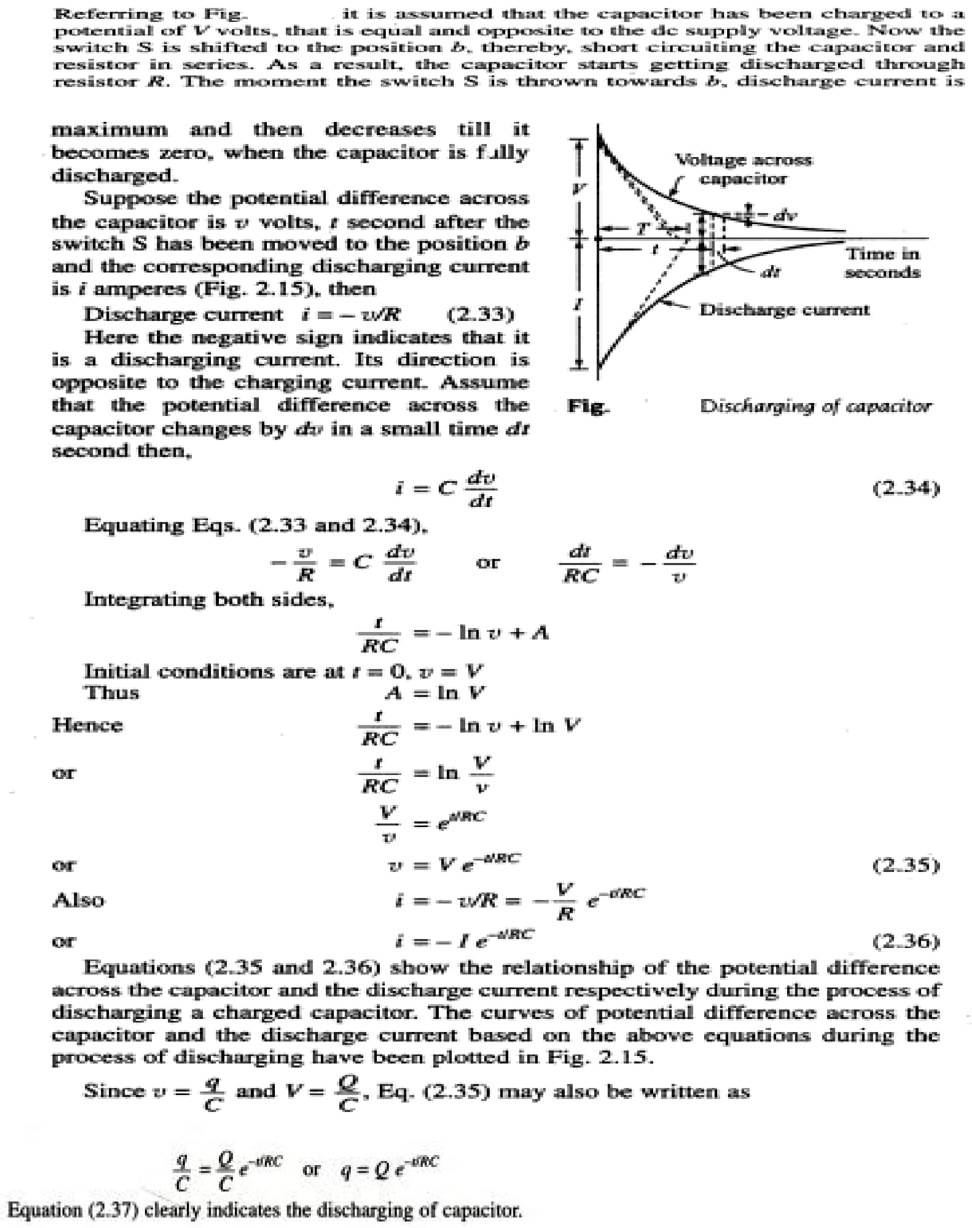
Q.2 a. Derive an expression for the current flowing at any instant during the discharge of a capacitor C across a resistor R.

Answer:



Referring to Fig. it is assumed that the capacitor has been charged to a potential of V volts, that is equal and opposite to the dc supply voltage. Now the switch S is shifted to the position b, thereby, short circuiting the capacitor and resistor in series. As a result, the capacitor starts getting discharged through resistor R. The moment the switch S is thrown towards b, discharge current is maximum and then decreases till it becomes zero, when the capacitor is fully discharged.

Suppose the potential difference across the capacitor is v volts, t second after the switch S has been moved to the position b and the corresponding discharging current is i amperes (Fig. 2.15), then

Discharge current $i = -v/R$ (2.33)

Here the negative sign indicates that it is a discharging current. Its direction is opposite to the charging current. Assume that the potential difference across the capacitor changes by dv in a small time dt second then,

Fig. *Discharging of capacitor*

$$i = C\frac{dv}{dt} \qquad (2.34)$$

Equating Eqs. (2.33 and 2.34),

$$-\frac{v}{R} = C\frac{dv}{dt} \quad \text{or} \quad \frac{dt}{RC} = -\frac{dv}{v}$$

Integrating both sides,

$$\frac{t}{RC} = -\ln v + A$$

Initial conditions are at $t = 0$, $v = V$

Thus $A = \ln V$

Hence $$\frac{t}{RC} = -\ln v + \ln V$$

or $$\frac{t}{RC} = \ln\frac{V}{v}$$

$$\frac{V}{v} = e^{t/RC}$$

or $$v = V\,e^{-t/RC} \qquad (2.35)$$

Also $$i = -v/R = -\frac{V}{R}\,e^{-t/RC}$$

or $$i = -I\,e^{-t/RC} \qquad (2.36)$$

Equations (2.35 and 2.36) show the relationship of the potential difference across the capacitor and the discharge current respectively during the process of discharging a charged capacitor. The curves of potential difference across the capacitor and the discharge current based on the above equations during the process of discharging have been plotted in Fig. 2.15.

Since $v = \frac{q}{C}$ and $V = \frac{Q}{C}$, Eq. (2.35) may also be written as

$$\frac{q}{C} = \frac{Q}{C}e^{-t/RC} \quad \text{or} \quad q = Q\,e^{-t/RC}$$

Equation (2.37) clearly indicates the discharging of capacitor.

b. The coil of a moving coil instrument is wound with 50 turns of wire. The flux density in the gap is 0.06 Wb/m^2 and the effective length of the coil side in the gap is 4cm. find the force acting on each side of the coil when the current is 40mA.

Answer:

Solution:

Force acting on one wire = BIl

Flux density in the gap, $B = 0.06\ \text{Wb/m}^2$

Current in the coil, $I = 40$ mA

$= 40 \times 10^{-3}$ A

Effective length of the coil side = 4 cm

= 0.04 m

Thus, force acting on one wire of the coil $= 0.06 \times 40 \times 10^{-3} \times 0.04$

$= 96 \times 10^{-6}$ N

Each wire of the coil will contribute to the total force F acting on a coil side.

Coil is wound with 50 turns of wire.

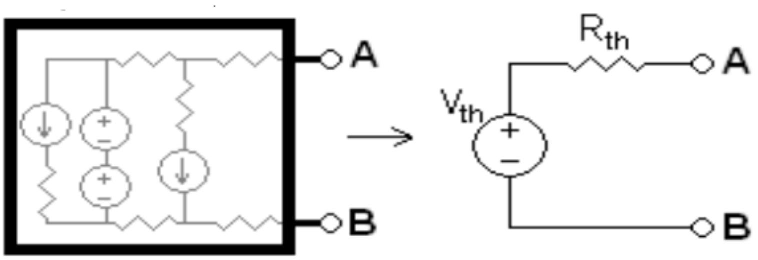
Thus, force acting on each coil side

$= 50 \times 96 \times 10^{-6} = 4.8 \times 10^{-3}$ N

Q.3 a. State and explain Thevenin's Theorem with suitable example.

Answer:

In circuit theory, Thévenin's theorem for linear electrical networks states that any combination of voltage sources, current sources, and resistors with two terminals is electrically equivalent to a single voltage source V in series with a single series resistor R. Those sources mentioned above can be either independent or dependent.



Thevenin's Theorem Review

Analyze Procedure:

1.Calculate the output voltage, V, when in open circuit condition (no load resistor—meaning infinite resistance). This is VTh.

2.Calculate the output current, IAB, when the output terminals are short circuited (load resistance is 0). RTh equals VTh divided by this IAB.

Step 2 could also be thought of as:

2a. Replace voltage sources with short circuits(wires), and current sources with open circuits(disconnections).

2b. Calculate the resistance between terminals A and B. This is RTh.

Thevenin's Voltage Example

- Find equivalent voltage source in new circuit
- Solution:

Between terminals A and B, we need to find out V. Since it's open circuit and there is no
current going through R1.Treat R1 as wire. ciucuit become simple three series resistor and
a voltage source.

Secondly, find the current.

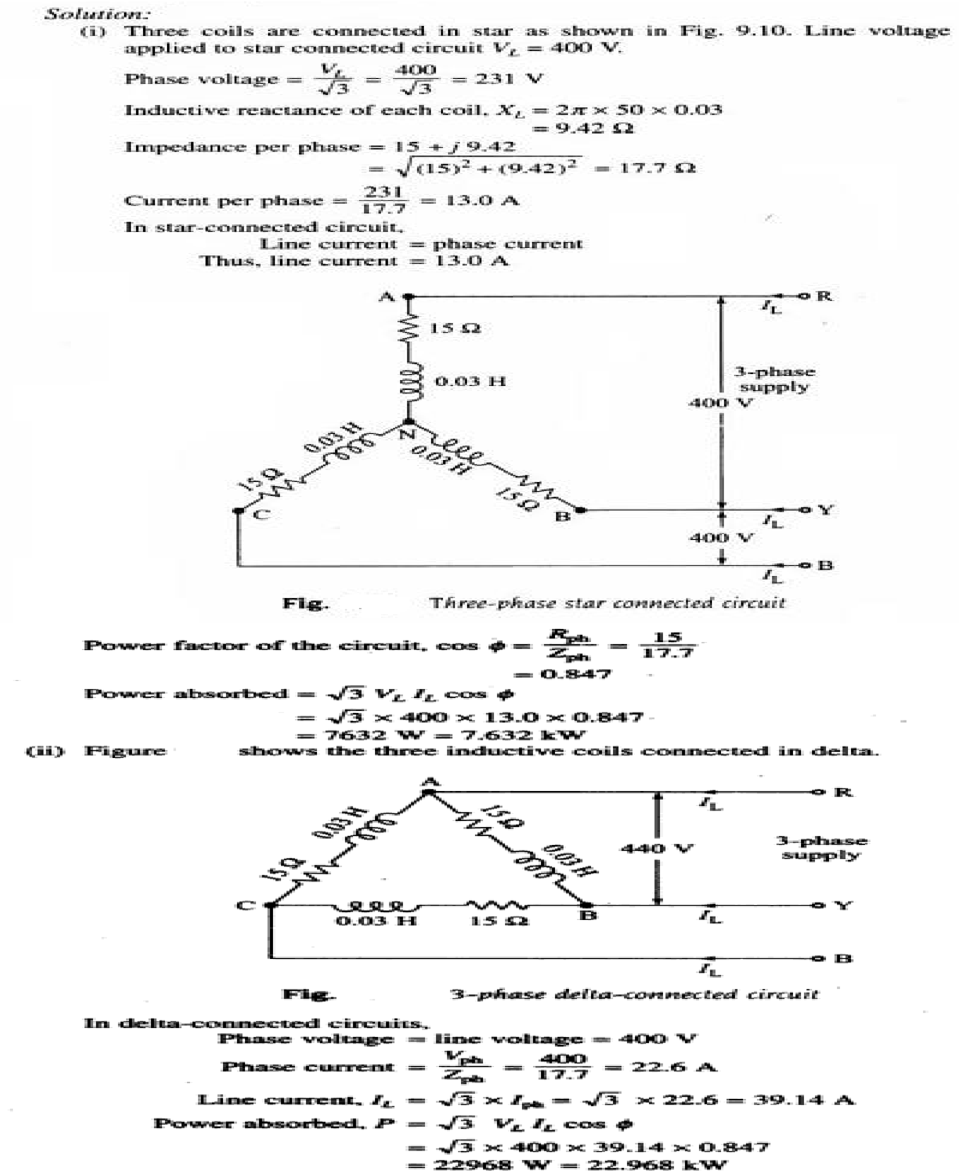
Thirdly, find the sum voltage across R3 and R2. That's the answer we're looking for

Example

b. Three inductive coils each with a resistance of 15 ohms and an inductance of 0.03 H are connected (i) in star and (ii) in delta, to 3-phase, 400V, 50Hz supply.

Calculate for each of the above case (i) phase current and line current and (ii) total power absorbed.

Answer:



Solution:

(i) Three coils are connected in star as shown in Fig. 9.10. Line voltage applied to star connected circuit $V_L = 400$ V.

$$\text{Phase voltage} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 231 \text{ V}$$

$$\text{Inductive reactance of each coil, } X_L = 2\pi \times 50 \times 0.03 = 9.42\ \Omega$$

$$\text{Impedance per phase} = 15 + j\,9.42 = \sqrt{(15)^2 + (9.42)^2} = 17.7\ \Omega$$

$$\text{Current per phase} = \frac{231}{17.7} = 13.0 \text{ A}$$

In star-connected circuit,

Line current = phase current

Thus, line current = 13.0 A

Fig. *Three-phase star connected circuit*

$$\text{Power factor of the circuit, } \cos\phi = \frac{R_{ph}}{Z_{ph}} = \frac{15}{17.7} = 0.847$$

$$\text{Power absorbed} = \sqrt{3}\,V_L I_L \cos\phi = \sqrt{3} \times 400 \times 13.0 \times 0.847 = 7632 \text{ W} = 7.632 \text{ kW}$$

(ii) Figure shows the three inductive coils connected in delta.

Fig. *3-phase delta-connected circuit*

In delta-connected circuits,

Phase voltage = line voltage = 400 V

$$\text{Phase current} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{17.7} = 22.6 \text{ A}$$

$$\text{Line current, } I_L = \sqrt{3} \times I_{ph} = \sqrt{3} \times 22.6 = 39.14 \text{ A}$$

$$\text{Power absorbed, } P = \sqrt{3}\,V_L I_L \cos\phi = \sqrt{3} \times 400 \times 39.14 \times 0.847 = 22968 \text{ W} = 22.968 \text{ kW}$$

Q.4 a. Draw the connection diagram of shunt and series DC motors and explain.

Answer:

DC Series Motor

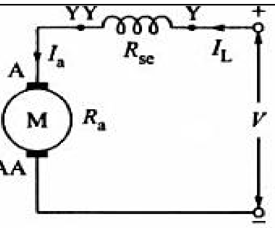


Fig. 17.28 Schematic diagram of series motor

The schematic diagram of a dc series motor is shown in Fig. 17.28.

Armature current,

I_a = series field current, $I_{se} = I_L$

Back emf, $E_b = V - I_a (R_a + R_{se})$ (17.28)

The series motor is an ideal motor where a high torque is required at low speeds and a moderate or small torque at high speeds. These motors are mainly used for operating cranes, hoists, elevators, electric trains, railway cars, etc. In their fractional horse power ratings, these are used for fans, vacuum cleaner, sewing machines and other applications in which the load is directly connected to the motor.

Shunt machine

- The armature and field winding are connected in parallel.
- The armature voltage and field voltage are the same.

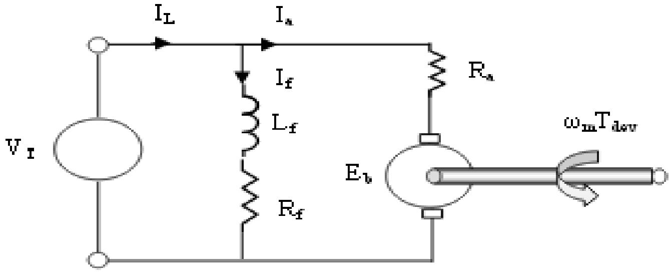


Figure Shunt DC Motor

Total current drawn from the supply, $I_L = I_f + I_a$
Total input power = $V_T I_L$

b. A 200 V dc shunt motor is taking a current of 70 A and runs at 500 rpm. The motor resistances are $Ra = 0.2\Omega$ and $Rsh = 100\Omega$. What resistance must be inserted in the armature circuit to reduce its speed to 350 RPM? Assume armature current is same.

Answer:

Here $I_L = 70A$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{100} = 2A$$

So $I_a = I_L - I_{sh} = 70 - 2 = 68A = I_{a1}$

$N_1 = 500\,\text{rpm}$

Back efm $E_{b1} = V_{a1}R_a$ = 200-(68x.2) = 186. 4Ω

Let Resistance (R) inserted in armature circuit

Now $N_2 = 350\,\text{rpm}$

& $E_{b2} = V - I_{a2}(R_a + R)$ = 200–68(0.2+R)

By speed equation

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$$

$$\frac{350}{500} = \frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} = \frac{200 - 68(0.2 + R)}{186.4}$$

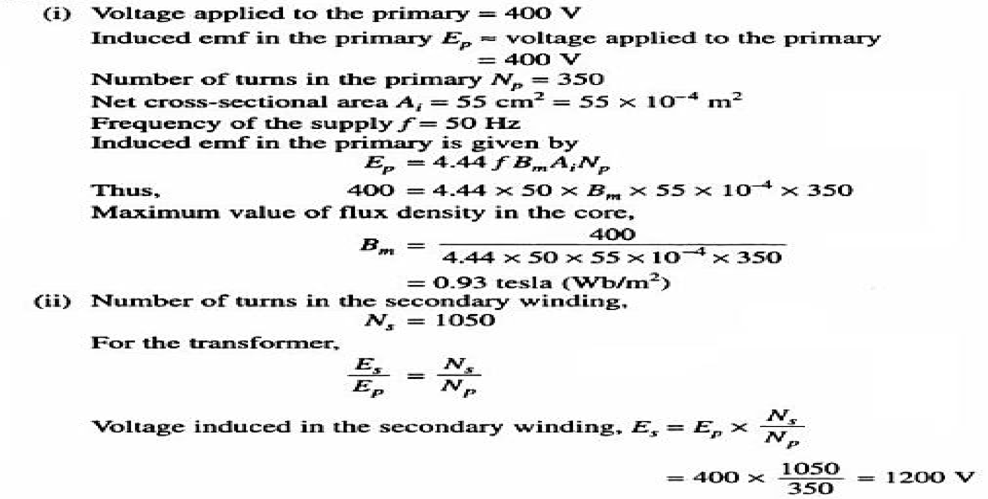
So R = 0.82 Ω

Q.5 a. A single-phase transformer has 350 primary and 1050 secondary turns. The net cross-sectional area of the core is 55cm^2. If the primary winding be connected to a 400V, 50Hz single phase supply, calculate:

(i) maximum value of flux density in the core

(ii) voltage induced in the secondary winding (

Answer:



(i) Voltage applied to the primary = 400 V

Induced emf in the primary E_p = voltage applied to the primary

$= 400$ V

Number of turns in the primary $N_p = 350$

Net cross-sectional area $A_i = 55\ \text{cm}^2 = 55 \times 10^{-4}\ \text{m}^2$

Frequency of the supply $f = 50$ Hz

Induced emf in the primary is given by

$$E_p = 4.44\, f B_m A_i N_p$$

Thus, $400 = 4.44 \times 50 \times B_m \times 55 \times 10^{-4} \times 350$

Maximum value of flux density in the core,

$$B_m = \frac{400}{4.44 \times 50 \times 55 \times 10^{-4} \times 350}$$

$= 0.93$ tesla (Wb/m^2)

(ii) Number of turns in the secondary winding,

$$N_s = 1050$$

For the transformer,

$$\frac{E_s}{E_p} = \frac{N_s}{N_p}$$

Voltage induced in the secondary winding, $E_s = E_p \times \frac{N_s}{N_p}$

$$= 400 \times \frac{1050}{350} = 1200\ \text{V}$$

b. A 3 phase, 4 pole, 50 Hz, 400V, 50hp star-connected induction motor is operating at a slip of 4 per cent, in order to deliver rated output power. Find out the following:

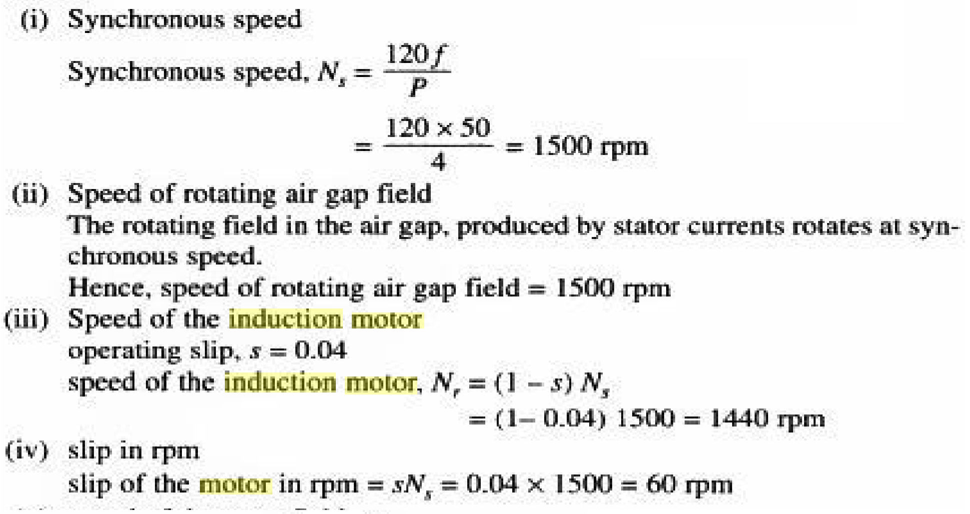
(i) synchronous speed

(ii) speed of rotating air gap field

(iii) speed of the induction motor

(iv) frequency of the rotor induced emf

Answer:



(i) Synchronous speed

Synchronous speed, $N_s = \frac{120f}{P}$

$$= \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

(ii) Speed of rotating air gap field

The rotating field in the air gap, produced by stator currents rotates at synchronous speed.

Hence, speed of rotating air gap field = 1500 rpm

(iii) Speed of the induction motor

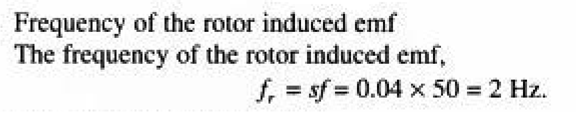
operating slip, $s = 0.04$

speed of the induction motor, $N_r = (1 - s)\, N_s$

$$= (1- 0.04)\, 1500 = 1440 \text{ rpm}$$

(iv) slip in rpm

slip of the motor in rpm $= sN_s = 0.04 \times 1500 = 60$ rpm



Frequency of the rotor induced emf

The frequency of the rotor induced emf,

$$f_r = sf = 0.04 \times 50 = 2 \text{ Hz.}$$

Q.6 a. With the help of energy band diagram explain how conduction takes place in conductors, semiconductors and insulators.

Answer:

On the basis of energy band materials are classified as insulators, conductors, and semiconductors.

Insulators:

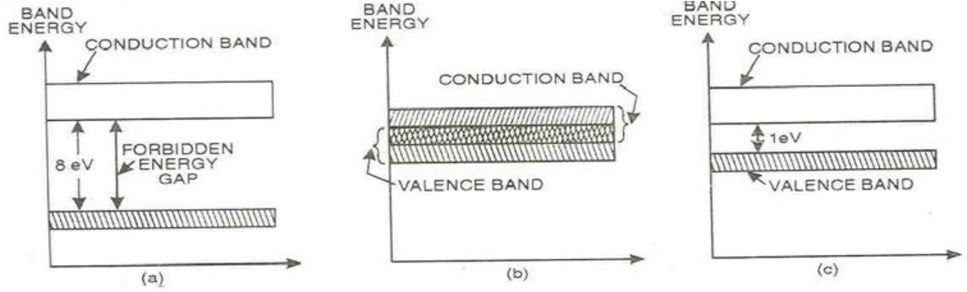
Substance like wood, glass, which do not allow the passage of current through them are known as insulators. The valence band of these substances is full whereas the conduction band is completely empty. The forbidden energy gap between valence band and conduction band is very large (8ev) as shown in the fig (a). Therefore a large amount of energy, i.e. a very high electric field is required to push the valence electrons to the conduction band. This is the reason, why such materials under ordinary conditions do not conduct at all and are designated as insulators.

Conductors:

Substances like copper, aluminium, silver which allow the passage of current through them are conductors. The valence band of these substances overlaps the conduction band as shown in fig (b). Due to this overlapping, a large number of free electrons are available for conduction. This is the reason, why aslight potential difference applied across them causes a heavy flow of current through them.

Semiconductors:

Substances like carbon, silicon, germanium whose electrical conductivity lies in between the conductors and insulators are known as semiconductors. The valence band of these substances is almost filled, but the conduction band is almost empty. The forbidden energy gap between valence and conduction band is very small (1ev) as shown in fig (c). Therefore comparatively a smaller electric field is required to push the valence electrons to the conduction band. This is the reason, why such materials under ordinary conditions do not conduct current and behaves as an insulator. Even at room temperature, when some heat energy is imparted to the valence electrons, a few of them cross over to the conduction band imparting minor conductivity to the semiconductors. As the temperature is increased, more valence electrons cross over to the conduction band and the conductivity of the material increases. Thus these materials have negative temperature co-efficient of resistance.



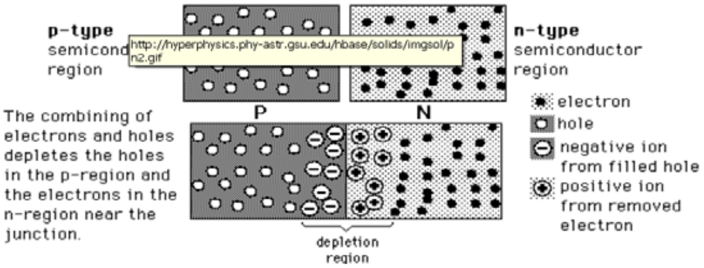
b. What is P-N junction? Explain the formation of potential barrier and depletion layer without external voltage. (

Answer:

A p–n junction is a junction formed by joining p-type and n-type semiconductors together in very close contact. The term junction refers to the boundary interface where the two regions of the semiconductor meet. If they were constructed of two separate pieces this would introduce a grain boundary, so p–n junctions are more often created in a single crystal of semiconductor by doping, for example by ion implantation, diffusion of dopants, or by epitaxy (growing a layer of crystal doped with one type of dopant on top of a layer of crystal doped with another type of dopant).

Formation of the Depletion Region.

At the instant of the PN junction formation free electrons near the junction diffuse across the junction into the P region and combine with holes.



Filling a hole makes a negative ion and leaves behind a positive ion on the N side.

These two layers of positive and negative charges form the depletion region, as the region near the junction is depleted of charge carriers.

As electrons diffuse across the junction a point is reached where the negative charge repels any further diffusion of electrons. The depletion region now acts as a barrier.

Barrier Potential.

The electric field formed in the depletion region acts as a barrier. External energy must be applied to get the electrons to move across the barrier of the electric field. The potential difference required to move the electrons through the electric field is called the barrier potential. Barrier potential of a PN junction depends on the type of semiconductor material, amount of doping and temperature. This is approximately 0.7V for silicon and 0.3V for germanium

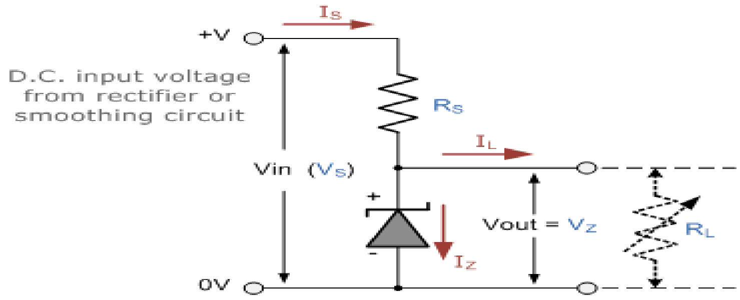
Q.7 a. With the help of neat diagram, explain zener diode voltage regulator.

Answer:

The Zener Diode Regulator

Zener Diodes can be used to produce a stabilised voltage output with low ripple under varying load current conditions. By passing a small current through the diode from a voltage source, via a suitable current limiting resistor (RS), the zener diode will conduct sufficient current to maintain a voltage drop of Vout. We remember from the previous tutorials that the DC output voltage from the half or full-wave rectifiers contains ripple superimposed onto the DC voltage and that as the load value changes so to does the average output voltage. By connecting a simple zener stabiliser circuit as shown below across the output of the rectifier, a more stable output voltage can be produced.

Zener Diode Regulator



The resistor, RS is connected in series with the zener diode to limit the current flow through the diode with the voltage source, VS being connected across the combination. The stabilised output voltage Vout is taken from across the zener diode. The zener diode is connected with its cathode terminal connected to the positive rail of the DC supply so it is reverse biased and will be operating in its breakdown condition. Resistor RS is selected so to limit the maximum current flowing in the circuit.

With no load connected to the circuit, the load current will be zero, (IL = 0), and all the circuit current passes through the zener diode which inturn dissipates its maximum power. Also a small value of the series resistor RS will result in a greater diode current when the load resistance RL is connected and large as this will increase the power dissipation requirement of the diode so care must be taken when selecting the appropriate value of series resistance so that the zeners maximum power rating is not exceeded under this no-load or high-impedance condition.

The load is connected in parallel with the zener diode, so the voltage across RL is always the same as the zener voltage, (VR = VZ). There is a minimum zener current for which the stabilization of the voltage is effective and the zener current must stay above this value operating under load within its breakdown region at all times. The upper limit of current is of course dependant upon the power rating of the device. The supply voltage VS must be greater than VZ.

One small problem with zener diode stabiliser circuits is that the diode can sometimes generate electrical noise on top of the DC supply as it tries to stabilise the voltage. Normally this is not a problem for most applications but the addition of a large value decoupling capacitor across the zeners output may be required to give additional smoothing.

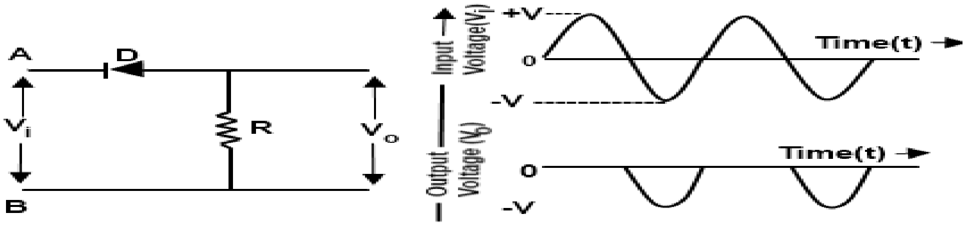
Then to summarise a little. A zener diode is always operated in its reverse biased condition. A voltage regulator circuit can be designed using a zener diode to maintain a constant DC output voltage across the load in spite of variations in the input voltage or changes in the load current. The zener voltage regulator consists of a current limiting resistor RS connected in series with the input voltage VS with the zener diode connected in parallel with the load RL in this reverse biased condition. The stabilized output voltage is always selected to be the same as the breakdown voltage VZ of the diode.

b. Sketch circuit diagram and input-output waveforms of a negative series clipper circuit and positive shunt clipper circuits.

Answer:

SERIES NEGATIVE CLIPPER

In a series negative clipper a diode is connected in a direction appositive to that of a positive clipper Fig 3 shows the circuit of a negative clipper.



(a) Positive Clipper (b) Output Waveform

Figure 1:Series Positive Clipper

During the positive half cycle pf the voltage, the terminal A is positive with respect to the terminal B There for the diode is forward biased and it acts it as a closed switch As a result ,all the input voltage appears across the resistor as shown in Fig 3(b). During the negative half cycle of the input voltage, the terminal B is positive with respect to the terminal A. Therefore the diode is reverse biased and it acts as an open switch, Thus there is no voltage drop across the resistor during the negative half cycle as shown in the output waveform.

It may be observed that if it is desired to remove or clip the negative half -cycle of the input , the only thing is to be done is to reverse the polarities of the diode in the circuit shown in Fig 1 such a clipper is then called a series negative clipper

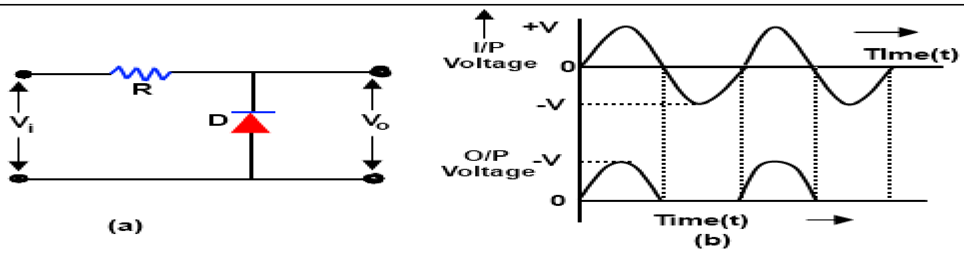


Figure 7: Shunt (parallel) Negative Clipper

Q.8 a. Sketch and explain the shape of the common emitter input and output characteristics. Explain how the characteristics are determined experimentally **(**

Answer:

COMMON EMITTER CHARACTERISTICS

The characteristic curves of the common emitter configuration are shown below. The input characteristic curve shows that the base-emitter junction must be biased at least by 500 mV before current will flow.

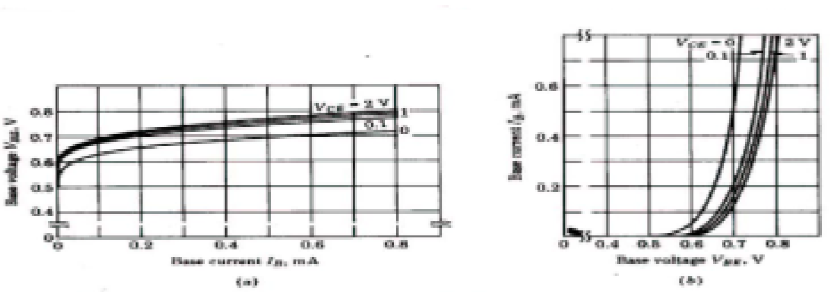


Figure (a) Common-emitter input characteristics (V_{BE} versus I_B) for the 2N2222A n-p-n transistor. (b) The same characteristics plotted with V_{BE} horizontal and I_B vertical. Note the similarity to a diode curve.

COMMON-EMITTER INPUT CHARACTERISTICS

The output curves show typical collector currents dependent upon the base current supplied by the input circuitry and the voltage drop measured across the collector and emitter terminals.

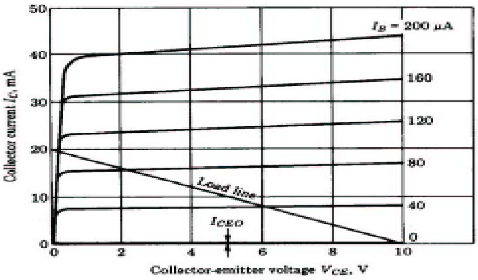


Figure Common-emitter output characteristics of a 2N2222A n-p-n silicon transistor. A load line corresponding to V_{CC} = 10 V and R_L = 500 is superimposed.

COMMON-EMITTER OUTPUT CHARACTERISTICS

To make the transistor functional you select resistors that create the base and collector currents, and v_{CE} voltage drop to make it perform to your specifications. If you measure the voltage across the collector and emitter terminals (V_{CE}) and you measure the power supply value (V_{CC}), the collector current (I_C) is zero and the transistor is said to be in the cutoff mode. If V_{CE} is zero volts then I_C is at the load line maximum and is said to be in saturation mode.

b. Compare the performance and characteristics of CB, CC and CE amplifiers.

Answer:

Transistor Configuration Comparison Chart

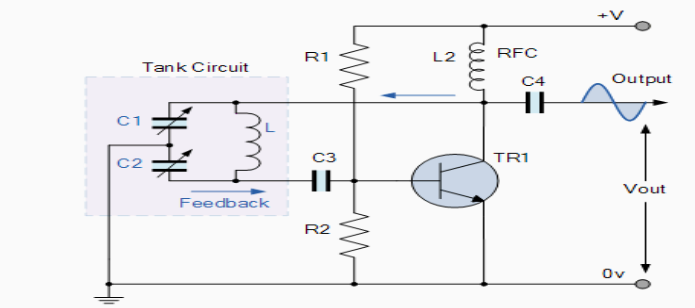
AMPLIFIER TYPE	**COMMON BASE**	**COMMON EMITTER**	**COMMON COLLECTOR**
INPUT/OUTPUT PHASE RELATIONSHIP	0°	180°	0°
VOLTAGE GAIN	HIGH	MEDIUM	LOW
CURRENT GAIN	LOW(α)	MEDIUM(β)	HIGH(γ)
POWER GAIN	LOW	HIGH	MEDIUM
INPUT RESISTANCE	LOW	MEDIUM	HIGH
OUTPUT RESISTANCE	HIGH	MEDIUM	LOW

Q.9 a. Draw circuit diagram and frequency response curve of single stage CE amplifier. Also discuss its working.

Answer: Refer article 12.1 of Text Book-II

b. Draw the circuit of Colpitt's oscillator and explain its operation.

Answer:



The transistor amplifiers emitter is connected to the junction of capacitors, C1 and C2 which are connected in series and act as a simple voltage divider. When the power supply is firstly applied, capacitors C1 and C2 charge up and then discharge through the coil L. The oscillations across the capacitors are applied to the base-emitter junction and appear in the amplified at the collector output.

The amount of feedback depends on the values of C1 and C2 with the smaller the values of C the greater will be the feedback.

The required external phase shift is obtained in a similar manner to that in the Hartley oscillator circuit with the required positive feedback obtained for sustained un-damped oscillations. The amount of feedback is determined by the ratio of C1 and C2 which are generally "ganged" together to provide a constant amount of feedback so as one is adjusted the other automatically follows. The frequency of oscillations for a Colpitts oscillator is determined by the resonant frequency of the LC tank circuit and is given as:

$$f_r = \frac{1}{2\pi\sqrt{LC_T}}$$

where C_T is the capacitance of C1 and C2 connected in series and is given as:.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \quad \text{or} \quad C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

The configuration of the transistor amplifier is of a common emitter configuration with the output signal 180^o out of phase with regards to the input signal. The additional 180^o phase shift require for oscillation is achieved by the fact that the two capacitors are connected together in series but in parallel with the inductive coil resulting in overall phase shift of the circuit being zero or 360^o.

Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the capacitor acts as a DC-blocking capacitors. The radio-frequency choke (RFC) is used to provide a high reactance (ideally open circuit) at the frequency of oscillation, (fr) and a low resistance at DC.

TEXT BOOKS

I. V.N. Mittle and Arvind Mittal, ‘Basic Electrical Engineering’, Tata McGraw-Hill Publishing Company Limited, 2nd edition, 2006.
II. Electronic Devices and Circuits, David A Bell, Fourth Edition, PHI (2006).