RADIO AMATEUR EXAM
GENERAL CLASS

By **4S7VJ**

CHAPTER- 2

2.1 Sine-wave

If a magnet rotates near a coil, an alternating e.m.f. (a.c.) generates in the coil. This e.m.f. gradually increase from zero to a maximum value and then decreases to zero and change the direction and continue again. If it is represent graphically it is call Sine-wave (fig 2.1). This is most important and most simple waveform. The portion between two similar consecutive points is one complete wave or one cycle. The maximum e.m.f. is the amplitude or peak value. The time taken for one wave is the period and the number of waves generated in one second is the frequency. Unit of frequency is cycles per second (c/s) or Hertz (Hz) and also use kilo Hertz (kHz), Mega Hertz (MHz) and Gega Hertz (GHz)

1000 Hz = 1 kHz
1000 kHz = 1 MHz
1000 MHz = 1 GHz

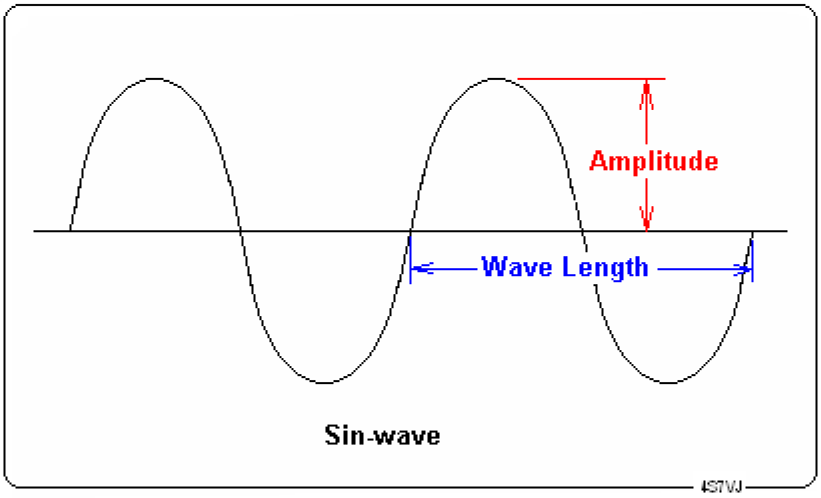

Fig 2.1

2.1.1 Other types of waves

Regarding sound waves, pure musical note represents a Sine-wave There are various types of complex wave forms like square wave, saw tooth wave, triangular wave. Human voice is very complicated wave form.

Any type of wave is a combination of a large number of sine waves having various frequencies and amplitudes. (may be a few number of waves or infinite number.)

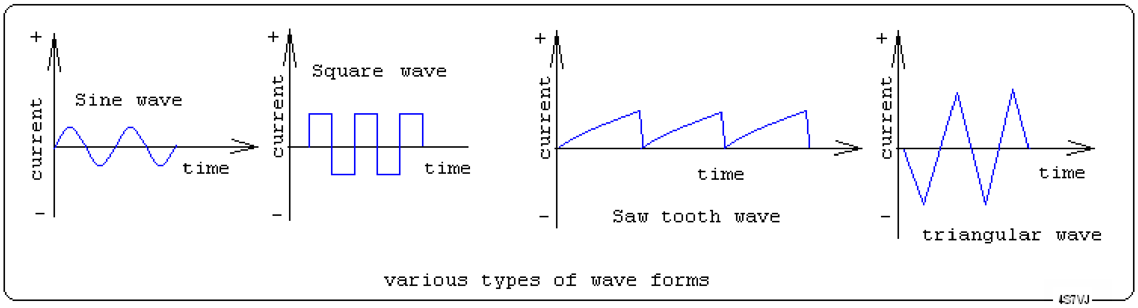

Fig. 2.2

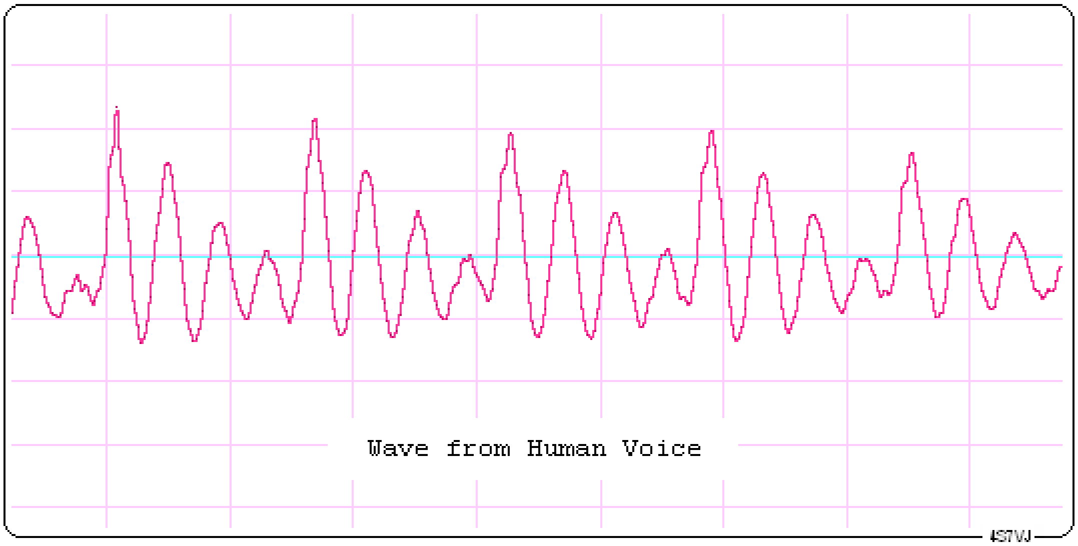

Fig.2.3

2.2 CURRENT, E.M.F & POWER IN A.C

2.2.1 Peak value

As mentioned in the explanation of sine wave (para-2.1) the maximum or amplitude of current or e.m.f. is the peak value.

2.2.2 Instantaneous value

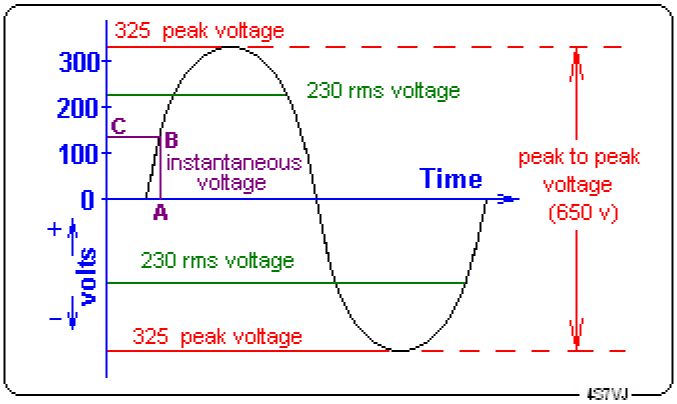

Fig. 2.4

In a.c. circuits current and voltage are varying always between zero and the peak value. The value at any instant is the instantaneous current or voltage. In the diagram of

Fig 2.2 point “B” represents the instant of “A”. Instantaneous voltage at this moment is represent by “C”.

2.2.3 R.M.S value (root mean square)

A "d.c. ampere " is a measure of a steady current, but the "a.c. ampere" must measure a current that is continually varying and periodically reversing direction. An "a.c. ampere" is defined as the current that will cause the same heating effect as one ampere of steady direct current. For sine-wave a.c. this effective value is equal to the maximum value or amplitude (peak value) multiply by 0.707.

rms current = 0.707 x peak current
= 70.7% of peak current

When we consider an a.c. voltage or current , obviously it is the **rms value.** With using advanced mathematics we can get the above relationship.

NB.:- The rms value is not the average value.

2.2.4 POWER IN A.C. CIRCUITS

For a.c. circuits, there are no meaning of rms-power or instantaneous power because the definition of power is the energy consumed in one second. But, if the power is varying, we can consider the average power during a limited period.

Power = rms current x rms voltage

Example:-

A soldering iron plugged into the AC-mains 240 V supply. If the current consumption is 125 mA. Calculate

1. power consumption
2. resistance of the iron element

Solution:-

Obviously 240 V and 125mA are rms values because, for a.c. circuits normally giving rms values only.

1. power = voltage x current
   = 240 x 0.125 (125mA = 0.125 A)
   = **30 watt**

2. according to the Ohm's law
   V = I x R or R = V / I
   resistance = 240/0.125
   = **1920 Ohms**

2.3 CAPACITANCE

2.3.1 CAPACITOR (CONDENSER)

Suppose two flat metal plates are placed closed to each other (but not touching) and are connected to a d.c. supply (battery) through a switch. At the instant the switch is closed, electrons will be (Fig. 2.5) attracted from the positive terminal of the battery, that means the plate attached to the positive terminal would be charged positively. The other plate will be charge with negative because it is attached to the negative terminal of the battery having excessive electrons. Then the voltage between two plates is equal to the e.m.f. of the battery. If the switch is open or disconnect the battery, then the plates remain charged. If a wire is touched between the two plates (short-circuit) the excess electrons from the negative plate will flow through the wire to the positive plate; Or we can say the positive charges will flow through the wire from positive plate to the negative. The plates have then been discharged. This arrangement having two metal plates separate with an insulating material (dielectric) called "CAPACITOR" or condenser.

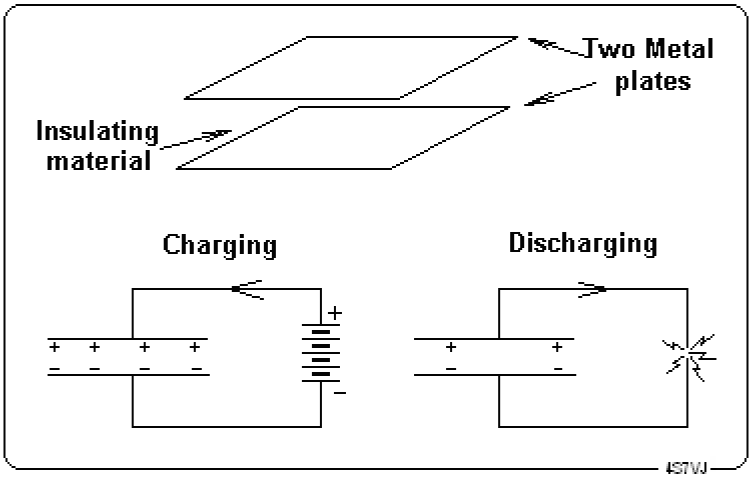

Fig.2.5

2.3.2 PROPERTIES OF CAPACITORS

The main property of a capacitor is storing electric charge or electrical energy. During the time the electrons ("-" or "+" charge) are moving, that is while the capacitor is being charged or discharged a current is flowing in the circuit even though the circuit is open by the gap between the capacitor plates. (filled with dielectric material). There can be no continuous flow of d.c. current through a capacitor, but it's appears like an a.c. current can pass easily, actually a.c. current passes through the external circuit, not through the capacitor. if the frequency is high enough, the charging and discharging time is very short. (micro seconds or mili seconds)

Summery :-

1. Storing electric charge
2. Cannot flow a d.c. current
3. Appears like A.C. current can flow

2.3.3 FARAD (unit of capacitance)

The size of a capacitor measured with its "CAPACITANCE". The capacitance is the amount of charge can be stored in a capacitor for maintain one volt of p.d. between two plates. The SI unit is "Farad". But the practical units are micro

Farad (µF), nano Farad (nF) and Pico Farad (pF), because the "Farad" is very large amount.

1000 pF = 1 nF
1000 nF = 1 µF
1000 µF = 1 mF

2.3.4 FACTORS AFFECTING FOR THE CAPACITANCE

Capacitance of a capacitor is depend on :-

1. Effective area of plates
   (area of one side of a plate and number of plates)
2. Separation between plates
3. Dielectric constant of the insulating material between plates

2.3.4.1 DIELECTRIC CONSTANT

If the space between the plates of a capacitor is filled with an insulating material (liquid or solid), the capacitance will be increased. The ratio of increment is called "dielectric constant" of the material. There is no unit for the dielectric constant because it's a ratio.

2.3.4.2 BREAKDOWN VOLTAGE

When a high voltage is applied to the plates of a capacitor, a considerable force is exerted on the electrons and nuclei of the dielectric. But the electrons do not detached from atoms because it is an insulator. However if the force is great enough, the dielectric will break down. Usually it will puncture and permit current to flow. The breakdown voltage depends upon the type and thickness of the dielectric.

Material	**Dielectric constant**	**Breaking Voltage (V/µm)**
Air	1.0	
Fiber	5 – 7.5	5.9 - 7
Formica	4.6 - 4.9	17.7
Glass	7.6 - 8	7.9 – 9.8

Glass (Pyrex)	4.8	13.2
Mica	5.4	150 - 220
Paper	3.0	7.8
Porcelain	5.1 - 5.9	1.5 - 3.9
Quartz	3.8	39
Teflon	2.1	39 - 78

2.3.5 PARALLEL PLATE CAPACITOR

We can calculate the capacitance of a parallel plate capacitor with using the following formula :-

$$\boxed{C = 0.881 K A / d}$$

Where K = dielectric constant of the material between two plates
A = surface area of a plate in sq.cm.
d = separation between two plates in mm.
C = capacitance in pF.

2.3.6 TYPES OF CAPACITORS

2.3.6.1 Variable capacitors

There are two types of variable capacitors; tuning condenser and trimmer condenser.

Tuning condenser:-

The capacitance can be vary between the minimum and maximum value with using a knob.

Trimmer condenser:-

The capacitance can be adjust and keep it in a steady value. Normally adjustment will be doing with a screw driver.

2.3.6.2 Fixed capacitor

Fixed capacitors can be divided into several types according to the type of dielectric material, as follows.

1. Mica capacitors

2. Ceramic capacitors
3. Paper capacitors
4. Tantalum capacitors
5. Electrolytic capacitor

Mica capacitors are use for high voltage applications. Ceramic and paper capacitors are use for low voltage applications, and those are comparatively cheap. Tantalum capacitors are high quality and expensive. Electrolytic capacitors are having high value of capacitance and polarity system.

2.3.7 COMBINATION OF CAPACITORS

Capacitors are available only for specific standard values. If we needed a non-standard value, we can combine two or more capacitors for, get the required value.

2.3.7.1 PARALLEL COMBINATION

The equivalent capacitance of a parallel combination of capacitors is equal to the sum of all values. If those are C1, C2, C3,...and equivalent capacitance is "C", then

$$\boxed{C = C1 + C2 + C3}$$

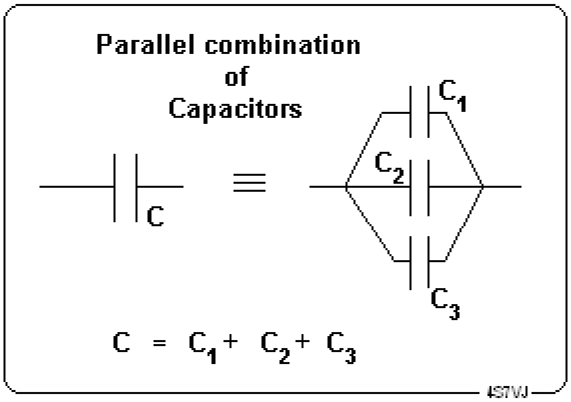

Fig.2.6

Eg:-

Three condensers of 100 pF, 0.001 μF and 1.5 nF connected in parallel. What is the equivalent capacitance?

C1 = 100 pF
C2 = 0.001 µF
= 0.001 x 1000,000 pF
= 1000 pF

C3 = 1.5 nF
= 1.5 x 1000 pF
= 1500 pF

C = C1 + C2 + C3
= 100 + 1000 + 1500
= **2600 pF = 2.6 nF = 0.0026 µF**

2.3.7.2 SERIES COMBINATION

If a series combination of capacitors having the values of C1, C2, C3,....and the equivalent capacitance is " C " then

$$\boxed{1/C = 1/C1 + 1/C2 + 1/C3}$$

N.B.
The equivalent value is always smaller than the smallest capacitor, for series combination.

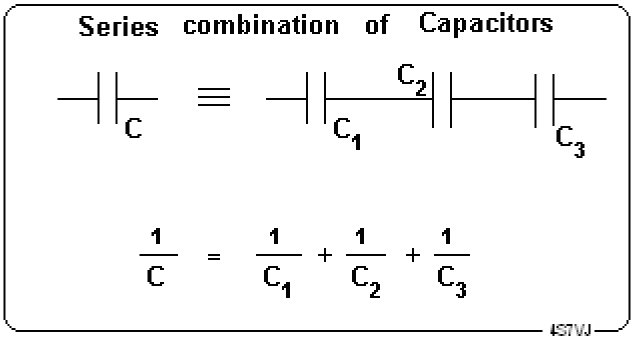

Fig. 2.7

Eg:-
Three capacitors having 50 pF, 150 pF and 0.0003 µF are connected in series. What is the equivalent capacitance ?

C1 = 50 pF

$$C2 = 150 \text{ pF}$$

$$C3 = 0.0003\ \mu\text{F} = 300 \text{ pF}$$

(The equivalent value is less than 50 pF
because the smallest capacitor is 50 pF)

$$1 / C = 1 / C1 + 1 / C2 + 1 / C3$$

$$= 1/50 + 1/150 + 1/300$$

$$= \frac{6 + 2 + 1}{300}$$

$$= 9 / 300$$

$$C = 300 / 9$$

$$= \underline{\mathbf{33.3\ pF}}$$

Eg:-

Four condensers of 50 pF, 150 pF, 100 pF and 80 pF are connected in series. Select the correct answer for the equivalent capacitance.

(1) 60.3 pF (2) 72 pF (3) 20.34 pF (4) 50.1 pF

With out doing any calculation you can select the third answer (20.34 pF) as the correct one. Because that is the only answer smaller than the smallest capacitor (50 pF).

2.3.7.3 <u>TWO CAPACITORS IN SERIES</u>

If two capacitors of C1 and C2 are in series, then equivalent value, C is given as

$$1/C = 1/C1 + 1/C2$$

OR

$$C = \frac{C1 \times C2}{C1 + C2}$$

Eg:-

100 pF and 150 pF capacitors connected in series. What is the equivalent capacitors ?

```
C = (C1xC2) / (C1+C2)
  = (100x150) / (100+150)
  = (100x150)/250
  = 60 pF
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2.3.7.4 SEVERAL NUMBERS OF EQUAL CAPACITORS IN SERIES

The capacitance of the each capacitors divide by the number of capacitors is equal to the equivalent value of equal series capacitors.

Eg:-
10 capacitors of 0.022 µF are connected in series.
What is the equivalent capacitance ?

Equivalent capacitance = 0.022/10
= **0.0022 µF**

2.3.8 ENERGY STORED IN A CAPACITOR

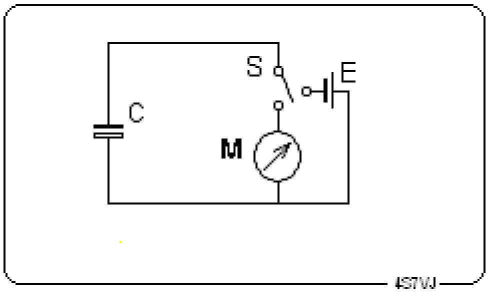

Fig 2.8

Connecting a dc source "E" to the terminals of a capacitor "C" through a two-way switch "S", the capacitor charge to the full EMF almost instantaneously, or we can say some amount of energy stored in the capacitor. Any miliameter "M" added to the circuit as Fig 2.6 and change the direction of "S". We can see instantaneous deflection of the meter. That means some amount of energy from the capacitor dissipated through the meter.
We can calculate this energy with using the following formula.

$$E = CV^2 / 2$$

Where, E = energy in Joules
C = capacitance in Farads

V = voltage across “C” or EMF of “E” in Volts

Example:-
A 1000μF capacitor should charge and store 1 joule of energy. What would be the voltage of the source?

C = 1000μF = 0.001 F, E = 1 J, apply the above formula

$$1 = 0.001 \times V^2/2$$
$$V^2 = 2/0.001$$
$$= 2000$$
$$V = \sqrt{2000}$$
$$= 44.7 \text{ volts}$$

2.4 INDUCTANCE

It is possible to show that the flow of current through a conductor is accompanied by magnetic effects. For an example, a compass needle brought near the conductor carrying a current, will be deflected from its normal north-south position. In other words, the current sets up a magnetic field. The transfer of energy to the magnetic field represents work done by the source. Power is required for doing work, and since power is equal to the current multiply by the voltage there must be a voltage drop in the circuit during the time in which energy is being stored in the field. This voltage drop is the result of an opposing voltage "induced" in the circuit while the field is building up to its final value. When the field becomes constant the induced e.m.f. or back e.m.f. disappears, since no further energy is being stored. Since the induced e.m.f. opposes the e.m.f. of the source it tends to prevent the current from rising rapidly when the circuit is closed. If the circuit is break or open circuit, the induced e.m.f. tends to prevent the current decreasing rapidly. In other words this e.m.f. is opposite polarity with the earlier. The amplitude of the induced e.m.f. is proportional to the rate of change of current. This property is called "Inductance".

2.4.1 The unit of inductance - HENRY

The unit of inductance is "Henry". Practically smaller units (mili Henry and micro Henry) are very useful for r.f. circuits and inductance of several Henrys is required in power supply circuits.

1000 µH = 1 mH
1000 mH = 1 H

2.4.2 FACTORS AFFECTING FOR THE INDUCTANCE

Inductance of a coil is depend on the following factors

1. Number of turns
2. Diameter of the coil
3. Length of the coil
4. Permeability of the material of the core

2.4.3 INDUCTANCE OF A SINGLE LAYER COIL

$$L = r^2n^2/(229r+254b)$$

r = radius of the coil in mm.
b = length of the coil in mm.
n = number of turn
L = inductance in µH.

$$L = r^2n^2/(9r+10b)$$

r = radius of the coil in inch
b = length of the coil in inch
n = number of turn
L = inductance in µH.

Eg :- Assume a coil having 20 turns wound on a former having a diameter of 20 mm and length of 25 mm. Calculate the inductance of the coil.

$r = 20/2 = 10$ mm.
$b = 25$ mm.

$$
\begin{aligned}
n &= 20\\
L &= 10^2 \times 20^2/(229 \times 10 + 254 \times 25)\\
&= 100 \times 400/(2290 + 6350)\\
&= 40000/8640\\
&= \underline{\mathbf{4.6\ \mu H}}
\end{aligned}
$$

2.4.4 INDUCTANCE IN SERIES

When two or more inductors are connected in series the total inductance is equal to the sum of the individual inductances, provided the coils are sufficiently separated so that no coil is in the magnetic field of another.

$$L = L1 + L2 + L3$$

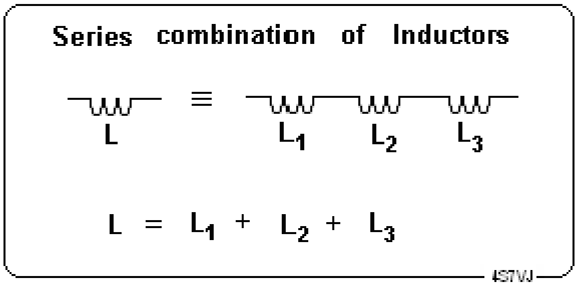

Fig. 2.9

2.4.5 INDUCTANCE IN PARALLEL

When inductors are connected in parallel and the coils are separated sufficiently, the total inductance is given by

$$\mathbf{1/L = 1/L1 + 1/L2 + 1/L3}$$

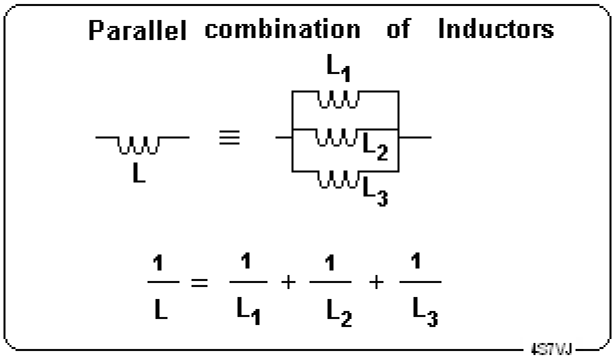

Fig. 2.10

If two inductors are connected in parallel, the total is given by the simpler form as follows.

$$L1 \times L2$$

$$L = \frac{\qquad}{L1 + L2}$$

2.4.6 MUTUAL INDUCTANCE

If two coils are arranged with their axes on the same line, a current sent through the first coil will cause a magnetic field which cuts the second coil. Consequently an e.m.f. will be induced in the second coil whenever the field strength is changing. This e.m.f. is similar to the induced e.m.f. of a single coil. (Self-induction) But since it appears in the second coil because of the current flowing in the first, it is a mutual effect and results from the "mutual inductance" between the two coils. If all the magnetic flux set up by one coil cuts all the turns of the other coil the mutual inductance has its maximum possible value. It will happen when they are very close to each other or one coil wound on the other. This type is called closely coupled or tightly coupled mutual inductors. When they are separated each other it is called loosely coupled inductors.

2.4.7 ENERGY STORED IN AN INDUCTOR

An inductor “L” connected with DC source “E” through a switch “S” according to the Fig 2.11(a). When closed the switch current increases to a steady value against the induced back EMF of the inductor. That means consume some energy for this action. When the switch opened an electric spark generates between the gap of the switch due to the high induced voltage. The electrical energy deposited in the inductor converts to light, heat, sound and RF energy.

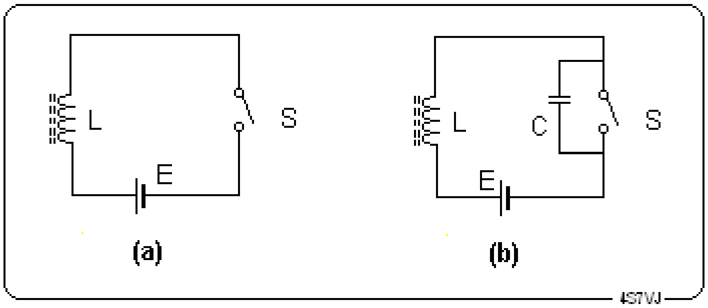

Fig. 2.11

The energy deposits in the inductor can be calculate by the following formula.

$$E = \frac{1}{2} L I^2$$

Where, E = energy in the inductor in **Joule**
L = inductance of the coil in **Henry**
I = current in the circuit at steady state in **Ampere**

During this incidence the contact points of the switch is getting damage due to the spark. We can avoid this damage by connecting a suitable capacitor between the terminals of the switch. (Fig 2.11-b)

2.5 TIME CONSTANT

2.5.1 Time-constant for C-R circuits

Connecting a DC source of e.m.f. to a capacitor causes the capacitor to become charged to the full e.m.f. instantaneously, if there is no resistance in the circuit. However if the circuit contains a resistance as in fig. 2.12(a), the resistance limits the current flow. Duration of time required for the e.m.f. between the capacitor plates to build up to the same value as the emf of the source is (Theoretically) infinite. During this building up period the current gradually decreases from its initial value, because the difference of e.m.f. between the source and the capacitor is gradually decreasing. Theoretically, the charging process is never really finished, but eventually the current drops to a value that is smaller than anything that can be measured. The "TIME CONSTANT" defined as the time duration, in seconds, required for the voltage across the capacitor to reach 63.2% (This is chooses for mathematical reason) of the applied e.m.f. Mathematically proved that the time constant is equal to the multiplication of the resistance and the capacitance(RC). Variation of the voltage with time is indicated by the fig. 2.12(a). If a charged capacitor discharged through a resistor as indicated in fig. 2.12(b) the same time constant applies. That means after a same period (TIME-CONSTANT) the voltage across the capacitor will be reduced by 63.2% of the initial value. The variation of the voltage with time is indicated by Fig. 2.12(b).

2.5.1.1 FORMULA FOR TIME-CONSTANT

$$\boxed{T = RC}$$

where, T = time-constant in second
C = capacitance in Farads
R = resistance in Ohms

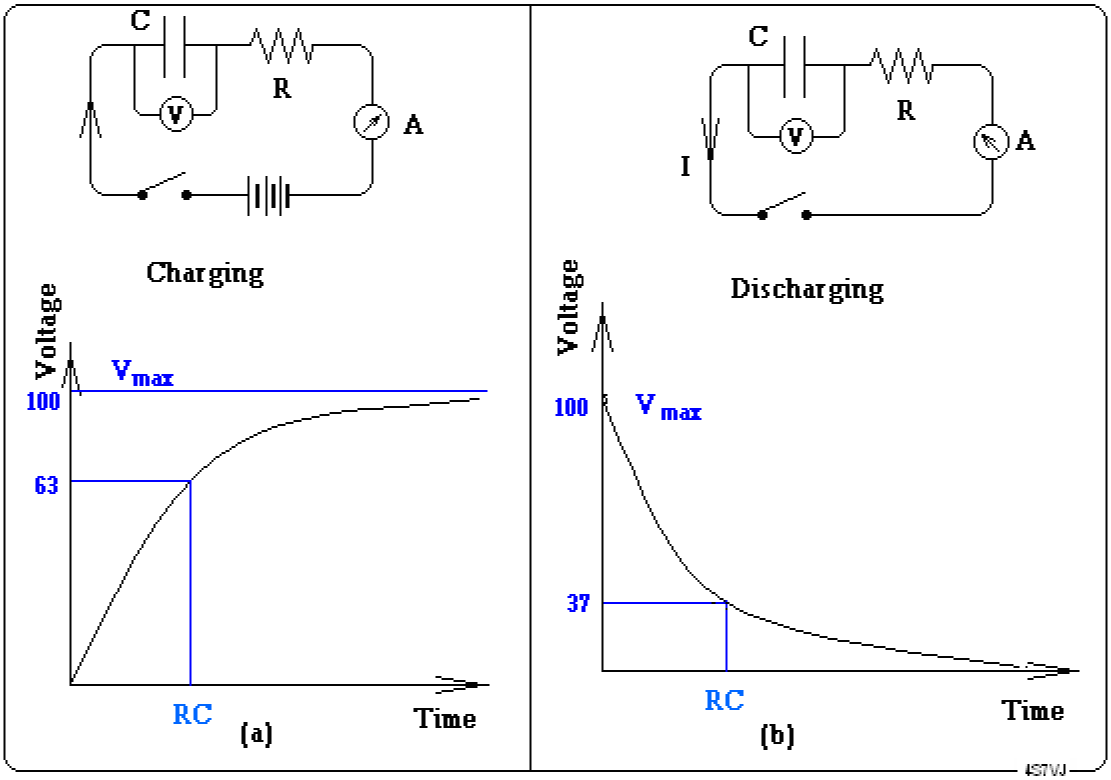

Fig. 2.12

Eg:-

What is the time-constant for a 2μF capacitor and 1.5 MΩ resistor.

1st method:-

$T = R \times C$
$T = 1.5 \times 1000000 \times 2/1000000$

= 1.5 x 2
= **<u>3 Sec.</u>**

2nd method :-

T = R (in MΩ) x C (in μ F)
= 1.5 x 2
= **<u>3 Sec.</u>**

Regarding the above example, if we used 100 V. dc source to charge 2 μF capacitor through 1.5 MΩ resistor, after 3 sec. the voltage across the capacitor will be 63.2 Volts and to reach 100 V takes a long time. After 6 sec. it will be 86.5 V (63.2+63.2% of(100-63.2))and 30 seconds later it will be 99.9 Volts.

After charged to 100 Volts, if it is discharged through the same resistor, in 3 seconds it will be reduced by 63.2 that means after 3 seconds the voltage across the capacitor will be 36.8 Volts. (100-63.2 = 36.8). After 30 seconds, the voltage will be 0.1 Volts, (100-99.9 = 0.1)

2.5.2 Time-constant for L-R circuits

A comparable situation exists when Inductance and Resistance connected in series with a dc source. We can consider an inductor as a series combination of the inductance and the resistance of the inductor.

According to the diagram of fig. 2.13(a), when closing the switch "S" would tend to flow a current through the circuit. Due to rapid change of current, a back e.m.f. will be develop in the inductor. The rate of change of current will be retard due to the result of this back e.m.f. The rising of the current represents by the fig. 2.13(b). If there is no inductance, the current will be reach to it's maximum value instantaneously. The time taken for the current to reach 63.2% of the maximum value is the time constant of the circuit.

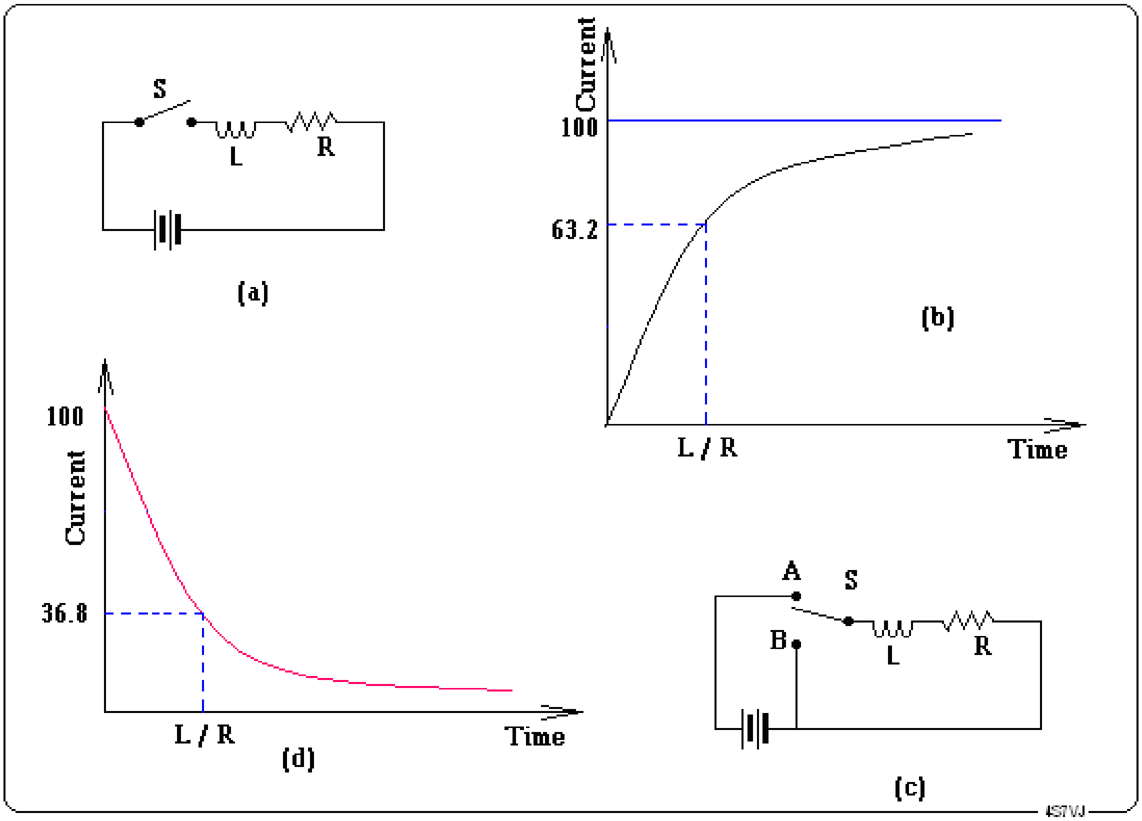

Fig.2.13

2.5.2.1 Formula for the time-constant

$$\boxed{T = \frac{L}{R}}$$

For L-R circuits explained as above the time-constant "T" is given as

where, T = time-constant in second
L = inductance in Henrys
R = resistance in Ohms

Example:-

A coil having an inductance of 5 H.and resistance of 200 Ohms. What is the time-constant?

If it is connected to a d.c. 12V. supply what is the steady current in the circuit?

time constant = L/R
= 5/200
= 0.025 sec = **25 mS.**

For calculate the steady current, apply the Ohm's law (V=IR)

the current, I = V/R
= 12/200
= 0.06 A. = **60 mA.**

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EXERCISES

2.1 An electric bulb connected to a 230 v. a.c. mains supply the current consumption is 500 mA. What is the resistance of the filament and the power consumption?
(ans:- 460 Ohms, 115 watt)

2.2 A capacitor made out of two aluminum plates having a surface area of 10 sq.cm. are placed in touch with a Formica sheet having a thickness of 1 mm. Calculate the capacitance. Dielectric constant of formica is 4.8
(ans :- 42.3 pF.)

2.3 Two capacitors of 100 pF and 500 pF combined in
(a) parallel.
(b) series
What are the equivalent capacitances ?
(ans :- 600 pF, 83.3 pF)

2.4 200 pF and 300 pF capacitors connected in series. What is the equivalent capacitance ?
(ans :- 120 pF)

2.5 Any number of capacitors of 120 pF available with you, how do you make a 15 pF capacitor.
(ans :- 8 capacitors in series)

2.6 Four capacitors having the values of 100 pF, 150 pF, 50 pF and 1 nF connected in series. Select the correct answer for the equivalent value.
(1) 0.0013 µF (2) 265.5 pF (3) 26.55 pF (4) 26.55 nF

(ans :- No 3.)

2.7 A 50 pF capacitor made out of two metal plates and a paper dielectric. If we stack another additional nine identical plates and same type of paper as dielectric for make a multi - parallel plate capacitor what is the total capacitance? (ans:-500 pF)

2.8 A capacitor of 100 μF connected with 1kΩ resistor. What is the time-constant of the circuit.
(ans:- 0.1 sec)

2.9 An inductor having 1.5 H., of inductance and 100Ω of resistance. What is the time constant?
If it is connected to a 10 V d.c. supply what is the steady current and and what is the energy stored in the inductor?
(ans:- 0.015 Sec, 100 mA., 0.0075 J)

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