UNIT-2
Part 1: ELECTROSTATICS

Q. 1 Define the following terms.

i)Electric flux (ii)Electric flux density (iii)Electric Field strength (iv)Relative Permittivity (v)Absolute Permittivity

Electric Flux:

*It is defined as "**the total number of electric field lines in an electric field**".* It is represented by the symbol ***ψ (psi).***

Electric flux, ψ =Q Coulomb

Electric Flux Density

*It is defined as "**the flux passing through unit area at right angle to the direction of field**".*

The electric flux density is denoted by **'D'.**

$$D = \frac{Q}{A} \frac{C}{m^2}$$

Electric Field Strength

*It is defined as "**the force experienced by unit positive charge at a particular point in a given electric field**".* It is denoted by '**E**'.

$$E = \frac{F}{Q} \frac{N}{C}$$

It is also called as Electric Field Intensity. It is different at different point in a non-uniform electric field and same at all points in uniform electric field. It can also be expressed in ***Volt/metre.***

Permitivity

*It is defined as "**readiness of a material or medium to allow passage of flux through it**".* The ratio of electric flux density in a vacuum or free space to the corresponding electric field strength is known as the permittivity of free space. It is denoted by [ε_0].

The permittivity of a vacuum or free space is

ε_0=8.854 x 10^{-12} Farad/metre.

Absolute Permitivity:

*It is defined as "**the ratio of electric flux density in a dielectric medium to the corresponding electric field Strength**".* It is denoted by [ε].

$$\varepsilon = \frac{D}{E} \textit{ Farad/metre}$$

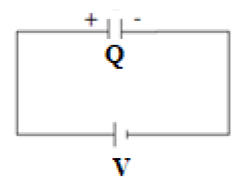
Relative Permittivity:

*It is defined as "**the ratio of electric flux density in a dielectric medium to that produced in free space by the same electric field strength under the same conditions**".* It is denoted by [ε_r]. Being a ratio it is unit less.

$$\varepsilon_r = \frac{D}{D_0}$$

Q.2 Define Capacitance.

*Capacitance is **the property of capacitor to store the electric charge.***



Let, V: be the applied voltage in Volt.

Q: be the charge stored by capacitor in Coulomb.

As experimentally,

$$Q \alpha V \; , \; Q = CV$$

Where C: be the constant called the capacitance of the capacitor

$$C = \frac{Q}{V}$$

It is measured in ***Farad.***

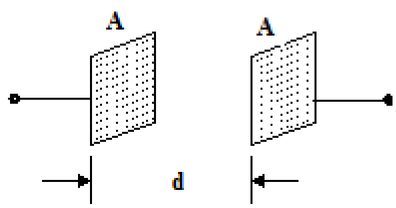
Q.3 what do you mean by dielectric strength and breakdown voltage?

When the applied voltage to a dielectric exceeds a certain value, then it breaks down. The electric current starts flowing through it. *Hence,* ***breakdown voltage is defined as the minimum voltage required to break it down.***

The ability of dielectric medium to resist its breakdown when potential difference is applied across it, is called dielectric strength. It is measured in V/m. It is usually expressed in **kV/mm.** Its value depends on the following factors:

- Thickness of the insulator,
- Temperature,
- Moisture,
- Shape of the electrodes.

Q.4 Derive the expression for parallel-plate Capacitor. State the factors affecting capacitance value.



Let,

A: be the area of each plate in m^2.

d: be the distance between the plates in m.

V: be the applied voltage between the plates.

ε_r: be the relative permittivity of dielectric medium between the plates

The electric field strength in the dielectric is given as,

$$E = \frac{V}{d} \; .....(1)$$

The flux density in the dielectric is given as,

$$D = \frac{Q}{A} \; ....(2)$$

Dividing equation (II) by (I),

$$\frac{D}{E} = \frac{Q}{A} \times \frac{d}{V}$$

$$\text{But, } \frac{D}{E} = \varepsilon_0 \varepsilon_r$$

$$\varepsilon_0 \varepsilon_r = \frac{Q}{A} \times \frac{d}{V} = \frac{CV}{A} \times \frac{d}{V}$$

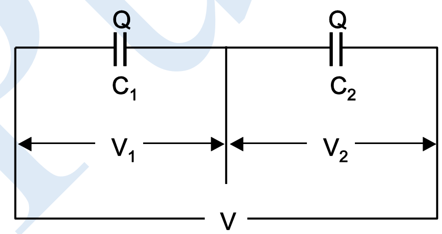
$$\varepsilon_0 \varepsilon_r = \frac{Cd}{A}$$

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \text{ Farad}$$

Factors affecting Capacitance value:

1. Relative permittivity (dielectric constant) of dielectric medium
2. Surface area of the plates
3. Distance between the plates

Q.5: Find the equivalent capacitance when the capacitors are connected in series.



Consider the two capacitors in series connected across the supply voltage 'V'.

Let, Q be the charge on each capacitor.

Then, $Q = C_1 V_1$

and $Q = C_2 V_2$

$\therefore$ $V_1 = \frac{Q}{C_1}$

And $V_2 = \frac{Q}{C_2}$

Also, the charge stored by equivalent capacitor,

$$Q = CV, \quad \text{i.e. } V = \frac{Q}{C}$$

As the charge on each capacitor and on equivalent capacitor is same, we have,

$$CV = C_1 V_1 = C_2 V_2$$

Now, the total voltage, $V = V_1 + V_2$

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

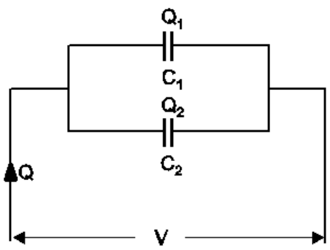
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

If the number of capacitors are connected in series then equivalent capacitance,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots\dots\dots \frac{1}{C_n}$$

Q.6: Find the equivalent capacitance when the capacitors are connected in parallel.

Consider, the two capacitors in parallel connected across the supply voltage 'V'.



Let, Q_1 be the charge on capacitor C_1

Q_2 be the charge on capacitor C_2

Then, $Q_1=C_1 V$, $Q_2=C_2 V$

Now, Q be the total charge in Coulomb.

$$Q=C.V.$$

Then, $Q=Q_1 + Q_2$

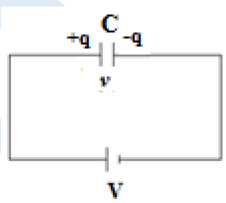
$$CV=C_1V + C_2V$$

$$C=C_1 + C_2$$

If the number of capacitors are connected in parallel then equivalent capacitance,

$$C=C_1 + C_2 + \dots\dots\dots C_n$$

Q.7: Derive the expression for energy stored in capacitor.



Let us consider a capacitor having capacitance 'C' Farad and charge to voltage 'V' volt. Let 'q' be the charge on capacitor in Coulomb. Then potential difference across the capacitor,

$$V = \frac{q}{C}$$

Now, the work done to move the charge of one Coulomb from one plate to another.

$$dw = vdq = \frac{q}{C}dq$$

This work done is stored in the form of potential energy in the electric field. Now, total energy stored in the capacitor when it is charged to 'Q' Coulomb,

$$dw = \int_0^Q \frac{q}{C}dq$$

$$W = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q$$

$$W = \frac{Q^2}{2C}$$

But, $Q \alpha CV$

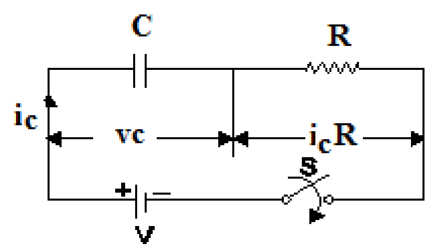
Substituting this in above equation, we have

$$W = \frac{1}{2}CV^2 Joule$$

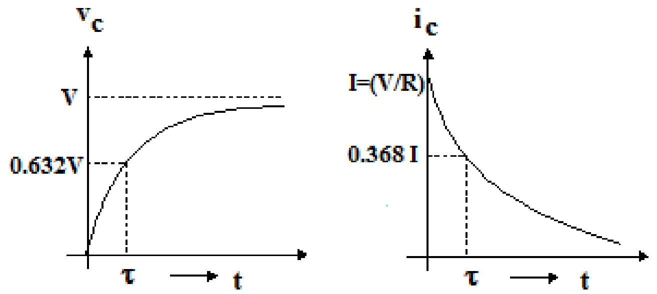
$$W = \frac{1}{2}QV\ Joule$$

Q.8: Sketch the curves for voltage across the charging capacitor and chargingcurrent when charged through resistance R and connected DC voltage.Also write down the expression for (i) voltage across the capacitor(ii) charging current (iii) time constant (iv) initial charging current.

Consider a circuit as shown in Fig. where capacitor C is connected in series with a resistance R across a battery having voltage V and with switch 'S'.



Curves for voltage and current during charging



Capacitor voltage during Charging

Capacitor current during charging

Expression for voltage

$$v_c = V\left(1 - e^{-t/RC}\right) volt$$

Expression for current

$$i_c = \frac{V}{R} e^{-t/RC} Amp \quad i_c = Ie^{-t/RC} Amp$$

Time constant

For voltage: Time constant τmay be defined **as the *time during which the capacitor voltage actually reaches to its 63.2% of its final value.***

For Current: It is defined as the ***time during which the capacitor current actually falls to 36.8% of its initial maximum value.***

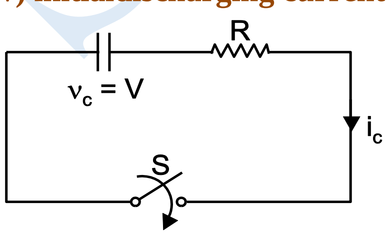
Expression for time constantτ

$$\tau = RC \text{ seconds}$$

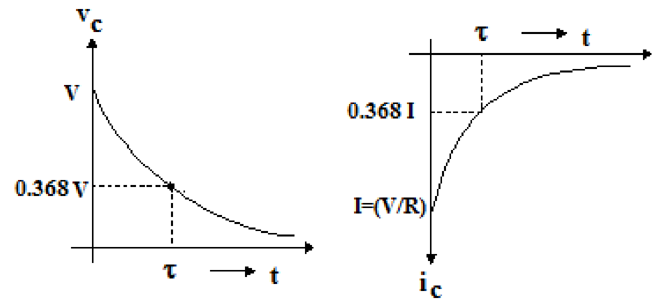
Expression for initial charging current

$$i_c = I = \frac{V}{R} Amp$$

Q.9: Sketch the curves for voltage across the discharging capacitor and dischargingcurrent when discharged through resistance R.Also write down the expression for (i) voltage across the capacitor(ii) discharging current (iii) time constant (iv) initialdischarging current.



Consider a circuit as shown in Fig. where capacitor 'C' is being discharged through a resistor 'R'. Capacitor is fully charged to voltage V volts and discharges through resistor R. The current flowing through the circuit is in the opposite direction to that of charging.



Capacitor voltage during discharging

Capacitor current during discharging

Expression for voltage

$$v_c = Ve^{-t/RC} Volt$$

Expression for current

$$i_c = -\frac{V}{R} e^{-t/RC} Amp \quad i_c = -Ie^{-t/RC} Amp$$

Time constant

For voltage: Time constant τmay be defined **as the *time during which the capacitor voltage actually falls to its 36.8% of its initial value.***

For Current: It is defined as the ***time during which the capacitor current actually falls to 36.8% of its initial maximum value.***

Expression for time constant τ

$$\tau = RC \text{ seconds}$$

Expression for initial discharging current

$$i_c = -I = -\frac{V}{R} Amp$$

10. Define the terms as related to alternating quantities.

(1)Waveform (2) Cycle (3) Instantaneous value (4) Periodic Time (5) Frequency (6) Amplitude

Waveform

Waveform is the pictorial representation of an alternating quantity

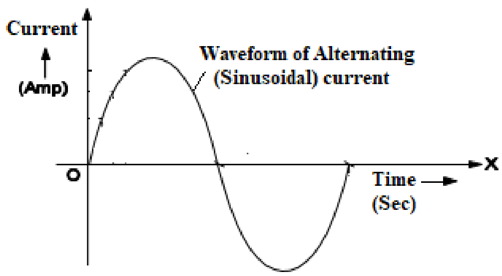
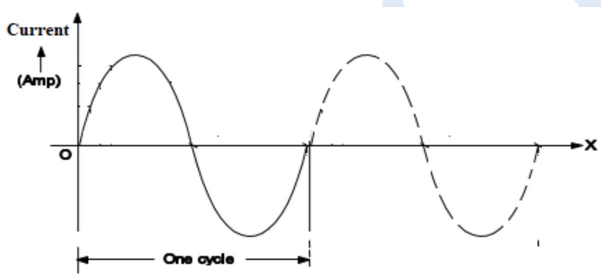


Fig. Waveform of Alternating Current

Fig. shows the waveform of alternating current.

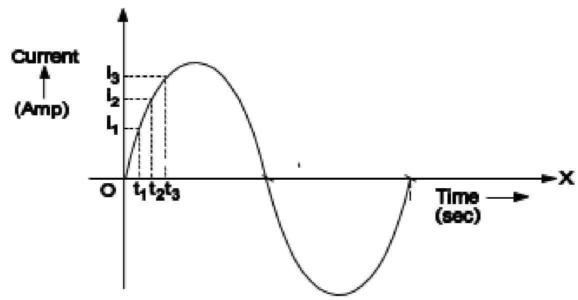
Cycle

Each repetition of a complete set of changes undergone by the alternating quantity is called ***cycle.*** These repetitions recur at equal intervals of time.



Instantaneous Value

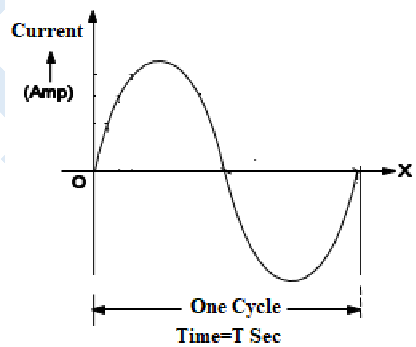
The value of an alternating quantity at a particular instant is known as its ***instantaneous value.***



e.g. i_1, i_2 and i_3 shown in Fig. are the instantaneous values of alternating current at different instances.

Time Period (T)

It is the time taken by the alternating quantity to complete one cycle.



Frequency (f)

The number of cycles completed per second by an alternating quantity is known as frequency. Its symbol is *f* and unit is ***cycles per second or Hertz*** denoted by Hz.

$$f = \frac{1}{T} Hz$$

Amplitude

The maximum value attained by an alternating quantity during its positive or negative half cycle is called as ***amplitude or peak value***

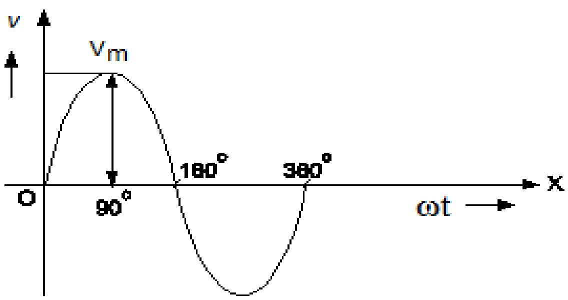


Figure shows the amplitude of A.C. voltage.

It is denoted by V_m or I_m where V_m represents peak value of voltage and I_m represents peak value of the current.

Q.11:Define RMS Value and derive the expression for RMS value of sinusoidal alternating current in terms of its peak value.

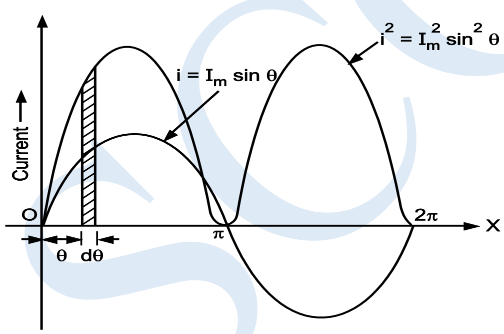
The **RMS** value of an alternating current is given by that value of ***direct current*** which, when flowing through a given circuit for a given time produces the same amount of heat as produced by alternating when flowing through the same circuit for the same time.

Alternating current can be expressed analytically as,

$i = I_m \sin\theta$ where, $\theta = \omega t$

Taking square of current,

$i^2 = I_m^2 \sin^2\theta$



Wave form for i^2 is plotted for an half cycle. To find the area under the curve (i^2), an interval of $d\theta$ is consider at a distance θ from origin.

$\therefore$ Area of squared curve over half cycle$= \int_0^{\pi} i^2 \cdot d\theta$

The length of base is π. Therefore, mean value of square of current over half cycle,

$$= \frac{\text{Area of squared curve over half cycle}}{\text{Length of base over half cycle}}$$

$$= \frac{\int_0^{\pi} i^2 d\theta}{\pi} \quad = \frac{1}{\pi}\int_0^{\pi} i^2 d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2\theta d\theta$$

$$= \frac{I_m^2}{\pi}\int_0^{\pi} \frac{1-\cos\theta}{2} d\theta$$

$$= \frac{I_m^2}{2\pi}\left(\theta - \frac{\sin 2\theta}{2}\right)$$

$$= \frac{I_m^2}{2\pi}\left((\theta)_0^{\pi} - \left(\frac{\sin 2\theta}{2}\right)_0^{\pi}\right)$$

$$= \frac{I_m^2}{2\pi}(\pi)$$

$$mean\,square\,value = \frac{I_m^2}{2}$$

$$Root\,mean\,square\,value = Irms = I = \frac{I_m}{\sqrt{2}}$$

Hence, root mean square i.e. r.m.s. value can be calculated as, $\boxed{I_{rms} = 0.707\, I_m}$

Q.12: Define Average value and derive the expression for average value of sinusoidal alternating current in terms of its peak value.

Average value of an alternating quantity is defined as the sum of all the instantaneous values over a given interval divided by the number of intervals of that interval.

Alternating current can be expressed analytically as,

$i = I_m \sin\theta$

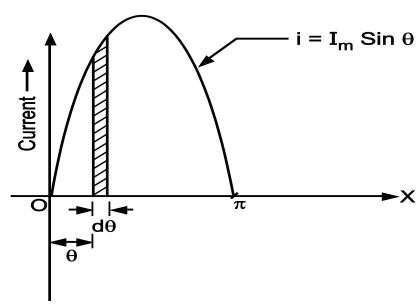


Figure shows one half cycles for instantaneous current. Here to find area under the curve, consider an interval of $d\theta$ at a distance θ from the origin.

Average value of current over a half cycle,

$$I_{av}=\frac{\text{Area under the curve over half cycle}}{\text{Length of base over half cycle}}$$

$$I_{avg}=\frac{1}{\pi}\int_0^{\pi} i d\theta$$

$$I_{avg}=\frac{\int_0^{\pi} i\ d\theta}{\pi}$$

$$I_{avg}=\frac{1}{\pi}\int_0^{\pi} I_m \sin\theta d\theta$$

$$I_{avg}=\frac{I_m}{\pi}\left(-\cos\theta\right)_o^{\pi}$$

$$I_{avg}=\frac{2I_m}{\pi}=0.637\,I_m$$

Thus average value of sine wave is equal to ***0.637 times the peak value.***

Q.13: Define form factor and peak factor

Form factor

The ratio of r.m.s value to average value of an alternating quantity is called as form factor. Thus, for sinusoidal voltage and current

Form factor, $K_f=\frac{\textit{R.M.S. value}}{\textit{Average value}}$

$$=\frac{0.707\times\text{Maximum value}}{0.637\times\text{Maximum value}}=\mathbf{1.11}$$

Peak factor

The peak factor of an alternating quaintly is defined as ratio of maximum value to the r.m.s. value. This factor may also be called as ***crest factor or amplitude factor.***

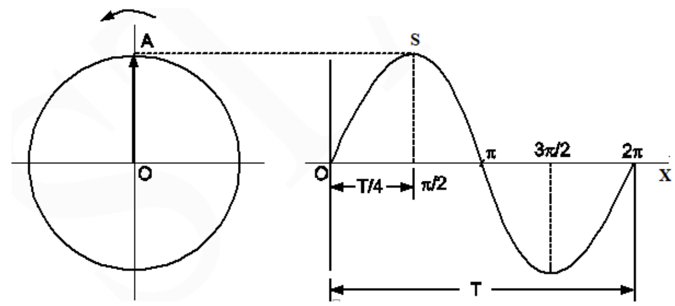
For sinusoidal voltage and current,

Peak factor, $K_p=\frac{\textit{Maximum value}}{\textit{R.M.S. value}}$

$$=\frac{\text{Maximum value}}{0.707\times\text{Maximum value}}=1.414$$

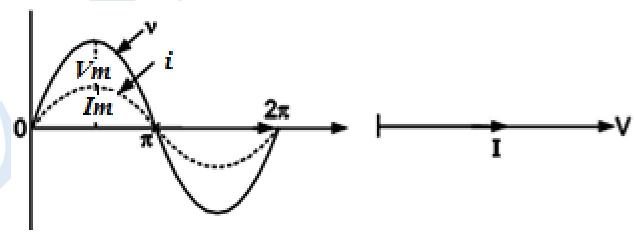
Q.14: What is phase of an electrical quantity? Explain the term in phase and out of phase of an electrical quantity along with phasor diagram.

Phase



The fraction of the time period (T) that elapses in achieving certain instantaneous value is known as phase of that alternating quantity. For example, in Fig. phase of the alternating quantity at point S is T/4 seconds or when expressed in terms of angle, it is π/2 radians.

In-phase Quantities



When two alternating quantities of the same frequency attain their corresponding values (e.g. zero, positive maximum, etc.) simultaneously, they are said to be **in phase** with each other.

The two alternating quantities v and i considered can be represented by the following equations:

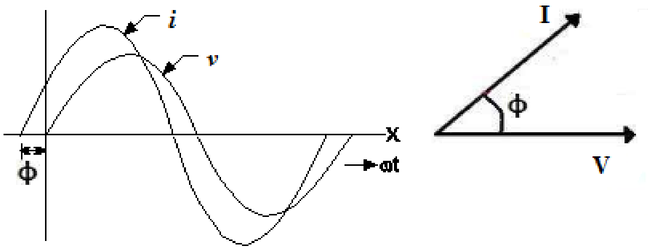
$$v=V_m\sin\theta=V_m\sin(\omega t)$$

$$i=I_m\sin\theta=I_m\sin(\omega t)$$

Out of phase Quantities

Two alternating quantities of the same frequency which attain their corresponding values at different instants are said to be out of phase.

Leading alternating quantity as one which attains its zero or maximum value earlier as compared with the other quantity.



Voltage is represented by the equation,

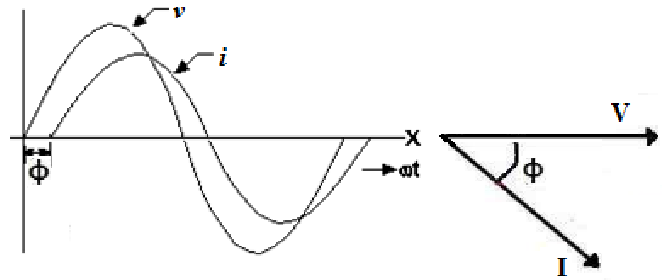
$$v = V_m \sin\theta = V_m \sin(\omega t)$$

And current is represented by,

$$i = I_m \sin(\theta + \phi) = I_m \sin(\omega t + \phi)$$

Here i is leading ahead v by ***Φ*.**

Similarly, **lagging** alternating quantity is that which attains its zero or maximum value latter than the other quantity.



Voltage is represented by the equation,

$$v = V_m \sin\theta = V_m \sin(\omega t)$$

And the current is represented by,

$$i = I_m \sin(\theta - \phi) = I_m \sin(\omega t - \phi)$$

Here i is lagging behind v by ***Φ*.**

Solved Numericals

Unit 2, Part A: Electrostatics

1) Three capacitors of capacitance 2 μF, 3μF and 7 μF are connected in series across 400 volt D.C. supply. Calculate

(i) Charge on each capacitor,

(ii) Potential difference across each capacitor,

(iii) Energy stored on each capacitor.

Solution :

Equivalent capacitance of series combination,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$= \frac{1}{2 \times 10^{-6}} + \frac{1}{3 \times 10^{-6}} + \frac{1}{7 \times 10^{-6}}$$

C_{eq} = 1.024 μF

(i) Charge on each capacitor,

Q = CV = $1.024 \times 10^{-6} \times 400$=**409.756 μC**

(ii) Potential difference across each capacitor.

Potential difference across2 μF,

$V_1 = \frac{Q}{C_1} = \frac{409.756 \times 10^{-6}}{2 \times 10^{-6}}$ = **204.878 volt**

Potential difference across 3 μF,

$V_2 = \frac{Q}{C_2} = \frac{409.756 \times 10^{-6}}{3 \times 10^{-6}}$ = **136.585 volt**

Potential difference across 7 μF,

$V_3 = \frac{Q}{C_3} = \frac{409.756 \times 10^{-6}}{7 \times 10^{-6}}$ = **58.536 volt**

(iii) Energy stored ,

First Capacitor : $\frac{1}{2} C_1 V_1^2$

$= \frac{1}{2} (2 \times 10^{-6}) \times (204.878)^2$=**0.0419 Joule**

Second Capacitor : $\frac{1}{2} C_2 V_2^2$

$= \frac{1}{2} (3 \times 10^{-6}) (136.585)^2$=**0.0279 Joule**

Third Capacitor : $\frac{1}{2} C_3 V_3^2$

$= \frac{1}{2} (7 \times 10^{-6}) \times (58.536)^2$=**0.0119 Joule**

2) Two capacitors of 2 μF and 4 μF are connected in parallel across 100 V D.C. supply. Determine

(i) Equivalent capacitance of their combination

(ii) Charge on each capacitor

(iii) Energy stored on each capacitor.

$C_{equ}=C_1 + C_2=2 \times 10^{-6} + 4 \times 10^{-6}=6 \times 10^{-6}$ F= **6 μF**

Charge on each capacitor,

$Q_1 = C_1V = 2 \times 10^{-6} \times 100=$**200 μC**

$Q_2 = C_2V = 4 \times 10^{-6} \times 100=$**400 μC**

Energy stored in each capacitor:

$E_1 = \frac{1}{2} C_1V^2 = \frac{1}{2} \times 2 \times 10^{-6} \times 100^2 =$ **0.01 Joule**

$E_2 = \frac{1}{2} C_2 V^2 = \frac{1}{2} \times 4 \times 10^{-6} \times 100^2 =$ **0.02 Joule**

3) The plate area of a parallel-plate capacitor is 0.01 sq. m. The distance between the plates is 2.5 cm. The insulating medium is air. Find its capacitance. What would be its capacitance, if the space between the plates is filled with an insulating material of relative permittivity 5 ?

Solution : A = 0.01 m², d = 2.5 cm.

(i) When the dielectric medium is air,

$$C = \frac{\epsilon_o A}{d} = \frac{8.854 \times 10^{-12} \times 0.01}{2.5 \times 10^{-2}} = \mathbf{3.54 \times 10^{-12}\ F}$$

(ii) When the dielectric medium having relative permittivity = 5.

$$C = \frac{\epsilon_o \epsilon_r A}{d} = \frac{8.854 \times 10^{-12} \times 5 \times 0.01}{2.5 \times 10^{-2}}$$

$= \mathbf{17.71 \times 10^{-12}\ F.}$

4) A capacitor consists of two parallel rectangular plates each 120 mm² separated by 1 mm in air. When voltage of 1000 volt is applied between the plates, an average current of 12 mA flows for 5 seconds. Calculate

(i) the charge on the capacitor,

(ii) electric flux density,

(iii) electric field strength in the dielectric.

Solution : A = 120 mm², d = 1 mm, V = 1000 volt

Capacitance of the capacitor,

$$C = \frac{\epsilon_o A}{d} = \frac{8.854 \times 10^{-12} \times 120 \times 10^{-6}}{1 \times 10^{-3}}$$

$= \mathbf{1.062 \times 10^{-12}\ Farad}$

(i) Charge on the capacitor, Q=CV

$=1.062 \times 10^{-12} \times 1000=$**$1.062 \times 10^{-9}$ Coulomb**

(ii) Electric flux density,

$$D = \frac{Q}{A} = \frac{1.062 \times 10^{-9}}{120 \times 10^{-6}} = \mathbf{8.854 \times 10^{-6}\ C/m^2}$$

(iii) Electric field strength,

$$E = \frac{D}{\epsilon_o} = \frac{8.854 \times 10^{-6}}{8.854 \times 10^{-12}} = \mathbf{1 \times 10^6\ V/m}$$

5) The capacitance of capacitor of two parallel plates each of 200 cm² area separated by a dielectric 4 mm thick is a 0.0004 μF. A potential difference of 20 kV is applied across it. Calculate

(i) the total charge on the plates,

(ii) potential gradient in V/m,

(iii) dielectric flux density,

(iv) relative permitivity of dielectric.

Solution : (i) Total charge on the plate,

$Q = CV=0.0004 \times 10^{-6} \times 20 \times 10^3 =$ **8×10^{-6} C**

(ii) Potential gradient, $E=\frac{dv}{dx} = \frac{V}{d}$

$$= \frac{20 \times 10^3}{4 \times 10^{-3}} = \mathbf{5 \times 10^6\ V/m}$$

(iii) Dielectric flux density, $D=\frac{Q}{A}$

$$= \frac{8 \times 10^{-6}}{200 \times 10^{-4}} = \mathbf{4 \times 10^{-4}\ C/m^2}$$

(iv) Relative permittivity, $E=\frac{D}{\epsilon_o \epsilon_r}$

$$\therefore \epsilon_r = \frac{D}{\epsilon_o E} = \frac{4 \times 10^{-4}}{8.854 \times 10^{-12} \times 5 \times 10^6} = \mathbf{9}$$

Unit 2, Part B: AC Fundamentals

6) An alternating current is given by i=14.14sin377t. Find (i)frequency, (ii) R.M.S. value of current, (iii) Average value of current (iv) Form Factor (v) Peak Factor (vi) instantaneous value of current, when t = 3 ms and (vii) time taken by current to reach 10 Amp for 1st time after passing through zero.

Solution : $i=14.14 \sin 377\, t = I_m \sin \omega t = I_m \sin 2\pi f t$

$$2\pi f=377$$

$$f=\frac{377}{2\pi} = \frac{377}{2\,(3.14)} = \mathbf{60\ Hz}$$

RMS value of current $I=\frac{I_m}{\sqrt{2}}=\frac{14.14}{\sqrt{2}} = \mathbf{10\ Amp}$

Average value of current $I_{av}=\frac{2I_m}{\pi}=\frac{2x14.14}{\pi}$

$= \mathbf{9.006\ Amp}$

$$\text{Form factor}=\frac{\text{RMS value}}{\text{Average value}} = \frac{10}{9.006} = 1.11$$

$$\text{Peak factor} = \frac{\text{Peak value}}{\text{RMS value}}=\frac{14.14}{10} = 1.414$$

i, when t=3 ms

$i= 14.14 \sin (377 \times (180/\pi) \times 3 \times 10^{-3})=\mathbf{12.79\ Amp}$

$i= 10$ Amp $t = ?$

$10=14.14 \sin (377\times (180/\pi)\times t)$

$$377\times (180/\pi)\times t=\sin^{-1}\left(\frac{10}{14.14}\right)$$

t=2.083 ms

7) Find the effective value of a resultant current in a wire which carries simultaneously a current of 10 Amp and alternating current given by

$$i = 12 \sin wt + 6 \sin\left(wt - \frac{\pi}{6}\right) + 4 \sin\left(5\, wt + \frac{\pi}{3}\right)$$

Solution : The effective value is the rms value of an alternating quantity.

$$i= I_{dc} + I_{m1} \sin wt + I_{m2} \sin\left(wt - \frac{\pi}{6}\right) + I_{m3} \sin\left(5wt + \frac{\pi}{3}\right)$$

$$\text{total current } i=10 + 12 \sin wt + 6 \sin\left(wt - \frac{\pi}{6}\right) + 4 \sin\left(5wt + \frac{\pi}{3}\right)$$

To get RMS value of current, let us find the heat produced by them when flows through a wire of resistance R for time t.

$$I^2 Rt = I_{dc}^2 Rt + \left(\frac{I_{m1}}{\sqrt{2}}\right)^2 Rt + \left(\frac{I_{m2}}{\sqrt{2}}\right)^2 Rt + \left(\frac{I_{m3}}{\sqrt{2}}\right)^2 Rt$$

$$I^2 = (10)^2 + \left(\frac{12}{\sqrt{2}}\right)^2 + \left(\frac{6}{\sqrt{2}}\right)^2 + \left(\frac{4}{\sqrt{2}}\right)^2 = 198$$

I=14.07 Amp.

8) A non sinusoidal voltage waveform has form factor of 1.15 and peak factor of 1.5. If the maximum value of voltage is 4500 V, calculate the average value and r.m.s. value of the

Solution : form factor = 1.15, peak factor = 1.5, $V_m = 4500$

$$\text{Peak factor}=\frac{\text{Peak value}}{\text{RMS value}}$$

$$\text{RMS value}=\frac{\text{Peak value}}{\text{Peak factor}} = \frac{4500}{1.5} = \mathbf{3000\ volt}$$

$$\text{Form factor}=\frac{\text{RMS value}}{\text{Average value}}$$

$$\frac{3000}{\text{Average value}} = 1.15$$

Average value= $\frac{3000}{1.15}$ = **2608.69 volt.**

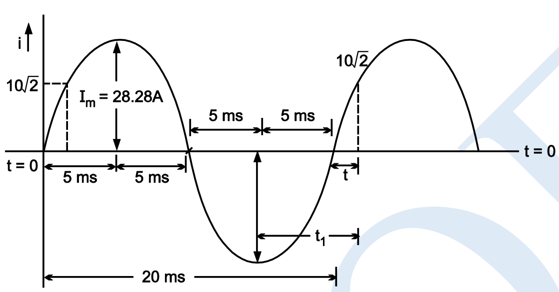
9) An alternating current varying sinusoidally with a frequency of 50 Hz has a r.m.s. value of 20Amp. At what time, measured from negative and positive maximum value, instantaneous current will be $10\sqrt{2}$ Amp.

$I_m = I \times \sqrt{2} = 20 \times \sqrt{2} = 28.28$ Amp

i = Im sin ωt=Im sin (2πft)

$= 28.28 \sin (2\pi \times 50 \times t)$

$=$ **28.28 sin (314 t) Amp.**



time required to reach $10\sqrt{2}$ first time from t = 0

$10\sqrt{2} = 20 \times \sqrt{2} \sin (314 \times$ **(180/π)**$\times$ t)

$\frac{10}{20} = 0.5 = \sin (314 \times$ **(180/π)**$\times$ t)

$314 \times$ **(180/π)**$\times$ t=$\sin^{-1}(0.5)$

t=0.00166 sec.= 1.66 ms

time required from -Ve maximum

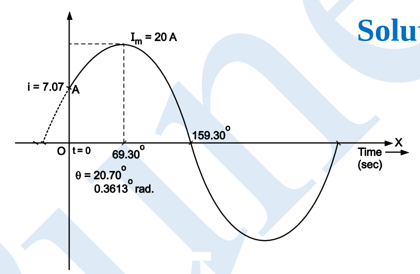
t_1 = 5 ms + 1.66 ms=**6.66 ms**

time required from + Ve maximum to zero is 5 ms

= 15 ms + 1.66 ms = **16.66 ms**

10) A 60 Hz sinusoidal current has an instantaneous value of 7.07 at t = 0 and r.m.s. value of $10\sqrt{2}$ A. Assuming current wave to enter positive half at t = 0. Determine (i) Expression for instantaneous current, (ii) Magnitude of current at t = 0.0125 second, (iii) Magnitude of current at t = 0.025 sec after t = 0.

Solution :



Solution : f =

frequency, f=60 Hz, $I_{rms}=10\sqrt{2}$ Amp.

i=7.07 A at t = 0

we know, $I_{max}=\sqrt{2} \cdot I_{rms}=\sqrt{2} \times 10\sqrt{2}$ =20 Amps

Given that, current wave when start at t = 0, enters in positive half i.e. (as per standard equation θ = 90° after is start, as shown in Figure).

∴ Here, current equation is, i= $I_m \sin (\omega t + \phi)$

(since i is not zero at t = 0)

where ϕ is the angle made by *i* w.r.t. reference axis.

$7.07=I_m \sin (\omega t + \phi)$

7.07=20 sin (ϕ)

$\phi = \sin^{-1}\left(\frac{7.07}{20}\right) = \sin^{-1}(0.3535)$

=20.70° or 0.3613 radian

(i) ∴expression is, $i=I_m \sin (\omega t + \phi)$

=20 sin (2π60 × t × **(180/π)**× 20.70)

put t =0.0124 sec, we get

i= 20 sin (120π ×× **(180/π)**× 0.0125 + *20.70)*=

put $t = 0.025$ sec, we get

$i = 20 \sin (120\pi \times \mathbf{(180/\pi)} \times \times 0.025 + 20.70)$

$=$ **– 7.07 Amp**

11) If $V_1 = 30 + j40 = 50\angle 53.13^0$ and $V_2 = 10 + j20 = 22.36\angle 63.435^0$

Find 1) $V_1 + V_2$ 2) $V_1 - V_2$ 3) $V_1 * V_2$ 4) $\frac{V_1}{V_2}$

$$V_1 + V_2 = (30+10) + j(40+20) = 40 + j60$$
$$= 72.11\angle 56.30$$

$$V_1 - V_2 = (30-10) + j(40-20) = 20 + j20$$
$$= 28.28\angle 45$$

$$V_1 * V_2 = 50\angle 53.13^0 * 22.36\angle 63.435^0$$
$$= 1118\angle 116.565^0$$

$$\frac{V_1}{V_2} = \frac{50\angle 53.13^0}{22.36\angle 63.435^0} = 2.236\angle -10.305^0$$

12) Find the resultant of three voltages given by

$V_1 = 10 \sin wt$, $V_2 = 20 \sin\left(wt - \frac{\pi}{4}\right)$, and $V_3 = 30 \cos\left(wt + \frac{\pi}{6}\right)$

Solution : $V_1 = 10 \sin wt$, $V_2 = 20 \sin\left(wt - \frac{\pi}{4}\right)$,

$V_3 = 30 \cos\left(wt + \frac{\pi}{6}\right) = 30 \sin\left(\frac{\pi}{2} + wt + \frac{\pi}{6}\right) = 30 \sin\left(wt + \frac{2\pi}{3}\right)$

$$\overline{V_{m1}} = V_{m1} \angle 0 = 10 \angle 0 = 10 + j0,$$

$$\overline{V_{m2}} = V_{m2} \angle -\frac{\pi}{4} = 20 \angle -45° = 14.14 - j\,14.14$$

$$\overline{V_{m3}} = V_{m3} \angle \frac{2\pi}{3} = 30 \angle 120° = -15 + j\,25.98$$

Resultant maximum value

$$\overline{V_{mR}} = \overline{V_{m1}} + \overline{V_{m2}} + \overline{V_{m3}}$$
$$= (10 + j0) + (14.14 - j\,14.14) + (-15 + j\,25.98)$$
$$= (10 + 14.14 - 15) + j(-14.14 + 25.98)$$
$$= 9.142 + j\,11.83 = 14.95 \angle 52.32° \text{ volt}$$

The expression for resultant voltage,

$v = V_{mR} \sin(\omega t + \phi) =$ **14.95 sin (ωt + 52.32°) volt**