ACE
Engineering Academy

Head Office : Sree Sindhi Guru Sangat Sabha Association, # 4-1-1236/1/A, King Koti, Abids, Hyderabad – 500001

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ESE-2019 MAINS TEST SERIES
Question Cum Answer Booklet (QCAB)

Electrical Engineering **Test-1** **Paper-I**

Time Allowed: 3 Hours **Maximum Marks: 300**

ACE HALL TICKET No. :

HALL TICKET No. : (Issued by UPSC)

NAME OF THE CANDIDATE :

NAME OF THE CENTRE :

BRANCH :

BATCH :

ROLL No. :

MOBILE No. :

TEST CODE : 701

DATE : 30-03-2019

INSTRUCTIONS TO CANDIDATES:

- This Question-cum- Answer (QCA) Booklet contains **80** pages. Immediately on receipt of booklet, please check that this QCA booklet does not have any misprint or torn or missing pages or items, etc. If so, get it replaced by a fresh QCA booklet.
- Candidates must read the instructions on this page and the following pages carefully before attempting the paper.
- Candidates should attempt all questions strictly in accordance with the specified instructions and in the space prescribed under each question in the booklet. Any answer written outside the space allotted may not be given credit.
- Question Paper in detachable form is available at the end of the QCA booklet and can be removed and taken by the candidates after conclusion of the exam

For filling by Examiners only

Question No.	Page No.	Marks
1	03	
2	12	
3	20	
4	28	
5	37	
6	47	
7	56	
8	64	
Grand Total		

Signature of the Invigilator

Signature of the Student

Marks Secured after Scrutiny

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions:

*There are **EIGHT*** questions divided in **TWO** Sections.

*Candidate has to attempt **FIVE** questions in all.*

*Question Nos. **1** and **5** are compulsory and out of the remaining, **THREE** are to be attempted choosing atleast **ONE** question from each Section.*

The number of marks carried by a question/part is indicated against it.

Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-Cum-Answer(QCA) Booklet in the space provided. No marks will be given for answers written in medium other than the authorized one.

Assume suitable data, if considered necessary and indicate the same clearly.

Unless otherwise mentioned, symbols and notations carry their usual standard meanings.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-Cum-Answer Booklet must be clearly struck off.

DONT'S:

1. Do not write your Name or Roll number or Sr. No. of Question-Cum-Answer-Booklet anywhere inside this Booklet. Do not sign the "Letter Writing" questions, if set in any paper by name, nor append your roll number to it.
2. Do not write anything other than the actual answers to the questions anywhere inside your Question-Cum-Answer-Booklet.
3. Do not tear off any leaves from your Question-Cum-Answer-Booklet. If you find any page missing, do not fail to notify the Supervisor/invigilator.
4. Do not write anything on the Question Paper available in detachable form or admission certificate and write answers at the specified space only.
5. Do not leave behind your Question-Cum-Answer-Booklet on your table unattended, it should be handed over to the Invigilator after conclusion of the exam.

DO'S :

1. Read the instructions on the cover page and the instructions specific to this Question Paper mentioned on the next page of this Booklet carefully and strictly follow them.
2. Write your Roll number and other particulars, in the space provided on the cover page of the Question-Cum-Answer-Booklet.
3. Write legibly and neatly. Do not write in bad/illegible handwriting.
4. For rough notes or calculations the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be valued.
6. Hand over your Question-Cum-Answer-Booklet personally to the invigilator before leaving the examination hall.
7. **Candidates shall be required to attempt answer to the part/sub-part of a question strictly within the pre-defined space. Any attempt outside the pre-defined space shall not be evaluated.**

SECTION - I

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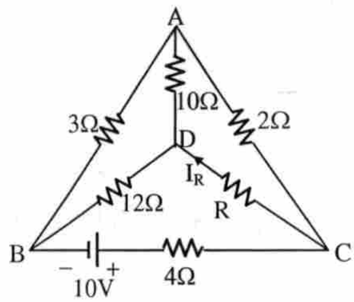
01.(a) Find the value of resistance R and current through it, in the circuit given below, when the branch AD caries no current. **12**



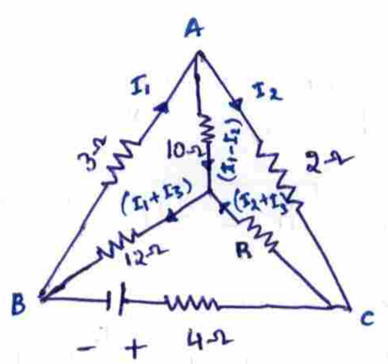
Sol Let current I_1, I_2 and I_3 flow in branches AB, AC and BC respectively. Hence current through branches AD, CD and DB are $I_1 - I_2$, $I_2 + I_3$ and $I_1 + I_3$ respectively.

Write KVL Equations in the 3 loops

$$-3I_1 - 10(I_1 - I_2) - 12(I_1 + I_3) = 0 \quad \text{——— (1)}$$

$$-2I_2 - R(I_2 + I_3) + 10(I_1 - I_2) = 0 \quad \text{——— (2)}$$

$$-R(I_2 + I_3) - 12(I_1 + I_3) + 10 - 4I_3 = 0 \quad \text{——— (3)}$$



But it is given that current through branch AB = 0

$I_1 - I_2 = 0 \quad , \quad I_1 = I_2 \longrightarrow (4)$

Using Equation (4) in Equation (1) we get

$$-3I_1 - 12(I_1 + I_3) = 0$$

$$\Rightarrow \quad I_3 = -\frac{5}{4} I_1 \longrightarrow (5)$$

Substitute Equations (4) and (5) in Equation (2)

$$-(2 + R) I_1 = -R \frac{5}{4} I_1$$

$$\therefore \quad \boxed{R = 8\ \Omega} \longrightarrow (6)$$

Substitute Value of (R) [i,e equation (6)] in equation (2) and Equation (3) along with equation (4), we get

$$\frac{5}{4} I_1 + I_3 = 0 \longrightarrow (7)$$

$$20 I_1 + 24 I_3 = 10 \longrightarrow (8)$$

On solving equation (7) and (8), we get

$\therefore \quad \boxed{I_1 = -1A} \; , \; \boxed{I_3 = 1.25\ A}$ and $\boxed{I_2 = I_1 = -1}$

$\therefore$ Current through Resistor 'R' i,e $I_R = I_2 + I_3$

$$\therefore \quad \boxed{I_R = -1 + 1.25 = 0.25\ \text{Amp}}$$

01.(b) The cylindrical surface ρ = 20 mm carries the current $\overline{K} = 100\hat{a}_z A/m$, while the surface ρ = 40mm has the solenoidal current $\overline{K} = 80\hat{a}_\phi A/m$. Calculate the magnitude of magnetic field intensity, $|\overline{H}|$ at (i) ρ = 10mm (ii) ρ = 30mm (iii) ρ = 50mm **12**

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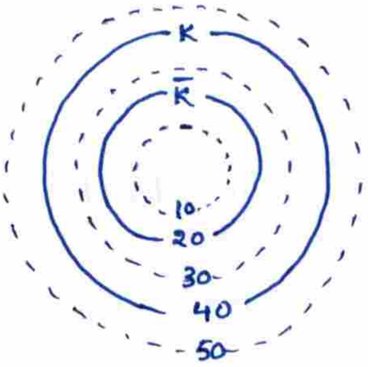
Sol: i) The Cylinder $\rho = 10\,mm$ do not encloses the cylinder of radious 20 mm

Hence $\overline{K} = 100\,\hat{a}_z$ will not contribute in $\overline{H}$ but due to Solenoid ($\rho = 40\,mm$, $\overline{K} = 80\,\hat{a}_\phi$). there will be Magnetic field intensity so we have.

$$\overline{H} = 80\,\hat{a}_z \; A/m$$

$$|\overline{H}| = 80 \; A/m$$



ii) The Cylinder $\rho = 30\,mm$ encloses the cylinder of radious 20 mm

Hence $\overline{K} = 100\,\hat{a}_z$ will contribute in Magnetic field Intensity. Apply Ampere Circuital law to the Circular path $\rho = 30\,mm$. As $\overline{K}$ is directed in $\hat{a}_z$ direction, H_ϕ component of Magnetic field intensity is produced.

Hence $\oint \bar{H} \cdot \bar{dL} = I_{enc}$

$$LHS = \oint \bar{H} \cdot \bar{dL} = \int_0^{2\pi} (H_\phi \hat{a_\phi})(\rho d\phi \hat{a_\phi}) = 2\pi \rho H_\phi$$

RHS $= I_{enc} =$ K x Circumference of circle with radius 20 mm

$$RHS = 100 \times 2\pi \rho H_\phi = 4\pi \text{ A}$$

$$\therefore \quad 2\pi \rho H_\phi = 4\pi \quad (\text{or}) \quad H_\phi = \frac{2}{\rho}$$

Hence at $\rho = 30$ mm

$$\bar{H} = \frac{2}{30 \times 10^{-3}} \hat{a_\phi} = 66.667 \hat{a_\phi}$$

Also due to solenoid $\bar{H} = 80 \hat{a_z}$ A/m

Hence $\bar{H}_{total} = 66.667 \hat{a_\phi} + 80 \hat{a_z}$ A/m

$$|\bar{H}| = \sqrt{(66.667)^2 + (80)^2} = 104.137 \text{ A/m}$$

iii) The cylinder of radius 50 mm lies out side to the solenoid. The property of the solenoid is to produce $\bar{H}$ inside the solenoid and not outside the solenoid. Hence the contributions from the solenoid to $\bar{H}$ will be zero. Now we have

$$\bar{H} = \frac{2}{\rho} \hat{a_\phi} = \frac{2}{50 \times 10^{-3}} \hat{a_\phi} = 40 \hat{a_\phi} \text{ A/m}$$

$|\bar{H}| = 40$ A/m

01.(c) (i) Show that the minimum conductivity of a semiconductor sample occurs when $n_{min} = n_i\sqrt{\frac{\mu_p}{\mu_n}}$

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(ii) what is the expression for the minimum conductivity σ_{min}?

(iii) calculate σ_{min} for Si at 300K and compare with the intrinsic conductivity.

$$\left(\mu_n = 1350\frac{cm^2}{V-sec}, \mu_p = 480\frac{cm^2}{V-sec}, n_i = 1.5\times10^{10}cm^{-3}\right)$$

6 + 3 + 3

Sol

i) The Conductivity of a Semiconductor is

$$\sigma = nq\mu_n + pq\mu_p \quad \text{———} \quad (1)$$

from Mass Action Law, we Know $np = n_i^2$

$$\Rightarrow p = \frac{n_i^2}{n}$$

$$\therefore \sigma = nq\mu_n + \frac{n_i^2}{n}q\mu_p$$

for Minimum conductivity at electron Concentration n_{min},

$$\frac{d\sigma}{dn} = 0$$

$$\Rightarrow q\mu_n - \frac{n_i^2}{n_{min}^2}q\mu_p = 0$$

$$\Rightarrow \mu_n = n_i^2\mu_p / n_{min}^2$$

$$n_{min}^2 = n_i^2\frac{\mu_p}{\mu_n}$$

$$\boxed{n_{min} = n_i\sqrt{\frac{\mu_p}{\mu_n}}}$$

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ii) $$\sigma_{min} = q\left(n_{min}\mu_n + \frac{n_i^2}{n_{min}}\mu_p\right)$$

$$\sigma_{min} = q\left[n_i\sqrt{\frac{\mu_p}{\mu_n}}\cdot\mu_n + \frac{n_i^2}{n_{min}}\sqrt{\frac{\mu_n}{\mu_p}}\cdot\mu_p\right]$$

$$\sigma_{min} = q\left[n_i\sqrt{\mu_n\mu_p} + n_i\sqrt{\mu_n\mu_p}\right]$$

$$\boxed{\sigma_{min} = 2qn_i\sqrt{\mu_n\mu_p}}$$

iii) For a Silicon Semiconductor

Intrinsic conductivity, $\sigma_i = n_i q(\mu_n + \mu_p)$

$$\sigma_i = 1.5\times10^{10}\times1.6\times10^{-19}(1350+480)$$

$$\boxed{\sigma_i = 4.4\times10^{-6}\ (\Omega\text{-cm})^{-1}}$$

Minimum Conductivity, $\sigma_{min} = 2q.n_i\sqrt{\mu_n.\mu_p}$

$$\sigma_{min} = 2\times1.6\times10^{-19}\times1.5\times10^{10}\times\sqrt{480\times1350}$$

$$\boxed{\sigma_{min} = 3.9\times10^{-6}\ (\Omega\text{-cm})^{-1}}$$

$$\therefore \boxed{\sigma_{min} < \sigma_i}$$

So the σ_{min} is less than the σ_i for a silicon semiconductor.

01.(d) Using source transformation, deduce the circuit into its equivalent circuit with Ideal voltage source in devices with a resistance. **12**

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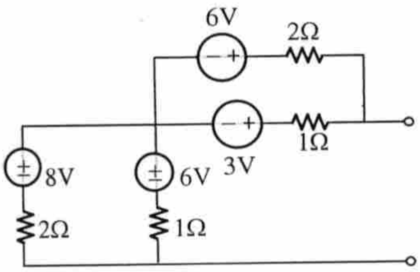
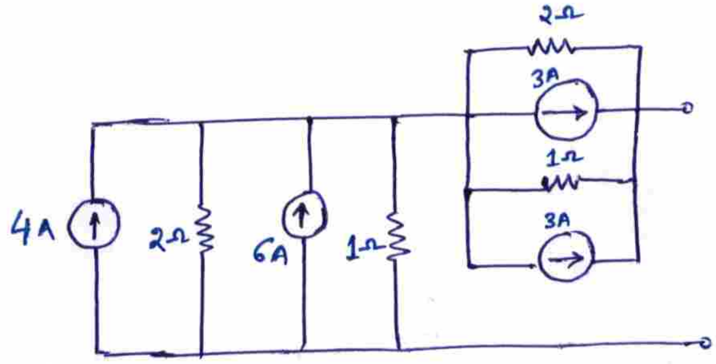
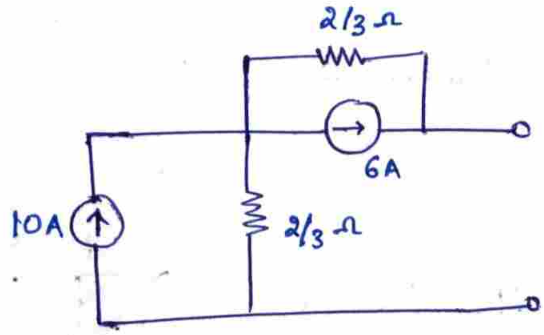


Sol Using Source transformation

Step : 1



Step : 2



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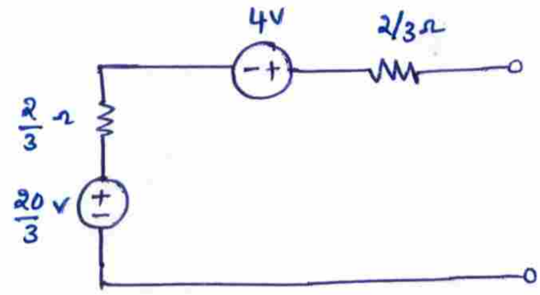
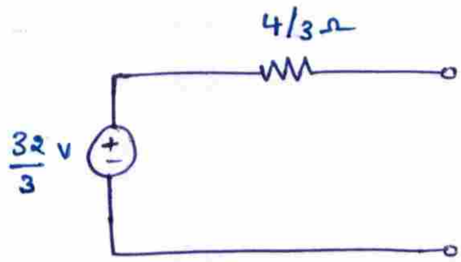
Step : 3

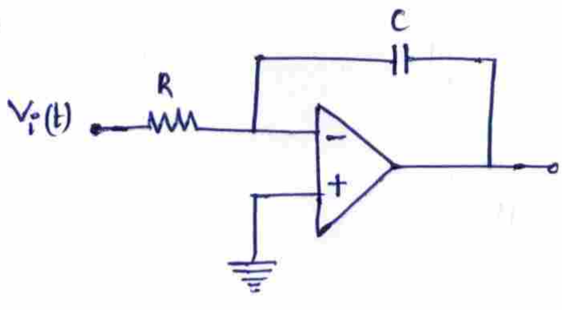


Step : 4



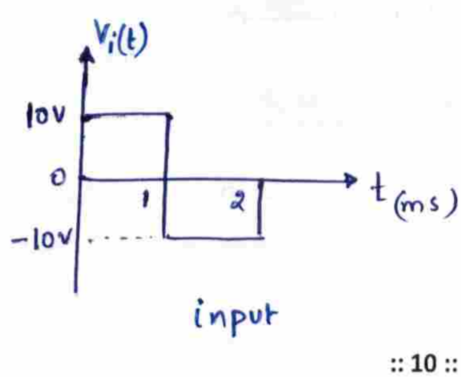
01.(e) (i) Consider a symmetrical square wave of 20V peak-to-peak, zero average, and 2-ms period applied to a Miller integrator. Find the value of the time constant (RC) such that the triangular waveform at the output has a 20-V peak-to-peak amplitude? **6**

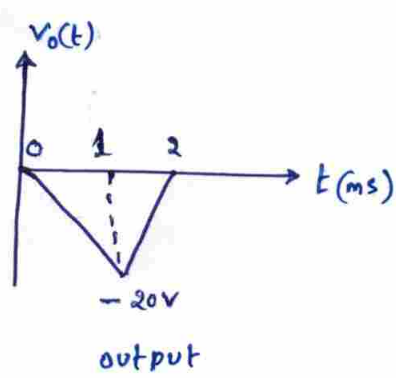
Sol i)



$$V_o(t) = \frac{-1}{CR}\int_0^t V_i(t)\,dt$$

The wave forms for one period of the input and the output signals are shown below:





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We have

$$-20 = -\frac{1}{CR}\int_0^{t(ms)} 10\, dt$$

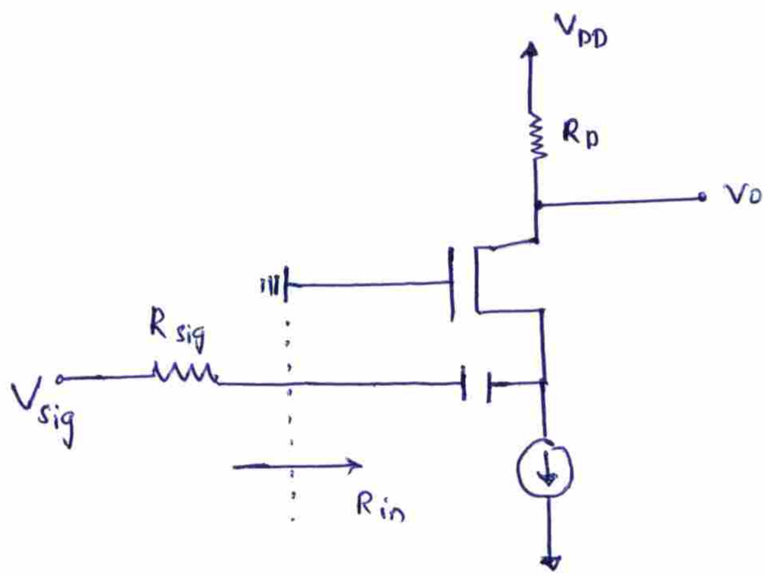
$$-20 = -\frac{1}{CR} \times 10 \times 1\ ms$$

$$CR = \frac{10}{20} \times 1\ msec$$

$\boxed{CR = 0.5\ msec}$ RC Circuit Time constant.

01.(e) (ii) A CG amplifier is required to match a signal source with $R_{sig} = 100\Omega$. At what current I_D should the MOSFET be biased if it is operated at an overdrive voltage of 0.20V? If the total resistance in the drain current is $2k\Omega$, what overall voltage gain is realized? **6**

Sol



$$R_{in} = \frac{1}{g_m} = R_{sig} = 100\ \Omega$$

$$g_m = 10\ mA/V.$$

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$$g_m = \frac{2I_D}{V_{ov}} = \frac{2I_D}{0.2V} \Rightarrow I_D = 1\,mA$$

$$G_V = \frac{V_o}{V_{sig}} = \frac{R_{in}}{R_{sig} + R_{in}} \cdot g_m \cdot R_D$$

$$= \left(\frac{1}{2}\right)(10\,mA/V)(2\,k\Omega)$$

$\therefore$ Gain $G_v = +10\,V/V$

02.(a) (i) A voltage V(t) = 10 sin ωt is applied to a series RLC circuit. At the resonant frequency of the circuit, the maximum voltage across the capacitor is 500 V. Bandwidth is 400 rad/sec and Impedance at resonance is 100Ω. Find the resonant frequency. Also find values of L&C of circuit. **12**

Sol

Applied Voltage to the Circuit $V_{max} = 10V$

$$V_{rms} = \frac{10}{\sqrt{2}} = 7.07\,V$$

Voltage Across Capacitor $V_c = 500V$

Magnification factor $Q = \frac{V_c}{V}$

$$Q = \frac{500}{7.07} = 70.7$$

Band width = 400 rad/sec

$$Q = \frac{\omega_r}{BW}$$

where ω_r = Resonant frequency

$\therefore \omega_r = 28280$ rad/sec

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$f_r = 4499 \text{ HZ}$

$BW = \frac{R}{L} \Rightarrow L = \frac{R}{BW}$

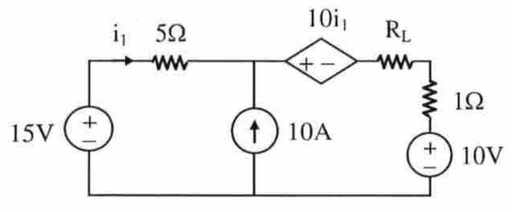
$L = \frac{100}{400}$

$L = 0.25 \text{ H}$

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

$C = \frac{1}{(2\pi f_r)^2 \cdot L} = \underline{\underline{5 \text{ nF}}}$

02.(a) (ii) For the network shown, determine R_L which will receive maximum power. **8**



Sol

Maximum power will received by R_L. when equivalent Resistance of network across $R_L = R_L$

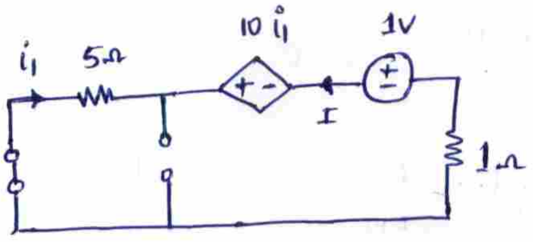
→ For this We need to find thevinine resistance.

→ For this we shall short all independent voltage sources and open all independent Current Sources.

→ Next we will place a voltage source of 1V in place of R_L. Then we will find 'I' through this source $R_{Th} = \frac{1}{I}$

$-I = i_1$

Use KVL



$-6I + 10i_1 = -1$

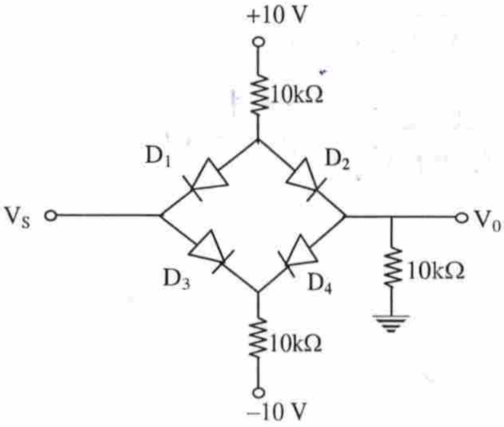
$16 I = 1$

$I = \frac{1}{16}$ A

$\therefore \quad R_{Th} = \frac{1}{I} = \frac{1}{\frac{1}{16}} = 16\,\Omega$

for Maximum Power Transfer $\boxed{R_L = R_{Th} = 16\,\Omega}$

02.(b) **(i)** Consider the following diode circuits. For the circuit shown below each diode has $V_\gamma = 0.7V$



Sketch the transfer characteristics for $-10 \le V_S \le 10V$? **8**

Sol

For $V_S > 0$, Then D_1 is OFF,

Current through D_2 is $i = \frac{10 - 0.7}{10 + 10}$

$i = 0.465$ mA

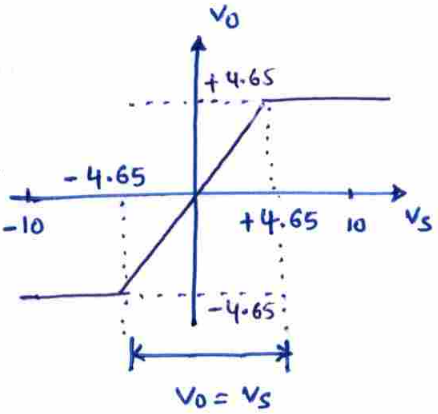
$V_0 = (10\ k\Omega) \cdot i = 4.65V$

$V_0 = 10 \times 10^3 \times 0.465 = 4.65V$

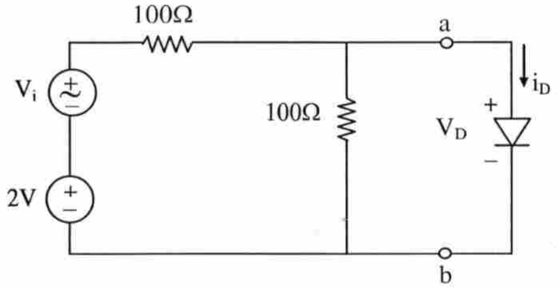
$V_0 = V_S$, for $0 < V_S < 4.65$

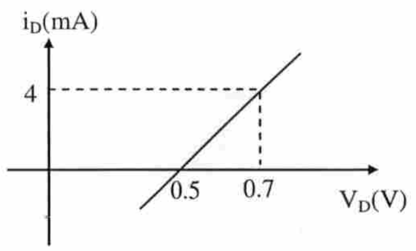
For Negative values of V_s,

The output is Negative of positive part.



02.(b) (ii) The diode in the circuit shown below has the non-linear terminal characteristics as shown in figure. Let the voltage be $V_s = \cos\omega t$ V.

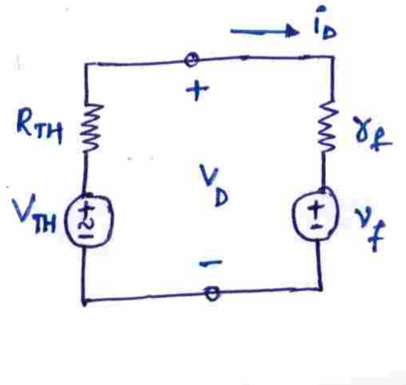




(a) The value of current i_D is?

(b) The voltage V_D is ? **4+3**

Sol a) The thevénin's Equivalent Circuit for the Network to the left of terminal 'ab' is shown below



$$V_{TH} = \frac{100}{200}(2 + \cos\omega t) = (1 + 0.5\cos\omega t)\ V$$

$$R_{TH} = 100 // 100 = 50\Omega$$

The Diode Can be Modelled with $V_f = 0.5V$

and $r_f = \frac{0.7 - 0.5}{0.004} = 50\Omega$

$$i_D = \frac{V_{TH} - V_f}{R_{TH} + r_f} = \frac{1 + 0.5\cos\omega t - 0.5}{(50 + 50)}$$

$$i_D = 5(1 + \cos\omega t)\ mA$$

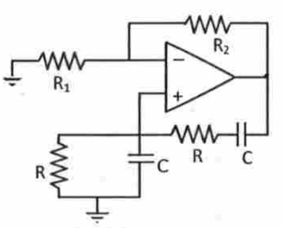
b) $V_D = r_f \cdot i_D + V_f$

$$= 50 \times 5(1 + \cos\omega t) \times 10^{-3} + 0.5$$

$$= 0.75 + 0.25\cos\omega t$$

$$= 0.25(3 + \cos\omega t)\ V$$

02.(b) (iii) Identify the below circuit, give the frequency of oscillations and also mention the condition for sustained oscillation? **5**



Sol The given Circuit is Wien bridge Oscillator Circuit.

The condition for frequency of oscillations is

$$\omega_0 = \frac{1}{RC}$$

$$f_0 = \frac{1}{2\pi RC}$$

The Condition for sustained oscillations is $\boxed{\frac{R_2}{R_1} > 2}$

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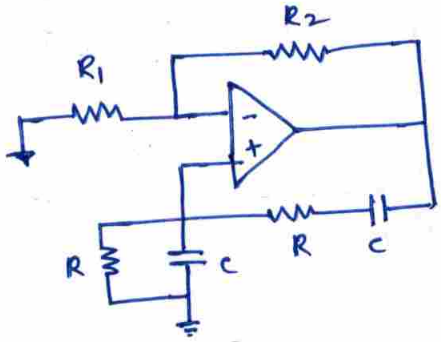
The Wien Bridge oscillator Circuit



02.(c) Conducting spheres at r = 2 and 6 cm are at potentials of 100 V and 0, respectively. The region between the spheres is filled with an inhomogeneous perfect dielectric for which $\varepsilon_r = \dfrac{0.3}{r + 0.04}$. Find:

(a) electric flux density, $\overline{D}(r)$

(b) electric field intensity, $\overline{E}(r)$

(c) Potential, V(r)

(d) capacitance, C. **20**

Sol

At $r = 2$ cm $= 0.02$ m , $V = 100$ V

At $r = 6$ cm $= 0.06$ m , $V = 0$ V

$$\varepsilon_r = \frac{0.3}{r + 0.04}$$

As the dielectric is perfect one so that

$\rho_v = 0$

Potential varies with 'r' coordinate as seen from given data. Hence change of potential with co-ordinates 'θ' and 'ϕ' is zero. i,e $\boxed{\frac{\partial v}{\partial \theta} = \frac{\partial v}{\partial \phi} = 0}$

Now $\quad \bar{\nabla} \cdot \bar{D} = \rho_v$

$$\bar{\nabla} \cdot (\varepsilon_0 \varepsilon_r \bar{E}) = \rho_v$$

$$\bar{\nabla} \cdot (-\varepsilon_r \bar{\nabla} v) = \frac{\rho_v}{\varepsilon_0}$$

Since $\quad \bar{\nabla} V = \frac{\partial v}{\partial r} \hat{a_r} + \frac{1}{r} \frac{\partial v}{\partial \theta} \hat{a_\theta} + \frac{1}{r \sin\theta} \frac{\partial v}{\partial \phi} \hat{a_\phi}$

$$\bar{\nabla} V = \frac{\partial v}{\partial r} \hat{a_r}$$

Hence $\quad \bar{\nabla} \cdot (\varepsilon_r \bar{\nabla} v) = \bar{\nabla} \cdot \left[\frac{0.3}{r+0.04} \frac{\partial v}{\partial r} \hat{a_r} \right] = 0$

Let $\bar{A} = A_r \hat{a_r} = \frac{0.3}{r+0.04} \frac{\partial v}{\partial r} \hat{a_r}$

i,e $\quad A_r = \frac{0.3}{r+0.04} \frac{\partial v}{\partial r}$

Now $\quad \bar{\nabla} \cdot \bar{A} = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 A_r) + \frac{1}{r \sin\theta} \frac{\partial}{\partial \theta} (A_\theta \sin\theta) + \frac{1}{r \sin\theta} \frac{\partial A_\phi}{\partial \phi}$

$$\bar{\nabla} \cdot \bar{A} = \frac{1}{r^2} \frac{\partial}{\partial r} \left[r^2 \left(\frac{0.3}{r+0.04} \frac{\partial v}{\partial r} \right) \right] = 0$$

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Integrating this equation twice, we get

$$V = \frac{A}{0.3}\left(\ln r - \frac{0.04}{r}\right) + B$$

where A, B $\longrightarrow$ are constants of integration

Substituting the Boundary Conditions in the Expression of potential, we have

$$100 = \frac{A}{0.3}\left(\ln 0.02 - \frac{0.04}{0.02}\right) + B \quad \text{——(1)}$$

$$0 = \frac{A}{0.3}\left(\ln 0.06 - \frac{0.04}{0.06}\right) + B \quad \text{——(2)}$$

from equation (1) and (2), we have

$$A = -12.336$$

$$B = -143.098$$

$$V = \frac{-12.336}{0.3}\left(\ln r - \frac{0.04}{r}\right) - 143.098$$

$$\boxed{V(r) = -41.12 \ln r + \frac{1.6448}{r} - 143.098}$$

$\hookrightarrow$ solution for (c)

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$$\bar{E} = -\bar{\nabla} V = -\frac{\partial v}{\partial r}\hat{a_r} = -\left[\frac{A(r+0.04)}{0.3r^2}\right]\hat{a_r}$$

$$\boxed{\bar{E}(r) = \frac{12.336\,(r+0.04)}{0.3r^2}\hat{a_r} = 41.12\left(\frac{1}{r}+\frac{0.04}{r^2}\right)\hat{a_r}\ V/m^2}$$

→ Solution for (b)

$$\boxed{\bar{D}(r) = \varepsilon_0\varepsilon_r\bar{E}(r) = \frac{0.3\,\varepsilon_0}{r+0.04}\times\frac{12.336(r+0.04)}{0.3r^2}\hat{a_r} = \frac{12.336\,\varepsilon_0}{r^2}\hat{a_r}\ C/m^2}$$

→ Solution for (a)

$$\rho_s = |\bar{D}(r)| = \frac{12.336\,\varepsilon_0}{r^2}$$

Area of a Sphere $= 4\pi r^2$

Charge on the sphere $= \rho_s \times$ Area $= 1.37\ nC$

Potential difference between Spheres $= 100 - 0 = 100$

$$C = \frac{1.37\times10^{-9}}{100}$$

$$\boxed{C = 13.725\ PF}$$

→ solution for (c)

03.(a) (i) With proper explanation show the electron drift velocity at 300k in pure silicon for $100\frac{V}{cm}$ is less than thermal velocity and comment on the electron drift velocity for 10^4V/cm. $\left(\mu_n = 1350\frac{cm^2}{V-sec}, m_o = 9.1\times10^{-31}kg, k = 1.38\times10^{-23}J/k\right)$

(ii) Calculate the intrinsic concentration of Germinium at 500K.

$(m_n = 0.55m, m_p = 0.37m)$ **12+8**

Sol i) Given Data

$$E = 100\ \frac{V}{cm}$$

$$\mu_n = 1350\ \frac{Cm^2}{V-sec}$$

As we know $V_d = \mu_n \cdot E$

$$V_d = 100 \times 1350$$

$$V_d = 1.35\times10^5\ \frac{Cm}{sec} \quad \text{——— (1)}$$

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Again, As We Know

$$\frac{1}{2} m_0 V_{Th}^2 = KT$$

where V_{Th} = Thermal Velocity

m_0 = mass of Electron.

$$V_{Th} = \sqrt{\frac{2KT}{m_0}}$$

$$V_{Th} = \sqrt{\frac{2 \times 1.38 \times 10^{-23} \times 300}{9.1 \times 10^{-31}}}$$

$$V_{Th} = 9.54 \times 10^{6} \frac{cm}{sec} \quad \text{———} \quad (2)$$

From Above two Equations (1) and (2), it is clear that the V_d (Drift Velocity) is less than thermal Velocity at $100 \frac{V}{cm}$

Now, Let us Calculate the drift velocity and thermal velocity for the Electric field of $10^4 v/cm$

$\therefore$ Drift Velocity at 10^4 V/cm. $V_d = \mu_n E$

$$V_d = 1350 \times 10^4$$

$$V_d = 1.35 \times 10^7 \text{ cm/sec}$$

Commet on Electric Drift velocity for 10^4 v/cm.

The Electron Drift Velocity for 10^4 V/cm is greater than thermal velocity.

ii) As We Know,

$$E_G = E_{G0} - \beta T$$

for "Ge", $\beta = 2.23 \times 10^{-4}$

$$E_{G0} = 0.785 \text{ eV}$$

At 500 K, $E_G = 0.785 - (2.23 \times 10^{-4} \times 500)$

$$E_G = 0.6735 \text{ eV}$$

$$KT = \frac{T}{3600} = \frac{500}{11600} = 43.1 \times 10^{-3} \text{ eV}$$

We Know $n_i^2 = 2.33 \times 10^{31} \times \left(\frac{m_n \times m_p}{m^2}\right)^{\frac{3}{2}} T^3 . e^{-\frac{E_G}{KT}}$

$$n_i^2 = 2.33 \times 10^{31} \times \left(\frac{0.55 \times 0.37 m^2}{m^2}\right)^{\frac{3}{2}} (500)^3 . e^{-\frac{0.6735}{0.0431}}$$

$$n_i^2 = 2.33 \times 10^{31} \times (0.55 \times 0.37)^{3/2} \times (500)^3 \times 1.635 \times 10^{-7}$$

$$n_i^2 = 4.375 \times 10^{31}$$

$$n_i = 6.61 \times 10^{15} \text{ cm}^{-3}$$

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03.(b) (i) For the circuit shown, the switch K is moved from position 1 to position 2 at t = 0. At t < 0 (steady state). K is at position 1.

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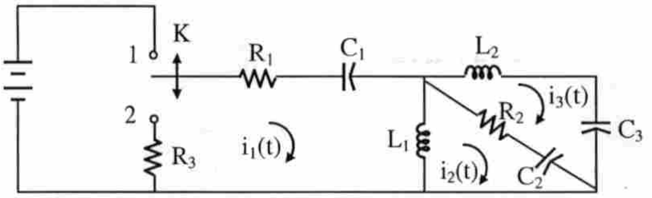
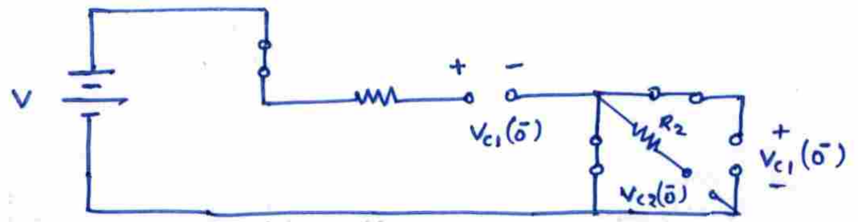
Show that $i_1(0^+) = i_2(0^+) = \dfrac{-V}{R_1 + R_2 + R_3}; i_3(0^+) = 0$ **10**



Sol

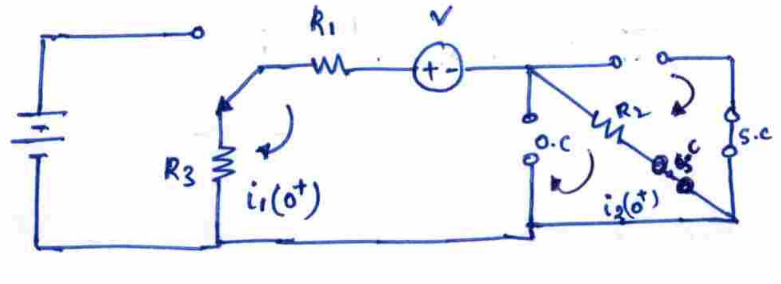
At $t = \bar{0}$, circuit is in steady state, and Switch 'K' is in position 1 (Capacitor $\longrightarrow$ open
Inductor $\longrightarrow$ short)



$V_{c1}(\bar{0}) = V$

$V_{c2}(\bar{0}) = V_{c3}(\bar{0}) = 0$

At $t = 0^+$



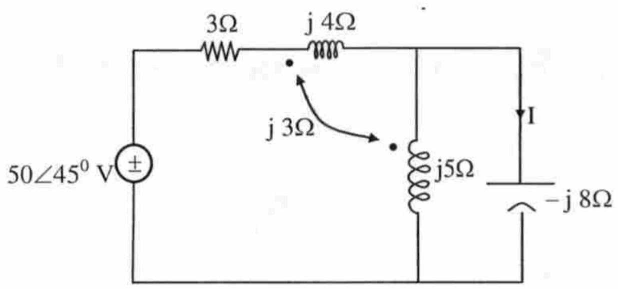
$$i_1(0^+) = i_2(0^+) \; ; \quad i_3(0^+) = 0$$

Using KVL

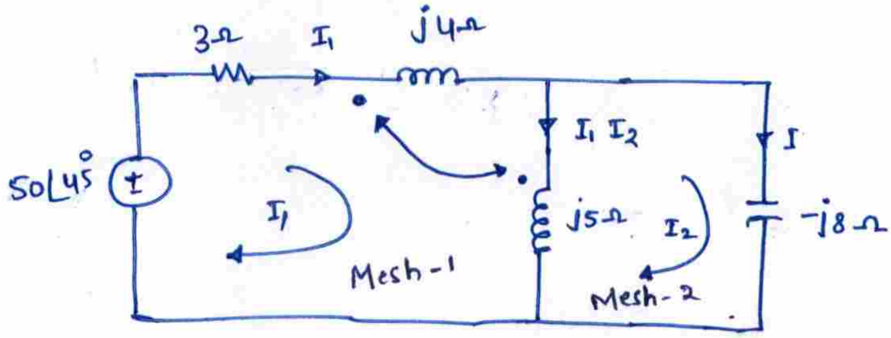
$$-R_1\, i_1(0^+) - V - R_2\, i_2(0^+) - R_3\, i_1(0^+) = 0$$

$$\therefore\; i_1(0^+) = i_2(0^+) = \frac{-V}{R_1 + R_2 + R_3}$$

03.(b) (ii) Find current 'I' using Mesh Analysis **10**



Sol



Mesh - 1 Equation :

$$-\left[50\angle 45^\circ\right] + (3 + j4)\,I_1 + j5\left[I_1 - I_2\right] + j3\left[I_1 - I_2\right] + j3\left[I_1\right] = 0$$

$$(3 + j15)\,I_1 - j8\,I_2 = 50\angle 45^\circ \longrightarrow (i)$$

Mesh-2 Equation :

$$j5\,[I_2 - I_1] - j8\,[I_2] - j3[I_1] = 0$$

$$-j8I_1 - j3I_2 = 0$$

$$8I_1 + 3I_2 = 0 \quad \text{———— (ii)}$$

Solving (i) and (ii)

$$I = I_2 = 3.66\angle 139.7^\circ \text{ Amp.}$$

03.(c) (i) Determine the energy density stored in free space by the fields:

(a) $10^3\hat{a}_x + 10^3\hat{a}_y A/m$

(b) $10^{-3}\hat{a}_x\, A/m + 10^{-3}\hat{a}_y T$ **5**

Sol a) Energy Density $= \frac{1}{2}\mu_0 H^2$

$$= \frac{1}{2} \times 4\pi \times 10^{-7} \times \left[\sqrt{(10^3)^2 + (10^3)^2}\right]^2$$

$$= 1.256 \text{ J/m}^3$$

b) Energy Density $= \frac{B^2}{2\mu_0}$

$$= \frac{\left[\sqrt{(10^{-3})^2 + (10^{-3})^2}\right]^2}{2 \times 4\pi \times 10^{-7}}$$

$$= 0.795 \text{ J/m}^3.$$

03.(c) (ii) A surface current density, $K = 20\hat{a}_x$ A/m, flows in the y=0 plane throughout the region $-5 < z < 5$m, $-\infty < x < \infty$. Find the magnetic field intensity, $\vec{H}$ at P(0, 10, 0)m in free space. **15**

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Sol:

$$d\bar{H} = \frac{\bar{K}\, ds \times \hat{a}_{12}}{4\pi d^2}$$

$\bar{K}$ lies on the $y=0$ plane

Hence $d\bar{s} = dx\, dz\, \hat{a}_y$

(or)

$$ds = dx\, dz$$

Point 2 is that point at which $\bar{H}$ is desired = (0, 10, 0) point 1 is the general point on the Surface current density = $(x, 0, z)$.

$$\therefore \quad \bar{R}_{12} = (0-x)\,\hat{a}_x + (10-0)\,\hat{a}_y + (0-z)\,\hat{a}_z$$

$$= -x\hat{a}_x + 10\,\hat{a}_y - z\,\hat{a}_z$$

$$d = |\bar{R}_{12}| = \sqrt{(-x)^2 + (10)^2 + (-z)^2}$$

$$= \sqrt{x^2 + z^2 + 100}$$

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$$\hat{a}_{12} = \frac{\bar{R}_{12}}{|\bar{R}_{12}|} = \frac{-x\,\hat{a}_x + 10\,\hat{a}_y - z\,\hat{a}_z}{\sqrt{x^2 + z^2 + 100}}$$

$$\therefore d\bar{H} = \frac{(20\,\hat{a}_x\, dx\,dz) \times (-x\,\hat{a}_x + 10\,\hat{a}_y - z\,\hat{a}_z)}{4\pi\,(x^2 + z^2 + 100)^{3/2}}$$

$$= \frac{5\,(10\,\hat{a}_z + z\,\hat{a}_y)\, dx\, dz}{\pi\,(x^2 + z^2 + 100)^{3/2}}$$

$$\therefore \bar{H} = \int d\bar{H}$$

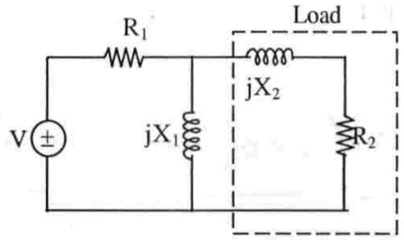
$$\bar{H} = \frac{5}{\pi}\left[\int_{-\infty}^{\infty}\int_{-5}^{5} \frac{10\,\hat{a}_z\, dx\,dz}{(x^2 + z^2 + 100)^{3/2}} + \int_{-\infty}^{\infty}\cdot\int_{-5}^{5} \frac{z\,a_y\, dx\,dz}{(x^2 + z^2 + 100)^{\frac{3}{2}}}\right]$$

$$\bar{H} = \frac{5}{\pi}\left[\int_{-5}^{5} \frac{20\,\hat{a}_z\, dz}{z^2 + 100} + \int_{-5}^{5} \frac{2z\,\hat{a}_y\, dz}{z^2 + 100}\right]$$

$$= \frac{5}{\pi}\left[\frac{20\,\hat{a}_z}{10}\left[\tan^{-1}\left(\frac{z}{10}\right)\right]_{-5}^{5} + \hat{a}_y\left[\ln(z^2 + 100)\right]_{-5}^{5}\right]$$

$$= 2.95\,\hat{a}_z \quad A/m$$

04.(a) (i) Find X_1 and X_2 in terms of R_1 and R_2 to give maximum power dissipation in R_2 **12**



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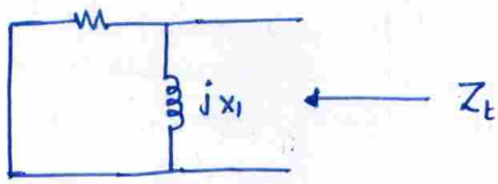
Sol



$$Z_t = \frac{R_1 (jx_1)}{R_1 + jx_1} = \frac{R_1 x_1^2 + jR_1^2 x_1}{R_1^2 + x_1^2}$$

$$Z_L = Z_t^*$$

$$R_2 + jX_2 = \frac{R_1 x_1^2}{R_1^2 + x_1^2} - j\frac{R_1^2 x_1}{R_1^2 + x_1^2}$$

So, $R_2 = \dfrac{R_1 x_1^2}{R_1^2 + x_1^2}$

then $x_1 = \pm R_1 \sqrt{\dfrac{R_2}{R_1 - R_2}}$ ——— (1)

Also $X_2 = -\frac{R_1^2 \cdot X_1}{R_1^2 + X_1^2}$ ———— (2)

Substitute (1) in (2)

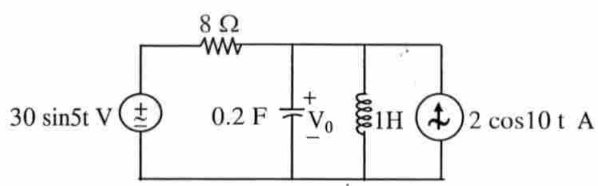
Then $X_2 = \sqrt{R_2(R_1 - R_2)}$

Final Answer

$X_1 = \pm R_1 \sqrt{\frac{R_2}{R_1 - R_2}}$

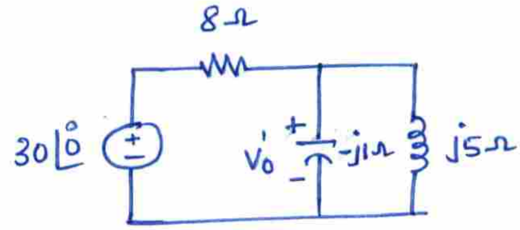
$X_2 = \sqrt{R_2(R_1 - R_2)}$

04.(a) (ii) In the circuit shown below, determine the value of V_0. **8**



Sol By Applying Super position theorem

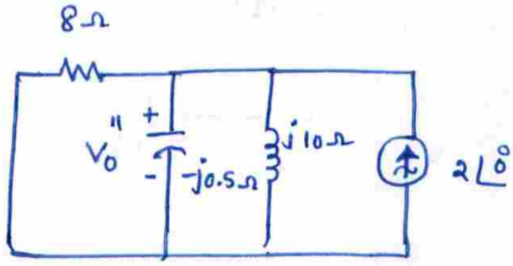
Case(i) : when 'V' alone acting, $V_0 = V_0'$



Using Nodal Analysis

$V_0' = 4.631 \angle -81.12^\circ$ V

Case (ii) : When 'V' alone acting $V_0 = V_0''$



Using Nodal Analysis

$$V_0'' = 1.051 \angle -86.24^\circ \text{ V}$$

$$V_0 = V_0' + V_0''$$

$$V_0 = 4.631 \sin(5t - 81.12^\circ) + 1.05 \cos(10t - 86.24^\circ) \text{ V}$$

Note : Input Sources are different frequencies

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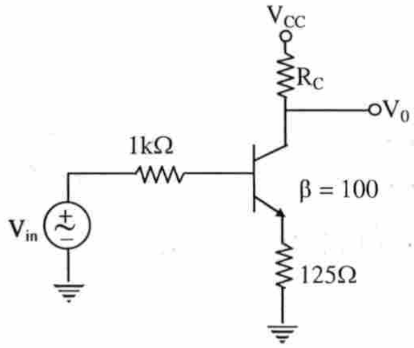
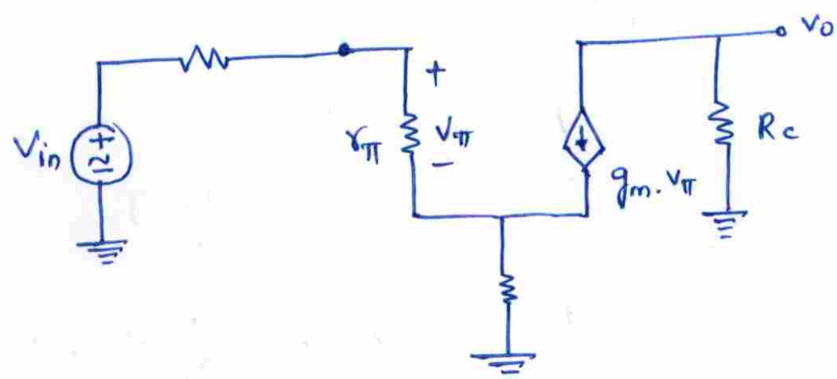
04.(b) **(i)** Consider the transistor amplifier circuit shown in figure below. Given that $\beta = 100$, $V_{thermal} = 25mV$ and voltage gain $|A_v| = 20$. If the transistor is biased with collector current $I_C = 1mA$, then the value of R_C is ? **10**



Sol: For the given amplifier Circuit, Voltage gain Can be Calculated as By Small Signal Equivalent Circuit.



Voltage gain

$$A_v = \frac{V_o}{V_{in}} = \frac{V_o}{V_A} \cdot \frac{V_A}{V_{in}}$$

From The circuit

$$\frac{V_A}{V_{in}} = \frac{r_\pi + (1+\beta) R_E}{r_\pi + (1+\beta) R_E + R_B}$$

and $$\frac{V_o}{V_A} = -g_m R_c \Big/ 1 + \left(\frac{1}{r_\pi} + g_m\right) R_E$$

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$$A_v = \frac{r_\pi + (1+\beta) R_E}{r_\pi + (1+\beta) R_E + R_B} \cdot \frac{-g_m \cdot R_C \cdot r_\pi}{r_\pi + (1+\beta) R_E}$$

$$= \frac{\beta \cdot R_C}{r_\pi + (1+\beta) R_E + R_B} \quad (\because g_m \cdot r_\pi = \beta)$$

or $$A_v = \frac{-R_C}{\frac{r_\pi}{\beta} + \left(\frac{1+\beta}{\beta}\right) \cdot R_E + \frac{R_B}{\beta}}$$

For $\beta >> 1$

$$A_v = \frac{-R_C}{\left(\frac{1}{g_m} + R_E + \frac{R_B}{\beta}\right)}$$

$$R_C = |A_v| \cdot \left[\frac{1}{g_m} + R_E + \frac{R_B}{\beta}\right]$$

Here $\beta = 100$, $R_B = 1\,k\Omega$, $R_E = 125\,\Omega$

$$g_m = \frac{I_C}{V_T} = \frac{1\,mA}{25\,mV} = \frac{1}{25} \cdot A/V$$

So. $$R_C = 20\left[25 + 125 + \frac{1000}{100}\right] = 3.2\,k\Omega$$

$$R_C = 3.2\,k\Omega.$$

Candidates must not write on this margin

04.(b) (ii) (a) A 0.18 – μm fabrication process is specified to have t_{ox} = 4nm ,μ_n = 450 cm^2/V-s, and V_t = 0.5V. Find the value of the process transconductance parameter K'_n. For a MOSFET with minimum length fabricated in this process, find the required value of W so that the device exhibits a channel resistance r_{DS} of 1 kΩ at V_{GS} = 1V. (Provided that ε_r = 3.9) **5**

(b) For a 0.8 – μm process technology for which t_{ox} = 15nm and μ_n = 550 cm^2/V-s, find C_{ox} , K'_n and the overdrive voltage V_{ov} required to operate a transistor having $\frac{W}{L} = 20$ in saturation with I_D = 0.2mA. What is the minimum value of V_{DS} needed? **5**

Candidates must not write on this margin

Sol

a)

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{34.5\ pF/m}{4\ nm} = 8.625\ fF/(\mu m)^2$$

$$\mu_n = 450\ Cm^2/v\text{-}sec$$

$$K_n' = \mu_n \cdot C_{ox} = (450\ cm^2/v\text{-}sec)(8.625\ fF/(\mu m)^2)$$

$$\therefore\ K_n' = 388\ \mu A/V^2$$

$$V_{ov} = (V_{GS} - V_t) = (1 - 0.5) = 0.5\ V$$

$$g_{DS} = \frac{1}{1\,K\Omega} = K_n' \cdot \frac{W}{L} \cdot V_{ov}$$

$$\Rightarrow \frac{W}{L} = 5.15$$

$L = 0.18\ \mu m$ so $W = 0.93\ \mu m$

Candidates must not write on this margin

b) $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{34.5 \text{ pF/m}}{15 \text{ nm}} = 2.30 \text{ fF}/\mu m^2$

$\mu_n = 550 \text{ cm}^2/\text{V-sec}$

$K_n' = \mu_n \cdot C_{ox} = 127 \ \mu A/V^2$

$I_D = \frac{1}{2} K_n' \left(\frac{W}{L}\right) \cdot V_{ov}^2$.

$= (0.2 \text{ mA}) \left(\frac{W}{L}\right)$

$= 20$

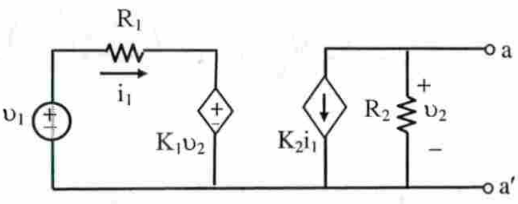
$\therefore V_{ov} = 0.40 \text{ V}$

$V_{DS,min} = 0.40$ for Saturation.

04. (c) For the circuit given

(i) Draw thevenin equivalent at a - a′

(ii) Draw Norton equivalent at a - a′ **12+8**



Sol

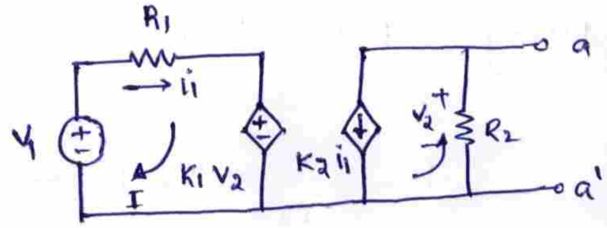
i) In loop I, using KVL

$V_1 - i_1 R_1 - K_1 V_2$ ——— (1)

Voltage across V_2 is $V_2 = -K_2 i_2 R_2$

For thevenin Voltage V_{th} across a-a′

$$V_{Th} = V_2 = -K_2 i_2 R_2$$



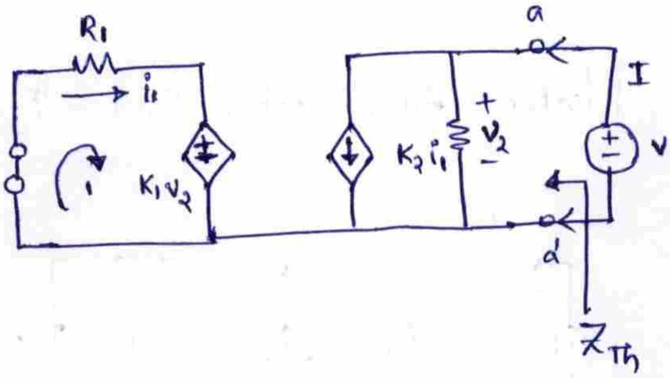
$$i_1 = -\frac{V_{Th}}{K_1 R_2} \longrightarrow (2)$$

Substitute equation (2) in equation (1)

$$V_1 + R_1\left(\frac{V_{Th}}{K_2 R_2}\right) - K_1 V_{Th} = 0$$

$$\therefore \; V_{Th} = \frac{K_2 R_2 V_1}{K_1 K_2 R_2 - R_1}$$

For $Z_{Thevenin}$ Across $a - a'$



from the circuit $v_2 = V$

From the loop (1). use KVL,

$$-R_1 i_1 - K_1 v_2 = 0 \implies i_1 = \frac{-K_1 v_2}{R_1} \longrightarrow (3)$$

Using KCL, find Current I

$$I = \frac{V_2}{R_2} + K_2 i_1 \longrightarrow (4)$$

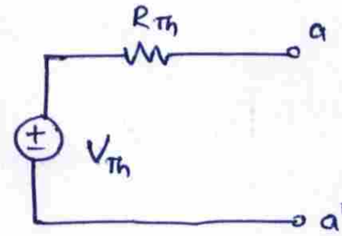
substute equation (3) in equation (4)

$$I = \frac{V_2}{R_2} + K_2\left(-\frac{K_1 V_2}{R_1}\right)$$

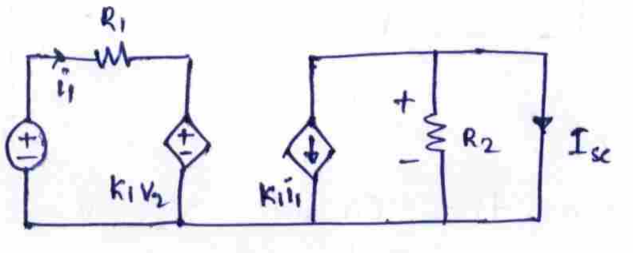
$$\therefore \frac{V_2}{I} = \frac{V}{I} = Z_{Th} = \frac{R_1 R_2}{R_1 - K_1 K_2 R_2}$$

$\therefore$ Thevenin Equivalent circuit is

$$Z_{Th} = \frac{R_1 R_2}{R_1 - K_1 K_2 R_2}$$

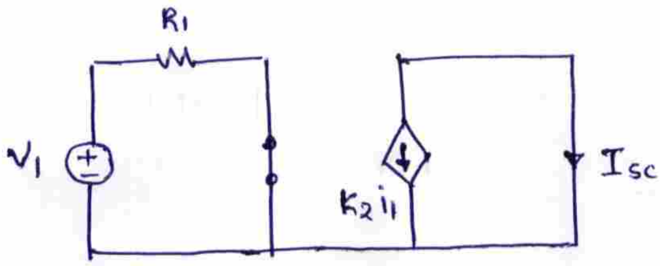


ii) For Norton equivalent, find I_{sc} through a-a'



$$V_2 = 0$$

$$\therefore K_1 V_2 = 0$$

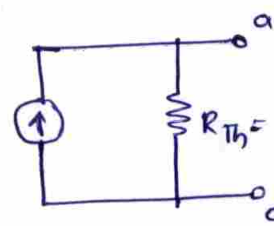


⇓

$$i_1 = \frac{V_1}{R_1}$$

$$I_{sc} = -K_2 i_1 \Rightarrow \therefore \boxed{I_{sc} = \frac{-K_2 V_1}{R_1}}$$

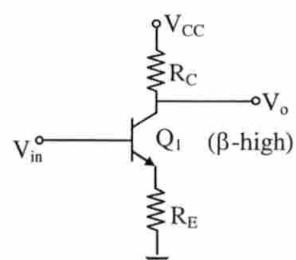
Norton Equivalent :



$$\frac{-K_2 V_1}{R_1} = I_{Th} \qquad R_{Th} = Z_{Th} = \frac{R_1 R_2}{R_1 - K_1 K_2 R_2}$$

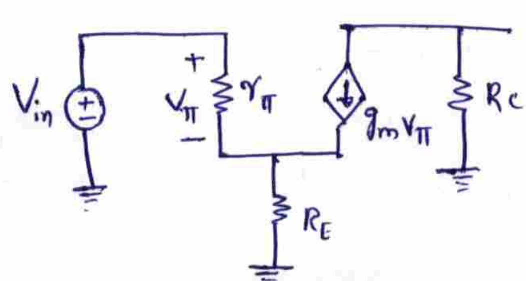
SECTION –II

05.(a) **(i)** In the following circuit, voltage drop across R_C an R_E are equal to $20V_T$ and $4V_T$ respectively. What is the gain of the circuit. (V_T is thermal voltage, assume β is high) ?



7

Sol By Small Signal Analysis of the given Circuit Voltage gain (A_v) is given as.



Candidates must not write on this margin

$$A_v = -\frac{R_C}{\frac{1}{g_m} + R_E}, \quad (\beta >> 1)$$

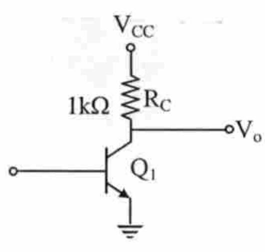
$$= -\frac{R_C}{R_E + \left(\frac{V_T}{I_C}\right)} = -\frac{R_C \cdot I_C}{R_E \cdot I_C + V_T}$$

β is large, so $I_C \simeq I_E$

$$A_v = -\frac{R_C \cdot I_C}{R_E \cdot I_E + V_T}$$

$$= -\frac{20 V_T}{4V_T + V_T} = -\frac{20}{5} = -4$$

05.(a) **(ii)** A bipolar amplifier circuit shown below, exhibits the following characteristics.



$I_C = I_S.\exp\left(\frac{V_{BE}}{2V_T}\right)$, $V_T = 25\text{mV}$.

If there is no early effect, then voltage gain of the amplifier for a bias current I_C = 1mA is? **5**

Sol:

$$I_C = I_S \exp\left[\frac{V_{BE}}{2V_T}\right]$$

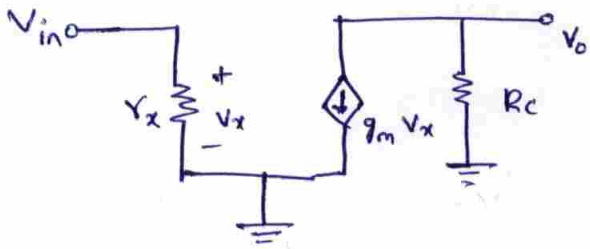
Transconductance $g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{2V_T}$

Candidates must not write on this margin

Output Impedence

$R_{out} = R_c$ ($\because$ since there is no early effect)

Equivalent Circuit is



Voltage gain is

$$\left|\frac{V_o}{V_{in}}\right| = g_m \cdot R_c = \frac{I_c \cdot R_c}{2V_T} = \frac{(1\,mA)(1\,K\Omega)}{2(0.025\,V)}$$

$$\Rightarrow \left|\frac{V_o}{V_{in}}\right| = 20$$

05.(b) A series circuit consisting of two pure elements has the following current and voltage

v = 100 sin(2000t + 50°)V

i = 20 cos(2000t + 20°)A

Find the elements and their values in the circuit? **12**

Sol

We can write $i = 20 \sin(2000t + 20^\circ + 90^\circ)$

($\because \sin(\theta + 90^\circ) = \cos\theta$)

$\therefore i = 20 \sin(2000t + 110^\circ)$ A

$\therefore$ Current leads voltage by $110^\circ - 50^\circ = 60^\circ$

And the Circuit Must Consist of R and C

$$\tan\theta = \frac{1}{\omega CR}$$

$$\therefore \frac{1}{\omega C} = R \tan 60^\circ = 1.73\ R$$

$$\frac{V_m}{I_m} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$R\sqrt{1+(1.73)^2} = \frac{100}{20}$$

$$\therefore \boxed{R = 2.5\,\Omega}$$

and $$C = \frac{1}{\omega(1.73R)}$$

$$\boxed{C = 115.6\ \mu F}$$

Candidates must not write on this margin

05.(c) For the diode - resistance circuit in the figure, the diode cut-in voltage is 0.6 and voltage drop across a conducting diode is 0.7 V.

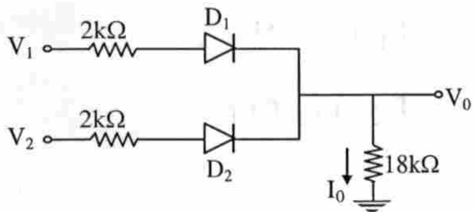
Calculate V_o and indicate the state of each diode for

(i) $V_1 = 10$ V , $V_2 = 0$V

(ii) $V_1 = 10$ V, $V_2 = 5$V

(iii) $V_1 = V_2 = 5$V

4 + 4 + 4



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Sol:

i) $V_1 = 10V \quad V_2 = 0V$

D_1 would conduct

$$I_0 = \frac{10-0.7}{(2+18)\,k\Omega} = 0.465 \text{ mA}$$

$$V_0 = 0.465 \times 18 = 8.37 \text{ V}$$

So, D_1 is ON

D_2 is OFF

ii) $V_1 = 10V \quad V_2 = 5V$

Assume that D_1 only conducts then as per part (a)

$$V_0 = 8.37 \text{ V.}$$

$V_2 - V_0 = 5 - 8.37 = -3.37\,V$

So D_2 does not Conduct as assumed

$V_0 = 8.37\,V$

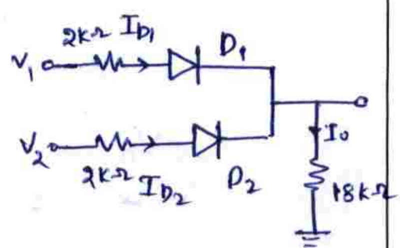
So D_1 is ON

D_2 is OFF

iii) $V_1 = V_2 = 5V$

Considering that D_1, D_2 both Conduct and output voltage is V_0, then $I_{D_1} + I_{D_2} = I_0$

$$I_{D_1} = \frac{5 - 0.7 - V_0}{2K\Omega} = \left(\frac{4.3 - V_0}{2}\right)$$



$$I_{D_2} = \frac{5 - 0.7 - V_0}{2K\Omega} = \frac{4.3 - V_0}{2}$$

$\therefore$ $I_{D_1} = I_{D_2}$, $I_0 = I_{D_1} + I_{D_2} = 4.3 - V_0$

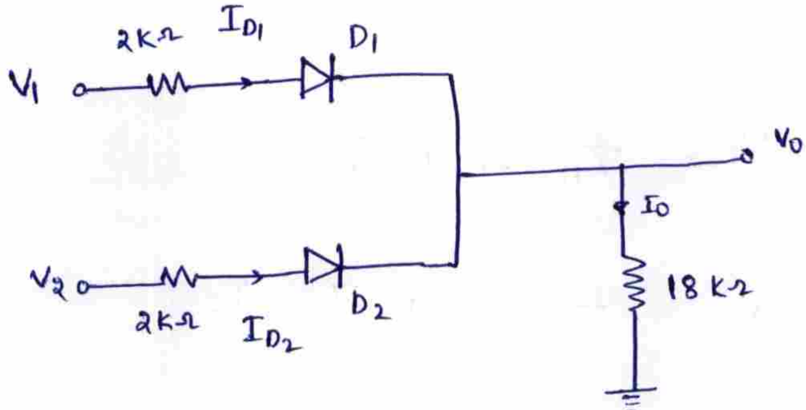
But $I_0 = \dfrac{V_0}{18 \times 10^3}$, $V_0 = 4.073\,V$

$V_1 - V_0 = V_2 - V_0 = 5 - 4.3 = 0.926\,V > 0.6V$

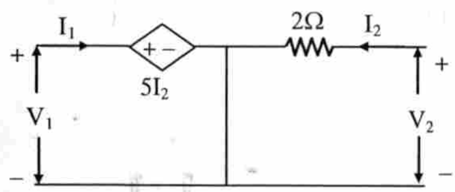
$\therefore$ our assumption that both diodes conduct is Correct

Hence $V_0 = 4.073\,V$

So, both D_1 and D_2 are ON



05.(d) Find Y and Z parameters for the following circuit. **12**



Sol

For two loops write KVL

$V_1 - 5I_2 = 0$

$V_2 - 2I_2 = 0$

$\therefore \quad V_1 = (0) I_1 + 5 I_2$

$V_2 = (0) I_1 + 2 I_2$

On Comparing with V_1, V_2

Candidates must not write on this margin

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$$Z = \begin{bmatrix} 0 & 5 \\ 0 & 2 \end{bmatrix}$$

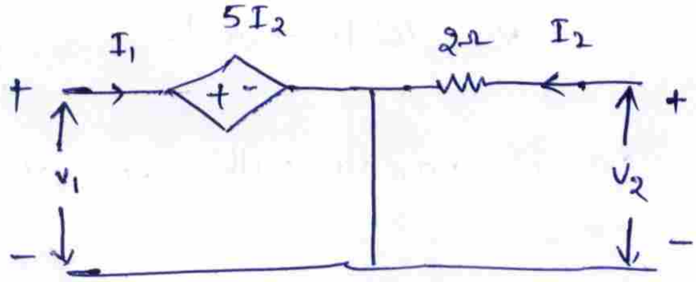
Y- parameters $[Y] = [Z]^{-1}$

$$= \frac{1}{|Z|} \begin{bmatrix} 2 & -5 \\ 0 & 0 \end{bmatrix}$$

$$|Z| = 0$$

$$[Y] = \begin{bmatrix} \infty & \infty \\ \infty & \infty \end{bmatrix}$$

Y – parameters are undefined



05.(e) Consider the common-source amplifier shown below. The transistor parameter are $V_{TN} = 1.5$ V, $k_n = 0.5$ mA/V^2 and $\lambda = 0.01$ V^{-1}. The resistance of source is $R_S = 4$ kΩ.

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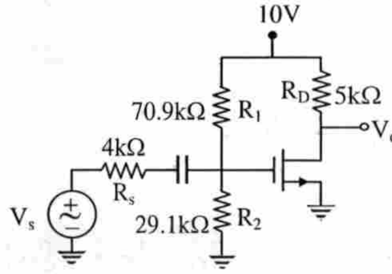


(i) The small-signal voltage gain $\left(\frac{V_o}{V_S}\right)$?

(ii) Amplifier output resistance (R_o)?

(iii) Amplifier input resistance (R_i)? **10+1+1**

Sol. i) DC Analysis

$$V_{GSQ} = \left(\frac{R_2}{R_1 + R_2}\right) \times 10$$

$$V_{GSQ} = \left(\frac{29.1}{70.9 + 29.1}\right) \times 10$$

$$V_{GSQ} = 2.91 \text{ V}$$

$$I_{DQ} = K_n \cdot (V_{GSQ} - V_{TN})^2$$

$$= (0.5\text{m})(2.91 - 1.5)^2$$

$$= 1 \text{ mA}.$$

Candidates must not write on this margin

$V_{DSQ} = 10 - I_{DQ} \cdot R_D = 10 - (1m)(5k) = 5V$

Since $V_{DSQ} > V_{GSQ} - V_{TN}$

The transistor is biased in the Saturation region

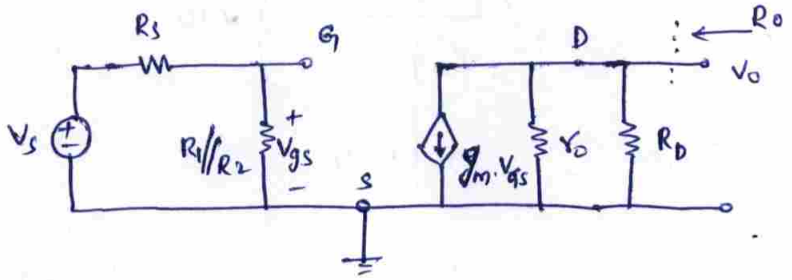
$$g_m = 2K_n (V_{GSQ} - V_{TN})$$

$$= 2(0.5)(2.91 - 1.5) = 1.41 \text{ mA/V}$$

$$r_o = (\lambda I_{DQ})^{-1} = [(0.01)(1 \text{ mA})]^{-1}$$

$$r_o = 100 \text{ k}\Omega$$

The small - signal equivalent circuit is shown below



$$V_{gs} = \frac{R_1 // R_2}{(R_1 // R_2) + R_S} \cdot V_s$$

$R_1 // R_2 = (70.9k) // (29.1 k\Omega)$

$= 20.6 \text{ k}\Omega$

$R_S = 4k\Omega$, $V_{gs} = 0.8 V_s$

$V_o = -g_m \cdot V_{gs} (r_o // R_D) = -(1.41m)(0.84 V_s)(100k // 5k)$

i) $\boxed{\frac{V_o}{V_s} = A_v = -5.6 \text{ V/V}}$

ii) $\boxed{R_o = R_D // r_o = 4.76 \text{ k}\Omega}$

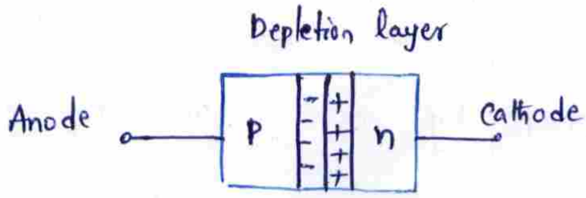
iii) $\boxed{R_i = R_1 // R_2 = 20.6 \text{ k}\Omega}$

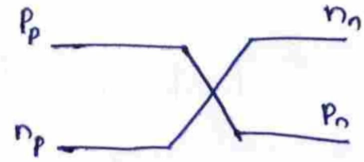
06.(a) Explain clearly the construction of a p-n junction diode and its use to convert sunlight directly into electricity. What distinguishes a solar cell from a conventional p-n junction diode? **20**

Candidates must not write on this margin

Sol: Construction of p-n Junction : A p-n junction Diode is formed by doping one side of a piece of silicon with p-type dopant (Boron) and the other side with a n-type dopant (phosphorous). Ge ~~Ge~~ can be used instead of silicon. the p-n Junction is a two terminal device. this is the basic construction of the p-n junction diode. it is one of the simplest semiconductor devices at as it allows current to flow in only one direction The p-n junction is an interface between a p-type and n-type region and is used to to construct diodes and transistors. At the Junction, Majority carriers diffuse across the junction, and this creates a depletion layer and a barrier potential ($V_{barrier}$) across the junction.

The Voltage $V_{barrier}$ Causes an Opposing current flow and the two flows from an equilibrium.





Electron-hole Concentration.

Application of p-n junction diode :

→ P-n junction diode in reverse biased Configuration is sensitive to light from a range between 40 nm – 1000 nm which Includes Visible light. therefore it can be used as a photo diode.

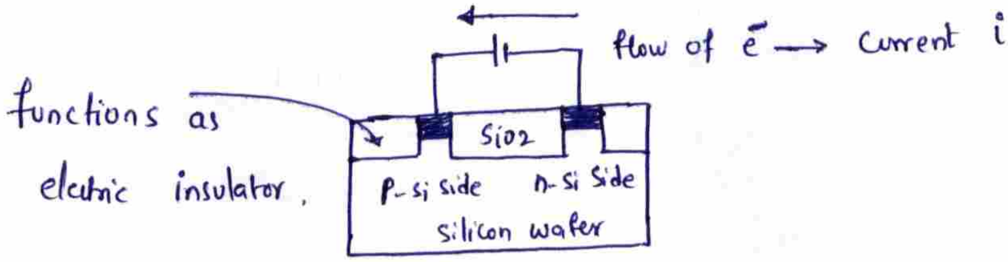
→ It can also be Used as a "solar cell"

→ P-n junction forward bias Condition is used in all LED lighting Applications.

Conversion of sun light into electricity :

The First photovoltaic device was built using a Si p-n junction by Russell ohl in 1939. A Silicon solar photovoltaic cells convert light energy into Electrical Energy. the photons from the Exposed light Promoted electrons flowing

From n-junction to p-junction i.e electric current flow



Working principle

→ The penetration depends on the wave length

→ Due to built in potential and electric field, electrons moves to the n-region, holes to the p-region.

→ Due to External load electrons recombine with Excess holes

→ The shorter wavelengths (higher absorbtion co-efficient) are absorbed in the n-region and the longer wavelengths in the p-region.

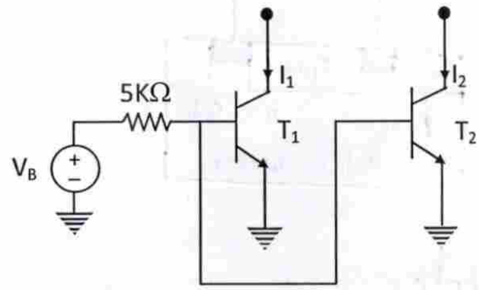
Difference between P-n junction Diode & Solar Cell

→ The Solar cell is a p-n junction diode optimized to Convert the incident Solar radiation to electrical energy.

→ The Major difference is the Metalization of the two electrodes the back side of the Solar cell is Completely metalized while the front side is partially metalized., but normal diode is Full metalized.

→ Solar cell allows light to pass but normal diode is opaque.

06.(b) **(i)** Consider the circuit shown in figure below, given that $I_{S_1} = 2I_{S_2} = 4\times10^{-6}\,A$, $\beta_1 = \beta_2 = 100$, and $I_1 = 1mA$. What is the value of V_B voltage? **12**



Sol:

$$I_1 = I_{S_1} e^{\frac{V_{BE_1}}{V_T}}.$$

$$I_2 = I_{S_2} e^{\frac{V_{BE_2}}{V_T}}$$

Assume $V_{BE_1} = V_{BE_2}$

$$\frac{I_1}{I_2} = \frac{I_{S_1} \cdot e^{V_{BE_1}/V_T}}{I_{S_2} \cdot e^{V_{BE_2}/V_T}}. \quad \text{also } I_{S_1} = 2 I_{S_2}$$

So $\frac{I_1}{I_2} = 2\frac{I_{S_2}}{I_{S_2}} = 2, \quad (\because I_{S_1} = 2 I_{S_2})$

We know that $\boxed{I_C = \beta I_B}$

So $I_1 = \beta_1 I_{B_1}$

$I_2 = \beta_2 I_{B_2}$

As $\beta_1 = \beta_2 \Rightarrow \frac{I_1}{I_2} = \frac{I_{B_1}}{I_{B_2}} = 2$

Candidates must not write on this margin

Applying KVL in Base-emitter loop, We get

$$V_B - (I_{B_1} + I_{B_2})R_B - V_{BE} = 0$$

$$V_{BE} = V_{BE_1} = V_T \ln\left(\frac{I_1}{I_{S_1}}\right)$$

$$= 26 \times 10^{-3} \ln\left(\frac{1\times10^{-3}}{4\times10^{-6}}\right)$$

$$= 143.56 \times 10^{-3} \text{ V}$$

$$I_{B_1} = \frac{I_1}{\beta_1} = \frac{1\times10^{-3}}{100} = 10\times10^{-6} \text{ A}$$

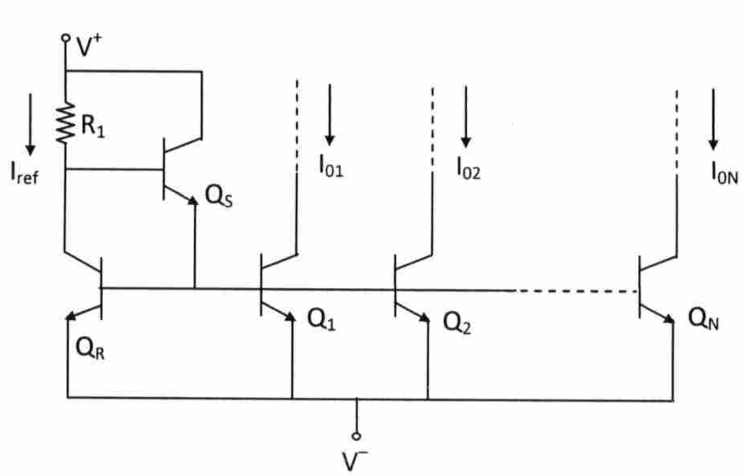
$$\frac{I_{B_1}}{I_{B_2}} = 2 \implies I_{B_1} = 2\times I_{B_2}$$

$$I_{B_2} = 5\times10^{-6} \text{ A}.$$

$$V_B = (I_{B_1} + I_{B_2})R_B + V_{BE}$$

$$V_B = (10\times10^{-6} + 5\times10^{-6})\times5\times10^{3} + 0.143 \text{ V} = 0.21855 \text{ V}$$

06.(b) (ii) All transistors in the 'N' output mirror shown below are matched with a finite gain β and early voltage $V_A = \infty$. The expression for each load current is? **8**



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Sol:

$$I_{ref} = I_{CR} + I_{BS} = I_{CR} + \frac{I_{ES}}{(1+\beta)}$$

$$I_{ES} = I_{BR} + I_{B1} + I_{B2} + \cdots + I_{BN}$$

$$I_{BR} = I_{Bi} \cdot \quad I_{CR} = I_{Ci} = I_{0i}$$

$$I_{ES} = (1+N)\, I_{BR} = \frac{(1+N)\cdot I_{CR}}{\beta}$$

Then $$I_{ref} = I_{CR} + \frac{I_{ES}}{(1+\beta)}$$

$$= I_{CR} + \frac{(1+N)\cdot I_{CR}}{\beta(1+\beta)}$$

$$= I_{0i}\left[1 + \frac{(1+N)}{\beta(1+\beta)}\right]$$

$$I_{0i} = \frac{I_{ref}}{\left[1 + \frac{(1+N)}{\beta(1+\beta)}\right]}$$

Where $i = 1, 2, \cdots N$.

06.(c) (i) Reduced incidence matrix of an oriental graph is given as

$$\begin{bmatrix} 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & -1 & -1 & -1 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

(a) Draw its graph

(b) How many trees are possible for this graph?

(c) Write the tie-set Matrix? **15**

Candidates must not write on this margin

a) Reduced Incidence Matrix

$$[A] = \begin{bmatrix} 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & -1 & -1 & -1 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

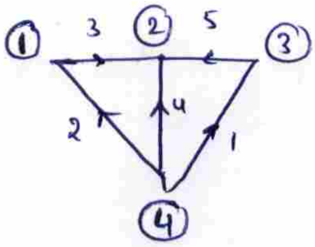
As algebric sum of column entries of an incidence matrix is zero. So incidence Matrix .

Branches/Nodes	1	2	3	4	5
(1)	0	−1	1	0	0
(2)	0	0	−1	−1	−1
(3)	−1	0	0	0	1
(4)	1	1	0	1	0

$a_{ij} = 1$ if branch j is oriented alway from node i, $a_{ij} = -1$ branch j is oriented towards 'i'

$a_{ij} = 0$ if branch 'j' is not incident on node i

Graph for Incidence matrix



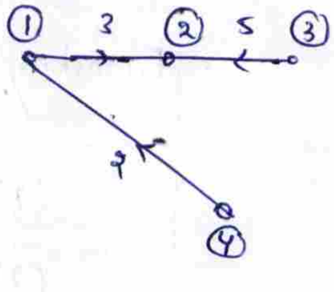
b) No. of trees = Determinant of $[A][A]^T$

$$[A][A^T] = \begin{bmatrix} 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & -1 & -1 & -1 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & -1 \\ -1 & 0 & 0 \\ 1 & -1 & 0 \\ 0 & -1 & 0 \\ 0 & -1 & 1 \end{bmatrix} = \begin{bmatrix} 2 & -1 & 0 \\ -1 & 3 & -1 \\ 0 & -1 & 2 \end{bmatrix}$$

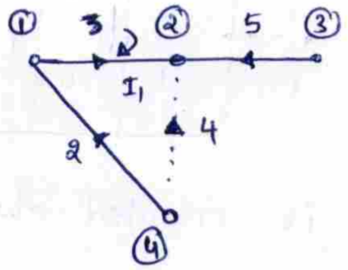
$$\text{Det } [A][A^T] = 2(6-1) + 1(-2) + 0 = 8.$$

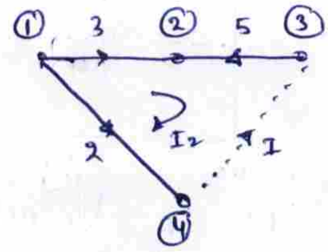
No. of possible tree = 8

c) Consider a tree from the graph



loop with above tree

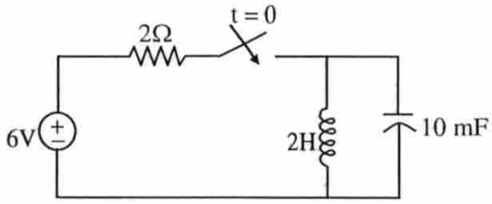




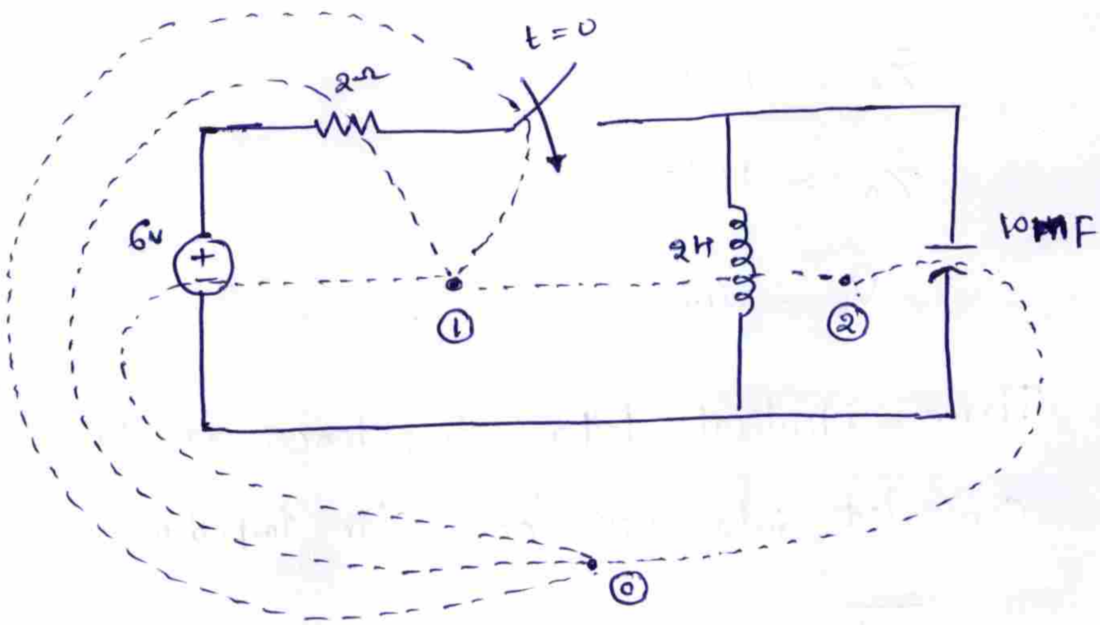
Tie set Matrix :

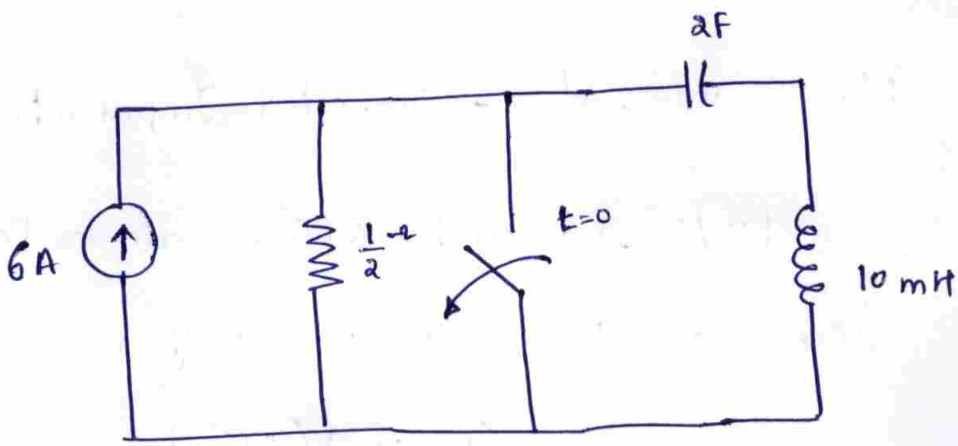
Tie sets / loop connect	1	2	3	4	5
I_1	0	1	1	-1	0
I_2	-1	1	1	0	-1

06.(c) **(ii)** Draw the Dual of the circuit shown below 5



Sol





07. (a) (i) Three identical impedances of $10\angle 30°\ \Omega$ each are connected star and another set of three identical impedances of $18\angle 60°\Omega$ are connected in delta. If both the sets of impedances are connected across a balanced, three-phase 400 V supply,

Find

(a) Line current

(b) Total volt-amperes

(c) Active power

(d) Reactive power. **15**

Candidates must not write on this margin

Sol: Given data

$$\bar{Z}_Y = 10\angle 30°\ \Omega$$

$$\bar{Z}_\Delta = 18\angle 60°\ \Omega$$

$$V_L = 400\ V$$

Three identical delta impedences can be converted into equivalent star impedence.

$$\overline{Z_Y'} = \frac{\bar{Z}_\Delta}{3} = \frac{18\angle 60°}{3} = 6\angle 60°\ \Omega$$

Now two-star-connected impedences

$10\angle 30°\ \Omega$ and $6\angle 60°\ \Omega$ are in parallel across a three-phase supply.

$$\bar{Z}_{eq} = \frac{(10\angle 30°)(6\angle 60°)}{10\angle 30° + 6\angle 60°} = 3.87\angle 48.83°\ \Omega$$

Candidates must not write on this margin

For a Star - Connected Impedences Load,

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94\ V$$

a) $$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{V_{ph}}{Z_{eq}} = \frac{230.94}{3.87} = 59.67\ A$$

Line current is $I_L = I_{ph} = 59.67$ Amp

b) Total Volt ampere.

$$S = \sqrt{3}\, V_L I_L = \sqrt{3} \times 400 \times 59.67$$

$$= 41.34\ \text{KVA}.$$

c) Active power : (P)

$$P = \sqrt{3}\, V_L I_L \cos\phi$$

$$= \sqrt{3} \times 400 \times 59.67 \times \cos(48.83^\circ)$$

$$= 27.21\ \text{KW}$$

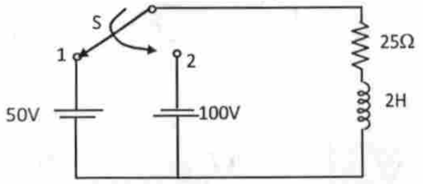
d) Reactive power : (Q) :

$$Q = \sqrt{3}\, V_L I_L \sin\phi$$

$$Q = \sqrt{3} \times 400 \times 59.67 \sin(48.83^\circ)$$

$$= 31.12\ \text{KVAR}$$

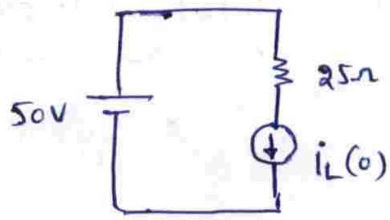
07.(a) (ii) In the circuit shown below, the switch S is in position '1' long enough to establish steady-state conditions and at t = 0 is switched to position '2'. Draw 's - domain' network :



5

Sol: When switch is in position 1: for long time

It will go to steady state condition Inductor will acts as a short circuit.

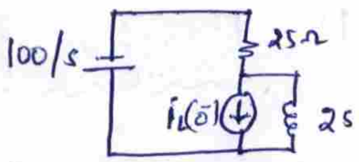


Current through Inductor $I_L = \frac{V}{R} = \frac{50}{25} = 2$ A

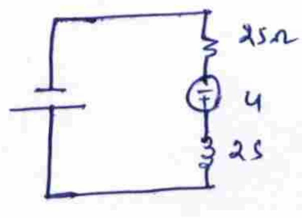
$i_L(0^-) = i_L(0^+) = 2$ A

When Switch moved to position 2

Inductor Acts as a current Source of 2A



By converting Inductor current and Inductor parallel network into series. it will look like



07.(b) (i) Explain varactor diode. Give its equivalent circuit and mention its applications. 10

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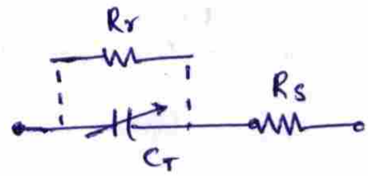
Sol Diodes made especially based on the voltage-variable Capacitors are called Varactors, Vari caps (or) Voltacaps. it is a type of diode designed to exploit the Voltage-dependent Capacitance of a reverse biased p-n junction. if the Varactor diode reverse Voltage is increases then depletion region size increases. Hence by varying the reverse bias of the Varactor diode, the Capacitance Can be varied.



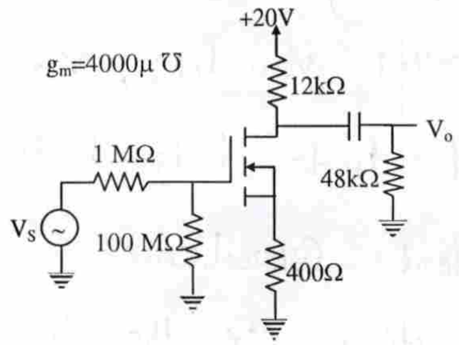
Circuit model

→ The Resistance 'R_s', Represents the body (ohmic) Series resistance of the diode. Typical values of C_T and R_s are 20 PF and 8.5 Ω respectively at a reverse bias voltage of 4 V. The Reverse diode resistance R_r shunting C_T is large (>1 MΩ). and hence is usually neglected.

Applications:

1) voltage tuning of the LC resonant circuit in radars, televisons etc.
2) They are commonly used in Voltage controlled Oscillators. Parametric amplifiers, frequency multipliers.

07.(b) (ii) Calculate the voltage gain $\left(\frac{V_o}{V_S}\right)$ of the circuit shown in the below figure. **10**



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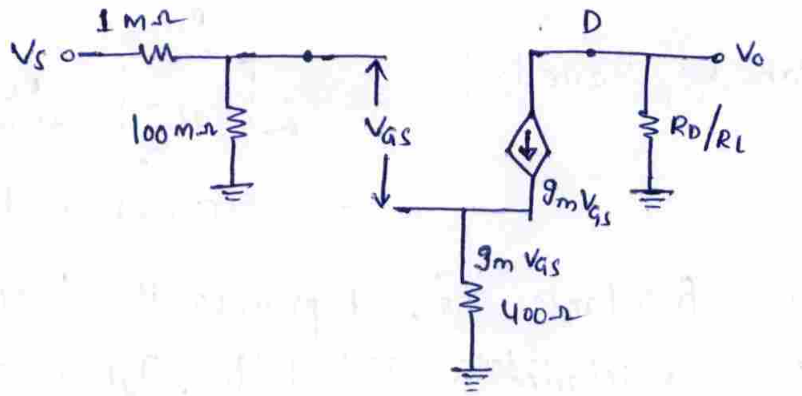
Sol:

Given $g_m = 400\,\mu\mho$

AC equivalent circuit.



$\therefore\ V_o = -g_m V_{GS} (R_D / R_L)$

$= -(12k \parallel 48k)(400\mu) V_{GS}$

$= -38.4\ V_{GS}$

$V_{in} = V_{GS} + g_m V_{GS} \times (400)$

$= V_{GS}\left[1 + (4000\mu) \times (400)\right]$

$= 2.6\ V_{GS}$

$$\frac{V_o}{V_{in}} = \frac{-38.4}{2.6}$$

$$= -14.769$$

Where $V_{in} = \dfrac{V_s\,[100\,M]}{1\,M + 100\,M}$

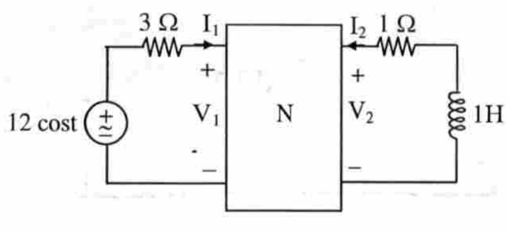
$$\therefore\ A_v = \frac{V_o}{V_s} = -14.769\left(\frac{100}{101}\right)$$

$$= -14.62$$

07. (c) (i) The z-parameters of a two-port network 'N' are given by,

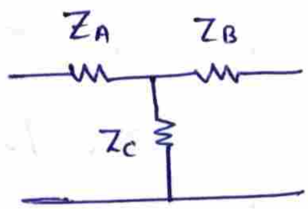
$$Z_{11} = \left[2s + \frac{1}{s}\right], Z_{12} = Z_{21} = 2s, Z_{22} = (2s+4)$$

Find the T-equivalent of Network N, If network N is connected to a source and aload as shown in figure by its T-equivalent, then find I_1, I_2, V_1 & V_2. **10**



Sol:

T – Network



$$Z_A = Z_{11} - Z_{12} = \frac{1}{S}$$

$$Z_B = Z_{22} - Z_{21} = 4$$

$$Z_C = Z_{12} = Z_{21} = 2S$$

$\therefore \quad S = j\omega = j1\Omega$

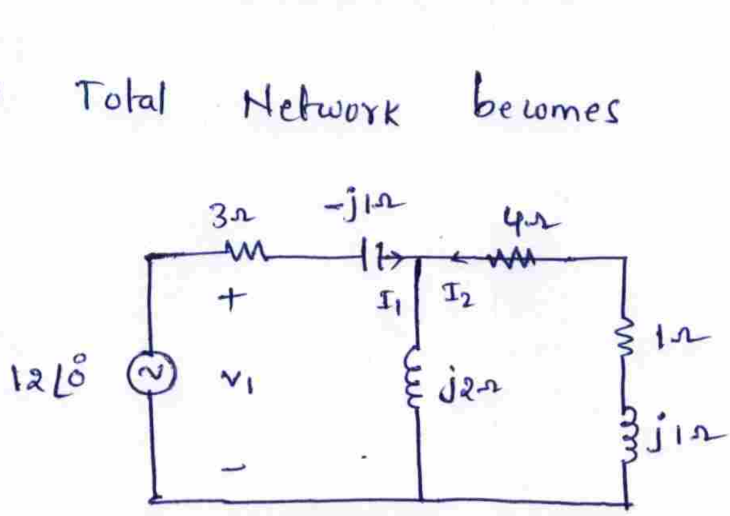
$\therefore \omega = 1$ · from source

$$Z_A = -j1\Omega$$

$$Z_B = 4\Omega$$

$$Z_C = +j2\Omega$$

So Total Network becomes



By Applying mesh Analysis in the above circuit

$$V_1 = 2.88 \angle 37.5^\circ$$

$$V_2 = 1.6 \angle 93.8^\circ$$

$$I_1 = 3.29 \angle -10.2^\circ$$

$$I_2 = 1.13 \angle -131.2^\circ$$

07.(c) **(ii)** Two loads connected in parallel are respectively 2kW at a power factor of 0.75 leading and 4 kW at power factor of 0.95 lagging. Calculate the combined power factor of the two loads. Find the complex power supplied by the source. **10**

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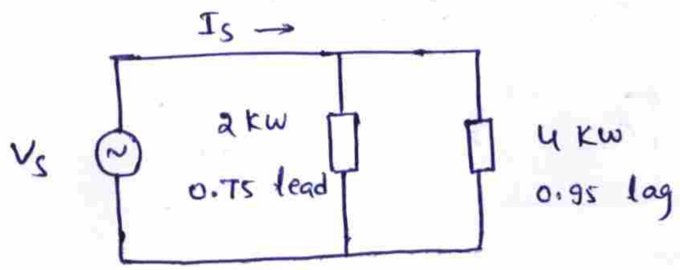
Sol



$P_1 = 2\text{ kW}$, $P_2 = 4\text{ kW}$, $P_T = 6\text{ kW}$

$P = S\cos\phi \Rightarrow S_1 = \dfrac{P_1}{\cos\phi_1} = \dfrac{2000}{0.75}$

$= 2666.67\ VA$

$S_2 = \dfrac{P_2}{\cos\phi_2} = \dfrac{4000}{0.95}$

$= 4210.52\ VA.$

$|S| = \sqrt{P^2 + Q^2}$

$Q_1 = \sqrt{S_1^2 - P_1^2}$

$Q_1 = \sqrt{(2666.67)^2 - (2000)^2}$

$\boxed{Q_1 = 1763 \text{ lead.}}$

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$$Q_2 = \sqrt{S_2^2 - P_2^2}$$

$$Q_2 = \sqrt{(4210.52)^2 - (4000)^2}$$

$$\boxed{Q_2 = 1314.7 \text{ lag}}$$

$$S_1 = 2000 - j1763$$

$$S_2 = 4000 + j1314.7$$

$$S_T = 6000 - j448.3$$

$$\cos\phi = \frac{P_T}{S_T} = \frac{6000}{\sqrt{(6000)^2 + (448.3)^2}} = 0.9972 \text{ lead.}$$

08.(a) (i) Consider a series-parallel circuit as shown calculate current through each resistor, the voltage across each resistor and voltage at each node of circuit. **8**

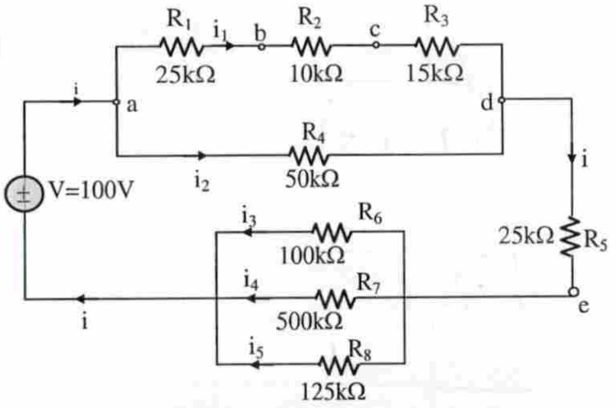

Figure: - Series parallel circuit

Sol

The Equivalent resistance of

R_1, R_2, R_3 is $(25+10+15) = 50\ k\Omega$

R_1, R_2, R_3, R_4 is $(50 \| 50) = 25\ k\Omega$

R_6, R_7, R_8 is $(100 \| 500 \| 125) = 50\ k\Omega$

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Since $R_1 + R_2 + R_3 = R_4$ we have $i_1 = i_2$

$\therefore$ $R_{eq} = (25 + 25 + 50)\ k\Omega = 100\ k\Omega$

$$i = \frac{V}{R_{eq}} = 1\ mA$$

Hence $i_1 = 0.5\ mA = i_2$

To Compute Values of Voltages across resistances R_1, R_2, R_3, R_4, R_5 and R_6.

$V_{R_1} = R_1 \times i_1 = 12.5\ V$

Similarly $V_{R_2} = 5V$

$V_{R_3} = 7.5\ V$

$V_{R_4} = 25\ V$

$V_{R_5} = R_5 \times i = 25\ V$

$$i_3 = \frac{(100 - 25 - 25)V}{100\ k\Omega} = 0.5\ mA$$

$$i_4 = \frac{50\ V}{500\ k\Omega} = 0.1\ mA$$

$$i_5 = \frac{50V}{125\ k\Omega} = 0.4\ mA$$

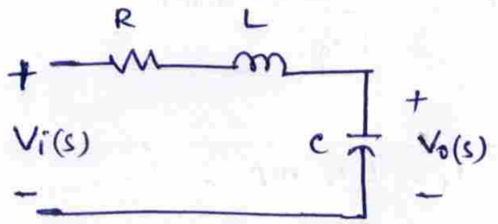
Now $V_b = V_a - V_{R_1} = 100 - 12.5 = 87.5\ V$

Similarly $V_c = 82.5\ V$ $V_d = 75\ V$, $V_e = 50\ V$.

08.(a) (ii) Derive the transfer function $H(s) = \frac{V_c(s)}{V_i(s)}$ of series RLC circuit find the quality factor when the transfer function is $H(s) = \frac{10^6}{s^2 + 20s + 10^6}$? **8**

Candidates must not write on this margin

Sol Given Series RLC Circuit



$$\frac{V_o(s)}{V_i(s)} = \frac{\frac{1}{cs}}{R + Ls + \frac{1}{cs}} = \frac{1}{LCs^2 + RCs + 1}$$

$$\frac{V_o(s)}{V_i(s)} = \frac{1/LC}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

Compare $H(s) = \frac{10^6}{s^2 + 20s + 10^6}$ with above equation.

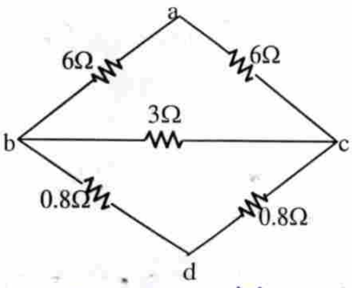
$\therefore \frac{1}{LC} = 10^6$

$\omega_0 = \frac{1}{\sqrt{LC}} = 10^3$ rad/sec

$R/L = 20$

$\therefore Q = \frac{\omega_0 L}{R} = \frac{10^3}{20} = 50.$

08.(a) **(iii)** Using star-delta transformation, determine resistance between a and d in given figure. **4**



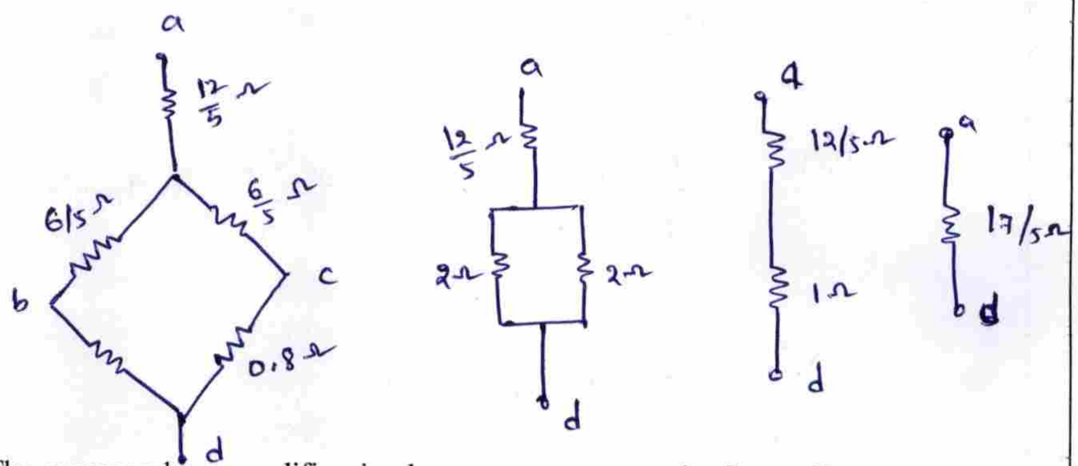
Sol

Convert Δ to Y.

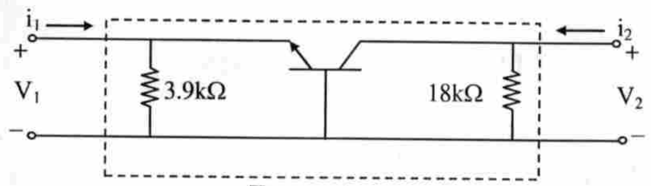
$$x = \frac{6 \times 6}{15} = \frac{12}{5}\ \Omega$$

$$y = \frac{6 \times 3}{6+6+3} = \frac{18}{15} = \frac{6}{5}\ \Omega$$

$$z = \frac{6}{5}\ \Omega$$



08.(b) **(i)** The common-base amplifier is drawn as a two-port in figure Shown below. The parameters are $\beta = 100$, $g_m = 3\text{mS}$, and $r_o = 800\ \text{k}\Omega$.

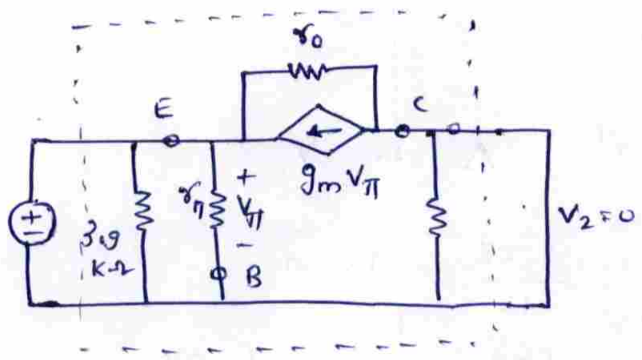


Two-port

The h - parameter h_{21} and h_{12} is **9**

Candidates must not write on this margin

Sol The Equivalent Small-Signal Circuit is shown below



$$r_\pi = \frac{\beta}{g_m} = \frac{100}{3\,mS} = 33.3\ K\Omega$$

$$h_{21} = \left.\frac{i_2}{i_1}\right|_{V_2=0}, \quad i_2 = \frac{V_\pi}{r_o} + g_m \cdot V_\pi$$

$\frac{V_\pi}{r_o}$ Can be neglected

$$h_{21} = \frac{i_2}{i_1}$$

$$h_{21} = \frac{-g_m}{\frac{1}{3.9K} + \frac{1}{r_\pi} + g_m}$$

$$h_{21} = \frac{-g_m r_\pi (3.9\,k\Omega)}{r_\pi + 3.9\,k\Omega + g_m r_\pi \cdot (3.9k)}$$

$\therefore\ h_{21} = 0.91$

<u>h_{12} :</u>

$V_1 = -V_\pi$

Applying nodal Analysis

$$\frac{V_1}{3.9k} + \frac{V_1}{r_\pi} + \frac{V_1 - V_2}{r_o} = g_m \cdot V_\pi$$

$$V_1 \left(\frac{1}{3.9k} + \frac{1}{r_\pi} + \frac{1}{r_o} \right) - \frac{V_2}{r_o} = -g_m \cdot V_1$$

$$\therefore \frac{V_1}{V_2} = \frac{\frac{1}{r_o}}{\frac{1}{3.9k} + \frac{1}{33.3k} + \frac{1}{800k} + 3m}$$

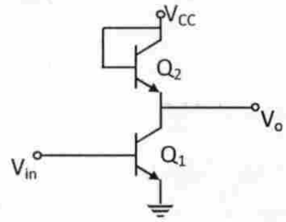
$$= 3.8 \times 10^{-4}$$

$$\therefore \boxed{h_{12} = 3.8 \times 10^{-4}}$$

Candidates must not write on this margin

08.(b) (ii) Consider an amplifier circuit shown in figure below. If the transistors Q_1 and Q_2 has parameters g_{m1}, $r_{\pi1}$ and g_{m2}, $r_{\pi2}$ respectively, then voltage gain $|A_v|$ is ? **6**

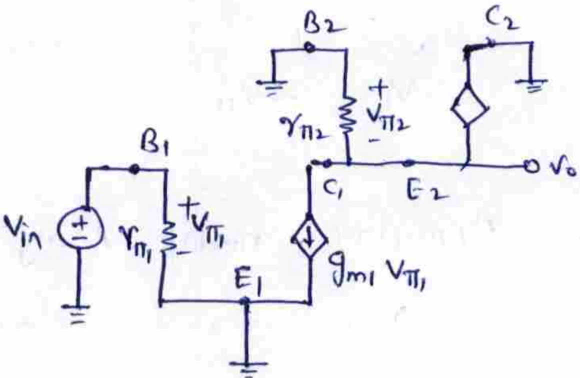
Candidates must not write on this margin



Sol

By Small Signal equivalent Circuit Analysis

In the Circuit



$$g_{m1} \cdot V_{\pi_1} + \frac{V_o}{r_{\pi2}} = g_{m2} \cdot V_{\pi2}$$

$$V_{\pi_1} = V_{in} , \quad V_o = -V_{\pi2}$$

So ,

$$g_{m1} v_{in} + \frac{V_o}{r_{\pi2}} = -g_{m2} \cdot V_o$$

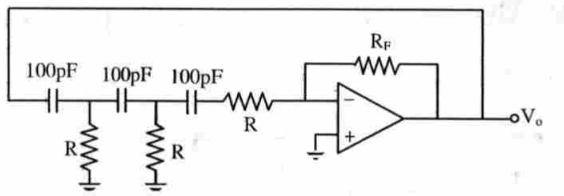
$$g_{m1} \cdot V_{in} = -\left[g_{m2} + \frac{1}{r_{\pi2}}\right] V_o$$

Voltage gain

$$|A_v| = \frac{V_o}{V_{in}} = \frac{g_{m1} \cdot r_{\pi2}}{1 + g_{m2} \cdot r_{\pi2}}$$

08.(b) **(iii)** The phase-shift oscillator shown below operate at f = 80 kHz the value of resistance R_F is ?

Candidates must not write on this margin



Sol **5**

The Oscillation frequency is

$$f = \frac{1}{2\pi\sqrt{6}RC}$$

$$80\text{ KHZ} = \frac{1}{2\pi\sqrt{6}\cdot R(100\times 10^{-12})}$$

$$R = \frac{1}{(80\times 10^{3})(2\pi\times\sqrt{6}\times 10^{-10})}$$

$$R = \frac{10^{6}}{8\times 2\pi\times\sqrt{6}} = 8.12\text{ k}\Omega$$

$$\frac{R_F}{R} = 29 \Rightarrow R_F = (8.12\text{ k}\Omega)(29)$$

$$\therefore \boxed{R_F = 236\text{ k}\Omega}$$

08.(c) (i) Select the value of K so that each of the following pairs of fields satisfies Maxwell's equations in a region where $\sigma = 0$ and $\rho_v = 0$:

(a) $\overline{D} = 5x\hat{a}_x - 2y\hat{a}_y + Kz\hat{a}_z\mu C/m^2$, $\overline{B} = 2\hat{a}_y mT$, $\mu = \mu_o$, $\varepsilon = \varepsilon_{.0}$

(b) $\overline{E} = 60\sin 10^6 t\sin 0.01z\hat{a}_x\ V/m$, $\overline{H} = 0.6\cos 10^6 t\cos 0.01z\hat{a}_y\ A/m$, $\mu = K$, $\varepsilon = C_1$

6

Sol:

a) $\overline{\nabla}\cdot\overline{D} = \rho_v = 0$

$$\Rightarrow \frac{\partial D_x}{\partial x} + \frac{\partial D_y}{\partial y} + \frac{\partial D_z}{\partial z} = 0.$$

Candidates must not write on this margin

$(5-2+K)10^{-6}$ (or) $K = -3\ \mu C/m^3$

$$\boxed{K = -3\mu C/m^3}$$

b) $\bar{\nabla} \times \bar{E} = \frac{\partial}{\partial z}\left(60 \sin 10^6 t \sin 0.01z\right)\hat{a_y}$

$$- \frac{\partial}{\partial y}\left(60 \sin 10^6 t \sin 0.01z\right)\hat{a_z}$$

$$\bar{\nabla} \times \bar{E} = 0.6 \sin 10^6 t \cos 0.01z\, \hat{a_y}$$

$$\frac{\partial \bar{B}}{\partial t} = \mu \frac{\partial \bar{H}}{\partial t} = K \times 0.6\left(-10^6\right) \sin 10^6 t \cos(0.01z)\hat{a_y}$$

$$= -K \times 6 \times 10^5 \sin 10^6 t \cos(0.01z)\hat{a_y}$$

Using the Equation

$\bar{\nabla} \times \bar{E} = -\frac{\partial \bar{B}}{\partial t}$, we get

$$0.6 = K \times 6 \times 10^5$$

(or) $\boxed{K = 10^{-6}\ H/m}$

08.(c) (ii) The core of toro, then find the number of turn required to obtain an inductance of 2.5H. id is $12cm^2$ and is made up of material with μ_r= 200. If the mean radius of a toroid is 50cm **6**

Candidates must not write on this margin

Sol

Inductance $L = 2.5\ H$

Area $A = 12\ cm^2$

$\mu_r = 200$

Mean Radius $R = 50\ cm$

Mean Length $l = 2\pi R$

Inductance of toroid is given by

$$L = \frac{\mu_0 \mu_r N^2 A}{l}$$

$$L = \frac{\mu_0 \mu_r N^2 A}{2\pi R}$$

$$N^2 = \frac{2\pi \times 50 \times 10^{-2} \times 2.5}{4\pi \times 10^{-7} \times 200 \times 12 \times 10^{-4}}$$

$$N^2 = 0.2604166 \times 10^{8}$$

$$\therefore \boxed{N = 5103 \text{ turns}}$$

08.(c) **(iii)** A current sheet with $\vec{K} = 5\hat{a}_y mA/m$ lies on the interface between two media, with μ_r=1 for region-I (x<0) and μ_r = 2 for region-II (x>0). If the magnetic field intensity in region-I is $\vec{H}_1 = 6\hat{a}_x + 30\hat{a}_y mA/m$, then what is the magnitude of magnetic field intensity at x > 0. **8**

Candidates must not write on this margin

Sol

Given $\bar{K} = 5 a_y \ mA/m$

$\bar{H}_1 = 6\hat{a}_x + 30\hat{a}_y \ mA/m$

$\bar{H}_{n1} = 6\hat{a}_x$

$\bar{H}_{t1} = 30\hat{a}_y$

$B_{n1} = B_{n2}$

$\mu_1 H_{n1} = \mu_2 H_{n2}$

$\bar{H}_{n2} = \left(\frac{1}{2}\right)(6\hat{a}_x)$

$\bar{H}_{n2} = (3\hat{a}_x) \ mA/m$

$\bar{H}_{t1} - \bar{H}_{t2} = \hat{a}_{n12} \times \bar{K}$

Where $\hat{a}_{n12}$ = Unit vector normal to the interface from region-I to region-II

$\hat{a}_{n12} = \hat{a}_x$

$30\hat{a}_y - \bar{H}_{t2} = \hat{a}_x \times (5\hat{a}_y)$

$H_{t2} = 30\hat{a}_y - 5\hat{a}_z \ mA/m$

$H_2 \text{ (at } x>0) = 3\hat{a}_x + 30\hat{a}_y - 5\hat{a}_z \ mA/m$

Magnitude of $H_2 = \sqrt{(3)^2 + (30)^2 - (-5)^2} = 30.56 \ mA/m$