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India's Best Institute for IES, GATE & PSUs

ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-5 : Computer Organization and Architecture + Materials Science [All topics]
Electronic Devices & Circuits-1 + Advanced Communications Topics-1 [Part Syllabus]
Analog & Digital Communication Systems-2 [Part Syllabus]

Name :

Roll No :

Test Centres				Student's Signature
Delhi ☐	Bhopal ☑	Jaipur ☐		
Pune ☐	Kolkata ☐	Bhubaneswar ☐	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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	172

Signature of Evaluator .... Cross Checked by ....

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Name : RAJESH TIWARI

Roll No : E C 2 3 M T S T 0 0 3 2

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

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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.

Section A : Computer Organization and Architecture + Materials Science

Q.1 (a) **(i)** Suppose that execution time for a program is directly proportional to instruction access time and that access to an instruction in the cache is 20 times faster than access to an instruction in the main memory. Assume that a requested instruction is found in the cache with probability 0.96, and also assume that if an instruction is not found in the cache, it must first be fetched from the main memory to the cache and then fetched from the cache to be executed. Compute the ratio of program execution time without the cache to program execution time with the cache.

(ii) If the size of the cache is doubled, assume that the probability of not finding a requested instruction there is cut in half. Repeat part (i) for a doubled cache size.

[6 + 6 marks]

(i) Let access time for cache is T sec

Access time for memory will be 20T sec

Instruction found in cache memory probability = 0.96

Instruction Not found in " " = 1−0.96 = 0.04

Total Execution time to access the N instruction

0.96N instruction will be found in cache

and 0.04N instruction will be found in main memory

Time with cache = $0.96N \times T + 0.04N(T + 20T)$

$= 1.8\ NT$

Time without cache = $N \times (20T) = 20NT$

Ratio of $\frac{\text{program execution time without cache}}{\text{program execution time with cache}} = \frac{2.0\ NT}{1.8NT}$

Ratio = 11.11

(ii) Probability of Not finding instruction cut in half

so probability of Not finding instruction = $\frac{0.04}{2}$ = 0.02

Probability of finding instruction in the cach = 1 − 0.02 = 0.98

Execution time with cache = $0.98\,N \times T + 0.02N\,(T+20T)$

$= 1.4NT$

Execution time without cache = $N \times 20T = 20NT$

$$\text{Ratio} = \frac{20NT}{1.4NT} = 14.29$$

Q.1 (b) Draw the flow chart explaining the Round Robin scheduling algorithm. Find out the average waiting time for the processes listed in the following process table assuming Round Robin scheduling with time quantum equal to 3 nsec.

P_{id}	Arrival time (nsec)	Burst time (nsec)
P_1	0	8
P_2	5	2
P_3	1	7
P_4	6	3
P_5	8	5
P_6	2	3

[12 marks]

Given time quantum is 3n sec

P1	P3	P6	P2	P4	P5	P1	P3
0 – 3	3 – 6	6 – 9	9 – 11	11 – 14	14 – 17	17 – 20	20 – 23

9 (P6 executed), 11 (P2 executed), 14 (P4 executed)

P5	P1	P3
23 – 25	25 – 27	27 – 28

25 (P5 executed), 27 (P1 executed), 28 (P3 executed)

Waiting time

WT = Execution time − Arrival time − Burst time

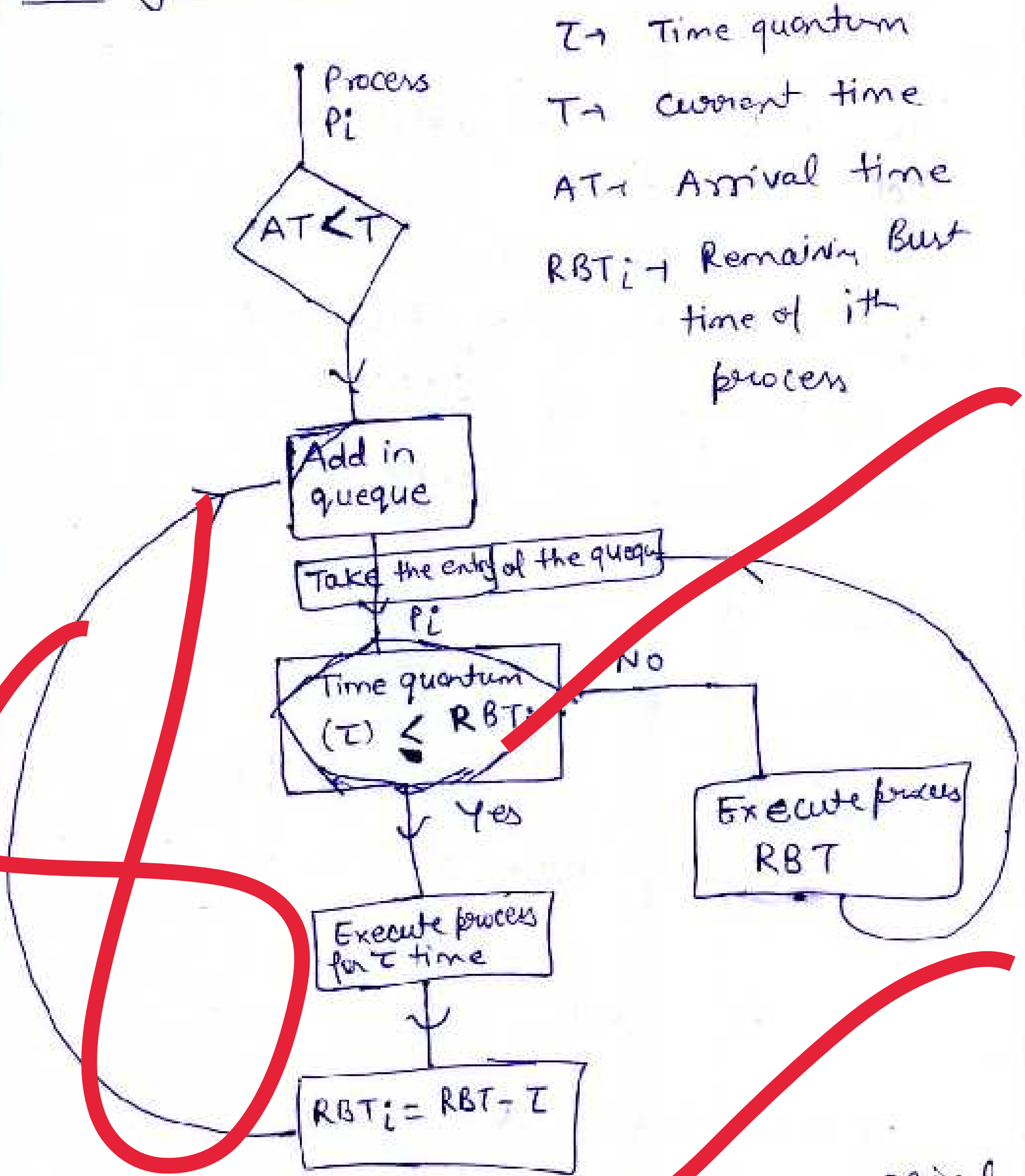
Process	Arrival time	Burst time	Execution time	Waiting Time
P1	0	8	27	19
P2	5	2	11	4
P3	1	7	28	20
P4	6	3	14	5
P5	8	5	25	12
P6	2	3	9	4

Average waiting time = $\frac{\text{Sum of waiting time of all process}}{\text{No. of process}}$

$$AWT = \frac{19+4+20+5+12+4}{6} \text{ nsec}$$

$$AWT = \frac{64}{6} \text{ nsec} = 10.67 \text{ nsec}$$

Round Robin flowchart



In Round Robin scheduling based on arrival time of the process we add the process into the queque.

If Burst time of process is less than time quantum then we execute process for remaining burst time and remove the process. If RBT is greater than time quantum then we reduce RBT by time quantum and add in the queque.

Q.1 (c) Calculate the angles of diffraction for red and green light incident on diffraction grating that has 500 lines per mm. The wavelength of red and green light are 7×10^{-7} m and 5.38×10^{-7} m respectively. Assume first order diffraction ($n = 1$). Can the contents of any incident light wave be examined by diffraction?

[12 marks]

By Bragg's law of refraction

$2d \sin\theta = n\lambda$

d is the distance b/w two layers

λ is the wavelength of the light

θ is the angle of diffraction

n is the order of diffraction

Given $n = 1$

$2d \sin\theta = \lambda$

d = There are 500 lines per mm so

distance b/w 2 lines = $\frac{1 \text{ mm}}{500} = 2 \mu m$

$d = 2 \mu m$

$2 \times 2 \mu m \cdot \sin\theta = \lambda$

$\sin\theta = \frac{\lambda}{4 \times 10^{-6}} \Rightarrow \theta = \sin^{-1}\left(\frac{\lambda}{4 \times 10^{-6}}\right)$

for red light $\lambda = 7 \times 10^{-7} m$

$\theta_{red} = \sin^{-1}\left(\frac{7\times10^{-7}}{2\times10^{-6}}\right) = 20.49°$

$\theta_{green} = \sin^{-1}\left(\frac{5.38\times10^{-7}}{2\times10^{-6}}\right) = 15.60°$

If we know the diffraction angle then we can tell about the type of incident light by knowing about it's wavelength

If we know θ then we can find λ

Q.1 (d) Germanium forms a substitutional solid solution with silicon. Compute the weight percent of germanium that must be added to silicon to yield an alloy that contains 2.43×10^{21} Ge atoms per cubic centimeter. The densities of pure Ge and Si are 5.32 and 2.33 g/cm^3, respectively. Assume the atomic weights for Germanium and Silicon as 72.59 and 28.09 g/mol respectively.

[12 marks]

Let weight pecent of germanium added is x%

Density of pure Ge

Q.1 (e) A computer has a cache, main memory, and a disk used for virtual memory. If a referenced word is in the cache, 15 nsec are required to access it. If it is in main memory but not in the cache, 50 nsec are needed to load it into the cache, and then the reference is started again. If the word is not in main memory, 10 msec are required to fetch the word from disk, followed by 50 nsec to copy it to the cache, and then the reference is started again. The cache hit ratio is 0.9 and the main memory hit ratio is 0.5. What is the average time in nsec required to access a referenced word in this system?

[12 marks]

Average time = Cache hit ratio × cache access time
+ cache miss ratio × main memory hit ratio × [Cache access time + Time to load from main memory to cache + Time to access main memory]

+ cache miss × main memory miss × [time taken to access virtual memory + time taken to load into cache + access time in cache]

$10\ msec = 10 \times 10^{-3} sec = 10^{7}\ nsec$

Average time = $0.9 \times [15\ nsec] + 0.1 \times [15 + 50]\ nsec \times 0.5$
$+ 0.1 \times 0.5 \times [15 + 50 + 10^{7}]\ nsec$

Average time = 500020 nsec
= 0.50002 msec

Q.2 (a) Consider two different machines, with two different instruction sets, both of which have a clock rate of 200 MHz. The following measurements are recorded on the two machines running a given set of benchmark programs.

Instruction Type	Instruction Count (millions)	Cycles per instruction
Machine A		
Arithmetic and logic	8	1
Load and store	4	3
Branch	2	4
Others	4	3
Machine B		
Arithmetic and logic	10	1
Load and store	8	2
Branch	2	4
Others	4	3

(i) Determine the effective CPI, MIPS rate and execution time for each machine.

(ii) Comment on results.

[15 + 5 marks]

CPI : cycle per instruction

$$CPI = \frac{\text{Total cycle for instruction}}{\text{Total Number of instruction}}$$

Machine A

$$CPI = \frac{8\times1 + 4\times3 + 2\times4 + 4\times3 \text{ million}}{8+4+2+4 \text{ million}}$$

$$CPI = \frac{40}{18} = \frac{20}{9} = 2.222$$

Machine B

$$CPI = \frac{10\times1 + 8\times2 + 2\times4 + 4\times3}{10+8+2+4}$$

$$= 1.917$$

Do not write in this margin

MIPS rate: No. of million instruction per second

$$\text{MIPS}: \frac{1 \times}{\text{Total No. of instruction (million) cycle} \times \text{Time taken for one cycle}}$$

Given clock frequency = 200 MHz

Time taken for one cycle = $\frac{1}{200 \times 10^6}$ sec

$= 5 \times 10^{-9}$ sec

$= 5$ n sec

Machine A

Total No. of instruction cycle (million) = $8 \times 1 + 4 \times 3 + 2 \times 4 + 4 \times 3$

$= 40$ (million) cycle

~~MIPS = 40 CPI x clock frequency~~

$$\text{MIPS} = \frac{1}{40 \times 10^6 \times 5 \times 10^{-9}} \text{ MIPS}$$

MIPS = 5

Machine B

$$\text{MIPS} = \frac{1}{46 \times 10^6 \times 5 \times 10^{-9}} = 4.3478$$

MIPS = 4.3478

Execution time = No. of instruction × CPI × time taken for each instruction

Machine A

$T_A = 40 \times 10^6 \times 5 \times 10^{-9}$ sec

$= 0.2$ sec

$T_B = 46 \times 10^6 \times 5 \times 10^{-9} = 0.23$ sec

CPI of Machine A is more than machine B so avg execution time per instruction is high in machine A. In the same time machine B can perform more instruction operation.
Execution time is more in machine B

Machine B is faster than machine A
because ~~CPI is low in~~ machine B

Q.2 (b) (i) Addition of 0.3 atomic % nickel and 0.4 atomic % silver into copper at 298 K increases the resistivity by 0.012 mΩ cm and 0.00018 mΩ m respectively. If the resistivity of copper is 0.025 mΩ cm at 298 K, determine the conductivity of the resulting alloy in $(\Omega\, m)^{-1}$.

(ii) Explain with graphical representation, how mobility varies with temperature?

[10 + 10 marks]

$\rho_{alloy} = \rho_{matrix} + C x (1-x)$
↳ Nordium constant

ρ_{alloy}: Resistivity of the alloy
ρ_{matrix}: Resistivity of copper.
x: % of the added metal.

Resistivity of alloy $= \frac{0.3}{100} \times 0.012$ m-Ω cm
$+ \frac{0.4}{100} \times 0.00018$ m-Ω cm
$+ 0.993 \times 0.025$ m-Ω cm

Resistivity of alloy = 0.0248672 m-Ω cm

Conductivity $= \frac{1}{\rho_{alloy}} = \frac{1}{0.0248672 \text{ m-}\Omega\text{-cm}}$

Conductivity = $4.0222 \times 10^4 \ \Omega^{-1} cm^{-1}$

$= 4.0224 \times 10^6 (\Omega m)^{-1}$.

$= 4.0224 \times 10^6 \ (\Omega m)^{-1}$

(ii) Mobility is ~~due~~ affected by two parameter

~~Mobility/ def~~

Mobility is proportional to the collision time

The mobility due to lattice vibration are ~~directly~~ inversely proportional to time

$\mu_L \propto T^{-3/2}$ (for T > 100k)

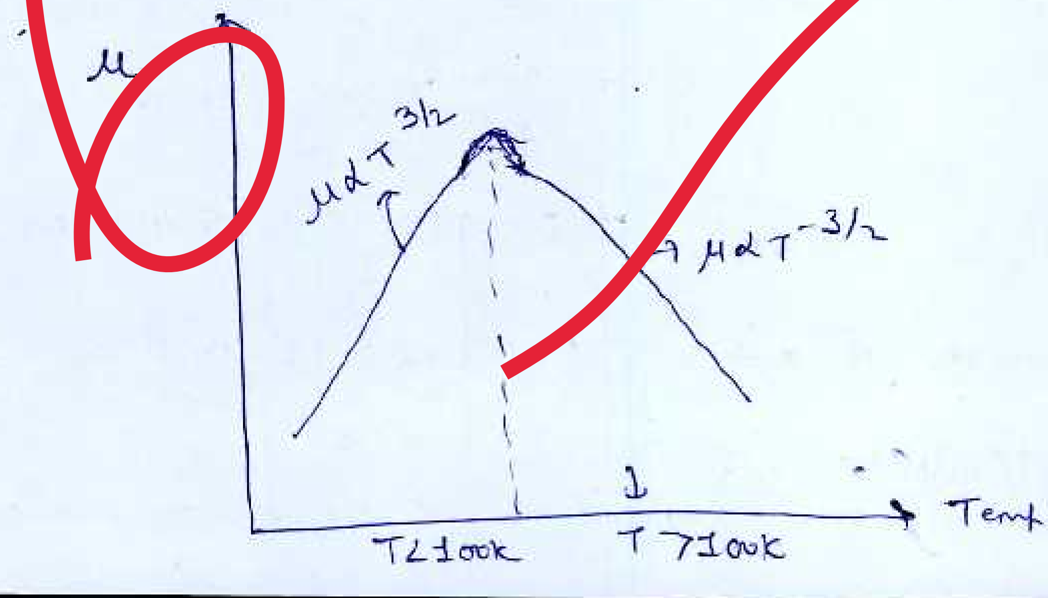
$\mu_I \propto T^{3/2}$ (for T < 100k)

as temp increases mobility decreases

Mobility due to collision with Impurity ion increase with increase in temp and it is effective for T(< 100k)

$$\frac{1}{\mu_{eff}} = \frac{1}{\mu_L} + \frac{1}{\mu_I}$$

$$\mu_{eff} = \frac{\mu_L \times \mu_I}{\mu_L + \mu_I}$$



Q.2 (c) (i) Enumerate the differences between Carbon Dots and Quantum Dots.

(ii) At 100°C, copper (Cu) has a lattice constant of 3.655 Å. What is the density at this temperature? (Assume atomic weight of Cu as 63.55 g/mole).

[10 + 10 marks]

Quantum dot: They are the zero dimensional nano material whose all dimension are in nano range or dimensions are less than (100 nm)

$$\text{Density} = \left(\frac{N \times M}{N_A \; a^3}\right)$$

N → No. of atom present in the lattice of the crystal

M → Molecular / Atomic mass

N_A → Avagadero number → 6.023×10^{23} atoms

a → Lattice constant

Given $a = 3.655 \times 10^{-10}$ m

$M = 63.55$ g

$N_A = 6.023 \times 10^{23}$

$N = 4$ (for cu)

$$\text{Density} = \frac{4 \times 63.55 \text{ g}}{6.023 \times 10^{23} \times (3.655 \times 10^{-10})^3 \text{ m}^3}$$

Density = 8644948.81 g/m³

= 8.6449 g/cm³

Density = 8.6449 g/cm³

Q.3 (a) Consider a pure Si crystal that has $\varepsilon_r = 11.9$.

(i) What is the electronic polarizability due to valence electrons per Si atom?

(ii) Assume that a Si crystal sample electroded on opposite faces and has a voltage applied across it. By how much is the local field greater than the applied field?

(iii) What is the resonant frequency f_0 corresponding to ω_0?

Consider the density of the Si crystal, the number of Si atoms per unit volume, N is given as $5 \times 10^{28}\ m^{-3}$.

[6 + 8 + 6 marks]

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Q.3 (b) **(i)** **1.** What is superconductivity and how the superconductors are classified?

2. The superconducting state of a lead specimen has critical temperature of T_c. It has critical magnetic field of 8.2×10^5 A/m at 0 K. If the critical field at 5 K for this specimen is 4.1×10^5 A/m, then find value of T_c at 5 K.

(ii) Calculate the first three energy levels for an electron in a quantum well of width 10 Å with infinite walls.

(Assume, Plank's constant, $h = 6.63 \times 10^{-34}$ J.s, depth of well, $L = 1$ nm,
mass of electron, $m = 9.11 \times 10^{-31}$ kg)

[10 + 10 marks]

Q.3 (c) (i) A process has been allocated 3 page frames. Assume that none of the pages of the process are available in memory initially. The process makes the following sequence of page references (reference string) : 1, 2, 1, 3, 7, 4, 5, 6, 3, 1.

If optimal page replacement policy is used, how many page faults occur for the above reference string?

(ii) Least recently used (LRU) page replacement policy is a practical approximation to optimal page replacement. For the above reference string, how many more page faults occur with LRU than with the optimal page replacement policy?

[10 + 10 marks]

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Q.4 (a) Consider zero, one, two and three address machines. Write programs to compute

$$X = (A + B \times C)/(D - E \times F)$$

for each of the four machines. The instructions available for use are as follows:

'0' address	'1' address	'2' address	'3' address
PUSH M	LOAD M	MOV $(X \leftarrow Y)$	MOV $(X \leftarrow Y)$
POP M	STORE M	ADD $(X \leftarrow X+Y)$	ADD $(X \leftarrow Y+Z)$
ADD	ADD M	SUB$(X \leftarrow X-Y)$	SUB $(X \leftarrow Y-Z)$
SUB	SUB M	MUL$(X \leftarrow X \times Y)$	MUL $(X \leftarrow Y \times Z)$
MUL	MUL M	DIV$(X \leftarrow X/Y)$	DIV $\left(X \leftarrow \frac{Y}{Z}\right)$
DIV	DIV M		

[20 marks]

Q.4 (b) **(i)** Define the following:

1. Translators **2.** Assemblers **3.** Compilers

4. Converters **5.** Interpreters

(ii) **1.** Consider a magnetic material of 20 cm length carries a 1 Amp current. If the magnetic susceptibility of the material is 0.5×10^{-2}, calculate the flux density in the material in Tesla.

2. Distinguish between hard and soft magnetic material.

[10 + 10 marks]

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Q.4 (c) **(i)** What is lossless join decomposition property in DBMS? If a relation 'R' is decomposed into two relations R_1 and R_2, then what are the conditions if it is lossless decomposition?

(ii) Find out which one of the given below decomposition of $R(VWXYZ)$ are lossless decomposition and lossy decomposition.

$R(VWXYZ)$

$Z \to Y, \quad Y \to Z, \quad X \to YV, \quad VW \to X$

1. $R_1(VWX), R_2(XYZ)$
2. $R_1(VWX), R_2(YZ)$
3. $R_1(VW), R_2(WXYZ)$

[8 + 12 marks]

Section B : Electronic Devices & Circuits-1 + Advanced Communications Topics-1 + Analog & Digital Communication Systems-2

Q.5 (a) A new semiconductor has density of states $N_C = 10^{19}\ cm^{-3}$, $N_V = 5 \times 10^{18}\ cm^{-3}$ and energy gap, $E_g = 2$ eV. If it is doped with 10^{17} donors (fully ionized), calculate electron, hole and intrinsic carrier concentrations at 627°C. (Assume E_g, N_C and N_V are independent of temperature.)

[12 marks]

Given $N_C = 10^{19}\ cm^{-3}$

$N_V = 5\times10^{18}\ cm^{-3}$

$E_g = 2eV$

$N_D = 10^{17}$ donor/cm^3

$T = 627°C = 627+273\ K = 900K \rightarrow V_T = \frac{kT}{q} = 0.0775 eV$

$$n_i = \sqrt{N_C N_V}\ e^{-\frac{E_g}{2kT/q}}$$

$$n_i = \sqrt{10^{19} \times 5\times10^{18}}\ e^{-\frac{2eV}{2\times0.775eV}}$$

$$n_i = 1.7772\times10^{13}\ cm^{-3}$$

$N_D >> n_i$

So $n \simeq N_D \simeq 10^{17}\ cm^{-3}$

$$p = \frac{n_i^2}{N_D} = \frac{(1.772 \times 10^{13})^2}{10^{17}}$$

$p = 3.158 \times 10^{9}\ cm^{-3}$

Electron concentration $n = 10^{17}\ cm^{-3}$

Hole concentration $p = 3.158 \times 10^{9}\ cm^{-3}$

Intrinsic concentration $n_i = 1.7772 \times 10^{13}\ cm^{-3}$

Q.5 (b) Draw the following data formats for the bit stream 1100110:

(i) Polar NRZ

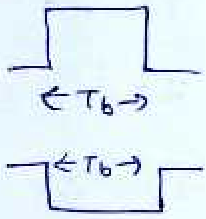
(ii) Unipolar RZ

(iii) Alternate Mark inversion (AMI)

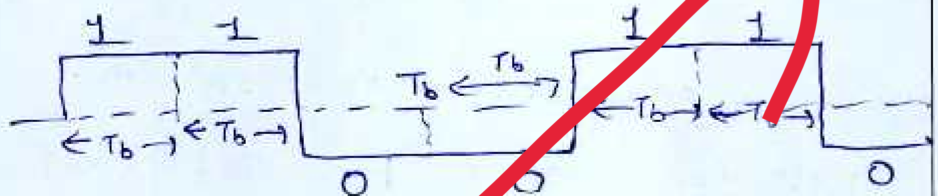
(iv) Manchester

[12 marks]

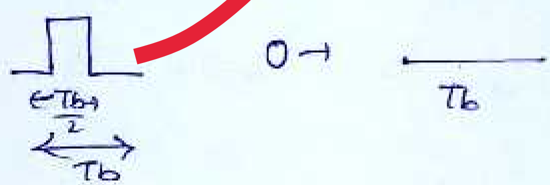
Polar NRZ: 1 → 0 →



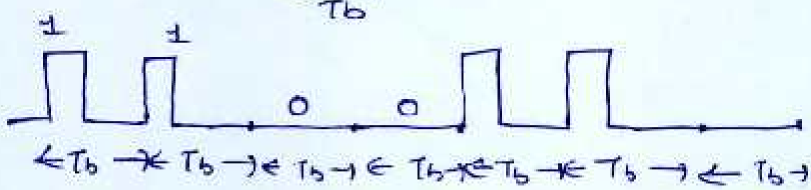
1100 110 :



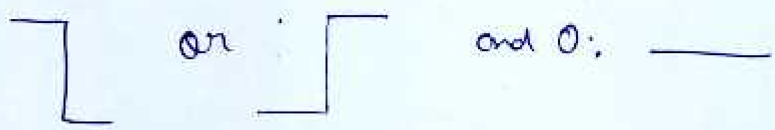
Unipolar RZ: 1 → 0 →



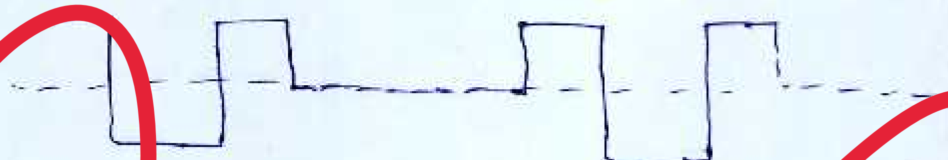
1100 110:



AMI: 1: or and 0:



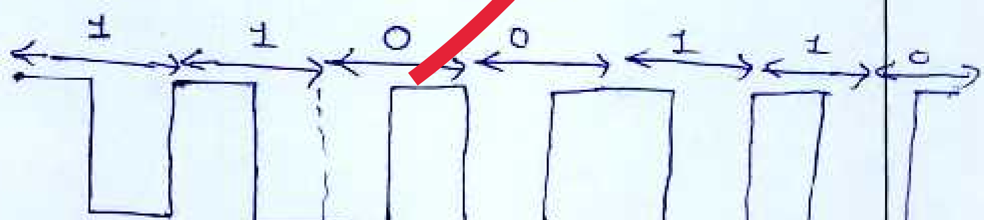
1100110:



10

Machester 1: 0:

1100 110:



Q.5 (c) The cell-site transmitted power increased by 3 dB (or doubled). For the same minimum acceptable received signal power and all other parameters remaining unchanged, prove that the coverage area is increased by $\sqrt{2}$ times. Assume mobile radio operating environment conditions.

[12 marks]

Q.5 (d) Consider the two 8-point QAM signal constellation shown in figure below. The minimum distance between adjacent points is 2A. Determine the average transmitted power for each constellation assuming that the signal points are equally probable. Which constellation is more power efficient?

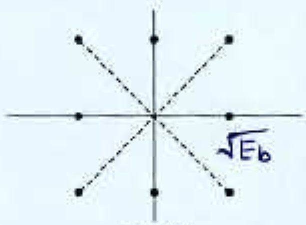


Fig. (a)

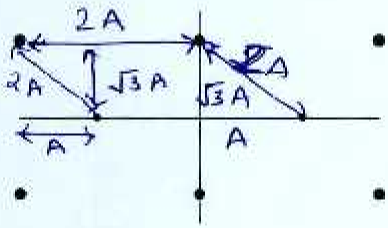


Fig. (b)

[12 marks]

Fig

Q.5 (e) Describe some methods to reduce co-channel interference and can the value of cluster size be increased more than 7 to minimise the effect of co-channel interference in cellular communication?

[12 marks]

Q.6 (a) (i) Explain TCP/IP reference model briefly.

(ii) Define cryptography and its type briefly.

[14 + 6 marks]

Q.6 (b) A city with a coverage area of 500 sq. km is covered with a 12-cell system each with a radius of 1.241 km. The total spectrum allocated is 36 MHz with a full duplex channel bandwidth is 30 kHz. Assume a GoS of 0.02 for an Erlang B system is specified and the offered traffic per user is 0.05 Erlangs.

Compute

(i) The number of cells in the service area.

(ii) The number of channels per cell.

(iii) Traffic intensity of each cell.

(iv) The maximum carried traffic.

(v) The total number of users that can be served for 2% GoS.

Use the Erlang B chart as given below:

No. of channels 'C'	**Capacity (Erlangs) for GoS**		
	0.02	0.005	0.002
5	1.36	1.13	0.9
10	4.46	3.96	3.43
20	12	11.1	10.1
40	29.0	27.3	25.7
70	56.1	53.7	51.0
100	84.0	80.9	77.4

[20 marks]

Q.6 (c) **(i)** Consider a binary memoryless source X with two symbols x_1 and x_2. Show that $H(X)$ is maximum when both x_1 and x_2 are equiprobable.

(ii) An analog message signal bandlimited to 2.8 kHz is sampled above Nyquist rate to have a guard band of half of message signal bandwidth. The samples are quantized into 4 levels. The quantization levels Q_1, Q_2, Q_3 and Q_4 are assumed to be independent and occur with equal probabilities. Determine the information rate of the source.

[10 + 10 marks]

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Q.7 (a) **(i)** **1.** A Si sample is doped with 10^{17} boron atoms/cm^3. What is the electron concentration, n_0 at 300 K? What is the resistivity?

2. A Ge sample is doped with 3×10^{13} Sb atoms/cm^3. Using the requirements of space charge neutrality, calculate the electron concentration n_0 at 300 K.

[Assume, $n_i = 1.5 \times 10^{10}$ cm^{-3} for Si and $n_i = 2.5 \times 10^{13}$ cm^{-3} for Ge, $\mu_p = 250 \frac{\text{cm}^2}{\text{Vs}}$]

(ii) The total current in a semiconductor is constant and is composed of electron drift current and hole diffusion current. The electron concentration is constant and equal to 10^{16} cm^{-3}. The hole concentration is given by

$$p(x) = 10^{15} \exp\left(\frac{-x}{L}\right) \text{cm}^{-3};\ x \geq 0$$

where, $L = 12$ µm. The hole diffusion coefficient, $D_p = 12$ cm^2/s and electron mobility $\mu_n = 1000 \frac{\text{cm}^2}{\text{V-s}}$. The total current density is $J = 4.8$ A/cm^2. Calculate:

1. hole diffusion current density for $x > 0$.
2. electron current density for $x > 0$.
3. electric field for $x > 0$.

[10 + 10 marks]

① Given $n_i = 1.5 \times 10^{10}$ cm^{-3}

$N_A = 10^{17}$ /cm^3

$N_A >> n_i$

So $p_0 \simeq N_A \simeq 10^{17}$/cm^3

$$n_0 = \frac{n_i^2}{p_0} \frac{(1.5\times10^{10})^2}{10^{17}} = 2250/\text{cm}^3$$

$$\rho = \frac{1}{(nq\mu_n + pq\mu_p)} \approx \frac{1}{qN_A\mu_p}$$

$$\rho \approx \frac{1}{1.6\times10^{-19} \times 10^{17} \times 250} = 0.24966\ \Omega\text{-cm}$$

Resistivity = $0.24966\ \Omega$ cm

(2) Ge doped with 3×10^{13} Sb atoms/cm³

Sb is a donor type impurity so

we have $N_D = 3\times10^{13}/cm^3$

$N_A = 0$

Total positive charge is equal to

$p_o + N_D = n_o$ (By charge neutrality)

$$p_o = \frac{n_i^2}{n_o}$$

$$\frac{n_i^2}{n_o} + N_D = n_o$$

$$n_o^2 - n_o N_D - n_i^2 = 0$$

By quadratic formula.

$$n_o = \frac{N_D}{2} + \sqrt{\frac{N_D^2 + 4n_i^2}{4}}$$

$$n_o = \frac{N_D}{2} + \sqrt{\frac{N_D^2}{4} + n_i^2}$$

put $N_D = 3\times10^{13}$ and $n_i = 2.5\times10^{13}$

$$n_o = \frac{3\times10^{13}}{2} + \sqrt{\frac{(3\times10^{13})^2}{4} + (2.5\times10^{13})^2}$$

$$n_o = 4.415\times10^{13}\ cm^{-3}$$

(ii) Hole diffusion current density

Q.7 (b) An n-type Si sample of thickness L is inhomogeneously doped with phosphorus donor whose concentration profile is given by $N_D(x) = N_0 + (N_L - N_0)\left(\frac{x}{L}\right) \text{cm}^{-3}$. Find:

(i) Electric potential across the sample at thermal equilibrium.

(ii) Electric potential when $\frac{N_L}{N_0} = 0.75$ (Assume: $D_n = 12 \text{ cm}^2/\text{s}$; $\mu_n = 3000 \frac{\text{cm}^2}{\text{V-s}}$)

[15 + 5 marks]

$$n q \mu_n E + q D_n \frac{dn}{dx} = 0 \rightarrow \text{(Equilibrium)}$$

$$E = -\frac{D_n}{\mu_n} \frac{1}{n} \frac{dn}{dx} = -\frac{D_n}{\mu_n} \frac{1}{n} \frac{dn}{dx}$$

$$N_D(x) = \left(N_0 + (N_L - N_0)\left(\frac{x}{L}\right)\right) \text{cm}^{-3}$$

$$\frac{dn}{dx} = \frac{N_L - N_0}{L}$$

$$E(x) = -\frac{D_n}{3000} \times \frac{1}{N_0 + (N_L - N_0)\frac{x}{L}} \times \frac{(N_L - N_0)}{L}$$

$$\phi(x) = -\int E(x)\, dx$$

$$\phi(x) = \frac{-D_n}{3000} \times \frac{N_L - N_0}{L} \left[\int \frac{1}{N_0 + (N_L - N_0)\frac{x}{L}} dx\right]$$

$$\int \frac{1}{N_0 + (N_L - N_0)\frac{x}{L}} dx$$

Let $u = N_0 + (N_L - N_0)\frac{x}{L}$

$$du = \frac{N_L - N_0}{L} dx$$

$$\int \frac{1}{u}\,dx = \int \frac{1}{u} \times \frac{du}{\frac{N_L - N_o}{L}}$$

$$\int \frac{1}{u}\,dx = \frac{1}{\frac{N_L - N_o}{L}} \ln|u|$$

$$= \frac{1}{\frac{N_L - N_o}{L}} \ln\left(N_o + (N_L - N_o)\frac{x}{L}\right)$$

$$\boxed{\phi(x) = \frac{-D_n}{\mu_n} \times \ln\left(N_o + (N_L - N_o)\frac{x}{L}\right) + C}$$

↳ potential profile.

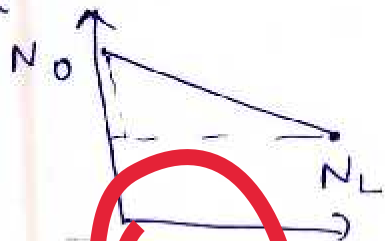
$$\phi(x) = \frac{-D_n}{\mu_n} \ln\left(N_o + (N_L - N_o)\frac{x}{L}\right) + \frac{D_n}{\mu_n}\ln N_o$$

~~Given $\frac{N_L}{N_o} = 0.75$~~

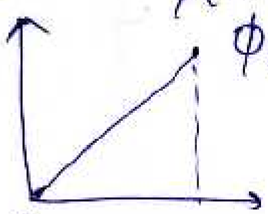
$$\boxed{\phi(x) = \frac{D_n}{\mu_n} \ln\left[\frac{N_o}{N_o + (N_L - N_o)\frac{x}{L}}\right]}$$

Let $N_o > N_L$ or $\frac{N_L}{N_o} < 1$

then



at $x = L$ we have $\phi(x) = \phi_{bi}$



$$\boxed{\phi_{bi} = \frac{D_n}{\mu_n}\ln\left(\frac{N_o}{N_L}\right) = 1.151 \times 10^{-3}}$$

for At $x = 0$ we have $\phi(x) = 0$

So $C = \frac{D_n}{\mu_n}\ln(N_o)$

$$\phi(x) = \frac{-D_n}{\mu_n} \times \ln\left(N_o + (N_L - N_o)\frac{x}{L}\right) + \frac{D_n}{\mu_n}\ln(N_o)$$

$$\phi(L) = -\frac{12}{3000} \times \ln(N_L) + \frac{D_n}{\mu_n}\ln(N_o) = \frac{D_n}{\mu_n}\ln\left(\frac{N_o}{N_L}\right)$$

Ans $\boxed{\phi_{bi} = 1.151 \times 10^{-3}\,V}$

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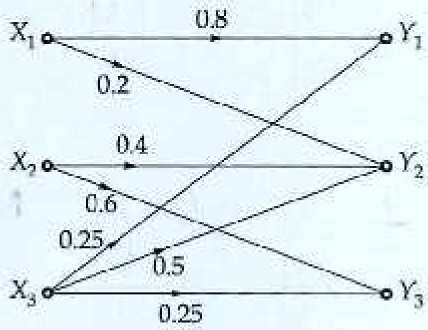
Q.7 (c) **(i)** Consider the discrete source transmit messages X_1, X_2 and X_3 with the probabilities 0.25, 0.5 and 0.25 respectively. The source is connected to the channel as given in below figure. Determine the value of $H\left(\frac{X}{Y}\right)$.



(ii) Consider a linear block code with generator matrix shown below:

$$G = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

Determine maximum and minimum hamming weight.

[4 + 6 marks]

$H(X,Y) = H(Y) + H\left(\frac{X}{Y}\right) = H(X) + H\left(\frac{Y}{X}\right)$

$H\left(\frac{X}{Y}\right) = H(X,Y) - H(Y)$

$[\quad\quad]$

$H[X,Y] = P(x)_{diagonal} \times P\left(\frac{Y}{X}\right)$

P

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~~P(y/x) = xP~~

$P(y) = P(x)\; P\left(\frac{y}{x}\right)$

$$P\left(\frac{y}{x}\right) = \begin{matrix} & y_1 & y_2 & y_3 \\ x_1 & 0.8 & 0.2 & 0 \\ x_2 & 0 & 0.4 & 0.6 \\ x_3 & 0.25 & 0.5 & 0.25 \end{matrix}$$

$P[x] = [0.25 \quad 0.5 \quad 0.25]$

$$P[y] = [0.25 \quad 0.5 \quad 0.25] \begin{bmatrix} 0.8 & 0.2 & 0 \\ 0 & 0.4 & 0.6 \\ 0.25 & 0.5 & 0.25 \end{bmatrix}$$

$P[y] = [0.2625 \quad 0.375 \quad 0.3625]$

$H[y] = -\sum P(y)\log_2 P(y)$

$H[y] = -[0.2625\log_2(0.2625) + 0.375\log_2(0.375) + 0.3625\log_2(0.3625)]$

$H[y] = 1.56784$ bits/symbol

$P(x,y) = (P[x])_d \times P\left(\frac{y}{x}\right)$

$$= \begin{bmatrix} 0.25 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 0.25 \end{bmatrix} \begin{bmatrix} 0.8 & 0.2 & 0 \\ 0 & 0.4 & 0.6 \\ 0.25 & 0.5 & 0.25 \end{bmatrix}$$

$$P(x,y) = \begin{bmatrix} 0.2 & 0.05 & 0 \\ 0 & 0.2 & 0.3 \\ 0.0625 & 0.125 & 0.0625 \end{bmatrix}$$

$$H(x,y) = -\sum\sum p(x_i, y_j) \log_2 (x_i, y_j)$$

$$H(X,Y) = \{0.2 \log_2 (0.2) + 0.05 \log_2 (0.05)$$
$$+ 0.2 \log_2 (0.2) + 0.3 \log_2 (0.3)$$
$$+ 0.0625 \log_2 (0.0625)$$
$$+ 0.125 \log_2 (0.125)$$
$$+ 0.0625 \log_2 (0.0625)$$

$H(X,Y) = 2.01986$ bits/symbol

$H\left(\frac{X}{Y}\right) = H(X,Y) - H(Y)$

$= 0.452$ bits/symbol

(ii) Maximum hamming weight = 2
Min = 1

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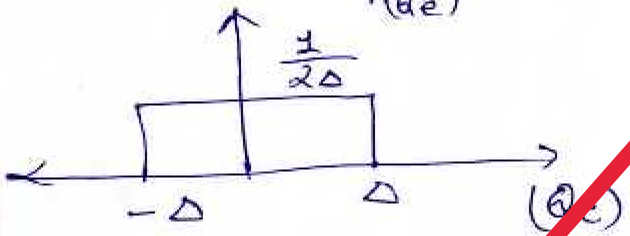
Q.8 (a) **(i)** Derive equation for the maximum output signal to quantization noise ratio of the Delta modulation system for a sinusoidal input.

(ii) Consider a low-pass signal with a bandwidth of 3 kHz. A linear delta modulation system, with step size $\Delta = 0.1$ V, is used to process this signal at a sampling rate ten times the Nyquist rate. For 1 V amplitude of a test sinusoidal signal of frequency 1 kHz, evaluate the output signal to noise ratio in dB under (a) prefiltered, (b) postfiltered conditions.

[14 + 6 marks]

$\Delta \rightarrow$ Is the step size

For Δ-modulation error will lie between $-\Delta$ and Δ



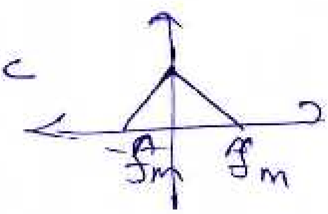
power of noise = $E[n(Q_e)^2]$

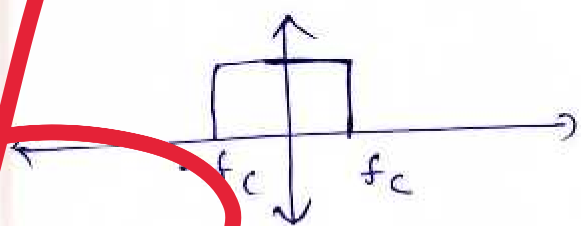
Power of noise = $\int_{-\Delta}^{\Delta} Q_e^2 \times \frac{1}{2\Delta} \, dQ_e$

power of noise = $\frac{\Delta^2}{3}$

let Input signal is $A_m \sin \omega t$

filter with cutoff frequency f_c



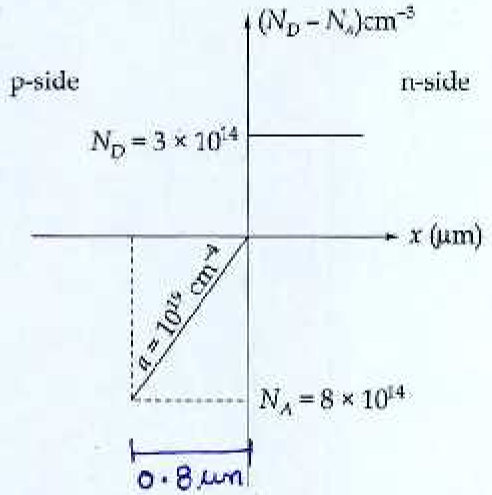


Signal output voltage: $A_m \times \frac{f_m^3}{f_c^3}$

$$SNR = \frac{3}{8\pi^2} \frac{f_m^3}{\omega f_m^2}$$

$$(SNR) = \frac{3}{8\pi^2}\left\{\frac{f_m^3}{\omega f_c^2}\right\}$$

Q.8 (b) A diffused silicon p-n junction has a linearly graded junction on p-side and a uniform doping on n-side as shown below:



If the depletion width on the p-side is 0.8 μm at zero bias. Find:

(i) total depletion layer width.

(ii) maximum E-field on p-side and n-side at zero bias.

(iii) draw built-in potential on p-side and n-side.

(Assume, $\epsilon_s = 11.9\epsilon_0$)

[20 marks]

Let width on n-side is W_n

Given $W_p = 0.8\ \mu m$, x is in cm

$N_A(x) = -(10^{19})x + 8\times10^{14}$ (cm^{-3})

$N_A(x) = 8\times10^{14} - x\times10^{19}$ cm^{-3}

In equilibrium (zero bias) total charge (per unit area) on p-side will be equal to total charge on n-side

Total charge on p-side (per unit area) $= \frac{1}{2}\times 8\times10^{14}\times 0.8\times10^{-4}$ cm

$= 3.2\times10^{10}\ /cm^2$

Total charge on n-side $= N_D \times W_n$

$= 3\times10^{14}\times W_n$

$3.2\times10^{10} = 3\times10^{14}\times W_n$

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$W_n = 1.067 \times 10^{-4}$ cm

$W_n = 1.067\ \mu m$

Total depletion layer width = $W_n + W_p = 1.067 + 0.8 =$
$= 1.867\ \mu m$

(ii) $\frac{dE}{dx} = \frac{\rho_v}{\varepsilon}$

$E = \int \frac{\rho_v}{\varepsilon} dx$

$\rho_v = q N_D$ (on n-side)

$E(x) = \frac{q N_D}{\varepsilon_s}(x) + C$

At $x = w_n \rightarrow E(x)$ will be zero

So we get $C = -\frac{q N_D}{\varepsilon_s}(w_n)$

$E(x) = \frac{q N_D}{\varepsilon_s}(x - w_n)$

E_{max} on n-side $= \frac{q N_D}{\varepsilon_s} w_n$.

P-side

$\rho_v(x) = -q(-10^{19} x + 8 \times 10^{14})$

$E_p(x) = -\frac{q}{\varepsilon_s}\int(-10^{19}x + 8 \times 10^{14})dx$

$E_p(x) = -\frac{q}{\varepsilon_s}\left(-\frac{x^2}{2} 10^{19} + 8 \times 10^{14} x\right) + C$

At $x = w_p$ we get $E_p(x) = 0$

$$E_p(x) = + \frac{qx^2}{2\varepsilon_s} 10^{19} - \frac{q}{\varepsilon_s}(8\times10^{4})x + \frac{q}{2\varepsilon_s}(8\times10^{14})\times w_p$$

$$E_{p\,max} = \frac{q}{2\varepsilon_s} 8\times10^{14}\times w_p$$

$$E_{n\,max} = \frac{qN_D}{\varepsilon_s} w_n$$

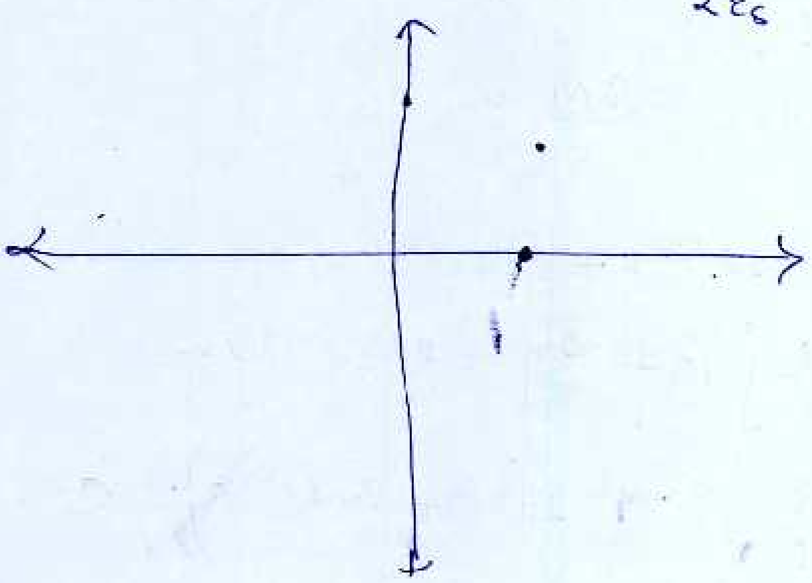
Built in potential $\phi(x) = -\int E \cdot dx$

n-side

$$\phi_n(x) = -\frac{qN_D}{\varepsilon_s}\left(\frac{x^2}{2} - w_n x\right) + C$$

p-side

$$\phi_p(x) = \frac{q}{2\varepsilon_s}\frac{x^3}{3}\times10^{19} - \frac{q}{2\varepsilon_s}(8\times10^{4})x^2 + \frac{q}{2\varepsilon_s} 8\times10^{14}\times w_p \times x + C$$



Q.8 (c) An ISP is granted a block of addresses starting with 190.100.0.0/16 [65,536 addresses]. The ISP needs to distribute these addresses to three groups of customers as follows:

(a) The first group has 64 customers; each needs 256 addresses.

(b) The second group has 128 customers; each needs 128 addresses.

(c) The third group has 128 customers; each needs 64 addresses.

Design the subblocks and find out how many addresses are still available after these allocations.

[20 marks]

Given Block of address are 190.100.0.0/16

we have mask of 16 bit so address will be available from 190.100.0.0 to 190.100.255.255 (Total 65,536 address)

ⓐ First group has 64 customer and each need 256 address so total address required are 64×256 = 16384

~~[illegible]~~.

1011 1110 0110 0100 00 00 0000 0000 0000
to
1011 1110 0110 0100 00 11 1111 1111 1111

190.100.0.0 to 190.100.63.255

190.100.0.0/18 Block for first group.

(b) 128 customer each needs 256 address

Total address required = 128 × 256 = 16384

1011 1110 0110 0100 0100 0000 00000000

to

1011 1110 0110 0100 0111 1111 1111 1111

190.100.64.0 to 190.100.127.255

190.100.64.0/18 Block for second group

(c) 128 customer each needs 128 address.

Total address required = 128 × 128 = 8192

1011 1110 0110 0100 1000 0000 00000000

1011 1110 0110 0100 1001 1111 1111 1111

190.100.128.0 to 190.100.159.255

190.100.128.0/19 Block for third group

Remaining address = 65536 − 16384 − 16384 − 8192

= 24576 address remain

18

oooo

(190)

190

1011 1110 0110 0100

0000 0000 0000 0000

64×256 16384

~~128×128~~ 16384

128× 64 = 8192

Space for Rough Work

1 instruction = CPI x time take

$$E_F = E_i + \frac{kT}{q} \ln\left(\frac{N_D}{i}\right)$$

$$\frac{1}{CPI \times \text{time taken}}$$

$$n = N_c \, e^{\frac{q(E_c - E_F)}{kT}}$$

$$E_F = E_c - kT \ln \frac{N_D}{n_v}$$

$$\nabla \cdot E = \frac{\rho_v}{\varepsilon_0}$$

$$E_C - E_F = kT \ln\left(\frac{n}{N_C}\right)$$

$$\frac{dE}{dx} = \frac{\rho_v}{\varepsilon_0}$$

$$E_c - E_F = kT \ln\left(\frac{n}{N_C}\right)$$

$$\frac{d^2\phi}{dx}$$

qN_D

$$n = N_c \, e^{\left(\frac{E_c - E_F}{V_T}\right)}$$

$$V = -\int E \, dx$$

$$p = N_v \, e^{\frac{(E_F - E_v)}{V_T}}$$

$V = \phi$

$$np = N_c N_v \, e^{\left\{\frac{E_c - E_F + E_F - E_v}{V_T}\right\}}$$

$$E = \int \frac{\rho_v}{\varepsilon_0} dx$$

$$n_i \, e^{\frac{E_c - E_v}{kT}}$$

$$n_i = \sqrt{N_c N_v} \, e^{\frac{E_g}{2kT}}$$

$$n q \mu_n E + q D_n \frac{dn}{dx} = 0$$

$N_A - N_D$

$$\frac{dn}{dx} = -$$

$$n \mu_n E = -D_n \frac{dn}{dx}$$

$$E = -\frac{D_n}{\mu_n n} \frac{dn}{dx}$$