MADE EASY

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	173

Signature of Evaluator ....

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.

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]

Soln (i) Program execution time without cache

Let Access time of Main memory (T_m)

$$T_m = 20T$$

Total program execution time when program has 'N' instruction

$$T_1 = 20T \times N$$

→ with cache

Access time of cache $(T_c) = T_m/20 = T$

Total program execution time with 'N' instruction

$$T_2 = N[0.96\,T_c + 0.04[T_m + T_c]]$$

$$= N[0.96T + 0.04[21T]]$$

$$= N(1.8T)$$

$$\text{Ratio} = \frac{\text{Execution time without cache}}{\text{Execution time with cache}}$$

$$= \frac{20TN}{1.8TN} = 11.11$$

(ii) If cache size is doubled

$$P_b[\text{Miss cache}] = \frac{1-0.96}{2} = 0.02$$

$$\text{Ratio} = \frac{N\,T_m}{N\left[(1-0.02)T_c + (0.02)(T_c + T_m)\right]}$$

$$= \frac{N(20)T}{N\left[0.98T + 0.02(T + 20T)\right]}$$

$$= \frac{20}{0.98 + 21 \times 0.02}$$

$$\boxed{\text{Ratio} = 14.28}$$

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]

Ready Queue :- P_1 P_3 P_6 P_2 P_4 P_1 P_3 P_5 P_1 P_3

P_1	P_3	P_6	P_2	P_4	P_5	P_1	P_3	P_5	P_1	P_3

→ 0 3 6 9 11 14 17 20 23 25 27 28

in nsec

	BT	CT	CT − BT = waiting time
P_1	8 5 2 0	27	19
P_2	2 0	11	9
P_3	7 4 1 0	28	21
P_4	3 0	14	11
P_5	5 2 0	25	20
P_6	3 0	9	6

$$\text{Avg waiting time} = \frac{19 + 9 + 21 + 11 + 20 + 6}{6}$$

$$= 14.33 \text{ nsec}$$

Do not write in this margin

Flow chart

Do not write in this margin

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]

Sol^n $n = 1$ $\lambda_1 = 7 \times 10^{-7}$ m $\lambda_2 = 5.38 \times 10^{-7}$ m

$d = \frac{10^{-3}}{500}$ m

$= 2 \times 10^{-6}$ m

$n\lambda_1 = 2d \sin\theta$

→ For red light $\lambda_1 = 7 \times 10^{-7}$ m

putting all values

(1) $7 \times 10^{-7} = 2d \sin\theta_1$

$7 \times 10^{-7} = 2 \times 10^{-6} \sin\theta_1$

$3.5 \times 10^{-1} = \sin\theta_1$

$\sin^{-1} 0.35 = \theta_1$

$\boxed{\theta_1 = 20.40°}$

→ For green light

$\lambda_2 = 5.38 \times 10^{-7}$ m

$n\lambda_2 = 2d \sin\theta_2$

$5.38 \times 10^{-7} = 2 \times 2 \times 10^{-6} \times \sin\theta_2$

$1.345 \times 10^{-1} = \sin\theta_2$

$\boxed{7.73° = \theta_2}$

Do not write in this margin

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]

Sol^n

Weight of Germanium $(W_G) = 72.59$ g/mol

Weight of Silicon $(W_{Si}) = 28.09$ g/mol

$d_{Ge} = 5.32$ g/cm^3

$d_{Si} = 2.33$ g/cm^3

Mole of Germanium per cm^3 $= \frac{d_{Ge}}{W_G} = \frac{5.32 \text{ g/cm}^3}{72.59 \text{ g/mol}}$

$= 0.073$ mol/cm^3

Mole of silicon per cm^3 $= \frac{d_{Si}}{W_{Si}} = \frac{2.33}{28.09}$

$= 0.083$ mol/cm^3

1 mole of Ge $= 6.02 \times 10^{23}$ atoms

2.43×10^{21} Ge atoms/cm^3 $= \frac{2.43 \times 10^{21}}{6.02 \times 10^{23}}$ mol/cm^3

$= 0.00403$ mol/cm^3

grams of Ge to have 0.00403 mol/cm^3 = 3.97 gram/cm^3

grams of Si to have 0.00403 mol/cm^3 = 1.36 gram/cm^3

4

Hence

weight % of germanium = $\frac{3.97}{3.97 + 1.36} \times 100$

= 74.48%

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]

Soln

$T_c = 15$ nsec

$T_m = 50$ nsec

$T_D = 10$ msec

(H_1) Hit ratio of cache = 0.9

(H_2) Hit ratio of main memory = 0.5

Avg time required for execution $= H_1 T_c + (1-H_1) H_2 (T_c + T_m) + (1-H_1)(1-H_2)[T_c + T_m + T_D]$

$= 0.9 \times 15 \times 10^{-9} + (0.1)(0.5) \times 65 \times 10^{-9} + (0.1)(0.5)[65 \times 10^{-9} + 10^{-2}]$

$= 13.5 \times 10^{-9} + 3.25 \times 10^{-9} + 0.05[0.01]$

$= 16.75 \times 10^{-9} + 5 \times 10^{-4}$

Avg time $= 5.0001675 \times 10^{-4}$ sec

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]

Machine :- A

Total instruction = (8 + 4 + 2 + 4) million

= 18 millions

total cycles = (8 × 1 + 4 × 3 + 2 × 4 + 4 × 3) million

= 40 millions

→ CPI (Machine A) = $\frac{40}{18}$ = 2.22

→ MIPS = $\frac{18}{40 \times \frac{1}{200 \times 10^6}}$ = 90

→ Execution time = 40 millions × $\frac{1}{200 \times 10^6}$

= 0.2 sec

Machine = B

total instruction = (10 + 8 + 2 + 4)

= 24 millions

total cycles = (10×1 + 8×2 + 2×4 + 4×3) Millions

= 46 millions

$$CPI = \frac{46}{24} = 1.92$$

$$MIPS = \frac{24}{46 \times \frac{1}{2 \times 10^8}} = 104.34$$

→ execution time = $\frac{46 \times 10^6}{2 \times 10^8}$

= 0.23 sec

Since MIPS for machine B is more hence Machine B is faster than machine A.

15

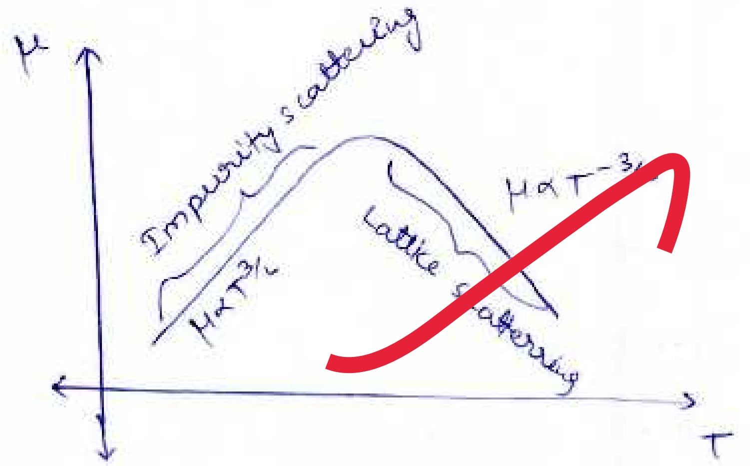
6

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]

(ii)



- Mobility in material is due to two component.

① lattice scattering

② Impurity scattering

① Lattice scattering :- In lattice scattering the moving electron interact with lattice particle and the moment of e⁻ is hindered. When the temperature is increased the lattice vibration also increases hence the interaction of e^- increases with lattice which result in low mobility of electron. Lattice scattering is dominant at relatively high temperature.

② Impurity scattering :- When e^- travel they reaches in the vicinity of impurities and there mobility is affected but when temperature is increased the electron speed also increases hence e^- spend less time in the vicinity of impurities and their mobility is increased.

$$\mu \propto \frac{T^{3/2}}{N_I}$$

(i) Nickel (%) = 0.3 % Silver (%) = 0.4 %

$\rho_1 = \rho_{cu} x_{cu} + \rho_{Ni} x_{ni}$

$\rho_1 = 0.997 \rho_{cu} + 0.003 \rho_{Ni}$

$\Delta\rho = \rho_1 - \rho_{cu}$

$= 0.997 \rho_{cu} + 0.003 \rho_{Ni} - \rho_{cu}$

$0.012 \times 10^{-6} = 0.003 \rho_{Ni} - 0.003 \rho_{cu}$

$12 \times 10^{-9} = 0.003 \rho_{Ni} - 0.003 \times 0.025 \times 10^{-3}$

$12 \times 10^{-6} = 0.003 \rho_{Ni} - 7.5 \times 10^{-8}$

$\rho_{Ni} = 29\ m\Omega\ cm$

$\rho_2 = \rho_{cu} x_{cu} + \rho_{si} x_{si}$

$\rho_2 = 0.996 \rho_{cu} + 0.004 \rho_{si}$

$\Delta\rho = \rho_2 - \rho_{cu}$

$18 \times 10^{-8} = 0.004 \rho_{si} - 0.004 \rho_{cu}$

$\boxed{\rho_{si} = 7 \times 10^{-5}}\ \Omega\ cm$

Do not write in this margin

Resistivity ~~conductive~~ of alloy $= 0.993\,\rho_{Cu} + 0.003\,\rho_{Ni} + 0.004\,\rho_{Si}$

$= 0.993 \times 0.025 \times 10^{-3} + 0.003 \times 29 \times 10^{-3} + 0.004 \times 7 \times 10^{-5}$

$= 2.4825 \times 10^{-5} + 8.7 \times 10^{-6} +$

$= 1.12 \times 10^{-4}\ \Omega cm$

$= 0.112 \times 10^{-3}\ \Omega cm$

$\rho = 0.112 \times 10^{-5}\ \Omega m$

$\sigma = 0.89 \times 10^{6}\ /\Omega m$

8

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]

(ii) $a = 3.655 \times 10^{-10}\ m$ $A = 63.55\ g/mole$

$$\text{density} = \frac{n \cdot A}{N_A V_c}$$

Cu = FCC

$n = 4$

$$d = \frac{4 \times 63.55}{6.022 \times 10^{23} \times (3.655 \times 10^{-10})^3}$$

$$= \frac{254.2}{~~6.022~~\ 2.94 \times 10^{-5}}$$

$d = 8.64 \times 10^{6}\ g/m^3$

$d = 8.64 \times 10^{3}\ kg/m^3$

5+4

Do not write in this margin

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]

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]

Do not write in this margin

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]

Do not write in this margin

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]

Do not write in this margin

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.

$R(VWXYZ)$

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

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

[8 + 12 marks]

Do not write in this margin

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]

Sol^n Given $N_c = 10^{19}/cm^3$ $N_v = 5\times10^{18}/cm^3$

$E_g = 2eV$ $N_D = 10^{17}$ $T = 627°C$

$T = 900°K$

$$E_{Fi} = \frac{E_c + E_v}{2} - \frac{kT}{2} \ln \frac{N_c}{N_v}$$

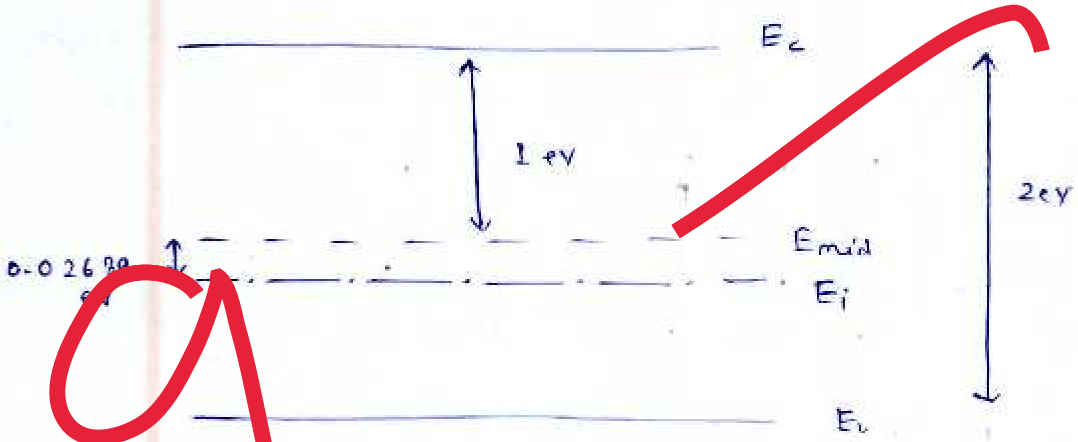
$$= E_{mid} - \frac{900}{11600 \times 2} \ln \frac{10^{19}}{5\times10^{18}}$$

$$= E_{mid} - 0.0388 \ln 2$$

$$= E_{mid} - 0.02689$$

let concn of intrinsic carrier at 627°c = n_i'

$E_{Fi} - E_{mid}$ =



$E_c - E_i = 1 + 0.02689$

$= 1.02689$ eV

$V_T \ln \frac{N_c}{n_i'} = 1.02689$ eV

$\frac{T}{11600} \ln \frac{N_c}{n_i'} = 1.02689$

$\ln \frac{N_c}{n_i'} = \frac{1.02689 \times 11600}{900}$

$\frac{N_c}{n_i'} = 559876.2808$

Intrinsic concentration at 627°c: $n_i' = 1.78 \times 10^{13}$

n (electron concentration) $= \frac{N_D}{2} + \sqrt{\left(\frac{N_D}{2}\right)^2 + n_i^2}$

$= \frac{10^{17}}{2} + \sqrt{\frac{10^{34}}{4} + 3.19 \times 1.26}$

$n \cong 10^{17}$

hole concentration $(p) = \frac{n_i^2}{n} = 3.168 \times 10^9$

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

(i) Polar NRZ

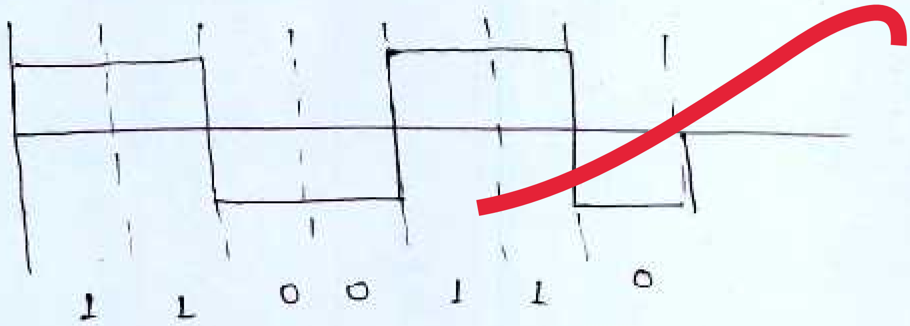
(ii) Unipolar RZ

(iii) Alternate Mark inversion (AMI)

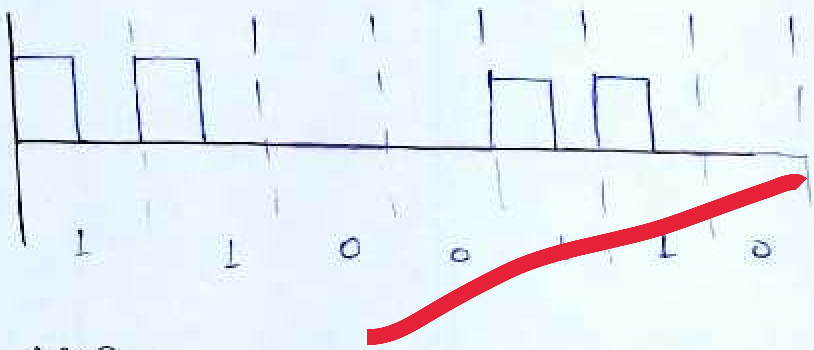
(iv) Manchester

[12 marks]

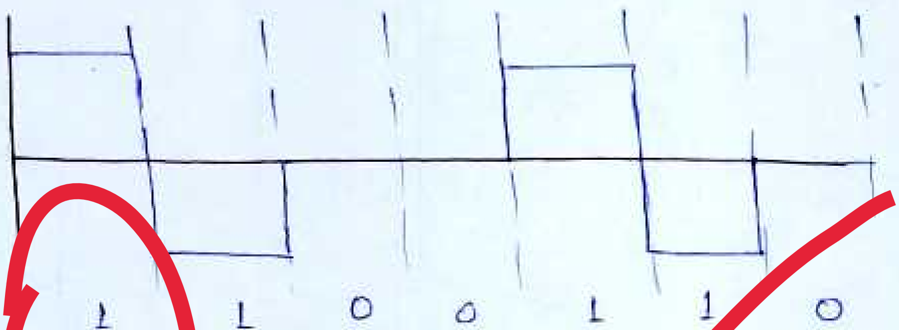
Sol^n (i) Polar NRZ



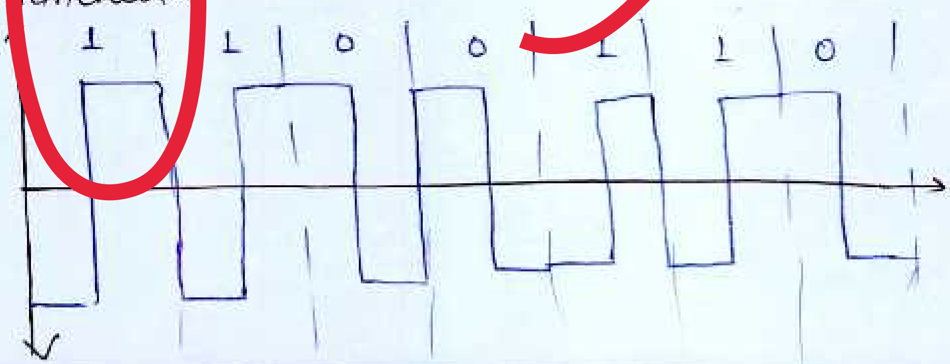
(ii) Unipolar RZ



(iii) AMI



(iv) Manchester



Do not write in this margin

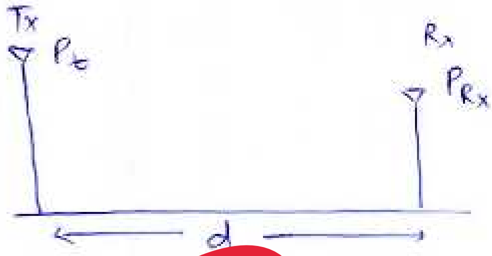
Q.5 (c) The cell-site transmitted power increased by 3 dB (or doubled). For the same minimum acceptable received signal power and all other parameters remaining unchanged, prove that the coverage area is increased by $\sqrt{2}$ times. Assume mobile radio operating environment conditions.

[12 marks]

Case – 1

Initially let transmitted power be P_{t1}

and received power be P_{r1}



According to FRISS eqn

$$P_{r1} = \frac{P_{t1}\, G_t\, A_e}{4\pi d^2}$$

Let minimum power acceptable at receiver is P_{min}

$$P_{r1} \geq P_{min}$$

$$\frac{P_{t1}\, G_t\, A_e}{4\pi d^2} \geq P_{min} \Rightarrow d^2 \leq \frac{P_t\, G_t\, A_e}{P_{min}} \quad \text{— (B)}$$

Case – 2

When $P_{Tx}' = 2P_t$

According to FRISS eqn

$$P_r' = \frac{P_{Tx}'\, G_t\, A_e}{4\pi d_2^2}$$

$$P_r' = \frac{2P_t\, G_t\, A_e}{4\pi d_2^2}$$

Minimum power is same

$$P_r' \geq P_{min}$$

$$\frac{2P_t\, G_t\, A_e}{4\pi d_2^2} \geq P_{min}$$

$$d_2^2 \leq \frac{2P_t G_t A_e}{P_{min}} \quad \text{— (A)}$$

From eqn (A) and (B)

$$d_2^2 = 2d^2$$

$$\boxed{d_2 = \sqrt{2}\, d}$$

Hence proved

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?

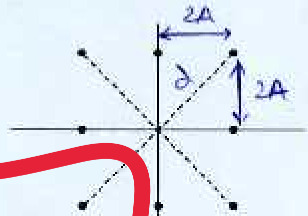


Fig. (a)

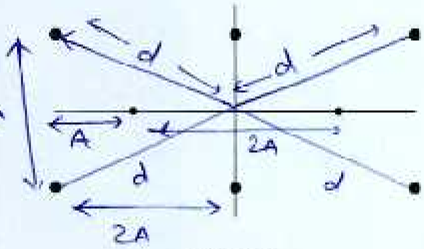


Fig. (b)

[12 marks]

For fig (a)

$d^2 = (2A)^2 + (2A)^2$

$d^2 = 4A^2 + 4A^2$

$d^2 = 8A^2$

$\boxed{d = 2\sqrt{2}A}$

Also

$\sqrt{E_s} = d$

$E_s = d^2$

$\boxed{E_s = 8A^2}$

symbol energy

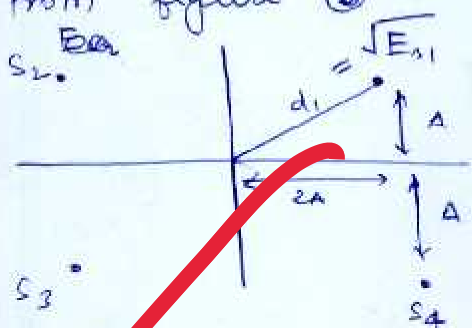
Since all symbol are equiprobable

Avg energy $= \frac{1}{8} \times 8 \times E_s$

$= 8A^2$

Case-1

From figure (b)



$d_1^2 = (2A)^2 + A^2$

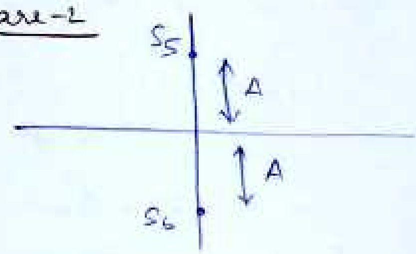
$= 4A^2 + A^2$

$d_1^2 = 5A^2$

$E_{s1} = d_1^2 = 5A^2$

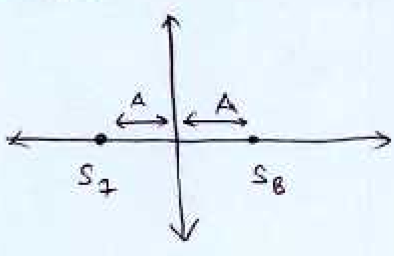
$\boxed{E_{s1} = E_{s2} = E_{s3} = E_{s4} = 5A^2}$

Case-2



$E_{s5} = A^2 = E_{s6}$

Case-3



$E_{s7} = E_{s8} = A^2$

Avg energy for figure (b)

$$= \frac{1}{8}\left[4 \times 5A^2 + 2 \times A^2 + 2 \times A^2\right]$$

$$= \frac{1}{8}\left[20A^2 + 4A^2\right]$$

$$= 3A^2$$

Since avg energy of figure (b) is less than avg energy of figure (a) Hence constellation of figure (b) is more power efficient

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]

Sol^n ① Power management :- Transmitted power from Base station has to be managed such that it doesn't reach to other co-channel & interfere with signal.

② Frequency reuse :- frequency ~~reuse~~ reuse factor should be high enough that two co-channels are sufficiently fart apart to. be interfered.

③ Frequency allocation :- A cell should be alloted sufficient number of frequency channel for proper traffic management so that the ~~Ads~~ probability of two MS to be on same frequency from two different co-channel is low.

→ Yes the value of cluster size can be increased more than 7 to decrease co-channel interf--erence, but the thing that should be considered is there should not too few frequency channel per cell. If for less number of frequency channel we increase cluster size then channels per cells decreases which can increase the possibility of call blocking.

8

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

(ii) Define cryptography and its type briefly.

[14 + 6 marks]

Do not write in this margin

Do not write in this margin

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]

Do not write in this margin

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]

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, $\mu_p = 250 \frac{cm^2}{Vs}$]

(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

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

where, $L = 12\ \mu m$. The hole diffusion coefficient, $D_p = 12\ cm^2/s$ and electron mobility $\mu_n = 1000 \frac{cm^2}{V\text{-}s}$. 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]

Soln (a) (i)

(1) $N_A = 10^{17}$ atom/cm3

$p \simeq 10^{17}$ atoms/cm3

$n_i = 1.5 \times 10^{10}$/cm3

According to equillibrium eqn

$n_0 p = n_i^2$

$n_0 = \frac{n_i^2}{p} = \frac{2.25 \times 10^{20}}{10^{17}}$

$n_0 = 2.25 \times 10^{3}$ /cm3

~~$\rho = \frac{1}{n_0 \mu_n e + p \mu_p e} = \frac{1}{2.25 \times 10^3 \times}$~~

conductivity

$\sigma_{Si} = n_0 \mu_n e + p \mu_p e$

since $n_0 << p$

therefor

$$\sigma_{si} \simeq p\mu_p e$$

$$= 10^{17} \times 250 \times 1.6 \times 10^{-19}$$

$$= 400 \times 10^{-2}$$

$$= 4 \ /\Omega cm$$

$$\boxed{\rho_{si} = \frac{1}{\sigma_{si}} = 0.25 \ \Omega cm}$$

(2) $N_D = 3 \times 10^{13}$ atoms/cm^3

when Sb doped in Ge, Sb atoms acquires +ve charge Now according to space charge neutrality

+ve charge = -ve charge

Sb atoms conce. = e^- concentration

therfore $\boxed{n_o = 3 \times 10^{13}}$ /cm^3

(ii) Given

$n = 10^{16}$ /cm^3

$L = 12 \mu m$, $P(x) = 10^{15} \exp\left[-\frac{x}{L}\right]$ /cm^3 $x>0$

$D_p = 12 \ cm^2/s$

$\mu_n = 1000 \ cm^2/V\text{-}sec$

$J = 4.8 \ A/cm^2$

(1) Hole diffusion current density

$$J_p = -eD_p \frac{dp}{dx}$$

$$= -eD_p \frac{d}{dx} 10^{15} e^{-x/L}$$

$$= \frac{-1.6 \times 10^{-19} \times 12 \times 10^{15} e^{-x/L}}{-L}$$

Do not write in this margin

$$J_p = \frac{19.2\times10^{-4}\, e^{-x/12\times10^{-4}}}{12\times10^{-4}}$$

$$\boxed{J_p(x) = 1.6 \times e^{-x\times10^{4}/12}} \quad A/cm^2$$

(2) electron current density

~~$J_n = \frac{I}{A}$~~ ~~$= neA$~~

$J_n(x) + J_p(x) = J$

$J_n(x) = J - J_p(x)$

$$\boxed{J_n(x) = 4.8 - 1.6\, e^{-x\times10^{4}/12}} \quad \text{—(A)}$$

(3) Electric field

for $J_n(x) = neV_d$

$= ne\mu_n E$

Putting in eqn (A)

$$ne\mu_n E = 4.8 - 1.6\, e^{-x\times10^{4}/12}$$

$$10^{16}\times1.6\times10^{-19}\times1000\times E = 4.8 - 1.6\, e^{-x\cdot10^{4}/12}$$

$$\boxed{E = 3 - e^{-x\cdot10^{4}/12}} \quad V/m$$

9

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]

Soln By poisson eqn

$$\nabla^2 V = -\frac{\rho_v}{\epsilon} \rightarrow \text{vol charge density}$$

$$\nabla V = -\int \frac{\rho_v}{\epsilon} dx$$

$$\nabla V = -\frac{q}{\epsilon}\int N_D(x)\, dx$$

$$= -\frac{q}{\epsilon}\int \left(N_0 + (N_L - N_0)\frac{x}{L}\right) dx$$

$$= -\frac{q}{\epsilon}\left[N_0 x + (N_L - N_0)\frac{x^2}{2L}\right] + c$$

(i) due to concentration profile e^- will diffuse towards low concentration and accumulate there now this accumulation will ~~tries~~ try to stop further flow of current ie

diffusion current = Drift current

$$q D_n \frac{dn}{dx} = n \mu_n q E_{bi}$$

$$E_{bi} = \frac{q D_n \frac{dn(x)}{dx}}{n q \mu_n}$$

$$E_{bi} = \frac{D_n \frac{d}{dx}\left[N_0 + (N_L - N_0)x/L\right]}{n \mu_n}$$

$$E_{bi} = \frac{D_n \left[\frac{N_L - N_0}{L} \right]}{n \mu_n}$$

Now

built-in electric field

$$\text{electric potential} = E_{bi} \times L$$

$$\boxed{V = \frac{D_n}{n\mu_n}[N_L - N_0]}$$

(ii)

$$V_x = \frac{D_n [N_L - N_0]}{\mu_n \left[N_0 + (N_L - N_0)\frac{x}{L} \right]} \qquad \left\{ n = N_0 + (N_L - N_0)\frac{x}{L} \right\}$$

→ at $x = L$

$$V = \frac{D_n}{\mu_n} \frac{[N_L - N_0]}{N_0 + N_L - N_0}$$

$$= \frac{D_n}{\mu_n}\left[1 - \frac{N_0}{N_L} \right]$$

Given $\frac{N_L}{N_0} = 0.75 \Rightarrow \frac{N_0}{N_L} = 4/3$

$$V = \frac{12}{3000}[1 - 4/3]$$

$$\boxed{V = -1.33 \times 10^{-3} \text{ Volt}} = -1.33 \text{ mV}$$

→ at $x = 0$

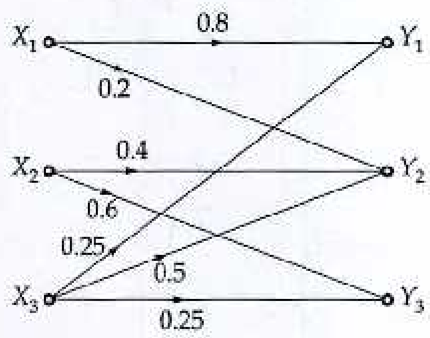
$$V(0) = \frac{D_n}{\mu_n} \frac{[N_L - N_0]}{N_0}$$

$$= \frac{12}{3000}[0.75 - 1]$$

$$= -1 \times 10^{-3} \text{ Volt}$$

$$\boxed{V(0) = -1 \text{ mV}}$$

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.

[14 + 6 marks]

(i)

$$H\left(\frac{X}{Y}\right) = -\sum\sum P(x, y) \log_2 P(x/y)$$

$$P(Y/X) = \begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \end{array} \begin{bmatrix} Y_1 & Y_2 & Y_3 \\ 0.8 & 0.2 & 0 \\ 0 & 0.4 & 0.6 \\ 0.25 & 0.5 & 0.25 \end{bmatrix}$$

$$P(x, y) = P(X)_d \, P(Y/X)$$

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

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

$H(X,Y) = -\sum_i \sum_j P(x_i y_j) \log_2 P(x_i, y_j)$

$= -[0.2 \log_2 0.2 + 0.05 \log_2 0.05 + 0.2 \log_2 0.2$

$+ 0.3 \log_2 0.3 + 0.0625 \log_2 0.0625 + 0.125 \log_2 0.125$

$+ 0.0625 \log_2 0.0625]$

$= -[-0.464 - 0.216 - 0.464 - 0.5210$

$- 0.25 - 0.375 - 0.25]$

$H(X,Y) = 2.54$ bits / symbol

$P(Y) = P(X)\, P(Y/X)$

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

$P(Y) = \begin{bmatrix} 0.2625 & 0.375 & 0.3625 \end{bmatrix}$

$H(Y) = -\sum P(y) \log_2 P(y)$

$= -[0.2625 \log_2 0.2625 + 0.375 \log_2 0.375$

$+ 0.3625 \log_2 0.3625]$

$= 0.5065 + 0.5306 + 0.5306$

$= 1.5677$ bit / symbol

$H(X/Y) = H(X,Y) - H(Y)$

$= 2.54 - 1.5677$

$H(X/Y) = 0.9723$ bits / symbol

(ii) From generator matrix

Parity bits = 3

Msg bits = 3

Msg	Codeword	Weight
000	000 000	0
001	001 110	3
010	010 011	3
011	011 101	4
100	100 101	3
101	101 011	4
110	110 110	4
111	111 000	3

Minimum hamming weight = 0

Maximum hamming weight = 4

20

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

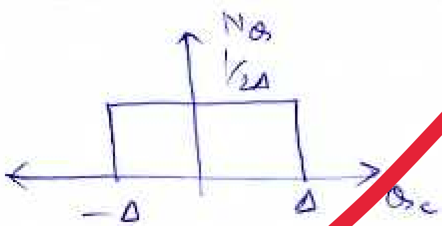
(ii) Consider a low-pass signal with a bandwidth of 3 kHz. A linear delta modulation system, with step size $\Delta = 0.1$ V, is used to process this signal at a sampling rate ten times the Nyquist rate. For 1 V amplitude of a test sinusoidal signal of frequency 1 kHz, evaluate the output signal to noise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

[14 + 6 marks]

(i) Let input $= A_m \cos 2\pi f_m t$

(Si) i/p signal power $= \frac{A_m^2}{2}$

PDF of noise in delta modulation



$$\text{Power}[N_Q] = \int Q_e^2 f_{N_Q}\, dQ_e$$

$$= \frac{1}{2\Delta}\int_{-\Delta}^{\Delta} Q_e^2\, dQ_e$$

$$= \frac{1}{2\Delta}\left|\frac{Q_e^3}{3}\right|_{-\Delta}^{\Delta}$$

$$= \frac{1}{6\Delta}\left[\Delta^3 + \Delta^3\right]$$

$$N_o = \frac{2\Delta^3}{3\cdot 2\Delta} = \frac{\Delta^2}{3}$$

Signal to noise ratio $= \frac{S_i}{N_o}$

$$= \frac{\frac{A_m^2}{2}}{\frac{\Delta^2}{3}}$$

$$\boxed{SNR = \frac{3}{2}\cdot\frac{A_m^2}{\Delta^2}} \text{ — (c)}$$

Do not write in this margin

(ii) (a) Prefiltered

$f_m = 3\,kHz$ $A_m = 1$ $\Delta = 0.1$ $f_s = 10 f_{Nyquist}$

$S_o = \frac{A_m^2}{2}$ $f_s = 10 \times 2 f_m$

$= \frac{1}{2}$ watt $= 10 \times 2 \times 3k$

$= 60\,kHz$

$N_o = \frac{\Delta^2}{3} \frac{f_M}{f_{sam}}$

$= \frac{(0.1)^2}{3} \times \frac{3k}{60k}$

$= \frac{0.01}{60}$

$\left(\frac{S}{N}\right)_o = \frac{1/2}{\frac{0.01}{60}} = \frac{30}{0.01}$

$\boxed{\frac{S}{N_o} = 3000}$ $= 34.77\,dB$

(b) Post filtered

$f_m = 1\,kHz$; $A_m = 1$; $\Delta = 0.1$; $f_s = 10 f_{Nyquist}$

$= 60\,kHz$

~~$= 10 \times 2 f_m$~~

~~$= 10 \times 2 \times 1k$~~

$= 20k$

$S_o = \frac{A_m^2}{2}$

$= 0.5$ watt

$N_o = \frac{\Delta^2}{3} \times \frac{f_m}{f_{sam}}$

$= \frac{(0.1)^2}{3} \times \frac{1k}{60k}$

$= \frac{0.01}{3} \times \frac{1}{60}$

$= \frac{0.01}{180}$

$\frac{S_o}{N_o} = \frac{0.5}{\frac{0.01}{180}}$

$= 9000$

$\boxed{\frac{S}{N} = 39.54\,dB}$

2 2 4 4

→ continuation of part (i)

$$\left(\frac{S}{N}\right)_o = \frac{3\,A_m^2}{2\,\Delta^2} \quad \text{— (B)}$$

To avoid slope overload

$$\Delta = \frac{d}{dt} A_m \cos 2\pi f_m t$$

$$\Delta = A_m 2\pi f_m \sin 2\pi f_m t$$

$$|\Delta| = A_m 2\pi f_m$$

Putting in eqn (B)

$$\left(\frac{S}{N}\right)_o = \frac{3}{2} \cdot \frac{A_m^2}{A_m^2 4\pi^2 f_m^2}$$

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

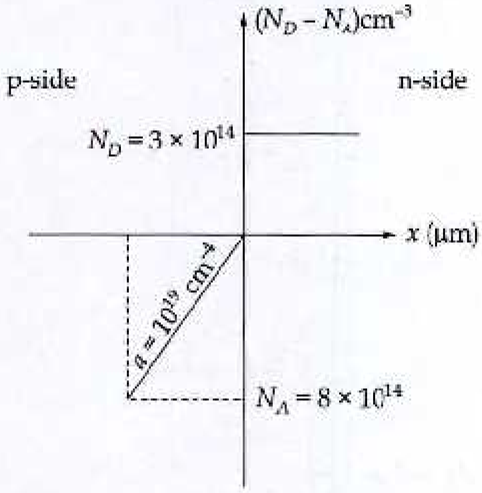
when there is LPF at Rx side and its cutoff frequency is f_c with sampling frequency f_s

$$\boxed{\left(\frac{S}{N}\right)_o = \frac{3\,f_s^2 f_c}{8\pi^2 f_m^2}}$$

4

Do not write in this margin

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]

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]

oooo

Space for Rough Work

Space for Rough Work

$$\frac{\frac{Am^2}{2}}{\frac{\Delta^2}{12}}$$

$$\frac{6Am^2}{\Delta^2}$$

$$\frac{6Am^2 2^{4n}}{4A^2}$$

$$H(X/Y) = H(X,Y) - H(Y)$$

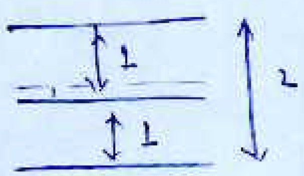
$\Delta =$ ~~4πA~~

$G = \frac{4\pi A_e}{\lambda^2}$

$A_e = \frac{\lambda^2 G}{4\pi}$

E

B   N
Al   P
Ga   As
         Sb
         In



1000000

$\Delta = Am 2\pi f_m$

$\Delta^2 = Am^2 4\pi^2 f_m^2$

$\frac{3}{2} \cdot \frac{Am^2}{Am^2 4\pi^2 f m^2}$

$= \frac{3}{8\pi^2}$