Computer Science & Information Technology

Computer Networks

Comprehensive Theory

with **Solved Examples** and **Practice Questions**

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Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 011-45124660, 8860378007
Visit us at: www.madeeasypublications.org

Computer Networks

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Computer Networks

Goal of the Subject

The main goal of networking is "Resource sharing", and it is to make all programs, data and equipment available to anyone on the network without the regard to the physical location of the resource and the user.

A second goal is to provide high reliability by having alternative sources of supply. For example, all files could be replicated on two or three machines, so if one of them is unavailable, the other copies could be available.

Another goal is saving money. Small computers have a much better price/performance ratio than larger ones. This goal leads to networks with many computers located in the same building. Such a network is called a LAN (Local Area Network).

Another closely related goal is to increase the systems performance as the work load increases by just adding more processors. With central mainframes, when the system is full, it must be replaced by a larger one, usually at great expense and with even greater disruption to the users.

Computer networks provide a powerful communication medium. A file that was updated/ modified on a network can be seen by the other users on the network immediately.

Computer Networks

INTRODUCTION

Although Computer network is a vast subject on its own, in this book we tried to keep it around the GATE syllabus. Each topic required for GATE is crisply covered with illustrative examples and each chapter is provided with Student Assignment at the end of each chapter so that the students get the thorough revision of the topics that he/she had studied. This subject is carefully divided into eight chapters as described below.

1. **Networking Fundamentals and Physical layer:** In this chapter we discuss transmission medium, noise that cause bit errors, types of transmission media, concept of protocol layering. Finally we discuss the IP addressing, Subnetting and Network address translation.
2. **Data Link layer:** In this chapter we discuss Delays in computer networks, Protocol layering, Circuit-switched and Packet switching. Data link layer functions, farming methods, error correction and detection methods, Sliding window protocols for flow control the Static and dynamic channel allocation methods. Then we finally discuss Networking devices like Repeaters, Hubs, Bridges, Switches, Routers and Gateways.
3. **Network Layer:** In this chapter we discuss the classification of routing algorithms, Distance vector and Link state routing protocols. We also cover congestion control algorithms at network layer, Internet protocol, and finally we cover the network layer protocols namely ARP, RARP, ICMP and IPv4 & NAT.
4. **Transport Layer Protocols:** In this chapter we discuss the TCP protocol as connected oriented service and reliable service provider, TCP congestion control, TCP timers and finally we discuss UDP.
5. **Application Layer and Protocols:** In this chapter we discuss the various protocols used at application layer: DNS, HTTP, SMTP, Telnet, UDP, FTP etc.

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CHAPTER 01

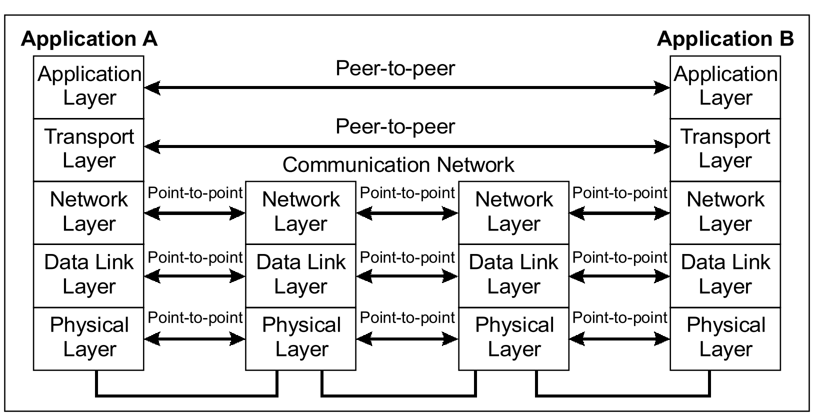
Networking Fundamentals and Physical Layer

1.1 Introduction

1.1.1 Protocol Layering

There are several advantages of protocol layering.

1. Protocol layering enables us to divide a complex task into several smaller simpler tasks. This is referred to as modularity.
2. It allows to separate the services from the implementation.
3. Intermediate systems need only some layers but not all layers. Protocol layering helps us in designing the system or devices with required number of layers implemented in it.



1.1.2 OSI layer vs TCP/IP layer

OSI (Open System Interconnection)	TCP (Transmission Control Protocol/ Internet Protocol)
• OSI provide layer function and also defines functions of all layers	• TCP/IP model the transport layer does not guarantees delivery of packets
• IN OSI model the transport layer guarantees the delivery of packets	• Follows vertical approach
• Follows horizontal approach	• TCP/IP does not have a separate presentation layer
• OSI model has a separate presentation layer	• TCP/IP model cannot be used in any other application
• OSI is a general model	• The network layer in TCP/IP model provides connectionless services
• Network layer of OSI model provide both connection oriented and connectionless service	• TCP/IP model does not fit any protocol
• Protocols are hidden in OSI model and are easily replaced as the technology changes	• In TCP/IP replacing protocol is not easy
• OSI model defines services, interfaces and protocols very clearly and makes clear distinction between them	• In TCP/IP it is not clearly separated its services, interfaces and protocols.
• It has 7 layer	• It has 5 layers

The Open Systems Interconnection (OSI) model is a standard "reference model" created by the International Organization for Standardization (ISO) to describe how the different software and hardware components involved in a network communication should divide labor and interact with one another.

It defines a seven-layer set of functional elements, ranging from the physical interconnections at Layer 1 (also known as the physical layer, or PHY interface) all the way up to Layer 7, the application layer.

The Transmission Control Protocol (TCP) and the Internet Protocol (IP) are two of the network standards that define the Internet.

IP defines how computers can get data to each other over a routed, interconnected set of networks. TCP defines how applications can create reliable channels of communication across such a network. Basically, IP defines addressing and routing, while TCP defines how to have a conversation across the link without garbling or losing data. TCP/IP grew out of research by the U.S. Dept. of Defense and is based on a loose rather than a strict approach to layering. Many other key Internet protocols, such as the Hypertext Transfer Protocol (HTTP), the basic protocol of the Web, and the Simple Mail Transfer Protocol (SMTP), the core e-mail transfer protocol, are built on top of TCP. The User Datagram Protocol (UDP), a companion to TCP, sacrifices the guarantees of reliability that TCP makes in return for faster communications.

TCP/IP doesn't map cleanly to the OSI model, since it was developed before the OSI model and was designed to solve a specific set of problems, not to be a general description for all network communications.

ISO/OSI Layer	TCP/IP Model	Sample Protocols	Devices
7. Application	Application	**SOAP, XML**	**XML Appliances**
6. Presentation 5. Session 4. Transport		HTTP, HTTPS FTP TELNET SMTP, NTP	Content Service Switch Layer 4-7 Switches
3. Network	Transport	TCP, UDP	Router, Layer-3 Switch
2. Data Link	Network	IP, ICMP, IGMP, IPX	Switches, Bridges
1. Physical	Link	Network Interface: Ethernet, Token Ring, FDDI	Hubs, Repeaters

Two layers in the OSI model, session and presentation, are missing from the TCP/IP protocol suite. These two layers were not added to the TCP/IP protocol suite after the publication of the OSI model. The application layer in the suite is usually considered to be the combination of three layers in the OSI model. The OSI model did not replace the TCP/IP protocol suite because it was completed when TCP/IP was fully in place and because some layers in the OSI model were never fully defined.

1.1.3 Similarities between OSI Model and TCP/IP Model

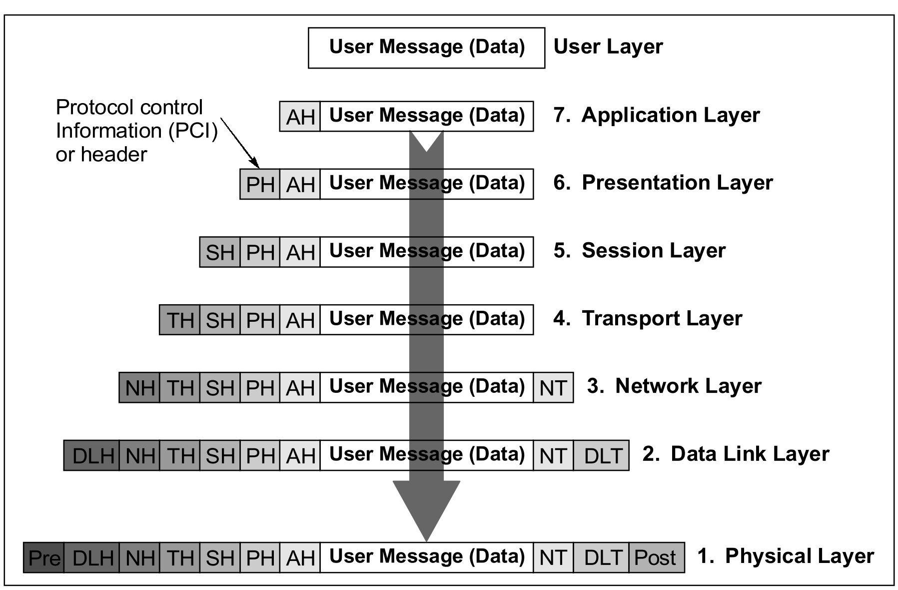
1. Both of them use a layered architecture to explain data communication process in computer networks.
2. Each layer performs well-defined functions in both models.
3. Similar types of protocols are used in both models.
4. OSI and TCP/IP reference models are open in nature.
5. Both models give a good explanation on how various types of network hardware and software interact during a data communication process.
6. Data hiding principle is well maintained on each layer in the two models. The core level functional details of each layer are not revealed to other layers.
7. Transport layer defines end-end data communication process and error-correction techniques in both the models.
8. OSI and TCP/IP reference models process data in the form of packets to perform routing.

1.1.4 Encapsulation and Decapsulation

Messages generated by application are encapsulated by every layer before passing on to the layer below it. Information that is encapsulated where is from layer-to-layer. This encapsulated information is also called as 'header'.

The TCP header information includes the port address, Ack information, checksum and other useful information. The network layer header includes source and destination IP address, header checksum, fragmentation information and other useful information.

Data link layer includes the MAC address information, error control, error detection, error correction and other useful information.



OSI Layer and Message passing

1.1.5 Data Flow

Communication between two devices can be simplex, half-duplex, or full-duplex.

(a) **Simplex:** In simplex *mode*, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive.

Example: Keyboards and Traditional Monitors.

(b) **Half-Duplex:** In half-duplex, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa.

Example: Walkie-talkies and Citizen band (CB) Radio.

(c) **Full-Duplex:** In full-duplex, both stations can transmit and receive simultaneously.

Example: Telephone networks.

The simplex mode can use the entire capacity of the channel to send data in one direction. The half-duplex mode is used in cases where there is no need for communication in both direction at the same time; the entire capacity of the channel can be utilized for each direction.

The full-duplex mode is used when communication in both directions is required all the time. The capacity of the channel, however, must be divided between the two directions.

1.1.6 Network Topologies

(a) **Mesh Topology:** In mesh topology, every device has a dedicated point-to-point link to every other device. The term *dedicated* means that the link carries traffic only between the two devices it connects. Node 1 must be connected to $n-1$ nodes, node 2 must be connected to $n-1$ nodes, and finally node n must be connected to $n-1$ nodes. Hence in total we need $n(n-1)$ physical links. Every node must have $n-1$ input/output (I/O) ports.

(b) **Star Topology:** In a start topology, each device has a dedicated point-to-point link only to a central controller, usually called a **hub**. The devices are not directly linked to one another. Unlike a mesh topology, a star topology does not allow direct traffic between devices. In a star, each device needs only one link and one I/O port to connect it to any number of others.

(c) **Bus Topology:** A bus topology is multipoint. One long cable acts as **backbone** to link all the devices in a network. A drop line is a connection running between the device and the main cable.

(d) **Ring Topology:** In a ring topology, each device has a dedicated point-to-point connection with only the two devices on either side of it. A signal is passed along the ring in one direction, from device to device, until it reaches its destination. Each device in the ring incorporates a repeater. Each device is linked to only its immediate neighbours.

1.2 Circuit-Switched vs Packet Switched Network

Circuit Switching

A **circuit-switched network** consists of a set of switches connected by physical links. A circuit-switched network is made of a set of switches connected by physical links, in which each link is divided into n channels.

Circuit switching takes place at the physical layer. Before starting communication, the stations must make a reservation for the resources to be used during the communication. These resources, such as channels (bandwidth in FDM and time slots in TDM), switch buffers, switch processing time, and switch input/output ports, must remain dedicated during the entire duration of data transfer until the **teardown phase**.

Example - 1.1 Let us consider the telephone channel having bandwidth B = 4 kHz. Assuming there is no noise, determine channel capacity for the following encoding levels: (a) 2 and (b) 128.

Solution:

(a) $C = 2B = 2 \times 4000 = 8$ Kbits/s

(b) $C = 2 \times 4000 \times \log_2 128 = 8000 \times 7 = 56$ Kbits/s

Effects of Noise

When there is noise present in the medium, the limitations of both bandwidth and noise must be considered. A noise spike may cause a given level to be interpreted as a signal of greater level, if it is in positive phase or a smaller level, if it is negative phase. Noise becomes more problematic as the number of levels increases.

Shannon Capacity (Noisy Channel)

In presence of Gaussian band-limited white noise, Shannon-Hartley theorem gives the maximum data rate capacity

$$C = B \log_2 (1 + S/N),$$

Signal to noise ratio is represented in dB (decibel).

$\log_{10}(S/N)$ is in bells

$10 \times \log_{10}(S/N)$ is in decibels

+ve value of S/N means signal power is dominating, where as –ve value of S/N represents noise power is dominating signal.

Where S and N are the signal and noise power, respectively, at the output of the channel. This theorem gives an upper bound of the data rate which can be reliably transmitted over a thermal-noise limited channel.

Example: Suppose we have a channel of 3000 Hz bandwidth, we need an S/N ratio (i.e. signal to noise ration, SNR) of 30 dB to have an acceptable bit-error rate. Then, the maximum data rate that we can transmit is 30,000 bps. In practice, because of the presence of different types of noises, attenuation and delay distortions, actual (practical) upper limit will be much lower.

NOTE: In case of extremely noisy channel, C = 0. Between the Nyquist Bit Rate and the Shannon limit, the result providing the smallest channel capacity is the one that establishes the limit.

Example - 1.2 A channel has B = 4 KHz. Determine the channel capacity for each of the following signal-to-noise ratios: (a) 20 dB, (b) 30 dB, (c) 40 dB.

Solution:

(a) $C = B \log_2 (1 + S/N) = 4 \times 10^3 \times \log_2 (1 + 100) = 4 \times 10^3 \times 3.32 \times 2.004 = 26.6$ kbits/s

(b) $C = B \log_2 (1 + S/N) = 4 \times 10^3 \times \log_2 (1 + 1000) = 4 \times 10^3 \times 3.32 \times 3.0 = 39.8$ kbits/s

(c) $C = B \log_2 (1 + S/N) = 4 \times 10^3 \times \log_2 (1 + 10000) = 4 \times 10^3 \times 3.32 \times 4.0 = 53.1$ kbits/s

Example - 1.3 A channel has B = 4 KHz and a signal-to-noise ratio of 30 dB. Determine maximum information rate for 4-level encoding.

Solution:

For B = 4 KHz and 4-level encoding the Nyquist Bit Rate is 16 Kbps.

Again for B = 4 KHz and S/N of 30 dB the *S*hannon capacity is 39.8 Kbps.

The smallest of the two values has to be taken as the Information capacity I = 16 Kbps.

Example-1.27 Assume host A having an IP address of 125.32.16.5 with a subnet mask of 255.255.255.128. Also, assume another host B, having an IP address of 125.32.16.120 with a subnet mask of 255.255.255.192.

Which of the following is correct?

(a) 'A' assumes 'B' to be on the same network.
(b) 'B' assumes 'A' to be on the same network.
(c) Both 'A' and 'B' assume each other to be on the same network.
(d) Neither of the two assume themselves to be on the same network.

Solution: (a)

IP address of 'A' = 125.32.16.5
Subnet mask of 'A' = 255.255.255.128
Subnet ID of A according to 'A' = 125.32.16.0
IP address of 'B' = 125.32.16.120
Subnet ID of B according to 'A' = 125.32.16.0

Hence 'A' assumes 'B' to be on the same network

IP address of 'B' = 125.32.16.120
Subnet mask of 'B' = 255.255.255.192
Subnet ID of B according to 'B' = 125.32.16.64
Subnet ID of A according to 'B' = 125.32.16.0

Hence 'B' assumes 'A' to be on different network.

Summary

- A data communications system must transmit data to the correct destination in an accurate and timely manner.
- The five components that make up a data communications system are the message, sender, receiver, medium and protocol. Text, numbers, images, audio, and video are different forms of information. Data flow between two devices can occur in one of three ways: simplex, half-duplex, or full-duplex.
- **Base-band** is defined as one that uses digital signaling, which is inserted in the transmission channel as voltage pulses.
- **Broadband** systems are those, which use analog signaling to transmit information using a carrier of high frequency.
- Co-axial cable has superior frequency characteristics compared to twisted-pair and can be used for both analog and digital signaling.
- The term broadband refers to analog transmission over coaxial cable.
- Fibre optics has very high data rate, and low error rate.
- Unguided transmission is used when running a physical cable (either fiber or copper) between two end points is not possible.
- The baud rate or signaling rate is defined as the number of distinct symbols transmitted per second, irrespective of the form of encoding.
- The bit rate or information rate is the actual equivalent number of bits transmitted per second.

- The **bit rate** represents the number of bits sent per second, whereas the **baud rate** defines the number of signal elements per second in the signal. Depending on the encoding technique used, baud rate may be more than or less than the data rate.
- In the standard Manchester coding there is a transition at the middle of each bit period. A binary **1** corresponds to a **low-to-high transition** and a binary **0** to a **high-to-low transition** in the middle.
- In Differential Manchester, inversion in the middle of each bit is used for synchronization.
- IP defines how computers can get data to each other over a routed, interconnected set of networks. TCP defines how applications can create reliable channels of communication across such a network.

Student's Assignment

Q.1 For a class B network an appropriate mask with 200 subnets each with 220 systems is
(a) 255.255.255.254 (b) 255.255.255.0
(c) 255.255.255.220 (d) 255.255.200.220

Q.2 Consider the following statements regarding OSI model
(*i*) It divides the network communication into smaller and simpler components, aiding component development, design and troubleshooting.
(*ii*) It allows multiple-vendor development through standardization of network components.
(*iii*) It prevents the changes in one layer from affecting the other layers, allowing for quicker development.
(*iv*) It usually do not correspond exactly to the protocol stack running on an actual system.
Which of the above are true?
(a) (*i*) and (*iv*) only (b) (*ii*) and (*iii*) only
(c) (*i*), (*ii*) and (*iv*) only (d) All of these

Q.3 An organization is granted the block 190.76.0.0/16. The administrator wants to create 1024 subnets using 10 bits. The first and last addresses in subnet 1024 respectively are
(a) 190.76.255.0/26 and 190.76.255.255/26
(b) 190.76.255.1/16 and 190.76.255.255/16
(c) 190.76.255.192/26 and 190.76.255.255/26
(d) 190.76.255.192/16 and 190.76.255.255/16

Q.4 What is the netmask of gateway interface in a sub-C network where only 14 hosts exist and IP address of one of the hosts in 193.146.129.76?
(a) 255.255.129.76
(b) 255.255.129.240
(c) 255.255.255.240
(d) 255.255.255.255

Q.5 The number of bits in IPv6 address is
(a) 64 (b) 128
(c) 256 (d) None of these

Q.6 In Hexadecimal colon notation, a 128-bit long IPv6 address is divided into ________ sections, each comprising ________ hexadecimal digits.
(a) 4, 2 (b) 8, 4
(c) 16, 2 (d) 4, 8

Q.7 Given the following IP address and network mask, what is the broadcast address?
IP : 160.168.30.100
Net Mask : 255.255.240.0
(a) 160.168.31.255 (b) 160.168.30.255
(c) 160.168.240.255 (d) 160.168.255.255

Q.8 The Router connecting company's network to the Internet applies the mask 255.255.252.0 to the destination address of incoming IP packets. Find the corresponding subnetwork for the destination IP address of packet 159.133.7.220.
(a) 159.133.7.0 (b) 159.133.0.0
(c) 159.133.4.0 (d) 159.133.6.0

Q.9 Let X and Y be the number of 0's in the binary notation of network ID and Direct Broadcast Address (DBA) respectively for the IP address 200.25.80.67 (classfull address). The value of $X \log_2 Y$ is _______.

Q.10 For a class C network if IP address of a computer is 200.99.39.112 and subnet mask is 255.255.255.224 the decimal value of last octet of last host of sixth subnet is _______.

Q.11 Match **List-I** and **List-II** and select the correct answer using the codes given below the lists:

List-I (Packets)

A.

	Source IP	Destination IP
Data	250.255.255.255	50.50.50.50

B.

	Source IP	Destination IP
Data	24.50.48.30	255.255.255.255

C.

	Source IP	Destination IP
Data	24.66.50.77	24.50.30.20

List-II

1. Unicast packet within network
2. This packet never exists
3. Limited broadcasting

Codes:

	A	B	C
(a)	1	2	3
(b)	2	3	1
(c)	3	1	2
(d)	2	1	3

Q.12 Consider a class C network has an IP address of one of the computers is 202.23.65.119. Which of the following can be host on network?
(a) 202.23.65.0
(b) 202.23.0.0
(c) 0.0.0.119
(d) None of these

Q.13 An organization is granted the block 190.76.0.0/16. The administrator wants to create 1024 subnets using 10 bits. What is the first and last addresses in last subnet which can assign to host?
(a) 90.76.255.0/26 and 190.76.255.255/26
(b) 190.76.255.1/16 and 190.76.255.255/16
(c) 190.76.255.193/26 and 190.76.255.254/26
(d) 190.76.255.192/16 and 190.76.255.255/16

Q.14 Consider the following IP address:
(*i*) 210.15.16.62
(*ii*) 210.15.16.94
(*iii*) 210.15.16.127
(*iv*) 210.15.16.191

Which of following IP address may represents last host of any subnet if subnet mask is 255.255.255.224?
(a) (*i*) and (*ii*)
(b) (*i*) and (*iii*)
(c) (*ii*) and (*iv*)
(d) (*iii*) and (*iv*)

Q.15 A router uses the following routing table:

Network Address	Mask	Interface
205.32.0.0	/25	R0
205.32.16.0	/26	R1
205.32.32.0	/24	R2
205.32.16.32	/27	R3

Find the next hop (where router will send the packet), if the router has IP address "205.32.16.63".
(a) R0
(b) R1
(c) R2
(d) R3

Q.16 An organization is granted the block 172.89.0.0/16. The administrator wants to create 1024 subnets using 10 bits. The first and last addresses of any host in subnet 1024 respectively are
(a) 172.89.255.0/26 and 172.89.255.255/26
(b) 172.89.255.1/26 and 172.89.255.245/26
(c) 172.89.0.1/26 and 164.76.255.255/26
(d) 172.89.0.1/26 and 172.89.255.245/26

Q.17 If the broadcast address of the subnet is given as 173.140.31.255, which of the following mask cannot suit the above address?
(a) 255.255.240.0
(b) 255.255.248.0
(c) 255.255.192.0
(d) Both (b) and (c)

Q.18 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Passive scanning
B. Active scanning
C. Association

List-II

1. Assigning a one or two word SSID to the access point.

2. Creating a virtual wire between itself and AP by the wireless station.
3. Scanning channels and listening for beacon frames.
4. Broadcasting a probe frame that will be received by all APs within the wireless Host's range.

Codes:

	A	B	C
(a)	3	2	1
(b)	3	4	2
(c)	4	2	1
(d)	4	3	1

Q.19 In a block of addresses, we know the IP address of one of the host is 128.44.82.16 / 25. Which of the following represent first address and last addresses that can be assign to host in the block?
(a) 128.44.82.0 and 128.44.82.126
(b) 128.44.82.1 and 128.44.82.127
(c) 128.44.82.1 and 128.44.82.126
(d) 128.44.82.0 and 128.44.82.127

Q.20 In the network 143.128.67.235 / 20, if x represent the decimal value of 3rd octet and y represent the decimal value of 4th octet of last IP address assigned to any host, then value of $x \times y$ is ________.

Q.21 Consider a IP address 201.24.58.69 in classful address, if the number of 1's in directed broadcast address is a and number of 1's in network ID, of the given IP address is b, value of $a + b$ ________.

Q.22 Consider a class B network with 100 subnets each with 160 system. What is the subnet mask of this network?
(a) 255.255.255.190 (b) 255.255.255.0
(c) 255.255.254.0 (d) 250.255.254.128

Q.23 An organization is granted the block 178.52.0.0/16, the administrator wants to create 510 subnets, what is the first and last IP address respectively in the last subnet that can be assign to the host?
(a) 178.52.255.120/25, 178.52.254.254/25
(b) 178.52.255.129/16, 178.52.255.129/16
(c) 178.52.255.128/26, 178.52.255.254/25
(d) 178.52.255.129/25, 178.52.255.254/25

Q.24 Consider the following IP addresses and which of the following IP address may represents last host of any subnet, given subnet mask is 255.255.255.224?
(i) 196.24.63.127
(ii) 196.24.63.94
(iii) 196.24.63.62
(a) (i) and (ii) (b) (ii) and (iii)
(c) (i) and (iii) (d) Only (i)

Answer Key:

1. (b)	**2.** (d)	**3.** (c)	**4.** (c)	**5.** (b)
6. (b)	**7.** (a)	**8.** (c)	**9.** (96)	**10.** (222)
11. (b)	**12.** (c)	**13.** (c)	**14.** (a)	**15.** (d)
16. (d)	**17.** (c)	**18.** (b)	**19.** (c)	**20.** (20066)
21. (28)	**22.** (c)	**23.** (d)	**24.** (b)	

Student's Assignments — Explanations

1. **(b)**
Given:
Number of subnets = 200 ($2^7 < 200 < 2^8$)
Number of systems per subnet = 220
Default mask for class B = 255.255.0.0
(i.e., 16 bits for NID and 16 Bits for HID)

Check whether $\boxed{200 \times 220 < 2^{16}}$

Now, $\underset{\text{NID}}{\underline{\text{16 bits}}} = \dfrac{\text{16 bits}}{\underset{\text{SID}}{\text{8 bits}} \quad \underset{\text{HID}}{\text{8 bits}}}$

We can use 255 . 255 . 255 . 0

2. **(d)**
(*i*) OSI model reduces complexity by breaking network communication into smaller and simpler components. It provides a teaching tool to help network administrators understand the communication process used between networking components.

(*ii*) OSI model defines the process for connecting two layers together, promoting interoperability between vendors. It allows vendors to compartmentalize their design efforts to fit a modular design, which eases implementations and simplifies troubleshooting.

(*iii*) OSI model ensures interoperable technology.

(*iv*) The data link layer protocols often include physical layer specifications. The network and transport layer protocols work together to provide a cumulative end-to-end communication service.

∴ All are true.

3. (c)

Number of subnets = 1024

Bits required for subnet = 10

Network mask = 255.255.255.192

Number of hosts / subnet = $2^6 - 2$

Ranges are:

190.76.0.0/26 to 190.76.0.63/26 ——— 1st subnet

190.76.0.64/26 to 190.76.0.127/26 ——— 2nd subnet

190.76.0.128/26 to 190.76.0.191/26 ——— 3rd subnet

190.76.0.192/26 to 190.76.0.255/26 ——— 4th subnet

190.76.1.0/26 to 190.76.1.63/26 ——— 5th subnet

⋮

190.76.255.128/26 to 190.76.255.191/26 ——— 1023th subnet

190.76.255.192/26 to 190.76.255.255/26 ——— 1024th subnet

4. (c)

Only 14 hosts exists in the network. Therefore only 4 bits are sufficient for host bits.

The remaining 4 bits (MSB bits) of the last octet are part of Network ID.

Therefore the mask would be - 255.255.255.240

5. (b)

IPv6 uses 128 bit address, where as IPv4 uses 32 bit address.

6. (b)

An IPv6 address is represented as eight groups of 4 hexadecimal digits, each group representing 16 bits (2 octets). The groups are separated by colons (:).

∴ Option (b) is correct

7. (a)

In the Broadcast Address, All the host bits need to be 1.

Network ID is the result obtained after bitwise AND operation of IP and Net Mask.

```
        160.168.30.100
        255.255.240.0
        -------------
i.e.    160.168.16.00
```

By expanding 3rd octet we observe

```
16:  0001      0000
     └──┘      └──┘
   Network     Host
    bits       bits
```

∴ Broadcast address is 160.168.31.255 obtained by placing 1's in host bits.

8. (c)

```
IP Address : 159.133.7.220
      Mask:  255.255.252.0
             -------------
             159.133.4.0
```

Boolean AND operation

The subnetwork is 159.133.4.0.

9. (96)

The IP address 200.25.80.67 belongs to class C network. Therefore network ID is 200.25.80.0 and DBA is 200.25.80.255.

The binary representation contains:

11001000.00011001.01010000.00000000

⇒ 24 0's in network ID

11001000.00011001.01010000.11111111

⇒ 16 0's in network IP

∴ $24 \log_2 16 = 24 \times 4 = 96$

10. (222)

Since the subnet mask is 255.255.255.224 that means the first 3 bits of subnet are reserved for subnet id and rest 5 are host id bits.