillator at a frequency 10GHz

Merits:

1)It's size is very small 2) Extremely high frequency response. 3)very low power consumption 4)very wide temperature of operation

Demerits:

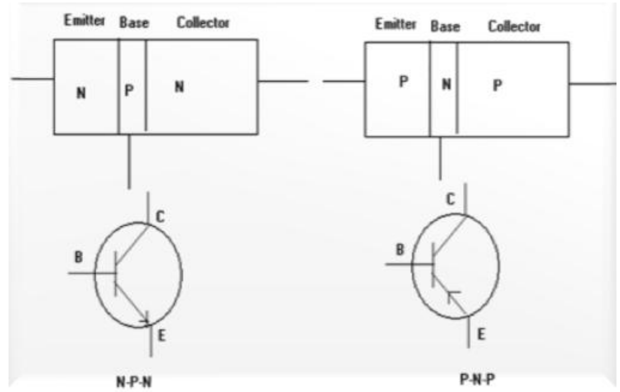
1) Instability due to negative resistance 2)unwanted signal feed through 3)Low voltage range (0-1v)
4) No isolation between input and out put.

Bipolar junction Transistor(BJT):

Introduction : Transistor was invented in 1948 by john Bardeen and Brattain of Bell Laboratories, USA.

Construction and Working of pnp transistor:

Construction :P-N-P consists of a silicon (Germanium) crystal in which N-Type Silicon is sandwiched between two layers of P-Type silicon, to form P-N-P transistor. There are three terminals in a transistor.They are

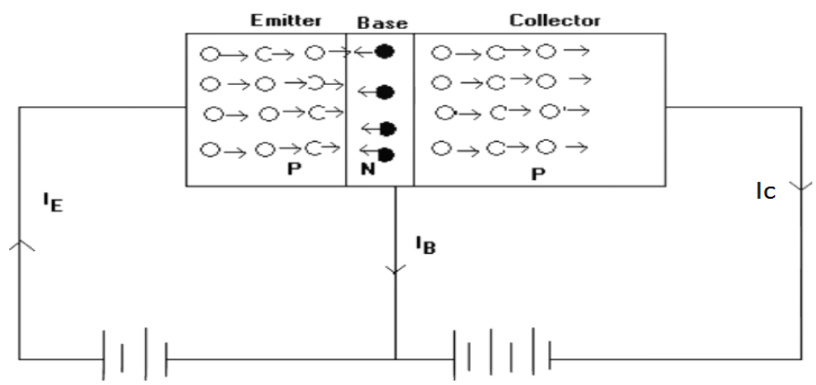


1. **Emitter**: It can supply a large number of majority charge carriers. The emitter is heavily doped
2. **Collector**: It collects charge carriers. It is always reverse biased. The collector is moderately doped.
3. **Base**: The middle section which forms two p-n junctions is known as 'Base'. The base is lightly doped

The base is much thinner than the emitter and collector is wider than the emitter.

The Base –emitter junction is forward biased and base –collector junction is reverse biased.

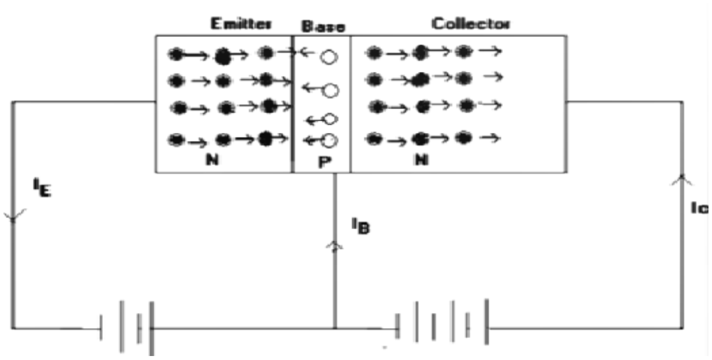
Working: Holes in the emitter and electrons in the base are repelled towards the emitter junction by the forward voltage. Majority holes are reached the base by diffusion. These holes are minority charge carriers in the base region. Though the collector junction is reverse biased for minority charge carriers it is forward biased . Hence holes are reached the collector. At the same time electrons are emitted from the battery which combines with the holes.



For each neutralization one covalent bond breaks down at the emitter. Holes are current carriers with in the transistor and electrons are the current carriers in the connecting wires. Here holes are moving from low resistance path to high resistance path. Hence transistor works as an amplifier.

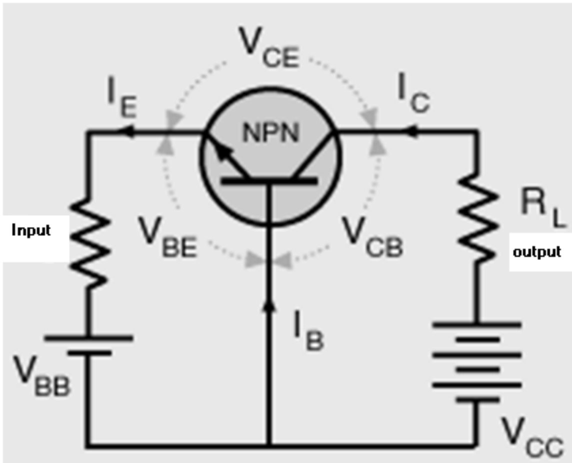
Working of n-p-n transistor :

(This can be explained as above)



Transistor connections: One of the three terminals of the transistor is common for both input and output. Accordingly a transistor can be connected in three ways. They are

1)Common Base :

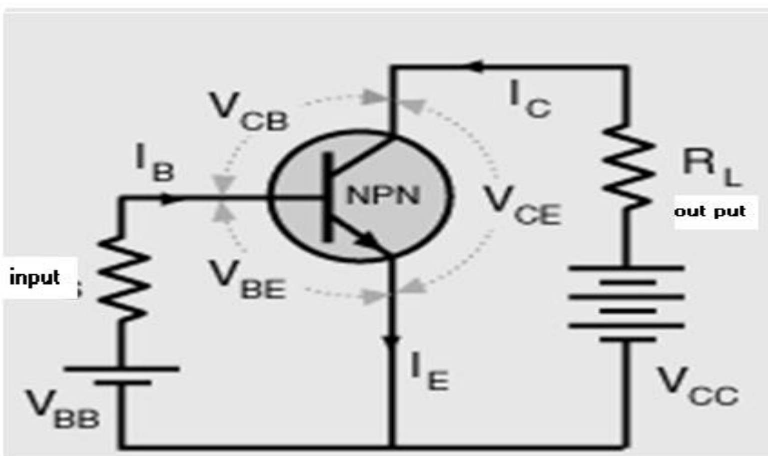


Current amplification factor $\propto$: It is the ratio of output current to input current. In Common base configuration

$$\text{current amplification factor} \quad \propto = \frac{\triangle Ic}{\triangle I_E}$$

since $Ic < i_E$ $\qquad$ $\propto$ is less than 1(0.9 to .99)

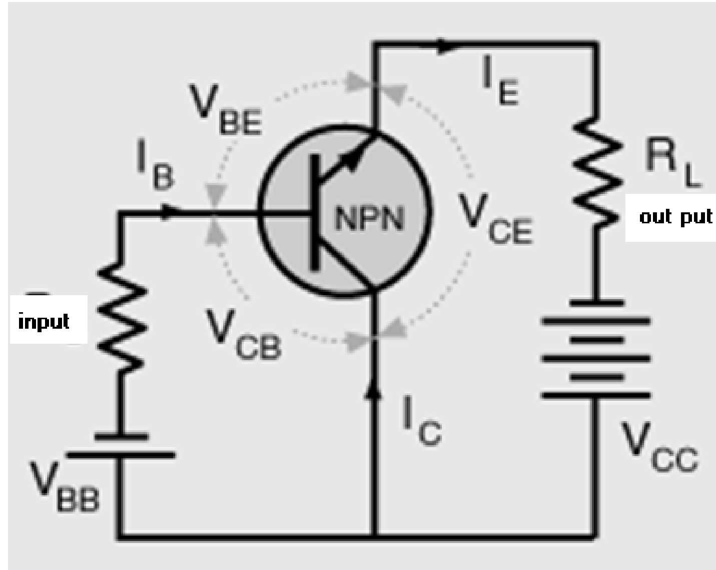
2) <u>Common Emitter</u> :current amplification factor $\beta = \Delta I_c / \Delta I_b$



A CCORDING TO KIRCHOF'S LAW

$I_E = I_B + I_C$

3)**Common Collector :**



$$\text{ammplification factor } \gamma = \frac{\Delta I_E}{\Delta I_B}$$

Transistor characteristics:

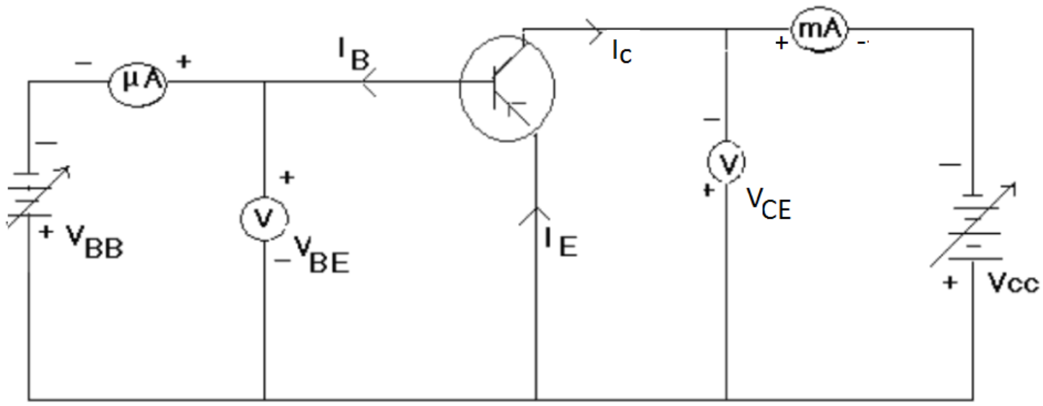
Input characteristics: The curves showing the variation of the base current I_B with emitter voltage V_{BE} at constant collector voltage V_{CB} are called the emitter or input characteristics of a transistor.

Active region: The region in which emitter junction is forward biased and collector junction is reverse biased is called active region.

Saturation region: The region in which both emitter and collector junctions are forward biased is called Saturation region.

Cut-off region: The region in which both emitter and collector junctions are reverse biased is called Cut-off region.

Common-emitter characteristics: In the case of pnp transistor, emitter base junction is made forward bias by connecting –ve terminal of the battery to base and +ve terminal



of the battery to emitter . Emitter collector junction is made reverse bias by connecting –ve terminal of the battery to collector and +ve terminal of the battery to emitter .V_{BE} measures the voltage between emitter and base.V_{CE} measures the voltage between collector and emitter .µA measures base current and mA measures collector current.

Input characteristics

Input characteristics : Curves showing the variation of the base current with base-emitter voltage at constant collector-emitter voltage are called the input characteristics of a transistor.

Important points: 1) The curves are just like P-N junction diode forward biased characteristics .

2) The Base current increases non linearly with increase in base voltage.

3) Input resistance of a CE circuit is higher compared to that in CB configuration.

4) Input characteristics are slightly dependent upon the V_{CE}

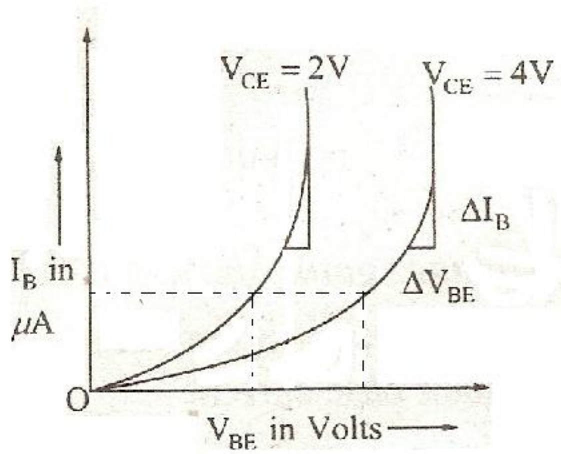


Fig (1)

Output characteristics : Curves showing the variation of the collector current with the collector voltage at constant base current are called the output characteristics. of a transistor

Important points:1)The collector current varies rapidly with V_{CE} for very small voltage up to 2 V .After this collector current becomes almost constant and is decided entirely by base current

2) Collector voltage has only a minute effect on collector current for low values of base current . But as the base current rises, the effect of Collector voltage on the collector current also increases.

3) The collector current is not zero when base current is zero. (due to minority charge carriers)

4)A small input current produces a large output current Hence it exhibits a current amplification.

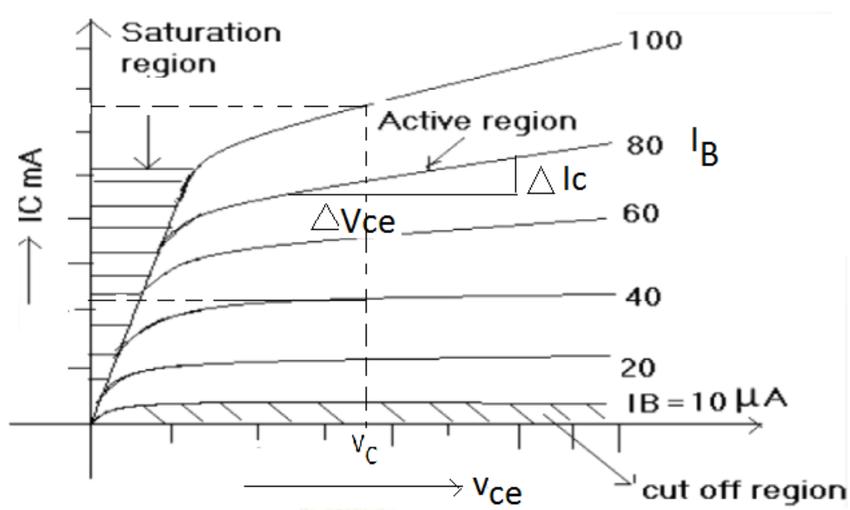


Fig 2

Determination h -parameters from transistor characteristics:

Determination parameters h_{fe} and h_{oe}: Fig:2 shows the output characteristics of a common emitter transistor. From this figure ΔI_c, ΔV_{ce} , ΔI_b are calculated. Hence we can calculate hoe and h_{fe} by using the formulae

$h_{oe}=\Delta I_c / \Delta V_{ce}$

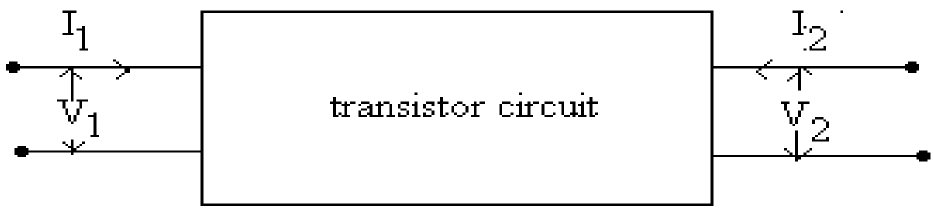
and $h_{fe} =\Delta I_c / \Delta I_b$

Determination parameters h_{re} and h_{ie}: Fig:1 shows the input characteristics of a common emitter transistor. From this figure ΔV_{ce}, ΔV_{be} , ΔI_b are calculated. Hence we can calculate h_{re} and h_{ie} by using the formulae

$h_{re}=\Delta V_b / \Delta V_{ce}$

and $h_{ie} =\Delta V_b / \Delta I_b$

Transistor h- parameters: Treating four poles transistor circuit as a two port net work as shown in the fig .The pair of left terminals represents input terminals, while at the right represents output terminals. For each pair of terminals, there are two variables, the current and voltage. These four variables can be represented by



$V_1=h_{11}I_1+h_{12}V_2$------------------------- (1)

$I_2=h_{21}I_1+h_{22}V_2$--------------------------(2)

The parameters h_{11}, h12, h21 and h_{22} which relates the four variables of the two port network are called h-parameters .It may be defined by first puttingV_2=0and we get two equations .they are

$$h_{11} = \left|\frac{V_1}{I_1}\right|_{V_2=0} = h_{ix} = inputimpedance$$

$$h21 = \left|\frac{I_2}{I_1}\right|_{V2=0} = h_{fx} = forwardcurrentgain$$

By putting i_1=0 we get two equations .they are

$$h_{12} = \left|\frac{V_1}{V_2}\right|_{I1=0} = reversevoltageratio$$

$$h_{22} = \left|\frac{I_2}{V_2}\right|_{I1=0} = outputadmit\tan ce$$

In case of common collector configuration,the h-parameters are

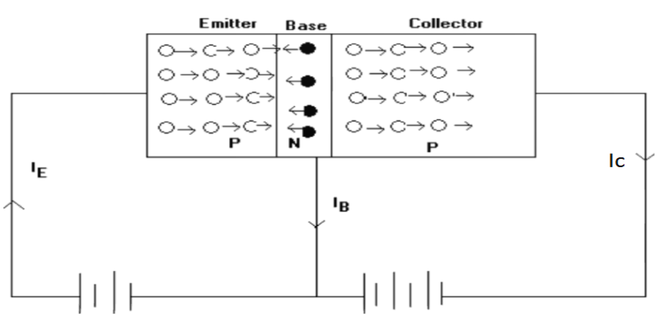
h_{ic},h_{fc},h_{rc},h_{oc}

In case of common emitter configuration,the h-parameters are

h_{ie},h_{fe},h_{re},h_{oe}

Transister as an amlifier:

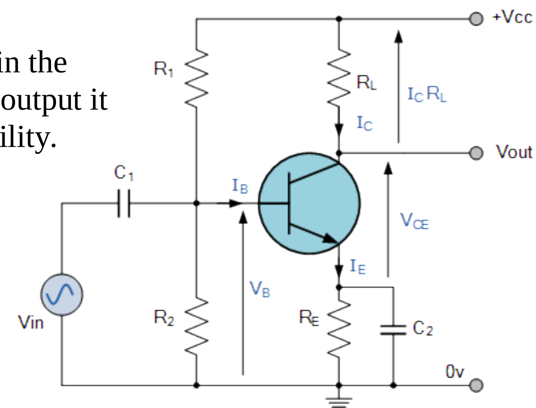
Amplifier: An amplifier is an electronic device that increases the voltage, current, or power of a signal.



In PNP transister (common emitter configuration) Holes in the emitter and electrons in the base are repelled towards the emitter junction by the forward voltage. Majority holes are reached the base by diffusion. These holes are minority charge carriers in the base region. Though the collector junction is reverse biased for minority charge carriers it is forward biased. Hence holes are reached the collector. Here holes are moving from low resistance path to high resistance path. Because emitter junction is forward bias i.e low resistance path and collector junction is reverse bias i.e high resistance path.

Power $P = i^2 R$.

Here i is almost constant but resistance is greatly increased. Hence transistor works as an amplifier.



Working: The single stage common emitter amplifier circuit is as shown in the figure. It consists of voltage divider biasing. The R_L resistor is used at the output it is called as the load resistance. The R_E resistor is used for the thermal stability. The C_1 capacitor is used to separate the AC signals from the DC biasing voltage and the capacitor is known as the coupling capacitor.
If the R_2 resistor increases then there is an increase in the forward bias. The alternating current is applied to the base of the transistor of the common emitter amplifier circuit then there is a flow of small base current. Hence there is a large amount of current flow through the collector with the help of the R_C resistance. The voltage near the resistance R_C will change because the value is very high and the values are from 4 to 10 k ohm. Hence there is a huge amount of current present in the collector circuit which amplified from the weak signal, therefore common emitter transistor work as an amplifier circuit.

DIELECTRICS

INTRODUCTION: Dielectrics are the substances which do not contain free electrons. The electrons are tightly bound to the nucleus of the atom.
Ex: glass, mica, rubber etc.
Dielectric material increases the capacity of a capacitor. It helps in maintaining two large metal plates at very small separation.

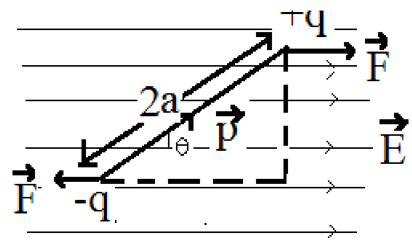
Difference between Dielectrics and conductors:

S.No.	Dielectrics	conductors
1	Dielectric materials does not contain free electrons.	Conductors contain free electrons.
2	The dielectric does not conduct electricity.	Conductors conduct electricity.
3	On the application of electric field, the electrons may be able to move to and fro about their mean position.	On the application of electric field, the free electrons may be able to move throughout the material.
4	For a particular field strength, the dielectric loses its insulation character.	-

Electric dipole moment:

DIPOLE : A dipole is a pair of equal and opposite charges separated by a small distance.

Dipole Moment : Dipole moment is the product of magnitude of charge and the distance between them. Its SI unit is Coulomb metre (Cm) or Debye (D). The direction of dipole is usually defined from the negative charge towards the positive charge.



Let q be the magnitude of charge and 2a be the distance between the charges, then the dipole moment p=2aq

As shown in the fig. electric dipole placed in electric field of strength E, the torque is given by

$\tau = force \times perpendicular\ distance$

$\tau = F \times 2a\ sin\theta$

$\tau = qE \times 2a\ sin\theta \quad \because F = qE$

$\tau = pE\ sin\theta \quad \because p = 2aq$

$\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$

Polarization: We know that a conductor or insulator consists of a positive nuclei and negative electrons. In a conductor, electrons are free to move while in dielectric they are bound to the nucleus. Let a dielectric slab is placed between the two metallic plates which can be charged to equal and opposite charges.

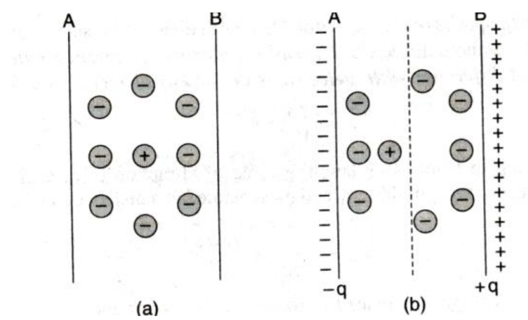
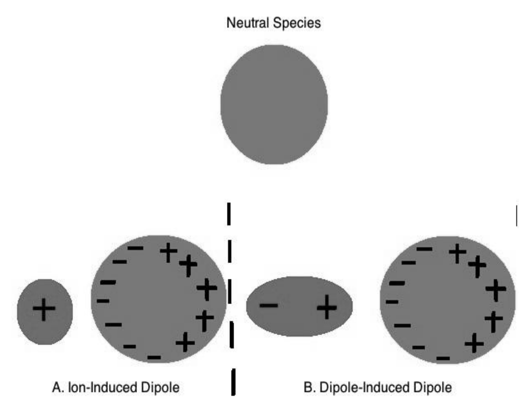


Figure (a) shows the electronic structure of an atom when the two plates are not charged. When an electrostatic field is established between the two plates as shown in the figure (b) the electrons are slightly displaced towards the positively charged plate while the positively charged nucleus towards the negatively charged plate. The electronic displacement is a function of the magnitude of the charges on plates and the nature of dielectric. In this way, the dielectric is acted upon by the forces and is said to be polarized. Now the distorted atom is called as electric dipole. We have studied that an electric dipole has an electric dipole moment. The electric dipole moment per unit volume is called as **dielectric polarization**.

Molecular polarizability: Polarizability allows us to better understand the interactions between non polar atoms and molecules and other electrically charged species, such as ions or polar molecules with dipole moments.



Neutral non polar species have spherically symmetric arrangements of electrons in their electron clouds. When in the presence of an electric field, their electron clouds can be distorted as shown in the f**igure.** A neutral non polar species' electron cloud is distorted by A) an Ion and B.) A polar molecule is to induce a dipole moment.

The case of this distortion is defined as the polarizability of the atom or molecule. The created distortion of the electron cloud causes the originally non polar molecule or atom to acquire a dipole moment. This induced dipole moment is related to the polarizability of the molecule or atom and the strength of the electric field by the following equation: $\mu_{ind} = \alpha E$

Where

- E denotes the strength of the electric field and
- α is the polarizability constant with units of C m^2V^{-1}.

Relation between D, E and P: The three electric vectors are 1) electric intensity 2) Dielectric polarization and 3) Electric displacement.

1) Electric intensity (E): The electric intensity at any point in the electric field is numerically equal to the force experienced by a unit positive charge placed at that point.
2) Dielectric polarization (P): when a dielectric is polarized, the distorted atom is called an electric dipole. The electric dipole moment per unit volume is called as dielectric polarization.
3) Electric displacement (D) : When a dielectric slab is placed between the plates of a parallel plate condenser the medium is polarized. Now, induced surface charges appear. The charge is negative on the surface near the positive plate of the condenser and positive charge nearer the negative plate. Let q'be the induced surface charge.
Now the charge q on the plate of the condenser and Induced surface charge $q'$are related as

$$\frac{q}{k\epsilon_0 A} = \frac{q}{\epsilon_0 A} - \frac{q'}{\epsilon_0 A}$$
$$\frac{q}{\epsilon_0 A} = \frac{q}{k\epsilon_0 A} + \frac{q'}{\epsilon_0 A}$$
$$\frac{q}{A} = \epsilon_0 \left(\frac{q}{k\epsilon_0 A}\right) + \frac{q'}{A}$$

We know that $\frac{q}{k\epsilon_0 A} = E$ and $\frac{q'}{A} = P$ and also we put the ratio $\frac{q}{A} = D$

$$\therefore D = \epsilon_0 E + P$$

Here D is called Electric displacement.

Dielectric constant: The dielectric constant is the ratio of the permittivity of a substance to the permittivity of free space. It is an expression of the extent to which a material concentrates electric flux, and is the electrical equivalent of relative magnetic permeability. As the dielectric constant increases, the electric flux density increases, if all other factors remain unchanged. This enables objects of a given size, such as sets of metal plates, to hold their electric charge for long periods of time, and to hold large quantities of charge. Materials with high dielectric constants are useful in the manufacture of high-value capacitors.

Electric susceptibility: When a dielectric material is placed in air electric field. It becomes electrically polarized. For the most material the polarization is proportional to electric field E.

i.e $P \propto E$

$$\therefore P = \chi_e E$$

Where $\chi_e = \textbf{Electric susceptibility}$

$$\therefore \chi_e = \frac{P}{E}$$

Definition: It is the ratio of polarization to the electric field strength in the dielectric.
Units: $C^2/N\text{-}m^2$

Relation between dielectric constant and susceptibility:
The relation between dielectric constant and susceptibility is given by
$D = \epsilon_0 E + P$
We know that $D = \epsilon E$ and $P = \chi_e E$
Substituting the above values in eqn $D = \epsilon_0 E + P$ we get
$\epsilon E = \epsilon_0 E + \chi_e E$
$\epsilon = \epsilon_0 + \chi_e$

$\therefore \frac{\epsilon}{\epsilon_0} = 1 + \frac{\chi_e}{\epsilon_0}$

$But \quad k = \frac{\epsilon}{\epsilon_0} = dielectric\ constant$

$\therefore k = 1 + \frac{\chi_e}{\epsilon_0}$

From the above equation it is clear that the value of k for all dielectric is greater than 1.For empty space χ_e is equal to zero

$Therefore\ k = 1$

Boundary conditions at the dielectric surface: The rules governing the behavior of E and D at the boundary between two dielectrics are known as Boundary conditions.

The following are the two Boundary conditions:

1) The normal component of electric displacement D is the same on both sides of the boundary of two media of different dielectrics.
2) The tangential components of the electrical intensities are the same on both sides of the dielectrics.

What are the differences between permittivity and permeability

Permittivity (denoted by ε; measured in farads/meter, F/m) is the property that permits a substance to store energy in, and release energy from, an **electric field**. This property allows a substance to buffer any change in the applied electric field. The higher the permittivity of the medium, the more energy is absorbed by the medium resulting in greater attenuation of the applied electric field.

Permeability (denoted by μ; measured in henrys/meter, H/m) is the property that enables a substance to store energy in, and release energy from, a **magnetic field**. This property allows a substance to oppose any change in the electric current produced by an applied electric field. The higher the permeability of the medium, the more the medium will oppose any change in electric current.

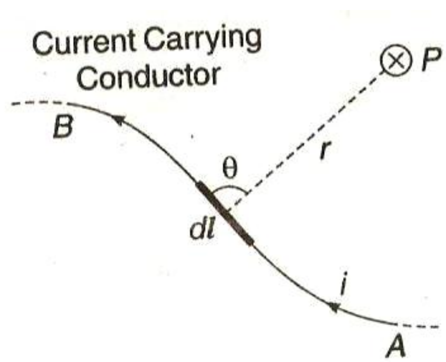
ELECTRIC AND MAGNETIC FIELDS

BIOT-SAVART'S LAW:

IN 1820, BIOT and SAVART performed a series of experiments to study the magnetic field produced by various current carrying conductors.

LAW:

The magnetic induction dB at a point P due to small element d*l* of a current carrying conductor is directly proportional to the current i, length d*l*, the sine of angle between length of element and the line joining the element to the point P and inversely proportional to the square of the distance r of the point P from the element d*l*.



$$dB \alpha \frac{idl\sin\theta}{r^2}$$

When the conductor is placed in vacuum or air, then

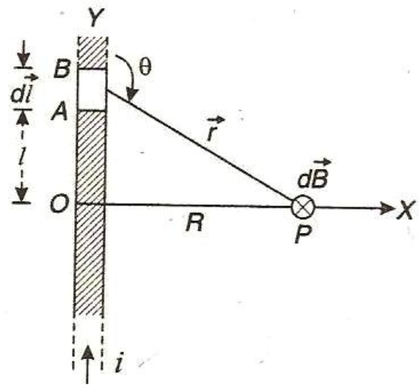
$$dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2} ---------------- (1)$$

PERMEABILITY:

Permeability is the measure of the ability of a material to support the formation of a magnetic field within itself. Hence, it is the degree of magnetization that a material obtains in response to an applied **magnetic** field. The resultant filed at P can be obtained by integrating

eq. (1) $\therefore B = \int dB$

MAGNETIC FIELD DUE TO LONG STRAIGHT CURRENT CARRYING CONDUCTOR:



Let us consider an infinitely long conductor placed in vacuum and carrying current i ampere as shown in the fig. let a point P at a distance r from the conductor. Let Θ be the angle between element length dl and the line joining the point P to the conductor

According to biot-savarts law, the magnetic induction

$$dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2}$$

The magnetic induction due to whole conductor is given by

$$B = \int dB = \frac{\mu_0 i}{4\pi}\int_{-\infty}^{+\infty}\frac{\sin\theta dl}{r^2} ----------(1)$$

From the fig

$$r = \left(l^2 + R^2\right)^{\frac{1}{2}}$$

$$\sin\theta = \sin(\pi - \theta) = \frac{R}{r}$$

$$\sin\theta = \frac{R}{\left(l^2 + R^2\right)^{\frac{1}{2}}}$$

$$\therefore B = \frac{\mu_0 i}{4\pi}\int_{-\infty}^{+\infty}\frac{Rdl}{\left(l^2 + R^2\right)^{\frac{3}{2}}} ----------(2)$$

Let l=R tan α

$$dl = R\sec^2\alpha d\alpha$$

Then the limits of integration will be $\frac{-\pi}{2} to \frac{\pi}{2}$

$$B = \frac{\mu_0 i}{4\pi}\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}}\frac{R.R\sec^2\alpha d\alpha}{\left(R^2\tan^2\alpha + R^2\right)^{\frac{3}{2}}}$$

$$= \frac{\mu_0 i}{4\pi}\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}}\frac{R^2\sec^2\alpha d\alpha}{R^3(1+\tan^2\alpha)^{\frac{3}{2}}}$$

$$= \frac{\mu_0 i}{4\pi}\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}}\frac{d\alpha}{R\sec\alpha} = \frac{\mu_0 i}{4\pi R}\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}}\cos\alpha d\alpha$$

$$= \frac{\mu_0 i}{4\pi R}[\sin\alpha]_{\frac{-\pi}{2}}^{\frac{\pi}{2}} = \frac{\mu_0 i}{4\pi R}(1+1)$$

$$B = \frac{\mu_0 i}{2\pi R} weber/m^2$$

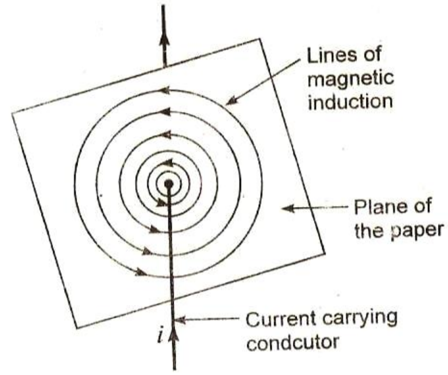
This is the expression for magnetic field induction near a straight long conductor.

The lines of magnetic induction around a straight current carrying conductor are as shown in the fig (b). The lines are denser near the conductor and become rarer as the distance increases.

AMPERE'S LAW:

According to Ampere's law

The line integral of magnetic field B along closed curve is equal to μ_0 times the net current i through the area bounded by the curve.

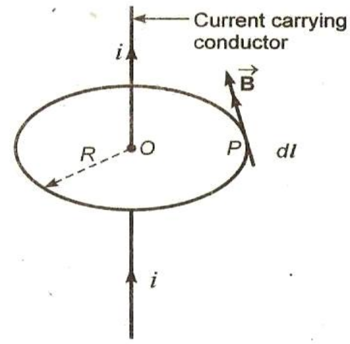


$$\oint B.dl = \mu_0 i$$

Here μ_0 is the permeability of the free space.

PROOF:

Consider a long straight conductor carrying current i as shown in the fig. If we consider a circular path of radius R then the magnetic induction B at the point of circular path will be B= $\frac{\mu_0 i}{2\pi R}$



The direction of B will be along the tangent of circular path. The magnitude of B is constant at all points on the circle and B is parallel to the circuit element dl.

The line integral of B along the circular path is given by

$$\oint B.dl = \oint Bdl\cos 0 = B\int dl = B.2\pi r$$

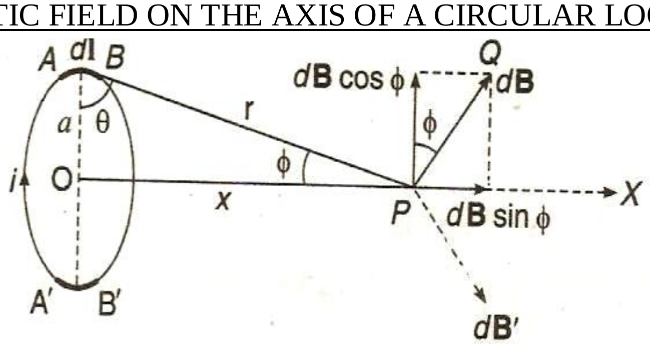
By substituting the value of B in the above eqn. we get

$$\oint B.dl = \frac{\mu_0 i}{2\pi r} 2\pi r = \mu_0 i$$

$$\oint B.dl = \mu_0 i$$

This is ampere's law.

MAGNETIC FIELD ON THE AXIS OF A CIRCULAR LOOP:



As shown in the fig consider a circular coil of radius a and carrying a current i. Let a point P on the axis of the coil at a distance x from the centre. Now we want to calculate field at a point P. Consider a small element AB of length dl. Let r be the distance of the element from the point P and θ be the angle between the direction of the current and the line joining the element to the point 0 .

The magnetic field dB at point P due to current element AB of length dl is given by

$$dB = \frac{\mu_0}{4\pi}\frac{idl \times r}{r^3} = \frac{\mu_0}{4\pi}\frac{idl\sin 90}{r^2} = \frac{\mu_0}{4\pi}\frac{idl}{r^2}$$

Here dB is perpendicular to r. This can be resolved into two components as dBcos ϕ and dBsin ϕ . If we take another element A^1B^1 opposite to AB of the same length, it will also produce electric field dB at P. The direction of dB now will be opposite to the previous one. This can also be resolved into two components as dBcos ϕ and dBsin ϕ. The components along the axis will add up while the components perpendicular to the axis will cancel. If we consider the whole circular coil, magnetic field along the axis

$$B = \int dB \sin\phi$$

$$= \frac{\mu_0 i}{4\pi r^2} \int dl \sin\phi = \frac{\mu_0 i}{4\pi r^2} \int dl \left(\frac{a}{r}\right)$$

$$= \frac{\mu_0 i a}{4\pi r^3} \int dl = \frac{\mu_0 i a}{4\pi r^3} . 2\pi a \qquad \text{Because } \sin\Phi = a/r$$

$$= \frac{\mu_0 i a^2}{2r^3}$$

$$B = \frac{\mu_0 i a^2}{2\left(a^2 + x^2\right)^{\frac{3}{2}}} \; weber/m^2$$

If there are N turns in the coil then B= $\frac{\mu_0 N i a^2}{2\left(a^2 + x^2\right)^{\frac{3}{2}}}$

SPECIAL CASES:

(1) At the centre of the coil: in this case x=0

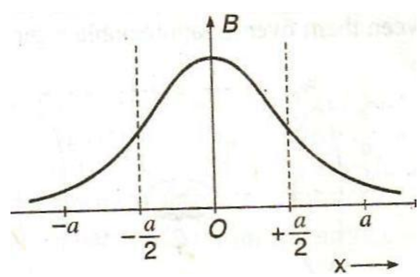
$$B = \frac{\mu_0 N i a^2}{2a^3} = \frac{\mu_0 N i}{2a}$$

(2) At very far off the loop ie x>>a

$$\left(a^2 + x^2\right)^{\frac{3}{2}} \approx x^3$$

$$B = \frac{\mu_0 N i a^2}{2x^3}$$

VARIATION OF FIELD:



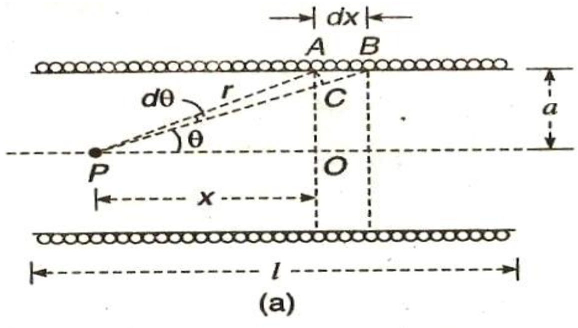
The variation of the field B long the axis of a coil is represented in the fig. From the fig it is clear that B is greatest at the centre of the coil and decreases on both sides as we move away from the centre. Near the points a/2 the field decreases uniformly with increasing distance.

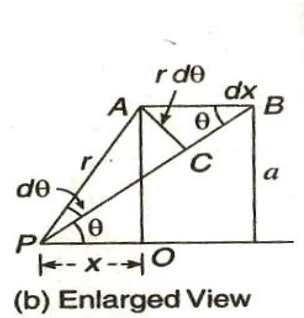
MAGNETIC FIELD INDUCTION DUE TO A SOLENOID:

SOLENOID:

A long wire wound in the form of helix is known as solenoid.

Consider a long solenoid of length *l* meter and radius 'a' meter as shown in the fig. Let N be the total no: of turns. Then the no: of turns n per meter will be $\left(\frac{N}{l}\right)$. Let the solenoid carries a current i ampere.





(1) <u>field at an inside point:</u>

Let the solenoid be divided into n number of narrow equidistant coils. Now we consider one such coil of width dx. Let x be the distance of point P from the centre O of the coil.

The field at P due to elementary coil dx is given by

$$dB = \frac{\mu_0 (ndx) i a^2}{2\left(a^2 + x^2\right)^{\frac{3}{2}}}\, weber/m^2 \text{-------------}(1)$$

$$from \Delta ABC. \sin\theta = \frac{rd\theta}{dx}$$

$$dx = \frac{rd\theta}{\sin\theta}$$

$$from \Delta APO \left(a^2 + x^2\right) = r^2$$

By substituting the above values in eq (1) we get

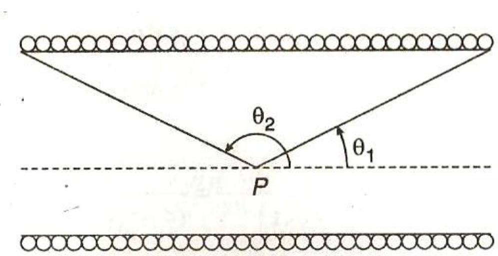
$$dB = \frac{\mu_o n \left(r \frac{d\theta}{\sin\theta} \right) i a^2}{2r^3}$$

$$= \frac{\mu_o n i a^2 d\theta}{2r^2 \sin\theta} = \frac{\mu_0 n i d\theta}{2\sin\theta} \left(\frac{a}{r}\right)^2$$

$$= \frac{\mu_0 n i d\theta}{2\sin\theta} \sin^2\theta \qquad \sin\theta = \frac{a}{r}$$

$$= \frac{\mu_0 n i d\theta}{2} \sin\theta \text{-----------------}(2)$$

The field induction B at point P due to whole solenoid can be obtained by integrating the eq(2) within the limits $\theta_1 and \theta_2$ as shown in the fig (2).



$$B = \int_{\theta_1}^{\theta_2} dB = \int_{\theta_1}^{\theta_2} \frac{\mu_0 n i \sin\theta d\theta}{2}$$

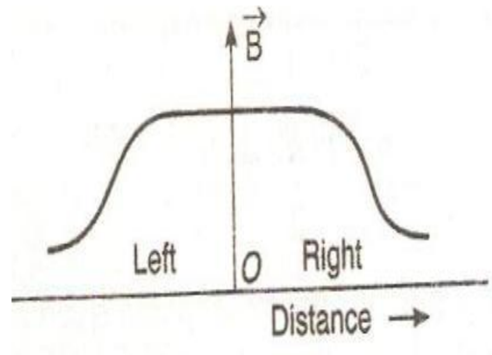
$$= \frac{\mu_0 n i}{2} \left[-\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$B = \frac{\mu_0 n i}{2} \left[\cos\theta_1 - \cos\theta_2\right] \text{----------}(3)$$

If P is at the centre of very long solenoid then $\theta_1 = 0$ *and* $\theta_2 = \pi$

$$B = \frac{\mu_0 ni}{2} .2$$

$$B = \mu_0 ni$$



(ii) FIELD AT AN AXIAL END POINT:

In this case $\theta_1 = 0 \;\; and \;\; \theta_2 = 90°$

$$B = \frac{\mu_0 ni}{2}$$

Half of its magnitude at the centre.

The variation of B with the distance from the centre of a solenoid is shown in the fig.

FIELD AT THE CENTER OF SOLENOID OF FINITE LENGTH:

Consider a point P at the centre of a solenoid of finite length. That is P is at a distance *l*/2 from the end.

$$\cos\theta_1 = \frac{\frac{l}{2}}{\left(a^2 + \left[\frac{l}{2}\right]^2\right)^{\frac{1}{2}}} = \frac{l}{\left(4a^2 + l^2\right)^{\frac{1}{2}}}$$

$$and \;\; \cos(\pi - \theta_2) = \frac{\frac{l}{2}}{\left[a^2 + \left(\frac{l}{2}\right)^2\right]^{\frac{1}{2}}} = \frac{l}{\left(4a^2 + l^2\right)^{\frac{1}{2}}}$$

$$\cos\theta_2 = \frac{l}{\left(4a^2 + l^2\right)^{\frac{1}{2}}}$$

By substituting the above values in eq. (3) we get

$$B = \frac{\mu_0 ni}{2}\left[\frac{l}{\left(4a^2 + l^2\right)^{\frac{1}{2}}} + \frac{l}{\left(4a^2 + l^2\right)^{\frac{1}{2}}}\right]$$

$$= \frac{\mu_0 nil}{\left(4a^2 + l^2\right)^{\frac{1}{2}}}$$

$$B = \frac{\mu_0 iN}{\left(4a^2 + l^2\right)^{\frac{1}{2}}}$$

This expression gives the field at the center of the solenoid of finite length.

MOTION OF CAHRGED PARTICLE IN ELECTRIC FIELD:

(1) When the charged particle moves perpendicular to the electric field, it follows a parabolic path.
(2) If the charged particle moves in the direction of electric field, it experiences a force qE in the direction of electric field.
(3) If the charged particle moves in opposite direction of electric field, it experiences a force –qE.
(4) When the particle leaves the plate, it follows a straight line path which is tangent to the parabola. The angle is given by

$$\tan\theta = \frac{qEl}{mv_x^2}$$

Where q=charge of the particle
E=electric field
l=length of the plate
m=mass of the particle
v_x=initial velocity along X-axis

MOTION OF CAHRGED PARTICLE IN MAGNETIC FIELD:

When a charged particle having a charge q travels with velocity v in magnetic field B, it experiences a force F is given by

F=q (vxB) or F=qvB $\sin\theta$

SPECIAL CASES:

(1) if the particle is at rest (v=0) then F=0
(2) if the particle is moving along the line of magnetic field ($\theta = 0$), then F=0.
(3) If $\theta = 90$, then F is maximum =qvB

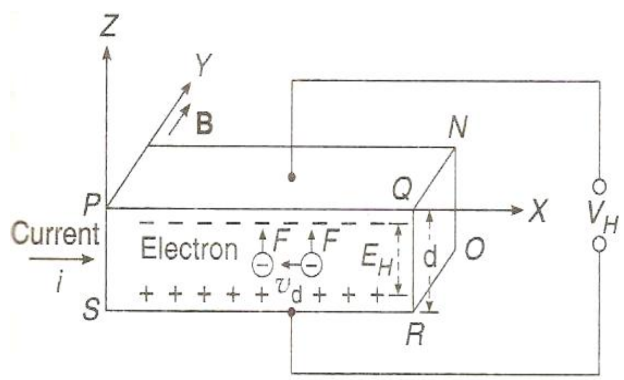
Angular velocity $\omega = \frac{qB}{m}$

Or $f = \frac{\omega}{2\pi} = \frac{qB}{2\pi m}$

Time period $T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$

HALL EFFECT:

In 1879 E.H.Hall discovered that when a magnetic field is applied perpendicular to a current carrying conductor, a potential difference is developed on the opposite side of the conductor perpendicular to both magnetic field and current directions. This effect is known as Hall Effect.



This effect is useful to know the sign of the charge carries in electric conductor.

EXPLANATION: As shown in the fig let a uniform, thick metal strip placed with its length parallel to its X-axis. Let a current i is passed in the conductor along X-axis. A magnetic field B is applied along Y-axis. Due to its magnetic field, the charge carriers experience a force F perpendicular to XY-plane along Z-axis. The direction of this force is given by the Fleming's left hand rule. If the charge carriers are electrons then they will experience a force in the positive direction of Z-axis as shown in the fig. Hence the transverse p.d is created. This is known as hall emf. If charge carriers are positive, then the sign of the emf is reversed. Hence we can find the nature of the charge carriers.

Due to displacement of charge carriers Hall Electric field E_H is established as shown in the fig. This field opposes the sideway drift of the charge carriers. At the equilibrium state the magnetic deflecting force on the charge carriers are balanced by the electric force due to electric field.

Magnetic deflecting force =q (v_d x B)

Electric force =qE_H

At the equilibrium $q(v_d X B) + qE_H = 0$

$$E_H = -(V_d X B) ------------- (1)$$

If we consider only magnitude, then

$$E_H = V_d B --------------- (2)$$

We know that $V_d = \frac{j}{nq} ------------- (3)$ where j=current density

n= no: of charge carriers per unit volume

From eq (2) and (3) we have

$$E_H = \frac{1}{nq} jB ---------------- (4)$$

If V_H be the hall voltage in equilibrium then

$$E_H = \frac{V_H}{d} --------------- (5)$$ Where d= width of the bar

By measuring current i in the slab the current density can be calculated by using $\frac{i}{A}$, where A is the area of cross section of the slab. On substituting the values of E_H, j and B in eq (4) we can calculate the value of $\left(\frac{1}{nq}\right)$.

<u>HALL COEFFICIENT:</u>

The ratio of hall electric field E_H to the product of current density j and magnetic induction B is known as hall coefficient.

$$R_H = \frac{E_H}{jB} = \frac{1}{nq} \qquad \because From \;\; eq(4)$$

R_H is –ve for electrons and +ve for holes.

APPLICATIONS OF HALL EFFECT:

(1) It gives the information of the sign of the charge carriers in electric conductor.
(2) Hall effect is helpful in understanding the electric conduction in metals and semi-conductors.
(3) Hall effect can be used to measure the drift velocity of charge carriers using the eq $V_d = \frac{j}{nq}$.
(4) Hall co-efficient gives the number of current carriers per unit volume.

$$n = \frac{iB}{qLdE_H}$$

(5) Strong magnetic field can be measured by using Hall Effect.

$$B = \frac{nqLdE_d}{i}$$

(6) The mobility of the charge carrier can be measured by the conductivity of the material and hall electric field.

$$\mu = \sigma E_H$$

ELECTRIC FIELD INTENSITY AND POTENTIAL

INTRODUCTION: According to electronic theory, every substance is made up of atoms. Every atom has a central heavy portion called nucleus. It contains protons and neutrons. Around the nucleus, electrons revolve in different orbits. The number of electrons in an atom is equal to the number of protons. Hence an atom is electrically neutral.

A positively charged particle means the deficiency of electrons in an atom. A negatively charged body means the excess of electrons in an atom.

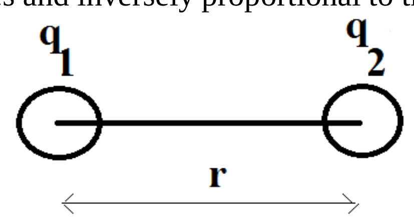
Greek philosopher Thales discovered that when Amber is rubbed with wool, it attracts light bodies like piece of paper. It has been discovered that when a glass rod is rubbed with silk, the glass rod is electrified with positive charge and when a piece of ebonite is rubbed with cat skin, the ebonite is electrified with negative charge. Further it has been discovered that same kind of charge repel each other while unlike charges attract each other.

QUANTISATION OF CHARGE:

Milliken oil drop experiment have shown that electric charges is not continuous but it is made up of integral multiples (1,2,3…) of a certain minimum electric charge. Hence we say that charge is quantized.

COULOMB'S LAW:

The force of attraction or repulsion between two stationary point charges is directly proportional to the product of two charges and inversely proportional to the square of the distance between them.



$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$= 9\times10^9 \frac{q_1 q_2}{r^2}$$

If some insulating material (wax, paper, glass etc) is placed between the charges then

$$F = \frac{1}{4\pi\varepsilon_0 k}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

Here k is known as dielectric constant of the medium.

ELECTRIC FIELD:

The region surrounding an electric charge or a group of charges in which another charge experiences a force is called electric field.

INTENSITY OF ELECTRIC FIELD:

The force experienced by a unit positive charge placed at a point in an electric field is known as intensity of electric field at that point.

$$E = \frac{F}{q_0} \quad N/coulomb$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

ELECTRIC LINES OF FORCE:

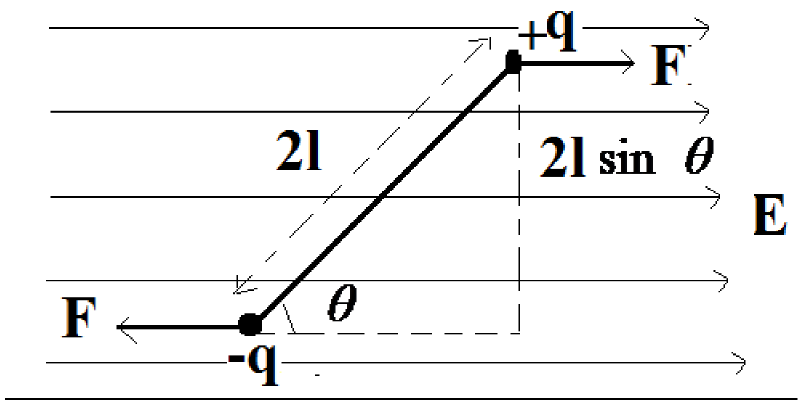
It is an imaginary smooth curve drawn in an electric field along which a free isolated positive charge will move. The tangent at any point on it gives the direction of the field at that point.

ELECTRIC DIOPOLE:

The arrangement of two equal and opposite charges at fixed distance is called the electric dipole.

P=q.2l coulomb. Meter

COUPLE ON ELECTRIC DIPOLE IN UNIFORM ELECTRIC FIELD:



$$\tau = FX2l\sin\theta$$
$$= qEX2l\sin\theta$$
$$= 2qlE\sin\theta$$
$$= pE\sin\theta$$

ELECTRIC FLUX:

The total number of electric lines of force crossing the surface in a direction normal to the surface is known as electric flux .

$$\phi_E = \oint E.\Delta s = E.s ----------(1)$$

If θ is the angle between E and ΔS then

$$E.\Delta S = Eds\cos\theta$$

$$\therefore \phi_E = \int E.dS\cos\theta = EA\cos\theta \qquad \because \int ds = A$$

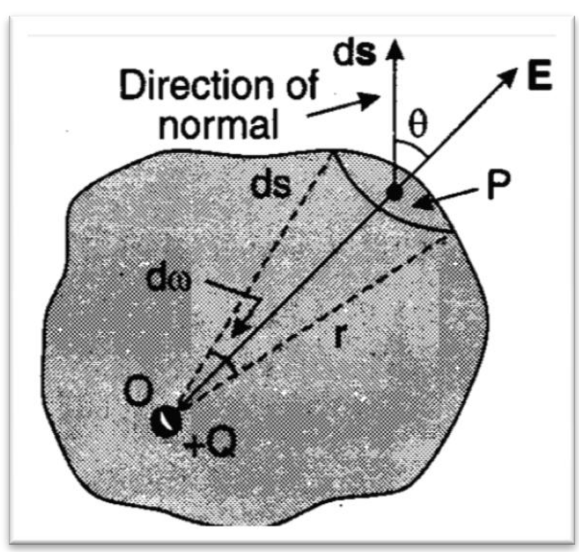
GAUSS LAW:

Gauss law is the converse of coulomb's law. It states that total normal electric flux ϕ_E over a closed surface is $\frac{1}{\varepsilon_0}$ times the total charge Q enclosed within the surface.

ie $\phi_E = \oint E.dS = \oint EdS\cos\theta = \left(\frac{1}{\varepsilon_0}\right)Q$

PROOF: WHEN THE CHARGE IS WITHIN THE SURFACE:

Let the charge +Q is placed at O within a closed surface of irregular shape as shown in the figure. Consider a point P on the surface at a distance r from O. now take a small area ds around P. The normal to the surface ds is represented by a vector **ds** which makes an angle θ with the direction of electric field E along OP. the electric flux dϕ_E outwards through the area dS is given by



$$d\phi_E = \overline{E}.\overline{dS} = EdS\cos\theta ---------- (1)$$

From coulomb's law $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} ---------- (2)$

By substituting esq. (2) in esq. (1) we have $d\phi_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}ds\cos\theta$

But $\frac{ds\cos\theta}{r^2}$ is equal to the solid angle dω subtended by ds at O.

$$\therefore d\phi_E = \frac{Q}{4\pi\varepsilon_0}d\omega$$

The total flux ϕ_E is given by $\phi_E = \frac{Q}{4\pi\varepsilon_0}\int d\omega = \frac{Q}{4\pi\varepsilon_0}.4\pi$ $\qquad \because \int d\omega = 4\Pi$

$$\therefore \phi_E = \frac{Q}{\varepsilon_0}$$

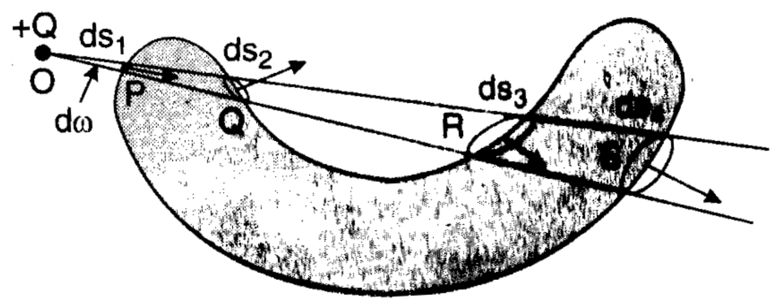
Let the closed surface encloses several charges say $+Q_1, +Q_{2,} Q_3 ---, -Q_1^1, -Q_2^1, -Q_3^1 ----$ then the total flux is given by

$$\phi_E = \frac{1}{\varepsilon_0}\left[Q_1 + Q_2 + Q_3 + ... - Q_1^1 - Q_2^1 - Q_3^1......\right]$$

$$= \frac{1}{\varepsilon_0}\sum Q$$

Hence the normal electric flux over the closed surface is equal to $\frac{1}{\varepsilon_0}$ times. The total charges enclosed within the surface. Hence gauss law is proved.

WHEN THE CHARGE IS OUTSIDE THE SURFACE:



Let a point charge +Q be placed at O outside the closed surface as shown in the fig. Now a cone of solid angle $d\omega$ from O cuts the surface area $ds_{1,} ds_2$, ds_3, ds_4 at points P, Q, R, and S respectively. The electric flux for an outward normal is positive while for inward drawn normal is negative.

The electric flux at P through area $ds_1 = \frac{-Q}{4\pi\varepsilon_0}d\omega$

The electric flux at Q through area $ds_2 = \frac{+Q}{4\pi\varepsilon_0}d\omega$

The electric flux at R through area $ds_3 = \frac{-Q}{4\pi\varepsilon_0}d\omega$

The electric flux at S through area $ds_4 = \frac{+Q}{4\pi\varepsilon_0}d\omega$

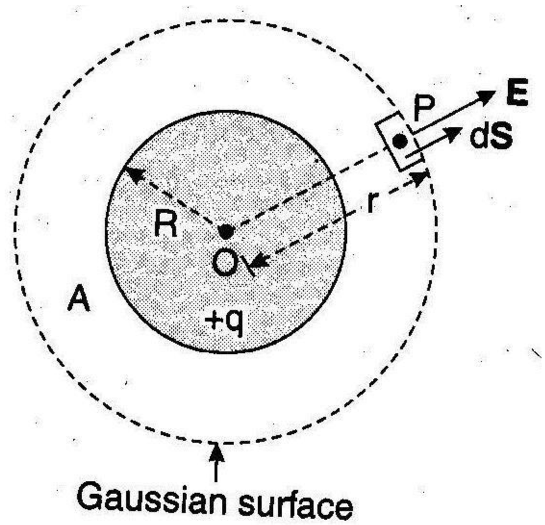
Total flux = $-\frac{Q}{4\pi\varepsilon_0}d\omega+\frac{Q}{4\pi\varepsilon_0}d\omega-\frac{Q}{4\pi\varepsilon_0}d\omega+\frac{Q}{4\pi\varepsilon_0}d\omega=0$

Hence the total electric flux over the whole surface due to an external change is zero. Hence gauss's theorem is verified.

APPLICATIONS OF GAUSS'S LAW:

(1) Uniformly charged sphere:

Case (1) At a point outside the charged sphere:



As shown in the fig let us consider a sphere of radius R with center "0".Let a charge "q" be uniformly distributed over it. Let "P" be an external point at a distance "r" from the center "o" of the sphere. In order to calculate the electric field E at point P, we construct a Gaussian surface of radius OP. the direction of E is along the outward normal to the Gaussian surface ds. The angle between E and ds is zero degree. Hence for a small Gaussian surface

$$E.ds=E\ ds\cos 0^0=Eds$$

$\therefore$The electric flux through the entire Gaussian is given by

$$\phi_E=\oint E.ds=E\int ds=E4\pi r^2 \text{ ------- (1)}$$

According to gauss's law, the total electric flux over a closed surface is $\frac{1}{\varepsilon_0}$ times the charge within the surface.

$$E.4\pi r^2=\frac{q}{\varepsilon_0}$$

$$\therefore E=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\ N/coulomb$$

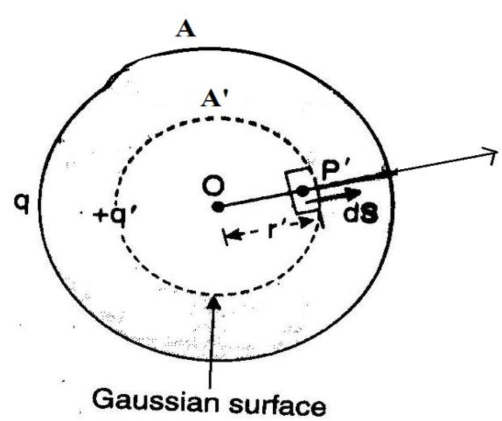
In vector form $E=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ N/coulomb

Case (2): At a point on the surface :

In this case r=R

$$\therefore E=\frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}\ N/coulomb$$

Case (3): At a point inside the charged sphere:



As shown in the fig, let a point p^1 which is inside the charged sphere at a distance r^1 from the center 'o'. The outward flux for small Gaussian surface will be

E.ds=Eds (angle between E and ds is zero)

The electric flux through the entire Gaussian surface is given by

$$\phi_E=\oint Eds=E\oint ds=E.4\pi r'^2$$

The total charge enclosed by the Gaussian surface=volume enclosed by it ×charge per unit volume.

$$=\frac{4}{3}\pi r'^3 \times \rho$$

Hence $\rho = \frac{total\ charge}{total\ volume} = \frac{q}{\frac{4}{3}\pi R^3} = \frac{3q}{4\pi R^3}$

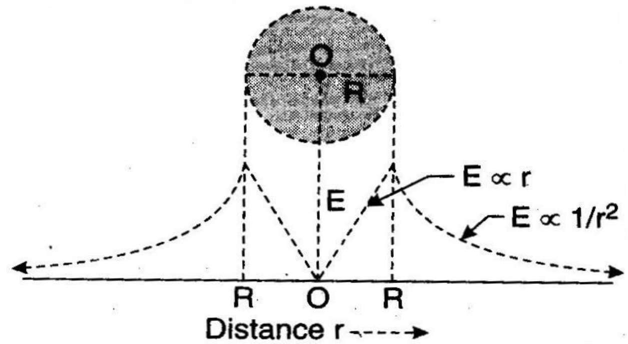
Charge enclosed in Gaussian surface $= \frac{4}{3}\pi r'^3 \times \frac{3q}{4\pi R^3}$

$$= q\left(\frac{r'}{R}\right)^3$$

From Gauss's law

$$E.4\pi r'^2 = \frac{1}{\varepsilon_0} q\left(\frac{r'}{R}\right)^3$$

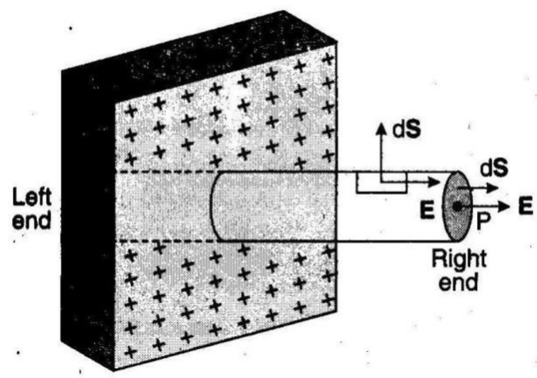
$$\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{qr'}{R^3}$$



From the above equation it is clear that E is proportional to r' .The variation of electric field as a function of distance r is as shown in the following fig.

From the above fig it is clear that electric field outside the sphere is inversely proportional to the square of the distance. It is the maximum on the surface of the sphere. But within the conducting sphere electric field will be zero.

ELECTRIC FIELD DUE TO INFINITE CONDUCTING SHEET OF CHARGE:



As shown in the fig, let us consider charged conducting surface of charge density σ. We have to calculate the electric field at a point P near the surface and outside the conductor. For this purpose we construct a cylindrical Gaussian surface. The direction of electric field near the surface is perpendicular to the surface. The electric flux through the curved surface is zero because there is no component of E normal to the surface. The electric flux through flat surface inside the conductor is zero. The electric flux through flat surface passing through P is EA. Here A is the cross sectional area of the small cylindrical box.

Total electric flux through the Gaussian surface= $\int_S E.ds = EA$

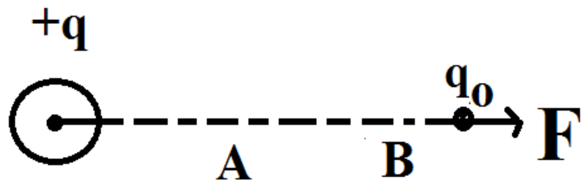
According to gauss's law

Total flux= $\frac{1}{\varepsilon_0}$ (total charge enclosed by Gaussian surface)

E A= $\frac{1}{\varepsilon_0}(A\sigma)$

E= $\frac{\sigma}{\varepsilon_0}$

ELECTRIC POTENTIAL:



The electric charge flows from a point of higher potential to a point at a lower potential.

Let us consider an electric field due to a positive charge +q as shown in the fig. let a positive test charge $+q_o$ in this field. It experiences an electric repulsive force F due to +q. suppose the test charge is moved by external agent from B to A, work W has to be done against the repulsive force.

<u>POTENTIAL DIFFERENCE:</u>

The ratio of work done in taking a test charge from one point to another point in an electric field to the magnitude of the test charge is known as potential difference between the two points.

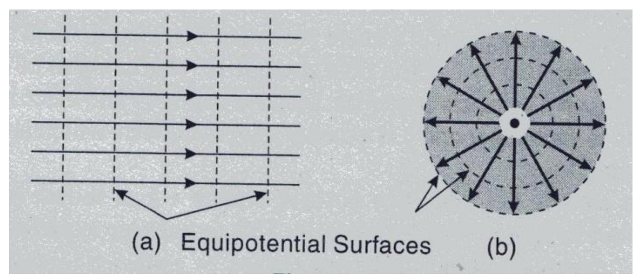
Potential difference $V_A - V_B = \frac{W}{q_0}$

If the point B is at infinite distance then $\mathbf{V_B=0}$.

$$\mathbf{V_A} = \frac{W}{q_0}.$$

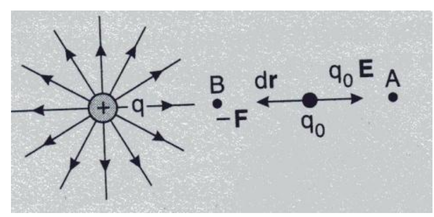
<u>ELECTRIC POTENTIAL:</u>

The work done by an external agent in carrying a unit positive test charge from infinity to that point is known as electric potential.



<u>Equipotential surfaces:</u> A surface on which the potential is same at every point. The locus of all points which have the same electric potential is called equipotential surface. As the potential difference between any two points on the equipotential is zero and hence, no work is done in taking a charge from one point to another. This is only possible when the charge is taken perpendicular to the field. Hence the lines of force at every point of the equipotential surface are perpendicular to the surface.

In case of uniform field, where lines of forces are straight and parallel, the equipotential surfaces are planes perpendicular to the lines of forces as shown in the fig (a)



<u>POTENTIAL DUE TO A POINT CHARGE:</u> Consider a point charge +q as shown in the fig. its electric field E is out ward along radial line. Now we want to calculate the potential at a point B situated at a distance r_B from the charge +q.For this purpose we select two points A and B along radial line.Let a test charge q_0 be moved from A to B.

The force exerted by the field of charge q on test chage q_0 is q_0E.

Now to move the test charge q_0 towards B ,a force - q_0E must be applied.

Therefore the workdone by external agent to move the charge q_0 through small distance dr is given by

$dW = qE.dr = q_0 E dr \cos 180^0 = -q_0 E dr$

We know that $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

$\therefore Total\ workdone\ in\ moving\ the\ test\ charge\ from\ A\ to\ B =$

$$W_{AB} = \int_{r_A}^{r_B} -\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r^2}\text{dr} = -\frac{qq_0}{4\pi\varepsilon_0}\left[-\frac{1}{r}\right] = \frac{qq_0}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

So the potential difference between two points will be

$$V_B - V_A = \frac{W_{AB}}{q_0} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

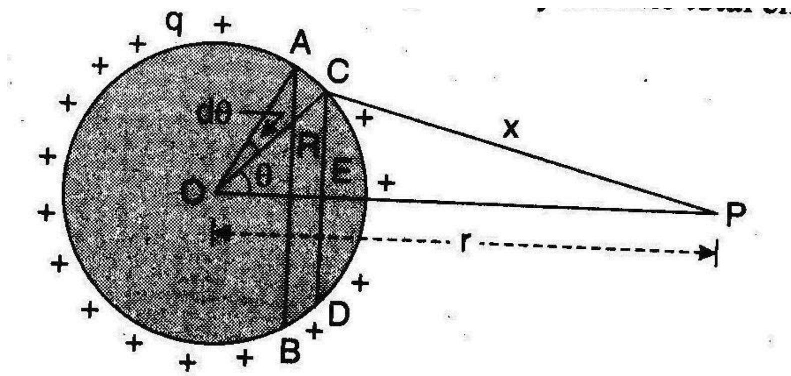
If A is at infinity distance then $V_A=0$

By dropping the suffix we get

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

This expression shows that at a distance r on all sides of charge q, the potential is the same.

POTENTIAL DUE TO CHARGED SPHERICAL CONDUCTOR:



As shown in the figure let us consider a conducting charged spherical conductor with centre O and radius R. let σ be the surface charge density and the total charge be q. here whole charge is distributed uniformly on the surface of the sphere. There will be no charge inside the sphere. Now we want to calculate the potential at an external point p which is at a distance r from center 'o'. For this purpose we divide the sphere into a number of rings with centers on OP. ABCD is a ring between planes AB and CD.

Let cp=x

$\angle cop = \theta$

$\angle Aoc = d\theta$

From the right angled triangle OEC

$$CE = OC\sin\theta = R\sin\theta$$

From sector AOC

$$AC = R\,d\theta$$

Circumference of the ring $= 2\Pi R\sin\theta$

Area of the ring $= 2\Pi R\sin\theta . R d\theta$

$$= 2\Pi R^2 \sin\theta d\theta$$

Charge on the ring=area of the ring x charge density

$$= 2\Pi R^2 . \sin\theta d\theta \sigma$$

Where $\sigma = \frac{total\ charge\ on\ shell}{total\ surface\ area} = \frac{q}{4\Pi R^2}$

Charge on the ring $= 2\Pi R^2 \sin\theta d\theta . \frac{q}{4\Pi R^2}$

$$= \frac{q\sin\theta d\theta}{2} ------(1)$$

The potential at P due to the charge on the ring

$$dV = \frac{1}{4\Pi\varepsilon_0}\frac{dq}{x}$$

$$dV = \frac{1}{4\Pi\varepsilon_0 x}\frac{q\sin\theta d\theta}{2}$$

$$= \frac{q\sin\theta d\theta}{8\Pi\varepsilon_0 x} - - - - - - - -(2)$$

From the figure $x^2 = R^2 + r^2 - 2Rr\cos\theta$ $\because x^2 = (OP - OE)^2 + CE^2 = r^2 + R^2\cos^2\theta - 2Rr\cos\theta + R^2\sin^2\theta$

Differentiating the above equation we get

$$2xdx = 2Rr\sin\theta d\theta$$

$$\sin\theta d\theta = \frac{2xdx}{2Rr} = \frac{xdx}{Rr}$$

Substituting the above equation in equ (2) we have

$$dV = \frac{qxdx}{8\Pi\varepsilon_0 Rrx} = \frac{qdx}{8\Pi\varepsilon_0 Rr} - - - - - - - -(3)$$

In order to obtain the p.d due to whole spherical shell we integrate the above equation within the limits

X=r-R and x=r+R

Hence

$$V = \int_{r\_R}^{r+R}\frac{qdx}{8\Pi\varepsilon_0 Rr} = \frac{q}{8\Pi\varepsilon_0 Rr}\left[x\right]_{r-R}^{r+R}$$

$$= \frac{q}{8\Pi\varepsilon_0 Rr}(2R)$$

$$V = \frac{1}{4\Pi\varepsilon_0}\frac{q}{r} - - - - - -(4)$$

From the above equation it is clear that, potential is inversely proportional to the distance.

(1.) When p lies on the surface:

In this case r=R

$$.: V = \frac{1}{4\Pi\varepsilon_0}\frac{q}{R}$$

(2.) When p lies inside the shell:

In this case integration limits becomes

X=R-r and x=R+r hence

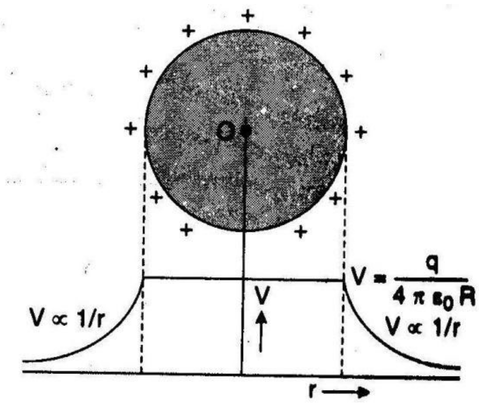
$$V = \int_{R-r}^{R+r}\frac{qdx}{8\Pi\varepsilon_0 Rr} = \frac{q}{8\Pi\varepsilon_0 Rr}.\int_{R-r}^{R+r}dx$$

$$V = \frac{q}{8\Pi\varepsilon_0 Rr}[R + r - R + r] = \frac{q}{8\Pi\varepsilon_0 Rr}.2r$$

$$V = \frac{1}{4\Pi\varepsilon_0}\frac{q}{R}$$

Thus the potential at an internal point is the same as that on the surface of the sphere.

The veriation of potential with distance is as shown in the fig

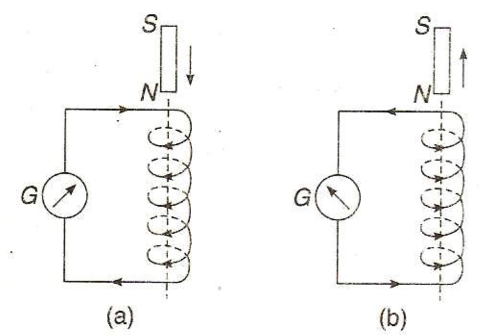


ELECTROMAGNETIC INDUCTION

INTRODUCTION:

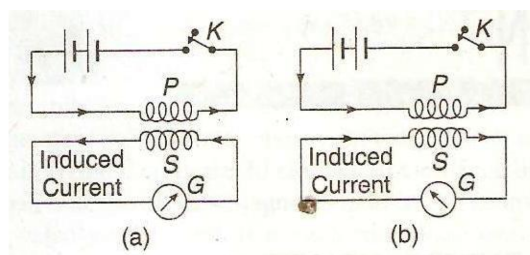
Oersted discovered the existence of the magnetic field due to current flowing in a conductor. In 1831, faraday discovered that whenever magnetic lines of force are cut by a closed circuit, induced current flows in the circuit and lasts only as long as the change lasts. This phenomenon is known as electromagnetic induction.

FARADAY'S EXPERIMENT NO (1):



As shown in the fig (a) when a magnet is inserted in the coil, the galvanometer shows a deflection in one direction and when it is withdrawn from the coil as shown in the fig (b), the galvanometer shows the deflection in the other direction. When the magnet is stationary, there is no deflection in the galvanometer. If the pole of the magnet is reversed, the deflection of the galvanometer also reversed. When the magnet is moved fast, the deflection in the galvanometer is large.

EXPERIMENT NO (2):



As shown in the fig (a) consider a primary coil which is connected to a battery and secondary coil is connected to galvanometer. When the key K is pressed the galvanometer shows deflection in one direction. When the key K is released as shown in the fig (b), the galvanometer shows deflection in other direction.

If the current in the primary circuit is constant, there is no deflection in the galvanometer. Hence the deflection in the galvanometer is observed only at make and break.

Similar effects are observed while increasing or decreasing the primary current on changing the relative position of the coil.

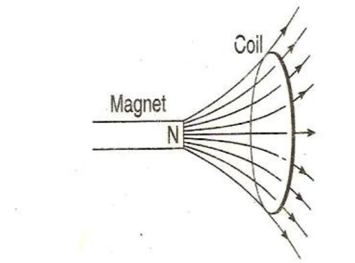
EXPLANATION:

While the magnet moves towards the coil or away from the coil, the flux linked with the coil changes. Hence in both the cases an induced emf is obtained in the coil.

FARADAY'S LAWS:

(1) Whenever the magnetic flux linked with the coil is changed, an emf is induced in the coil.

(2) The magnitude of induced emf is directly proportional to the -ve rate of variation magnetic flux linked with the coil.



If ϕ_B be the magnetic flux linked with the coil at any instant and e be the emf, then

$$e = -\frac{d\phi_B}{dt}$$

If there N turns in the coil then

$$e = -N\frac{d\phi_B}{dt}$$

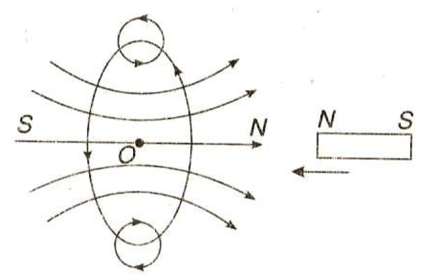
In integral form faradays law can be represented by

$$\oint E.dl = -\frac{d}{dt}\int_s B.ds$$

In differential form Faraday's law can be represented by

$$curl \;\; E = \frac{-\partial B}{\partial t}$$

LENZ'S LAW:



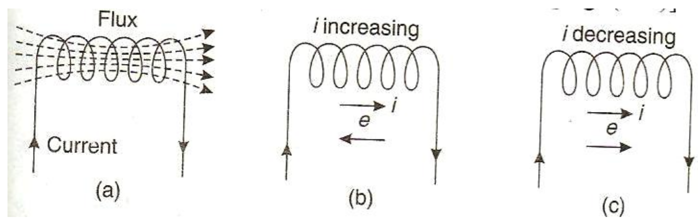
The direction of induced emf in a closed circuit is such that it opposes the original cause that produces it.

EXPLANATION:

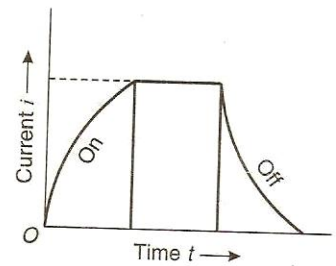
The law is based on the conservation of energy. When the applied flux density B in a closed circuit increasing, the emf induced in the closed circuit is in such a direction as to produce a filed which tends to decrease B. Thus, the induced current is in a direction such that it produces a magnetic flux tending to oppose the original change of flux. That is tending to keep the total flux constant in the circuit.

Suppose North Pole of the magnet is moved towards a coil connected to a galvanometer as shown in the figure. An induced current in the coil produces its own magnetic field. The face of the coil towards the north pole of the magnet becomes a north pole. So there will be force of repulsion between them. Hence, the direction of induced current is such that it opposes the motion of the magnet.

Self-inductance:



This phenomenon was discovered by J. Henry in 1832. When current flows in a coil magnetic field is set up in it. If the current passing through the coil changes with time, an induced emf is set up in the coil. The induced emf opposes any change of the original current. This phenomenon is called self- inductance.



When the magnetic field linked with the coil changes, an emf is induced in the coil .It is called self-inductance. The emf is known as back emf.

When the current in the coil is switched on, self induction opposes the growth of the current. When the current is switched off, the self- induction opposes the decay of current as shown in the fig,

CO-EFFICIENT OF SELF-INDUCTION:

The total magnetic flux ϕ_b linked with the coil is proportional to the current i flowing through the coil.

$$\phi_b \propto i$$
$$\phi_b = Li$$

Where L= self inductance

If i=1A then $\phi_b = L$

SELF-INDUCTANCE:

The co-efficient of self induction is numerically equal to the magnetic flux linked with the coil when 1A current flows through it.

NOTE:

(1) $e = -\frac{d\phi_B}{dt} = -L\frac{di}{dt}$

(2)
$$dW = -eidt = +L\frac{di}{dt}.idt$$
$$W = L\int_0^{i_0} i\frac{di}{dt}dt = \frac{1}{2}Li_0^2$$

SELF INDUCTANCE OF LONG SOLENOID:

Consider a long air core solenoid of length *l* meter; cross sectional area A m^2 and number of turns n. Suppose a current i flow through it, the magnetic field inside the solenoid is given by

$B = \mu_0 ni$ Weber/m^2

Magnetic flux through each turn $\phi_b = BA = \mu_0 niA$ *Weber*

Total magnetic flux linked with the solenoid = $\mu_0 niA \times N$

$$= \mu_0 niA \times nl$$
$$= \mu_0 n^2 iAl$$

The self inductance of the coil =Li=total flux linked with solenoid.

$$Li = \mu_0 n^2 iAl$$
$$L = \mu_o n^2 Al$$
$$= \mu_0 \left(\frac{N}{l}\right)^2 Al$$
$$L = \frac{\mu_0 N^2 A}{l} \quad Henry$$

<u>Energy stored in magnetic field</u>: consider a long solenoid of length *l* and cross-sectional area A. when a current 'i' flow in it, a magnetic field is established. This field is uniform inside and negligible outside. The volume of the solenoid is A*l*. The amount of work done in establishing a current i_o in the solenoid $\frac{1}{2} L i_0^2$ is stored as energy in the magnetic field.

U= energy stored=$\frac{1}{2} L i_0^2$

We know that $L = \mu_0 n^2 Al$ where n= number of turns in solenoid per meter.

$\therefore U = \frac{1}{2}(\mu_0 n^2 Al) i_0^2 = \frac{1}{2}\frac{(\mu_0 n i_0)^2}{\mu_0} Al$

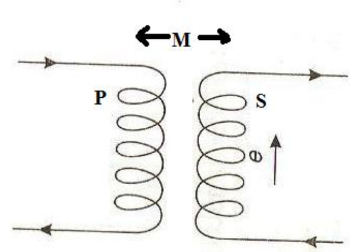
But B= $\mu_0 n i_0$

$$\therefore U = \frac{1}{2}\frac{B^2}{\mu_0} Al$$

$\therefore$ Energy per unit volume = $u = \frac{U}{Al} = \frac{1}{2}\frac{B^2}{\mu_0}$ Joule/m^3

This equation tells that inductance in a circuit plays the same role as the mass or inertia does in mechanical motion.

<u>CO-EFFICIENT OF MUTUAL INDUCTION:</u> Let us consider two coils as shown in the fig. when a current is passed in the primary coil P, there is a change of magnetic flux linked with it, an induced emf is set in the secondary coil S. This phenomenon is called mutual inductance.



The secondary circuit also induces an emf in the primary. Let a current i in the primary P produces a magnetic flux ϕ_B in the secondary S. For two coils situated in fixed relative positions, it is observed that the flux linked with the secondary is proportional to the current in primary.

$$\phi_b \propto i$$
$$\phi_b = Mi ------------ (1)$$

Here M= co-efficient of mutual inductance or mutual inductance of the two coils

<u>Units:</u> Henry

The emf produced in the secondary S is given by

$$e = -\frac{d\phi_b}{dt}$$
$$e = -\frac{d}{dt}(Mi) = -M\frac{di}{dt} ------------- (2)$$

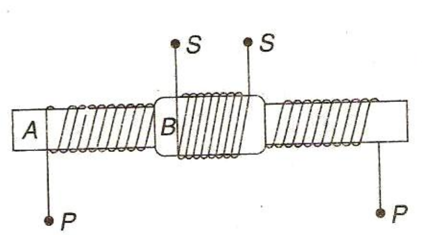
<u>MUTUAL INDUCTANCE:</u>

It is the flux linked with a circuit due to a unit current flowing through the other.

<u>HENRY:</u>

When the current changing at the rate of one amp/sec in one circuit induces an emf of 1volt in the other circuit then the mutual inductance of the two coils is known as one Henry.

<u>MUTUAL INDUCTANCE OF TWO COILS:</u>



Let us consider a long air solenoid with primary A and secondary B as shown in the fig.

Let the no. of turns in primary and secondary be n_1 and n_2 respectively. Let the length of the primary coil be *l*, area of the cross section be 'a' and current flows through the primary be i then the magnetic field inside the primary is given by

$$B = \mu_0 \frac{n_1}{l} i \quad Weber/m^2$$

Magnetic flux through each of the primary

$$\phi = \mu_0 \frac{n_1}{l} i \times a \quad Weber$$

Total magnetic flux linked with secondary $= \mu_0 \frac{n_1}{l} ian_2$ Weber

If M be the mutual inductance of the two coils, the total flux linked with the secondary is Mi

$$\therefore Mi = \frac{\mu_0 n_1 i}{l} \times a \times n_2$$

$$M = \frac{\mu_0 n_1 n_2 a}{l}$$

COFFICIENT OF COUPLING:

Let us consider two coils very close to each other and having number of turns n_1 and n_2. Let i_1 and i_2 be the currents flowing in the two coils. By definition

$$L_1 = \frac{n_1 \phi_1}{i_1} \text{ and } L_2 = \frac{n_2 \phi_2}{i_2}$$

Here ϕ_1 and ϕ_2 are the magnetic fluxes linked with coils (1) and (2) due to their own currents i_1 and i_2 respectively.

When a current i_1 is passed through the first coil, the total flux linked with n_2 turns of second coil will be $n_2 \phi_{21}$,then

$$n_2 \phi_{21} = M_{21} i_1$$

Similarly when a current i_2 is passed through the second coil, the total flux linked with n_1 turns of primary coil will be $n_1 \phi_{12}$

$$n_1 \phi_{12} = M_{12} i_2$$

If the two coils are wound on the same core, then the coupling is said to be perfect

$$\therefore \phi_{12} = \phi_2 ; \phi_{21} = \phi_1$$

In this situation $M_{12} = M_{21} = M_{\max}$

$$\therefore n_2 \phi_1 = M_{\max} i_1 ----(1)$$
$$\therefore n_1 \phi_2 = M_{\max} i_2 ----(2)$$

Multiplying equ (1) and (2) we get

$$M_{\max}^2 i_1 i_2 = n_1 n_2 \phi_1 \phi_2$$

$$M_{\max}^2 = \frac{n_1 n_2 \phi_1 \phi_2}{i_1 i_2} = \left(\frac{n_1 \phi_1}{i_1}\right)\left(\frac{n_2 \phi_2}{i_2}\right)$$
$$= L_1 L_2$$
$$\therefore M_{\max} = \sqrt{L_1 L_2}$$

In actual particle only a fraction of the flux is linked with one coil due to current in the other coil.

$\therefore$Expression for mutual inductance between two coils $M = K\sqrt{L_1 L_2}$

Where k= coefficient of coupling between the two coils. (k varies from0 to 1)

SPECIAL CASES:

(1.) If k=1 the coupling is tight

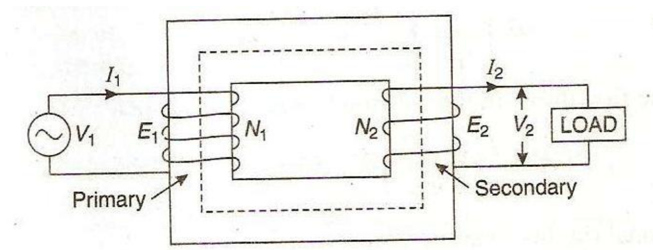
(2.) If k=0 there is no coupling

(3.) If k>0 and k<1 there is optimum coupling.

TRANSFORMER:

A transformer is an A.C static device which transfers electric power from one circuit to another. It is working on the principle of mutual induction. It can raise or lower the voltage in a circuit. But there is corresponding decrease or increase in current. There is no change in frequency.

CONSTRUCTION:



Any transformer has two coils electrically insulated but magnetically linked. For this the two coils are wound on a common core. The coil which receives energy from A.C source is known as primary P and the coil which delivers the energy to load is known as secondary S. If the number of turns in the primary is greater than in the secondary then the transformer is known as step down transformer. If the number of turns in the primary is less than in the secondary then the transformer is known as step up transformer. The relation among current i , voltage v and number of turns N can be written as $\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$

WORKING:

When an alternating voltage is applied to the primary, an alternating current is set up in it. As the winding is linked with a magnetic emf, it produces an oscillating flux in the core. This alternating flux links with the turns of the secondary coil. Hence alternating current is induced in the secondary coil.

From faraday's law of electromagnetic induction induced emf

$$e = M\frac{di}{dt}$$

Energy losses: Although transformers are very efficient devices, small energy losses do occur in them due to four main causes:

1) **Resistance of windings**: Even though we use low resistance copper wire for the windings still has resistance and thereby contribute to heat loss.

2) **Flux leakage**: The flux produced by the primary coil may not be all linked to the secondary coil if the design of the core is bad.
3) **Eddy currents**: The changing magnetic field not only induces currents in the secondary coil but also currents in the iron core itself. These currents flow in little circles in the iron core and are called eddy currents. The eddy currents cause heat loss. The heat loss, however, can be reduced by having the core laminated. (Thin sheets of soft iron insulated from one another).
4) **Hysteresis** – The magnetization of the core is repeatedly reversed by the alternating magnetic field. The repeating core magnetization process expends energy and this energy appears as heat. The heat generated can be kept to a minimum by using a magnetic material which has a low hysteresis loss. Hence, soft iron is often chosen for the core material because the magnetic domains within it changes rapidly with low energy loss.

Efficiency: The efficiency of the transformer is defined as the ratio of output power to the input power.

$$\eta = \frac{output\ power}{input\ power} = \frac{V_2 I_2}{V_1 I_1}$$

Applications: 1.It is used in transmitters, receivers, telephones and televisions.

2. It is used in welding and electric furnaces.

3. It is used to transmit a.c power over a long distances without electric loss.

PROBLEMS PAPER V

1. Two spheres each of radius 10 cm are charged to 10^{-9} C and 2×10^{-9} C respectively are separated by 2m from their centers. Find the potential at the midpoint of their centers.

Ans: Given

r =1m

$q_1 = 10^{-9}$ C

$q_2 = 2\times10^{-9}$ C

Potential $V = \frac{1}{4\pi\varepsilon_o} \times \frac{q}{r}$

$$= 9\times10^{9}\left(\frac{2\times10^{-9}}{1} + \frac{1\times10^{-9}}{1}\right)$$

$\therefore V = \mathbf{27\ V}$

2) Find the intensity of electric field on the surface of a sphere of radius 1cm and charge 100 C.

Ans: Given

q = 100 C, r = 1 cm = 0.01 m

Electric field intensity $E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{q}{r^2}$

$$E = 9 \times 10^9 \times \frac{100}{0.01^2} = 9 \times 10^9 \times \frac{100}{0.0001} = 9 \times 10^9 \times 10^6$$

E = 9×10^{15} V/m

3) A thin spherical shell of metal has radius of 0.25 m and carries a charge of 0.2 μC. Calculate the electric field intensity i) on the surface of the shell ii) 3 m away from the centre of the shell.

Ans: Given

$q = 0.2\times10^{-6}$ C,

R = 0.25 m

R=3m

Electric field on the surface of the shell $E=\frac{1}{4\pi\varepsilon_o}.\frac{q}{R^2}=9\times10^9.\frac{0.2\times10^{-6}}{0.25^2}$

$E = 28.8\times10^3$ N/C

Electric field outside the shell $E=\frac{1}{4\pi\varepsilon_o}.\frac{q}{r^2}=9\times10^9.\frac{0.2\times10^{-6}}{3^2}=200N/C$

4) Calculate the magnetic induction at the center of a circular coil of radius 20cm and 40 turns having a current of 2amp in it.

Ans: Given

I = 2amp, $\mu_o = 4\pi\times10^{-7}$

N = 40

a = 20 cm = 20×10^{-2}m

$$B=\frac{\mu_o NI}{2a}=\frac{4\times3.14\times10^{-7}\times40\times2}{2\times20\times10^{-2}}$$

$$=\frac{1004.8}{40}\times10^{-5}$$

= 2.512×10^{-6} Tesla

5) An infinitely long conductor carries a current of 100mA. Find the magnetic field at a point 10cm away from it.

Ans: Given

I = 100mA = 0.1 A

d = 10cm=0.1m

$$B=\frac{\mu_o I}{2\pi d}=\frac{4\pi\times10^{-7}\times0.1}{2\pi\times0.1}$$

= 2×10^{-7} Wb/m^2

6) A current of 1amp is flowing in a circular coil of radius 10cm and 20 turns. Calculate the intensity of magnetic field at a distance 10cm on the axis and at the center.

Ans: Given

n = 20, I = 1 amp, a = 10cm = 0.1m

$$B = \frac{\mu_o nI}{2a}$$

$$\therefore H = \frac{B}{\mu_o} = \frac{\mu_o nI}{\mu_o 2a} = \frac{20\times1}{2\times0.1} = 100 \text{ amp/m}$$

At a distance 10 cm from the centre of the axis (x = 10 cm = 0.1m)

$$B = \frac{\mu_o nIa^2}{2(a^2+x^2)^{3/2}}$$

$$H = \frac{nIa^2}{2(a^2+x^2)^{3/2}} = \frac{20\times1\times0.01}{2(0.1^2+0.1^2)^{3/2}} = \frac{0.2}{2\times\left(2\times0.1\right)^{3/2}}$$

$$= \frac{0.2}{2\times\left(\sqrt{2}\right)^{2\times\frac{3}{2}}\times\left(0.1\right)^3}$$

$$\frac{0.2}{2\times\left(\sqrt{2}\right)^{2\times\frac{3}{2}}\times\left(0.1\right)^3} = \frac{0.2}{2\times\left(\sqrt{2}\right)^3\times\left(0.001\right)}$$

$$= \frac{0.2}{0.002\times\left(1.414\right)^3} = \frac{0.2}{0.002\times2.827} = 35.37 amp/m$$

7) The length of a solenoid is 50cm, radius is 5 cm and the number of turns is 100. Calculate its self inductance. $\mu_o = 4\pi\times10^{-7}$ H/m.

Ans: Given

Length of solenoid l = 50cm = 0.5 m

Radius r = 5 cm = 5 $\times10^{-2}$ m

No. of turns N = 100

No. of turns per unit length $n = N / l$

Self inductance $L = \mu_o n^2 lA = \frac{\mu_o N^2 lA}{l^2} = \frac{\mu_o N^2 A}{l} = \frac{4\pi\times10^{-7}\times100^2\times\pi\times\left(5\ \times10^{-2}\right)^2}{0.5}$

$$= \frac{4\times3.14\times3.14\times25}{0.5}\times10^{-5} = 19.71\times10^{-5} H$$

8) Calculate the energy stored in the magnetic field of a solenoid of inductance 5mH when a maximum current of 3amp flows through it.

Ans: Given

Inductance of coil L = 5mH =5×10^{-3} H

Current I = 3 amp

Energy stored in the magnetic field $U = \frac{1}{2}LI^2 = \frac{1}{2} \times 5 \times 10^{-3} \times 3^2 = 22.5 \times 10^{-3} J$

9) A straight wire core solenoid 2m long with 20000 turns and area of cross section 10cm^2 carries a closely wound secondary of 1000 turns near the centre. Calculate the mutual inductance.

Ans: Given

μ = 1 for air, l = 2m

$n_1 = N/l$ = 20,000/2 = 10,000

Area A = 10cm^2 = 10×10^{-4} m^2

n_2 = 1000, $\mu_o = 4\pi \times 10^{-7}$ H/m

Mutual inductance $M = \mu_o n_1 n_2 A = 4\pi \times 10^{-7} \times 10000 \times 1000 \times 10^{-3}$ = 12.56 mH

10) Calculate the self inductance of a solenoid of length 2m and area of cross section 0.01m^2 with 3000 turns.

Ans: Given

l = 2m; A = 0.01m^2; N = 3000 turns; $n = N/2$ = 3000/2 = 1500

Self inductance $L = \mu_o n^2 l A = 4\pi \times 10^{-7} \times (1500)^2 \times 2 \times .01 =$ = 0.0565 H

11) A long solenoid having 200 turns per cm carries a current 1.5amp. At the center of it is placed a 100 turn coil of cross sectional area 3.14×10^{-4}m^2. When the current in the solenoid changed to 1 amp in 0.05sec, what is the e.m.f. induced in the coil.

Ans: Given

$B = \mu_o n i \ = 4\pi \times 10^{-7} \times 200 \times 1.5 \ = 0.038$ wb/m^2

Flux through each turn of the coil of area A = 3.14×10^{-4}m^2 is given by

$$\varphi_B = BA = \ = 0.038 \times 3.14 \times 10^{-4} = 1.2 \times 10^{-5} \text{wb}$$

When the current is reversed, the change in flux = 1.2×10^{-5} – (-1.2×10^{-5})

= 2.4×10^{-5} wb

Induced emf $e = N \frac{d\varphi_B}{dt} = 100 \times \frac{2.4 \times 10^{-5}}{0.05} = 0.048\text{V}$

12) A 50cm long solenoid having 500 turns and radius 2cm is wound on an iron core of μ_r = 800. What will be the average e.m.f. induced in the solenoid if the current in it changes from 0 to 2amp in 0.05sec.

Ans: Given

$\mu_r = 800$

$\mu_o = 4\pi \times 10^{-7}$

$N = 500$

$A = \pi (0.02)^2 = 0{,}001256 \quad m^2$

$l = 50cm = 50 \times 10^{-2} m$

$$L=\frac{\mu_r\mu_0N^2A}{l}=\frac{800\times4\pi\times10^{-7}\times(500)^2\times0.001256}{50\times10^{-2}}$$
$$=0.63H$$

Induced emf $e=-L\frac{di}{dt}=-0.63\times\frac{(2-0)}{0.05}=25.2\text{ V}$

13) Calculate the resonant frequency of an LCR series circuit with L = 5 mH, C = 0.1 μF and R = 100 KΩ.

Ans: Given

L = inductance = 5mH = 5×10^{-3}H

C = capacitance = 0.1 μF = 0.1×10^{-6} F

R = resistance = 100 KΩ =100×10^{3} Ω

Resonant frequency of LCR series circuit

$$f_o=\frac{1}{2\pi}\sqrt{\frac{1}{LC}}=\frac{1}{2\times3.14}\sqrt{\frac{1}{5\times10^{-3}\times0.1\times10^{-6}}}=707\times10^4\,Hz$$
$$f_o=7.07\times10^6\,Hz$$

14) Calculate the resonant frequency of an LCR parallel resonant circuit with L=10 mH, C = 1 μF and R = 1 KΩ.

Ans: Given L = 10mH = 10×10^{-3}H, C = 1 μF = 10^{-6} F and R = 1 KΩ.

Resonant frequency $f=\frac{1}{2\pi\sqrt{LC}}$

$\therefore f=\frac{1}{2\pi\sqrt{10\times10^{-3}\times1\times10^{-6}}}$ = 1592 Hz

15) In a transistor, base current and emitter current are 0.08mA and 9.6mA respectively. Calculate collector current α and β.

Ans: $I_E = I_B + I_C$

$I_C = I_E - I_B$ = 9.6 – 0.08 = 9.52 mA

$$\alpha=\frac{I_C}{I_E}=\frac{9.52}{9.6}=0.992$$

$$\beta=\frac{I_C}{I_B}=\frac{9.52}{0.08}=119$$

16. A sperical drop of water carrying a charge of 3 X 10^{-6} C has a potential of 500 volt at its surface what is the radius of the drop?

Given

V=500 volt

$q = 3 \times 10^{-6}$ C

r= ?

$$V = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r}$$

or
$$r = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{V}$$

Substituting the given values, we have

$$r = (9 \times 10^9) \times \frac{(3 \times 10^{-6}}{500}$$

$$= \mathbf{54} \text{ m}$$

17) The dielectric constant of water is 78 . calculate its electrical permittivity.

Solution. We know that $\varepsilon = k\,\varepsilon_0$

$\therefore$
$$\varepsilon = 78 \times (8.85 \times 10^{-12})$$
$$= \mathbf{690.3} \times \mathbf{10^{-12}} \text{ F/m}$$

18) The dielectric constant of medium is 4. electric field in the dielectric is 10^{-6} V/m . calculate electric displacement and polarization. Take $\epsilon_0 = 9 \times 10^{-12} F/m$

Solution. We know that

$$D = k\,\varepsilon_0\,E \quad \text{and} \quad P = \varepsilon_0\,(k-1)\,E$$

Given that, $k = 4, E = 10^6$ V/m and $\varepsilon_0 = 9 \times 10^{-12}$ F/m

$\therefore$
$$D = 4 \times (9 \times 10^{-12}) \times 10^6$$
$$= \mathbf{36} \times \mathbf{10^{-6}} \text{ C/m}^2$$

and
$$P = (9 \times 10^{-12}) \times (4-1) \times 10^6$$
$$= \mathbf{27} \times \mathbf{10^{-6}} \text{ C/m}^2$$

19) The dielectric susceptibility of a material is 36 x 10^{-12} $C^2/N\text{-}m^2$. Calculate the value of dielectric constant and absolute permittivity of the material take $\epsilon_0 = 9 \times 10^{-12} F/m$

Solution. We know that

$$k = 1 + \frac{\chi}{\varepsilon_0} \quad \text{and} \quad \varepsilon = k\,\varepsilon_0$$

Given that $\chi = 36 \times 10^{-12}$ C/N-m^2 and $\varepsilon_0 = 9 \times 10^{-12}$ F/m

$\therefore$
$$k = 1 + \frac{36 \times 10^{-12}}{9 \times 10^{-12}} = 1 + 4 = \mathbf{5}$$

and
$$\varepsilon = 5 \times (9 \times 10^{-12})$$
$$= \mathbf{45} \times \mathbf{10^{-12}} \text{ F/m}$$

20) An Infinity long conductor carries a current of 10 milli Amps find the magnetic field and intensity at a point 10 c.m away from it.

Solution. We know that

$$B = \frac{\mu_0 i}{2\pi R}$$

Here, $\mu_0 = 4\pi \times 10^{-7}$, $i = 10 \times 10^{-3}$ amp and $R = 10\,\text{cm} = 0.1\,\text{m}$.

$$\therefore \quad B = \frac{(4\pi \times 10^{-7})(10 \times 10^{-3})}{2\pi \times 0.1} = \mathbf{2 \times 10^{-8}}\ \text{tesla}$$

Further, $$H = \frac{B}{\mu_0} = \frac{2 \times 10^{-8}}{4\pi \times 10^{-7}} = \frac{1}{2\pi} = \mathbf{0.01591}\ \text{amp / m}$$

21) A solenoid of length 100 cm has 1000 turns wound on it. Calculate the magnetic field at the middle point of its axis when a current of 2 amp is passed through it.

Solution. Given that $l = 100\,\text{cm} = 1\,\text{m}$

$$\therefore \quad \text{Number of turns/metre} = \frac{1000}{1} = 1000$$

Now,
$$B = \mu_0 N i$$
$$= (4\pi \times 10^{-7}) \times (1000) \times 2$$
$$= \mathbf{0.002573}\ \text{Wb/m}^2$$

22) A long solenoid has 20 turns per c.m. Calculate the magnetic induction at the interior point on the axis for a current of 20 m.A.

Solution. $B = \mu_0 n i$, where n = number of turns per unit length.

Here, $n = 20$ turns/cm $= 20 \times 100 = 2000$ turns per unit length

and
$$i = 20\,\text{mA} = 20 \times 10^{-3}\ \text{A}$$

$$\therefore \quad B = (4\pi \times 10^{-7})(2000)(20 \times 10^{-3})$$
$$= 16\pi \times 10^{-6}$$
$$= \mathbf{50.24 \times 10^{-6}}\ \text{weber/m}^2$$

23) What is self inductance of a 50 cm long solenoid with 2 c.m diameter and having 200 turns . Where $\mu_0 = 4\pi \times 10^{-7} H/m$

Solution.
$$L = \frac{\mu_0 N_2 a}{l} = \frac{(4\pi \times 10^{-7})\, N^2 a}{l}$$
$$= 31.55 \times 10^{-6}\ \text{H}$$
$$= \mathbf{31.55}\ \mu\text{H}$$

24) A coil has 600 turns.Its self inductance 100 m.H. Find the self inductance of another same type of soil having 500 turns.

Solution. We know that $L \propto N^2$

$$\therefore \quad \frac{L_1}{L_2}\left(\frac{N_1}{N_2}\right)^2 \quad \text{or} \quad \frac{100}{L_2} = \left(\frac{600}{500}\right)^2$$

or
$$L_2 = \frac{(500)^2 \times 100}{(600)^2}$$
$$= \mathbf{69.44}\ \text{mH}$$

25) An air core solenoid has 1000 turns and is one metre long . Its cross sectional area is 6 x 10^{-4} m^2. Calculate its self inductance . $\mu_0 = 4\pi \times 10^{-7} H/m$

Solution. Self inductance, $L = \mu_0 n^2 l A$

Given that, $l = 1$ m, $A = 6 \times 10^{-4}$ m^2, $N = 1000$ and $\mu_0 = 4\pi \times 10^{-7}$ h/m

Here, $n = \frac{N}{l} = \frac{1000}{1} = 1000$

26) A 20 Henry inductor carries a Steady Current of 2 ampere. How can a 200 volt self induced EMF can be made to appear in the inductor.

Solution. $e = -L\frac{di}{dt} = L\frac{di}{dt}$ (numerically)

or $\frac{di}{dt} = \frac{e}{L} = \frac{200}{20}$

$= \mathbf{10}$ **amp./sec**

27) Calculate the energy stored in the magnetic field of a solenoid of inductance 5 m.H, when a maximum current of 3 ampere flows through it.

Solution. $U = \frac{1}{2} L i^2 = \frac{1}{2} \times (5 \times 10^{-3}) \times (3)^2$

$= \mathbf{22.5 \times 10^{-3}}$ **joule.**

28) Two coils, a primary of 600 turns and secondary of 30 turns are wound on an iron ring of mean radius 0.1 metre and cross section 4 x 10^{-2} m^2area. Find the mutual inductance ($\mu_r of\ iron = 800$)

Solution. $M = \mu_r \times \frac{\mu_0 n_1 n_2 A}{l}$

Here, $\mu_r = 800$, $\mu_0 = 4\pi \times 10^{-7}$, $n_1 = 600$, $n_2 = 30$

$A = 4 \times 10^{-2}$ m^2 and $l = 2\pi r = 2\pi \times 0.1 = 0.2\pi$ metre

Substituting these values, we get

$$M = 800 \times \left[\frac{(4\pi \times 10^{-7}) \times 600 \times 30 \times (4 \times 10^{-2})}{0.2\pi}\right]$$

$= \mathbf{1.152}$ henry

29) In a series of RLC circuit R=100 Ohm, L = 0.5 Henry and C= 40 μF . Calculate resonant frequency and Q-factor. Answer. The resonant frequency f is given by

$$f = \frac{1}{2\pi} \times \frac{1}{\sqrt{(LC)}}$$

$$= \frac{1}{2\pi} \times \frac{1}{\sqrt{\{0.5 \times (40 \times 10^{-6})\}}} = 35.608 \text{ Hz}$$

$$Q = \frac{\omega L}{R} = \frac{2\pi f L}{R}$$

$$= \frac{2 \times 3.14 \times 35.608 \times 0.5}{100}$$

$= \mathbf{1.118}$

30) Calculate the resonant frequency of an LCR parallel resonant circuit with = 10 m.H,C=1 μF and R equal to 1Ω.

Solution. The resonant frequency f is given by

$$f = \frac{1}{2\pi}\sqrt{\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)} \approx \frac{1}{2\pi}\sqrt{\left(\frac{1}{LC}\right)}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1}{(10\times10^{-3})(1\times10^{-6})}} = \frac{1}{2\pi}\sqrt{(10^8)} = \frac{10^4}{2\pi}$$

$$= \mathbf{1592}\text{ Hz.}$$

31) In a Step down Transformer having primary to secondary turn ratio 20:1 , the input voltage applied is 250 volt and output current is 8 amp Assuming 100% efficiency , calculate the

1. voltage across secondary coil
2. current in primary coil
3. power output

Answer:

(i) Here $$\frac{n_s}{n_p} = n = \frac{1}{20}$$

$$E_p = 250 \quad \text{and} \quad i_s = 8 \text{ amp.}$$

$$\frac{E_s}{E_p} = \frac{n_s}{n_p} \quad \text{or} \quad E_s = \frac{n_s}{n_p} \times E_p$$

$$E_s = \frac{1}{20} \times 250$$

$$= \mathbf{12.5}\text{ V}$$

(ii) $$\frac{i_p}{i_s} = \frac{n_s}{n_p}$$

$$i_p = \frac{n_s}{n_p} \times i_s$$

$$i_p = \frac{1}{20} \times 8 = \mathbf{0.4}\text{ amp.}$$

(iii) $$\text{Power output} = E_s\, i_s$$

$$= 12.5 \times 8 = \mathbf{100}\text{ watt}$$

32) In a Transistor base current and current are 0.08 m.amp and 9.8 m.A respectively. Calculate collector current,α and β.

Answer:

We know that $I_E = I_B + I_C$

$$I_C = I_E - I_B = 9.6 - 0.08$$
$$= \mathbf{9.52} \text{ mA}$$
$$\alpha = \frac{I_C}{I_E} = \frac{9.52}{9.6}$$
$$= \mathbf{0.9915}$$
$$\beta = \frac{I_C}{I_B} = \frac{9.52}{0.08}$$
$$= \mathbf{119}$$

33) A transistor has an I_C of 100 m A and I_B of 0.5 mA. what is the value of $\alpha_{dc.}$

Answer:

Here $I_E = I_C + I_B = 100 + 0.5 = 100.5$ mA

$$\alpha_{dc} = \frac{I_C}{I_E} = \frac{100}{100.5}$$
$$= \mathbf{0.995}$$