Subject Name Solutions

4341102 – Summer 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Define Continuous time Signal and Discrete time Signal with Wave form.

Solution

Signal Type	Definition	Waveform
Continuous Time Signal	Signal defined for all values of time with no breaks	`mermaid graph LR; A[t] --> B[x(t)]; style B fill:#fff,stroke:#333,stroke-width:2`
Discrete Time Signal	Signal defined only at discrete time intervals	`mermaid graph LR; A[n] --> B[x[n]]; style B fill:#fff,stroke:#333,stroke-width:2`

Diagram:

```
                     Continuous                          Discrete
Signal                                                       o
Amplitude    /{      /                                      |}
            /  {    /                                       o     o}
           /    {  /                                        |     |}
          /      {/                                  o      |     |      o}
         /                {                           |      o     |      |}
{-{-}{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}
                                                  |   |      |     o      |
                                                  o   o      |            |
                                                                          o
```

Mnemonic

"Continuous Curves, Discrete Dots"

Question 1(b) [4 marks]

Explain Energy and power signal.

Solution

Parameter	Energy Signal	Power Signal
Definition	Has finite energy but zero average power	Has finite average power but infinite energy
Mathematical Expression	$\int \lvert x(t)\rvert^2 dt < \infty$	$\lim(\text{T}\rightarrow \infty)(1/2T) \int \lvert x(t)\rvert^2 dt < \infty$
Examples	Pulse, Decaying exponential	Sine wave, Square wave
Nature	Finite duration or decreasing amplitude	Periodic or infinite duration

Diagram:

```
     Energy Signal                          Power Signal
        /{                                  /    /    /}
       /  {                                /    /    /  }
      /    {                              /    /    /    }
 {-{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} time   {-}{-}{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}
    /        {                          /}
   /          {                        /}
                                     Never ends...
```

Mnemonic

"Energy Expires, Power Persists"

Question 1(c) [7 marks]

Explain block diagram of digital communication system.

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Source] {-{-}{} B[Source Encoder]}
    B {-{-}{} C[Channel Encoder]}
    C {-{-}{} D[Digital Modulator]}
    D {-{-}{} E[Channel]}
    E {-{-}{} F[Digital Demodulator]}
    F {-{-}{} G[Channel Decoder]}
    G {-{-}{} H[Source Decoder]}
    H {-{-}{} I[Destination]}
{Highlighting}
{Shaded}
```

Block	Function
Source	Generates message to be transmitted
Source Encoder	Converts message to digital sequence, removes redundancy
Channel Encoder	Adds controlled redundancy for error detection/correction
Digital Modulator	Converts digital symbols to waveforms suitable for channel
Channel	Transmission medium, adds noise and distortion
Digital Demodulator	Converts received waveforms back to digital symbols
Channel Decoder	Detects/corrects errors using added redundancy
Source Decoder	Reconstructs original message from digital sequence

Mnemonic

"Send Signals Carefully, Digital Messages Communicate Data Safely"

Question 1(c) OR [7 marks]

Explain Unit Step function and Unit impulse function.

Solution

Function	Mathematical Definition	Properties	Applications
Unit Step Function (u(t))	u(t) = 0 for t < 0u(t) = 1 for t ≥ 0	- Represents sudden transition- Integral of impulse function	System response analysis
Unit Impulse Function ((t))	(t) = 0 for t ≠ $0(t)dt = 1$	- Infinitesimally narrow pulse- Sampling property- Derivative of step function	Sampling, system analysis

Diagrams:

```
  Unit Step Function                 Unit Impulse Function
            \_\_\_\_\_\_                             \^{}
           |                                  |
           |                                  |
           |                               (infinite)
\_\_\_\_\_\_\_\_\_\_\_|                                     |
                                              |
{-{-}{-}{-}{-}{-}{-}{-}{-}{-}0{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} t       {-}{-}{-}{-}{-}{-}0{-}{
```

Mnemonic

"Step Stays steady after zero, Impulse Instantly appears then vanishes"

Question 2(a) [3 marks]

A signal carries 8 bit/signal elements. If 1000 signal elements sent per second. Find the bit rate.

Solution

Parameter	Value
Bits per signal element	8 bits
Signal elements per second	1000
Calculation	Bit rate = (Bits per signal element) $\times (Signal elements per second)$
Bit rate	= 8 $\times 1000 = 8000 bits/second or 8 kbps$

Mnemonic

"Bits per signal $\times Signals per second = Bits per second''$

Question 2(b) [4 marks]

Explain Even and Odd signal.

Solution

Signal Type	Mathematical Definition	Properties	Examples
Even Signal	x(-t) = x(t)	- Symmetric about y-axis- Cosine is even	Cosine function, |t|

Odd Signal	x(-t) = -x(t)	- Anti-symmetric about y-axis- Sine is odd	Sine function, t

Diagram:

```
        Even Signal                        Odd Signal
            /{                                 /}
           /  {                               /}
          /    {                             /}
         /      {                           /}
 {-{-}{-}{-}{-}{-}{-}0{-}{-}{-}{-}{-}{-}{-}{-}{-}                  {-}{-}{-}{-}{-}{-}{-}0{-}{-}{-}{-
         {      /                        /}
          {    /                        /}
           {  /                        /}
            {/                        v}
```

Mnemonic

"Even reflects Exactly, Odd reflects Oppositely"

Question 2(c) [7 marks]

Explain the block diagram of ASK modulator and de-modulator with waveform.

Solution

ASK Modulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Input] {-{-}{} B[Product Modulator]}
    C[Carrier Generator] {-{-}{} B}
    B {-{-}{} D[ASK Output]}
{Highlighting}
{Shaded}
```

ASK Demodulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[ASK Signal] {-{-}{} B[Envelope Detector]}
    B {-{-}{} C[Comparator]}
    C {-{-}{} D[Digital Output]}
{Highlighting}
{Shaded}
```

Waveforms:

```
Digital Input:   \_\_\_\_\_        \_\_\_\_\_
                |     |     |     |
         \_\_\_\_\_\_\_|     |\_\_\_\_\_|      |\_\_\_\_\_

Carrier:  /{//////////////}

ASK Output:      /{//       ///}
                |      |     |      |
         \_\_\_\_\_\_\_|      |\_\_\_\_\_|       |\_\_\_\_\_
```

Concept	Description
ASK Modulation	Amplitude varies according to digital data (0 or 1)
Modulator Components	Product modulator multiplies carrier with digital signal
Demodulator Components	Envelope detector extracts amplitude, comparator regenerates digital signal

Mnemonic

"ASK Adjusts Signal's Knockout amplitude"

Question 2(a) OR [3 marks]

A signal has a bit rate of 4000 bit/second and a baud rate of 1000 baud. How many data elements are carried by each signal element?

Solution

Parameter	Value
Bit rate	4000 bits/second
Baud rate	1000 baud (signal elements/second)
Formula	Number of data elements = Bit rate $\div Baudrate$
Data elements per signal	= 4000 $\div$1000 = $4 bits/signalelement$

Mnemonic

"Bits divided by Bauds equals Bits per signal"

Question 2(b) OR [4 marks]

Explain Periodic and aperiodic signal.

Solution

Signal Type	Definition	Mathematical Condition	Examples
Periodic Signal	Repeats after fixed time interval	x(t) = x(t+T) for all t	Sine wave, Square wave
Aperiodic Signal	Does not repeat after any time interval	x(t) $\neq x(t+T) for any T$	Pulse, Noise

Diagram:

```
   Periodic Signal                  Aperiodic Signal
   /{    /    /                         /}
  /  {  /    /                         /  }
 /    {/    /                         /    \_\_\_\_\_\_\_\_\_\_\_}
                                       /
One period (T) {-{-}|                   /}
```

Mnemonic

"Periodic Perfectly repeats, Aperiodic Alters always"

Question 2(c) OR [7 marks]

Explain the block diagram of PSK modulator and de-modulator with waveform.

Solution

PSK Modulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Input] {-{-}{} B[Phase Shifter]}
    C[Carrier Generator] {-{-}{} B}
    B {-{-}{} D[PSK Output]}
{Highlighting}
{Shaded}
```

PSK Demodulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[PSK Signal] {-{-}{} B[Product Detector]}
    C[Carrier Recovery] {-{-}{} B}
    B {-{-}{} D[Low Pass Filter]}
    D {-{-}{} E[Decision Device]}
    E {-{-}{} F[Digital Output]}
{Highlighting}
{Shaded}
```

Waveforms:

```
Digital Input:   \_\_\_\_\_       \_\_\_\_\_
               |     |     |     |
        \_\_\_\_\_\_\_\_|     |\_\_\_\_\_|     |\_\_\_\_\_

Carrier:  /{/////////////}

PSK Output: /{///////////}
           (0^)   (180^) (0^)  (180^)
           Phase shifts at bit transitions
```

Parameter	Description
PSK Modulation	Phase shifts according to digital data (0 or 1)
Phase States	$0°forbit‘1', 180°forbit‘0'$
Advantages	Better noise immunity than ASK

Mnemonic

"PSK Phases Shift with Knowledge"

Question 3(a) [3 marks]

Explain the working of FSK modulator with block diagram and output Waveform.

Solution

FSK Modulator Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Input] {-{-}{} B[Voltage Controlled Oscillator]}
    B {-{-}{} C[FSK Output]}
{Highlighting}
{Shaded}
```

FSK Waveforms:

```
Digital Input:   \_\_\_\_\_       \_\_\_\_\_
                |     |     |     |
         \_\_\_\_\_\_\_\_|     |\_\_\_\_\_|     |\_\_\_\_\_

FSK Output: /{//  /////  ///}
           (f1)    (f2)       (f1)
```

- **Principle**: Digital bit '1' sends carrier with frequency f1, bit '0' sends carrier with frequency f2
- **Working**: Voltage controlled oscillator changes frequency based on input bit value

Mnemonic

"Frequency Shifts for Knowledge transmission"

Question 3(b) [4 marks]

Draw the PSK modulation waveform for the sequence of 1010110110.

Solution

```
Digital Input:  \_\_\_     \_\_\_     \_\_\_\_\_\_\_     \_\_\_\_\_\_\_
               |   |   |   |   |       |   |       |
          \_\_\_\_\_|   |\_\_\_|   |\_\_\_|       |\_\_\_|       |\_\_\_

          1     0     1     0     1     1     0     1     1     0

PSK Output:
          /{/ // // // // // // // // //}
          0^   180^ 0^   180^ 0^   0^   180^ 0^   0^   180^

Phase:    0^   180^ 0^   180^ 0^   0^   180^ 0^   0^   180^
```

Table for PSK modulation:

Bit	Phase
1	0°
0	180°

Mnemonic

"One-Zero, Phase-Shifts, Keep-Signal Modulated"

Question 3(c) [7 marks]

Draw the ASK and FSK modulation waveform for the sequence of 1100110101.

Solution

Digital Input Sequence: 1100110101

```
Digital Input:  \_\_\_\_\_\_\_         \_\_\_\_\_\_\_     \_\_\_     \_\_\_
               |       |       |       |   |   |   |   |
          \_\_\_\_\_\_|       |\_\_\_\_\_\_\_\_|       |\_\_\_\_|   |\_\_\_\_|   |\_\_\_

          1     1     0     0     1     1     0     1     0     1

ASK Output:
          /{/  //         //  //        //        //}

          On    On    Off   Off   On    On    Off   On    Off   On

FSK Output:
          /{/  //  /// /// //  //  /// //  /// //}

          f1    f1    f2    f2    f1    f1    f2    f1    f2    f1
```

Table for comparison:

Bit	ASK	FSK
1	Carrier ON (high amplitude)	Higher frequency (f1)
0	Carrier OFF (zero/low amplitude)	Lower frequency (f2)

Mnemonic

"Amplitude Shows Knowledge, Frequency Shifts Knowledge"

Question 3(a) OR [3 marks]

Explain the working of MSK modulator with block diagram and output Waveform.

Solution

MSK Modulator Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Input] {-{-}{} B[Serial to Parallel]}
    B {-{-}{}|I{-}Channel| C[I{-}Channel Modulator]}
    B {-{-}{}|Q{-}Channel| D[Q{-}Channel Modulator]}
    E[Carrier Generator] {-{-}{} C}
    E {-{-}{}|90^ Phase Shift| D}
    C {-{-}{} F[Adder]}
    D {-{-}{} F}
    F {-{-}{} G[MSK Output]}
{Highlighting}
{Shaded}
```

MSK Features:

- Continuous phase FSK with frequency deviation exactly half bit rate
- Phase changes occur smoothly (no abrupt phase changes)
- Better spectral efficiency than FSK

Mnemonic

"Minimum Shift Keeps spectrum narrow"

Question 3(b) [4 marks]

Draw the constellation diagram of 8-PSK and 16-QAM.

Solution

8-PSK Constellation:

```
           001  *    *  000
               /|{  /|}
                |    |
          010 * |    | * 111
              { |    | /}
               {|    |/}
          011  *     *  110
               /|{  /|}
               / {   /}
          100 *   { /  * 101}
```

16-QAM Constellation:

```
    *     *     *     *
   0000  0001  0100  0101

    *     *     *     *
   0010  0011  0110  0111

    *     *     *     *
   1000  1001  1100  1101

    *     *     *     *
   1010  1011  1110  1111
```

Modulation	Description
8-PSK	8 points equally spaced around circle, 3 bits per symbol
16-QAM	16 points in square grid, varying amplitude and phase, 4 bits per symbol

Mnemonic

"PSK Points on Single circle, QAM Quadrature Amplitude Matrix"

Question 3(c) OR [7 marks]

Draw BPSK and QPSK modulation waveform for 1010101011.

Solution

BPSK Modulation:

```
Digital Input:  \_\_\_     \_\_\_     \_\_\_     \_\_\_
               |   |   |   |   |   |   |   |
          \_\_\_\_\_|   |\_\_\_|   |\_\_\_|   |\_\_\_|   |\_\_\_\_\_


          1     0     1     0     1     0     1     0     1     1


BPSK Output:
          /{/  //  //  //  //  //  //  //  //  //}
          0^    180^  0^    180^  0^    180^  0^    180^  0^    0^
```

QPSK Modulation (grouping bits in pairs):

```
                    10            10            10            11
```

```
Input Pairs:    |{-{-}{-}{-}{-}{-}{-}{-}|   |{-}{-}{-}{-}{-}{-}{-}{-}|   |{-}{-}{-}{-}{-}{-}{-}{-}|   |

I{-Channel:      \_\_\_      \_\_\_      \_\_\_      \_\_\_      \_\_\_}
               |   |    |   |    |   |    |   |    |   |
          \_\_\_\_\_|   |\_\_\_\_\_|   |\_\_\_\_\_|   |\_\_\_\_\_|   |\_\_\_\_\_|   |\_\_\_\_
                1      0      1      0      1      0      1      1

Q{-Channel:     \_\_\_      \_\_\_      \_\_\_           \_\_\_}
              |   |    |   |    |   |         |   |
          \_\_\_\_|   |\_\_\_\_\_|   |\_\_\_\_|   |\_\_\_\_\_\_\_\_\_|   |\_\_\_\_
                0      1      0      1      0      1      1

QPSK Phase:     90^     270^    90^     270^    90^     270^    90^     45^
```

Bit Pair	QPSK Phase
10	90°
00	180°
01	270°
11	0°

Mnemonic

"Binary Phase Shifts Keys, Quadrature Phase Shifts Keys"

Question 4(a) [3 marks]

Encode the data using Shanon Fano code for below probability sequence. P = {0.30, 0.25, 0.20, 0.12, 0.08, 0.05}

Solution

Symbol	Probability	Shannon-Fano Code
S1	0.30	00
S2	0.25	01
S3	0.20	10
S4	0.12	110
S5	0.08	1110
S6	0.05	1111

Process:

1. Sort symbols by decreasing probability
2. Split into two groups with nearly equal probability (0.30+0.25=0.55, 0.20+0.12+0.08+0.05=0.45)
3. Assign 0 to first group, 1 to second group
4. Recursively continue for each subgroup

Mnemonic

"Separate, Fano divides, Code efficiently"

Question 4(b) [4 marks]

Explain Hamming code.

Solution

Aspect	Description
Definition	Linear error-correcting code that detects double errors and corrects single errors
Parity bits	For m data bits, need k parity bits where 2^k $\geq m + k + 1$
Position	Parity bits placed at positions 1, 2, 4, 8, 16... (powers of 2)
Error detection	Calculate syndrome to locate error position

Example Hamming(7,4):

```
Positions:  1   2   3   4   5   6   7
            P1  P2  D1  P4  D2  D3  D4

Parity check equations:
P1 checks: P1, D1, D2, D4
P2 checks: P2, D1, D3, D4
P4 checks: P4, D2, D3, D4
```

Mnemonic

"Hamming Helps Handle Bit Errors"

Question 4(c) [7 marks]

Compare TDMA and FDMA.

Solution

Parameter	TDMA (Time Division Multiple Access)	FDMA (Frequency Division Multiple Access)
Basic Principle	Divides channel by time slots	Divides channel by frequency bands
Resource Allocation	Each user gets entire bandwidth for short time	Each user gets portion of bandwidth all the time
Guard Period	Time guard bands between slots	Frequency guard bands between channels
Synchronization	Strict timing synchronization required	No timing synchronization needed
Efficiency	Higher, due to burst transmission	Lower, due to fixed assignment
Complexity	More complex	Relatively simple
Examples	GSM, DECT	FM radio, Traditional satellite systems

Diagram:

```
TDMA:                          FDMA:
        User 1  User 2  User 3        \^{}
Time    |{-{-}{-}{-}{-}|{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}|{-}{-}{-}        | User 3}
slots   |{-{-}{-}{-}{-}|{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}|{-}{-}{-}        |{-}{-}{-}{-}{-}{-}{-}}
        |{-{-}{-}{-}{-}|{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}|{-}{-}{-}  Freq. | User 2}
                                       |{-{-}{-}{-}{-}{-}{-}}
                                       | User 1
                                       |{-{-}{-}{-}{-}{-}{-}{-}}
                                          Time
```

Mnemonic

"Time Divides Multiple Access, Frequency Divides Multiple Access"

Question 4(a) OR [3 marks]

Encode the data using Huffman code for below probability sequence. P = {0.4, 0.2, 0.2, 0.1, 0.1}

Solution

Symbol	Probability	Huffman Code
S1	0.4	0
S2	0.2	10
S3	0.2	11
S4	0.1	100
S5	0.1	101

Process:

1. Start with sorted probabilities
2. Combine lowest two probabilities (0.1+0.1=0.2)
3. Rearrange and repeat until only two nodes remain
4. Assign bits by traversing tree

Tree Construction:

```
                  1.0
                 /   {}
                /     {}
            0.6       0.4(S1)
           /   {}
          /     {}
       0.4      0.2(S2,S3)
      /   {     / }
   0.2    0.2  0  1
  /   {}
0.1    0.1
```

Mnemonic

"Huffman Helps encode High-frequency data"

Question 4(b) OR [4 marks]

Explain parity code.

Solution

Aspect	Description
Definition	Simple error detection scheme that adds parity bit
Types	Even parity: total 1s is evenOdd parity: total 1s is odd
Calculation	XOR all data bits to generate parity bit
Capability	Detects odd number of errors, cannot correct errors

Examples:

```
Even Parity:
Data: 1011  Parity: 0  Coded: 10110 (Even number of 1s: 4)

Odd Parity:
Data: 1011  Parity: 1  Coded: 10111 (Odd number of 1s: 5)
```

Mnemonic

"Parity Provides Primitive Error detection"

Question 4(c) OR [7 marks]

Explain FDMA Technique in detail.

Solution

FDMA (Frequency Division Multiple Access):

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Available Bandwidth] {-{-}{} B[Frequency Division]}
    B {-{-}{} C[User 1 Channel]}
    B {-{-}{} D[User 2 Channel]}
    B {-{-}{} E[User 3 Channel]}
    B {-{-}{} F[User N Channel]}
{Highlighting}
{Shaded}
```

Parameter	Description
Basic Principle	Total bandwidth divided into non-overlapping frequency bands
Channel Assignment	Each user assigned dedicated frequency band
Guard Bands	Small frequency gaps between channels to prevent interference
Duplexing	Usually implemented with FDD (Frequency Division Duplexing)
Advantages	Simple implementation, no synchronization required
Disadvantages	Inefficient for bursty traffic, fixed allocation wastes bandwidth
Applications	AM/FM radio, Traditional cable TV, First-generation mobile systems

Frequency Allocation:

```
Frequency
    \^{}
    |   Guard Bands
    |    ↓  ↓  ↓  ↓  ↓
    |   |{-{-}|{-}{-}|{-}{-}|{-}{-}|{-}{-}}
    |   |  |  |  |  |
    |   |  |  |  |  |{-{-} User N}
    |   |  |  |  |
    |   |  |  |  |{-{-} User 3}
    |   |  |  |
    |   |  |  |{-{-} User 2}
    |   |  |
    |   |  |{-{-} User 1}
    |   |
    |{-{-}{-}|{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} Time}
```

Mnemonic

"Fixed Division for Multiple Access"

Question 5(a) [3 marks]

Explain E1 Career system.

Solution

Parameter	Description
Description	European standard digital transmission format
Capacity	2.048 Mbps
Channel Structure	32 time slots (numbered 0-31)
Voice Channels	30 voice channels (64 kbps each)
Signaling	Time slot 16 for signaling
Frame Alignment	Time slot 0 for synchronization

Diagram:

```
One E1 Frame (32 time slots)
 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 0 | 1 | 2 |...| 15| 16| 17|...| 30| 31| 0 | 1 | 2 |...|
|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|

TS0: Frame alignment
TS16: Signaling
TS1{-15, TS17{-}31: Voice/data channels (30 channels)}
```

Mnemonic

"E1 Enables 30 + 2 time slots"

Question 5(b) [4 marks]

Explain TDMA Access technique.

Solution

Parameter	Description
Definition	Multiple access technique that divides time into slots for different users
Working Principle	Each user gets entire bandwidth for a short time period
Frame Structure	Time divided into frames, frames divided into slots
Guard Time	Small time gap between slots to prevent overlap
Synchronization	Requires precise timing synchronization

TDMA Frame Structure:

```
             One TDMA Frame
 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
|       |       |       |       |       |      |
| TS 1  | TS 2  | TS 3  | TS 4  | TS 5  | ...  |
|\_\_\_\_\_\_\_\_|\_\_\_\_\_\_\_\_|\_\_\_\_\_\_\_\_|\_\_\_\_\_\_\_\_|\_\_\_\_\_\_\_\_|\_\_\_\_\_\_\_|
   |       |       |
   |       |       |{-{-}{-} User 3}
   |       |
   |       |{-{-}{-} User 2}
   |
   |{-{-}{-} User 1}

Each time slot (TS) contains:
{- User data}
{- Guard time}
{- Synchronization bits}
{- Control bits}
```

Mnemonic

"Time Divides Multiple Access"

Question 5(c) [7 marks]

Explain IoT — Concept, Features, Advantages and Disadvantages.

Solution

IoT Concept:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Physical Objects] {-{-}{}|Sensors| B[Internet Connectivity]}
    B {-{-}{} C[Data Collection]}
    C {-{-}{} D[Data Analysis]}
    D {-{-}{} E[Automated Actions]}
    E {-{-}{} A}
{Highlighting}
{Shaded}
```

Aspect	Description
Concept	Network of physical objects embedded with sensors, software, and connectivity
Features	- Connectivity (devices connected to internet)- Intelligence (smart decision making)- Sensing (collecting data from environment)- Automation (minimal human intervention)- Scalability (handles many devices)
Advantages	- Improved efficiency and productivity- Better resource management- Enhanced decision making- Convenience and time-saving- New business opportunities
Disadvantages	- Security vulnerabilities- Privacy concerns- Complexity in implementation- Compatibility issues- Dependence on internet

Application Areas:

- Smart homes, cities
- Healthcare monitoring
- Industrial automation
- Agriculture
- Transportation

Mnemonic

"Internet of Things: Connected, Automated, Smarter Decisions"

Question 5(a) OR [4 marks]

Explain T1 Career TDM system.

Solution

Parameter	Description
Description	North American standard digital transmission format
Capacity	1.544 Mbps

Channel Structure	24 time slots (channels) + 1 framing bit
Voice Channels	24 voice channels (64 kbps each)
Frame Structure	193 bits per frame ($24 \times 8 + 1$)
Signaling	Robbed bit signaling (least significant bit)

Diagram:

```
One T1 Frame (193 bits)
 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
|   |       |       |       |       |       |       |       |
| F | Ch 1  | Ch 2  | Ch 3  |  ...  | Ch 22 | Ch 23 | Ch 24 |
|\_\_\_|\_\_\_\_\_\_\_|\_\_\_\_\_\_\_|\_\_\_\_\_\_\_|\_\_\_\_\_\_\_|\_\_\_\_\_\_\_|\_\_\_\_\_\_\_|\_\_\_

F: Framing bit
Each channel: 8 bits (1 byte)
```

Mnemonic

"T1 Transmits 24 channels"

Question 5(b) OR [3 marks]

Compare TDM and FDM.

Solution

Parameter	TDM (Time Division Multiplexing)	FDM (Frequency Division Multiplexing)
Basic Principle	Divides channel by time	Divides channel by frequency
Signal Separation	In time domain	In frequency domain
Guard Bands	Time guard bands	Frequency guard bands
Implementation	Digital technique	Analog technique (originally)
Crosstalk	Less susceptible	More susceptible
Synchronization	Required	Not required

Diagram:

```
TDM:                          FDM:
     Ch1  Ch2  Ch3  Ch1            \^{}
Time  |{-{-}|{-}{-}|{-}{-}|{-}{-}|{-}{-}             | Ch3}
      |{-{-}|{-}{-}|{-}{-}|{-}{-}|{-}{-}  Frequency  |{-}{-}{-}{-}{-}}
      |{-{-}|{-}{-}|{-}{-}|{-}{-}|{-}{-}             | Ch2}
                                   |{-{-}{-}{-}{-}}
                                   | Ch1
                                   |{-{-}{-}{-}{-}{-}{-}}
                                      Time
```

Mnemonic

"Time Divides Multiplexing, Frequency Divides Multiplexing"

Question 5(c) OR [7 marks]

Explain security components of information security.

Solution

The CIA Triad of Information Security:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Information Security] {-{-}{} B[Confidentiality]}
    A {-{-}{} C[Integrity]}
    A {-{-}{} D[Availability]}
    B {-{-}{} E[Encryption, Access Controls]}
    C {-{-}{} F[Hashing, Digital Signatures]}
    D {-{-}{} G[Redundancy, Fault{-}tolerance]}
{Highlighting}
{Shaded}
```

Component	Description	Implementation Methods
Confidentiality	Protection against unauthorized access	- Encryption- Access controls- Authentication- Steganography
Integrity	Ensuring data is accurate and unaltered	- Hashing- Digital signatures- Version control- Checksums
Availability	Ensuring systems are accessible when needed	- Redundancy- Backups- Disaster recovery- Fault tolerance
Authentication	Verifying identity	- Passwords- Biometrics- Smart cards- Multi-factor
Non-repudiation	Preventing denial of actions	- Digital signatures- Audit logs- Timestamps

Security Threats:

- Malware (viruses, worms, trojans)
- Social engineering
- Denial of Service (DoS)
- Man-in-the-middle attacks
- Insider threats

Mnemonic

"CIA Protects All Network Data"