Full Syllabus Test : Paper-I

DETAILED EXPLANATIONS

PART-A

1. Solution:

The phenomenon of Piezoelectricity and Ferroelectricity are compared as follows :

Piezoelectricity	Ferroelectricity
(i) Material generates potential when mechanical stress is applied across it.	(i) Material exhibits spontaneous polarisation in presence of elastic field.
(ii) Larger class of material.	(i) Ferroelectronics are subclass of piezoelectrics.
(iii) All piezoelectric materials are not ferroelectirc.	(iii) All ferroelectric materials are piezoelectrics.
(iv) Used in applications like pressure-transducer.	(iv) Used in application like transformer core.
(v) e.g., Rochelle salt quartz	(v) e.g., Lead titanate $PbTiO_3$

2. Solution:

Factors affecting resistivity of materials:

1. **Charge carrier density (n)**: Resistivity of an electric material is inversely proportional of an electric carriers present in the material $\rho \propto \frac{1}{n}$ As number of charge carriers increase, conductivity increases and hence resistivity decreases.
2. **Average collision time (τ):** $\rho \propto \frac{1}{\tau}$ Resistivity is inversely proportional to average collision time. Also, $\tau \propto \frac{1}{\sqrt{\text{Temp.}}}$ so if n is constant $\rho \propto \sqrt{\text{Temp.}}$

   So, resistivity increases with increase in temperature if n is constants (in case of metals).

3. Solution:

Super conductors can be used to produce strong magnetic field.

- Super conductors are used for winding of exciting field of generators of low heating.
- Super conductors can be used for transmission purpose.
- Super conductors can be used in the electrical switching elements (cryotrons).
- Super conductors are also used in high levitated trains.

4. Solution:

$$H_c = H_0\left[1-\left(\frac{T}{T_c}\right)^2\right]$$

Here,

$$H_0 = 64 \times 10^3 \text{ A/m}$$

$$T_c = 7.26 \text{ K}$$

$$H_c(5\text{ K}) = 64\times 10^3\left[1-\left(\frac{5}{7.26}\right)^2\right]$$

$$= 33.6438 \times 10^3 \text{ A/m}$$

5. Solution:

3-phase transformers: Three-phase transformers must have zero relative phase displacement on the secondary sides and must be connected in a proper phase sequence. Only the transformers of the same phase group can be paralleled. For example, Y/Y and Y/D transformers cannot be paralleled, as their secondary voltages will have a phase difference of 30°.

6. Solution:

In dc series motor, if saturation and armature reaction are neglected, then main flux ϕ is directly proportional to armature current I_a. Therefore, f = CI_a where C is any constant.

$$E_a = k_a \phi \omega_m = V_t - I_a (r_a + r_s)$$

$$\omega_m = \frac{V_t}{k_a\phi} - \frac{I_a(r_a + r_s)}{k_a\phi}$$

$$= \frac{V_t}{k_a C I_a} - \frac{(r_a + r_s)}{k_a C}$$

From above, since speed depend upon inversely to current so at no load speed of the series motor becomes dangerously high due to small no load current.

So, we can say that d.c. series motor is highly variable speed motor.

7. Solution:

$$E_g = V + I_a R_a;$$

E_g = generator induced voltage

V = terminal voltage of the machine

$$E_m = V - I_a R_a;$$

E_m = motor induced voltage

Difference in induced voltage,

$$E_g - E_m = (V + I_a R_a) - (V - I_a R_a)$$

$$= 2 I_a R_a = 2 \times 20 \times 1$$

$$= 40 \text{ V}$$

8. Solution:

As torque remains same, I_a same in both cases.

Starting $\rightarrow E_b = 0$

$$\therefore \quad E_b = V - I_a (R_a + R_{ext} + R_{se})$$

$$0 = 240 - 40 (0.3 + R_{ext})$$

$$\therefore \quad R_{ext} = 5.7 \ \Omega$$

9. Solution:

The synchronous machine oscillates about the operating point, due to:

1. a sudden change in load.
2. a fault in the supply system.
3. a load or write containing harmonic torques.
4. a sudden change in field current.

This oscillatory behaviour of the synchronous machines is known as hunting.

10. Solution:

Infinite line: A transmission line of finite length (lossless or lossy) that is terminated at one end with a impedance equal to the characteristic impedance appears to the source like a infinitely long transmission line and produces no reflections.

Voltage reflection coefficients,

$$(\rho_v) = 0$$

Voltage transmission coefficient,

$$(T_v) = 1 + T_v = 1$$

At this condition:
$$V_S = V_L$$
V_S = source voltage,
V_L = load voltage

11. Solution:

Infinite Bus: A system Bus of constant voltage and constant frequency regardless of the load is called infinite busbar system or simply infinite bus. The characteristics of an infinite bus are as follows:

- The terminal voltage remains constant, because the incoming machine is too small to increase or decrease it.
- The frequency remains constant, because the system inertia is too large to enable the incoming machine to alter the frequency of the system.
- The synchronous impedance is very small since the system has a large number of alternators in parallel.

12. Solution:

(a) Diversity Factor: Diversity factor is defined as the ratio of the sum of individual maximum demand to the simultaneous maximum demand of the whole group of consumers.

$$\text{Diversity factor} = \frac{\text{Sum of individual maximum demands}}{\text{Simultaneous maximum demand of the consumers}}$$

13. Solution:

Plant Use Factor: Another factor which affects the cost of energy is the plant use factor and is defined as

$$\text{Plant use factor} = \frac{\text{Annual energy generated}}{\text{(Capacity of plant)} \times \text{(No. of hours plant is actually in operation during the year)}}$$

14. Solution:

A bundle conductor is a conductor made up of two or more sub-conductors and is used as one phase conductor. The reactance of the bundle conductors is reduced because the self GMD of the conductors is increased,

$$L = 2\times10^{-7}\ln\left(\frac{D_m}{D_{sA}}\right)\text{H/m}$$

By bundling the conductors the self GMD of the conductors is increased thereby; the critical disruptive voltage is increased and hence corona loss is reduced.

15. Solution:

$$\text{Breaking current} = \frac{2000}{\sqrt{3}\times33} = 34.99 \text{ kA}$$

$$\text{Making current} = 2.55 \times 34.99 = 89.22 \text{ kA} \cong 90 \text{ kA}$$

$$\text{Rating of C.B.} = \sqrt{3} \times \text{Line voltage} \times \text{Breaking current}$$

$$\text{Making current} = 2.55 \times \text{Breaking current}$$

16. Solution:

- The absorption of electric energy by a dielectric material subjected to an alternating E-field is known as dielectric losses. The result in dissipation of the electric energy as heat in the material and in this dielectric constant in such case in a complex quantity where imaginary part corresponds the loss.
  So, complex dielectric constant is expressed as

$$\in_r^* = \in_r' - j\in_r''$$

- The complex dielectric constant incorporates all the contributions of polarization.
- The imaginary part of the equation is so that rise to absorption of energy by the material from the alternating field.

17. Solution:

- Ceramics are dielectric material having large band gap E_g. So in working temperature range they behave as an insulator.
- Some materials (ceramic) such as glass, paper, Teflon are very good electric insulators.
- These ceramics are used for high voltage power transmission because of their good insulating properties. These are normally glass, porcelain, or composite polymer materials.
- Insulators made from porcelain rich in alumina are used where high mechanical strength is criterion.

- Porcelain has a dielectric strength of 4 – 10 kV/mm.
- Recently some electric utilities have begun converting to polymer composite materials for some types of insulators.
- Ceramic insulator are also used at railway.

18. Solution:

Comparison of Steam Power Plant with Hydroelectric Power Plant:

Item	Steam Power Plant	Hydroelectric Power Plant
1. Initial cost (approximate) per kW in rupees	Initial cost is lower than those of hydroelectric and nuclear power plant (1000 to 1500).	Initial cost is very high because of dam construction and excavation work (1500 to 4000).
2. Running cost	Higher than hydroelectric and nuclear plant because of the requirement of huge amount of coal.	Practically nil because not fuel is required.
3. Cost of fuel	Maximum because huge amount of coal is transported to the plant site.	Practically nil.
4. Maintenance cost	Quite high as skilled operating staff is required.	Quite low.
5. Transmission and distribution cost	Quite low as these are generally located near the load centres.	Quite high as these are located quite away from the 10%.
6. Fixed cost per annum (interest) on capital	13%	10%

19. Solution:

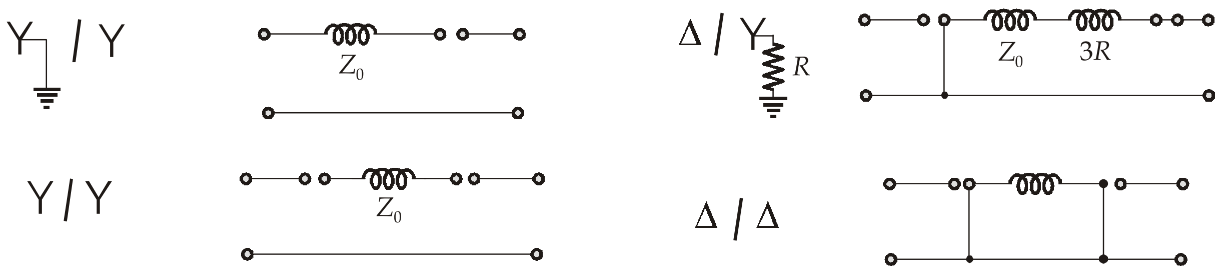
The receiving end voltage, in power system, can be controlled by using
- Shunt capacitors
- Series capacitors
- Synchronous transformers
- Boster transformers

The first three methods are categorised as reactive var injection method.

For an isolated small system, the voltage control is done by adjusting the excitation of the generator at the sending end. The larger the reactive power required by the load the more is the excitation to be provided at the sending end.

20. Solution:

Zero sequence equivalent circuit of transformers,

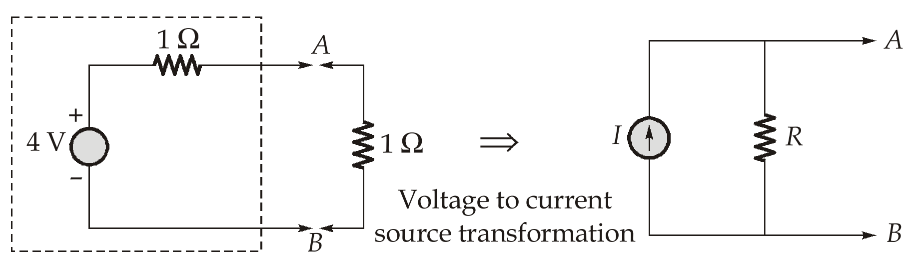


PART-B

21. Solution:

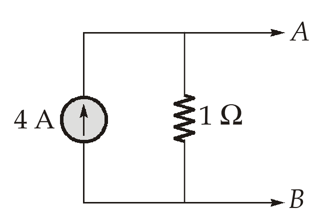
Source Transformation:

- Any voltage source consists of an ideal voltage source in series with an internal impedance (for ideal voltage source, this impedance being zero, the output voltage becomes independent of the load current) while any current source is an ideal current source in parallel with an internal impedance (for ideal current source, this parallel impedance is infinity such that the source current does not face any branching through this internal impedance path.
- The voltage and current sources are mutually transferable.
- For any voltage source, if the ideal voltage be V and internal resistance be R, the voltage source can be replaced by current source I with the internal resistance in parallel to the current source and the value of I is given by $I = V/R$.



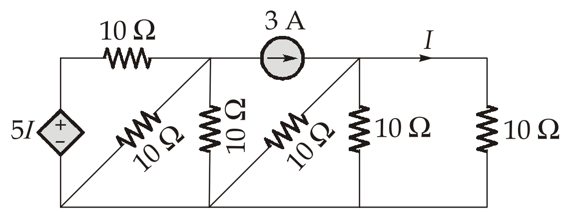
where, $R = 1\ \Omega$ and $I = \frac{V}{R} = \frac{4}{1} = 4\text{ A}$

Hence,

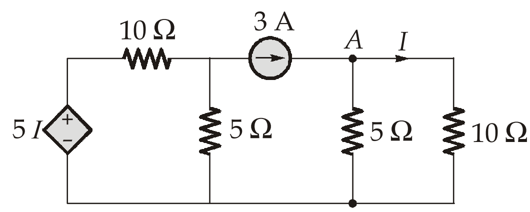


is the valid equivalent network.

22. Solution:



The given circuit above can be simplified as,



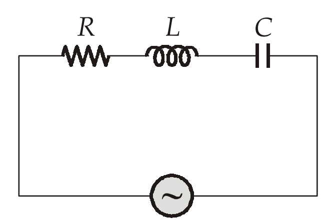
using current division on node *A*,

$$I = \frac{5}{5+10} \times 3 = 1 \text{ A}$$

23. Solution:

For series RLC circuit, excited from AC source.

Given that :



$$R = 100\ \Omega$$
$$L = 0.5\text{ H}$$
$$C = 0.4\ \mu\text{F}$$

1. Resonant frequency,

$$\omega_0 = \frac{1}{\sqrt{LC}} = 2.23 \times 10^3 \text{ rad/s}$$

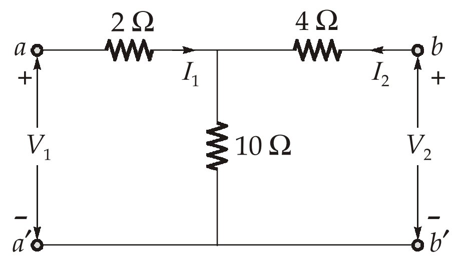
2. Bandwidth, $\text{B.W.} = \omega_2 - \omega_1 = \frac{R}{L} = 200 \text{ rad/s}$

3. Quality factor, $Q = \frac{\omega_0}{\text{B.W.}} = \frac{\omega_0}{\omega_2 - \omega_1} = 11.15$

24. Solution:

From this (*T*) network,

$$V_1 = 2 I_1 + 10 (I_1 + I_2) = 12 I_1 + 10 I_2$$
$$V_2 = 4 I_2 + 10 (I_1 + I_2) = 10 I_1 + 14 I_2$$
$$10 I_1 = V_2 - 14 I_2$$



$$\therefore \quad V_1 = 12\frac{(V_2 - 14\,I_2)}{10} + 10\,I_2$$

$$\therefore \quad V_1 = 1.2\,V_2 - 1.4 \times 12\,I_2 + 10\,I_2$$

$$= 1.2\,V_2 - 6.8\,I_2 \qquad ...(i)$$

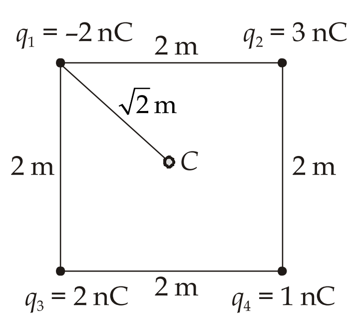
$$I_1 = 0.1\,V_2 - 1.4\,I_2 \qquad ...(ii)$$

$$\therefore \quad \begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} 1.2 & 6.8 \\ 0.1 & 1.4 \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

The [$ABCD$] parameters of the network is

$$\therefore \quad T = \begin{bmatrix} 1.2 & 6.8 \\ 0.1 & 1.4 \end{bmatrix}$$

25. Solution:



Net potential at, the center,

$$C,\ V_C = \frac{1}{4\pi\xi_0}\frac{q_1}{r} + \frac{1}{4\pi\xi_0}\frac{q_2}{r} + \frac{1}{4\pi\xi_0}\frac{q_3}{r} + \frac{1}{4\pi\xi_0}\frac{q_4}{r}$$

$$= [-2\times10^{-9} + 3\times10^{-9} + 10^{-9} + 2\times10^{-9}]\times\frac{1}{4\pi\xi_0}\times\frac{1}{\sqrt{2}}\ \text{V}$$

$$V_C = \frac{4\times10^{-9}\times9\times10^{9}}{\sqrt{2}}\ \text{V} = 18\sqrt{2}\ \text{V}$$

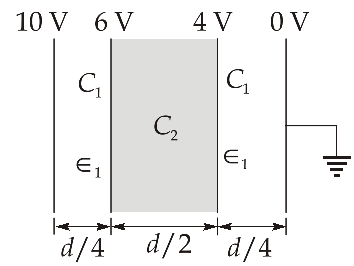
26. Solution:

According to given condition:

All the three dielectrics are connected in series, so charge will be same throughout the dielectrics.

$$C_1 = \frac{\epsilon_0\epsilon_1 \times A}{d/4} = \frac{4\epsilon_0\epsilon_1 \times A}{d}$$

$$C_2 = \frac{\epsilon_0\epsilon_1 A}{d/2} = \frac{2\epsilon_0\epsilon_2 A}{d}$$



$$Q_1 = Q_2$$

$\therefore$ $$C_1V_1 = C_2V_2$$

$\therefore$ $$\frac{4\epsilon_0\epsilon_1 A}{d} \times 4 = \frac{2\epsilon_0\epsilon_2 A}{d} \times 2$$

$\Rightarrow$ $$\frac{\epsilon_1}{\epsilon_2} = \frac{1}{4}$$

27. Solution:

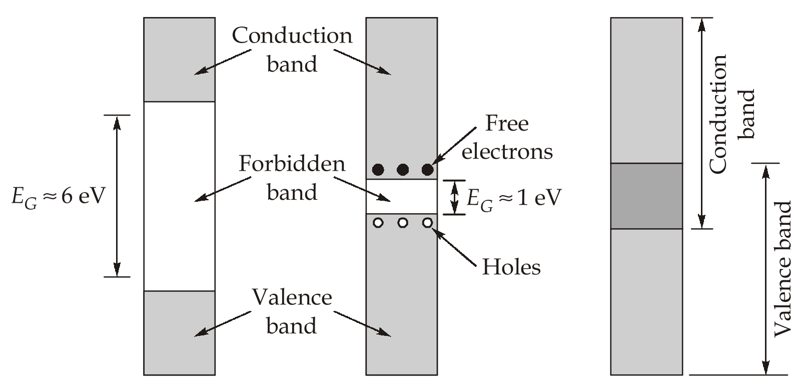


Fig. (a) Fig. (b) Fig. (c)

Insulators:

- An insulating material has an energy band diagram as shown in figure (a).
- It has a very wide forbidden-energy gap ($\simeq$ 6 eV) separating the filled valence region from the vacant conduction band. Because of this, it is practically impossible for an electron in the valence band to jump the gap, reach the conduction band.
- At room temperature, an insulator does not conduct. However it may conduct if its temperature is very high or if a high voltage is applied across it. This is termed as the **breakdown of the insulator.**
- **Example:** diamond.

Semiconductors:

- A semiconductor has an energy-band gap as shown in figure (b).
- At 0°K semiconductor materials have the same structure as insulators except the

difference in the size of the band gap E_G, which is much smaller in semiconductors ($E_G \simeq 1$ eV) than in insulators.

- The relatively small band gaps of semiconductors allow for excitation of electrons from the lower (valence) band to the upper (conduction) band by reasonable amount of thermal or optical energy.
- The difference between semiconductors and insulators is that the conductivity of semiconductors can increase greatly by thermal or optical energy.
- **Example:** Ge and Si.

Metals:

- There is no forbidden energy gap between the valence and conduction bands. The two bands actually overlap as shown in figure (c).
- Without supplying any additional energy such as heat or light, a metal already contains a large number of free electrons and that is why it works as a good conductor.
- **Example:** Al, Cu etc.

28. Solution:

$$\tan\delta = \frac{\epsilon_r''}{\epsilon_r'}$$

Dielectric constant, $\epsilon_r^* = 4.8$

$$E = 60 \text{ kV/cm} = 60 \times 10^5 \text{ V/m}$$

$$\omega = 2\pi \times 100 \text{ and } \epsilon_r'' = 4.8 \times \tan\delta = 4.8 \times 10^{-3}$$

$$\omega = 200\pi \text{ rad/sec}$$

Dielectric losses/unit area $= \frac{1}{2}\omega \epsilon_0 \epsilon_r'' E^2$

$$= \frac{1}{2} \times 2\pi \times 100 \times \epsilon_0 \times 4.8 \times 10^{-3} \times (60 \times 10^5)^2$$

$$= 480.66 \text{ W}$$

29. Solution:

Hystersis energy density = Area under B-H curve

Hystersis energy density = $2.4 \times 20 = 48$ J/m^3

Volume of toroidal core = Area × Mean length

$$= 10 \times 10^{-4} \times 15 \times 10^{-2} = 150 \times 10^{-6} \text{ m}^3$$

Now, Hystersis energy loss, E = (Hystersis energy density) × (Volume of toroidal core)

$$E = 48 \times 150 \times 10^{-6} = 7.2 \text{ mJ}$$

Hystersis power loss, $P = \frac{E}{T} = E \times f = 7.2 \times 10^{-3} \times 400$

$$P = 2.88 \text{ Watts}$$

30. Solution:

Hysteresis loss, $p_h \propto f B^x \propto f\left(\frac{V}{f}\right)^x$

$$\frac{p_{h_1}}{p_{h_2}} = \frac{f_1}{f_2}\left(\frac{V_1}{V_2} \times \frac{f_2}{f_1}\right)^x$$

$$\frac{700}{p_{h_2}} = \frac{50}{100}\left(\frac{1000}{2000} \times \frac{100}{50}\right)^x$$

or $$p_{h2} = \frac{700 \times 100}{50} = 1400 \text{ W}$$

Eddy current loss, $p_e \propto B^2 f^2 \propto f^2\left(\frac{V}{f}\right)^2$

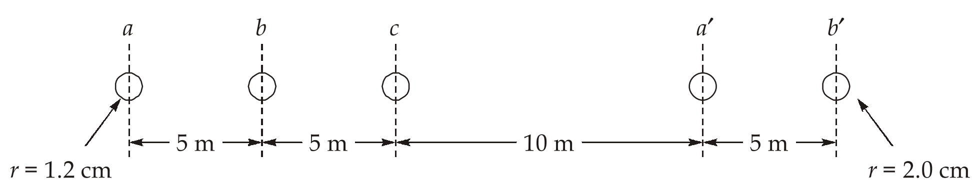
$$\frac{p_{e_1}}{p_{e_2}} = \left(\frac{f_1}{f_2}\right)^2\left(\frac{V_1}{V_2} \times \frac{f_2}{f_1}\right)^2$$

$$\frac{300}{p_{e_2}} = \left(\frac{50}{100}\right)^2\left(\frac{1000}{2000} \times \frac{100}{50}\right)^2$$

$$p_{e2} = 300 \times 4 = 1200 \text{ W}$$

Total core loss, $p_c = p_{h2} + p_{e2} = 1400 + 1200 = 2600$ W

31. Solution:



As the configuration is unsymmetric inductive per circuit is

$$L = L_1 + L_2$$

$$L_1 = 2 \times 10^{-7} \ln \frac{D_{m1}}{D_{s1}}$$

$$L_2 = 2 \times 10^{-7} \ln \frac{D_{m2}}{D_{s2}}$$

Here, $D_{m1} = D_{m2}$

$$D_{m1} = \sqrt[3]{D'_{m_1} D''_{m_1} D'''_{m_1}}$$

$$Dm' = \sqrt{Daa'Dab'} = \sqrt{20 \times 25} = 22.36 \text{ m}$$

$$Dm'' = \sqrt{Dba'Dbb'} = \sqrt{10 \times 15} = 12.24$$

$$Dm_1 = \sqrt[3]{22.36 \times 17.32 \times 12.24} = 16.8 \text{ m}$$

Here, $D_{m1} = D_m = 16.8$ m

$$D_{s1} = \sqrt[9]{(D_{aa}D_{ab}D_{ac})(D_{ba}D_{bb}D_{bc})(D_{ca}D_{cb}D_{cc})}$$

$$Daa = Dbb = Dcc = 0.7788 \times 1.2 = 0.9345$$

$$= \sqrt[9]{(0.9345)^3(500)^4(1000)^2} = 71.845 \text{ cm}$$

$$D_{s2} = \sqrt[4]{Da'a'Da'b'Db'a'Db'b'}$$

Here, $Daa' = Db'b' = 0.7788 \times 2 = 1.5576$

$$D_{s2} = \sqrt{1.5576 \times 500} = 27.906 \text{ cm}$$

$$L_1 = 2 \times 10^{-7} \ln \frac{1680}{71.845} = 6.3 \times 10^{-7} \text{ H/mt}$$

$$= 0.63 \text{ mH/km}$$

$$L_2 = 2 \times 10^{-7} \ln \frac{1680}{27.906} = 8.1954 \times 10^{-7} \text{ H/mt}$$

$$= 0.81954 \text{ mH/km}$$

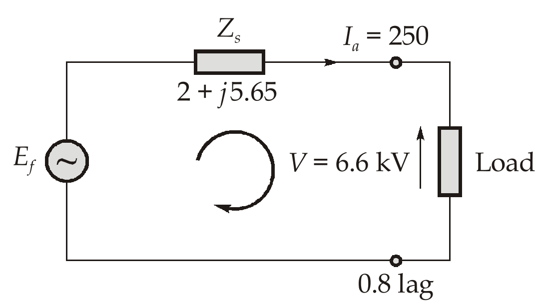
Total inductance, $L = L_1 + L_2$

$$= 1.45 \text{ mH/km}$$

32. Solution:

Synchronous impedance,

$$Z_s = \frac{E_f}{I_{sc}} = \frac{1500}{250} = 6\ \Omega$$



$$Z_s = \sqrt{X_s^2 + r_a^2}$$

Synchronous reactance,

$$X_s = \sqrt{Z_s^2 - r_a^2} = \sqrt{(6)^2 - (2)^2}$$

or $X_s = 5.656\ \Omega$

$$\bar{V} = 6.6 \times 10^3 \angle 0°$$

$$I_a = 250 \text{ A}$$

Load p.f. $\cos\phi = 0.8$ lag

$$\bar{I}_a = 250\angle{-36.9}$$

$$Z_s = 2 + j5.65 = 5.99\ \angle 70.5°$$

$$\bar{E} = \bar{V} + \bar{I}_a \bar{Z}_s = 6600\angle 0° + 250\angle -36.9° \times 5.99\angle 70.5°$$

$$\bar{E} = 7.89\angle 6.03 \text{ kV}$$

Terminal voltage if load is switched off,

$$V_t = E_f = 7.89 \text{ kV}$$

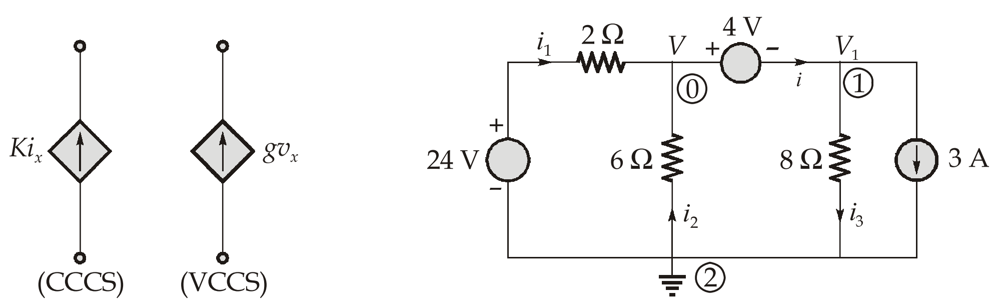
PART-C

33. Solution:

Dependent or controlled source:

In which the source quantity is determined by a voltage or current existing at some other location in the system source such as these appear in the equivalent electrical models for many electronic devices such as transistors, operational amplifier and integrated circuits.

Current controlled current source (CCCS) and Voltage controlled current source (VCCS)



By nodal analysis, $(-i_1) + (-i_2) + i = 0$

$$-\left(\frac{24-V}{2}\right) + \left(-\frac{0-V}{6}\right) + i = 0$$

$$\frac{(V-24)}{2} + \frac{V}{6} + i = 0 \quad \text{...(i)}$$

and $V_1 = V - 4$

KCL at node 1, $-i + \frac{V_1}{8} + 3 = 0$

$$i = \left(\frac{V-4}{8} + 3\right) \quad \text{...(ii)}$$

Combining both equation (i) and (ii),

$$\therefore \quad \frac{V-24}{2} + \frac{V}{6} + \frac{V-4}{8} + 3 = 0$$

$12\ V - 24 \times 12 + 4\ V + 3\ V - 12 + 3 \times 24 = 0$

$$9\ V = 24\left(12 + \frac{1}{2} - 3\right)$$

$\therefore$ $V = 12\text{ V}, V_1 = 8\text{ V},$

$$i_1 = \frac{24-12}{2} = 6\text{ A}$$

$$i_2 = -\frac{12}{6} = -2\text{ A}$$

$$i_3 = 1\text{ A}$$

34. Solution:

Gauss law states that the total electric flux crossing any closed surface is equal to the total charge enclosed by that closed surface.

$$\psi \text{ crossing closed surface} = Q_{\text{enclosed}} \quad \text{... (i)}$$

Given $\vec{D}$ electric flux density then electric flux crossing closed surface is

$$\psi \text{ crossing closed surface} = \oiint \vec{D}\cdot d\vec{S} \quad \text{... (ii)}$$

Put (ii) in (i),

$$\Rightarrow \quad \oiint \vec{D}\cdot d\vec{S} = Q_{\text{enclosed}} \quad \text{... (iii)}$$

Inside a closed surface volume is present. Total charge in a volume inside closed surface is

$$Q_{\text{enc}} = \iiint \rho_v dv \quad \text{... (iv)}$$

Put (iv) in (iii),

$$\oiint \vec{D}\cdot d\vec{S} = \iiint \rho_v dv \quad \text{... (v)}$$

From divergence theorem,

$$\oiint \vec{D}\cdot d\vec{S} = \iiint (\vec{\nabla}\cdot\vec{D})\, dv \quad \text{... (vi)}$$

Put (vi) in (v),

$$\iiint (\vec{\nabla}\cdot\vec{D})\, dv = \iiint \rho_v dv$$

Compare both sides, $\vec{\nabla}\cdot\vec{D} = \rho_v$ ... (viii)

equation (viii) says divergence of electric flux density is equal to volume charge density.

35. Solution:

Armature Reaction: When the armature of a d.c. machine carries current, the distributed armature winding produces its own mmf (distributed) known as armature reaction. The machine air-gap is now acted upon by the resultant mmf distribution caused by simultaneous action of the field ampere-turns ($A\,T_f$) and armature ampere-turns ($A\,T_a$). As a result the air-gap flux density gets distorted as compared to the flat-topped (trapezoidal) wave with quarterwave symmetry when the armature did not carry any current.

The effect of armature mmf

1. net reduction in the main field flux per pole.
2. distortion of the main field flux wave along the air-gap periphery.

This reduction in flux causes a decrease in the generator terminal voltage.

The cross-magnetizing effect of armature mmf can be minimised at the design and construction stage of a d.c. machine. Various methods of mitigating the effects of armature reaction:

(a) **High-reluctance Pole Tips:** If the reluctance of the pole tips is increased, then the magnitude of armature cross flux is reduced and the distortion of the resultant flux density wave is minimised.

(b) **Reduction in Armature Flux:** Another constructional technique of reducing the armature cross flux is to create more reluctance in the path of armature flux without reducing the main field flux. This is achieved by using field-pole laminations having several rectangular holes punched in them.

(c) **Strong Main-field Flux:** During the design of a d.c. machine, it should be ensured that the main field mmf is sufficiently strong in comparison with full-load armature mmf.

(d) **Interpoles:** The effect of armature reaction in the interpolar zone can be overcome by inter poles, placed in between the main poles.

(e) **Compensating Winding:** The effect of armature reaction under the pole shoes can be limited by using compensating winding. This winding is embedded in slots cut in the pole faces of the d.c. machine.

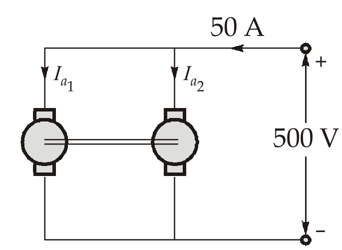
36. Solution:

$$E_{a_1} = E_{a_2} = V - R_a I_a$$

$$= 500 - (0.36)(50) = 482 \text{ V}$$

$$N_{m_1} = 700 \text{ rpm}$$

$$N_{m_2} = 750 \text{ rpm}$$



$\because$ $$E_{a_1} = K\,\phi_1 N_{m_1}$$

and $$E_{a_2} = K\,\phi_2 N_{m_2}$$

$\because$ $$E_{a_1} = E_{a_2}$$

then, $$\frac{\phi_1}{\phi_2} = \frac{N_{m_2}}{N_{m_1}}$$

or $$\frac{\phi_1}{\phi_2} = \frac{750}{700} = \frac{15}{14} \qquad ...(i)$$

when two motors are connected in series and mechanically coupled.

$$E_{a_1} + E_{a_2} = 500 - 50\,(0.72)$$

$$E_{a_1} + E_{a_2} = 464 \text{ V} \qquad ...(ii)$$

Since, $N_{m_1} = N_{m_2} = N_m$ (For mechanical coupled motors)

then, $\frac{E_{a_2}}{E_{a_1}} = \frac{\phi_2}{\phi_1} = \frac{14}{15}$ [(From equation (i)]

or, $$E_{a_2} = \frac{14}{15} E_{a_1}$$

From equation (ii), $E_{a_1} + \frac{14}{15} E_{a_1} = 464$

$\Rightarrow$ $$E_{a_1} = 240 \text{ V}$$

Comparing with data of separate operation for machine (i),

$$E_{a_1} = K\,\phi\, N_{m_1}$$

or, $$\frac{E'_{a_1}}{E''_{a_1}} = \frac{N'_{m_1}}{N''_{m_1}}$$

$$\frac{240}{482} = \frac{N}{700}$$

$$N = 348.55 \text{ rpm}$$

Similar result can be obtained from machine 2.

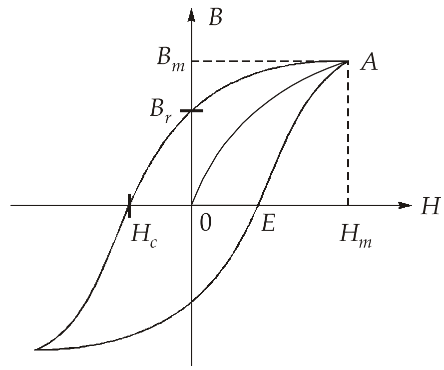
If, $$E'_{a_2} = 224$$

or, $$\frac{224}{482} = \frac{N}{750}$$

$$N = 348.55 \text{ rpm}$$

37. Solution:

Below the ferromagnetic curie temperature, ferromagnetic materials show a increase in susceptibility and exhibit B-H characteristics. Starting with a virgin specimen ($B = H = 0$) if H is increased, B at first increases, until at the point of saturation. This point, further increase $\bar{H}$ causes negligible change in $\vec{B}$. At saturation, if now H is decreased the curve will go through another path which is shown in the figure. When $\bar{H} = 0$, some residual flux will remain in the specimen is called residual or remnant flux density.

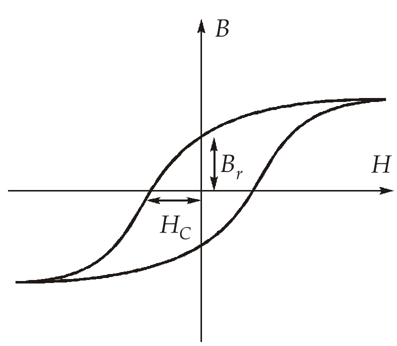
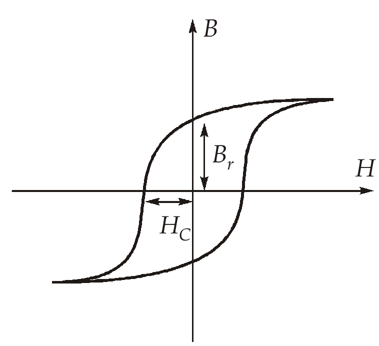


Further increase of $\bar{H}$ in negative direction, reduce the flux density to zero, is called the coercive force. Further increase of $\bar{H}$ leads to saturation.

Depending upon the coercive force and remnant flux density magnetic material are divided into two which are soft and hard magnetic materials.

Ferro magnetic material mainly we divided into two,

Ferromagnetic

Soft magnetic material	**Hard magnetic material**
High permeability, low retentivity, low coercivity and small hysteresis loss Suitable for making electromagnets, core of transformers etc. Example: Soft iron, supermalloy (used in magnetic shielding)	High permeability, high retentivity, high coercivity, large hysteresis loss and high curie temperature. Suitable for permanent magnet Example: Alnico
 Soft magnetic material	 Hard magnetic material

Example for hard magnetic material:

- **Alnico:** It is an alloy of aluminium, nickel and cobalt. Mainly used in PMMC.
- **Tungsten steel:** In which tungsten content is more than (50%).
- **Carbon steel:** Used in compass needle.

❍❍❍❍