MADE EASY

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ESE 2026 : 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-1 [Part Syllabus]
Analog & Digital Communication Systems-2 [Part Syllabus]

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☐	Bhopal ☑	Jaipur ☐	
Pune ☐	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	17
Q.2	
Q.3	43
Q.4	
Section-B	
Q.5	39
Q.6	31
Q.7	38
Q.8	
Total Marks Obtained	168

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.

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Section A : Computer Organization and Architecture + Materials Science

Q.1 (a) A 32-bit CPU is interfaced with a high speed I/O device having a data transfer rate of 100 MBps. The system employs a DMA controller operating in cycle stealing mode. The I/O device contains an internal buffer that initiates a DMA transfer only after it has accumulated 8 words of data. The CPU operates with a machine cycle time of 5 ns. Assuming each word transfer requires exactly one machine cycle of the CPU, calculate:

(i) The percentage of time the CPU remains consumed during the DMA operation.

(ii) The percentage of time the CPU remains busy with its own processing.

[12 marks]

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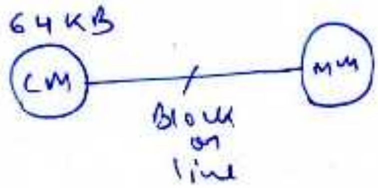
Q.1 (b) How many bits of storage are required for the tag array of a 64 KB cache with 128-byte cache lines and two-way set-associativity if the cache is write back but does not require any additional bits of data in the tag array to implement write-back policy? Assume that the system containing the cache uses 32-bit addresses.

[12 marks]

Given:



Cache line = 128 B ; 32 bit Address

Cache Size = 64 KB N-way = 2

∴ no. of Cache lines = $\frac{\text{Cache size}}{\text{line size}}$

$= \frac{64\,KB}{128\,B} = \frac{2^{16}\,B}{2^{7}\,B}$

$= 2^{9}\;B$

$\therefore$ No. of Sets = $\frac{\text{\# Lines in CM}}{\text{N-way}}$

$= \frac{2^9}{2} = 2^8$

$\therefore$ Address binding

← 32 bit →

tag	Set offset	word offset
17 bits	8 bits	7 bit

word offset = $\log_2$(size of block/line)

$= \log_2 2^7 = 7$ bits

set offset = $\log_2$(# of sets)

$= \log_2 2^8 = 8$ bits

$\therefore$ tag bits = $[32 - (7+8)]$ bits

tag bits = 17 bits Ans.

6

incomplete Solution

Do not write in this margin

Q.1 (c) Write a C-program to print first hundred Fibonacci numbers' fib(i) given by,

fib(i) = fib(i – 1) + fib(i – 2)

It is given that, fib(0) = fib(1) = 1

[12 marks]

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Q.1 (d) (i) Calculate the density of BCC metal having atomic radius, 1.24 Å and atomic weight, 50 g/mol.

(ii) A plane cuts crystal axes at $a = 3$, $b = 2$ and $c = \infty$, find the Miller indices.

(iii) Find the interplanar spacing of (321) plane with Lattice parameter $a = 4$ Å.

[4 + 4 + 4 marks]

(i) For BCC N = 2 (no. of total Atoms)

$$\rho = \frac{NM}{N_A V_C}$$

M → Atomic wt.

N_A → Avogadro no.

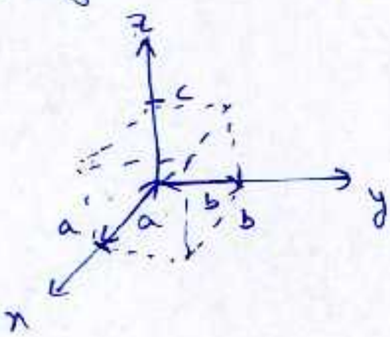
V_C → Volume.

$$\rho = \frac{2 \times 50}{6.022 \times 10^{23} \times (1.24 \times 10^{-8})^3}$$

∴ $\rho = 87.09$ grams/cm3

2

(ii) Given: $a = 3$, $b = 2$ and $c = \infty$



Miller indices $= \frac{1}{a}, \frac{1}{b}, \frac{1}{c}$

$= \frac{1}{3}, \frac{1}{2}, \frac{1}{\infty}$

$= \left[\frac{1}{3}, \frac{1}{2}, 0\right] \times 6$

∴ Miller indices = [2 3 0] (Ans)

(iii) given : (h, k, l) = 3, 2, 1

$$d = \frac{a}{\sqrt{h^2+k^2+l^2}} = \frac{4}{\sqrt{(3)^2+(2)^2+(1)^2}}$$

(2)

$$d = 1.06904 \text{ Å}$$ (Ans)

(interplanar spacing)

Q.1 (e) Curie temperature of iron (Fe) is 1043 K. Assume that Fe atom when in metallic form have magnetic moment of two Bohr magneton per atom. Fe has body centered cubic structure with lattice parameter a = 0.286 nm. Calculate,

(i) Saturation magnetization

(ii) Curie constant

(iii) Weiss field constant

Given, magnetic moment, $\mu_B = 9.27 \times 10^{-24}$ A-m^2, $\mu_0 = 4\pi \times 10^{-7}$ Henry/meter, $K_B = 1.38 \times 10^{-23}$ Joule/Kelvin.

[12 marks]

given: $T_C(Fe) = 1043$ K

magnetic moment = 2 B.M/atom.

BCC (str) ∴ (N = 2)

Go through Soln

(i) Saturation magnetization.

(1)

$$M_s = \mu_B \times 2 \times N \times 6.022 \times 10^{23}$$

$$= 2 \times 9.27 \times 10^{-24} \times 2 \quad \text{A-m}$$

$$M_s = 3.708 \text{ A-m}$$

(ii) By Curie's weiss Law :

$$\chi_m = \frac{C}{T - \theta}$$

given $T_c = 1043K$.

0

Q.2 (a) (i) Consider the following set of processes, with the arrival time and length of the CPU burst (in milliseconds):

Process	Arrival Time	Burst Time
P_1	0	6
P_2	1	4
P_3	2	3
P_4	3	1
P_5	4	2
P_6	5	1

Draw the Gantt chart and compute the average process waiting time using Shortest Remaining Time First (SRTF) scheduling algorithm.

(ii) What are the differences between concurrency and parallelism in the context of processes in operating systems?

[14 + 6 marks]

(i) Given:

Pid	AT(ms)	BT (ms)
P_1	0	6
P_2	1	4
P_3	2	3
P_4	3	1
P_5	4	2
P_6	5	1

Good
(14)

For Shortest Remn Time First (SRTF)

→ Considering with premption model.

Process Gantt chart.

All process arrived here.

P_1	P_2	P_3	P_4	P_5	P_6	P_5	P_3	P_2	P_1

0 1 2 3 4 5 6 7 9 12 17

[P_1:6] [P_1:5, P_2:4] [P_1:5, P_2:3, P_3:3] [P_1:5, P_2:3, P_3:2, P_4:1] [P_1:5, P_2:3, P_3:2, P_4:0, P_5:2] [P_1:~~5~~, P_2:~~3~~, P_3:~~2~~, P_4:0, P_5:✗, P_6:✗]

↳ schedule A/q to their BT left.

Redrawing the Gantt chart :

P_1	P_2	P_3	P_4	P_5	P_6	P_5	P_3	P_2	P_1

0 1 2 3 4 5 6 7 9 12 17

Now,

Pid	CT (ms)	TAT (ms) (CT-AT)	WT (ms) (TAT-BT) (ms)
P_1	17	17	11
P_2	12	11	7
P_3	9	7	4
P_4	4	1	0
P_5	7	3	1
P_6	6	1	0

where CT → completion time

TAT → Turn around time

WT → waiting time.

$$\text{Average waiting Time} = \frac{11+7+4+0+1+0}{6}$$

$$= \boxed{3.833\ ms}$$

(Ans)

(ii)

~~Coherency~~ Concurrency and Parallelism are two different types of process in OS.

-> Parallelism means the particular task is divided into many small tasks and they Run independently, at last they combine a give a final output.

-> Hence, it reduces the average process time in the Operating system.

Go through Sol'n

-> In Concurrency, one after the one process is scheduled, so that the CPU works at maximum utilisation

-> It provides the shortest and best structed path for All the process to act Concurrently and hence reducing the Access time of the CPU.

-> Thus it Reduces the Acess time of the CPU.

2

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Q.2 (b) **(i)** The demagnetization curve of a rare-earth alloy is of a parabolic shape given as $B = 1.1 - 4.4 \times 10^{-6} H^2$, where B is in Wb/m^2 and H is in kA/m.

Calculate:

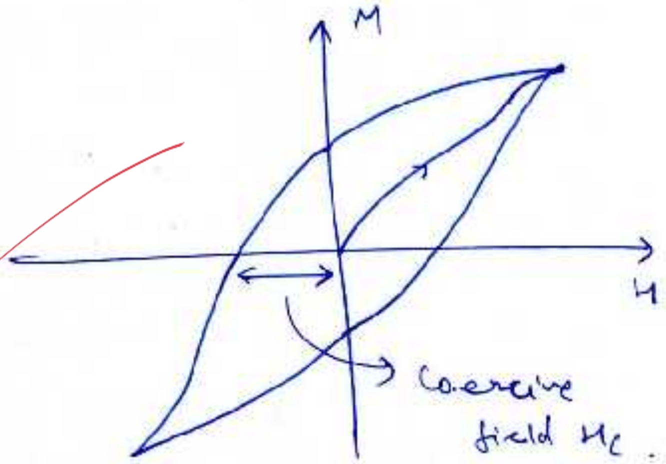
1. Coercive field H_C
2. $(BH)_{max}$

(ii) A long narrow rod has an atomic density $5 \times 10^{28}/m^3$. Each atom has a polarizability of 10^{-40} F-m^2. Find the internal electric field when an axial field of 1 V/m is applied.

[10 + 10 marks]

(i) Given: $B = 1.1 - 4.4 \times 10^{-6} H^2$

(1) $H_c = ?$



We know,

$\Rightarrow B = \mu_0 [M + H]$

$\Rightarrow B = \mu_0 M + \mu_0 H$

$\Rightarrow \frac{B - \mu_0 H}{\mu_0} = M$

$\Rightarrow M = \frac{B}{\mu_0} - H$

$$\Rightarrow M = \frac{1.1 - 4 \times 10^{-6} H^2}{\mu_0} - H$$

At $M = 0$, we get H_C

$\therefore \Rightarrow \frac{1.1 - 4 \times 10^{-6} H^2}{\mu_0} - H = 0$

$$\Rightarrow \frac{1.1 - 4.4\times10^{-6} H^2}{\mu_0} - H = 0$$

$$\Rightarrow 1.1 - 4.4\times10^{-6} H^2 - H\mu_0 = 0$$

$$\Rightarrow 4.4\times10^{-6} H^2 + 4\pi\times10^{-7} H - 1.1 = 0$$

On solving the Quadratic Eqn ;

we get :

$$H_C = 499.857 , -500.142$$

As from the Hysteresis Curve : H_C would be a negative value.

we get $\boxed{H_C = -500.1428 \text{ kA/m}}$

(2) $(BH)_{max}$.

given : $B = 1.1 - 4.4\times10^{-6} H^2$

$(BH)_{max}$ = area under the curve.

Avoid silly mistakes

9

Good

10

(ii) given: $N = 5 \times 10^{28} / m^3$

$\alpha = 10^{-40}$ F-m²

$E_i = ?$

$E = 1$ V/m.

Rod

we know, $P = N \alpha E_i$

$$E_i = E + \frac{\gamma P}{\varepsilon_0}$$

$$E_i = E + \frac{\gamma N \alpha E_i}{\varepsilon_0}$$

$$\Rightarrow E_i - \frac{\gamma N \alpha E_i}{\varepsilon_0} = E$$

$$\Rightarrow E_i \left[1 - \frac{\gamma N \alpha}{\varepsilon_0}\right] = E$$

$$\Rightarrow E_i = \left[\frac{E}{1 - \frac{N\alpha}{3\varepsilon_0}}\right] \quad \left[\gamma = \frac{1}{3} \text{ for cubic crystal}\right]$$

put the values.

$$\Rightarrow E_i = \left[\frac{1}{1 - \frac{5 \times 10^{28} \times 10^{-40}}{3 \times 8.854 \times 10^{-12}}}\right]$$

$$\Rightarrow \boxed{E_i = 1.23189 \text{ V/m}}$$ (Ans)

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Q.2 (c) (i) Explain the sol-gel process of synthesis of Nanomaterials.

(ii) Explain mechanical properties of nano-materials along with their applications.

[15 + 5 marks]

(i) In the Manufacturing of Nanomaterials, There are two approach mainly :

(i) Top down approach.

(ii) Bottom up approach.

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→ In manufacturing through Bottom up approach Sol-gel process is used for Synthesis.

⇒ In this process we synthesise nanoparticles from atom by atom, to molecule to molecule level. In this, method chemical processes are involved, one such process is Sol-gel process.

→ It is chemical process in which, we prepare a gel of the compound and transfer it to the Substrate, then by chemical processes, the Substrate is etched out according to the manufacturer. i.e Substrate gets dissolved in the gel poured on it.

incomplete soln

(ii) Mechanical properties of Nano-materials are:-

→ They have large surface to volume ratio, which helps in the production of variety of nano-materials like nano-tubes, nano-wires, etc.

→ They have good Thermal properties, hence they can be used in till higher temperatures.

→ Some Nanomaterials have luminescence property, which is further used in the production of OLED devices (organic LEDs)

→ They have UV-Ray reflecting properties, hence used in sunscreens to protect skin from harmful Rays.

→ Nano-materials also have Magnetic properties, they find applications in Biomedical industries, treatment of Cancer, etc.

3

Q.3 (a) (i) What is the main advantage of Ferrimagnetic materials (ferrites) over ferromagnetic materials? Enumerate electric and magnetic properties of ferrites.

(ii) Write a short note on optical properties of semiconducting Nanoparticles.

[10 + 10 marks]

Q.3 (b) (i) Explain the following components of Entity-Relationship Model (ER Model) of DBMS:

1. Entity
2. Attributes
3. Relationship
4. Domain

(ii) Consider 8-way set associative cache of 64 KB organised into 32B blocks. CPU generates 28 bit physical address to access the data. The cache controller contains tag information with 2 valid bits, 2 update bits and 3 replacement bits along with the bits needed to identify the memory block mapped in the cache. Find the tag space in the line and tag directory size.

[8 + 12 marks]

Q.3 (c) Explain briefly the different types of polarization occurring in dielectric materials. If a dielectric material contains 3.2×10^{19} polar molecules/m^3 and the relative permittivity of material is $\in_r = 2.4$ with applied external electric field $\vec{E} = 10^4 \overrightarrow{a_x}$ V/m, then calculate the value of polarization and dipole moment of each molecule. (Consider all molecules have same dipole moment)

[20 marks]

Q.4 (a) **(i)** Find the highest normal form of a relation $R(A, B, C, D, E)$ with functional dependencies $(A \rightarrow D, B \rightarrow A, BC \rightarrow D, AC \rightarrow BE)$.

(ii) **1.** A hard disk with 20 platters has 4096 tracks/platter, 1024 sectors/track and 512 byte sectors. What is the total capacity?

2. An array of hard disk has to be designed of capacity of 512 GB or more. If the technology used to manufacture the disks allows 2048 byte sectors, 4096 sectors/track, 8192 tracks/platter, how many such disks are required, assuming 2 platters/disk.

[10 + 10 marks]

Q.4 (b) Show that in the mean field approximation, the magnetization of a ferromagnetic system of spin $\frac{1}{2}$ moments just below the curie temperature has the dominant temperature dependence $(T_C - T)^{1/2}$.

[20 marks]

Q.4 (c) Memory sub-system for a product has been designed with 3-level memory hierarchy within a budget of ₹ 22,000. The known and unknown parameters for the design are tabulated below:

Memory Type	Access Time	Capacity	Cost per kilobyte in ₹
Cache	5 ns	1 MB	1
Main Memory	–	128 MB	0.1
Solid State Drive (SSD)	5 μs	–	0.001

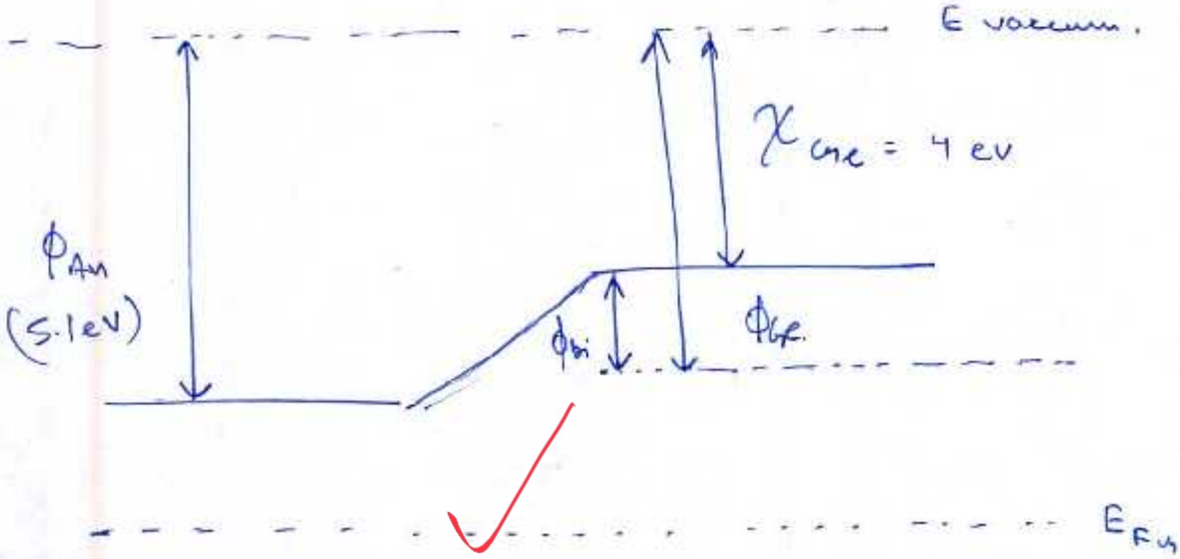
The design achieved an effective memory access time of 20 ns with cache hit ratio 0.95 and main memory hit ratio 0.99. The SSD can be only in integer power of 2 in GB.

Find out the missing parameters in the above table. **[20 marks]**

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

Q.5 (a) Find the height of the potential barrier of Au-n-Ge Schottky contact at room temperature (T = 293 K) if ρ_{Ge} = 1 Ω-cm, ϕ_{Au} = 5.1 eV and χ_{Ge} = 4.0 eV. Electron mobility in Ge is 3900 $cm^2 V^{-1}s^{-1}$, density of states in the conduction band is $N_C = 1.98 \times 10^{15} \times T^{3/2}$ cm^{-3}. (where ϕ_{Au}: work function of Gold: ϕ_{Au}, χ_{Ge} Electron affinity of Ge)

[12 marks]



ρ_{Ge} = 1 Ω-cm. = σ_{Ge}.

(6)

$\therefore \sigma_{Ge} = N_D q \mu_{Ge}$

$\Rightarrow N_D = \frac{1}{q \mu_{Ge}} = \frac{1}{1.6 \times 10^{-19} \times 3900}$

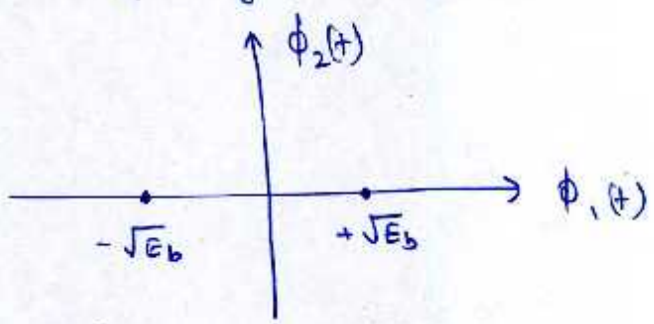
$\Rightarrow$ $N_D = 1.60 \times 10^{15}$ #/cm³

$\phi_{bi} = \frac{KT}{q} \ln\left(\frac{N_D}{n_i}\right)$

Q.5 (b) Derive expressions of error probability for BPSK, BASK, and BFSK signalling schemes using signal constellation approach.

[9 marks]

(1) BPSK (binary PSK) (1-D Mod^n scheme)



$s_1(t) = \sqrt{E_b}\,\phi_1(t)$; $0 \le t \le T_b$

$s_2(t) = -\sqrt{E_b}\,\phi_2(t)$; $0 \le t \le T_b$

$P_e = Q\sqrt{\frac{E_d}{2N_0}}$ or $Q\left(\sqrt{\frac{d_{min}^2}{2N_0}}\right)$

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$\therefore d_{min} = 2\sqrt{E_b}$

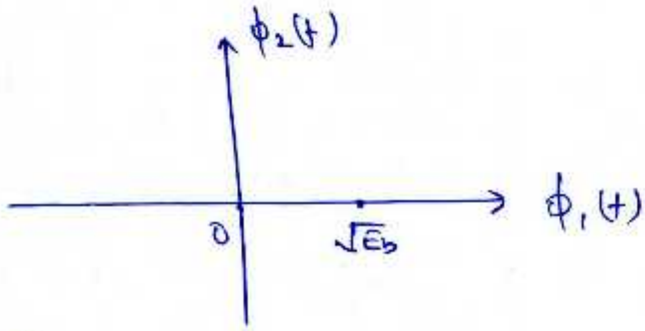
$$P_e = Q\left(\sqrt{\frac{d_{min}^2}{2N_0}}\right) = Q\left(\sqrt{\frac{4^2 E_b}{\cancel{2}N_0}}\right)$$

$$\therefore \boxed{P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)} \quad \text{(Ans) (PSK)}$$

(2) BASK: (Binary ASK) (1D Mod^n Scheme)

$s_1(t) = \sqrt{E_b}\,\phi_1(t)$; $0 \le t \le T_b$

$s_2(t) = 0$; $0 \le t \le T_b$



$\therefore d_{min} = \sqrt{E_b}$

$$P_e = Q\left(\sqrt{\frac{d_{min}^2}{2N_0}}\right) = Q\left(\sqrt{\frac{E_b}{2N_0}}\right)$$

$$\therefore \boxed{P_e = Q\left(\sqrt{\frac{E_b}{2N_0}}\right)} \quad \text{(Ans) (ASK)}$$

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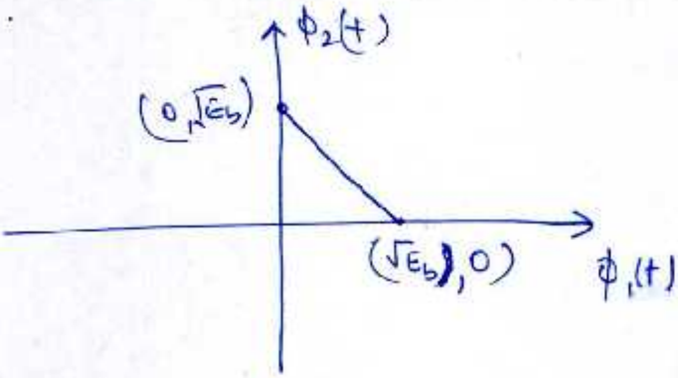
(3) BFSK ; (Binary FSK) (2D - Mod^n Scheme)

$s_1(t) = \sqrt{E_b}\,\phi_1(t)$; $0 \le t \le T_b$

$s_2(t) = \sqrt{E_b}\,\phi_2(t)$; $0 \le t \le T_b$

$$d_{min} = \sqrt{(\sqrt{E_b})^2 + (\sqrt{E_b})^2}$$

$$= \sqrt{2E_b}$$



$$\therefore P_e = Q\left(\sqrt{\frac{d_{min}^2}{2N_0}}\right)$$

$$\boxed{P_e = Q\left(\sqrt{\frac{E_b}{N_0}}\right)}$$ (Ans) (FSK)

Q.5 (c) A common control device in a telephone exchange is required to commence operation within a average period of 10 msecs after receiving a calling signal.

(i) If the device is held, on average for 50 msecs per call, how many calls can it handle per hour?

(ii) If the device is required to handle 18,000 calls per hour, what is the maximum permissible average holding time?

[12 marks]

(i) Given: T_H (Holding time) = 50 ms/call

T_C (commencing time) = 10 ms / call.

Total time per a call on average = 60 ms/call

1 Hour = 60 min

1 Hour = 60 × 60 Seconds.

$\therefore$ Calls / hours $= \dfrac{60 \times 60}{60 \times 10^{-3}}$ calls.

$= 6 \times 10^4$ calls.

$\therefore$ In 1 hour = 60 000 calls (Ans)

(ii) Given: 18 000 calls per Hour.

then T_H (max) = ?

Total time per call on average = ~~(TH + 100)~~

$= (T_H + 10)$ ms/calls

A/Q, $\Rightarrow$ 18000 calls per Hour.

$\therefore \Rightarrow \dfrac{60 \times 60}{(T_H + 10) \times 10^{-3}} = 18000$

$\Rightarrow \dfrac{60 \times 60 \times 10^3}{18000} = (T_H + 10)$

$\Rightarrow 200 = T_H + 10$

$\Rightarrow T_H = 190$ ms

$\therefore$ Maximum Holding time = 190 ms.

(Ans)

Q.5 (d) An n-type semiconductor has excess carrier holes 10^{14} cm^{-3}, a minority carrier life time 10^{-6} sec in the bulk material, and a minority carrier lifetime 10^{-7} sec at the surface. Assume zero applied electric field and let $D_p = 10$ cm^2/sec. Determine the steady-state excess carrier concentration as a function of distance from the surface ($x = 0$) of the semiconductor.

[12 marks]

Given: $p = 10^{14}$ cm^{-3}

$\tau_p = 10^{-6}$ s (At bulk)

$\tau_p = 10^{-7}$ s (At surface)

$E = 0$ V/cm

$D_p = 10$ cm^2/s

From Continuity Eqn.

$$\frac{d[\delta p]}{dt} = \frac{d^2[\delta p]}{dx^2} + \frac{R_p}{\tau_p}$$

Given is steady state, $\therefore \frac{d[\delta P]}{dt} = 0$

On solving the above differential equation.

we get :

$$p(x) = p(0)\left(1 - e^{-x/L_p}\right)$$

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where L_p = Diffusion length.

$$L_p = \sqrt{D_p \tau_p} = \sqrt{10^{-7} \times 10} = 10^{-3} \text{ cm}$$

$p(0) = 10^{14}$ cm^{-3}

$$\therefore \quad p(x) = 10^{14}\left(1 - e^{-x/10^{-3}}\right)$$

$$\boxed{p(x) = 10^{14}\left(1 - e^{1000x}\right)}$$ (Ans)

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Q.5 (e) Given the data stream 1110010100, sketch the transmitted sequence of pulses for each of the following line codes:

(i) Unipolar nonreturn-to-zero

(ii) Polar nonreturn-to-zero

(iii) Unipolar return-to-zero

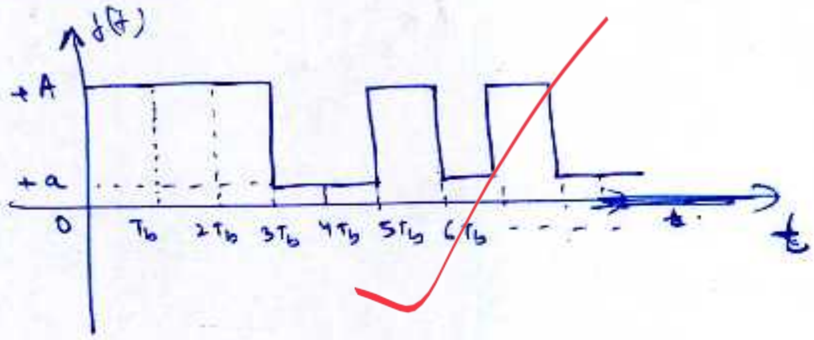
(iv) Bipolar return-to-zero

(v) Manchester code

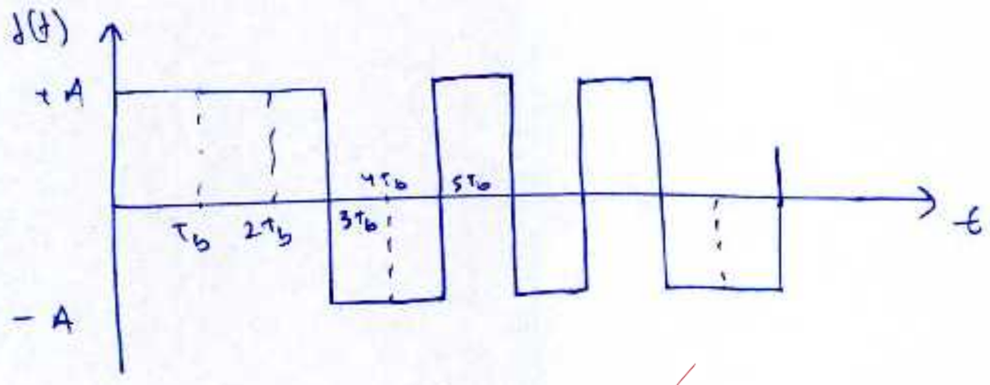
[15 marks]

(i) Data Stream: 111 00 10100

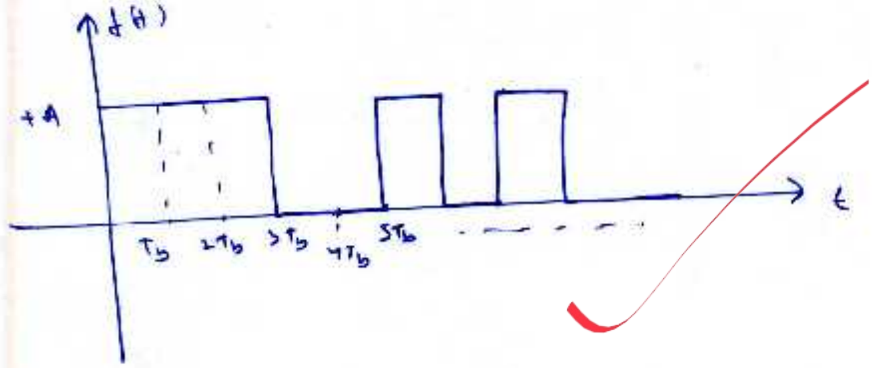
(Unipolar NRZ)



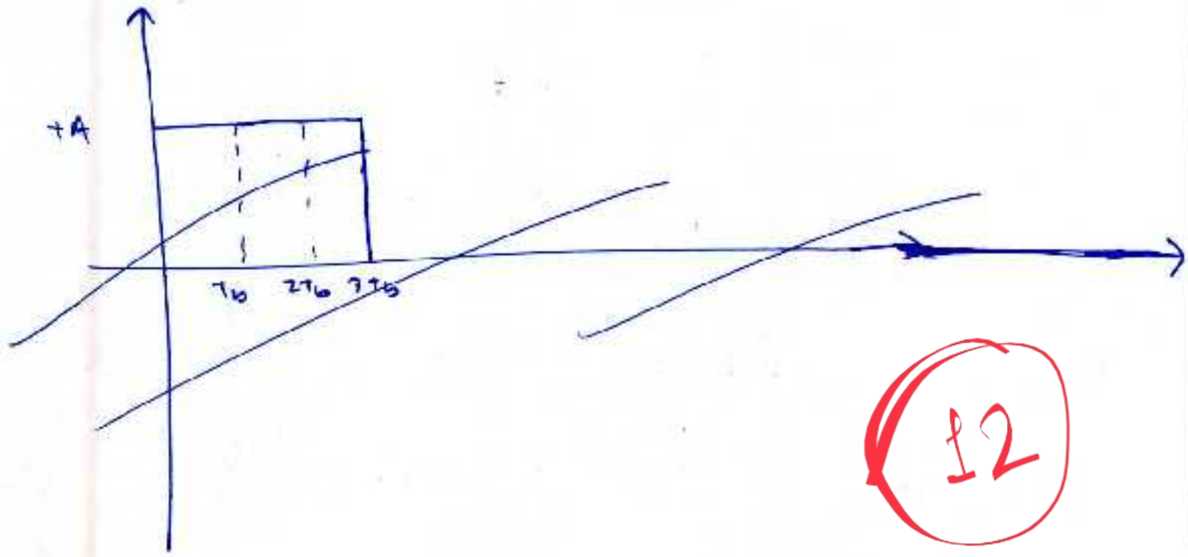
(ii) Polar NRZ



(iii) Unipolar RZ.



(iv) Bipolar. RZ (Alternate +A, -A)



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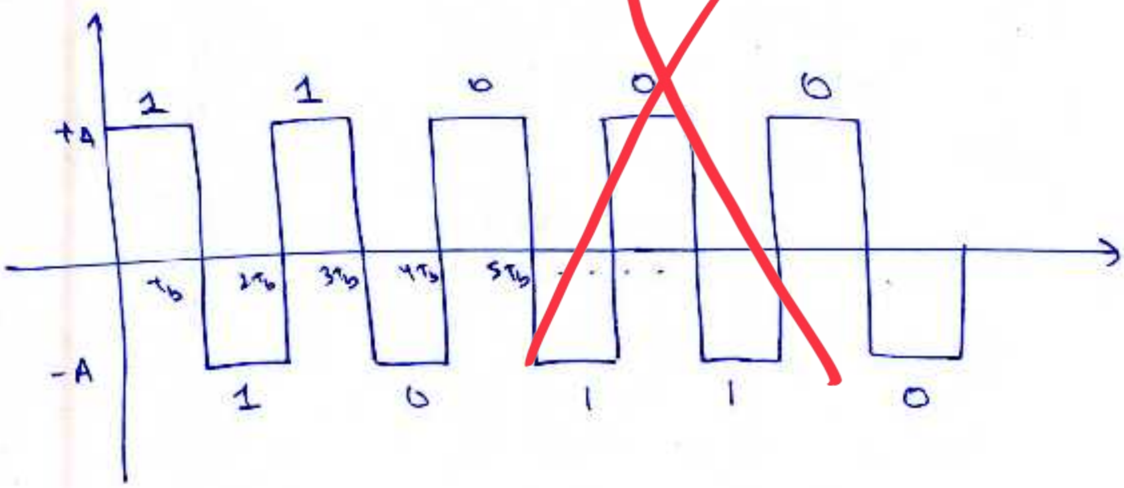
(iv) Bipolar RZ



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Q.6 (a) For a particular semiconductor, $E_g = 1.5$ eV, $m_p^* = 10m_n^*$, $T = 300$ K and $n_i = 1 \times 10^5/\text{cm}^3$.

(i) Determine the position of the intrinsic Fermi energy level with respect to the center of the bandgap. Also derive the formula used.

(ii) Impurity atoms are added so that the Fermi energy level is 0.45 eV below the center of the bandgap.

1. Determine whether acceptor or donor atoms are added.

2. What is the concentration of impurity atoms added?

[20 marks]

(i) Given: $E_g = 1.5$ eV ; $m_p^* = 10\, m_n^*$

$T = 300$ K and $n_i = 1 \times 10^5 / \text{cm}^3$

We know, $n = N_C \cdot e^{-(E_C - E_F)/KT}$ — ①

$p = N_V \cdot e^{-(E_F - E_V)/KT}$ — ②

At Thermal Equilibrium $n = p = n_i$

$\Rightarrow N_C\, e^{-(E_C - E_F)/KT} = N_V \cdot e^{-(E_F - E_V)/KT}$

$\Rightarrow \dfrac{e^{-(E_C - E_F)/kT}}{e^{-(E_F - E_V)/kT}} = \dfrac{N_V}{N_C}$

$\Rightarrow e^{-(E_C - E_F)/kT + (E_F - E_V)/kT} = \dfrac{N_V}{N_C}$

$\Rightarrow e^{-\frac{[2E_F + (E_C + E_V)]}{kT}} = \dfrac{N_V}{N_C}$

Take ln on both sides

$$\Rightarrow \quad \frac{-2E_f + (E_c + E_v)}{kT} = \ln\left(\frac{N_v}{N_c}\right)$$

$$\Rightarrow \quad E_f = \left(\frac{E_c + E_v}{2}\right) + \frac{kT}{2}\ln\left(\frac{N_v}{N_c}\right)$$

$\left(\frac{E_c+E_v}{2}\right) \rightarrow E_{midgap}$.

$$\Rightarrow \quad E_f = E_{midgap} + \frac{kT}{2}\ln\left(\frac{N_v}{N_c}\right)$$

now we know $\left(\frac{N_v}{N_c}\right) \propto \left(\frac{m_p}{m_n}\right)^{3/2}$

~~$\Rightarrow \quad E_f = E_{midgap} + \frac{3}{4} kT \ln$~~

$$\Rightarrow \quad \boxed{E_f = E_{midgap} - \frac{3}{4} kT \ln\left(\frac{m_n}{m_p}\right)}$$

given: $m_p = 10 m_n$. : put in above eqn.

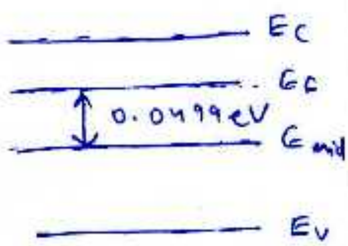
$$\Rightarrow \quad E_f = E_{midgap} + \frac{3}{4} \times 0.026 \ln\left(\frac{m_n}{10 m_n}\right)$$

$$\Rightarrow \quad E_f = E_{midgap} + 0.0449$$

$$\Rightarrow \quad \boxed{E_f - E_{midgap} = +0.0449\ eV}$$ (Ans)

Or

$$\boxed{E_f - E_{midgap} = 0.045\ eV}$$



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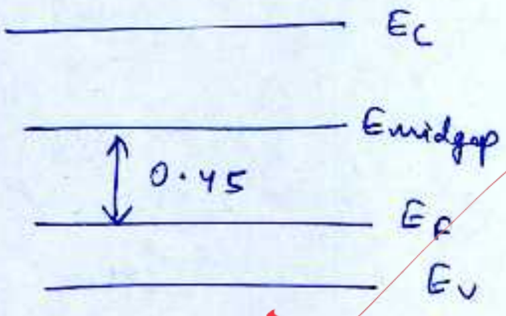
(ii) given: Emidgap is above the Fermi level.

i.e



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$\therefore$ $E_{midgap} - E_F = 0.45$ eV.

① → Fermi level lies in the valence band.

hence, Acceptor atoms are added.

② Concentration of N_A = ? –

we know, $N_A = n_i \cdot e^{(E_i - E_F)/KT}$

$\therefore$ $N_A = 1 \times 10^5 \; e^{0.45 \, eV/KT}$

$N_A = 3.285 \times 10^{12}$ #/cm3

(Ans)

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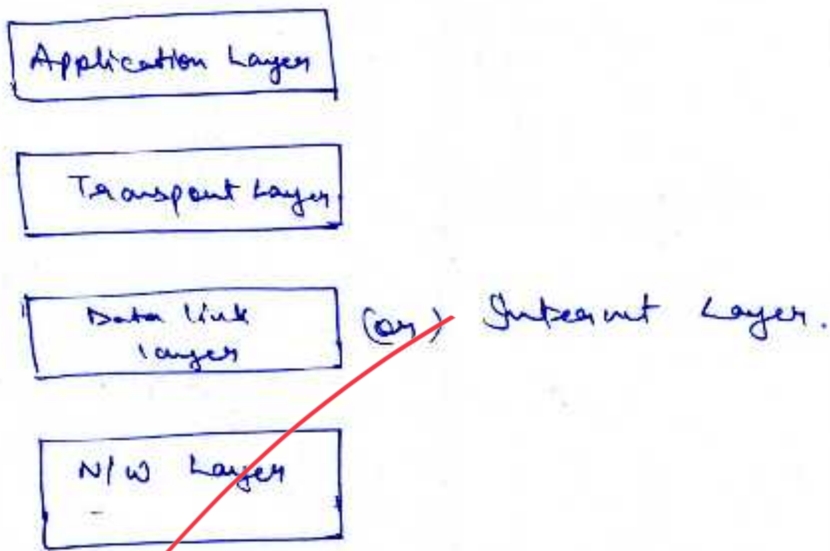
Q.6 (b) Describe in detail the layered architecture of TCP/IP protocol and define type of address used at each layer.

[20 marks]

· TCP / IP Architecture.

we have.



⊙ N/w Layer → It uses physical Address i.e (MAC) Address, which can be seen by the user.

⊙ Data link layer → It uses IP Address, which is controlled by the server.

⊙ Transport layer →

⊙ Application layer →

→ In TCP/IP Architecture, there are total 4 layers i.e Application layer, Transport layer, Datalink layer also called internet layer and Network Layer.

→ Network Layer:

→ In this layer routers are connected. It is responsible for finding the shortest path of travel of Data.

→ Data link Layer:

→ It is also called as internet layer. It is responsible for the security check up of file transfer, it takes ~~cause~~ care of cryptographic processes.

→ Transport Layer:

→ It is the term end to end layer, responsible for data transmission. It takes services from Application layer and provides service to Datalink layer. It is also responsible for timing synchronization

→ Application Layer:-

→ Many protocols like http, SMTP, TCP are used under this layer, data transmission takes firstly through this layer only.

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Q.6 (c) Compare the performance of a DPCM system with a μ-law companded PCM system ($\mu = 255$) for telephone-quality speech signals. The signal-to-quantization noise ratio (SNR) is given by:

$(SNR)_{dB} = \alpha + 6n$

where n is the number of bits per sample. For μ-law PCM, $\alpha \approx 4.77 - 20\log_{10}(\ln(1 + \mu))$.

For DPCM, α ranges from –3 dB to 15 dB.

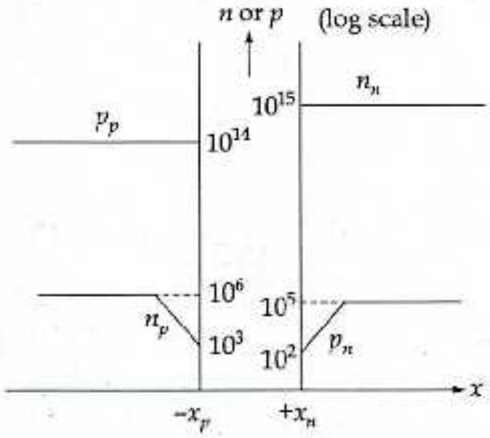
Calculate:

(i) The SNR improvement (in dB) offered by DPCM over companded PCM for a constant bit rate.

(ii) The reduction in the number of bits per sample required by DPCM to achieve the same SNR as compared to PCM.

[20 marks]

Q.7 (a) The figure below is a dimensioned plot of the steady state carrier concentrations inside a pn step junction diode maintained at room temperature.



(i) Is the diode forward or reverse biased? Explain how you arrived at your answer.

(ii) Do low-level injection conditions prevail in the quasineutral regions of the diode? Explain how you arrived at your answer.

(iii) What are the p-side and n-side doping concentrations?

(iv) Determine the applied voltage, V_A.

(v) Determine the built-in potential, V_{bi}.

[20 marks]

(i) given : At thermal Equillibrium, the concentration. $n_n = 10^{15} /cm^3$

$P_p = 10^{14} / cm^3$.

Hence, $N_D > N_A$ under equillibrium.

given: junction diode is in Reverse Bias as there is formation of Depletion layer which is neutral of any mobile charges and hence there is a potenial barrier in the diode.

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(ii) Low- level injection condition does not prevail in the quasineutral region because as soon as injection is done, Recombination starts to take place by the bulk carriers, hence after few time, there is no mobile charge left in the neutral Region, it again becomes depleated of mobile charges quickly.

(iii) In p-side, we have:

p concn or $N_A = 10^{14}$

In N-side, we have

n concⁿ = $N_D = 10^{15}$

(under Equilibrium)

(iv) $V_A = ?$

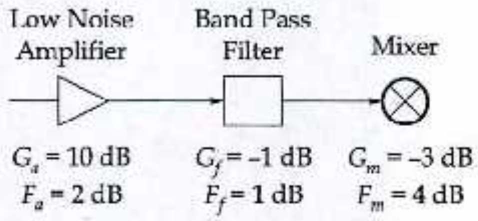
(v) $V_{bi} = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$

$= 0.026 \ln\left(\frac{10^{14} \times 10^{15}}{2.25 \times 10^{20}}\right)$

$V_{bi} = 0.517$ volts

(1)

Q.7 (b) The block diagram of a wireless receiver front end is shown below:



(i) Compute the overall Noise Figure of the sub-system.

(ii) Compute equivalent noise temperature (overall) assuming system temperature $T_0 = 290$ K.

(iii) Compute overall gain.

(iv) Compute output noise power assuming input noise power from the feeding antenna at 150 K temperature and IF bandwidth of 10 MHz.

(v) Compute input power if we require minimum signal to noise ratio of 20 dB.

(vi) Compute minimum signal voltage assuming characteristic impedance of 150 Ω.

[20 marks]

(i)

$G_1 = 10$ $\quad G_2 = 0.79$ $\quad G_3 = 0.50$

$F_1 = 10^{0.2} = 1.58$ $\quad F_2 = 1.26$ $\quad F_3 = 2.51$

$$F_{overall} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 \cdot G_2}$$

$$= 1.58 + \frac{1.26 - 1}{10} + \frac{2.51 - 1}{10 \times 0.79}$$

$$= 1.58 + 0.026 + 0.1911$$

$F_{overall} = 1.797$ or $F_{overall} = 2.545$ dB

(ii) $T_0 = 290\,K$

$F = 1 + \frac{T_e}{T_0}$

$\Rightarrow T_e = T_0(F-1)$

$T_1 = 290(F_1 - 1)$

$= 290(1.58 - 1)$

$= 168.2\,K$

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$T_{eq} = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2}$

$T_{eq} = 168.2 + \frac{T_0(F_2-1)}{10} + \frac{T_0(F_3-1)}{10 \times 0.79}$

$= 168.2 + \frac{290(1.26-1)}{10} + \frac{290(2.51-1)}{10 \times 0.79}$

$= 168.2 + 7.54 + 55.43$

$\boxed{T_{eq} = 231.17\,K}$ Ans.

(iii) Overall gain.

$G_{over} = G_a(dB) + G_f(dB) + G_m(dB)$

$= 10(dB) - 1(dB) - 3(dB)$

$\boxed{G_{over} = 6\,dB}$ (Ans)

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(iv) $N = N_0 B$

$N = K T_e B$

$N = 1.38 \times 10^{-23} \times 150 \times 10 \times 10^6$

$N = 2.07 \times 10^{-14}$ W

$\boxed{N(dB) = -136.84\,dB}$ (Ans)

(v) $(S/N) = 20\,dB = 100$

$S = 100 \times N = 100 \times 2.07 \times 10^{-14}$

$= 2.07 \times 10^{-12} = 2.07\ pW$

$\therefore$ $S_i = 2.07\ pW$ (Ans) (or) $S(dB) = -116.84\ dB$

(vi) $R = 150$

$S = \frac{A_c^2}{2R}$ $\therefore \Rightarrow 2.07 \times 10^{-12} = \frac{A_c^2}{2 \times 150}$

$\Rightarrow$ $A_c = 6.21 \times 10^{-10}$ volts (Ans)

Q.7 (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:

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

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

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

Design the sub-blocks for allocation of IP addresses and find out how many addresses are still available after these allocations.

[20 marks]

(i) Given : 190.100.0.0/16 (65,536 Addr)

64 customers need 256 Address ($n = 8$)

$\therefore$ prefix leng = $32 - n = 32 - 8 = 24$

For 1st custom ⇒ 190.100.0.0/24 — 190.100.0.255/24

For 2nd custom ⇒ 190.100.1.0/24 — 190.100.0.255/24

⋮

64th custom ⇒ 190.100.63.0/24 — 190.100.63.255/24

Total Address Alloted = 64 × 256
= 16384

(ii) 128 customers, 128 Addresses each. (n = 7)

Prefix length = (32-7) = 25

1st customer = 190.100.64.0/25 — 190.100.64.127/25

2nd customer = 190.100.64.128/25 — 190.100.64.255/25

⋮

128th customer = 190.100.128.128/25 — 190.100.128.255/25

total Address Allotted = 128 × 128

= 16384

(iii) 128 customers, needs 64 Address

prefix length = (32 − 6) = 26

1st customer = 190.100.129.0/26 — 190.100.129.63/26

2nd customer = 190.100.129.64/26 — 190.100.129.127/26

3rd customer = 190.100.129.128/26 — 190.100.129.192/26

4th customer = 190.100.129.193/26 — 190.100.129.255/26

⋮

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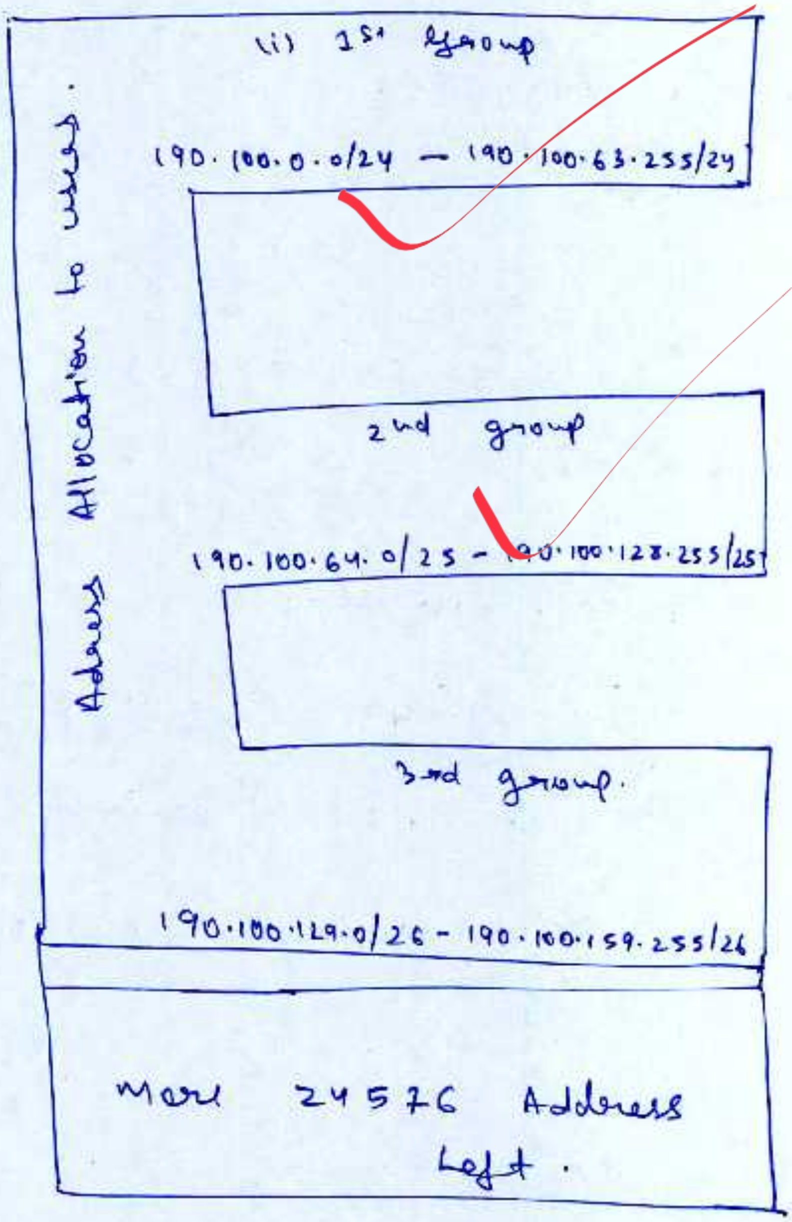
128th customer = 190.100.159.193/26 — 190.100.159.255/26

Total Address Allotted = 128 × 64

= 8192

No. of Address still left = {65,536 − (16384 + 16384 + 8192)}

= 24576 Address.



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Q.8 (a) (i) Explain the concept of frequency reuse in mobile cellular system and also write the relationship between frequency reuse distance 'D', cell radius 'R' and number of cells per cluster 'N'.

(ii) A digital transmission system is required to transmit data at a bit rate of 8 kbps over a channel with an available bandwidth of 5 kHz.

1. Determine the minimum value of M required for an M-ary QAM system if rectangular pulses are used and also determine the minimum value of M required if Nyquist pulses are used.
2. If QPSK modulation is employed using Raised cosine pulses, calculate the maximum possible value of the roll-off factor (α) that can be supported by the channel.

[10 + 10 marks]

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Q.8 (b) Using the drift-diffusion equation, derive the following equations for the 1-D electron current density, J_n and hole current density J_p:

$$J_n(x) = \sigma_n(x)\frac{d(E_{Fn}/q)}{dx};$$

$$J_p(x) = \sigma_p(x)\frac{d(E_{Fp}/q)}{dx}$$

where, E_{Fn} and E_{Fp} are electron and hole quasi-fermi levels, respectively.

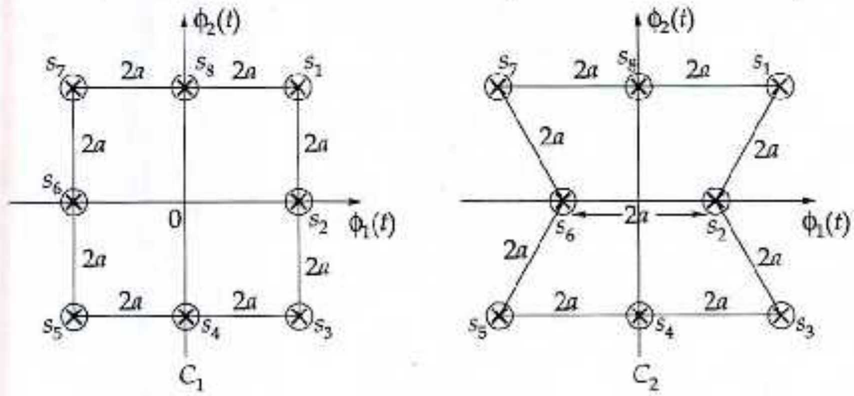
[20 marks]

Q.8 (c) Consider two 8-ary signal constellations, C_1 and C_2, shown in the figure below. The basis functions are $\phi_1(t)$ and $\phi_2(t)$. Assume all signal points are equiprobable and the minimum distance between any two adjacent signalling points is $d_{\min} = 2a$.

(i) Calculate the average symbol energy (E_{avg}) for both constellations.

(ii) Compare the probability of symbol error (P_e) for C_1 and C_2 in an AWGN channel.

(iii) Determine which constellation is more power efficient and by how much (in dB).



[20 marks]

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Space for Rough Work

Space for Rough Work

Space for Rough Work

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