IPv4 Subnetting – Sections

Section 1: Analyzing Individual Subnets

Section 2: Converting Subnet Masks

Section 3: Analyzing IP Networks

Section 4: Identifying the Subnets of a Network

Section 5: Analyzing Designs Using Masks

Section 6: Subnetting and the Exam

IPv4 Subnetting – Section 5

*** Interpreting Subnet Masks**

Variable Length Subnet Masks (VLSM)

* Choosing a Subnet Mask

In This Lesson...

Interpreting Subnet Masks

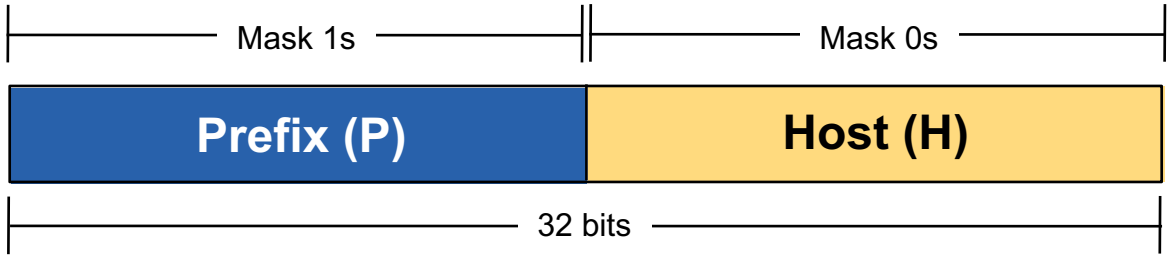
- **Process: Find the Number of Hosts/Subnet**
- Process: Find the Number of Subnets
- Learning Stages and Practice

Text Rules: Find Number of Host Addresses

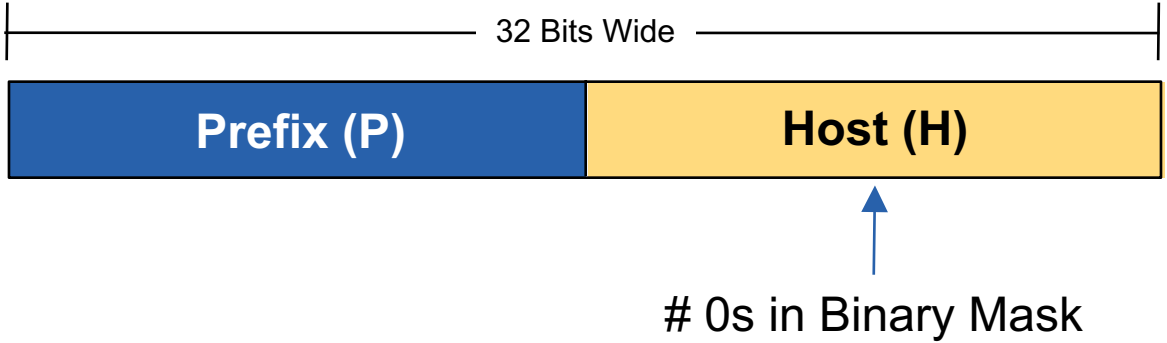
1. **Write the Mask in Prefix Format (/P) (Convert as Needed)**

2. **Find H: The Number of Host Bits**
   A. H = 32 - P

3. **Find the Size of the Subnet**
   A. 2^H : The Size Including Reserved Numbers
   B. $2^H - 2$: The Size Excluding Reserved Numbers

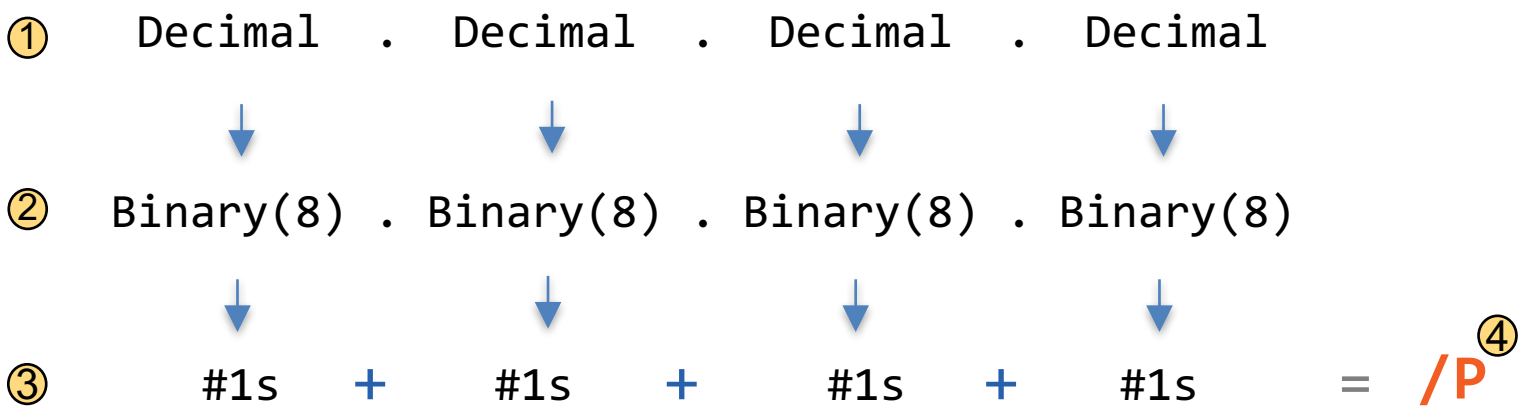


Visual Rules: Find Number of Host Addresses



$$\#\ \text{Hosts/Subnet} = 2^{H}$$

Reminder: Convert DDN Mask to Prefix



Reminder: The Nine DDN Octet Values

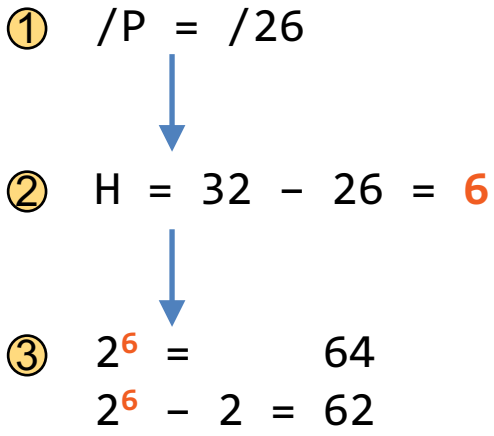
Decimal Octet Value	Binary	Number of Binary 1's
0	00000000	0
128	10000000	1
192	11000000	2
224	11100000	3
240	11110000	4
248	11111000	5
252	11111100	6
254	11111110	7
255	11111111	8

Reminder: 2^H and $2^H - 2$

H	2^H	$2^H - 2$ (# Hosts)
0	1	N/A
1	2	N/A
2	4	2
3	8	6
4	16	14
5	32	30
6	64	62
7	128	126

H	2^H	$2^H - 2$ (# of Hosts)
8	256	254
9	512	510
10	1024	1022
11	2048	2046
12	4096	4094
13	8192	8190
14	16,384	16,382
15	32,768	32,766

Example 1: /26



Example 2: /21

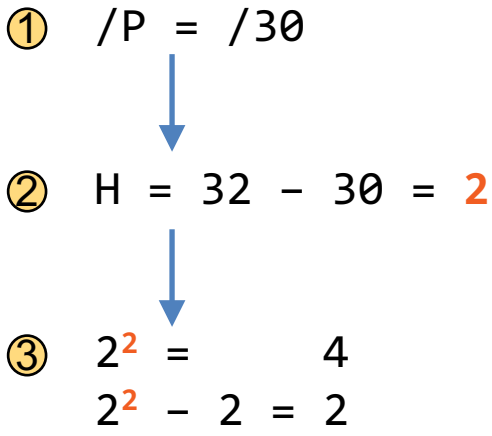
① /P = /21

② H = 32 – 21 = 11

③ 2^{11} = 2048

2^{11} – 2 = 2046

Example 3: /30



In This Lesson...

Interpreting Subnet Masks

- Process: Find the Number of Hosts/Subnet
- **Process: Find the Number of Subnets**
- Learning Stages and Practice

Text Rules: Find the Number of Subnets

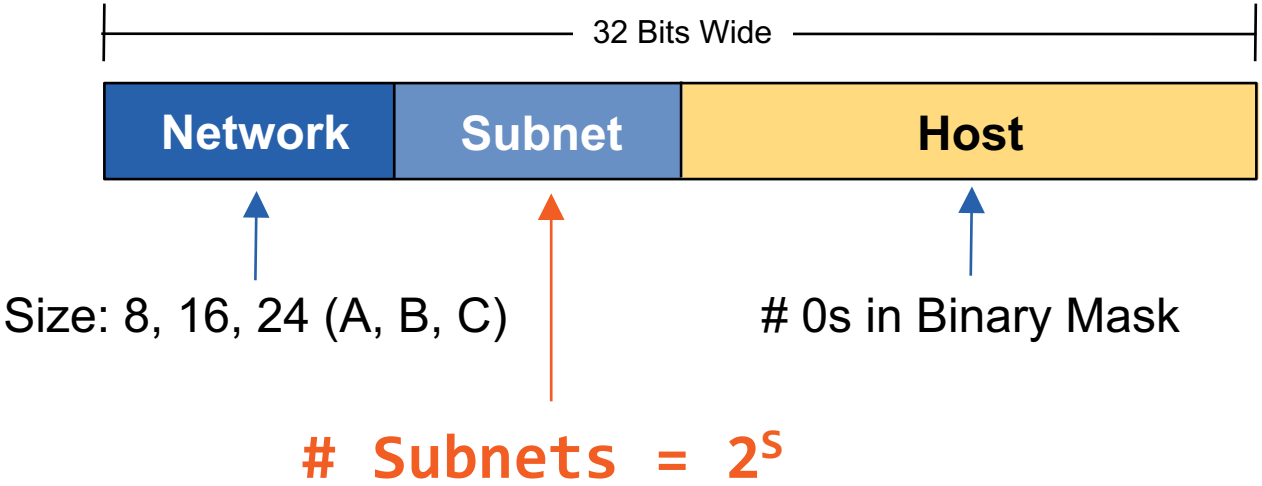
1. **Write Two Key Input Facts:**
   A. The Mask in Prefix Format (/P) (Convert as Needed)
   B. The Network Class (A, B, or C)

2. **Find the Number of Network, Subnet, and Host Bits**
   A. H = 32 – P
   B. N = 8, 16, or 24 Based on Class (A, B, C) Respectively
   C. S = P – N, or S = 32 – N – H

3. **Find the Number of Subnets**
   A. 2^S : The Number of Subnets

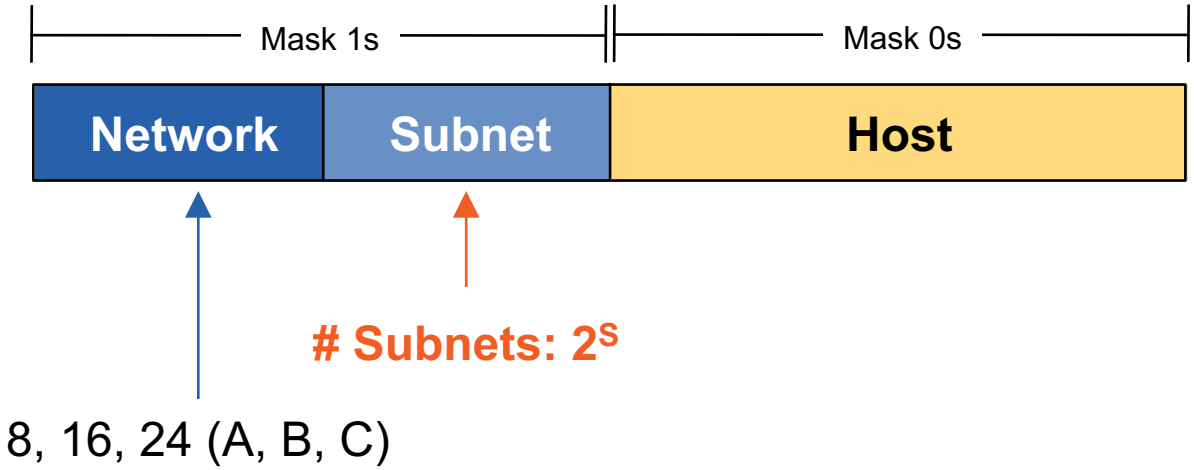
Class	N
A	8
B	16
C	24

Visual Rules: Find the Number of Subnets



Assumptions for “Find Number of Subnets”

- **1 Classful Network**
- **1 Subnet Mask for All Subnets**
- **NOT VLSM!**



Example 1: Class A, /19

Class A

① /P = /19

② H = 32 – 19 = 13
N = 8
S = 19 – 8 = 11

③ 2^{11} = 2048

Example 2: Class B, /21

Class B

① /P = /21

② H = 32 – 21 = 11
N = 16
S = 21 – 16 = 5

③ $2^5 = 32$

Example 3: Class C, /30

Class C

① /P = /30

② H = 32 – 30 = 2
N = 24
S = 30 – 24 = 6

③ 2^6 = 64

In This Lesson...

Interpreting Subnet Masks

- Process: Find the Number of Hosts/Subnet
- Process: Find the Number of Subnets
- **Learning Stages and Practice**

Stages

Stage	Primary Study Goal	Have You Understood and Memorized Ideas and Processes?	Do You Get 100% Correct?	Do You Go Fast?
1	Learning	**No**		
2	Perfecting	Yes	**No**	
3	Accelerating	Yes	Yes	**No**
4	Completed	**Yes**	**Yes**	**Yes**

Stage 1 (Learn) Advice for This Exercise

The Usual Approach

1. Use Notes/Examples
2. Check Answer if Unsure
3. Investigate Mistakes
4. **Ask Instructor to Work the Problem!**

Specifically…

1. Copy Powers of 2 from Table as Needed
2. Think Visually

Graduate to Stage 2 Now if:

1. Could Hide All Notes **Except Powers of 2** and Still Answer!

Stage 2 (Perfect) Advice for This Exercise

The Usual Approach:

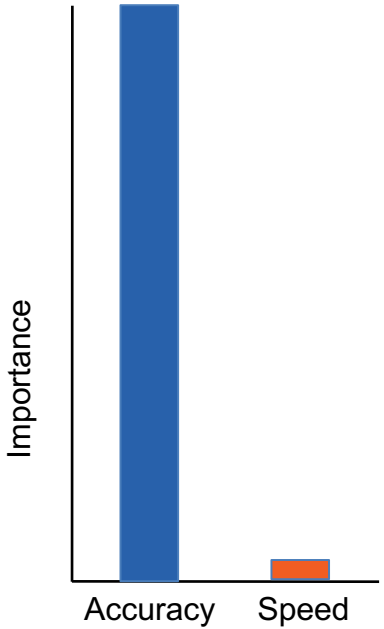
1. No Notes
2. Take Your Time
3. Complete a Question Set before Checking Answers

For These Processes:

1. Today: OK to Use Powers of 2 Table
2. **Memorize or Pre-Write Powers of 2 for Exam Day?**

Graduate to Stage 3 Now if:

1. You get 100% Correct on Two Sets
2. Confident about Writing your Pre-exam Notes
3. Can Move on if Still Working to Memorize Powers of 2



Stage 3 (Accelerate) Advice for this Exercise

Usual Approach: Time Trial

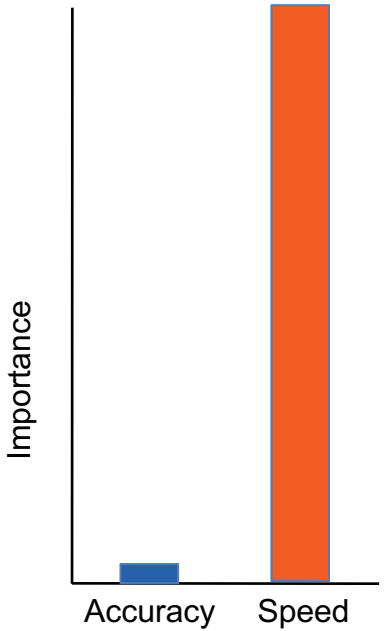
1. Write Pre-exam Notes
2. Set a Per-item Time Goal
3. Start Clock
4. Complete the Entire Question Set
5. Compare your Speed to Time Goal

Specific for this Process:

1. Memorize Powers of 2
2. Practice Pre-Exam Writing Plan
3. Speed Goal: Based on Prefix Mask

Graduate to Stage 4 Now if:

1. Meet Speed Goals



Speed Goals for CCNA Exam

Subnetting Processes	Book Speed Goals	Your Speed Goal	Your Current Speed	Your Current Stage
Find Classful Network Facts *	10			
Convert Mask Formats *	10			
Find Subnet Facts	30			
Interpret Design w/ Mask	15			
Choose One Mask	15			
Find All Subnet IDs *	45			

* These Time Estimates Do Not Include the Time to Write/Type the Answers

Practice!

Exercises for:

“Interpreting Existing Subnet Masks”

Come Back to Class!

Exercises for:

"Interpreting Existing Subnet Masks"

Time Finished!

IPv4 Subnetting – Sections

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IPv4 Subnetting – Section 5

* Interpreting Subnet Masks

Variable Length Subnet Masks (VLSM)

* Choosing a Subnet Mask

In This Lesson...

The Impact of VLSM on the Exams

- **VLSM Concepts**
- Questions Changed by VLSM
- VLSM Practice

VLSM

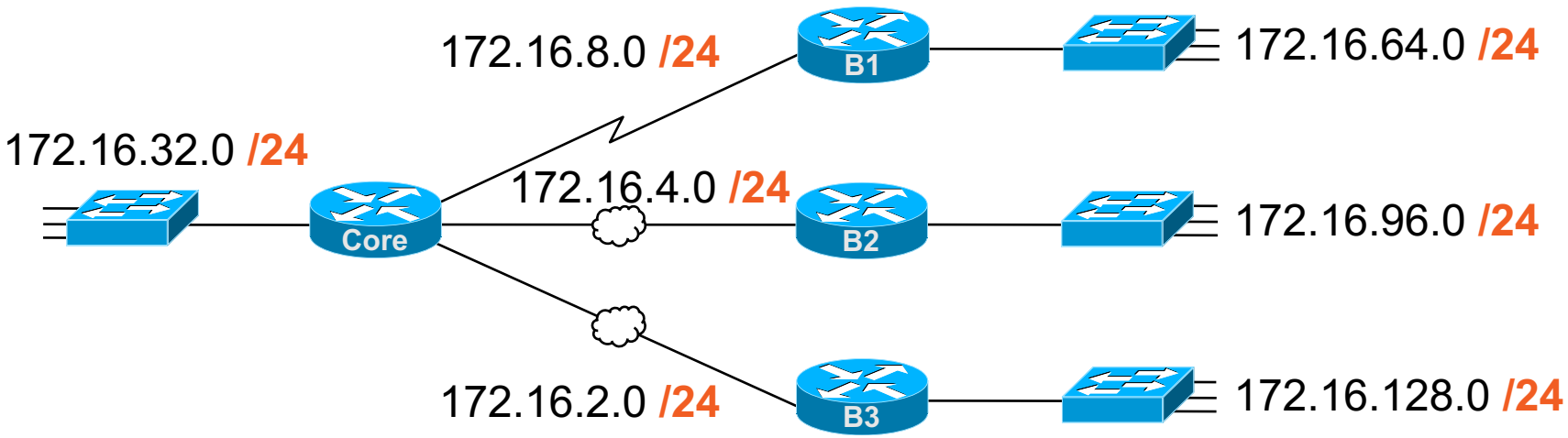
Correct Definition:

- Using >1 Mask, in Subnets of One Classful Network

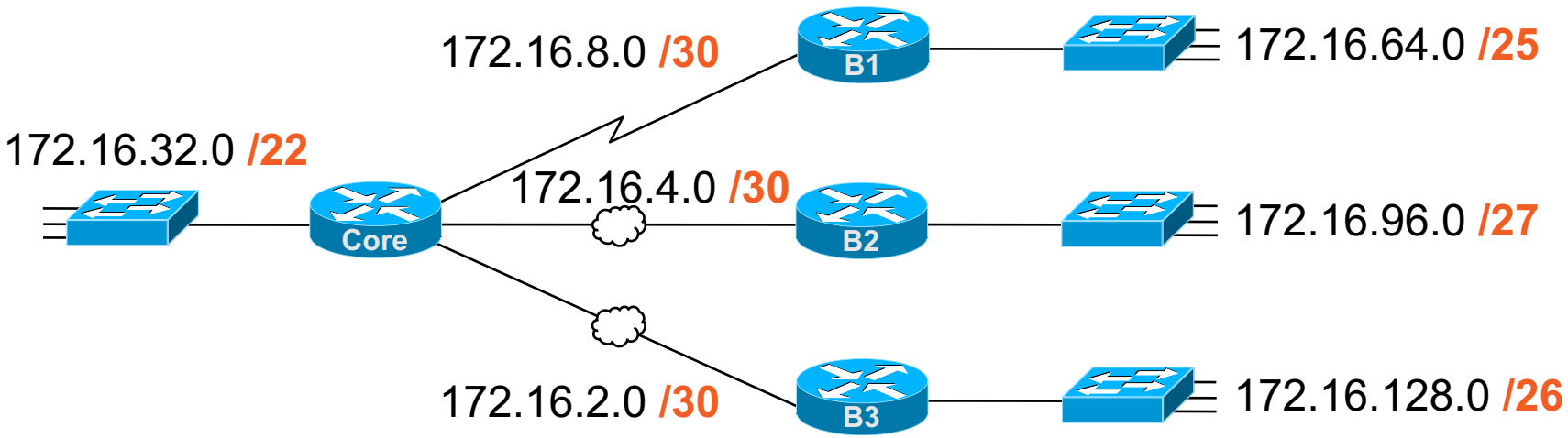
Common Misconceptions:

- Using >1 Mask in a TCP/IP Network
- Varying (Changing) the Subnet Mask Dynamically Over Time

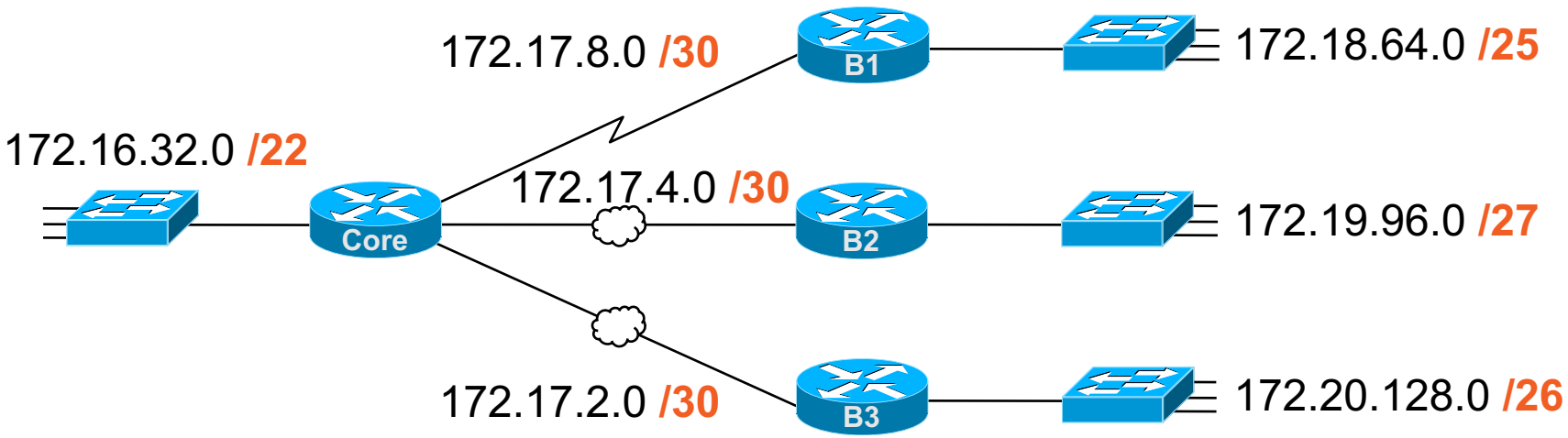
VLSM, or Not? (Example 1)



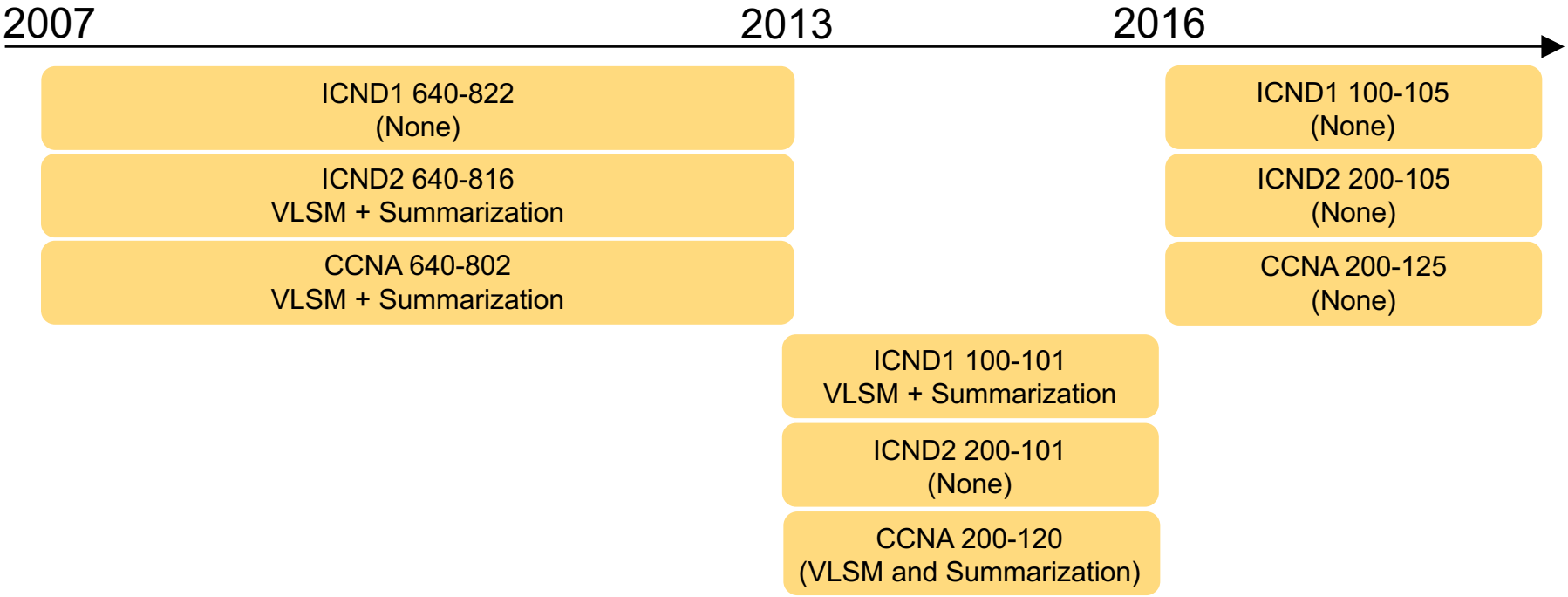
VLSM, or Not? (Example 2)



VLSM, or Not? (Example 3)



VLSM and the CCNA Exams



VLSM and Routing Protocols

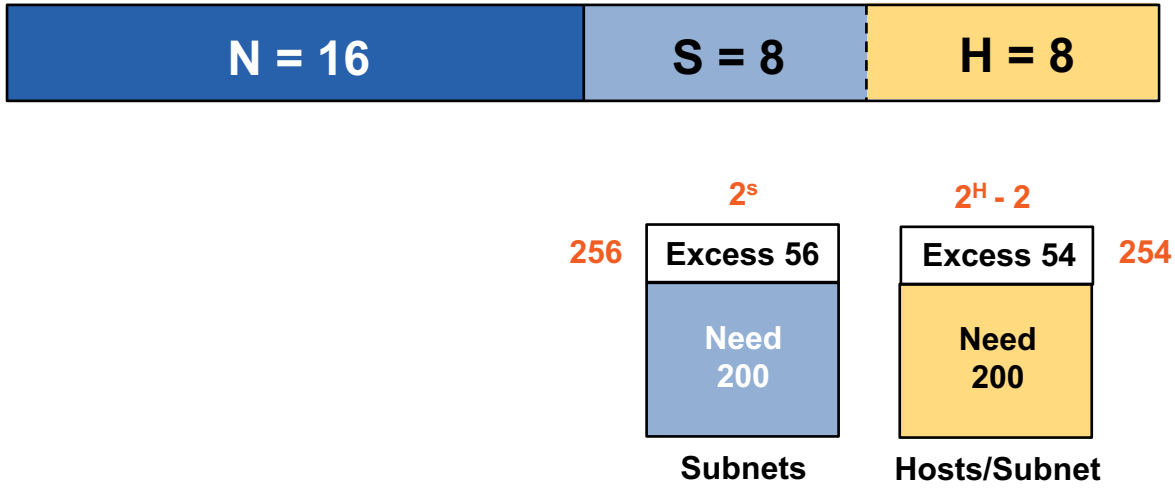
Routing Protocol	Is it Classless?	Sends Mask in Updates?	Supports VLSM?	Supports Manual Route Summarization?
IGRP	No	No	No	No
RIPv1	No	No	No	No
RIPv2	Yes	Yes	Yes	Yes
EIGRP	Yes	Yes	Yes	Yes
OSPF	Yes	Yes	Yes	Yes

In This Lesson...

The Impact of VLSM on the Exams

- VLSM Concepts
- **Questions Changed by VLSM**
- VLSM Practice

How Many Subnets in a Network?

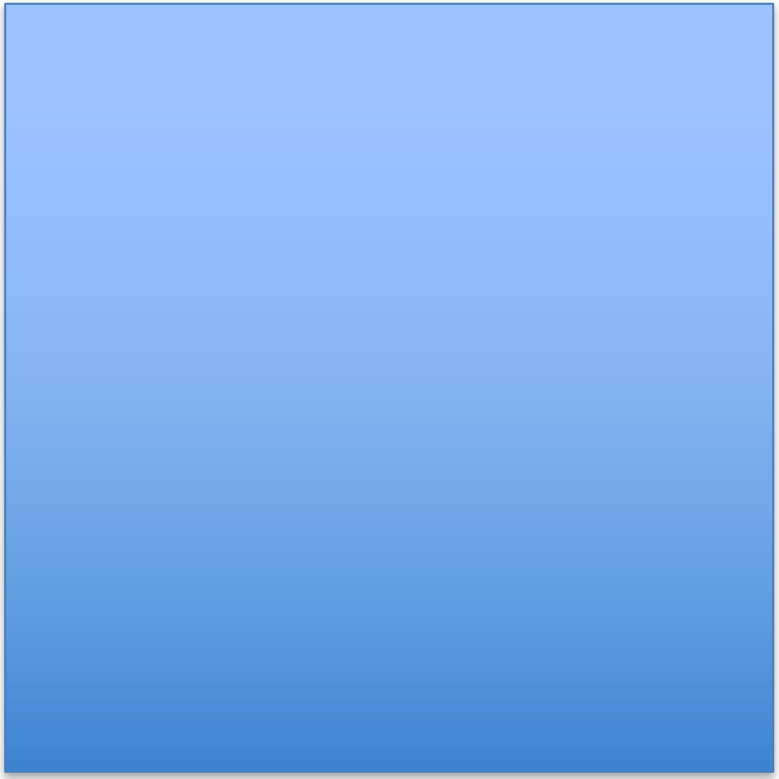


Exam: Numbers of Subnets and Hosts

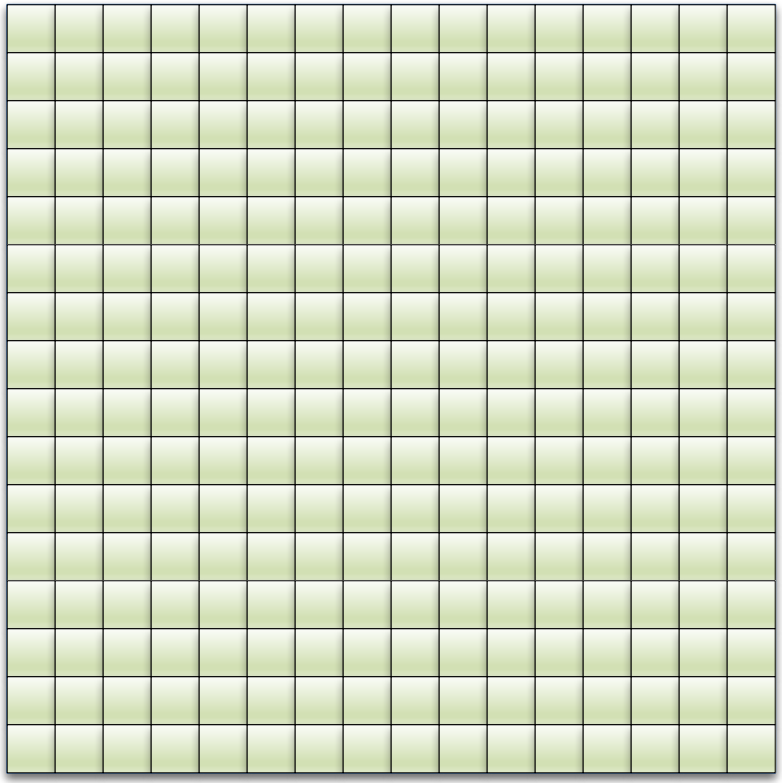
With VLSM: >1 Mask Used Within a Network

- Cannot Answer: “How Many Subnets in the Network?
- Cannot Answer: “Host Many Hosts in **Every** Subnet?”
- Can Answer: “Host Many Hosts in a **Specific** Subnet?”

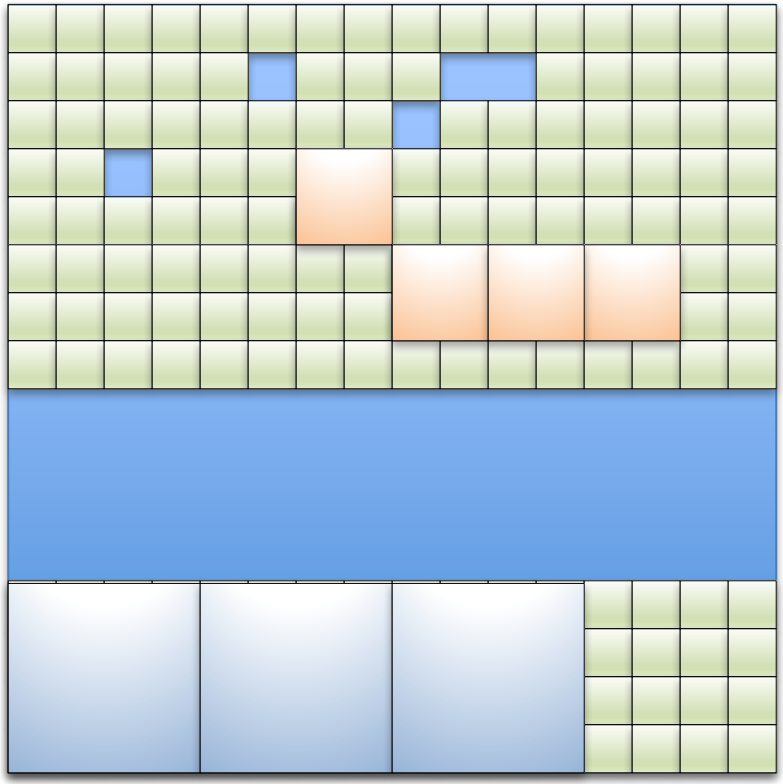
Idea: One Network



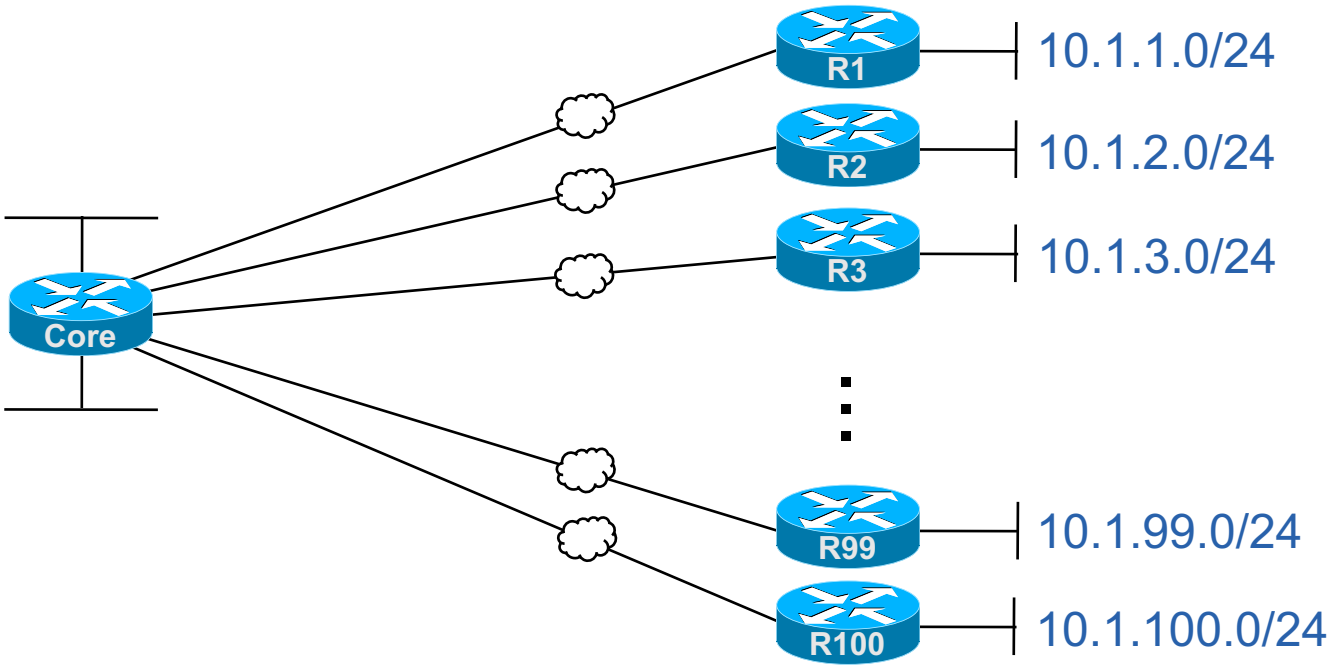
Idea: 256 Same-Size Subnets (Not VLSM)



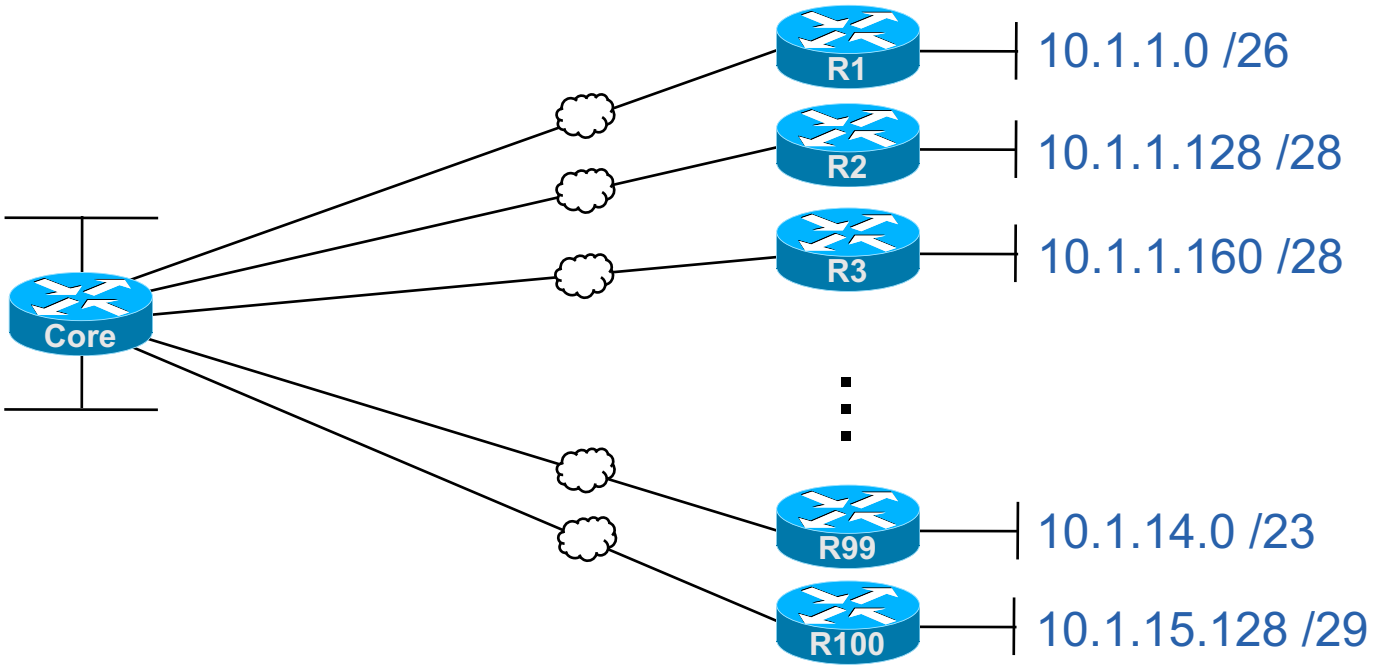
Idea: VLSM: Unpredictable Total Subnets



Not VLSM: Can You Find the Overlap(s)?



VLSM: Can You Find the Overlap(s)?



Overlap Math

Subnet:	10.1.14.0 /23
ID:	10.1.14.0
1st :	10.1.14.1
Last :	10.1.15.254
Broadcast :	10.1.15.255

Subnet:	10.1.15.128 /29
ID:	10.1.15.128
1st :	10.1.15.129
Last :	10.1.15.134
Broadcast :	10.1.15.135

Matching Routing Tables

```
Core# show ip route
! Legend omitted for brevity

     10.0.0.0/8 is variably subnetted, 240 subnets, 8 masks
D       10.1.1.0/26 [90/2172416] via 10.2.1.1, 00:00:34, G0/1.1
D       10.1.1.128/28 [90/2172416] via 10.2.1.5, 00:00:34, G0/1.2
D       10.2.1.160/28 [90/2172416] via 10.2.1.9, 00:00:34, G0/1.3
D       10.1.14.0/23 [90/2172416] via 10.2.2.141, 00:00:34, G0/1.99
D       10.1.15.128/29 [90/2172416] via 10.2.2.145, 00:00:34, G0/1.100
! Lines omitted for brevity
```

Summary: VLSM and the Exam

Definition:	Know What it Is!
Recognition:	Know VLSM When You See It!
Speed:	Slow Down for Overlaps
Old School:	RIPv1 and IGRP Were Confused by It
When VLSM:	Cannot Predict # Subnets, Nor Specific Subnet IDs

In This Lesson...

The Impact of VLSM on the Exams

- VLSM Concepts
- Questions Changed by VLSM
- **VLSM Practice**

VLSM Practice Problems in ICND1 Book

- ICND1 Official Cert Guide
  - Part of Safari
  - Many Practice Questions
  - Appendix H: VLSM

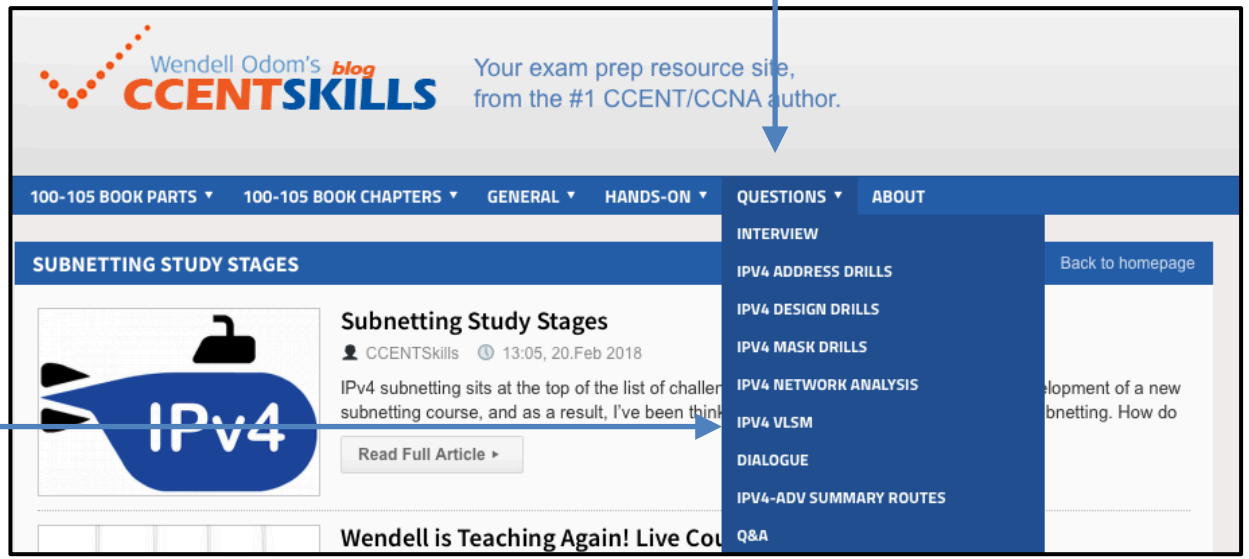
Book Element	Types of Problems
Appendix D	Find Classful Facts
Appendix E	Convert Masks
Appendix E	Interpret Masks
Appendix F	Find Subnet Facts
Appendix G	Choose Masks
Appendix G	Find All Subnets
Appendix H	**VLSM**

VLSM Practice Problems in Wendell's Blog

- Wendell's CCENT Skills Blog
  - blog.certskills.com/ccent
  - Look in "Questions" Tab
  - IPv4 VLSM

Click "Questions"

VLSM Questions



Build Your Own VLSM Overlap Questions

- Choose Any Two IP Addresses from the Same Network
- Choose a Different Mask for Each
- Ask Yourself: Do Their Subnets Overlap?
- Use Any Subnetting Calculator to Check Your Work
  - Windows: Solarwinds Subnetting Calculator
  - Linux/Mac: ipcalc command-line tool

```
Wendell-Odoms-iMac:~ wendellodom$  ipcalc -b 192.168.1.55/27

Address:   192.168.1.55
Netmask:   255.255.255.224 = 27
Wildcard:  0.0.0.31
=>
Network:   192.168.1.32/27
HostMin:   192.168.1.33
HostMax:   192.168.1.62
Broadcast: 192.168.1.63
Hosts/Net: 30                    Class C, Private Internet
```

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IPv4 Subnetting – Section 5

* Interpreting Subnet Masks

Variable Length Subnet Masks (VLSM)

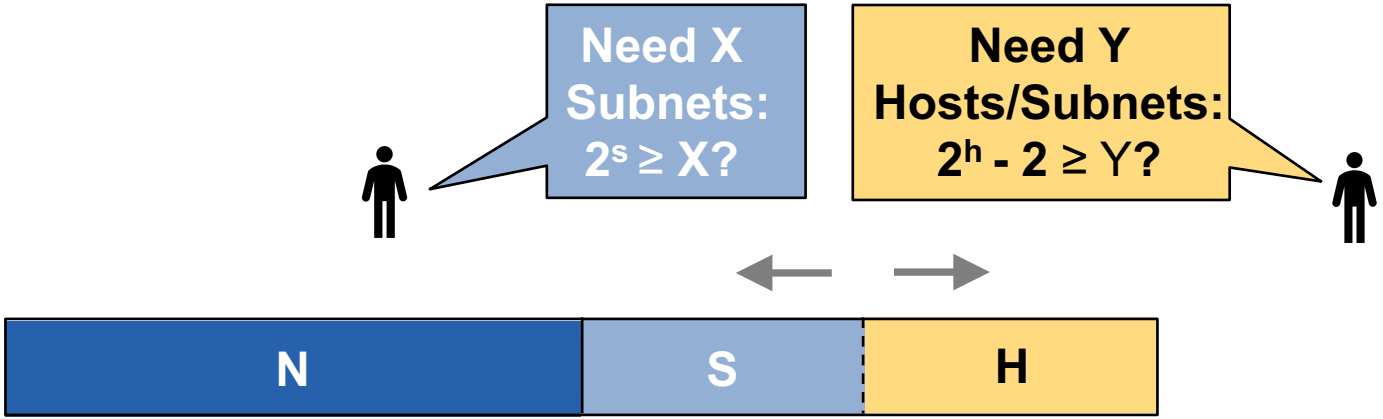
*** Choosing a Subnet Mask**

In This Lesson...

Choosing a Subnet Mask

- **Introduction: Mask Design**
- Example: No Masks Meet the Need
- Example: One Mask Meets the Need
- Example: Multiple Masks Meet the Need
- Process: Mask Design
- Example of the Process
- Learning Stages and Practice

Choose One Mask for All Subnets



1. Find N: Class Determines # of 1s to Begin: 8, 16, or 24
2. Choose S: Need Additional 1s in Mask to Create Enough Subnets
3. Choose H: Ensure Enough 0s in Mask to Create Enough Hosts

Aside: Unique Numbers Based on Digits

1 Bit, $2^1 = 2$ Values:	2 Bits, $2^2 = 4$ Values:	3 Bits, $2^3 = 8$ Values:
0	00	000
1	01	001
	10	010
	11	011
		100
		101
		110
		111

Reference: Powers of 2

Power	Decimal
2^0	1
2^1	2
2^2	4
2^3	8
2^4	16
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024

Power	Decimal
2^{11}	2048
2^{12}	4096
2^{13}	8192
2^{14}	16,384
2^{15}	32,768
2^{16}	65,536
2^{17}	131,072
2^{18}	262,144
2^{19}	524,288
2^{20}	1,048,576

In This Lesson...

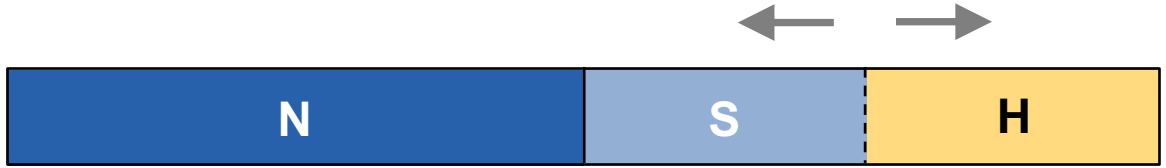
Choosing a Subnet Mask

- Introduction: Mask Design
- **Example: One Mask Meets the Need**
- Example: Multiple Masks Meet the Need
- Example: No Masks Meet the Need
- Process: Mask Design
- Example of the Process
- Learning Stages and Practice

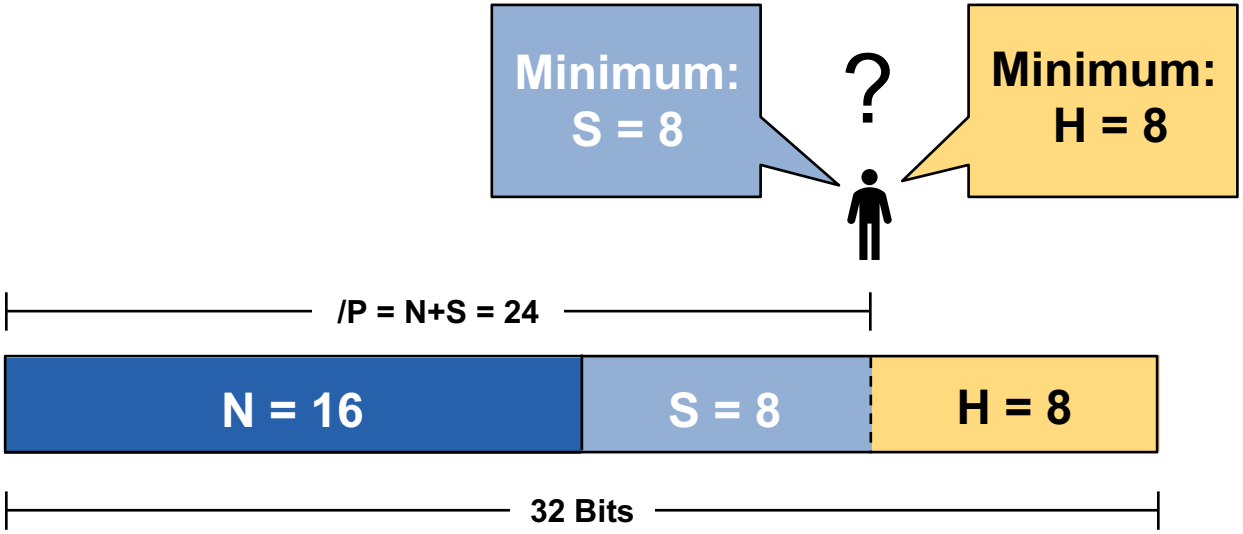
Requirements Example #2

- Class B Network 172.16.0.0
- Prepare for:
  - **200** Subnets
  - **150** Hosts Per Subnet
- One Mask Only
  - That is: NOT VLSM

Power	Decimal
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024



Requirement: 8 Subnet and 8 Host Bits



Example 1: Masks Vs. Requirements

- **200** Subnets
- **150** Hosts/Subnet

Mask	N	S	H	2^S	$2^H - 2$
/22	16	6	10	64	1022
/23	16	7	9	128	510
/24	16	8	8	256	254
/25	16	9	7	512	126
/26	16	10	6	1024	62

In This Lesson...

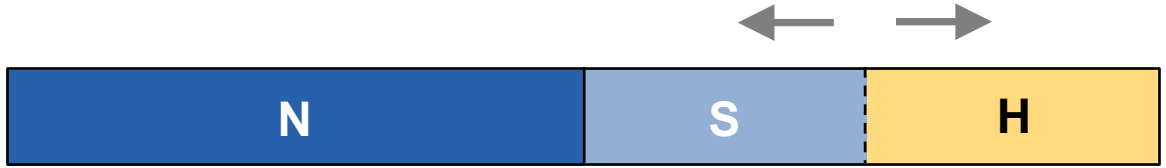
Choosing a Subnet Mask

- Introduction: Mask Design
- Example: One Mask Meets the Need
- **Example: Multiple Masks Meet the Need**
- Example: No Masks Meet the Need
- Process: Mask Design
- Example of the Process
- Learning Stages and Practice

Requirements Example #2

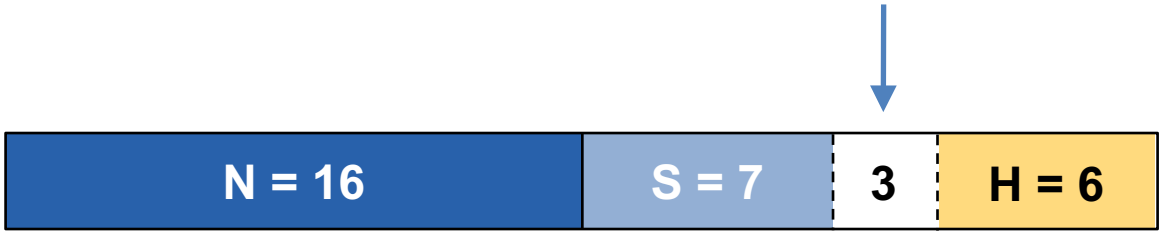
- Class B Network 172.16.0.0
- Prepare for:
  - ~~200~~ **100** Subnets
  - ~~150~~ **50** Hosts Per Subnet
- One Mask Only
  - That is: NOT VLSM

Power	Decimal
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024



Requirement: 7 Subnet and 6 Host Bits

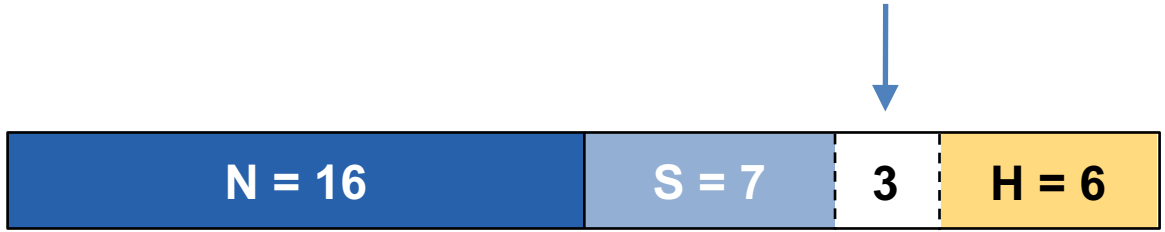
Could be Subnet, Host, Mix

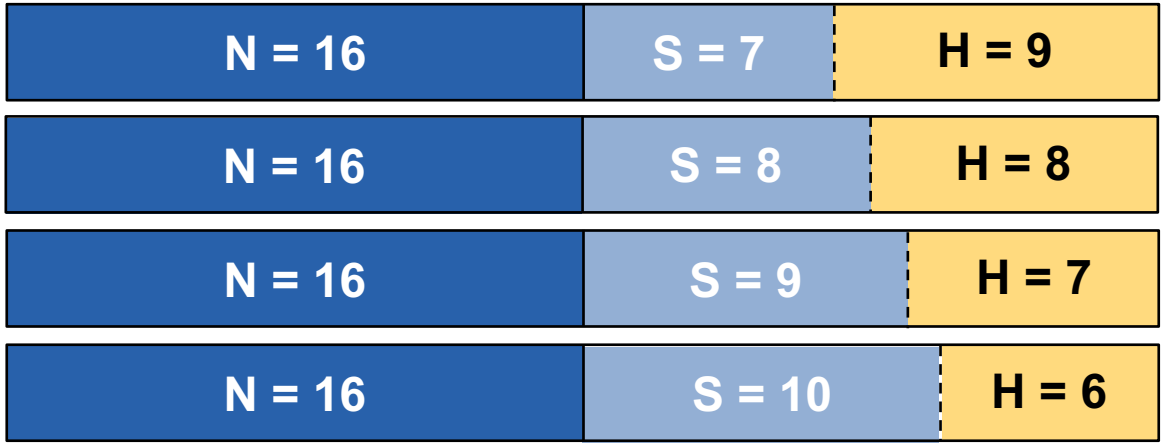


11111111 11111111 1111111_ __000000

Start w/ S_{min}, Work Upwards

Could be Subnet, Host, Mix





/23 (16 + 7)

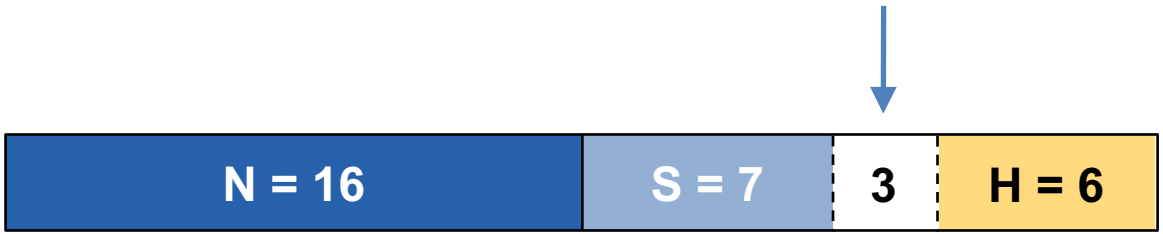
/24 (16 + 8)

/25 (16 + 9)

/26 (16 + 10)

Same Masks - Binary

Could be Subnet, Host, Mix



11111111	11111111	1111111**0** **00**000000	/23 (16 + 7)
11111111	11111111	1111111**1** **00**000000	/24 (16 + 8)
11111111	11111111	1111111**1** **10**000000	/25 (16 + 9)
11111111	11111111	1111111**1** **11**000000	/26 (16 + 10)

Example 2: Masks Vs. Requirements

- **100** Subnets
- **50** Hosts/Subnet

Mask	N	S	H	2^S	$2^H - 2$
/22	16	6	10	64	1022
/23	16	7	9	128	510
/24	16	8	8	256	254
/25	16	9	7	512	126
/26	16	10	6	1024	62
/27	16	11	5	2048	30

In This Lesson...

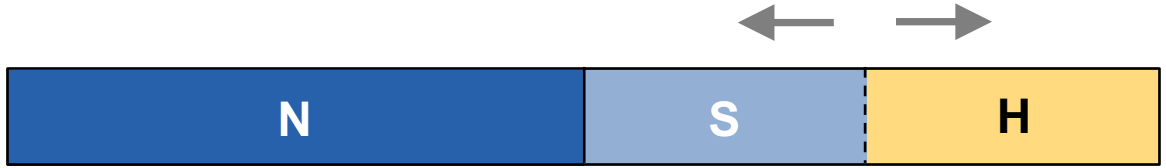
Choosing a Subnet Mask

- Introduction: Mask Design
- Example: One Mask Meets the Need
- Example: Multiple Masks Meet the Need
- **Example: No Masks Meet the Need**
- Process: Mask Design
- Example of the Process
- Learning Stages and Practice

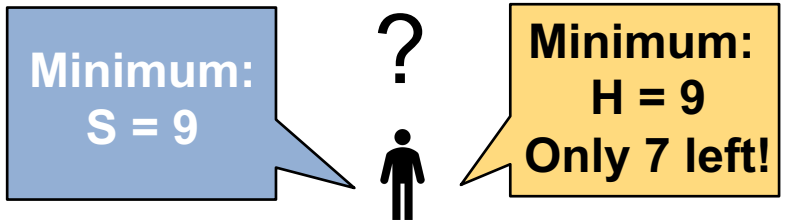
Requirements Example 3

- Class B Network 172.16.0.0
- Prepare for:
  - ~~200~~ ~~100~~ 500 Subnets
  - ~~150~~ ~~50~~ 300 Hosts Per Subnet
- One Mask Only
  - That is: NOT VLSM

Power	Decimal
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024



Requirement: 9 Subnet and 9 Host Bits



Example 3: Masks Vs. Requirement

- **500** Subnets
- **300** Hosts/Subnet

Mask	N	S	H	2^S	$2^H - 2$
/22	16	6	10	64	1022
/23	16	7	9	128	510
/24	16	8	8	256	254
/25	16	9	7	512	126
/26	16	10	6	1024	62

In This Lesson...

Choosing a Subnet Mask

- Introduction: Mask Design
- Example: One Mask Meets the Need
- Example: Multiple Masks Meet the Need
- Example: No Masks Meet the Need
- **Process: Mask Design**
- Example of the Process
- Learning Stages and Practice

Text Rules: Choosing a Subnet Mask

1. **Find N: The Exact Number of Network Bits**

2. **Find S_{min}: The Minimum Number of Subnet Bits:**
   - S_{min}: Smallest S for Which 2^S => # Subnets

3. **Find H_{min}: The Minimum Number of Host Bits:**
   - H_{min}: Smallest H for Which $2^H - 2$ => # Host Addresses Per Subnet

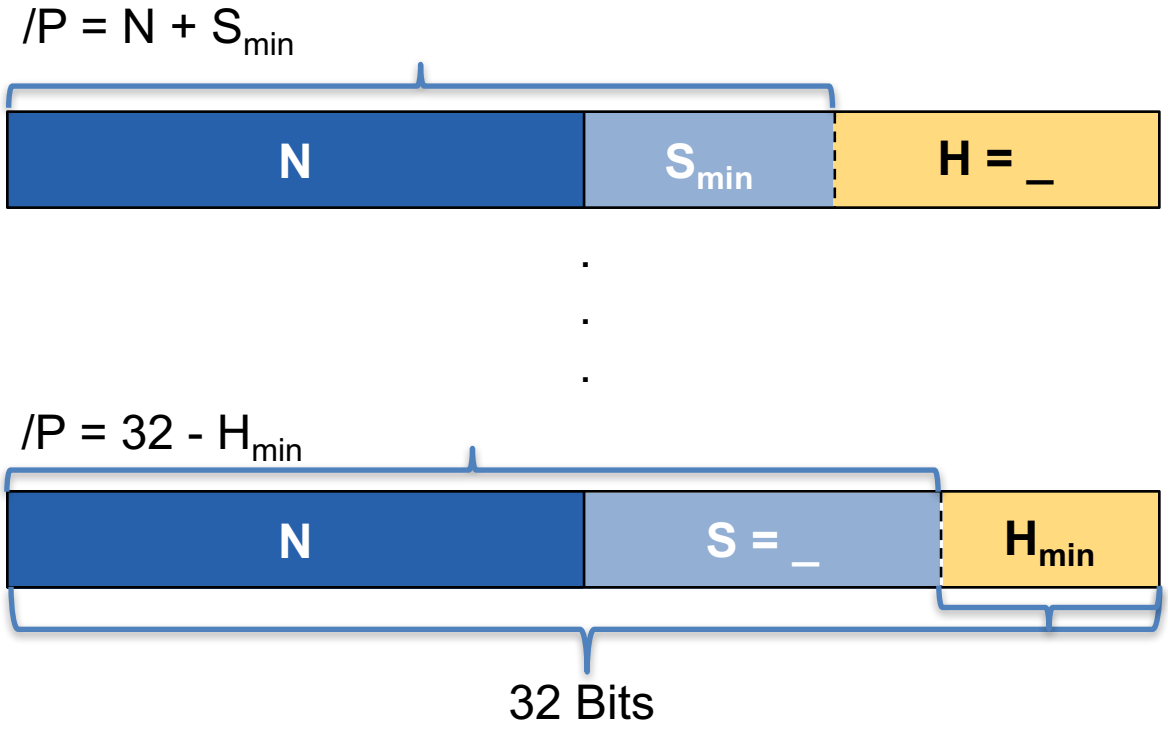
4. **Based on Total = N + S_{min} + H_{min}**

   A. Total > 32: No Masks Meet the Need!

   B. Total = 32: One Mask Meets the Need!
      - P = N + S_{min}

   C. Total < 32: Multiple Masks Meet the Need
      - Maximize # Hosts/Subnet: **P = N + S_{min}**
      - Maximize # Subnets: **P = 32 – H_{min}**

Visual Rules: If >1 Mask Allowed



Most Host Bits!
Maximizes # Hosts!

Most Subnet Bits!
Maximizes # Subnets!

Summary: Finding the Range of Masks

In This Lesson...

Choosing a Subnet Mask

- Introduction: Mask Design
- Example: One Mask Meets the Need
- Example: Multiple Masks Meet the Need
- Example: No Masks Meet the Need
- Process: Mask Design
- **Example of the Process**
- Learning Stages and Practice

Requirements Example #4

- Class C Network 192.168.2.0

- Prepare for:
  - **8** Subnets
  - **2** Hosts Per Subnet

- One Mask Only
  - That is: NOT VLSM

Power	Decimal
2^2	4
2^3	8
2^4	16
2^5	32

Example 4 Solution: Following Formal List

1. N = 24 (Class C)
2. S_{min} = 3
3. H_{min} = 2
4. Total = 24 + 3 + 2 = 29
   - Shortest Mask: **$P = N + S_{min} = /27$**
   - Longest Mask: **$P = 32 – H_{min} = /30$**
   - Allowed Masks: **/27 - /30**

Requirements

- Class C Network
- **8** Subnets
- **2** Hosts Per Subnet

Power	Decimal
2^2	4
2^3	8
2^4	16
2^5	32

Example 4 Masks Vs. Requirements

- **8** Subnets
- **2** Hosts Per Subnet

Mask	N	S	H	2^S	$2^H - 2$
/27	24	3	5	8	30
/28	24	4	4	16	14
/29	24	5	3	32	6
/30	24	6	2	64	2

In This Lesson...

Choosing a Subnet Mask

- Introduction: Mask Design
- Example: One Mask Meets the Need
- Example: Multiple Masks Meet the Need
- Example: No Masks Meet the Need
- Process: Mask Design
- Example of the Process
- **Learning Stages and Practice**

Stages

Stage	Primary Study Goal	Have You Understood and Memorized Ideas and Processes?	Do You Get 100% Correct?	Do You Go Fast?
1	Learning	**No**		
2	Perfecting	Yes	**No**	
3	Accelerating	Yes	Yes	**No**
4	Completed	**Yes**	**Yes**	**Yes**

Stage 1 (Learn) Advice for This Exercise

The Usual Approach

1. Use Notes/Examples
2. Check Answer if Unsure
3. Investigate Mistakes
4. **Ask Instructor to Work the Problem!**

Specifically…

1. Copy Powers of 2 from Table as Needed
2. Think Visually

Graduate to Stage 2 Now if:

1. Could Hide All Notes **Except Powers of 2** and Still Answer!

Stage 2 (Perfect) Advice for This Exercise

The Usual Approach:

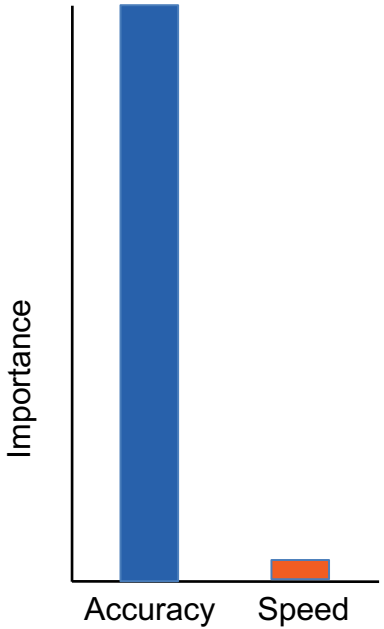
1. No Notes
2. Take Your Time
3. Complete a question set before checking answers

Specifically...

1. OK to Use Powers of 2 Table
2. **Memorize or Pre-Write Powers of 2 for Exam Day?**

Graduate to Stage 3 Now if:

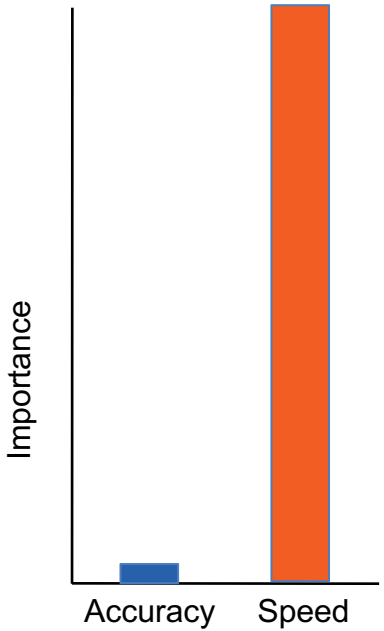
1. You get 100% correct on two exercise sets
2. Confident about writing your pre-exam notes
3. Can Move on if Still Working to Memorize Powers of 2



Stage 3 (Accelerate) Advice for this Exercise

Usual Approach: Time Trial

1. Set a per-item time goal
2. Write pre-exam Notes
3. Start Clock
4. Complete the entire question set
5. Compare your speed to time goal



Specifically:

1. Memorize Powers of 2
2. Practice Pre-Exam Writing Plan
3. Speed Goal: Based on Prefix Mask

Graduate to Stage 4 Now if:

1. Meet Speed Goals

Speed Goals for CCNA Exam

Subnetting Processes	Book Speed Goals	Your Speed Goal	Your Current Speed	Your Current Stage
Find Classful Network Facts *	10			
Convert Mask Formats *	10			
Find Subnet Facts	30			
Interpret Design w/ Mask	15			
Choose One Mask	15			
Find All Subnet IDs *	45			

* These Time Estimates Do Not Include the Time to Write/Type the Answers

Practice!

Exercises for:

“Choosing
Subnet Masks”

Come Back to Class!

Exercises for:

"Choosing
Subnet Masks"

Time Finished!