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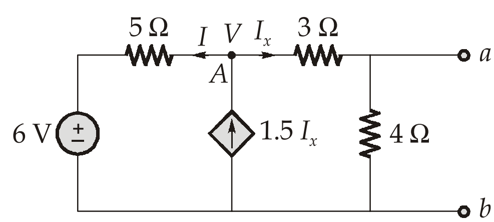
Detailed Solutions

SSC-JE 2018 Mains Test Series (PAPER-II)

Electrical Engineering Test No : 1

Q.1 (a) Solution:

To get V_{th} we determine voltage drop in 4 Ω



Applying KCL at node A, we get

$$I = 0.5\, I_x$$

$$\frac{V-6}{5} = 0.5\frac{V}{7}$$

$$7\, V - 42 = 2.5\, \text{V}$$

$$4.5\, V = 42$$

$$V = \frac{84}{9}\, \text{V}$$

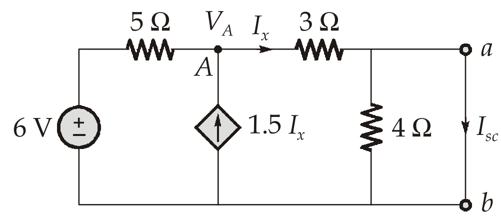
Applying voltage division rule,

$$V_{\text{th}} = V_{ab} = \frac{84}{9} \times \frac{4}{7} = 5.33\ \text{V}$$

To get R_{th}

We find I_{SC} then apply, $$R_{\text{th}} = \frac{V_{th}}{I_{SC}}$$

For I_{SC}



Applying KCL at node A, we get

$$\frac{V_A - 6}{5} + I_x = 1.5\, I_x$$

Put, $$V_A = 3I_x$$

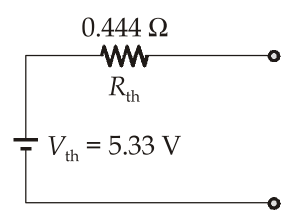
$$\frac{3I_x - 6}{5} = 0.5\, I_x$$

$\Rightarrow$ $$3I_x - 6 = 2.5\, I_x$$

$$0.5\, I_x = 6$$

$$I_{SC} = I_x = 12 \text{ A}$$

$$R_{\text{th}} = \frac{V_{th}}{I_{SC}} = \frac{5.33}{12} = 0.444\ \Omega$$



Q.1 (b) Solution:

Let balanced load is star connected and V and I be the phase voltage and phase current respectively cos ϕ is the power factor of the load.

Phase voltage, $V = 231$ V

and phase current, $I = 30$ A

If the first case, the wattmeter measures the power in one phase,

$\therefore$ $$VI \cos\phi = 5.54 \times 10^3$$

(or) $$\cos\phi = \frac{5.54 \times 10^3}{231 \times 30} = 0.8$$

and $$\sin\phi = 0.6$$

When the current coil is connected in the R phase and the pressure coil circuit is connected across the Y and B phases, reading of wattmeter is:

$$= V_{YB} I_R \cos(90 - \phi) = \sqrt{3} VI \sin\phi$$

But $VI \sin\phi$ is the reactive power of each phase and therefore the wattmeter indicates $\sqrt{3} \times$ Reactive power of each phase

$$\text{Magnitude of reading} = \sqrt{3} \times 231 \times 30 \times 0.6 \times 10^{-3} = 7.2 \text{ kW}$$

Q.1 (c) Solution:

$$E_a = K_a \phi N$$

$$\phi = K_a\left[\frac{E_a}{N}\right] = K_a\left[\frac{V - I_a R_a}{N}\right]$$

$$\phi_{(\text{no load})} = K_a\left[\frac{250 - 1.6 \times 0.7}{1250}\right] = 0.2\, K_a$$

$$\phi_{(\text{load})} = K_a\left[\frac{250 - 40 \times 0.7}{1150}\right] = 0.193\, K_a$$

$$\text{Reduction in } \phi \text{ due to armature reaction} = \frac{0.2 - 0.193}{0.2} = 0.035 \text{ or } 3.5\%$$

Q.1 (d) Solution:

$$i(t) = \begin{cases} 5t, & 0 < t < 2 \\ -10, & 2 < t < 4 \end{cases}$$

The rms value is,

$$I_{\text{rms}} = \sqrt{\frac{1}{T}\int_0^T i^2 dt}$$

$$= \sqrt{\frac{1}{4}\left[\int_0^2 (5t)^2 dt + \int_2^4 (-10)^2 dt\right]}$$

$$= \sqrt{\frac{1}{4}\left[\frac{25t^3}{3}\Big|_0^2 + 100t\Big|_2^4\right]} = \sqrt{\frac{1}{4}\left(\frac{200}{3} + 200\right)} = 8.165 \text{ A}$$

The power absorbed by a 9 Ω resistor is,

$$P = I_{\text{rms}}^2 R$$

$$= (8.165)^2 \times 9$$

$$= 600 \text{ W}$$

Q.1 (e) Solution:

Using the linear approximations, the value of resistance at any temperature is given by,

$$R = R_0(1 + \alpha_0 \Delta t)$$

$$R = 100[1 + (0.00392 \times (50 - 25)°C)]$$

$$= 109.8\ \Omega$$

Suppose t_2 is the unknown temperature then,

$$200 = 100[1 + (0.00392 \times (t_2 - 25)°C)]$$

$$(t_2 - 25)°\text{ C} = \frac{1}{0.00392}$$

$$\therefore \quad t_2 = 280.102°\text{ C}$$

Q.2 (a) Solution:

Given, $N = 200, \quad l = 600\text{ mm}$

$a = 500\text{ mm}^2, \ I = 4\text{ A}$

(i) $$\vec{H} = \frac{NI}{l} = \frac{200 \times 4}{60 \times 10^{-2}} = 1333.33\text{ AT/m}$$

(ii) $$\vec{B} = \mu\vec{H} = 4\pi \times 10^{-7} \times 1333.33$$

$$= 1.68 \times 10^{-3}\text{ T}$$

(iii) $$\text{Total flux} = B \cdot A = 1.68 \times 10^{-3} \times 500 \times 10^{-6}$$

$$= 0.84\ \mu\text{Wb}$$

Q.2 (b) Solution:

(i) 4 tube lights of 40 W working for 5 hr. per day,

Power consumption = $4 \times 40 \times 5 = 800$ Whr

(ii) 2 filaments of 60 W working for 8 hr. per day

Power consumption = $2 \times 60 \times 8 = 960$ Whr

(iii) 1 water heater rated 2 kW working for 1 hr. per day

Power consumption = $1 \times 2 \times 10^3 \times 1 = 2000$ Whr

(iv) 1 water pump of 0.5 kW rating working for 3 hr. per day

Power consumption = $1 \times 0.5 \times 10^3 \times 3 = 1500$ Whr

Total power consumption per day (in watts hr.)

= $800 + 960 + 2000 + 1500 = 5260$ Whr.

Total power consumption per day (in kWhr.) = $\frac{5260}{1000} = 5.26$ kWh

and 1 kWh = 1 unit

Cost of 1 unit is ₹ 3.50

So, the cost of energy per month (i.e. in 30 day)

$$= 3.50 \times 5.26 \times 30$$
$$= ₹\ 552.30$$

Q.2 (c) Solution:

It is given that,

$$V_L = 400 \text{ V}$$
$$I_L = 10 \text{ A}$$
$$\cos\phi = 0.866$$
$$\therefore \quad \phi = \cos^{-1}(0.866) = 30°$$
$$W_1 = V_L I_L \cos(30° - \phi)$$
$$= 400 \times 10 \times \cos 0° = 4000 \text{ W}$$
$$W_2 = V_L I_L \cos(30° + \phi)$$
$$= 400 \times 10 \times \cos 60°$$
$$= 4000 \times \frac{1}{2} = 2000 \text{ W}$$

Q.2 (d) Solution:

Let R_1 and L_1 be the effective resistance and inductance of the specimen respectively.

At balance
$$(R_1 + j\omega L_1)\frac{1}{j\omega C_4} = R_3\left(R_2 + \frac{1}{j\omega C_2}\right)$$
$$L_1 = R_2 R_3 C_4$$
$$= 834 \times 100 \times 0.1 \times 10^{-6} \text{ H} = 8.34 \text{ mH}$$

and
$$R_1 = \frac{R_3 C_4}{C_2}$$
$$= \frac{100 \times 0.1}{0.12} = 83.33\,\Omega$$

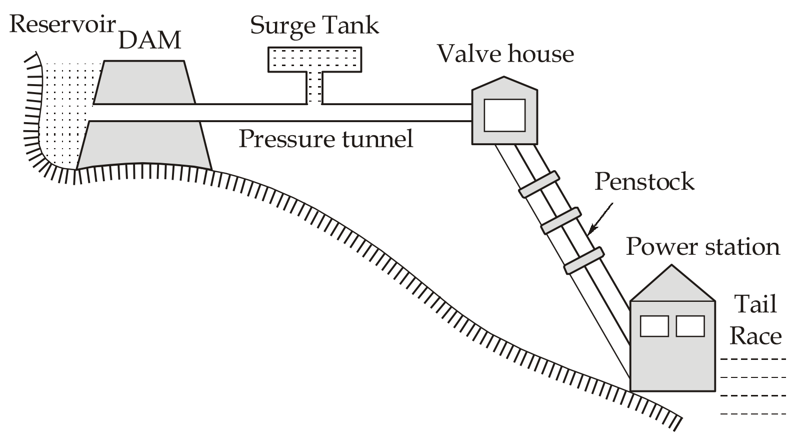
Reactance of specimen at 2 kHz

$$X_1 = 2\pi \times 2 \times 1000 \times 8.34 \times 10^{-3} = 104.8\ \Omega$$

$\therefore$ Impedance of specimen, $Z_1 = \sqrt{(83.33)^2 + (104.8)^2} = 133.89\,\Omega$

Q.3 (a) Solution:

Schematic arrangement of a Hydroelectric plant



The chief requirements for hydroelectric power plant is the availability of water in huge quantity at sufficient head and this requirement can be met by constructing a dam across a river or a lake.

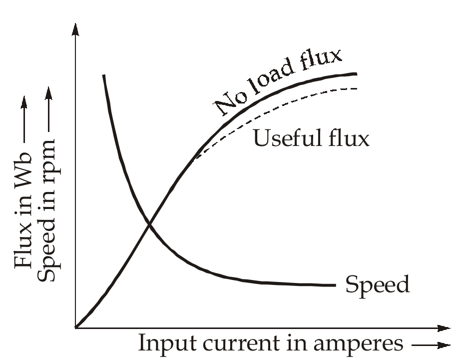
An artificial storage reservoir is formed by constructing a dam across a river (or) a lake and a pressure tunnel is taken off from the reservoir to the valve house at the start of the penstock. The valve house contains mains sluice valves for controlling water flow to the power station and automatic isolating valves for cutting off water supply in case the penstock bursts. A surge tank is also provided just before the valve house for better regulation of water pressure in the system.

From the reservoir the water is carried to valve house through pressure tunnel and from valve house to the water turbine through pipes of large diameter made of steel or reinforcement concrete, called the penstock.

The water turbine converts hydraulic energy into mechanical energy and the alternator coupled to the water turbine converts mechanical energy into electrical energy.

Water after doing useful work is discharged to the tail race.

Q.3 (b) Solution:

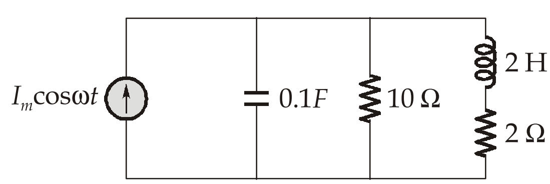


In case of a dc series motor, the mmf due to the exciting coils increases in direct proportion to the line or armature current, so (neglecting armature reaction effects) the value of flux varies with the load current according to the ordinary magnetization curve. Owing to armature reaction, the actual curve representing the useful flux falls below the open-circuit magnetization curve. With larger currents the magnetic circuit gets saturated and flux Φ tends to approach a constant value.

From the speed equation, it is obvious that speed is proportional to back emf E_b and inversely proportional to flux per pole Φ. With the increase in armature current voltage drop in armature circuit and series field $[I(R_a + R_{se})]$ increases and, therefore, back emf E_b decreases, as shown in figure above. However, under normal conditions $I(R_a + R_{se})$ drop is quite small and may be neglected. Thus if the applied voltage remains constant, speed N is inversely proportional to flux Φ. If a curve is drawn between speed and input (or line) current I, it will be a rectangular hyperbola before magnetic saturation as up to saturation point the magnetization curve is a straight line. In this region, the speed decreases abruptly with the increase in input current. After magnetic saturation, the flux Φ tends to become constant and speed-current characteristic becomes a straight line and speed decreases slightly due to voltage drop in armature and series field, as shown in figure. The speed becomes zero when the input current is the normal short-circuit current of the motor i.e., equal to applied voltage divided by the motor resistance $(R_a + R_{se})$. Normally this current is many times full-load value. Since on no load the speed is dangerously high, the machine may get damaged due to heavy centrifugal forces set up in the rotating parts. This is the reason that series motors are never started on no load.

Q.3 (c) Solution:

This is a case of parallel circuit, so calculating admittance is simpler.



The input admittance is,

$$Y = Y_1 + Y_2 + Y_3$$

$$Y = j\omega 0.1 + \frac{1}{10} + \frac{1}{2 + j2\omega}$$

$$= 0.1 + j\omega 0.1 + \frac{2 - j\omega 2}{4 + 4\omega^2}$$

At resonance, Imaginary $(Y) = 0$

$$0.1\omega_0 - \frac{2\omega_0}{4+4\omega_0^2} = 0$$

$$0.1\ \omega_0 = \frac{2\omega_0}{4+4\omega_0^2}$$

$$4+4\omega_0^2 = 20$$

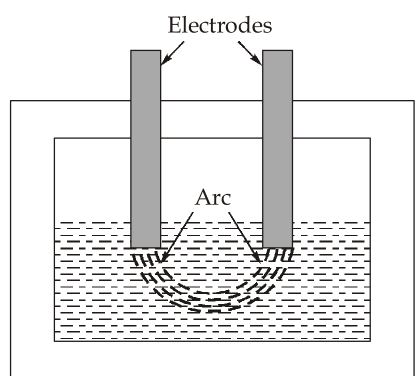
$$\omega_0^2 = 4$$

$$\omega_0 = 2\ \text{rad/sec}$$

Q.3 (d) Solution:

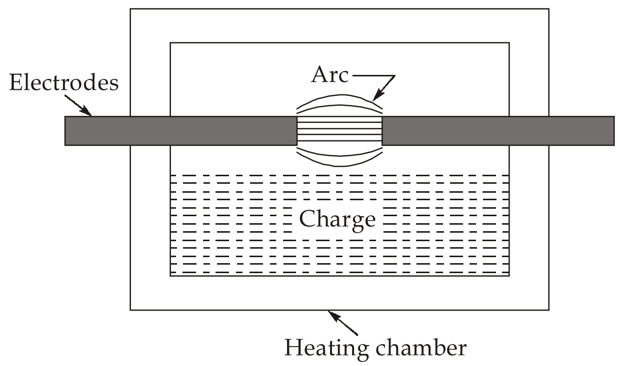
Direct Arc Furnace:

- In a direct arc furnace charge acts as one of the electrodes and the charge is heated by producing arc between the electrodes and the charge.



- In a direct arc furnace, the arc is in direct contact with the charge and heat is also produced by flow of current through the charge itself, the charge can be therefore, heated to highest temperature.
- In case of a single-phase arc furnace two electrodes are taken vertically down ward through the roof of the furnace to the surface of the charge, and in a 3-phase furnace three electrodes put at the corners of an equilateral triangle, project on the charge through the roof and three arcs are formed.
- The current passing through the charge develops electromagnetic field and necessary stirring action is automatically obtained by it. Thus uniform heating is obtained.
- The power factor is about 0.8 lagging in direct arc furnace.

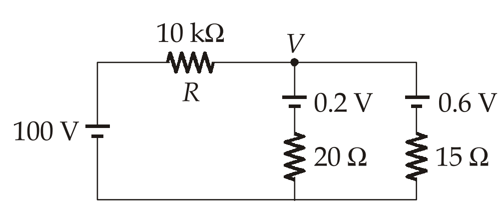
Indirect Arc Furnace:



- In this case arc is formed between two electrodes above the charge, and heat is transmitted to the charge solely by radiation.
- In this case the temperature of the charge is lower than that in case of direct arc furnace.
- In this furnace current does not flow through the charge, there is no stirring action and the furnace is required to be rocked mechanically. For that the furnace is made of cylindrical shape, with the electrodes projecting through the chamber from each end and along the horizontal axis.
- Its construction limits the number of electrodes to two, so single-phase supply is required. The size of the furnace is thus limited by the amount of single-phase load.

Q.4 (a) Solution:

In the circuit if we assume that both the diodes are forward biased so we have circuit as,



Applying nodal to the circuit,

$$\frac{V-100}{10k}+\frac{V-0.2}{20}+\frac{V-0.6}{15} = 0$$

$$V\left[\frac{1}{10k}+\frac{1}{20}+\frac{1}{15}\right]-\left[\frac{100}{10k}+\frac{0.2}{20}+\frac{0.6}{15}\right] = 0$$

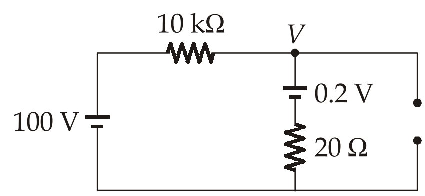
$$V = 0.5138 \text{ V}$$

from the value of V it is clear that D_2 will remain OFF (reverse biased) so our assumption is wrong. Assume only D_1 is ON.

So, we have,

$$I_{D1} = \frac{100-0.2}{10k+20} = 9.96 \text{ mA}$$

$$V = 0.3992 \text{ V}$$

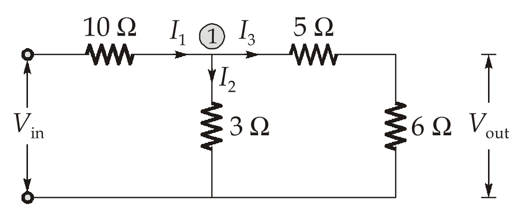


Means D_2 remains off so,

$$I_{D_2} = 0 \text{ Amp}$$

and $$I_{D_1} = 9.96 \text{ mA}$$

Q.4 (b) Solution:



Let voltage at node-1 is V_1,

Applying KCL at node-1

$$I_1 = I_2 + I_3$$

$$\frac{V_{in}-V_1}{10} = \frac{V_1}{3} + \frac{V_1}{11}$$

$$\frac{V_{in}-V_1}{10} = \frac{14V_1}{33}$$

$$\frac{V_{\text{in}}}{10} = \frac{14V_1}{33} + \frac{V_1}{10} = \frac{140V_1+33V_1}{330}$$

$$\frac{V_{\text{in}}}{10} = \frac{173}{330}V_1$$

$$\Rightarrow \quad V_{\text{in}} = \frac{173}{33}V_1$$

Apply voltage division rule,

$$V_{\text{out}} = \frac{6\times V_1}{11}$$

$$\frac{V_{out}}{V_{in}} = \frac{6V_1}{11} \times \frac{33}{173V_1} = \frac{18}{173} = 0.104$$

Q.4 (c) Solution:

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

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

$$\text{Rotor speed} = N = 950 \text{ rpm}$$

$$\text{Slip, } s = \frac{N_s - N}{N_s} = \frac{1500 - 950}{1500} = 0.367$$

$$\omega = \frac{2\pi N}{60} = 99.48 \text{ rad/sec.}$$

$$\text{Shaft torque} = 110 \text{ N-m}$$

Net mechanical output or shaft power = Shaft torque × Rotor speed (rad/sec.)

$$P_G = 110 \times 99.48$$

$$= 10942 \text{ W} = 10.942 \text{ kW}$$

Gross mechanical output of the rotor = Shaft power + Mechanical losses

$$= 10.942 + 0.1 = 11.042 \text{ kW}$$

$$\text{Power input to the rotor} = \text{Air gap power} = P_G$$

As we know that,

Gross mechanical output of the rotor = $(1 - s)\, P_G$

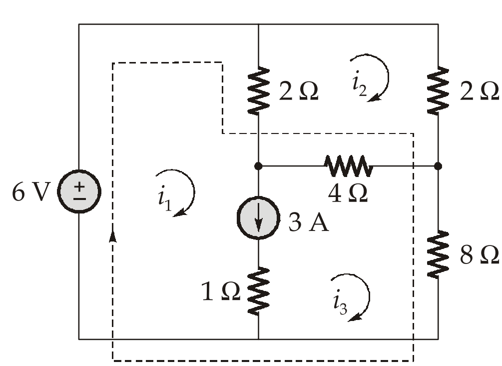
$$(1 - s)\, P_G = 11.042 \text{ kW}$$

$$\text{Power input to the rotor} = \frac{11.042}{1 - 0.367} = 17.443 \text{ kW}$$

$$\text{Rotor copper loss} = sP_G = 0.367 \times 17.443 = 6.40 \text{ kW}$$

Q.4 (d) Solution:

Here, a current source is connected between two meshes



$$i_1 - i_3 = 3 \text{ A} \quad \text{...(i)}$$

By KVL for the supermesh,

$$2(i_1 - i_2) + 4(i_3 - i_2) + 8i_3 = 6$$

$$2i_1 - 6i_2 + 12i_3 = 6 \quad \text{...(ii)}$$

By KVL for the second mesh

$$2i_2 + 4(i_2 - i_3) + 2(i_2 - i_1) = 0$$

$$8i_2 - 4i_3 - 2i_1 = 0 \quad \text{...(iii)}$$

Solving equation, (i), (ii) and (iii),

$$i_1 = 3.473 \text{ A}$$

$$i_2 = 1.105 \text{ A}$$

and $$i_3 = 0.473 \text{ A}$$

Q.5 (a) Solution:

The idealizing assumptions made are listed below:

- The primary and secondary windings have zero resistance. It means that there is no ohmic power loss and no resistive voltage drop in the ideal transformer.
- There is no leakage flux so that all the flux is confined to the core and links both the windings.
- The core has infinite permeability so that zero magnetizing current is needed to establish the requisite amount of flux in the core.
- The core-loss (hysteresis as well as eddy-current loss) is considered zero.

Fig. (a) shows an ideal transformer having a primary of N_1 turns and a secondary of N_2 turns on a common magnetic core.

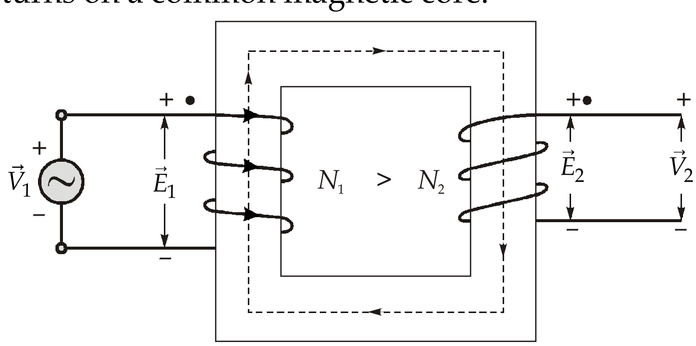


Fig. (a)

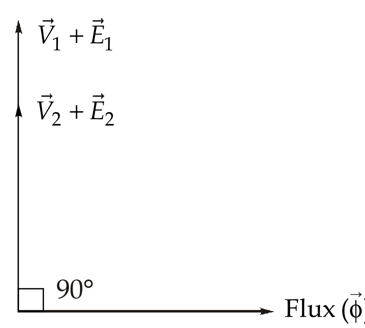


Fig. (b)

$$V_1 = V_m \cos \omega t$$

the secondary is initially assumed to be an open circuited.

$$E_1 = V_1 = N_1 \frac{d\phi}{dt}$$

$$E_2 = N_2 \frac{d\phi}{dt}$$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = a$$

Since a, the transformation ratio is a constant, E_1 and E_2 are in phase.

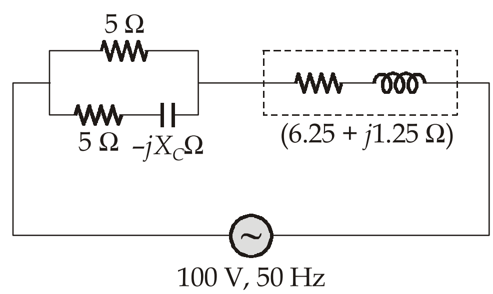
Hence, $$\frac{V_1}{V_2} = \frac{E_1}{E_2} = \frac{N_1}{N_2} = a$$

An ideal transformer changes (transforms) voltages in direct ratio of the number of turns in the two windings.

$$\frac{V_1}{V_2} = \frac{E_1}{E_2} = \frac{N_1}{N_2} = a$$

Q.5 (b) Solution:

From the given data circuit is,



Equivalent impedance of above circuit,

$$= \frac{(5)(5-jX_C)}{5+5-jX_C} + 6.25 + j1.25$$

$$= \frac{25-5(jX_C)}{10-jX_C} + 6.25 + j1.25$$

$$= \frac{(25-j5X_C)(10+jX_C)}{100+X_C^2} + 6.25 + j1.25$$

$$= \frac{5X_C^2+250-j25X_C}{100+X_C^2} + 6.25 + j1.25$$

For resonance, imaginary part of the equivalent is zero,

$$\frac{25X_C}{100+X_C^2} = 1.25$$

$$25\,X_C = 125 + 1.25X_C^2$$

$$X_C^2 + 100 - 20X_C = 0$$

$$X_C = 10$$

Now,
$$X_C = \frac{1}{\omega C}$$

$$10 = \frac{1}{2\pi \times 50 \times C}$$

$$C = \frac{1}{1000\pi} = 318.3\ \mu\text{F}$$

Q.5 (c) Solution:

The current in coil *ab* is entering at the dot marked terminal, where as in coil *cd* the current is leaving, we can write the equations as

$$V_1 = L_1\frac{di_1}{dt} - M\frac{di_2}{dt}$$

$$V_2 = L_2\frac{di_2}{dt} - M\frac{di_1}{dt}$$

$$M = K\sqrt{L_1L_2} = 0.5\times\sqrt{36} = 3$$

$$V_1 = 4\frac{d}{dt}[5\cos(50t - 30°)] - 3\left[\frac{d}{dt}2\cos(50t - 30°)\right]$$

$$V_1 = 20[-\sin(50t - 30°) \times 50] - 6[-\sin(50t - 30°) \times 50]$$

at $t = 0$,

$$V_1 = 500 - 150 = 350\ \text{V}$$

$$V_2 = -3\frac{d}{dt}[5\cos(50t - 30°)] - 9\frac{d}{dt}[2\cos(50t - 30°)]$$

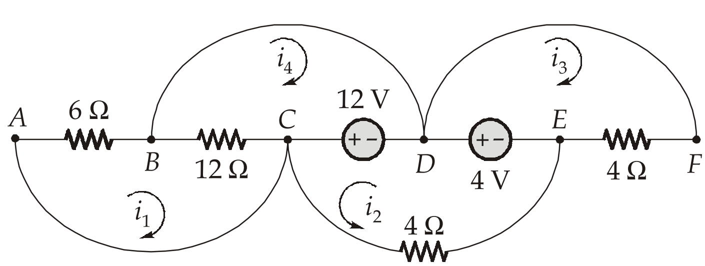
$$V_2 = -15[-\sin(50t - 30°) \times 50] + 18[50\sin(50t - 30°)]$$

at $t = 0$,

$$V_2 = -375 + 450 = 75\ \text{V}$$

Q.5 (d) Solution:

There are four meshes in the circuit



Applying KVL in first loop

$$6i_1 + 12(i_1 - i_4) = 0$$
$$18i_1 = 12i_4$$
$$i_4 = \frac{3}{2}i_1 \quad ...(i)$$

Applying KVL in loop-4

$$12(i_4 - i_1) - 12 = 0$$
$$12(i_4 - i_1) = 12$$
$$i_4 = i_1 + 1 \quad ...(ii)$$

Put equation (i) in equation (ii), we get

$$\frac{1}{2}i_1 = 1$$
$$i_1 = 2\text{ A}$$

and $i_4 = 3\text{ A}$

Applying KVL in loop-3,

$$4 - 4i_3 = 0$$
$$4i_3 = 4$$
$$i_3 = 1\text{ A}$$

Applying KVL in loop-2,

$$4i_2 = 16$$
$$i_2 = 4\text{ A}$$

Therefore the required current are,

$$i_1 = 2\text{ A}$$
$$i_2 = 4\text{ A}$$

and $i_3 = 1\text{ A}$

Power delivered by the 12 V source

$$= 12 \times (3 + 4) = 84\text{ W}$$

Power delivered by 4 V source $= 4 \times 5 = 20\text{ W}$

Q.6 (a) Solution:

(i) Advantages of PMMC instruments:

- The scale is uniformly divided.
- The power consumption is very low (25 μW - 200 μW).
- The torque-weight ratio is high which gives a high accuracy. The accuracy is of the order of generally 2 percent of full scale deflection.
- A single instrument may be used for many different current and voltage ranges by using different values for shunts and multipliers.

- Since the operating force are large on account of large flux densities which may be as high as 0.5 Wb/m^2, the errors due to stray magnetic fields are small.
- Self-shielding magnets make the core magnet mechanism particularly useful in aircraft and aerospace application, where a multiplicity of instruments must be mounted in close proximity to each other.

Disadvantages:

- These instruments are useful only for d.c. The torque reverses if the current reverses. If the instrument is connected to a.c. the pointer cannot follow the rapid reversals and the deflection corresponds to mean torque, which is zero. Hence the instruments can not be used for a.c.
- The cost of these instruments is higher.

(ii) Advantages of interconnection of power stations are following:

- With interconnected power station, the peak load can be exchanged between the generating stations. From the load curve if there is peak load demand which is more than rated capacity of the plant then the excess load can be shared by other interconnected stations.
- With interconnected power station system, the economical operation of the plant is possible. The total load is arranged in such a way that more efficient plants can be used as base load stations which can work continuously throughout the year at high load factor and the less efficient plants can be made to operate as peak load plants. Also, larger generator unit can be employed to reduce capital cost per kW.
- Various interconnected power stations, have their different load curves due to which maximum demand on the system is reduced as compared to sum of individual maximum demands on various stations. Thus the effective capacity of the system increased as their is improvement in diversity factor.
- It can be seen that the load curves of the two different power stations are not identical. In worst condition the peak loads may occur a time different by few minutes. Thus the maximum demands on individual power stations are not occurring simultaneously, it is possible to work with lesser installed capacity with interconnected power station system.
- In abnormal conditions every power station should have reserve stand by unit to be put in operation with interconnected system the reserve capacity is reduced which increase efficiency of the system.
- The reliability and continuity of the supply is improved with interconnected power station system. With fault condition occurring in any one station, the supply can be maintained with the help of other stations.

(iii) Short circuit ratio of a synchronous machine is defined as the ratio of the field current required to generate rated voltage on open circuit to the field current required to circulate rated armature current on short circuit,

$$\text{SCR} = \frac{I_f \text{ for rated O.C. voltage}}{I_f \text{ for rated S.C. current}} = \frac{1}{X_{s\text{p.u.}}}$$

SCR is the inverse of per unit synchronous reactance of the machine.

Importance of SCR: It affects the operating characteristic, physical size and cost of the machine. With a low value of the SCR a synchronous generator has a large variation in terminal voltage with a change in load. It implies that machine is sensitive to load variation.

In order to keep terminal voltage constant, field current is to be varied over a wide range. The synchronizing power is small if the SCR is small. As synchronizing power keeps the machine in synchronism, a low value of SCR has a low stability limit. A machine with low SCR is less stable when operating in parallel with other generators. But armature current under short circuit conditions is small for low SCR.

A synchronous machine with high SCR has a better voltage regulation and improved stability limit. But it leads to high short-circuit fault current.

The size and cost of a synchronous machine also depends upon the SCR.

$$L_s \propto \frac{1}{\text{Reluctance of air gap}}$$

$L_s \rightarrow$ Synchronous inductance

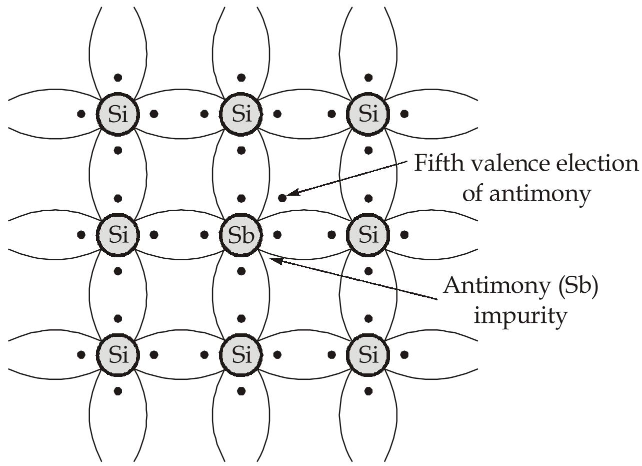
$$\text{SCR} \propto \frac{1}{L_s}$$

SCR $\propto$ air gap reluctance or length SCR may be increased by increasing the length of air gap. But large air gap leads to increase in overall diameter and size which adds to cost.

So, large SCR will increase size, weight and cost of the machine.

Q.6 (b) Solution:

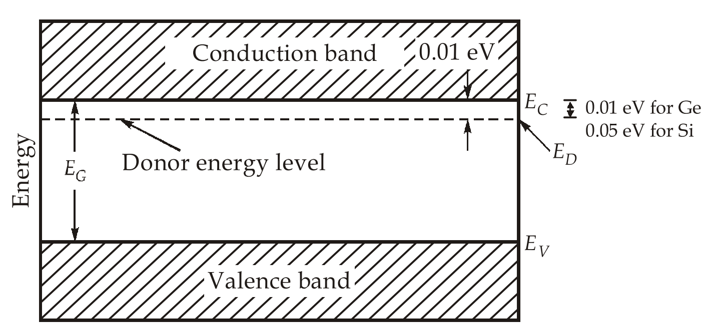
***n*-type Semiconductor:**



An n-type semiconductor is created by introducing impurity elements that have five valence electrons (pentavalent), such as antimony, arsenic and phosphorus. The effect of such impurity elements is indicated in figure. Note that the four covalent bonds are still present. There is, however an additional fifth electron due to the impurity atom, which is unassociated with any particular covalent bond. This remaining electron loosely bound to its parent atom (antimony) atom, is relatively free to move within the newly formed n-type material. Since the inserted impurity atom has donated a relatively "free" electron to the structure.

Diffused impurities with five valence electrons are called donor atoms.

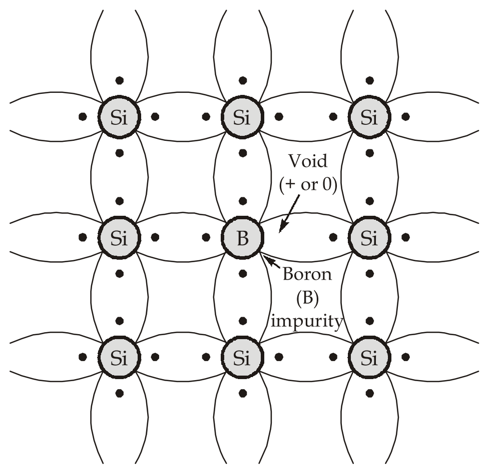
When impurities or lattice defects are introduced into an otherwise perfect crystal, additional levels are created in the energy band structure, usually within the band gap. For example, an impurity from column V of the periodic table (P, As and Sb) introduces an energy level very near the conduction band in *Ge* or *Si*. Such an impurity level is called a donor level. In case of germanium, the distance of new discrete allowable energy level is only 0.01 *eV* (0.05 *eV* in silicon) below the conduction band, and therefore at room temperature almost all the "fifth" electrons of the donor material are raised into the conduction band.



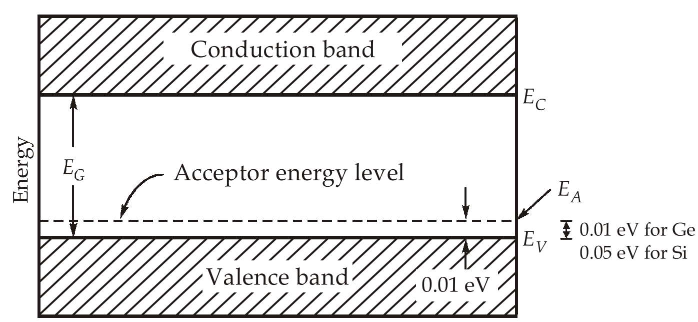
***p*-type semiconductor:**

The p-type semiconductor is formed by doping a pure germanium or silicon crystal with impurity atoms having three valence electrons. The elements most frequently used for this purpose are Boron, Gallium and Indium.

Note that, there is now an insufficient number of electrons to complete the covalent bonds of the newly formed lattice. The resulting vacancy is called a hole and is represented by a small circle or a plus sign, indicating the absence of a negative charge. Since the resulting vacancy will readily accept a free electron.



The diffused impurities with three valence electrons are called acceptor atoms.



The resulting *p*-type material is electrically neutral for the same reasons described for the n-type material.

Atoms from Column-III (B, Al, Ga and In) introduce impurity levels in Ge or Si near the valence band. These levels are empty of electrons at 0K. At low temperatures, enough thermal energy is available to excite electrons from the valence band into the impurity level, leaving behind holes in the valence band.

Since this type of impurity level **"accepts"** electrons from the valence band, it is called an acceptor level.

Q.6 (c) Solution:

Difference between Neutral and Earth wire

S.No.	Neutral wire	Earth wire
1.	It is directly connected to the neutral point of the supply system.	It may be directly connected to the neutral point to supply system.
2.	It serves as a return conductor.	It may carry current only in case of a fault.
3.	It may not be connected to earth at an intermediate point on the line.	It must be connected to earth at least at 3 places in a km.
4.	Its potential at some point may be substantially far from zero. It is therefore, insulated from the pole on which it is supported. In this case, the insulation is smaller in size than the one supporting the phase conductor.	It is supported to be at zero potential. It is not mounted on any insulator and is in direct metallic contact with the support metal work.

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