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ESE – 2019

(MAINS)

Questions with Detailed Solutions

ELECTRICAL ENGINEERING

PAPER – I

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ELECTRICAL ENGINEERING

ESE MAINS-2019 PAPER-1

PAPER REVIEW

Overall paper was easy, some model questions from ACE Test Series are appeared in this paper. In Section-A more weightage given to Electromagnetic Fields subject and Section-A is easy as compared to Section-B. So choosing three questions from Section-A will fetch you to score good marks.

Section-A Subjects	**LEVEL**	**Marks**
Engineering Mathematics	Easy	72
Electric Circuits & Fields	Easy	96
Electrical Materials	Easy	72
Section –B Subjects	**LEVEL**	**Marks**
Electrical & Electronic Measurements	Easy	84
Computer Fundamentals	Moderate	72
Basic Electronic Engineering	Moderate	84

SECTION - A

1(a) Determine the eigen vectors of the matrix $\begin{bmatrix} -2 & 2 & -3 \\ 2 & 1 & -6 \\ -1 & -2 & 0 \end{bmatrix}$

Show that those eigen vectors are linearly independent. **12 M**

Sol: Let A = $\begin{vmatrix} -2 & 2 & -3 \\ 2 & 1 & -6 \\ -1 & -2 & 0 \end{vmatrix}$

Characteristic equation is $|A - \lambda I| = 0$

$$\begin{vmatrix} -2-\lambda & 2 & -3 \\ 2 & 1-\lambda & -6 \\ -1 & -2 & 0-\lambda \end{vmatrix} = 0$$

By simplifying, $\lambda^3 + \lambda^2 - 21\lambda = 0$

$\Rightarrow (\lambda-5)(\lambda+3)^2 = 0$

Eigen values are 5, −3, −3

Eigen vector corresponding to $\lambda = 5$:

$(A - 5I)X = 0$

$$\begin{bmatrix} -7 & 2 & -3 \\ 2 & -4 & -6 \\ -1 & -2 & -5 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$R_2 \to 7R_2 + 2R_1$

$R_3 \to 7R_3 - R_1$

$$\begin{bmatrix} -7 & 2 & -3 \\ 0 & -24 & -48 \\ 0 & -16 & -32 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$R_3 \to 3R_3 - 2R_2$

$$\begin{bmatrix} -7 & 2 & -3 \\ 0 & -24 & -48 \\ 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$-7x + 2y - 3z = 0$

$-24y - 48z = 0 \Rightarrow y + 2z = 0$

Let $z = k_1$ (parameter)

$\Rightarrow y = -2k_1 \Rightarrow x = -k_1$

$$\therefore \text{ Eigen vector } X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -k_1 \\ -2k_1 \\ k_1 \end{bmatrix} = k_1 \begin{bmatrix} -1 \\ -2 \\ 1 \end{bmatrix}$$

Eigen vector corresponding to $\lambda = -3$:

$(A + 3I)\, X = 0$

$$\begin{bmatrix} - & 2 & -3 \\ 2 & -4 & -6 \\ -1 & -2 & -5 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$R_2 \to R_2 - 2R_1$

$R_3 \to R_3 + R_1$

$$\begin{bmatrix} 1 & 2 & -3 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$x + 2y - 3z = 0$

Let $z = k_2$ & $y = k_3$

$\Rightarrow x = -2k_3 + 3k_2$

$$\therefore \text{ Eigen vectors } X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -2k_3 + 3k_2 \\ k_3 \\ k_2 \end{bmatrix}$$

$$= k_2 \begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix} + k_3 \begin{bmatrix} -2 \\ 1 \\ 0 \end{bmatrix}$$

$$\therefore \text{Eigen vectors are } \begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix} \text{ and } \begin{bmatrix} -2 \\ 1 \\ 0 \end{bmatrix}$$

$$\therefore \text{ Finally eigen vectors are } \begin{bmatrix} -1 \\ -2 \\ 1 \end{bmatrix}, \begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix} \text{ and } \begin{bmatrix} -2 \\ 1 \\ 0 \end{bmatrix}$$

Verification for linearly independent:

Let B = $\begin{bmatrix} -1 & 3 & -2 \\ -2 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$

$|B| = -(-1) - 3(-1) - 2(-2)$

$= 1 + 3 + 4$

$= 8$

$\neq 0$

$\therefore$ The columns of B are linearly independent i.e., the eigen vectors $\begin{bmatrix} -1 \\ -2 \\ 1 \end{bmatrix}$, $\begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix}$ and $\begin{bmatrix} -2 \\ 1 \\ 0 \end{bmatrix}$ are linearly independent.

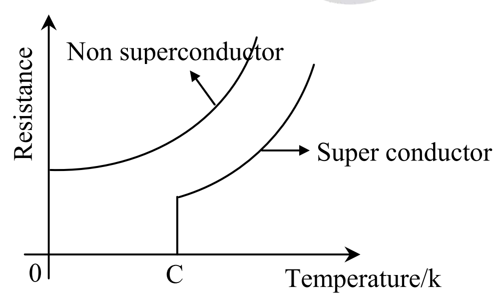
1(b) Discuss superconductivity, super conducting materials and their applications. 12

Sol: Superconductivity:

The resistivity of some materials abruptly becomes zero below a specific critical temperature. It is called Superconductivity. It was first observed in pure mercury at the critical temperature of 4.2° K. Different materials have different critical temperatures.

Superconductors and superconducting materials are metals, ceramics, organic materials, or heavily doped semiconductors that conduct electricity without resistance.

Superconducting materials can transport electrons with no resistance, and hence release no heat, sound, or other energy forms. Superconductivity occurs at a specific material's critical temperature (T_c). As temperature decreases, a superconducting material's resistance gradually decreases until it reaches critical temperature. At this point resistance drops off, often to zero, as shown in the graph.



Applications of Superconductivity:

Superconductors have many, diverse applications as given below.

1. Electromagnets:

Type – II superconductors are wound into solenoids to produce very high magnetic fields upto about 50 Tesla at a cost 1000 times less than the ordinary metal wire solenoids. Also, they are smaller in size.

2. Lossless power transmission:

Superconductor wires can be used to transmit electrical power from one point to another without any power dissipation. Only problem with them now is to maintain the entire system at low temperatures.

3. Cryotronics:

This new branch of electronics uses superconductors materials in low temperature application, which will have practically zero power dissipation. Superconductor are used in VLSI and creating super sensitive miniature receivers capable of detecting extremely weak radio signals giving, extension of radio bands into the microwave region up to infrared etc. Cryotron switches, gate amplifiers, oscillators are also being made

4. Josephson junctions:

In AC Josephson effect, the frequency of the oscillation super current is

$$\nu = \frac{2eV}{h} = 483.6\ \text{MHz}/\mu\text{V}$$

This can be used to construct microwave resonators with quality factor of 10^{-11}. (For conventional resonators, the quality factor limit is about 1.8×10^{-3}). Josephsons junctions are also used in ultra fast memory elements in computers. They are also used in SQUIDs.

5. SQUID:

Superconducting quantum interference device (SQUID) is useful in detecting extremely small magnetic fields of about 10^{-11} Tesla. They are useful in accurately measuring earth's fields, in detecting mineral deposits (or) oil deposits, medical diagnostics etc.

6. Magnetic Levitation:

To levitate is to lift. Magnetic levitation means making an object to lift in air due to magnetic repulsion. As superconductors are perfectly diamagnetic, repulsion will be thousands of times more powerful.

This concept is used in Maglev (or) Bullet trains. As there is no contact with the track, these trains can travel with very high speeds of about 560 mph.

7. Bearings:

Meissner effect is used here. The mutual repulsion between two superconductor can be used to produce bearings, which can operate without power loss and friction.

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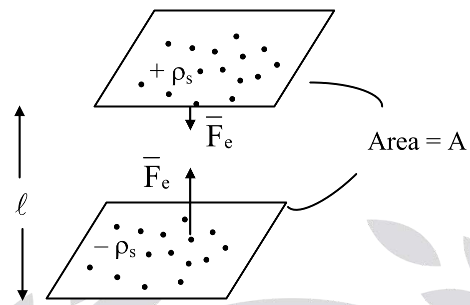
1(c) Find the force with which the plates of a parallel-plate capacitor attract each other. Also determine the pressure on the surface of the plate due to the field. **12**

Sol:



Let us consider a parallel Plate capacitor of area 'A' and plate separation 'ℓ' carrying a charge density $+\rho_s$ on one plate and $-\rho_s$ on the other. Separation between the plates is small compared to area.

The energy associated with the electrostatic field between the plates is

$$W_E = \frac{1}{2}\in E^2(A\ell)(J)$$

Suppose the plates are moved an infinitesimal (or) differential distance 'dℓ' apart , then

$$\frac{1}{2}\in E^2A(d\ell) = Fd\ell$$

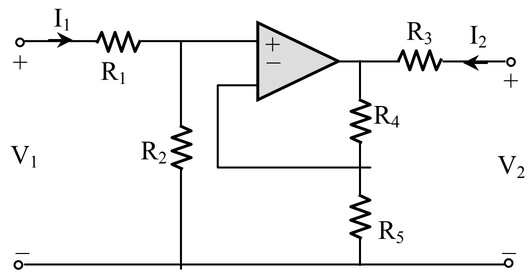
$\therefore$ The total (normal) force between the metal plates is

$$F = \frac{1}{2}\in E^2A(\text{or})\frac{1}{2}\in\left(\frac{V}{d}\right)^2 A\ \ (N)$$

Pressure : It is defined as force per unit area. Therefore the pressure on the surface of metal plate in the presence of electric field is given by

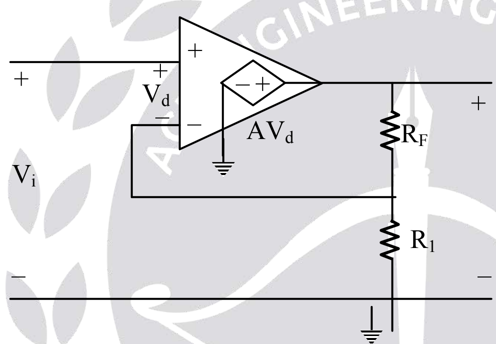
$$P = \frac{F}{A} = \frac{1}{2}\in E^2(\text{or})\frac{1}{2}\in\left(\frac{V}{d}\right)^2(\text{or})\frac{1}{2}\left(\vec{D}.\vec{E}\right)\ N/m^2$$

1(d)



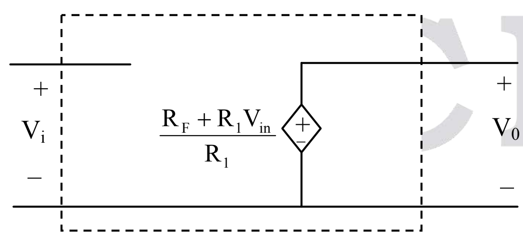
Find the z parameters of the network shown in the figure. Is the network reciprocal? If so why? Assume the operational amplifier is ideal. **12**

Sol: Fundamentals of OP – AMP

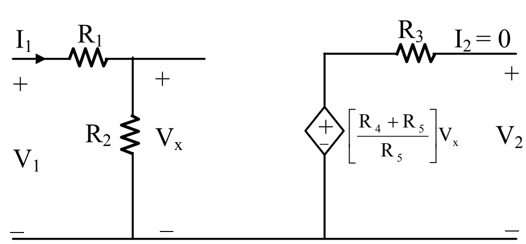


Most Op – amps have sufficiently large gain 'A' that the loop gain satisfies the condition AB>>1, Then 1+ AB ≈ AB

→ Now equivalent circuits is



Now the equivalent circuit is,



For Z_{11} & Z_{21} $\rightarrow$ $I_2 = 0$

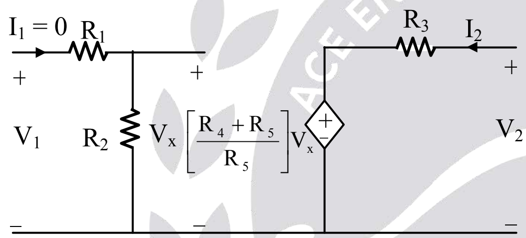
For $V_1 = (R_1 + R_2)\,I_1 \rightarrow$ $Z_{11} = \dfrac{V_1}{I_1} = R_1 + R_2$

Now $V_x = I_1 R_2$

So, $V_2 = \left[\dfrac{R_4 + R_5}{R_5}\right].V_x = \left[\dfrac{R_4 + R_5}{R_5}\right].R_2.I_1$

So, $Z_{21} = \dfrac{V_2}{I_1} = \dfrac{R_2(R_4 + R_5)}{R_5}$

For Z_{22} & Z_{12} $\rightarrow I_1 = 0$



$Z_{12} = \dfrac{V_1}{I_2}\Big|_{I_1=0}$

$\therefore\ V_x = V_1$

$V_1 = I_2 R_5$

$\dfrac{V_1}{I_2} = R_5$ $\qquad$ $Z_{12} = R_5$

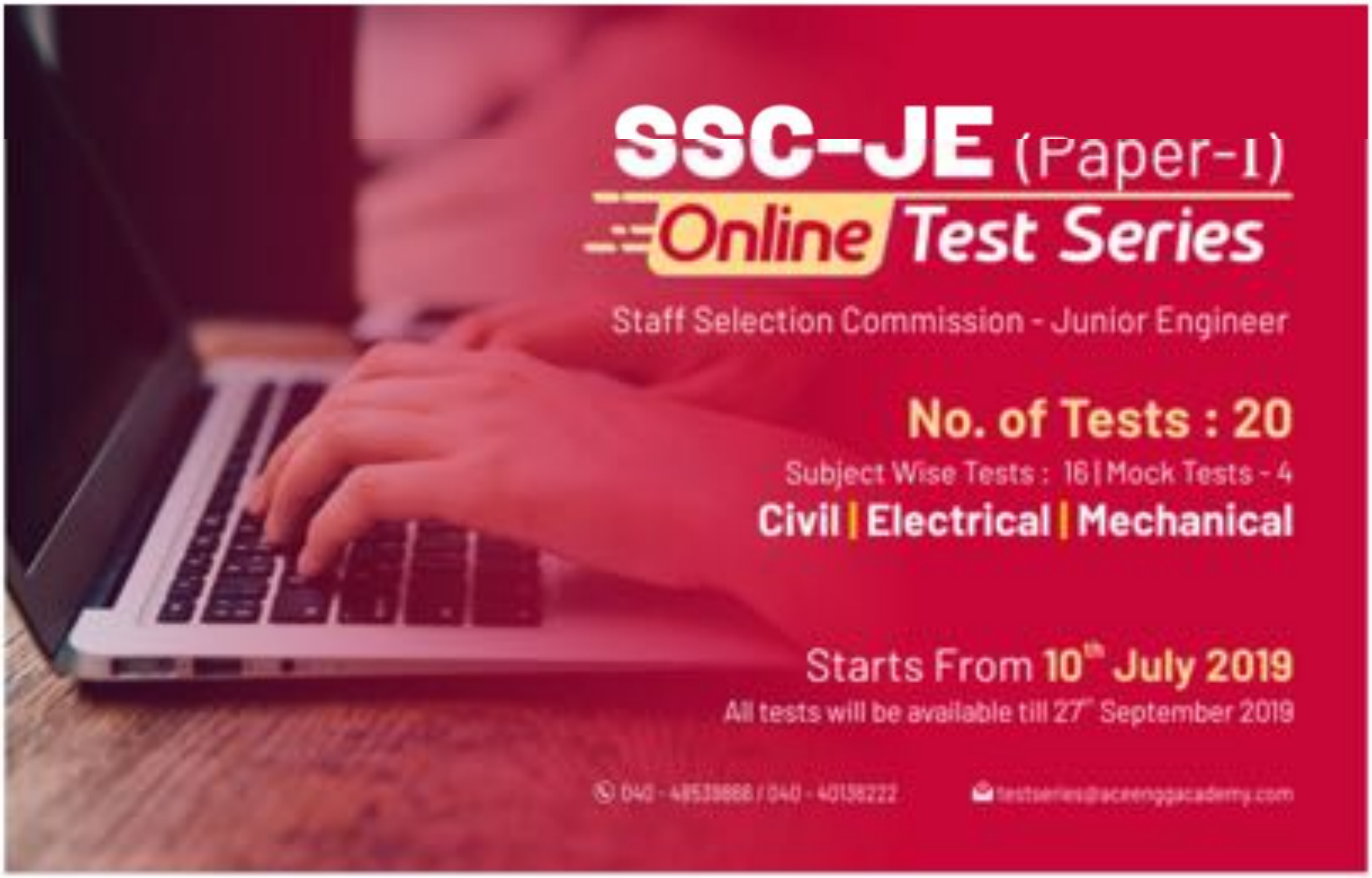
$Z_{22} = \dfrac{V_2}{I_2}\Big|_{I_1=0}$ $\qquad$ $V_2 = (R_3 + R_4 + R_5)\,I_2$

$\dfrac{V_2}{I_2} = R_3 + R_4 + R_5$

$Z_{22} = R_3 + R_4 + R_5$

$Z_{12} \neq Z_{21}$

So, this circuit is not reciprocal.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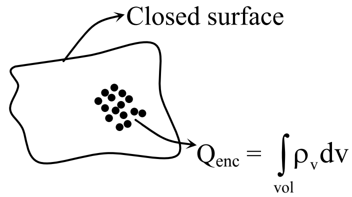
1(e) Volume charge density is the same as the divergence of the electric flux density Using Gauss's law, derive equations to prove it. 12

Sol: From Gauss's law

$$Q_{enc} = \oint_S \vec{D}.d\vec{S}$$



$$\int_{vol} \rho_v dv = \oint_S \vec{D}d\vec{S}$$

$$\int_{vol} \rho_v dv = \int_{vol} (\nabla.\vec{D})dv$$

$\therefore \rho_v = \nabla.\vec{D}$ $\rightarrow$ Maxwell's equation

Volume charge density is same as, divergence of electric flux density (or) displacement flux density.

2(a) Find the difference between the values of $\int_c \phi d\vec{r}, \phi(x,y) = x^3y + 2y$ from (1,1,0) to (2,4,0) along the curve $y=x^2$, z = 0 and along the straight line joining (1,1,0) and (2,4,0). Hence evaluate $\int_c (\nabla.\vec{f})d\vec{r}$, where $\vec{f} = \frac{1}{4}x^4y\hat{i} + y^2\hat{j} + xy\hat{k}$ along the curve which is a parabola $y = x^2$, z = 0 from (1, 1, 0) to (2, 4, 0). 20

Sol: Along $y = x^2, z = 0$

$\Rightarrow dy = 2xdx$ & $dz = 0$

Let A = (1, 1, 0) & B = (2, 4, 0)

$$\int_C \phi d\bar{r} = \int_A^B (x^3y + 2y)(dx\bar{i} + dy\bar{j} + dz\bar{k})$$

$$= \int_A^B (x^5 + 2x^2)dx\bar{i} + 2xdx\bar{j} + 0\bar{k}$$

$$= \int_1^2 (x^5 + 2x^2)(\bar{i} + 2x\bar{j})dx$$

$$= \int_1^2 \left[(x^5 + 2x^2)\bar{i} + (2x^6 + 4x^3)\bar{j}\right]dx$$

$$= \left[\left(\frac{x^6}{6} + \frac{2x^3}{3}\right)\bar{i} + \left(\frac{2x^7}{7} + \frac{4x^4}{4}\right)\bar{j}\right]_1^2$$

$$= \left[\left(\frac{2^6}{6}+\frac{2^4}{3}\right)-\left(\frac{1}{6}+\frac{2}{3}\right)\right]\bar{i}+\left[\left(\frac{2^8}{7}+2^4\right)-\left(\frac{2}{7}+1\right)\right]\bar{j}$$

$$= \frac{91}{6}\bar{i}+\frac{359}{7}\bar{j} \quad \text{.......... (1)}$$

Case (ii):

Along the line joining A(1, 1, 0) & B(2, 4, 0)

$z = 0 \Rightarrow dz = 0$

$(y-1) = \frac{(4-1)}{(2-1)}(x-1)$

$\therefore \quad y = 3x - 4$

$dy = 3dx$

$$\int_C \phi d\bar{r} = \int_A^B (x^3+2y)(dx\bar{i}+dy\bar{j}+dz\bar{k})$$

$$= \int_A^B \left[x^3+2(3x-4)\right](dx\bar{i}+3dx\bar{j})$$

$$= \int_{A`}^B (x^3+6x-8)(\bar{i}+3\bar{j})dx$$

$$= (\bar{i}+3\bar{j})\int_1^2 (x^3+6x-8)dx$$

$$= (\bar{i}+3\bar{j})\left[\frac{x^4}{4}+6\left(\frac{x^2}{2}\right)-8x\right]_1^2$$

$$= (\bar{i}+3\bar{j})\left[4+12-16-\left(\frac{1}{4}+3-8\right)\right]$$

$$= (\bar{i}+3\bar{j})\left(0+\frac{19}{4}\right)$$

$$= \left(\frac{19}{4}\bar{i}+\frac{57}{4}\bar{j}\right) \quad \text{............. (2)}$$

The difference between (1) and (2)

$$\left(\frac{91}{6}-\frac{19}{4}\right)\bar{i}+\left(\frac{359}{7}-\frac{57}{4}\right)\bar{j}$$

$$= \frac{125}{12}\bar{i}+\frac{1037}{28}\bar{j}$$

Given $\bar{f} = \left(\frac{1}{4}x^4 y\bar{i} + y^2\bar{j} + xy\bar{k}\right)$

$$\nabla.\bar{f} = (x^3 y + 2y) = (x, y)$$

$$\int_C (\nabla.\bar{f})d\bar{r} = \int_C \phi(x, y)d\bar{r}$$

$$= \frac{91}{6}\bar{i} + \frac{359}{7}\bar{j}$$

[Along the curve $y = x^2$ & $z = 0$ from case (i)]

2(b) (i) State Hall effect and discuss the applications of Hall effect. **12**

(ii) A flat silver strip of width 1.5 cm and thickness 1.5 mm carries a current of 150 amperes. A magnetic field of 2.0 Tesla is applied perpendicular to the flat face of the strip. The emf developed across the width of the strip is measured to be 17.9 μV (Hall effect). Estimate the number density of free electrons in the metal. **8**

Sol: (i) Hall Effect:

This effect is based on the behavior of a charge carrier in electric and magnetic fields. It was primarily used to find the sign of the charge carriers in conductors. It is also useful in finding the drift velocity (V_d), carrier concentration, magnetic field strength, conductivity / resistivity of the material, mobility of charge carriers and the type of semiconductor.

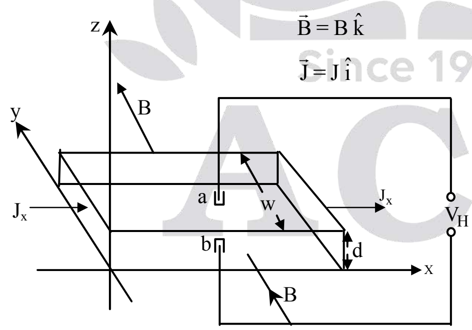


Fig. Hall effect in semiconductor

Consider a uniform, thick metal strip, with its length along x-axis: 'w' be the width, and d be the thickness of the strip. A uniform transverse magnetic field $\vec{B}$ is applied along the y-axis.

When a current 'i' established along the x-axis, the charge carriers experience a deflecting force along z-axis given by $\vec{F} = q(\vec{V}_d \times \vec{B})$.

From Fleming's left hand rule, we get that, let the charge carriers be +ve (or) –ve, this force deflects charges towards upper surface of the strip. This accumulation of charges develops a potential difference across upper and lower surfaces called Hall potential difference V_{ab}.

If the charge carriers are +ve, Hall PD $V_H = V_{ab} = +ve$

If the charge carriers are –ve, Hall PD $V_H = -ve$

Thus by the sign of Hall emf, we can find the sign of charge carriers. This Hall emf, produces a transverse stall off electric field $E_H = \frac{b}{n}$ 'a' and 'b'. This E_H acts in opposite direction to magnetic force.

$$E_H = \frac{V_H}{d} \qquad \ldots\ldots\ldots\ldots(1)$$

Soon an equilibrium position is reached where the net force on the carriers is zero. i.e.,

$qE_H + q(V_d \times B) = 0$

$E_H = -(V_d \times B)$

$$|E_H| = V_dB \qquad \ldots\ldots\ldots\ldots(2)$$

Thus drift velocity can be measured as

$$V_d = \frac{J}{nq} \qquad \ldots\ldots\ldots\ldots(3)$$

We can find the carrier concentration 'n' also. From (2) and (3) we have

$$\frac{E_H}{JB} = \frac{1}{nq} = R_H \qquad \ldots\ldots\ldots\ldots(4)$$

The ratio is defined as Hall coefficient.

This Hall coefficient R_H is –ve, if the sign 'q' of charge carriers is –ve.

$R_H = \frac{1}{nq}$ is +ve for +ve charge carriers.

$$\frac{E_H}{JB} = \frac{1}{nq}$$

$J = \sigma E$ (Ohm's law)

$$\sigma = \frac{nqE_H}{BE}$$

$$\therefore \sigma = \frac{nqV_H}{BEd}$$

Thus conductivity or resistivity $\left(\rho = \frac{1}{\sigma}\right)$ can be measured. Also we have

$V_d = \mu E$

$$\mu = \frac{V_d}{E} = \frac{E_H}{BE}$$

Thus mobility of the carriers can be found.

For monovalent metals, R_H is –ve and for some divalent alkaline earth metals like Mg, Zn etc., R_H = +ve. This is because their filled valance band gives rise to hole conduction.

Applications:

Hall voltage experiment it used to find

(i) Type of semiconductor

(ii) Number of electrons per unit volume

(iii) Electrical conductivity of metal

(iv) Mobility of an electron

(ii) given data;

$b = 1.5\text{ cm} = 1.5 \times 10^{-2}\text{ m}$

$d = 1.5\text{ mm} = 1.5 \times 10^{-3}\text{ m}$

$I = 150\text{ A}$

$B = 2.0$ Tesla

$V_H = 17.9\ \mu V = 17.9 \times 10^{-6}\text{ V}$

$n = ?$

We know that

$$V_H = \frac{BI}{ned}$$

$$n = \frac{BI}{V_H ed}$$

$$n = \frac{2 \times 150}{17.9 \times 10^{-6} \times 1.6 \times 10^{-19} \times 1.5 \times 10^{-3}}$$

$= 6.98 \times 10^{28}\text{ m}^{-3}$

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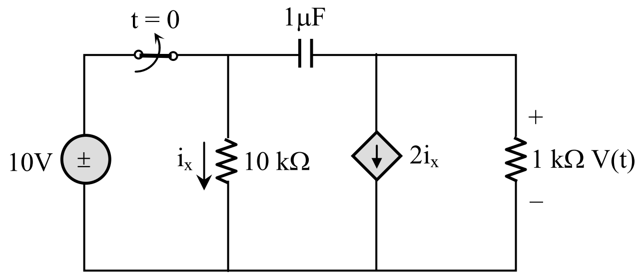
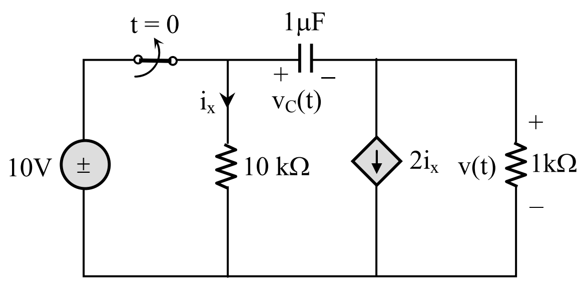
2(c)



For the circuit shown in figure,

(i) Find the expression of V(t), the voltage across 1kΩ resistor when the switch is opened at time t=0.

(ii) Sketch V(t) with respect to time (t) and mark the time constant τ **20**



Sol: 1) $t = 0^- : i_x = \dfrac{10}{10000} = \dfrac{1}{1000}$ A.

C acts as open

$$v(t) = \frac{2}{1000}1000(-1) \quad = -2 \text{ V}$$

$v_c(t) = 12$ V

2) $t = 0^+ : v_c(t) = 12$ V

$12 = i_x\ 10{,}000 + 3i_x\ 1000 = 13000 i_x$

$$i_x = \frac{12}{13000} \text{ A}$$

$$v = -\frac{36}{13} \text{ volts}$$

3) $10^{-6}\dfrac{dv_c}{dt} = -i_x$

$v_c(t) = 10000 i_x + 3000 i_x = 13000 i_x$

$$\frac{dv_c}{dt} = 13000\frac{di_x}{dt}$$

$$10^{-6}\left(13000\frac{di_x}{dt}\right) = -i_x$$

$$\frac{13}{1000}\frac{di_x}{dt} + i_x = 0$$

$$\Rightarrow \frac{di_x}{dt} + \frac{1000}{13} i_x = 0$$

$$i_x = Ae^{-\frac{t}{13/1000}}$$

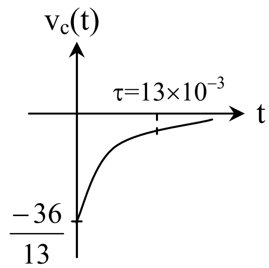
$$A = \frac{12}{13000}$$

$$i_x = \frac{12}{13000} e^{\frac{-t}{\tau}}$$

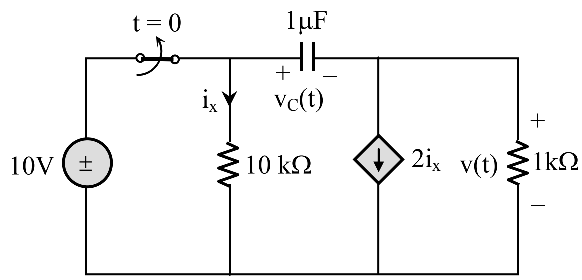
τ = 13 milli sec

$$V(t) = -\frac{36}{13} e^{\frac{-t}{\tau}}$$

$$t = 0^+ : v(t) = \frac{-36}{13}\ V$$



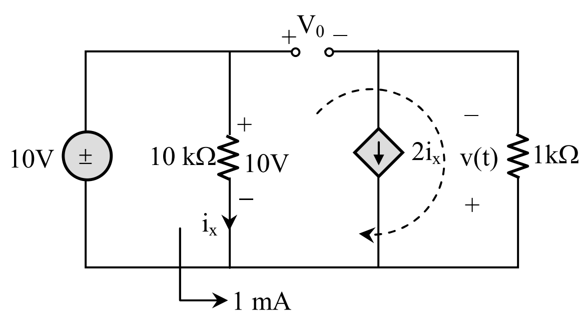
Method 2:



- This is a source free 1st order R-C circuit and state-variable is voltage across capacitor
- Let us select $v_c(t)$ across capacitor

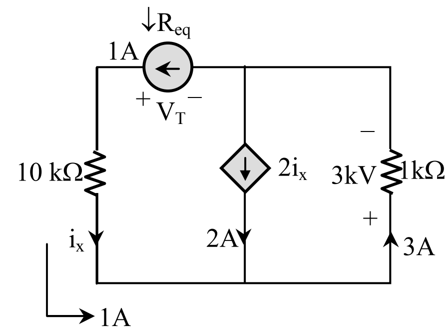
$V_c(t) = V_0 e^{-t/\tau}$

First, 'V_0' ($t = 0^-$)



KVL $-10 + V_0 - 2 = 0 \Rightarrow V_0 = +12$ volts

Now $T = R_{eq}C$



$-V_T + 10\text{ K} + 3\text{K} = 0 \rightarrow V_T = 13000$ V

$$R_{eq} = \frac{V_T}{1} = 13000\ \Omega$$

$T = R_{eq}\,C = (13000)(1\times 10^{-6}) = 13$ msec

So, $V_c(t) = 12e^{\frac{-t}{13\times10^{-3}}}$

$$\text{Now } i_x = C\frac{dV_c(t)}{dt} = 1\ \mu\frac{d}{dt}\left(12e^{-\frac{t}{13\times10^{-3}}}\right)$$

$$i_x = \frac{-12}{13000}e^{\frac{-t}{13\times10^{-3}}}$$

But capacitor discharges so, i_x is +ve

$$i_x = \frac{12}{13000}e^{\frac{-t}{13\times10^{-3}}}$$

$$\text{Now, } V(t) = -3(i_x)(1\times10^3) = \frac{-36}{13}e^{\frac{-t}{13\times10^{-3}}}$$

At $t = 0$

$$V(t) = \frac{-36}{13}\text{V}$$

3(a) A string of flexible wire stretched on a sitar has its ends fixed at x = 0 and x = 20. Initially at t = 0, the string is at rest and takes the shape as defined by h(x) = μ(20x – x²), μ being a constant, and then it is released to vibrate. Formulate this boundary value problem and solve that to find the displacement at any point x at an instant t. The solution, to be obtained, should involve definite constants not the arbitrary ones. **20**

Sol: Given that $h(x, 0) = \mu(20x - x^2) \Rightarrow \frac{dh}{dt} = 0$ when $t = 0$

And $h(0, t) = h(20, t) = 0$(here length $l = 20$)

Hence based on the above conditions

$$H(x,t) = \sum_{n=1}^{\infty} a_n \cos\left(\frac{n\pi Ct}{20}\right)\sin\left(\frac{n\pi x}{20}\right) \quad \ldots\ldots\ldots\ldots. (1)$$

Where $a_n = \frac{2}{20}\int_0^{20} h(x,0)\sin\left(\frac{n\pi x}{20}\right)dx$

$$= \frac{1}{10}\int_0^{20} \mu(2x - x^2)\sin\left(\frac{n\pi x}{20}\right)dx$$

$$= \frac{\mu}{10}\int_0^{20} x(20-x)\sin\left(\frac{n\pi x}{20}\right)dx$$

$$= \frac{\mu}{10}\left[x(20-x)(-\cos\left(\frac{n\pi x}{20}\right)\left(\frac{20}{n\pi}\right) - (20-2x)\left(-\sin\frac{n\pi x}{20}\right)\left(\frac{400}{n^2\pi^2}\right) + (-2)\cos\left(\frac{n\pi x}{20}\right)\left(\frac{8000}{n^3\pi^3}\right)\right]_0^{2\pi}$$

$$a_n = \frac{\mu}{10}\left[-\frac{16000}{n^3\pi^3}\cos n\pi + \frac{16000}{n^3\pi^3}\right]$$

$$= \frac{1600\mu}{n^3\pi^3}[1 - \cos n\pi]$$

$$= \begin{cases} \frac{3200\mu}{n^3\pi^3}; \ n = 1,3,5.... \\ 0 \qquad ; \ n = 2,4,6.... \end{cases}$$

$$= \frac{1600\mu}{(2m-1)^3\pi^3} \ ; \ [n = (2m-1), m = 1, 2, 3, ...] \ .... (2)$$

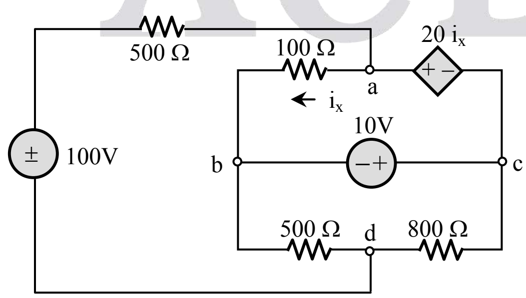
Substitute eqn. (2) in (1)

$$h(x, t) = \frac{3200\mu}{\pi^3}\sum_{m=1}^{\infty}\frac{1}{(2m-1)^3}\cos\left[\frac{(2m-1)\pi Ct}{20}\right]\sin\left[\frac{(2m-1)\pi x}{20}\right]$$

(Here c & m are definite constants only)

This gives the displacement of an point 'x' and at an instant 't'.

3(b)

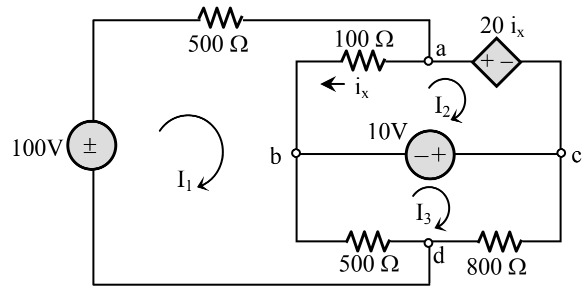


For the circuit shown in the figure,

(i) Find the node voltages.

(ii) Power absorbed by the 800 Ω resistor. **20**

Sol:



From mesh analysis in loop-1:

$-100 + 500I_1 + 100(I_1 - I_2) + 500(I_1 - I_3) = 0$

$1100I_1 - 100I_2 - 500I_3 = 100$

$11I_1 - I_2 - 5I_3 = 1$ …………….. (1)

In loop-2:

$100(I_2 - I_1) + 20i_x + 10 = 0$

Where $i_x = I_1 - I_2$

$100I_2 - 100I_1 + 20(I_1 - I_2) + 10 = 0$

$80I_2 - 80I_1 = -10$ …………… (2)

In loop-3:

$500(I_3 - I_1) - 10 + 800I_3 = 0$

$500I_1 + 1300I_3 = 10$

$-50I_1 + 130I_3 = 1$ ………….. (3)

By simplifying eq. (1), (2) and (3)

$I_1 = 0.113$ A, $I_2 = -0.012$ A and $I_3 = 0.051$ A

(i) Node voltages V_a, V_b & V_c

$V_a = 100 - I_1 \times 500$

$= 100 - 0.113 \times 500$

$= 43.5$ V

$V_b = 500 \times (I_1 - I_3)$

$= 31$ V

$V_c = 800 \times I_3$

$= 40.8$ V

(ii) Power absorbed by 800 Ω resistor

$P = I_3^2 \times 800$

$= (0.051)^2 \times 800$

$= 2.08$ W

3(c) List properties of ceramic materials and write their applications in technology. 20

Sol: Properties of Ceramic materials:

- Ceramic materials are inorganic, non-metallic materials made from compounds of metal and non-metals.
- They may be crystalline or non-crystalline and are formed by action of heat and subsequent heating.
- They do not have large number of free electrons. Electrons are being covalently shared as in case of ionic bonds.
- Due to presence of ionic & covalent bond, ceramic materials are solid, inert hard, brittle, strong in compression, weak in shearing and tension.
- Other characteristics are low thermal expansion, low water absorption also good electrical properties.
- They are classified in two groups based on permittivity.
- Permittivity less than 12 ($\varepsilon_r < 12$)

  Ex. Porcelain, Alumina, etc
- Porcelain informally referred as 'china clay' is used as an insulator in transmission and distribution, also used in fuses, plugs and sockets.
- Most common use of porcelain is for utilitarian wares and artistic objects.
- Alumina is used in some sodium vapour lamps and also in preparation of coating suspensions in CFLs.
- Permittivity greater than 12 ($\varepsilon_r > 12$)

  Ex: Barium titanate ($BaTiO_3$) calcium copper titanate
- Barium titanate is used for capacitors, microphones and other transducers.
- CCTO has permittivity of approximately 12000 at room temperature and is used for reducing size of capacitors.

High permittivity materials mainly used in semi conductor manufacturing process to replace silicon dioxide.

Applications:

(i) *Aluminium oxide / Alumina* (Al_2O_3): it is one of most commonly used ceramic material. It is used in many applications such as to contain molten metal, where material is operated at very high temperatures under heavy loads, as insulators in spark plugs, and in some unique applications such as dental and medical use. Chromium doped alumina is used for making lasers.

(ii) *Aluminium nitride* (AlN): because of its typical properties such as good electrical insulation but high thermal conductivity, it is used in many electronic applications such as in electrical circuits operating at a high frequency. It is also suitable for integrated circuits. Other electronic ceramics include – barium titanate ($BaTiO_3$) and Cordierite ($2MgO$-$2Al_2O_3$-$5SiO_2$).

(iii) *Diamond* (C): it is the hardest material known to available in nature. It has many applications such as industrial abrasives, cutting tools, abrasion resistant coatings, etc. it is, of course, also used in jewelry.

(iv) *Lead zirconium titanate* (PZT): it is the most widely used piezoelectric material, and is used as gas igniters, ultrasound imaging, in underwater detectors.

(v) *Silica* (SiO_2): is an essential ingredient in many engineering ceramics, thus is the most widely used ceramic material. Silica-based materials are used in thermal insulation, abrasives, laboratory glassware, etc. it also found application in communications media as integral part of optical fibers. Fine particles of silica are used in tires, paints, etc.

(vi) *Silicon carbide* (SiC): it is known as one of best ceramic material for very high temperature applications. It is used as coatings on other material for protection from extreme temperatures. It is also used as abrasive material. It is used as reinforcement in many metallic and ceramic based composites. It is a semiconductor and often used in high temperature electronics. Silicon nitride (Si_3N_4) has properties similar to those of SiC but is somewhat lower, and found applications in such as automotive and gas turbine engines.

(Vii)*Titanium oxide* (TiO_2): it is mostly found as pigment in paints. It also forms part of certain glass ceramics. It is used to making other ceramics like $BaTiO_3$.

(viii) *Titanium boride* (TiB_2): it exhibits great toughness properties and hence found applications in armor production. It is also a good conductor of both electricity and heat.

(ix) *Uranium oxide* (UO_2): it is mainly used as nuclear reactor fuel. It has exceptional dimensional stability because its crystal structure can accommodate the products of fission process.

(x) *Yttrium aluminium garnet* (YAG, $Y_3Al_5O_{12}$): it has main application in lasers (Nd-YAG lasers).

4(a) (i) An electrostatic filed in xy-plane is given by ϕ (x,y), = $3x^2y - y^3$. Find he stream function ψ such that the complex potential $\omega = \phi + i\psi$ is an analytic function **8**

(ii) Find three Laurent's series expansions of the function f(z) = $\dfrac{1}{3z - z^2 - 2}$ and specify the regions in which those expansions are valid **12**

Sol: (i) Given $\phi(x, y) = 3x^2y - y^3$

$$\frac{\partial\phi}{\partial x} = 6xy, \ \frac{\partial\phi}{\partial y} = 3x^2 - 3y^2$$

By C-R equations $\dfrac{\partial\phi}{\partial x} = \dfrac{\partial\psi}{\partial y}, \quad \dfrac{\partial\phi}{\partial y} = -\dfrac{\partial\psi}{\partial x}$

$$\therefore \ \frac{\partial\psi}{\partial y} = 6xy, \frac{\partial\psi}{\partial x} = -3x^2 + 3y^2$$

We know that $\dfrac{d\omega}{dz} = f'(z) = \dfrac{\partial\phi}{\partial x} + i\dfrac{\partial\psi}{\partial x}$

$$= 6xy + I\,(-3x^2+3y^2)$$

By Milne Thompson method, put x = z, y = 0 and integrate

$$\Rightarrow \quad \frac{d\omega}{dz} = f'(z) = 0 + i(-3z^2)$$

$$\Rightarrow \quad \omega = f(z) = -3i\frac{z^3}{3} + C$$

$$= -iz^3 + C$$

$$= -i\ (x+iy)^3 + C$$

$$= -i\,(x^3+3x^2iy-3xy^2 - iy^3)+C$$

$$= (3x^2y-y^3) + i(3xy^2 - x^3) + C$$

$\therefore$ Closely $\phi = 3x^2y - y^3$

$$\psi = 3xy^2 - x^3$$

(ii) $f(z) = \dfrac{1}{3z - z^2 - 2}$

$$= -\frac{1}{z^2 - 3z + 2}$$

$$= \frac{-1}{(z-2)(z-1)}$$

By applying partial fractions

$$= \frac{A}{(z-1)} + \frac{B}{(z-2)}$$

$A(z-2) + B(z-1) = -1$

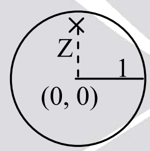
$A = 1,\ B = -1$

$$\Rightarrow \frac{1}{z-1} - \frac{1}{z-2}$$

Case (i): $z < 1$

$$\Rightarrow \frac{1}{z-1} - \frac{1}{z-2}$$

$$\Rightarrow \frac{-1}{1-z} + \frac{1}{2(1-z/2)}$$



$\Rightarrow -(1-z)^{-1} + ½\,(1-z/2)^{-1}$

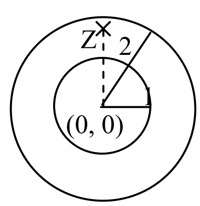
$$\Rightarrow -[1 + z + z^2 \;\ldots\ldots] + \frac{1}{2}\left[1 + \frac{z}{2} + \left(\frac{z}{2}\right)^2 \ldots\ldots\right]$$

$$\left(\frac{1}{2} - 1\right) + \left(\frac{1}{2^2} - 1\right)z + \left(\frac{1}{2^3} - 1\right)z^2 + \ldots\ldots\ldots\ldots\ldots\ldots$$

$\displaystyle\sum_{n=0}^{\infty}\left(\frac{1}{2^{n+1}} - 1\right)z^n$ valid for $|z| < 1$

Case (ii): $1 < z < 2$

$$\Rightarrow \frac{1}{z-1} - \frac{1}{z-2}$$

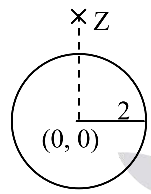


$$\Rightarrow \frac{1}{z}\left(\frac{1}{1 - \frac{1}{z}}\right) + \frac{1}{2\left(1 - \frac{z}{2}\right)}$$

$$\Rightarrow \frac{1}{z}\left[1-\frac{1}{z}\right]^{-1}+\frac{1}{2}\left[1-\frac{z}{2}\right]^{-1}$$

$$\Rightarrow \frac{1}{z}\left[1+\frac{1}{z}+\left(\frac{1}{z}\right)^{2}.....\right]+\frac{1}{2}\left[1+\frac{z}{2}+\left(\frac{z}{2}\right)^{2}......\right]$$

Case (iii): $z > 2$



$$\Rightarrow \frac{1}{z-1}-\frac{1}{z-2}$$

$$\Rightarrow \frac{1}{z\left(1-\frac{1}{z}\right)}-\frac{1}{z\left(1-\frac{2}{z}\right)}$$

$$\Rightarrow \frac{1}{z}\left(1-\frac{1}{z}\right)^{-1}-\frac{1}{z}\left(1-\frac{2}{z}\right)^{-1}$$

$$\Rightarrow \frac{1}{z}\left[1+\frac{1}{z}+\left(\frac{1}{z}\right)^{2}......\right]-\frac{1}{z}\left[1+\frac{2}{z}+\left(\frac{2}{z}\right)^{2}.......\right]$$

$$\Rightarrow \frac{1}{z^2}(1-2)+\frac{1}{z^3}(1-2^2)+\ \ldots\ldots\ldots$$

$$\sum_{n=1}^{\infty}\frac{(1-2^n)}{z^{n+1}} \quad \text{valid for } |z|>2$$

4(b) What are magnetic materials? Give classification of magnetic materials and name some materials in each class. 20

Sol: Magnetic materials are materials studied and used mainly for their magnetic properties. The magnetic response of a materials is largely determined by the magnetic dipole moment associated with the intrinsic angular momentum, or spin, of its electrons. A material's response to an applied magnetic field can be characterized as diamagnetic, paramagnetic, ferromagnetic or antiferromagnetic.

The classification for the magnetic materials is as below.

Nickel – Ferromagnetic material

Silver- Diamagnetic material

Tungsten – Parametric material

Sodium chloride - Diamagnetic material

We know that value of μ_r decides the magnetic strength required to magnetize a material.

- Among the given materials, silver and sodium chloride are diamagnetic so their permeability value is less than unity and hence will require highest amount of magnetic strength to magnetic them.
- Tungsten is paramagnetic material with permeability slightly greater than unity and hence will require high amount of magnetic strength to magnetic it.
- Nickel is a ferromagnetic material which has very high value of permeability so, amount of strength required to magnetize it will be very less and least among the given materials.

4(c) (i) Show that in a source-free region ($J = 0$, $\rho_v = 0$), Maxwell's equations can be reduced to two. Identify the two all – embracing equations. 10

(ii) Determine the total charge for the following: 10

(A) on a line $0 \le x \le 5$m if $\rho_L = 12x^2$ milli C/m

(B) on a cylinder $\rho = 3$, $0 \le z \le 4$m if $\rho_s = \rho z^2$ nC/m^2

Sol: (i) Consider the Maxwell's equations for static electromagnetic fields.

$$\nabla.\vec{D} = \rho_v$$

$$\nabla\times \vec{H} = \vec{J}$$

$$\nabla \times \vec{E} = 0$$

$$\nabla. \vec{B} = 0$$

For source free region: $\vec{J} = 0$ & $\rho_v = 0$

$$\nabla.\vec{D} = 0$$

$$\nabla \times \vec{H} = 0$$

- $\vec{J} = 0$, indicates only volume current density is zero, but there are other sources (like line current and sheet current) can present to contribute magnetic field.
- $\rho_v = 0$, indicate only volume charge density is zero, but there are other source, (like line charge and surface charge densities) can present to contribute electric flux density.

(ii) A. Given: Charge density, $\rho_l = 12x^2$ milliC/m; $0 \le x \le 5$m

Total charge $Q = \int_{\text{Line}} \rho_\ell d\ell$

$$= 10^{-3}\int_{x=0}^{5} 12x^2 dx$$

$$= 12 \times 10^{-3} \left.\frac{x^3}{3}\right|_0^5$$

$$= 4 \times 125 \times 10^{-3}$$

$$\therefore \qquad Q = 500 \text{ mC}$$

B. Given: Charge densities, $\rho_S = \rho z^2$ nC/m^2; $\rho = 3$, $0 \le z \le 4$

Total charge, $Q = \int \rho_S dS$

$$= 10^{-9} \int_{z=0}^{4} \int_{\phi=0}^{2\pi} \rho z^2 \rho d\phi dz \qquad \text{given, } \rho = 3$$

$$= (3)^2 \times 10^{-9} \left.\frac{z^3}{3}\right|_0^4 (2\pi)$$

$$= 3 \times 10^{-9} \times 64 \times 2\pi$$

$$\therefore \qquad Q = 1.206\ \mu\text{C}$$

SECTION – B

5(a) (i) Determine the possible base of the number in the operation mentioned below

23+ 44 + 14 + 32 = 223 **4**

Sol: $(23)_x + (44)_x + (14)_x + (32)_x = (223)_x$

$2x + 3 + 4x + 4 + x + 4 + 3x + 2 = 2x^2 + 2x + 3$

$10x + 13 = 2x^2 + 2x + 3$

$2x^2 - 8x - 10 = 0$

$2x^2 - 10x + 2x - 10 = 0$

$2x(x - 5) + 2(x - 5) = 0$

$(2x + 2)(x - 5) = 0$

$x = -1, 5$

The possible base is $x = 5$

5(a) (ii) Find the minimal sum of products (SOP) expression of the following boolean function f (a,b,c,d)

f (a,b,c,d) = abc + abd + a′bc′ + cd + bd′

where a′, b′, c′ and d′ are complements of variables a,b,c, and d respectively. **4**

Sol: Method 1:

$abc + abd + a'bc' + bd' + cd$

Take b common

$= b(ac + ad + a'c' + d') + cd$ $\quad (\because ad + d' = a + d')$

$= b(ac + a + d' + a'c') + cd$

$= b(a + c + d' + a'c') + cd$

$= b(a + c' + c + d') + cd$ $\quad (\because a + a'c' = a + c')$

$= b(1) + cd$ $\quad (\because c + c' = 1)$

$= b + cd$

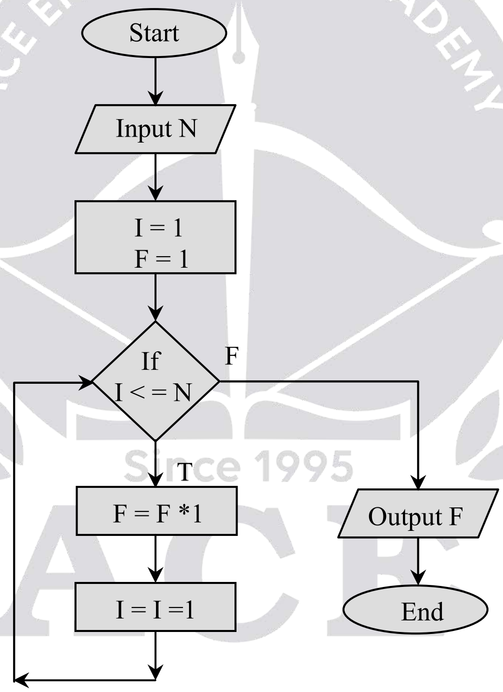
Method 2:

$f(a, b, c, d) = abc + abd + \bar{a}b\bar{c} + cd + b\bar{d}$

ab \ cd	00	01	11	10
00			1	
01	1	1	1	1
11	1	1	1	1
10			1	

$$f = b + cd$$

5(a) (iii)



What computation is performed by the given flowchart? Perform dry run and write down problem statement. **4**

Sol: Problem statement:

Calculate factorial value of given input number N.

START Input N

Step 1: I= 1, F =1

(Initialization)

Step 2: if (I < = N)

goto step 3;

else

goto step 6;

Step 3: F = F×I;

Step 4: I = I+1;

Step 5: goto step 2;

Step 6: Output F;

END

Example:

Suppose N = 4

Step 1: I = 1, F = 1

Step 2: (1< = 4) True

Step 3: F = 1 × 1 = 1

Step 4: I = 1+1 = 2

Step 2: (2 < = 4) True

Step 3: F = 1×2 = 2

Step 4: I = 2+1 = 3

Step 2: (3 < = 4) True

Step 3: F = 2×3 = 6

Step 4: I = 3+1 = 4

Step 2: (4 < = 4) True

Step 3: F = 6 ×4 = 24

Step 4: I = 4+1 = 5

Step 2: (5 < = 4) False

Step 6: Output 24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EE TOTAL 78
CE TOTAL 88
ME TOTAL 89
& MANY MORE...
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5 (b) A $4\frac{1}{2}$ digit and a $3\frac{1}{2}$ digit voltmeter on 10V range are used for voltage measurements.

(i) Find the resolution of each meter.

(ii) How would the reading 0.7582 be displayed on these two meters? 12

Sol: (i) For $4\frac{1}{2}$ digit voltmeter in 10 V range

Resolution = $\frac{V_{FSD}}{10^N}$, Where N = no. of full digits

$= \frac{2\times10}{2\times10^4} = 0.001$

For $3\frac{1}{2}$ digit voltmeter

Resolution = $\frac{2\times10}{2\times10^3} = 0.01$

(ii) For $4\frac{1}{2}$ digit voltmeter 0.7582 is displayed as

$\Rightarrow$

0	0	.7	5	8

For $3\frac{1}{2}$ digit voltmeter 0.7582 is displayed as

$\Rightarrow$

0	0	.7	5

5(c) A 1000/5A, 50 Hz current transformer at its rated load of 50VA has an iron loss of 0.5W and a magnetizing current of 8A. Calculate the ratio error and phase angle when rated output is supplied to a meter whose resistance is 0.4Ω and inductance is 0.7mH. 12

Sol: Nominal ratio, k_n = 1000/5 = 200

In the absence of any other data, the turns ratio is taken to the nominal ratio, n = 200.

Neglecting the burden of the secondary winding, the total burden of the secondary circuit is equal to the burden of the meter.

$\therefore$ Burden of secondary circuit = 50 VA

Voltage across primary winding $E_p = \frac{VA}{I_P} = \frac{50}{1000} = 0.05V$

Loss component of current $I_e = \frac{\text{Iron loss}}{E_P} = \frac{0.5}{0.05} = 10A$

Magnetizing current I_m = 8 A

Secondary circuit phase angle,

$$\delta = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left(\frac{2\times\pi\times 50\times 0.7\times 10^{-3}}{0.4}\right) = 28.78°$$

$\therefore$ $\cos\delta = 0.876$, $\sin\delta = 0.481°$

Actual ratio:

$$R = n + \frac{I_e\cos\delta + I_m\sin\delta}{I_s}$$

$$R = 200 + \frac{10\times 0.876 + 8\times 0.481}{5}$$

$$= 202.52$$

$$\text{Ratio error} = \frac{k_n - R}{R}\times 100$$

$$= \frac{200 - 202.52}{202.52}\times 100$$

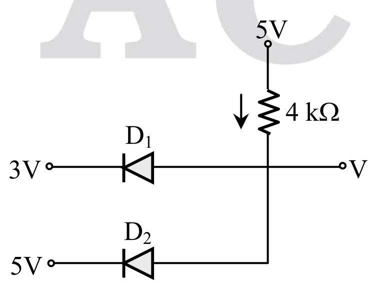
$$= -1.24\%$$

$$\text{Phase angle, } \theta = \frac{180}{\pi}\left[\frac{I_m\cos\delta - I_e\sin\delta}{nI_s}\right]$$

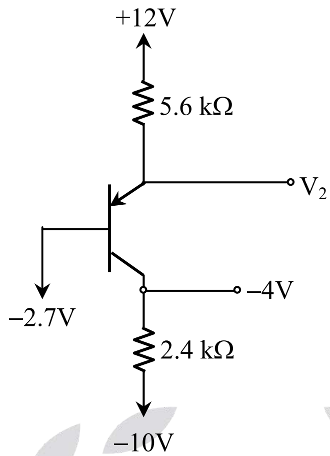
$$= \frac{180}{\pi}\left[\frac{8\times 0.876 - 10\times 0.481}{200\times 5}\right]$$

$$= 0.125°$$

5(d)

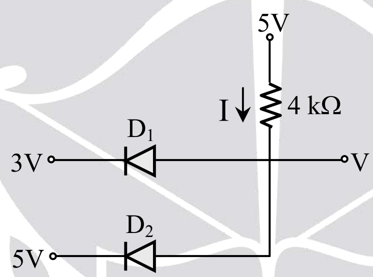


(i) For the circuit shown in the above figure using ideal diodes, find the values of the voltage V and current I indicated in the figure. 6

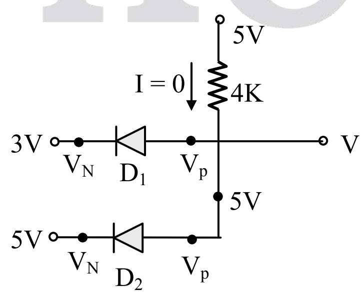


(ii) For the circuits in the above figure assume that the transistor have very large β. Some measurements have been made on these circuits, the results are indicated in the figure. Find the values of the voltage V_2. **6**

Sol: (i)

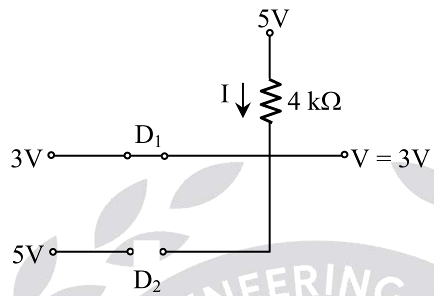


Step (1): Open circuit test



	V_P	V_N	$V_{P \text{ to } N}$	STATUS
D_1	5V	3V	5–3 = 2V	ON
D_2	5V	5V	5 – 5 = 0V	OFF

Step (2): $\because$ D_1 is ON & D_2 is OFF, the given circuit can be simplified as shown below



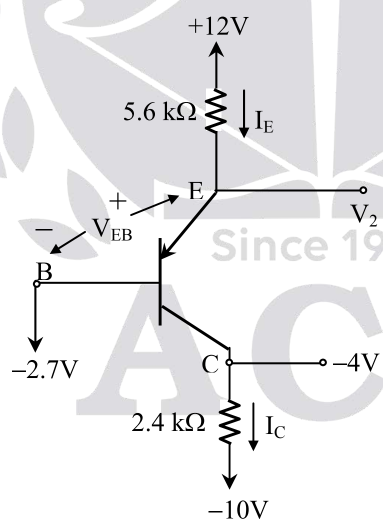
$\therefore$ V = 3V ….. (1)

KVL for output loop

5V–I4k – V = 0 ….. (2)

$$\Rightarrow I = \frac{5V - 3V}{4k\Omega} = \frac{2V}{4k\Omega} = 0.8mA \text{ ….. (3)}$$

(ii)



Method: (1)

Step (1): KVL for collector loop:

$-4V - I_c\, 2.4\text{ k}\Omega + 10V = 0$ ……. (1)

$$\Rightarrow I_C = \frac{10V - 4V}{2.4k\Omega} = 2.5mA \text{ …… (2)}$$

$\Rightarrow I_E = I_C = 2.5$ mA ………….. (3)

[$\because \beta$ is large]

Step(2): KVL for Emmiter loop:

$12V - 5.6\ k\Omega\ I_E - V_2 = 0$ …….. (4)

$\Rightarrow V_E = V_{EB} + V_B$ ………………….. (5)

Method (2):

Consider $V_{EB} = V_E - V_B$ …… (1)

$\Rightarrow V_E = V_{EB} + V_B$ …… (2)

$= 0.7\ V - 2.7\ V$ ….. (3)

$\therefore V_E = V_2 = -2V$ ……… (4)

5(e) (i) Bipolar junction transistors (BJTs) are considered " normally off" devices, because their natural state with no signal applied to the base is no conduction between emitter and collector, like an open switch. Are junction field effect transistors (JEETs) considered the same? Why or why not? Justify your answer. **6**

(ii) How an n-channel enhancement mode MOSFET can be used to switch a motor on and off? Justify your answer. **6**

Sol: (i) JFET is normally ON because of the presence of a channel between source and drain, so when a voltage is applied between drain and source, drain current begins to flow even if the gate to source voltage is zero. By applying a voltage at the gate we can only deplete the channel that is already present which is unlike a BJT where we first have to turn on the base emitter diode for the transistor to start conducting. So BJT is normally OFF and JFET is normally ON.

(ii) Power MOSFETs can be used to control the movement of DC motors or brushless stepper motors directly from computer logic or by using pulse-width modulation (PWM) type controllers. As a DC motor offers high starting torque and which is also proportional to the armature current, MOSFET switches along with a PWM can be used as a very good speed controller that would provide smooth and quiet motor operation.

As the motor load is inductive, a simple flywheel diode is connected across the inductive load to dissipate any back emf generated by the motor when the MOSFET turns it 'OFF'.

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6(a) (i) What are the different types of registers generally contained in the central processing unit? Explain functions of each Register used in computer systems. 10

(ii) List the steps involved in interrupt drivers I/O with suitable pseudo code/flowchart from the view of an I/O module. 10

Sol: (i) Types of Registers are as Following :

Memory Address Register(MAR):

This register holds the memory addresses of data and instructions. This register is used to access data and instructions from memory during the execution phase of an instruction. Suppose CPU wants to store some data in the memory or to read the data from the memory. It places the address of the required memory location in the MAR.

Program Counter:

The **program counter (PC)**, commonly called as **instruction pointer** (IP) in Intel x86 microprocessors, and sometimes called the instruction address register, or just part of the instruction sequencer in some computers, is a processor register

It is a 16 bit special function register in the 8085 microprocessor. It keeps track of the next memory address of the instruction that is to be executed once the execution of the current instruction is completed. In other words, it holds the address of the memory location of the next instruction when the current instruction is executed by the microprocessor.

Accumulator Register:

This Register is used for storing the Results those are produced by the System. When the CPU will generate Some Results after the Processing then all the Results will be Stored into the **AC Register**.

Memory Data Register (MDR):

MDR is the register of a computer's control unit that contains the data to be stored in the computer storage (e.g. RAM), or the data after a fetch from the computer storage. It acts like a buffer and holds anything that is copied from the memory ready for the processor to use it. MDR hold the information before it goes to the decoder.

MDR which contains the data to be written into or readout of the addressed location. For example, to retrieve the contents of cell 123, we would load the value 123 (in binary, ofcourse) into the MAR and perform a fetch operation. When the operation is done, a copy of the contents of cell 123 would be in the MDR. To store the value 98 into cell 4, we load a 4 into the MAR and a 98 into the MDR and perform a store. When the operation is completed the contents of cell 4 will have been set to 98, by discarding whatever was there previously.

The MDR is a two-way register. When data is fetched from memory and placed into the MDR, it is written to in one direction. When there is a write instruction, the data to be written is placed into the MDR from another CPU register, which then puts the data into memory.

The Memory Data Register is half of a minimal interface between a micro program and computer storage, the other half is a memory address register.

Index Register:

A hardware element which holds a number that can be added to (or, in some cases, subtracted from) the address portion of a computer instruction to form an effective address. Also known as base register. An index register in a computer's CPU is a processor register used for modifying operand addresses during the run of a program.

Memory Buffer Register(MBR):

This register holds the contents of data or instruction read from, or written in memory. It means that this register is used to store data/instruction coming from the memory or going to the memory.

Data Register:

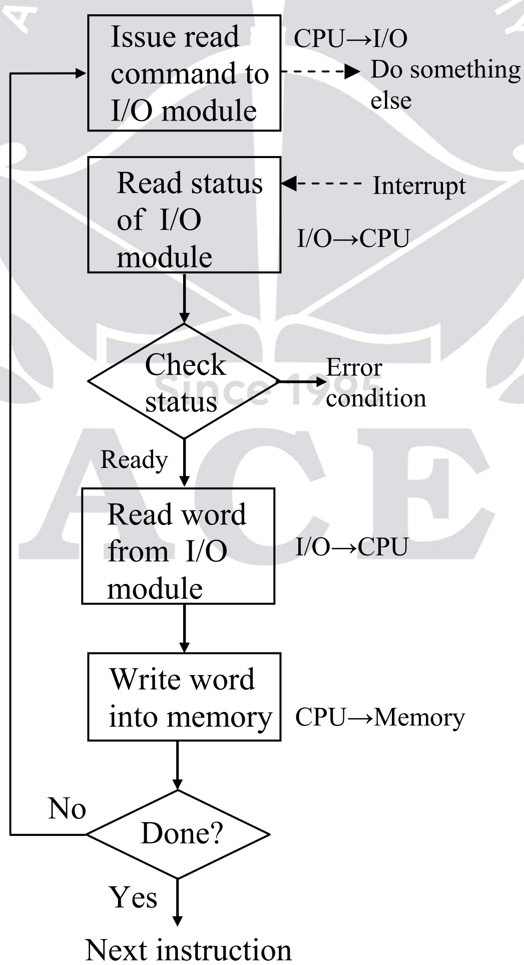
A register used in microcomputers to temporarily store data being transmitted to or from a peripheral device.

(ii) Interrupt driven I/O is an alternative scheme dealing with I/O. Interrupt I/O is a way of controlling input/output activity whereby a peripheral or terminal that needs to make or receive a data transfer sends a signal. This will cause a program interrupt to be set. At a time appropriate to the priority level of the I/O interrupt. Relative to the total interrupt system, the processors enter an interrupt service routine. The function of the routine will depend upon the system of interrupt levels and priorities that are implemented in the processor. The interrupt technique requires more complex hardware and software, but makes far more efficient use of the computer’s time and capacities.

1. CPU issues read command.
2. I/O module gets data from peripheral whilst CPU does other work.
3. I/O module interrupts CPU.
4. CPU requests data.
5. I/O module transfers data.

Interrupt Processing

1. A device driver initiates an I/O request on behalf of a process.
2. The device driver signals the I/O controller for the proper device, which initiates the requested I/O.
3. The device signals the I/O controller that is ready to retrieve input, the output is complete or that an error has been generated.
4. The CPU receives the interrupt signal on the interrupt-request line and transfer control over the interrupt handler routine.
5. The interrupt handler determines the cause of the interrupt, performs the necessary processing and executes a "*return from*" interrupt instruction.
6. The CPU returns to the execution state prior to the interrupt being signaled.
7. The CPU continues processing until the cycle begins again.



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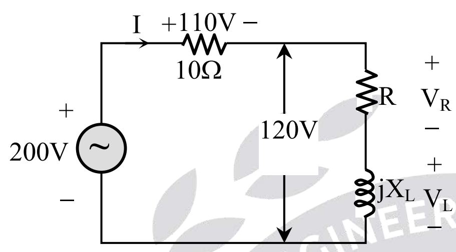
6(b) In a single-phase power measurement test by three-voltmeter method, the following readings were obtained. Across AC mains is 200V; across the non-inductive resistance of 10Ω is 110V, across the load consisting of resistance (R) and inductance (L) is 120V.

(i) Calculate the power supplied to the load.

(ii) Calculate inductive reactance (X_L) and resistance (R) of the load. **20**

Sol: From the question



From circuit $I = \frac{110}{10} = 11$ A

From circuit $120 = \sqrt{V_R^2 + V_L^2}$

$V_R = IR$, $V_L = IX_L$

$120 = \sqrt{(IR)^2 + (IX_L)^2}$

Square on both sides

$120^2 = I^2(R^2 + X_L^2)$

$\Rightarrow 14400 = 121 \times (R^2 + X_L^2)$

$(R^2 + X_L^2) = 119$ ………………. (1)

From circuit, $200 = \sqrt{[(10+R)I]^2 + (IX_L)^2}$

Square on both sides

$40000 = I^2\,[(10 + R)^2 + X_L^2]$

$\frac{40000}{121} = [100 + R^2 + X_L^2 + 20R]$

From eqn (1)

$330.578 = 100 + 119 + 20R$

$R = 5.578\ \Omega$

$R^2 + X_L^2 = 119$

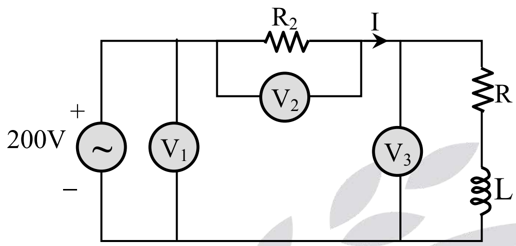
$X_L^2 = 87.8859 \Rightarrow X_L = 9.374\ \Omega$

(i) $P_{Load} = I^2R = 121 \times 5.578$

$P_{Load} = 674.938$ W

(ii) $R = 5.578\ \Omega$, $X_L = 9.374\ \Omega$

Method 2:



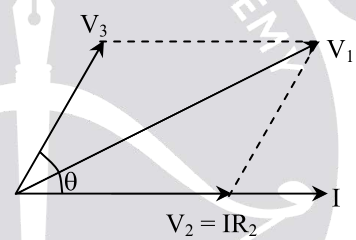
From phasor diagram,

$V_1^2 = V_2^2 + V_3^2 + 2V_2V_3\cos\theta$

$V_1^2 = V_2^2 + V_3^2 + 2IR_2V_3\cos\theta$

$V_1^2 = V_2^2 + V_3^2 + (V_3I\cos\theta)2R_2$

$= V_2^2 + V_3^2 + P \times 2R_2$



Power = $\dfrac{V_1^2 - V_2^2 - V_3^2}{2R_2}$

From given data

$V_1 = 200$ V; $R_2 = 10\ \Omega$, $V_2 = 110$ V, $V_3 = 120$ V

Power = $\dfrac{(200)^2 - (110)^2 - (120)^2}{2 \times 10}$

= 675 W

Current (I) = $\dfrac{110}{10}$ = 11 Amp

$\cos\theta = \dfrac{P}{V_3I} = \dfrac{675}{120 \times 11} = 0.511$

$\theta = 59.27^o$

Load impedance (Z) = $\dfrac{V_3}{I} = \dfrac{120}{11} = 10.9\ \Omega$

Load resistance (R) = $Z\cos\theta$ = 10.9 cos59.27 = 5.57 Ω

Load inductive reactance = $z\sin\theta$ = 10.9sin59.27 = 9.37 Ω

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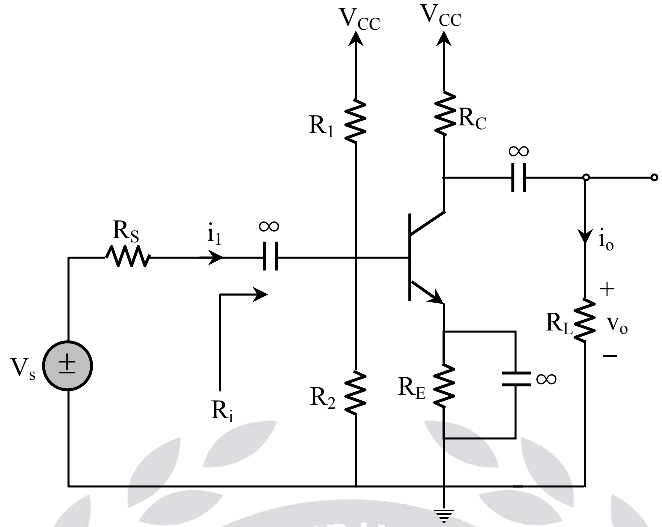
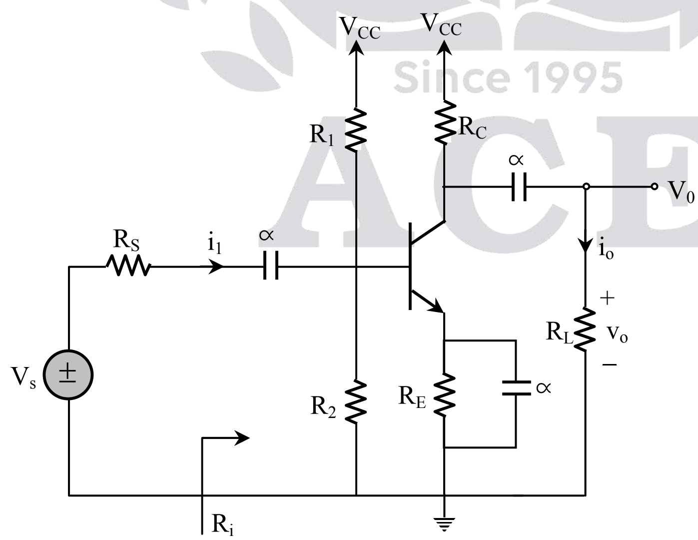
6(c)



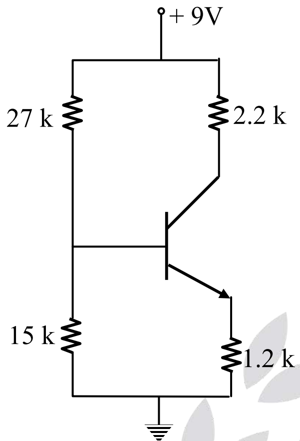
For the common – emitter amplifier shown in the figure, let V_{cc} = 9V, R_1 = 27 kΩ, R_2 = 15 kΩ, R_E = 1.2 kΩ and R_c = 2.2 kΩ. The transistor has β = 100 and V_A = 100 V (V_A = Early voltage). Calculate the dc bias current I_E. If the amplifier operates between a source for which R_s = 10 kΩ and a load of 2 kΩ (R_L), replace the transistor with its hybrid – π model, and find the values of R_i and voltage gain v_0/v_s Assume V_{EE} = 0.7V, V_T(thermal voltage) = 25mV. **20**

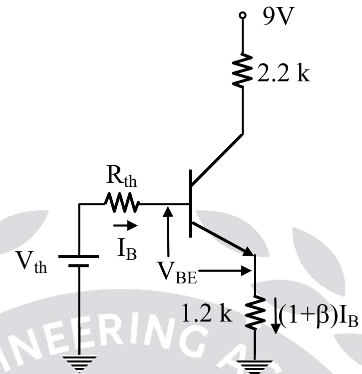
Sol:



Case (i): DC model of the given circuit

1. All AC sources = 0
2. All the capacitors are open i.e $X_c = \infty$





$V_{th} = \dfrac{15k(9V)}{15k + 27k} = 3.214V$ ………. (1)

R_{th} = 15k//27k = 9.642 kΩ ……… (2)

Step(1): KVL for input loop

$V_{th} - I_B R_{th} - V_{BE} - (1+\beta)\ I_B\ 1.2\ k\Omega = 0$ …… (3)

$\Rightarrow I_B = \dfrac{3.214V - 0.7V}{9.642k + 101 \times 1.2k\Omega} = 0.0192\,mA$….. (4)

$\therefore I_E = 1+\beta)I_B = 101 \times 0.0192\ mA = 1.9392\ mA$ ….. (5)

& $I_c = \beta I_B = 100 \times 0.0192\ mA = 1.92\ mA$…. 5(a)

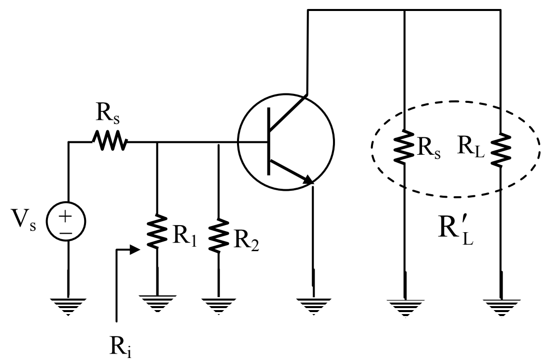
Step(2): $g_m = \dfrac{I_E}{V_T} = \dfrac{1.9392mA}{25mV} = 0.077568\,℧$ …(6)

$\therefore r_\pi = \dfrac{\beta}{g_m} = \dfrac{100}{0.077568}$ ℧

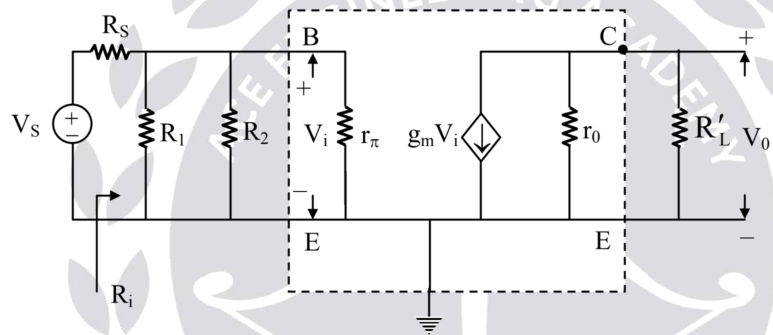
$= 1.289\ k\Omega$…… (7)

Case(ii): AC model of the given circuit

1. All DC sources = 0 & 2 $X_c = 0$



Small-signal model using π model of



Step(1): From the ckt,

$R_i = R_s + R_1 \| R_2 \| r_\pi$ ……. (1)

$= 10\ k\Omega + 27\ k \| 15k \| 1.289\ k\Omega$

$\therefore\ R_i = 11.137\ k\Omega$ …… (2)

Step(2): $R_{L_{Total}} = r_0 \| R_c \| R_L$ ….. (3)

$= \dfrac{V_A}{I_C} \| 2.2k \| 2k$ ….. (4)

$= \dfrac{100V}{1.92mA} \| 1.0476k$

$= 52.08k \| 1.0476k$

$\Rightarrow R_{L_{Total}} = 1.027\ k\Omega$ ……. (5)

Step(3): $\dfrac{V_0}{V_i} = -g_m R_{L_{total}} = -0.077568\ \mho \times 1.027 \times 10^3\ \Omega$

$$= 79.66 \;\ldots\ldots (6)$$

Step(4): $\dfrac{V_0}{V_s} = \dfrac{V_0}{V_i}\left(\dfrac{R_i}{R_i + R_s}\right)$

$$= -79.66\left[\frac{11.137k}{21.137k}\right] \ldots\ldots (7)$$

$$\therefore \frac{V_0}{V_s} = -41.97 \ldots\ldots (8)$$

7(a) (i) Write a program in any programming language to find highest common factor (HCF) of two positive integer numbers. 10

(ii) In Virtual memory based system, suppose we have an average of one page fault after every 10,000,000 instructions. A normal instruction takes 4ns (4 nano seconds), and a page fault causes the instructions to take an additional 10 milli seconds. What is the average instruction time, taking page faults into account? 10

Sol: (i)

```
int HCF (int a, int b)
{
    int x;
    while (b)
    {
        x = b;
        b = (a) mod (b);    // a%b
        a = x;
    }
    return a;    // HCF (GCD)
}
void main( )
{
    int p, q;
    printf("Enter two integer numbers");
    scanf("%d%d", &p, &q);
```

printf("HCF of %d and %d is %d", p, q, HCF(p, q));

}

(ii) Page fault rate (P)= $\frac{1}{10^7}$

Instruction execution time (I) = 4ns

(without page fault)

extra (additional) time taken (E) = 10 ms = 10^7 ns taken by instruction when page fault occur.

Average instruction time = I + P ×E

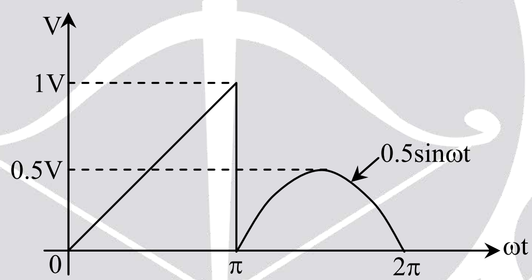
$$= 4\text{ns} + \frac{1}{10^7} \times 10^7\,\text{ns}$$

$$= 5\text{ ns}$$

7(b) Calculate the reading of

(i) Moving Coil voltmeter

(ii) Moving iron voltmeter



When these voltmeters are measuring the voltage of the waveform shown in the figure. **20**

Sol: (i) Moving coil voltmeter (V_{avg}) $= \frac{1}{2\pi}\left[\int_0^{\pi}\left(\frac{\omega t}{\pi}d\omega t\right) + \int_{\pi}^{2\pi}\left[-0.5\sin\omega t\ d\omega t\right]\right]$

$$= \frac{1}{2\pi}\left[\left(\frac{\omega t^2}{2}\right)_0^{\pi}.\frac{1}{\pi} + 0.5(\cos\omega t)_{\pi}^{2\pi}\right]$$

$$= \frac{1}{2\pi}\left[\frac{\pi^2}{2}\frac{1}{\pi} + 0.5(1+1)\right] = \frac{1}{2\pi}\left[\frac{\pi}{2}+1\right] = 0.409\ \mathbf{V}$$

(ii) moving iron voltmeter (V_{rms}) $= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi}\frac{\omega t^2}{\pi^2}d\omega t + \int_{\pi}^{2\pi}0.25\sin^2\omega t\ d\omega t\right]}$

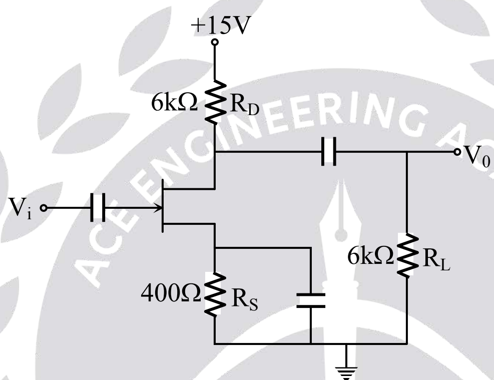
$$= \sqrt{\frac{1}{2\pi}\left[\frac{1}{\pi^2}\left(\frac{\omega t^3}{3}\right)_0^{\pi} + 0.25\int_{\pi}^{2\pi}\left(\frac{1-\cos 2\omega t}{2}\right)_{\pi}^{2\pi} d\omega t\right]}$$

$$= \sqrt{\frac{1}{2\pi}\left[\frac{1}{\pi^2}.\frac{\pi^3}{3} + 0.125\left((\omega t)_{\pi}^{2\pi} - 0\right)\right]}$$

$$= \sqrt{\frac{\pi}{3} + 0.125 \times \pi}$$

$$= 0.4787 \text{ Vs}$$

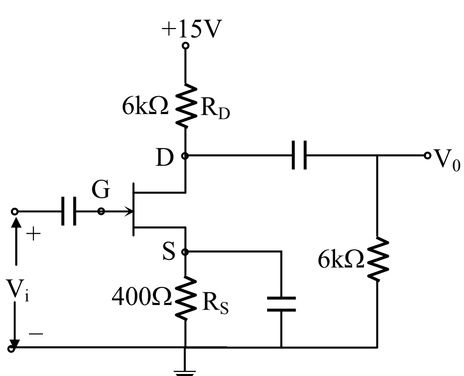
7(c)



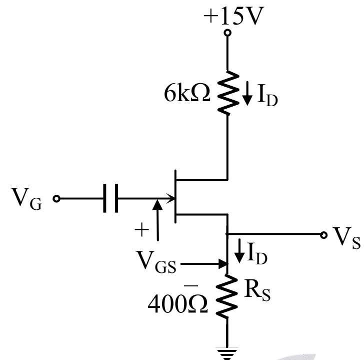
(i) In the given JEET as amplifier shown in the figure, the drain current changes form 4mA to 6mA. When the gate voltage is changed from –3.8 V to – 3.5 V in the amplifier circuit. Calculate the voltage gain of the amplifier. **12**

(ii) Explain the Barkhausen criterion for an oscillator circuit. How will the oscillator circuits performance be affected if the Barkhausen criterion ralls below 1, or goes much above 1? **8**

Sol: (i)



Case (i): Consider the DC model of given circuit



Step(1): When V_G = –3.8 V⇒ I_D = 4mA:

KVL for G-S loop:

$V_G - V_{GS} - I_D R_S = 0$ …… (1)

$\Rightarrow V_{GS2} = -3.8\text{ V} - 4\text{mA} \times 0.4\text{ k}\Omega = -5.4\text{ V}$ …. (2)

Step(2): When V_G = –3.5 V⇒ I_D = 6mA:

KVL for G-S loop:

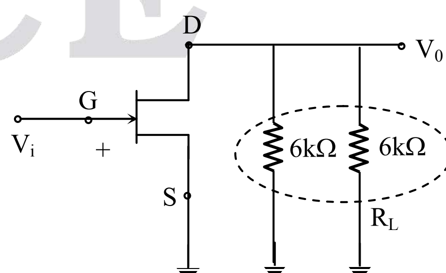
$\Rightarrow V_{GS1} = -3.5\text{ V} - 6\text{mA} \times 0.4\text{ k}\Omega = -5.9\text{ V}$ …. (3)

Step(3): Transconductance, $g_m = \dfrac{\partial I_D}{\partial V_{GS}}$ …… (4)

$$\Rightarrow g_m = \frac{I_{D_2} - I_{D_1}}{V_{GS_2} - V_{GS_1}} = \frac{6\text{mA} - 4\text{mA}}{-5.4\text{V} - (-5.9\text{V})} = \frac{2\text{mA}}{0.5\text{V}} = 4\text{ m℧} \text{...... (5)}$$

Case(ii): AC model

Common –Source Amplifier



$A_V = \dfrac{V_0}{V_i} = -g_m R_L$ …… (1)

$= -4\text{ m℧}\ [6k\|6k]$ ….. (2)

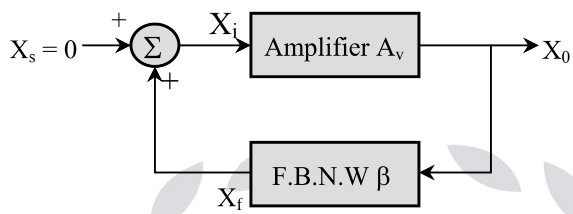
$= -4\text{ m℧} \times 3\text{k}\Omega$ ….. (3)

$\therefore A_v = -12$ …… (4)

(ii) Barkhausen criterion in oscillators:

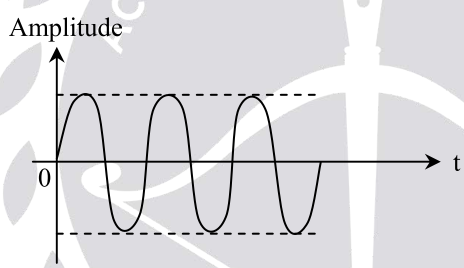
In an oscillator circuit, to sustain the oscillations or to maintain the constant amplitude in the oscillations, "Barkhausen criterion" is to be implemented. i.e., loop gain of the system, $A_v\beta$ should be equal to unity.

i.e., $A_v\beta = 1$ ………. (1)



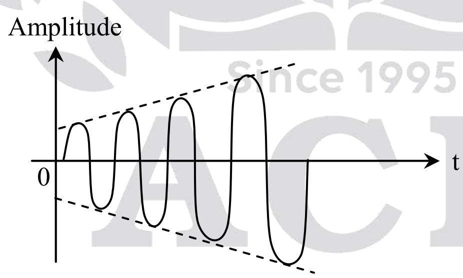
Case (i):

If Barkhausen criterion is properly implanted i.e. if $A_v\beta = 1$, the oscillations becomes sustained as shown below



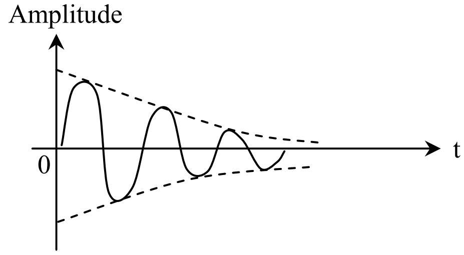
Case (ii):

If $A_v\beta > 1$, oscillations becomes overdamped as shown below:



Case (iii):

If $A_v\beta < 1$, oscillations becomes underdapmed, as shown below:



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8(a) (i) Write a programm in any programming language to sum of the following series up to N terms:

$\angle 1 + \angle 2 + \angle 3 + \angle 4 + \angle 5 + \ldots\ldots.. + \angle N$

Where $\angle N$ = factorial of N. **10**

Sol:

```
int fact (int x)
{
   int R = 1, i = 2;
   while (i < = x)
   {
      R = R * i;
      i + +;
   }
   return R;
}

void main( )
{
      int N, sum = 0, t = 1;
      printf("enter integer value of N");
      scanf("%d", &N);
      while ( t < = N)
      {
         sum = sum + fact (t);
         t + + ;
      }
      printf("Result is %d", sum);
}
```

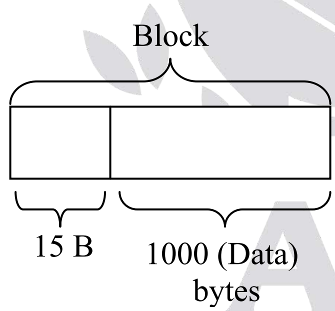
8(a) (ii) A company wishes to transmit numerous 10,000 bytes files between two computer systems connected through a computer network. Each byte consists of 8 data bits, no parity bits used in this application. Error is not a factor for transmission. What is the overhead percentage if a single file is sent asynchronously? What is the overhead percentage if the file is sent synchronously using blocks with 1000 data bytes in each block and each block is accompanied by 15 special bytes? Assume in asynchronous communication 1 start bit and 2 stop bits sent with each data byte. Comment, which transmission method is most efficient.

10

Sol: Asynchronous transmission:

$$\text{Efficiency}_{(\text{Asynchronous})} = \frac{8}{11} = 72.72\%$$

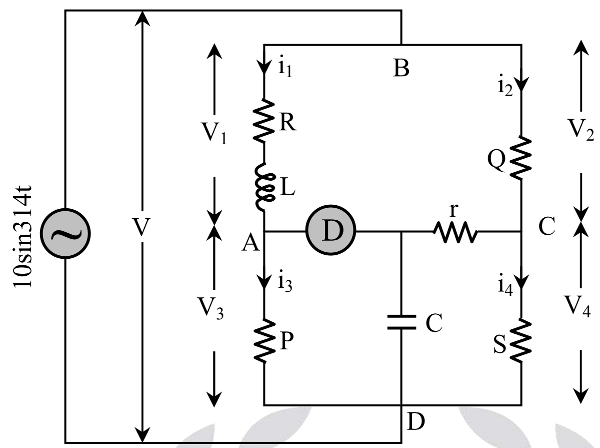
Synchronous transmission:



$$\text{Efficiency}_{(\text{Synchronous})} = \frac{1000}{1015} = 98.52\%$$

- Synchronous transmission is better over asynchronous transmission.
- In synchronous more than one byte (group of bytes are sending in one block).

8(b)



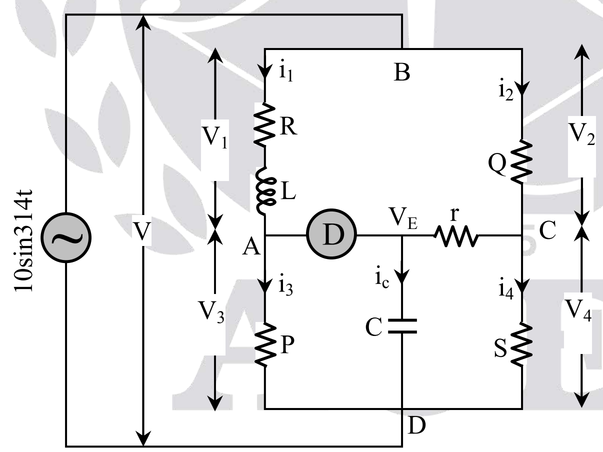
The bridge network shown in the figure measures the inductance (L) and resistance (R) if the impedance between A and B is unknown.

(i) Find R and L if bridge balance is obtained for Q = S = 1000Ω, P = 100 Ω, r = 50 Ω, C = 1 μF.

(ii) Draw the vector diagram showing the voltage and current at every point of the network.

20

Sol: (i)



L = self inductance to be measured

R = resistance of self inductor

P, Q, S = known non-inductive resistances

C = Fixed standard capacitor

In balanced bridge current through meter is is 0 A

Then, at balance $i_1 = i_3$ and $i_2 = i_c + i_4$

Now, $V_A = V_E$

$$i_1P = i_c \times \frac{1}{j\omega C}$$

$$i_c = j\omega i_1 PC$$

Writing other balance equation

$i_1(R + j\omega L) = i_2Q + i_c r$ …………..…… (1)

$i_c\left(r + \frac{1}{j\omega C}\right) = (i_2 - i_c)S$ ………………..….. (2)

Substituting the value of i_c in the above equations (1) and (2), we have

$i_1(R + j\omega L) = i_2Q + j\omega i_1 PCr$

$i_1(R + j\omega L - j\omega PrC) = i_2Q$ ……………..….. (3)

$j\omega i_1 PC\left(r + \frac{1}{j\omega C}\right) = i_2S - j\omega i_1 PCS$

$i_1(j\omega PrC + P + j\omega PCS) = i_2S$ ………….. (4)

From eqn. (3) substitute value of i_2 in eqn. (4)

$i_1(j\omega PrC + P + j\omega PCS) = \frac{i_1S}{Q}(R + j\omega L - j\omega PrC)$

Equating real and imaginary terms

$PrC + PCS = \frac{LS}{Q} - \frac{PrCS}{Q}$ and $P = \frac{RS}{Q}$

$PrC + PCS + \frac{PrCS}{Q} = \frac{LS}{Q}$

$L = \frac{Q}{S}\left(PrC + PCS + \frac{PrCS}{Q}\right)$

$L = \frac{PCrQ}{S} + PQC + PrC$

$L = \frac{CP}{S}(rQ + QS + rS)$

$L = \frac{CP}{S}[r(Q + S) + QS]$

From the values given in question

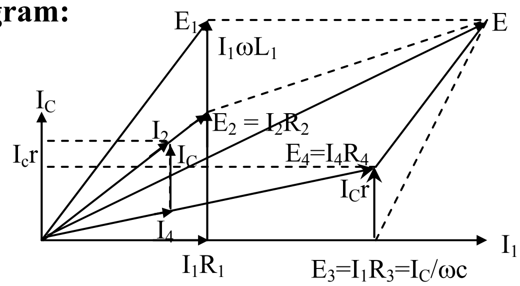
$L = \frac{10^{-6} \times 100}{10^3}[50(2000) + 10^6]$

$L = 0.11$ H

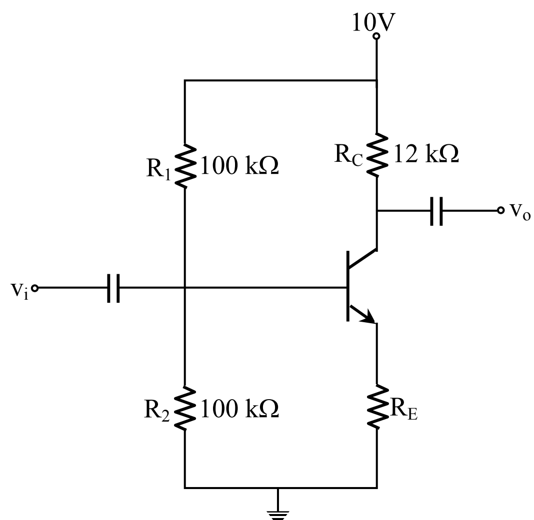
$$R = \frac{QP}{S} = \frac{1000 \times 100}{1000}$$

$R = 100\ \Omega$

(ii) **Phasor diagram:**



8(c)



(i) Common emitter (CE) amplifier shown in the figure has voltage gain 400 when $R_E = 0$. Stability is brought through negative feedback by adding resistor R_E. Find the value of resistor R_E using feedback concepts so that final voltage gain is equal to 200. 10

(ii) Not all "zener" diodes breakdown in the exact same manner. Some operate on the principle of zener breakdown, while other operate on the principle of avalanche breakdown. How do the temperature coefficients of theses two zener diode types compare? Are you able to discern whether a zener diode uses one principle or the other just from its break down voltage rating? Justify your answer. 10

Sol: (i) **Case(i):** When $R_E = 0$

The circuit is CE amplifier without feedback.

$|A_v| = 400$ ….. (1) [given]

Case(ii): When R_E is added to the circuit, it becomes a current-series feedback amplifier.

Step(1): Gain with negative feedback,

$$A_{V_f} = \frac{A_V}{1 + A_V\beta} \text{ ……... (2)}$$

$$\Rightarrow \quad 1 + A_V\beta = \frac{400}{200} = 2 \text{ ………….. (3)}$$

$$\Rightarrow \quad A_V\,\beta = 1 \text{ ……………….... (4)}$$

$$\Rightarrow \quad |\beta| = \frac{1}{400} \text{ ……………….. (5)}$$

Step(2): But $\beta = \dfrac{V_f}{V_0} = \dfrac{i_e R_E}{I_0 R_C} = \dfrac{i_e R_E}{-i_C R_C} = \dfrac{i_e R_E}{-i_e R_C} = \dfrac{-R_E}{R_C}$ ……. (6)

$$\Rightarrow |\beta| = \frac{R_E}{R_C} \text{ ……………. (7)}$$

Step(3): equation (7) = equation (5)

$$\Rightarrow \quad \frac{R_E}{R_C} = \frac{1}{400} \text{ …………… (8)}$$

$$\therefore \quad R_E = \frac{12k\Omega}{400} = 30\Omega \text{ …..... (9)}$$

(ii) A diode can go into breakdown in two ways: Zener and avalanche

Zener breakdown occurs in those diodes that are heavily doped on both sides and the breakdown is due to field ionization in the depletion layer caused by the very strong electric field in the depletion layer. The associated breakdown voltage decreases with temperature as the bonds become weaker with temperature. And usually the breakdown voltage is quite small for zener breakdown.

Avalanche breakdown occurs in light to moderately doped diodes and this due to impact ionization in the depletion layer. The associated breakdown voltage increases with temperature due to increased lattice scattering. Usually the breakdown voltage for Avalanche breakdown is quite large.

From the breakdown voltage of a given diode we can decide the dominant breakdown mechanism. If the breakdown voltage is less than 6V then zener breakdown is dominant and if the breakdown voltage is more than 6V then Avalanche breakdown voltage is the dominant breakdown mechanism.

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