how to master

SUBNETTING

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Introduction

Binary and hexadecimal numbers are a complete mystery for many of us. Often we don't find it really interesting because on the internet there are plenty of "subnet" or "binary" calculators where you can easily calculate from decimal to binary to hexadecimal or the other way around, without knowing how the exact calculation works.

This is no problem when you are not configuring or designing networks on a daily basis, but it will be a problem as soon as you take a networking exam, so it's best to know how to do these calculations off the top of your head.

Another advantage you will have is once you have mastered the art of binary calculations you can immediately "see" how big a network is and what the subnet mask is when people start throwing numbers at you.

One of the things I do in life is work as a Cisco Certified System Instructor (CCSI) and I noticed many people have trouble finding out what the subnet mask is, how many hosts are in a subnet, how to do summarization and so they fail at passing exams like CCNA or CCNP. Anyone working with networks on a professional level should be able to do binary calculations if you ask me.

This book will teach you how to calculate subnets and subnet masks, how to calculate the numbers of hosts available etc. for class A,B and C networks. And the best part: **You will be able to do this off the top of your head, no need to write stuff down!** Once you have mastered the tricks in this book you will wonder why you ever had difficulty solving subnetting questions :)

Enjoy reading my book and good luck mastering your binary and subnetting skills!

René Molenaar

P.S. There are 10 types of people in the world: Those that understand ***binary***, and those who don't!

P.P.S. If you have any questions or comments about this book, please let me know:

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1. Binary Basics

Before we start calculating subnets and talk about IP addressing, let's first check out some basics of binary calculations. We are all used to work with decimal numbers where we count from 1 till 10. This is easy because we have 10 fingers so we don't have to count off the top of our head.

In the binary system, we only work with 0 or 1.

0 = Off
1 = On

Bits	128	64	32	16	8	4	2	1

The bit on the far left side is called the most significant bit (MSB) because this bit has the highest value. The bit on the far right side is called the least significant bit (LSB) because this one has the lowest value.

So how do we convert decimal numbers into binary? Let me show you an example:

If we want the decimal number "0" in binary this means we leave all the bits "off".

Bits	128	64	32	16	8	4	2	1
0	0	0	0	0	0	0	0	0

Let's take the number 178 and turn it into binary, just start at the left and see which bits "fit in" to make this number. 128 + 32 + 16 + 2 = 178.

Bits	128	64	32	16	8	4	2	1
178	1	0	1	1	0	0	1	0

Just one more! Let's turn 255 into binary. 128 + 64 + 32 + 16 + 8 + 4 + 2 +1 = 255

Bits	128	64	32	16	8	4	2	1
255	1	1	1	1	1	1	1	1

As you can see 255 is the highest decimal number you can create when you have 8 bits to play with.

As you can see, whenever you add a bit, the decimal value doubles. For example: 2,4,8,16,32,64,128,256,512,1024,2048 and so on. This is called the "powers of 2".

This is a good moment to create your own "cheat sheet" . Take a piece of paper and write down the 8 bits for yourself.

Exercise 1:

See if you can solve the following decimal to binary calculations:

Bits	128	64	32	16	8	4	2	1
12								
54								
187								
192								
44								
147								

Now try to do it the other way around and calculate from binary to decimal:

Bits	128	64	32	16	8	4	2	1
	1	1	0	0	1	0	1	0
	0	0	1	1	1	0	0	1
	0	1	0	1	0	1	0	1
	1	1	1	1	0	0	1	1
	0	0	1	0	0	0	0	1
	1	0	0	0	0	1	1	1

The appendix of this book will show you the answers.

2. Welcome to Subnetting

Before we start calculating subnets, the first thing we need to do is take a look at what subnets and IP addresses are.

An IP address is a numeric value that you configure on every device in a network, think about computers, laptops, servers but also networking equipment like routers, firewalls and switches. The IP address identifies every device with a "unique" number. Devices within the same IP subnet are able to communicate without using a router.

Let's take a look at some of the terminology you might encounter when we talk about IP addresses:

IP Terminology:

Bit(s)	A bit has 2 possible values, 1 or 0. (on or off)
Byte	A byte is 8 bits.
Octet	An octet is just like a byte 8 bits, you often see byte or octet both being used.
Nibble	A nibble is 4 bits, we'll talk about this more in the Hexadecimal chapter.
Network address	When we talk about routing, the network address is important. Routers use the network address to send IP packets to the right destination. 192.168.1.0 with subnet mask 255.255.255.0 is an example of a network address.
Subnet	A subnet is a network that you split up in multiple smaller subnetworks.
Broadcast address	The broadcast address is being used by applications and computers to send information to all devices within a subnet, 192.168.1.255 with subnet mask 255.255.255.0 is an example of a broadcast address.

Hierarchical IP addressing:

IP addresses are 32 bits, divided in 4 "blocks" also known as 4 bytes or octets. Every byte has 8 bits. 4x8 = 32 bits.

There are many ways to write down an IP address:

Decimal:	192.168.1.1
Binary:	11000000.10101000.0000001.0000001
Hexadecimal:	C0.A8.01.01

Decimal is what we are used to work with, as this is the way you normally configure an IP address in operating systems like Microsoft Windows, Linux or most networking equipment. Hexadecimal you won't see often but for example you might encounter this in the windows registry.

IP addresses are hierarchical unlike non-hierarchical addresses like MAC-addresses. This has some advantages, you can use a lot of IP addresses (with 32 bits the biggest number you can create is 4,3 billion or to be precise 4,294,967,296). The advantage of having a hierarchical model is needed for routing, imagine that every router on the planet would need to know every IP address on the planet. Routing wouldn't be very efficient that way…

A better solution is a hierarchical model where we use "network", "subnet" and "hosts".

Try to compare this to phone numbers:

0031	This is the country code for The Netherlands
013	This is the city code for Tilburg
1234567	This is a single number for a customer.

The complete phone number is 0031-013-1234567.

IP addresses use a similar hierarchical structure.

<u>Network addresses:</u>

Every subnet has 1 network address!

The network address is a unique identification of the network. Every device within the same subnet shares this network address in its IP address, for example:

192.168.100.1
192.168.100.2
192.168.100.3

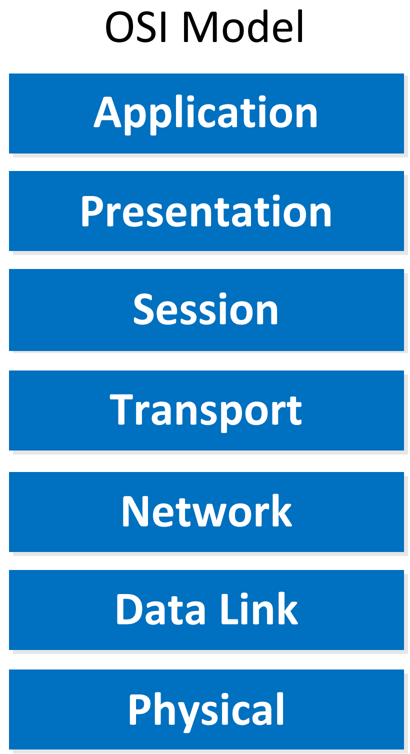
192.168.100. is the network address and .1, .2 and .3 are host addresses. The IP address will tell you in what subnet they are located. The network address has to be the same for all the hosts; the host part has to be unique. When the Internet was invented they created different "classes" of networks each with a different size. At this moment there are 3 classes that are important to us:

	8 bits	**8 bits**	**8 bits**	**8 bits**
Class A:	Network	Host	Host	Host
Class B:	Network	Network	Host	Host
Class C:	Network	Network	Network	Host
Class D:	Multicast			
Class E:	Research			

Broadcast addresses:

Every subnet has 1 broadcast address!

When we talk about broadcasts in IP world, we talk about layer3 broadcasts. In case you have no idea what I'm talking about…take a look at the OSI model:



The OSI model describes a layered approach of a network, getting into the details of all the different layers of the OSI model is outside the scope of the book, but to get an understanding of broadcasts it's important to look at layer 2 and layer 3.

There's a layer2 and layer3 broadcast, and there's a big difference between them. When we look at a LAN (Local Area Network) we are probably using Ethernet. MAC addresses are used to uniquely identify a network device, for example: 00:50:56:c0:00:08 is a MAC address that uniquely identifies my computer. On a LAN it's possible to send a layer 2 broadcast so that all computers on the LAN segment will receive this message (Ethernet Frame). The destination MAC address would be FF:FF:FF:FF:FF:FF (when you read the hexadecimal chapter you'll see that FF:FF:FF:FF:FF:FF is a string with only 1's in binary).

Now let's take a look at a layer 3 broadcast. Layer 3 is where we talk about IP addressing, and we can also send a broadcast. For example take the 192.168.1.0 network.

192.168.1.255 for this subnet is the broadcast address, this means when we send an IP packet to 192.168.1.255 that all hosts on this subnet will receive this packet. Pretty neat right? Some old applications might still use this form of communication.

Class A:

Back to our network addresses, let's take a look at Class A. The first bit always has to be a 0. This leaves us 7 bits to "play" with. The lowest value you can create by changing all bits to "0" is 0. By changing all 7 bits to "1" you get 127.

Bits	128	64	32	16	8	4	2	1
0	0	0	0	0	0	0	0	0
127	0	1	1	1	1	1	1	1

64 + 32 + 16 + 8 + 4 + 2 + 1 = 127.

As you can see the Class A range is between 0 and 127.

Class B:

For a class B network the first bit has to be a 1. The second bit has to be a 0.

Bits	128	64	32	16	8	4	2	1
128	1	0	0	0	0	0	0	0
191	1	0	1	1	1	1	1	1

128 + 32 + 16 + 8 + 4 + 2 +1 = 191

As you can see class B networks always start with 128 and the last network is 191.

Class C:

For a class C network the first bit has to be a 1, the second bit a 1 and the third a 0.

Bits	128	64	32	16	8	4	2	1
192	1	1	0	0	0	0	0	0
223	1	1	0	1	1	1	1	1

128 + 64 = 192

128 + 64 + 16 + 8 + 4 + 2 + 1 = 223

As you can see Class B networks start at 192 and the last network is 223.

Class D and E:

There is also a class D for multicast traffic which starts at 224 and ends at 239. Class E is for "research usage". We are not going to use these classes for our binary calculations.

Class A Addressing:

A class A network has 1 byte reserved for the network address which means the other 3 bytes are left for hosts. This means we have a couple of networks and every network can have a lot of hosts (how to determine how many hosts each network has we will see later!).

Byte	Byte	Byte	Byte
Network	Hosts	Hosts	Hosts

If we look at the IP address 53.21.43.63 then "53" is the network address and "21.43.63" is the host address, all machines on this subnet will have the "53" as network address.

Byte	Byte	Byte	Byte
Network	Hosts	Hosts	Hosts
53.	21.	43.	63

Class B Addressing:

A class B network has 2 bytes reserved for the network address which means the other 2 bytes are left for hosts. This means we have even more networks but less hosts per network compared to class A.

Byte	Byte	Byte	Byte
Network	Network	Hosts	Hosts

For example, 172.16.100.68, the network address is 172.16. and the host address is 100.68.

Byte	Byte	Byte	Byte
Network	Network	Hosts	Hosts
172.	16.	100.	68

Class C Addressing:

A class C network has 3 bytes reserved for the network address which means the other byte is left for hosts. Now we have a lot of networks but only a few hosts per network.

Byte	Byte	Byte	Byte
Network	Network	Network	Hosts

Another example, 192.168.200.53, the network address is 192.168.200. and the host address is .53.

Byte	Byte	Byte	Byte
Network	Network	Network	Hosts
192.	168.	200.	53

Private IP addressing

There is a difference between public and private IP addresses. The people who invented the IP addressing scheme decided it would be a good idea to have a range of networks that are not routable on the internet. Now this isn't entirely true, I should say "should not be routed on the internet". It's up to the service providers to filter these networks.

If every device on the planet would require a unique IP address then we would have already run out of address space by now. Instead, there are some private ranges you can use for your internal networks and these are not accessible from the internet. Now perhaps you are wondering why you are able to access the internet from your home computer?

The answer to this question is that you have 1 public IP address that you got from your internet provider, and all your home computers have private IP addresses. Your router runs NAT (Network address Translation) and makes sure all private IP addresses will be translated to your single public IP address. This way all computers can access the internet by using a single private IP address! (and we can all browse/surf the internet all day long…)

These are the Private IP address ranges:

Class A:	10.0.0.0 – 10.255.255.255
Class B:	172.16.0.0 – 172.31.255.255
Class C:	192.168.0.0 – 192.168.255.255

If you made it through this chapter and you understand everything….very good! When in doubt please reread this chapter since it's important you understand everything before continuing, since we are going to start calculating subnets…ready? Let's go!

3. Subnetting: The beginning

Let’s take a Class C network and take a good look at it, so we can play around with binary numbers.

For example: 192.168.1.0

In binary it looks like this:

	192	168	1	0
IP address	**11000000**	10101000	00000001	00000000

In the previous chapter I explained that a class C network consists of 3 bytes for the network part, and one byte for hosts:

Byte	Byte	Byte	Byte
Network	**Network**	**Network**	**Hosts**
192.	**168.**	**1.**	**0**

Now the question is…how does a network device know which part is the network-part, and which side is the host-part? Is it because it’s a Class C network? Is it some secret rule that everyone just knows about?

The answer is no, we use something called a subnet mask! For this network, it would be the following subnet mask:

255.255.255.0

Now what does this subnet mask exactly do? The word “mask” might tell you that it must mean that it’s hiding something…but that is not the case, and to show you the answer we have to look at some binary numbers:

IP address (decimal)	192	168	1	0
IP address (binary)	11000000	10101000	00000001	00000000
Subnet mask (decimal)	**255**	**255**	**255**	**0**
Subnet mask (binary)	11111111	11111111	11111111	00000000

The subnet mask will specify which part of the IP address is the network-part and which part is the host-part. The 1 means it’s the network-part, the 0 means the host-part.

To clarify this let me just take the binary numbers, the subnet mask tells you the first 24 bits are the network-address and the 8 bits that are left we can use for hosts.

IP address	11000000	10101000	00000001	00000000
Subnet mask	11111111	11111111	11111111	00000000

For our 192.168.1.0 example this means 24 bits are reserved for network and 8 bits are reserved for hosts.

Let’s write down those 8 host-bits:

	128	64	32	16	8	4	2	1

What’s the highest value you can create with 8 bits? Let’s have a look:

128 + 64 + 32 + 16 + 8 + 4 + 2 +1 = 255

	128	64	32	16	8	4	2	1
255	1	1	1	1	1	1	1	1

Cool! So now we know that with 8 bits the highest value we can create is 255, does this mean we can have 255 hosts in this network? The answer is no because for every network there are 2 addresses we can’t use:

1) Network address: this is the address where all the host bits are set to 0.

IP address	192	168	1	0
	11000000	10101000	00000001	00000000

2) Broadcast address: this is the address where all the host bits are set to 1.

IP address	192	168	1	255
	11000000	10101000	00000001	11111111

*The network address has all hosts bits set to **0**!*
*The broadcast address has all host bits set to **1**!*

Alright so let’s take 255 – 2 = 253. Does this mean we can have a maximum of 253 hosts on our network?

The answer is still no! I messed with your head because the highest value you can create with 8 bits is not 255 but 256. Why? Because you can also use a value of “0”.

Does this make your head spin? Let's take a look at our 192.168.1.0 network in binary:

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**0**
	11111111	11111111	11111111	00000000

Network	192	168	1	0
	11000000	10101000	00000001	00000000

Broadcast	192	168	1	255
	11000000	10101000	00000001	11111111

The network address has all host bits set 0, so in decimal this is 0.
The broadcast address has all host bits set to 1, so in decimal this is 255.

This means everything in between we can use for hosts, 1 – 254 so that's 254 valid IP addresses we can use to configure hosts!

Don't start counting at "1", but start counting at "0". The "0" is a valid number.

Great! So now you have seen what a network looks like in binary, what the subnet mask does, what the network and broadcast addresses are and that we can fit in 254 hosts in this Class C network.

Now let's say I don't want to have a single network where I can fit In 254 hosts, but I want to have 2 networks? Is this possible? It sure is! Basically what we are doing is taking a Class C network and chop it in 2 pieces, and this is what we call subnetting. Let's take a look at it in binary:

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**0**
	11111111	11111111	11111111	00000000

If we want to create more subnets we need to borrow bits from the host-part. For every bit you borrow you can double the number of subnets, by borrowing 1 bit we create 2 subnets out of this single network. There are 8 host-bits so if we steal one to create more subnets this means we have only 7 bits left for hosts.

What will the new subnet mask be? Let's take a look at it in binary:

Subnet mask	255	255	255	128
	11111111	11111111	11111111	10000000

The first 24 bits are the same so we only have to look at the 4th octet, let's write down those bits:

128	64	32	16	8	4	2	1
1	0	0	0	0	0	0	0

Calculate it back to decimal and you'll have 128. The subnet mask will be 255.255.255.128.

The second question is, how "big" are these 2 subnets and how many hosts can we fit in?

128	64	32	16	8	4	2	1
N/A	1	1	1	1	1	1	1

We have 7 bits left so let's do the binary to decimal calculation:

64 + 32 + 16 + 8 + 4 + 2 +1 = 127.

Don't forget about the 0! Because we can use the 0 the highest value we can create with 7 bits is 128.

Our original class C network has now been divided in 2 subnets with a size of 128 each. So what will the network addresses of the 2 new subnets be? Let's work this example out in binary:

Subnet #1:

By applying the new subnet mask we only have **7 host bits** to play with.

192.168.1.0
255.255.255.128

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**128**
	11111111	11111111	11111111	10000000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.0

Network	192	168	1	0
	11000000	10101000	00000001	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.1

Network	192	168	1	1
	11000000	10101000	00000001	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.126

Network	192	168	1	126
	11000000	10101000	00000001	01111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.127

Broadcast	192	168	1	127
	11000000	10101000	00000001	01111111

<u>Subnet #2:</u>

The first subnet ended at 192.168.1.127 so we just continue with the next subnet at 192.168.1.128:

192.168.1.128
255.255.255.128

IP address	192	168	1	128
	11000000	10101000	00000001	10000000
Subnet mask	**255**	**255**	**255**	**128**
	11111111	11111111	11111111	10000000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.128

Network	**192**	**168**	**1**	**128**
	11000000	10101000	00000001	10000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.129

Network	**192**	**168**	**1**	**129**
	11000000	10101000	00000001	10000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.254

Network	**192**	**168**	**1**	**254**
	11000000	10101000	00000001	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.255

Broadcast	**192**	**168**	**1**	**255**
	11000000	10101000	00000001	11111111

That's it! That's the first network we just subnetted in 2 subnets and we found out what the network and broadcast addresses are, and what IP addresses we can use for hosts.

Let me show you another one, we take the same Class C 192.168.1.0 network but now we want to have 4 subnets. For every host-bit we borrow we can double the number of subnets we can create, so by borrowing 2 host bits we can create 4 subnets.

Every "host-bit" you "borrow" doubles the number of subnets you can create.

What will the new subnet mask be? Let's take a look at it in binary:

Subnet mask	255	255	255	192
	11111111	11111111	11111111	11000000

Calculate it from binary to decimal: 128+64 = 192.

The new subnet mask will be 255.255.255.192.

Subnet #1:

By applying the new subnet mask we only have **6 host bits** to play with.

192.168.1.0
255.255.255.192

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**192**
	11111111	11111111	11111111	11000000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.0

Network	192	168	1	0
	11000000	10101000	00000001	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.1

Network	192	168	1	1
	11000000	10101000	00000001	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.62

Network	192	168	1	62
	11000000	10101000	00000001	00111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.63

Broadcast	192	168	1	63
	11000000	10101000	00000001	00111111

Subnet #2:

The first subnet ended at 192.168.1.63 so we just continue with the next subnet at 192.168.1.64:

192.168.1.64
255.255.255.192

IP address	192	168	1	64
	11000000	10101000	00000001	01000000
Subnet mask	**255**	**255**	**255**	**192**
	11111111	11111111	11111111	11000000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.64

Network	192	168	1	64
	11000000	10101000	00000001	01000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.65

Network	192	168	1	65
	11000000	10101000	00000001	01000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.126

Network	192	168	1	126
	11000000	10101000	00000001	01111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.127

Broadcast	192	168	1	127
	11000000	10101000	00000001	01111111

Subnet #3:

The second subnet ended at 192.168.1.127 so we just continue with the next subnet at 192.168.1.128:

192.168.1.128
255.255.255.192

IP address	192	168	1	128
	11000000	10101000	00000001	10000000
Subnet mask	**255**	**255**	**255**	**192**
	11111111	11111111	11111111	11000000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.128

Network	192	168	1	128
	11000000	10101000	00000001	10000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.129

Network	192	168	1	129
	11000000	10101000	00000001	10000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.190

Network	192	168	1	190
	11000000	10101000	00000001	10111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.191

Broadcast	192	168	1	191
	11000000	10101000	00000001	10111111

Subnet #4:

The second subnet ended at 192.168.1.191 so we just continue with the next subnet at 192.168.1.192:

192.168.1.192
255.255.255.192

IP address	192	168	1	192
	11000000	10101000	00000001	11000000
Subnet mask	**255**	**255**	**255**	**192**
	11111111	11111111	11111111	11000000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.192

Network	192	168	1	192
	11000000	10101000	00000001	11000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.193

Network	192	168	1	193
	11000000	10101000	00000001	11000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.254

Network	192	168	1	254
	11000000	10101000	00000001	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.255

Broadcast	192	168	1	255
	11000000	10101000	00000001	11111111

There we go! We just chopped down our 192.168.1.0 class C network into 4 subnets! If you understand everything up to this point…great job! Does this look like a lot of work? Honestly…yes it is!

I promise you to show you some tricks to calculate Class C, B and even A subnets without touching any binary numbers….and even better, you don't have to write stuff down you can do it off the top of your head.

The reason I don't show you this right away is that you need to understand what is happening "under the engine" before you can apply some shortcuts.

Exercise 2:

Now it's time for you to calculate some subnets, see if you can solve the following questions:

1. Take the 192.168.1.0 Class C network and create 8 subnets out of it. Write down the following information:
   a. The first 2 subnets.
   b. The network addresses.
   c. The broadcast addresses.
   d. The usable host IP addresses.
2. Take the 192.168.1.0 Class C network and create 16 subnets out of it. Write down the following information:
   a. The first 2 subnets.
   b. The network addresses.
   c. The broadcast addresses.
   d. The usable host IP addresses.

The appendix of this book will show you the answers.
Okay so we have played enough with Class C networks, let's try a Class B network. You'll see that it's exactly the same thing.

Let's take the 172.16.100.0 Class B network with subnet mask 255.255.0.0 and create 2 subnets out of it:

IP address	**172**	**16**	**100**	**0**
	11000000	00010000	01100100	00000000
Subnet mask	**255**	**255**	**0**	**0**
	11111111	11111111	00000000	00000000

If we want to create more subnets we need to borrow bits from the host-part. For every bit you borrow you can double the number of subnets, by borrowing 1 bit we create 2 subnets out of this single network. Now the difference with a Class C network is that we have more host-bits to play with, that's all.

What will the new subnet mask be? Let's take a look at it in binary:

Subnet mask	255	255	128	0
	11111111	11111111	10000000	00000000

As you can see the net subnet mask will be 255.255.128.0 and we have 7+8 = 15 host bits left to play with.

How "big" are these 2 subnets? Well we have 15 bits so let's take a look:

	16384	8192	4096	2048	1024	512	256	128	64	32	16	8	4	2	1
N/A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

16384 + 8192 + 4096 + 2048 + 1024 + 512 + 256 + 128 + 64 + 32 + 16 + 8 + 4 + 2 +1 = 32767.

Don't forget about the 0! So the highest value you can create with 15 bits is **32768**.

If you want to know to know how many usable host IP addresses you have, you take 32768 – 2 (because of the network and broadcast address).

32768 – 2 = 32766 usable host IP addresses. That's a lot of computers/laptops/servers!

A much faster way to calculate this is by using the "powers of 2" that I explained earlier:

2 to the power of 15 (or 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2) = 32768.

32768 minus 2 (network + broadcast address) = 32766.

Does this make sense to you? Good! My promise is still standing…I will show you how to solve these subnetting questions without touching any binary, you just need to make sure you understand the math that is going on first.

Let's calculate what the subnets look like.

<u>Subnet #1:</u>

By applying the new subnet mask we only have **15 host bits** to play with.

172.16.0.0
255.255.128.0

IP address	172	16	0	0
	10101100	0001000	00000000	00000000
Subnet mask	**255**	**255**	**128**	**0**
	11111111	11111111	10000000	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 172.16.0.0

Network	172	16	0	0
	10101100	0001000	00000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 172.16.0.1

Network	172	16	0	1
	10101100	0001000	00000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 172.16.127.254

Network	172	16	127	254
	10101100	0001000	01111111	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 172.16.127.255

Network	172	16	127	255
	10101100	0001000	01111111	11111111

<u>Subnet #2:</u>

The first subnet ended at 172.16.127.255 so we just continue with the next subnet at 172.16.128.0:

172.16.128.0
255.255.128.0

IP address	172	16	128	0
	10101100	0001000	10000000	00000000
Subnet mask	**255**	**255**	**128**	**0**
	11111111	11111111	10000000	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 172.16.128.0

Network	172	16	128	0
	10101100	0001000	10000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 172.16.128.1

Network	172	16	128	1
	10101100	0001000	10000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 172.16.255.254

Network	172	16	255	254
	10101100	0001000	11111111	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 172.16.255.255

Network	172	16	255	0
	10101100	0001000	11111111	11111111

Alright so we just subnetted this 172.16.0.0 class B network into 2 subnets, you are doing the exact same thing but now you have more bits to play with…

Exercise 3:

Now see if you can solve these questions:

1. Take the 172.16.0.0 Class B network and create 4 subnets out of it. Write down the following information:
    a. The first 3 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.
2. Take the 172.16.0.0 Class B network and create 128 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

The appendix of this book will show you the answers.

So subnetting a class B network wasn't that hard right? Let's try a Class A network and see what happens:

Let's take the 10.0.0.0 Class A network with subnet mask 255.0.0.0 and create at least 12 subnets out of it:

IP address	10	0	0	0
	00001010	00000000	00000000	00000000
Subnet mask	**255**	**0**	**0**	**0**
	11111111	00000000	00000000	00000000

If we want to create more subnets we need to borrow bits from the host-part. For every bit you borrow you can double the number of subnets (remember the "powers of 2" ?), by borrowing 4 bits we can create 16 subnets out of this single network. 3 bits would not be enough because we can only create 8 subnets then.

What will the new subnet mask be? Let's take a look at it in binary:

Subnet mask	255	240	0	0
	11111111	11110000	00000000	00000000

As you can see the subnet mask will be 255.240.0.0 and we have 4+8+8 = 20 host bits left to play with.

How "big" are these 16 subnets? Well we have 20 bits so let's just use the "powers of 2" to solve this question:

2 to the power of 20 = 1.048.576

If you want to know to know how many usable host IP addresses you have, you take 1.048.576– 2 (because of the network and broadcast address).

1.048.576– 2 = 1.048.574 usable host IP addresses. That's lots and lots of computers/laptops/servers!

Let's calculate what the subnets look like, I'm not going to do all of them, just 3 of them. By now you should be familiar what the math looks like.

Subnet #1:

By applying the new subnet mask we only have **20 host bits** to play with.

10.0.0.0
255.240.0.0

IP address	10	0	0	0
	00001010	00000000	00000000	00000000
Subnet mask	**255**	**240**	**0**	**0**
	11111111	11110000	00000000	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 10.0.0.0

Network	10	0	0	0
	00001010	00000000	00000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 10.0.0.1

Network	10	0	0	1
	00001010	00000000	00000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 10.15.255.254

Network	10	15	255	254
	00001010	00001111	11111111	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 10.15.255.255

Network	10	15	255	255
	00001010	00001111	11111111	11111111

Subnet #2:

The broadcast address of Subnet #1 was 10.15.255.255 so our next subnet starts at 10.16.0.0

10.16.0.0
255.240.0.0

IP address	10	16	0	0
	00001010	00001000	00000000	00000000
Subnet mask	255	240	0	0
	11111111	11110000	00000000	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 10.16.0.0

Network	10	16	0	0
	00001010	00010000	00000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 10.16.0.1

Network	10	16	0	1
	00001010	00010000	00000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 10.31.255.254

Network	10	31	255	254
	00001010	00011111	11111111	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 10.31.255.255

Network	10	31	255	255
	00001010	00011111	11111111	11111111

Subnet #3:

The broadcast address of Subnet #2 was 10.31.255.255 so our next subnet starts at 10.32.0.0

10.32.0.0
255.240.0.0

IP address	10	32	0	0
	00001010	00100000	00000000	00000000
Subnet mask	**255**	**240**	**0**	**0**
	11111111	11110000	00000000	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 10.32.0.0

Network	10	32	0	0
	00001010	00100000	00000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 10.32.0.1.

Network	10	32	0	1
	00001010	00100000	00000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 10.47.255.254

Network	10	47	255	254
	00001010	00101111	11111111	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 10.47.255.255

Network	10	47	255	255
	00001010	00101111	11111111	11111111

Alright so that's subnetting a Class A network! I showed you how to do all of this in binary and by now you should have a good understanding how it works "under the engine". In the next chapter I'll show you how to do subnetting a whole lot faster, and even off the top of your head!

4. Subnetting: The Fast Way

You have probably seen enough binary numbers now, so let’s work some more with decimal numbers. We can do subnetting just by working with decimal numbers.

As you have seen in the binary examples, the rule of “powers of 2” is very useful. By taking an extra bit the decimal value doubles every time:

- For every host bit you borrow the number of subnets you can create doubles.
- Every host bit left doubles the size of the subnet.

Instead of thinking/working in binary, we’ll start thinking in **“blocks”**.

Take this 192.168.1.0 network with subnet mask 255.255.255.0 as an example:

We know because the subnet mask is 255.255.255.0 we have 8 bits left, and with 8 bits the highest “number” we can create is 256.

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255.

Don’t forget about the 0! The 0 is being used so the highest value you can create is <u>256</u>.

Visualize this as a block:

We want to subnet our 192.168.1.0 network, so we’ll chop our “block” in 2 pieces.

When we chop this block in 2, this is what we get:

So now we created 2 subnets out of our Class C network, the next questions are:

- What are the network addresses?
- What are the broadcast addresses?
- What is the subnet mask?
- What are the usable host IP addresses?

The network addresses we can write down, they are both blocks of "128", we'll start at 192.168.1.0 and the 2nd subnet will be 192.168.1.128. From .0 - .127 = "128".

Subnet #1: Network: 192.168.1.0

Subnet #2: Network: 192.168.1.128

The second question is, what are the broadcast addresses? Well we know that the broadcast address is the last address within a subnet, so we can just write those down.

Now we know the network addresses:

Subnet #1:	Network:	192.168.1.0
	Broadcast:	192.168.1.127
Subnet #2:	Network:	192.168.1.128
	Broadcast:	192.168.1.255

The third question, what is the subnet mask? To solve this question I'll teach you a new trick.

Take "256" minus "block size" will give you the subnet mask:

256 – 128 = 128.

The subnet mask will be 255.255.255.128

This is a trick to remember, I would write it down on your cheat sheet.

One question left; what are the usable host IP addresses?

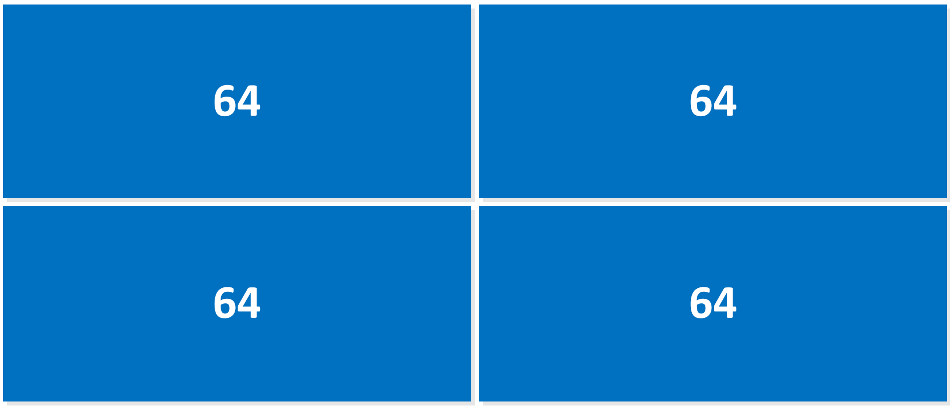
- The first usable host IP address comes after the network address.
- The last usable host IP address comes before the broadcast address.
- Everything in between is a usable host IP address.

Subnet #1:	Network:	192.168.1.0
	First Host:	192.168.1.1
	Last Host:	192.168.1.126
	Broadcast:	192.168.1.127
Subnet #2:	Network:	192.168.1.128
	First Host:	192.168.1.129
	Last Host:	192.168.1.254
	Broadcast:	192.168.1.255

That was a lot faster right? We just subnetted this Class C network, calculated the network address, broadcast address and the usable host IP addresses.

Let’s try one more!

We’ll take the 192.168.1.0 Class C network but now we’ll chop it into 4 pieces, so we get 4 “blocks”.



We have the same set of questions to answer:

- What are the network addresses?
- What are the broadcast addresses?
- What is the subnet mask?
- What are the usable host IP addresses?

Let’s write down the networks, all “blocks” of 64:

Subnet #1: Network: 192.168.1.0

Subnet #2: Network: 192.168.1.64

Subnet #3: Network: 192.168.1.128

Subnet #4: Network: 192.168.1.192

Now we know the networks we can write down the broadcast addresses:

Subnet #1: Network: 192.168.1.0
Broadcast: 192.168.1.63

Subnet #2: Network: 192.168.1.64
Broadcast: 192.168.1.127

Subnet #3: Network: 192.168.1.128
Broadcast: 192.168.1.191

Subnet #4: Network: 192.168.1.192
Broadcast: 192.168.1.255

What is the subnet mask?

Take "256" minus "block size" will give you the subnet mask:

256 – 64 = 192.

The subnet mask will be 255.255.255.192

One more step, we need to fill in the usable host IP addresses:

Subnet #1:	Network:	192.168.1.0
	First Host:	192.168.1.1
	Last Host:	192.168.1.62
	Broadcast:	192.168.1.63
Subnet #2:	Network:	192.168.1.64
	First Host:	192.168.1.65
	Last Host:	192.168.1.126
	Broadcast:	192.168.1.127
Subnet #3:	Network:	192.168.1.128
	First Host:	192.168.1.129
	Last Host:	192.168.1.190
	Broadcast:	192.168.1.191
Subnet #4:	Network:	192.168.1.192
	First Host:	192.168.1.193
	Last Host:	192.168.1.254
	Broadcast:	192.168.1.255

Wasn't that a lot easier then doing everything in binary? Once you know the rules doing everything in decimal is much faster.

<u>Exercise 4:</u>

Now see if you can solve these questions:

1. Take the 192.168.2.0 Class C network and create 8 subnets out of it. Write down the following information:
    a. The first 3 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.
2. Take the 192.168.2.0 Class C network and create 32 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

The appendix of this book will show you the answers.

Can we apply this same method for Class B networks? Sure! The only difference with a Class C network is we have more space because we are now playing with the 3rd octet.

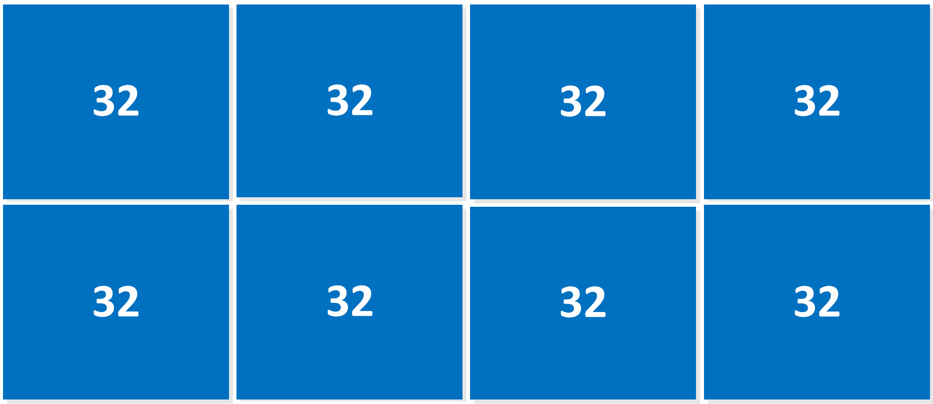
Let's take the 172.16.0.0 network and create 8 subnets.

We still have the same questions to answer:

- What are the network addresses?
- What are the broadcast addresses?
- What is the subnet mask?
- What are the usable host IP addresses?

We start with our block of "256" but now we are playing with the 3rd octet:

If we chop "256" into 8 blocks we get blocks with a size of "32".



Let's write down the first 3 subnets and their network addresses:

Subnet #1: Network: 172.16.0.0

Subnet #2: Network: 172.16.32.0

Subnet #3: Network: 172.16.64.0

Let's write down the broadcast addresses, remember this is the last address within the subnet:

Subnet #1:	Network:	172.16.0.0
	Broadcast:	172.16.31.255
Subnet #2:	Network:	172.16.32.0
	Broadcast:	172.16.63.255
Subnet #3:	Network:	172.16.64.0
	Broadcast:	172.16.95.255

What will the subnet mask be?

256 – 32 – 224

255.255.224.0

Last question, what are the usable host IP addresses?

Subnet #1:	Network:	172.16.0.0
	First Host:	172.16.0.1
	Last Host:	172.16.31.254
	Broadcast:	172.16.31.255
Subnet #2:	Network:	172.16.32.0
	First Host:	172.16.32.1
	Last Host:	172.16.63.254
	Broadcast:	172.16.63.255
Subnet #3:	Network:	172.16.64.0
	First Host:	172.16.64.1
	Last Host:	172.16.95.254
	Broadcast:	172.16.95.255

Exercise 5:

Now see if you can solve these questions:

1. Take the 172.16.0.0 Class B network and create 2 subnets out of it. Write down the following information:
    a. The 2 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.
2. Take the 172.16.0.0Class B network and create 16 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

The appendix of this book will show you the answers.

Can we apply the same trick for a Class A network? No problem, we just need to play with the 2nd octet this time.

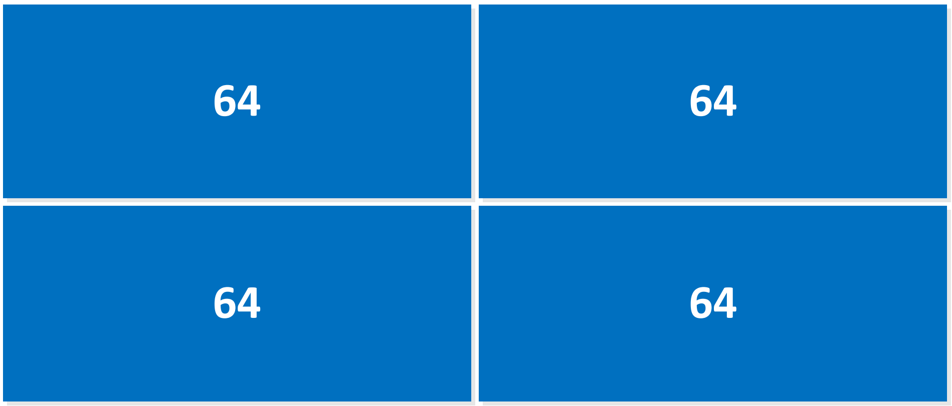
Let's take the 10.0.0.0 network and create 4 subnets.

Same questions, different answers:

- What are the network addresses?
- What are the broadcast addresses?
- What is the subnet mask?
- What are the usable host IP addresses?

We start with our block of "256" but now we are playing with the 2nd octet:

Let's chop it into 4 blocks:



Let's write down the networks, all "blocks" of 64:

Subnet #1: Network: 10.0.0.0

Subnet #2: Network: 10.64.0.0

Subnet #3: Network: 10.128.0.0

Subnet #4: Network: 10.192.0.0

Step 2, write down the broadcast addresses:

Subnet #1:	Network:	10.0.0.0
	Broadcast:	10.63.255.255
Subnet #2:	Network:	10.64.0.0
	Broadcast:	10.127.255.255
Subnet #3:	Network:	10.128.0.0
	Broadcast:	10.191.255.255
Subnet #4:	Network:	10.192.0.0
	Broadcast:	10.255.255.255

So what will the subnet mask become?

256 – 64 = 192.

That will make 255.192.0.0.

Last question, what are the usable host IP addresses?

Subnet #1:	Network:	10.0.0.0
	First Host:	10.0.0.1
	Last Host:	10.63.255.254
	Broadcast:	10.63.255.255
Subnet #2:	Network:	10.64.0.0
	First Host:	10.64.0.1
	Last Host:	10.127.255.254
	Broadcast:	10.127.255.255
Subnet #3:	Network:	10.128.0.0
	First Host:	10.128.0.1
	Last Host:	10.191.255.254
	Broadcast:	10.191.255.255
Subnet #4:	Network:	10.192.0.0
	First Host:	10.192.0.1
	Last Host:	10.255.255.254
	Broadcast:	10.255.255.255

Exercise 6:

Now see if you can solve these questions:

1. Take the 10.0.0.0 Class A network and create 2 subnets out of it. Write down the following information:
    a. The 2 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.
2. Take the 10.0.0.0 Class A network and create 4 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

The appendix of this book will show you the answers.

Right now you should have a good understanding how you can create subnets without touching any binary numbers and work with decimal only, this method is a lot faster. If you still feel like you don't completely understand it I would suggest rereading this chapter and doing some more exercises.

5. Classless Inter-Domain Routing

Once upon a time when the IP addressing scheme was invented, the people who developed this thought it would be enough to have 3 different classes as we have seen so far, class A,B and C networks. There were only 3 subnet masks:

Class A	255.0.0.0	16,777,216
Class B	255.255.0.0	65,536
Class C	255.255.255.0	256

These networks are also known as "classful networks".

When the internet started growing rapidly in the beginning of the 90's this caused some problems. There were only 16.000 class B networks available which are used by a lot of medium sized companies, imagine they only needed 1000 IP addresses this would mean about 15.000 IP addresses would be wasted. A class C would be too small because you only have 256 IP addresses, and taking a couple of class C networks is no scalable option.

The solution to this problem is Classless Inter-Domain Routing, in other words we stop working with the classful networks and start working with classless networks.

Classless networks means we don't use the Class A,B or C networks anymore but are free to use any subnet mask we like, and most often you will see this in a bit-notation.

For example:

192.168.1.0
255.255.255.0

Is the same as 192.168.1.0 /24

Instead of writing down the full subnet mask we only specify how many bits the subnet mask is.

172.16.1.0
255.255.0.0

Is the same as: 172.16.1.0 /16

10.0.0.0
255.0.0.0

Is the same as: 10.0.0.0 /8

One more:

172.16.1.64
255.255.255.192

Is the same as: 172.16.1.64 /26.

Here’s a little overview with the CIDR notation and the full subnet mask:

255.0.0.0	/8
255.128.0.0	/9
255.192.0.0	/10
255.224.0.0	/11
255.240.0.0	/12
255.248.0.0	/13
255.252.0.0	/14
255.254.0.0	/15
255.255.0.0	/16
255.255.128.0	/17
255.255.192.0	/18
255.255.224.0	/19
225.225.240.0	/20
255.255.248.0	/21
255.255.252.0	/22
255.255.254.0	/23
255.255.255.0	/24
255.255.128.0	/25
255.255.192.0	/26
255.255.224.0	/27
255.255.240.0	/28
255.255.248.0	/29
255.255.252.0	/30

Do you see the pattern here? The numbers are the same; it’s just a different octet you are playing with. For example take a look at /11 or /19. 255.224.0.0 or 255.255.224.0. Or for example /18 or /26. 255.255.192.0 and 255.255.255.192.

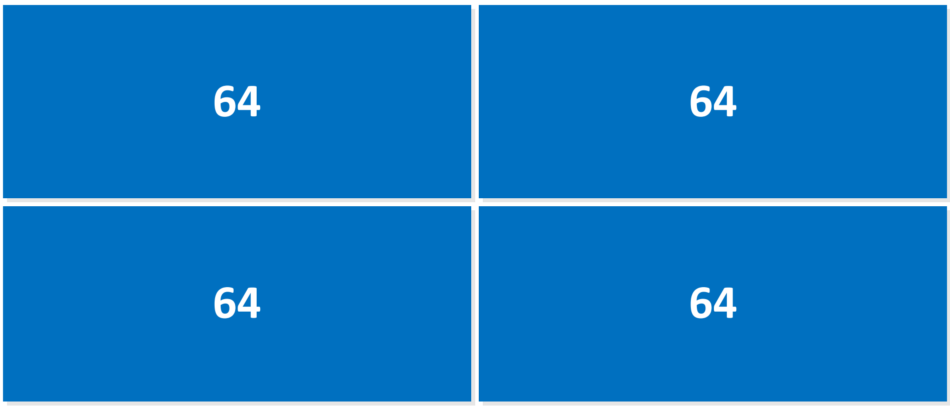
Expand your own cheat sheet by adding the CIDR notation and the subnet masks. I would also recommend that you write down the size of the subnet mask behind it. For example take the /26 mask. You know the subnet mask is 255.255.255.192. 256 – 192 = 64. So the size of the subnets is “64”.

I believe the CIDR notation is easier then writing down the complete subnet mask, saves some time. Unfortunately on most operating systems and network equipment you still have to configure the full subnet mask instead of the CIDR notation.

6. Variable length subnet mask (VLSM)

Until this chapter we have been subnetting using a 'fixed size' for our blocks, so for example we took a 192.168.1.0 Class C network and divided it in 4 blocks:

Create 4 blocks out of it:



Is this a really efficient way of creating subnets? Let's say I would have the following requirements:

- One subnet for 12 hosts.
- One subnet for 44 hosts.
- One subnet for 2 hosts (point-to-point links are a good example where you only need 2 IP host addresses).
- One subnet for 24 hosts.

I have 4 subnets so it's no problem, but I'm still wasting a lot of IP addresses. If we use a block of 64 for our subnet where I only need 2 IP addresses I'm throwing 62 IP addresses away.

Now you might think why we could care about this because we are using a private network address (192.168.1.0) and we have plenty of space. This is true, try to think about this on a global scale with the Internet. We don't want to throw away valuable public IP addresses.

Let’s say I want to subnet my 192.168.1.0 network in the most efficient way, let’s take look at the requirements I just showed you again:

- One subnet for 12 hosts.
- One subnet for 44 hosts.
- One subnet for 2 hosts.
- One subnet for 24 hosts.

What kind of subnets would we need to fit in these hosts? Let’s see:

- 12 hosts, the smallest subnet would be a block of 16.
- 44 hosts, the smallest subnet would be a block of 64.
- 2 hosts, the smallest subnet would be a block of 4.
- 24 hosts, the smallest subnet would be a block of 32.

We take our block of “256”:

And divide it with the blocks we just specified:

We just saved ourselves some valuable IP addresses, now the next thing to do is answer the following questions:

- What are the network addresses?
- What are the broadcast addresses?
- What is the subnet mask?
- What are the usable host IP addresses?

When using VLSM, start with the biggest subnet first! Otherwise you have overlapping address space.

It's a good idea to remember the idea of "blocks" because you will visualize the size of the subnets this way.

The network addresses:

Subnet #1: Network: 192.168.1.0

Subnet #2: Network: 192.168.1.64

Subnet #3: Network: 192.168.1.96

Subnet #4: Network: 192.168.1.112

Subnet #5: Network: 192.168.1.116 (this is where the Free space starts)

Let's fill in the broadcast addresses:

Subnet #1:	Network:	192.168.1.0
	Broadcast:	192.168.1.63
Subnet #2:	Network:	192.168.1.64
	Broadcast:	192.168.1.95
Subnet #3:	Network:	192.168.1.96
	Broadcast:	192.168.1.111
Subnet #4:	Network:	192.168.1.112
	Broadcast:	192.168.1.115

Because we have different subnet sizes, we need to calculate the subnet mask for each subnet.

Subnet #1: Block size: 64

256 – 64 = 192 so the subnet mask is 255.255.255.192

Subnet #2: Block size: 32

256 – 32 = 224 so the subnet mask is 255.255.255.224

Subnet #3: Block size: 16

256 – 16 = 240 so the subnet mask is 255.255.255.240

Subnet #4: Block size: 4

256 – 4 = 252 so the subnet mask is 255.255.255.252

The only thing left to do is fill in the usable host IP addresses:

Subnet #1:	Network:	192.168.1.0
	First host:	192.168.1.1
	Last host:	192.168.1.62
	Broadcast:	192.168.1.63
Subnet #2:	Network:	192.168.1.64
	First Host:	192.168.1.65
	Last Host:	192.168.1.94
	Broadcast:	192.168.1.95
Subnet #3:	Network:	192.168.1.96
	First host:	192.168.1.97
	Last host:	192.168.1.110
	Broadcast:	192.168.1.111
Subnet #4:	Network:	192.168.1.112
	First host:	192.168.1.113
	Last host:	192.168.1.114
	Broadcast:	192.168.1.115

Here we go, we just subnetted our 192.168.1.0 /24 by using VLSM.

Let’s try another example but this time we use a Class B 172.16.0.0 network with different requirements:

- One subnet for 340 hosts.
- One subnet for 250 hosts.
- One subnet for 31 hosts.
- One subnet for 20 hosts.
- One subnet for 8 hosts.

To solve this question first we need to determine the “block” that we require:

- To fit in 340 hosts we need 2x 256, or a block of “512”.
- To fit in 250 hosts we need a block of 256.
- To fit in 31 hosts we need a block 64.
- To fit in 20 hosts we need a block of 32.
- To fit in 8 hosts we need a block 16.

Because of the network and broadcast address, in a block of 32 you only have 30 usable host IP addresses. That’s why we need a block of 64 to fit in 31 hosts.

Let's write down the subnets and network addresses:

Subnet #1: Network: 172.16.0.0

Subnet #2: Network: 172.16.2.0

Subnet #3: Network: 172.16.3.0

Subnet #4: Network: 172.16.3.64

Subnet #5: Network: 172.16.3.96

Subnet #6: Network: 172.16.3.112 (this is where the Free space starts)

Now we need to find the broadcast addresses:

Subnet #1:	Network:	172.16.0.0
	Broadcast:	172.16.1.255
Subnet #2:	Network:	172.16.2.0
	Broadcast:	172.16.2.255
Subnet #3:	Network:	172.16.3.0
	Broadcast:	172.16.3.63
Subnet #4:	Network:	172.16.3.64
	Broadcast:	172.16.3.95
Subnet #5:	Network:	172.16.3.96
	Broadcast:	172.16.3.111

Let's find out what the subnet masks are:

Subnet #1:

For this subnet we are using a block of "512" which is a combination of two blocks of "256".

Normally a subnet with a "256" block would have a subnet mask of 255.255.255.0 or /24 in CIDR notation (/24 means 24 bits for the subnet mask).

If we combine 2x "256" block and create one "512" block this means we use one bit less from our host bits to create subnets, so basically we get a /23. The subnet mask will be 255.255.254.0

Create your own cheat sheet to look up the CIDR-to-subnet mask conversion instead of calculating it for every question. This saves valuable time especially on exams.

Subnet #2:

This subnet is a block of “256” so the same as a Class C network, the subnet mask is 255.255.255.0

Subnet #3:

This is a block of 64.

256 – 64 = 192

The subnet mask is 255.255.255.192

Subnet #4:

This is a block of 32.

256 – 32 = 224

The subnet mask is 255.255.255.224

Subnet #5:

This is a block of 16.

256 – 16 = 240

The subnet mask is 255.255.255.240

We need to fill in the usable host IP addresses:

Subnet #1:	Network:	172.16.0.0
	First Host:	172.16.0.1
	Last Host:	172.16.1.254
	Broadcast:	172.16.1.255
Subnet #2:	Network:	172.16.2.0
	First Host:	172.16.2.1
	Last Host:	172.16.2.254
	Broadcast:	172.16.2.255
Subnet #3:	Network:	172.16.3.0
	First Host:	172.16.3.1
	Last Host:	172.16.3.62
	Broadcast:	172.16.3.63
Subnet #4:	Network:	172.16.3.64
	First Host:	172.16.3.65
	Last Host:	172.16.3.94
	Broadcast:	172.16.3.95
Subnet #5:	Network:	172.16.3.96
	First Host:	172.16.3.97
	Last Host:	172.1.6.3.110
	Broadcast:	172.16.3.111

Exercise 7:

Now see if you can solve these questions:

1. Take the 192.168.4.0 Class C network and create the following subnets:
    a. One subnet with a block of 128.
    b. One subnet with a block of 64.
    c. One subnet with a block of 16.
    d. Write down the network/broadcast addresses and the host IP addresses.
2. Take the 172.16.0.0 Class B network and create the following subnets:
    a. Two subnets with a block of 128.
    b. One subnet with a block of 64.
    c. One subnet with a block of 32.
    d. Write down the network/broadcast addresses and the host IP addresses.
3. Take the 172.16.0.0 class B network and create the following subnets:
    a. One subnet that fits 240 hosts.
    b. One subnet that fits 31 hosts.
    c. One subnet that's fits 7 hosts.
    d. Write down the network/broadcast addresses and the host IP addresses.

The appendix of this book will show you the answers.

If you made it this far and tackled all the different subnetting questions…good job! You have seen how to solve these questions in binary, decimal and by using CIDR and VLSM.

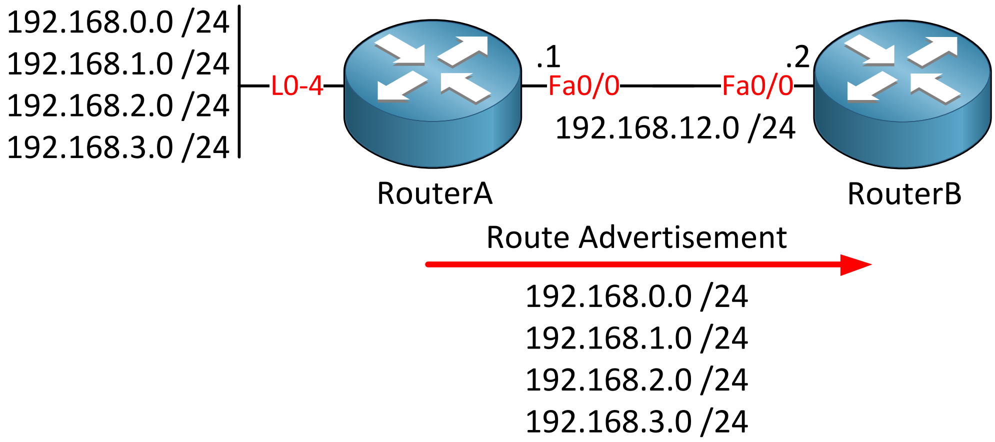
7. Summarization

When you are into networking and routing in particular, you are probably familiar with the concept of summarization.

In the picture below we see 2 routers, routerA has the following networks configured:

- 192.168.0.0 / 24
- 192.168.1.0 / 24
- 192.168.2.0 / 24
- 192.168.3.0 / 24

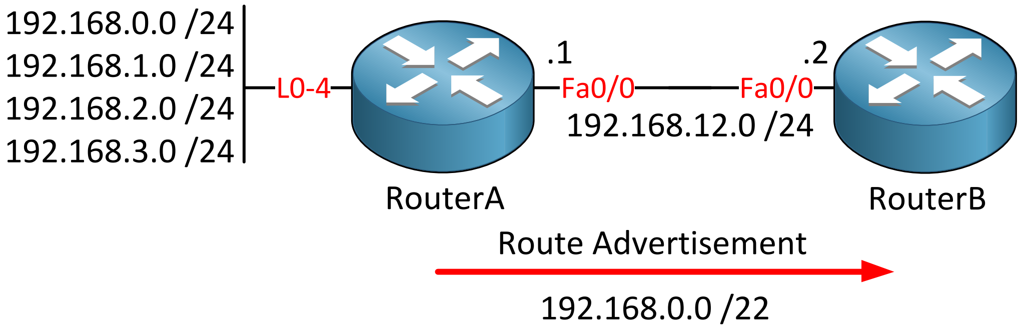
When we configure a routing protocol, all 4 networks will be advertised and seen in the routing table of RouterB:



RouterB's routing table will look like this:

```
RouterB#show ip route eigrp
D    192.168.0.0/24 [90/30720] via 192.168.12.1, 00:21:53, FastEthernet0/0
D    192.168.1.0/24 [90/30720] via 192.168.12.1, 00:21:50, FastEthernet0/0
D    192.168.2.0/24 [90/30720] via 192.168.12.1, 00:21:53, FastEthernet0/0
D    192.168.3.0/24 [90/30720] via 192.168.12.1, 00:21:50, FastEthernet0/0
```

By configuring summarization we can make sure the routing table on Router B will become smaller and have only a single entry, check out the following picture and routing table:



RouterB's routing table:

```
RouterB#show ip route eigrp
D    192.168.0.0/22 [90/156160] via 192.168.12.1, 00:00:03, FastEthernet0/0
```

As you can see there is only a single entry in router B's routing table, which is a summary of the 4 networks on Router A.

There's a whole lot to talk about summarization which is outside the scope of this book, but the skills needed to create good summaries are the same as for subnetting.

If we want to create a summary for these networks:

- 192.168.0.0 / 24 subnet mask 255.255.255.0
- 192.168.1.0 / 24 subnet mask 255.255.255.0
- 192.168.2.0 / 24 subnet mask 255.255.255.0
- 192.168.3.0 / 24 subnet mask 255.255.255.0

We need to think about the CIDR notation / subnet mask we choose for this summary, so what numbers matches these 4 networks?

As you can see we have 4 networks, or when we speak in 'blocks' it's a block of 4.

Take 256 – 4 = 252.

The subnet mask will be 255.255.252.0

This is also called 'supernetting'.

Another way to look at it is by using the CIDR notation. You know a /24 is a '256' block. Using a /23 means you have 2x 256, and a /22 means you have 4x 256.

Let’s do another example, let’s say you want to summarize the following subnets:

172.16.0.0 / 16	subnet mask 255.255.0.0
172.17.0.0 / 16	subnet mask 255.255.0.0
172.18.0.0 / 16	subnet mask 255.255.0.0
172.19.0.0 / 16	subnet mask 255.255.0.0
172.20.0.0 / 16	subnet mask 255.255.0.0
172.21.0.0 / 16	subnet mask 255.255.0.0
172.22.0.0 / 16	subnet mask 255.255.0.0
172.23.0.0 / 16	subnet mask 255.255.0.0

That’s 8 networks we want to summarize into 1 single entry, what will the CIDR notation / subnet mask be?

8 networks that’s a ‘block’ of 8.

256 – 8 = 248

The subnet mask will be 255.248.0.0

Or if you feel like just using the CIDR notation:

172.16.0.0 / 16 is one network.

172.16.0.0 / 15 is 2 networks.

172.16.0.0 / 14 is 4 networks.

172.16.0.0 / 13 is 8 networks.

So a /13 will be the answer to this question.

Exercise 8:

See if you can create the following summaries:

1. Combine the following networks into a single summary:
    a. 192.168.1.0 / 24
    b. 192.168.2.0 / 24
2. Now try this one:
    a. 172.16.0.0 / 16
    b. 172.16.1.0 / 16
    c. 172.16.2.0 / 16
    d. 172.16.3.0 / 16
3. Last one:
    a. 10.0.0.0 / 8
    b. 11.0.0.0 / 8
    c. 12.0.0.0 / 8
    d. 13.0.0.0 / 8
    e. 14.0.0.0 / 8
    f. 15.0.0.0 / 8
    g. 16.0.0.0 / 8
    h. 17.0.0.0 / 8

The appendix of this book will show you the answers.

8. Hexadecimal calculations

In the networking universe you sometimes have to calculate from binary to hexadecimal, or from decimal to hexadecimal and the other way around. MAC addresses and IPv6 are a good example of this.

In the decimal system we count from 1-10, in the hexadecimal system we count from 1 – F. Check out this example:

Decimal	Hexadecimal
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	A
11	B
12	C
13	D
14	E
15	F

That's not so bad right? Now if you want to calculate from binary to hexadecimal there's a trick you need to master. Let's say you have the decimal number "255" in binary:

	128	64	32	16	8	4	2	1
128	1	1	1	1	1	1	1	1

If you want to convert this to hexadecimal you need to cut the 8 bits in 2 parts of 4-bits (4 bits is also known as a "nibble").

1111 1111

Now take a single nibble, and convert it into decimal:

	8	4	2	1
15	1	1	1	1

Do the same for the next nibble:

	8	4	2	1
15	1	1	1	1

Now take a look at the chart decimal-to-hexadecimal and you'll see that 15 in decimal is equal to "F" in hexadecimal.

So the hexadecimal value = FF. Normally you see hexadecimal values written as 0xFF. If you see the "0x" you know it's a hexadecimal value.

Let's try another decimal value and calculate it into hexadecimal, for example 118:

	128	64	32	16	8	4	2	1
112	0	1	1	1	0	1	1	0

0111 0110

Now take a single nibble, and convert it into decimal:

	8	4	2	1
7	0	1	1	1

Do the same for the next nibble:

	8	4	2	1
6	0	1	1	0

As you can see this will be 0x76 in hexadecimal.

Exercise 9:

Now see if you can solve these questions:

1. Take the decimal number 140 and calculate it into hexadecimal
2. Take the decimal number 94 and calculate it into hexadecimal.
3. Take the hexadecimal number 0xAD and calculate it into decimal.
4. Take the hexadecimal number 0xCD and calculate it into decimal.

The appendix of this book will show you the answers.

9. Tackling miscellaneous subnetting questions

This will be the final chapter, right now you have seen all the different tools needed to become a true binary and subnetting calculations artist. In this chapter I will show you some of the common subnetting questions you might encounter and how to tackle them.

The cheat sheet you created so far is a great tool to solve these kind of questions.

Subnetting Question #1:

You have the IP address 192.168.1.22 / 27 and are wondering what kind of IP address this is, a network address? Broadcast address? Or perhaps a valid host IP address? Let's find out:

a) First we need to find out what subnet mask the /27 is.

/24 = 255.255.255.0
/25 = 255.255.255.128
/26 = 255.255.255.192
/27 = 255.255.255.224

b) Now we know the subnet mask we need to find out how big this subnet is:

256 – subnet mask = size of subnet.
256 – 224 = 32.

So the size of this subnet is "32".

c) Now we can write down the subnets:

Subnet #1:

Network 192.168.1.0

Subnet #2:

Network 192.168.1.32

Subnet #3:

Network 192.168.1.64

d) Now we can write down the broadcast address, as you can see 192.168.1.22/27 is an IP address in subnet #1.

Subnet #1:

Network	192.168.1.0
Broadcast	192.168.1.31

Subnet #2:

Network	192.168.1.32
Broadcast	192.168.1.63

e) Let's write down the valid host IP addresses for subnet #1:

Subnet #1:

Network	192.168.1.0
First Host	192.168.1.1
Last Host	192.168.1.30
Broadcast	192.168.1.31

And here you go, 192.168.1.22 is a valid IP address you can use to configure a host.

<u>Subnetting Question #2:</u>

You are given the 172.16.5.32 / 28 network, how many hosts can you configure in this subnet?

The best way to tackle this question is to use the "powers of 2" formula to calculate the number of IP addresses for hosts.

We have 32 bits in total, 28 bits are used for the network address. This means we have 4 bits left for hosts.

2 to the power of 4 = 16

The size of this subnet is "16" – 2 (network and broadcast address) means there are 14 IP addresses we can use to configure hosts.

<u>Subnetting Question #3:</u>

You are given the 172.16.0.0 IP address with subnet mask 255.255.192.0, what's the maximum number of subnets you can squeeze out of this subnet?

The best way to solve this question is to use the "powers of 2" formula to determine how many subnets you can create.

A subnet mask of 255.255.192.0 are 8 + 8 + 2 = 18 bits that are being used for networks.

The smallest subnet you can create is a /30 or subnet mask 255.255.255.252. For every host bit we borrow we can double the number of subnets.

IP address	172	16	0	0
	00001010	00010000	00000000	00000000
Subnet mask	**255**	**255**	**192**	**0**
	11111111	11111000	11000000	00000000

If you take a look at the binary table this means you have 12 host bits left that you can borrow for extra subnets. 2 to the power of 12 = 4096 subnets.

<u>Exercise 10:</u>

See if you can solve the following subnetting questions:

1. You are given the 192.168.1.44 /28 address, what kind of address is this? Broadcast? Network? Usable for a host?
2. You are given the 192.168.7.64 /29 address, what kind of address is this? Broadcast? Network? Usable for a host?
3. You are given the 10.1.4.3 /18 address, what kind of address is this? Broadcast? Network? Usable for a host?
4. You are given the 172.16.4.3 /22 address, what kind of address is this? Broadcast? Network? Usable for a host?
5. You are given the 192.168.1.0/25 address, what is the maximum number of subnets you can create?

10. Create your own cheat sheet

If you are practicing on the binary and subnetting questions it's easy to have a cheat sheet. It's even better if you know how to create one yourself, so let's take a look how to do this:

1) Write down 8 bits:

128	64	32	16	8	4	2	1

2) Now write down the CIDR notations and the subnet masks behind it. Write down everything from /16 to /30. For example, you know that a /24 is 255.255.255.0. If you take a /26 you are borrowing 2 host-bits:

128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0

128+64 = 192. So the subnet mask is 255.255.255.192

3) Now you have the CIDR notations and the subnet masks, it's time to write down the size of the subnets. Remember this formula:

   256 – subnet mask = size of subnet.

   For example, take the /26 CIDR notation with subnet mask 255.255.255.192.

   256 – 192 = 64. So the size of the subnet mask is "64".

   Write down all of them from /16 to /30.

That's it! If you get any questions on subnetting you can see in the blink of an eye what the CIDR notation is, the subnet mask and how big the subnet size is. This will save time because you don't have to do the calculations over and over again.

11. Final Thoughts

Here we are, you worked your way through all the different chapters that showed you how to solve any binary or subnetting question. The last thing you need to do to become a true binary and subnetting calculations artist is *practice, practice and even more practice*! The easiest way to do this is to write down some IP addresses and random subnet masks and ask yourself the same questions I did in all of the chapters.

What is the network address, what is the broadcast address, how many valid hosts, what is the CIDR notation and so on. You can always check your answers by using one of the many subnet calculators you can find on the internet. Just search Google for "subnet calculator" and you'll find plenty of them.

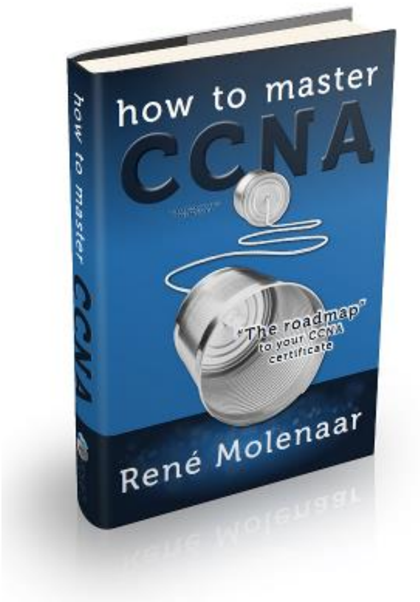
One last word of advice: If you do a Cisco exam you always get a tutorial before you start the exam which takes 15 minutes. These 15 minutes are not withdrawn from your exam time so this is valuable time you can spend at creating your own cheat sheet. If you get exam questions where you need to calculate subnets you can save a lot of time by looking it up in your cheat sheet instead of calculating over and over again.

I hope you enjoyed reading my book and truly learned something! If you have any questions or comments about the book please let me know by sending an e-mail to info@gns3vault.com or drop a message at my website: www.gns3vault.com

I wish you good luck practicing those binary and subnetting skills!

René Molenaar

PS – If you are serious about your career in networking you might be interested in achieving your Cisco CCNA certification. In my book "How to Master CCNA" I explain everything you need to know in order to pass CCNA. Just click on the picture below to get started!



Appendix A – Answers to exercises

Exercise 1:

See if you can solve the following decimal to binary calculations:

To solve this question just take the decimal number and start at the MSB (most significant bit) and see if it “fits in”. To convert the decimal number 12 to binary, 128 is too big, 64 as well, 32 also, 16 is too big so we put a “0” here. 8 fits and when we add 4 we already have 12.

Bits	128	64	32	16	8	4	2	1
12	0	0	0	0	1	1	0	0
54	0	0	1	1	0	1	1	0
187	1	0	1	1	1	0	1	1
192	1	1	0	0	0	0	0	0
44	0	0	1	0	1	1	0	0
147	1	0	0	1	0	0	1	1

Now try to do it the other way around and calculate from binary to decimal:

You need to add all the bits with a “1” to get the decimal value, for example the first one:

128 + 64 + 8 + 2 = 202

Bits	128	64	32	16	8	4	2	1
202	1	1	0	0	1	0	1	0
57	0	0	1	1	1	0	0	1
85	0	1	0	1	0	1	0	1
243	1	1	1	1	0	0	1	1
33	0	0	1	0	0	0	0	1
135	1	0	0	0	0	1	1	1

Exercise 2:

Now it's time for you to calculate some subnets, see if you can solve the following questions:

1. Take the 192.168.1.0 Class C network and create 8 subnets out of it. Write down the following information:
   a. The first 2 subnets.
   b. The network addresses.
   c. The broadcast addresses.
   d. The usable host IP addresses.

To solve this we'll write down the IP address and subnet mask in binary first:

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**0**
	11111111	11111111	11111111	00000000

Every bit we borrow from the "host bits" doubles the number of subnets we can create. We want 8 subnets, so we'll need to borrow 3 host bits.

Let's take a look at the new subnet mask in binary:

Subnet mask	255	255	255	224
	11111111	11111111	11111111	11100000

The first 24 bits didn't change so we only need to take a look at the 4th octet. Let's take a look at it in binary:

128	64	32	16	8	4	2	1
1	1	1	0	0	0	0	0

Add up the numbers to calculate the subnet mask in decimal. 128 + 64 + 32 = 224. The new subnet mask will be 255.255.255.224

The second question is, how "big" are these 8 subnets and how many hosts can we fit in?

128	64	32	16	8	4	2	1
N/A	N/A	N/A	1	1	1	1	1

We have 5 bits left so let's do the binary to decimal calculation:

16 + 8 + 4 + 2 +1 = 31

Don't forget about the 0! Because we start counting at 0 the highest value we can create with 5 bits is 32.

Our original class C network has now been divided in 8 subnets with a size of 32 each. So what will the network addresses of the 8 new subnets be? Let's work this example out in binary:

Subnet #1:

By applying the new subnet mask we only have **5 host bits** to play with.

192.168.1.0
255.255.255.224

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**224**
	11111111	11111111	11111111	11100000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.0

Network	192	168	1	0
	11000000	10101000	00000001	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.1

Network	192	168	1	1
	11000000	10101000	00000001	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.30

Network	192	168	1	30
	11000000	10101000	00000001	00011110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.31

Broadcast	192	168	1	31
	11000000	10101000	00000001	00011111

Subnet #2:

The first subnet ended at 192.168.1.31 so we just continue with the next subnet at 192.168.1.32:

192.168.1.32
255.255.255.224

IP address	192	168	1	32
	11000000	10101000	00000001	00100000
Subnet mask	**255**	**255**	**255**	**224**
	11111111	11111111	11111111	11100000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.32

Network	192	168	1	32
	11000000	10101000	00000001	00100000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.33

Network	192	168	1	33
	11000000	10101000	00000001	00100001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.62

Network	192	168	1	62
	11000000	10101000	00000001	00111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.63

Broadcast	192	168	1	63
	11000000	10101000	00000001	00111111

That's it! That's the first network we just subnetted in 8 subnets and we found out what the network and broadcast addresses are, and what IP addresses we can use for hosts.

2. Take the 192.168.1.0 Class C network and create 16 subnets out of it. Write down the following information:
    a. The first 2 subnets.
    b. The network addresses.
    c. The broadcast addresses.
    d. The usable host IP addresses.

To solve this we'll write down the IP address and subnet mask in binary first:

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**0**
	11111111	11111111	11111111	00000000

Every bit we borrow from the "host bits" doubles the number of subnets we can create. We want 16 subnets, so we'll need to borrow 4 host bits.

Let's take a look at the new subnet mask in binary:

Subnet mask	255	255	255	240
	11111111	11111111	11111111	11110000

The first 24 bits didn't change so we only need to take a look at the 4th octet. Let's take a look at it in binary:

128	64	32	16	8	4	2	1
1	1	1	1	0	0	0	0

Add up the numbers to calculate the subnet mask in decimal. 128 + 64 + 32 + 16= 240. The new subnet mask will be 255.255.255.240

The second question is, how "big" are these 16 subnets and how many hosts can we fit in?

128	64	32	16	8	4	2	1
N/A	N/A	N/A	N/A	1	1	1	1

We have 4 bits left so let's do the binary to decimal calculation:

8 + 4 + 2 +1 = 15

Don't forget about the 0! Because we start counting at 0 the highest value we can create with 4 bits is 16.

Our original class C network has now been divided in 16 subnets with a size of 16 each. So what will the network addresses of the 16 new subnets be? Let's work this example out in binary:

Subnet #1:

By applying the new subnet mask we only have **4 host bits** to play with.

192.168.1.0
255.255.255.240

IP address	192	168	1	0
	11000000	10101000	00000001	00000000
Subnet mask	**255**	**255**	**255**	**240**
	11111111	11111111	11111111	11110000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.0

Network	192	168	1	0
	11000000	10101000	00000001	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.1

Network	192	168	1	1
	11000000	10101000	00000001	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.14

Network	192	168	1	14
	11000000	10101000	00000001	00001110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.15

Broadcast	192	168	1	15
	11000000	10101000	00000001	00001111

Subnet #2:

The first subnet ended at 192.168.1.15 so we just continue with the next subnet at 192.168.1.16:

192.168.1.16
255.255.255.240

IP address	192	168	1	16
	11000000	10101000	00000001	00010000
Subnet mask	**255**	**255**	**255**	**240**
	11111111	11111111	11111111	11110000

Network address:

The network address has all host bits set to 0, so the network address will be: 192.168.1.16

Network	192	168	1	16
	11000000	10101000	00000001	00010000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 192.168.1.17

Network	192	168	1	17
	11000000	10101000	00000001	00010001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 192.168.1.30

Network	192	168	1	30
	11000000	10101000	00000001	00011110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 192.168.1.31

Broadcast	192	168	1	31
	11000000	10101000	00000001	00011111

That’s it! That’s the first network we just subnetted in 16 subnets and we found out what the network and broadcast addresses are, and what IP addresses we can use for hosts.

Exercise 3:

Now see if you can solve these questions:

1. Take the 172.16.0.0 Class B network and create 4 subnets out of it. Write down the following information:
    a. The first 3 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

Let's take the 172.16.100.0 Class B network with subnet mask 255.255.0.0 and create 4 subnets out of it:

IP address	172	16	0	0
	11000000	00010000	00000000	00000000
Subnet mask	**255**	**255**	**0**	**0**
	11111111	11111111	00000000	00000000

If we want to create 4 subnets we need to borrow bits from the host-part. For every bit you borrow you can double the number of subnets, by borrowing 2 bits we create 4 subnets out of this single network. Now the difference with a Class C network is that we have more host-bits to play with, that's all.

What will the new subnet mask be? Let's take a look at it in binary:

Subnet mask	255	255	192	0
	11111111	11111111	11000000	00000000

As you can see the net subnet mask will be 255.255.192.0 and we have 6+8 = 14 host bits left to play with.

Let's calculate what the subnets look like.

Subnet #1:

By applying the new subnet mask we only have **14 host bits** to play with.

172.16.0.0
255.255.192.0

IP address	172	16	0	0
	10101100	0001000	00000000	00000000
Subnet mask	**255**	**255**	**192**	**0**
	11111111	11111111	11000000	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 172.16.0.0

Network	172	16	0	0
	10101100	0001000	00000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 172.16.0.1

Network	172	16	0	1
	10101100	0001000	00000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 172.16.63.254

Network	172	16	63	254
	10101100	0001000	00111111	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 172.16.63.255

Network	172	16	63	255
	10101100	0001000	00111111	11111111

Subnet #2:

The first subnet ended at 172.16.63.255 so we just continue with the next subnet at 172.16.64.0:

172.16.64.0
255.255.192.0

IP address	172	16	64	0
	10101100	0001000	01000000	00000000
Subnet mask	**255**	**255**	**192**	**0**
	11111111	11111111	11000000	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 172.16.64.0

Network	172	16	64	0
	10101100	0001000	01000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 172.16.64.1

Network	172	16	64	1
	10101100	0001000	01000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 172.16.127.254

Network	172	16	127	254
	10101100	0001000	01111111	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 172.16.127.255

Network	172	16	127	255
	10101100	0001000	01111111	11111111

2. Take the 172.16.0.0 Class B network and create 128 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

Let's take the 172.16.100.0 Class B network with subnet mask 255.255.0.0 and create 128 subnets out of it:

IP address	172	16	0	0
	10101100	0001000	00000000	00000000
Subnet mask	**255**	**255**	**0**	**0**
	11111111	11111111	00000000	00000000

If we want to create 128 subnets we need to borrow bits from the host-part. For every bit you borrow you can double the number of subnets, by borrowing 7 bits we create 128 subnets out of this single network.

What will the new subnet mask be? Let's take a look at it in binary:

Subnet mask	255	255	254	0
	11111111	11111111	11111110	00000000

As you can see the net subnet mask will be 255.255.254.0 and we have 1+8 = 9 host bits left to play with.

Let's calculate what the subnets look like.

Subnet #1:

By applying the new subnet mask we only have **9 host bits** to play with.

172.16.0.0
255.255.254.0

IP address	172	16	0	0
	10101100	0001000	00000000	00000000
Subnet mask	**255**	**255**	**254**	**0**
	11111111	11111111	11111110	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 172.16.0.0

Network	172	16	0	0
	10101100	0001000	00000000	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 172.16.0.1

Network	172	16	0	1
	10101100	0001000	00000000	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 172.16.1.254

Network	172	16	1	254
	10101100	0001000	00000001	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 172.16.1.255

Network	172	16	1	255
	10101100	0001000	00000001	11111111

Subnet #2:

The first subnet ended at 172.16.1.255 so we just continue with the next subnet at 172.16.2.0:

172.16.2.0
255.255.254.0

IP address	172	16	2	0
	10101100	0001000	00000010	00000000
Subnet mask	**255**	**255**	**254**	**0**
	11111111	11111111	11111110	00000000

Network address:

The network address has all host bits set to 0, so the network address will be: 172.16.2.0

Network	172	16	2	0
	10101100	0001000	00000010	00000000

First usable host IP address:

The first usable host IP address is the one that comes after the network address, so this will be: 172.16.2.1

Network	172	16	2	1
	10101100	0001000	00000010	00000001

Last usable host IP address:

The last IP address we can use for a host is the one before the broadcast address, so this will be: 172.16.2.254

Network	172	16	3	254
	10101100	0001000	00000011	11111110

Broadcast address:

The broadcast address has all host bits set to 1 so the broadcast address we get is: 172.16.3.255

Network	172	16	3	255
	10101100	0001000	00000011	11111111

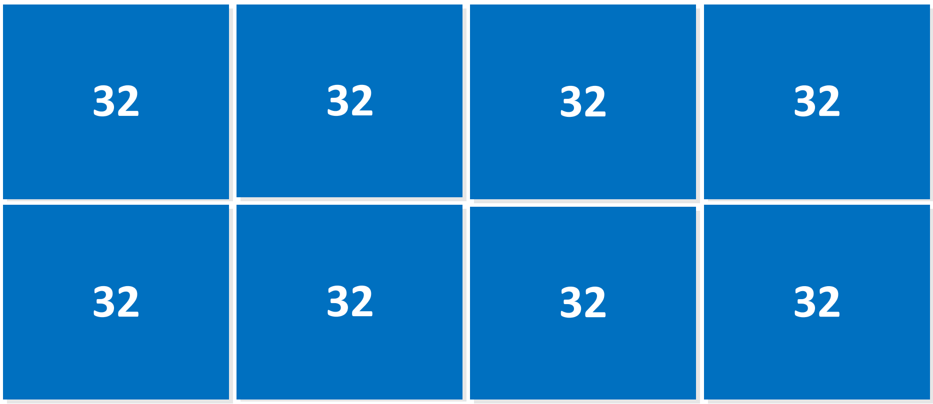
Exercise 4:

Now see if you can solve these questions:

1. Take the 192.168.2.0 Class C network and create 8 subnets out of it. Write down the following information:
    a. The first 3 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

Remember the biggest "block" we can have with 8 bits is "256".

We'll take the 192.168.1.0 Class C network but now we'll chop it into 8 pieces, so we get 8 "blocks".



Let's write down the networks, all "blocks" of 32:

Subnet #1: Network: 192.168.1.0

Subnet #2: Network: 192.168.1.32

Subnet #3: Network: 192.168.1.64

Subnet #4: Network: 192.168.1.96

Now we know the networks we can write down the broadcast addresses, this is the last IP address of the subnet:

Subnet #1:	Network:	192.168.1.0
	Broadcast:	192.168.1.31
Subnet #2:	Network:	192.168.1.32
	Broadcast:	192.168.1.63
Subnet #3:	Network:	192.168.1.64
	Broadcast:	192.168.1.95

What is the subnet mask?

Take "256" minus "block size" will give you the subnet mask:

256 – 32 = 224.

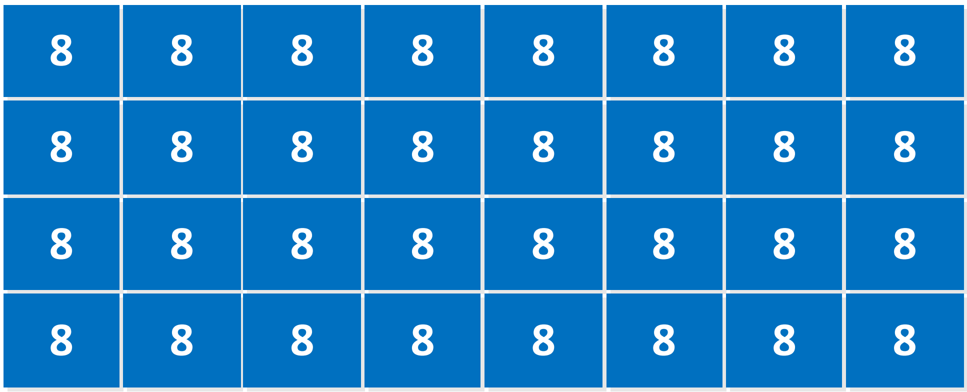
The subnet mask will be 255.255.255.224

One more step, we need to fill in the usable host IP addresses:

Subnet #1:	Network:	192.168.1.0
	First Host:	192.168.1.1
	Last Host:	192.168.1.30
	Broadcast:	192.168.1.31
Subnet #2:	Network:	192.168.1.32
	First Host:	192.168.1.33
	Last Host:	192.168.1.62
	Broadcast:	192.168.1.63
Subnet #3:	Network:	192.168.1.64
	First Host:	192.168.1.65
	Last Host:	192.168.1.94
	Broadcast:	192.168.1.95

2. Take the 192.168.2.0 Class C network and create 32 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

We'll take the 192.168.1.0 Class C network but now we'll chop it into 32 pieces, so we get 32 "blocks".



Let's write down the networks, all "blocks" of 8:

Subnet #1: Network: 192.168.1.0

Subnet #2: Network: 192.168.1.8

Subnet #3: Network: 192.168.1.16

Subnet #4: Network: 192.168.1.24

Now we know the networks we can write down the broadcast addresses, this is the last IP address of the subnet:

Subnet #1:	Network:	192.168.1.0
	Broadcast:	192.168.1.7
Subnet #2:	Network:	192.168.1.8
	Broadcast:	192.168.1.15
Subnet #3:	Network:	192.168.1.16
	Broadcast:	192.168.1.23
Subnet #4:	Network:	192.168.1.24
	Broadcast:	192.168.1.31

What is the subnet mask?

Take "256" minus "block size" will give you the subnet mask:

256 – 8 = 248.

The subnet mask will be 255.255.255.248

One more step, we need to fill in the usable host IP addresses:

Subnet #1:	Network:	192.168.1.0
	First Host:	192.168.1.1
	Last Host:	192.168.1.6
	Broadcast:	192.168.1.7
Subnet #2:	Network:	192.168.1.8
	First Host:	192.168.1.9
	Last Host:	192.168.1.14
	Broadcast:	192.168.1.15
Subnet #3:	Network:	192.168.1.16
	First Host:	192.168.1.17
	Last Host:	192.168.1.22
	Broadcast:	192.168.1.23
Subnet #4:	Network:	192.168.1.24
	First Host:	192.168.1.25
	Last Host:	192.168.1.30
	Broadcast:	192.168.1.31

Exercise 5:

Now see if you can solve these questions:

1. Take the 172.16.0.0 Class B network and create 2 subnets out of it. Write down the following information:
    a. The 2 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

Let's take the 172.16.0.0 network and create 2 subnets.

We start with our block of "256" but now we are playing with the 3rd octet:

If we chop "256" into 2 blocks we get blocks with a size of "128".

Let's write down the first 3 subnets and their network addresses:

Subnet #1: Network: 172.16.0.0

Subnet #2: Network: 172.16.128.0

Let's write down the broadcast addresses:

Subnet #1:	Network:	172.16.0.0
	Broadcast:	172.16.127.255

Subnet #2:	Network:	172.16.128.0
	Broadcast:	172.16.255.255

What will the subnet mask be?

256 – 128 – 128

255.255.128.0

Last question, what are the usable host IP addresses?

Subnet #1:	Network:	172.16.0.0
	First Host:	172.16.0.1
	Last Host:	172.16.127.254
	Broadcast:	172.16.127.255

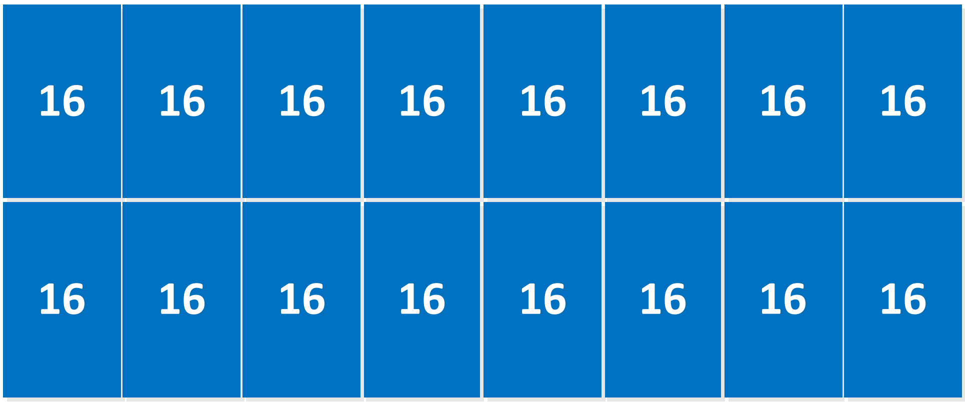
Subnet #2:	Network:	172.16.128.0
	First Host:	172.16.128.1
	Last Host:	172.16.255.254
	Broadcast:	172.16.255.255

2. Take the 172.16.0.0 Class B network and create 16 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

Let's take the 172.16.0.0 network and create 2 subnets.

We start with our block of "256" but now we are playing with the 3rd octet:

If we chop "256" into 16 blocks we get blocks with a size of "16".



Let's write down the first 4 subnets and their network addresses:

Subnet #1: Network: 172.16.0.0

Subnet #2: Network: 172.16.16.0

Subnet #3: Network: 172.16.32.0

Subnet #4: Network: 172.16.48.0

Let's write down the broadcast addresses:

Subnet #1:	Network:	172.16.0.0
	Broadcast:	172.16.15.255
Subnet #2:	Network:	172.16.16.0
	Broadcast:	172.16.31.255
Subnet #3:	Network:	172.16.32.0
	Broadcast:	172.16.47.255
Subnet #4:	Network:	172.16.48.0
	Broadcast:	172.16.63.255

What will the subnet mask be?

256 – 16 = 240

255.255.240.0

Last question, what are the usable host IP addresses?

Subnet #1:	Network:	172.16.0.0
	First Host:	172.16.0.1
	Last Host:	172.16.15.254
	Broadcast:	172.16.15.255
Subnet #2:	Network:	172.16.16.0
	First Host:	172.16.16.1
	Last Host:	172.16.31.254
	Broadcast:	172.16.31.255
Subnet #3:	Network:	172.16.32.0
	First Host:	172.16.32.1
	Last Host:	172.16.47.254
	Broadcast:	172.16.47.255
Subnet #4:	Network:	172.16.48.0
	First Host:	172.16.48.1
	Last Host:	172.16.63.254
	Broadcast:	172.16.63.255

Exercise 6:

Now see if you can solve these questions:

1. Take the 10.0.0.0 Class A network and create 2 subnets out of it. Write down the following information:
    a. The 2 subnets.
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

Let’s take the 10.0.0.0 network and create 2 subnets.

We start with our block of “256” but now we are playing with the 2nd octet:

If we chop “256” into 2 blocks we get blocks with a size of “128”.

Let’s write down the first 2 subnets and their network addresses:

Subnet #1:	Network:	10.0.0.0
Subnet #2:	Network:	10.128.0.0

Let’s write down the broadcast addresses:

Subnet #1:	Network:	10.0.0.0
	Broadcast:	10.127.255.255
Subnet #2:	Network:	10.128.0.0
	Broadcast:	10.255.255.255

What will the subnet mask be?

256 – 128 = 128

255.128.0.0

Last question, what are the usable host IP addresses?

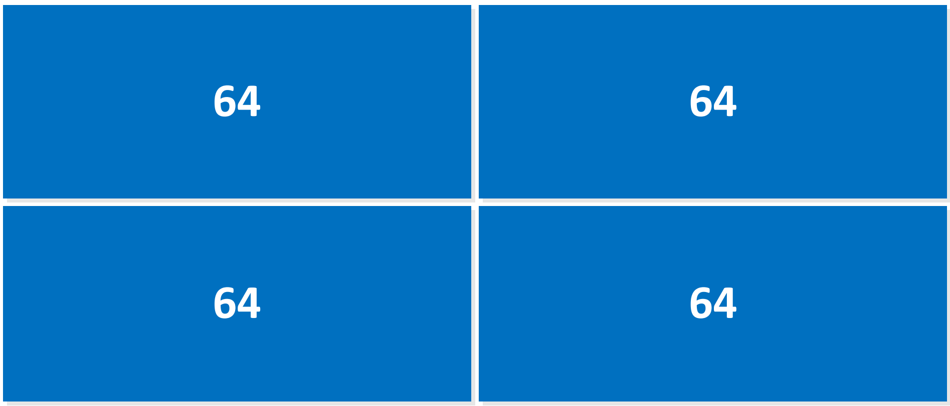
Subnet #1:	Network:	10.0.0.0
	First Host:	10.0.0.1
	Last Host:	10.127.255.254
	Broadcast:	10.127.255.255
Subnet #2:	Network:	10.128.0.0
	First Host:	10.128.0.1
	Last Host:	10.255.255.254
	Broadcast:	10.255.255.255

2. Take the 10.0.0.0 Class A network and create 4 subnets out of it. Write down the following information:
    a. The first 4 subnets
    b. The network addresses
    c. The broadcast addresses
    d. The usable host IP addresses.

Let’s take the 10.0.0.0 network and create 4 subnets.

We start with our block of “256” but now we are playing with the 2nd octet:

If we chop “256” into 4 blocks we get blocks with a size of “64”.



Let’s write down the first 4 subnets and their network addresses:

Subnet #1: Network: 10.0.0.0

Subnet #2: Network: 10.64.0.0

Subnet #3: Network: 10.128.0.0

Subnet #4: Network: 10.192.0.0

Let's write down the broadcast addresses:

Subnet #1:	Network:	10.0.0.0
	Broadcast:	10.63.255.255
Subnet #2:	Network:	10.64.0.0
	Broadcast:	10.127.255.255
Subnet #3:	Network:	10.128.0.0
	Broadcast:	10.191.255.255
Subnet #4:	Network:	10.192.0.0
	Broadcast:	10.255.255.255

What will the subnet mask be?

256 – 64 = 192

255.192.0.0

Last question, what are the usable host IP addresses?

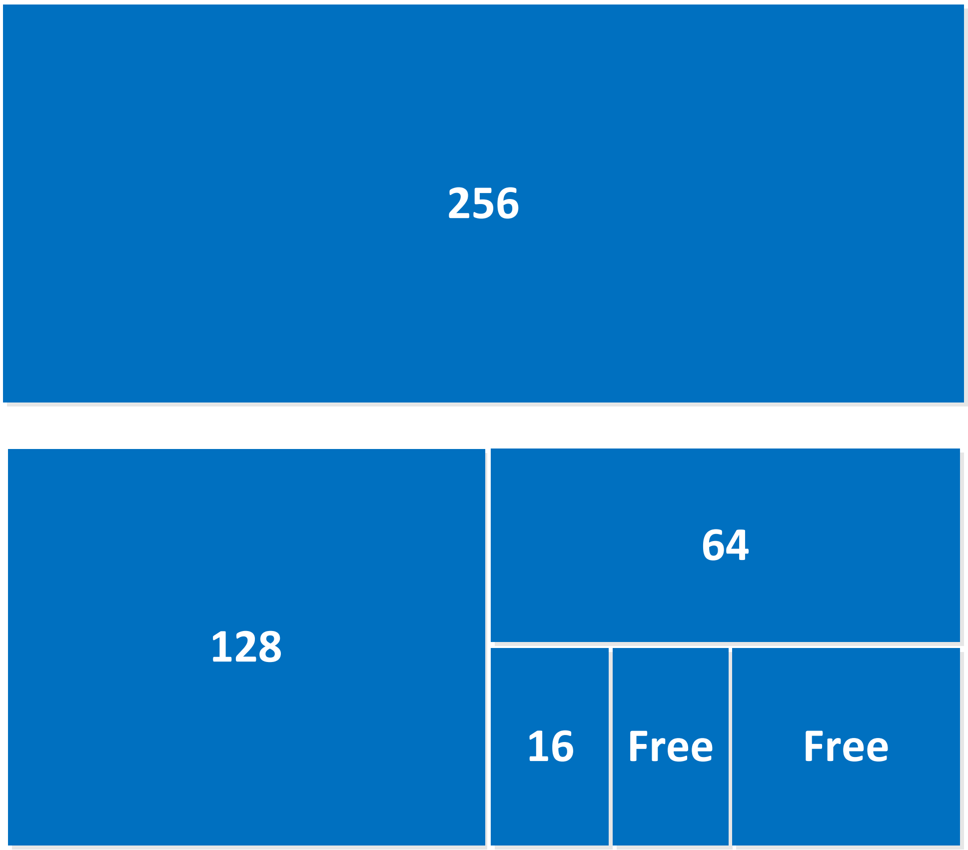
Subnet #1:	Network:	10.0.0.0
	First Host:	10.0.0.1
	Last Host:	10.63.255.254
	Broadcast:	10.63.255.255
Subnet #2:	Network:	10.64.0.0
	First Host:	10.64.0.1
	Last Host:	10.127.255.254
	Broadcast:	10.127.255.255
Subnet #3:	Network:	10.128.0.0
	First Host:	10.128.0.1
	Last Host:	10.191.255.254
	Broadcast:	10.191.255.255
Subnet #4:	Network:	10.192.0.0
	First Host:	10.192.0.1
	Last Host:	10.255.255.254
	Broadcast:	10.255.255.255

Exercise 7:

Now see if you can solve these questions:

1. Take the 192.168.4.0 Class C network and create the following subnets:
   a. One subnet with a block of 128.
   b. One subnet with a block of 64.
   c. One subnet with a block of 16.
   d. Write down the network/broadcast addresses and the host IP addresses.

Let's take our block of "256" and divide it into the blocks we need:



Now we can write down the subnets:

Subnet #1: Network: 192.168.4.0

Subnet #2: Network: 192.168.4.128

Subnet #3: Network: 192.168.4.192

Let's write down the subnet masks for the 3 subnets:

256 – block size = subnet mask.

Subnet #1: 256 – 128 = 128. The subnet mask is 255.255.255.128
Subnet #2: 256 – 64 = 192. The subnet mask is 255.255.255.192
Subnet #3: 256 – 16 = 240. The subnet mask is 255.255.255.240

We have the subnets and subnet masks, let's write down the broadcast addresses:

Subnet #1:	Network:	192.168.4.0
	Broadcast:	192.168.4.127
Subnet #2:	Network:	192.168.4.128
	Broadcast:	192.168.4.191
Subnet #3:	Network:	192.168.4.192
	Broadcast:	192.168.4.207

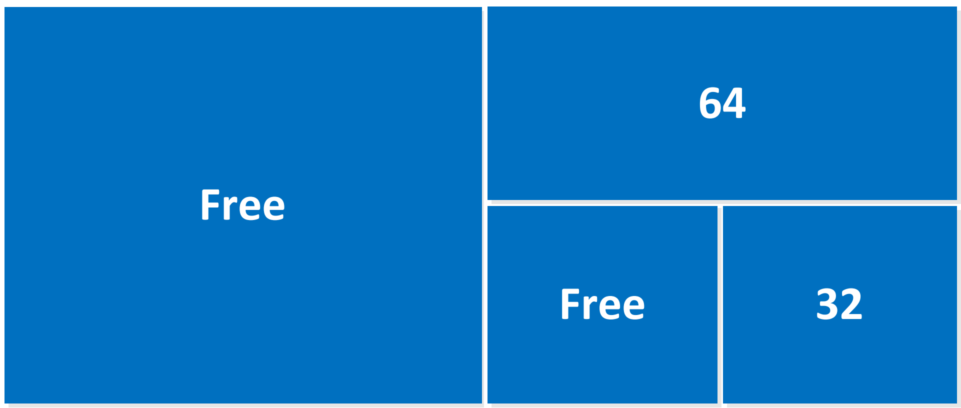
The last step is to fill in the usable host IP addresses:

Subnet #1:	Network:	192.168.4.0
	First Host:	192.168.4.1
	Last Host:	192.168.4.126
	Broadcast:	192.168.4.127
Subnet #2:	Network:	192.168.4.128
	First Host:	192.168.4.129
	Last Host:	192.168.4.190
	Broadcast:	192.168.4.191
Subnet #3:	Network:	192.168.4.192
	First Host:	192.168.4.193
	Last Host:	192.168.4.206
	Broadcast:	192.168.4.207

2. Take the 172.16.0.0 Class B network and create the following subnets:
    a. Two subnets with a block of 128.
    b. One subnet with a block of 64.
    c. One subnet with a block of 32.
    d. Write down the network/broadcast addresses and the host IP addresses.

Let's take our block of "256" and divide it into the blocks we need:

We need 2 "blocks" of 128, which means our block of "256" is full now. This is no problem because we are using a Class B network, we just take another block.



Now we can write down the subnets:

Subnet #1:   Network: 172.16.0.0

Subnet #2:   Network: 172.16.0.128

Subnet #3:   Network: 172.16.1.0

Subnet #4:   Network: 172.16.1.64

Let’s write down the subnet masks for the 4 subnets:

256 – block size = subnet mask.

Subnet #1:   256 – 128 = 128. The subnet mask is 255.255.255.128
Subnet #2:   256 – 128 = 128. The subnet mask is 255.255.255.128
Subnet #3:   256 – 64 = 192. The subnet mask is 255.255.255.192
Subnet #4:   256 – 32 = 224. The subnet mask is 255.255.255.224

We have the subnets and subnet masks, let's write down the broadcast addresses:

Subnet #1:	Network:	172.16.0.0
	Broadcast:	172.16.0.127
Subnet #2:	Network:	172.16.0.128
	Broadcast:	172.16.0.255
Subnet #3:	Network:	172.16.1.0
	Broadcast:	172.16.1.63
Subnet #4:	Network:	172.16.1.64
	Broadcast:	172.16.1.95

The last step is to fill in the usable host IP addresses:

Subnet #1:	Network:	172.16.0.0
	First Host:	172.16.0.1
	Last Host:	172.16.0.126
	Broadcast:	172.16.0.127
Subnet #2:	Network:	172.16.0.128
	First Host:	172.16.0.129
	Last Host:	172.16.0.254
	Broadcast:	172.16.0.255
Subnet #3:	Network:	172.16.1.0
	First Host:	172.16.1.1
	Last Host:	172.16.1.62
	Broadcast:	172.16.1.63
Subnet #4:	Network:	172.16.1.64
	First Host:	172.16.1.65
	Last Host:	172.16.1.94
	Broadcast:	172.16.1.95

Take the 172.16.0.0 class B network and create the following subnets:

e. One subnet that fits 240 hosts.
f. One subnet that fits 31 hosts.
g. One subnet that's fits 7 hosts.
h. Write down the network/broadcast addresses and the host IP addresses.

Let's take a look at the blocks we need. First of all we need a subnet that fits 240 hosts, that's a single block of "256":

We'll take another block and divide it:

Let's write down the subnets:

Subnet #1: Network: 172.16.0.0

Subnet #2: Network: 172.16.1.0

Subnet #3: Network: 172.16.1.64

Let's write down the subnet masks for the 3 subnets:

256 – block size = subnet mask.

Subnet #1: 256 – 256 = 0. The subnet mask is 255.255.255.0
Subnet #2: 256 – 64 = 192. The subnet mask is 255.255.255.192
Subnet #3: 256 – 16 = 240. The subnet mask is 255.255.255.240

We have the subnets and subnet masks, let's write down the broadcast addresses:

Subnet #1:	Network:	172.16.0.0
	Broadcast:	172.16.0.255
Subnet #2:	Network:	172.16.1.0
	Broadcast:	172.16.1.63
Subnet #3:	Network:	172.16.1.64
	Broadcast:	172.16.1.79

The last step is to fill in the usable host IP addresses:

Subnet #1:	Network:	172.16.0.0
	First Host:	172.16.0.1
	Last Host:	172.16.0.254
	Broadcast:	172.16.0.255
Subnet #2:	Network:	172.16.1.0
	First Host:	172.16.1.1
	Last Host:	172.16.1.62
	Broadcast:	172.16.1.63
Subnet #3:	Network:	172.16.1.64
	First Host:	172.16.1.65
	Last Host:	172.16.1.78
	Broadcast:	172.16.1.79

Exercise 8:

See if you can create the following summaries:

1. Combine the following networks into a single summary:
   a. 192.168.1.0 / 24
   b. 192.168.2.0 / 24

When we did the subnetting exercises, you had to borrow a host-bit to create multiple subnets. If you wanted 2 subnets out of the /24 network, you would get 2x a /25. With summarization we go the other way around. This means that to combine 2x /24 you can use a /23.

Your summary address will be 192.168.1.0 /23.

If you want to know the subnet mask, there's an easy trick:

256 – number of networks = subnet mask.

256 – 2 = 254. The subnet mask of the summary will be 255.255.254.0

2. Now try this one:
   a. 172.16.0.0 / 16
   b. 172.16.1.0 / 16
   c. 172.16.2.0 / 16
   d. 172.16.3.0 / 16

To combine 2x a /16 network, you will have /15. If you want to combine 4x a /16 network you will have a /14.

Your summary address will be 172.16.0.0 /14.
If you want to know the subnet mask:

256 – number of networks = subnet mask.

256 – 4 = 252. The subnet mask of the summary will be 255.252.0.0

3. Last one:
   a. 10.0.0.0 / 8
   b. 11.0.0.0 / 8
   c. 12.0.0.0 / 8
   d. 13.0.0.0 / 8
   e. 14.0.0.0 / 8
   f. 15.0.0.0 / 8
   g. 16.0.0.0 / 8
   h. 17.0.0.0 / 8

A single network is a /8.
2x networks is a /7.
4x networks is a /6.
8x networks is a /5.

So in this case your summary address will be 10.0.0.0 /5.

For the subnet mask:

256 – number of networks = subnet mask.

256 – 8 = 248. The subnet mask of the summary will be 248.0.0.0

Exercise 9:

Now see if you can solve these questions:

1. Take the decimal number 140 and calculate it into hexadecimal

Let's write down 140 in binary first:

	128	64	32	16	8	4	2	1
140	1	0	0	0	1	1	0	0

Now we need to cut this byte in 2 pieces so we have 2 nibbles:

	8	4	2	1
8	1	0	0	0

	8	4	2	1
12	1	1	0	0

For hexadecimal you need to keep in mind this table:

Decimal	Hexadecimal
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	A
11	B
12	C
13	D
14	E
15	F

As you can see 12 = C.

The hexadecimal value will be 8C, also written as 0x8C.

2. Take the decimal number 94 and calculate it into hexadecimal.

Let's write down 94 in binary first:

	128	64	32	16	8	4	2	1
94	0	1	0	1	1	1	1	0

Now we need to cut this byte in 2 pieces so we have 2 nibbles:

	8	4	2	1
5	0	1	0	1

	8	4	2	1
14	1	1	1	0

14 in hexadecimal is "E" (take a look at the chart).

So the hexadecimal value will be 0x5E.

3. Take the hexadecimal number 0xAD and calculate it into decimal.

If you take a look at the chart, you see that "A" is 10 in decimal and "D" is 13 in decimal.

Let's write that down in 2 nibbles and do the decimal to binary conversion:

	8	4	2	1
10	1	0	1	0

	8	4	2	1
13	1	1	0	1

Now put the 2 nibbles together and create a byte, then do the binary to decimal conversion:

	128	64	32	16	8	4	2	1
173	1	0	1	0	1	1	0	1

And there you go, the answer is "173".

4. Take the hexadecimal number 0xCD and calculate it into decimal.

If you take a look at the chart, you see that "C" is 12 in decimal and "D" is 13 in decimal.

Let's write that down in 2 nibbles and do the decimal to binary conversion:

	8	4	2	1
12	1	1	0	0

	8	4	2	1
13	1	1	0	1

Now put the 2 nibbles together and create a byte, then do the binary to decimal conversion:

	128	64	32	16	8	4	2	1
205	1	1	0	0	1	1	0	1

And there you go, the answer is "205".

Exercise 10:

See if you can solve the following subnetting questions:

1. You are given the 192.168.1.44 /28 address, what kind of address is this? Broadcast? Network? Usable for a host?

To solve this question you need to know how many bits the subnet is with a /28 mask. If you use a /28 you are borrowing 4 host-bits from the 4th octet:

	128	64	32	16	8	4	2	1
	1	1	1	1	0	0	0	0

128+64+32+16 = 240. The subnet mask is 255.255.255.240

256 – Subnet mask = size of subnet.
256 – 240 = 16.

Now we know the size of the subnets, we can write them down:

Subnet #1: Network: 192.168.1.0

Subnet #2: Network: 192.168.1.16

Subnet #3: Network: 192.168.1.32

Subnet #4: Network: 192.168.1.48

As you can see the 192.168.1.44 IP address belongs to the third subnet and is a valid IP address for a host.

2. You are given the 192.168.7.64 /29 address, what kind of address is this? Broadcast? Network? Usable for a host?

If you use a /29 you are borrowing 5 host-bits from the 4th octet:

	128	64	32	16	8	4	2	1
	1	1	1	1	1	0	0	0

128+64+32+16+8 = 248. The subnet mask is 255.255.255.248

256 – Subnet mask = size of subnet.
256 – 248 = 8.

Now we know the size of the subnets, we can write them down:

Subnet #1: Network: 192.168.7.0

Subnet #2: Network: 192.168.7.8

Subnet #3: Network: 192.168.7.16

Subnet #4: Network: 192.168.7.24

Subnet #5: Network: 192.168.7.32

Subnet #6: Network: 192.168.7.40

Subnet #7: Network: 192.168.7.48

Subnet #8: Network: 192.168.7.56

Subnet #9: Network: 192.168.1.64

As you can see the 192.168.7.64 IP address is the network address for subnet #9.

3. You are given the 10.1.4.3 /18 address, what kind of address is this? Broadcast? Network? Usable for a host?

With a /18 mask you are borrowing 2 host-bits from the 3rd octet, let's see what the subnet mask is:

128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0

128+64 = 192. The subnet mask is 255.255.192.0
256 – Subnet mask = size of subnet.
256 – 192 = 64.

Now we can write down the subnets:

Subnet #1: Network: 10.1.0.0

Subnet #2: Network: 10.1.64.0

As you can see 10.1.4.3 /18 is an IP address in Subnet #1 and is a valid host IP address.

4. You are given the 172.16.4.3 /22 address, what kind of address is this? Broadcast? Network? Usable for a host?

With a /22 mask you are borrowing 6 host-bits from the 3rd octet, let's see what the subnet mask is:

128	64	32	16	8	4	2	1
1	1	1	1	1	1	0	0

128+64+32+16+8+4 = 252. The subnet mask is 255.255.252.0

256 – Subnet mask = size of subnet.

256 – 252 = 4.

Now we can write down the subnets:

Subnet #1: Network: 172.16.0.0

Subnet #2: Network: 172.16.4.0

Subnet #3: Network: 172.16.8.0

As you can see 172.16.4.3 /22 is an IP address in Subnet #2 and is a valid host IP address.

5. You are given the 192.168.1.0/25 address, what is the maximum number of subnets you can create?

With a /25 mask you are borrowing 1 host bit from the 4th octet.

128	64	32	16	8	4	2	1
1	0	0	0	0	0	0	0

Remember a /30 is the smallest subnet you can create. This means we can borrow 5 more host-bits to create subnets.

2 to the power of 5 = 32 subnets that we can create.