Chapter 12. Analyzing Classful IPv4 Networks

This chapter covers the following exam topics:

Troubleshooting

Troubleshoot and correct common problems associated with IP addressing and host configurations.

When operating a network, you often start investigating a problem based on an IP address and mask. Based on the IP address alone, you should be able to determine several facts about the Class A, B, or C network in which the IP address resides. These facts can be useful when troubleshooting some networking problems.

This chapter lists the key facts about classful IP networks and explains how to discover these facts. Following that, this chapter lists some practice problems. Before moving to the next chapter, you should practice until you can consistently determine all these facts, quickly and confidently, based on an IP address.

"Do I Know This Already?" Quiz

Use the "Do I Know This Already?" quiz to help decide whether you might want to skim this chapter, or a major section, moving more quickly to the "Exam Preparation Tasks" section near the end of the chapter. You can find the answers at the bottom of the page following the quiz. For thorough explanations, see DVD Appendix C, "Answers to the 'Do I Know This Already?' Quizzes."

Table 12-1. "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
Classful Network Concepts	1–6

1. Which of the following are not valid Class A network IDs? (Choose two answers.)
   a. 1.0.0.0
   b. 130.0.0.0
   c. 127.0.0.0
   d. 9.0.0.0
2. Which of the following are not valid Class B network IDs?
   a. 130.0.0.0
   b. 191.255.0.0
   c. 128.0.0.0
   d. 150.255.0.0
   e. All are valid Class B network IDs
3. Which of the following are true about IP address 172.16.99.45's IP network? (Select two answers.)
   a. The network ID is 172.0.0.0.

b. The network is a Class B network.

c. The default mask for the network is 255.255.255.0.

d. The number of host bits in the unsubnetted network is 16.

4. Which of the following are true about IP address 192.168.6.7's IP network? (Select two answers.)

a. The network ID is 192.168.6.0.

b. The network is a Class B network.

c. The default mask for the network is 255.255.255.0.

d. The number of host bits in the unsubnetted network is 16.

5. Which of the following is a network broadcast address?

a. 10.1.255.255

b. 192.168.255.1

c. 224.1.1.255

d. 172.30.255.255

6. Which of the following is a Class A, B, or C network ID?

a. 10.1.0.0

b. 192.168.1.0

c. 127.0.0.0

d. 172.20.0.1

Answers to the "Do I Know This Already?" quiz:

Foundation Topics

Classful Network Concepts

Imagine that you have a job interview for your first IT job. As part of the interview, you're given an IPv4 address and mask: 10.4.5.99, 255.255.255.0. What can you tell the interviewer about the classful network (in this case, the Class A network) in which the IP address resides?

This section, the first of two major sections in this chapter, reviews the concepts of *classful IP networks* (in other words, Class A, B, and C networks). In particular, this chapter examines how to begin with a single IP address and then determine the following facts:

- Class (A, B, or C)
- Default mask
- Number of network octets/bits
- Number of host octets/bits
- Number of host addresses in the network
- Network ID
- Network broadcast address

• First and last usable address in the network

IPv4 Network Classes and Related Facts

IP version 4 (IPv4) defines five address classes. Three of the classes, Classes A, B, and C, consist of unicast IP addresses. Unicast addresses identify a single host or interface so that the address uniquely identifies the device. Class D addresses serve as multicast addresses, so that one packet sent to a Class D multicast IPv4 address can actually be delivered to multiple hosts. Finally, Class E addresses are experimental.

The class can be identified based on the value of the first octet of the address, as shown in Table 12-2.

Key Topic

Table 12-2. IPv4 Address Classes Based on First Octet Values

Class	First Octet Values	Purpose
A	1–126	Unicast (large networks)
B	128–191	Unicast (medium-sized networks)
C	192–223	Unicast (small networks)
D	224–239	Multicast
E	240–255	Experimental

CCENT and CCNA focus mostly on the unicast classes (A, B, and C) rather than Classes D and E. After you identify the class as either A, B, or C, many other related facts can be derived just through memorization. Table 12-3 lists that information for reference and later study; each of these concepts is described in this chapter.

Key Topic

Table 12-3. Key Facts for Classes A, B, and C

	Class A	Class B	Class C
First octet range	1 – 126	128 – 191	192 – 223
Valid network numbers	1.0.0.0 – 126.0.0.0	128.0.0.0 – 191.255.0.0	192.0.0.0 – 223.255.255.0
Total networks	$2^7 - 2 = 126$	$2^{14} = 16,384$	$2^{21} = 2,097,152$
Hosts per network	$2^{24} - 2$	$2^{16} - 2$	$2^8 - 2$
Octets (bits) in network part	1 (8)	2 (16)	3 (24)
Octets (bits) in host part	3 (24)	2 (16)	1 (8)
Default mask	255.0.0.0	255.255.0.0	255.255.255.0

Actual Class A, B, and C Networks

Table 12-3 lists the range of Class A, B, and C network numbers. However, some key points can be lost just referencing a table of information. This section examines the Class A, B, and C network numbers, focusing on the more important points and the exceptions and unusual cases.

First, the number of networks from each class significantly differs. Only 126 Class A networks exist: network 1.0.0.0, 2.0.0.0, 3.0.0.0, and so on, up through network 126.0.0.0. However, 16,384 Class B networks exist, with over 2 million Class C networks.

Next, note that the size of networks from each class also significantly differs. Each Class A network is relatively large—over 16 million host IP addresses per network—so they were originally intended to be used by the largest companies and organizations. Class B networks are smaller, with over 65,000 hosts per network. Finally, Class C networks, intended for small organizations, have 254 hosts in each network. Figure 12-1 summarizes those facts.

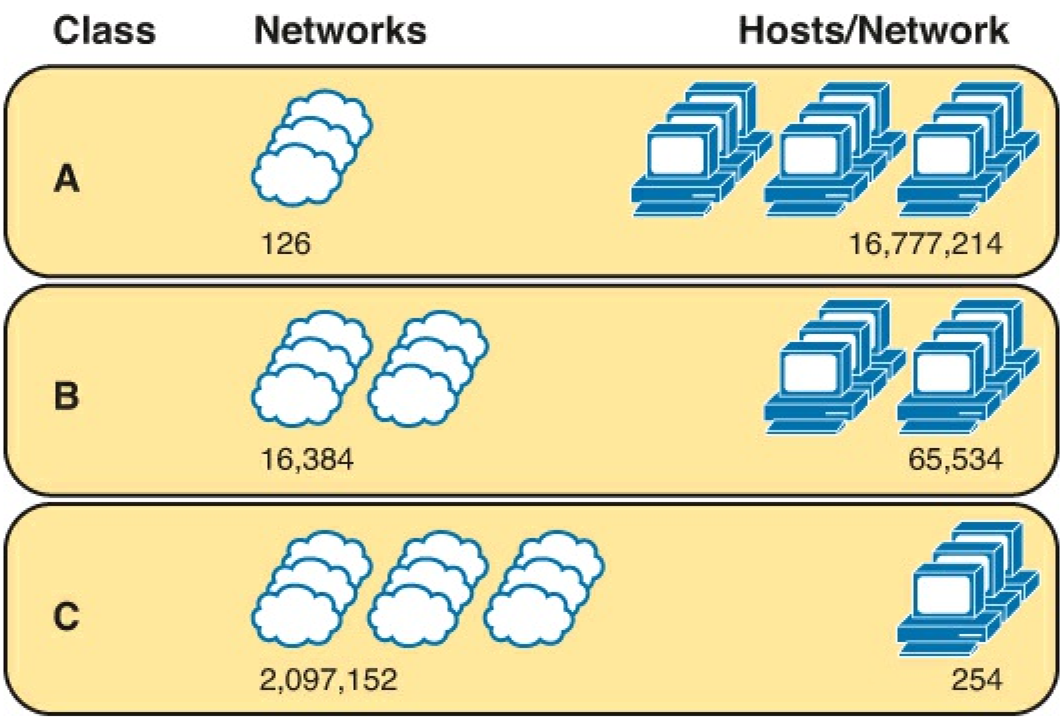

Figure 12-1. Numbers and Sizes of Class A, B, and C Networks

Address Formats

In some cases, an engineer might need to think about a Class A, B, or C network as if the network has not been subdivided through the subnetting process. In such a case, the addresses in the classful network have a structure with two parts: the *network part* (sometimes called the *prefix*) and the *host part*. Then, comparing any two IP addresses in one network, the following observations can be made:

Key Topic

The addresses in the same network have the same values in the network part.

The addresses in the same network have different values in the host part.

For example, in Class A network 10.0.0.0, by definition, the network part consists of the first octet. As a result, all addresses have an equal value in the network part, namely a 10 in the first octet. If you then compare any two addresses in the network, the addresses have a different value in the last three octets (the host octets). For example, IP addresses 10.1.1.1 and 10.1.1.2 have the same value (10) in the network part, but different values in the host part.

Figure 12-2 shows the format and sizes (in number of bits) of the network and host parts of IP addresses in Class A, B, and C networks, before any subnetting has been applied.

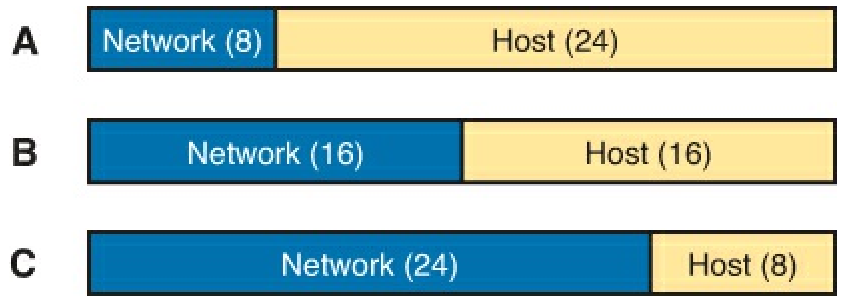

Figure 12-2. Sizes (Bits) of the Network and Host Parts of Unsubnetted Classful Networks

Default Masks

Although we humans can easily understand the concepts behind Figure 12-2, computers prefer numbers. To communicate those same ideas to computers, each network class has an associated *default mask* that defines the size of the network and host parts of an unsubnetted Class A, B, and C network. To do so, the mask lists binary 1s for the bits considered to be in the network part and binary 0s for the bits considered to be in the host part.

For example, Class A network 10.0.0.0 has a network part of the first single octet (8 bits) and a host part of last three octets (24 bits). As a result, the Class A default mask is 255.0.0.0, which in binary is

11111111 00000000 00000000 00000000

Figure 12-3 shows default masks for each network class, both in binary and dotted-decimal format.

Key Topic

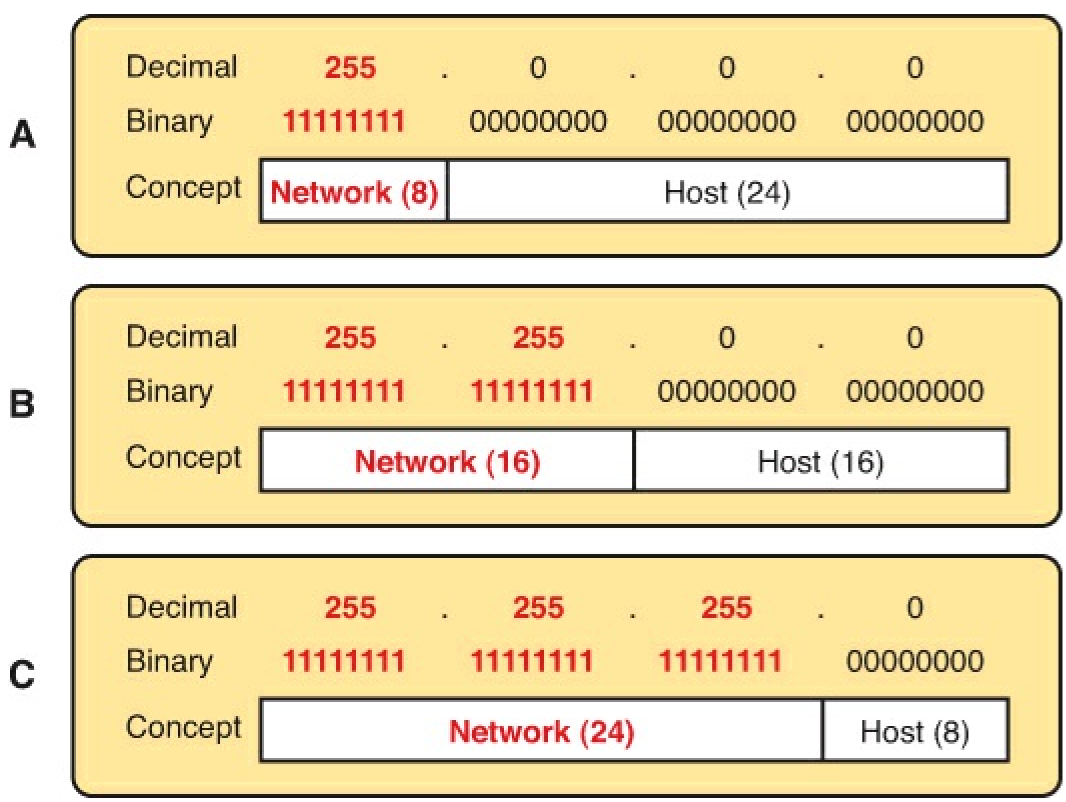

Figure 12-3. Default Masks for Classes A, B, and C

Note

Decimal 255 converts to the binary value 11111111. Decimal 0, converted to 8-bit binary, is 00000000. See Appendix A, "Numeric Reference Tables," for a conversion table.

Number of Hosts per Network

Calculating the number of hosts per network requires some basic binary math. First, consider a case where you have a single binary digit. How many unique values are there? There are, of course, two values: 0 and 1. With 2 bits, you can make four combinations: 00, 01, 10, and 11. As it turns out, the total combination of unique values you can make with N bits is 2^N.

Host addresses—the IP addresses assigned to hosts—must be unique. The host bits exist for the purpose of giving each host a unique IP address by virtue of having a different value in the host part of the addresses. So, with H host bits, 2^H unique combinations exist.

However, the number of hosts in a network is not 2^H; instead, it is $2^H - 2$. Each network reserves two numbers that would have otherwise been useful as host addresses, but have instead been reserved for special use: one for the network ID and one for the network broadcast address. As a result, the formula to calculate the number of host addresses per Class A, B, or C network is

Key Topic

$$2^H - 2$$

where H is the number of host bits.

Deriving the Network ID and Related Numbers

Each classful network has four key numbers that describe the network. You can derive these four numbers if you start with just one IP address in the network. The numbers are as follows:

- Network number
- First (numerically lowest) usable address
- Last (numerically highest) usable address
- Network broadcast address

First, consider both the network number and first usable IP address. The *network number*, also called the *network ID* or *network address*, identifies the network. By definition, the network number is the numerically lowest number in the network. However, to prevent any ambiguity, the people that made up IP addressing added the restriction that the network number cannot be assigned as an IP address. So, the lowest number in the network is the network ID. Then, the first (numerically lowest) host IP address is *one larger than* the network number.

Next, consider the network broadcast address along with the last (numerically highest) usable IP address. The TCP/IP RFCs define a network broadcast address as a special address in each network. This broadcast address could be used as the destination address in a packet, and the routers would forward a copy of that one packet to all hosts in that classful network. Numerically, a network broadcast address is always the highest (last) number in the network. As a result, the highest (last) number usable as an IP address is the address that is simply *one less than* the network broadcast address.

Simply put, if you can find the network number and network broadcast address, finding the first and last usable IP addresses in the network is easy. For the exam, you should be able to find all four values with ease; the process is as follows:

Key Topic

Step 1. Determine the class (A, B, or C) based on the first octet.

Step 2. Mentally divide the network and host octets based on the class.

Step 3. To find the network number, change the IP address's host octets to 0.

Step 4. To find the first address, add 1 to the fourth octet of the network ID.

Step 5. To find the broadcast address, change the network ID's host octets to 255.

Step 6. To find the last address, subtract 1 from the fourth octet of the network broadcast address.

The written process actually looks harder than it is. Figure 12-4 shows an example of the process, using Class A IP address 10.1.2.3, with the circled numbers matching the process.

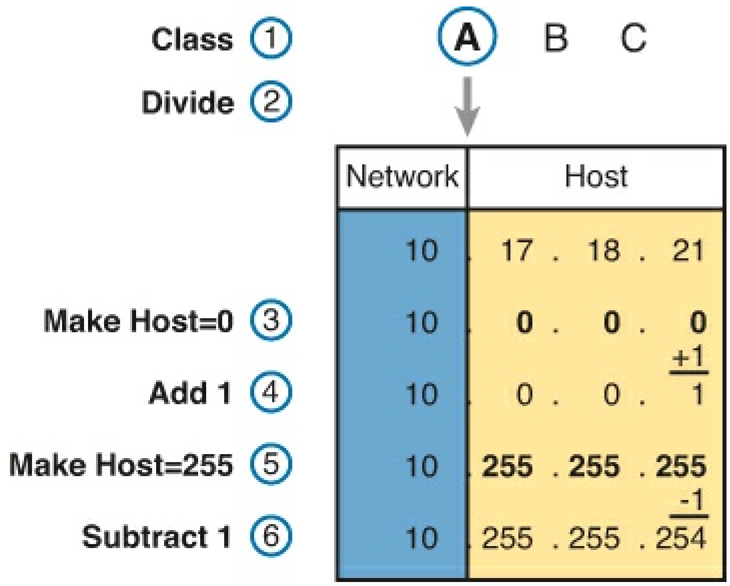

Figure 12-4. Example of Deriving the Network ID and Other Values from 10.17.18.21

Figure 12-4 shows the identification of the class as Class A (Step 1) and the number of network/host octets as 1 and 3, respectively. So, to find the network ID at Step 3, the figure copies only the first octet, setting the last three (host) octets to 0. At Step 4, just copy the network ID and add 1 to the fourth octet. Similarly, to find the broadcast address at Step 5, copy the network octets, but set the host octets to 255. Then, at Step 6, subtract 1 from the fourth octet to find the last (numerically highest) usable IP address.

Just to show an alternative example, consider IP address 172.16.8.9. Figure 12-5 shows the process applied to this IP address.

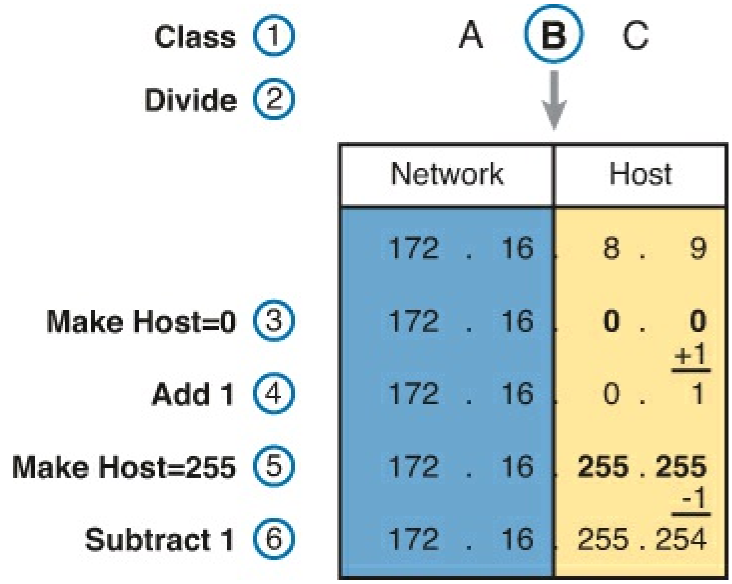

Figure 12-5. Example Deriving the Network ID and Other Values from 172.16.8.9

Figure 12-5 shows the identification of the class as Class B (Step 1) and the number of network/host octets as 2 and 2, respectively. So, to find the network ID at Step 3, the figure copies only the first two octets, setting the last two (host) octets to 0. Similarly, Step 5 shows the same action, but with the last two (host) octets being set to 255.

Unusual Network IDs and Network Broadcast Addresses

Some of the more unusual numbers in and around the range of Class A, B, and C network numbers can cause some confusion. This section lists some examples of numbers that make many people make the wrong assumptions about the meaning of the number.

For Class A, the first odd fact is that the range of values in the first octet omits the numbers 0 and 127. As it turns out, what would be Class A network 0.0.0.0 was originally reserved for some broadcasting requirements, so all addresses that begin with 0 in the first octet are reserved. What would be Class A network 127.0.0.0 is still reserved because of a special address used in software testing, called the loopback address (127.0.0.1).

For Class B (and C), some of the network numbers can look odd, particularly if you fall into a habit of thinking that 0s at the end means the number is a network ID, and 255s at the end means it's a network broadcast address. First, Class B network numbers range from 128.0.0.0 to 191.255.0.0, for a total of 2^{14} networks. However, even the very first (lowest number) Class B network number (128.0.0.0) looks a little like a Class A network number, because it ends with three 0s. However, the first octet is 128, making it a Class B network with a two-octet network part (128.0).

For another Class B example, the high end of the Class B range also might look strange at first glance (191.255.0.0), but this is indeed the numerically highest of the valid Class B network numbers. This network's broadcast address, 191.255.255.255, might look a little like a Class A broadcast address because of the three 255s at the end, but it is indeed the broadcast address of a Class B network.

Other valid Class B network IDs that look unusual include 130.0.0.0, 150.0.0.0, 155.255.0.0, and 190.0.0.0. All of these follow the convention of a value from 128 to 191 in the first octet, a value from 0 to 255 in the second octet, and two more 0s, so they are indeed valid Class B network IDs.

Class C networks follow the same general rules as Class B, but with the first three octets defining the network. The network numbers range from 192.0.0.0 to 223.255.255.0, with all addresses in a single network sharing the same value in the first three octets.

Similar to Class B networks, some of the valid Class C network numbers do look strange. For example, Class C network 192.0.0.0 looks a little like a Class A network because of the last three octets being 0, but because it is a Class C network, it consists of all addresses that begin with three octets equal to 192.0.0. Similarly, Class C network 223.255.255.0, another valid Class C network, consists of all addresses that begin 223.255.255.

Other valid Class C network IDs that look unusual include 200.0.0.0, 220.0.0.0, 205.255.255.0, and 199.255.255.0. All of these follow the convention of a value from 192 to 223 in the first octet, a value from 0 to 255 in both the second and third octets, and a 0 in the fourth octet.

Practice with Classful Networks

As with all areas of IP addressing and subnetting, you need to practice to be ready for the CCENT and CCNA exams. Before the exam, you should master the concepts and processes in this chapter and be able to get the right answer every time—with speed. I cannot overemphasize the importance of mastering IP addressing and subnetting for the exams: Know the topics, and know them well.

However, you do not need to completely master everything in this chapter right now. You should practice some now to make sure that you understand the processes, but you can use your notes, use this book, or whatever. After you practice enough to confirm you can get the right answers using any help available, you understand the topics in this chapter well enough to move to the next chapter.

Then, before the exam, practice until you master the topics in this chapter and can move pretty fast. Table 12-4 summarizes the key concepts and suggestions for this two-phase approach.

Table 12-4. Keep-Reading and Take-Exam Goals for This Chapter's Topics

Time Frame	After Reading This Chapter	Before Taking the Exam
Focus On...	Learning how	Being correct and fast
Tools Allowed	All	Your brain and a notepad
Goal: Accuracy	90% correct	100% correct
Goal: Speed	Any speed	10 seconds

Practice Deriving Key Facts Based on an IP Address

Practice finding the various facts that can be derived from an IP address, as discussed throughout this chapter. To do so, complete Table 12-5.

Table 12-5. Practice Problems: Find the Network ID and Network Broadcast

	IP Address	Class	Number of Network Octets	Number of Host Octets	Network ID	Network Broadcast Address
1	1.1.1.1					
2	128.1.6.5					
3	200.1.2.3					
4	192.192.1.1					
5	126.5.4.3					
6	200.1.9.8					
7	192.0.0.1					
8	191.255.1.47					
9	223.223.0.1					

The answers are listed in the section "Answers to Earlier Practice Problems," later in this chapter.

Practice Remembering the Details of Address Classes

Tables 12-2 and 12-3, shown earlier in this chapter, summarized some key information about IPv4 address classes. Tables 12-6 and 12-7 show sparse versions of these same tables. To practice recalling those key facts, particularly the range of values in the first octet that identifies the address class, complete these tables. Then, refer to Tables 12-2 and 12-3 to check your answers. Repeat this process until you can recall all the information in the tables.

Table 12-6. Sparse Study Table Version of Table 12-2

Class	First Octet Values	Purpose
A		
B		
C		
D		
E		

Table 12-7. Sparse Study Table Version of Table 12-3

	Class A	Class B	Class C
First octet range			
Valid network numbers			
Total networks			
Hosts per network			
Octets (bits) in network part			
Octets (bits) in host part			
Default mask			

Additional Practice

For additional practice with classful networks, consider the following:

- DVD Appendix D, "Practice for Chapter 12: Analyzing Classful IPv4 Networks," has additional practice problems. This appendix also includes explanations about how to find the answer of each problem.
- Create your own problems. You can randomly choose any IP address and try to find the same information asked for by the practice problems in this section. Then, to check your work, use any subnet calculator. Most subnet calculators list the class and network ID.

Exam Preparation Tasks

Review All the Key Topics

Review the most important topics from this chapter, noted with the Key Topic icon. Table 12-8 lists these key topics and where each is discussed.

Key Topic

Table 12-8. Key Topics for Chapter 12

Key Topic Elements	Description	Page Number
Table 12-2	Address classes	335
Table 12-3	Key facts about Class A, B, and C networks	335
List	Comparisons of network and host parts of addresses in the same classful network	336
Figure 12-3	Default masks	337
Paragraph	Function to calculate the number of hosts per network	338
List	Steps to find information about a classful network	338

Complete the Tables and Lists from Memory