

# Subject Name Solutions

4341102 – Winter 2023

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

Discuss the various communication channels characteristics.

### Solution

Channel Characteristic	Description
<b>Bit rate</b>	Maximum number of bits transmitted per second
<b>Baud rate</b>	Number of signal units/symbols transmitted per second
<b>Bandwidth</b>	Range of frequencies required for transmission
<b>Repeater distance</b>	Maximum distance between repeaters to maintain signal quality
<b>Noise immunity</b>	Ability to resist interference from external sources

### Mnemonic

“BBRN” - “Better Bandwidth Requires Nice planning”

## Question 1(b) [4 marks]

Give the difference between even and odd signal.

### Solution

Even Signal	Odd Signal
<b>Mathematical representation:</b> $x(-t) = x(t)$	<b>Mathematical representation:</b> $x(-t) = -x(t)$
<b>Symmetry:</b> Mirror symmetry around y-axis	<b>Symmetry:</b> Origin symmetry (rotational)
<b>Fourier series:</b> Contains only cosine terms	<b>Fourier series:</b> Contains only sine terms
<b>Examples:</b> $\cos(t)$ , $t^2$	<b>Examples:</b> $\sin(t)$ , $t^3$

### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A["Signal x(t)"] --> B[Test symmetry]
    B --> C["x(-t) = x(t)"]
    C --> D[Even Signal]
    B --> E["x(-t) = -x(t)"]
    E --> F[Odd Signal]
    C --> G[Mirror symmetry]
    E --> H[Origin symmetry]
```

### Mnemonic

“EVEN signals are Equal when flipped, ODD signals are Opposite when flipped”

### Question 1(c) [7 marks]

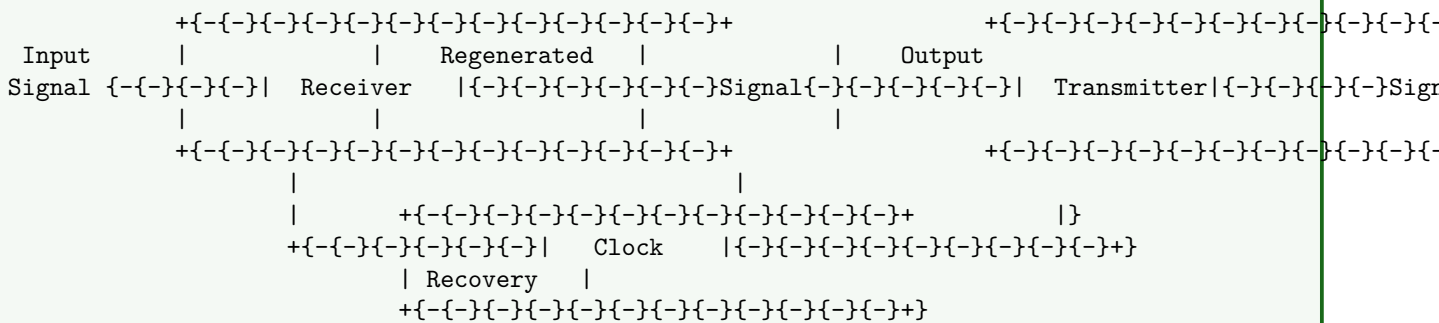
Define repeater. Explain how repeater works with help of necessary circuit and waveforms.

#### Solution

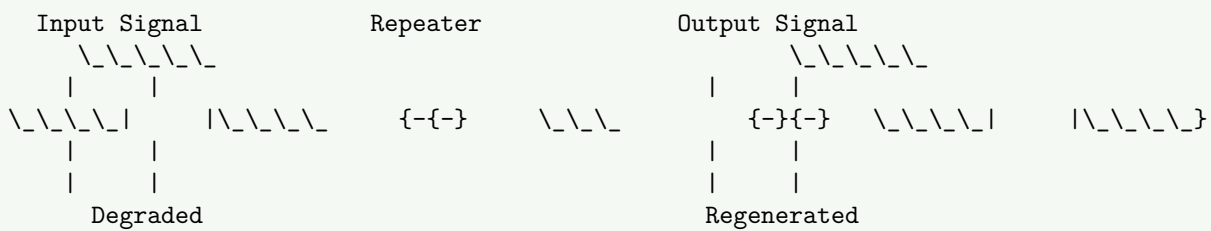
**Repeater:** A device that receives, amplifies, and retransmits a signal to extend the transmission distance without degradation.

**Working Principle:** Repeaters regenerate digital signals to overcome attenuation and noise accumulation in transmission lines.

**Circuit Diagram:**



**Waveform:**



- **Signal reception:** Detects incoming weak/distorted signals
- **Amplification:** Strengthens the signal power
- **Regeneration:** Reconstructs original digital waveform
- **Retransmission:** Sends restored signal to next segment

### Mnemonic

“RARE” - “Receive, Amplify, Regenerate, Emit”

### Question 1(c) OR [7 marks]

Draw block diagram of digital communication system and explain in detail.

#### Solution

```

flowchart LR
    A[Information 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[Information Sink]]
    
```

Block	Function
<b>Information Source</b>	Generates message to be transmitted (voice, video, data)
<b>Source Encoder</b>	Converts source data to digital form and removes redundancy
<b>Channel Encoder</b>	Adds controlled redundancy for error detection/correction
<b>Digital Modulator</b>	Converts digital data to signals suitable for transmission
<b>Channel</b>	Physical medium through which signals travel
<b>Digital Demodulator</b>	Extracts digital data from received signals
<b>Channel Decoder</b>	Detects/corrects errors using added redundancy
<b>Source Decoder</b>	Reconstructs original source information

#### Mnemonic

“Send Clear Data Messages, Carefully Decode Secure Information”

### Question 2(a) [3 marks]

Define Unit step function, Unit impulse function, Unit ramp function.

#### Solution

Function	Definition	Mathematical Form
<b>Unit Step Function</b>	Takes value 0 for negative time and 1 for positive time	$u(t) = \{0, t < 0; 1, t \geq 0\}$
<b>Unit Impulse Function</b>	Infinitely high, zero width pulse with area 1	$\delta(t) = \{\infty, t = 0; 0, t \neq 0\}$
<b>Unit Ramp Function</b>	Increases linearly with time for positive time values	$r(t) = \{0, t < 0; t, t \geq 0\}$

#### Mnemonic

“SIR” - “Step Instantly, Impulse Rapidly, Ramp Gradually”

### Question 2(b) [4 marks]

Define Continuous time and discrete time signals and explain with example.

#### Solution

Signal Type	Definition	Example	Representation
<b>Continuous-time Signal</b>	Defined for all values of time within its duration	Sinusoidal wave $x(t) = \sin(t)$	Smooth, unbroken curve
<b>Discrete-time Signal</b>	Defined only at specific time instants	Digital samples $x[n] = \sin(nTs)$	Sequence of distinct values

### Diagram:

Continuous{-time: }

$$\begin{array}{cccccc} & / & & / & & / \\ & / & \{ & / & & / \\ \{-\} & \{-\} & \{-\} & \{-\} & \{-\} & \{-\} \end{array}$$

Discrete{-time:}

$$\begin{array}{cccccc} & o & & o & & o \\ & / & & / & & / \\ \{-\} & \{-\} & \{-\} & \{-\} & \{-\} & \{-\} \end{array}$$

- **Continuous-time:** Defined for all time  $t \in R$  (infinite values)
- **Discrete-time:** Defined only at specific instants  $n \in Z$  (countable values)

### Mnemonic

“CADD” - “Continuous Always, Discrete Dots”

## Question 2(c) [7 marks]

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

### Solution

**ASK (Amplitude Shift Keying):** A digital modulation technique where binary data is represented by varying the amplitude of a carrier wave.

**ASK Modulator:**

flowchart LR

```
A[Digital Input] --{-{-} B[Product Modulator]]
C[Carrier Generator] --{-{-} B
B --{-{-} D[Bandpass Filter]]
D --{-{-} E[ASK Output]]
```

**ASK Demodulator:**

flowchart LR

```
A[ASK Input] --{-{-} B[Envelope Detector]]
B --{-{-} C[Low Pass Filter]]
C --{-{-} D[Comparator]]
D --{-{-} E[Digital Output]]
```

**Waveforms:**

Digital Input:

$$\begin{array}{ccccccccc} \backslash & \backslash & \backslash & & \backslash & \backslash & \backslash & & \backslash & \backslash & \backslash \\ \backslash & \backslash & \backslash & | & \backslash & \backslash & \backslash & | & \backslash & \backslash & \backslash & | & \backslash & \backslash & \backslash & | & \backslash & \backslash & \backslash \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & & 1 & 0 & 1 & & 1 & 0 & 1 & & 1 & 0 & 1 \end{array}$$

Carrier Wave:

$$/ \{ / / / / / / / / / / / / / / / \}$$

ASK Output:

$$\begin{array}{ccccccccc} / \{ / & // & // & // \} \\ \backslash & \backslash & \backslash & / & \{ \backslash & \backslash & / & \backslash & \backslash & \backslash & \backslash & / & \backslash & \backslash & / & \backslash & \backslash & \backslash \\ \text{High} & \text{Low} & \text{High} & \text{Low} & \text{High} & \text{Low} & \text{High} & & \text{High} & \text{Low} & \text{High} & & \text{High} & \text{Low} & \text{High} & & \text{High} & \text{Low} & \text{High} \end{array}$$

- **Modulator:** Varies carrier amplitude based on digital input
- **Demodulator:** Extracts envelope and compares to threshold

### Mnemonic

“APE” - “Amplify when Positive, Eliminate when zero”

### Question 2(a) OR [3 marks]

Explain Singularity function.

#### Solution

**Singularity Function:** Mathematical functions that have discontinuities or undefined values at specific points.

#### Common Singularity Functions

**Unit Step Function  $u(t)$**   
**Unit Impulse Function  $\delta(t)$**   
**Unit Ramp Function  $r(t)$**

#### Properties

Jumps from 0 to 1 at  $t=0$   
Infinite at  $t=0$ , zero elsewhere, with area=1  
Derivative of unit step is impulse

#### Relationships:

- $\delta(t) = d/dt[u(t)]$
- $u(t) = \int \delta(t) dt$
- $r(t) = \int u(t) dt$

### Mnemonic

“SIR” - “Singularities Include Rapid changes”

### Question 2(b) OR [4 marks]

Give the difference between bit rate and baud rate.

#### Solution

Parameter	Bit Rate	Baud Rate
<b>Definition</b>	Number of bits transmitted per second	Number of symbols transmitted per second
<b>Unit</b>	bits per second (bps)	symbols per second (Baud)
<b>Relation</b>	Bit rate = Baud rate $\times$ Number of bits per symbol	Baud rate = Bit rate $\div$ Number of bits per symbol
<b>Example</b>	In QPSK, if Baud rate = 1200, Bit rate = 2400 bps	In 16-QAM, if Bit rate = 9600 bps, Baud rate = 2400

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Transmission Rate] --{-}{ B[Bit Rate]}
    A --{-}{ C[Baud Rate]}
    B --{-}{|"bits/second"| D[Information Transfer Rate]}
    C --{-}{|"symbols/second"| E[Modulation Rate]}
    F[Modulation Technique] --{-}{ G[Bits per Symbol]}
    G --{-}{ H["Bit Rate = Baud Rate Bits per Symbol"]}
{Highlighting}
{Shaded}
```

### Mnemonic

“BBSR” - “Bits for Binary Speed, Bauds for Symbol Rate”

### Question 2(c) OR [7 marks]

Explain the Principle of 8-PSK signal. Also draw constellation diagram and waveforms of its.

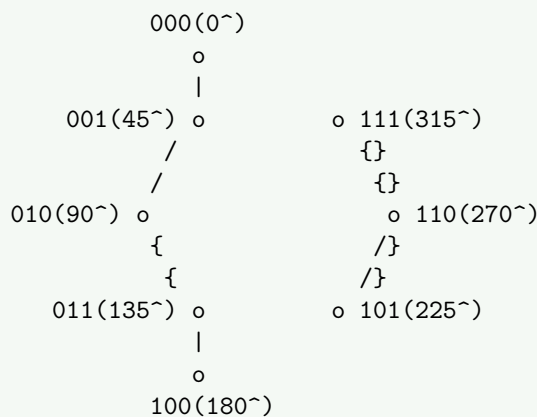
#### Solution

**8-PSK (Phase Shift Keying):** A digital modulation technique where data is encoded by shifting the phase of a carrier signal to 8 different positions.

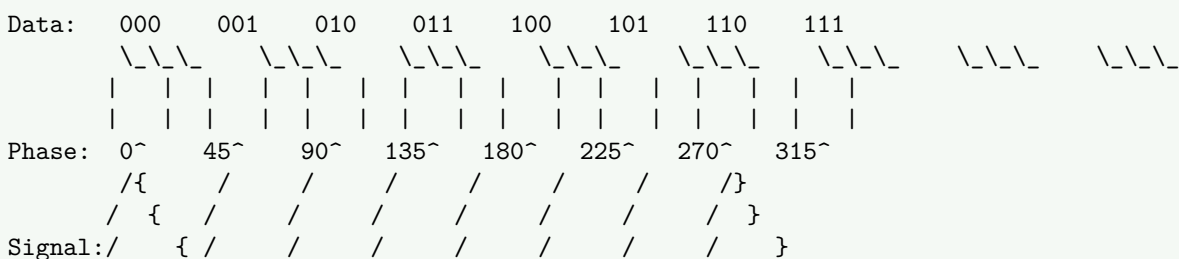
**Principle:**

- Each symbol represents 3 bits ( $\log_2 8 = 3$ )
- Phase shifts in multiples of  $45^\circ$  ( $360^\circ \div 8$ )
- Maintains constant amplitude

**Constellation Diagram:**



**Waveform:**



- **Bandwidth efficiency:** 3 bits per symbol
- **Constant amplitude:** Better power efficiency
- **Error probability:** Higher than BPSK/QPSK but lower than 16-PSK

### Mnemonic

“8 Points Shifted in K-circle” (8-PSK)

### Question 3(a) [3 marks]

Explain the block diagram of FSK modulator.

#### Solution

**FSK (Frequency Shift Keying):** A digital modulation technique where binary data is represented by varying the frequency of a carrier wave.

flowchart LR

A[Binary Input] --> B[Switch]

```

C[Oscillator f1] {-{-} B}
D[Oscillator f2] {-{-} B}
B {-{-} E[Bandpass Filter]]
E {-{-} F[FSK Output]]

```

Component	Function
<b>Binary Input</b>	Digital data (0s and 1s) to be transmitted
<b>Oscillator 1</b>	Generates carrier at frequency $f_1$ for bit '1'
<b>Oscillator 2</b>	Generates carrier at frequency $f_2$ for bit '0'
<b>Switch</b>	Selects appropriate frequency based on input bit
<b>Bandpass Filter</b>	Smooths transitions between frequencies

### Mnemonic

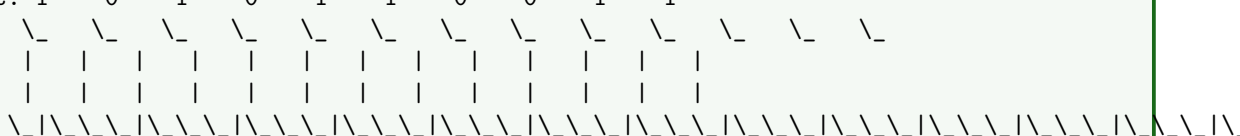
“FISO” - “Frequency Input Selects Oscillator”


### Question 3(b) [4 marks]

Draw the ASK and FSK modulation waveform for the sequence of 1010110011.

#### Solution

Binary Input: 1    0    1    0    1    1    0    0    1    1

ASK Output: 

FSK Output: 

High freq (1) Low(0) (1) Low(0) (1)(1) Low(0) Low(0) (1)(1)

#### Explanation:

- **ASK:** High amplitude for bit '1', low amplitude for bit '0'
- **FSK:** Higher frequency  $f_1$  for bit '1', lower frequency  $f_2$  for bit '0'

### Mnemonic

“ASK changes Amplitude, FSK changes Frequency”

### Question 3(c) [7 marks]

Explain PSK signal generation and detection with help of its functional diagram.

#### Solution

**PSK (Phase Shift Keying):** A digital modulation technique where data is encoded by changing the phase of a carrier signal.

**PSK Modulator:**

flowchart LR

```

A[Binary Input] {-{-} B[Bipolar Converter]]
B {-{-} C[Product Modulator]]
D[Carrier Generator] {-{-} C}

```

C {-{-} E[PSK Output]]}

### PSK Demodulator:

flowchart LR

A[PSK Input] {-{-} B[Product Demodulator]]

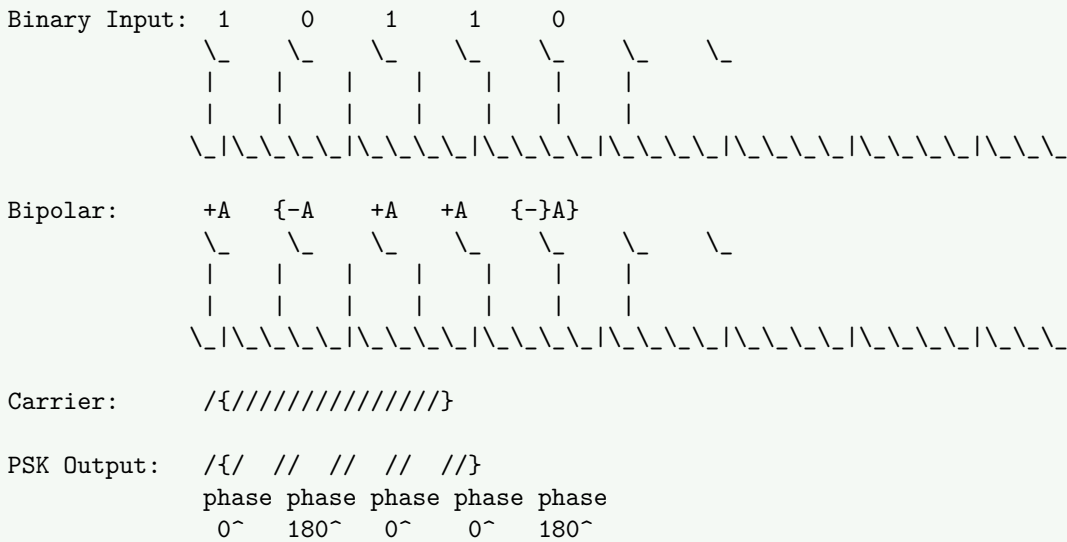
C[Carrier Recovery] {-{-} B}

B {-{-} D[Low Pass Filter]]

D {-{-} E[Decision Device]]

E {-{-} F[Binary Output]]

### Waveforms:



- **Generation:** Binary 1  $\rightarrow 0^\circ$  phase, Binary 0  $\rightarrow 180^\circ$  phase
- **Detection:** Coherent demodulation with carrier recovery
- **Advantages:** Better noise immunity than ASK

### Mnemonic

“PSK Phases Shift with Knowledge of carrier”

### Question 3(a) OR [3 marks]

Compare Bits PER Symbol for digital modulation techniques-ASK, FSK, PSK, QPSK, 8-PSK and 16-QAM.

### Solution

Modulation Technique	Bits per Symbol	States	Bandwidth Efficiency
ASK	1	2	1 bit/Hz
FSK	1	2	0.5 bit/Hz
PSK (BPSK)	1	2	1 bit/Hz
QPSK	2	4	2 bits/Hz
8-PSK	3	8	3 bits/Hz
16-QAM	4	16	4 bits/Hz



### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Modulation Techniques]
    A --> B[ASK/FSK/BPSK  
1 bit/symbol]
    A --> C[QPSK  
2 bits/symbol]
    A --> D[8-PSK  
3 bits/symbol]
    A --> E[16-QAM  
4 bits/symbol]
{Highlighting}
{Shaded}
```

### Mnemonic

“As Frequency/Phase States Quadruple, Bandwidth Efficiency Doubles”

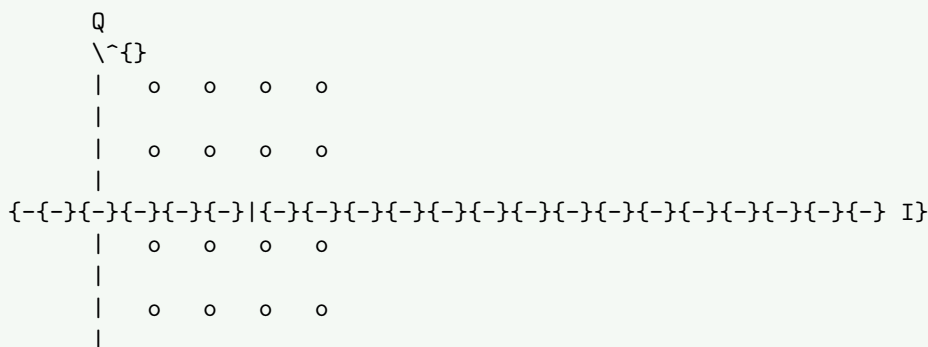
### Question 3(b) OR [4 marks]

Draw and explain the constellation diagram of 16-QAM.

### Solution

**16-QAM (Quadrature Amplitude Modulation):** A modulation technique that combines amplitude and phase modulation, where each symbol represents 4 bits.

**Constellation Diagram:**



**Explanation:**

- **16 distinct states:** Each point represents a unique 4-bit combination
- **Carries 4 bits per symbol:**  $\log_2 16 = 4$
- **Modulation parameters:** Both amplitude and phase are varied
- **Symbol mapping:** Gray coding used to minimize bit errors

### Mnemonic

“16 Quadrants Arranged in Matrix”

### Question 3(c) OR [7 marks]

Explain the Principle of MSK signal. Also draw constellation diagram and waveforms of its.

### Solution

**MSK (Minimum Shift Keying):** A continuous phase FSK modulation with a modulation index of 0.5, ensuring smooth phase transitions.

**Principle:**

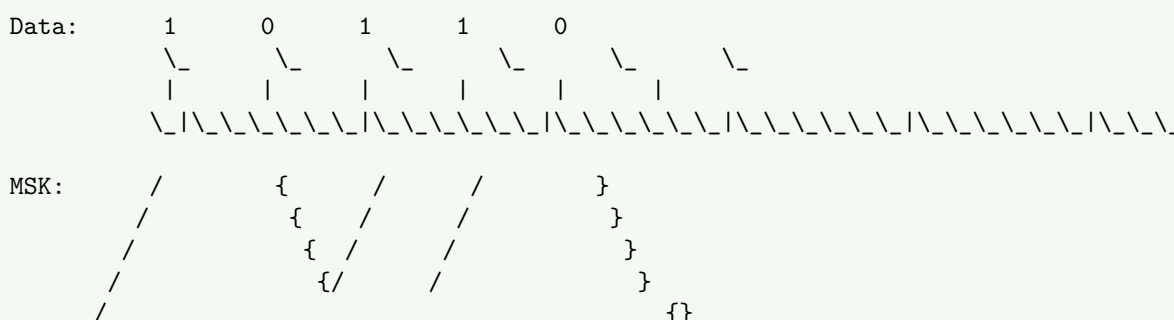
- Special case of CPFSK (Continuous Phase FSK)
- Frequency separation exactly equals half the bit rate
- Maintains continuous phase, avoiding abrupt transitions

- Modulation index  $h = 0.5$

**Constellation Diagram:**



**Waveforms:**



**Key Features:**

- **Constant envelope:** Better power efficiency
- **Spectral efficiency:** Narrower bandwidth than BFSK
- **Continuous phase:** Smoother transitions, reduced spectral spreading
- **OQPSK relation:** Can be viewed as offset QPSK with sinusoidal pulse shaping

### Mnemonic

“MSK Makes Smooth K-transitions”

### Question 4(a) [3 marks]

Describe the procedure to troubleshoot the FDD multiplexing circuit.

#### Solution

Step	Troubleshooting Procedure
1. <b>Signal Verification</b>	Check input signals at each frequency band
2. <b>Filter Analysis</b>	Verify bandpass filters for each channel
3. <b>Modulator Testing</b>	Test frequency translation in each channel
4. <b>Power Levels</b>	Measure signal strength at input/output
5. <b>Isolation Check</b>	Test for cross-talk between channels

```

flowchart LR
    A[Start] --> B[Check Input Signals]
    B --> C[Signals OK?]
    C -- Yes --> D[Test Filters]
    C -- No --> E[Fix Input Source]
    D --> F[Filters OK?]
    F -- Yes --> G[Test Modulators]
    F -- No --> H[Replace/Adjust Filters]

```

### Mnemonic

“SFMPI” - “Signal, Filter, Modulator, Power, Isolation”

## Question 4(b) [4 marks]

Compare E1 carrier with T1 carrier.

### Solution

Parameter	E1 Carrier	T1 Carrier
<b>Standard</b>	European standard	North American standard
<b>Data Rate</b>	2.048 Mbps	1.544 Mbps
<b>Voice Channels</b>	30 channels	24 channels
<b>Time Slots</b>	32 time slots (TS0, TS1-TS15, TS16, TS17-TS31)	24 time slots + framing bit
<b>Signaling</b>	Channel 16 used for signaling	Robbed bit signaling
<b>Frame Size</b>	256 bits	193 bits
<b>Bit Rate per Channel</b>	64 kbps	64 kbps

### Mnemonic

“ET-DR” - “European Thirty, Double Rate”

## Question 4(c) [7 marks]

Explain CDMA technique in detail.

### Solution

**CDMA (Code Division Multiple Access):** A multiple access technique where multiple users share the same frequency band simultaneously by using unique spreading codes.

```

flowchart LR
    A[User Data] --> B[Spreading]
    C[Unique Code] --> B
    B --> D[Transmission]
    D --> E[Despreading]
    E --> F[Same Code]
    F --> G[User Data Recovery]

```

Key Feature	Description
<b>Spreading Codes</b>	Unique orthogonal or pseudo-random codes assigned to each user
<b>Process Gain</b>	Ratio of spread bandwidth to original bandwidth
<b>Interference Rejection</b>	Users with different codes appear as noise to each other
<b>Soft Handoff</b>	Mobile can communicate with multiple base stations simultaneously

**Power Control  
Capacity**

Critical to solve near-far problem  
Not strictly limited by frequency, but by acceptable noise level

**Working Principle:**

- Each bit is multiplied by a high-rate spreading code (chips)
- Resulting signal occupies much wider bandwidth
- Receiver uses same code to recover original data
- Other signals appear as random noise, rejected by correlation

**Mnemonic**

“CUPS” - “Codes Uniquely Provide Separation”

**Question 4(a) OR [3 marks]**

Write a short not on classification of multiplexing techniques.

**Solution**

**Multiplexing Techniques:** Methods to combine multiple signals for transmission over a single medium.

Type	Based On	Examples
<b>Frequency Division Multiplexing (FDM)</b>	Frequency domain	Radio broadcasting, cable TV
<b>Time Division Multiplexing (TDM)</b>	Time domain	Digital telephone systems, GSM
<b>Code Division Multiplexing (CDM)</b>	Code domain	CDMA cellular systems
<b>Wavelength Division Multiplexing (WDM)</b>	Wavelength domain	Fiber optic communications
<b>Space Division Multiplexing (SDM)</b>	Spatial domain	MIMO wireless systems

**Mermaid Diagram (Code)**

```
{Shaded}
{Highlighting}[]
graph TD
    A[Multiplexing Techniques] --- B[Frequency Division]
    A --- C[Time Division]
    A --- D[Code Division]
    A --- E[Wavelength Division]
    A --- F[Space Division]
{Highlighting}
{Shaded}
```

**Mnemonic**

“FTCWS” - “Five Techniques Create Wide Systems”

**Question 4(b) OR [4 marks]**

Draw and explain block diagram of Time Division Multiplexing technique (TDM).

## Solution

**Time Division Multiplexing (TDM):** A technique where multiple signals share the same channel by allocating different time slots to each signal.

flowchart LR

```

A1[Input 1] --> B1[Sampler 1]
A2[Input 2] --> B2[Sampler 2]
A3[Input 3] --> B3[Sampler 3]
A4[Input 4] --> B4[Sampler 4]
B1 --> C[Commutator]
B2 --> C
B3 --> C
B4 --> C
C --> D[TDM Channel]
D --> E[Decommutator]
E --> F1[Filter 1]
E --> F2[Filter 2]
E --> F3[Filter 3]
E --> F4[Filter 4]
F1 --> G1[Output 1]
F2 --> G2[Output 2]
F3 --> G3[Output 3]
F4 --> G4[Output 4]

```

Component	Function
<b>Samplers</b>	Sample each input signal at rate $\geq 2 \times \text{highest frequency}$
<b>Commutator</b>	Sequentially selects samples from each input channel
<b>TDM Channel</b>	Carries the combined signal
<b>Decommutator</b>	Distributes received samples to appropriate channels
<b>Filters</b>	Reconstruct original signals from samples

## Mnemonic

“SCTDF” - “Sample, Combine, Transmit, Distribute, Filter”

## Question 4(c) OR [7 marks]

Explain TDMA technique in detail.

## Solution

**TDMA (Time Division Multiple Access):** A channel access method where multiple users share the same frequency channel by dividing it into different time slots.

flowchart TD

```

A[TDMA Frame] --> B[Slot 1br /User 1]
A --> C[Slot 2br /User 2]
A --> D[Slot 3br /User 3]
A --> E[Slot 4br /User 4]
A --> F[Slot 5br /User 5]
A --> G[Slot 6br /User 6]

```

Key Feature	Description
<b>Frame Structure</b>	Fixed-length frames divided into time slots
<b>Guard Time</b>	Small time gaps between slots to prevent overlap
<b>Synchronization</b>	Requires precise timing coordination
<b>Channel Utilization</b>	Each user gets entire bandwidth for short duration
<b>Power Efficiency</b>	Transmitters operate intermittently, saving power
<b>Capacity</b>	Limited by available time slots in frame

**Implementation Details:**

- Each user transmits in rapid bursts within assigned slot
- Non-continuous transmission allows handsets to measure signal strengths of nearby cells
- Used in GSM (8 slots per frame), DECT, satellite systems
- Easily adapts to varying data rates by assigning multiple slots

**Mnemonic**

“TDMA Takes Distinct Moments for Access”

**Question 5(a) [3 marks]**

Define probability and write its Significance in communication.

**Solution**

**Probability:** A measure of the likelihood of an event occurring, expressed as a number between 0 and 1.

Significance in Communication	Explanation
<b>Reliability Analysis</b>	Calculating error probabilities and system reliability
<b>Noise Performance</b>	Evaluating system performance in presence of random noise
<b>Information Theory</b>	Foundation for Shannon's channel capacity theorem
<b>Signal Detection</b>	Determining optimal detection thresholds

**Mnemonic**

“PRONIS” - “PRObability Numerically Indicates Signal quality”

**Question 5(b) [4 marks]**

Explain Huffman code with suitable example.

**Solution**

**Huffman Code:** A variable-length prefix coding algorithm that assigns shorter codes to more frequent symbols.

**Example:** Consider symbols A, B, C, D with probabilities 0.4, 0.3, 0.2, 0.1

**Huffman Coding Process:**

**Mermaid Diagram (Code)**

```

{Shaded}
{Highlighting}[]
graph LR
    A[A:0.4, B:0.3, C:0.2, D:0.1] --> B[B[A:0.4, B:0.3, CD:0.3]]
    B --> C[C[A:0.4, BCD:0.6]]
    C --> D[D[ABCD:1.0]]
    D --> E["A(0) | BCD(1)"]
    E --> F["A(0) | B(10) | CD(11)"]
    F --> G["A(0) | B(10) | C(110) | D(111)"]
{Highlighting}
{Shaded}

```

Symbol	Probability	Huffman Code
A	0.4	0

B	0.3	10
C	0.2	110
D	0.1	111

Average Code Length =  $0.4 \times 1 + 0.3 \times 2 + 0.2 \times 3 + 0.1 \times 3 = 1.9 \text{ bits/symbol}$

### Mnemonic

“HEMP” - “Huffman Encodes More Probable symbols with shorter codes”

## Question 5(c) [7 marks]

Explain concept and key features of Internet of Things (IoT).

### Solution

**Internet of Things (IoT):** A network of physical objects embedded with sensors, software, and connectivity that enables them to collect and exchange data.

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[IoT Ecosystem] --- B[Smart Devices]
    A --- C[Connectivity]
    A --- D[Data Analytics]
    A --- E[User Interface]
    A --- F[Security]
    B --- G[Sensors & Actuators]
    C --- H[Protocols & Standards]
    D --- I[Cloud Computing]
    E --- J[Apps & Services]
    F --- K[Authentication & Encryption]
{Highlighting}
{Shaded}
```

Key Feature	Description
<b>Connectivity</b>	Devices connected to internet/each other via various protocols (Wi-Fi, Bluetooth, LPWAN, 5G)
<b>Sensing Capability</b>	Ability to detect physical parameters through sensors
<b>Intelligence</b>	Data processing at device (edge) or cloud level
<b>Interoperability</b>	Ability to work across different platforms and systems
<b>Automation</b>	Autonomous functioning without human intervention
<b>Scalability</b>	Ability to handle growth in number of connected devices

#### Applications:

- Smart homes (thermostats, security systems)
- Healthcare (wearable devices, remote monitoring)
- Industrial automation (predictive maintenance)
- Smart cities (traffic management, waste management)
- Agriculture (precision farming, livestock monitoring)

### Mnemonic

“CSIA” - “Connect, Sense, Interpret, Automate”

### Question 5(a) OR [3 marks]

Define Channel Capacity in terms of SNR and its importance in communication.

#### Solution

**Channel Capacity:** Maximum rate at which information can be transmitted over a communication channel with arbitrarily small error probability.

**Shannon's Channel Capacity Formula:**  $C = B \times \log_2(1 + SNR)$

Where:

- C = Channel capacity in bits per second
- B = Bandwidth in Hertz
- SNR = Signal-to-Noise Ratio

Importance in Communication	Explanation
<b>Performance Limit</b>	Sets theoretical maximum data rate for error-free transmission
<b>System Design</b>	Guides selection of modulation, coding schemes
<b>Bandwidth Efficiency</b>	Shows tradeoff between bandwidth and SNR
<b>Link Budget Analysis</b>	Helps determine required transmit power

#### Mnemonic

"CBLSN" - "Capacity equals Bandwidth times Log of Signal-to-Noise ratio"

### Question 5(b) OR [4 marks]

Explain Shanon Fano code with suitable example.

#### Solution

**Shannon-Fano Coding:** A technique that assigns variable-length codes to symbols based on their probabilities by recursively dividing the set of symbols into two subsets with approximately equal probabilities.

**Example:** Consider symbols A, B, C, D with probabilities 0.4, 0.3, 0.2, 0.1

**Shannon-Fano Procedure:**

1. Sort symbols by probability: A(0.4), B(0.3), C(0.2), D(0.1)
2. Divide into groups with nearly equal probability:
  - Group 1: A(0.4) - assigned '0'
  - Group 2: B(0.3), C(0.2), D(0.1) = 0.6 - assigned '1'
3. Recursively divide Group 2:
  - Group 2.1: B(0.3) - assigned '10'
  - Group 2.2: C(0.2), D(0.1) = 0.3 - assigned '11'
4. Divide Group 2.2:
  - C(0.2) - assigned '110'
  - D(0.1) - assigned '111'

Symbol	Probability	Shannon-Fano Code
A	0.4	0
B	0.3	10
C	0.2	110
D	0.1	111

**Average Code Length** =  $0.4 \times 1 + 0.3 \times 2 + 0.2 \times 3 + 0.1 \times 3 = 1.9 \text{ bits/symbol}$

#### Mnemonic

"SFDS" - "Shannon Fano Divides Symbolsets"



### Question 5(c) OR [7 marks]

Draw and explain block diagram of Digital telephone exchange.

#### Solution

**Digital Telephone Exchange:** A system that connects telephone calls by converting analog voice signals to digital form and switching them through digital circuits.

flowchart LR

```
A[Subscribers] --> B["Digital Line Units (DLU)"]
B --> C["Line/Trunk Group (LTG)"]
C --> D["Switching Network (SN)"]
D --> E["Central Processor (CP)"]
E --> D
D --> C
C --> B
B --> A
F["Operation & Maintenance Center"] --> E
```

Block	Function
<b>Digital Line Units (DLU)</b>	Interface between subscriber lines and exchange, perform A/D conversion, line coding
<b>Line/Trunk Group (LTG)</b>	Manages signaling, multiplexes/demultiplexes subscriber channels
<b>Switching Network (SN)</b>	Core switching fabric, establishes connection paths between channels
<b>Central Processor (CP)</b>	Controls all exchange operations, call processing, routing decisions
<b>Operation &amp; Maintenance Center</b>	Monitors system performance, fault detection, traffic analysis

**Key Features:**

- **Time Division Switching:** Connects different time slots
- **Space Division Switching:** Connects different physical paths
- **Stored Program Control:** Software-based call processing
- **Common Channel Signaling:** Separate signaling channel (SS7)
- **Non-blocking Architecture:** All calls can be connected simultaneously

#### Mnemonic

“DLSCO” - “Digital Lines Switch Calls Orderly”