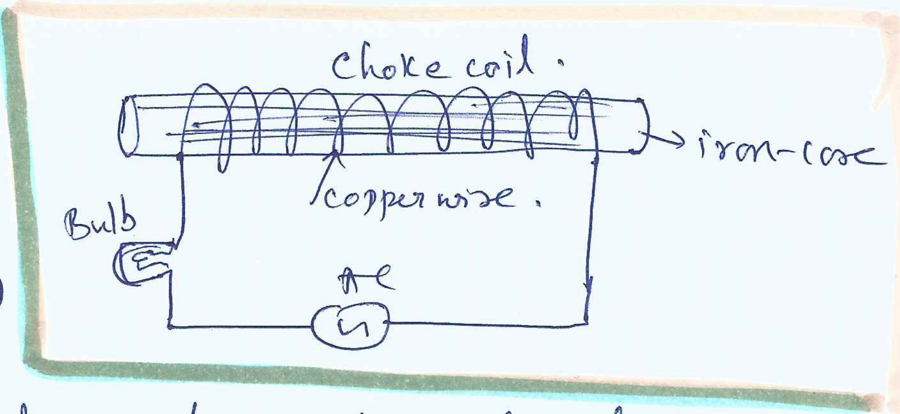
Not in Syllabus

Choke coil :



- In DC circuit, current is reduced by resistance and hence I^2R loss per second as heat (in resistor)
- In AC circuit, ~~however, be~~ the current may however be reduced by means of a device which involves little loss of energy. This device is called "Choke-coil".

A thick copper wire is wound on a soft-iron laminated core. Since wire is of copper and thick, its R is almost zero. However, due to large of turns and high permeability of the iron-core, L is quite high. Therefore, the choke-coil offers large reactance (ωL) and contributes to the impedance $\sqrt{R^2+(\omega L)^2}$ of the circuit. Thus it reduces AC current appreciably.

Resistance R also can be inserted in the circuit, but suffers "$I^2_{rms}R$" loss (as heat) in each cycle of current. On the other hand, the loss of energy in a choke-coil is almost negligible.

power dissipated in the choke-coil (LR circuit) is given by

$$P = V_{rms} I_{rms} \cos\phi \longrightarrow (1)$$

where $\cos\phi$ = powerfactor $= \dfrac{R}{\sqrt{R^2+(\omega L)^2}}$

- Since R of choke-coil is nearly zero and L is very high

$$\cos\phi \simeq 0$$

$\therefore P = 0 \;\; \therefore$ Average power dissipated in choke-coil will be nearly zero. This is why a choke-coil is provided in fluorescent tubes operated on AC mains.

→ R of choke coil is not exactly zero, so some energy is lost as heat. In addition, energy is also lost due to hysteresis-loss in the iron-core of the choke coil. The loss of energy due to eddy currents is reduced by laminating the iron-core. Choke-coil can be used only for AC circuits, not in DC circuits, since for DC, $\omega = 0$; $\omega L = 0$; only R is there which is also too low.

LC oscillations (Ch. 7.8 NCERT book)

We know that a capacitor and an inductor can store electrical and magnetic energy respectively.

Electrical energy in capacitor = $U_E = \frac{q^2}{2C}$
Magnetic energy in inductor = $U = \frac{1}{2}LI^2$ → (1)

Consider a charged capacitor in the circuit shown. When key K is closed, C is getting discharged resulting in current i. This develops induced emf in L which opposes growth of current. Therefore, the current will not instantaneously raise to its maximum value in the circuit due to back emf in L.

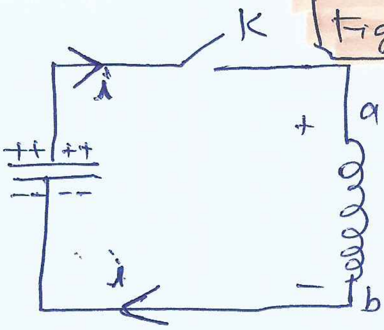


Fig (1)

In fig (2), region (1) of current cycle

→ current is sinusoidally increasing, charge in C is decreases and i increases, flux in L is increasing. When current reaches max I_{max}, capacitor is fully discharged and max magnetic flux sets up in L. So, in region (1), electrical energy in C is transferred as magnetic energy in L.

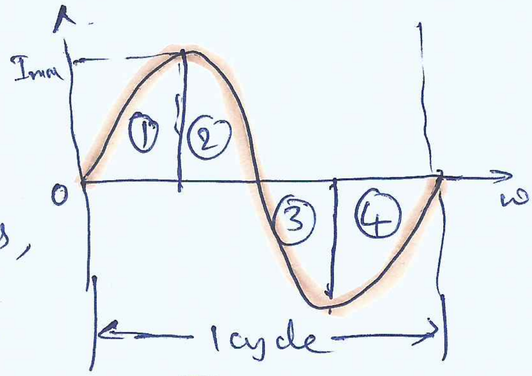


Fig 2

→ Region (2) in Fig (2) :→ Since C has no charge, the current flows and charges the capacitor, hence decreasing the flux in L. At the end of region (2), C is fully charged with opposite polarity (opposite to fig (1)) ⟹ bottom side of C in C has +ve charge like $\frac{--|--}{++|++}$). So, magnetic energy in L is transferred as electrical energy in C.

compare this to Fig (1)

→ Region (3) in fig (2) :— At the start of region (3), C is fully charged. See fig (3) where C is charged with polarity opposite to Fig (1).

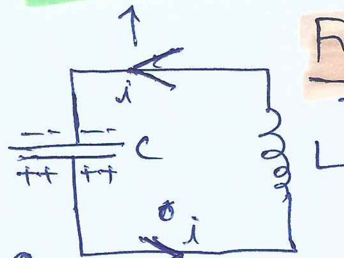


Fig (3)

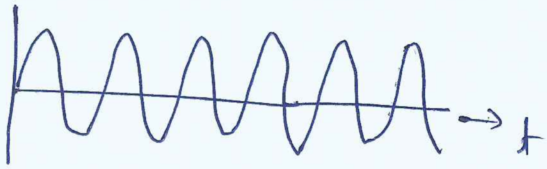
P.T.O

Therefore, C is getting discharged resulting in current which is in opposite direction to fig (1). [See Fig (3)]
At the end of region (3), C is fully discharged and max. flux sets up in L. So, at the end of region (3), electrical energy in C is transferred as magnetic energy in L.

→ **Region (4) in fig (2):**

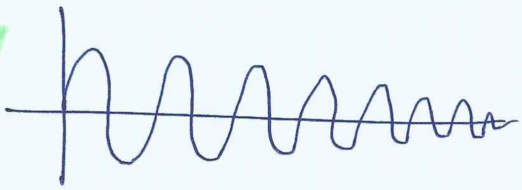
Since C has no charge, current starts flowing from L and charging the capacitor (with polarity as shown in fig (1)). Magnetic flux starts decreasing. At the end of region (4), magnetic energy in L is fully transferred as electrical energy in C.

→ This cycle repeats and thus energy in the system oscillates betn C and L. If there is no loss of energy (due to resistance or radiation etc...), then the LC circuit oscillates with constant amplitude.
This is called undamped oscillations.



$$\boxed{\text{Freq} = \frac{1}{2\pi\sqrt{LC}}}$$

→ In actual situation, there are losses in the circuit and the amplitude of the oscillations goes on decreasing and finally die away.
⟹ Called as damped oscillations.



The losses are mainly due to some resistance (in L). And even if R is assumed to be zero, the energy is radiated as electromagnetic waves ⟹ there will be damped oscillations in actual situation.
If we need to sustain oscillations with constant amplitude, external power in proper phase is required.

P.T.O.

 contd from (71)

This LC electrical oscillator system is similar to mechanical oscillations of a block attached to a spring.

Following table gives analogy bet^n mechanical and electrical system

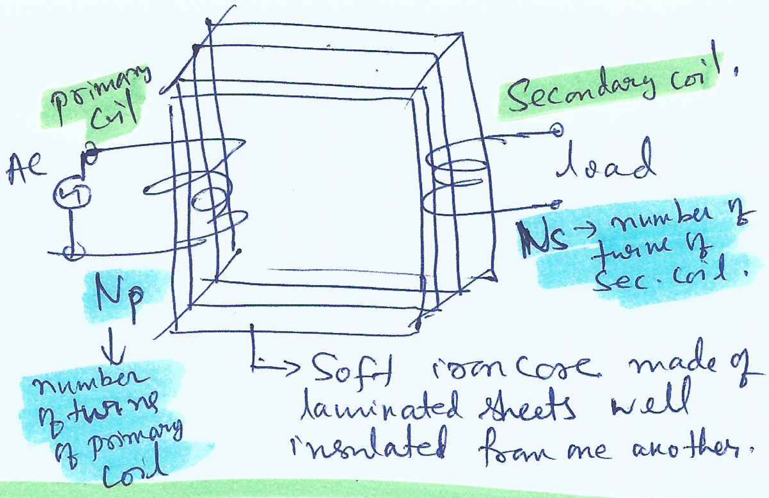
Mechanical System	Electrical System
mass m	Inductance L
Force constant k	Reciprocal Capacitance $1/c$
Displacement x	Charge q
velocity $v = \frac{dx}{dt}$	Current $i = \frac{dq}{dt}$
Mechanical energy	Electromagnetic energy
$E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$	$U = \underbrace{\frac{1}{2}\frac{q^2}{C}}_{\text{electrical energy}} + \underbrace{\frac{1}{2}Li^2}_{\text{Mechanical energy}}$

Transformers :

For many applications, it is required to transform AC voltage from one to another of greater or smaller value. This is done by a device called "transformer" using the principle of mutual induction.

- Higher AC voltage to Lower AC voltage → Step-down transformer
- Lower AC voltage to higher AC voltage → Step-up transformer.

When AC is applied to primary, due to mutual inductance, emf sets in secondary coil. The value of emf depends on the number of turns in the secondary coil.



$$\boxed{\frac{V_s}{V_p} = \frac{N_s}{N_p}} \longrightarrow (1)$$

if $N_s > N_p$ → Step-up transformer (voltage) ⇒ current is stepped-down

if $N_s < N_p$ → Step-down transformer (voltage) ⇒ current is stepped up.

$\frac{N_s}{N_p} = K$ → transformer Ratio.

Ex: 100 turns, 200 turns, $V_p = 220V$, 10A → ?

$V_s = \frac{N_s}{N_p} \cdot V_p = \frac{200}{100} \times 220 = 440\,V$ and current @ 5A.

Above equations (1) apply to ideal transformer (without any energy losses). But in actual transformers, small energy losses do occur due to the following reasons.

Efficiency of transformer $\boxed{\eta = \frac{\text{output power}}{\text{input power}} = \frac{V_s I_s}{V_p I_p}} \longrightarrow (2)$

→ In ideal transformer $\eta = 1$ or 100% ⇒ there is no power loss

→ practically there are many energy losses, hence $\eta < 100\%$ or $\eta < 1$

P.T.O.

Contd from (73)

Energy losses in a transformer.

① Copper loss is the energy loss in the form of heat in the copper coils of a transformer. This is due to joule heating of conducting copper wires. These are minimized by using thick wires.

② Flux leakage : There is always some flux leakage. Not all of the flux due to primary passes through secondary due to poor design of the core or the air gaps in the core. It can be reduced by winding the primary and secondary coils one over the other.

③ Eddy currents : (Iron loss) : The alternating magnetic flux induces eddy currents in the iron core and causes heating of the iron core. The effect is reduced by taking ~~having~~ laminated cores.

④ Hysteresis loss : This is the loss of energy due to repeated magnetisation and demagnetisation of the iron-core ~~when~~ when AC is fed to it. This loss appears as heat and is kept to a minimum by using a magnetic material (like soft iron-core) which has a low hysteresis loss

⑤ Magnetostriction → i.e. humming noise of transformer.

⇒ $\boxed{\text{Therefore, best transformer that could be made using remedies as mentioned above can have 90\% efficiency}}$.

Uses of transformer :

① voltage regulators for TV, refrigerator, computer etc...
② in induction furnaces
③ A step-down transformer is used for welding purposes.
④ in the transmission of AC over long distances :

- At the AC generating station, voltage is stepped-up (so that the current is reduced ⇒ I^2R loss is cut down) and transmitted over long distances to an area sub-station near the consumers. There, the voltage is stepped-down to some value. It is further stepped-down to 240V before reaching our homes.
- Normally at generating station, voltage is stepped-up to 132KV and then transmitted over long distances. ~~Furt~~ Further, this voltage is reduced in steps using number of step-down transformers, finally reaching end-user with 220V, 50Hz (for domestic use)

~~100~~ ~~100~~

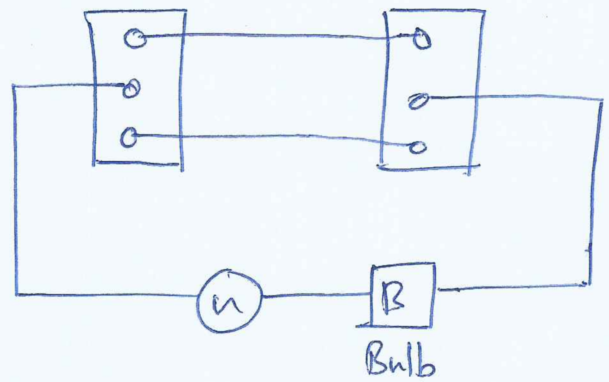
-74 a-

Not in 12th NCERT Syllabus.

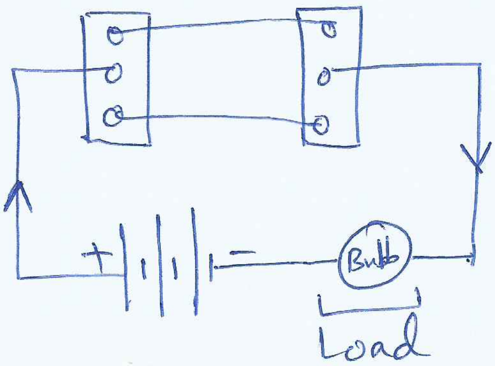
General Knowledge :

Staircase 2-way Switching circuit :

Given → 2 switches (2-way)
→ AC source
→ bulb

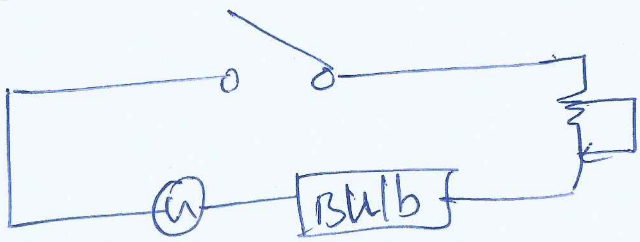


for AC



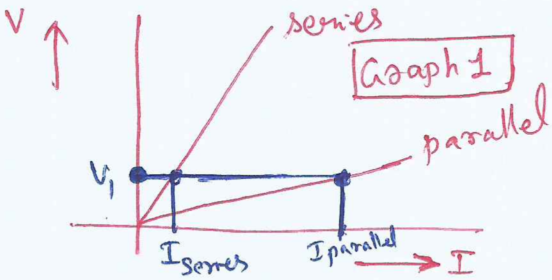
for DC

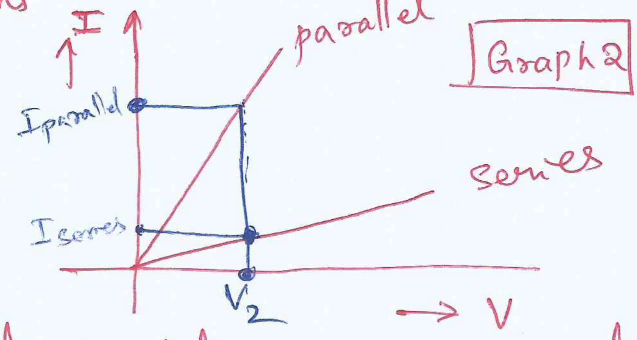
Schematic



Rheostat
Regulator
potentiometer
preset.

problem: Two students perform the experiments on series & parallel combinations of two given resistors R_1 and R_2 and plot the following graphs





which of the graphs are correctly labelled in terms of the words series and parallel. Justify your answer.

Ans:

Since resistance in series circuit is greater than that in parallel circuit,

$\boxed{I_2 > I_1} \longrightarrow$ (i)

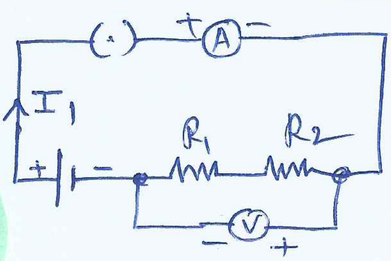
parallel ~~ccor~~ circuit current > series circuit current

Graph 1: from graph 1, for a constant voltage V_1, parallel current > series current

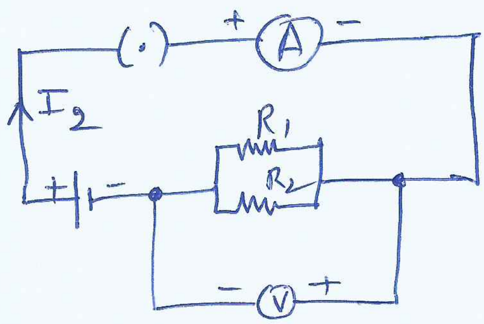
Graph 2: From graph 2, for a constant voltage V_2, the parallel current > series current

$\therefore$ Both graphs are correct

Series connection.



parallel connection.



74 C

74 C

Average Value of AC.

* For one complete cycle, the 'average value' of AC = 0

* However, the "average" value over half a cycle is a finite quantity

How to calculate?

$$\boxed{i = i_o \sin\theta}$$

$$I_{average} = \frac{1}{\pi}\int_0^{\pi} i\, d\theta = \frac{I_o}{\pi}\int_0^{\pi} \sin\theta\, d\theta$$

$$= \frac{i_o}{\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{i_o}{\pi}\left[\cos\theta\right]_{\pi}^{0} = \frac{i_o}{\pi}\left[1+1\right]$$

$$\boxed{I_{ave} = \frac{2 i_o}{\pi}} = 0.637\, i_o$$

$\therefore$ "Average" or "mean" value of AC = 63.7% of peak value

AC Generator

XII CBSE Nooten page 587

① A circular coil of radius 8.0 cm and 20 turns rotates about its vertical diameter with an angular speed of $50\ s^{-1}$ in a uniform magnetic field of magnitude 0.03 T. Find the maximum and average emf's induced in the coil. If the coil forms a closed loop of resistance $10\ \Omega$, how much power is dissipated as heat?

→ formula $e_{max} = (NBA\omega)$ volts

Where $N = 20$ turns

$B = 0.03\ T$

$A = \pi r^2 = \pi (0.08)^2$

ω = Angular speed = 50

$\therefore e_{max} = 20 \times 0.03 \times \pi (0.08)^2 \times 50$

$= 10^3 \times 0.03 \times \pi (0.08)^2$

$= 30\pi (0.08)^2$

(i) $\boxed{e_{max} = 0.6\ V}$

(ii) $e_{ave} = 0$

(iii) Power dissipated $= P = \dfrac{e_{rms}^2}{R} = \dfrac{(e_{max}/\sqrt{2})^2}{R}$

$= \dfrac{e_{max}^2}{2 \times R} = \dfrac{0.6 \times 0.6}{2 \times 10}$

$= \dfrac{0.036}{2} = 0.018\ W$

② A circular coil of radius 30 cm and $R = \pi^2\ \Omega$ is ~~rotated~~ rotated at a rate of 200 rpm about an axis normal to a magnetic field of 10^{-2} T. The amplitude of the a.c. induced in the coil will be

$i_0 = \dfrac{e_0}{R} = \dfrac{NBA\omega}{\pi^2} = \dfrac{1 \times 10^{-2} \times \cancel{\pi} (0.3)^2 \times \dfrac{20\cancel{\pi}}{3}}{\cancel{\pi^2}}$

$= \dfrac{0.2 \times 0.3 \times \cancel{0.3}}{\cancel{3}} = 6\ mA$

$N = 1$

$B = 10^{-2}\ T$

$A = \pi (0.3)^2$

$\omega = 2\pi \cdot \dfrac{200}{60} = \dfrac{20\pi}{3}$

IMP

74 e

① The electric mains in a house in India is marked 220 V - 50 Hz. Write the eqⁿ for instantaneous voltage.

→ Eq. of instantaneous voltage

$$v = v_0 \sin(\omega t)$$
$$= v_0 \sin(2\pi f t)$$

Given $V_{rms} = 220V$ $\therefore V_0 = 220\sqrt{2} = 311 V$

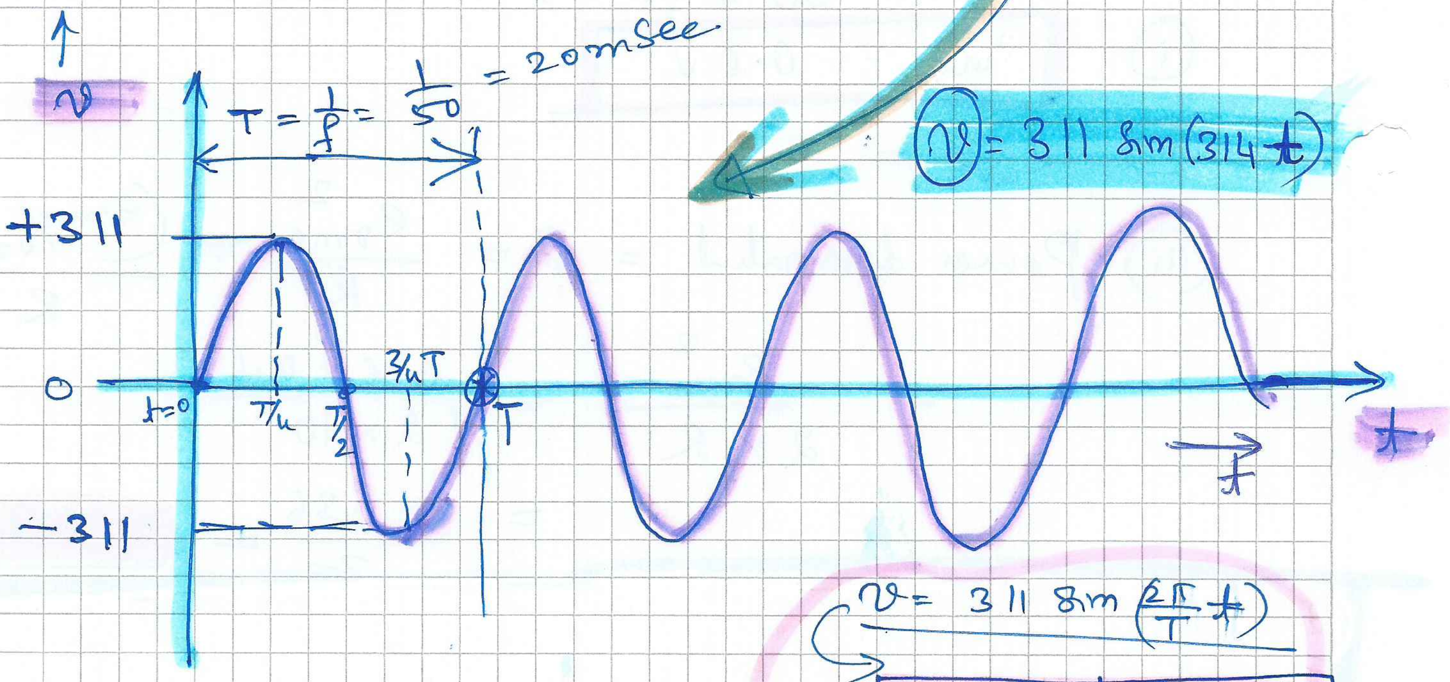
$f = 50 Hz$ $\therefore 2\pi f = 100\pi = 314$

$$\therefore \boxed{v = 311 \sin(314 t)}$$

② Same as above for US ?

done

$$v = 110\sqrt{2} \sin(2\pi \times 60 \times t)$$
$$\boxed{v = 156 \sin(120\pi t)}$$



$v = 311 \sin(314 t)$

$v = 311 \sin\left(\frac{2\pi}{T} t\right)$

t	v
0	0
T/4	311
T/2	0
3/4 T	-311
T	0

done

Q: A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.

(a) obtain the current amplitude and rms value

(b) obtain rms values of potential drops across each element

(c) what is the average power transferred to the inductor? capacitor?

(d)

(e) What is the total ave. power absorbed by the circuit [Average implies "averaged over one cycle".]

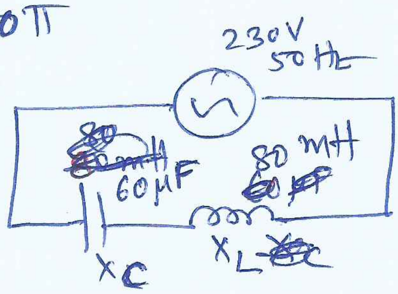
(f) In the above problem, if 15 Ω R is added in series, obtain the ave. power transferred to each element of the circuit and the total power absorbed.

Ans: Given $L = 80\,mH = 80 \times 10^{-3}\,H$

$C = 60\,\mu F = 60 \times 10^{-6}\,F$

$V_{rms} = 230\,V \quad \therefore V_m = 230\sqrt{2} = 325\,V$

$f = 50\,Hz \quad \therefore \omega = 2\pi f = 100\pi$



$$\text{Current } i = \frac{V_m}{\left(\omega L - \frac{1}{\omega C}\right)} \sin\omega t = I_m \sin\omega t$$

$$\therefore I_m = \frac{V_m}{\omega L - \frac{1}{\omega C}} = \frac{325\,V}{-28\,A} = \boxed{-11.6\,A}$$

$\omega L = 2\pi f L = 100\pi L$

$= \cancel{80\times}100\pi \times 80 \times 10^{-3}$

$= 8\pi \simeq 25\,\Omega$

$\omega C = 2\pi f C = 100\pi C$

$= 100\pi \times 60 \times 10^{-6}$ (corrected to 10^{-3})

$= 6\pi \times 10^{-3}$

$\frac{1}{\omega C} = \frac{1000}{6\pi} \simeq 53\,\Omega$

$\therefore \omega L - \frac{1}{\omega C} = 25 - 53$

$= -28\,\Omega$

(a) $|I_m| = 11.6\,A \quad \because I_m = -11.6\,A$

$\therefore I_{rms} = \frac{11.6}{\sqrt{2}} = \boxed{-8.24\,A}$

Since $\omega L < \frac{1}{\omega C}$, $-$ve sign appears. Circuit is predominantly ~~capacitative~~ capacitive.

(b) Voltage across L and C

$V_L = ? \quad V_C = ?$

$V_L = I_{rms} \times X_L = I_{rms} \times \omega L = 8.24 \times 25 \boxed{\simeq 207\,V}$

$V_C = I_{rms} \times X_C = I_{rms} \times \frac{1}{\omega C} = 8.24 \times 53 \simeq \boxed{437\,V}$

As we know that ~~L and~~ L and C are 180° out of phase, therefore they get subtracted. That is why applied emf $= 437 - 207 = \underline{230\,V}$

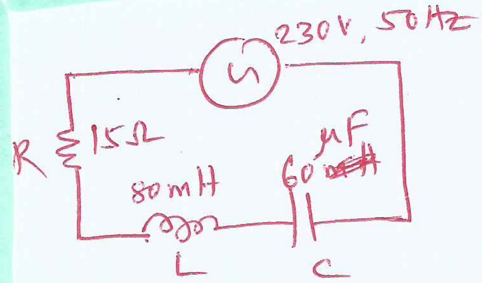
P.T.O

 Contd from (75)

(c) Whatever be the current I in L, actual voltage across L leads current by $\pi/2$. Therefore average power consumed by L is zero $\Rightarrow$ ave. power transferred over a complete cycle by the source ~~is zero~~ to the inductor is zero.

(d) For C, voltage lags current by 90°, again, ave. power consumed by C is zero. $\Rightarrow$ ave. power transferred over a complete cycle by the source to the capacitor is zero.

(e) Total ~~power~~ average power absorbed by the circuit, is hence, zero.



(f) When R = 15 Ω added, hence current should be recalculated.

$$\therefore I_m = \frac{V_m}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{325}{\sqrt{15^2 + (-28)^2}}$$

$$I_m = \frac{325}{\sqrt{225 + 784}} = \frac{325}{\sqrt{1009}} \simeq 10.23\text{ A}$$

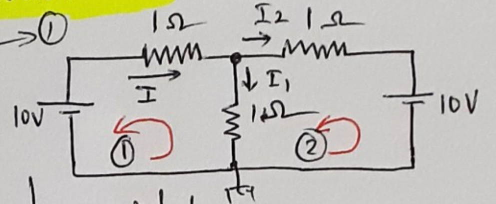
$$\therefore I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{10.23\text{ A}}{\sqrt{2}} = 7.23\text{ A}.$$

- Ave. power to R $= P_R = I_{rms}^2 R = (7.23)^2 \times 15 \simeq 790$ W
- Ave power to L $= 0$
- Ave. power to C $= 0$

Total power per cycle absorbed $P = P_R + P_L + P_C = 790$ W

-75b-

Find the currents in the given circuit



Kirchoff junction rule $\boxed{I = I_1 + I_2}$ → (1)

$-I_1 - I + 10 = 0$ (I loop)

Since $I = I_1 + I_2$

$I_1 + I = 10$

$2I_1 + I_2 = 10$ → (2)

2nd loop

$-I_2 + I_1 - 10 = 0$

$\boxed{I_1 - I_2 = 10}$ → (3)

From (2) and (3),

$$\begin{aligned} 2I_1 + \cancel{I_2} &= 10 \\ + \quad I_1 - \cancel{I_2} &= 10 \\ \hline 3I_1 &= 20 \end{aligned}$$

$\therefore I_1 = 6.7\,A$

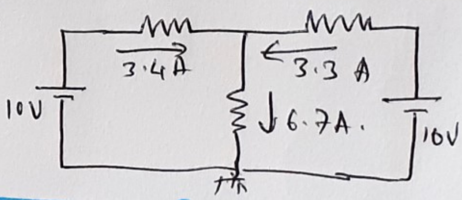
$$\begin{aligned} \cancel{2I_1} + I_2 &= 10 \\ (-) \quad \cancel{2I_1} - 2I_2 &= 20 \\ \hline 3I_2 &= -10 \end{aligned}$$

$I_2 = -3.3\,A$.

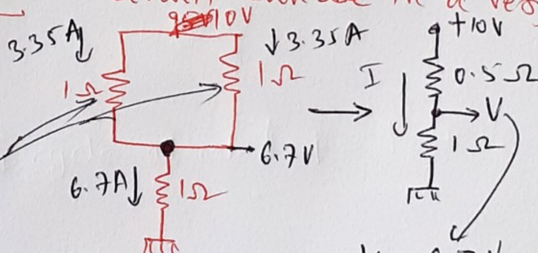
$\therefore I = I_1 + I_2$

$= 6.7 - 3.3 = 3.4\,A$

$\therefore$ $\boxed{\begin{aligned} I &= 3.4\,A \\ I_1 &= 6.7\,A \\ I_2 &= -3.3\,A \end{aligned}}$ → Circuit becomes



Another method: Circuit can be in a very simplified form



$\therefore I = \frac{10}{1.5}\,A$

$= \frac{\cancel{100}^{20}}{\cancel{15}_3}$

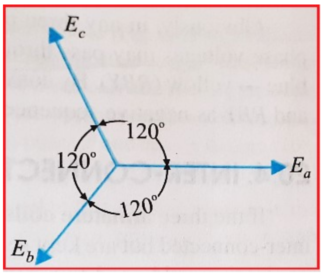
$\boxed{I = 6.7\,A}$

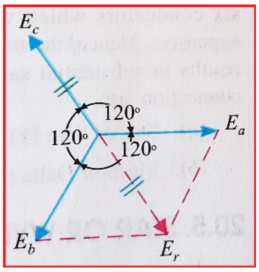
$V = 6.7\,V$

Since these 2 resistors are equal, the current through them are same, so $\frac{6.7\,A}{2} = 3.35\,A$ in each resistor

Info only : Difference Between Single Phase and 3-Phase Power Supplies

- Voltage between phase and neutral is called **"Phase voltage" (especially in Star configuration – see later for explanation)**
- Voltage between two phases is called "**Line voltage**".
- The formula between them is: **Line voltage = 1.73*(Phase voltage)**
- Phase voltage is 220V to 250V AC ,& Line voltage is 380V to 440V AC





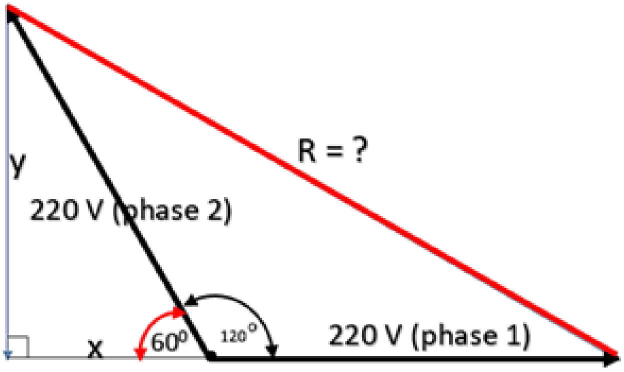
A 3-phase generator has 3 independent windings which are 120^0 apart, so that it can generate 3 independent voltages. In terms of the sinusoidal waveforms generated from a 3-phase generator, the sine waves are having 120^0 phase difference between phases as shown in the figure.
We can consider these 3 phases as vectors and voltage difference between any two adjacent waveforms is the resultant of the 2 vectors.

Let us see how to calculate the voltage between two phases (**Line voltage**)

$R = \sqrt{(x+220)^2 + y^2}$;

- $x = 220 \cos 60^0 = 220 \times 0.5 = 110$
- $y = 220 \sin 60^0 \approx 220 \times 0.87 \approx 191$

$R = \sqrt{(330)^2 + (191)^2} = 381\ V$ ------------------------ **(1)**



We have seen above, **Line voltage = 1.73*(Phase voltage)**

$\boldsymbol{Line\ voltage = 1.73\ x\ 220\ V = 381\ V}$ **-----(2)**

Therefore (1) and (2) are same, so we can use the formula:

Line voltage = 1.73*Phase voltage.

NOTE: There is a difference between a "direct 3-phase supply" and a "3-phase supply split into three single phase supplies". What is supplied by BESCOM to houses is "split 3-phase lines". For houses that get 3-phase connection, there are 4 wires coming to the house → 3 phases and 1 neutral

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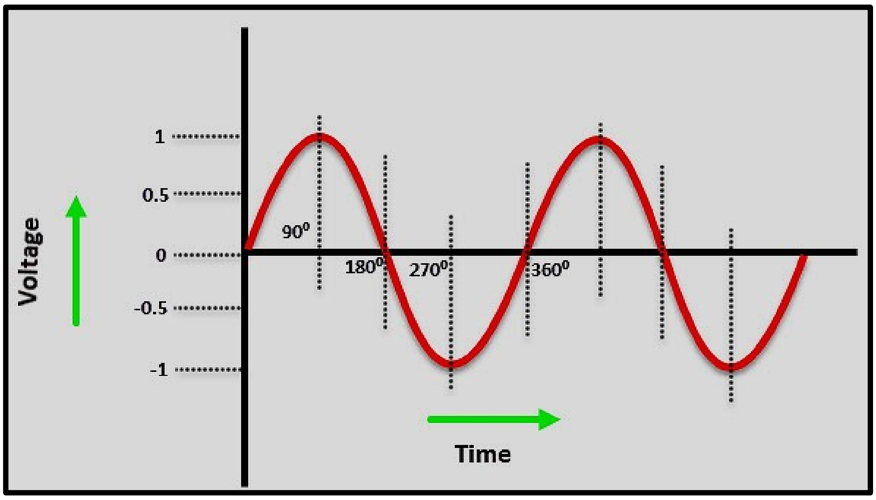
Background

Almost 90% of the electrical energy we use in our day-to-day life is from alternating source. Be it our home appliances, office equipment or industrial machines, we use AC source to power these devices.
If you are a beginner, then Alternating Current or simply AC is a type of electric power in which the electric current changes periodically, both magnitude and direction. Further, depending on the application, AC Power can be delivered in either a Single Phase or a Three Phase system.
A Single Phase AC Power system consists of two wires known as the phase (or sometimes a Line or Live) and the neutral wire. In case a three phase system, you use either three wires or four wires for transmitting power (no neutral in three wire three phase power).
Let us now go into the details of single phase and three phase systems and also see the difference between single phase and three phase power supplies.

What is Single Phase Power Supply?

As mentioned earlier, in a Single Phase Power Supply, the power is distributed using only two wires called Phase and neutral. Since AC Power takes the shape of a sinusoidal wave, the voltage in a single phase supply peaks at 90^0 during the positive cycle and again at 270^0 during the negative cycle.



The phase wire carries the current to the load and the neutral wire provides the return path of the current. Usually, the single phase voltage is 230V and the frequency is 50Hz (depending on where you live).
Since the voltage in a single phase supply rises and falls, a constant power cannot be delivered to the load.

Advantages

- It is very common form of power supply to most small power requirement. Almost all residential supplies are single phase supplies as the domestic appliances require a small amount of power to run lights, fans, coolers, heaters, small air conditioners etc.
- The design and operation of a single phase power supply system is often simple.
- Depending on the region, a single phase supply is sufficient for loads up to 2500 Watts.

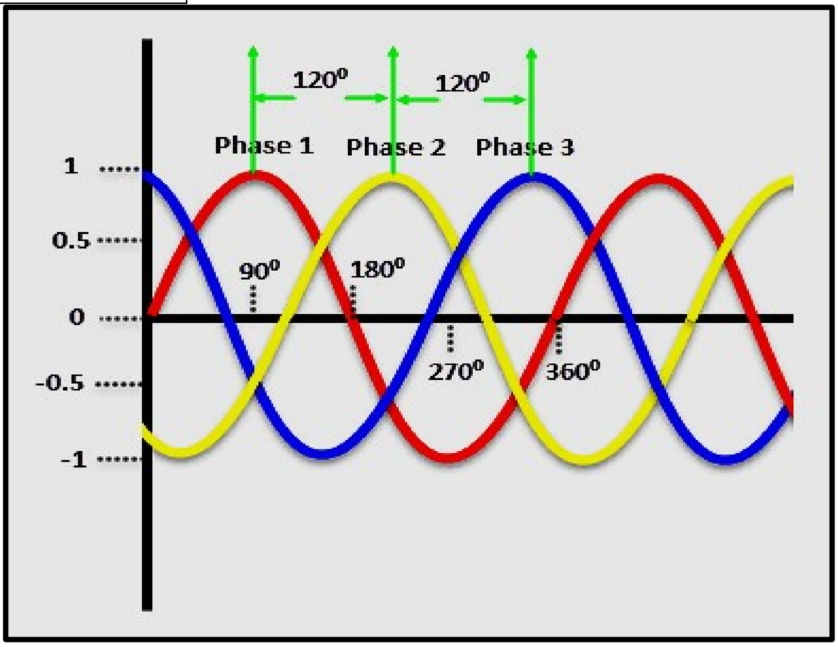
Disadvantages

- Small single phase motors (usually less than 1kW) cannot start directly with the help of a single phase supply as there isn't sufficient initial torque for the motor. So, additional circuitry like a Motor Starters (like a starter capacitor in fans and pumps) are needed for proper operation.
- Heavy loads like industrial motors and other equipment cannot be run on a single phase supply.

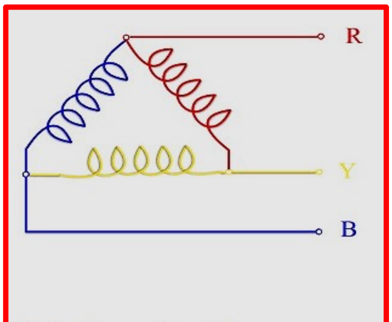
What is Three Phase Power Supply?

A Three Phase Power Supply consists of three power wires (or the three phases). Additionally, depending on the type of the circuit (which there are two types), you might or might not have a neutral wire. In a three phase power supply system, each AC Power Signal is 120^0 out of phase with each other.

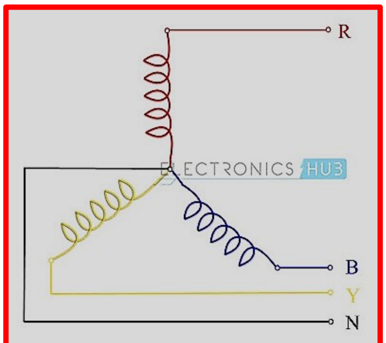
In a three phase power supply, during one cycle of 360^0, each phase would have peaked in voltage twice. Also, the power never drops to zero. This steady stream of power and ability to handle higher loads makes a three phase supply suitable for industrial and commercial operations.



As mentioned earlier, there are two types of circuit configurations in a 3-phase power supply. They are the Delta and the Star (or Wye). In Delta configuration, there is no neutral wire and all the high voltage systems use this configuration.
Coming to a star or wye configuration, there is a neutral wire (the common terminal of the star circuit) and a ground wire (sometimes).



Delta Connection (Δ)



Star Connection (Y or WYE)

The voltage between two phases in a 3-phase power supply is ≈415V while that between a phase & the neutral is 240V. Hence, you can provide 3-single phase supplies using a three phase supply (this is how it is normally done for residential and small business loads).

Advantages

- For the same power, a three phase power supply uses less wire than a single phase power supply.
- Three phase power supply is usually the preferred network for commercial and industrial loads. Although in some countries (like most European Countries, for example), even the residential supply is a three phase supply.
- You can run larger loads very easily.
- Large three phase motors (usually used in industries) do not require a starter as the phase difference in the three phase power supply will be sufficient to provide enough initial torque for the motor to start.
- Almost all the power generated in a three phase power. Although there is a concept of multi-phase power, studies found that a three phase power supply is more economical and easy to produce.
- The overall efficiency of 3-phase power supply is higher when compared to that of a single phase power supply for the same load.

Difference between Single and Three Phase Power Supplies

- Let us now take a look at the difference between single phase and three phase power supplies.
- In a single phase power supply, the power is supplied through two wires called Phase and Neutral. In 3-phase power supply, the power is supplied through three wires (four wires if neutral wire is included).
- The voltage of single phase supply is 230V whereas it is 415V in a three phase supply.
- For the same amount of power, a single phase supply requires more wire that that of a three phase supply.
- Efficiency of a 3-phase power supply is significantly higher than a single phase supply & the power transfer capability is also more.
- Since a single phase power supply uses only two wires, the overall complexity of the network is less when compared to a four wire three phase supply (neutral included).

Do You need a Three-Phase Power Supply?

- Depending on your requirement, your power distribution company will suggest either a single-phase power supply or a three-phase power supply. For small homes and shops, a single-phase supply is sufficient.
- But if you have a large home with three to four air conditioning units (all might run at a same time), water heaters, high HP submersible pump, washing machine, double-door refrigerator etc., then you might need a three-phase supply so that load on each phase is distributed properly.
- Since we don't have direct three-phase devices, what the power distribution company does is that the three-phases from the three-phase supply are given as three separate single phase supplies. For example, if you have three bedrooms with three ACs, then each room will be provided with a different phase.
- It is common for apartments and communities to have dedicated transformers so that they can step down 11kV which comes directly from the substation to 240V without depending on the street transformer.