ACE
Engineering Academy

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

Electronics & Telecommunication 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 : 601

DATE : 30-03-2019

INSTRUCTIONS TO CANDIDATES:

- This Question-cum- Answer (QCA) Booklet contains **84** 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	11	
3	21	
4	30	
5	39	
6	48	
7	58	
8	69	
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:

*Answers must be written in **ENGLISH** only.*

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

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

*Questions no. **1** and **5** are **compulsory** and out of the remaining, **THREE** are to be attempted choosing at least **ONE** question from each section.*

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

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams / figures, wherever required, shall be drawn in the space provided for answering the question itself.

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

Candidates should attempt all questions in the space prescribed under each question in the Question-cum-Answer (QCA) Booklet. Any answer written outside the space allotted may not be given credit.

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.

Values of constants which may be required:

Electron charge = -1.6×10^{-19} Coulomb

Free space permeability = $4\pi \times 10^{-7}$ Henry/m

Free space permittivity = $(1/36\pi) \times 10^{-9}$ Farad/m

Velocity of light in free space = 3×10^{8} m/sec

Boltzmann constant = 1.38×10^{-23} J/K

Planck's constant = 6.626×10^{-34} J-s

DONT'S:

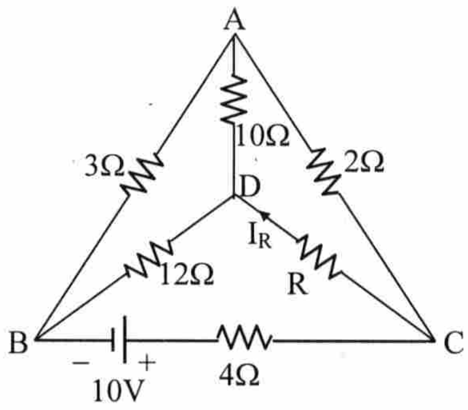
1. Do not write your Name or Roll number or Sr. No. of Question-Cum-Answer-Booklet anywhere inside this Booklet. Do not sign the "Letter Writing" questions, if set in any paper by name, nor append your roll number to it.
2. Do not write anything other than the actual answers to the questions anywhere 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.**

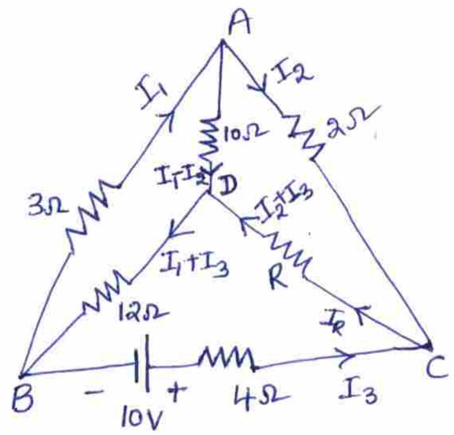
SECTION - A

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 M)

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.

By writing KVL equations in the three 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 is zero

$$I_1 - I_2 = 0 \Rightarrow \boxed{I_1 = I_2} \quad \text{------}(4)$$

Using eq.(4) in eq.(1), we get

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

$$\Rightarrow \boxed{I_3 = -\frac{5}{4} I_1} \text{ ------ } (5)$$

Substitute eq.(4) and eq.(5) in eq.(2)

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

$$\therefore \boxed{R = 8\Omega} \text{ ------ } (6)$$

Substitute value of R (i.e eq.(6)) in eq.(2) and eq.(3) and along with eq.(4), we get

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

$$20I_1 + 24I_3 = 10 \text{ ------ } (8)$$

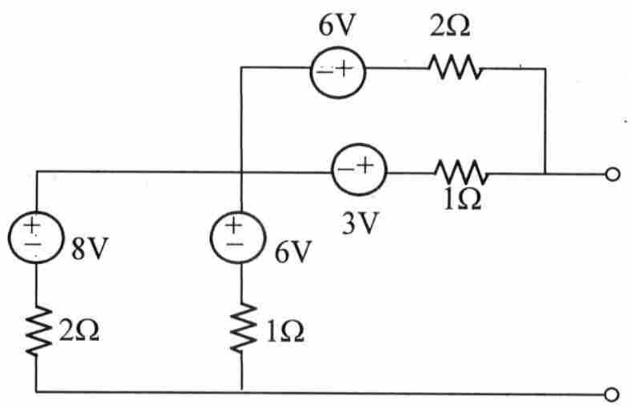
On solving eq.(7) and (8), we get

$$I_1 = -1A \; ; \; I_3 = 1.25A \text{ and } I_2 = I_1$$

$$\therefore \boxed{I_2 = -1A}$$

$\therefore$ Current through resistor 'R' i.e $\boxed{I_R = I_3 + I_2} = -1 + 1.25 = 0.25$ Amp

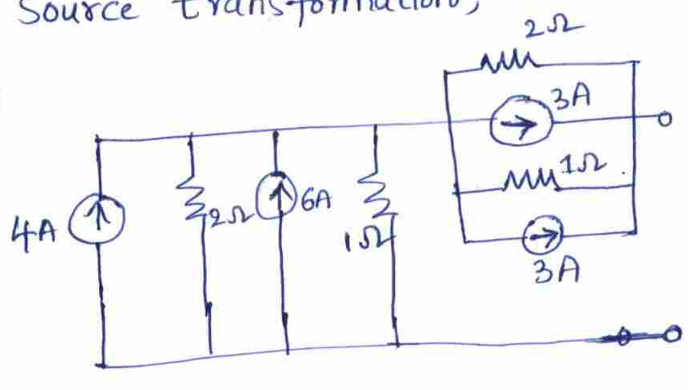
01. (b) Using source transformation, deduce the circuit into its equivalent circuit with Ideal voltage source in devices with a resistance.



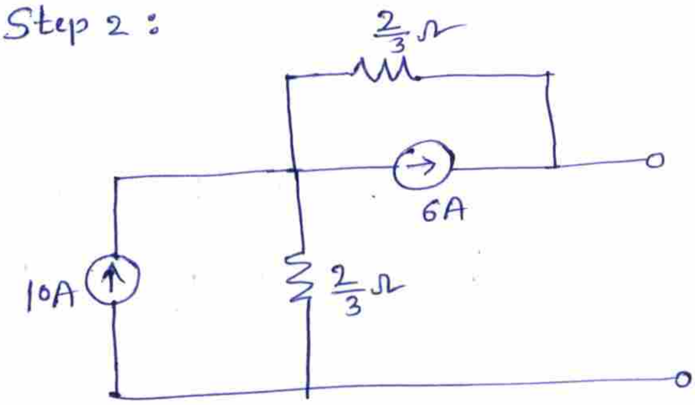
(12 M)

Sol: Using Source transformation,

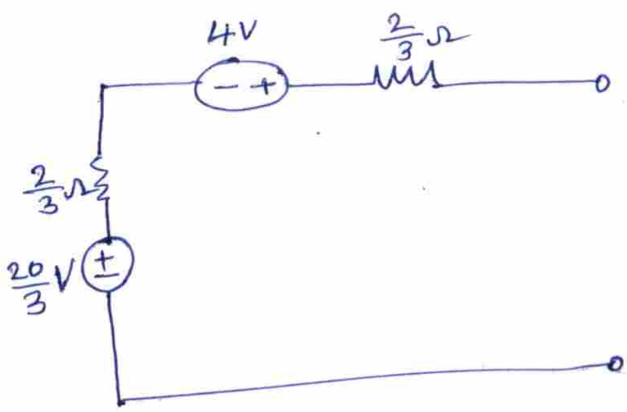
Step 1:



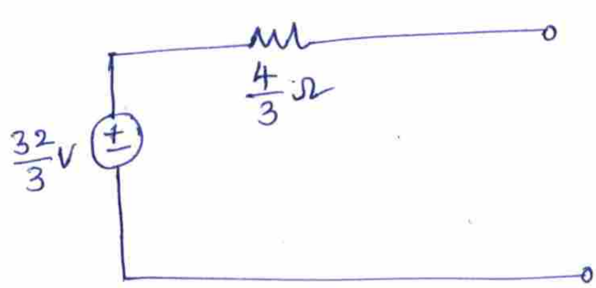
Step 2 :



Step 3 :



Step 4 :



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01. (c) State & explain Tellegen's theorem ? **(12 M)**

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Sol: Tellegen's theorem states that,

"In any arbitary jumped network, the algebraic sum of the powers in all branches at any instant is zero".

All branch currents and voltages in that network must satisfy Kirchoff's laws. Thus this theorem is based on Kirchoff's two Laws (i.e KCL and KVL), but not on the type of circuit elements.

Explanation :

Consider two networks N_1 and N_2, having the same graph with same reference directions assigned to branches in two networks, but with different Values.

Let V_{1K}, i_{1K} be the voltages and currents in N_1 and V_{2K} and i_{2K} be voltages and currents in N_2. By Tellegen's Theorem,

$$\boxed{\sum_{K=1}^{b} V_{1K} \cdot i_{2K} = 0} \text{ and } \boxed{\sum_{K=1}^{b} V_{2K} \cdot i_{1K} = 0}$$

If t_1 and t_2 are two different times of observation,

$$\therefore \boxed{\sum_{k=1}^{b} V_{1k}(t_1) \cdot i_{1k}(t_2) = 0}$$

$\therefore$ Tellegen's Theorem depicts Conservation of power.

01. (d) **(i)** A Si sample is doped with 10^{18} As atom/cm^3.

(A) what is the equilibrium hole concentration 'P_o' at 300 K?

(B) Show the position of E_{Fn} relative to E_i in band diagram.

(ii) Find N_d for Si with 10^{16}cm^{-3} boron atoms and a certain number of donors, so that

$$E_{Fn} - E_{F_i} = 0.36\text{ev.} \quad \left(\overline{K}T = 0.0259\text{ev}, n_i = 1.5\times10^{10}\text{cm}^{-3}\right)$$

(6 + 6)M

Sol:

(i) (A) Given data

for silicon at 300k, $n_i = 1.5\times10^{10}$ cm^{-3}

$N_d = 10^{18}$ cm^{-3}.

Since $N_d >> n_i$, we can approximate $n_o = N_d$.

$$\therefore \text{Hole concentration } (P_o) = \frac{n_i^2}{n_o} = \frac{n_i^2}{N_d}$$

$$= \frac{(1.5\times10^{10})^2}{10^{18}} = 2.25\times10^{2}\text{ cm}^{-3}.$$

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(B) As we know,

$$E_{Fn} - E_i = KT \ln\left(\frac{n_o}{n_i}\right)$$

$$\Rightarrow E_{Fn} - E_i = 0.0259 \ln\left(\frac{10^{18}}{1.5\times 10^{10}}\right)$$

$$= 0.466\ eV = 0.466\ eV$$

$\therefore$ Position of E_{Fn} relative to E_i is $0.466\ eV$.

$$\boxed{E_{Fn} - E_i = 0.466\ eV}$$

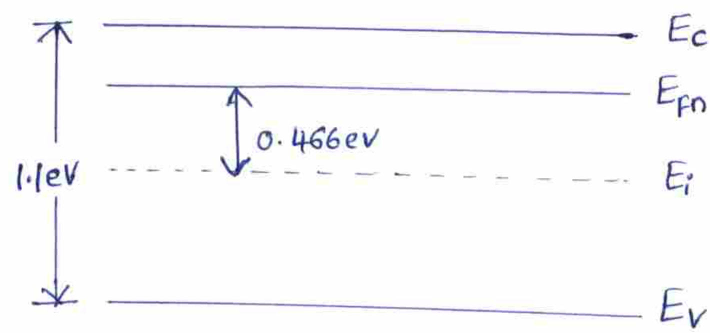

Fig. Band Diagram.

(ii) As we know,

$$\boxed{n_0 = n_i \cdot e^{\frac{E_{Fn}-E_{Fi}}{KT}}}$$

$$\Rightarrow n_0 = (1.5\times10^{10}) \cdot e^{\frac{0.36}{0.0259}}$$

$$\Rightarrow n_0 = 1.63\times10^{16}\ cm^{-3}.$$

Again, $\boxed{n_0 = N_d - N_A}$

$$\Rightarrow N_d = n_0 + N_A$$

$$\Rightarrow N_d = 1.63\times10^{16} + 10^{16}$$

$\therefore$ Donor Concentration $\boxed{(N_d) = 2.63\times10^{16}\ cm^{-3}.}$

01. (e) **(i)** Show that the minimum conductivity of a semiconductor sample occurs when

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

(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)M

Sol:

(i) The conductivity of a semiconductor is

$$\sigma = nq\mu_n + pq\mu_p \longrightarrow (1)$$

from mass-action law, we know $np = n_i^2$

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

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

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For minimum conductivity at electron concentration n_{min},

$$\boxed{\frac{\partial \sigma}{\partial n} = 0}$$

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

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

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

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

$\therefore$ Minimum conductivity of a semiconductor sample occurs when, $n_{min} = n_i \cdot \sqrt{\frac{\mu_p}{\mu_n}}$.

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

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

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

$$\therefore \boxed{\sigma_{min} = 2q n_i \sqrt{\mu_n \cdot \mu_p}}$$

(iii) for a 'Si' semiconductor

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

$\Rightarrow \sigma_i = 1.5\times10^{10} \times 1.6\times10^{-19}\,(1350+480)$

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

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

$\Rightarrow \sigma_{min} = 2\times1.6\times10^{-19}\times1.5\times10^{10}\times\sqrt{1350\times480}$

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

So, the minimum Conductivity is less than the intrinsic conductivity for a silicon semiconductor.

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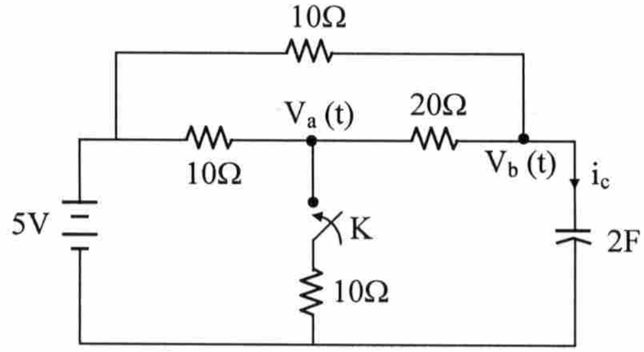
02. (a) For the circuit shown, the switch K is closed at t = 0. At t < 0, the circuit is in steady state. Determine V_a, V_b, i_c at $t = 0^-$, $t = 0^+$, & $t = \infty$.

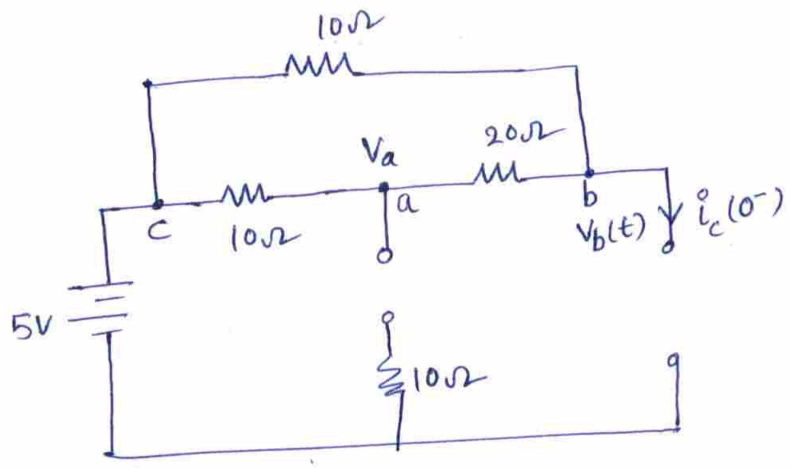


(20 M)

Sol:

At $t = 0^-$ Circuit is in steady state,

(C = open , L = short).



$i_c(0^-) = 0$ Amp.

Using KCL, at node a and c

$$\frac{V_a - 5}{10} + \frac{V_a - V_b}{20} = 0 \longrightarrow (1)$$

$$\frac{5 - V_b}{10} + \frac{5 - V_a}{10} = 0 \longrightarrow (2)$$

On solving equations (1) & (2)

$V_a = V_b = 5V.$

$\therefore \boxed{V_a(0^-) = V_b(0^-) = 5V \quad \& \quad i_c(0^-) = 0A.}$

At $t = 0^+$, the circuit is

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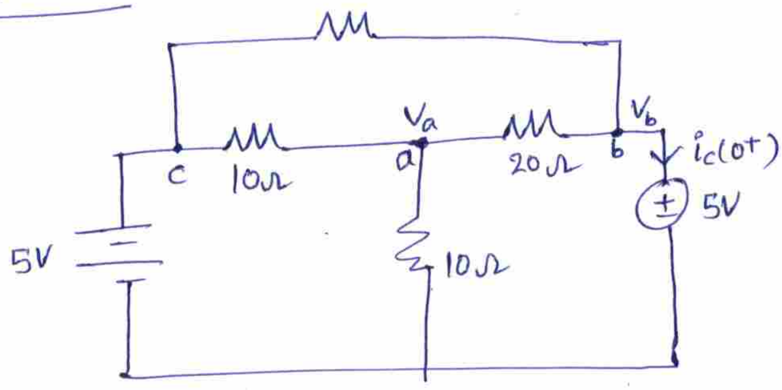
At $t = 0^+$:



Use KCL at node a and b

$$\boxed{V_b(0^+) = 5V.}$$

$$\therefore \; i_c(0^+) = \frac{5-5}{10} + \frac{V_a - 5}{20} \longrightarrow (3)$$

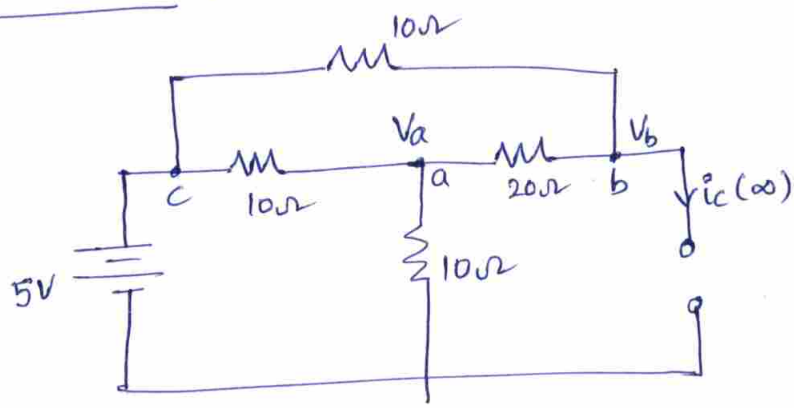
$$\frac{V_a}{10} + \frac{V_a - 5}{10} + \frac{V_a - 5}{20} = 0 \longrightarrow (4)$$

On solving equations (3) & (4), we get

$$\therefore \; \boxed{V_a(0^+) = 3V}$$

$$\therefore \; \boxed{i_c(0^+) = -\frac{1}{10}\text{ Amp} = -0.1\text{ Amp.}}$$

At $t = \infty$:



KCL at node a and c,

$$\frac{V_a-5}{10}+\frac{V_a}{10}+\frac{V_a-V_b}{20}=0 \longrightarrow (5)$$

$$\frac{5-V_b}{10}+\frac{5-V_a}{10}=0 \longrightarrow (6)$$

Solving equations (5) & (6), we get

$$\boxed{V_a(\infty)=\frac{20}{7}\,V};$$

$$\boxed{V_b(\infty)=\frac{30}{7}\,V} \quad \text{and}$$

$$\boxed{i_c(\infty)=0 \text{ Amp.}}$$

02. (b) **(i)** A voltage V(t) = 10sin(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 M)**

Sol:

Applied Voltage to the circuit

$$V_{max}=10V$$

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

Voltage across Capacitor,

$$V_c=500V$$

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Magnification factor (or) Quality factor

$$Q = \frac{V_c}{V_{rms}} = \frac{500}{7.07} = 70.7$$

Bandwidth = 400 rad/sec.

As we know that, $\boxed{Q = \frac{W_r}{BW}}$

where, ω_r = Resonant frequency

BW = Bandwidth.

Substitute the given values of Bandwidth and Quality factor (Q) in the above equation, we get

$$70.7 = \frac{\omega_r}{400}$$

$\Rightarrow$ Resonant Frequency $(W_r) = 70.7 \times 400$

$$\Rightarrow \boxed{W_r = 28280 \text{ rad/sec.}}$$

$$\therefore f_r = \frac{W_r}{2\pi} = \frac{28280}{2\pi} = 4499 \text{ Hz.}$$

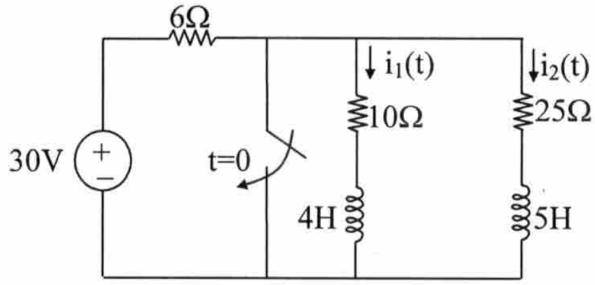
$$BW = \frac{R}{L} \Rightarrow L = \frac{R}{BW} = \frac{100}{400} = 0.25 \text{ H.}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = \frac{1}{(2\pi f_r)^2 \times L} = 5 \text{nF.}$$

Thus,

$\boxed{L = 0.25 \text{ H}}$ $\boxed{C = 5 \text{nF}}$

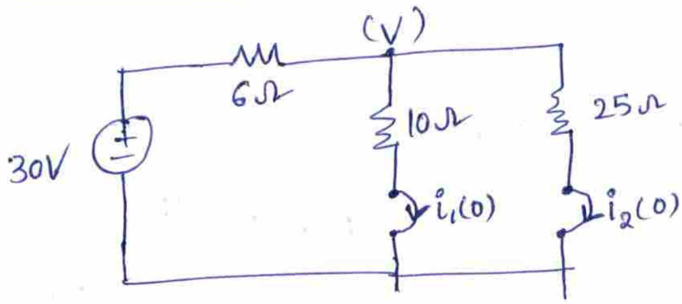
(ii) Find $i_1(t)$ and $i_2(t)$ for $t>0$ in the circuit shown below.



(8 M)

Sol:

Circuit at $t<0$,



By nodal analysis, $\frac{V-30}{6} + \frac{V}{10} + \frac{V}{25} = 0.$

$\Rightarrow V\left(\frac{1}{6}+\frac{1}{10}+\frac{1}{25}\right) = 5 \quad \Rightarrow V = 16.3$ Volts.

$$\boxed{\begin{aligned} i_1(0^-) &= 1.63\,A \\ i_2(0^-) &= 0.652\,A. \end{aligned}}$$

from the circuit at $t=\infty$

$I_1(\infty) = 0$ Amp. & $I_2(\infty) = 0$ Amp.

$$I(t) = I(\infty) + \left[I(0^+) - I(\infty)\right] \cdot e^{-t/\tau}$$

Here $\tau_1 = \frac{4}{10} = \frac{2}{5}$ sec

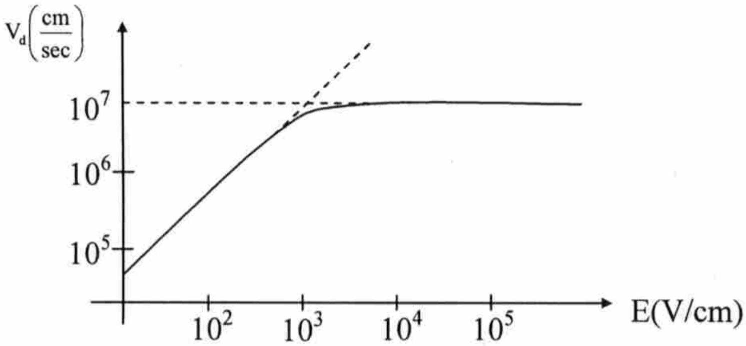
$\tau_2 = \frac{5}{25} = \frac{1}{5}$ sec.

$\therefore\ i_1(t) = i_1(0^+) \cdot e^{-t/\tau_1} \Rightarrow i_1(t) = 1.63\, e^{-2.5t}$ Amp.

$i_2(t) = i_2(0^+) \cdot e^{-t/\tau_2} \Rightarrow i_2(t) = 0.652\, e^{-5t}$ Amp.

Thus, $\boxed{i_1(t) = 1.63\, e^{-2.5t}\ A}$ $\quad\boxed{i_2(t) = 0.652\, e^{-5t}\ A}$

02. (c) **(i)**



The above figure shows the graph between electric field (V/cm) and drift velocity $\left(\frac{cm}{sec}\right)$.

Refer the above figure for the below question.

A silicon bar 1 μm long and 100 μm^2 in cross-section area is doped with $10^{17} cm^{-3}$ phosphorus. Find the current at 300k with 10V applied voltage. **(10 M)**

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Sol:

Given data

Length, $l = 1 \mu m$

$= 10^{-4} cm.$

Area, $A = 100 \mu m^2 = 100 \times (10^{-6})^2 . m^2$

$= 100 \times 10^{-12} m^2$

$= 10^{-6} cm^2$

Applied Voltage, $V = 10$ Volts

Donor concentration i.e $N_D = 10^{17} cm^{-3}$

As we know, Electric field $(E) = \frac{V}{l}$

$\Rightarrow E = \frac{10}{10^{-4}}$

$\Rightarrow \boxed{E = 10^5 V/cm.}$

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from the given graph we conclude that, with 10^5 V/cm electric field the sample is in Velocity Saturation region.

$\therefore$ Drift Velocity, $\boxed{V_d = 10^7 \text{ cm/sec.}}$

As we know,

$\boxed{I = \sigma E A}$, where σ = Conductivity, E = Electric Field, A = Area.

$\Rightarrow I = nq\mu_n EA$

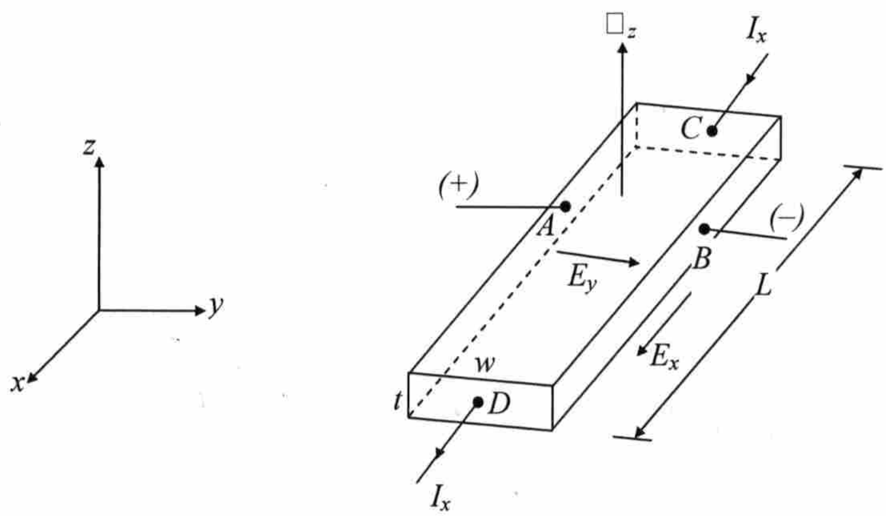
$\Rightarrow E = nqAV_d$. $(\because V_d = \mu_n \cdot E)$

$\Rightarrow I = 1.6 \times 10^{-19} \times 10^{17} \times 10^{-6} \times 10^{7}$

$\Rightarrow I = 0.16$ Amps.

$\therefore$ Current at 300k with 10V applied Voltage is, $\boxed{I = 0.16 A}$

(ii)



Referring above figure, consider a semiconductor bar with W = 0.1mm, t = 10μm, and L = 5mm. For magnetic flux density, B = 10^{-4}wb/cm^2 in the direction shown and current of 1mA, we have V_{AB} = –2mV and V_{CD} = 100mV. Find the type, concentration and mobility of the majority carrier.

(10 M)

Sol:

Given data

$W = 0.1 \times 10^{-3}$ m

$= 0.1 \times 10^{-1}$ cm

$t = 10 \times 10^{-6}$ m $= 10 \times 10^{-4} = 10^{-3}$ cm.

$L = 5$mm $= 5 \times 10^{-3}$ m $= 5 \times 10^{-1}$ cm

$B = 10^{-4}$ wb/cm^2

From the sign of V_{AB}, we can see that the majority carriers are electrons. So, the given specimen is **n-type**.

$$n_o = \frac{I_x \cdot B_z}{qt(-V_{AB})} = \frac{10^{-3} \times 10^{-4}}{1.6\times10^{-19} \times 10^{-3} \times 2\times10^{-3}}$$

$$\Rightarrow \boxed{n_o = 3.125\times10^{17}\ cm^{-3}}$$

$$\text{Resistivity } (\rho) = \frac{R}{L/wt} = \frac{V_{CD}/I_x}{L/wt}$$

$$\Rightarrow \rho = \frac{0.1/10^{-3}}{0.5/(0.01\times10^{-3})}$$

$$\therefore \rho = 0.002\ (\Omega\text{-cm})$$

Mobility of electron is given as –

$$\boxed{\mu_n = \frac{1}{\rho q n_o}}$$

$$\Rightarrow \mu_n = \frac{1}{(0.002)(1.6\times10^{-19})(3.125\times10^{17})}$$

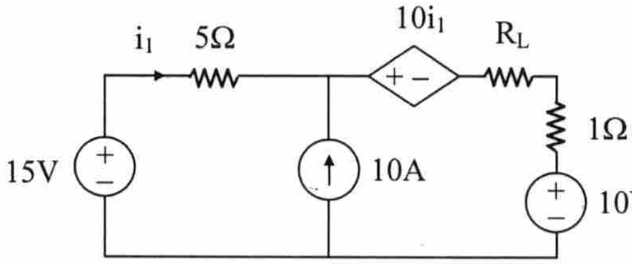
$$\Rightarrow \mu_n = 10{,}000\ \frac{cm^2}{V\text{-}sec}$$

$\therefore$ Mobility of the majority carrier is

$$\boxed{\mu_n = 10{,}000\ \frac{cm^2}{V\text{-}sec}}$$

Candidates must not write on this margin

03. (a) For the network shown, determine R_L which will receive maximum power.



(10 M)

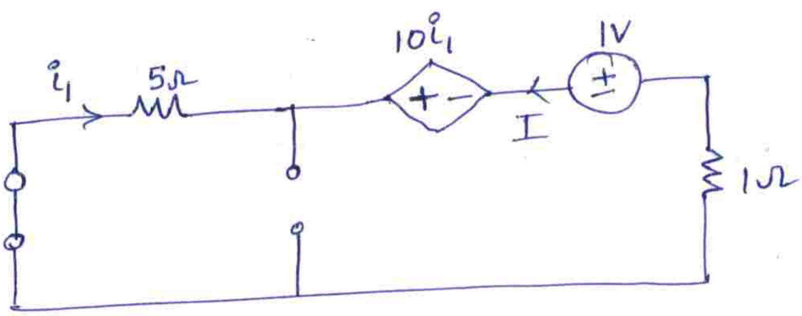
Sol:

Maximum power will be Received by R_L when equivalent resistance of the network across R_L is equals to R_{th}.

For this we need to find Thevenine resistance. For this we shall short all independent voltage sources & 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 (Resistance) Source.

$$R_{th} = \frac{1V}{I}$$



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$$\boxed{-I = i_1}$$

$\therefore$ Use KVL,

$-6I + 10i_1 = -1$

$-6(+I) + 10(-I) = -1$

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

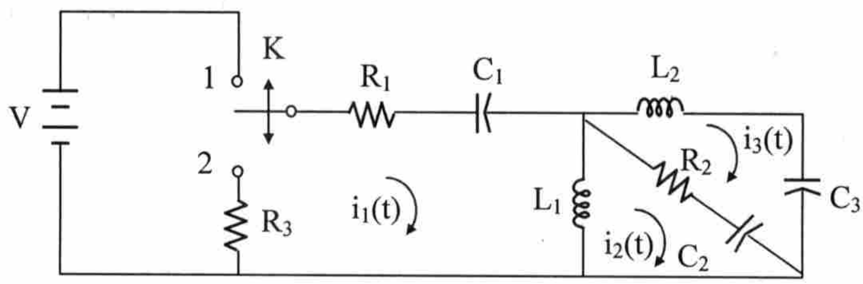
$\therefore \boxed{R_{th} = \frac{1}{I}} = 16\Omega.$

$\therefore$ For maximum power transfer

$$\boxed{R_L = R_{th} = 16\Omega.}$$

03. (b) 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 position1.

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

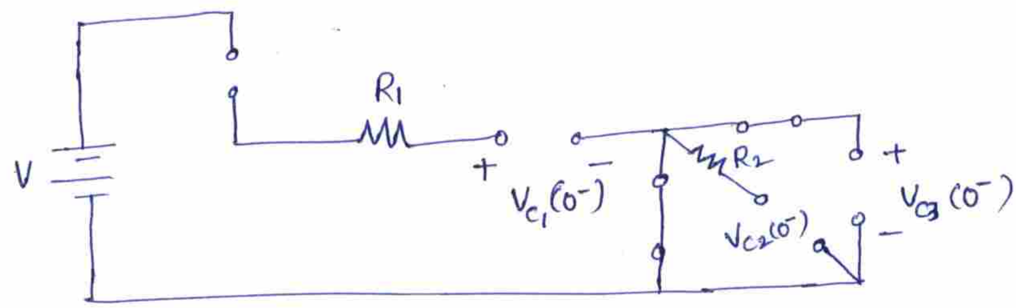


(10 M)

Sol:

At $t=0^-$, circuit is in steady state and switch K is in position 1 (Capacitor : Open ; Inductor : Short).

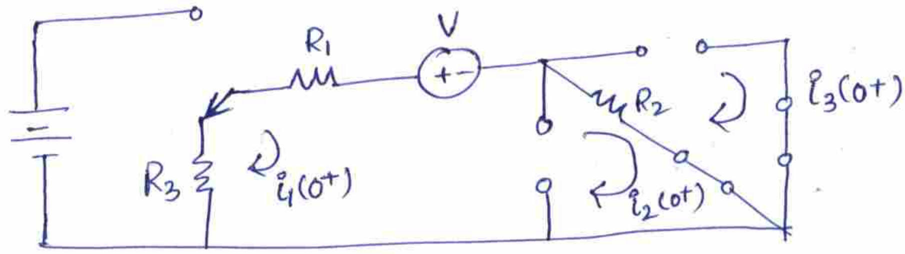
Candidates must not write on this margin



$$\therefore \boxed{V_{c_1}(0^-) = V} \text{ Volts}$$

$$\boxed{V_{c_2}(0^-) = V_{c_3}(0^-) = 0}$$

At $t = 0^+$



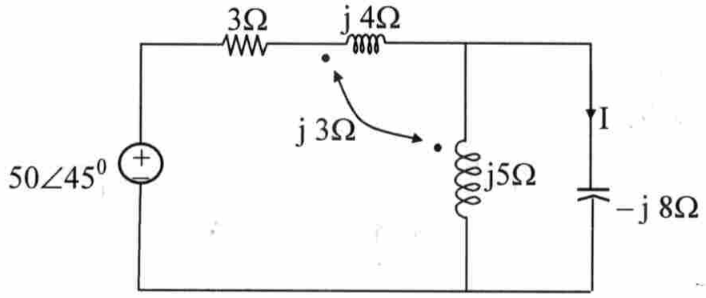
$i_1(0^+) = i_2(0^+)$; $i_3(0^+) = 0$.

Using KVL,

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

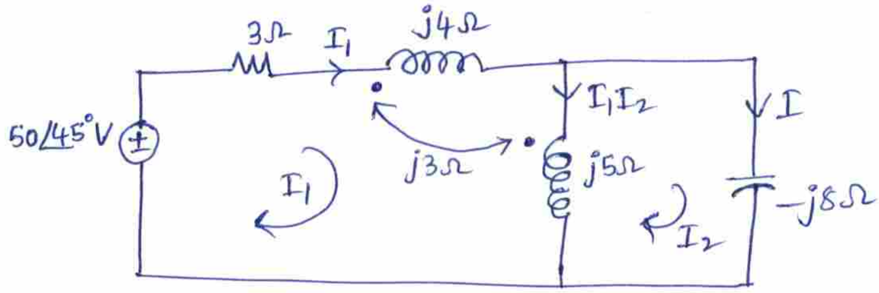
$$\therefore \boxed{i_1(0^+) = i_2(0^+) = \frac{-V}{R_1 + R_2 + R_3}}$$

03. (c) Find current 'I' using Mesh Analysis



(10 M)

Sol:



Mesh – (1) Equation :

$$-\left[50\angle 45^\circ\right] + (3+j4)I_1 + j5\left[I_1 - I_2\right] + j3\left[I_1 - I_2\right] + j3I_1 = 0$$

$$(3+j15)I_1 - j8I_2 = 50\angle 45^\circ \longrightarrow \text{(i)}$$

Mesh – (2) Equation :

$$j5\left[I_2 - I_1\right] - j8I_2 - j3I_1 = 0$$

$$-j8I_1 - j3I_2 = 0$$

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

Solving (i) & (ii), we get

$$\boxed{I = I_2 = 3.66\angle -310.33^\circ A}$$

03. (d) A 0.46 μm thick sample of GaAs is illuminated with manochromatic light of $h\nu = 2ev$. The absorption co-efficient 'α' is $5 \times 10^4\ cm^{-1}$. The power incident on the sample is 10mW.

(i) Find the total energy absorbed by the sample per second (J/s).

(ii) Find the rate of excess thermal energy given up by the electrons to the Lattice before recombination (J/s).

(8 + 2)M

Candidates must not write on this margin

Sol:

(i) The intensity of light transmitted through the sample of thickness is, $I_t = I_0 \cdot e^{-\alpha l}$

Given data

$I_0 = 10mW$
$= 10^{-2} W$

$l = 0.46\ \mu m$
$= 0.46 \times 10^{-4} cm$

$\alpha = 5 \times 10^4\ cm^{-1}$

$\therefore \boxed{I_t = I_0 e^{-\alpha l}}$

$\Rightarrow I_t = 10^{-2} \cdot e^{-[5 \times 10^4 \times 0.46 \times 10^{-4}]}$

$= 10^{-3} W$

$\Rightarrow \boxed{I_t = 1mW}$

Thus the absorbed power is

$10mW - 1mW = 9mW$ (or) $9 \times 10^{-3}\ J/s$.

(ii) The fraction of each photon energy unit which is converted to heat is

$$\frac{2-1.43}{2} = 0.285$$

Thus the amount of energy converted to heat per second is

$$0.285 \times 9 \times 10^{-3} = 2.57 \times 10^{-3} \text{ J/s}.$$

03. (e) Draw the low frequency small signal model of FET and explain how FET is much more Ideal amplifier than the conventional transistor at low frequencies ? **(10 M)**

Sol: The low frequency small signal model of FET has a Norton's output circuit with a dependent current generator whose current is proportional to the gate-to-source voltage.

the proportionality factor is the transconductance g_m, output resistance is r_d. The input resistance between gate and source is infinite, since it is assumed that the reverse biased gate takes no current. for the same reason the resistance between gate and drain is assumed to be infinite.

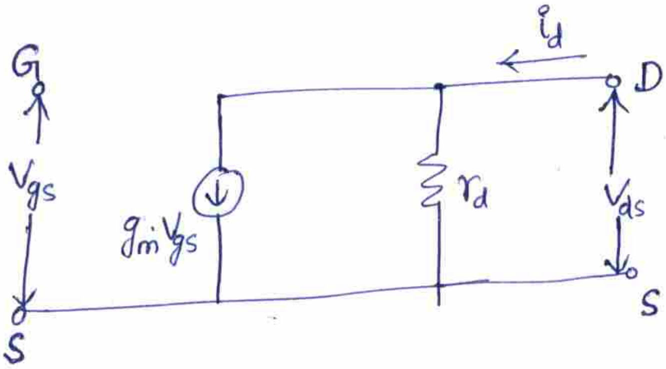


fig : Low frequency small - signal FET Model.

FET is a more ideal amplifier :

1. In a conventional transistor, current generator depends upon the input current, where as in FET model the generator current depends upon the input Voltage.

2. There is no feedback at low frequencies from output to input in FET, whereas such feedback exists in conventional transistor through h_{fe}.

3. Input resistance of FET is almost infinite, compared to input resistance of conventional transistor. Hence, FET is a much more ideal amplifier than a conventional transistor at low frequencies.

Candidates must not write on this margin

03. (f) Explain varactor diode. Give its equivalent circuit and mention its applications. **(10 M)**

Candidates must not write on this margin

Sol:

Diodes made especially based on the Variable – Voltage Capacitors are called Varactors, Vari caps (or) Volta caps. It is a type of diode designed to exploit the Voltage – dependent capacitance of a reverse biased pn – junction. If the Varactor diode reverse Voltage is increases then the depletion region size increases. Hence by Varying the reverse-bias of the Varactor diode, the Capacitance be Varied.

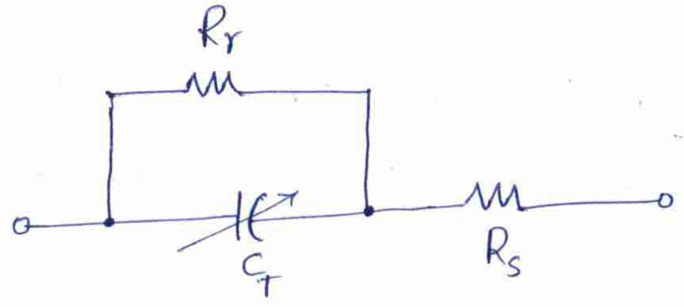


Fig. Circuit model of Varactor diode.

Fig: symbol.

The resistance R_s, represents the body (ohmic) series resistance of the diode. Typical values of C_T and R_s are 20pF and 8.5Ω respectively at a reverse-bias of 4V. The reverse diode resistance R_r shunting C_T is large (>1MΩ), and hence is usually neglected.

$$\boxed{C_T = \frac{C_0}{\sqrt{V_{bi} + V_R}}}$$

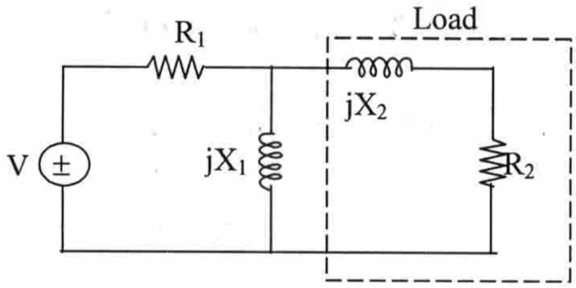
C_0 = constant.
V_{bi} = Built-in potential
V_R = Reverse applied voltage

Applications :

1. Voltage tuning of the LC resonant circuits in radars, televisions etc.

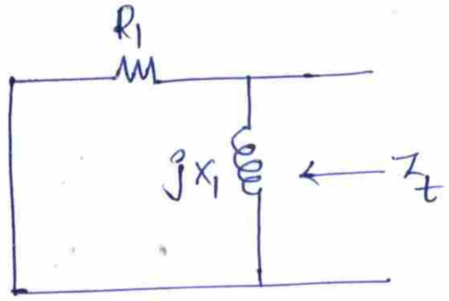
2. They are commonly used in voltage-controlled oscillators, parametric amplifiers, frequency multipliers, self-balancing bridge circuits and automatic-frequency control circuits.

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



(10 M)

Sol:



$$Z_t = \frac{R_1(jX_1)}{R_1 + jX_1} = \frac{R_1 X_1^2 + jR_1^2 X_1}{R_1^2 + X_1^2}$$

$$\because \quad Z_L = Z_t^*$$

$$R_2 + jX_2 = \frac{R_1 X_1^2}{R_1^2 + X_1^2} - j\frac{R_1^2 X_1}{R_1^2 + X_1^2}$$

So, $$R_2 = \frac{R_1 X_1^2}{R_1^2 + X_1^2}$$

Then $$X_1 = \pm R_1 \cdot \sqrt{\frac{R_2}{R_1 - R_2}} \longrightarrow (1)$$

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

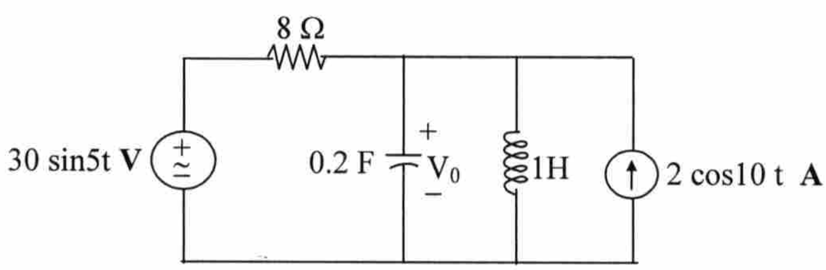
Substitute ① in ②

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

$\therefore$ The final Answer is :

$$\boxed{\begin{aligned} X_1 &= \pm R_1 \cdot \sqrt{\frac{R_2}{R_1 - R_2}} \\ X_2 &= \sqrt{R_2(R_1 - R_2)} \end{aligned}}$$

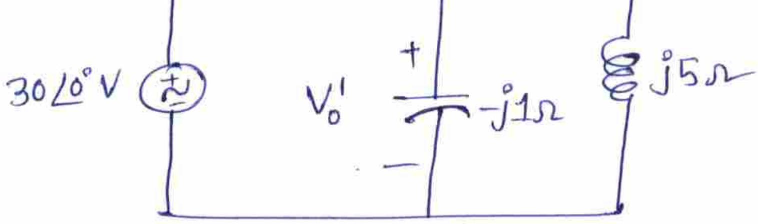
(ii) In the circuit shown below, determine the value of V_0.



(10 M)

Sol: By applying Super-position Theorem

Case -1 : When 'V' alone acting, $V_0 = V_0'$



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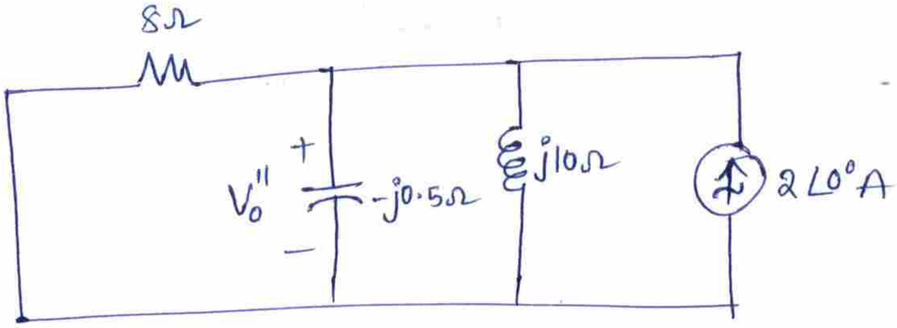
Using Nodal Analysis,

$$V_o' = 4.631 \angle -81.12^\circ \, V.$$

Case-2 : When 'current source (I)' alone acting,

$$V_o = V_o''.$$



Using Nodal Analysis,

$$V_o'' = 1.051 \angle -86.24^\circ \, V$$

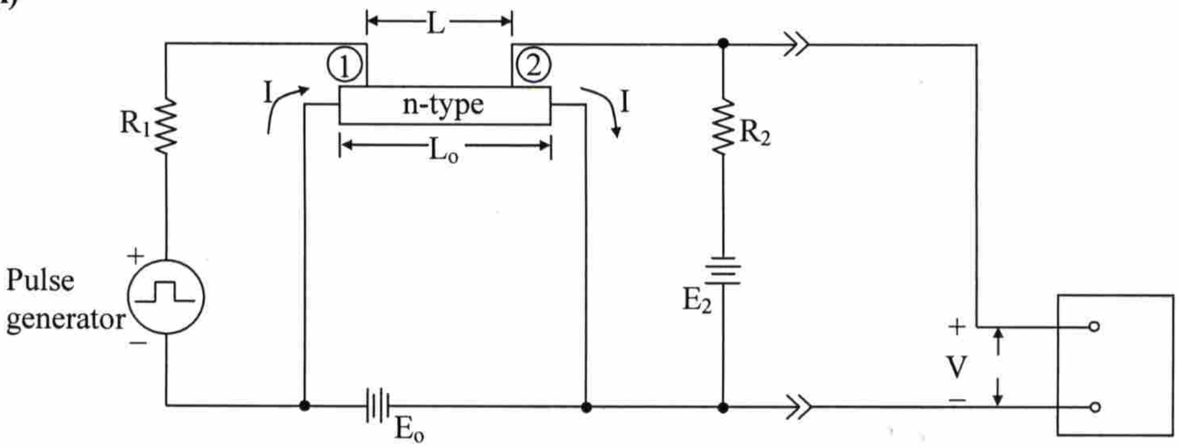
$$\therefore \; V_o = V_o' + V_o''$$

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

Note :

Input sources are at different frequencies.

04. (b) **(i)**



An n-type 'Ge' sample is used in the experiment shown in the above figure. The length of the sample is 1 cm, and the probes (1) and (2) are separated by 0.95 cm. The battery voltage E_o is 2V. A pulse arrives at point (2) 0.25ms after injection at (1), the width of the pulse Δt is 117 μs. Calculate the electron mobility. **(8 M)**

Candidates must not write on this margin

Sol:

Given data

$L_o = 1\text{ cm}$

$L = 0.95\text{ cm}$

$E_o = 2\text{ Volts}$

$\Delta t = 117\ \mu\text{sec}$.

As we know,

$$\text{mobility} = \frac{\text{Drift Velocity}}{\text{Electric field}}$$

(or)

$$\boxed{\mu_n = \frac{V_d}{E}}$$

Candidates must not write on this margin

$$\Rightarrow \mu_n = \frac{L/0.25ms}{E_0/L_0}$$

$$\Rightarrow \mu_n = \frac{0.95cm/(0.25\times10^{-3})}{2/1cm} = 1900 \frac{cm^2}{V\text{-}sec}$$

$\therefore$ Mobility of electron is,

$$\boxed{\mu_n = 1900 \frac{cm^2}{V\text{-}sec}}$$

(ii) An n-type silicon bar of width 10mm and height 5mm with majority carrier concentration of $10^{20}cm^{-3}$ is placed in a transverse magnetic field of 2.16 $\frac{wb}{m^2}$. Calculate the magnitude of the Hall voltage developed if an electric field of 6 V/cm is applied across the specimen in perpendicular to the magnetic field ($\mu_n = 1500\ cm^2/V\text{-sec}$). **(12 M)**

Sol:

Given data,

Width, $W = 10mm$
$= 10\times10^{-3} m$
$= 10\times10^{-1} cm$

Magnetic field, $B = 2.16\ wb/m^2$
$= 2.16\times10^{-4} \frac{wb}{cm^2}$

Mobility, $\mu_n = 1500 \frac{cm^2}{V\text{-}sec}$.

Candidates must not write on this margin

Electric field, $E = 6 \frac{V}{cm}$

Height, $d = 5mm = 5\times10^{-1}$ cm

As we know,

Hall Voltage, $V_H = \frac{BI}{\rho W}$

$$\Rightarrow V_H = \frac{BJA}{qN_D \cdot W}, \quad (\because I = J.A, \ \rho = qN_D)$$

$$\Rightarrow V_H = \frac{B(\sigma E)(d\times W)}{qN_D \times W}, \quad \left[\because \begin{matrix} J = \sigma E \\ A = d\times W \end{matrix}\right]$$

$$\Rightarrow V_H = \frac{B(N_D q \mu_n E)(d\times W)}{qN_D \times W}, \quad [\because \sigma = qN_D\mu_n]$$

$$\Rightarrow \boxed{V_H = B\mu_n E d}$$

$$\Rightarrow V_H = \left(2.16 \frac{wb}{m^2}\right)\times\left(1500 \frac{cm^2}{V\text{-}sec}\right)\times\left(6 \frac{V}{cm}\right)\times(0.5\ cm)$$

$$\Rightarrow V_H = \left(2.16\times10^{-4} \frac{wb}{cm^2}\right)\times\left(1500 \frac{cm^2}{V\text{-}sec}\right)\times\left(6\frac{V}{cm}\right)\times(0.5cm)$$

$$\Rightarrow V_H = 0.972 \text{ Volts.}$$

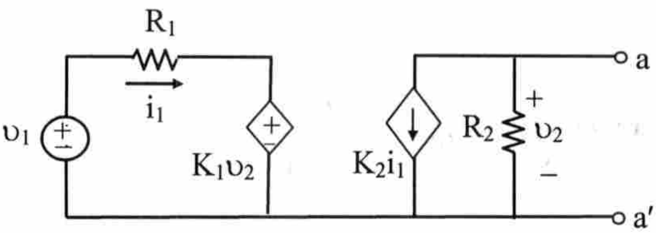
$\therefore$ Hall voltage is given as

$$\boxed{V_H = 0.972 \text{ volts}}$$

04. (c) For the circuit given, draw

(i) Thevenin's equivalent circuit at a - a′

(ii) Norton's equivalent circuit at a - a′



(12 + 8)M

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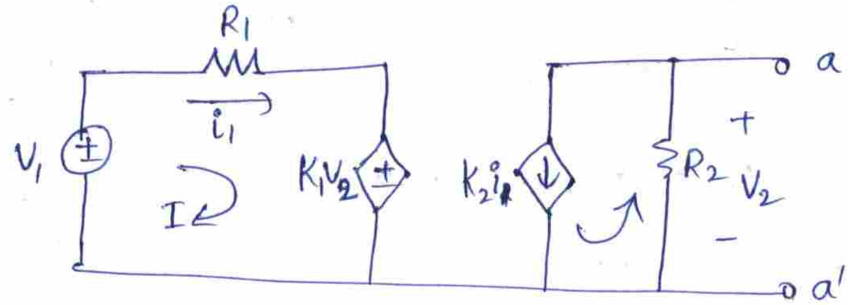
Sol:

(i)



In loop I, using KVL

$$V_1 = i_1 \cdot R_1 + K_1 V_2 \longrightarrow (1)$$

Voltage across R_2 is, $V_2 = -K_2 \cdot i_1 \cdot R_2$

For Thevenin Voltage V_{th} across $a-a'$,

$$V_{th} = V_2 = -K_2 \cdot i_1 \cdot R_2$$

$$i_1 = -\frac{V_{th}}{K_2 \cdot R_2} \longrightarrow (2)$$

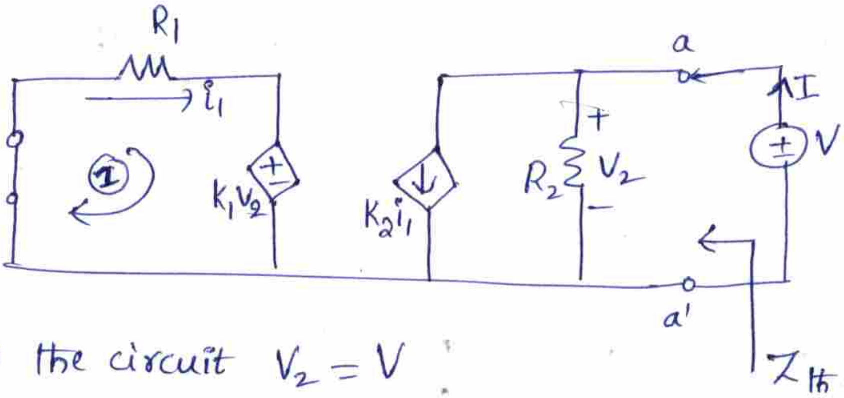
Candidates must not write on this margin

Substitute eq. ② in eq. ①

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

$$\therefore V_{th} = \frac{K_2 \cdot R_2 V_1}{K_1 K_2 R_2 - R_1}$$

For Z_{th} across a-a':



From the circuit $V_2 = V$

From loop ①, use KVL

$$-R_1 i_1 - K_1 V_2 = 0 \Rightarrow i_1 = \frac{-K_1 V_2}{R_1} \rightarrow ③$$

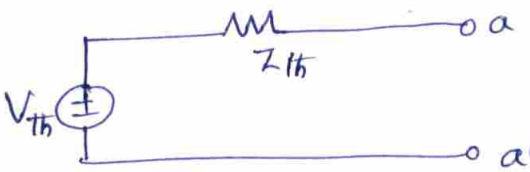
Using KCL, Current(I) $= \frac{V_2}{R_2} + K_2 i_1 \rightarrow ④$

Substitute eq. ③ in eq. ④

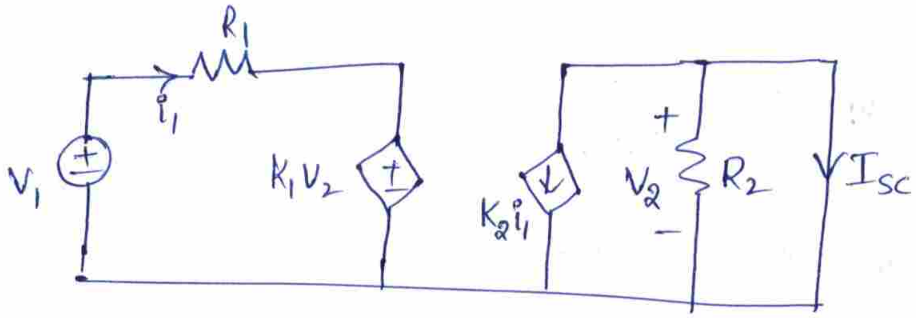
$$I = \frac{V_2}{R_2} + K_2\left[\frac{-K_1 V_2}{R_1}\right]$$

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

$\therefore$ Thevenin Equivalent is given as



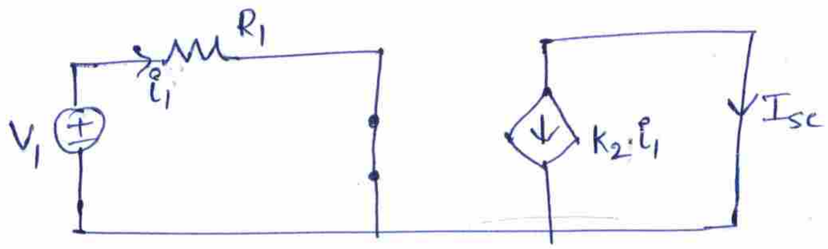
(ii) For Norton's equivalent, find I_{sc} through $a-a'$



From above circuit, we can simply say that

$$V_2 = 0$$

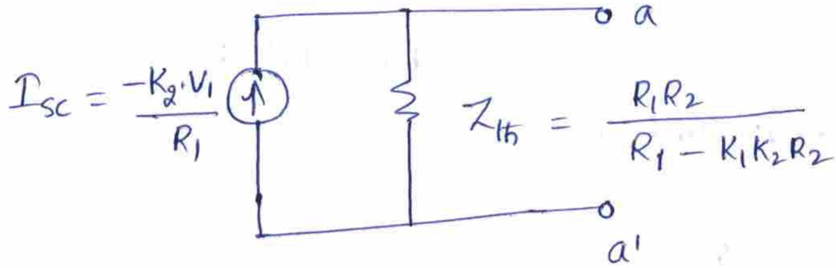
$$\therefore K_1V_2 = 0.$$



$$i_1 = \frac{V_1}{R_1} \quad ; \quad I_{sc} = -K_2 \cdot i_1$$

$$\therefore I_{sc} = -\frac{K_2V_1}{R_1}$$

Norton's Equivalent is given as,



SECTION - B

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05. (a) A series circuit consist 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 M)**

Sol:

We can write,

$$i = 20 \sin(2000t + 20^\circ + 90^\circ) \quad (\because \sin(\theta + 90^\circ) = \cos\theta)$$

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

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

And the circuit must consists of resistance & Capacitance.

$$\tan\theta = \frac{1}{WCR}$$

$$\therefore \frac{1}{WC} = R \cdot \tan 60^\circ = 1.73R.$$

$$Z = \frac{V_m}{I_m} = \sqrt{R^2 + \left(\frac{1}{WC}\right)^2} = \frac{100}{20} = 5$$

$$\Rightarrow \quad 5 = \sqrt{R^2 + \left(\frac{1}{WC}\right)^2}$$

$$\Rightarrow R\sqrt{1 + (1.73)^2} = \frac{100}{20} = 5$$

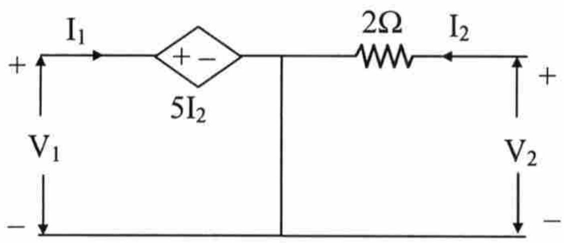
$$\Rightarrow R = \frac{5}{\sqrt{1+(1.73)^2}}$$

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

and Capacitance (C) $= \dfrac{1}{\omega(1.73R)} = 115.6\,\mu F.$

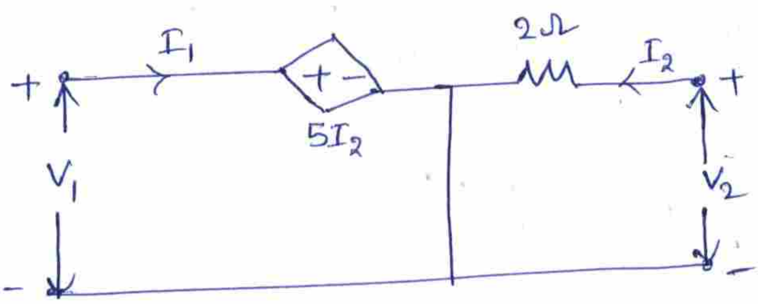
$$\therefore \boxed{C = 115.6\,\mu F}$$

05. (b) Find Y and Z parameters for the following circuit.



(12 M)

Sol:



For two loops, write KVL

$V_1 - 5I_2 = 0.$

$V_2 - 2I_2 = 0$

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

$V_2 = (0)I_1 + 2I_2$

On comparing with,

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

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

$$[Z] = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} = \begin{bmatrix} 0 & 5 \\ 0 & 2 \end{bmatrix}$$

$$Y\text{-Parameter} = [Y] = [Z]^{-1}$$

$$\Rightarrow \quad [Y] = \frac{1}{|Z|} \begin{bmatrix} 2 & -5 \\ 0 & 0 \end{bmatrix}$$

Here $|Z| = 0$, so

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

$\therefore$ Y-parameters are undefined.

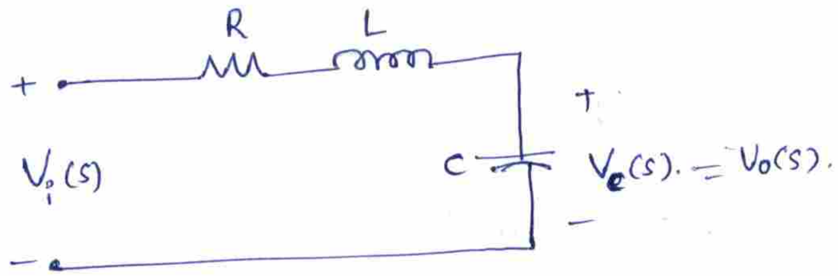
Candidates must not write on this margin

05. (c) 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 $H(s)=\frac{10^6}{s^2+20s+10^6}$ **(12 M)**

Candidates must not write on this margin

Sol:

Given series RLC circuit,



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

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

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

equation,

$$\therefore \quad \frac{1}{LC} = 10^6 \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}} = 10^3 \text{ rad/sec}$$

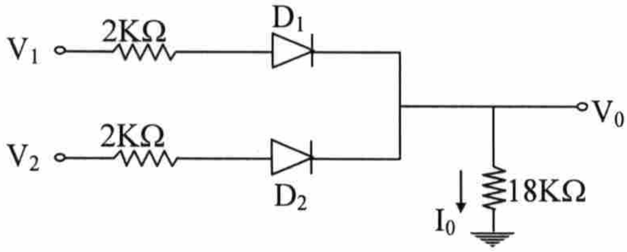
$$\frac{R}{L} = 20$$

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

From the given transfer function of Series RLC Circuit, the Quality factor is given as —

$$\therefore \boxed{Q = 50}$$

05. (d) 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) M

Sol:

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

D_1 would conduct.

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

$V_0 = 0.465 \times 18 = 8.37V.$

$\boxed{\text{SO } D_1 \text{ is ON and } D_2 \text{ is OFF.}}$

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

Assume that D_1 only conducts, then as per part (i)

$V_0 = 8.37V.$

$V_2 - V_0 = 5 - 8.37 = -3.37V.$

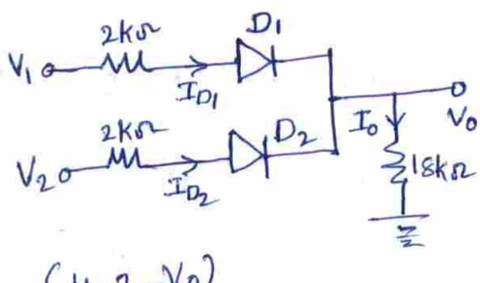
So D_2 doesnot conduct as assumed.

$\therefore V_0 = 8.37V.$

$\boxed{\text{So, } D_1 \text{ is ON and } D_2 \text{ is OFF.}}$

(iii) $V_1 = V_2 = 5V.$

Considering that D_1, D_2 both conduct and output voltage is V_0.



Then $I_{D_1} + I_{D_2} = I_0$

Here, $I_{D_1} = \dfrac{5 - 0.7 - V_0}{2k\Omega} = \dfrac{(4.3 - V_0)}{2k\Omega}$

Candidates must not write on this margin

Similarly,

$$I_{D_2} = \frac{5-0.7-V_o}{2k\Omega} = \frac{4.3-V_o}{2}$$

$$\therefore \quad I_{D_1} = I_{D_2}$$

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

But $I_0 = \frac{V_0}{18\times10^3} \Rightarrow 4.3V - V_0 = \frac{V_0}{18\times10^3}$

$$\Rightarrow V_0 = 4.3V.$$

$V_1 - V_0 = V_2 - V_0 = 5-4.3 = 0.7V > 0.6V$

$\therefore$ Our assumption is correct i.e both diodes are conduct.

Hence $V_0 = 4.3V$.

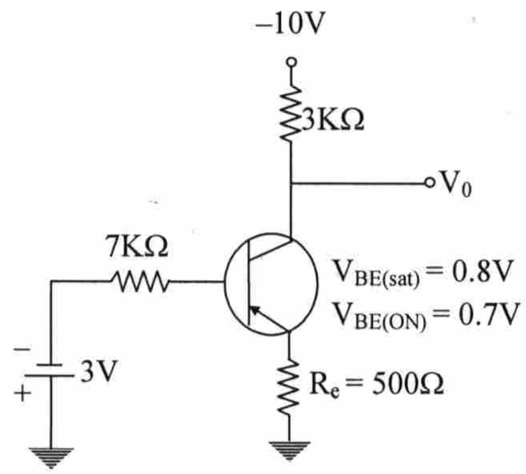
$\boxed{\text{So, both } D_1 \text{ \& } D_2 \text{ are ON.}}$

05. (e) For the circuit shown, assume $\beta = 100$.

i) Find if the silicon Transistor is in cut-off, saturation or in active region.

ii) Find V_o

iii) Find the minimum value of the resistor that should be added at emitter for which the transistor operates in the active region.



(5 + 2 + 5)M

Sol:
(i) By KVL

$$-500\times I_E - 0.7 - 7\times10^3 \times I_B + 3 = 0$$

$$\Rightarrow 7\times10^3 I_B + 500\times 101\, I_B = 2.3$$

$$\Rightarrow I_B = \frac{2.3}{7\times10^3 + 50.5\times10^3}$$

$$\Rightarrow I_B = \frac{2.3}{57.5\times10^3} = 40\mu A.$$

$$\therefore \beta_{dc}\cdot I_B = 4mA.$$

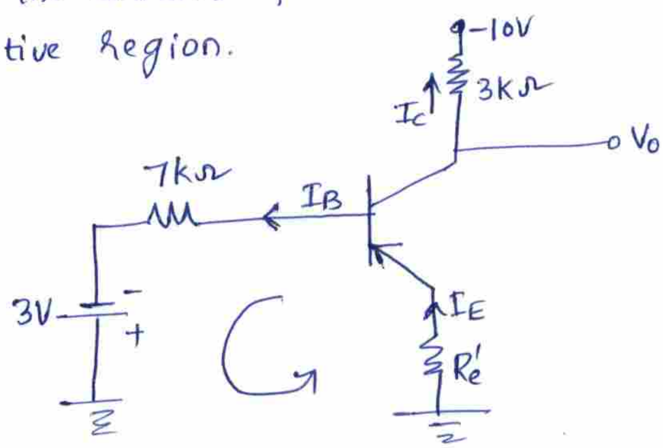
$$I_{C(sat)} = \frac{10-0.2}{3.5\times10^3} = \frac{9.8}{3.5\times10^3} = 2.8mA.$$

$\therefore$ As $\beta_{dc}\cdot I_B > I_{C(sat)}$, So Transistor is in Saturation mode.

(ii) $V_o = V_{CE,sat} + I_E.R_e = -0.2 + (-2.8\times0.5) \simeq -1.6V$

$\therefore \boxed{V_o = -1.6V}$

(iii) Let us consider, the resistor R_e' that should be added at the emitter for which the transistor Opeeates in active Region.



By KVL,

$$-I_E \cdot R_e' - 0.7 - 7\times10^3 \cdot I_B + 3 = 0$$

$$\Rightarrow I_E \cdot R_e' + (10^3 \times 7) \cdot I_B = 2.3$$

$$\Rightarrow (1+\beta) I_B \cdot R_e' + (7\times10^3) I_B = 2.3$$

$$\Rightarrow I_B = \frac{2.3}{101 R_e' + (7\times10^3)}$$

$$\therefore I_c = \beta I_B = \frac{2.3\times100}{101 R_e' + 7\times10^3}$$

$$I_E = (1+\beta) I_B = \frac{2.3\times101}{101 R_e' + 7\times10^3}$$

By KVL,

$$-I_E \cdot R_e' - V_{EC} - I_c \times 3\times10^3 + 10 = 0.$$

$$\Rightarrow V_{EC} = 10 - I_E \cdot R_e' - 3\times10^3 \cdot I_c$$

$\therefore$ for the transistor to be operate in active region,

$$V_{EC} > 0.2$$

$$\Rightarrow 10 - I_E \cdot R_e' - 3\times10^3 I_c > 0.2$$

$$\Rightarrow \frac{2.3\times101 R_e'}{101 R_e' + 7\times10^3} + \frac{3\times10^3 \times 2.3\times100}{101 R_e' + 7\times10^3} < 9.8$$

$$\Rightarrow (690 - 68.6)\times10^3 < (989.6 - 232.3) R_e'$$

$$\Rightarrow R_e' > 820.54\ \Omega$$

$$\Rightarrow \boxed{R'_{e\,(\text{minimum})} = 821\ \Omega.}$$

Since 500Ω resistor is already present at emittee,

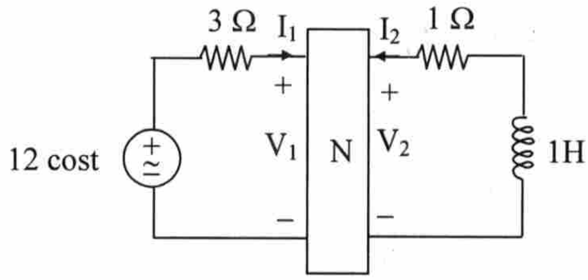
$\therefore$ The minimum value of resistor to be added at emitter is $821 - 500 = 321\Omega$.

Candidates must not write on this margin

06. (a) **(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 a load as shown in figure by its T-equivalent, then find I_1, I_2, V_1 & V_2.



(15 M)

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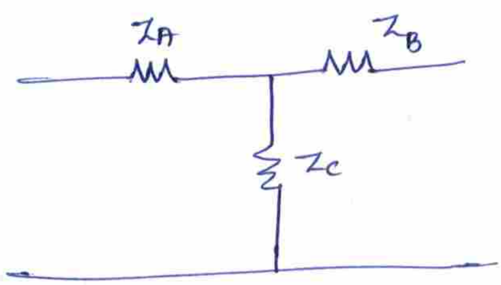
Sol:

T–Network



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

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

$Z_C = Z_{12} = Z_{21} = 2s.$

$\because s = j\omega = j1\Omega$

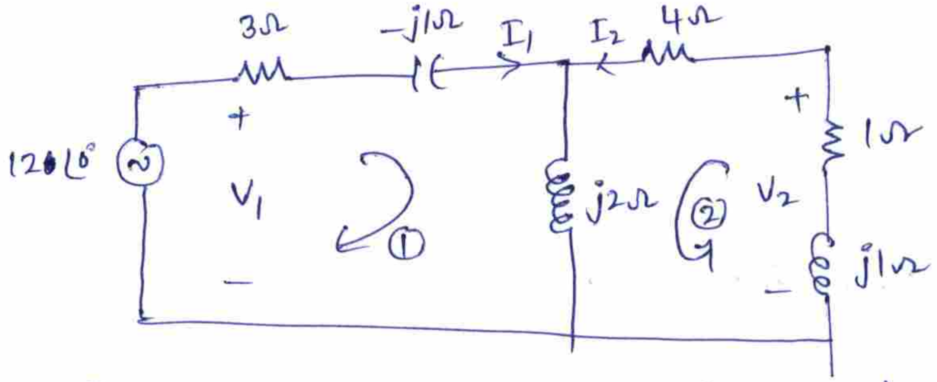
$\because \omega = 1$, from Source

$Z_A = -j1\Omega$

$Z_B = 4\Omega$

$Z_C = +j2\Omega$

So, the total Network become



By applying mesh analysis in the above circuit

KVL in loop 1,

$$3I_1 - jI_1 + j2(I_1 + I_2) = 12$$

$$(3 - j + 2j) I_1 + j \cdot 2 \cdot I_2 = 12$$

$$(3 + j) I_1 + j2I_2 = 12 \longrightarrow 1$$

KVL in loop 2

$$(j + 1 + 1) I_2 + j2(I_1 + I_2) = 0$$

$$\Rightarrow \quad 2jI_1 + (4 + j) I_2 = 0 \longrightarrow 2$$

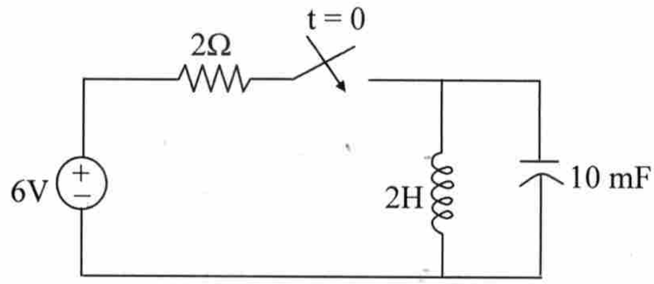
Solving 1 & 2 we get

$$\boxed{\begin{aligned} I_1 &= 3.29 \angle -10.2^\circ \text{ A} \\ I_2 &= 1.13 \angle -131.2^\circ \text{ A} \end{aligned}}$$

$V_1 = 12 - 3I_1 \Rightarrow \boxed{V_1 = 2.88 \angle 37.5^\circ}$ Volts

$V_2 = (1 + j)(-I_2) \Rightarrow \boxed{V_2 = 1.6 \angle 93.8^\circ}$ Volts

(ii) Draw the Dual of the circuit shown below



(5 M)

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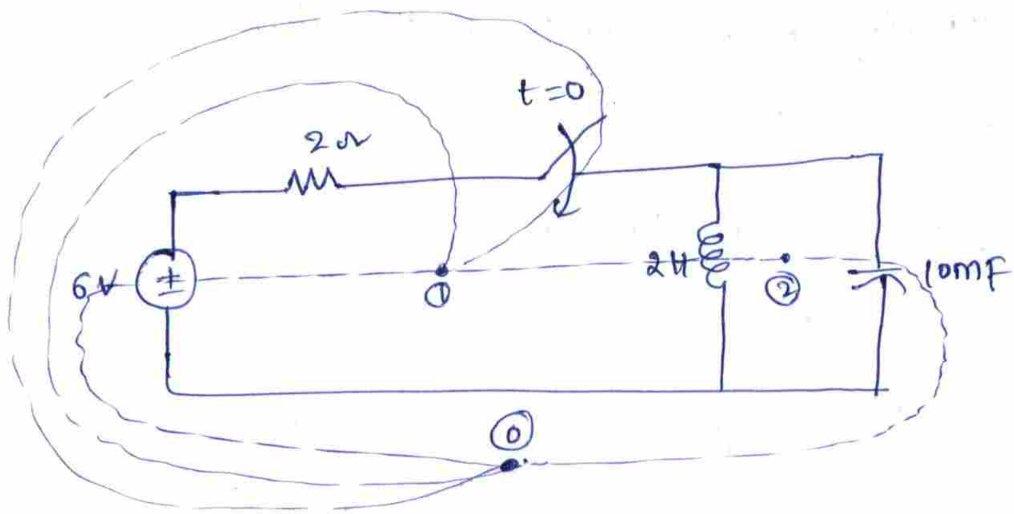
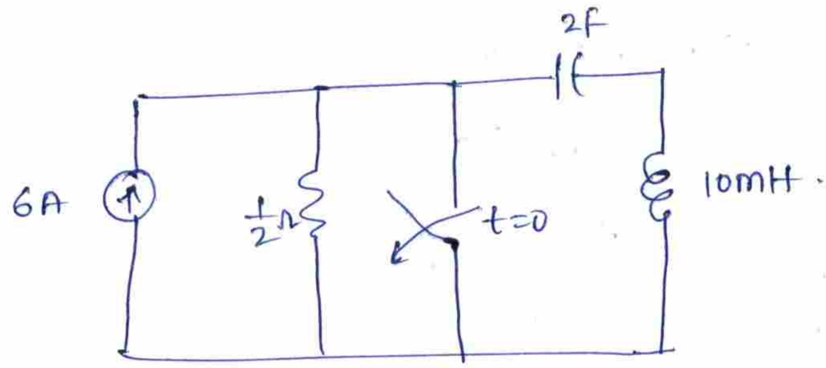
Sol: Steps of Dual import from material





06. (b) **(i)** 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 M)

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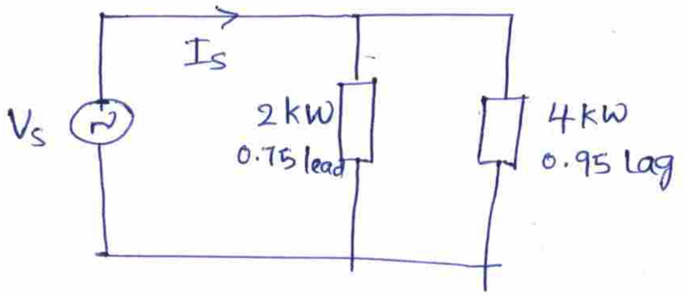
Sol:



$P_1 = 2kW, \; P_2 = 4kW, \; P_T = 6kW$

$P = S\cos\phi \Rightarrow S_1 = \dfrac{P_1}{\cos\phi_1} = \dfrac{2000}{0.75} = 2666.67VA$

$\therefore \boxed{S_1 = 2666.67 \text{ VA}}$

$\Rightarrow S_2 = \dfrac{P_2}{\cos\phi_2} = \dfrac{4000}{0.95} = 4210.52VA$

$\therefore \boxed{S_2 = 4210.52 \text{ VA.}}$

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

$\Rightarrow Q_1 = \sqrt{S_1^2 - P_1^2} = \sqrt{(2666.67)^2 - (2000)^2}$

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

Similarly, $Q_2 = \sqrt{S_2^2 - P_2^2} = \sqrt{(4210.52)^2 - (4000)^2}$

Candidates must not write on this margin

$\Rightarrow Q_2 = 1314.7$ Lag.

$\therefore \boxed{Q_2 = 1314.7 \text{ Lag.}}$

$S_1 = 2000 - j1763$

$S_2 = 4000 + j1314.7$

$\boxed{S_T = 6000 - j448.3}$

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

$\Rightarrow \cos\phi = 0.9972$, lead.

$\therefore \boxed{\cos\phi = 0.9972 \text{ lead.}}$

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

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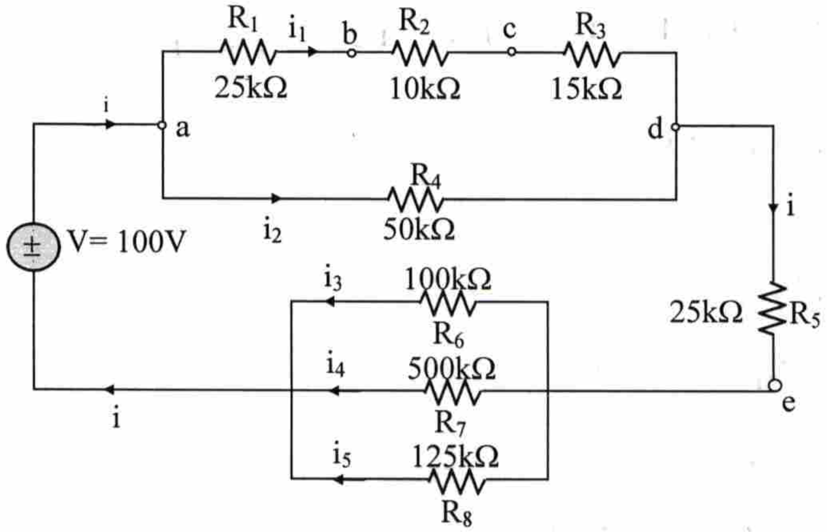


Figure: Series parallel circuit

(10 M)

Sol:

The equivalent resistance of

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

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

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

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 $i_1 = 0.5\,mA = i_2$

Candidates must not write on this margin

To ~~compute~~ (calculate) the values of voltage 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,

$$V_{R_2} = 5V$$
$$V_{R_3} = 7.5V$$
$$V_{R_4} = 25V$$
$$V_{R_5} = R_5 \times i = 25V$$

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

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

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

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

Similarly,

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

Thus,

$$\boxed{\begin{aligned} i_1 = i_2 &= 0.5mA \\ i_3 &= 0.5mA \\ i_4 &= 0.1mA \\ i_5 &= 0.4mA \end{aligned}} \qquad \boxed{\begin{aligned} V_{R_1} &= 12.5V \\ V_{R_2} &= 5V \\ V_{R_3} &= 7.5V \\ V_{R_4} &= 25V \\ V_{R_5} &= 25V \end{aligned}}$$

06. (c) (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. $\left(\mu_n = 1350\frac{cm^2}{V-sec}, m_o = 9.1\times10^{-31}kg, k = 1.38\times10^{-23}J/k\right)$ **(12 M)**

Candidates must not write on this margin

Sol:

Given data

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

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

As we know,

$$\boxed{V_d = \mu_n \cdot E}$$

$\therefore$ Drift velocity, $V_d = \mu_n \cdot E = 1350 \times 100 = 1.35\times10^5\ \frac{cm}{sec}$

$$\Rightarrow \boxed{V_d = 1.35\times10^5\ \frac{cm}{sec}} \rightarrow (1)$$

Again, As we know

$$\frac{1}{2} m_o \cdot V_{th}^2 = KT$$

where, V_{th} = Thermal Velocity, K = Boltzmann's const.

m_o = mass of electron.

$$\Rightarrow \boxed{V_{th} = \sqrt{\frac{2KT}{m_o}}}$$

$$\Rightarrow V_{th} = \sqrt{\frac{2\times1.38\times10^{-23}\times300}{9.1\times10^{-31}}}$$

$$\Rightarrow \boxed{V_{th} = 9.54 \times 10^{6} \frac{cm}{sec}} \rightarrow (2)$$

From above two equations (1) & (2), it is clear that the drift velocity is less than the 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,

$$V_d = \mu_n \cdot E$$

$$\Rightarrow V_d = 1350 \times 10^4 \text{ cm/sec}$$

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

Comment :

The electron drift velocity for $10^4 \frac{V}{cm}$ is greater than thermal velocity.

(ii) Calculate the intrinsic concentration of Germanium at 500K. ($m_n = 0.55m$, $m_p = 0.37m$) **(8 M)**

Candidates must not write on this margin

Sol:

As we know,

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

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

$E_{G0} = 0.785\ eV$

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

$\Rightarrow E_G = 0.6735\ eV.$

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

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

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

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

$$\Rightarrow n_i^2 = 4.3715 \times 10^{31}$$

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

$\therefore$ $\boxed{\text{Intrinsic Concentration, } n_i = 6.61 \times 10^{15}\ cm^{-3}.}$

07. (a) Reduced incidence matrix of an oriental graph is given as

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

(i) Drawn its graph

(ii) How many tress are possible for this graph?

(iii) Write the tie-set Matrix ? **(15 M)**

Candidates must not write on this margin

Sol:

(i) Reduced Incidence matrix

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

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

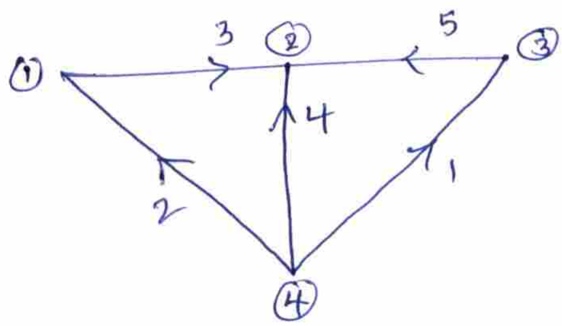
Branches/Nodes	1	2	3	4	5
(1)	0	−1	1	0	0
(2)	0	0	−1	−1	−1
(3)	−1	0	0	0	1
(4)	1	1	0	1	0

$a_{ij} = 1$, if j is oriented away from node i

and $a_{ij} = -1$, if branch 'j' is Oriented toward node 'i'.

$a_{ij} = 0$, if branch 'j' is incident on node 'i'.

∴ Graph for incidence Matrix



(ii) Number of trees = Determinant $[A] \cdot [A^T]$.

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

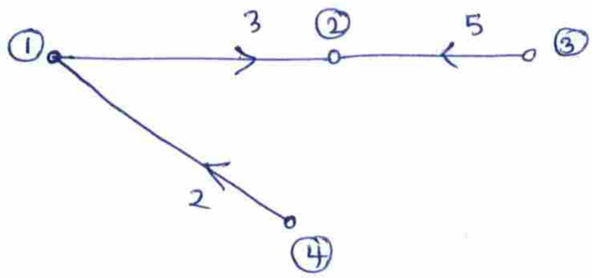
$$\Rightarrow [A][A^T] = \begin{bmatrix} 2 & -1 & 0 \\ -1 & 3 & -1 \\ 0 & -1 & 2 \end{bmatrix}$$

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

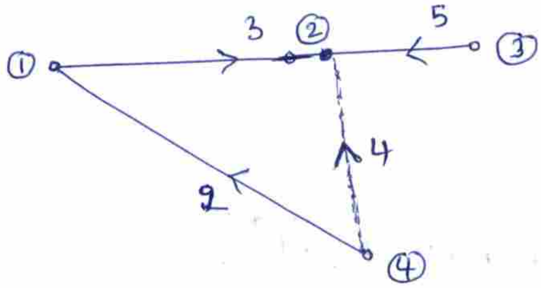
$$= 10 - 2 = 8$$

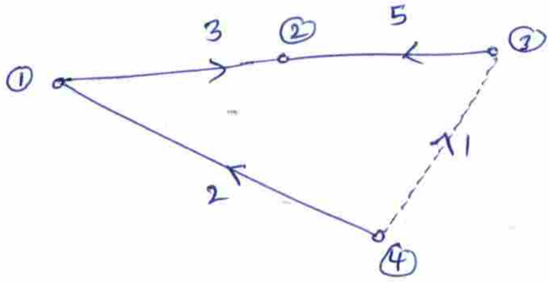
∴ $\boxed{\text{Number of possible trees} = 8}$

(iii) Consider a tree from the graph



Loop with above tree



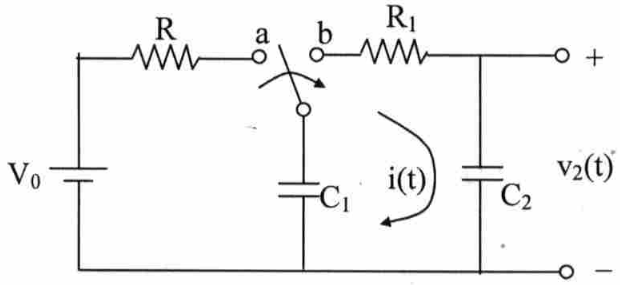


Tie-set matrix

Tiesets/Loop connect	1	2	3	4	5
I_1	0	1	1	-1	0
I_2	-1	1	1	0	1

Candidates must not write on this margin

07. (b) The switch is moved from the position a to b at t = 0, having been in the position a for a long time before t = 0. The capacitor C_2 is uncharged at t = 0. Find i(t) and $v_2(t)$ for t > 0.



(15 M)

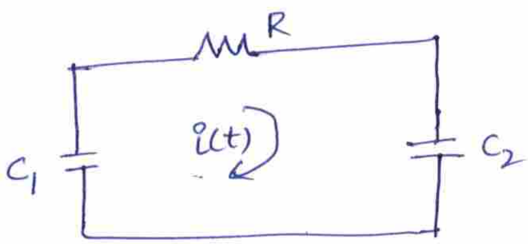
Sol: At $t=0^-$, the network has attained steady-state condition. Hence, the capacitor acts as an open-circuit and it will charge to V_0 volts.

$$\boxed{V(0^-) = V_0.}$$

Since the voltage across the capacitor does not change instantaneously.

$$\therefore\ V(0^+) = V_0$$

$$i(0^+) = \frac{V_0}{R_1}$$



Writing KVL equation for t>0,

$$-\frac{1}{C_1}\int_0^t i\,dt + V_0 - R_1 \cdot i - \frac{1}{C_2}\int_0^t i\,dt = 0 \rightarrow (1)$$

Candidates must not write on this margin

Differentiating equation ①, we get

$$-\frac{i}{C_1} - R_1\frac{di}{dt} - \frac{i}{C_2} = 0$$

$$\frac{di}{dt} + \frac{1}{R_1}\left[\frac{C_1+C_2}{C_1C_2}\right]i = 0$$

The solution of this differential equation is given by

$$i(t) = K \cdot e^{-\frac{1}{R_1}\left[\frac{C_1+C_2}{C_1C_2}\right]t}$$

At $t=0$, $\boxed{i(0) = \frac{V_0}{R_1}}$

$$K = \frac{V_0}{R_1}$$

$$\therefore \quad i(t) = \frac{V_0}{R_1} \cdot e^{-\frac{1}{R_1}\left[\frac{C_1+C_2}{C_1C_2}\right]t}$$

$$\Rightarrow \quad i(t) = \frac{V_0}{R_1} \cdot e^{-\frac{1}{R_1C}t}$$

where $C = \frac{C_1C_2}{C_1+C_2}$

$$V_2(t) = \frac{1}{C_2}\int_0^t i\,dt$$

$$= \frac{1}{C_2}\int_0^t \frac{V_0}{R_1} \cdot e^{-\frac{1}{R_1C}t}\,dt$$

Candidates must not write on this margin

$$V_2(t) = \frac{V_0}{R_1 C_2} \cdot R_1 C \left[1 - e^{-\frac{1}{R_1 C}t}\right]$$

$$\therefore \boxed{V_2(t) = \frac{V_0}{C_2} C \left[1 - e^{-\frac{1}{R_1 C}t}\right]}, \text{ for } t > 0.$$

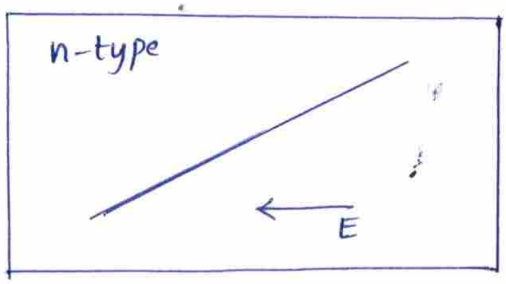
07. (c) **(i)** Show Electron drift, electron diffusion, current diffusion density and current drift density flow in the n-type bar with respect to electric field and describe the effects on drift and diffusion current densities when,

(A) Electron concentration is doubled.

(B) Constant electron concentration is added uniformly.

(10 M)

Sol:



← Electron diffusion (High to Low concentration)

→ current density (J_n) for diffusion

→ Electron drift

← Current density (J_n) for drifts.

In n-type bar current flows in the opposite direction of electron flow because of negative charge.

Initially,

Diffusion current density $= qD_n \cdot \frac{dn}{dx}$

$$\Rightarrow J_n(\text{diffusion}) = qD_n \cdot \frac{dn}{dx}$$

Drift current density $= qn\mu_n \cdot E$

$$\Rightarrow J_n(\text{drift}) = qn\mu_n \cdot E$$

(A) Doubled Electron Concentration

$$J_n'(\text{diffusion}) = \left[qD_n \cdot \frac{d(2n)}{dx} \right]$$

$$\Rightarrow J_n'(\text{diffusion}) = 2\left[qD_n \cdot \frac{dn}{dx}\right]$$

$$\therefore J_n'(\text{diffusion}) = 2 J_n(\text{diffusion})$$

$$J_n'(\text{drift}) = q(2n)\mu_n \cdot E = 2[qn\mu_n E]$$

$$\therefore \boxed{J_n'(\text{drift}) = 2 J_n(\text{drift})}$$

So, if we doubled the electron concentration then both drift & diffusion current density also doubles.

(B) Add Constant Concentration (n_+)

$$J_n''(\text{diffusion}) = qD_n \frac{d}{dx}(n+n_+)$$

$$= qD_n \cdot \frac{dn}{dx} + qD_n \cdot \frac{dn_+}{dx}$$

$$\Rightarrow J_n''(\text{diffusion}) = qD_n \frac{dn}{dx} \quad \left[\because \frac{dn_+}{dx} = 0, \text{ as '}n_+\text{' is a constant.}\right]$$

$$\Rightarrow \boxed{J_n''(\text{diffusion}) = J_n(\text{diffusion})}$$

$$J_n''(\text{drift}) = q(n+n_+)\mu_n \cdot E$$

$$\Rightarrow J_n''(\text{drift}) = qn\mu_n E + qn_+\mu_n E$$

$$\Rightarrow \boxed{J_n''(\text{drift}) = J_n(\text{drift}) + qn_+\mu_n E}$$

So, if we add constant concentration (n_+), diffusion current density remains same but drift current density will increases by $qn_+\mu_n E$.

(ii) Calculate intrinsic resistivity and conductivity of silicon at room temperature.

$$\left(\mu_n = 1300\frac{cm^2}{V-sec}, \mu_p = 500\frac{cm^2}{V-sec}, n_i = 1.5\times10^{10}cm^{-3}\right)$$ **(5 M)**

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Sol:

Given data

$\mu_n = 1300 \frac{cm^2}{V-sec}$

$\mu_p = 500 \frac{cm^2}{V-sec}$

$n_i = 1.5\times10^{10} cm^{-3}$

$T = 300K$

$\therefore \sigma_i = n_i(\mu_n+\mu_p)q$

$\Rightarrow \sigma_i = 1.5\times10^{10}\times(1300+500)\times1.6\times10^{-19}$

$\Rightarrow \sigma_i = 4.32\times10^{-6}(\Omega-cm)^{-1}$

$\therefore$ Resistivity $(\rho_i) = \frac{1}{\sigma_i}$

$\Rightarrow \rho_i = \frac{1}{4.32\times10^{-6}}$

$\Rightarrow \boxed{\rho_i = 23.481\times10^{3}(\Omega-cm).}$

$\therefore$ Intrinsic Conductivity $(\sigma_i) = 4.32\times10^{-6}(\Omega-cm)^{-1}$

Intrinsic resistivity $(\rho_i) = 23.481\times10^{3}(\Omega-cm)$

07. (d) In a very long p-type silicon bar with Cross-section area = 0.5cm^2 and $N_a = 10^{17}\text{cm}^{-3}$, we inject holes such that the steady state excess hole concentration is $5\times10^{16}\text{cm}^{-3}$ at x = 0.

$$\left(\mu_p = 500\frac{\text{cm}^2}{\text{V}-\text{sec}}, \tau_p = 10^{-10}\text{ sec}, E_g = 1.1\text{eV}, V_T = 0.0259\text{V}, n_i = 1.5\times10^{10}\text{cm}^{-3}\right)$$

(i) What is the steady state separation between E_p and E_c at x = 1000 A°?

(ii) What is the hole current?

(iii) How much is the excess stored hole charge?

(5 + 5 + 5)M

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Sol: Given data

Cross-sectional Area $= 0.5\ \text{cm}^2$

$P_o = Na = 10^{17}\ \text{cm}^{-3}$

Excess hole $= \Delta p = 5\times10^{16}\ \text{cm}^{-3}$

(i) $D_p = \frac{KT}{q}\mu_p = 0.0259\times500 = 12.95\ \text{cm}/\text{s}.$

$L_p = \sqrt{D_p\cdot\tau_p} = \sqrt{12.95\times10^{-10}} = 3.6\times10^{-5}\ \text{cm}.$

$$\boxed{p = P_o + \Delta p\cdot e^{-x/L_p}}$$

$$\Rightarrow p = 10^{17} + (5\times10^{16}).\ e^{-\frac{10^{-5}}{3.6\times10^{-5}}}$$

$$\Rightarrow \boxed{p = 1.379\times10^{17}}\ \text{cm}^{-3}$$

As we know,

$$p = n_i\cdot e^{\frac{E_i-E_p}{KT}}$$

$$\Rightarrow E_i - E_p = KT\ln\left(\frac{p}{n_i}\right)$$

$$\Rightarrow E_i - E_p = 0.0259\ \ln\left(\frac{1.379\times10^{17}}{1.5\times10^{10}}\right)$$

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$\Rightarrow E_i - E_p = 0.415\ eV$

$\therefore E_c - E_p = \frac{E_g}{2} + E_i - E_p$

$\Rightarrow E_c - E_p = \frac{1.1}{2} + 0.415$

$\Rightarrow \boxed{E_c - E_p = 0.965\ eV.}$

(ii) We can calculate the hole current using the equation

$I_p = -qAD_p \cdot \frac{dp}{dx}$, (where $p = p_0 + \Delta p \cdot e^{-x/L_p}$)

$\Rightarrow I_p = qA\frac{D_p}{L_p}(\Delta p) \cdot e^{-x/L_p}$

$\Rightarrow I_p = 1.6\times10^{-19} \times 0.5 \times \frac{12.95}{3.6\times10^{-5}} \times 5\times10^{16} \cdot e^{-\frac{10^{-5}}{3.6\times10^{-5}}}$

$\Rightarrow I_p = 1.09\times10^{3}\ A.$

$\therefore \boxed{\text{Hole current } (I_p) = 1.09\times10^{3}\ A.}$

(iii) The excess stored hole charge,

$Q_p = qA(\Delta p)L_p.$

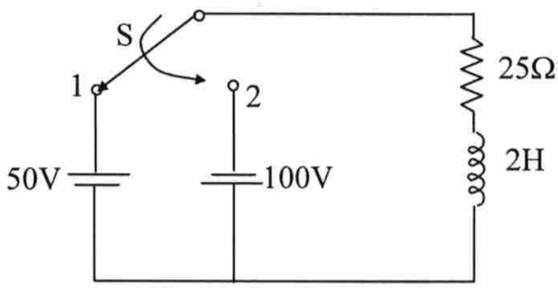
$\Rightarrow \quad Q_P = 1.6 \times 10^{-19} \times (0.5)(5 \times 10^{16})(3.6 \times 10^{-5})$

$\Rightarrow \quad Q_P = 1.44 \times 10^{-7}\ C$

$\therefore$ Excess stored hole charge,

$$\boxed{Q_P = 1.44 \times 10^{-7}\ C}$$

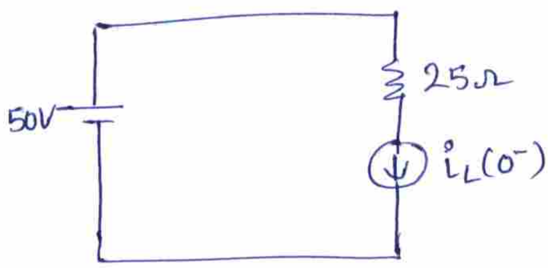
08. (a) **(i)** In the circuit shown below, the switch S is in position '1' long enough to establish steady - state conditions and at t = 0 is switched to position '2'. Draw 's - domain' network :



(10 M)

Sol:

When switch is in position '1' for long time, it will go to steady – state condition where inductor will acts as a short - circuit.



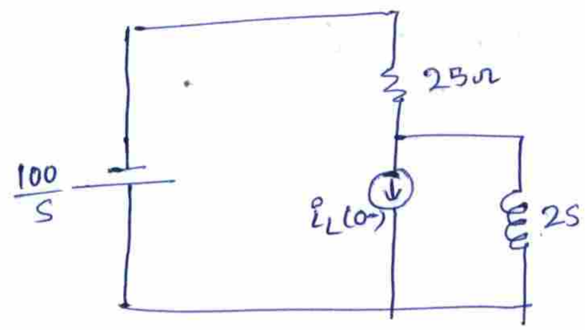
Current through inductor,

$$I_L = \frac{V}{R} = \frac{50}{25} = 2A.$$

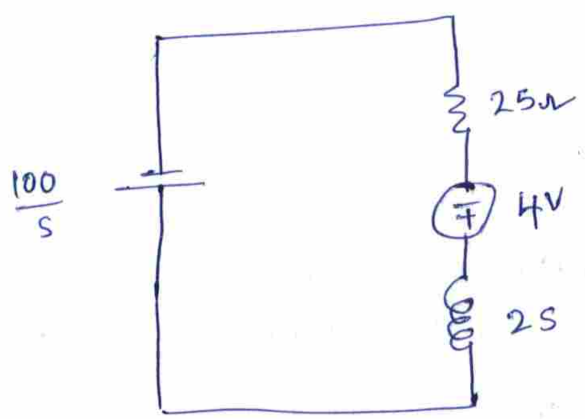
$$i_L(0^-) = i_L(0^+) = 2A.$$

When switch moved to position (2)

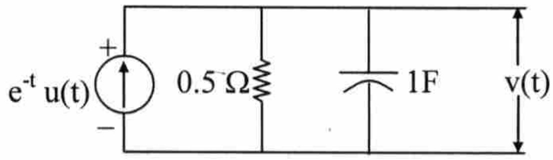
Inductor acts as a current source of 2A.



By Conversting inductor current and inductor parallel network into series, it will look like

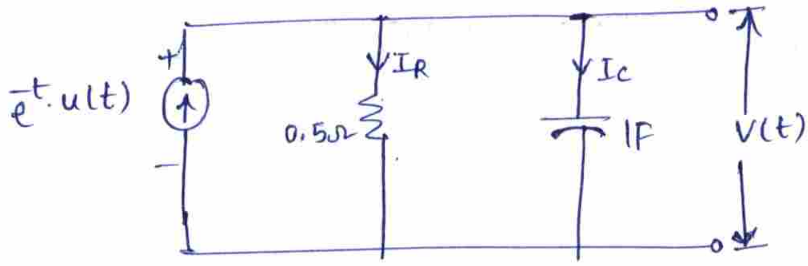


(ii) Using Laplace transform method, obtain expression for v(t) in the following network.



(10 M)

Sol:



By applying KCL

$i(t) = I_R + I_c$

$LT\left[e^{-t}.u(t)\right] = V(S)\left[2+s\right] \rightarrow ①$

The laplace transform is given by

$\text{Laplace Transform}\left[e^{-t}.u(t)\right] = \frac{1}{s+1}$

$\text{Laplace}\left[v(t)\right] = V(s).$

Taking the Laplace transform on both sides of eq. ①, we get

$$\frac{1}{s+1} = V(s)\left[2+s\right]$$

$$\Rightarrow V(s) = \frac{1}{(s+1)(s+2)}$$

$$\Rightarrow V(s) = \frac{1}{(s+1)} - \frac{1}{(s+2)}$$

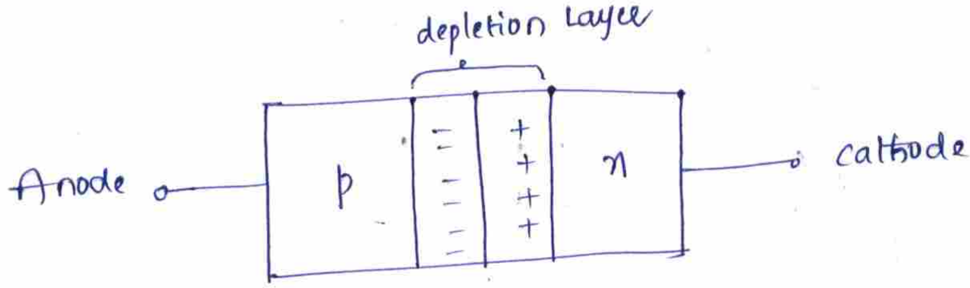
By applying Inverse laplace Transform on both sides, we get

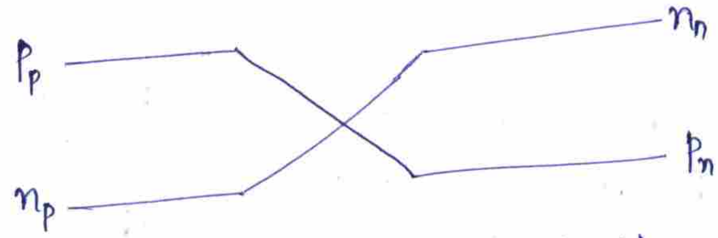
$$\boxed{V(t) = \left(e^{-t} - e^{-2t}\right) \cdot u(t)}$$

08. (b) 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 M)**

Sol: Construction of p-n Junction :

A p-n junction diode is formed by doping one side of a piece of silicon with a p-type dopant (Boron) and other side of N-type dopant (phosporous). Ge can be used as 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 most simplest semiconductor devices as it allows Current to flow only one direction. The p-n junction is an interface between P-type and n-type regions and is used to Construct diodes and transistors. At the junction, majority carriers diffuse across the junction which results 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 form an equilibrium.





Electron – hole concentration.

Applications :

→ p-n junction diode, in reverse biased configuration is sensitive to light from a range between 400nm – 1000nm, which includes visible light. Therefore it can be used as a photo diode.

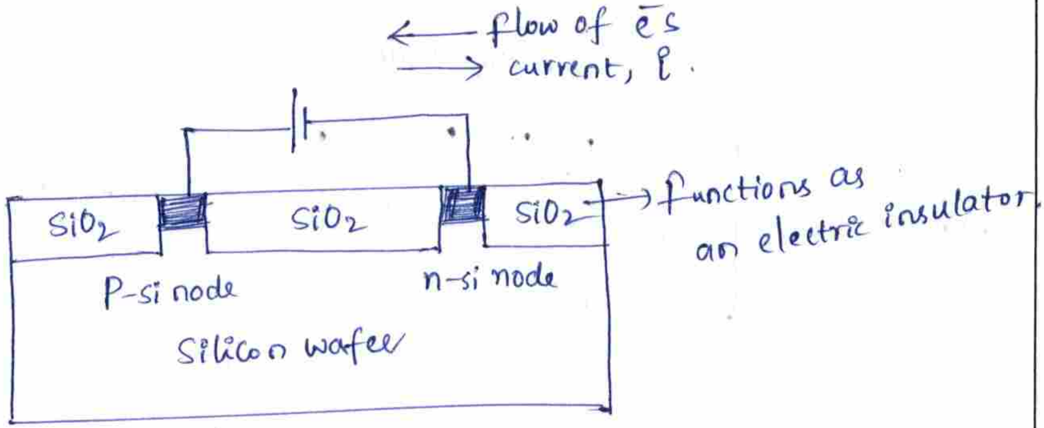
→ It can also be used as a "solar cell".

→ p-n junction forward bias condition is used in all LED lighting applications.

Conversion of sun light into electricity :

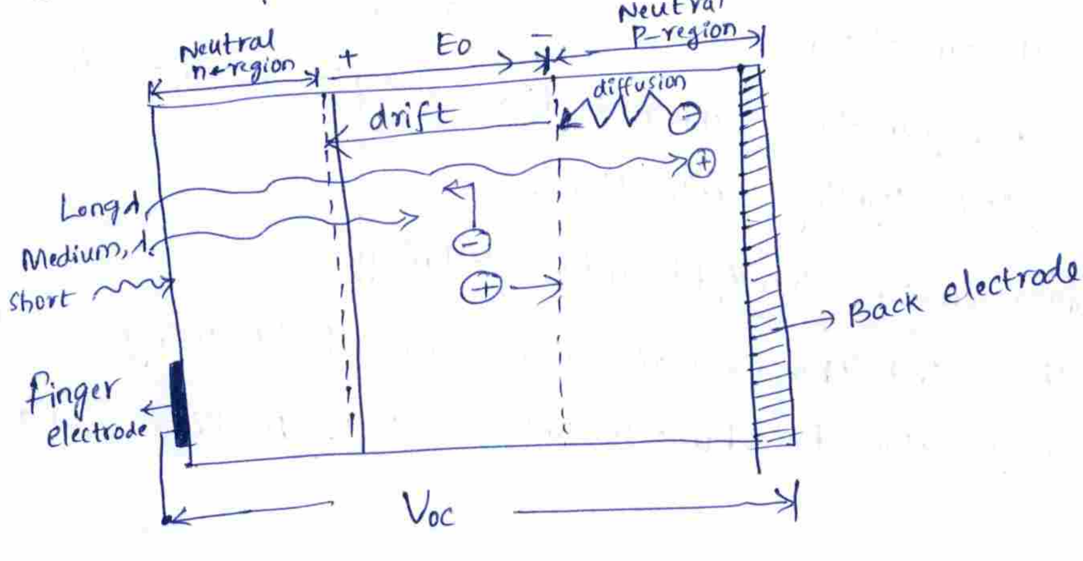
The first photo voltaic device was built using a Si p-n junction by Russell Ohl in 1939. A silicon solar

Photo voltaic cells converts lights (photon) energy into electric energy. The photons from the exposed light prompted electrons flowing from n-junction to p-junction i.e electric current flow.



Working Principle :

The n-region is heavily doped and thin so that the light can penetrate through it easily. The p-region is lightly doped so the most of depletion region lies in the p-side. Electron-hole pairs are generated in the depletion region and due to built-in potential & electric field, electrons moves to the n-region & holes to the p-region. When an external load is applied, the excess ēs travel through the load to recombine with holes. EHPs generated can contribute to photo current.



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Difference between p-n junction and Solar cell :

The solar cell is a pn-junction diode optimized to convert the incident solar radiation to electrical energy. Like wise every diode is optimized for its specific application, such as rectifier diode & zener diodes.

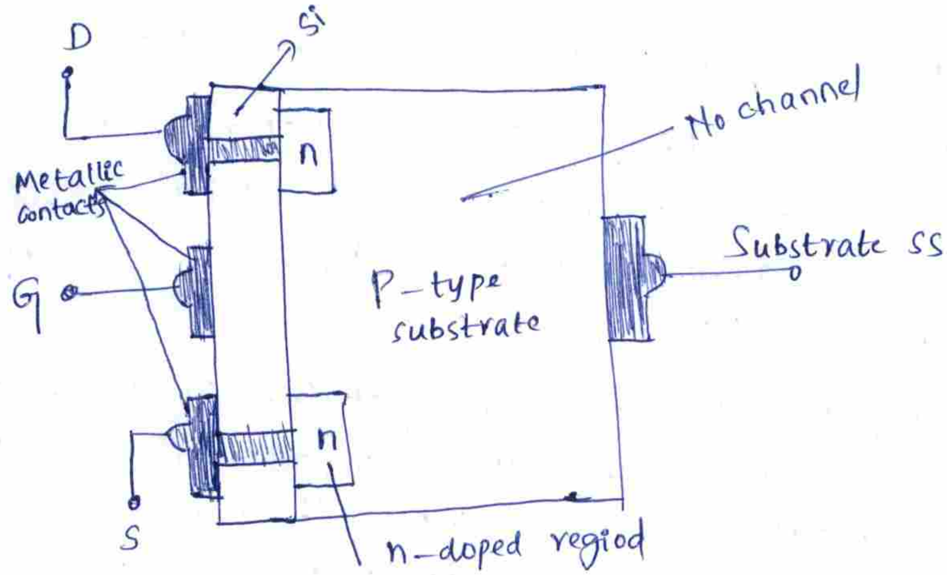
The major difference is the Metalization of the two electrodes. The back side of the solar cell is normally the anode is completely metalized while the front side electrode is partially metalized in the form of metal fingers & buss bars to allow light to pass to the active solar cell material absorbed in the material to generate the photo current and collecting the photo current by the metal grid to access electrically the front electrode. Normal diode is fully metalized from both sides.

08. (c) (i) Describe the constructional features of n-channel E-MOSFET. **(10 M)**

Sol: Construction of n-channel E-MOSFET :

The Fig. (a) shows the basic construction of n-channel enhancement type MOSFET. Two lightly doped n-regions are diffused into a lightly doped p-type substrate. The source and drain are taken out through metallic contacts to n-doped regions as shown in fig (a). But the Channel between two n-regions is absent in E-MOSFET.

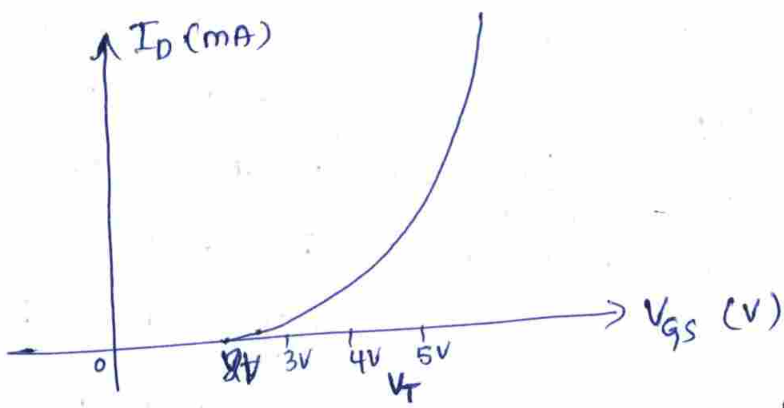
The SiO_2 layer is still present in the E-MOSFET, to isolate the gate metallic platform from the region between the drain and source, but now it is simply separated from a section of the p-type material.



fig(a). Construction of n-channel EMOSFET.

Transfer characteristics :

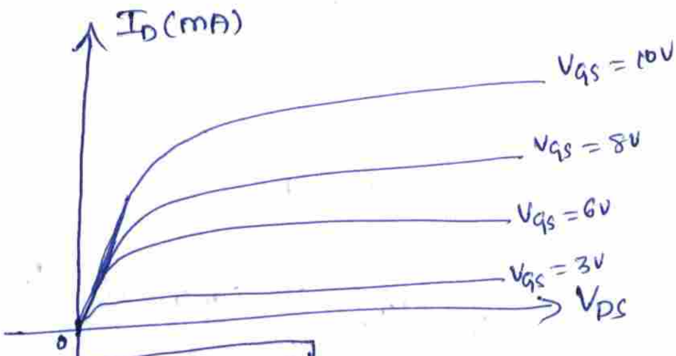
Here V_{DS} is applied and V_{GS} is kept zero (by directly connecting gate to the source). At this time practically no current flows.



If we increase the magnitude of V_{GS} in the positive direction, the concentration of electrons near the SiO_2 surface increases. At a particular value of V_{GS} there is a measurable current flow between drain and source. This value of V_{GS} is called Threshold voltage denoted by V_T.

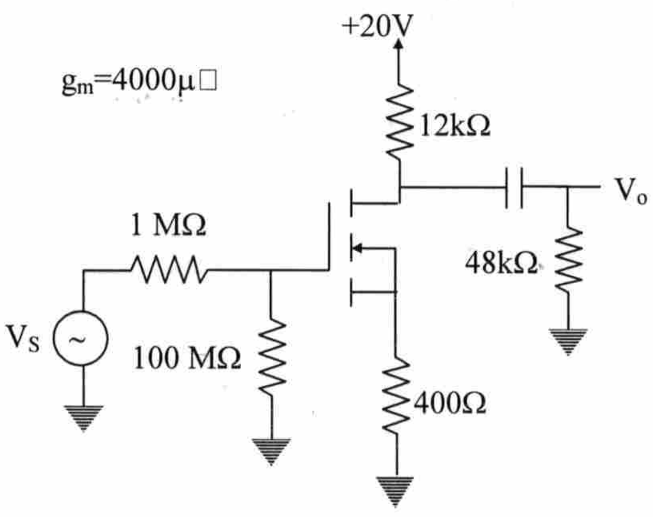
Thus we can say that in an enhancement type n-channel MOSFET, a positive gate voltage above threshold value induces a channel and hence the drain current is increased by creating a thin layer of negative charges in the substrate region adjacent to the SiO_2 layer.

Drain characteristics :



$$\boxed{I_D = K(V_{GS} - V_T)^2}, \text{ where } K = \frac{I_{D(ON)}}{\{V_{GS(ON)} - V_T\}^2}$$

(ii) Calculate the voltage gain $\left(\frac{V_o}{V_s}\right)$ of the circuit shown in the below figure.

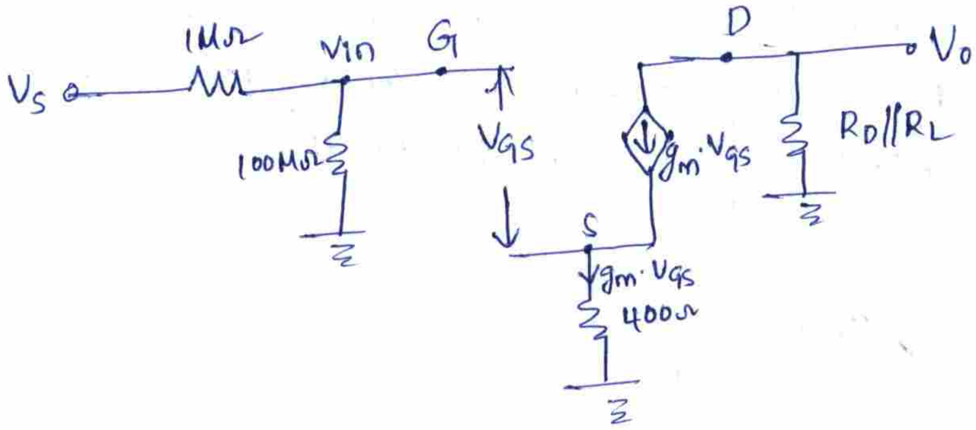


(10 M)

Sol: Given that

Trans conductance (g_m) = 4000 µ℧

Ac equivalent circuit



$$\therefore \quad V_o = -g_m \cdot V_{gs} \, (R_D \| R_L)$$

$$= -(12k \| 48k)\,(4000\mu)\, V_{gs}$$

$$= -38.4\, V_{gs}.$$

$$V_{in} = V_{gs} + g_m \cdot V_{gs} \times 400$$

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

$$= 2.6\, V_{gs}.$$

$$\frac{V_o}{V_{in}} = \frac{-38.4}{2.6} = -14.769$$

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

$\therefore$ Voltage gain

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

$$= -14.62$$

$\therefore$ $\boxed{A_v = -14.62}$

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