MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-7 : Full Syllabus Test (Paper-I)

Name : ....

Roll No :

Test Centres				Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	Pune ☐	
Kolkata ☐	Hyderabad ☐			

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	37
Q.2	54
Q.3	38
Q.4	/
Section-B	
Q.5	47
Q.6	35
Q.7	/
Q.8	/
Total Marks Obtained	211

Signature of Evaluator: Ch. [signature]

Cross Checked by ....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

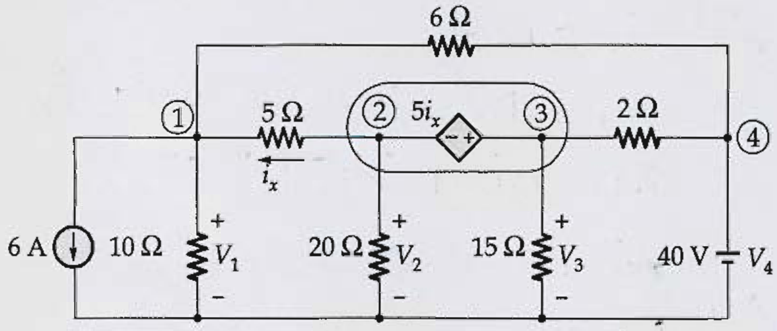
DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, 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 evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Do not write in this margin

Section A

Q.1 (a) Find the node voltages V_1, V_2, V_3 and V_4 in the circuit given below:



[12 marks]

Apply KCL at node 1 -

$$+6+\frac{V_1}{10}+\frac{V_1-V_2}{5}+\frac{V_1-V_4}{6}=0 \qquad \therefore \boxed{V_4 = 40V}$$

$$\frac{V_1}{10}+\frac{V_1}{5}+\frac{V_1}{6}-\frac{V_2}{5}-\frac{V_4}{6}=-6 \quad -(1)$$

2 | 10, 5, 6
5 | 5, 5, 3
3 | 1, 1, 3

Now apply super node at node 2 & 3:-

$$V_3 - V_2 = 5i_x \qquad \frac{V_2}{20}+i_x+\frac{V_3}{15}+\frac{V_3-40}{2}=0$$

Apply KCL at 4 node →

$$\frac{40-V_3}{2}+\frac{40-V_1}{6}=0 \qquad \frac{120-3V_3+40-V_1}{6}=0$$

$$V_1+3V_3=160 \qquad V_3-V_2=5\left(\frac{V_2-V_1}{5}\right)$$

$$V_1+3(2V_2-V_1)=160 \qquad V_3 = 2V_2 - V_1$$

for eq (1) $\quad V_1+6V_2-3V_1=160$

$$6V_2-2V_1=160 \qquad \boxed{V_3 = 48.33V}$$

$$\frac{3V_1+6V_1+5V_1}{30}-\frac{V_2}{5}-\frac{V_4}{6}=-6 \qquad \frac{14V_1-6V_2-40\times5}{30}=-6$$

$$14V_1-6V_2=-180+200$$

$$\frac{14V_1}{30}-\frac{V_2}{5}-\frac{40}{6}=-6 \qquad 14V_1-6V_2=20$$

$$7V_1-3V_2=10 \qquad 7V_1-3V_2=10$$

$$3V_2-V_1=80 \qquad 7\times15-3V_2=10$$

$$6V_1=90 \quad V_1=\frac{90}{6}=15 \quad \boxed{V_1=15} \qquad 105-10=3V_2$$

$$\Rightarrow \frac{95}{3} = \boxed{V_2 = 31.66V}$$

6

Do not write in this margin

Q.1 (b) Implement a Full subtractor with two 4 × 1 multiplexers.

[12 marks]

Full subtractor ⇒ i/p, A, B, Cin

Subtractor = $A \oplus B \oplus C$

Borrow = ~~$\bar{A}B + B\bar{C} + \bar{C}A$~~ = ~~$A \oplus B\ \dot{C}n$~~

= ~~$\bar{A}B$~~ $A\bar{B} + (A \oplus B)\ Cin$

= ~~$A\bar{B} + A\bar{B}Cin + \bar{A}B\ Cin$~~

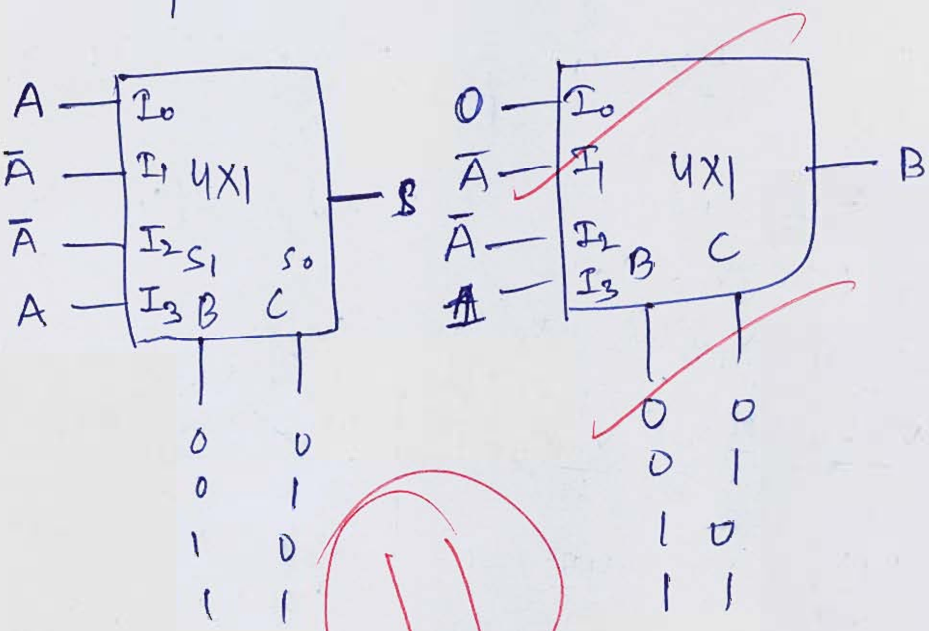
A-B-C

A	B	C	S	B
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

Sub = $A \oplus B \oplus C$

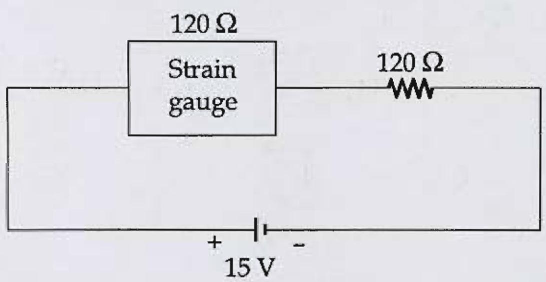
Borrow = $BC + \bar{A}(B \oplus C)$

when BC are i/p & A is borrow bit



11

Q.1 (c) A strain gauge having a resistance of 120 Ω and a gauge factor of 2 is connected in series with a ballast resistance of 120 Ω across 15 V supply as shown below:



Calculate the difference between the output voltage (voltage across the strain gauge) with no stress applied and with a stress of 150 MN/m². The modulus of elasticity of the material undergoing strain is 200 GN/m².

[12 marks]

given! - $R = 120\Omega$ $GF = 2$ Stress $= 150 MN/m^2$

$Y = 200 GN/m^2$

without stress → $V_{o_1} = \frac{120}{120+120} \times 15 = \frac{120}{240} \times 15$

$V_{o_1} = 7.5V$

with stress →

$Y = \frac{stress}{strain}$ strain $= \frac{150 \times 10^6}{200 \times 10^9} = 0.75 \times 10^{-3}$

$G_f = \frac{\Delta R/R}{\Delta l/l}$ $2 \times \frac{\Delta l}{l} = \frac{\Delta R}{R}$ ⇒ $2 \times 0.75 \times 10^{-3} = \frac{\Delta R}{R}$

$1.5 \times 10^{-3} = \frac{\Delta R}{R}$

$\Delta R = 1.5 \times 10^{-3} \times 120$

$\Delta R = 180 \times 10^{-3} \Rightarrow 0.18\ \Omega$

$R_{new} = R + \Delta R \Rightarrow 120 + 0.18\ \Omega$

$\Rightarrow 120.18\ \Omega$

$V_{o_2} = \dfrac{120.18}{(120.18 + 120)} \times 15$

$V_{o_2} = \dfrac{120.18}{240.18} \times 15 \Rightarrow 7.505V$

difference in o/p voltage $= V_{o_2} - V_{o_1}$

$\Delta V_o = 7.5056 - 7.5$

$= 5.6 \times 10^{-3} = 0.0056V$

$\boxed{\Delta V_o = 0.0056V}$

11

Q.1 (d) A typical paper clip weighs 0.59 g. Assume that it is made from BCC iron. Calculate:

(i) The number of unit cells.

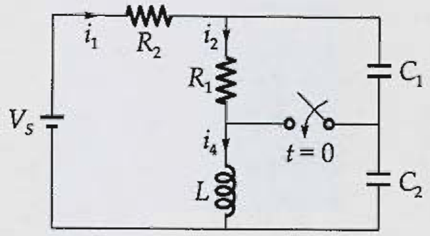
(ii) The number of iron atoms in the paper clip.

(Assume for BCC iron, lattice parameter $a_0 = 2.866 \times 10^{-8}$ cm, atomic mass = 55.847 g/mol, Density $\rho = 7.87$ g/cm^3)

[12 marks]

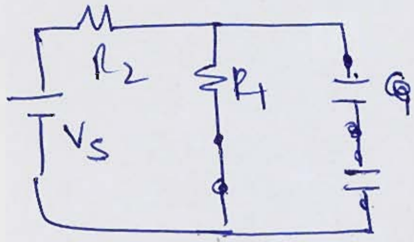
Do not write in this margin

Q.1 (e) Determine the current i_1, i_2 and i_4 at $t = 0^+$ for the circuit given below. Assume that the voltage source is applied at $t = -\infty$.



[12 marks]

at $t = 0^-$

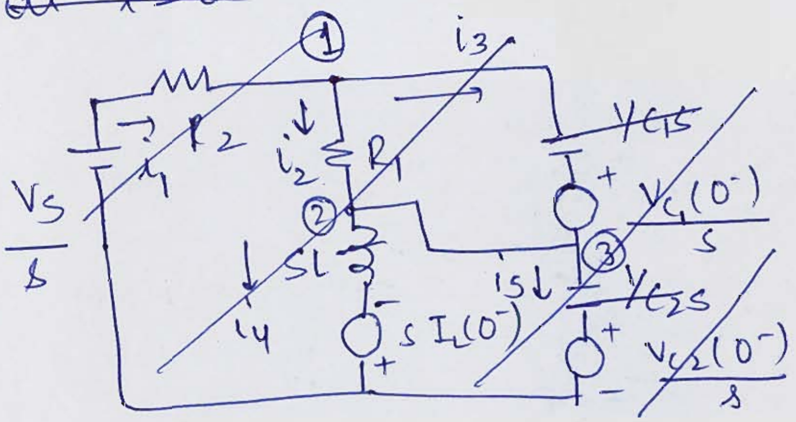


$i_L(0^-) = \left(\frac{V_s}{R_1 + R_2}\right)$

$V_{c_1}(0^-) = \frac{V_{R_1} \times C_2}{(C_1 + C_2)}$ $\quad V_{c_2}(0^-) = \frac{V_{R_1} \times C_1}{(C_1 + C_2)}$

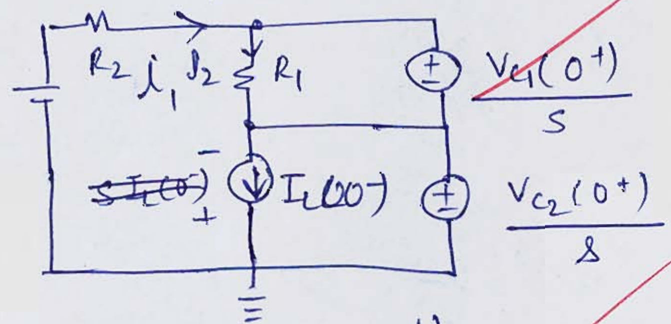
$V_{R_1} = R_1 \times i_{L_1}$

~~at $t = 0^+$~~



~~$\frac{V_1 - V_s/s}{R_2} + \frac{V_1 - V_2}{R_1}$~~

at $t = 0^+$



$i_1 = \frac{V_s/s - \left(\frac{V_{c1}(0^+) + V_{c2}(0^+)}{s}\right)}{R_1} = \frac{V_s - (V_{c_1}(0^+) + V_{c_2}(0^+))}{R_1 s}$

$i_2 = \frac{V_{c1}(0^+)/s}{R_1} = \frac{V_{c_1}(0^+)}{R_1 s}$

$i_4 = I_L(0^+) \Rightarrow \left(\frac{V_s}{R_1+R_2}\right)$

$i_1 = \frac{V_s - 2 \times \frac{V_s \times R_1}{R_1+R_2}}{R_1} \Rightarrow \frac{V_s(R_1+R_2) - 2V_s R_1}{(R_1+R_2) R_1}$

$i_1 = \frac{V_s(R_2 - R_1)}{(R_1+R_2)R_1}$

$i_2 = \frac{V_{R_1} \times C_2}{(C_1+C_2) \times R_1 s} \Rightarrow \frac{V_s \times R_1}{(R_1+R_2)} \cdot \frac{C_2}{(C_1+C_2) R_1 s}$

$i_2 = \frac{V_s C_2}{(R_1+R_2)(C_1+C_2)s}$

$i_4 = \frac{V_s}{R_1+R_2}$

Q.2 (a) **(i)** An assembly line has 3 safe sensors and one emergency shutdown switch. The line should keep moving unless any of the following conditions arise:

1. If the emergency switch is pressed.
2. If the sensor 1 and sensor 2 are activated at the same time.
3. If sensor 2 and sensor 3 are activated at the same time.
4. If all the sensors are activated at the same time.

Design a combinational circuit for above case using only two input NAND gates.

(ii) In a particular design which uses 5 bits for integral part and 7 bits for fractional part, the result of some operation is 7B8 Hex. Find the corresponding decimal equivalent.

[15 + 5 marks]

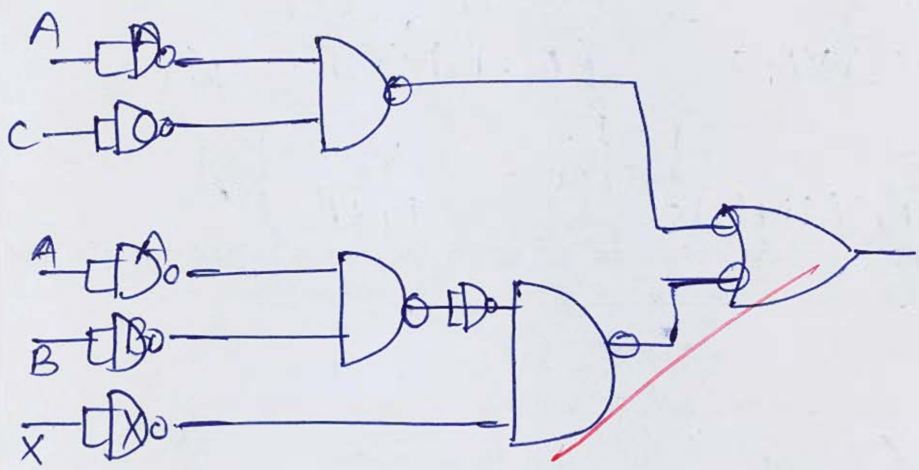
(i) emer = A; sensor = B, C, X

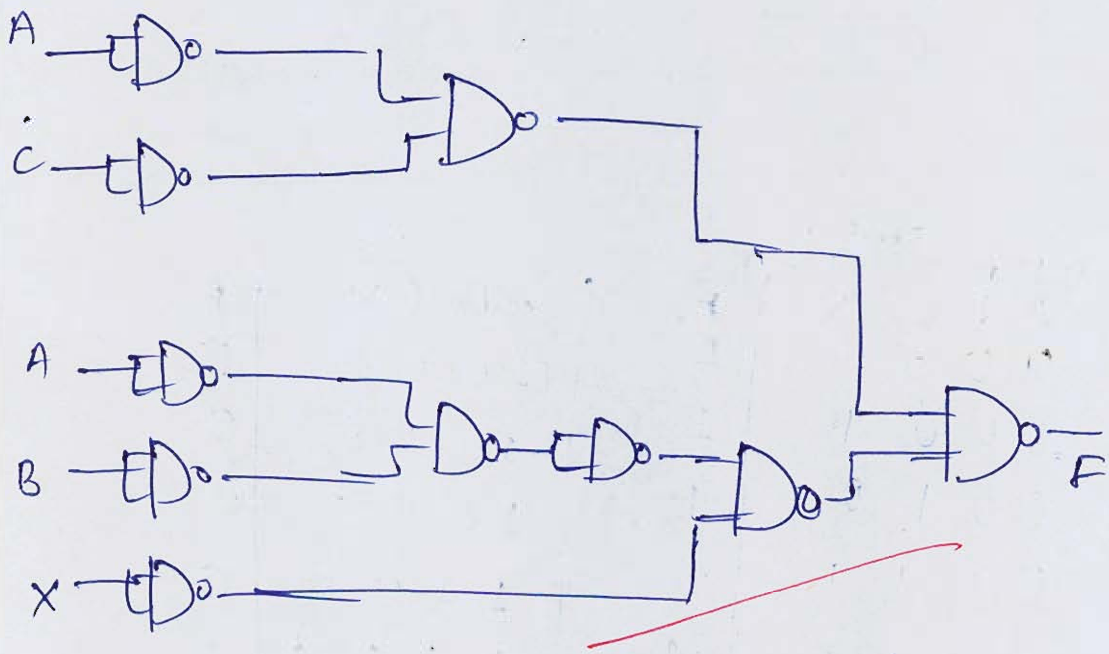
A	B	C	X	F
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0

A	B	C	X	F
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	0	0
1	1	1	0	0
1	1	1	1	0

AB \ CX	00	01	11	10
00	1 (0)	1 (1)	3	1 (2)
01	1 (4)	1 (5)	7	6
11	12	13	15	14
10	8	9	11	10

$$F = \bar{A}\bar{C} + \bar{A}\bar{B}\bar{X}$$





14

(ii) 7B8 Hex

↓

0111 1011 1000

7 B 8

0111 1011 1000

5 bit for integral; 7 bits for fractional

Now for integral part: $\overset{2^4}{0}\,\overset{2^3}{1}\,\overset{2^2}{1}\,\overset{2^1}{1}\,\overset{2^0}{1}$

$\Rightarrow (8+4+2+1) = 15$

fraction part $\Rightarrow$ 0111000

$= 0\times\frac{1}{2} + 1\times\left(\frac{1}{2}\right)^2 + 1\times\left(\frac{1}{2}\right)^3 + 1\times\left(\frac{1}{2}\right)^4 + 0\times\left(\frac{1}{2}\right)^5 + 0\times\left(\frac{1}{2}\right)^6$
$+ 0\times\left(\frac{1}{2}\right)^7$

$\Rightarrow 1\times\frac{1}{4} + 1\times\frac{1}{8} + \left(\frac{1}{16}\right) = \frac{(4+2+1)}{16} = \frac{7}{16}$

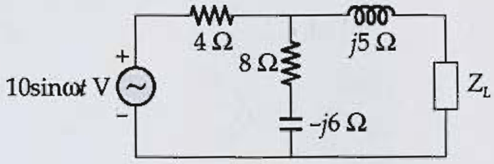
$= 0.4375$

corresponding decimal equivalent $= 15.04375$

$(7B8)_{Hex} = 15.04375$

5

Q.2 (b) (i) Determine the load impedance Z_L that maximizes the average power drawn from the circuit shown below,



Find the maximum power drawn from the circuit.

(ii) Derive the expression for the average power of an AC circuit.

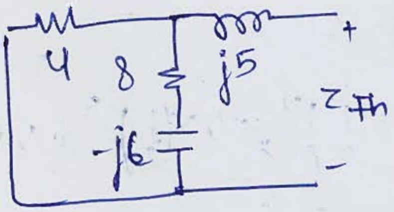
[20 marks]

given :- Z_L to maximise power.

For Max Power Transfer Theorem -

$Z_L = Z_{Th}^*$ and $P_{max} = \frac{V_{Th}^2}{4Z_{th}}$

To calculate Z_{Th} put indep. power source = 0



$[4 \| (8-j6)] + j5 = Z_{Th}$

$\frac{4 \times (8-j6)}{4+8-j6} + j5 = Z_{Th}$

$Z_{th} = \frac{32 - j24}{(12-j6)} + j5 = \frac{~~8~~ 16 - j12}{(2-j)}$

$Z_{th} = \frac{16 - j12}{2-j3} + j5 = \frac{(16-j12)(2-j3)}{4+9} + j5$

$Z_{Th} = \frac{32 - j48 - j24 - 36}{13} + j5$

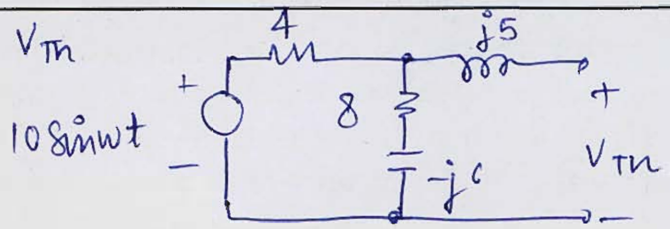
$Z_{Th} = \frac{-4 - j72}{13} + j5 = \frac{-4 - j72 + j65}{13}$

$Z_{Th} = \frac{-4 - j7}{13} = \frac{-4 - j7}{13}$

$Z_{Th}^* = \frac{-4 + j7}{13}$ $Z_{Th}^* = Z_L = |Z_L| = \sqrt{\left(\frac{4}{13}\right)^2 + \left(\frac{7}{13}\right)^2}$

$|Z_L| = \frac{1}{13}\sqrt{16 + 49} \Rightarrow 0.6201 \angle \alpha\ \Omega$

Now V_{Th}



$$V_{Th} = \frac{8-j6}{(4+8-j6)} \times 10\sin\omega t = \left[\frac{8-j6}{12-j6}\right] \times 10 \sin\omega t$$

$$V_{Th} = 0.745 \angle -10.304 \times 10 \sin\omega t$$

$$V_{Th} = 7.45 \sin(\omega t - 10.304)$$

$$P_{max} = \frac{V_{Th}^2}{4R_{th}} \Rightarrow \frac{(7.45)^2}{4 \times 0.6201} = 22.376\ W$$

(ii) Power = V × I

Impedance = $Z \angle \theta_Z$

$$P_{avg} = \frac{1}{T}\int_0^T P_i \, dt$$

$$\boxed{Z = R + jX}$$

$P_{instantaneous}$ Power = $V\angle\theta_V \times I \angle \theta_I$

Let $V = V_m \cos\omega t$

$I = I_m \cos(\omega t - \theta)$

$$I_m = \frac{V}{|Z|\angle\theta_Z}$$

$$I = \frac{V}{|Z|}\cos(\omega t - \theta_Z)$$

$$P_{avg} = \frac{1}{T}\int_0^T V_m \cos\omega t \cdot \frac{V}{|Z|}\cos(\omega t - \theta_Z)\,dt$$

$$P_{avg} = \frac{1}{T}\frac{V_m^2}{2Z}\int_0^T\left[\cos(2\omega t - \theta_Z) + \cos(-\theta_Z)\right]dt$$

Since $\frac{1}{T}\int_0^T \cos(2\omega t - \theta_Z)\,dt = 0$

$$P_{avg} = \frac{V_m^2}{2|Z|} \times \frac{1}{T}\int_0^T \cos(\theta_Z)\,dt \Rightarrow \frac{V_m^2}{2|Z|}\cos\theta_Z$$

$$\boxed{P_{avg} = \frac{V_m^2}{2|Z|}\cos\theta_Z}\ W$$

Do not write in this margin

Q.2 (c) **(i)** A long n-type semiconductor bar is placed along positive x-axis and is illuminated by a constant light source at one end (at $x = 0$). This illumination resulted in the generation of excess carriers at the surface (at $x = 0$) and these excess carriers are diffused into the bar. The variation of the minority carriers, in the bar along the positive x-axis, is given by,

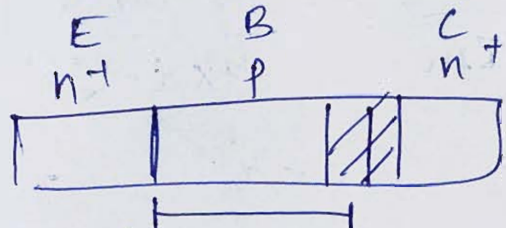
$$p_n(x) = p_{n0} + p_n' e^{-\frac{x}{L_p}} \; ; x > 0$$

Prove that L_p is the average distance travelled by the diffusing carriers before they recombine.

(ii) In an n^+-p-n^+ transistor with uniform base doping, the neutral base width (that is, the undepleted portion of the base) is 1.2 μm when $V_{CB} = 5$ V. The depletion layer of the collector-base junction extended into base region for this case is 0.3 μm. Find the value of the collector-base voltage V_{CB} at which the entire base gets depleted. Neglect the built-in potential as well as the depletion layer width at the emitter-base junction.

[14 + 6 marks]

(ii) given :-



Since n+ region is heavy doping so all depletion width seen in base side only

$W_B = 1.2\,\mu m$ when $V_{CB} = 5\,V$

$W_{CB} = 0.3\,\mu m$

$$W_B = \sqrt{\frac{2\epsilon}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)(\phi_{bi} + V_R)}$$

4

$$x_n = \sqrt{\frac{2\epsilon}{q}\left(\frac{1}{N_A}\right)(V_R)}$$

$$\boxed{x_n \propto \sqrt{V_R}}$$

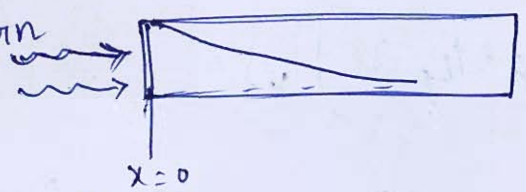
$$\frac{x_{n_1}}{x_{n_2}} = \sqrt{\frac{V_{R_1}}{V_{R_2}}} \Rightarrow \frac{0.3}{1.2} = \sqrt{\frac{5}{V_{R_2}}}$$

$\frac{1}{4} = \sqrt{\frac{5}{V_{R_2}}}$ $\frac{1}{16} = \frac{5}{V_{R_2}}$ $V_{R_2} = 5 \times 16$

$\boxed{V_{R_2} = 80V}$

at applying reverse bias 80V
we get whole base region depleted.

(ii) Gn



continuity eqn :-

$$\frac{dp}{dt} = -\frac{1}{q}\frac{dJ_p}{dx} + (G_p - R_p)$$

$$J_p = pq\mu_p E - qD_p \frac{dp}{dx}$$

$$\frac{dp}{dt} = -\frac{1}{q}\left[pq\mu_p \frac{dE}{dx} + q\mu_p E\frac{dp}{dx} - qD_p\frac{d^2p}{dx^2}\right] + (G_p - R_p)$$

$$\frac{dp}{dt} = -p\mu_p\frac{dE}{dx} - \mu_p E\frac{dp}{dx} + D_p\frac{d^2p}{dx^2} + G_p - R_p$$

Now at steady state $\frac{dp}{dt} = 0$, $E = 0$ $R_p = 0$

$$D_p\frac{d^2p}{dx^2} + G_p = 0$$

$$D_p\frac{d^2p}{dx^2} + \frac{\delta p}{\tau_p} = 0$$

$$\frac{d^2(\delta p)}{dx^2} + \frac{\delta p}{(D_p\tau_p)} = 0 \quad \delta p = Ae^{-x/L_p} + Be^{x/L_p}$$

$\boxed{L_p = \sqrt{D_p\tau_p}}$

So excess charge carries

$$\delta p(x) = p_0 e^{-x/L_p}$$

$$p = p_{no} + \delta p$$

$$p = p_{no} + p_{no} e^{-x/L_p}$$

$$\boxed{p = p_{no}(1 + e^{-x/L_p})}$$

L_p is the average distance travelled before recombination.

Q.3 (a) A combinational circuit consists of inputs A, B, S_1S_0 (= S) and an output F defined as follows:

(i) If (S = 0) then $F = \overline{A}$.

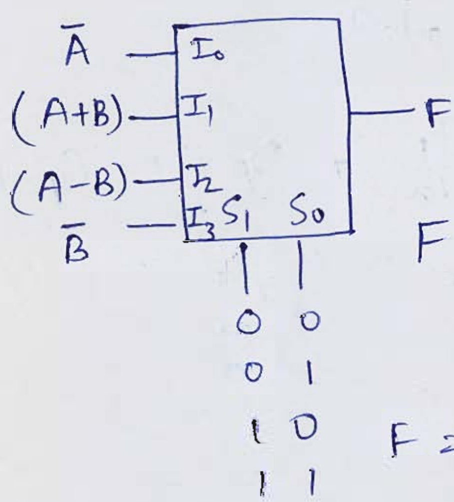
(ii) If (S = 1) then $F = A + B$.

(iii) If (S = 2) then $F = A - B$.

(iv) If (S = 3) then $F = \overline{B}$.

Build the logic circuit with a full adder, a 4 × 1 multiplexer, XOR gate and an inverter.

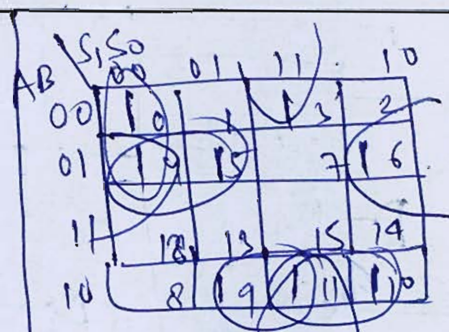
[20 marks]



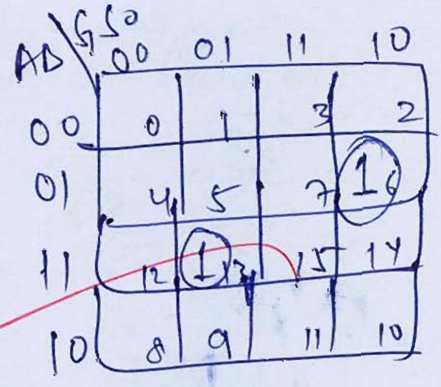
$$F = \overline{S}_1\overline{S}_0\overline{A} + \overline{S}_1S_0(A+B) + S_1\overline{S}_0(A-B) + S_1S_0\overline{B}$$

$$F = \overline{S}_1\overline{S}_0\overline{A} + \overline{S}_1S_0A + \overline{S}_1S_0B + S_1\overline{S}_0A + S_1\overline{S}_0B + S_1S_0\overline{B}$$

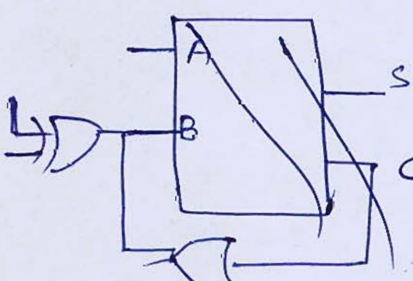
A	B	S_1	S_0	F	C
0	0	0	0	1	0
0	0	0	1	0	0
0	0	1	0	0	0
0	0	1	1	1	0
0	1	0	0	1	0
0	1	0	1	1	0
0	1	1	0	1	1
0	1	1	1	0	0
Φ	0	0	0	0	0
1	0	0	1	1	0
Φ	0	1	0	1	0
1	0	1	1	1	0
1	1	0	0	0	0
1	1	0	1	0	1
1	1	1	0	0	0
1	1	1	1	0	0



$F = A\bar{B}S_0 + A\bar{B}S_1 + \bar{A}B\bar{S}_1 + \bar{S}_1\bar{S}_0\bar{A} + \bar{A}B\bar{S}_0 + \bar{B}S_0S_1$

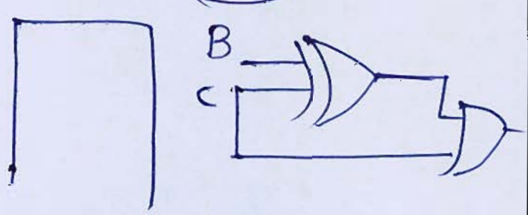


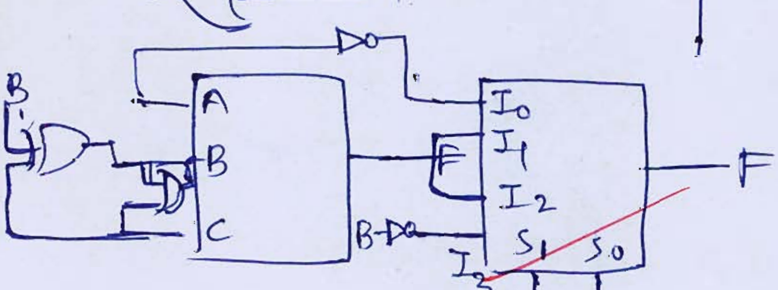
$\bar{A}BS_1\bar{S}_0 + AB\bar{S}_1S_0$



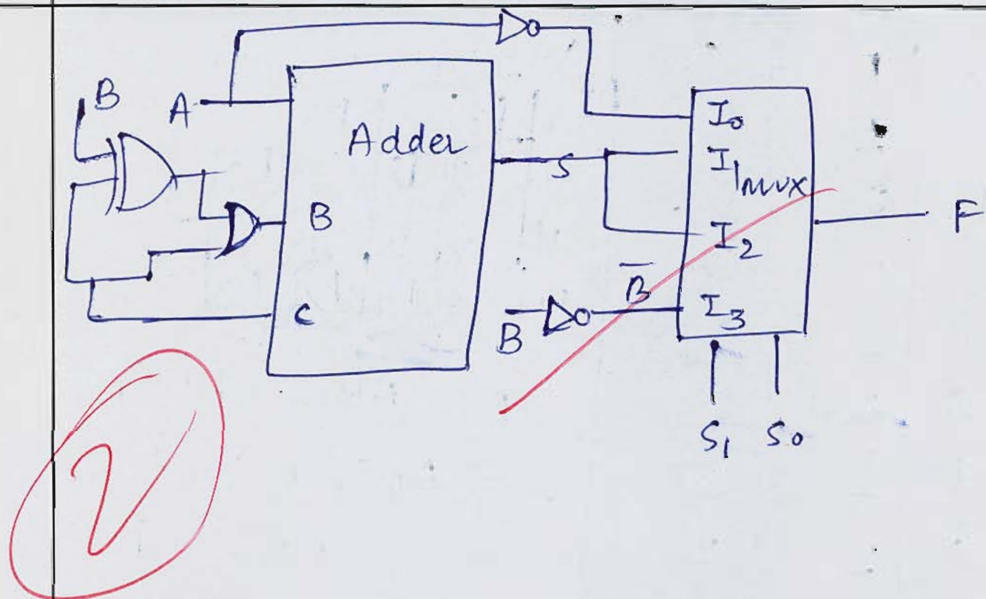
$A + B + C = A + B + 0$

$A - B = A + (\bar{B} + 1)$





Do not write in this margin

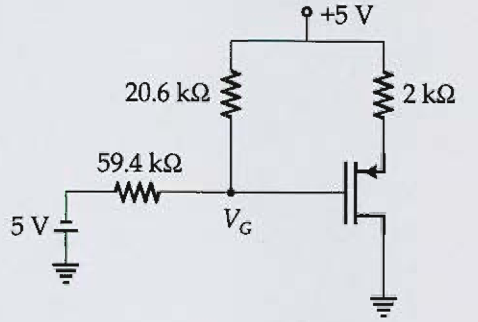


Q.3 (b) Consider a CsBr crystal (one $Cs^+ - Br^-$ pair per unit cell) with a lattice parameter (a) of 0.430 nm. The electronic polarizability of Cs^+ and Br^- ions are 3.35×10^{-40} F-m^2 and 4.5×10^{-40} F-m^2 respectively, and the mean ionic polarizability per ion pair is 5.8×10^{-40} F-m^2. Determine the value of dielectric constant at **(i)** very low frequencies and **(ii)** optical frequencies.

[20 marks]

Do not write in this margin

Q.3 (c) Consider the circuit shown in the figure below:

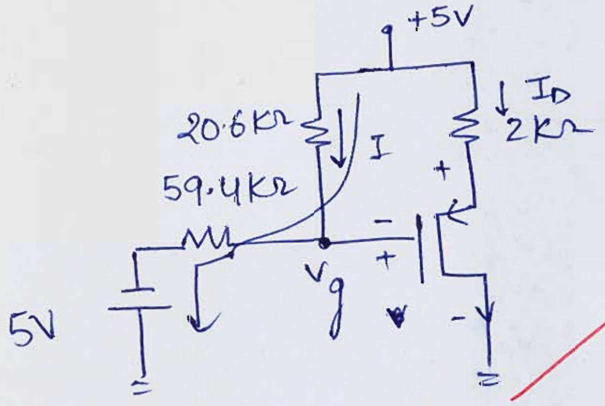


The transistor parameters are $V_{TP} = -1.5$ V and $\frac{\mu_p C_{ox} W}{2L} = 0.5$ mA/V^2. Calculate:

(i) The value of V_{SG}.
(ii) The value of I_D.
(iii) The value of V_{SD}.

[20 marks]

given:- $V_{Tp} = -1.5V$ $\frac{\mu p C_{ox} W}{2L} = 0.5 mA/V$



Assume in saturation region.

for V_g, apply KVL, $-5 + 20.6 I + 59.4 I - 5 = 0$

$10 = (20.6 + 59.4) I$

$I = \frac{10}{80}$ $I = 0.125 mA$.

18

$-5 + 20.6 I + V_g = 0$ $V_g = 5 - 20.6 \times 0.125$

$V_g = 5 - 2.575$

$\boxed{V_g = 2.425V}$

$-5 + 2 I_D + V_{sg} + 59.4 \times I - 5 = 0$

~~$V_{sg} = 5 - 2 I_D$~~ $I_D = \frac{\mu n C_{ox} W}{2L} (V_{sg} - |V_T|)^2$

~~$\frac{5 - V_{sg}}{2} = 0.5 (V_{sg} - |V_T|)^2$~~

$\frac{2.575 - V_{sg}}{2} = I_D$

Do not write in this margin

~~$\frac{5-V_{sg}}{2.575-V_{sg}}$~~ $2.575 - V_{sg} = (V_{sg} - 1.5)^2 \Rightarrow$ ~~$5 - V_{sg} = V_{sg}^2 + 2.25 - 3V_{sg}$~~

~~$V_{sg}^2 - 3V_{sg} + V_{sg} + 2.25 - 5 = 0$~~ $V_{sg}^2 - 2V_{sg} - 0.325 = 0$

~~$V_{sg}^2 - 2V_{sg} - 2.75 = 0$~~ ~~$V_{sg} = 2.93\,V$~~ $V_{sg} = 2.15$

$V_{sg} = -0.151$

~~$V_{sg} = -0.9364\,V$~~

$V_{sg} > V_{Th}$ ~~$V_{sg} = 2.93$~~ $V_{sg} = 2.15$

~~$I_D = \frac{5-2.93}{2} \Rightarrow 1.035\,mA$~~. $\frac{2.575-2.15}{2} = I_D = 0.2125\,mA$.

~~$V_{SD} = 5 - 2I_D \Rightarrow 5 - 2 \times 1.035 = 2.93\,V$~~

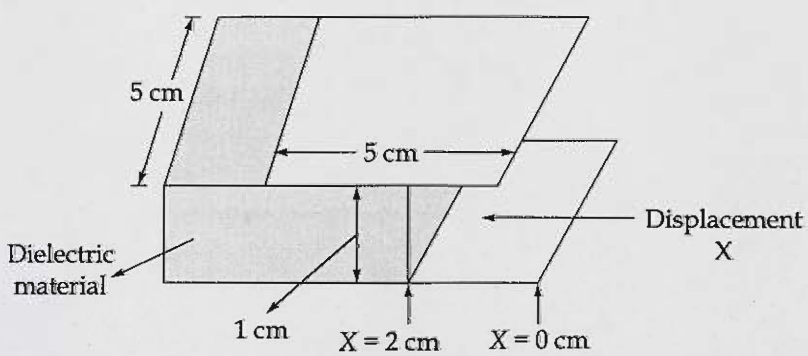
$V_{SD} = 5 - 2I_D \Rightarrow 5 - 2 \times 0.2125 = 4.575\,V$

$\boxed{V_{SD} = 4.575\,V}$

Q.4 (a) **(i)** A $4\frac{1}{2}$ digit and a $3\frac{1}{2}$ digit voltmeter on 100 V and 10 V range respectively are used for voltage measurements.

1. Find the resolution of each meter.
2. How would a voltage of 0.4312 V be displayed on these two meters?

(ii) A capacitive transducer is used for the measurement of linear displacement, X as shown below:



The parallel plate has a dimension of 5.0 cm × 5.0 cm and is separated by a distance of 1.0 cm. The space between the plates is filled with a dielectric material 1.0 cm thick, which has a dielectric constant of 4.0. If dielectric constant for air is 1.0, determine the value of the capacitance when X is equal to

1. 0.0 cm
2. 2.0 cm

[6 + 14 marks]

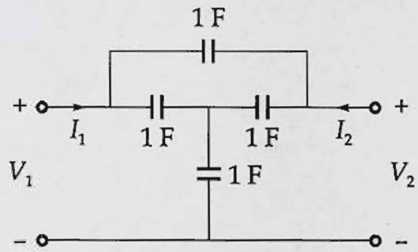
Q.4 (b) **(i)** Design RS flip-flop using NMOS.

(ii) A 50 kVA, 2000/200V, 50 Hz transformer has an iron loss of 400 watt. The high voltage winding has a resistance of 0.6 Ω and low voltage winding have a resistance of 0.006 Ω. Calculate the efficiency if the load has power factor 0.8 (lagging) and operating at half-load.

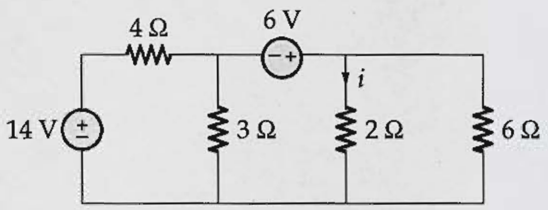
[10 + 10 marks]

Do not write in this margin

Q.4 (c) **(i)** Determine y-parameters of circuit shown below in s-domain.



(ii) For the circuit shown below,



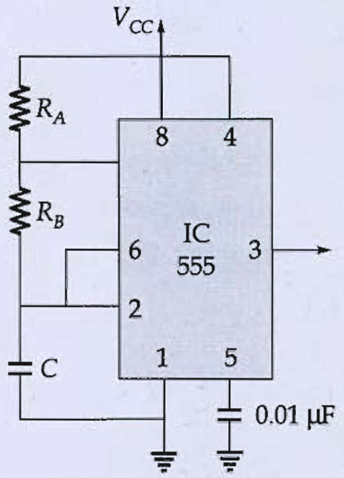
find the current i .

[12 + 8 marks]

Do not write in this margin

Section B

Q.5 (a) In the astable multivibrator shown in figure below:



where, $R_A = 2.2\ k\Omega$, $R_B = 3.9\ k\Omega$ and $C = 0.1\ \mu F$

Determine:

(i) Positive pulse width.

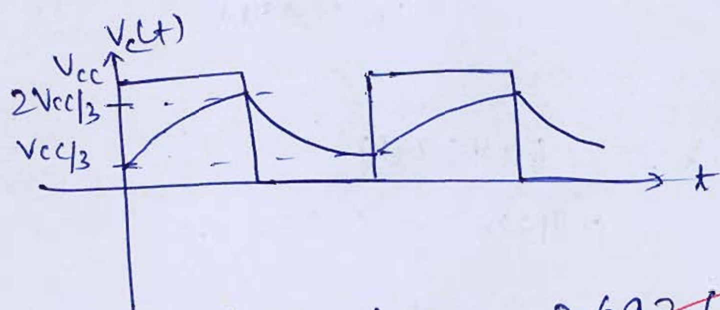
(ii) Negative pulse width.

(iii) Free running frequency.

(iv) Duty cycle.

[12 marks]

given $R_A = 2.2 K\Omega$ $R_B = 3.9 K\Omega$ $C = 0.1 \mu F$



For charging time = $0.693 (R_A + R_B) C$

For discharging time = $0.693 (R_B C)$

$T_{charging}$ in (+ve) pulse = $0.693(2.2+3.9)C$

$T_{charge} = 0.693(6.1) \times 0.1 \times 10^{-3} = 0.42273$ msec

$T_{discharge} = 0.693 \times 3.9 \times 0.1 \times 10^{-3} = 0.27027$ msec

~~Tcharge corr~~

Tdischarge corresponds to negative pulse width.

(i) Positive pulse width = 0.42273 msec

(ii) Negative pulse width = 0.27027 msec

(iii) Free running freq. = $\frac{2\pi}{T_{total}}$

$T_{Total} = T_{ch} + T_{dis}$

$\Rightarrow 0.42273 + 0.27027$

$\Rightarrow 0.693$ msec

$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.693} \times 10^3 = 9.06$ KHz

(iv) Duty cycle = $\frac{T_{ON}}{T_{ON} + T_{OFF}}$

Duty cycle = $\frac{0.42273}{0.42273 + 0.27027}$

$\Rightarrow \frac{0.42273}{0.693} = 0.61$

% duty cycle ≃ 61%

11

Do not write in this margin

Q.5 (b) A thermistor has a resistance of 3.9 kΩ at the ice point (0°C) and 794 Ω at 50°C. The resistance temperature relationship is given by,

$R = \alpha R_0^{\beta/T}$

where, R = resistance at temperature (T) in Kelvin,

R_0 = resistance at ice point (273 K),

α, β are constants.

(i) Calculate the constants α and β.

(ii) Calculate the range of resistance measured in the case of temperature variation from 40°C-100°C.

[12 marks]

given :- $R = \alpha R_0^{\beta/T}$

at $T = 273\,K$ $R_0 = 3.9\,k\Omega$

~~3.9 kΩ =~~

at $T = 273 + 50 = 323\,K$ ~~$R = 794\,\Omega$~~

~~794 = 3900 α~~ $794 = \alpha (3900)^{\beta/323}$

at $T = 273\,K$ $R = R_0$

$R_0 = \alpha R_0^{\beta/T}$ ~~$R_0^{\left(1-\frac{\beta}{T}\right)} = \alpha$~~

$794 = R_0^{\left(1-\frac{\beta}{273}\right)} \cdot R_0^{\beta/323}$

$794 = R_0^{\left(1 + \frac{\beta}{323} - \frac{\beta}{273}\right)}$ ~~$\Rightarrow 794 = R_0^{\left(1 + \frac{(-50\beta)}{323 \times 273}\right)}$~~

$$794 = (3900)^x$$

$$\ln 794 = x \ln(3900)$$

$$x = \frac{\ln 794}{\ln(3900)} \Rightarrow x \Rightarrow 0.807$$

$$x = 1 + \left(\frac{-50\beta}{323 \times 273}\right) = 0.807$$

$$(1 - 0.807) = \frac{50\beta}{323 \times 273}$$

$$\beta = \frac{0.193 \times 323 \times 273}{50} = \boxed{340.371 = \beta}$$

$$\alpha = R_0\left(1 - \frac{\beta}{273}\right) \quad \alpha = 3900\left(1 - \frac{340.371}{273}\right)$$

$$\alpha = 3900^{(-0.2467)}$$

$$\boxed{\alpha = 0.1300422}$$

(ii) at $T = 40°C$ $T = 273 + 40 = 313K$

$$R = 0.1300422\, R_0^{(\beta/313)}$$

$$R = 0.1300422(3900)^{\frac{340.371}{313}}$$

$$\boxed{R = 1045.147\,\Omega}$$

(iii) at $T = 100°C$ $T = 273 + 100 = 373K$.

$$R = 0.1300422\, R_0^{\left(\frac{340.371}{373}\right)}$$

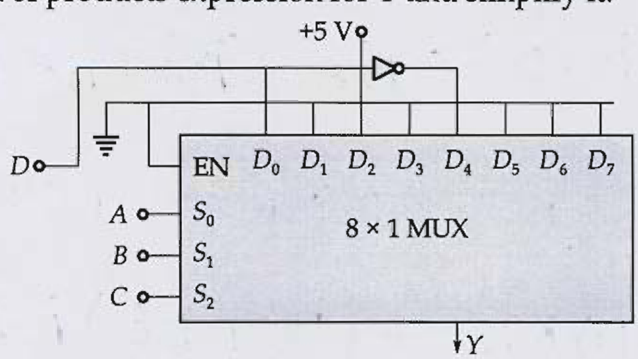
$$R = 0.1300422(3900)^{\left(\frac{340.371}{373}\right)}$$

$$\boxed{R = 246.043\,\Omega}$$

Q.5 (c) The circuit given below shows how an 8-bit MUX can be used to generate a four-variable logic function, even though the MUX has only 3 SELECT inputs. Three of the logic variables *A*, *B* and *C* are connected to the SELECT inputs. The fourth variable *D* and its inverse $\bar{D}$ are connected to selected data inputs of the MUX as required by the desired logic function. The other MUX data inputs are tied to a LOW or a HIGH as required by the function.

(i) Setup a truth table showing the output-*Y* for the 16 possible combinations of input variables.

(ii) Write the sum of products expression for *Y* and simplify it.



[12 marks]

D	C	B	A	Y
0	0	0	0	0
0	0	0	1	0
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	1
1	0	0	1	0
1	0	1	0	1
1	0	1	1	0
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0

$$Y = \bar{D}\bar{C}B\bar{A} + \bar{D}C\bar{B}\bar{A} + D\bar{C}\bar{B}\bar{A} + D\bar{C}B\bar{A}$$

$$\boxed{Y = \bar{D}\bar{C}B\bar{A} + \bar{D}C\bar{B}\bar{A} + D\bar{C}\bar{B}\bar{A} + D\bar{C}B\bar{A}}$$

$$Y = \bar{D}\bar{C}B\bar{A} + D\bar{C}B\bar{A} + \bar{D}C\bar{B}\bar{A} + D\bar{C}\bar{B}\bar{A}$$

$$Y = (\bar{D}+D)\bar{C}B\bar{A} + (\bar{D}C + D\bar{C})\bar{B}(\bar{A}+A$$

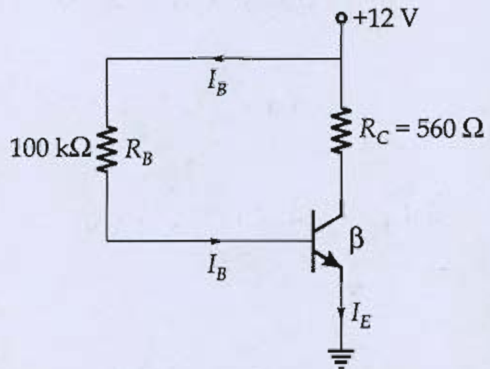
$$Y = \bar{D}\bar{C}B\bar{A} + D\bar{C}B\bar{A} + \bar{D}C\bar{B}\bar{A} + D\bar{C}\bar{B}\bar{A}$$

$$Y = (\bar{D}+D)\bar{C}B\bar{A} + (\bar{D}C + D\bar{C})\bar{B}\bar{A}$$

$$Y = \bar{C}B\bar{A} + (D \oplus C)\bar{B}\bar{A}$$

$$\boxed{Y = \bar{C}BA + (D \oplus C)\bar{B}\bar{A}}$$

Q.5 (d) A base bias circuit in figure below is subjected to an increase in temperature from 25°C to 75°C. If β = 100 at 25° and 150 at 75°C, determine the percentage change in Q-point values (V_{CE} and I_C) over this temperature range.



(Neglect any change in V_{BE} and the effects of any leakage current)

[12 marks]

given:- $\beta_{25} = 100$ $\beta_{75} = 150°c$

% Δ Qpoint = ? V_{CE}, I_C = Q point.

Assume in BJT in active region since we are talking about q point.

$-12 + 100\,k I_B + 0.7 = 0$

$\frac{12 - 0.7}{100k} = I_B = 0.113\,mA = 113\,\mu A$.

~~at~~

at 25°C $\beta = 100$ $I_{C_1} = \beta I_B$

$I_{C_1} = 100 \times 113\mu A = 11.3 mA$

~~at~~ $-12 + I_C R_C + V_{CE} = 0$

$V_{CE_1} = 12 - I_C R_C$

$V_{CE_1} = 12 - 11.3 \times 560 \times 10^{-3}$

$V_{CE_1} = 12 - 6.328 = 5.672 V$

at 75°C $\beta = 150$

$I_{C_2} = 150 \times 113 \mu A = 16.95 mA$

$V_{CE_2} = 12 - 16.95 \times 560 \times 10^{-3}$

$V_{CE_2} = 12 - 9.492 = 2.508 V$

% change in $I_C = \frac{I_{C_2} - I_{C_1}}{I_{C_1}} \times 100$

$\Rightarrow \frac{16.95 - 11.3}{11.3} \times 100 = 50\%$

% change in $V_{CE} = \frac{2.508 - 5.672}{5.672} \times 100$

$= -55.78\%$

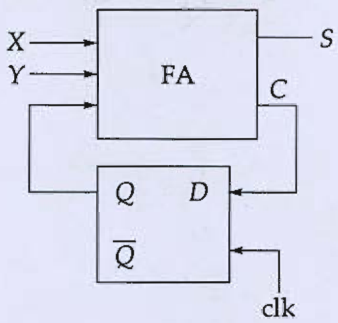
11

% change in Qpoint will be (%ΔV_{CE}, %ΔI_C)

% ΔQ = (−55.78%, 50%)

Do not write in this margin

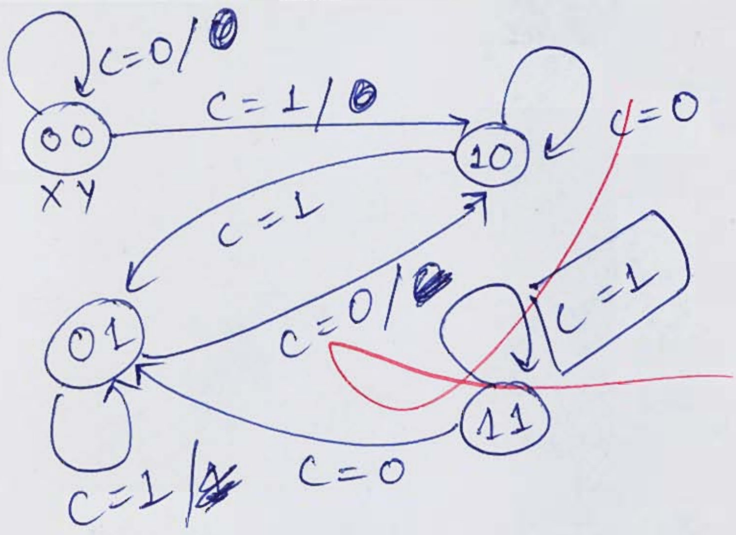
Q.5 (e) A sequential circuit has one flip-flop, two inputs X and Y, and one output S. It consists of a full adder circuit connected to a D flip-flop as shown. Derive the state table and state diagram of the given sequential circuit.

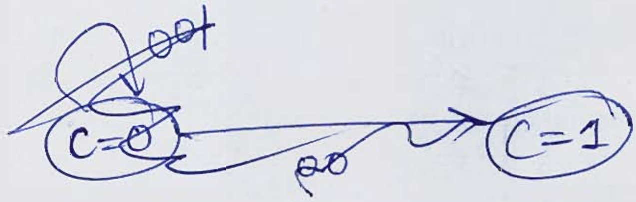


[12 marks]

X	Y	C	S	C	$Q^+ = D$	C^+
0	0	0	0	0	0	0
0	0	1	1	0	0	0
0	1	0	1	0	0	0
0	1	1	0	1	1	1
1	0	0	1	0	0	0
1	0	1	0	1	1	1
1	1	0	0	1	1	1
1	1	1	1	1	0	1

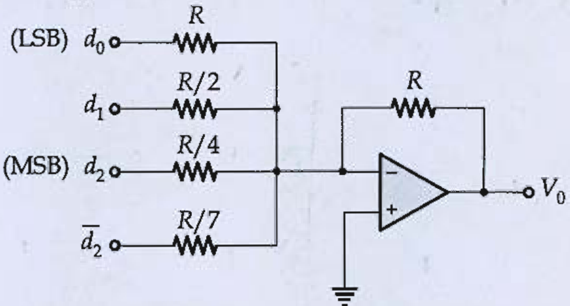
Do not write in this margin





Q.6 (a) **(i)** Consider the circuit shown in the figure below:

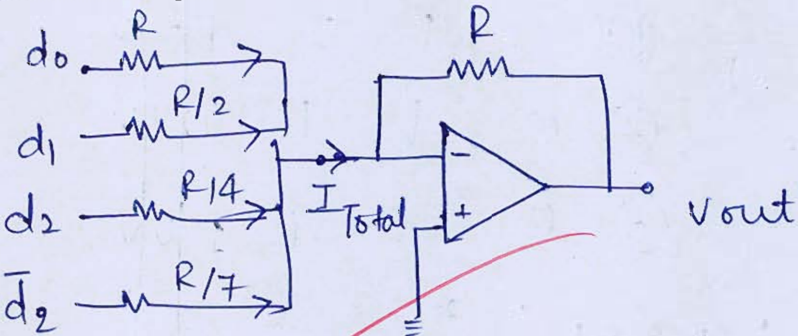
$$d_i = \begin{cases} +\frac{1}{2}\text{V}; & \text{for logic}-0 \\ -\frac{1}{2}\text{V}; & \text{for logic}-1 \end{cases}$$



Derive an expression for output voltage V_0 in terms of input logic values. Using the result obtained, determine the value of V_0 for all the possible binary combinations of input and comment on the operation performed by the circuit.

(ii) Define the terms resolution, settling time and temperature sensitivity with respect to digital-to-analog converters.

[15 + 5 marks]



$I_{Total} = I_1 + I_2 + I_3 + I_4$

$$I_T = \left[\frac{d_0}{R} + \frac{d_1}{R/2} + \frac{d_2}{R/4} + \frac{\overline{d}_2}{R/7}\right]$$

$$I_T = \left[\frac{d_0}{R} + \frac{2d_1}{R} + \frac{4d_2}{R} + \frac{7\overline{d}_2}{R}\right]$$

$$I_T = \frac{1}{R}\left[d_0 + 2d_1 + 4d_2 + 7\overline{d}_2\right]$$

$\text{Vout} = -I_T \times R$ $\quad V_0 = -\frac{R}{R}\left[d_0 + 2d_1 + 4d_2 + 7\overline{d}_2\right]$

$$V_0 = -\left[d_0 + 2d_1 + 4d_2 + 7\overline{d}_2\right]$$

~~Let calculate it assumed $\overline{d}_2 = d_3$~~

d_3	d_2	d_1	d_0
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0

	$\bar{d}_2$	d_2	d_1	d_0	V_0
①	1	0	0	0	0V
②	1	0	0	1	1V
③	1	0	1	0	2V
④	1	0	1	1	3V
⑤	0	1	0	0	-3V
⑥	0	1	0	1	-2V
⑦	0	1	1	0	-1V
⑧	0	1	1	1	0V

This are the final combinatn

① $V_0 = -\left[\frac{1}{2} + 2\times\frac{1}{2} + 4\times\frac{1}{2} + 7\times-\frac{1}{2}\right] = -\left[\frac{7}{2} - \frac{7}{2}\right] = 0$

② $V_0 = -\left[-\frac{1}{2} + 2\times\frac{1}{2} + 4\times\frac{1}{2} + 7\times-\frac{1}{2}\right] = -\left[3 - 4\right] = 1V$

③ $V_0 = -\left[\frac{1}{2} + 2\times-\frac{1}{2} + 4\times\frac{1}{2} + 7\times-\frac{1}{2}\right] = -\left[\frac{2}{2}(-2)\right] = 2V$

$\frac{1}{2} - 1 + 2 - \frac{7}{2} \quad 1 - 3$

13

④ $V_0 = -\left[-\frac{1}{2} + 2\times-\frac{1}{2} + 4\times\frac{1}{2} + 7\times-\frac{1}{2}\right] = -\left[-1 - 4\right] = 3V$

$-\frac{1}{2} - 1 + 2 - \frac{7}{2}$

⑤ $V_0 = -3V$ ⑥ $V_0 = -2V$ ⑦ $V_0 = -\frac{1}{2} + 2\times\frac{1}{2} + 4\times-\frac{1}{2} + 7\times\frac{1}{2}$

$-3 + 4 = -1$

⑧ $V_0 = 0V$

Resolution :- It is defined as minimum voltage correspond to 1 LSB. $\frac{V_{FS}}{(2^n-1)}$ = Resolutn

Settling Time → The time required to give stable o/p called as settling time & conversiontime

Temperature sensitivity = It is defined as the change in o/p of system wrt to change in Temp.

$$S = \frac{\partial O/P}{\partial Temp}$$

4

Q.6 (b) In a dynamometer type wattmeter the moving coil has 500 turns of mean diameter 30 mm. Estimate the torque if the axes of the field and the moving coils are at (i) 60° (ii) 90° when the flux density produced by field coil is 15×10^{-3} Wb/m^2, the current in moving coil is 0.05 A and the power factor is 0.866.

[20 marks]

Q.6 (c) (i) In a silicon *pn*-junction, the ratio of electron current crossing the depletion region to the total current is defined as the electron injection efficiency. Determine the expression for electron injection efficiency as a function of N_a/N_d where N_a = acceptor concentration on *p*-side and N_d = donor concentration on *n*-side. Assume $T = 300K$, $\tau_{p0} = \tau_{n0}$ and $\mu_n = 2.4\,\mu_p$.

(ii) The critical magnetic field for a superconducting tin at 4 K and 3 K are 0.02T and 0.03T respectively. Calculate the critical magnetic field at 2 K.

[10 + 10 marks]

(i)

electron injection $\eta = \dfrac{I_{PE}}{I_{PE} + I_{NE}}$

$$I_{PE} = Aq \frac{D_P}{L_P} \times \frac{n_i^2}{N_D} \left(e^{V/\eta V_T} - 1\right)$$

$$I_{nE} = Aq \frac{D_n}{L_n} \frac{n_i^2}{N_A} \left(e^{V/nV_T} - 1\right)$$

$$\eta = \frac{Aq \dfrac{D_P}{L_P} \dfrac{n_i^2}{N_D}}{Aq \dfrac{D_P}{L_P} \dfrac{n_i^2}{N_D} + Aq \dfrac{D_n}{L_n} \dfrac{n_i^2}{N_A}}$$

$$\eta = \frac{\dfrac{D_P}{L_P} \times \dfrac{1}{N_D}}{\dfrac{D_P}{L_P} \times \dfrac{1}{N_D} + \dfrac{D_n}{L_n} \times \dfrac{1}{N_A}}$$

$\dfrac{D_n}{\mu_n} = V_T$

$L_n = \sqrt{D_n \tau_n}$

$\dfrac{D_n}{\mu_n} = 26mV$

$D_n = \mu_n \times V_T \qquad D_P = \mu_p \times V_T$

$D_n = 2.4 \mu_p \times V_T \qquad D_p = \mu_p \times V_T$

$$\eta = \frac{\frac{\mu_p \times V_T}{\sqrt{\mu_p \times V_T \times \tau_p}} \frac{1}{N_D}}{\frac{1}{N_D} \frac{\mu_p \times V_T}{\sqrt{\mu_p \times V_T \times \tau_p}} + \frac{\mu_n \times V_T}{\sqrt{\mu_n V_T \tau_n}} \times \frac{1}{N_A}}.$$

$$\eta = \frac{\sqrt{\frac{\mu_p V_T}{\tau_p}} \times \frac{1}{N_D}}{\sqrt{\frac{\mu_p V_T}{\tau_p}} \times \frac{1}{N_D} + \sqrt{\frac{\mu_n V_T}{\tau_n}} \times \frac{1}{N_A}}$$

$$\eta = \frac{\sqrt{\frac{\mu_p \times V_T}{\tau_p}} \times \frac{1}{N_D}}{\sqrt{\frac{\mu_p \times V_T}{\tau_p}} \times \frac{1}{N_D} + \sqrt{\frac{2.4 \mu_p V_T}{\tau_n}} \cdot \frac{1}{N_A}}$$

$$\eta = \frac{\frac{1}{N_D}}{\frac{1}{N_D} + \sqrt{2.4} \frac{1}{N_A}} \Rightarrow \frac{\frac{1}{N_D}}{\frac{1}{N_D} + 1.54 \frac{1}{N_A}}$$

$$\boxed{\eta = \frac{N_A}{N_A + 1.54 N_D}}$$

A

(ii) for critical magnetic field.

$$H_C = H_0 (T - T_c)^2$$

$$\frac{0.02 = H_0(4-T_c)^2}{0.03 = H_0(3-T_c)^2} \Rightarrow \sqrt{\frac{0.02}{0.03}} = \frac{4-T_c}{3-T_c}$$

$$0.816 = \frac{4-T_c}{3-T_c} \Rightarrow 0.816(3-T_c) = 4-T_c$$

$$0.816 \times 3 - 0.816\,T_c = 4 - T_c \qquad T_c - 0.816\,T_c = 4 - 2.448$$

$$0.184\,T_c = 1.552 \qquad T_c = \frac{1.552}{0.184} = 8.434\ K$$

$$H_0 = \frac{0.02}{(4-8.434)^2} = 1.017 \times 10^{-3}\ T$$

$$H = H_0(T-T_c)^2 \qquad H = 1.017 \times 10^{-3}(2-8.434)^2$$

$$H = 42.100\ T \times 10^{-3} \qquad \boxed{H = 0.042\,T}$$

Q.7 (a) **(i)** Draw a logic circuit for 4-bit even parity checker.

(ii) Solve for 'x' in the below equations for the given number systems:

1. $(70)_8 + (122)_6 = (211)_x$
2. $(135)_{12} = (x)_8 + (78)_9$ **[14 + 6 marks]**

Q.7 (b) A star connected 3 phase alternator delivers a 3-phase star connected load at a power factor of 0.8 lagging. A wire connects the load and alternator. The terminal voltage at no load is 2500 V, and at full load of 1460 kW is 2200 V. Determine the terminal voltage when it delivers a 3 phase star connected load having a resistance of 6 Ω and reactance of 8 Ω per phase. Assume constant current and field excitation. Neglect the armature resistance.

[20 marks]

Q.7 (c) Design a parallel binary multiplier that multiplies a 4-bit number $B = B_3B_2B_1B_0$ by a 3-bit number $A = A_2A_1A_0$ to form the product $P = P_6P_5P_4P_3P_2P_1P_0$.

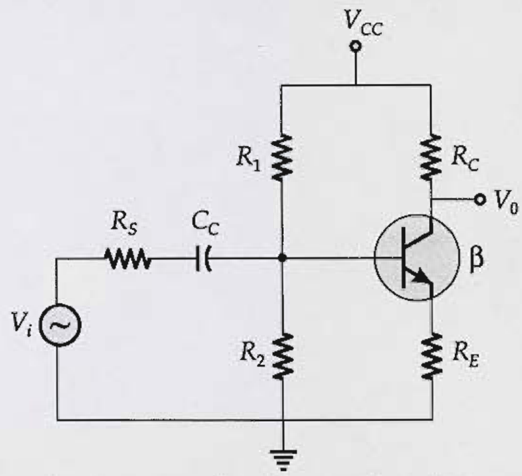
[20 marks]

Q.8 (a) (i) A 3 phase, 10 kW, 6 pole, 50 Hz, 400 V delta connected induction motor runs at 960 rpm on full load. If it draws 85 A on direct on line starting, calculate the ratio of the starting torque to full load torque with Y-Δ starter. Power factor and full load efficiency are 0.88 and 90% respectively.

(ii) A 6 pole, 50 Hz, three phase induction motor has a maximum torque of 200 N-m when it is running at a speed of 900 rpm. The resistance of the rotor is 0.25 Ω. Neglecting the stator impedance, determine the torque at 5% slip.

[10 + 10 marks]

Q.8 (b) Consider the common emitter amplifier as shown in the figure below:

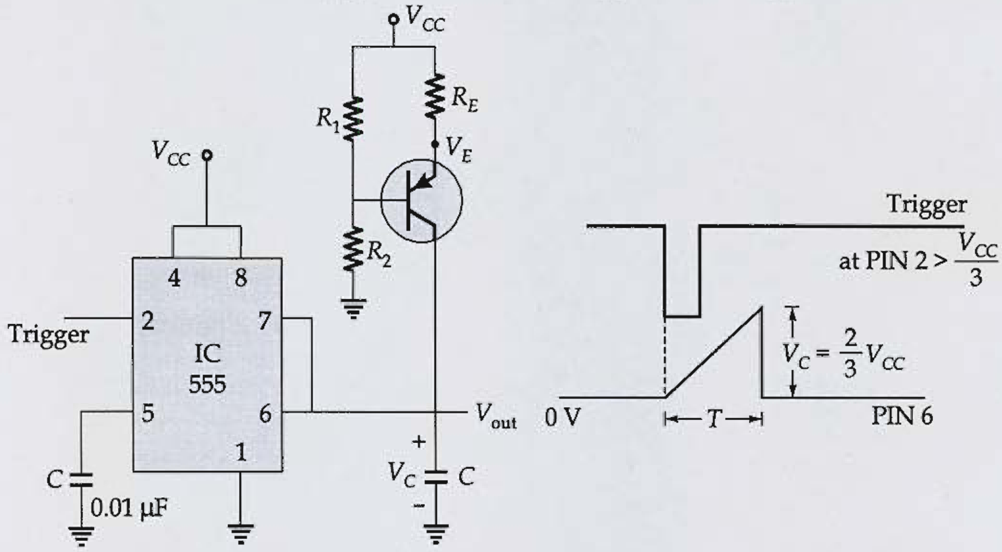


Derive the expression for the overall voltage gain of the transistor $A_V(s)$ as a function of input capacitance C_C. Also draw the approximate magnitude plot for the voltage gain $A_V(s)$. [Assume $V_A = \infty$]

[20 marks]

Do not write in this margin

Q.8 (c) Consider the linear ramp generator with trigger and ramp waveform as shown below:



Determine the time period (T) of ramp waveform.

[20 marks]

OOOO

Space for Rough Work

Space for Rough Work