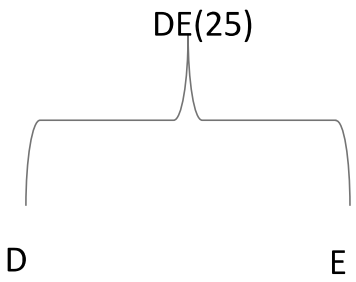
Huffman Coding
And
Arithmetic Coding

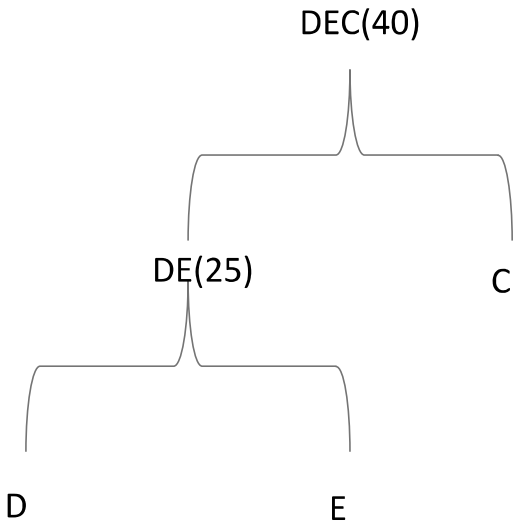
Huffman Coding

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



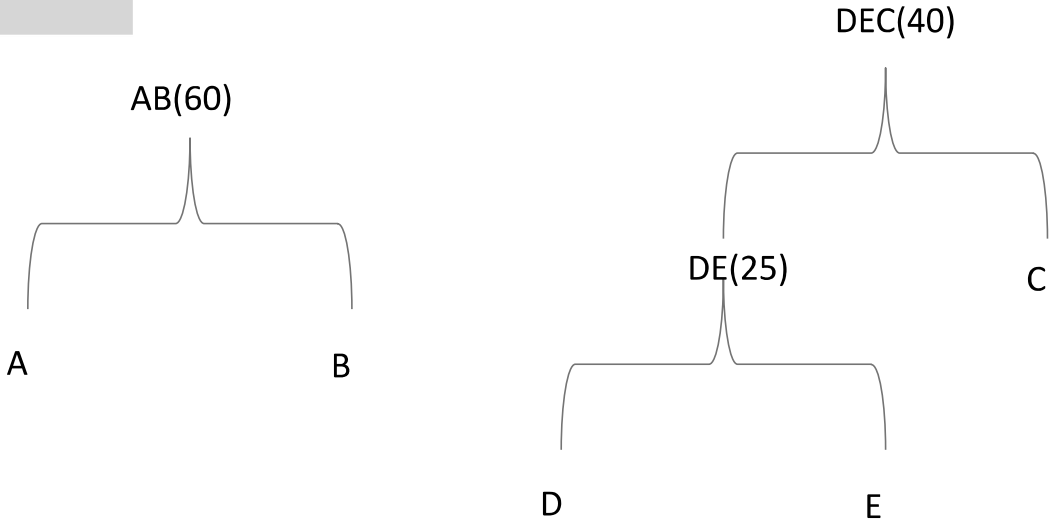
Huffman Coding

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



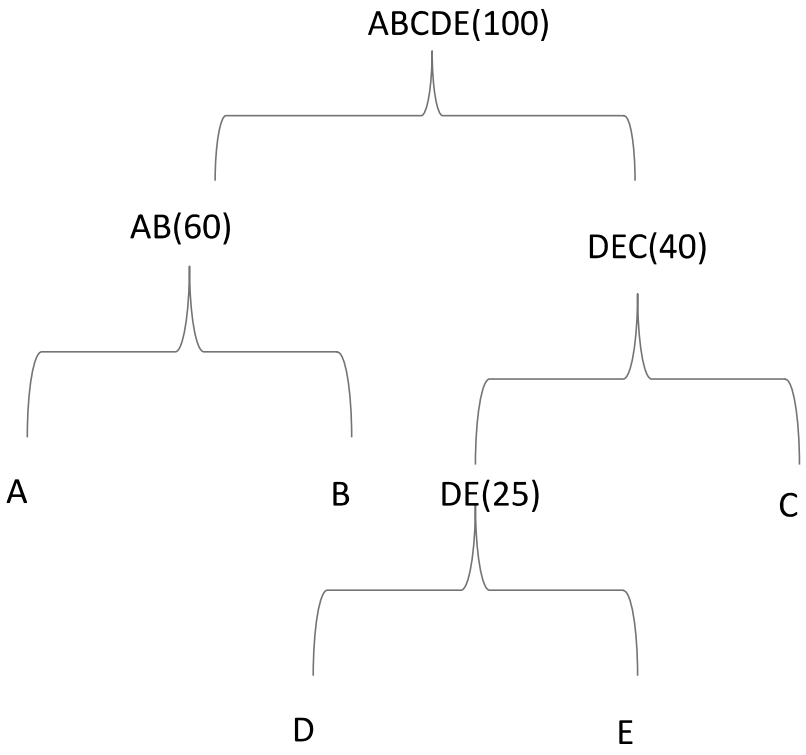
Huffman Coding

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



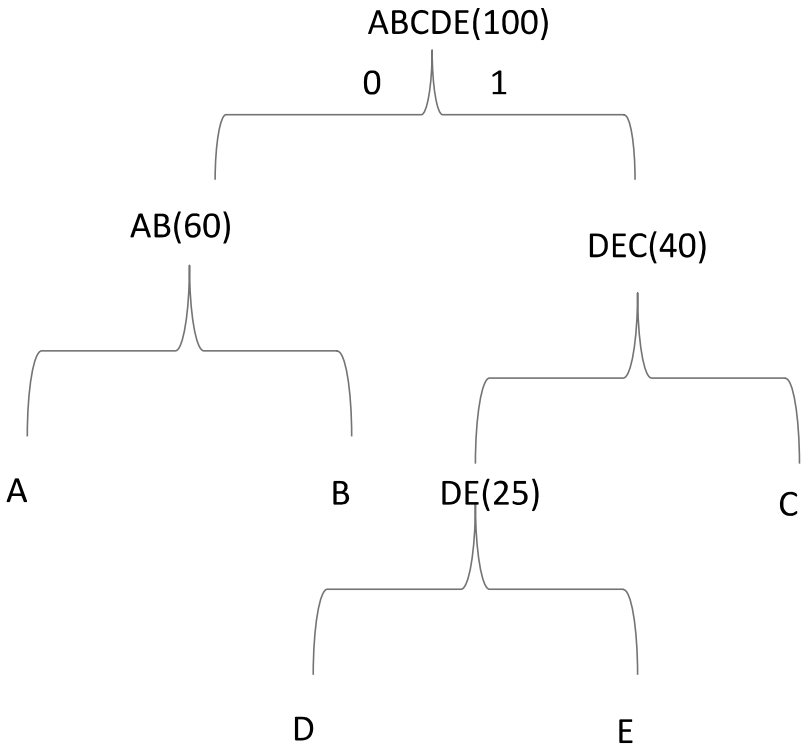
Huffman Coding

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



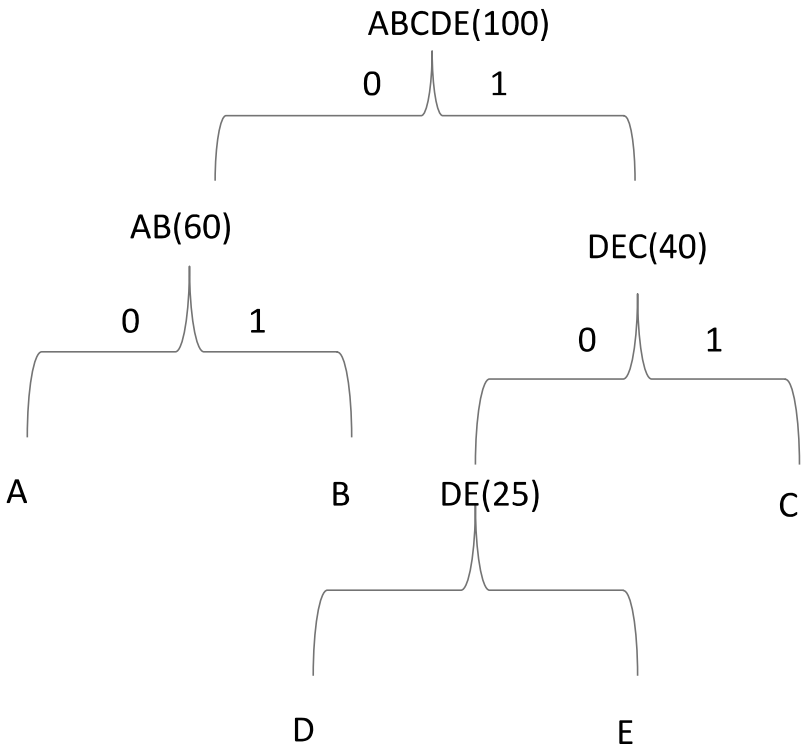
Huffman Coding

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



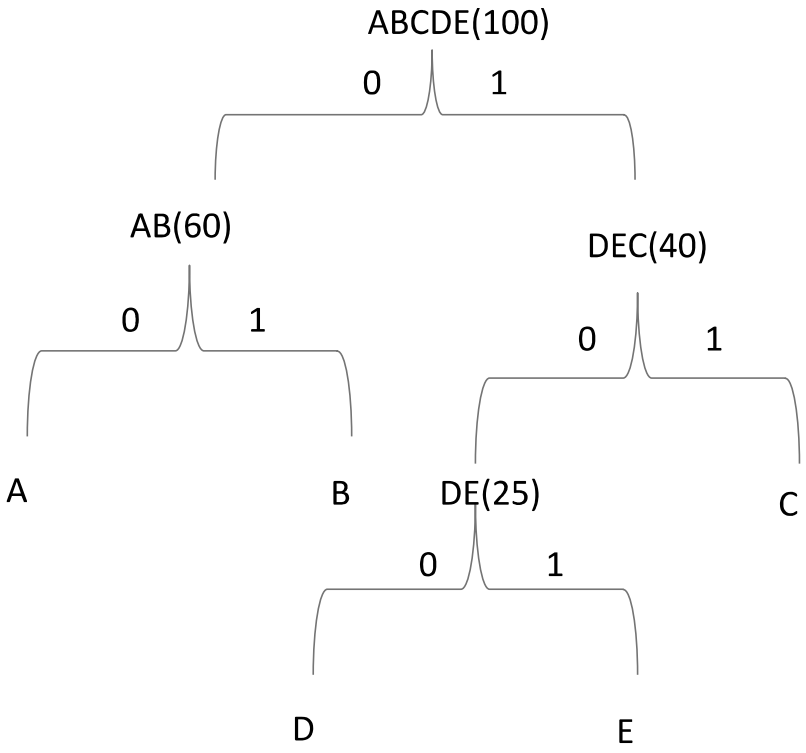
Huffman Coding

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*0.85=0.722	
AB	0.85*0.10=0.085	
AC	0.85*0.05=0.042	
BA	0.10*0.85=0.085	
BB	0.10*0.10=0.010	
BC	0.10*0.05=0.005	
CA	0.05*0.85=0.042	
CB	0.05*0.10=0.005	
CC	0.05*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	**0.41734+0.00002*0.5=0.417350**	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

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

}

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

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

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

}

Here Code for German is 0.17350 which falls in the range from 0.1 to 0.3
Output Symbol 'E'

Code = (0.17350 – 0.1) / (0.3- 0.1) = **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

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

}

Here Code for German is 0.3675 which falls in the range from 0.3 to 0.4
Output Symbol 'R'

Code = (0.3675 – 0.3) / (0.4- 0.3) = **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

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

}

Here Code for German is 0.675 which falls in the range from 0.6 to 0.7
Output Symbol 'M'

Code = (0.675 – 0.6) / (0.7- 0.6) = **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

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

}

Here Code for German is 0.75 which falls in the range from 0.7 to 0.8
Output Symbol 'A'

Code = (0.75 – 0.7) / (0.8- 0.7) = **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

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

}

Here Code for German is 0.5 which falls in the range from 0.5 to 0.6
Output Symbol 'N'

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

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256

LZW Coding

INPUT:

WYS*WYGWYS*WYSWYSG

		DICTIONARY	
Symbol	Output Code	SYMBOL	Address to Dictionary
W	63	WY	256
Y	65	YS	257

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

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

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

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

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

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			