Name of the teacher— Mrs. Monika Sharma

Department of Physics and Electronics

Name of the course— B.Sc. (H) Physics

Semester- IV

Name of the paper—Electrical circuits and Network Skills

Paper code-32223903

Lecture timings: 10:40 to 12:40 AM

Topics to be covered:

Name of the unit: Previous year question paper

- *Solution of the questions*

Question 5

Describe the construction and working of a Bridge-Rectifier. What will be the effect of a capacitor connected in parallel with the load on the output of the bridge rectifier ? (7,3)

Answer

Bridge rectifier

A bridge rectifier is a type of full wave rectifier which uses four or more diodes in a bridge circuit configuration to efficiently convert the Alternating Current (AC) into Direct Current (DC).

Bridge rectifier construction

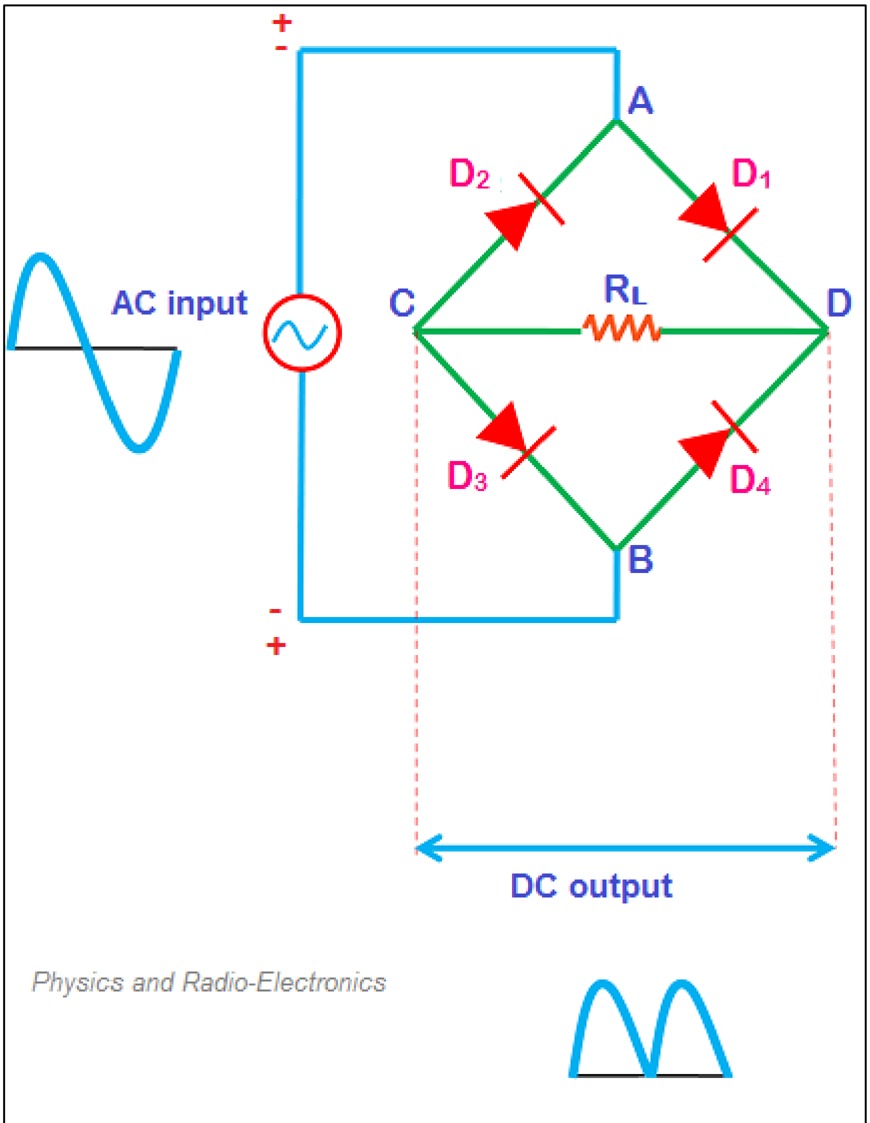


Fig: Bridge Rectifier

The construction diagram of a bridge rectifier is shown in the below figure. The bridge rectifier is made up of four diodes namely D_1, D_2, D_3, D_4 and load resistor R_L. The four diodes are connected in a closed loop (Bridge) configuration to efficiently convert the Alternating Current (AC) into Direct Current (DC). The main advantage of this bridge circuit configuration is that we do not require an expensive center tapped transformer, thereby reducing its cost and size.

The input AC signal is applied across two terminals A and B and the output DC signal is obtained across the load resistor R_L which is connected between the terminals C and D.

The four diodes D_1, D_2, D_3, D_4 are arranged in series with only two diodes allowing electric current during each half cycle. For example, diodes D_1 and D_3 are considered as one pair which allows electric current during the positive half cycle whereas diodes D_2 and D_4 are considered as another pair which allows electric current during the negative half cycle of the input AC signal.

How bridge rectifier works?

When input AC signal is applied across the bridge rectifier, during the positive half cycle diodes D_1 and D_3 are forward biased and allows electric current while the diodes D_2 and D_4 are reverse biased and blocks electric current. On the other hand, during the negative half cycle diodes D_2 and D_4 are forward biased and allows electric current while diodes D_1 and D_3 are reverse biased and blocks electric current.

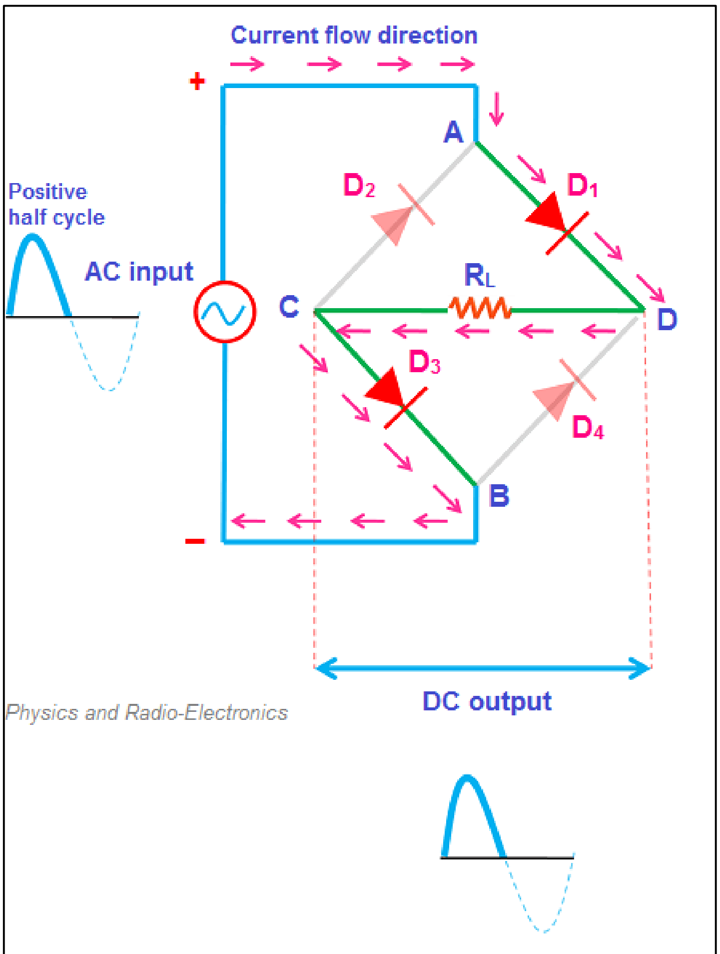


Fig A: Bridge rectifier during positive half cycle

During the positive half cycle, the terminal A becomes positive while the terminal B becomes negative. This causes the diodes D_1 and D_3 forward biased and at the same time, it causes the diodes D_2 and D_4 reverse biased.

The current flow direction during the positive half cycle is shown in the figure A (I.e. A to D to C to B).

During the negative half cycle, the terminal B becomes positive while the terminal A becomes negative. This causes the diodes D_2 and D_4 forward biased and at the same time, it causes the diodes D_1 and D_3 reverse biased.

The current flow direction during negative half cycle is shown in the figure B (I.e. B to D to C to A).

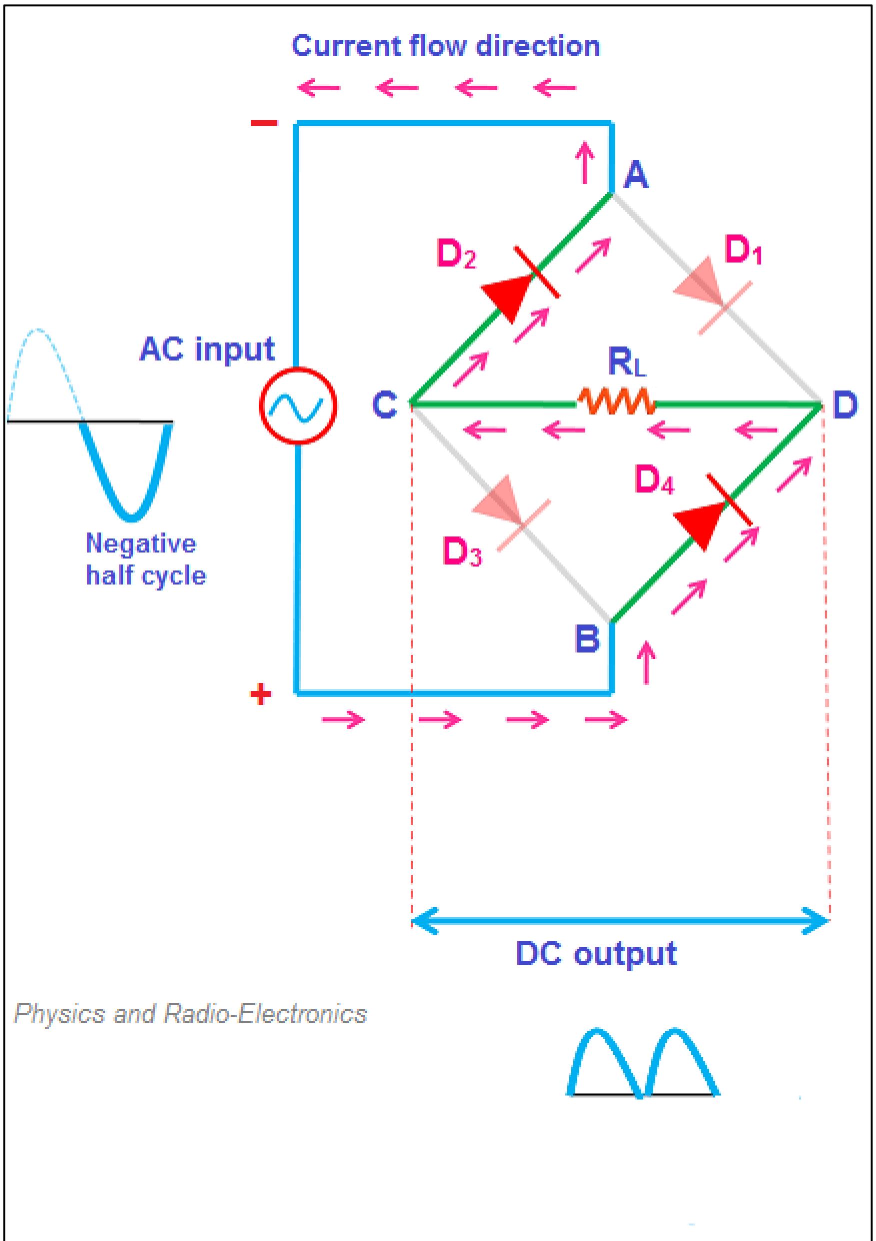
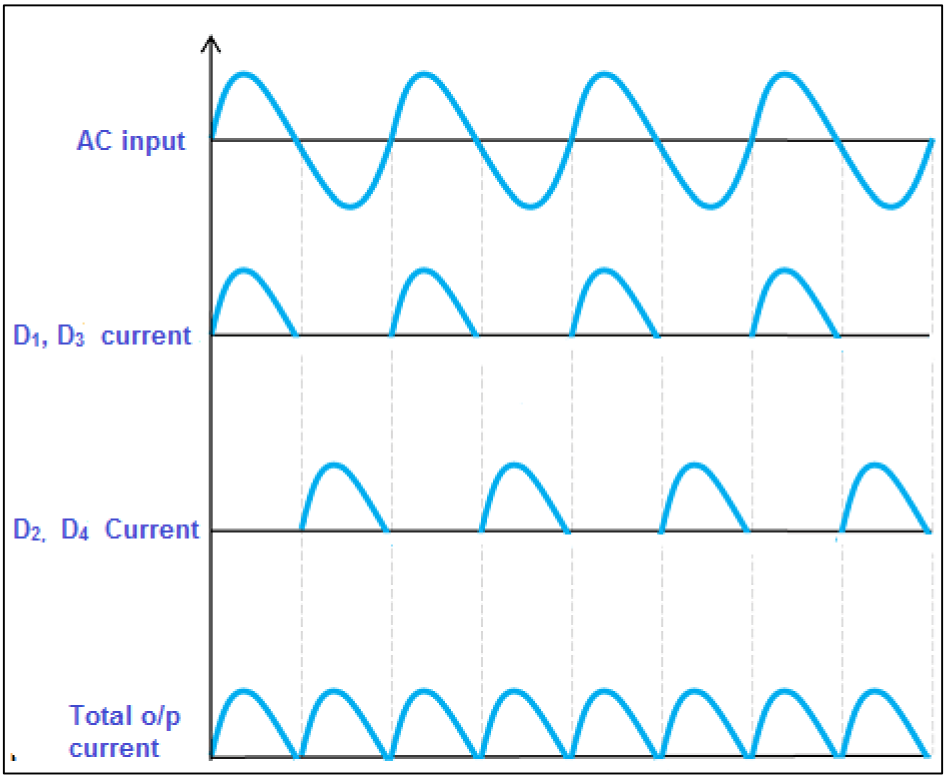


Fig B: Bridge rectifier during negative half cycle

From the above two figures (A and B), we can observe that the direction of current flow across load resistor R_L is same during the positive half cycle and negative half cycle. Therefore, the polarity of the output DC signal is same for both positive and negative half cycles. The output DC signal polarity may be either completely positive or negative. In our case, it is completely positive. If the direction of diodes is reversed then we get a complete negative DC voltage.

Thus, a bridge rectifier allows electric current during both positive and negative half cycles of the input AC signal.

The output waveforms of the bridge rectifier is shown in the below figure.



Characteristics of bridge rectifier

Peak Inverse Voltage (PIV)

The maximum voltage a diode can withstand in the reverse bias condition is called Peak Inverse Voltage (PIV)

or

The maximum voltage that the non-conducting diode can withstand is called Peak Inverse Voltage (PIV).

During the positive half cycle, the diodes D_1 and D_3 are in the conducting state while the diodes D_2 and D_4 are in the non-conducting state. On the other hand, during the negative half cycle, the diodes D_2 and D_4 are in the conducting state while the diodes D_1 and D_3 are in the non-conducting state.

The Peak Inverse Voltage (PIV) for a bridge rectifier is given by

PIV = V_{Smax}

Ripple factor

The smoothness of the output DC signal is measured by using a factor known as ripple factor. The output DC signal with very fewer ripples is considered as the smooth DC signal while the output DC signal with high ripples is considered as the high pulsating DC signal.

Ripple factor is mathematically defined as the ratio of ripple voltage to the pure DC voltage.

The ripple factor of the bridge rectifier is 0.48 which is same as the center tapped full wave rectifier.

Rectifier efficiency

The rectifier efficiency determines how efficiently the rectifier converts Alternating Current (AC) into Direct Current (DC).

High rectifier efficiency indicates a most reliable rectifier while the low rectifier efficiency indicates a poor rectifier.

Rectifier efficiency is defined as the ratio of the DC output power to the AC input power.

The maximum rectifier efficiency of a bridge rectifier is 81.2% which is same as the center tapped full wave rectifier.

Advantages of bridge rectifier

Low ripples in the output DC signal

The DC output signal of the bridge rectifier is smoother than the half wave rectifier. In other words, the bridge rectifier has fewer ripples as compared to the half wave rectifier. However, the ripple factor of the bridge rectifier is same as the center tapped full wave rectifier.

High rectifier efficiency

The rectifier efficiency of the bridge rectifier is very high as compared to the half wave rectifier. However, the rectifier efficiency of bridge rectifier and center tapped full wave rectifier is same.

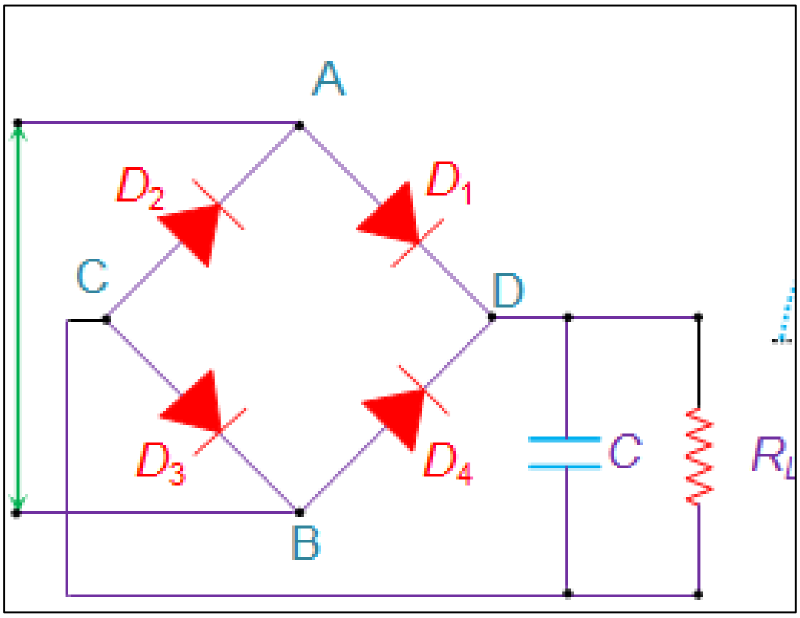
Low power loss

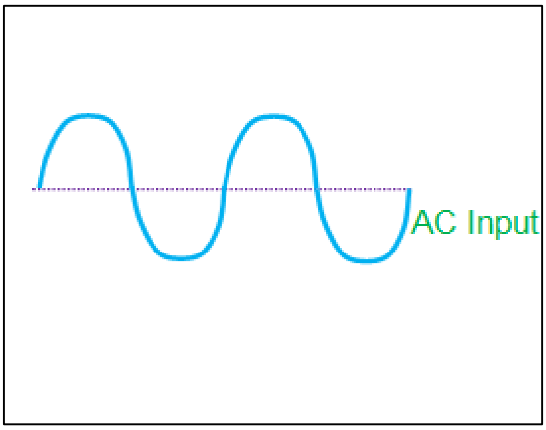
In half wave rectifier only one half cycle of the input AC signal is allowed and the remaining half cycle of the input AC signal is blocked. As a result, nearly half of the applied input power is wasted.

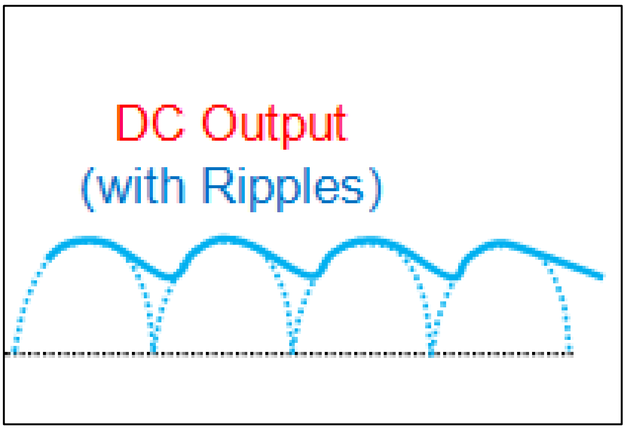
However, in the bridge rectifier, the electric current is allowed during both positive and negative half cycles of the input AC signal. So the output DC power is almost equal to the input AC power.

What if a capacitor is connected in load?

It is to be noted that the bridge rectifier's DC will be pulsating in nature. In order to obtain pure form of DC, one has to use capacitor in conjunction with the bridge circuit.







In this design, the positive pulse at the input causes the capacitor to charge through the diodes D_1 and D_3. However as the negative pulse arrives at the input, the charging action of the capacitor ceases and it starts to discharge via R_L. This results in the generation of DC output which will have ripples in it as shown in the figure. This ripple factor is defined as the ratio of AC component to the DC component in the output voltage. In addition, the mathematical expression for the ripple voltage is given by the equation

$$V_r = \frac{I_l}{fC}$$

Where, V_r represents the ripple voltage. I_l represents the load current. f represents the frequency of the ripple which will be twice the input frequency. C is the Capacitance.

Further, the bridge rectifiers can be majorly of two types, viz., Single-Phase Rectifiers and Three-Phase Rectifiers. In addition, each of these can be either Uncontrolled or Half-Controlled or Full-Controlled. **Bridge rectifiers** for a particular application are selected by considering the load current requirements. These bridge rectifiers are quite advantageous as they can be constructed with or without a transformer and are suitable for high voltage applications.

However here two diodes will be conducting for every half-cycle and thus the voltage drop across the diodes will be higher.

Lastly one has to note that apart from converting AC to DC, bridge rectifiers are also used to detect the amplitude of modulated radio signals and to supply polarized voltage for welding applications.

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Question 6

(a) **Discuss the basic design and working of a single phase motor. What are the advantages of a polyphase motor ?**

Answer

Single phase Induction Motors:

Single-phase a.c supply is commonly used for lighting purpose in shops, offices, houses, schools etc..Hence instead of d.c motors, the motors which work on single-phase a.c. supply are popularly used. These a.c motors are called **single-phase induction motors**. A large no. of domestic applications use *single-phase induction motors*. Here we will learn **how does single phase induction motor work**.

The power rating of these motors is very small. Some of them are even fractional horsepower motors, which are used in applications like small toys, small fans, hairdryers etc.

Construction of Single Phase Induction Motors:

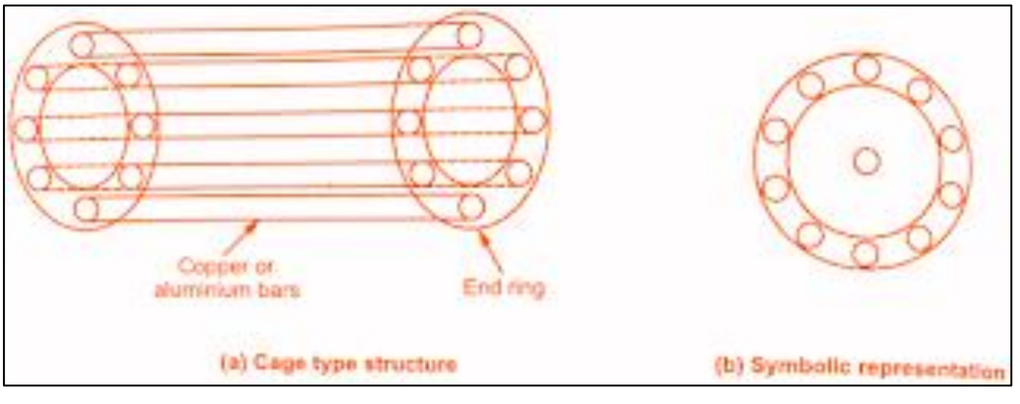
Similar to a d.c motor, **single-phase induction motor** also has two main parts, one rotating and other stationary. The stationary part in *single-phase induction motors* is **Stator** and the rotating part is **Rotor**.

The stator has laminated construction, made up of stampings. The stampings are lotted on its periphery to carry the winding called **stator winding** or main winding. This is excited by a single-phase a.c supply. The laminated construction keeps iron losses to the minimum. The stampings are made up of material from silicon steel which minimises the hysteresis loss.

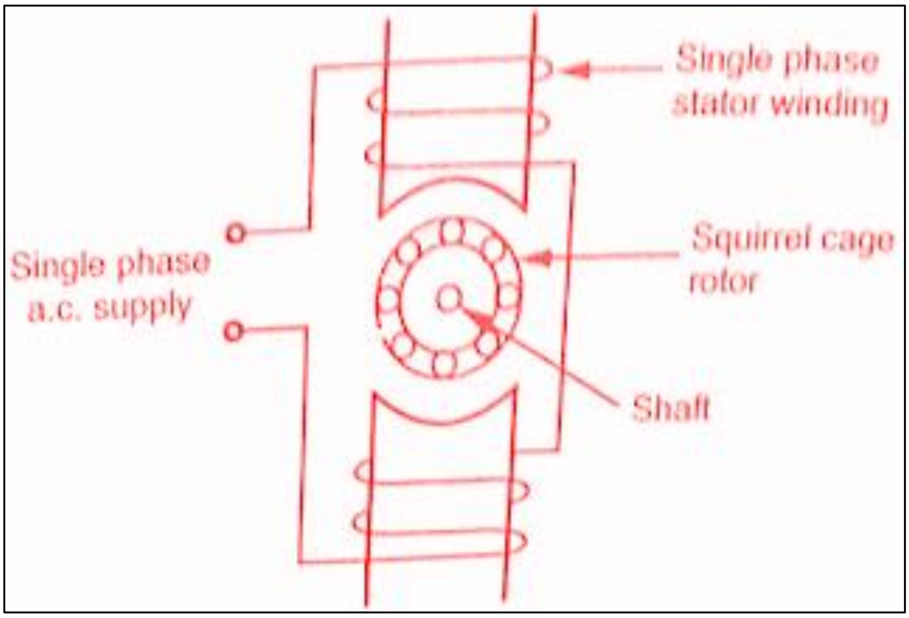
The stator winding is wound for a certain definite number of poles means when excited by single-phase a.c supply, stator produces the magnetic field which creates the effect of the certain definite number of poles. The number of poles for which stator winding is wound decides the synchronous speed of the motor. The synchronous speed is denoted as Ns and it has a fixed relation with supply frequency f and number of poles P. The relation is given by,

$$N_s = 120f/p \ \text{RPM}$$

The induction motor never rotates with the synchronous speed but rotates at a speed that is slightly less than the synchronous speed. The rotor construction is of squirrel cage type. This rotor consists of uninsulated copper or aluminium bars, placed in the slots. The bars are permanently shorted at both the ends with the help of conducting rings called end rings. The entire structure looks like cage hence it is called a squirrel cage rotor. The **construction of single-phase induction motors** is shown in below figure:



As the bars are permanently shorted to each other, the resistance of the entire rotor is very very small. The air gap between stator and rotor is kept uniform and as small as possible. The main feature of this rotor is that it automatically adjusts itself for the same the number of poles as that of the stator winding. The schematic diagram of two-pole **single phase induction motor** is shown in the below figure:



Working Principle of Single Phase Induction Motors:

For the motoring action, there must exist two fluxes which interact with each other to produce the torque. In d.c motors, field winding produces the main flux while d.c supply given to armature is responsible to produce armature flux. The main flux and armature flux interact to produce the torque.

In the **single-phase induction motor**, single-phase a.c supply is given to the stator winding. The stator winding carries an alternating current which produces the flux which is also alternating in nature. This flux is called the main flux. This flux links with the rotor conductors and due to transformer action e.m.f gets induced in the rotor. The induced emf drives current through the rotor as the rotor circuit is the closed circuit.

This rotor current produces another flux called rotor flux required for the motoring action. Thus second flux is produced according to the induction principle due to induced e.m.f hence the motor is called **induction motor**. As against this in d.c motor a separate supply is required to the armature to produce armature flux. This is an important difference between d.c motor and an induction motor.

Double Revolving Field Theory in single-phase induction motors:

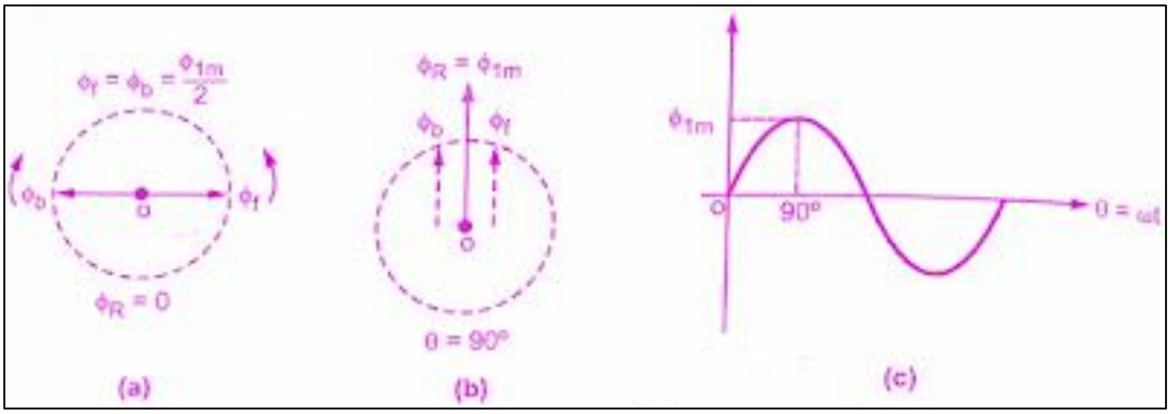
According to this theory, any alternating quantity can be resolved into two rotating components which rotate in opposite directions and each having magnitude as half of the maximum magnitude of the alternating quantity. In case of *single-phase induction motors*, the stator winding produces an alternating magnetic field having the maximum magnitude of $\Phi 1m$.

According to **double-revolving field theor**y, consider the two components of the stator flux, each having magnitude half of maximum magnitude of stator flux i.e (Φ1m/2). Both these components are rotating in opposite directions at the synchronous speed Ns which is dependent on frequency and stator poles.

Let Φf is forward component rotating in anticlockwise direction while Φb is the backward component rotating in a clockwise direction. The resultant of these two components at any instant gives the instantaneous value of the stator flux at that instant. So resultant of these two is the original stator flux. The below figure shows the stator flux and its two components Φf and Φb. .

At the start, both the components are shown the opposite to each other in figure(a). Thus the resultant ΦR = 0. This is nothing but the instantaneous value of stator flux at the start. After 90°, as shown in figure(b), the two components are rotated in such a way that both are pointing in the same direction.

Hence the resultant ΦR is the algebraic sum of the magnitudes of the two components. So ΦR = (Φ1m/2) + (Φ1m/2) =Φ1m.This is nothing but the instantaneous value of the stator flux at 0 = 90° as shown in figure(c). Thus continuous rotation of two components gives the original alternating stator flux.

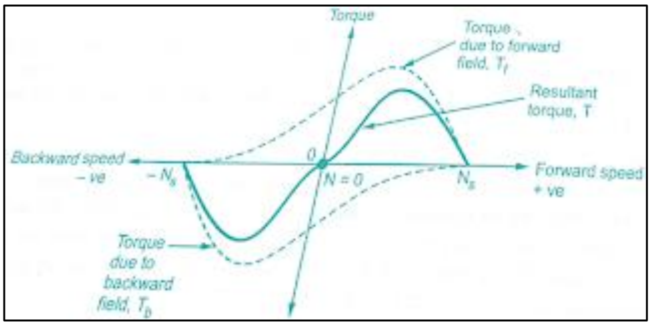


Both the components are rotating and hence get cut by the rotor conductors. Due to the cutting of flux, e.m.f gets induced in the rotor which circulates the rotor current. The rotor current produces rotor flux. This flux interacts with forwarding component Φf to produce a torque in one particular direction say anticlockwise direction. While the rotor flux interacts with the backward component Φb to produce a torque in the clockwise direction. So if anticlockwise torque is positive then clockwise torque is negative.

At the start, these two torques are equal in magnitude but opposite in direction. Each torque tries to rotate the rotor in its own direction. Thus net torque experienced by the rotor is zero at the start. And hence the **single-phase induction motors are not self-starting.**

Torque-Speed Characteristics in Single-phase Induction Motors:

The two oppositely directed torques and the resultant torque can be shown effectively with the help of **torque-speed characteristics**. It can be seen that at start N = 0 and at that point resultant torque is zero. So **single phase induction motors** are not self starting.However if the rotor is given an initial rotation in any direction, the resultant average torque increases in the direction in which rotor is initially rotated and the motor starts rotating in that direction.

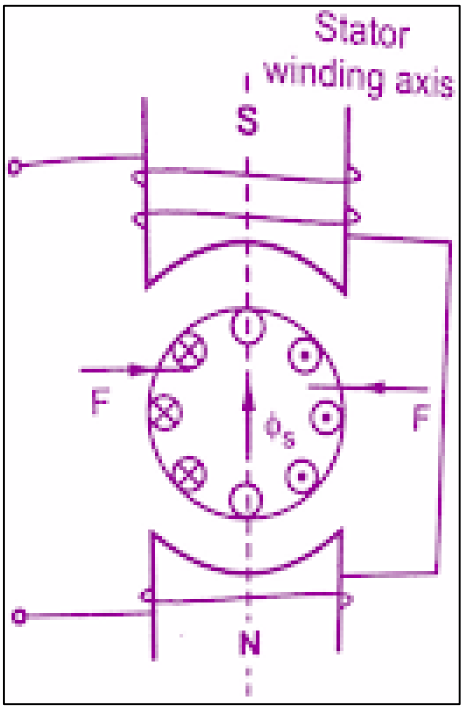


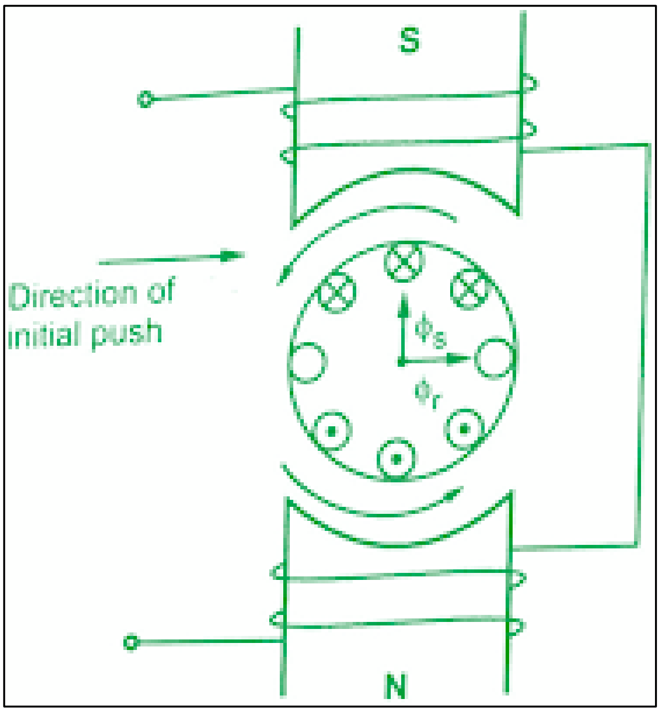
But in practice, it is not possible to give initial torque to rotor externally hence some modifications are done in the **construction of single phase induction motors** to make them self starting.Another theory which can also be used to explain **why single phase induction motor is not self starting** is cross-field theory.

Cross Field Theory in single phase induction motors:

Consider a **single phase induction motor** with standstill rotor as shown in the below figure.The stator winding is excited by the single phase a.c. supply.This supply produces an alternating flux Φs which acts along the axis of the stator winding.Due to this flux, emf gets induced in the rotor conductors due to transformer action.

As the rotor is closed one, this e.m.f circulates current through the rotor conductors.The direction of the rotor current is as shown in the below figure.The direction of rotor current is so as to oppose the cause producing it, which is stator flux Φs.





Now Fleming's left hand rule can be used to find the direction of the force experienced by the rotor conductors.It can be seen that when Φs acts in upward direction and increasing positively, the conductors on left experience force from left to right while conductors on right experience force from right to left.Thus overall, the force experienced by the rotor is zero.Hence no torque exists on the rotor and rotor can not start rotating.

We have seen that there must exist two fluxes separated by some angle so as to produce rotating magnetic field. According to **cross field theory**, the stator flux can be resolved into two components which are mutually perpendicular. One acts along the axis of the stator winding and other acts perpendicular to it.

Assume now that an initial push is given to the rotor in an anticlockwise direction. Due to the rotation, rotor physically cuts the stator flux and dynamically emf gets induced in the rotor. This is called speed e.m.f or rotational emf. The direction of such emf can be obtained by Fleming's right-hand rule and this emf is in phase with the stator flux Φs.

The direction of emf is shown in the figure below. This emf is denoted as E2N. This emf circulates current through rotor which is I2N. This current produces its own flux called rotor flux Φr. This axis of Φr is at 90° to the axis of stator flux hence this rotor flux it called cross-field.

Advantages of poly phase system over single phase systems

The advantages of poly phase system over single phase systems are given below:

1. Power delivered is constant. In single phase circuit the power delivered is pulsating and objectionable for many applications.
2. For a given frame size a poly phase machine gives a higher output than a single phase machine.
3. Poly phase induction motors are self starting and are more efficient. Single phase motor has no starting torque and requires an auxiliary means for starting.
4. Comparing with single phase motor, three phase induction motor has higher power factor and efficiency.
   Three phase motors are very robust, relatively cheap, generally smaller, have self-starting properties, provide a steadier output and require little maintenance compared with single phase motors.
5. For transmitting the same amount of power at the same voltage, a three phase transmission line requires less conductor material than a single phase line. The three phase transmission system is so cheaper. For a given amount of power transmitted through a system, the three phase system requires conductors with a smaller cross-sectional area. This means a saving of copper and thus the original installation costs are less.
6. Poly phase motors have uniform torque whereas most of the single phase motors have pulsating torque.
7. Parallel operation of three-phase generators is simpler then that of single phase generator.
8. Poly phase system can set up rotating magnetic field in stationary windings.