# CSS331: Fundamentals of Data Communications
# Midterm Mock Exam

curated by The Peanuts

Name Nonprawich I. ID 6622772422 Section............ Seat No............

**Conditions:** Semi-closed Book

## Directions:

1. This exam has 11 pages (including this page).
2. Write your name at the top.
3. Reading the problem is optional, but answering without reading is a bold strategy.
4. Answers must be written in English only
5. Work alone. Collaboration is for your group projects, not exams.
6. Good luck, babe!

*For solution,* ***click here****.*
*Solution will unlock soon.*

# Question 1

(a) What are the main layers in the TCP/IP protocol suite? List them in order from bottom to top and briefly describe the function of each layer.

The TCP/IP protocol suite consists of **5 layers** (from bottom to top):

**1. Physical Layer**

- **Function**: Covers the physical interface between data transmission device and transmission medium
- Handles characteristics of transmission medium, nature of signals, data rate, and relatec electrical/mechanical specifications

**2. Network Access/Data Link Layer**

- **Function**: Defines how data should be sent using the network
- Responsible for transmission of data between two devices on the same network
- Includes how bits should be optically signaled by hardware devices and interfaces with network medium (cables, fiber, etc.)

**3. Network Layer (Internet Layer)**

- **Function**: Sends packets from source to destination
- Handles routing protocols, multicast group management, and network-layer address assignment
- Primary protocol: IP (Internet Protocol)

**4. Transport Layer (Host-to-Host)**

- **Function**: Provides data transport from process on source system to process on destination system
- Determines data flow control, ensures error-free delivery in correct sequence
- Controls reliability through flow control, error control, and segmentation
- Primary protocols: TCP (reliable) and UDP (unreliable but faster)

**5. Application Layer**

- **Function**: Interacts with software application programs (closest to end-user)
- Identifies communication partners, determines resource availability, synchronizes communication
- Examples: HTTP, FTP, SMTP, SSH

(b) Explain the difference between simplex, half-duplex, and full-duplex transmission modes. Give one real-world example for each.

## (b) Transmission Modes

**Simplex Transmission**

- **Definition**: One-way communication only (unidirectional)
- One device always transmits, the other always receives
- **Real-world example**: Push notifications to mobile devices (server only sends, device only receives)

**Half-Duplex Transmission**

- **Definition**: Two-way communication, but only in one direction at a time
- Both devices can send and receive, but not simultaneously
- **Real-world example**: Walkie-talkie communication (on Apple Watch or traditional radios) - you must press a button to talk and release to listen

**Full-Duplex Transmission**

- **Definition**: Two-way communication in both directions simultaneously
- Both devices can send and receive data at the same time
- **Real-world example**: FaceTime or telephone calls where both people can speak simultaneously and hear each other

# Question 2

(a) A periodic signal has a frequency of 50 kHz. Calculate:

- The period T
- The wavelength if the signal travels at the speed of light ($c = 3 \times 10^8$ m/s)

$T = \frac{1}{f} = \frac{1}{50 \times 10^3} = 2 \times 10^{-2} \times 10^{-3} = 2 \times 10^{-5}$ sec.

$= 20\ \mu s$ #

$v = f\lambda$

$\lambda = vT$

$= (3 \times 10^8)(2 \times 10^{-5})$

$= 6 \times 10^3$

$\lambda = 6000$ m

$= 6$ km #

(b) What is the difference between attenuation and noise? How can each be mitigated in a communication system?

**(b) Attenuation vs Noise**

**Attenuation:**

- **Definition:** Reduction in signal strength over distance as it travels through the transmission medium
- **Effect:** Signal becomes weaker but maintains its original shape and characteristics
- **Mitigation:**
  - For analog signals: Use **amplifiers** to boost signal strength
  - For digital signals: Use **repeaters** to regenerate the original signal

**Noise:**

- **Definition:** Unwanted signals that interfere with or corrupt the original signal during transmission
- **Types:** Thermal noise (white noise), crosstalk, impulse noise, intermodulation noise
- **Effect:** Degrades signal quality and can cause bit errors in digital systems
- **Mitigation:**
  - Use shielded cables to reduce electromagnetic interference
  - Implement error detection and correction codes
  - Increase signal-to-noise ratio (SNR)
  - Use proper grounding and filtering techniques

**Key Difference:** Attenuation affects signal strength uniformly, while noise adds unwanted random variations to the signal.

(c) A signal has a spectrum from 2 MHz to 6 MHz.

- What is the absolute bandwidth?
- If this signal experiences attenuation, would you use an amplifier or a repeater to boost it if the signal is (i) analog? (ii) digital?

Absolute bandwidth $= f_H - f_L = 6\text{ MHz} - 2\text{ MHz} = 4\text{ MHz}$ #

**Signal Boosting for Attenuation:**

**(i) For Analog Signals:** Use an **amplifier**

- Amplifiers boost the entire signal including any noise that may be present
- Suitable for analog signals where the signal shape must be preserved
- More cost-effective for analog transmission

**(ii) For Digital Signals:** Use a **repeater**

- Repeaters regenerate the original digital signal by detecting the bits and retransmitting clean digital pulses
- Eliminates accumulated noise and distortion
- Provides better signal quality restoration for digital data
- More expensive but ensures signal integrity

The choice depends on whether you need to preserve the analog waveform characteristics (amplifier) or can regenerate the digital information (repeater).

## Question 3

(a) Consider a channel with bandwidth B = 3 MHz and signal-to-noise ratio SNR = 127.

- Calculate the Shannon capacity of the channel.
- Using Nyquist's theorem, how many signal levels M would be required to achieve this capacity?

$$C = B\log_2(1+SNR)$$
$$= 3\log_2(1+127)$$
$$= 3\log_2(128)$$
$$C = 21 \text{ Mbps} \; \#$$

$$C = 2B\log_2 M$$
$$21 = 2(3)\log_2 M$$
$$\frac{21}{6} = \log_2 M$$
$$3.5 = \log_2 M$$
$$M = 2^{3.5}$$
$$= 2^3 \cdot 2^{0.5}$$
$$= 8 \cdot \sqrt{2}$$
$$M \approx 11.31$$

∴ We need $M = 12$ signal levels to achieve this capacity #

(b) A voice-grade telephone channel has a bandwidth of 3.4 kHz.

- If we use 16 signal levels (M), what is the maximum data rate according to Nyquist?
- If the SNR is 30 dB, what is the $\boxed{\text{Shannon capacity?}}$ (Note: SNR in dB $= 10\log_{10}(\text{SNR})$)
- Which limit is more restrictive in this case?

$$C = 2B\log_2 M$$
$$= 2(3.4)\log_2(16)$$
$$= 2(3.4)(4)$$
$$C = 27.2 \text{ kbps} \; \#$$

$$C = B\log_2(1+SNR)$$
$$= 3400\log_2(1+1000)$$
$$C \approx 33.9 \text{ kbps} \; \#$$

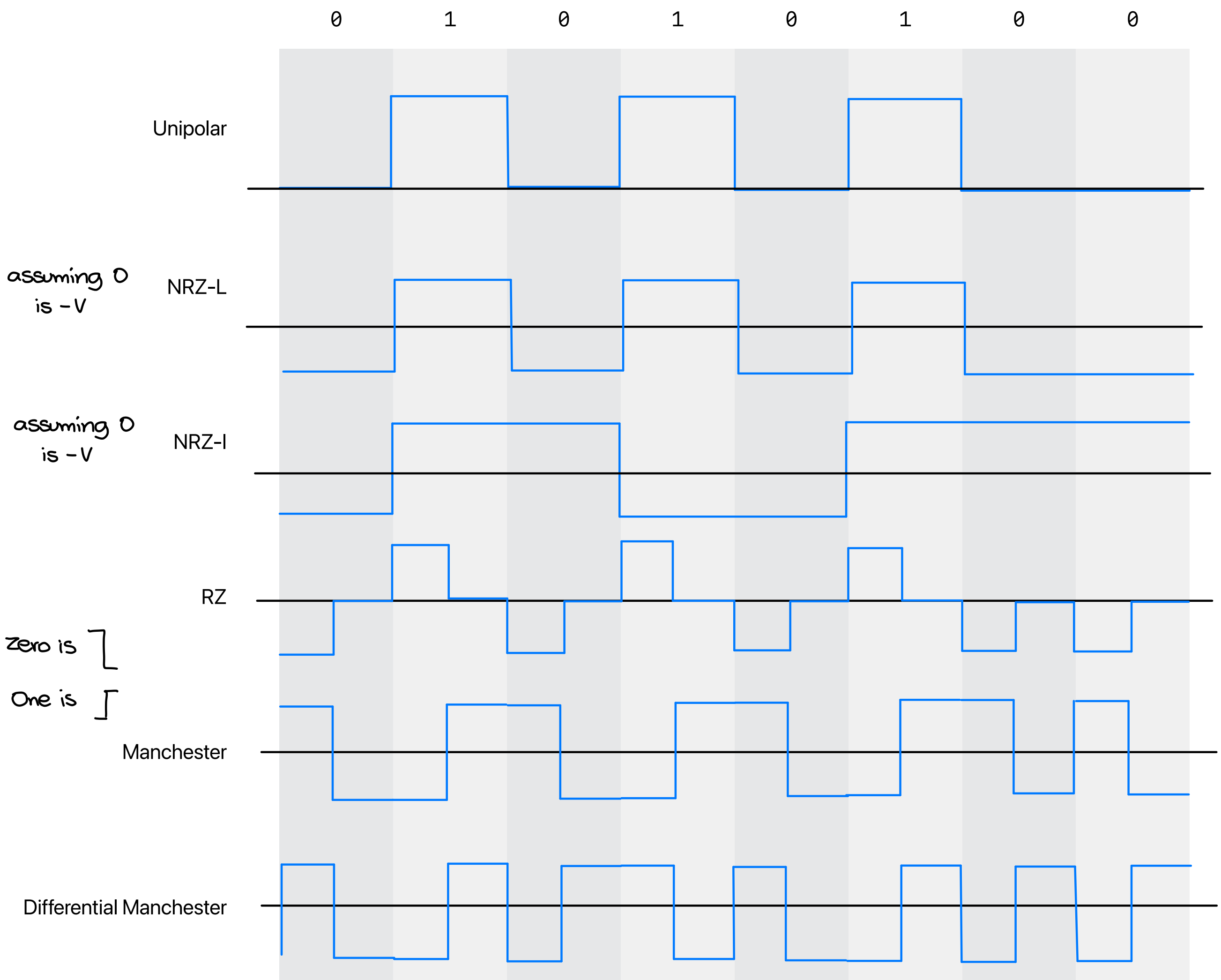
$$SNR_{dB} = 10\log_{10} SNR$$
$$3\cancel{0} = 1\cancel{0}\log_{10} SNR$$
$$10^3 = SNR$$
$$\therefore SNR = 1000$$

∴ The Nyquist limit (27.2 kbps) is more restrictive in this case

This means that even though the channel could theoretically support up to 33.9 kbps based on its SNR, the practical limit is 27.2 kbps when using 16 signal levels. To approach the Shannon limit, we would need to use more signal levels (which increases system complexity and cost).

## Question 4

Draw the waveforms for transmitting the first 8 bits of **"T"** in ASCII (01010100) using the following encoding techniques. Use +V for positive voltage and -V for negative voltage as appropriate.

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## Question 5

(a) The following data is to be transmitted using even parity VRC:

```
1011001
0110110
1001011
1110101
```

Add the appropriate VRC (parity) bit to each row. Show your work.

→ data

01011001
00110110
01001011
11110101

(b) Using the data from part (a) (without VRC bits), calculate the LRC (Longitudinal Redundancy Check) using even parity. The transmission is from left to right. Show all steps.

1011001
0110110
1001011
1110101

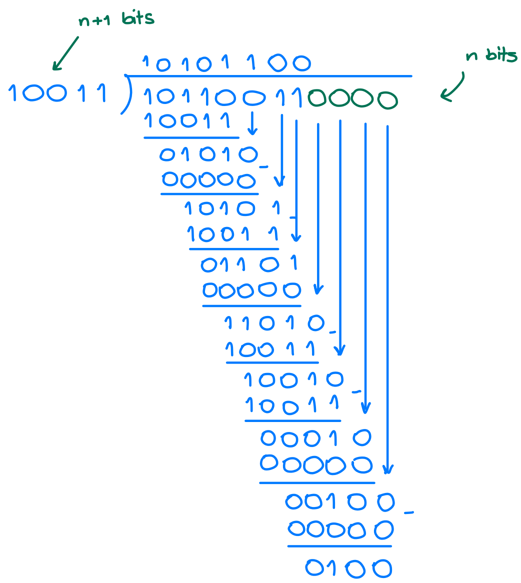
LRC: 1010001

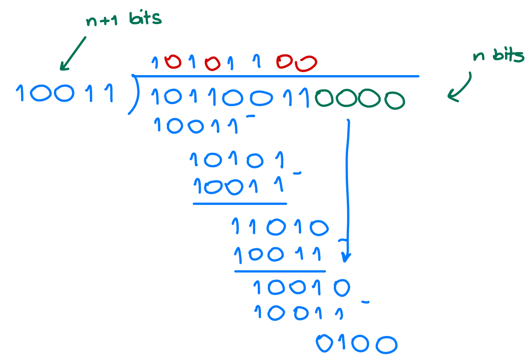
## Question 6

Given:

- Data (D): 10110011
- Divisor (P): 10011

(a) Calculate the CRC checksum using binary division. Show all steps of the division process.




(b) What is the transmitted frame (data + CRC)?

∴ 101100110100 #

# Question 7

Given:

7 bits

- Message M(x) = 1101011 $= x^6+x^5+x^3+x+1$

5 bits (n+1 bits)

- Generator P(x) = 11001 $= x^4+x^3+1$

(a) Express $x^n M(x)$ in polynomial form, where n is determined by the degree of P(x).

11010110000 $= x^{10}+x^9+x^7+x^5+x^4$

(b) Perform polynomial division to find the remainder C(x).

$$
\begin{array}{r l}
 & x^6 + x^3 + x \\
x^4+x^3+1 \,) & x^{10}+x^9+x^7+x^5+x^4 \\
 & x^{10}+x^9+x^6 \\
\hline
 & x^7+x^6+x^5 \\
 & x^7+x^6+x^3 \\
\hline
 & x^5+x^4+x^3 \\
 & x^5+x^4+x \\
\hline
 & x^3+x \leftarrow C(x)
\end{array}
$$

(c) What is the transmitted frame F(x) in binary form?

Transmit $F(x) = x^n M(x) + C(x)$

$= x^{10}+x^9+x^7+x^5+x^4+x^3+x$ #

# Question 8

Given 8-bit binary data words:

```
10101100
11001010
11110000
01010101
```

10101100 $\longrightarrow$ 172
11001010 $\longrightarrow$ 202
11110000 $\longrightarrow$ 240
01010101 $\longrightarrow$ 85

(a) Calculate the checksum using one's complement addition. Show the addition steps.

$$
\begin{array}{r}
172 \\
202 \\
240 \\
85 \\
\hline
\end{array}
$$

Sum $\longrightarrow$ 699

$$
\begin{array}{rl}
10\ 1011\ 1011 & 699 \\
+ \quad 10 & \\
\hline
1011\ 1101 & 189 \\
0100\ 0010 & 66
\end{array}
$$

(b) What is the transmitted frame (data + checksum)?

∴ 172, 202, 240, 85, 66 #

# Question 9

(a) For a data word of 11 bits, how many redundancy bits are needed for single-bit error correction? Show your calculation using the formula $2^r \geq m + r + 1$.

$2^1 \ngeq 11 + 1 + 1$

$2^2 \ngeq 11 + 2 + 1$

$2^3 \ngeq 11 + 3 + 1$

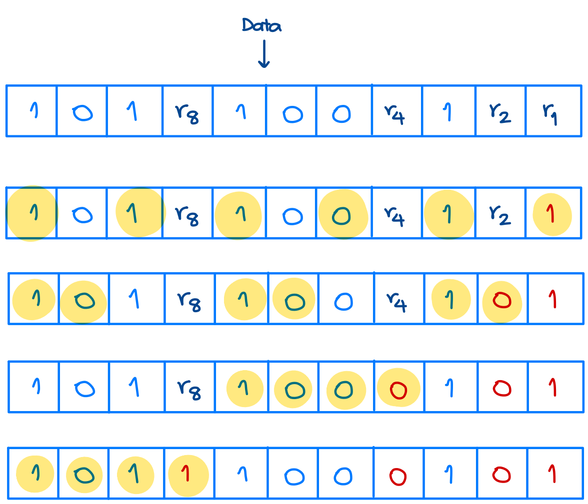
$2^4 \geq 11 + 4 + 1$ ✓

$\therefore r = 4$

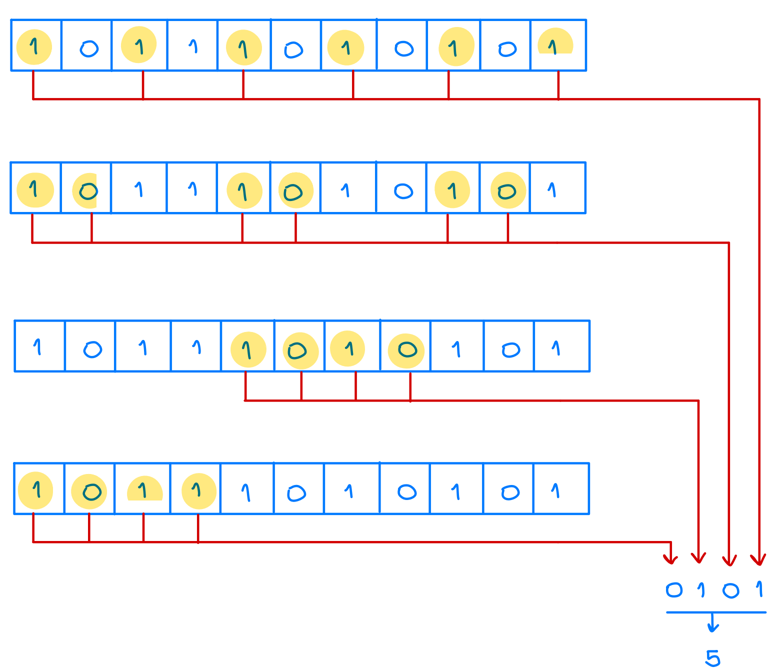
(b) Given the 7-bit data word: 1011001

Calculate the Hamming code with odd parity. Show:

- The position of each redundancy bit
- The calculation of each redundancy bit value
- The final transmitted code.
- Suppose the receiver receives the code `10111010101`. Show how to determine which bit is in error.




Code: 10111000101




∴ The bit in position 5 is in error #

# Question 10

(a) List three advantages of optical fiber over twisted pair cable.

**(a) Three Advantages of Optical Fiber over Twisted Pair Cable**

Based on your course materials, here are three key advantages of optical fiber over twisted pair cable:

**1. Greater Capacity and Bandwidth**

- Optical fiber supports data rates of hundreds of Gbps over tens of kilometers
- Much higher bandwidth capability compared to twisted pair which typically supports up to 1 MHz (multipair cables)
- Enables high-speed, long-distance communications

**2. Lower Attenuation (Signal Loss)**

- Optical fiber: 0.2 to 0.5 dB/km attenuation
- Twisted pair: 0.2 to 0.7 dB/km attenuation (but much lower frequency range)
- Less signal loss over distance, allowing for greater repeater spacing (40 km vs 2 km for twisted pair)

**3. Electromagnetic Isolation and Security**

- Not vulnerable to electromagnetic interference (EMI), impulse noise, or crosstalk
- Not affected by external magnetic fields (unlike twisted pair)
- High degree of security from eavesdropping since light signals don't radiate electromagnetic energy
- Immune to radio frequency interference (RFI)

**Additional advantages mentioned in your materials include:**

- Smaller size and lighter weight (considerably thinner than twisted pair)
- Lower cost and fewer sources of error over long distances

(b) An FM radio signal has an original bandwidth of 15 kHz. What is the required bandwidth for FM transmission? If this signal is transmitted through free space at 100 MHz, what is its wavelength?

(1) Required FM bandwidth $= 10 \times 15$ kHz

$= 150$ kHz #

(2) $\lambda = \frac{c}{f}$

$= \frac{3 \times 10^8}{100 \times 10^6}$

$\lambda = 3$ metres #