Using this method implies that you have a solid understanding of the following table:

Reference Table

Remember, subnetting involves the “borrowing” of consecutive bits from left to right; starting from the Greatest Significant Bit.

Decimal	128	64	32	16	8	4	2	1
Base Value	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Borrowed Bits	+1	+2	+3	+4	+5	+6	+7	+8
Borrowed bits in binary	1	1	1	1	1	1	1	1
Total	128	192	224	240	248	252	254	255

Key Concepts to remember:

Subnet Mask/ Netmask/ Prefix-length

- A subnet mask/ netmask/ prefix-length is a 32-bit number associated with an ip address that identifies the network and host portions (ID) of an ip address. Each bit that is turned on [1] is a part of the network portion; whereas, each bit that is turned off [0] is a part of
- the host portion.

What does this mean?
Any portion of the subnet mask that is a network or host bit also applies to the IP address.
e.g 192.168.1.0/24

Subnet mask = 255.255.255.0, Red text = network portion, black text = host portion

These portions are also applied to the IP address:

192.168.1.0/24 → Any IP address beginning with 192.168.1 will be within the same network.

Classes of IP addresses

The IP address Class represents the default subnet mask of the IP address based on the value of the first octet in the address.

Class A

- A value of 1-126: Class A, Default Subnet Mask = 255.0.0.0 or /8 in CIDR Notation
  Subnet mask in binary: 11111111.00000000.00000000.00000000

Class B

- A value of 128-191: Class B, Default Subnet mask = 255.255.0.0 or /16 in CIDR Notation
  Subnet mask in binary: 11111111.11111111.00000000.00000000

Class C

- A value of 192-223: Class C Default Subnet mask = 255.255.255.0 or /24 in CIDR Notation
  Subnet mask in binary: 11111111.11111111.11111111.00000000

Private IP Address Ranges [**RFC 1918**]

- Private address ranges are non-routable IP addresses that are used on local networks. This means that they cannot be used to access the internet, nor they cannot be directly accessible from the internet. The private address ranges are specified in **RFC 1918** and are shown below.
- Public IP addresses are the only routable IP addresses that can be used to access the internet and can be directly accessible from the internet. These are typically purchased from your ISP.

RFC 1918 Ranges

- Type A Private IP Address: [10.0.0.0 - 10.255.255.255] /8
- Type B Private IP Address: [172.16.0.0 - 172.31.255.255] /16
- Type C Private IP Address: [192.168.0.0 - 192.168.255.255] /24

CIDR Notation

- Classless Interdomain Routing (CIDR) notation represents the number of network bits **(subnet bits)** as a / followed by the number of bits that are "turned on" [1].
- Referring back to the classes, Type A = /8, Type B = /16, Type C = /24

LSB [Least Significant Bit], Interval or "Magic Number"

- The value of the last network bit [1], in decimal notation, that is turned on in the subnet mask.
- With the interval, you can determine the range/total amount of IP addresses [from network address to broadcast address] within the subnets.

For example 192.168.1.0/27

Subnet Mask in decimal = 255.255.255.0
In binary: 11111111.11111111.11111111.00000000

In this example, the least significant bit is a decimal value of 1.

Classful Addresses

The same process of finding the interval applies to Classful Addresses as well.
Class A: 10.10.10.0/8
Subnet mask in binary: 11111111.00000000.00000000.00000000
The least significant bit aka interval is 1.

Class B: 172.17.4.0/16
Subnet mask in binary: 11111111.11111111.00000000.00000000
The least significant bit aka interval is 1.

Class C: 192.168.1.0/24
Subnet mask in binary: 11111111.11111111.11111111.00000000
The least significant bit aka interval is 1.

You can also view a classful address as being the previous classful address + 8 borrowed bits:
e.g. 192.168.0.0/24 = /16 + /8 borrowed bits

Subnetting

- the process of dividing a large network into smaller networks; aka "borrowing" bits from the host portion and allocating them to the network portion. Refer to the borrowed bits section above.

Mixed Octet

- the octet that is going to be manipulated, based off of the CIDR Notation:
- Octet 1 will be dictated by a subnet mask of /1 - /8 ;
  - e.g 10.10.10.1 /8
- Octet 2 will be dictated by a subnet mask of /9 - /16
  - E.g 172.18.3.2/16
- Octet 3 will be dictated by a subnet mask of /17 - /24
  - E.g 192.168.1.0
- Octet 4 will be dictated by a subnet mask of /25 - /32
  - 192.168.6.32

Finding the IP Address Range [subnet] (Subnet Association)

To find the range we must first:

1. Determine the mixed octet in the IP address based off of the subnet mask
2. Determine the least significant bit (LSB) based off the subnet mask
3. Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**
    - This will determine the multiple that will be used to find the network address. If the value in the mixed octet is evenly divisible by the LSB, then the value in the mixed octet is already the network address, therefore you can skip step 4.
4. Take the quotient (which is the missing multiple) from the division of the mixed octet by the least significant bit, and multiply it by the least significant bit. This will be your network address.

Lets go through a few examples to display this:

Classful Address Ranges

E.g 10.150.211.1 /8

1. Determine the mixed octet based off the subnet mask:

10.150.211.1 /8

2. Determine the LSB based off the subnet mask

/8 = 11111111.00000000.00000000.00000000

This last value represents a decimal value of 1; LSB = 1

3. Determine the network address by dividing the value in the mixed octet by the least significant bit.

10/1 = 10

- 10 is evenly divisible by 1, therefore 10 will be the start of our IP address range.
- Since we are starting from the beginning, **the host bits (last 24 octets) will begin at 0, NOT 1:**

Network address: 10.0.0.0

- The broadcast address will be the maximum value in the host octets that reside in the 10.x.x.x network. The maximum number that can occupy an octet in binary is 255. Therefore:

Broadcast address: 10.255.255.255

Putting it all together:

Range: 10.0.0.0 - 10.255.255.255

Your usable IP address range will be all hosts between the network address and broadcast address:

Usable Address Range: 10.0.0.1 - 10.255.255.254

E.g 172.17.33.4 /16

1. Determine the mixed octet based off the subnet mask:

172.17.33.4 /16

2. Determine the LSB based off the subnet mask

/16 = 11111111.11111111.00000000.00000000

The last value represents a decimal value of 1; LSB = 1

3. Determine the network address by dividing the value in the mixed octet by the least significant bit.

17/1 = 17

- Since 17 is evenly divisible by 1, 17, preceded by the previous octet of 172, will be the start of our IP address range.
- Since we are starting from the beginning, **the host bits (last 16 octets) will begin at 0, NOT 1:**

  Network address: 172.17.0.0

- The broadcast address will be the maximum value in the host octets that reside in the 172.17.x.x network. The maximum number that can occupy an octet in binary is 255. Therefore:

  Broadcast address: 172.17.255.255

Putting it all together:

Range: 172.17.0.0 - 172.17.255.255

Your usable IP address range will be all hosts between the network address and broadcast address:

Usable Address Range: 172.17.0.1 - 172.17.255.254

E.g 192.168.3.21/24

1. Determine the mixed octet based off the subnet mask:

192.168.3.21 /24

2. Determine the LSB based off the subnet mask

/24 = 11111111.1111111.11111111.00000000

The last value represents a decimal value of 1; LSB = 1

3. Determine the network address by dividing the value in the mixed octet by the least significant bit.

3/1 = 3

- Since 3 is evenly divisible by 1, 3, preceded by the previous octets of 192 & 168, will be the start of our IP address range.
- Since we are starting from the beginning, **the host bits (last 8 octets) will begin at 0, NOT 1:**
  Network address: 192.168.3.0

- The broadcast address will be the maximum value in the host octets that reside in the 192.168.3.x network. The maximum number that can occupy an octet in binary is 255. Therefore:
  Broadcast address: 192.168.3.255

Putting it all together:
Range: 192.168.3.0 - 192.168.3.255

Your usable IP address range will be all hosts between the network address and broadcast address:
Usable Address Range: 192.168.3.1 - 192.168.3.254

Classless (Subnetted) Address Ranges

E.g 109.37.101.37/28

1. Determine the mixed octet based off the subnet mask:

109.37.101.37 /28

2. Determine the LSB based off the subnet mask

/28 = 11111111.11111111.11111111.11110000
The last number within the subnet mask represents a decimal value of 16; LSB = 16

3. Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**

37/16 = 2 remainder 5, the remainder will be ignored

4. Take the quotient (which is the missing multiple) from the division of the mixed octet by the least significant bit, and multiply it by the least significant bit. This will be your network address.

Quotient = 2; LSB = 16
    2 * 16 = 32

32, preceded by network octets of 109, 37, & 101 will be our network address.

Network Address: 109.37.101.32

- The broadcast address will be the network address of the next network - 1 .

We can find the next network address by taking the network address that determined (109.37.101.32) and adding the LSB to it:

109.37.101.32
+ 16
—-------------------
109.37.101.48 = Network address of the next network .

Broadcast address of the previous network:

109.37.101.48
\- 1
—-------------------
109.37.101.47 = Broadcast address of previous network

Another way of looking at this:
Technically, the network address 32 is inclusive, meaning that inclusive 32 + 16 is actually 47. However, people are accustomed to the beginning and ending values in a range of numbers being non-inclusive (exclusive) e.g. [1-5] → in a range between numbers 1 and 5, people will

typically count this as 3 numbers (2, 3, 4), instead of 5 if numbers 1 and 5 were included in the range (1, 2, 3, 4, 5).
To avoid this, you can take the network address and add the (LSB - 1) to find the broadcast address:

Network address 109.37.101.32
LSB = 16, LSB - 1 → 16 - 1 = 15

109.37.101.32
+ 15
—-------------------
Broadcast address = 109.37.101.47

Putting it all together:
Range: 109.37.101.32 - 109.37.101.47

Your usable IP address range will be all hosts between the network address and broadcast address:
Usable Address Range: 109.37.101.33 - 109.37.101.46

E.g 172.29.22.68 /22

1. Determine the mixed octet based off the subnet mask:

172.29.22.68 /22

2. Determine the LSB based off the subnet mask

/22 = 11111111.11111111.11111100.00000000
The last number within the subnet mask represents a decimal value of 4; LSB = 4

3. Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**

22/4 = 5 remainder 2, the remainder will be ignored

4. Take the quotient (which is the missing multiple) from the division of the mixed octet by the least significant bit, and multiply it by the least significant bit. This will be your network address.

Quotient = 5; LSB = 4

5* 4 = 20

20, preceded by network octets of 172 and 29 will be start of our IP address range. **The last host octet will start at 0, not 1:**

Network Address: 172.29.20.0

- The broadcast address will be the network address of the next network - 1 .

We can find the next network address by taking the network address that determined (109.37.101.32) and adding the LSB to it:

172.29.20.0
+ 4
—-------------------
172.29.24.0 = Network address of the next network .

Broadcast address of the previous network:

172.29.24.0
- 1
—-------------------
172.29.23.0

Network Address: 172.29.23.255

Remember, we have an entire host octet that remains after the network portion: 172.29.20.**x**. The broadcast address is the last address that is within the range; the last (maximum) value that can be in an octet is 255. That is why the broadcast address 172.29.23.255, and not 172.29.23.0

Another way of looking at this:

Technically, the network address 20 is inclusive, meaning that inclusive 20 + 4 is actually 23. However, people are accustomed to the beginning and ending values in a range of numbers being non-inclusive (exclusive) e.g. [1-5] → in a range between numbers 1 and 5, people will typically count this as 3 numbers (2, 3, 4), instead of 5 if numbers 1 and 5 were included in the range (1, 2, 3, 4, 5).

To avoid this, you can take the network address and add the (LSB - 1) to find the broadcast address:

Network address: 172.29.20.0 /22

LSB = 4, LSB - 1 → 4 - 1 = 3

172.29.20.0
+ 3

—-------------------
Broadcast address = 172.29.23.255
Don’t forget those last 8 host bits. The highest value in an octet is 255.

Putting it all together:

Range: 172.29.20.0 - 172.29.23.255

Your usable IP address range will be all hosts between the network address and broadcast address:

Usable Address Range: 172.29.20.1 - 172.29.23.254

E.g 193.207.253.111 /10

1. Determine the mixed octet based off the subnet mask:

193.207.253.111 /10

2. Determine the LSB based off the subnet mask

/10 = 11111111.11000000.00000000.00000000
The last number within the subnet mask represents a decimal value of 64; LSB = 64

3. Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**

207/64 = 3 remainder 15, the remainder will be ignored

4. Take the quotient (which is the missing multiple) from the division of the mixed octet by the least significant bit, and multiply it by the least significant bit. This will be your network address.

Quotient = 3; LSB = 64

3 * 64 = 192

192, preceded by network octet 193 will be the start of our IP address range. **The last host octet will start at 0, not 1:**

Network Address: 193.192.0.0

- The broadcast address will be the network address of the next network - 1 .

We can find the next network address by taking the network address that determined (193.192.0.0) and adding the LSB to it:

193.192.0.0
+ 64
—-------------------
193.256.0.0 = Network address of the next network

Well we know that the maximum number in an octet is 255, therefore this additional 1 will take effect on the previous octet (193)

Actual Network address of the next network: 194.0.0.0

Broadcast address of the previous network:

194.0.0.0
- 1
—-------------------
193.0.0.0
Broadcast Address: 193.255.255.255

Remember, the highest value we can have in an octet is 255, so the second network octet will max at 255. Also, we have 2 entire host octets that remain after the network portion: 193.192.**x**.**x**. The broadcast address is the last address that is within the range; the last (maximum) values that can be in the octets is 255. That is why the broadcast address 193.255.255.255, and not 193.255.0.0

Another way of looking at this:
Technically, the network address 192 is inclusive, meaning that inclusive 192 + 64 is actually 255. However, people are accustomed to the beginning and ending values in a range of numbers being non-inclusive (exclusive) e.g. [1-5] → in a range between numbers 1 and 5, people will typically count this as 3 numbers (2, 3, 4), instead of 5 if numbers 1 and 5 were included in the range (1, 2, 3, 4, 5).
To avoid this, you can take the network address and add the (LSB - 1) to find the broadcast address:

Network address: 193.192.0.0 /10
LSB = 64, LSB - 1 → 64 - 1 = 63

193.192.0.0
+ 63
—-------------------
Broadcast address = 193.255.255.255

Don’t forget those last 16 host bits. The highest value in an octet is 255.

Putting it all together:

Range: 193.192.0.0 - 193.255.255.255

Your usable IP address range will be all hosts between the network address and broadcast address:

Usable Address Range: 193.192.0.1 - 193.255.255.254

E.g 10.187.39.77 /5

1. Determine the mixed octet based off the subnet mask:

10.187.39.77 /5

2. Determine the LSB based off the subnet mask

/5 = 11111000.00000000.00000000.00000000

The last number within the subnet mask represents a decimal value of 8; LSB = 8

3. Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**

10/8 = 1 remainder 2, the remainder will be ignored

4. Take the quotient (which is the missing multiple) from the division of the mixed octet by the least significant bit, and multiply it by the least significant bit. This will be your network address.

Quotient = 1; LSB = 8

1 * 8 = 8

8 will be the start of our IP address range. **The last host octets will start at 0, not 1:**

Network Address: 8.0.0.0

- The broadcast address will be the network address of the next network - 1 .

We can find the next network address by taking the network address that determined (8.0.0.0) and adding the LSB to it:

8.0.0.0
+8
—-------------------
16.0.0.0 = Network address of the next network

Broadcast address of the previous network:

16.0.0.0
- 1
—-------------------
15.0.0.0
    Broadcast Address: 15.255.255.255

Remember, we have 3 entire host octets that remain after the network portion: 8.**x**.**x**.**x**. The broadcast address is the last address that is within the range; the last (maximum) value that can be in the octets is 255. That is why the broadcast address 15.255.255.255, and not 15.0.0.0

Another way of looking at this:
Technically, the network address 8 is inclusive, meaning that inclusive 8 + 8 is actually 15. However, people are accustomed to the beginning and ending values in a range of numbers being non-inclusive (exclusive) e.g. [1-5] → in a range between numbers 1 and 5, people will typically count this as 3 numbers (2, 3, 4), instead of 5 if numbers 1 and 5 were included in the range (1, 2, 3, 4, 5).
To avoid this, you can take the network address and add the (LSB - 1) to find the broadcast address:

    Network address: 8.0.0.0 /5
    LSB = 8, LSB - 1 → 8 - 1 = 7

        8.0.0.0
      + 7
      —------------------
    Broadcast address = 15.255.255.255

Don’t forget those last 24 host bits. The highest value in an octet is 255.

Putting it all together:
    Range: 8.0.0.0 - 15.255.255.255

Your usable IP address range will be all hosts between the network address and broadcast address:

Usable Address Range: 8.0.0.1 - 15.255.255.254

Formulas

1. Host bits and Network bits

Subnet mask→ $32\ bits\ =\ n\ +\ h,\ where\ n\ =\ network\ bits,\ \ h\ =\ host\ bits$

Meaning:

- Remember that a subnet mask is 32 bits long and is composed of two parts: the network portion and the host portion.
- With that being said, network bits and host bits can be derived from that base equation:

$h\ =\ 32\ -n$ → where h = host bits, n = network bits

$n\ =\ 32 - h$

E.g. 129.33.22.7 /30

Total bits in subnet mask = 32

Network bits = 30

32 - n = h → 32 - 30 = 2 host bits

E.g. 123.214.5.22 /18

Total bits in subnet mask = 32

Network bits = 18

32 - n = h → 32 - 18 = 14 host bits

2. Borrowed Bits

$b\ = n - d$

- Where b = borrowed bits, n = network bits based on the actual subnet mask in use , d = the default network bits based of the class of the IP address

E.g. 157.63.44.21 /23

1. Determine the Class of the IP address based on the value of the first octet:

157.63.44.21 /23

This is a Class B IP address → This has a default subnet mask of /16

2. Subtract the number of network bits in the default subnet mask from the number of network bits of the actual subnet mask:

Default network bits = /16
Actual network bits = /23

23-16 = 7 “borrowed bits” ; b = 7

E.g. 37.19.21.101 /26

1. Determine the class of the IP address based on the value of the first octet:

37.19.21.101 /26

This is a Class A IP address → This has a default subnet mask of /8

3. Subtract the number of network bits in the default subnet mask from the number of network bits of the actual subnet mask:

Default network bits = /8
Actual network bits = /26

26 - 8 = 18 “borrowed bits”; b = 18

3. Total IP addresses per subnet

Method 1

IP addresses per subnet = 2^{h} or 2^{32-n}

- where h = “host bits”, and n = network bits.

E.g. 192.168.1.0 /25

1. Determine the number of host bits:

Host bits = 32 bits - network bits → 32 - 25 = 7 host bits; h = 7

2. Determine IP addresses per subnet

Total IP addresses per subnet = $2^h \rightarrow 2^7$ = 128 addresses per subnet

Method 2

THIS METHOD ONLY WORKS WITH SUBNET MASKS THAT RANGE FROM /25 - /32.

Total IP addresses per subnet = LSB

In case you haven't noticed, your LSB will also give you the number of IP addresses per subnet.

E.g. 192.168.1.0 /25

/25 = 11111111.11111111.11111111.10000000

This decimal value at this bit = 128; LSB = 128

Here's the Check:

Total IP addresses = 2^h, where h = host bits || $2^{32-25} \;\; --> \;\; 2^7 = 128\; total\; addresses$

As it turns out, our total IP addresses per subnet is 128, and our LSB is also 128.
Therefore, total IP addresses = LSB

E.g. 192.168.11.9/29

LSB = 8 || $2^{32-29} \;\; --> \;\; 2^3 = 8\; total\; hosts\; per\; subnet$

4. Total Assignable hosts per subnet

   Assignable IP addresses per subnet = $(2^h - \; number\; of\; reserved\; addresses)$

   #### Cisco Design

In Cisco Network Design, there are 2 addresses that are reserved in an IP address range: the network address and broadcast address.

In this case the formula is:

IP addresses per subnet = $2^h \; - \; 2$

E.g. 172.99.201.3 /20

1. Determine the number of host bits

Host bits = 32 bits - network bits → 32 - 20 = 12 host bits; h = 12

2. Determine IP addresses per subnet

IP addresses per subnet = $2^h \rightarrow 2^{12}$ = 4096 addresses per subnet

3. Determine Assignable hosts per subnet

Assignable IP addresses per subnet = $(2^h - \ number\ of\ reserved\ addresses)$
Assignable IP addresses per subnet = $(2^h - \ 2\ ) \rightarrow (2^{12} - \ 2\ )$
Assignable IP addresses per subnet = 4094

AWS Design

In AWS Network Design, there are 5 addresses that reserved in an IP address range: the network address (1st address on a network), the router address (2nd address on a network), DNS Server address (3rd address on a network), future use address (4th address on a network), and broadcast address (last address on a network)

In this case, the formula is:

IP addresses per subnet = $2^h \ - \ 5$

E.g. 10.150.67.1 /21

1. Determine the number of host bits

Host bits = 32 bits - network bits → 32 - 21 = 11 host bits; h = 11

2. Determine IP addresses per subnet

IP addresses per subnet = $2^h \rightarrow 2^{11}$ = 2048 addresses per subnet

3. Determine Assignable hosts per subnet

Assignable IP addresses per subnet = $(2^h - \ number\ of\ reserved\ addresses)$
Assignable IP addresses per subnet = $(2^h - \ 2\ ) \rightarrow (2^{11} - \ 5\ ) \rightarrow$ 2048 - 5
Assignable IP addresses per subnet = 2043

5. Total subnets

Method 1

Total subnets = 2^b , where b = “borrowed bits”

Method 2

Total subnets = Total IPs per subnet based on the default subnet mask / total IPs per subnet based on your actual subnet mask

E.g. 111.111.111.111 /15

Method 1

1. Determine the class of the IP address based on the value of the first octet:

111.111.111.111 /15

This is a Class A IP address → This has a default subnet mask of /8

2. Subtract the number of network bits in the default subnet mask from the number of network bits of the actual subnet mask:

Default network bits = /8
Actual network bits = /15

15 - 8 = 7 “borrowed bits”; b = 7

3. Determine the amount of total subnets based on the formula

Total subnets = $2^b \rightarrow 2^7 \rightarrow$ 128 total subnets

Method 2

1. Determine the class of the IP address based on the value of the first octet:

111.111.111.111 /15

This is a Class A IP address → This has a default subnet mask of /8

2. Determine the IP addresses per subnet for this network based on the default network bits:

Host bits = 32 bits - network bits → 32 - 8 = 24 host bits; h = 24

IP addresses per subnet = $2^h \rightarrow 2^{24}$ = 16,777,216 addresses per subnet

3. Determine the IP addresses per subnet for this network based on the actual network bits in use:

Host bits = 32 bits - network bits → 32 bits - 15 network bits = 17 host bits; h = 17

IP addresses per subnet = $2^h \rightarrow 2^{17}$ = 131,072 addresses per subnet

4. Divide IP addresses per subnet based on the default network bits by the IP addresses per subnet based on the actual network bits

Total subnets = Total IPs per subnet based on the default subnet mask / total IPs per subnet based on your actual subnet mask

Total subnets = 16,777,216 addresses per subnet / 131,072 addresses per subnet
Total subnets = 128

Subnet/Host Determination

1. Determine the class of the IP address based on the value of the first octet

2. Determine the host bits that will satisfy the least amount of IP addresses per subnet

$(2^h \geq r)\, ! > 2.3(r)$ or $(2^h \geq r) < 2.3(r)$

r = host requirement, & $!>$ means not greater than

3. With the host bits, determine the subnet mask

Network bits = 32 bits - host bits

4. Find your total subnets to make sure your subnet mask is correct

Total subnets = 2^b

You are designing a subnet mask for the 172.18.0.0 network. You want 3200 subnets with at least 9 hosts on each subnet. What subnet mask should you use?

Step 1: Determine the Class of the IP address based on the value of the first octet:

172.18.0.0

Class B → default subnet mask of /16

Step 2: Determine the host bits that will satisfy the least amount of IP addresses per subnet
Host requirement <= 9 hosts; r = 9
$(2^h \geq r)\,! > 2.3(r)$ or $(2^h \geq r) < 2.3(r)$

$(2^4 >= 9)\,! > 2.3(9)$ → (16 > 9) < 20.7; 4 host bits will satisfy the host requirement' h = 4

Step 3: Determine the subnet mask based on the host bits
Network bits = 32 bits - host bits → 32 - 4 = 28 network bits → /28 subnet mask
Actual subnet mask = /28

Step 4: Check the amount of subnets based on the amount of borrowed bits
Default subnet bits = /16
Actual subnet bits = /28

b → 28 - 16 = 12 borrowed bits; b = 12
Total subnets = 2^b

$3200 \leq 2^{12}$
$3200 <= 4096$

A subnet mask of /28 will satisfy both the subnet and host requirement.

Which subnet does 192.168.59.169/26 belong to?

Step 1: Determine the mixed octet based on the subnet mask:

- 192.168.59.169 /26

Step 2: Determine the LSB based on the subnet mask:

/26 = 11111111.11111111.11111111.11000000

The decimal value of the last 1 is 64; LSB = 64

3. Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**

169/64 = 2 remainder 41, the remainder will be ignored

4. Take the quotient (which is the missing multiple) from the division of the mixed octet by the least significant bit, and multiply it by the least significant bit. This will be your network address.

Quotient = 2; LSB = 64
    2 * 64 = 128

128, preceded by network octets 192, 168, and 59 will be the start of our IP address range.
Network Address: 192.168.59.128

- The broadcast address will be the network address + LSB -1

192.168.59.128
  +   63
—--------------------
192.168.59.191 = Broadcast address

What is the broadcast address of the network 172.23.2.0 /23?

Step 1: Determine the mixed octet based on the subnet mask
- 172.23.2.0 /23

Step 2: Determine the LSB based on the subnet mask:

/23 = 11111111.11111111.11111110.00000000

The decimal value of the last 1 is 2; LSB = 2

3. Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**

2/2 = 1 ; Since the mixed octet is evenly divided by the LSB, 2, preceded by network octets 172 & 23, will be the start of our IP address range:
    Network Address: 172.23.2.0

- The broadcast address will be the network address + LSB -1

172.23.2.0
    + 1
—--------------------
172.23.3.0; remember we must include the last value for the host octet: 255.

Broadcast address = 172.23.3.255

Alternate Subnet Determination

6. What is the subnet mask, first available host address of subnet one (NOT subnet zero), and the maximum number of hosts per subnet for the network below?
You need to allow for the maximum number of hosts. You may be able to use the subnet zero and the all-ones subnet. RFC 1878

Network ID: 121.0.0.0
Subnets Required: 8
Subnet Mask:?
1st Available Host Address of Subnet 1: ?
Max # of hosts/subnet: ?

Step 1: Determine the class of the IP address in question

121.0.0.0
Class A IP address → Default subnet mask of /8

Step 2: Determine the amount of borrowed bits required to satisfy the subnet requirement, this is based on the total subnets formula.

- Minimum subnets = $(2^b >= \ subnet\ requirement) \ < \ 2.3(subnet\ requirement)$
- Minimum subnets = $(2^3 >= 8) \ < \ 2.2(8) \rightarrow (8 >= 8) \ < \ 17.6$

3 borrowed bits will satisfy the subnet requirement of 8 subnets

Step 3: Determine the new subnet mask based off the borrowed bits and the class of the IP address

- Default network bits of 8 + borrowed bits of 3 = 11 or /11 subnet mask

Step 4: Determine the LSB based on the new subnet mask

/11 in binary is 11111111.11100000.00000000.00000000

The last decimal value is 32; LSB = 32

Step 5: Determine the mixed octet based on the new subnet mask
121.0.0.0 / 11

Step 6: Determine the IP address ranges based on the LSB

- Determine the network address by dividing the value in the mixed octet by the least significant bit. **We will not use any fractions, decimals, remainders if the mixed is not evenly divisible by the LSB.**

0/32 = 0

- Take the quotient (which is the missing multiple) from the division of the mixed octet by the least significant bit, and multiply it by the least significant bit. This will be your network address.

Quotient = 0; LSB = 32
0 * 32 = 0

0, preceded by network octet 121 will be the start of our IP address range. **The last host octets will start at 0, not 1:**

Network Address: 121.0.0.0
Broadcast Address: 121.31.255.255
Range [Subnet 0] : 121.0.0.0 - 121.31.255.255

Range [Subnet 1]: 121.32.0.0 - 121.63.255.255
Usable host range: 121.32.0.1 - 121.63.255.254

Step 7: Determine the amount of host bits and IP addresses based off of the subnet mask
Actual subnet bit mask = /11 → subnet bits = 11

Host bits = 32 bits - network bits → 32 -11 = 21 host bits; h = 21

Total IP addresses per subnet = 2^h → 2,097,152 addresses per subnet

Total Assignable hosts per subnet = $2^h - 2$ → 2,097,152 - 2 = 2,097,150 hosts per subnet

Step 8: Fill in the blanks
Network ID: 121.0.0.0
Subnets Required: 8
Subnet Mask:

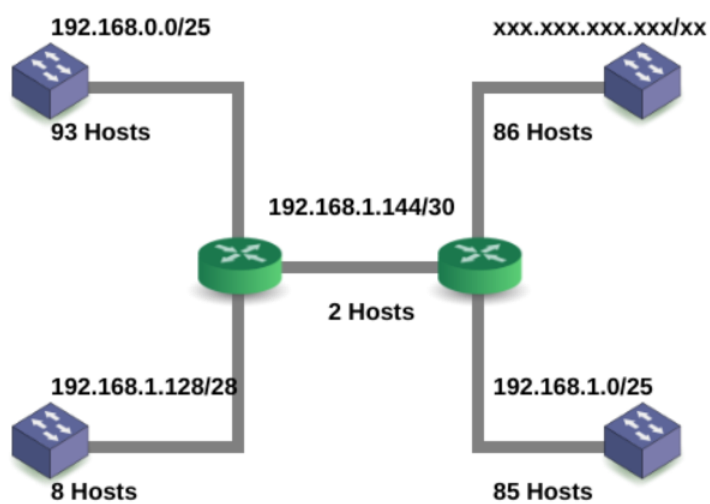
/11 or 255.224.0.0

1st Available Host Address of Subnet 1:
121.32.0.1

Max # of hosts/subnet:
2097150 hosts per subnet

Topology Related Scenarios

What is the network address and subnet mask (in CIDR notation) of the hidden (xxx.xxx.xxx.xxx/xx) subnet? The whole network has a network address and subnet mask of 192.168.0.0/23



Step 1: Determine the range for the whole network given the network address and subnet mask.
Mixed Octet:
192.168.0.0 /23

The whole network has a network address and subnet mask of 192.168.0.0/23
LSB = 2
The range for the whole network is [192.168.0.0 - 192.168.1.255]

Step 2: Determine the ranges for each network given the subnet masks. **Start from the network with the greatest hosts and work your way down, continuing the range from the previous network**. Be sure to consider the IP addresses of the known hosts/networks as well. If a network address and subnet mask is unavailable, choose a subnet mask that satisfies the given host requirements.

Network 1: 93 Hosts
192.168.0.0/25: Range = [192.168.0.0 - 192.168.0.127]

Network 2: 86 Hosts
Network address is unavailable; host requirement is 86 hosts,
$2^7 > 86$
7 host bits will satisfy this requirement.

$network\ bits\ =\ 32\ bits\ -\ host\ bits, \rightarrow$ 32 - 7 = 25 network bits;
a subnet mask of /25 will be used

Continue from the previous range:
192.168.0.128/25
Range: 192.168.0.128 - 192.168.0.255

Answer: 192.168.0.128/25

Subnetting Resources

Subnet Association Questions

http://www.subnettingquestions.com/

Address Range Determination

https://www.nybi.org/subnet-2.php

Alternate Subnet Association Questions

https://www.nybi.org/subnet-1.php

Topology-related Scenarios

https://subnettingpractice.com/

Supernetting

Supernetting is the opposite of subnetting, it involves the process of the host portion “borrowing” bits from the network portion. In other words, bits from the network portion will be allocated to the host portion.

CIDR

Classless Interdomain Routing is the actual network terminology for supernetting.
Classless inter-domain routing shortens the classful subnet mask. Instead of adding one’s to the subnet mask we remove them.
Classless inter-domain routing summarizes networks by removing subnet bits [from the network portion].

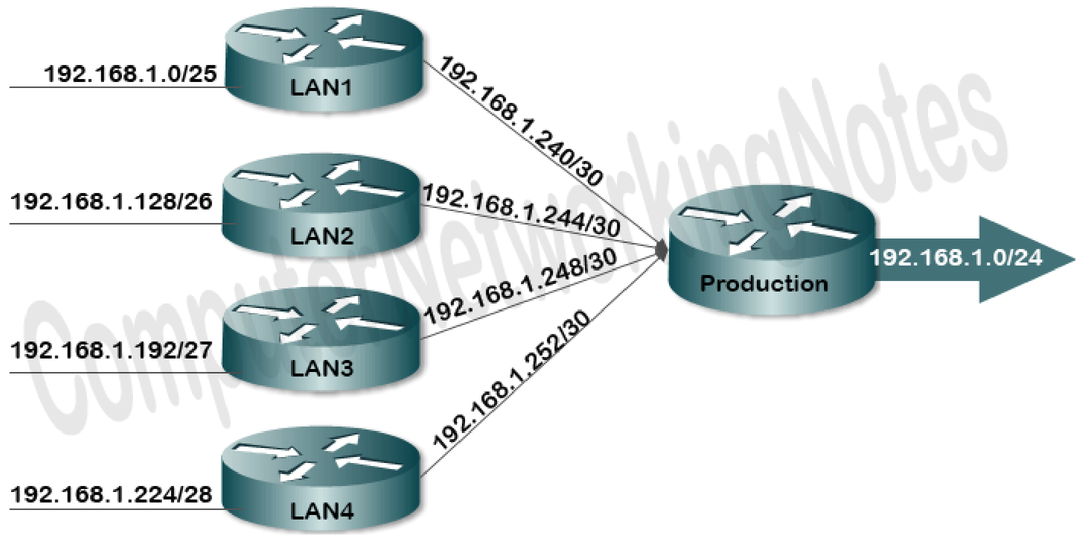
Where is CIDR used?

CIDR can be useful for example, service providers. They have to maintain lots and lots of networks in the routing table and instead of advertising each individual route, maybe for each individual customer, they could send an aggregated route. They could send a single network advertisement which could encompass multiple networks.

Route Summarization

Route Summarization/Route Aggregation, where routes to multiple networks with similar network prefixes are combined into a single routing entry, with the routing entry pointing to a Super network, encompassing all the networks. This in turn significantly reduces the size of routing tables and also the size of routing updates exchanged by routing protocols. Without Supernetting, routers will share all routes from routing tables as they are. With Supernetting, it will summarize them before sharing. Route summarization reduces the size of routing updates dramatically.

The following figure shows an example of Supernetting.



In the above example, 8 subnets are summarized in a single subnet.

Advantages of Supernetting

Supernetting provides the following advantages.

- It reduces the size of routing updates.
- It provides a better overview of the network.
- It decreases the use of resources such as Memory and CPU.
- It decreases the required time in rebuilding the routing tables.

Example

Summarize these IP addresses into one network: (A summarized route)
• 192.168.0.0/24
• 192.168.1.0/24
• 192.168.2.0/24
• 192.168.3.0/24

Step 1: Write all the IP Addresses in binary like so:

192.168.0.0/24
11000000.10101000.00000000.00000000

192.168.1.0/24
11000000.10101000.00000001.00000000

192.168.2.0/24
11000000.10101000.00000010.00000000

192.168.3.0/24
11000000.10101000.00000011.00000000

Step 2: Find matching bits from left to right

11000000.10101000.00000000.00000000
11000000.10101000.00000001.00000000
11000000.10101000.00000010.00000000
11000000.10101000.00000011.00000000

- To avoid possible confusion, start by matching bits starting from the last IP address, then work your way up.

Step 3: Re-write the matching numbers and add zeros for the non-matching bits; because you are converting network bits into host bits, each "newly acquired" host bit will be represented with a 0. Remember, network bits are represented with 1, host bits are represented with 0.

This new network address will be your NEW NETWORK ID, the route that you will be advertising. (A summarized route)
11000000.10101000.00000000.00000000 = 192.168.0.0

Step 4: Find the new subnet mask. Put "1s" in the matching networking part, and all zeros in the host part.

11111111.11111111.11111100.00000000
This your new subnet mask 255.255.252.0
Your new summarized route is 192.168.0.0/22

Wildcard Masks

Wildcard Masks are utilized in ACLs, to allow or deny traffic to a particular network; and routing protocols, to advertise certain routes in the routing table. In terms of the syntax, Wildcard masks are essentially the inverse of subnet masks:

- **Wildcard mask bit 0:** Match the corresponding bit value in the address. [Network Bit]
- **Wildcard mask bit 1:** Ignore the corresponding bit value in the address.[Host Bit]

To determine the wildcard mask of a subnet, you need to subtract 255.255.255.255 from the subnet mask:
e.g 255.255.255.0

    255.255.255.255
– 255.255.255.0
—-------------------------------------

0.0.0.255 is the Wildcard Mask

Shortcut

With that being said, simply inverse the values of each octet in the subnet mask to find the wildcard mask:
e.g 255.255.255.0 = 0.0.0.255

Wildcard Masks with Borrowed Bits

The same process applies to networks with borrowed bits: you need to subtract the decimal value of the subnet mask from 255.255.255.255:
e.g 255.255.224.0

```
        255.255.255.255
    –   255.255.224.0
—-----------------------------------
0.0.31.255 is the Wildcard Mask
```

Shortcut

Simply inverse the non-mixed octets of the subnet mask and only subtract the decimal value of the mixed octet from .255:
255.255.224.0
Non-mixed Octets: 0.0.?.255

Decimal value of Mixed Octet: .224

```
        .255
    -   .224
—---------------
        .31
```

Full Wildcard Mask = 0.0.31.255

172.17.215.6 255.255.240.0

Internal = 16
Mixed Octet = .215
Ranges = 172.17.208.0

172.17.224.0