Q.2a. Compare electric and magnetic circuits. (8)

Answer:

S.No.	Electric circuit	Magnetic circuit
1.	The closed path for electric current is called electric circuit.	The closed path for magnetic flux is called magnetic circuit.
2.	Current flows through the circuit.	Flux is set up in the circuit.
3.	Current flows due to Emf (volts).	Flux is created by Mmf (Amp).
4.	Resistance opposes the flow of current	Reluctance opposes the creation of flux.
5.	Current, $I = \frac{\text{emf}}{\text{resistance}}$ Amp.	Flux $= \frac{\text{mmf}}{\text{reluctance}}$ weber.
6.	Resistance, $R = \frac{\rho l}{A}$ ohm.	Reluctance. $S = \frac{l}{\mu_o \mu_r A}$ AT/Wb.
7.	Voltage drop $= IR$.	mmf drop $= \phi S$.
8.	Electric intensity, $E = V/d$.	Magnetic intensity, $H = NI/l$.
9.	Conductance $= \frac{1}{R}$.	Permeance $= \frac{1}{S}$
10.	Conductivity.	Permeability.
11.	Current density $= I/A$.	Flux density $= \phi/A$.

4.18.2. Dissimilarities

1.	Electric current actually flows in an electric circuit.	Magnetic flux does not flow.
2.	There are number of electric insulators. For example, air.	There is no magnetic insulator, flux can be set up even in air.
3.	When current flows through an electric circuit, energy is expended as long as the current flows. The expended energy is dissipated as heat.	No energy is expended in a magnetic circuit. In other words, energy is required in creating flux and not in maintaining.
4.	If we keep temperature constant, then resistance of an electric circuit is constant.	Reluctance depends on flux density, $\mu = \frac{B}{H}$ is not constant, even if the material remains same.

b. A magnetic circular ring of diameter 0.2 meter has cross-sectional area of 0.1 meter^2 & relative permeability 1000. An excitation coil of 500 turns is wound over this ring. **(8)**

(i) Calculate reluctance of ring

(ii) MMF to established flux density of 1 T in this ring
(iii) Current in ring to established flux density of part(ii)
(iv) Magnetic flux in ring

Answer:

(i) Reluctance $S = \frac{l}{\mu_0 \mu_r A}$

$= \frac{0.2}{4\pi \times 10^{-7} \times 1000 \times 0.1}$

$= 1592$

2

(ii) MMF = Flux x Reluctance $= \phi S$

$= \phi \cdot \frac{l}{\mu_0 \mu_r A} = B \cdot \frac{l}{\mu_0 \mu_r}$

$= 1 \cdot \frac{0.2}{4\pi \times 10^{-7} \times 1000}$

2

$= 159$ AT

(iii) MMF = NI

$I = \frac{MMF}{N} = 0.318$ Amp

2

(iv) Flux $\phi = BA = 1 \times 0.1 = 0.1$ Weber

2

Q.3 a. State & explain superposition theorem with suitable example. **(8)**

Answer:

3.2. SUPERPOSITION THEOREM

"It states that in any linear, active, bilateral network, having more than one excitation source, response across any element is the algebraic sum of responses obtained by each source considered independently with all other independent sources made inoperative". Independent voltage sources are made inoperative by replacing the source with its internal resistance. For ideal voltage source, since the internal resistance is zero, so we replace it by a short circuit. Independent current sources are made inoperative by replacing them with their conductance in parallel. Since the shunt conductance of ideal current sources is zero, it implies resistance is infinitely high and is, therefore, replaced by open circuit. Dependent sources present in the network are neither replaced by short circuit nor open circuit.

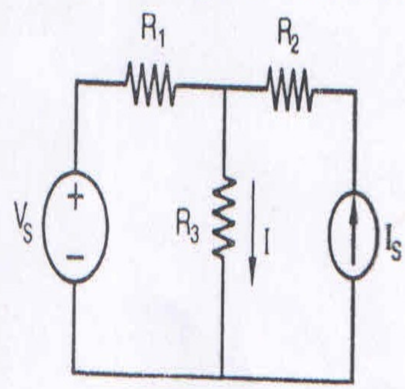


Fig. 3.1.

Explanation. Consider the circuit shown in Fig. 3.1, where two sources (voltage and current sources) are acting together.

If we want to determine current through resistance R_3 using superposition, theorem we take one source at a time, making the other inoperative.

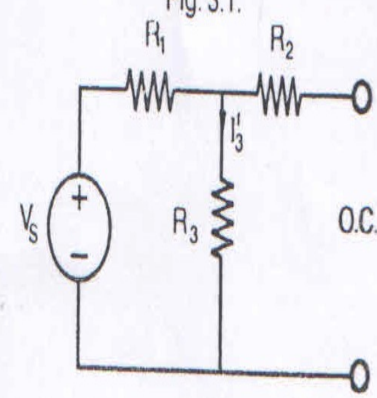


Fig. 3.2.

(*i*) **Case I.** Consider the voltage source and the ideal current source is open circuited.

(Since the internal resistance of ideal current source is infinite).

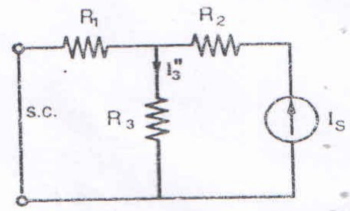


Fig. 3.3.

03

$$I_3' = \frac{V_s}{R_1 + R_3} \quad ...(3.1)$$

(*ii*) **Case II.** Consider the current source and replace the ideal voltage source by short-circuit.

(Since the internal resistance of ideal voltage source is zero).

3

By current division rule :

$$I_3'' = I_s \times \frac{R_1}{R_1 + R_3} \quad ...(3.2)$$

Now, if both the sources are acting together, then by superposition theorem, current response

$$I_3 = I_3' + I_3'' \quad ...(3.3)$$

2

Superposition theorem is applicable to both currents and voltage but not for power. It can be applied to a.c. circuits also where phasor sum is to be considered instead of algebraic sum. The Theorem iss applicable only to linear networks *i.e.* those which possesses properties of linearity.

b. Three impedances having per phase impedance Zp = (3+j4) ohm are connected in star. This three phase load is connected across 400 volt supply, calculate: **(8)**
   (i) Phase voltage
   (ii) Phase current
   (iii) Line current
   (iv) Power consumed by load

Answer:

$$Z_p = 3 + j4 = 5\angle 53^\circ$$

$$\phi = 53^\circ$$

$$pf = \cos\phi = \cos 53^\circ = 0.6$$

here $V_L = 400$ Volt

for star connection

Phase voltage $(V_P) = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 231$ Volt 2

Phase current $(I_P) = \frac{V_P}{Z_P}$ 2

$= \frac{231}{5} = 46.2\ A$

Line current $(I_L) = I_P = 46.2\ A$ 2

Power in 3-ϕ load $= \sqrt{3}\, V_L I_L \cos\phi$ 2

$= \sqrt{3} \times 400 \times 46.2 \times 0.6$

$= 19204\ W$

$= 19.2\ KW$

Q.4 a. Derive torque equation of DC motor. **(8)**

Answer:

~~13.10.~~ **TORQUE**

The measure of causing the rotation of a wheel or the turning or twisting moment of a force about the axis is called the torque.

Torque is measured by the product of force and the radius at which this force acts.

Consider a wheel of radius r metres acted by a circumferential force F newtons, as shown in fig 13.11. Let the force F cause the wheel to rotate at n rps.

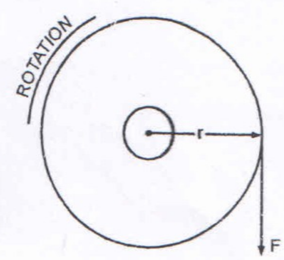


Fig. 13.11

$$\text{Torque, } T = F \times r \text{ newton-metres}$$

$$\text{Work done per revolution} = F \times \text{distance moved} = F \times 2\pi r \text{ joules}$$

$$\text{Work done per second} = F \times 2\pi r \times n$$

$$= F \times r \times 2\pi n \text{ joules/second or watts}$$

Since $F \times r$ = Torque, T and $2\pi n = \omega$, angular velocity in radians per second

$$\text{So work done per second} = T\omega \text{ joules per second or watts} \quad ...(13.24)$$

$$\text{So power developed, } P = T\omega = T \times \frac{2\pi N}{60} = 0.105\ NT \text{ watts} \quad ...(13.25)$$

13.11. ARMATURE TORQUE

Let T_e be the electro-magnetic torque developed in newton-metres by the motor running at n rps.

Power developed = Work done per second = $T_e \ \omega = T_e \times 2\pi n$ watts ...(i)

Electrical equivalent of mechanical power developed by the armature, as mentioned in Art 13.5, also

$= E_b \ I_a$ watts ...(ii)

Comparing expressions (i) and (ii) we have

$$T_e \times 2\pi n = E_b \ I_a$$

$$\text{or } T_e = \frac{E_b I_a}{2\pi n} = 0.159 \frac{E_b I_a}{n} \text{ N-m} \quad ....(13.26)$$

$$\text{Also } T_e = \frac{E_b I_a}{2\pi \frac{N}{60}} = 9.55 \frac{E_b I_a}{N} \text{ N-m} \quad ... (13.27)$$ where N is speed in rpm

Substituting $E_b = \Phi Z \frac{N}{60} \times \frac{P}{A}$ in expression (13.27) we have

$$T_e = 9.55 \times \Phi \times Z \times \frac{N}{60} \times \frac{P}{A} \times \frac{I_a}{N} = 0.159 \, \Phi Z P \frac{I_a}{A} \text{ newton-metres} ...(13.28)$$

6

b. A Pole DC shunt motor has armature winding resistance Ra = 0.3 ohm and shunt field resistance(R_{sh} = 100Ω) When motor connected with 400 volt supply, draws 40 Amp current and running at 1000 RPM. Calculate resistance must be inserted in armature circuit to reduce speed up to 800 RPM. Assume torque is constant. **(8)**

Answer:

$$I_{sh} = \frac{V}{R_{sh}} = \frac{400}{100} = 4A = I_f.$$

$$I_{L_1} = 40 A = I_{L2}$$

$$I_{a_1} = I_{L_1} - I_f = 40 - 4 = 36 A.$$

$$E_{b1} = V - I_{a_1} R_a$$

$$= 400 - 36 \times 0.3$$

$$= 400 - 10.8 = 389.2 \text{ Volt}$$

1 2

$$N_1 = 1000 \text{ RPM}$$

$$I_{a_2} = I_{L2} - I_f = 36 A$$

$$\phi_1 = \phi_2.$$

$$E_{b2} = V - I_{a2}(R_a + R) \quad \& \quad N_2 = 800 \text{ RPM}$$

$$= 400 - 36(0.3 + R)$$

$$= 400 - 10.8 - 36R$$

$$= 389.2 - 36R$$

by speed equation

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2} = \frac{E_{b2}}{E_{b1}}$$

$$389.2 - 36R = 311.36$$

$$36R = 77.84$$

$$R = \frac{77.84}{36} = 2.16\,\Omega$$

Q.5 a. Discuss rotating magnetic field and principle of operation of three phase induction motor. **(8)**

Answer:

11.1. ROTATING FIELDS OF A THREE PHASE SUPPLY

An induction motor is a device based on rotating field produced when a three phase supply is impressed across a three-phase winding, physically displaced at 120° to each other in space. The diagram in Fig. 11.1 (*a*) represents in winding of a two-pole, three-phase system. The three windings are spaced 120° apart. These windings may be connected to the three-phase mains either as star (Y) or as delta (Δ). In either case the currents that flow at any instant in the coils are given by the curves as in Fig. 11.1 (*b*). At any instant *A*, for example, the current in phase 1 is ($+I_{max}$), that in phase 2 is $\left(-\frac{I_{max}}{2}\right)$ and that in phase 3 is also $\left(=\frac{I_{max}}{2}\right)$.

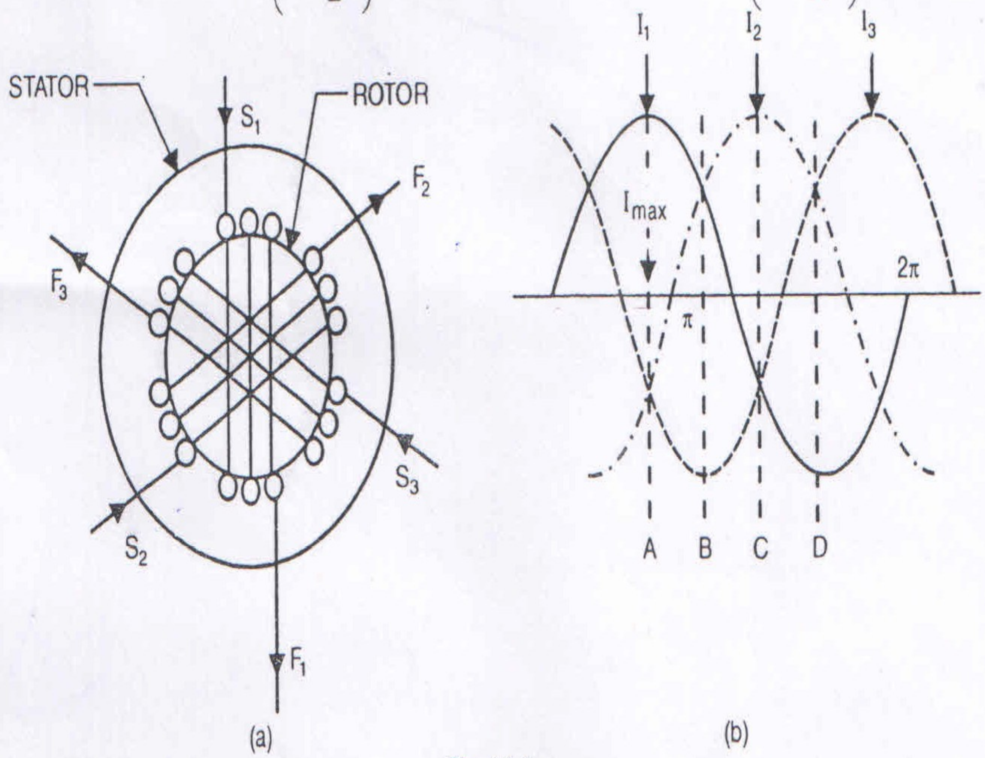


Fig. 11.1.

The resultant magnetic field produced by the winding at instants *A*, *B*, *C* and *D*, etc., are shown in Fig. 11.2, which shows that a revolving field is produced which is of constant magnitude and which goes through one revolution while the current in one phase passes through one complete cycle.

11.3. PRINCIPLE OF ROTATION OF THE ROTOR

The effect of connecting the stator windings to a balanced 3-phase supply is to produce a constant magnetic flux having a definite synchronous speed. Let us assume that this magnetic flux is rotating in anti-clockwise direction [Fig. 11.5 (*a*)]. Consider the instant when the rotor is yet stationary ; the flux, crossing the air-gap, will cut the conductors wound over the rotor, and the moving flux has a speed relative to the stationary rotor. This relative motion between the magnetic field and the rotor conductors induces and e.m.f. in the conductors. The magnitude of induced e.m.f. and direction of the induced current in the rotor conductors may be found by Faraday's Laws and Fleming's righthand rule respectively. It may be noted that it is the flux and rotor relative motion which is the cause of induced e.m.f., so if the stator flux is assumed stationary and the rotor in motion, an e.m.f. will even then be induced in the rotor conductors. Further the induced e.m.f., depending on this relative motion, will be proportional to the relative speed, which, in practice means the rotor speed (the stator being immobile). 5

The current induced in the closed circuited rotor windings will tend to oppose the cause which produces it. (Lenz's law of electromagnetic induction) ; *i.e.*, the

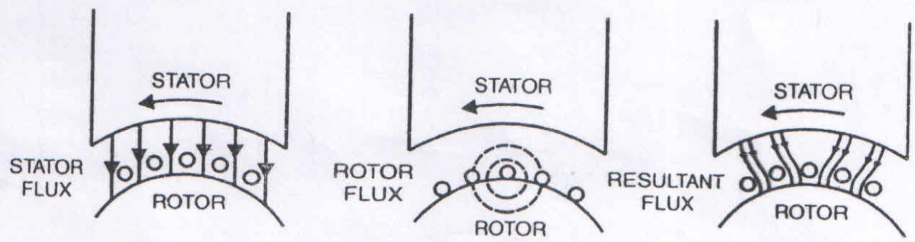


Fig. 11.5. 2

motion of the rotor relative to the magnetic flux. The rotor begins to move in the same direction as the magnetic flux and to attain the same speed as the flux, but it does not, in practice, achieve this.

Fig. 11.5 (*b*) shows the direction of the induced e.m.f. in the rotor conductors. And Fig. 11.5 (*c*) shows the resultant flux which bends round the conductor and it is under the influence of this force that the rotor begins to rotate in the anti clockwise direction. This direction of rotation is the same as the direction of rotation of the magnetic flux of the stator. 1

b. Magnetic core of $1-\phi$ transformer is made by CRGO silicon steel (μ_r = 4000). Its mean length is 0.8 meter & area of cross- section is 0.2 meter^2. **(8)**

(i) Calculate Reluctance of core.
(ii) What is current in primary winding (which has 500 turns) to set flux density of 2 Tesla in the core
(iii) Calculate emf induced in primary winding. Assume supply frequency 50Hz.
(iv) Calculate number of turns & emf induced in secondary winding if transformation ratio is 2.

Answer:

(I) Reluctance $(S) = \frac{l}{\mu_0 \mu_r A}$

$= \frac{0.8}{4\pi \times 10^{-7} \times 4000 \times 0.2}$

$= 796$

2

(II) $B = 2T$ & $A = 0.2\ m^2$.

$\phi m = B \cdot A = 0.4$ Wb.

$MMF = \phi \times S = 0.4 \times 796$

$= 318$ AT

2

$MMF = N_1 I_1$

$I_1 = \frac{MMF}{N_1} = .637$ Amp.

(III) $E_1 = 4.44\ \phi m N_1 f$.

$= 44400$ Volt

2

(IV) $K = 2$.

$E_2 = K E_1 = 88800$ Volt

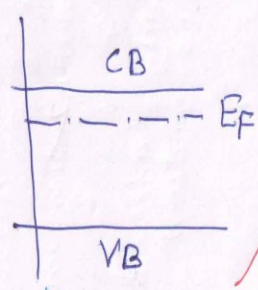
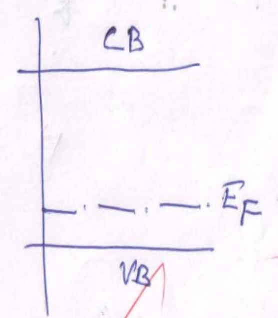
$N_2 = K N_1 = 1000$ Turns.

2

8

Q.6 **a.** Compare N-Type & P-Type Extrinsic semiconductors. **(8)**

Answer:

	N Type	P Type
Base atom	Si or Ge	Si or Ge
Doping Impurity	V group	III group
Nature of Impurity	Donar	Accepter
Majority charge Carriers	Electrons (N_D)	Holes (N_A)
Minority charge Carriers	holes (n_i^2/N_D)	electrons (N_i^2/N_A)
Conductivity	$\sigma_N \cong q\,\mu_e N_D$	$\sigma_P \cong q\,\mu_h N_A$
Energy level	Energy of CB decreases	Energy of VB Increases
Fermi level	Goes up 	Goes Down 

b. Draw V-I characteristic of P-N Junction diode and explain working of diode in forward and reverse bias. **(8)**

Answer:

4.3 *V-I* CHARACTERISTICS OF A *PN*-JUNCTION DIODE

We would like to know how a device responds when it is connected in an electrical circuit. This information is obtained by means of a graph, known as its *V-I* characteristics, or simply characteristics. It is a graph between the voltage applied across its terminals and the current that flows through it. For a typical *PN*-junction diode, the characteristic is shown in Fig. 4.5. It tells us how much diode current flows for a particular value of diode voltage.

To obtain this graph, we set up a circuit in the laboratory. This circuit is shown in Fig. 4.6*a*. Note that in this circuit, the *PN*-junction is represented by its schematic *symbol*. The details of the diode symbol appear in Fig. 4.6*b*. The *P* region of the diode is called the *anode*, and the *N* region the *cathode*. The symbol looks like an arrow pointing from the *P* region to the *N* region. It serves as a reminder to us that the *conventional* current flows easily from the *P* region to the *N* region of the diode.

In the circuit (Fig. 4.6*a*), the dc battery V_{AA} is connected to the diode through the potentiometer *P*. Note that the dc battery is pushing the conventional current in the same direction as the diode arrow. Hence, the diode is *forward-biased*. Since current flows easily through a forward-biased diode, a resistance *R* is included in the circuit so as to limit the current. If excessive current is permitted to flow through the diode, it may

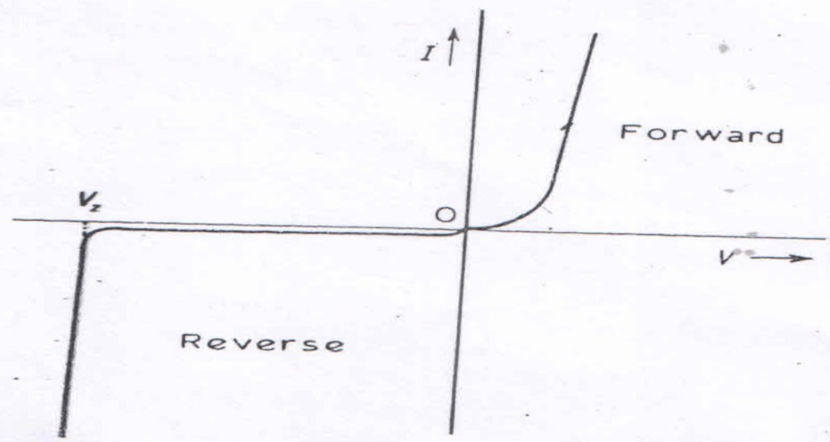


Fig. 4.5 *V-I* characteristic of a *PN*-junction diode

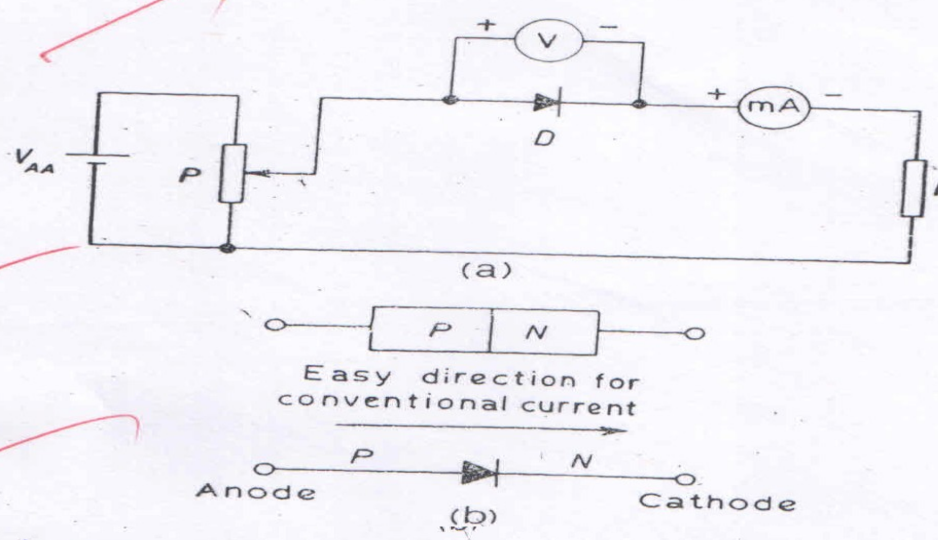


Fig. 4.6 **(*a*)** Circuit used to obtain the *V-I* characteristic of a diode for forward bias; (*b*) Symbol of the diode

get permanently damaged. The potentiometer helps in varying the voltage applied to the diode. The milliammeter measures the current in the circuit. The voltmeter measures the voltage across the diode.

Figure 4.7 shows the magnified view of a silicon-diode characteristic when the diode is forward-biased. Note that the voltage is plotted along the horizontal axis, as voltage is the independent variable. Each value of the diode voltage produces a particular current. The current, being the dependent variable, is plotted along the vertical axis.

Q.7 a. With the help of schematic, explain working of full wave (bridge) rectifier and draw wave forms also. **(8)**

Answer:

Bridge Rectifier A more widely used full-wave rectifier circuit is the **bridge** rectifier, shown in Fig. 4.18. It requires four diodes instead of two, but avoids the need for a centre-tapped transformer. During the positive half-cycle of the secondary voltage, diodes $D2$ and $D4$ are conducting and diodes $D1$ and $D3$ are nonconducting. Therefore, current flows through the secondary winding, diode $D2$, load resistor R_L and diode $D4$, as shown in Fig. 4.18*b*. During negative half-cycles of the secondary voltage, diodes $D1$ and $D3$ conduct, and the diodes $D2$ and $D4$ do not conduct. The current therefore flows through the secondary winding, diode $D1$, load resistor R_L and diode $D3$, as shown in Fig. 4.18*c*. In both cases, the current passes through the load resistor *in the same direction*. Therefore, a fluctuating, unidirectional voltage is developed across the load. The load voltage waveform is shown in Fig. 4.18*d*.

Peak Inverse Voltage Let us now find the peak inverse voltage that appears across a nonconducting diode in a bridge rectifier. Figure 4.19 shows the bridge rectifier circuit at the instant the secondary voltage reaches its positive peak value, V_m. The diodes $D2$ and $D4$ are conducting, whereas diodes $D1$ and $D3$ are reverse biased and are nonconducting. The conducting diodes $D2$ and $D4$ have almost zero resistance (and hence zero voltage drops across them). Point B is at the same potential as the point A. Similarly, point D is at the same potential as the point C. The entire voltage V_m across the secondary winding appears across the load resistor R_L. The reverse voltage across the nonconducting diode $D1$ (or $D3$) is also V_m. Thus,

$$\text{PIV} = V_m \tag{4.13}$$

Output dc Voltage in Various Rectifiers The voltage waveform in Fig. 4.18*d* is exactly the same as that in Fig. 4.16*d*. In both the rectifier circuits, the load voltage is the same. However, there is one difference. In the bridge rectifier, V_m is the maximum voltage across the secondary winding. But in the centre-tap rectifier, V_m represents the maximum voltage across half the secondary winding.

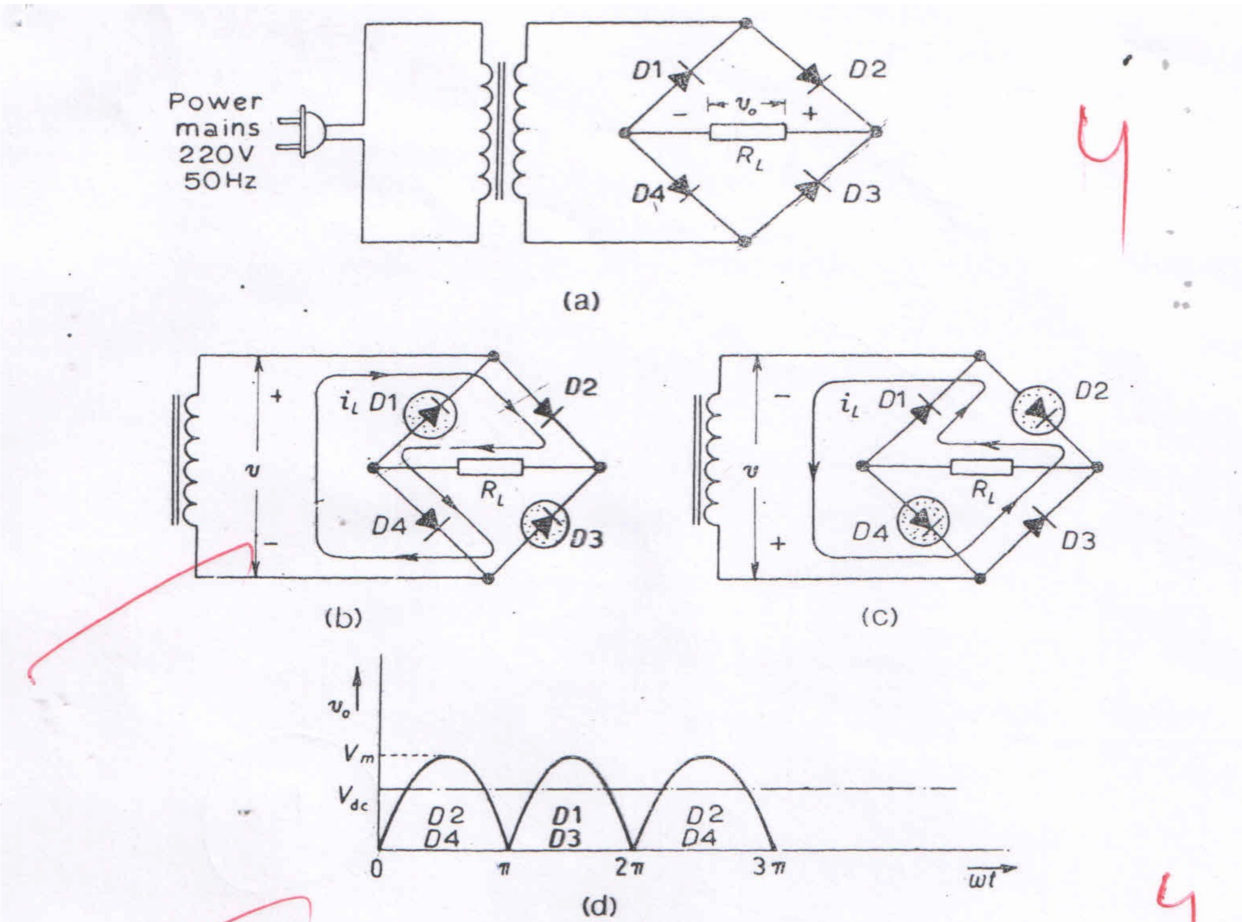


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Fig. 4.18 Bridge rectifier

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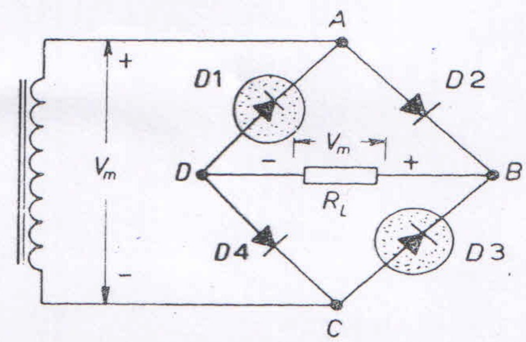

Fig. 4.19 The **PIV** across the nonconducting diode **D1** or **D3** is V_m

Now let us compare the full-wave rectified voltage waveform (of Fig. 4.18*d* or Fig. 4.16*d*) with the **half-wave** rectified voltage waveform (of Fig. 4.13*b*). In a half-wave rectifier, **only** positive half-cycles are utilized for the dc output. But a full-wave rectifier utilizes both the half-cycles. There-

b. Calculate series resistance Rs in Voltage regulator circuit shown in **Fig.2**. Here zener diode current is 2A. **(8)**

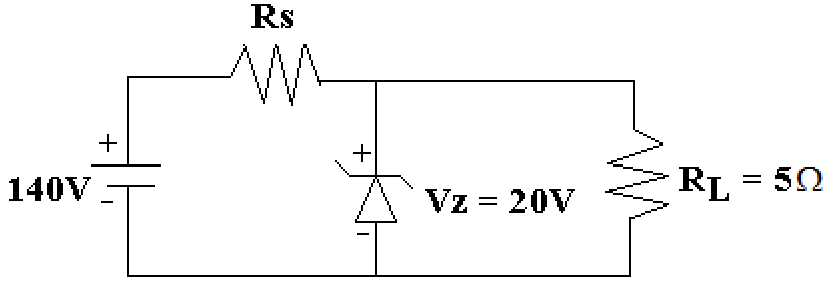

Fig.2

Answer:

here $V_Z = V_0 = 20$ Volt

$$I_L = \frac{V_0}{R_L} = \frac{20}{5} = 4\,A \quad 2$$

$$I_Z = 2\,A \quad 1$$

$$I_S = I_L + I_Z = 4 + 2 = 6\,A \quad 2$$

here $V = I_S R_S + V_Z$ 1

$$\text{so } R_S = \frac{V - V_Z}{I_S} \quad 1$$

$$= \frac{140 - 20}{6}$$

$$= \frac{120}{6} = 20\,\Omega \quad 1$$

Q.8 a. Explain input & output V-I characteristics of transistor in CE configuration. **(8)**

Answer:

Input CE Characteristics In CE configuration, i_B and v_{BE} are the input variables. The output variables are i_C and v_{CE}. We can use the circuit arrangement of Fig. 5.17 to determine the input characteristics of a *PNP* transistor (for an *NPN* transistor, terminals of all the batteries, milli-ammeters and voltmeters will have to be reversed). Typical input characteristics are shown in Fig. 5.18. They relate i_B to v_{BE} for different values of V_{CE}. These curves are similar to those obtained for CB configuration (Fig. 5.12). Note that the change in output voltage V_{CE} does not result in a large deviation of the curves. In fact, for the commonly used dc voltages, the effect of changing V_{CE} on input characteristics may be ignored.

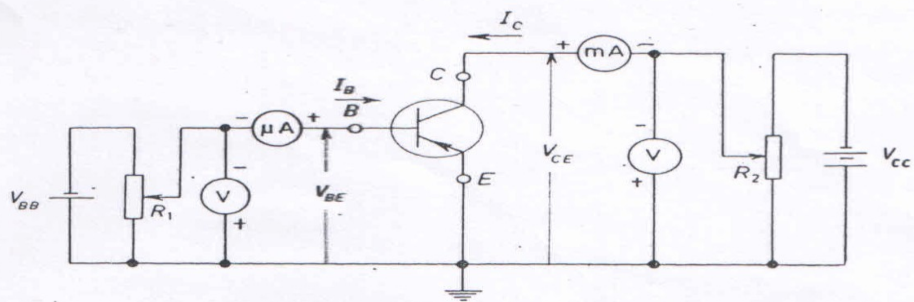

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Fig. 5.17 Circuit arrangements for determining the static characteristics of a *PNP* transistor, in CE configuration

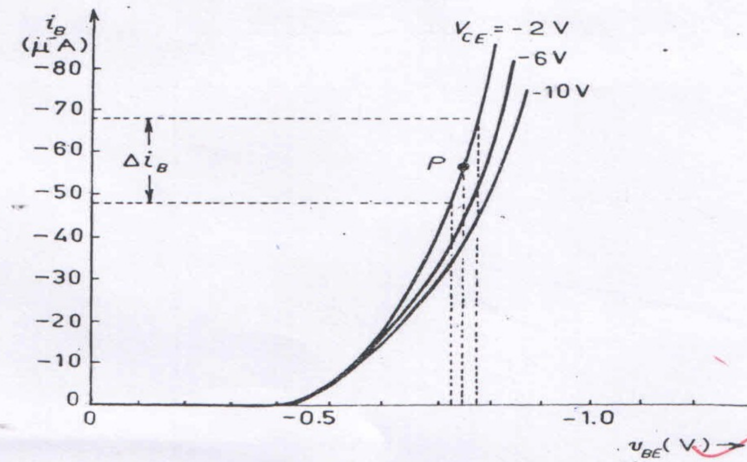

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Fig. 5.18 Common-emitter input characteristics of a *PNP* transistor

We can find out the *dynamic input resistance* of the transistor at a given voltage V_{BE}, from Fig. 5.18. It is given by the reciprocal of the slope of the curve at that point. That is,

$$r_i = \left.\frac{\Delta v_{BE}}{\Delta i_B}\right|_{V_{CE}=\text{const.}} \tag{5.18}$$

For example, the input resistance of the transistor at the point

2

$$V_{BE} = -0.75 \text{ V, and } V_{CE} = -2 \text{ V}$$

is calculated from Fig. 5.18, as follows·

$$r_i = \left.\frac{\Delta v_{BE}}{\Delta i_B}\right|_{V_{CE}=-2\text{V}} = \frac{0.78-0.72}{(68-48)\times10^{-6}} = \frac{0.06}{20\times10^{-6}} = 3 \text{ k}\Omega$$

The value of r_i is typically 1 kΩ, but can range from 800 Ω to 3 kΩ.

Output CE Characteristics From the circuit arrangement of Fig. 5.17, we can also determine the output characteristics of a *PNP* transistor. Figure 5.19 shows typical output characteristics of a *PNP* transistor. They relate the output current i_C, to the voltage between collector and emitter, v_{CE}, for various values of input current, I_B. Note that the quantities v_{CE}, i_C and I_B are all negative for a *PNP* transistor. If the transistor is *NPN* type, we reverse the terminals of the batteries V_{CC} and V_{BB}, so that v_{CE}, i_C and I_B become positive.

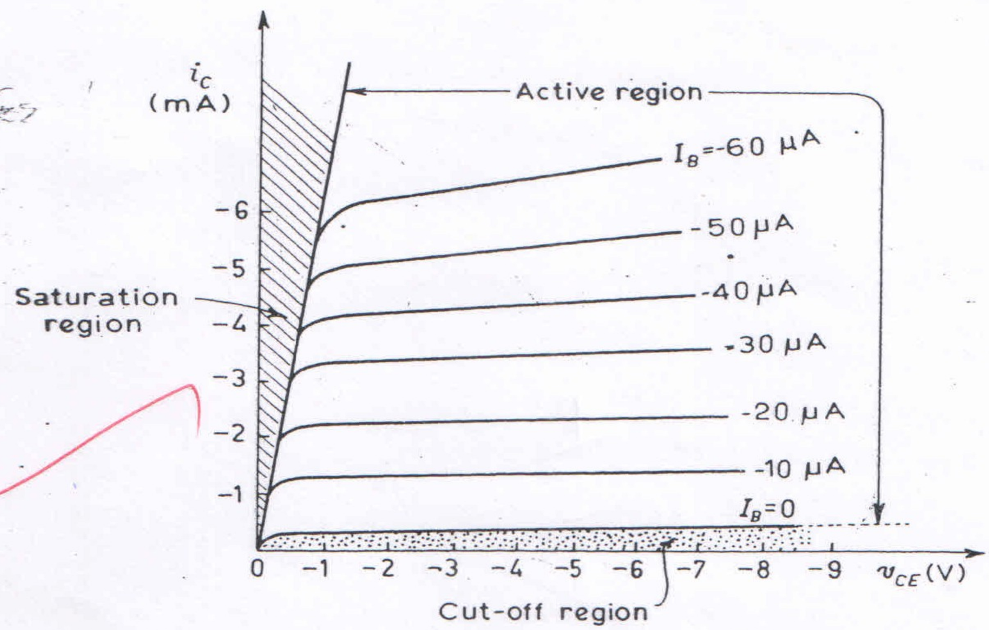

Fig. 5.19 Common-emitter output characteristics of a *PNP* transistor

A study of these output characteristics reveals following interesting points:

(i) In the active region, i_C increases slowly as v_{CE} increases. The slope of these curves is somewhat greater than the CB output characteristics (see Fig. 5.13). We know that β_{dc} is equal to the ratio I_C/I_B. For each curve of Fig. 5.19, the input current I_B is constant, but current i_C increases with v_{CE}. This indicates that β_{dc} increases with v_{CE}.

(ii) When v_{CE} falls below a few tenths of a volt, i_C decreases rapidly as v_{CE} decreases. This occurs as v_{CE} drops below the value of V_{BE}; the collector-base junction then becomes forward-biased. In this condition, both junctions of the transistor are forward-biased. The transistor is working in the *saturation region*. It is called saturation region, because the current I_C no longer depends upon the input current I_B.

(iii) In the active region, the collector current is β_{dc} times greater than the base current. Thus, small input current, I_B, produces a large output current I_C.

(iv) The collector current is not zero when I_B is zero. It has a value of I_{CEO}, the reverse leakage current. The current I_{CEO} is related with

b. With the help of circuit diagram, explain working of voltage divider bias and comments on thermal stability of this circuit. **(8)**

Answer:

7.6.4 Voltage Divider Biasing Circuit

This is the most widely used biasing circuit. It is shown in Fig. 7.25. Compare this circuit with the one shown in Fig. 7.19. Here, an additional resistor R_2 is connected between base and ground. The name "voltage divider" comes from the voltage divider formed by the resistors R_1 and R_2. By suitably selecting this voltage divider network, the operating point of the transistor can be made almost independent of beta (β). This is why this circuit is also called "biasing circuit independent of beta".

Approximate analysis To determine the operating point, we first consider the input section of the circuit, redrawn in Fig. 7.26.

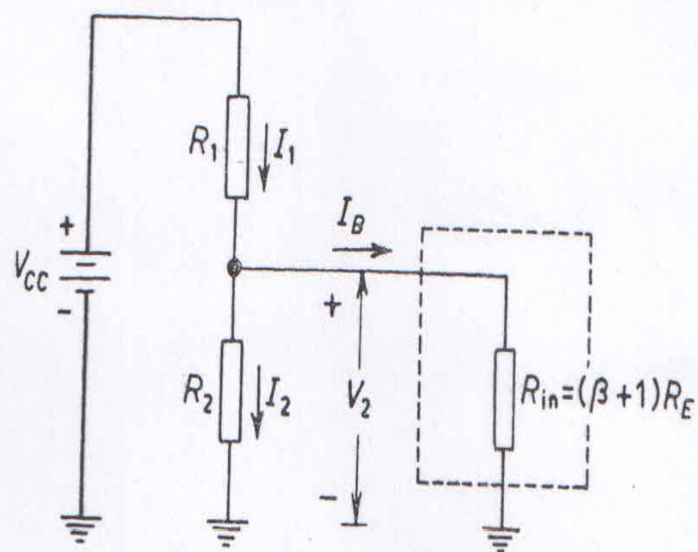

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Fig. 7.26 Input section of the voltage divider biasing circuit

We make a basic assumption: The base current I_B is very small compared to the currents in R_1 and R_2. That is

$$I_1 \simeq I_2 \gg I_B$$

The above assumption is valid because, in practice, the resistance seen looking into the base (R_{in}) is much larger than R_2. We can apply the voltage-divider theorem to find the voltage across the resistor R_2 (same as base voltage V_B),

$$V_B = V_2 = \frac{R_2}{R_1+R_2} \times V_{CC} \quad (7.22)$$

The voltage across the emitter resistor R_E equals the voltage across R_2 minus the base-to-emitter voltage V_{BE}. That is

$$V_E = V_2 - V_{BE}$$

The current in the emitter is then calculated from

$$I_E = \frac{V_E}{R_E} = \frac{V_2 - V_{BE}}{R_E} \quad (7.23)$$

The voltage at the collector (measured with respect to ground) V_C equals the supply voltage V_{CC} minus the voltage drop across R_C,

$$V_C = V_{CC} - I_C R_C$$

4

The collector-to-emitter voltage is then given as

$$V_{CE} = V_C - V_E = (V_{CC} - I_C R_C) - I_E R_E$$

or

$$V_{CE} \simeq V_{CC} - (R_C + R_E) I_C \quad (7.24)$$

since I_C and I_E are approximately equal.

Note that in the above analysis, nowhere does β appear in any equation. It means that the operating point does not depend upon the value of β of the transistor. This is why the voltage divider circuit is most widely used. In the mass production of transistors, one of the main problems is the wide variation in β. It varies from transistor to transistor of the same type. For example, the transistor AC127 has a minimum β of 50 and maximum β of 150 for an I_C of 10 mA and a temperature of 25 °C. If this biasing circuit is used, no problem is faced on replacement of the transistor in the circuit. The operating point remains where it was fixed in the original design.

Q.9 Draw circuit diagram & explain working of the following: **(16)**

(i) Two stage CE amplifier

(ii) Phase shift oscillator

Answer:

~~9.3.1~~ Resistance-Capacitance Coupling

Figure 9.2 shows how to couple two stages of amplifiers using resistance-capacitance (*RC*) coupling scheme. This is the most widely used method. In this scheme, the signal developed across the collector resistor R_C of the first stage is coupled to the base of the second stage through the capacitor C_C. The coupling capacitor C_C blocks the dc voltage of the first stage from reaching the base of the second stage. In this way, the dc biasing of the next stage is not interfered with. For this reason, the capacitor C_C is also called a *blocking capacitor*.

Some loss of the signal voltage always occurs due to the drop across the coupling capacitor. This loss is more pronounced when the frequency of the input signal is low. (This point is discussed in more detail in Sec. 9.4.1). This is the main drawback of this coupling scheme. However, if we are interested in amplifying ac signals of frequencies greater than about 10 Hz, this coupling is the best solution. It is the most convenient and least expensive way to build a multi-stage amplifier.

4

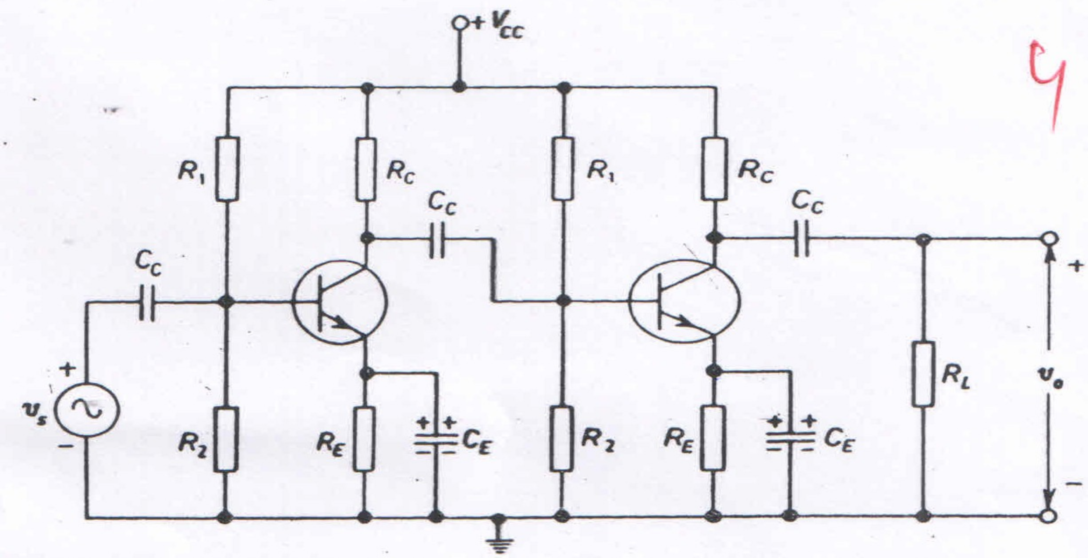

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Fig. 9.2 Two-stage *RC*-coupled amplifier using transistors

RC coupling scheme finds applications in almost all audio small-signal amplifiers used in record players, tape recorders, public-address systems, radio receivers, television receivers, etc.

Triode (or pentode) amplifiers can also be cascaded by *RC* coupling. Figure 9.3 illustrates how *RC* coupling is used for two stages of triode amplifiers. Here, the cathode resistor R_K and capacitor C_K provide the self bias in the circuit. The operating point of a triode amplifier is independent of temperature. Therefore, the need of stabilization of the operating point does not arise. The circuit is much simpler than the one using transistors. But it requires high dc voltage (of the order of 300 V) supply.

~~13.6.2~~ Phase-Shift Oscillator

Figure 13.11 shows a phase-shift oscillator using a vacuum triode. A bipolar transistor or an FET could also be used in the circuit. Here, the combination $R_K C_K$ provides self-bias for the amplifier. As shown in the figure, the phase of the signal at the input (for the time being, we assume the presence of the signal at the input) gets reversed when it is amplified by the amplifier. The output of the amplifier goes to a feedback network. The feedback network consists of three identical *RC* sections. Each *RC* section provides a phase shift of 60°. Thus a total of $60° \times 3 = 180°$ phase shift is provided by the feedback network. The output of this network is now in the same phase as the originally assumed input to the amplifier, as shown in figure. If the condition $A\beta = 1$ is satisfied, oscillations will be maintained. 3

It may be shown by a straightforward (but a little complicated) analysis that the frequency at which the *RC* network provides exactly 180° phase-shift is given by

$$f_o = \frac{1}{2\pi RC\sqrt{6}} \tag{13.6}$$

This must then be the *frequency of oscillation*. Also, it can be shown that at this frequency, the feedback factor of the *RC* network is 2

$$\beta = \frac{1}{29} \tag{13.7}$$

This equation has special significance. For self starting the oscillations, we must have $A\beta > 1$. This means the gain *A* of the amplifier must be greater than 29; only then oscillations can start.

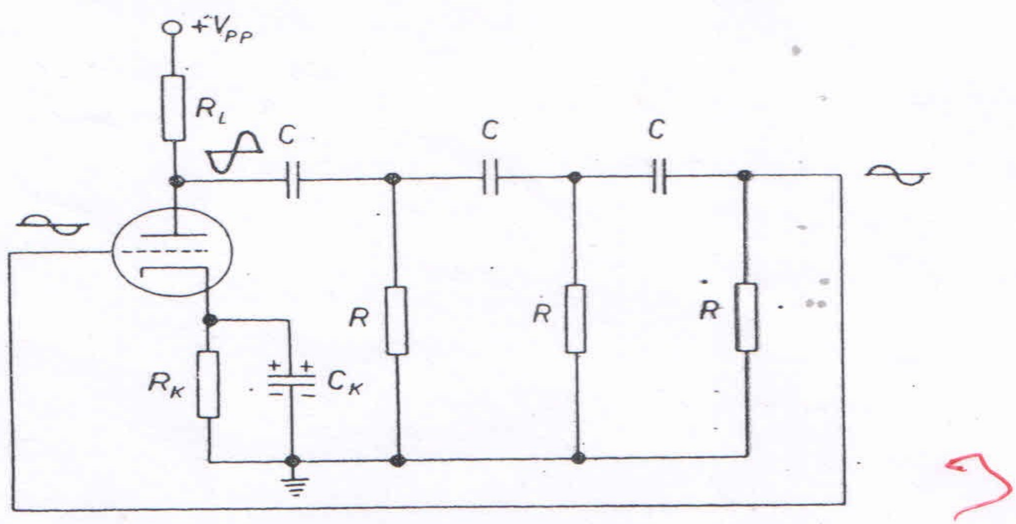

Fig. 13.11 Phase-shift oscillator

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