ESE-2021
(MAINS)

QUESTIONS WITH DETAILED SOLUTIONS

ELECTRONICS & TELECOMMUNICATION ENGINEERING

PAPER-I

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ELECTRONICS & TELECOMMUNICATION ENGINEERING

ESE_MAINS_2021_PAPER – I

Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

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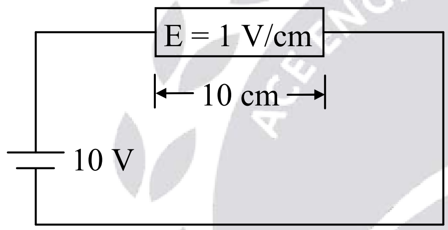
SECTION - A

01. (a) An N-type silicon bar of conductivity σ = 1/Ω-cm has a battery applied across it as shown in the figure below. Assume a hypothetical situation in which the battery is able to sweep some electrons into a region of length 0.03 cm in the middle of the bar, thereby locally increasing the electron density in the region by 1% of the thermal equilibrium density. Make the rough calculation of the order of magnitude of the electric field which will develop there due to this increase in majority carrier density.

Assume, mobility of electron $\mu_n = 1350\ cm^2/V\text{-}s$,

Permittivity of Si $\varepsilon_{Si} = 10^{-12}$ F/cm. **(12 M)**

N type Si σ = 1/Ω-cm



Sol: The electric field can be given as

$$E_x = -V_T \frac{1}{n(x)} \frac{dn(x)}{dx}$$

$n(x) = n_0 + 1\%\ n_0 x \qquad 0 \le x \le 0.03$ cm

$n(x) = n_0 + 0.01\ n_0 x \qquad 0 \le x \le 0.03$ cm

Given $\sigma = 1\ (\Omega\text{-cm})^{-1}$

$\Rightarrow P = 1\ \Omega$-cm

$$P = \frac{1}{n_0 q \mu_n} \Rightarrow n_0 = \frac{1}{p q \mu_n}$$

$$n_0 = \frac{1}{1 \times 1.6 \times 10^{-19} \times 1350} = 4.63 \times 10^{15} / cm^3$$

$$\frac{dn(x)}{dx} = \frac{d}{dx}(n_0 + 0.01 n_0 x) = 0.01 n_0$$

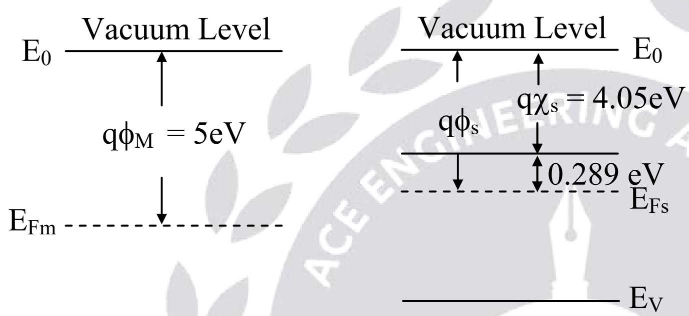
$$E_x = -V_T \left(\frac{1}{n_0 + 0.01 n_0 x} \right) 0.01 n_0 = -V_T \left(\frac{0.01}{1 + 0.01x} \right)$$

At x = 0.03

$$E_x = -0.026 \times \frac{0.01}{1 + (0.01)(0.03)} = 2.6 \times 10^{-4}\ V/cm = 0.26\, mV/cm$$

01. (b) The work function ϕ_m of platinum is 5eV and the electron affinity for silicon is x_{Si} = 4.05eV. Determine the barrier height ϕ_{Bn} (barrier height for transfer of electron from metal to semiconductor) and ϕ_{Bp} (barrier height for transfer) of holes from metal to semiconductor). Also calculate the built-in voltage V_{bi} for metal-semiconductor contact of platinum with N-type silicon having doping concentration $N_D = 2.8 \times 10^{14}/cm^3$. Assume that effective density of states in the conduction band edge is $N_C = 2.8 \times 10^{19}/cm^3$, KT = 0.025 eV at room temperature, E_G = 1.1eV. (12 M)

Sol:



$$q\phi_s = q\chi_s + (E_C - E_{Fs})$$

$$E_c - E_{fs} = KT\, ln\left(\frac{N_C}{N_D}\right) = 0.025\, ln\left(\frac{2.8\times10^{19}}{2.8\times10^{14}}\right)$$

$= 0.287$ eV

$q\phi_s$ = 4.05 eV + 0.289 eV = 4.339 eV

$\phi_{Bn} = \phi_m - \phi_s = 5 - 4.339 = 0.661$ V

(or)

$q\phi_{Bn}$ = 0.661 eV

$\phi_{Bp} = -\phi_{Bn} = -0.661$ V

(or)

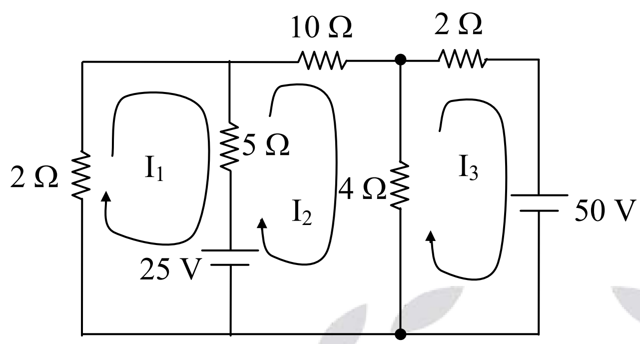
$q\phi_{Bp}$ = – 0.661 eV

Built in potential

$$V_{bi} = V_T \ln\left(\frac{N_D N_C}{n_i^2}\right)$$

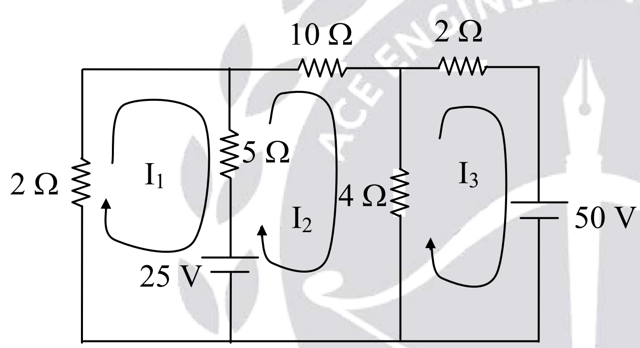
$$= 0.025 \times \ln\left(\frac{2.8\times10^{14}\times2.8\times10^{19}}{(1.5\times10^{10})^2}\right) = 0.78\,V$$

01. (c) Write the mesh current matrix equation for the network of figures shown by inspection, and solve for the currents.



(12 M)

Sol:



By KVL for (1)

$2I_1 + (I_1 - I_2)\,5 + 25 = 0$

$7I_1 - 5I_2 + 25 = 0$ ……..(1)

By KVL for (2)

$10I_2 + (I_2 - I_3)\,4 - 25 + (I_2 - I_1)\,5 = 0$

$-5I_1 + 19I_2 - 4I_3 = 25$ ……..(2)

By KVL for (3)

$2I_3 + 50 + (I_3 - I_2)\,4 = 0$

$-4I_2 + 6I_3 - 50 = 0$ ……(3)

From (1)(2) & (3)

$$\begin{bmatrix} 7 & -5 & 0 \\ -5 & 19 & -4 \\ 0 & -4 & 6 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -25 \\ 25 \\ -50 \end{bmatrix}$$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{\begin{vmatrix} -25 & -5 & 0 \\ 25 & 19 & -4 \\ -50 & -4 & 6 \end{vmatrix}}{\begin{vmatrix} 7 & -5 & 0 \\ -5 & 19 & -4 \\ 0 & -4 & 6 \end{vmatrix}} = \frac{-25(114-16)+5(150-200)}{7(114-16)+5(-30)}$$

$$= \frac{-2450-250}{686-150} = \frac{-2700}{536}$$

$I_1 = -5.037$ A

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{\begin{vmatrix} 7 & -25 & 0 \\ -5 & 25 & -4 \\ 0 & -50 & 6 \end{vmatrix}}{536}$$

$$= \frac{7(150-200)+25(-30)}{536}$$

$$= \frac{-350-750}{536} = \frac{-1100}{536}$$

$= -2.05$A

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{\begin{vmatrix} 7 & -5 & -25 \\ -5 & 19 & 25 \\ 0 & -4 & -50 \end{vmatrix}}{536}$$

$$= \frac{7(-950+100)+5(250)-25(20)}{536}$$

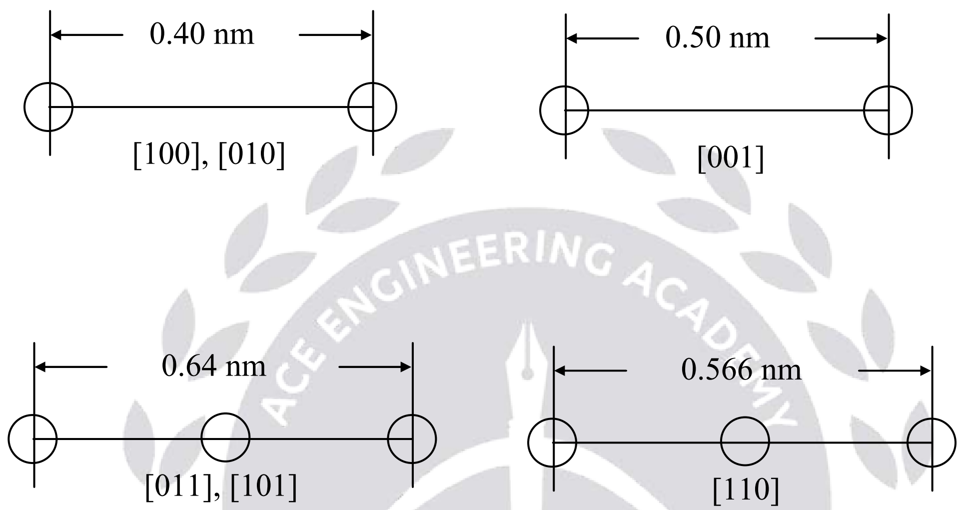
$$= \frac{-850\times 7+1250-500}{536} = \frac{-5200}{536} = -9.7\text{A}$$

$I_1 = -5.037$A

$I_2 = -2.05$A

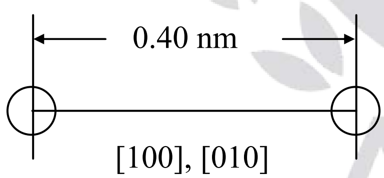
$I_3 = -9.7$A

01. (d) The atomic packing schemes for some hypothetical material for several different crystallographic directions are shown. For each direction the circles represents only those atoms contained within a unit cell, where circles are reduced from their actual diameter/size.



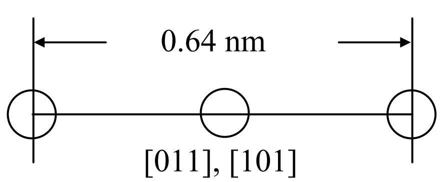
Identify the unit cell and the crystal system it belongs to. (12 M)

Sol:

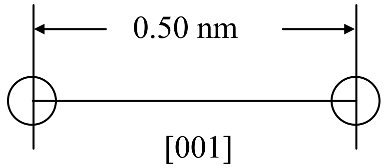


The given direction represent a side of a unit cell

$a_y = a_x = 0.40\text{nm}$ (X,Y - direction)

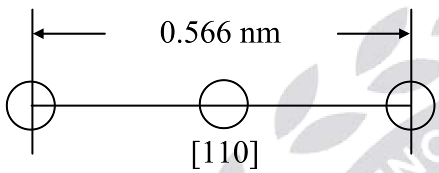


The given direction represent a Face diagonal $\sqrt{2}a = 0.64\text{nm}$



The given direction also represent a side of unit cell in 2-direction

$a_z = 0.50\text{nm}$



The given direction is a x-y-Face diagonal

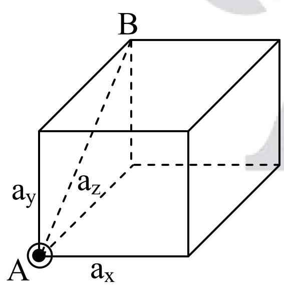
$\sqrt{2}a_{xy} = 0.566\text{nm}$

$a_x = a_y \neq a_z$

X-Y Face diagonal = $\sqrt{2}a_x$

$= \sqrt{2} \times 0.4$

$= 0.5656$



Y-Z Face diagonal

(AB) = $\sqrt{a_z^2 + a_y^2} = \sqrt{0.5^2 + 0.4^2} = 0.64\text{nm}$

Conclusion: From the above, the crystal system is Face centered tetragonal structure and unit cell is Tetragonal.

01. (e) What are the different types of batteries? How is the right battery selected for an application? (12 M)

Sol: CLASSFICATION OF CELLS:

Cells are divided into two main types. The primary cell and the secondary cell.

Primary Cells: The Primary cell once it has exhausted its activity is of no further use, i.e., once discharged cannot be recharged.

Ex: Copper zinc cell

Classification of primary cells: Primary cells may be either wet or dry type

(a) **Wet cell:** In wet cell, the electrolyte is in completely liquid form. In this cell, the positive plate is copper and the negative plate is zinc and electrolyte is dilute sulphuric acid. The voltage level is 1.5V.

(b) **Dry cell:** In dry cell, as absorbent material is saturated with the electrolyte and is then placed in contact with the plates.

(i) In dry cell, zinc case is acting as negative plate and carbon rod as the positive plate. The electrolyte is the Ammonium chloride (NH_4Cl). It delivers an emf of 1.5V when it is in good condition.

(ii) Dry cells deteriorate even when not in use owing to the evaporation of the electrolyte and decomposition of zinc electrode.

(iii) **Polarization:** Polarization is due to an accumulation of hydrogen on positive plate, which results in increased internal resistance and lower battery voltage and capacity. The use of depolarizing agent manganese dioxide. (MnO_2) tends to prevent this.

(iv) **Local action:** Local action refers to counter voltage set up in a plate because of chemical impurities. It is prevented in the dry cell by amalgamating with zinc and mercury.

Secondary cells:

The secondary cell can be recharged by sending current through it in the reverse direction. The secondary cells are also called as storage cells

Ex: lead-acid cell.

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(a) The advantages of storage cell over primary cell are

(i) it can be recharged

(ii) it can be built to provide heavier current capabilities

(iii)it is more economical in the long run

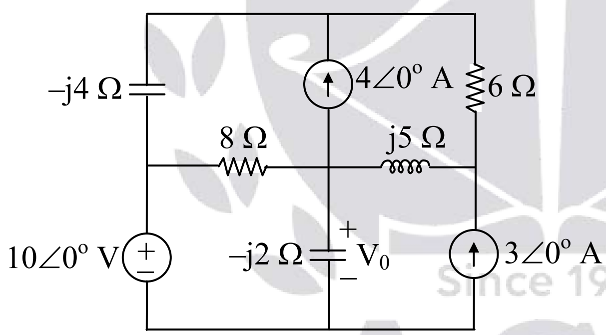
(b) A hydrometer is used to determine the specific gravity of lead-acid cells.

(c) The number of plates in a lead acid is an odd integer. The reason for this is that the negative group has one more plate than positive group.

(d) The lead acid cell depends on its action on the presence of two plates cover with PbO_2 and Pb respectively in a solution of dilute H_2SO_4 of specific gravity 1.21 or near about.

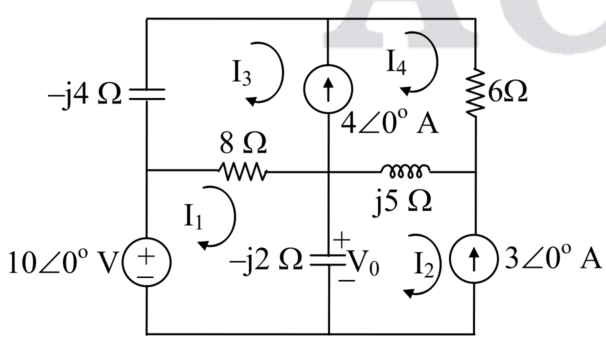
(e) When a lead acid cell is fully charged, the positive plate is dark chocolate brown in colour and negative plate is in slate gray colour. During discharging both anode and cathode become $PbSO_4$ which is whitish in colour.

02. (a) Solve for V_0 in the circuit shown in the figure.



(20 M)

Sol:



$-10 + (8-j2)\, I_1 - (-j2)\, I_2 - 8I_3 = 0$

(or) $(8-j2)\, I_1 + j2\, I_2 - 8I_3 = 10$ _______(1)

$I_2 = -3$ ______(2)

$(8-j4)I_3 - 8I_1 + (6+j5)I_4 - j5I_2 = 0$ ______(3)

$I_4 = I_3 + 4$ ____(4)

Combine (1) and (2)

$(8-j2)I_1 - 8I_3 = 10 + j6$ ______(5)

Combine (2) and (4)

$-8\, I_1 + (14 + j)\, I_3 = (-24-j35)$ _____(6)

Matrix form

$$\begin{bmatrix} (8-j2) & -8 \\ -8 & (14+j) \end{bmatrix}\begin{bmatrix} I_1 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10+j6 \\ -24-j35 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} (8-j2) & -8 \\ -8 & (14+j) \end{vmatrix} = (50-j20)$$

$$\Delta_1 = \begin{vmatrix} (10+j6) & -8 \\ (-24-j35) & (14+j) \end{vmatrix} = (-58-j186)$$

$$\text{So, } I_1 = \frac{\Delta_1}{\Delta} = \frac{(-58-j186)}{50-j20} = 3.618\angle 274.5^\circ \text{ A}$$

Then finally V_0 is

$V_0 = -j2(I_1 - I_2) = -j2\,[3.618\angle 274.5^\circ + 3] = -7.2134 - j6.568$

$V_0 = 9.756\ \angle 222.32^\circ$ V

02. (b) An MOS capacitor having the gate oxide thickness, t_{ox} = 0.1 μm and substrate boron doping density $N_A = 10^{15}/cm^3$ is biased in the depletion mode with a gate voltage, V_G. If the surface potential is 0.2V for this bias condition, determine the following:

(5×4 = 20 M)

(i) Peak electric in silicon substrate

(ii) electric field in the oxide

(iii) The gate voltage V_G

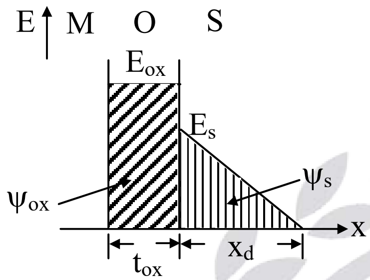
(iv) Thermal equilibrium hole concentration, P_P and the hole concentration, P_s at the silicon surface.

Note: That $\varepsilon_0 = 8.854 \times 10^{-14}$ F/cm, $\varepsilon_s = 12$ for silicon and $\varepsilon_{ox} = 4$ for SiO_2.

Sol: $t_{ox} = 0.1\mu m$

$N_A = 10^{15} / cm^3$

$\psi_s = 0.2V$



(i) $\psi_s = \frac{1}{2} x_d E_s$

$E_s = \frac{2\psi_s}{x_d}$ - Peak electric field at the surface

$|Q_d| = qN_A x_d$

Depletion width (x_d) = $\frac{|Q_d|}{qN_A} = \frac{\sqrt{2qN_A\varepsilon_s\psi_s}}{qN_A} = \sqrt{\frac{2\varepsilon_s\psi_s}{qN_A}}$

$$x_d = \sqrt{\frac{2\times12\times8.854\times10^{-14}\times0.2}{1.6\times10^{-19}\times10^{15}}}$$

$x_d = 5.15 \times 10^{-5}$ cm

$$E_s = \frac{2\psi_s}{x_d} = \frac{2\times0.2}{5.15\times10^{-5}} = 7.8 \text{ kV/cm}$$

(ii) To Calculate the peak electric field in oxide, apply boundary conditions.

$D_{n1} = D_{n2}$

$\varepsilon_1 E_{n1} = \varepsilon_2 E_{n2}$

$\varepsilon_{ox} E_{ox} = \varepsilon_s E_s$

$$\Rightarrow E_{ox} = \left(\frac{\varepsilon_s}{\varepsilon_{ox}}\right) E_s = \left(\frac{12}{4}\right) 7.8\ \text{kV/cm} = 23.4\ \text{kV/cm}$$

(iii) $V_G = \psi_{ox} + \psi_s$

$$\psi_{ox} = t_{ox} E_{ox} = 0.1\times10^{-4}\ \text{cm}\times 23.4\ \text{kV/cm}$$

$\psi_{ox} = 0.234$ V

$V_G = 0.234 + 0.2$

$V_G = 0.434$ V

(iv) The equilibrium hole concentration

$p_p = N_A = 10^{15} / \text{cm}^3$

Surface holes concentration

$$p_s = n_i e^{\frac{(E_i - E_{FS})}{KT}}$$

$q\psi_s$ is the extent of band bending at the surface

$$\Rightarrow p_s = n_i e^{\frac{q\psi_s}{KT}} = 1.5\times10^{10}\times e^{\frac{0.2}{0.026}}$$

$p_s = 3.3\times10^{13}/\text{cm}^3$

02. (c) (i) A silicon P-N junction photodiode has a uniform area of cross-section of A = 0.04 cm^2. In the p-region, $N_A = P_p = 1.5 \times 10^{15}$/cm^3 and in the N-region, $N_D = n_n = 1.5\times 10^{13}$/cm^3. The intrinsic carrier density in silicon is $n_i = 1.5 \times 10^{10}$/cm^3. The diffusion constant for electrons and holes are $D_n = 35$ cm^2/s and $D_p = 12.5$ cm^2/s. Holes lifetime in the N-region is $\tau_p = 100$ μ sec and electron lifetime in the p-region is $\tau_n = 35$ μsec and electron lifetime in the P-region is $\tau_n = 35$ μ sec. Assuming that light of a suitable mixture of wavelength falls on the diode producing an idealized generation of EHP, $G_L = 10^{16}$ pairs/sec/cm^2 uniformly at all points within the volume of diode, and the diode is kept short circuited, calculate the light induced current through the photodiode. (15 M)

(ii) In the photodiode of Q2(c)(i), if instead of short circuiting, the diode is kept open circuited, calculate the open circuit photo voltage, V_{oc} across the diode. Assume $V_T = 0.026$ V at room temperature. (5 M)

Sol:

(i) $A = 0.04 \text{ cm}^2$

$N_A = 1.5 \times 10^{15}$ /cm^3

$N_D = 1.5 \times 10^{13}$ /cm^3

$n_i = 1.5 \times 10^{10}$ /cm^3

$D_n = 35$ cm^2 / sec, $D_p = 12.5$ cm^2/sec

$\tau_n = 35$ μsec, $\tau_p = 100$ μsec

$$L_n = \sqrt{D_n\tau_n} = \sqrt{35\times 35\times 10^{-6}} = 35\times 10^{-3} \text{ cm}$$

$$L_p = \sqrt{D_p\tau_p} = \sqrt{12.5\times 100\times 10^{-6}} = 3.5\times 10^{-2} \text{ cm}$$

$$I_L = AqG' (W + L_n + L_p)$$

$$W = \sqrt{\frac{2\varepsilon V_0}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)}$$

$$V_0 = V_T ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$= 0.026 \times ln\left(\frac{1.5\times10^{15}\times1.5\times10^{13}}{(1.5\times10^{10})^2}\right)$$

$V_0 = 0.48\,V$

$$W = \sqrt{\frac{2\times12\times8.854\times10^{-14}\times0.48}{1.6\times10^{-19}}\left(\frac{1}{1.5\times10^{15}}+\frac{1}{1.5\times10^{13}}\right)} = 6.5\times10^{-4}\text{ cm}$$

$I_L = AqG'\ (W + L_n + L_p)$

$= 0.04 \times 1.6 \times 10^{-19} \times 10^{16}\ (6.5\times10^{-4} + 35\times10^{-3} + 3.5\times10^{-2})$

$I_L = 4.521\ \mu A$

(ii) Open-Circuit voltage

$$V_{OC} = V_T\, ln\left(1+\frac{I_L}{I_o}\right)$$

$$I_o = Aq\left[\frac{D_p}{L_pN_D}+\frac{D_n}{L_pN_A}\right]n_i^2$$

$$I_0 = 0.04 \times1.6\times10^{-19}\left(\frac{12.5}{3.5\times10^{-2}\times1.5\times10^{13}}+\frac{35}{35\times10^{-3}\times1.5\times10^{15}}\right)(1.5\times10^{10})^2$$

$I_0 = 3.5\times10^{-11}$ A

$$V_{oc} = 0.026\ ln\left(1+\frac{2.5\times10^{-6}}{3.5\times10^{-11}}\right)$$

$= 0.3\,V$

03. (a) (i) Explain, how Burgers vector is invariant for the type of dislocation. (10 M)

(ii) Out of (100) and (110) crystallographic planes, which plane will have more surface energy for copper single crystal? (10 M)

Given: Bond energy per bond for copper = 65.4 kJ/mol

Lattice parameter for copper = 3.61 Å

Avogadro's number = 6.023×10^{23} g/mol

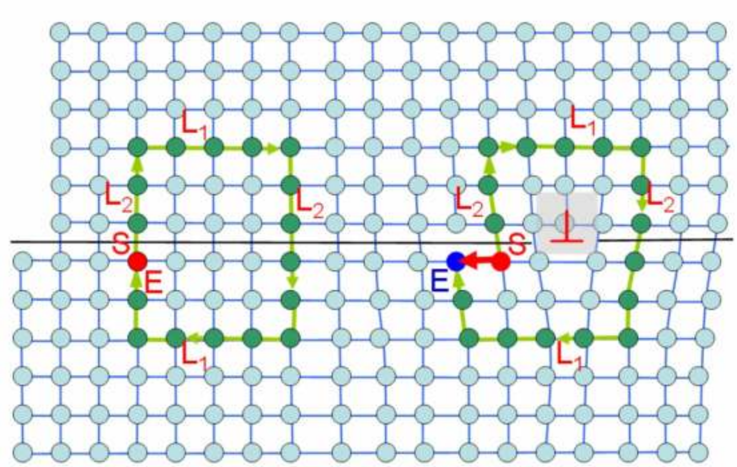
Sol:

(i) Burger's vector is a direction and magnitude of dislocation motion.

In edge dislocation, burger's vector is parallel to the applied force but it is perpendicular to the dislocation line.

In screw dislocation, burger's vector is perpendicular to the applied force but it is parallel to the dislocation vector.

The burger's vector is not necessary to be straight. When it is curved some parts can be a screw dislocation and some parts an edge dislocation. For a given vector that points in one direction along the dislocation, the burger's vector is invariant.



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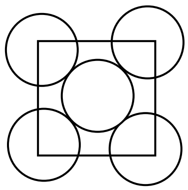
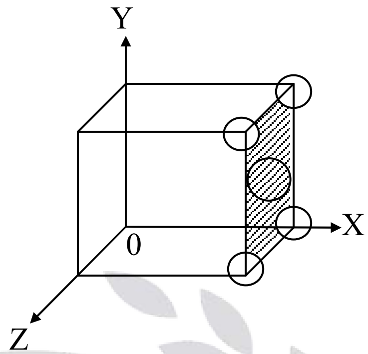
(ii) Copper is FCC structure metal:

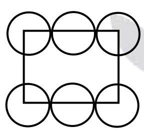
(100) Plane:-

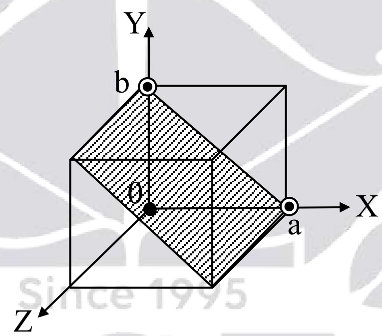




Planar density = $\frac{2}{a^2}$

(110) Plane:-





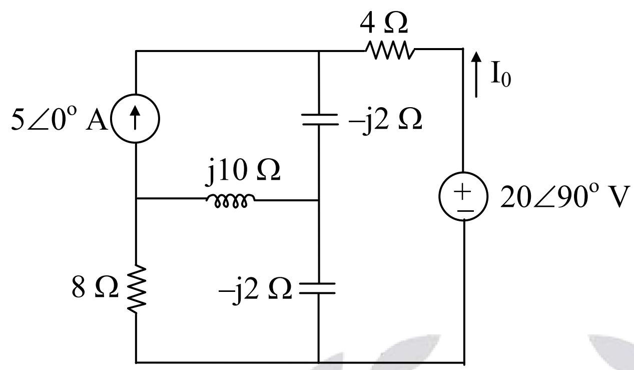
Planar density = $\frac{2}{\sqrt{2}a^2} = \frac{\sqrt{2}}{a^2}$

Planar density of (100) > Planar density of (110)

Planar density $\alpha \frac{1}{\text{Surface energy}}$

So surface energy in (110) plane is greater than (100).

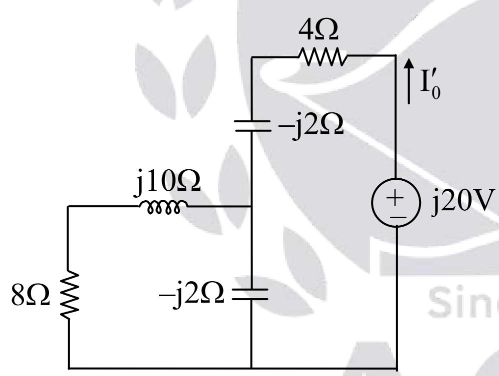
03. (b) Use the superposition theorem to find I_0 in the circuit shown in the figure.



(20 M)

Sol: Let $I_0 = I_0' + I_0''$

Statement I: Due to voltage source only

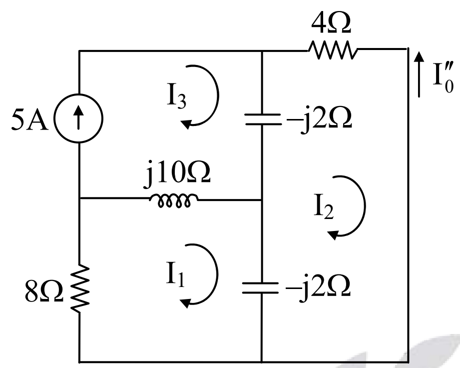


$$Z = \frac{-j2(8+j10)}{-j2+8+j10} = (0.25 - j2.25)$$

$$\text{So, } I_0' = \frac{j20}{4 - j2 + 2} = \frac{j20}{(4.25 - j4.25)}$$

$$I_0' = (-2.353 + j2.353)$$

Statement II: Due to current source only



Mesh-1

$(8+j8)\ I_1 - j10\ I_3 + j2I_2 = 0$______(1)

Mesh-2

$(4-j4)\ I_2 + j2\ I_1 + j2I_3 = 0$______(2)

Mesh-3

$I_3 = 5$______(3)

Substituting (2) & (3) we get

$(4 - j4)\ I_2 + j2\ I_1 + j10 = 0$

$I_1 = (2 + j2)\ I_2 - 5$_______(4)

Sub (3) and (4) in (2)

$(8+j8)[(2+j2)I_2 - 5] - j50 + j2\ I_2 = 0$

$$I_2 = \frac{(90 - j40)}{34} = (2.647 - j1.176)$$

$$I_0'' = -[I_2] = (-2.647 + j1.176)$$

By Superposition Theorem

$$I_0 = I_0' + I_0'' = (-5 + j3.529)$$

$$= 6.12 \angle 144.78^{\circ}$$

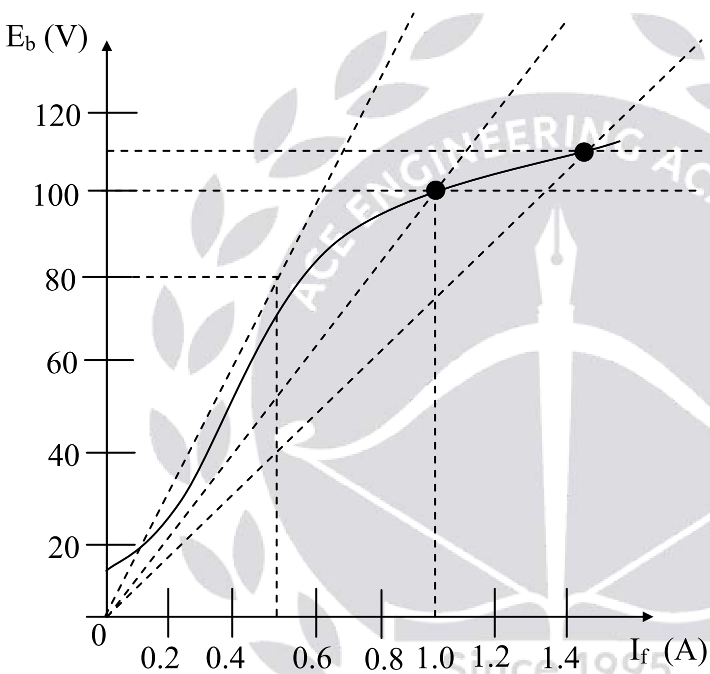
03. (c) A separately excited DC generator is characterized by the magnetization curve of the figure shown below.

(i) If the prime mover is driving the generator at 800 rev/min, what is the no-load terminal voltage, V_a ?

(ii) If a 1-Ω load is connected to the generator, what is the generated voltage ?

Generator ratings : 100 V, 100 A, 1000 rev/min

Circuit parameters : R_a = 0.14 Ω, V_f = 100 V, R_f = 100 Ω **(20 M)**



Sol:

(i) At no load, $I_a = 0$

$E \alpha N$

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

$$\Rightarrow E_2 = \frac{E_2}{E_1} \times E_1$$

$$= \frac{800}{1000} \times 100 = 80V$$

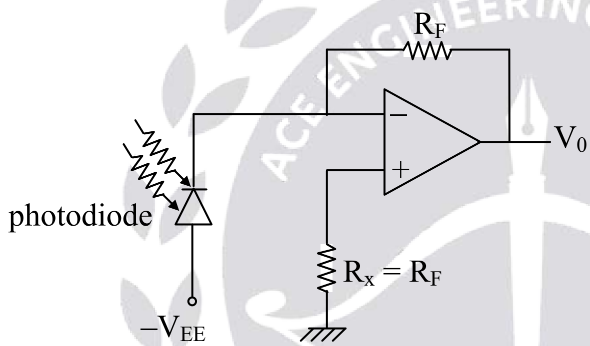
(ii) $E_{g_2} = V + I_a(R_a + R_{ext})$

$= 100 + 100\ (0.14 + 1)$

$= 100 + 114$

$= 214$ Volt

04. (a) (i) Design a photo detector circuit of the form as shown in the figure below to give an output voltage of V_0 = – 200 mV at an incident power density of D_P = 500 nW/cm^2. The current responsitivity of the photodiode is D_i = 1 A/W, and the active area is a = 400 mm^2.



(10 M)

(ii) The measured values of a diode at a junction temperature of 25°C are given by

$$V_D = \begin{cases} 0.5V \text{ at } I_D = 5\mu A \\ 0.6V \text{ at } I_D = 100\mu A \end{cases}$$

Determine the (I) Emission coefficient η, and (II) the leakage current I_s. Assume V_T = 25.8mV. **(10 M)**

Sol:

(i) (1) photo diode need to be always in reverse bias So, $-V_{EE}$ must to be selected to make it reverse bias.

(2) Sine responsivity (or) sensitivity

$$R = \frac{I_P}{P_0} = 1A/W$$

Where $I_P \rightarrow$ photo diode output current

$P_O \rightarrow$ incident optical power

where optical power,

$P_0 = I_x A$,

where $I_x \rightarrow$ power /unit area received by light W/cm^2.

Given $I_x = 500 nW/cm^2$

Also, where A $\rightarrow$ Area (Achieve Area), Given A = 400mm^2

Hence, diode current, $I_P = R \times P_0$

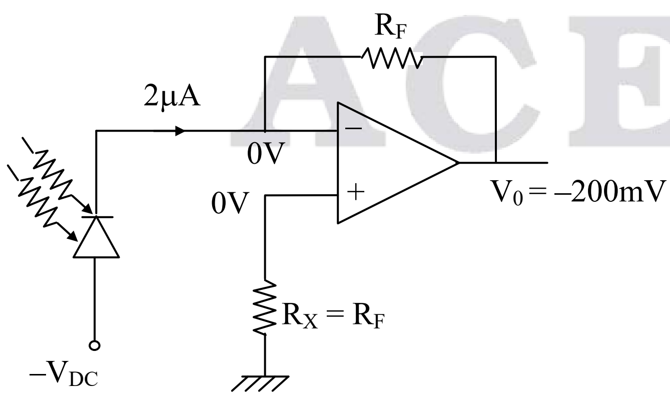
$= 1A/w \times 500 nw/cm^2 \times 400 mm^2$.

$\therefore\ I_p = 1 \times 500 \times 10^{-9} W/cm^2 \times 4 cm^2$

$= [1 \times 500 \times 10^{-9} \times 4]$ Amp

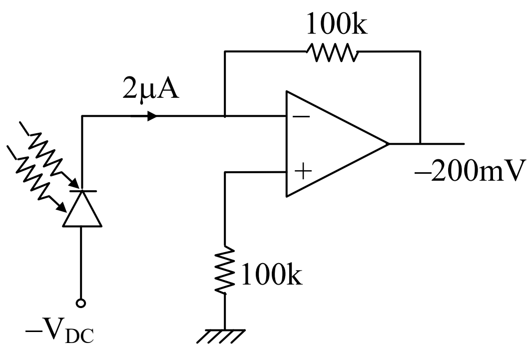
$= 2\mu A$

(3) Now from the circuit, by virtual short, $I_{R_f} = 2\mu A = \dfrac{0-(-200m)}{R_f}$



Hence, $R_f = \dfrac{200mA}{2\mu A} = 100k\Omega$

Hence the design is →



(ii) $I = I_s(e^{V/\eta V_T} - 1) \approx I_s e^{V/\eta V_T}$

$V_{D1} = 0.5V \rightarrow I_{D1} = 5\mu A$

$V_{D2} = 0.6V \rightarrow I_{D2} = 100\mu A$

$I_D = I_s e^{V_D/\eta V_T}$

$\Rightarrow V_D = \eta V_T \, ln\left(\frac{I_D}{I_S}\right)$

$V_{D2} - V_{D1} = \eta V_T \, ln\left(\frac{I_{D2}}{I_{D1}}\right)$

$0.6 - 0.5 = \eta \times 0.0258 \times ln\left(\frac{100\mu A}{5\mu A}\right)$

$\eta = 1.294$

$\rightarrow I_{D1} = I_s e^{V_{D1}/\eta V_T}$

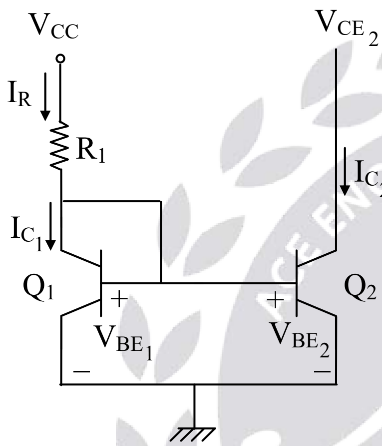
$\Rightarrow I_S = \frac{5 \times 10^{-6}}{e^{0.5/1.294 \times 0.0258}}$

$I_S = 1.56 \times 10^{-12}$ A

04. (b) (i) (I) Design the basic current source shown in the figure below to give an output current, $I_0 = 5\ \mu A$.

(II) For Q4(b)(i)(I) calculate the output resistance R_0, Thevenin's equivalent voltage V_{TH}, and the collector current ratio if $V_{CE_2} = 20V$.

The BJT parameters are $\beta_F = 100$, $V_{CC} = 30V$, $V_{BE_1} = V_{BE_2} = 0.7V$, and the early voltage $V_A = 150V$.



(5×2 = 10 M)

(ii) Using the phasor approach, determine the current i(t) in a circuit described by the integro-differential equation $4i + 8\int idt - 3\dfrac{di}{dt} = 50\cos(2t + 75^\circ)$. (10 M)

Sol:

(i) **(I)** Now from the given data,

$\beta_{F_1} = \beta_{F_2} \Rightarrow$ we could consider as identical transistors

Then the design would be $\rightarrow$

$$I_{B_1} = I_{B_2} \Rightarrow I_B = 2I_{B_1} = 2I_{B_2}$$

$$I_{C_1} = I_{C_2} \Rightarrow I_{C_1} = I_{C_2} = I_0 = 5\mu A$$

Also, $I_{ref} = I_{C_1} + I_B = 5\mu + 2I_{B_2}$

$$\therefore\ I_{ref} = 5\mu + \frac{2}{\beta_F} I_{C_2} = 5\mu + \frac{2}{100} \times 5\mu$$

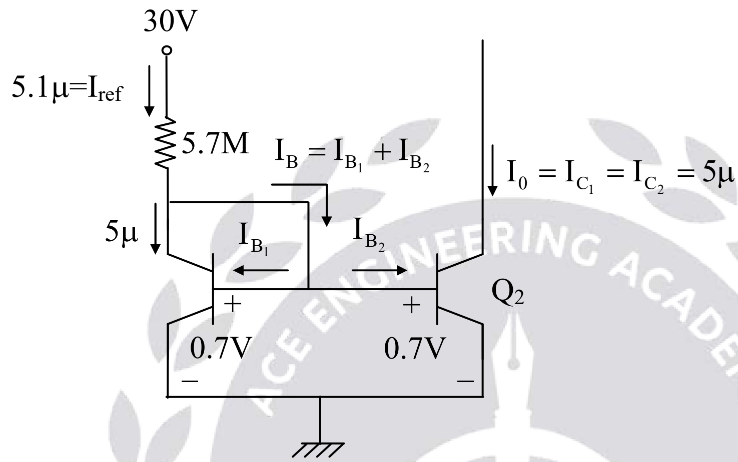
$$\therefore\ I_{ref} = 5\mu\left[1 + \frac{2}{100}\right] = 5.1\mu A$$

Now from circuit

$$R_1 = \frac{30 - .07}{I_{ref}} = \frac{30 - 0.7}{5.1\mu}$$

$R_1 = 5.7M\Omega$

Hence the design is →



(II) Since $I_{C_1} = I_{C_{01}} \exp\left(\frac{V_{BE_1}}{V_T}\right)\left(1 + \frac{V_{CE_1}}{V_A}\right)$

In forward achieve due to early effect

Also, since $I_{C_2} = I_{C_{02}} \exp\left(\frac{V_{BE_2}}{V_T}\right)\left(1 + \frac{V_{CE_2}}{V_A}\right)$

So, $\frac{I_{C_1}}{I_{C_2}}$ for $V_{BE_1} = V_{BE_2}$

$$I_{0_1} = I_{0_2}$$

and $V_{CE_2} = 20V$, with V_A for both transistors = 150V

Then from circuit,

$V_{CC} = I_{ref}(R_1) + V_{CE_1}$

$30 = 5.1\mu\,(5.7\mu) + V_{CE_2}$

$\Rightarrow V_{CE_1} = 30 - 29.07 = 0.93V$

$$\therefore\ \frac{I_{C_1}}{I_{C_2}} = \frac{1+\frac{V_{CE_1}}{V_A}}{1+\frac{V_{CE_2}}{V_A}} = \frac{1+\frac{0.93}{150}}{1+\frac{20}{150}} = \frac{1.0062}{1.133} = 0.88$$

$$\therefore\ \frac{I_{C_1}}{I_{C_2}} = 0.88\ \ \text{(or)}\ \ \frac{I_{C_2}}{I_{C_1}} = 1.128$$

Also output resistance, $R_0 = (r_0)_{Q_2} = \frac{V_A}{I_{C_2}} = \frac{150\,V}{5\,\mu A} = 30\,M\Omega$.

(ii) Considering the given function is clearly KVL

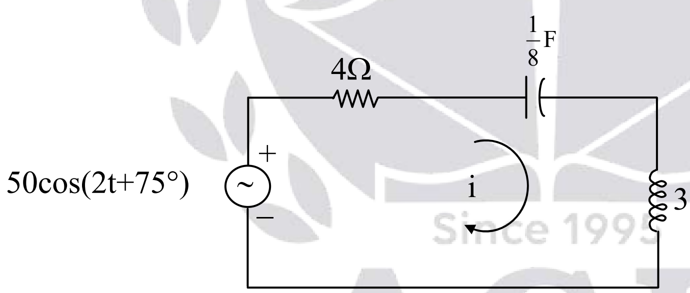
$$iR + \frac{1}{C}\int idt + L\frac{di}{dt} = V_S$$

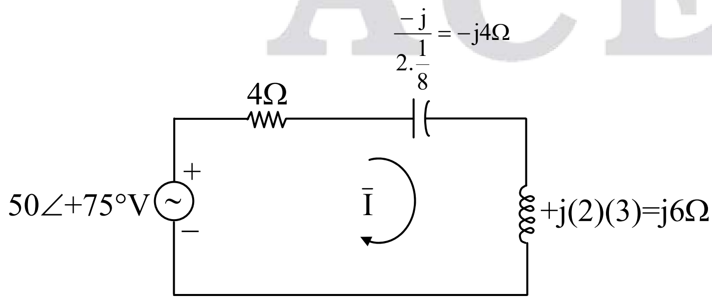
But R = 4Ω

$C = \frac{1}{8}$

L = 3H

ω = 2 (given)





$$-[50\angle 75^o] + \bar{I}4 - j4\bar{I} + 6\bar{I} = 0$$

$$\bar{I}[4 + j2] = 50\angle 75^o$$

$$\bar{I} = \frac{50\angle 75^\circ}{(4 + j2)} = \frac{50\angle 75^\circ}{4.472\angle 26.56^\circ}$$

$$\bar{I} = 11.18\angle 48.78 = 11.18\cos(2t + 48.44)\,A$$

04. (c) (i) Draw a schematic cross-sectional view of a MOSFET transistor. How is the insulating layer fabricated in it and what are the parameters that control the thickness of this layer? (10 M)

(ii) Classify magnetic materials; and calculate the saturation magnetization and the saturation flux density for nickel. (10 M)

Given : Density of nickel = $8.90 g/cm^3$

Atomic weight of nickel = 58.71g/mol

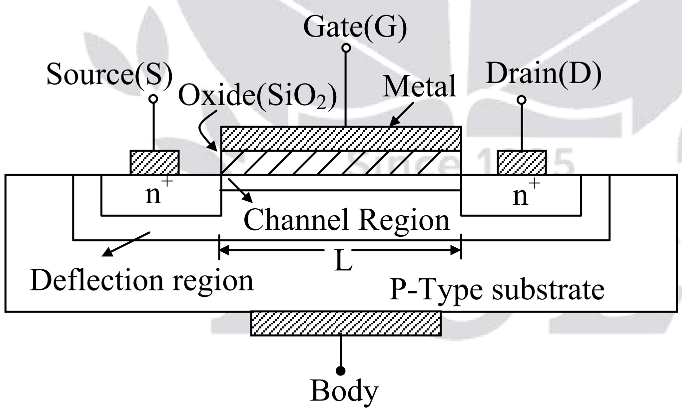
Net magnetic moment per atom for nickel = 0.60 Bohr magneton

Bohr magneton = 9.27×10^{-27} A-m^2

Avogadro's number = 6.023×10^{23} g/mol

Sol:

(i)



Cross sectional view of MOSFET

→ In MOSFET, the insulating layer we use is known as SiO_2 layer. The insulating silicon dioxide layer is formed through a process of self-limiting oxidation, which is described by the Deal-grove model. A conductive gate material is subsequently deposited over the gate oxide to form the transistor.

Thermal Oxidation:

It is the process of growing a thin layer of oxide on the surface of a wafer. This process is usually performed at a temperature between 900°C & 1100°C. It uses either dry oxidation or wet oxidation.

For dry oxidation — For wet oxidation

$Si + O_2 \rightarrow SiO_2$ — $Si + 2H_2O \rightarrow SiO_2 + 2H_2$

The most commonly used mathematical model to estimate oxide thickness is Deal-grove model

$$t = \frac{Ax + y^2x^2}{B}$$

Parameter that Control the thickness of SiO_2

→ Pressure

→ temperature

→ Diffusion time

(ii) Classification of magnetic material

(a) Dia magnetic material

(b) Para magnetic material

(c) Ferro magnetic material

(d) Antiferro magnetic material

(e) Ferri magnetic material

Given data $\rho_{Ni} = 8.9$ g/cm^3

AW = 58.71 g/mol

Net magnetic moment per atom = 0.6 Bohr magneton

Bohr magneton = 9.27×10^{-27} A-m^2

Avagadro's number = 6.023×10^{23} g/mol

No. of atoms per unit volume in Ni = $N = \frac{\rho \times AN}{AW}$

$$N = \frac{8.9\times10^6 \times 6.023\times10^{23}}{58.71} = 0.9130\times10^{29}\,\text{atoms/m}^3$$

Saturation magnetization = $\mu_s = N\times D_m$

$$= \left(\frac{\rho \times AN}{AW}\right) \times 0.6 \times 9.27 \times 10^{-27}$$

$$= \frac{8.9 \times 10^{6} \times 6.023 \times 10^{23}}{58.71} \times 0.6 \times 9.27 \times 10^{-27}$$

$$= 5.078 \times 10^{2} \text{ A/m}$$

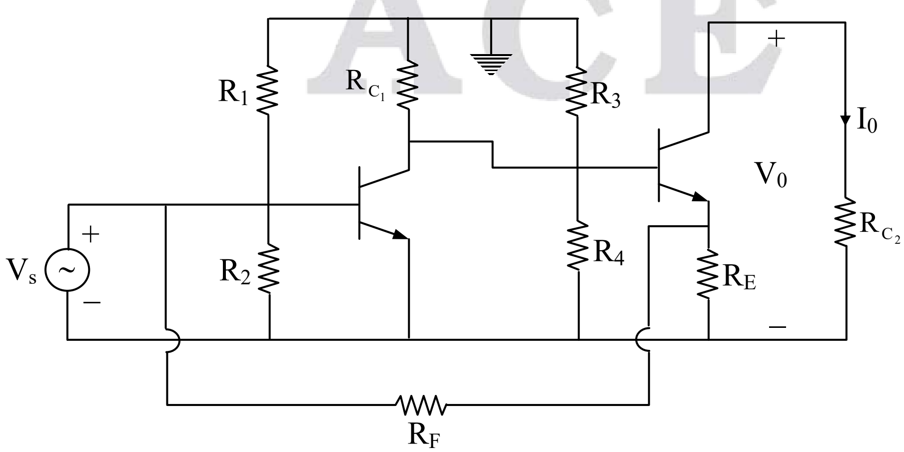
Saturation flux density = $B_s = \mu_0 \, \mu_s$

$$= 4\pi \times 10^{-7} \times 5.078 \times 10^{2}$$

$$= 63.77 \times 10^{-5} \text{ Wb/m}^2$$

SECTION - B

05. (a) The open loop gain of the amplifier shown in the figure below has break frequency at f_{p1} = 100kHz, f_{p2} = 1 MHz and f_{p3} = 10 MHz. The low frequency gain is A_o = 200 A/A and the emitter resistance R_E = 500 Ω. Determine the value of compensating capacitor C_F and resistance R_F to give (i) low frequency closed loop gain of A_f = 20 A/A and cancel the pole f_{p1} = 100 kHz, and (ii) to add pole of f_p = 10 MHz and cancel the pole f_{p1} = 100 kHz.



(12 M)

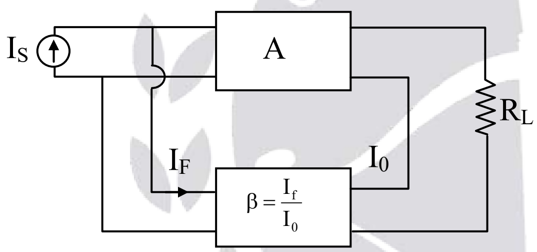
Sol: Given the open loop amplifier 3 break frequencies

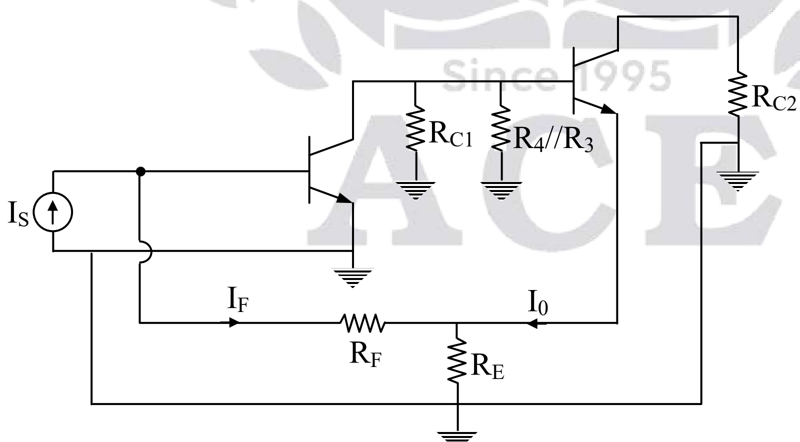
$$A = \frac{A_0}{\left(1+\frac{S}{\omega_1}\right)\left(1+\frac{S}{\omega_2}\right)\left(1+\frac{S}{\omega_3}\right)}$$

$$= \frac{200}{\left(1+j\frac{\omega}{\omega_1}\right)\left(1+j\frac{\omega}{\omega_2}\right)\left(1+j\frac{\omega}{\omega_3}\right)}$$

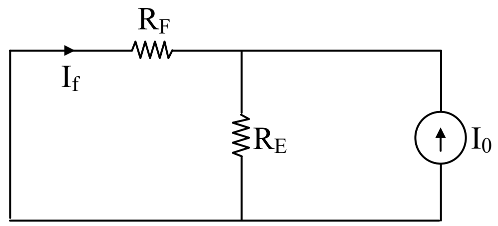
$$= \frac{200}{\left(1+j\frac{f}{100k}\right)\left(1+j\frac{f}{1M}\right)\left(1+j\frac{f}{10M}\right)}$$

Feedback is shunt series (or) current shunt feedback





The closed loop gain $\frac{I_0}{I_S} = \frac{A}{1+A\beta} = \frac{1}{\beta}$



$$-I_f = \frac{I_0 . R_E}{R_E + R_F}$$

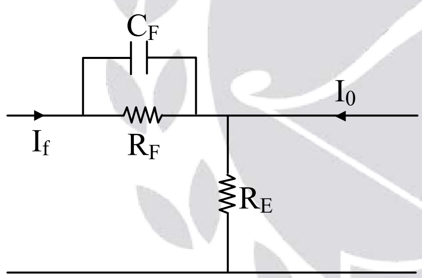
$$\beta = \frac{I_f}{I_0} = \frac{-R_E}{R_E + R_F}$$

$$\text{closed loop gain } = \frac{1}{\beta} = \frac{R_E + R_F}{R_E} = 20\left(\frac{A}{A}\right)$$

But $R_E = 500\Omega$ (given)

$$\therefore\ 1 + \frac{R_F}{500} = 20 \rightarrow R_F = 9.5k\Omega$$

Let us design a compensation network



$$\beta = \left|\frac{I_f}{I_0}\right| = \frac{R_E}{R_E + \left(R_F // \frac{1}{SC_F}\right)} = \frac{R_E}{R_E + \frac{R_F}{1 + SC_F R_F}}$$

$$= \frac{R_E(1 + SC_F R_F)}{R_F + R_E(1 + SC_F R_F)}$$

$$= \frac{R_E(1 + SC_F R_F)}{(R_E + R_F)\left(1 + \frac{SC_F R_F R_E}{R_F + R_E}\right)}$$

$$A\beta = \frac{A_0\left(\frac{R_E}{R_E + R_F}\right)(1 + SC_F R_F)}{\left(1 + j\frac{f}{100k}\right)\left(1 + j\frac{f}{1M}\right)\left(1 + j\frac{f}{10M}\right)(1 + SC_F(R_F // R_E))}$$

In order to cancel a pole at 100kHz

$$f = \frac{1}{2\pi\tau} = \frac{1}{2\pi C_F R_F} = 100k$$

$R_F = 9.5k\Omega \rightarrow$

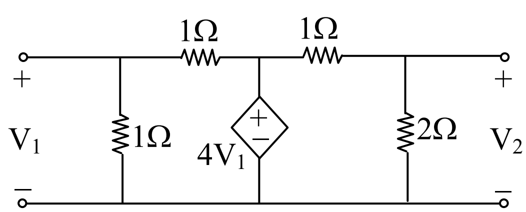
$$C_F = \frac{1}{2\pi R_F (100k)}$$

$\therefore C_F = 1.675 \times 10^{-10}F = 0.1675nF$

$$\left[\text{For } (1 + SCR_F) = \left(1 + j\frac{f}{100k}\right) = \left(1 + \frac{S}{\omega_1}\right)\right]$$

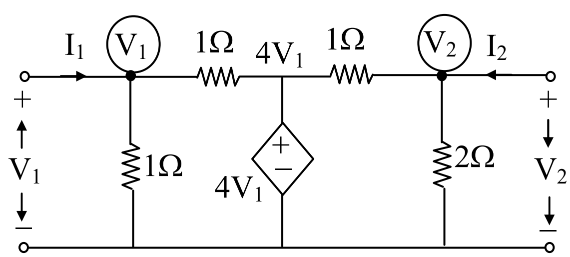
$$f = \frac{1}{2\pi C_F (R_F // R_E)} = \frac{1}{2\pi (0.1675nF)(500 // 9.5k)} = 2MHz$$

05. (b) Determine the Z-parameters for the two-port network shown and check for its symmetry and reciprocity.



(12 M)

Sol:



By KCL at V_1

$$I_1 = \frac{V_1}{1} + \frac{V_1 - 4V}{1}$$

$I_1 = -2V \qquad \text{-----} (1)$

By KCL at V_2

$$I_2 = \frac{V_2}{2} + \frac{V_2 - 4V_1}{1}$$

$$I_2 = \frac{3}{2}V_2 - 4V_1$$

$$I_2 = -4V_1 + \frac{3}{2}V_2 \qquad \text{- - - - - (2)}$$

From (1) & (2) get Y-Parameters

$$I_1 = -2V_1 + (0)V_2$$

$$I_2 = -4V_1 + \frac{3}{2}V_2$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} -2 & 0 \\ -4 & \frac{3}{2} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$[Z] = [Y]^{-1} = \frac{1}{-3-(0)} \begin{bmatrix} \frac{3}{2} & 0 \\ 4 & -2 \end{bmatrix}$$

$$[Z] = \begin{bmatrix} -\frac{1}{2} & 0 \\ -\frac{4}{3} & \frac{2}{3} \end{bmatrix}$$

$Z_{11} \neq Z_{22} \Rightarrow$ Network is not symmetry

$Z_{12} \neq Z_{21} \Rightarrow$ Network is not Reciprocal

05. (c) What is superconductivity? How are the superconducting materials classified? Give the applications of high temperature superconductors, in brief. (12 M)

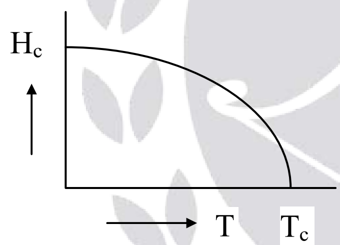
Sol: Super conductivity:- It is a state of material below a critical transition temperature it's resistivity is zero.

In 1911, Kammerling Onnes discovered that the resistivity of pure mercury decreases with temperature and abruptly becomes zero at a sharp critical temperature of 4.2K. At the $T<T_C$ material shows zero resistivity and becomes a superconductor, at $T \geq T_C$ it is a Normal Conductor (NC).

- About 21 elements are found to exhibit Superconductivity property. Generally the valency of the element varies between 2 and 8.
- Alkali metals like sodium, noble metals like Cu, Au, Ag etc and ferro, antiferro magnetic materials do not become superconductors.
- Type-II superconductors are usually alloys and transition metals
- Addition of non-magnetic impurities have no (or) very little effect on superconductivity.
- Addition of magnetic impurities decreases the critical temperature
- Currents once setup in superconductor rings continue to flow for very long time and are called *persistent currents*.
- Magnetic fields are capable of destroying superconductivity: It is called critical field

  $H_C = H_C(0)\left[1 - \frac{T^2}{T_C^2}\right]$ Thus H_C

  depends on the T of the super conductor below T_C.



Types of super conductor:-

(i) Type - I (soft) superconductors have only one critical field BC and can exist in two states only. (NC or SC).

- There are Type - II (hard) superconductors (usually alloys) which have two critical field values (B_{C1} & B_{C2}) and can exist in 3 states (NC, Mixed and SC).
- Between B_{C1} and B_{C2} , they exist in Mixed state, and do not show complete Meissner effect here they are superconducting but start allowing magnetic flux lines to pass through i.e. don't exhibit perfect diamagnetism.
- For Type – I SCs, magnetization M abruptly becomes zero at B_C whereas for Type – II SCs it gradually decreases to zero between B_{C1}andB_{C2} that is in mixed state.
- When a specimen becomes a superconductor, its thermal conductivity decreases $\Rightarrow$ the superconductivity is not due to ordinary conduction electrons.

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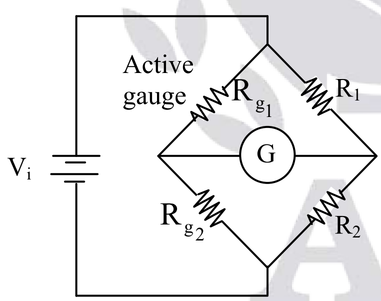
- When a specimen becomes a superconductor, its entropy decreases ⇒ superconducting state is less disorderly state.
- When a specimen becomes a superconductor, its electronic specific heat changes abruptly and decreases exponentially in superconducting state ⇒ There must be some energy gap in superconductors.

This energy gap in super conductors is about.

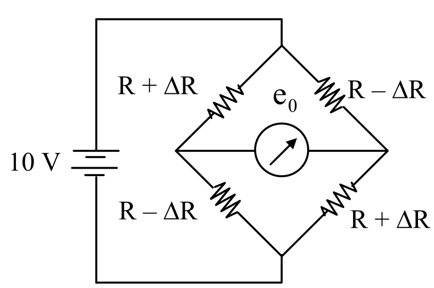
05. (d) How is the temperature compensation achieved in the measurement of strain?

The unstrained resistance of each of the four elements of the unbounded strain gauge is 120 Ω. The strain gauge has a gauge factor of 3 and is subjected to a strain of 10^{-4}. If the detector is a high impedance voltmeter, calculate the reading of this voltmeter for a battery voltage of 10 V. Assume the bridge arms A and D are under tension whereas arms B and C are under compression. (12 M)

Sol: In order to cancel the temperature effects on the strain gauge it is important to use a dummy gauge in the neighbourhood of the active gauge. Both the active and dummy gauges are identical in all aspects. They have same temperature coefficient of resistance & temperature coefficient of expansion.



Due to temperature changes, if any change in R_{g_1} is exactly compensated by the some change made in R_{g_2}. In above figure temperature compensation is shown.



$$\frac{\Delta R}{R} = G_f \varepsilon$$

$G_f = 3,\ R = 120\ \Omega$

$\varepsilon = 10^{-4}$

$e_i = 10V$

$\Delta R = 3 \times 10^{-4} \times 120 = 360 \times 10^{-4} = 0.036\,\Omega$

$R + \Delta R = 120.036\,\Omega$

$R - \Delta R = 119.964\,\Omega$

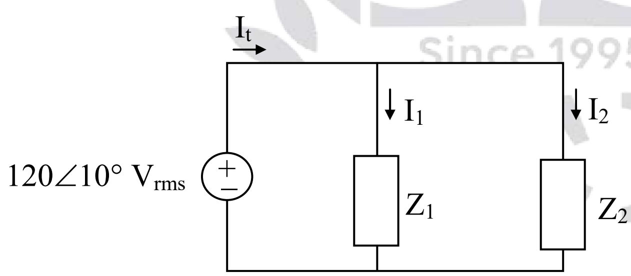
$$e_0 = e_i \times \left(\frac{R - \Delta R}{(R - \Delta R) + (R + \Delta R)} - \frac{R + \Delta R}{(R - \Delta R) + (R + \Delta R)} \right)$$

$$e_0 = 10 \times \left(\frac{119.964}{119.964 + 120.036} - \frac{120.036}{119.964 + 120.036} \right)$$

$$e_0 = 10 \times (0.49985 - 0.50015)$$

$$e_0 = -3mV$$

05. (e) In the circuit shown in figure $Z_1 = 60\angle -30^\circ\ \Omega$ and $Z_2 = 40\angle 45^\circ\ \Omega$. Calculate the total (i) apparent power. (ii) real power, (iii) reactive power, and (iv) P.f.



(12 M)

Sol: Current through Z_1 is

$$I_1 = \frac{V}{Z_1} = \frac{120\angle 10^\circ}{60\angle -30^\circ} = 2\angle 40^\circ\,A \qquad \text{(RMS)}$$

Current through Z_2 is

$$I_2 = \frac{V}{Z_2} = \frac{120\angle 10^\circ}{40\angle 45^\circ} = 3\angle -35^\circ\,A \qquad \text{(RMS)}$$

Complex power absorbed by the impedance are

$$S_1 = \frac{V_{RMS}^2}{Z_1^*} = \frac{(120)^2}{60\angle 30^\circ} = 240\angle -30^\circ$$

$= (207.85 - j120)$ VA's

$$S_2 = \frac{V_{RMS}^2}{Z_2^*} = \frac{(120)^2}{40\angle -45^\circ} = 360\angle 45^\circ$$

$= (254.6 + j254.6)$VA

Total complex power is

$S_T = S_1 + S_2 = (462.4 + j134.6)$ VA

(i) Total apparent power is

$$|S_T| = \sqrt{(462.4)^2 + (134.6)^2} = 481.6\text{VA}$$

(ii) Total real power is

$P_T = \text{Re}\,[S_T] = 462.4$W

(or) $P_T = P_1 + P_2$

(iii) Total reactive power is

$Q_T = \text{Im}[S_T] = 134.6$ VAR

(or) $Q_T = Q_1 + Q_2$

(iv) $\text{P.F} = \frac{P_T}{|S_T|} = \frac{462.4}{481.6} = 0.96(\text{lagging})$

06. (a) (i) In a CRT, the anode to cathode voltage is 2 kV. The parallel deflector plates are 1.5cm long and spaced 5 mm apart. The screen is 50 cm from the centre of the deflecting plates. Find the beam speed and deflection sensitivity of the tube. Mass of electron = 9.109×10^{-31} kg, Charge on electron = 1.602×10^{-19} C. (10 M)

(ii) The coil of a moving iron voltmeter has a resistance of 500 Ω and an inductance of 1.0 H. The series resistor is 2 k Ω. When 250 V dc is applied, the voltmeter reads 250 V. Find the reading when an ac voltage of 250 V, 50 Hz is applied. What is the per cent error? What capacitance must be connected in parallel with the series resistor to remove this error? (10 M)

Sol:

(i) $V_a = 2kV$

$L = 1.5cm$

$s = 5mm$

$D = 50\,cm$

$m = 9.109\times10^{-31}$ kg

$e = 1.602\times10^{-19}$ C

We know V_x = Beam Speed

$$\Rightarrow V_x = \sqrt{\frac{2eV_a}{m}} = \sqrt{\frac{2\times1.602\times10^{-19}C\times2kV}{9.109\times10^{-19}kg}} = 26.52\times10^{6}\ m/sec$$

S_V = Deflection Sensitivity

$$\Rightarrow S_V = \frac{LD}{2sV_a} = \frac{1.5\,cm\times50\,cm}{2\times5\,mm\times2kV} = 3.75\times10^{-4}\ m/V = 0.375\ mm/V$$

(ii) $R_m = 500\Omega$; $L_m = 0.1H$; $R_{se} = 2000\ \Omega$

$V_{DC} = 250V$

$V_{AC} = 250V$, f = 50Hz

$\%\in$ = ?　　　C = ?

$$I_{FSD} = \frac{V_{DC}}{R_{total}} = \frac{250}{2500} = 0.1A$$

$$V_{AC_{reading}} = 0.1\left[\sqrt{(2500)^2 + (2\times\pi\times50\times0.1)^2}\right]$$

$= 250.019$ volts

$$I_{AC} = \frac{250}{z} = \frac{250}{2500.19} = 0.099\,A$$

$$\%\in = \frac{0.0999-0.1}{0.1}\times100 = -0.1\%$$

$$C = 0.41\frac{L_m}{R_{se}^2} = 0.41\times\frac{0.1}{(2000)^2} = 1.025\times10^{-8}\ F$$

06. (b) (i) An ac bridge has the following constants:

arm AB, R = 1 k Ω in parallel with C = 0.159μF;

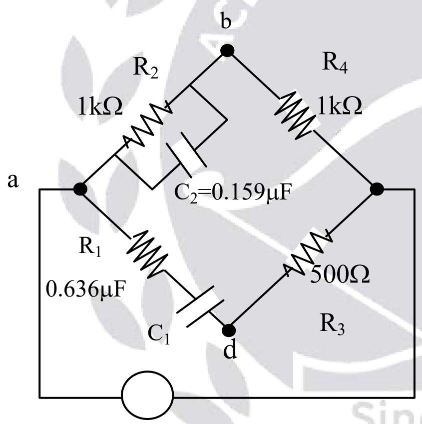
arm BC, R = 1 k Ω; arm CD, R = 500 Ω; arm DA, C = 0.636 μF in series with an unknown resistor. Find the frequency for which the bridge is in balance and determine the value of resistance in arm DA to produce this balance. (10 M)

(ii) A dynamometer type wattmeter connected normally to read power in a single phase circuit indicates the value P_1. A second reading P_2 is obtained when a capacitor of reactance equal to the pressure coil resistance is connected in series with pressure coil. Show that the phase angle of the load can be obtained from the expression:

$$\tan\phi = 1 - \frac{2P_2}{P_1}$$ **(10 M)**

Sol:

(i)



$Z_1Z_4 = Z_2\,Z_3$

$$\frac{R_1}{R_2} + \frac{C_2}{C_1} = \frac{R_3}{R_4}$$

$$\frac{R_1}{1000} + \frac{0.159\times10^{-6}}{0.636\times10^{-6}} = \frac{500}{1000}$$

$R_1 = 250\Omega$

$$f = \frac{1}{2\pi\ R_1R_2C_1C_2}$$

$$= \frac{1}{2\times\pi\times250\times100\times0.159\times10^{-6}\times0.636\times10^{-6}}$$

$= 62.9$ MHz

(ii) In a dynamometer type wattmeter, the pressure coil connected across the supply is highly resistive.

Now given, a capacitor of reactance equal to the pressure coil resistance is connected in series with the pressure coil.

$$Z = R_p + j(X_L - X_C) \approx R_p - j\,X_c$$

$$\text{Angle } \beta = \text{Tan}^{-1}\left(\frac{-X_C}{R_p}\right)$$

Given, $R_p = X_{C2}$

$\Rightarrow \beta = -45°$

Wattmeter reading $(P_1) = \frac{VI}{R_p}\cos\phi.(dM/d\theta)$

Wattmeter reading (P_2) due to angle β is = $\frac{VI}{R_p}\cos\beta\cos(\phi-\beta).(dM/d\theta)$

$$\frac{P_1}{P_2} = \frac{\frac{VI}{R_p}\cos\phi(dM/d\theta)}{\frac{VI}{R_p}\cos\beta\cos(\phi-\beta)(dM/d\theta)} = \frac{\cos\phi}{\cos\beta\cos(\phi-\beta)}$$

$$\frac{P_1}{P_2} = \frac{\cos\phi}{\cos(-45°)\cos(\phi+45°)}$$

$$\frac{P_2}{P_1} = \frac{\cos(\phi+45°)}{\sqrt{2}\cos\phi}$$

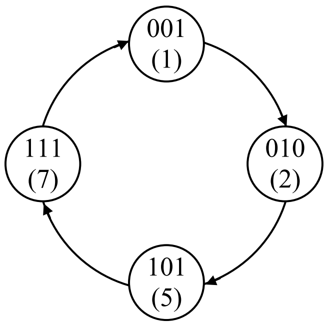
$$\frac{P_2}{P_1} = \frac{\cos(\phi+45°)}{\sqrt{2}\cos\phi}$$

$$\frac{P_2}{P_1} = \frac{\cos\phi\cos 45° - \sin\phi\sin 45°}{\sqrt{2}\cos\phi}$$

$$\frac{P_2}{P_1} = \frac{1}{2} - \frac{1}{2}\tan\phi$$

$$\therefore\ \tan\phi = \left(1 - \frac{2P_2}{P_1}\right)$$

06. (c) Design a counter with the irregular binary count sequence shown in the state diagram of the following figure. use J-K flip-flops.



(20 M)

Sol: From the state diagram,

$Q_C\ Q_B\ Q_A$	$Q_C^+\ Q_B^+\ Q_A^+$	$J_C\ K_C$	$J_B\ K_B$	$J_A\ K_A$
0 0 1	0 1 0	0 ×	1 ×	× 1
0 1 0	1 0 1	1 ×	× 1	1 ×
1 0 1	1 1 1	× 0	1 ×	× 0
1 1 1	0 0 1	× 1	× 1	× 0

From the above table,

$J_B = 1$; $K_B = 1$; $J_A = 1$; states 0, 3, 4, 6 are unused states consider them as don't cares.

K-map for J_C:-

$J_C(Q_C, Q_B, Q_A) = \Sigma m\ (2) + d\ (0, 3, 4, 6, 5, 7)$

$Q_C \backslash Q_BQ_A$				
	×	0	×	1
	×	×	×	×

$\therefore\ J_C = Q_B$

K-map for K_C:-

$K_C(Q_C, Q_B, Q_A) = \Sigma m\ (7) + d\ (0, 3, 4, 6, 1, 2)$

$Q_C \backslash Q_BQ_A$				
	×	×	×	×
	×	0	1	×

$\therefore\ K_C = Q_B$

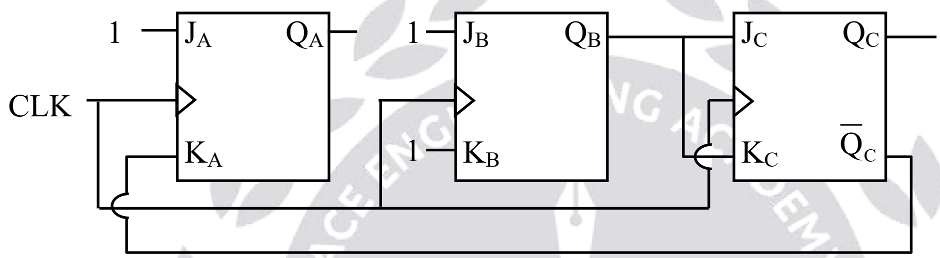
K-map for K_A:-

$K_A(Q_C, Q_B, Q_A) = \Sigma m\ (1) + d\ (0, 3, 4, 6, 2)$

$Q_C \backslash Q_B Q_A$

×	1	×	×
×	0	0	×

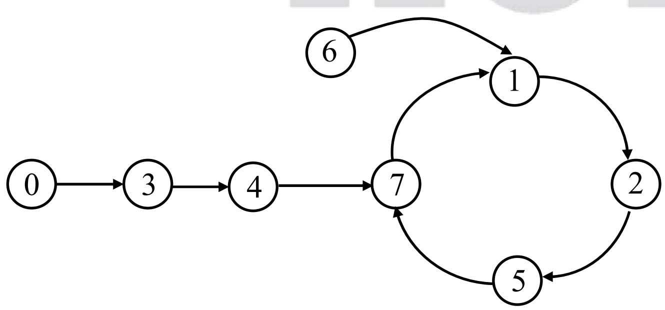
$\therefore\ K_A = \overline{Q}_C$



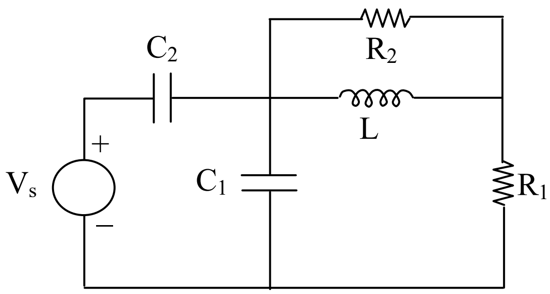
Lock-Out Condition:

P.S.	Inputs						N.S.
$Q_C\ Q_B\ Q_A$	J_C	K_C	J_B	K_B	J_A	K_A	$Q_C^+\ Q_B^+\ Q_A^+$
0 0 0	0	0	1	1	1	1	0 1 1
0 1 1	1	1	1	1	1	1	1 0 0
1 0 0	0	0	1	1	1	0	1 1 1
1 1 0	1	1	1	1	1	0	0 0 1

Even if the counter starts with 000, there is no problem ,the state diagram as follows



07. (a) (i) For the circuit shown, obtain the state equations for $R_1 = R_2 = R$.

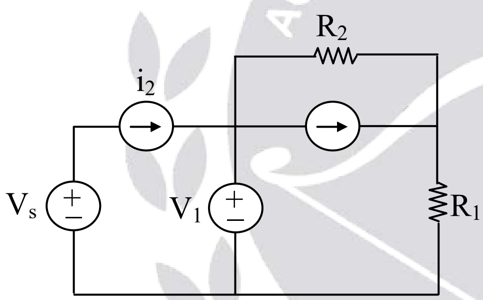


(12 M)

(ii) A two-element series circuit is connected across an ac source given by $e(t) = 200\sqrt{2}$ sin (314 t + 20°). The current in the circuit is found to be $i(t) = 10\sqrt{2}$ cos (314 t – 25°). Determine the parameters of the circuit. **(8 M)**

Sol:

(i)

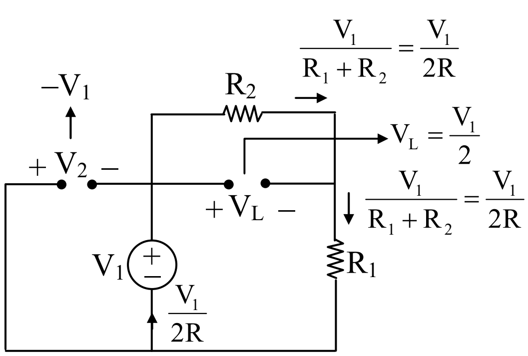


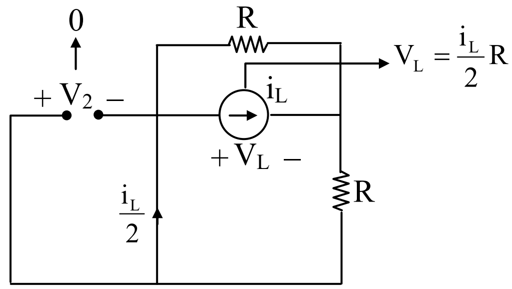
→ Here all voltage loop is formed by voltage source, C_1 and C_2

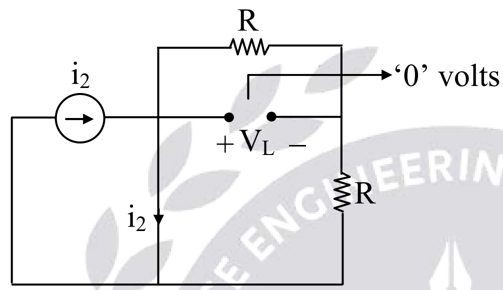
→ Let V_1 and i_L are the state variables

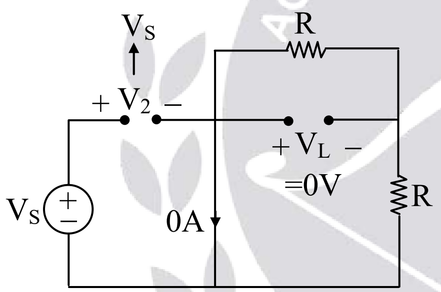
→ The capacitor C_2 excess element and its voltage $V_2 = [V_S - V_1]$

→ The order of complexity of network = 2









→ Voltage across inductor 'L' is sum of all four voltages

$$L\frac{di_L}{dt} = \frac{V_1}{2} - \frac{R}{2}i_L + 0 + 0$$

→ Also current through 'C_i' is sum of all four currents

$$C_1\frac{dV_1}{dt} = -\frac{V_1}{2R} - \frac{i_L}{2} + i_2 + 0$$

$$\text{but } i_2 = C_2\frac{dV_2}{dt} = C_2\frac{d}{dt}[V_S - V_1]$$

$$i_2 = C_2\frac{dV_S}{dt} - C_2\frac{dV_1}{dt}$$

Finally

$$\frac{di_L}{dt} = \frac{V_1}{2L} - \frac{R}{2L}i_L$$

$$\frac{di_L}{dt} = -\frac{R}{2L}i_L + \frac{V_1}{2L} \_\_\_\_\_\_(A)$$

$$\frac{dV_1}{dt} = -\frac{i_L}{2C_1} - \frac{V_1}{2RC_1} + \frac{i_2}{C_1} \_\_\_\_\_\_(B)$$

$$i_2 = C_2\frac{dV_S}{dt} - C_2\frac{dV_1}{dt} \_\_\_\_\_\_(C)$$

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dV_1}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R}{2L} & \frac{1}{RL} \\ -\frac{1}{2C_1} & -\frac{1}{2RC_1} \end{bmatrix}\begin{bmatrix} i_L \\ V_1 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{C_1} \end{bmatrix} i_2 \_\_\_\_\_\_(D)$$

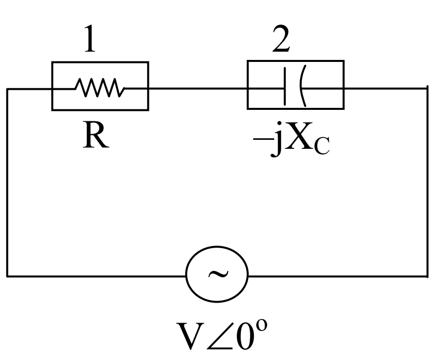
and $i_2 = [C_2 - C_2]\begin{bmatrix} \frac{dV_S}{dt} \\ \frac{dV_1}{dt} \end{bmatrix} \_\_\_\_\_\_(E)$

Substitute (E) in (D)

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dV_1}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R}{2L} & \frac{1}{2L} \\ -\frac{1}{2C_1} & -\frac{1}{2RC_1} \end{bmatrix}\begin{bmatrix} i_L \\ V_1 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{C_1} \end{bmatrix}[C_2 \quad -C_2]\begin{bmatrix} \frac{dV_S}{dt} \\ \frac{dV_1}{dt} \end{bmatrix}$$

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dV_1}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R}{2L} & \frac{1}{2L} \\ -\frac{1}{2C_1} & -\frac{1}{2RC_1} \end{bmatrix}\begin{bmatrix} i_L \\ V_1 \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ \frac{C_2}{C_1} & -\frac{C_2}{C_1} \end{bmatrix}\begin{bmatrix} \frac{dV_S}{dt} \\ \frac{dV_1}{dt} \end{bmatrix}$$

(ii) A two element series circuit



$$V(t) = 200\sqrt{2}\sin(314t + 20^\circ)V$$

$$i(t) = 10\sqrt{2}\cos(314t - 25^\circ)A$$

$$= 10\sqrt{2}\sin(314t - 25^\circ + 90^\circ)A$$

$$i(t) = 10\sqrt{2}\sin(314t + 65^\circ)A$$

$$V_t = \frac{200\sqrt{2}}{\sqrt{2}}\angle 20^\circ \text{ Volts} \quad i(t) = \frac{10\sqrt{2}}{\sqrt{2}}\angle 65^\circ \text{ Amps}$$

$$V = 200\angle 20^\circ \text{ Volts} \quad I = 10\angle 65^\circ \text{ Amps}$$

$$Z = \frac{V}{I} = \frac{200\angle 20^\circ}{10\angle 65^\circ} = 20\angle -45^\circ\,\Omega$$

$$Z = \frac{20}{\sqrt{2}} - j\frac{20}{\sqrt{2}} = \left(10\sqrt{2} - j10\sqrt{2}\right)$$

$$Z = (14.14 - j14.14)\Omega$$

$$R = 14.14\Omega$$

$$X_C = \frac{1}{\omega_C} = 14.14$$

$$C = \frac{1}{\omega(14.14)} = \frac{1}{(314)(14.14)} = 225.2\mu F$$

$$R = 14.14\Omega,\ C = 225.2\mu F$$

07. (b) (i) A chromel-constantan thermocouple has its cold junction at 0°C. The characteristics of the thermocouple is:

Temp. °C	**0**	**10**	**20**	**30**	**40**	**50**
emf mV	**0**	**0.593**	**1.191**	**1.8**	**2.415**	**3.02**

Find the temperature of the hot junction if the thermoelectric emf is 2.95 mV. (10 M)

(ii) A thermometer, initially at 70°C, is suddenly dipped in a liquid at 300°C. After 3 seconds, the thermometer indicates 200°C. After what time is the thermometer expected to give a reliable reading, say well within 1% of the actual value? (10 M)

Sol:

(i)

Temp - T(°C)	EMF - E (mV)
0	0
10	0.593
20	1.191
30	1.8
40	2.415
50	3.02

To fit the straight line

$$\frac{T-0}{50-0}=\frac{E-0}{3.02}$$

$$T=\frac{50}{3.02}\times 2.95\,\text{mV}$$

T = 48.84 °C

(ii) $\theta_0 = 70^\circ C$

$\theta_f = 300^\circ C$

$\theta(t) = \theta_f + (\theta_0 - \theta_f)e^{-t/\tau}$

$\theta(t) = 300 + (70-300)e^{-t/\tau}$

At t = 3sec $\quad \theta = 200^\circ C$

$200 = 300 + (70-300)e^{-3/\tau}$

$-100 = -230e^{-3/\tau}$

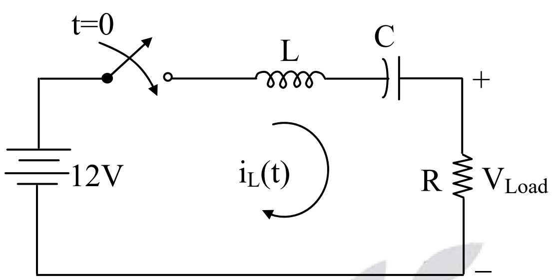
$0.435 = e^{-3/\tau}$

$$ln(0.435) = \frac{-3}{\tau}$$

$\tau = 3.604\,\text{sec}$

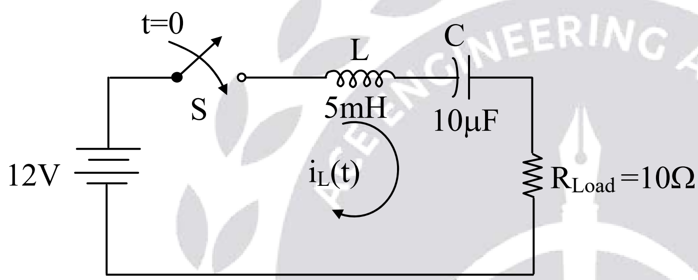
Since a reliable reading can be obtained at 5τ, the required time is = 5×3.604 ≈ 18 sec

07. (c) Find the load voltage as a function of time for the circuit shown in the figure. Assume no energy is stored in the capacitor and inductor before the switch closes. Circuit parameters: R = 10 Ω, C = 10μF, L = 5 mH.

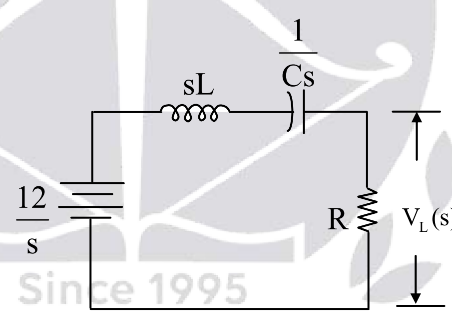


(20 M)

Sol:



For t > 0, 'S' is closed



$$V_L(s) = \frac{\frac{12}{s}\times R}{R + sL + \frac{1}{Cs}}$$

$$V_L(s) = \frac{12RC}{Cs^2 + RCs + 1} = \frac{12\,R/L}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$$V_L(s) = \frac{12\times\frac{10}{5m}}{s^2 + \frac{10}{5m}s + \frac{1}{10\times10^{-6}\times5\times10^{-3}}} = \frac{24000}{s^2 + 2000s + 20\times10^6}$$

$$V_L(s) = \frac{24000}{\sqrt{19}\times10^3}\left[\frac{\sqrt{19}\times10^3}{(s+1000)^2 + 19\times10^6}\right]$$

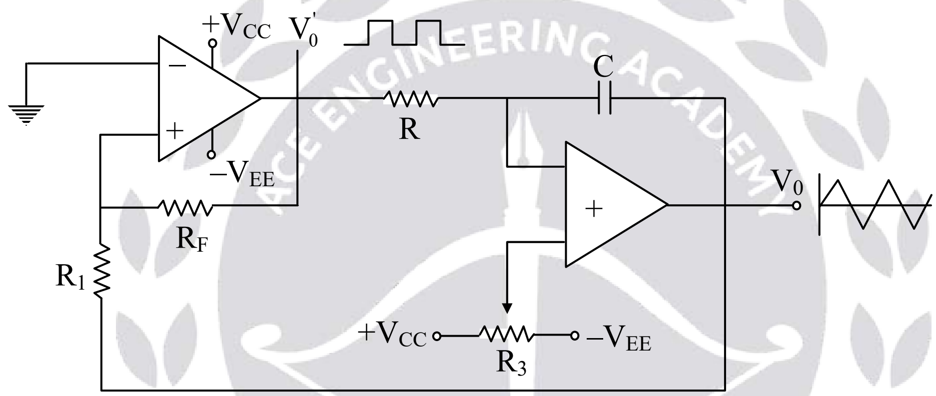
$$V_L(s) = \frac{24}{\sqrt{19}}\left[\frac{\sqrt{19}\times10^3}{(s+1000)^2 + \sqrt{19}\times(10^3)^2}\right]$$

By I.L.T

$$V_L(t) = \frac{24}{\sqrt{19}} e^{-1000t} \sin(\sqrt{19} \times 10^3)t$$

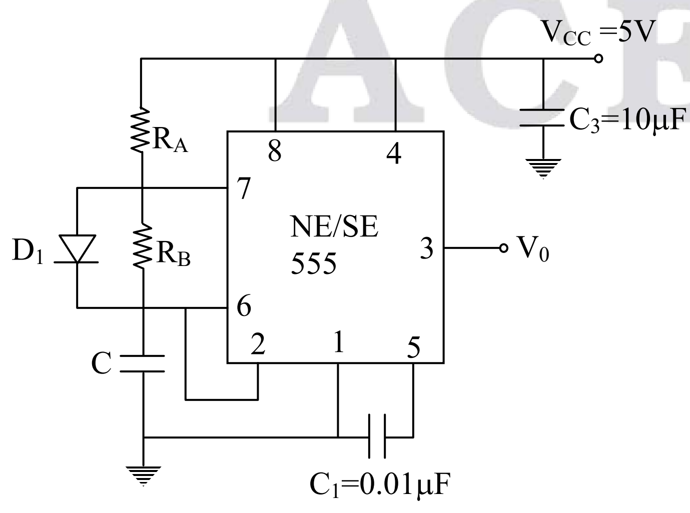
$$V_L(t) = 5.505 e^{-1000t} \sin 4358.89t \ \text{Volts} \qquad t > 0$$

08. (a) (i) Design a sawtooth waveform generator shown in the figure below, so that f_o = 4 kHz, threshold voltage V_{TH} = 5 V and the circuit has a duty cycle of 0.25. Assume $V_{sat} = |-V_{sat}|$ = 14 V, and R_1 = 10 kΩ, C = 0.01 μF.



(10 M)

(ii) Design a square wave generator as shown in the figure below, so that duty cycle is 50% and f_o = 2.5 kHz. Assume V_{CC} = 12 and C = 0.1 μF.



(10 M)

Sol:

(i) Step-1: Consider the formula for f_0 in a saw tooth waveform generator,

$$f_0 = \frac{R_f}{4RCR_1} \text{ ……(1)}$$

$$\Rightarrow R = \frac{R_f}{4f_0CR_1} \text{ ……..(2)}$$

Step-2: In the Schmitt trigger,

Consider $V_{UT} = -V_{LT} = \frac{R_1 V_{sat}}{R_1 + R_f}$ ……(3)

[∵ Duty cycle of saw tooth wave is 0.25 means duty cycle of square wave is 0.5,

i.e., $T_1 = \frac{T}{2} = \frac{T}{2}$]

$\Rightarrow R_1 + R_f = R_1 \frac{V_{sat}}{V_{Th}} = 10k\Omega\left(\frac{14V}{5V}\right) = 28k\Omega$ …….(4)

$\Rightarrow R_f = 28k\Omega - 10k\Omega = 18k\Omega$ ……….(5)

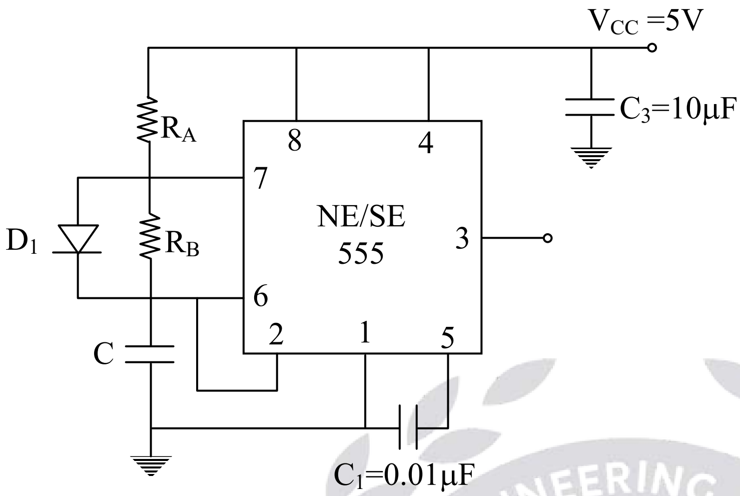
Step-3: Equation(5) in equation(2)

$$R = \frac{18k\Omega}{4.4kHz \times 0.01\mu F \times 10k\Omega} \text{ ………(6)}$$

$$= \frac{18k\Omega}{1.6}$$

$\therefore R = 11.25k\Omega$

(ii)



Step (1): During charging period of capacitor

$T_{charging} = 0.693\ R_AC$ _______(1)

During discharging period of capacitor,

$T_{Discharging} = 0.693\ R_BC$ _____(2)

Step (2) Duty cycle, $D = \dfrac{T_{charging}}{T_{charging} + T_{Discharging}}$ _____(3)

$$\Rightarrow\ 0.5 = \frac{0.693R_AC}{0.693R_AC + 0.693R_BC}$$

$$\Rightarrow\ 0.5 = \frac{R_A}{R_A + R_B}$$

$\Rightarrow R_A = R_B$ ______(4)

Step (3) counter $f_0 = \dfrac{1.45}{(R_A + R_B)C}$ ______(5)

$$\Rightarrow\ R_A + R_B = \frac{1.45}{2.5\text{kHz} \times 0.1\mu\text{F}}$$

$$\Rightarrow\ 2R_A = \frac{1.45}{0.25 \times 10^{-3}}$$

$= 5.8\text{k}\Omega$

$\therefore\ R_A = 2.9\text{k}\Omega$________(6)

Step (4): From equation (4)

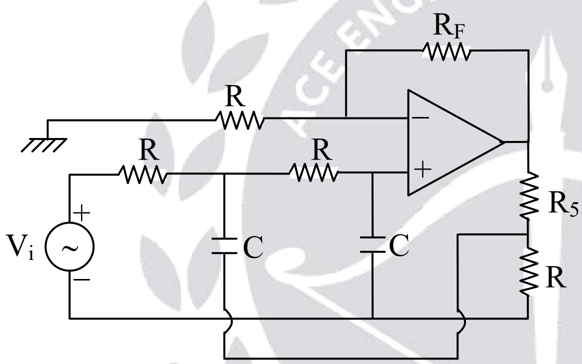
$R_B = R_A = 2.9k\Omega$________(7)

Step (5): Designed values.

$R_A = 2.9k\Omega$

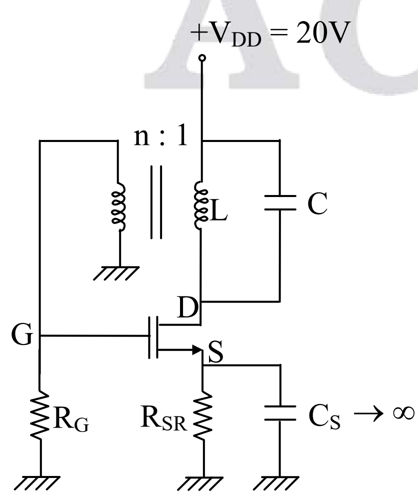
$R_B = 2.9k\Omega$

08. (b) (i) For a second order low pass filter as shown in the figure below, to give a high cutoff frequency of $f_H = f_o = 1$ kHz, a pass band gain K = 4, Q = 0.707 and C = 0.01 μF. Calculate resistance R, R_F and R5.



(10 M)

(ii) An LC tuned MOS oscillator is shown in the figure below. Find the value of oscillation frequency and n for L = 112.6μH and C = 0.01μF. The parameters of the MOSFET are $g_m = 5$ mA/V, $r_d = 25$ k Ω and $R_G = 10$ k Ω.



(10 M)

Sol:

(i) For LPF 2nd order, as Q = 0.707 ⇒ it is butterworth 2nd order LPF

$$\frac{V_0}{V_i} = \frac{k\omega_c^2}{S^2 + \frac{1}{Q}S\omega_c + \omega_c^2}$$

where $\omega_c = \frac{1}{RC}$

$$\Rightarrow f_c = \frac{1}{2\pi RC} = 1\text{kHz}$$

Given C = 0.01μ

$$\therefore 1k \times 2\pi \times 0.01\mu = \frac{1}{R}$$

$\therefore$ R = 16kΩ

Also, $k = 4 = \left[1 + \frac{R_f}{R}\right]$

$$\therefore 3 = \frac{R_f}{R} \Rightarrow R_f = 48k\Omega$$

(ii) Step (i) consider the general formula for frequency of oscillations in LC tuned oscillator,

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \_\_\_\_\_\_\_\_(1)$$

$$= \frac{1}{2\pi\sqrt{112.6\mu H \times 0.01\mu F}}$$

$$= \frac{1}{2\pi \times 1.06 \times 10^{-6}}\text{Hz}$$

$\therefore$ f_0 = 0.15MHz or = 150KHz _____(2)

Step (2): Consider the general formula for gain $|A_V| = g_m R_L$ _______(1)

where $R_L = r_d // \frac{R_G}{n^2}$ ________(2)

Note: at f_0, $|g_m R_L| = |A_V| = 1$ ________(3)

$$\Rightarrow R_L = \frac{1}{g_m} = \frac{1}{5mA/V} = 200\Omega \_\_\_\_\_(4)$$

Step (3): equation (4) in equation (3)

$$R_L = 200\Omega = 25k\Omega // \frac{10k\Omega}{n^2} \_\_\_\_\_\_\_\_(5)$$

$$\Rightarrow \frac{25k\Omega\left(\frac{10k}{n^2}\right)}{25k\Omega \frac{10k}{n^2}} = 200\Omega$$

$$\Rightarrow \frac{\frac{25k\Omega \times 10k\Omega}{n^2}}{\frac{25k\Omega \times n^2 + 10k\Omega}{n^2}} = 200\Omega \_\_\_\_\_(6)$$

$$\Rightarrow 250 \times 10^6\Omega = 5 \times 10^6 n^2 + 2 \times 10^6 = 10^6\,(5n^2 + 2) \_\_\_\_\_(7)$$

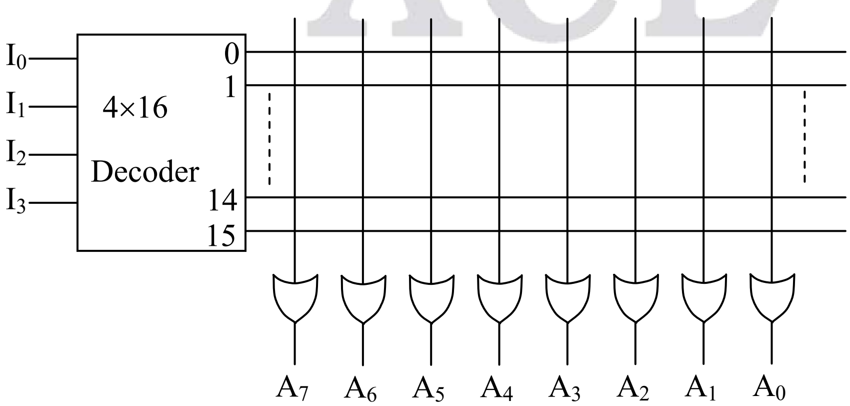
$$\Rightarrow 5n^2 = 248$$

$$\Rightarrow n^2 = 49.6 \_\_\_\_\_(8)$$

$$\therefore\ n = 7.04 \_\_\_\_\_(9)$$

08. (c) Draw a 16 × 8-bit ROM array, showing all the inputs and outputs. List the types of read-only memories and explain the differences. (20 M)

Sol:



TYPES OF ROMs

Two types of semiconductor technologies are used for the manufacturing of ROM ICs. These are bipolar technology and MOS technology which use bipolar devices and MOS devices respectively. The process of entering information into a ROM is referred to as programming the ROM. Bipolar ROMs and MOS ROMs use different mechanisms of programming. Depending upon the programming process employed, the ROMs are categorized as follows:

Mask programmable read-only memory (MROM)

In this type of read-only memory, the user specifies the data to be stores to the manufacturer of the memory. The data pattern specified by the user are programmed as a part of the fabrication process.

Once programmed, the data pattern can never be changed. This type of read-only memory is referred to as ROM. ROMs are highly suited for very high volume usage due to their low cost.

Programmable read-only memory (PROM)

This type of memory comes from the manufacturer without any data stored in it, i.e, empty. The data pattern is programmed electrically by the user using a special circuit known as PROM programmer It can be programmed only once during its life time. Once programmed, the data cannot be altered. This type of memory is known as PROM. These are highly suited for high volume usage due to their low cost of production.

Erasable Programmable read-only memory (EPROM)

In this type of memory, data can be written any number of times, i.e. they are reprogrammable. Before it is reprogrammed, the contents already stored are erased by exposing the chip to ultraviolet radiation for about 30 minutes. This type of memory is referred to as EPROM. EPROMs are possible only in MOS technology. Programming is done using a PROM programmer.

Electrically erasable and programmable read-only memory (EEPROM or E^2ROM)

This is another type of reprogrammable memory in which erasing is done electrically rather than exposing the chip to the ultraviolet radiation. It is referred to as EEPROM or electrically alterable ROM (EAROM).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AIR 1 SHASHANK GAUR EE
AIR 1 PRAKASH JHA E&T
AIR 1 GAURAV KUMAR CE
AIR 2 K S SHARADRAO ME
AIR 2 ABHISHEK SINGH EE
AIR 2 PARTH BATRA E&T
AIR 2 PRASHANT SINGH CE
AIR 3 SURAJ KUMAR S ME
AIR 3 VIKASH SHANKAR EE
AIR 3 RAHUL NAREDI E&T
AIR 3 KULDEEP JANGRA CE
AIR 4 SHUBHAM B ME
AIR 4 ANUPAM S EE
AIR 4 SHUBHAM E&T
AIR 4 ANISH BAGGA CE
AIR 5 KAMLESH PARWAR ME
AIR 5 MANOJ KUMAR E&T
AIR 5 PAVITRA GOYAL CE
AIR 6 MD ZUHAIB ME
AIR 6 VISHWA SIMHAA EE
AIR 6 SAURAV KUMAR S E&T
AIR 7 PRATEEK S ME
AIR 7 DINESH KUMAR S EE
AIR 7 RAGHAV PURWAR E&T
AIR 8 V SAIKRISHNA REDDY ME
AIR 8 GAGAN GHUNAWAT EE
AIR 8 RAM KRISHNA E&T
AIR 9 GANESH KUMAR A ME
AIR 9 AKSHAY KUMAR T EE
AIR 9 CHHAVI JAIN E&T
AIR 9 ARPIT JAIN CE
AIR 10 HEMABH TRIVEDI ME
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and many more...
TOTAL 36 RANKS IN TOP 10
ME 10
EE 09
E&T 10
CE 07