MADE EASY

Leading Institute for ESE, GATE & PSUs

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	20
Q.2	
Q.3	32
Q.4	
Section-B	
Q.5	33
Q.6	38
Q.7	35
Q.8	
Total Marks Obtained	158

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

- Revise CoA & MS.
- Attempt more no. [illegible]

Corp. office : 44 - A/1, Kalu Sarai, New Delhi-110016 | **Ph:** 9021300500 | **Web:** www.madeeasy.in

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) 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]

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]

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]

Do not write in this margin

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) Given, At. wt = 50 g/mol.

$R = 1.24\ \text{Å} = 1.24 \times 10^{-10}\ m = 1.24 \times 10^{-8}\ cm$

For BCC, N = 2

$a = \frac{4R}{\sqrt{3}}$

$\therefore a = \frac{4 \times 1.24 \times 10^{-8}}{\sqrt{3}} = 2.86 \times 10^{-8}\ cm.$

$\rho = \frac{N \times At.wt}{N_A \times a^3} = \frac{2 \times 50}{6.023 \times 10^{23} \times (2.86 \times 10^{-8})^3}$

Density $= \rho = 7.07\ g/cm^3.$

(ii) Intercept → $a = 3$, $b = 2$, $c = \infty$

Reciprocal → $1/3$, $1/2$, $\frac{1}{\infty}$

$\frac{1}{3}$, $1/2$, 0

(Multiply by 6)

Miller Indices ⇒ (2, 3, 0)

(ii) Interplanar spacing $d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$, $a = 4\text{Å}$, $a = 4\times10^{-8}$ cm

$d_{321} = \frac{a}{\sqrt{3^2+2^2+1}} = \frac{a}{\sqrt{14}} = \frac{4\times10^{-8} \text{ cm}}{\sqrt{14}}$

$d_{321} = \frac{4\text{Å}}{\sqrt{14}} = 1.069\ \text{Å}$

(OR)

1.069×10^{-8} cm.

Good 12

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, $\mu_B = 9.27\times10^{-24}$ A-m², $\mu_0 = 4\pi\times10^{-7}$ Henry/meter, $K_B = 1.38\times10^{-23}$ Joule/Kelvin.

[12 marks]

Given, $\mu_B = 9.27\times10^{-24}\ \text{A m}^2$, $\mu_0 = 4\pi\times10^{-7}$ H/m.

$K_B = 1.38\times10^{-23}$ J/K , $a = 0.286$ nm.

T_c of (Fe) = 1043 K. , (N = 2) → BCC (Fe)

(1) Saturation Magnetization ⇒ $M_s = \frac{N\cdot\mu_B}{a^3}$

8

$M_s = \frac{2\times 9.27\times10^{-24}}{(0.286\times10^{-9})^3}$

$M_s = 1.586\times10^{6}$ A/m

(ii) Curie constant, $C = \frac{\mu_0 N \mu_\beta^2}{3K_\beta}$ — $N = \frac{2}{a^3}$ Per unit volume

$$C = \frac{4\pi \times 10^{-7} \times 2 \times 9.27 \times 10^{-24}}{1.38 \times 10^{-23} \times (0.286 \times 10^{-9})^3}$$

$\Downarrow$ a^3

$C \cong 0.89\,K$

(iii) $T_c = C \cdot \lambda$ (For field constant)

$$\therefore \lambda = \frac{T_c}{C} = \frac{1043\,K}{0.89\,K}$$

$\lambda = 117.91$

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]

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]

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]

Do not write in this margin

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]

Main Advantage of Ferrites over Ferromagnetic →

- ⇒ They have extremely high electrical resistivity **.
- ⇒ ∴ (used in Transformers core)
- ⇒ Ideal for High frequency Applications. (in Transformer and μwave devices)
- Electric and Magnetic properties of ferrites →

(1) High Permeability (μ_r)

(2) Low Retentivity

(3) Low Coercivity

(4) Low Eddy current Loss.

(5) Narrow Hysteresis Loop.

(6) High Saturation Magnetization.

→

(7) High χ_m (Magnetic susceptibility)

(8) Spontaneous Magnetization (Exhibits).

(9) Ferromagnetic remains Ferromagnetic upto θ_c and becomes Paramagnetic beyond θ_c.

(10) High dielectric constant.

Do not write in this margin

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]

(i) Entity - Relationship (ER Model) of DBMS.

1 → Entity : (A 'thing' or 'object' in real world distinguishable from all other objects.),

2 → Attributes : (The descriptive properties associated by each entity.)

Ex. Name, salary.

7

3 → Relationship : (It tells us about association among several entities.)

4 → Domain : (Set of values for each attributes. .)

Ex. Domain for age b/w (18 to 30)

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 $\epsilon_r = 2.4$ with applied external electric field $\vec{E} = 10^4 \vec{a_x}$ V/m, then calculate the value of polarization and dipole moment of each molecule. (Consider all molecules have same dipole moment)

[20 marks]

Different types of polarization occurring in Dielectric materials are →

(1) Electronic or Induced polarization → Occurs due to electron cloud shifts relative to the nucleus, creating induced dipole moment.

$$P_e = 4\pi\epsilon_0 R^3 \cdot E = \alpha_e E$$

(2) Ionic polarization → Found in materials like (NaCl) where (+ve) and (-ve) ions are displaced in opposite direction.

(3) Orientational Polarization → Occurs mainly in polar dielectrics, originally randomly oriented dipoles align themselves in direction of applied electric field.

$$P_o = \frac{p_p^2 E}{3kT}$$

It depends on temperature, unlike (Ionic and Electronic)

(4) Space-charge polarization → Arises from accumulation of mobile carriers on the surface or grain boundaries within a material.

Given, $N = 3.2 \times 10^{19}$ molecules/m^3

$\varepsilon_r = 2.4$

$E = 10^4$ V/m.

$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

Polarization, **

$$\Rightarrow \quad P = \varepsilon_0 (\varepsilon_r - 1) E$$

$$P = 8.85 \times 10^{-12} \times (2.4 - 1) \times 10^4$$

$$P = 1.24 \times 10^{-7} \ C/m^2$$

$$\boxed{P = Np} \quad **$$

$$p = \text{Dipole Moment} = \frac{P}{N}.$$

$$p = \frac{1.24 \times 10^{-7} \ C/m^2}{3.2 \times 10^{19} \ /m^3}.$$

$$\boxed{p \cong 3.875 \times 10^{-27} \ C \cdot m}$$

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]

Do not write in this margin

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]**

Do not write in this margin

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]

Given, $T = 293K$, $\phi_{Au} = 5.1\ eV = \phi_m$

$\rho_{Ge} = 1\Omega\text{-cm}$, $\chi_{Ge} = 4.0\ eV$.

$\mu_{Ge} = 3900\ cm^2 V^{-1} s^{-1}$, $N_c = 1.98 \times 10^{15} \times T^{3/2}\ cm^{-3}$.

$$\phi_B = \phi_m - \chi_{Ge} = (5.1 - 4.0)\ eV$$

$$\phi_B = 1.1\ eV.$$

$N_D = \dfrac{1}{1.6\times10^{-19} \times 3900 \times 1} = 1.6\times10^{15} / cm^3$

$$1_{\Omega\text{-cm}} = \rho = \frac{1}{q\mu_{Ge} N_d} = \frac{1}{1.6\times10^{-19} \times 3900 \times N_D}$$

$N_D = 1.6\times10^{15} / cm^3$, $N_c = 1.98\times10^{15} \times (293)^{3/2}\ cm^{-3}$

$N_c = 9.94\times10^{18}\ cm^{-3}$.

$$E_F - E_{Fi} = KT \ln\left(\frac{N_c}{N_D}\right) = 0.0259 \ln\left(\frac{9.94\times10^{18}}{1.6\times10^{15}}\right)$$

$$E_F - E_{Fi} \cong 0.22\ eV.$$

12

$$V_{bi} \approx \phi_B - (E_F - E_{Fi})$$

$$\boxed{V_{bi} = 1.1 - 0.22 = 0.88\ eV.}$$

Do not write in this margin

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

[9 marks]

For BASK,

$1 \rightarrow A_c \cos 2\pi f_c t$ — $s_1(t)$

$0 \rightarrow 0$ — $s_2(t)$

We know

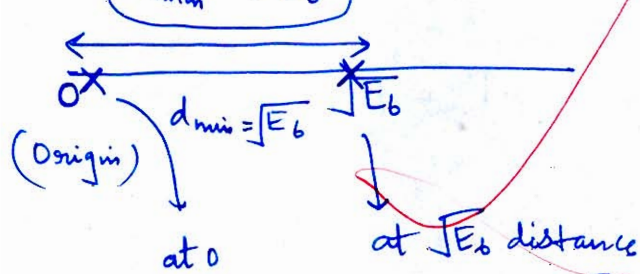
$E_b = P \times T_b.$

$E_b = \frac{A_c^2}{2} \times T_b = \frac{A_c^2}{2R_b}.$

$P_e = Q\sqrt{\frac{d_{min}^2}{2N_0}}$

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

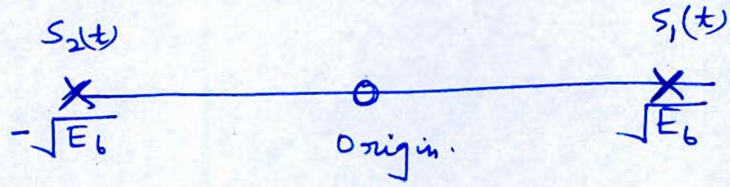
$d_{min}^2 = E_b$



For <u>BPSK</u>,

$$S_1(t) = A_c \cos 2\pi f_c t \longrightarrow \sqrt{E_b}$$

$$S_2(t) = -A_c \cos 2\pi f_c t \longrightarrow \sqrt{-E_b}$$



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

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

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

For <u>BFSK</u>,

$$\Rightarrow S_1(t) = A_c \cos 2\pi f_L t$$

$$\Rightarrow S_2(t) = A_c \cos 2\pi f_c t$$

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

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

$$= Q\sqrt{\left(\frac{E_b}{N_0}\right)}$$

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]

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 $D_p = 10 \text{ cm}^2/\text{sec}$

$\tau_p = 10^{-6}$ sec.

$\therefore L_p = \sqrt{D_p \tau_p} = \sqrt{10^{-6} \times 10} = \sqrt{10^{-5}}$

$L_p = 3.16 \times 10^{-3}$ cm **

$\delta p(x=0) = 10^{14} \text{ cm}^3.$

Now, $\delta p(x) = \delta p(x=0)\, e^{-x/L_p}$

$\delta p(x) = 10^{14} \cdot e^{-x/3.16 \times 10^{-3}}$

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]

Do not write in this margin

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 $E_g = 1.5\,eV$, $m_p^* = 10 m_n^*$, $T = 300\,K$

$n_i = 1\times10^5 / cm^3$.

$$E_{F_i} = \frac{E_c + E_v}{2} + \frac{3}{4} KT \ln\left(\frac{m_p^*}{m_n^*}\right)$$

$$E_{Fi} = E_{midgap} + \frac{3}{4} KT \ln\left(\frac{m_p^*}{m_n^*}\right)$$

$$E_{Fi} = E_{midgap} + \frac{3}{4} KT \ln\left(\frac{10 m_n^*}{m_n^*}\right)$$

$$\left(E_{Fi} = E_{midgap} + 0.0447 ev\right)$$

Intrinsic Fermi Level is 0.044 ev above midgap.

$$(\because m_p^* > m_n^*)$$

Derivation $\Rightarrow$

$$p = n_i \exp\left(-\frac{E_F - E_v}{KT}\right)$$

$$n = n_i \exp\left(-\frac{E_c - E_v}{KT}\right)$$

For intrinsic semiconductor ($n = p$)

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

$$2E_{Fi} = E_c + E_V + KT \ln\left(\frac{N_V}{N_C}\right)$$

$$E_{Fi} = \frac{E_c + E_V}{2} + \frac{KT}{2} \ln\left(\frac{N_V}{N_C}\right)$$

$$E_{Fi} = E_{midgap} + \frac{KT}{2}\ln\left(\frac{N_V}{N_C}\right)$$

$$N_V = 2\left(\frac{2\pi m_p^* h^2}{KT}\right)^{3/2} \quad \left[\because \frac{N_V}{N_C} = \left(\frac{m_p^*}{m_n^*}\right)^{3/2}\right]$$

$$N_C = 2\left(\frac{2\pi m_n^* h^2}{KT}\right)^{3/2}$$

$$\boxed{E_{Fi} = E_{midgap} + \frac{3}{4} KT \ln\left(\frac{m_p^*}{m_n^*}\right)}$$

10

N_V and N_C are effective density of states of V.B and C.B respectively.

(ii) Given E_F is 0.45 ev below the centre of bandgap.

∴ It means Fermi-level is closer to V.B

P-type → N_A is added.

$$E_F - E_{F_i} = KT \ln\left(\frac{N_A}{n_i}\right) \quad \text{—(1)}$$

~~$E_F - E_{F_i} = 25.8\times10^{-3} \ln\left(\frac{N_A}{1\times10^5}\right)$~~

~~$0.45\,ev = 25.8 \ln\left(\frac{N_A}{1\times10^5}\right)$~~

From (1)

$$N_A = n_i \exp\left(\frac{E_F - E_{Fi}}{KT}\right)$$

$$E_F - E_{Fi} = (E_F - E_{midgap}) + (E_{midgap} - E_F)$$
$$= (0.0447 + 0.45)$$

$$N_A = 1\times10^5 \exp\left(\frac{0.45 + 0.0447}{0.0259}\right)$$

$$N_A = 1\times10^5 \exp(19.1)$$

$$\left(N_A \cong 1.97\times10^{13} /cm^3 \text{ acceptor atoms}\right)$$

10

Do not write in this margin

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

[20 marks]

⇒ There are basically 4 layers in TCP / IP protocol ⇒.

Application layer.
Transport layer.
Network layer / Internet layer
Data link layer (OR) Network Access layer.

- Application Layer → This is the top most layer where user application interact with network. It handles high level protocols like FTP, SMTP, HTTP etc.

⇒ Type of Address used here are like URL's i.e. (email address)

- Transport layer → This layer ensures end to end communication and data integrity. It manages data transmission through TCP (Transmission Control Protocol) ↓ (For reliable delivery) and UDP (User Datagram Protocol.) ⇓ For speed

- The address used here are (16-bit numbers)
  ex → (PORT 80 for HTTP).

⇒ Network layer → This is also called Internet layer.
Mainly responsible for routing packets.
(Primary protocol used is IP.) → (Ip4, Ip6)
(IP - Internet protocol.)

The address used here are Ip address like,
(Ip4 vs Ip6)

⇒ Data link layer or Network Access layer ⇒ This layer combines the functionality of OSI's model Data link and Physical layer. It tells us about how data is physically sent over fiber optics or coper wire.

Address used here are → (MAC Address.) → 48-bit
↓
(Media Access control)

18

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.

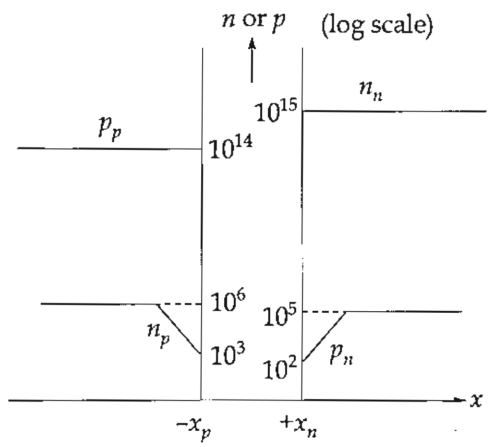
[20 marks]

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

For μ-law ⇒ $\alpha = 4.77 - 20(\ln(1+\mu))$

Do not write in this margin

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]

(P.T.O)

(i) $n_p = 10^6\ cm^{-3}$ and $P_n = 10^5\ cm^{-3}$ (From Figure mentioned in Ques.)

(n_p and P_n are minority carrier conc.)

These values of n_p and P_n are greater than typical thermal equilibrium values indicating carrier injection due to (F·B).

Ans → (F·B)

(ii) Yes, Low-level injection is prevailed here.

On the p-side → $\Delta n_p\ (10^{16}\ cm^{-3}) << P_p\ (10^{15}\ cm^{-3})$

On the n-side → $\Delta P_n\ (10^5) << n_n\ (10^{14})$

Since minority carriers are several order less than majority carriers, the cond^n is satisfied.

(iii) P-side (acceptor) → $N_A \approx P_p = 10^{15}\ cm^{-3}$

N-side (donor) → $N_D \approx N_n = 10^{14}\ cm^{-3}$

(iv) For Early v/g, we use ⇒ $P_n = P_{n_0} e^{\frac{qV_A}{KT}}$ OR $n_p = n_{p_0} e^{\frac{qV_A}{KT}}$

$P_{n_0} = \frac{n_i^2}{N_D} = \frac{10^{20}}{10^{14}} = 10^6\ cm^{-3}$

$n_{p_0} = \frac{n_i^2}{N_A} = \frac{10^{20}}{10^{15}} = 10^5\ cm^{-3}$.

$n_p = 10^6 \ cm^{-3}$

$n_{p_0} = 10^5 \ cm^{-3}$.

Now, $V_A = V_T \ln\left(\frac{n_p}{n_{p_0}}\right)$

$V_A = 0.0259 \ln\left(\frac{10^6}{10^5}\right) = 0.0259 \ln(10)$

$V_A \simeq 0.06 \ V$

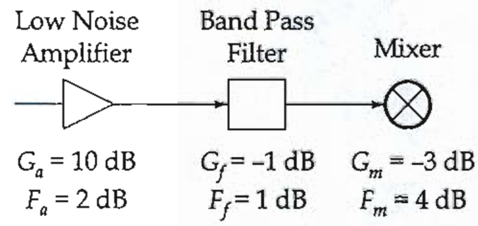
(v) Built in potential, $V_{bi} = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$

$V_{bi} = 0.0259 \ln\left(\frac{10^{15} \times 10^{14}}{10^{20}}\right)$

$V_{bi} = 0.0259 \ln(10^9)$

$V_{bi} \simeq 0.537 \ V$

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) Overall Noise Figure (F_{system}) $= F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$

$G_a = G_1 = 10\,dB = 10^{10/10} = 10$

$F_a = 2\,dB = F_1 = 10^{2/10} = 10^{0.2} = 1.585$

$G_f = G_2 = 10^{-1/10} = 0.794$

$F_f = F_2 = 10^{1/10} = 1.259$

$G_M = G_3 = 10^{-3/10} = 0.501$

$F_M = F_3 = 10^{4/10} = 2.512$

$F_{sub\text{-}system} = 1.585 + \frac{(1.259 - 1)}{10} + \frac{(2.512 - 1)}{10 \times 0.794}$

$F_{sub\text{-}system} \simeq 1.8013$

f_n dB $\rightarrow 10 \log_{10}(1.8013) \cong 2.556$ dB.

(ii) $T_{eq} = T_0(F_{sub-system} - 1)$

$T_{eq} = 290 \times (1.8013 - 1)$

$T_{eq} = 290 \times (0.8013)$

$T_{eq} = 232.377\ K.$

(iii) Overall Gain of system ⇒

$G_{overall} = G_a + G_f + G_m$

$= 10\,dB + (-1)\,dB + (-3)\,dB$

$G_{overall} = 6\,dB.$

$Gain = 10^{6/10} = 10^{0.6} = 3.98$

(iv) $P_{n_o} = KT_{in} B\, G_{overall} = (1.38 \times 10^{-23} \times 382.37 \times 10 \times 10^{6} \times 3.98)$

$(T_{in} = T_{ant} + T_e) \Rightarrow (382.37\ K)$

$P_{n_o} = 2.10 \times 10^{-13}\ W.$ **

(v) Given $(SNR)_{out} = 20\,dB = \frac{P_{sig\ o/p}}{P_{n\ o/p}}$

(100)

$P_{sig,\ o/p} = 100 \times P_{n\ o/p}$

$P_{in} = \frac{P_{sig\ o/p}}{G_{system}} = \frac{100 \times 2.10 \times 10^{-13}}{3.98} = 5.28 \times 10^{-12}\ W$

Do not write in this margin

(vi) $P_{in} = \dfrac{V^2}{Z}$, where $Z = 150\,\Omega$.

$V = \sqrt{P_{in} \cdot Z} = \sqrt{5.28 \times 10^{-12} \times 150}$

$V = 28.1 \times 10^{-6}$ V

$\boxed{V = 28.1\ \mu V}$

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]

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]

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.

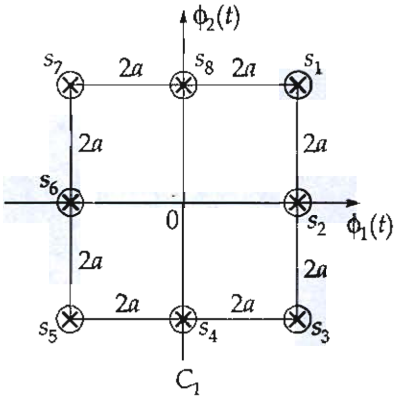
[20 marks]

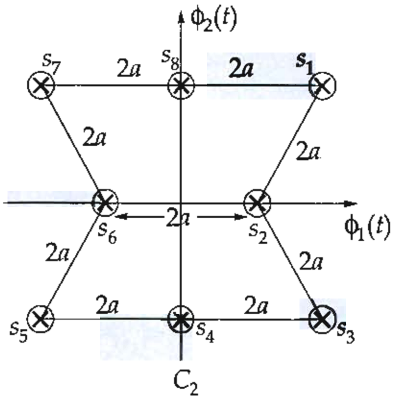
Q.8 (c) Consider two 8-ary signal constellations, C_1 and C_2, shown in the figure below. The basis functions are $\phi_1(t)$ and $\phi_2(t)$. Assume all signal points are equiprobable and the minimum distance between any two adjacent signalling points is $d_{min} = 2a$.

(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]

OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work