MADE EASY

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Detailed Solutions

ESE-2023 Mains Test Series

E & T Engineering Test No : 5

Section A : Computer Organization and Architecture + Materials Science

Q.1 (a) Solution:

(i) Let cache access time be 1 and main memory access time be 20.

Requested instruction is found in the cache with probability of 0.96 or 96%.

$\therefore$ Every instruction that is executed must be fetched from the cache and an additional fetch from the main memory must be performed for 4% of these cache accesses.

Speedup is defined as the ratio of program execution time without the cache to program execution time with cache.

$$\therefore \quad \text{Speedup factor} = \frac{\text{Program execution time without cache}}{\text{Program execution time with cache}}$$

$$= \frac{1\times 20}{[1\times 1 + 0.04\times 20]} = \frac{20}{1.8}$$

$$\text{Speedup factor } 'S' = 11.1$$

(ii) **Case (2)** When size of the cache is doubled, it is given that the requested instructions are found in the cache with probability of 98%.

Hence requested instructions are to be accessed from the main memory with probability of 2%

$\therefore$ Additional fetch from main memory must be performed for 2% of these cache accesses.

$$\therefore \quad \text{Speedup factor 'S'} = \frac{\text{Program execution time without cache}}{\text{Program execution time with cache}}$$

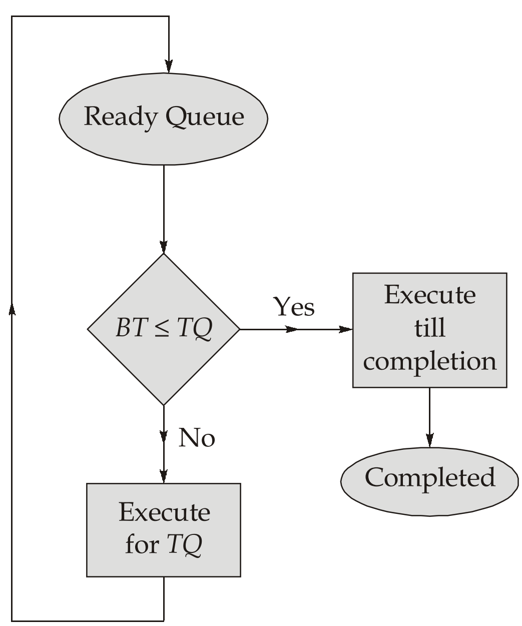
$$= \frac{1 \times 20}{[1 \times 1 + 0.02 \times 20]}$$

$$S = 14.29$$

Q.1 (b) Solution:

Round Robin Scheduling Algorithm: Round Robin scheduling algorithm is one of the most popular scheduling algorithm mainly used for multitasking and can be implemented in most of the operating systems.

This is the preemptive version of first come first serve scheduling. The algorithm focuses on time sharing. In this algorithm, every process gets executed in a cyclic way. A certain time slice is defined in the system which is called time quantum. Each process present in the ready queue is assigned the CPU for that time quantum, if the execution of the process is completed during that time then the process will terminate else the process will go back to the ready queue and waits for the next turn to complete the execution.



Here AT → Arrival Time, BT → Burst Time (remaining), TQ → Time Quantum

P_{id}	AT	BT	CT	TAT = CT – AT	WT = TAT – BT
P_1	0	8	25	25	17
P_2	5	2	14	9	7
P_3	1	7	26	25	18
P_4	6	3	17	11	8
P_5	8	5	28	20	15
P_6	2	3	9	7	4

Ready Queue: $P_1\ P_3\ P_6\ P_1\ P_2\ P_4\ P_3\ P_5\ P_1\ P_3\ P_5$

Gantt Chart:

P_1	P_3	P_6	P_1	P_2	P_4	P_3	P_5	P_1	P_3	P_5
0–3	3–6	6–9	9–12	12–14	14–17	17–20	20–23	23–25	25–26	26–28

0 3 6 9 12 14 17 20 23 25 26 28

$$\therefore \quad \text{Average waiting time, } T_{avg} = \frac{17+7+18+8+15+4}{6} = \frac{69}{6}$$

$$T_{avg} = 11.5 \text{ nsec}$$

Q.1 (c) Solution:

$$\text{The distance between two consecutives slits} = \frac{1}{\text{No. of slits per mm}}$$

$$= \frac{1}{500} \times 10^{-3} \text{m}$$

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

The diffraction angle for red light can be calculated as,

$$\sin\theta = \frac{n\lambda}{d}$$

for $n = 1$ (first order diffraction) and $\lambda = 7 \times 10^{-7}$ m

$$\sin\theta = \frac{1 \times 7 \times 10^{-7}}{2 \times 10^{-6}} = 0.35$$

$$\theta = 20.48°$$

The diffraction angle for green light can be calculated as,

$$\sin\theta = \frac{n\lambda}{d}$$

for ($n = 1$) first order diffraction and $\lambda = 5.38 \times 10^{-7}$ m

$$\therefore \qquad \sin\theta = \frac{1\times 5.38\times 10^{-7}}{2\times 10^{-6}} = 0.269$$

$$\theta = 15.6°$$

The angle of deviation (angle of diffraction) for different wavelengths are not the same. Hence, it is possible to examine the contents of an incident wave by looking at the different angles of deviation produced by the different components of a beam.

Q.1 (d) Solution:

We have to determine the weight percent of Ge that must be added to Si such that the resultant alloy will contain 2.43 × 10^{21} Ge atoms per cubic centimeter.

Given,
$$N_1 = N_{Ge} = 2.43 \times 10^{21} \text{ atoms/cm}^3$$
$$\rho_1 = \rho_{Ge} = 5.32 \text{ g/cm}^3$$
$$\rho_2 = \rho_{Si} = 2.33 \text{ g/cm}^3$$
$$A_1 = A_{Ge} = 72.59 \text{ g/mol}$$
$$A_2 = A_{si} = 28.09 \text{ g/mol}$$

Thus,
$$C_{Ge} = \frac{100}{1 + \frac{N_A \rho_{Si}}{N_{Ge} A_{Ge}} - \frac{\rho_{Si}}{\rho_{Ge}}}$$

$$= \frac{100}{1 + \left[\frac{(6.023\times 10^{23}\times 2.33)}{(2.43\times 10^{21}\times 72.59)}\right] - \left[\frac{2.33}{5.32}\right]}$$

$$C_{Ge} = 11.74\%$$

Q.1 (e) Solution:

Given, $H_c = 0.9$; $H_m = 0.5$; $H_D = 1$; $T_c = 15$ nsec; $T_m = 50$ nsec; $T_D = 10$ msec

Average time required to access a referenced word, given by T is calculated as

$$T = H_c T_c + (1 - H_c)H_m(T_c + T_m) + (1 - H_c)(1 - H_m)H_D(T_c + T_m + T_D)$$
$$= 0.9 \times 15 + (1 - 0.9)0.5(50 + 15) + (1 - 0.9)(1 - 0.5)(50 + 15 + 10 \text{ msec})$$
$$= 13.5 \text{ nsec} + 3.25 \text{ nsec} + 0.1 \times 0.5 \times (50 \times 10^{-9} + 15 \times 10^{-9} + 10 \times 10^{-3})\text{sec}$$
$$T = 500020 \text{ nsec}$$

Q.2 (a) Solution:

(i) Given, $f = 200$ MHz

For Machine A,

$$\text{Effective CPI} = \frac{\sum_i \text{CPI}_i \times I_{ci}}{I_c}$$

$$= \frac{(1\times8+3\times4+4\times2+3\times4)\times10^6}{(8+4+2+4)\times10^6} = \frac{40}{18}$$

$$\text{Effective CPI} = 2.22$$

$$\text{Effective MIPS} = \frac{f}{\text{Effective CPI}\times10^6}$$

$$\text{Effective MIPS} = \frac{200\times10^6}{2.22\times10^6} = 90$$

$$\text{Effective MIPS} = 90$$

Execution time = Instruction count (I_C) × Effective CPI × Clock cycle time

$$= \frac{(8+4+2+4)\times10^6\times2.22\times1}{200\times10^6}$$

$$\text{Execution time} = 0.2 \text{ sec}$$

For Machine B,

$$\text{Effective CPI} = \frac{\sum_i \text{CPI}_i \times I_{ci}}{I_c}$$

$$= \frac{(1\times10+2\times8+4\times2+3\times4)\times10^6}{(10+8+2+4)\times10^6}$$

$$\text{Effective CPI} = 1.92$$

$$\text{Effective MIPS} = \frac{f}{\text{Effective CPI}\times10^6}$$

$$\text{Effective MIPS} = \frac{200\times10^6}{1.92\times10^6}$$

$$\text{Effective MIPS} = 104$$

Execution time = Instruction count (I_C) × Effective CPI × Clock cycle time

$$= \frac{(10+8+2+4)\times10^6\times1.92\times1}{200\times10^6}$$

$$\text{Execution time} = 0.23 \text{ sec}$$

(ii) Although machine B has a higher MIPS than machine *A*, it requires a longer CPU time to execute the same set of benchmark programs.

Q.2 (b) Solution:

(i) Resistivity of alloy is given as:

$$\rho_{alloy} = \rho_{pure\ Cu} + \rho_{impurity}$$

$$\rho_{pure\ Cu} = 0.025 \text{ m}\ \Omega \text{ cm} = 0.025 \times 10^{-5}\ \Omega \text{ m}$$

$$\rho_{impurity} = 0.012 \times 10^{-5} + 0.018 \times 10^{-5}$$

$$= 0.03 \times 10^{-5}\ \Omega\text{-m}$$

∴ Resistivity of alloy:

$$\rho_{alloy} = 0.025 \times 10^{-5} + 0.03 \times 10^{-5}$$

$$= 0.055 \times 10^{-5}\ \Omega\text{-m}$$

Now, Conductivity (σ) $= \dfrac{1}{\rho_{alloy}}$

$$= \frac{1}{0.055 \times 10^{-5}} = 1.818 \times 10^{6} (\Omega \text{ m})^{-1}$$

(ii) Mobility is affected by temperature due to two mechanism:

(a) Lattice Scattering: "It occurs at relatively higher temperature i.e., $T > 100$ K".

- As temperature increases, lattice atoms gets energized, causing thermal vibrations.
- Due to thermal vibrations, number of collision between electrons increases.
- Since mean free time is proportional to collision intensity of electron, therefore mean free time decreases and hence mobility decreases represented as, $\mu \propto T^{-3/2}$.

(b) Impurity Scattering:

- It occurs at low temperature i.e., $T < 100$ K.
- It occurs due to impurity ions. At a low temperature electron travels at low velocity.
- When a low velocity electron, moves closer to impurity ion, it gets attracted or repelled by the ion and hence, electron cannot move freely or electron mobility decreases i.e. $\mu \propto T^{3/2}$.

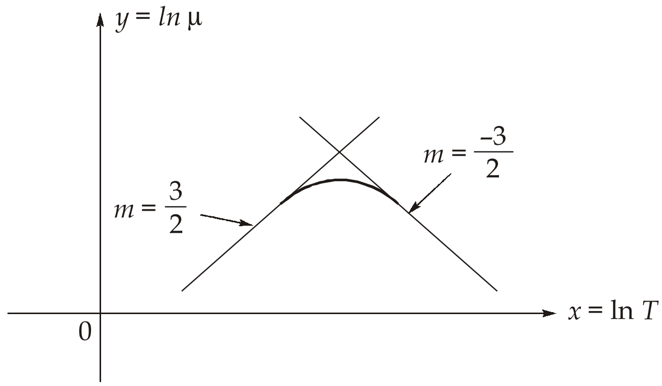
  From the above, we can write

$$\mu \propto T^m, \text{ where } m = \frac{3}{2} \text{ for } T < 100 \text{ K and } m = -\frac{3}{2} \text{ for } T > 100 \text{ K}$$

$$\mu = K \cdot T^m \quad \text{... } K = \text{constant}$$

$$\underbrace{\ln \mu}_{y} = \underbrace{\ln K}_{c} + m \underbrace{\ln T}_{x}$$

$$y = mx + c$$



Note: At room temperature, lattice scattering will be dominant.

Q.2 (c) Solution:

(i)

Carbon Dots	Quantum Dots
1. Carbon dots are small carbon nanoparticles having some form of surface passivation.	1. Quantum dots are small semiconductor particles on a nanoscale, having optical and electronic properties that differ from large particles according to quantum mechanics.
2. Top-down and bottom-up methods are used for production of carbon dots.	2. Colloidal synthesis, plasma synthesis, fabrication, electrochemical assembly can be used for production of Quantum dots.
3. The properties of carbon dots solely depends on their structures and compositions.	3. The properties of quantum dots are intermediate to those of bulk semiconductors and discrete atoms.
4. Carbon dots are used in bioimaging, sensing, drug delivery, catalysis, optronics etc.	4. Quantum dots are used in LEDs, single photon sources, quantum computing etc.
5. Luminescent due to surface defects.	5. Fluorescent due to quantum confinement

(ii) Since Cu is FCC structure, so

$$n = 4 \text{ atoms/unit cell}$$

given, lattice constant, $a = 3.655$ Å

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

$$\text{atomic weight} = 63.55 \text{ g/mole}$$

$$\frac{\text{atomic weight}}{\rho} \times 10^{-6} = \frac{N_A}{n} \times a^3$$

$$\text{density, } \rho = \frac{(63.55)(4)}{(6.023 \times 10^{23}) \times (3.655 \times 10^{-10})^3} = 8.64 \text{ g/cm}^3$$

Q.3 (a) Solution:

(i) By using Clausius – Mossotti equation

We have, $$\alpha_e = \frac{3\varepsilon_0}{N} \frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{3(8.85 \times 10^{-12})}{5 \times 10^{28}} \left[\frac{11.9 - 1}{11.9 + 2}\right]$$

$$\text{electronic polarizability, } \alpha_e = 4.17 \times 10^{-40} \text{ Fm}^2$$

(ii) The local field is

$$E_{\text{loc}} = E + \frac{1}{3\varepsilon_0} P \quad \text{...(1)}$$

We know that, $$P = \varepsilon_0(\varepsilon_r - 1)E$$

$$P = x_e \, \varepsilon_0 E \quad \text{...(2)}$$

Substitute (2) in equation (1) we get,

$$E_{\text{loc}} = E + \frac{1}{3\varepsilon_0} x_e \varepsilon_0 E$$

$$E_{\text{loc}} = E + \frac{x_e E}{3}$$

$$E_{\text{loc}} = E + \frac{(\varepsilon_r - 1)}{3} E$$

So the local field with respect to the applied field is,

$$\frac{E_{\text{loc}}}{E} = \frac{1}{3}(\varepsilon_r + 2)$$

$$\frac{E_{\text{loc}}}{E} = \frac{1}{3}[11.9 + 2] = 4.63$$

The local field is greater than the applied field by a factor of 4.63.

(iii) Since polarization is due to valence electrons and there are four per Si atom,

For electronic polarization, we have,

$$\omega_0 = \left(\frac{Ze^2}{m_e \alpha_e}\right)^{1/2} = \left[\frac{4(1.6 \times 10^{-19})^2}{(9.1 \times 10^{-31})(4.17 \times 10^{-40})}\right]^{1/2}$$

$$\omega_0 = 1.65 \times 10^{16} \text{ rad/sec}$$

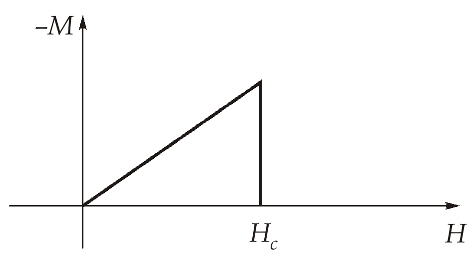
The corresponding resonant frequency is $\frac{\omega_0}{2\pi} = 2.6 \times 10^{15}$ Hz; which is typically associated with the electromagnetic waves of wavelength in the ultraviolet region.

Q.3 (b) Solution:

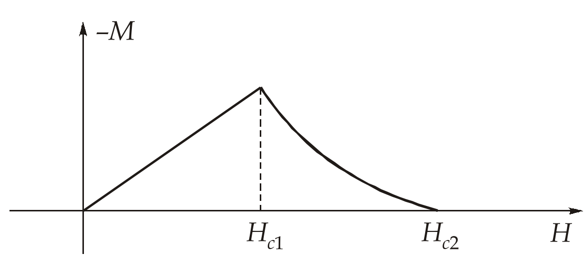
(i) **1.** **Superconductivity:** "A state of material in which it has zero resistivity is called super conductivity".

Types of superconductors:

(a) Type-I superconductors: Type-I or ideal superconductors are those superconductors when placed in a magnetic field repels the flux lines totally, till the magnetic field attains the critical value H_c i.e. they are completely diamagnetic and follow the Meissner effect upto the critical field H_c, and go to normal state beyond that as shown below:



(b) Type-II superconductors: It is also called hard superconductors, in which the ideal behaviour is seen up to a lower critical field H_{c1} beyond which the magnetization gradually changes and attains zero at an upper critical field designated as H_{c2} as shown below:



The Meissner effect is incomplete in the region between H_{c1} and H_{c2}; known as the Vortex region.

2.

$$H_c = 4.1 \times 10^5 \text{ A/m; at } T = 5 \text{ K}$$
$$H_0 = 8.2 \times 10^5 \text{ A/m; at } T = 0 \text{ K}$$

We know,
$$H_c = H_0\left[1-\left(\frac{T}{T_c}\right)^2\right]$$
$$4.1 \times 10^5 = 8.2\times10^5\left[1-\left(\frac{5}{T_c}\right)^2\right]$$
$$\frac{1}{2} = 1-\left(\frac{5}{T_c}\right)^2$$
$$\left(\frac{5}{T_c}\right)^2 = \frac{1}{2}$$
$$\frac{5}{T_c} = \frac{1}{\sqrt{2}}$$
$$T_c = 5\sqrt{2} = 7.07 \text{ K}$$

(ii) In a quantum well of an atom, n^{th} energy level is given by
$$E_n = \frac{n^2h^2}{8mL^2}$$

For first energy level,
$$E_1 = \frac{h^2}{8mL^2} = \frac{(6.63\times10^{-34})^2}{8\times9.11\times10^{-31}\times(10^{-9})^2}$$

$\therefore$
$$E_1 = 6.03 \times 10^{-20} \text{ J} = 0.377 \text{ eV}$$

For second energy level,
$$E_2 = \frac{4h^2}{8mL^2} = \frac{(6.63\times10^{-34})^2}{2\times9.11\times10^{-31}\times(10^{-9})^2}\text{ J}$$
$$E_2 = 1.508 \text{ eV}$$

For third energy level,
$$E_3 = \frac{9h^2}{8mL^2} = \frac{9(6.63\times10^{-34})^2}{8\times9.11\times10^{-31}\times(10^{-9})^2}\text{ J}$$
$$E_3 = 3.393 \text{ eV}$$

Q.3 (c) Solution:

(i) Given; Reference string: 1, 2, 1, 3, 7, 4, 5, 6, 3, 1

Optimal Page Replacement Policy:

	1	2	1	3	7	4	5	6	3	1
0	1	1	1	1	1	1	1	1	1	1
1		2	2	2	7	4	5	6	6	6
2				3	3	3	3	3	3	3
			*						*	*

The pages in the frames are replaced as shown below:

1				
2	7	4	5	6
3				

Hence, total no. of page hits = 3

Total no. of page faults = 10 – 3 = 7

(ii) Given: Reference string: 1, 2, 1, 3, 7, 4, 5, 6, 3, 1

Least Recently used

	1	2	1	3	7	4	5	6	3	1
0	1	1	1	1	1	4	4	4	3	3
1		2	2	2	7	7	7	6	6	6
2				3	3	3	5	5	5	1
			*							

The pages in the frames are replaced as shown below:

1	4	3
2	7	6
3	5	1

Hence total no. of pages hit = 1

∴ Total No. of page faults = 10 – 1 = 9

Hence, 2 more page faults occurs with LRU than with the optimal page replacement policy.

Q.4 (a) Solution:

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

Case (1) '0' Address Machine:

PUSH A	;	A
PUSH B	;	B
PUSH C	;	C
MUL	;	B × C
ADD	;	A + B × C B × C
PUSH D	;	D A + B × C
PUSH E	;	E D A + B × C
PUSH F	;	F E D A + B × C
MUL	;	E × F D A + B × C
SUB	;	D – E × F A + B × C
DIV	;	$(A + B \times C)/(D - E \times F)$
POP X	;	$X = (A + B \times C)/(D - E \times F)$

Case (2) '1' Address Machine:

LOAD E	;	$ACC \leftarrow E$
MUL F	;	$ACC \leftarrow E \times F$
STORE T	;	$M[T] \leftarrow ACC$
LOAD D	;	$ACC \leftarrow D$

SUB T	;	$ACC \leftarrow [D - [E \times F]]$
STORE T	;	$M[T] \leftarrow ACC$
LOAD B	;	$ACC \leftarrow B$
MUL C	;	$ACC \leftarrow B \times C$
ADD A	;	$ACC \leftarrow A + B \times C$
DIV T	;	$ACC \leftarrow (A + B \times C)/[D - (E \times F)]$
STORE X	;	$M[X] \leftarrow ACC$

Case (3) '2' Address Machine:

MOV R_0, E	;	$R_0 \leftarrow E$
MUL R_0, F	;	$R_0 \leftarrow E \times F$
MOV R_1, D	;	$R_1 \leftarrow D$
SUB R_1, R_0	;	$R_1 \leftarrow D - (E \times F)$
MOV R_0, B	;	$R_0 \leftarrow B$
MUL R_0, C	;	$R_0 \leftarrow B \times C$
ADD R_0, A	;	$R_0 \leftarrow A + (B \times C)$
DIV R_0, R_1	;	$R_0 \leftarrow (A + B \times C)/(D - E \times F)$
MOV X, R_0	;	$X \leftarrow R_0$

Case (4) '3' Address Machine:

MUL R_0, E, F	;	$R_0 \leftarrow E \times F$
SUB R_0, D, R_0	;	$R_0 \leftarrow D - (E \times F)$
MUL R_1, B, C	;	$R_1 \leftarrow B \times C$
ADD R_1, A, R_1	;	$R_1 \leftarrow A + B \times C$
DIV X, R_1, R_0	;	$X \leftarrow (A + B \times C)/(D - E \times F)$

Q.4 (b) Solution:

(i) **1.** **Translators:** In general, translators convert programs written in one language to another language. For example; Assemblers, compilers, converters and interpreters.

2. **Assemblers:** An assembler takes "Assembly language programs" as input and converts then into machine language. Usually assemblers are specific to processors.

For example, for intel family of processors the following assemblers are available.

MASM	Microsoft Assembler
TASM	Turbo Assembler
NASM	GNU Assembler

3. **Compilers:** Compilers takes high level language program as input and convert it into machine language. The compilers are specific to a language and we do not have universal compilers which take any "High level language program" and give machine language program which run's on any machine.
4. **Converters:** Converters, convert programs in one high level language to another high-level language. For example, Pascal to '*C*' and FORTRAN to '*C*' etc.
5. **Interpreters:** Interpreters takes high level language program instructions one after another and execute immediately. Usually interpreters are needed to identify run time errors, which are also called as bugs.

(ii) 1. We have;

$$I = 1 \text{ Amp}$$

$$l = 20 \text{ cm} = 20 \times 10^{-2} = 0.2 \text{ m}$$

$\therefore$ field strength; $H = \dfrac{I}{l} = \dfrac{1}{0.2} = 5 \text{ A/m}$

Now, magnetic flux density in material is given as;

$$\begin{aligned} B &= \mu \cdot H \\ &= \mu_0 \mu_r \cdot H \\ &= \mu_0(1 + \chi_m) \cdot H \,;\ \mu_r = 1 + \chi_m \\ &= 4\pi \times 10^{-7}(1 + 0.005) \cdot 5 \\ B &= 6.314 \times 10^{-6} \text{ Wb/m}^2 \\ &= 6.314 \times 10^{-6} \text{ Tesla} \end{aligned}$$

2.

Hard Magnetic Material	Soft Magnetic Material
• Difficult to magnetize and demagnetize.	• Can be easily magnetized and demagnetized.
• Low permeability.	• Higher permeability.
• High coercivity.	• Low coercivity.
• It maintain a constant magnetic property after magnetization at once.	• It does not maintain a constant magnetic property after magnetization at once.
• Large hysteresis loss.	• Small hysteresis loss.
• Ex: AlNiCo alloy, FeCrCo alloy, permanent magnet ferrites.	• Silicon-iron alloy, Nickel-iron alloy.

Q.4 (c) Solution:

(i) Lossless join decomposition: It is also called as non-additive property.

This property guarantees that the extra or less tuple generation problem does not occur and no information is lost from the origninal relation after decomposition. It is a mandatory property and must always hold good.

If a relation 'R' is decomposed into two relations R_1 and R_2 then it will be lossless if,

1. attribute (R_1) $\cup$ attribute (R_2) = attribute (R) i.e., Union of attributes of R_1 and R_2 must be equal to attribute of R i.e. each attribute of R must be either in R_1 or in R_2.
2. attribute (R_1) $\cap$ attribute (R_2) $\neq \phi$, i.e., intersection of attributes of R_1 and R_2 must not be NULL i.e. there may be some common attribute.
3. attribute (R_1) $\cap$ attribute (R_2) $\rightarrow$ attribute (R_1)

   'or'

   attribute (R_1) $\cap$ attribute (R_2) $\rightarrow$ attribute (R_2) i.e., common attribute must be a key for at least one relation (R_1 or R_2).

(ii) $R(VWXYZ)$

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

1. $R_1(VWX)$, $R_2(XYZ)$

For this composition to be lossless decomposition, it should hold all the three conditions.

Condition (1) $\rightarrow R_1(VWX) \cup R_2(XYZ) = R(VWXYZ)$

i.e., all attributes are available.

Condition (2) $\rightarrow R_1(VWX) \cap R_2(XYZ) = X \neq \phi$

i.e., X is common attribute.

Condition (3) $\rightarrow$ Now, X should be candidate key in either R_1 and R_2.

Let's check first in R_1:

$$(X)^+ \rightarrow VXYZ \rightarrow \text{Not a candidate key}$$

Let's check in R_2:

$$(X)^+ \rightarrow XYZV \quad \Rightarrow \quad \therefore \quad X \text{ is candidate key in } R_2$$

This decomposition of $R_1(VWX)$ and $R_2(XYZ)$ satisfy all three conditions. Hence, it is lossless join decomposition.

2. $R_1(VWX)$, $R_2(YZ)$

Condition (1) $\rightarrow R_1(VWX) \cup R_2(YZ) = R(VWXYZ)$

i.e., all attributes are available in either R_1 or R_2.

Condition (2) $\rightarrow R_1(VWX) \cap R_2(YZ) = \phi$

There is no common attribute.

$\therefore$ No need to check further. It is lossy decomposition.

3. $R_1(VW)$, $R_2(WXYZ)$

Condition (1) $\rightarrow R_1(VW) \cup R_2(WXYZ) = R(VWXYZ)$

i.e., all attributes are available in either R_1 or R_2.

Condition (2) $\rightarrow R_2(VW) \cap R_2(WXYZ) = W$

i.e., W is common attribute.

Condition (3) $\rightarrow W$ should be candidate key either in R_1 or R_2.

Let's first check in R_1

$(W)^+ \rightarrow W$

W is not candidate key in R_1.

Let's check in R_2

$(W)^+ \rightarrow W$

W is not candidate key in R_2.

$\therefore$ It does not satisfy 3^{rd} condition. So it is not lossless decomposition. It is a lossy decomposition.

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

Q.5 (a) Solution:

Given,

density of states in conduction band,

$$N_c = 10^{19}\ \text{cm}^{-3}$$

density of states in valence band,

$$N_v = 5 \times 10^{18}\ \text{cm}^{-3}$$

$$\text{Energy gap, } E_g = 2\ \text{eV}$$

$$\text{Temperature, } T = 627°\text{C} = 627 + 273 = 900\ \text{K}$$

$$\text{doping concentration, } n_d = 10^{17}\ \text{cm}^{-3}$$

We know that,

electron concentration, $n = n_d = N_c e^{-\frac{E_C - E_F}{KT}}$

$\therefore$ $$E_C - E_F = -KT \ln\left(\frac{n_d}{N_c}\right) = KT \ln\left(\frac{10^{17}}{10^{19}}\right)$$

where, $$KT = \frac{T}{11600} = \frac{900}{11600} = 0.078 \text{ eV}$$

$$E_C - E_F = -0.078 \ln(10^{-2}) = 0.36 \text{ eV}$$

$$E_F - E_V = [(E_C - E_V) - (E_C - E_F)]$$

$$= [E_g - (E_C - E_F)]$$

$$= [2 \text{ eV} - 0.36 \text{ eV}]$$

$$E_F - E_V = 1.64 \text{ eV}$$

Concentration of holes, $$p = N_v e^{-\frac{(E_F - E_V)}{KT}} = 5 \times 10^{18} e^{-\frac{1.64}{0.078}}$$

$$p = 3.7 \times 10^9 \text{ cm}^{-3}$$

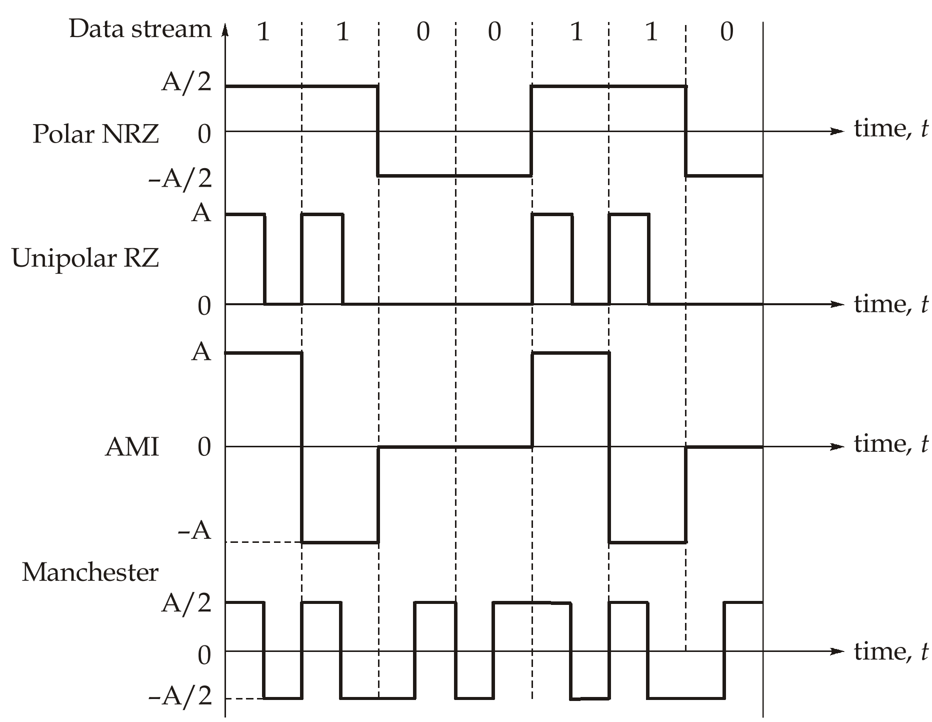
Intrinsic carrier concentration,

$$n_i = (N_c N_v)^{1/2} \exp(-E_g/2kT)$$

$$= (10^{19} \times 5 \times 10^{18})^{1/2} \exp(-2/(2*0.078))$$

$$n_i = 1.91 \times 10^{13} \text{ cm}^{-3}$$

Q.5 (b) Solution:



Q.5 (c) Solution:

For mobile radio operating environment,

$$P_r \propto P_t\, G_t\, G_r\, r^{-4}$$

When transmitted power (P_t) is increased by 3 dB, by keeping all other factors unchanged then,

$$P_r \propto P_t\, r^{-4}$$

$$P_{r1} \propto P_{t1}\, r_1^{-4} \quad \text{(before increasing } P_t\text{)}$$

$$P_{r2} \propto P_{t2}\, r_2^{-4} \quad \text{(after increasing } P_t\text{)}$$

for 3 dB increment in P_t,

$$10\log_{10}\left(\frac{P_{t2}}{P_{t1}}\right) = 3\text{ dB} \Rightarrow \frac{P_{t2}}{P_{t1}} = 2 \qquad \text{...(1)}$$

The minimum acceptable received signal power of the mobile remains unchanged, so when r is defined as the cell radius,

$$P_{r1} = P_{r2} = P_{r\,(\text{min})}$$

Hence,
$$P_{t1}r_1^{-4} = P_{t2}r_2^{-4}$$

$$r_2 = (2)^{1/4}\, r_1 \qquad \text{[from (1)]}$$

Let initial coverage area be A_1 and new coverage area be A_2, then

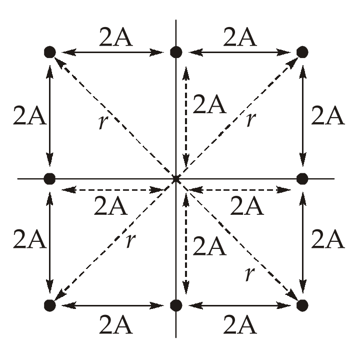
$$A_2 = \left(\frac{r_2}{r_1}\right)^2 A_1 \qquad \because \text{Area} \propto r^2$$

$\therefore$
$$A_2 = \sqrt{2}A_1$$

Q.5 (d) Solution:

Given, Minimum distance between adjacent points is 2A.

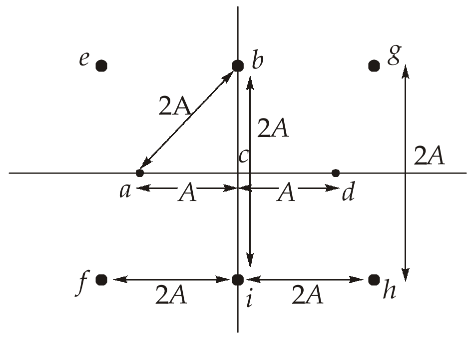
From fig (a): The constellation of fig. (a) has 4 points at a distance 2A from the origin and 4 points are at a distance $r = 2\sqrt{2}A$ from the origin. Thus, the average transmitted power of the constellation is



$$P_a = \frac{1}{8}\left[4\times(2A)^2 + 4\times(2\sqrt{2}A)^2\right]$$

$$P_a = 6A^2$$

From fig. (b): The second constellation has



In Δabc,

$$bc^2 = ab^2 - ac^2$$

$$= 4A^2 - A^2 = 3A^2$$

$$bc = \sqrt{3}A$$

Similarly in Δaci,

$$ci = \sqrt{3}A$$

Hence, two points are at a distance of $\sqrt{3}A$ and two points a and d are at a distance of A from the origin.

In Δbce,

$$ce^2 = eb^2 + bc^2$$

$$= (2A)^2 + (\sqrt{3}A)^2$$

$$ce = \sqrt{7}A$$

Hence, 4 points are at a distance of $\sqrt{7}A$ from the origin.

Thus, the average transmitted power of constellation is

$$P_b = \frac{1}{8}\left[2\times A^2 + 2\times(\sqrt{3}A)^2 + 4\times(\sqrt{7}A)^2\right]$$

$$P_b = \frac{9}{2}A^2$$

Since $P_b < P_a$, the second constellation is more power efficient.

Q.5 (e) Solution:

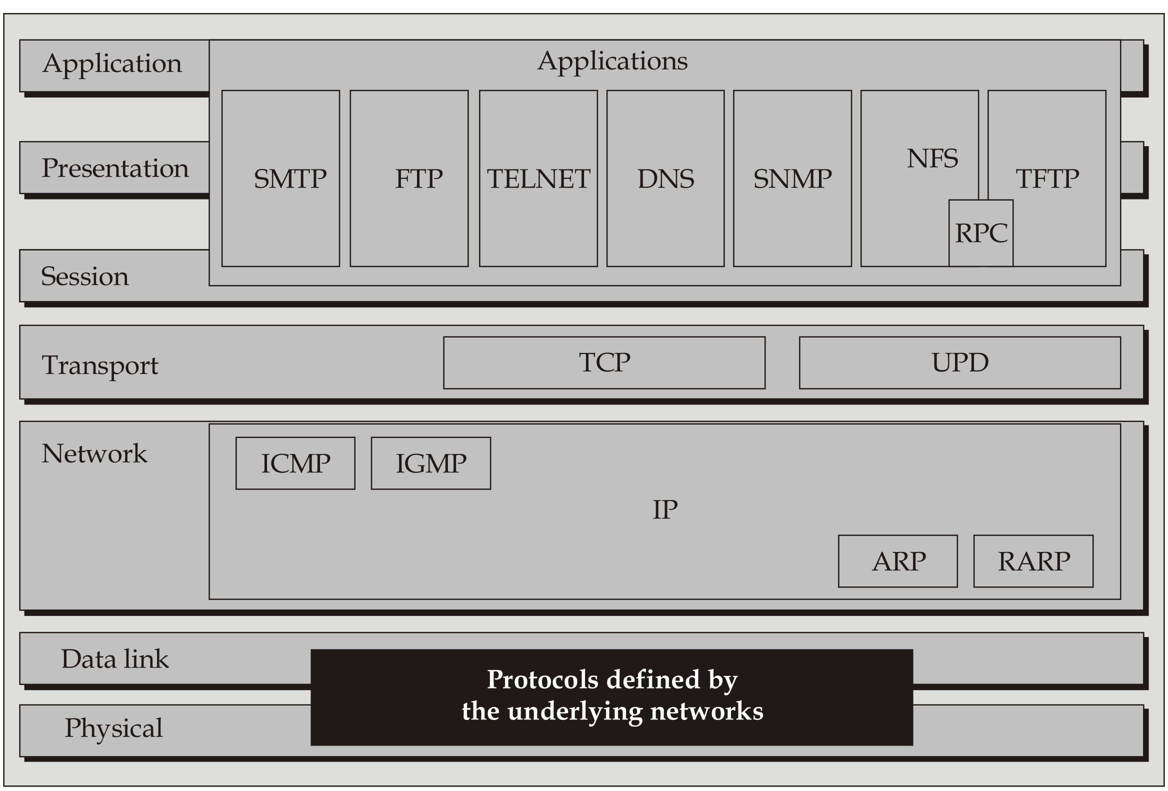
- The methods to reduce co-channel interference in cellular communication network include use of the higher value of cluster size (resulting in increased separation between two co-channel cells and hence, reduction in co-channel interference), lowering the antenna heights at the cell site institutions like high hill or a valley, using directional antennas at the cell-site, providing a notch in the center of the antenna pattern at the interfering cell-bit using umbrella pattern of a staggered discone antenna or using a parasite antenna with a single active element and use of diversity antenna system at the receiver.

- In most of the mobile radio environments, use of cluster size $K = 7$ is not sufficient to avoid co-channel interference. But increasing the value of K more than 7 would reduce the number of channels per cell assuming the available spectrum fixed in the system. This would result in reduction in the cell capacity and hence the spectrum efficiency.

  Therefore, there is trade-off among various system performance parameters such as system capacity, spectrum efficiency and signal quality so as to determine the optimum value of the cluster size.

Q.6 (a) Solution:

(i) The TCP/IP protocol suite is made of five layers: physical, data link, network transport and application. The first four layers provide physical standards, network interface, inter-networking and transport functions that correspond to the first four layers of the OSI model. The three topmost layers in the OSI model, however, are represented in TCP/IP by a single layer called the application layer.



TCP/IP is a hierarchical protocol made up of interactive modules, each of which provides a specific functionality, but they are not necessarily interdependent. The layers of the TCP/IP protocol suite contain relatively independent protocols that can be mixed and matched depending on the needs of the system. The term hierarchical means that each upper-level protocol is supported by one or more lower-level protocols.

At the transport layer, TCP/IP defines two protocols: Transmission Control Protocol (TCP), User Datagram Protocol (UDP) and Stream Control Transmission Protocol (SCTP). At the network layer, the main protocol defined by TCP/IP is Internetworking Protocol (IP), although there are some other protocols that support data movement in this layer.

1. **Application Layer:** An application are user process as cooperating with another process usually on a different host. Examples of applications include Telnet and the File Transfer Protocol (FTP). The interface between application and transport layers is defined by port numbers and sockets.

2. **Transport layer:** This layer provides end to end data transfer by delivering data from an application to its remote peer. Multiple applications can be supported simultaneously. The **most used transport layer protocol is Transmission Control Protocol (TCP)**, which provides connection oriented reliable data delivery, duplicate data suppression, congestion control, error control and flow control.

   Another transport layer protocol is the **User Data Protocol (UDP)**. It provides connectionless unreliable best effort service.

3. **Internet Layer:** This layer is also known as **network layer**. It provides "Virtual Network" an image of the network. Internet protocol is defined at internet layer.

   IP does not provide reliability, flow control or error recovery. These functions must be provided by higher layer. IP provides a routing function that attempts to deliver transmitted message to their destination.

4. **Host to Network Layer:** This is the lowest layer in the TCP/IP reference model and is concerned with the physical transmission of data. It represents the physical layer and data link layer. The host has to connect to the network using some protocol, so that it can send the IP Packets over it. This protocol varies from host to host and network to network.

(ii) **Cryptography:** It refers to tools and techniques used to make messages secure for communication between the participants and make messages immune to attack by hackers".

Cryptography can be divided into two types:

(a) Symmetric-key cryptography

(b) Asymmetric-key cryptography

(a) Symmetric-key Cryptography:

- It is also known as private key cryptography.
- Here, we use the same cryptographic keys for both encryption of plain text and decryption of cipher text.

(b) Asymmetric-key Cryptography:

- It is also known as public key cryptography.
- It is called asymmetric key cryptography because the same key cannot be used to encrypt and decrypt the message. In public key cryptography, there are two keys; a private key and a public key. The public key is announced to the public; where as the private key is kept by the receiver.
- The sender uses the public key of the receiver for encryption and the receiver uses his private key for decryption.

Q.6 (b) Solution:

(i) Total city coverage area = 500 sq km

$$\text{Cell radius, } R = 1.241 \text{ km}$$

The area of a cell [hexagon] can be calculated as

$$A_{\text{cell}} = 2.598\, R^2 = 2.598\, [1.241]^2$$

$$A_{\text{cell}} = 4 \text{ km}^2$$

Hence, total number of cells are

$$N_c = \frac{500}{4} = 125 \text{ cells}$$

(ii) The total number of channels per cell

$$= \frac{\left[\dfrac{\text{Allocated spectrum}}{\text{Channel BW}}\right]}{\text{Frequency Reuse factor}} = \frac{36 \times 1000}{30 \times 12}$$

$$= 100 \text{ channels per cell}$$

(iii) $$\text{Channels/cell} = 100$$

$$\text{and GoS} = 0.02$$

from the Erlang B chart, we have

$$\text{Traffic intensity per cell} = 84 \text{ Erlangs/cell}$$

(iv) Maximum carried traffic = Number of cells × traffic intensity per cell

= 125 × 84

= 10500 Erlangs

(v) Traffic per user = 0.05 Erlangs

$$\text{Total number of users} = \frac{\text{Total traffic}}{\text{Traffic per user}} = \frac{10500}{0.05}$$

Total number of users = 210000 users.

Q.6 (c) Solution:

(i) Let $p(x_1) = \alpha; \quad p(x_2) = 1 - \alpha$

$$H(X) = -\alpha \log_2 \alpha - (1-\alpha)\log_2(1-\alpha)$$

$$\frac{dH(X)}{d\alpha} = \frac{d}{d\alpha}\left[-\alpha \log_2 \alpha - (1-\alpha)\log_2(1-\alpha)\right]$$

Now;

$$\frac{dH(X)}{d\alpha} = -\log_2\alpha + \log_2(1-\alpha)$$

$$= \log_2 \frac{1-\alpha}{\alpha}$$

For maximum value;

$$\frac{dH(X)}{d\alpha} = 0$$

$$\log_2\left(\frac{1-\alpha}{\alpha}\right) = 0$$

$$\frac{1-\alpha}{\alpha} = 1$$

$$1 - \alpha = \alpha$$

$$\alpha = \frac{1}{2}$$

i.e.,

$$p(x_1) = \alpha = \frac{1}{2};\ p(x_2) = 1-\alpha = \frac{1}{2}$$

Hence, $H(X)$ is maximum when x_1 and x_2 are equiprobable.

(ii) We have; $f_m = 2.8$ kHz

Sampling freq. (f_s) = Nyquist Rate + Guard band

$$= 2f_m + \frac{f_m}{2} = 2\times 2.8 + \frac{2.8}{2}$$

= 7 kHz

= 7000 samples/sec

Entropy for samples with equiprobable quantization levels is given as;

$$H = \log_2 m; \quad m = \text{no. of quantization levels}$$
$$= \log_2 4$$
$$= 2 \text{ bits/sample}$$

$$\therefore \quad \text{Information Rate} = f_s \cdot H$$
$$= 7000 \times 2$$
$$= 14000 \text{ bits/sec}$$

Q.7 (a) Solution:

(i) 1. Given, $N_A = 10^{17}$ atoms/cm^3

since, $N_A >> n_i$

hole concentration,

$$p_0 = N_A = 10^{17} \text{ cm}^{-3}$$

electron concentration,

$$n_0 = \frac{n_i^2}{p_0}$$

$$n_0 = \frac{(1.5\times10^{10})^2}{10^{17}} = 2.25\times10^3 \text{ cm}^{-3}$$

We know that, conductivity, $\sigma \approx pq\mu_p$

where, $p = p_0$

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

$$\sigma = 4(\Omega\text{-cm})^{-1}$$

$$\therefore \quad \text{resistivity, } \rho = \frac{1}{\sigma}$$

$$\therefore \quad \rho = \frac{1}{4} = 0.25 \ \Omega\text{-cm}$$

2. Given, $N_d = 3 \times 10^{13}/\text{cm}^3$

Assume, $N_a \cong 0$ (not given)

The electron concentration, from the charge neutrality equation,

$$n_0 + N_a = p_0 + N_d$$

$$n_0 = \frac{n_i^2}{n_0} + N_d$$

$$n_0^2 - N_d n_0 - n_i^2 = 0$$

$$\therefore \qquad n_0 = \frac{N_d \pm \sqrt{N_d^2 + 4n_i^2}}{2}$$

$$\therefore \qquad n_0 = \frac{3\times10^{13} \pm \sqrt{(3\times10^{13})^2 + 4\times(2.5\times10^{13})^2}}{2}$$

$$= 4.4 \times 10^{13}\ \text{cm}^{-3}$$

(ii) Given, hole concentration,

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

diffusion length, $L = 12\ \mu\text{m}$

diffusion coefficient of holes, $D_p = 12\ \text{cm}^2/\text{s}$

mobility of holes, $\mu_p = 1000\ \text{cm}^2/\text{V-s}$

Total current density, $J = 4.8\ \text{A/cm}^2$

1. We know that,

hole current density,

$$J_{p,\text{ diff}} = -qD_p\frac{dp(x)}{dx}$$

$$= -1.6\times10^{-19}\times12\times\frac{10^{15}}{-12\times10^{-4}}\exp\left(\frac{-x}{12}\right)$$

$$J_{p,\text{ diff}} = 1.6\exp\left(\frac{-x}{12}\right)\text{A/cm}^2$$

2. We know that,

Total current density, $J_T = J_{p,\text{ diff}} + J_{n,\text{ drift}}$

$$J_{n,\text{ drift}} = J_T - J_{P,\text{ diff}}$$

$$J_{n,\text{ drift}} = 4.8 - 1.6\exp\left(\frac{-x}{12}\right)\text{A/cm}^2$$

3. We know that,

$$J_{n,\text{ drift}} = nq\mu_n E$$

$$4.8 - 1.6\exp\left(\frac{-x}{12}\right) = 10^{16}\times1.6\times10^{-19}\times1000\times E$$

$$\text{Electric field, } E = 3 - \exp\left(\frac{-x}{12}\right)\text{V/cm}$$

Q.7 (b) Solution:

(i) At thermal equilibrium, in a Si sample of n-type, the current density is zero.

$$J_n = q\mu_n n(x)E(x) + qD_n \frac{dn(x)}{dx} = 0$$

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

$$= -\frac{D_n}{\mu_n}\frac{1}{N_0 + (N_L - N_0)\left(\frac{x}{L}\right)} \cdot \frac{N_L - N_0}{L}$$

$$E(x) = -\frac{D_n}{\mu_n}\frac{N_L - N_0}{LN_0 + (N_L - N_0)x}$$

$$\text{potential, } V = \int_0^L E(x)\,dx$$

$$= \int_0^L -\frac{D_n}{\mu_n}\frac{N_L - N_0}{LN_0 + (N_L - N_0)x}dx$$

$$= \int_0^L -\frac{D_n}{\mu_n}\frac{1}{\frac{LN_0}{N_L - N_0} + x}dx$$

Let
$$u = \frac{LN_0}{N_L - N_0} + x$$
$$du = dx$$

$$= \int_{\frac{LN_0}{N_L - N_0}}^{\frac{LN_0}{N_L - N_0}+L} -\frac{D_n}{\mu_n}\frac{1}{u}du$$

$$= \frac{-D_n}{\mu_n}\ln\left[u\right]_{\frac{LN_0}{N_L - N_0}}^{\frac{LN_0}{N_L - N_0}+L}$$

$$= \frac{-D_n}{\mu_n}\left[\ln\left(\frac{LN_0}{N_L - N_0} + L\right) - \ln\frac{LN_0}{N_L - N_0}\right]$$

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

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

(ii) Given,

$$D_n = 12\ \text{cm}^2/\text{s}$$

$$\mu_n = 3000\ \text{cm}^2/\text{V-s}$$

$$\frac{N_L}{N_0} = 0.75$$

$\therefore$
$$V = \frac{-12}{3000}\ln[0.75]$$

$$V = 1.15\ \text{mV}$$

Q.7 (c) Solution:

(i) The channel matrix from channel is given as;

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

Now, joint probability matrix can be obtained as:

$$P(X; Y) = P[X]|_{\text{diagonal}} \cdot P\left[\frac{Y}{X}\right]$$

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

$$= \begin{bmatrix} 0.2 & 0.05 & 0 \\ 0 & 0.2 & 0.3 \\ 0.0625 & 0.125 & 0.0625 \end{bmatrix}$$

Now, the output probabilities $P(y_1)$, $P(y_2)$ and $P(y_3)$ can be obtained by adding the columns of $P(X ; Y)$

i.e.,
$$P(y_1) = 0.2 + 0.0625 = 0.2625$$

$$P(y_2) = 0.05 + 0.2 + 0.125 = 0.375$$

$$P(y_3) = 0 + 0.3 + 0.0625 = 0.3625$$

The conditional probability matrix $P\left(\frac{X}{Y}\right)$ can be obtained by dividing the columns of $P(X; Y)$ by $P(y_1)$, $P(y_2)$ and $P(y_3)$ respectively, giving

$$P(X|Y) = \begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \end{array}\begin{array}{c} \begin{array}{ccc} Y_1 & Y_2 & Y_3 \end{array} \\ \begin{bmatrix} 0.76 & 0.14 & 0 \\ 0 & 0.53 & 0.83 \\ 0.24 & 0.33 & 0.17 \end{bmatrix} \end{array}$$

Now;

$$H\left(\frac{X}{Y}\right) = -\sum_{j=1}^{3}\sum_{k=1}^{3} P(x_j, y_k)\cdot \log_2 P\left(\frac{x_j}{y_k}\right)$$

$$= -[0.2 \log_2 0.76 + 0.0625 \log_2 0.24 + 0.05 \log_2 0.14 + 0.2 \log_2 0.53 + 0.125 \log_2 0.33 + 0.3 \log_2 0.83 + 0.0625 \log_2 0.17]$$

$$= 0.97 \text{ bits/message}$$

(ii) We have;

$$G = \begin{array}{c} \begin{array}{cccccc} d_1 & d_2 & d_3 & P_1 & P_2 & P_3 \end{array} \\ \left[\begin{array}{ccc:ccc} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ \underbrace{0 \quad 0 \quad 1}_{I} & & & \underbrace{1 \quad 1 \quad 0}_{P} & & \end{array}\right] \end{array}$$

$$P_1 = d_1 \oplus d_3$$

$$P_2 = d_2 \oplus d_3$$

$$P_3 = d_1 \oplus d_2$$

Now all the possible codeword can be obtained as:

d_1	d_2	d_3	d_1	d_2	d_3	P_1	P_2	P_3	Hamming Weight
0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	1	1	1	0	3
0	1	0	0	1	0	0	1	1	3
0	1	1	0	1	1	1	0	1	4
1	0	0	1	0	0	1	0	1	3
1	0	1	1	0	1	0	1	1	4
1	1	0	1	1	0	1	1	0	4
1	1	1	1	1	1	0	0	0	3

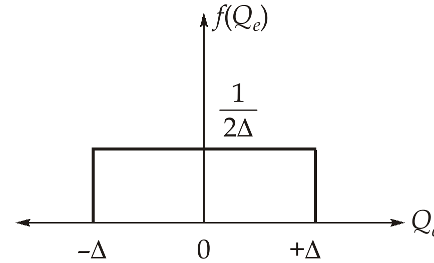
Hamming weight: No. of 1's in codeword

$\therefore$ Minimum Hamming weight = 0.

Maximum Hamming weight = 4.

Q.8 (a) Solution:

(i) For no slope overload distortion, Mean square value of quantisation noise is same as Granular noise and it is given as,

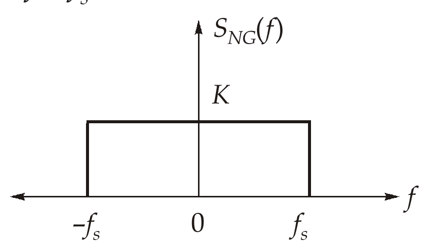


$$\text{Granular noise power, } N_G = \int_{-\Delta}^{\Delta} Q_e^2 f(Q_e) dQ_e$$

$$N_G = \frac{1}{2\Delta} \times \frac{Q_e^3}{3}\Bigg|_{-\Delta}^{\Delta}$$

$$N_G = \frac{\Delta^2}{3} \quad ...(1)$$

It is experimentally determined that the PSD of Granular noise is uniformly distributed between $-f_s \le f \le f_s$.



The Granular noise power N_G with the above PSD is given as

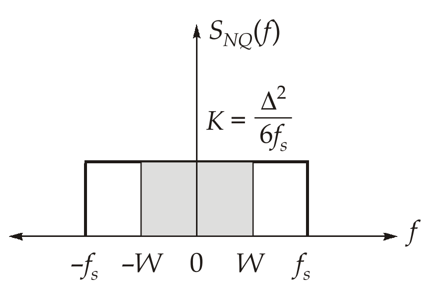
$$N_G = \text{Area[PSD]}$$

$$N_G = K \times 2f_s \quad ...(2)$$

from (1) and (2),
$$\frac{\Delta^2}{3} = K \times 2f_s$$

$$\therefore \quad K = \frac{\Delta^2}{6f_s} \quad ...(3)$$

At the final stage of receiver, there is low pass filter with cut-off frequency of 'W'.



$\therefore$ Granular noise power at output of LPF is given as

$$N_Q = \frac{\Delta^2}{6f_s} \times 2W$$

$$\therefore \qquad N_Q = \frac{\Delta^2 W}{3 f_s} \qquad \text{...(4)}$$

Let sinusoidal message signal is given as $m(t) = A_m \cos 2\pi f_m t$

$\therefore$ For no slope overload distortion,

$$A_m \le \frac{\Delta f_s}{2\pi f_m}$$

$$\therefore \qquad (A_m)_{\max} = \frac{\Delta f_s}{2\pi f_m} \qquad \text{...(5)}$$

The maximum allowed signal power for no slope overload distortion is

$$S_{0\,\max} = \frac{(A_m)^2_{\max}}{2} = \frac{\Delta^2 f_s^2}{2\left[4\pi^2 f_m^2\right]} = \frac{\Delta^2 f_s^2}{8\pi^2 f_m^2} \qquad \text{...(6)}$$

Now the maximum output signal to quantization noise power of DM system is given by,

$$(\text{SQNR})_{\text{o/p max}} = \frac{S_{0\max}}{N_Q} = \frac{\dfrac{\Delta^2 f_s^2}{8\pi^2 f_m^2}}{\dfrac{\Delta^2 W}{3 f_s}} \qquad \text{[From 4 and 6]}$$

$$\therefore \qquad (\text{SQNR})_{\text{o/p max}} = \frac{3 f_s^3}{8\pi^2 f_m^2 W}$$

(ii) Given, $A_m = 1$ V; $f_m = 1$ kHz; $\Delta = 0.1$ V

LPF bandwidth $W = 3 \times 10^3$ Hz

$$f_s = 10 \times \text{Nyquist Rate}$$

$$f_s = 10 \times 2 \times 10^3 = 20 \text{ kHz}$$

1. Under prefiltered condition, it is reasonable to assume that the granular quantization noise is uniformly distributed between $-\Delta$ and $+\Delta$. Hence the signal to noise ratio under pre-filtered condition is given as,

$$(\text{SNR})_{\text{prefiltered}} = \frac{A_m^2/2}{\Delta^2/3} = \frac{3A_m^2}{2\Delta^2} = \frac{3}{2}\left[\frac{1}{0.1}\right]^2$$

$$(\text{SNR})_{\text{prefiltered}} = 150$$

$$(\text{SNR})_{\text{prefiltered}} = 10 \log_{10}(150) = 21.76 \text{ dB}$$

2. The signal to noise ratio under the post filtered condition is

$$(\text{SNR})_{\text{postfiltered}} = \frac{3f_s^3}{8\pi^2 f_m^2 W} = \frac{3\times(20\times10^3)^3}{8\pi^2\times(10^3)^2\times3\times10^3} = 101.32$$

$$(\text{SNR})_{\text{postfiltered}} = 10\log_{10}(101.32) = 20.05 \text{ dB}$$

Q.8 (b) Solution:

(i) The overall space charge neutrality of the semiconductor requires that the total negative space charge per unit area in the p-side must equal the total positive space charge per unit area in the *n*-side, i.e.,

$$\frac{1}{2}[W_P\times N_A] = W_N\times N_D$$

$$\frac{1}{2}\left[0.8\times8\times10^{14}\right] = W_N\times3\times10^{14}$$

n-side depletion layer $W_N = 1.067\ \mu\text{m}$

$\therefore$ Total depletion layer width,

$$W = W_N + W_P$$
$$= 1.067 + 0.8$$
$$W = 1.867\ \mu\text{m}$$

(ii) For calculation of *E*-field $E(x)$,

We use poission's equation,

In *n*-side region, $$\frac{dE(x)}{dx} = \frac{q}{\epsilon_s}N_D$$

$$\Rightarrow \quad E(x_n) = \frac{q}{\epsilon_s}N_D x + k$$

At $x_n = 1.067\ \mu\text{m}$, $E(x_n) = 0$

$$\Rightarrow \quad k = \frac{-q}{\epsilon_s}N_D\times1.067\times10^{-4}$$

$$\therefore \quad E(x_n) = \frac{q}{\epsilon_s}N_D x - \frac{q}{\epsilon_s}N_D\times1.067\times10^{-4}$$

$$= \frac{q}{\epsilon_s}N_D\left[x-1.067\times10^{-4}\right]$$

Maximum E-field is obtained on *n*-side, at $x_n = 0$

$$\therefore \quad E_{\max} = E(x_n = 0) = \frac{q}{\epsilon_s}\times3\times10^{14}(0-1.067\times10^{-4})$$

$$= \frac{-1.6\times10^{-19}}{11.9\times8.85\times10^{-14}}\times3\times10^{14}\times1.067\times10^{-4}$$

Maximum E-field on n-side,

$$\therefore \quad E_{max} = -4.86 \times 10^3 \text{ V/cm}$$

In the p-side region,

$$\frac{dE(x)}{dx} = \frac{q}{\in_s}(ax) \qquad [\because N_A = ax]$$

$$\Rightarrow \quad E(x_p) = \frac{q}{2\in_s}\times ax^2 + K'$$

at $\quad x_p = -0.8\ \mu\text{m}, E(x_p) = 0$

$$0 = \frac{q}{2\in_s}\times a\times(0.8\times10^{-4})^2 + K'$$

$$\therefore \quad K' = \frac{-q}{2\in_s}\times a\times(0.8\times10^{-4})^2$$

$$\therefore \quad E(x_p) = \frac{q}{2\in_s}\times ax^2 - \frac{q}{2\in_s}\times a\times(0.8\times10^{-4})^2$$

$$\therefore \quad E(x_p) = \frac{q}{2\in_s}\times a\times\left[x^2-(0.8\times10^{-4})^2\right]$$

$$E_{max} = E(x_p = 0)$$

$$E_{max} = \frac{-q}{2\in_s}\times a\times(0.8\times10^{-4})^2$$

$$= \frac{-1.6\times10^{-19}}{2\times11.9\times8.85\times10^{-14}}\times10^{19}\times0.64\times10^{-8}$$

$\therefore$ Maximum electric field on P-side,

$$E_{max} = -4.86 \times 10^3 \text{ V/cm}$$

(iii) The built-in potential on p-side is given by,

$$V_{bi} = -\int_{-x_p}^{0} E(x)dx = -\int_{-x_p}^{0} E(x)dx$$

$$V_{bi}\Big|_{\text{on } p\text{-side}} = -\int_{-0.8\mu\text{m}}^{0}\left[\left(\frac{q}{2\in_s}\times a\times x^2\right)-\left[\frac{q}{2\in_s}\times a\times(0.8\times10^{-4})^2\right]\right]dx$$

$$= -\frac{q}{2\in_s}\times a\left[\int_{-0.8\mu\text{m}}^{0} x^2dx + \int_{-0.8\mu\text{m}}^{0}(0.8\times10^{-4})^2\, dx\right]$$

$$= \frac{-q}{2\in_s} \times a \left[\frac{x^3}{3} \Bigg|_{-0.8\,\mu\text{m}}^{0} + x \Bigg|_{-0.8\,\mu\text{m}}^{0} \right]$$

$$= \frac{q}{2\in_s} \times a \left[\frac{-(0.8\times10^{-4})^3}{3} - (0.8\times10^{-4})^3 \right]$$

$$= \frac{-q}{2\in_s} \times a \times (0.8\times10^{-4})^3 \left[1 + \frac{1}{3}\right]$$

$$= \frac{-1.6\times10^{-19}}{2\times11.9\times8.85\times10^{-14}} \times 10^{19} \times (0.8\times10^{-4})^3 \left(\frac{4}{3}\right)$$

$$V_{bi\text{ p-side}} = -0.52 \text{ V}$$

$$V_{bi} \text{ on } n\text{-side} = -\int_0^{1.067\times10^{-4}} \frac{q}{\in_s} N_D [x - 1.067\times10^{-4}] dx$$

$$= \frac{-q}{\in_s} N_D \left[\frac{x^2}{2}\right]_0^{1.067\times10^{-4}} + \frac{q}{\in_s} N_D \times (1.067\times10^{-4})^2$$

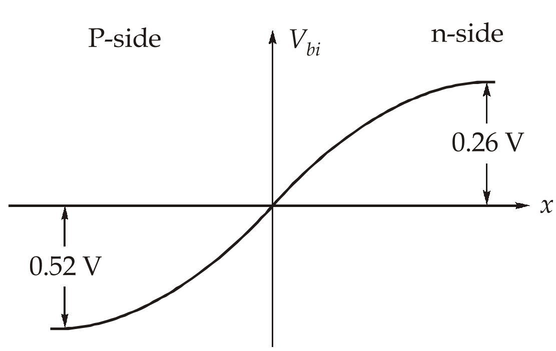
$$= \frac{-q}{\in_s} N_D \left[\frac{(1.067\times10^{-4})^2}{2} - (1.067\times10^{-4})^2 \right]$$

$$= \frac{-q}{\in_s} N_D \times (1.067\times10^{-4})^2 \left[\frac{1}{2} - 1\right]$$

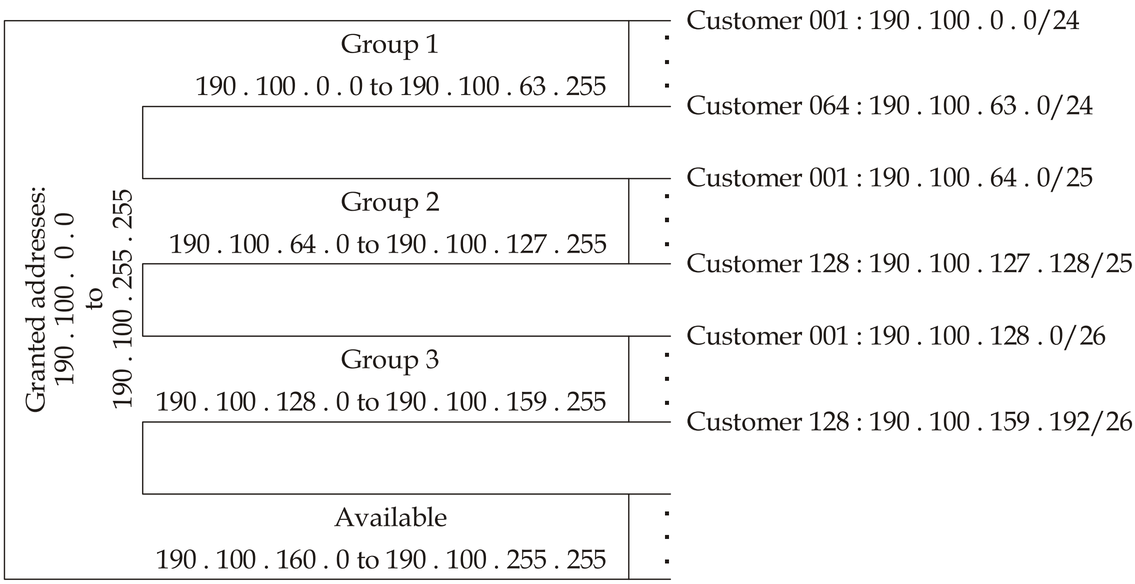
$$= \frac{q}{2\in_s} N_D \times (1.067\times10^{-4})^2$$

$$= \frac{1.6\times10^{-19}}{2\times11.9\times8.85\times10^{-14}} \times 3\times10^{14} \times (1.067\times10^{-4})^2$$

$$V_{bi}\big|_{n\text{-side}} = 0.26 \text{ V}$$



Q.8 (c) Solution:



Group 1:

For this group, each customer needs 256 addresses. This means that 8 ($\log_2 256$) bits are needed to define each host.

The prefix length is then 32 – 8 = 24. The addresses are

1st customer	:	190.100.0.0/24	190.100.0.255/24
2nd customer	:	190.100.1.0/24	190.100.1.255/24
⋮			
64th customer	:	190.100.63.0/24	190.100.63.255/24

Total = 64 × 256 = 16384

Group 2:

For this group, each customer needs 128 addresses. This means that 7($\log_2 128$) bits are needed to define each host. The prefix length is then 32 – 7 = 25. The addresses are

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	:	190.100.127.128/25	190.100.127.255/25

Total = 128 × 128 = 16384

Group 3:

For this group, each customer needs 64 addresses. This means that 6 ($\log_2 64$) bits are needed to each host. The prefix length is then 32 – 6 = 26. The address are:

1st customer	:	190.100.128.0/26	190.100.128.63/26
2nd customer	:	190.100.128.64/26	190.100.128.127/26
⋮			
128th customer	:	190.100.159.192/26	190.100.159.255/26

Total = 128 × 64 = 8192

∴ Number of granted addresses to the ISP : 65,536.

Number of allocated addresses by the ISP : 40,960

Number of available addresses : 24,576

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