1. Consider a virtual-circuit network. Suppose the VC number is a 16-bit field.

   (a) What is the maximum number of virtual circuits that can be carried over a link?
   Maximum number of VCs over a link = $2^16 = 65{,}536$.

   (b) Suppose a central node determines paths and VC numbers at connection setup. Suppose the same VC number is used on each link along the VC's path. Describe how the central node might determine the VC number at connection setup. Is it possible that there are fewer VCs in progress than the maximum as determined in part (a) yet there is no common free VC number?
   The centralized node could pick any VC number which is free from the set $\{0,1,\ldots,2^{16}-1\}$. In this manner, it is not possible that there are fewer VCs in progress than 65,536 without there being any common free VC number.

   (c) Suppose that different VC numbers are permitted in each link along a VC-s path. During connection setup, after an end-to-end path is determined, describe how the links can choose their VC numbers and configure their forwarding tables in a decentralized manner, without reliance on a central node.
   Each of the links can independently allocate VC numbers from the set $\{0,1,\ldots,2^{16}-1\}$. Thus, a VC will likely have a different VC number for each link along its path. Each router in the VC's path must replace the VC number of each arriving packet with the VC number associated with the outbound link.

2. Consider a router with a switch fabric, 2 input ports (A and B) and 2 output ports (C and D). Suppose the switch fabric operates at 1.5 times the line speed.

   (a) If, for some reason, all packets from A are destined to D, and all packets from B are destined to C, can a switch fabric be designed so that there is no input port queueing? Explain why or why not in one sentence.
   No. To have no input port queuing, the switching fabric should operate at a speed at least 2 times the line speed.

   (b) Suppose now packets from A and B are randomly destined to both C and D. Can a switch fabric be designed so that there is no input port queueing? Explain why or why not in one sentence.
   No. To have no input port queuing, the switching fabric should operate at a speed at least 2 times the line speed.

3. Consider a router that interconnects three subnets: Subnet 1, Subnet 2, and Subnet 3. Suppose all of the interfaces in each of these three subnets are required to have the prefix 245.2.15/24. Also suppose that Subnet 1 is required to support 123 interfaces, and Subnets 2 and 3 are required to support 60 interfaces each. Provide three network addresses (in the form of a.b.c.d/x) that satisfy these constraints.
   245.2.15.0/25
   245.2.15.128/26
   245.2.15.192/26

4. Suppose an ISP owns the block of addresses of the form 134.193.128/17. Suppose it wants to create 4 subnets from this block, with each block having the same number of IP addresses. What are the prefixes (of form a.b.c.d/x) for the 4 subnets?
Four equal size subnets: 134.193.128.x/19, 134.193.160.x/19, 134.193.192.x/19, 134.193.224.x/19
Since the subnet is divided in the third byte, the fourth byte of the address can be any number.

5. Suppose a small business network using NAT is connected to a router that has an external WAN IP address of 126.13.89.67. There are three hosts connected to the network, which has an internal address of 192.168/16. The internal addresses are 192.168.0.1, 192.168.0.2, and 192.168.0.3 for each host. The router internal address is 192.168.0.4.

   (a) Suppose the host located at 192.168.0.2 requests *two* TCP connections to a web server located at 128.119.40.68. The two connections are to be to the hosts local ports 3400 and 3401.
   Show valid source and destination IP addresses and port numbers for each of the 2 connection requests on both the LAN and WAN side of the router (start numbering NAT port assignments at port 5000).

LAN		WAN	
Source	Dest.	Source	Dest
192.168.0.2, 3400	128.119.40.68, 80	126.13.89.67, 5000	128.119.40.68, 80
192.168.0.2, 3401	128.119.40.68, 80	126.13.89.67, 5001	128.119.40.68, 80

6. A 4,540 octet datagram with ID = 142 and which includes a 20 octet IP header is to be transmitted across several networks from source to destination. An intermediate network can handle payloads of only 1,508 octets. Therefore the original IP packet needs to be fragmented. Show the data length, ID, more flag, and fragment offset field for the resulting IP fragments.

Segment	Length	ID	Flag	Offset
1	1508	142	1	0
2	1508	142	1	186
3	1508	142	1	372
4	76	142	0	558

7. A small company is assigned a network address of 128.243.14/24. The network administrator is asked to divide the network into 3 subnetworks. Subnetwork A must have an address space of 128 and subnetworks B and C must have an address space of 64 each. Show the address and mask $xxx.xxx.xxx.xxx/b$ for each of the 3 subnetworks (Label A, B, C).
128.243.14.0/25
128.243.14.128/26
128.243.14.192/26

8. An extended LAN consists of 3 single LAN segments (A, B, and C) connected together by a single switch. The data rate on each LAN segment is 100Mbps. There are 3 stations on segment A, 4 on segment B, and 5 on segment C. The network administrator observes the following traffic patterns in the extended LAN.
   A− >B = 0.2, A− >C =0.5
   B− >A = 0.3, B− >C =0.4
   C− >A = 0.2, C− >B =0.1
   Given that all stations have data to send, what is the maximum data rate for each station on each LAN?

$$
\begin{aligned}
3X_A + 0.3 * 4X_B + 0.2 * 5X_C &= 100 \\
4X_B + 0.2 * 3X_A + 0.1 * 5X_C &= 100 \\
5X_C + 0.5 * 3X_A + 0.4 * 4X_B &= 100
\end{aligned}
$$

$X_A = 22.86401925Mbps, X_B = 20.75812274Mbps, X_C = 6.498194946Mbps$

9. In a packet switched network with distance vector routing, node 1's table is initialized as follows: Node 1 next receives the following cost vector updates from its neighbors:

Table 1: Node 1 routing table

Destination Node	Cost	Next Node
1	0	–
2	4	2
3	2	3
4	3	4
5	∞	–
6	∞	–
7	∞	–

What does Node 1's routing table look like after the update?

Table 2: Node Cost Vectors

Node	Node 2	Node 3	Node 4
1	3	1	1
2	0	5	2
3	4	0	1
4	1	6	0
5	5	10	5
6	4	2	5
7	2	7	2

10. For the following graph G, use Dijkstra's algorithm to find the shortest paths from a to all other nodes. You must show all steps (iterations) starting with all temporary labels equal to ∞. And clearly showing which labels become permanent at each iteration and which nodes get temporary labels at each iteration.