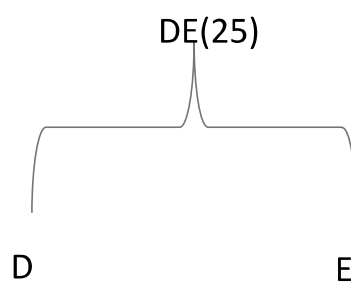


# Huffman Coding And Arithmetic Coding

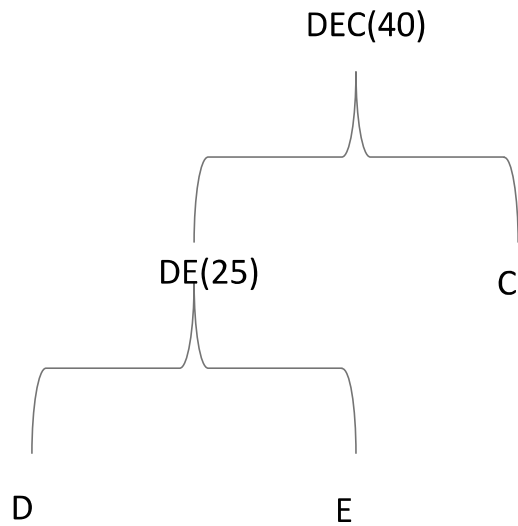
## Huffman Coding

Symbol	Frequency
A	30
B	30
C	15
D	15
E	10



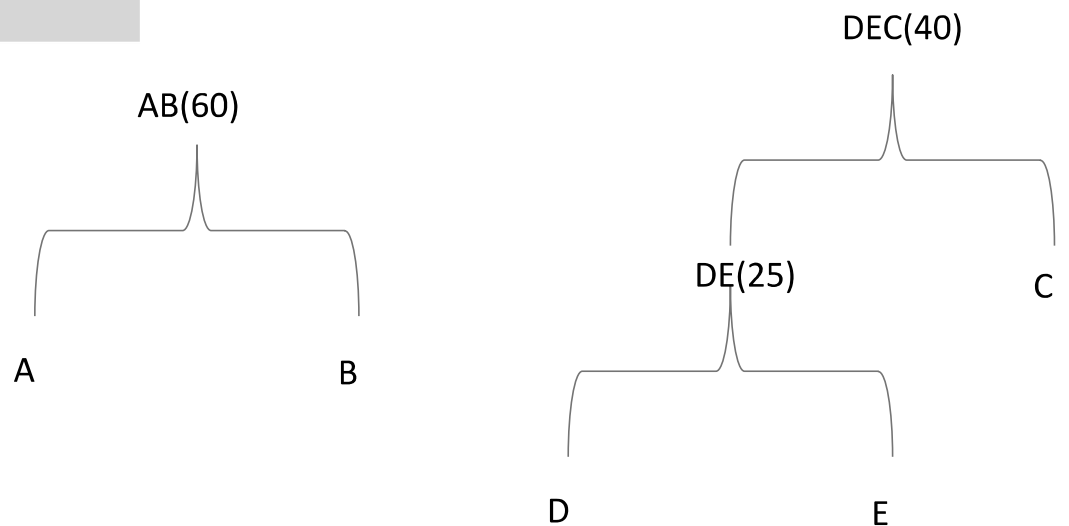
# Huffman Coding

Symbol	Frequency
A	30
B	30
C	15
D	15
E	10



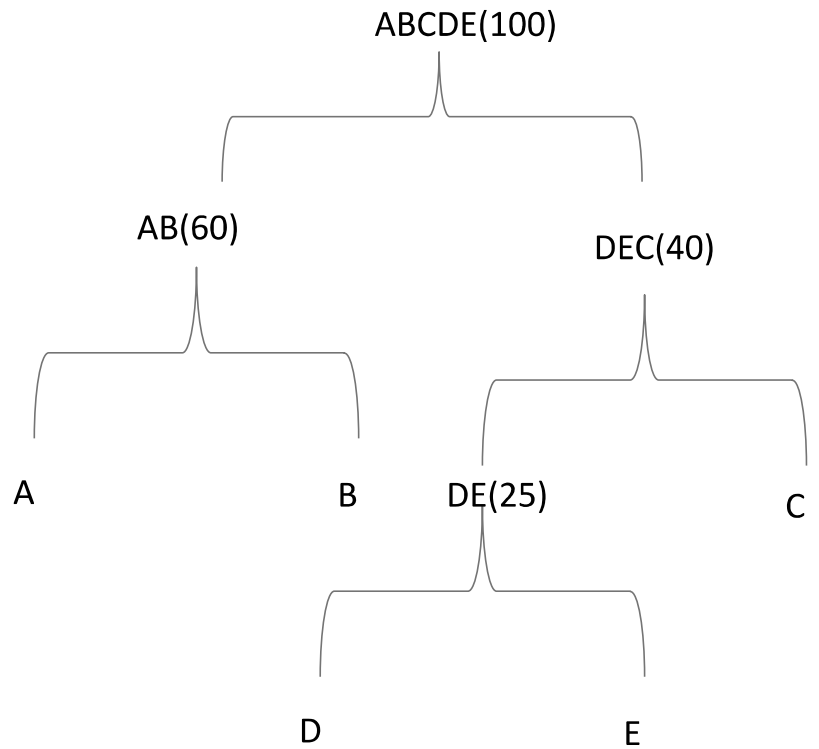
# Huffman Coding

Symbol	Frequency
A	30
B	30
C	15
D	15
E	10



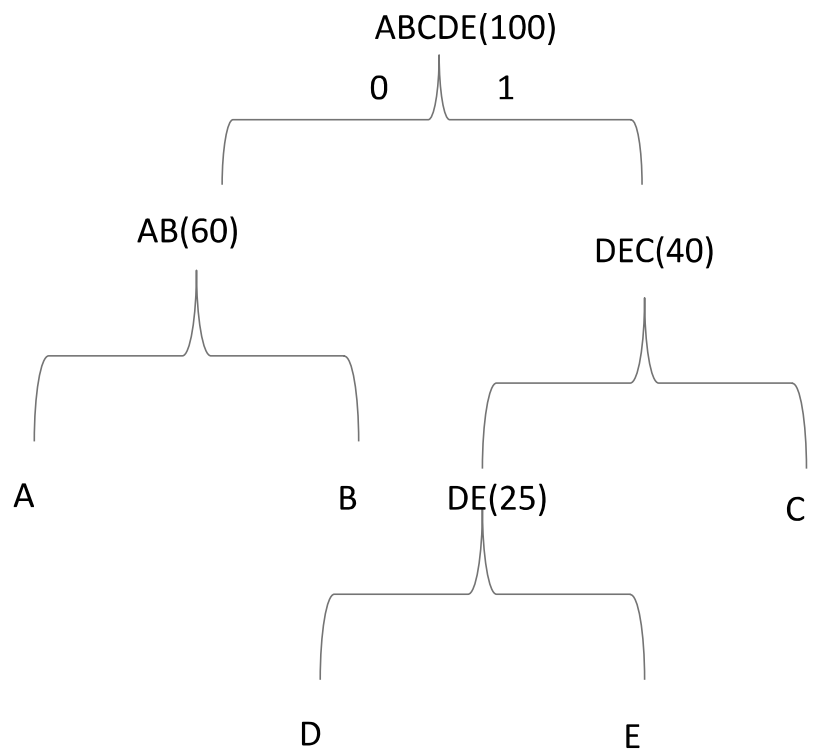
# Huffman Coding

Symbol	Frequency
A	30
B	30
C	15
D	15
E	10



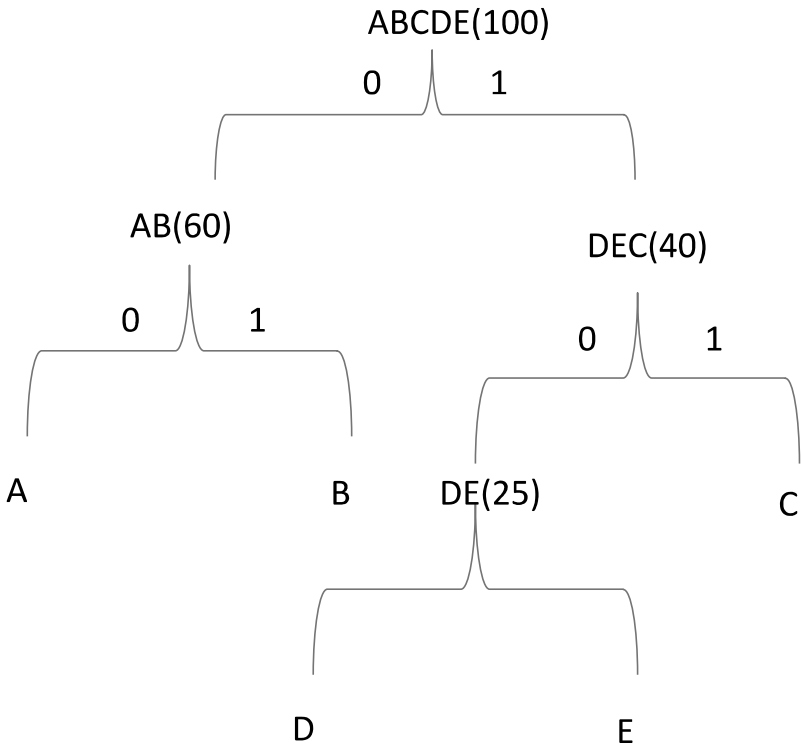
# Huffman Coding

Symbol	Frequency
A	30
B	30
C	15
D	15
E	10



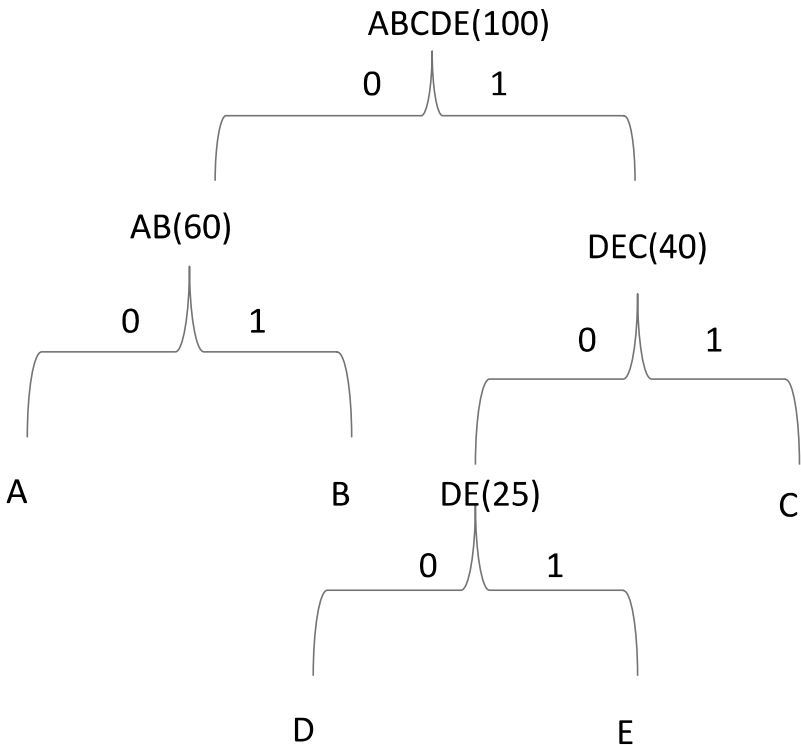
# Huffman Coding

Symbol	Frequency
A	30
B	30
C	15
D	15
E	10



# Huffman Coding

Symbol	Frequency	Code
A	30	00
B	30	01
C	15	11
D	15	100
E	10	101



# Huffman Coding (Example 2)

Symbol	Frequency	Code
A	20	
B	18	
C	16	
D	15	
E	15	
F	10	
G	4	
H	2	

## Huffman Coding (Example 2 solution)

Symbol	Frequency	Code
A	20	10
B	18	11
C	16	000
D	15	010
E	15	011
F	10	0010
G	4	00110
H	2	00111

# Extended Huffman Coding

Symbol	Probability	Huffman Code
A	0.85	0
B	0.10	10
C	0.05	11

## Extended Huffman Coding

Symbol	Probability	Huffman Code
A	0.85	0
B	0.10	10
C	0.05	11

Symbol	Probability	Huffman Code
AA	$0.85 \times 0.85 = 0.722$	
AB	$0.85 \times 0.10 = 0.085$	
AC	$0.85 \times 0.05 = 0.042$	
BA	$0.10 \times 0.85 = 0.085$	
BB	$0.10 \times 0.10 = 0.010$	
BC	$0.10 \times 0.05 = 0.005$	
CA	$0.05 \times 0.85 = 0.042$	
CB	$0.05 \times 0.10 = 0.005$	
CC	$0.05 \times 0.05 = 0.0025$	

# Extended Huffman Coding

Symbol	Probability	Huffman Code
A	0.85	0
B	0.10	10
C	0.05	11

Symbol	Probability	Huffman Code
AA	$0.85 * 0.85 = 0.722$	0
AB	$0.85 * 0.10 = 0.085$	100
AC	$0.85 * 0.05 = 0.042$	111
BA	$0.10 * 0.85 = 0.085$	101
BB	$0.10 * 0.10 = 0.010$	11011
BC	$0.10 * 0.05 = 0.005$	110101
CA	$0.05 * 0.85 = 0.042$	1110
CB	$0.05 * 0.10 = 0.005$	1101000
CC	$0.05 * 0.05 = 0.0025$	1101001

# Arithmetic Coding

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

# Arithmetic Coding

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

Arithmetic Code  
for  
GERMAN

## Arithmetic Code for **GERMAN**

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

```
LV=0
HV=1
DIFF=1
For every symbol in input
{
    LV=LV+DIFF*RANGE_FROM(SYMBOL)
    HV=LV+DIFF*RANGE_TO(SYMBOL)
    DIFF=HV-LV
}
PRINT LV
```



# Arithmetic Coding for GERMAN

```
LV_OLD=0
HV=1
DIFF=1
For every symbol in input
{
    LV=LV_OLD+DIFF*RANGE_FROM(SYMBOL)
    HV=LV_OLD+DIFF*RANGE_TO(SYMBOL)
    DIFF=HV-LV
    LV_OLD=LV
}
PRINT LV
```

SYMBOL	LV	HV	DIFF
---	0	1	1
G	$0+1*0.4= 0.4$	$0+1*0.5=0.5$	0.1
E	$0.4+0.1*0.1=0.41$	$0.4+0.1*0.3=0.43$	0.02
R	$0.41+0.02*0.3= 0.416$	$0.41+0.02*0.4=0.418$	0.002
M	$0.416+0.002*0.6=0.4172$	$0.416+0.002*0.7=0.4174$	0.0002
A	$0.4172+0.0002*0.7=0.41734$	$0.4172+0.0002*0.8=0.41736$	0.00002
N	<b><math>0.41734+0.00002*0.5=0.417350</math></b>	$0.41734+0.00002*0.6=0.417352$	0.000002

## EXAMPLE 2

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

Arithmetic Code  
for  
FRANCE

# EXAMPLE 3

SYMBOL	Probability	Range From	Range To
A	0.3	0.0	0.3
B	0.2	0.3	0.5
C	0.5	0.5	1.0

Arithmetic Code  
for  
AACBC

## Arithmetic Decoding GERMAN

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

While (Code != 0)

{

Output the symbol corresponding to Range

$$\text{Code} = \frac{\text{Code} - \text{Range\_From}(\text{symbol})}{\text{Range\_To}(\text{symbol}) - \text{Range\_From}(\text{symbol})}$$

}

Here Code for **GERMAN** is 0.417350 which falls in the range from 0.4 to 0.5  
Output Symbol 'G'

$$\text{Code} = (0.417350 - 0.4) / (0.5 - 0.4) = 0.17350$$

## Arithmetic Decoding GERMAN

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

While (Code != 0)

{

Output the symbol corresponding to Range

$$\text{Code} = \frac{\text{Code} - \text{Range\_From}(\text{symbol})}{\text{Range\_To}(\text{symbol}) - \text{Range\_From}(\text{symbol})}$$

}

Here Code for German is 0.17350 which falls in the range from 0.1 to 0.3

**Output Symbol 'E'**

$$\text{Code} = (0.17350 - 0.1) / (0.3 - 0.1) = \mathbf{0.3675}$$

## Arithmetic Decoding GERMAN

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

While (Code != 0)

{

Output the symbol corresponding to Range

$$\text{Code} = \frac{\text{Code} - \text{Range\_From}(\text{symbol})}{\text{Range\_To}(\text{symbol}) - \text{Range\_From}(\text{symbol})}$$

}

Here Code for German is 0.3675 which falls in the range from 0.3 to 0.4

**Output Symbol 'R'**

$$\text{Code} = (0.3675 - 0.3) / (0.4 - 0.3) = \mathbf{0.675}$$

## Arithmetic Decoding GERMAN

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

While (Code != 0)

{

Output the symbol corresponding to Range

$$\text{Code} = \frac{\text{Code} - \text{Range\_From}(\text{symbol})}{\text{Range\_To}(\text{symbol}) - \text{Range\_From}(\text{symbol})}$$

}

Here Code for German is 0.675 which falls in the range from 0.6 to 0.7

**Output Symbol 'M'**

$$\text{Code} = (0.675 - 0.6) / (0.7 - 0.6) = \mathbf{0.75}$$

## Arithmetic Decoding GERMAN

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

While (Code != 0)

{

Output the symbol corresponding to Range

$$\text{Code} = \frac{\text{Code} - \text{Range\_From}(\text{symbol})}{\text{Range\_To}(\text{symbol}) - \text{Range\_From}(\text{symbol})}$$

}

Here Code for German is 0.75 which falls in the range from 0.7 to 0.8

**Output Symbol 'A'**

$$\text{Code} = (0.75 - 0.7) / (0.8 - 0.7) = \mathbf{0.5}$$

# Arithmetic Decoding GERMAN

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

While (Code != 0)

{

Output the symbol corresponding to Range

$$\text{Code} = \frac{\text{Code} - \text{Range\_From}(\text{symbol})}{\text{Range\_To}(\text{symbol}) - \text{Range\_From}(\text{symbol})}$$

}

Here Code for German is 0.5 which falls in the range from 0.5 to 0.6

**Output Symbol 'N'**

$$\text{Code} = (0.5 - 0.5) / (0.6 - 0.5) = 0$$

## EXAMPLE 2

SYMBOL	Probability	Range From	Range To
Y	0.1	0.0	0.1
E	0.2	0.1	0.3
R	0.1	0.3	0.4
G	0.1	0.4	0.5
N	0.1	0.5	0.6
M	0.1	0.6	0.7
A	0.1	0.7	0.8
F	0.1	0.8	0.9
C	0.1	0.9	1.0

Arithmetic Decoding  
for  
**0.837591**

# EXAMPLE 3

SYMBOL	Probability	Range From	Range To
A	0.3	0.0	0.3
B	0.2	0.3	0.5
C	0.5	0.5	1.0

Arithmetic Decoding  
for  
0.0630

## Dictionary based Coding

- LZ77
- LZ78
- LZW

# LZW Coding

**Assume that there is an initial dictionary of 256 characters.**

Symbol	Address to Dictionary
	0
*	15
G	47
S	59
W	63
Y	65
	255

# LZW Coding

## INPUT:

**WYS\*WYGWYS\*WYSWYSG**

[illegible]

# LZW Coding

## INPUT:

**WYS\*WYGWYS\*WYSWYSG**

[illegible]

# LZW Coding

## INPUT:

**WYS\*WYGWYS\*WYSWYSG**

[illegible]



# LZW Coding

## INPUT:

**WYS\*WYGWYS\*WYSWYSG**

[illegible]

# LZW Coding

## INPUT:

WYS\*WYGWYS\*WYSWYSG

[illegible]

# LZW Coding

## INPUT:

WYS\*WYGWYS\*WYSWYSG

[illegible]

# LZW Coding

## INPUT:

WYS\*WYGWYS\*WYSWYSG

[illegible]

# LZW Coding

**INPUT:**

**WYS\*WYGWYS\*WYSWYSG**

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256
Y	65	YS	257
S	59	S*	258
*	15	*W	259
WY	256	WYG	260
G	47	GW	261
WY	256	WYS	262

# LZW Coding

**INPUT:**

**WYS\*WYGWYS\*WYSWYSG**

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256
Y	65	YS	257
S	59	S*	258
*	15	*W	259
WY	256	WYG	260
G	47	GW	261
WY	256	WYS	262
S*	258	S*W	263

# LZW Coding

**INPUT:**

**WYS\*WYGWYS\*WYSWYSG**

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256
Y	65	YS	257
S	59	S*	258
*	15	*W	259
WY	256	WYG	260
G	47	GW	261
WY	256	WYS	262
S*	258	S*W	263
WYS	262	WYSW	264

# LZW Coding

**INPUT:**

**WYS\*WYGWYS\*WYSWYSG**

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256
Y	65	YS	257
S	59	S*	258
*	15	*W	259
WY	256	WYG	260
G	47	GW	261
WY	256	WYS	262
S*	258	S*W	263
WYS	262	WYSW	264
WYS	262	WYSG	265

# LZW Coding

**INPUT:**

WYS\*WYGWYS\*WYSWYSG

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256
Y	65	YS	257
S	59	S*	258
*	15	*W	259
WY	256	WYG	260
G	47	GW	261
WY	256	WYS	262
S*	258	S*W	263
WYS	262	WYSW	264
WYS	262	WYSG	265
G	47		

# LZW Coding

**INPUT:**

WYS\*WYGWYS\*WYSWYSG

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256
Y	65	YS	257
S	59	S*	258
*	15	*W	259
WY	256	WYG	260
G	47	GW	261
WY	256	WYS	262
S*	258	S*W	263
WYS	262	WYSW	264
WYS	262	WYSG	265
G	47		
eof			

# LZW Coding (Ex. 2)

INPUT:

**ABACACBDACBDBDACBDAACD**

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
A		AB	256
B		BA	257
A		AC	258
C		CA	259

# LZW Coding (Ex. 2)

INPUT:

**ABACACBDACBDBDACBDAACD**

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
A		AB	256
B		BA	257
A		AC	258
C		CA	259
AC	258	ACB	260
B		BD	261
D		DA	262
ACB	260	ACBD	263

# LZW Coding (Ex. 2)

INPUT:

ABACACBDACBDBDACBDAACD

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
A		AB	256
B		BA	257
A		AC	258
C		CA	259
AC	258	ACB	260
B		BD	261
D		DA	262
ACB	260	ACBD	263
D		DB	264
BD	261	BDA	265
ACBD	263	ACBDA	266

# LZW Coding (Ex. 2)

INPUT:

ABACACBDACBDBDACBDAACD

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
A		AB	256
B		BA	257
A		AC	258
C		CA	259
AC	258	ACB	260
B		BD	261
D		DA	262
ACB	260	ACBD	263
D		DB	264
BD	261	BDA	265
ACBD	263	ACBDA	266
A		AA	267
AC	258	ACD	268
D			
eof			