الجامعة المستنصرية /كلية التربية / قسم علوم الحاسبات

4th Class
Computers & Data Security
أمنية الحاسوب والبيانات

أستاذ المادة

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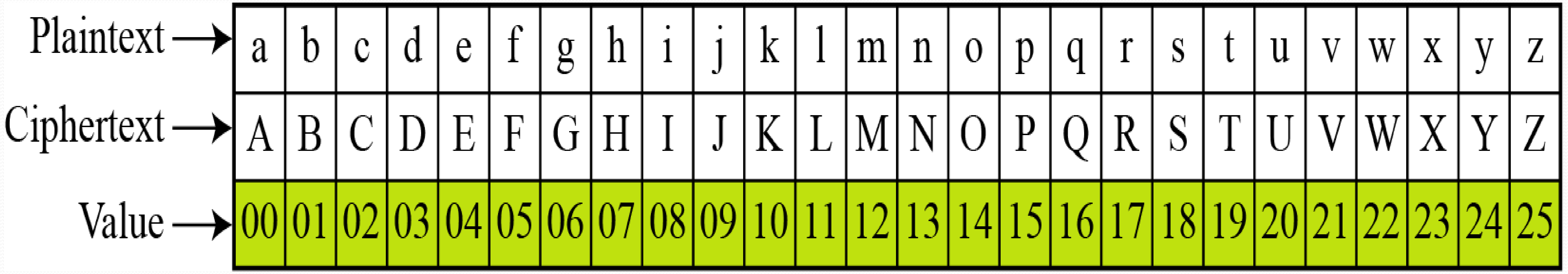
Substitution cipher

1. **Monoalphabetic Ciphers.**
   - It is simple substitution
   - involves replacing each letter in the message with another letter of the alphabet.
   - In monoalphabetic substitution, the relationship between a symbol in the plaintext to a symbol in the ciphertext is always one-to-one.

- **Additive Cipher:-** is the simplest monoalphabetic cipher. It is sometimes called a shift cipher and sometimes **a Caesar cipher**, but the term additive cipher better reveals its mathematical nature. When the cipher is additive, the plaintext, ciphertext, and key are integers in Z26.

Plaintext and ciphertext in Z26



Plaintext →	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
Ciphertext →	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Value →	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Additive Cipher

Plaintext
Alice
P
C = (P + k) mod 26
k
Encryption
C
Ciphertext
Plaintext
Bob
P
k
P = (C – k) mod 26
C
Decryption

- ***Example***
- Use the additive cipher with key = 15 to encrypt the plain text (hello).
- We apply the encryption algorithm to the plaintext, character by character:

Plaintext h e l l o

7 4 11 11 14

Encryption

(7+15) mod 26=22→ W, (4+15) mod 26=19 →T, (11 +15) mod 26=0 →A, (11+15) mod 26=0 →A,(14+15) mod 26=3 →D

Ciphertext WTAAD

- We apply the decryption algorithm to the plaintext character by character:

Ciphertext

W T A A D

22 19 0 0 3

Decryption

(22-15) mod 26=7→ h, (19-15) mod 26=4 →e, (0-15) mod 26=11 →l, (0-15) mod 26=11 →l,(3-15) mod 26=14 →o

Ciphertext h e l l o

- **Caesar Cipher: -** Named for Julious Caesar. Caesar used a key of 3 for his communications.

Plaintext	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Ciphertext	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	a	b	c

- **Cryptanalysis of the Caesar cipher: -**

- Example : - decrypt the following ciphertext:-
  wklv phvvdjh lv qrw wrr kdug wr euhdn
- By using the above table, replace the characters as show
  ciphertext = wklv phvvdjh lv qrw wrr kdug wr euhdn
  plaintext = THIS MESSAGE IS NOT TOO HARD TO BREAK

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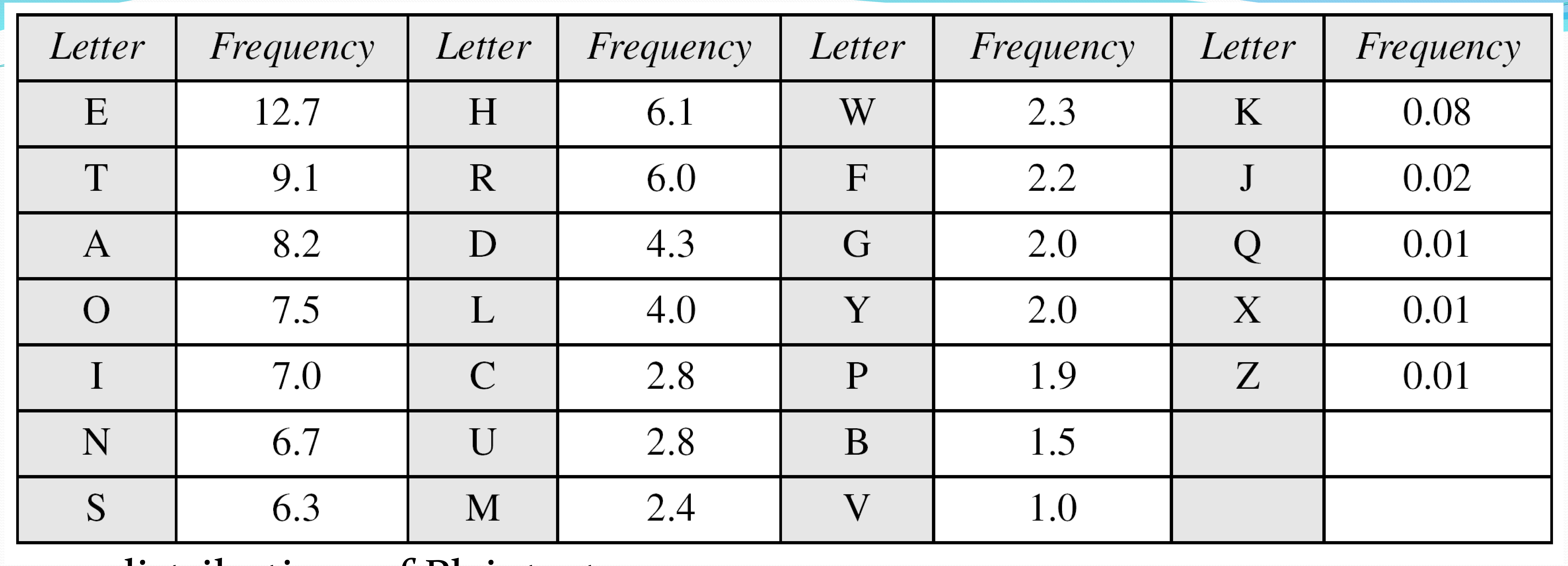
- ***Example:*** Eve has intercepted the ciphertext (UVACLYFZLJBYL). Show how she can use a brute-force attack to break the cipher.
- Eve tries keys from 1 to 7. With a key of 7, the plaintext is (not very

Ciphertext: UVACLYFZLJBYL

K = 1	→	**Plaintext:** tuzbkxeykiaxk
K = 2	→	**Plaintext:** styajwdxjhzwj
K = 3	→	**Plaintext:** rsxzivcwigyvi
K = 4	→	**Plaintext:** qrwyhubvhfxuh
K = 5	→	**Plaintext:** pqvxgtaugewtg
K = 6	→	**Plaintext:** opuwfsztfdvsf
K = 7	→	**Plaintext:** notverysecure

Table of Frequency of characters in English



Letter	*Frequency*	*Letter*	*Frequency*	*Letter*	*Frequency*	*Letter*	*Frequency*
E	12.7	H	6.1	W	2.3	K	0.08
T	9.1	R	6.0	F	2.2	J	0.02
A	8.2	D	4.3	G	2.0	Q	0.01
O	7.5	L	4.0	Y	2.0	X	0.01
I	7.0	C	2.8	P	1.9	Z	0.01
N	6.7	U	2.8	B	1.5		
S	6.3	M	2.4	V	1.0		

Frequency distributions of Plaintext :-

- E
- T
- A, O, R, N , I
- H , C , D , L, M
- .
- .
- X , J ,Z , Q

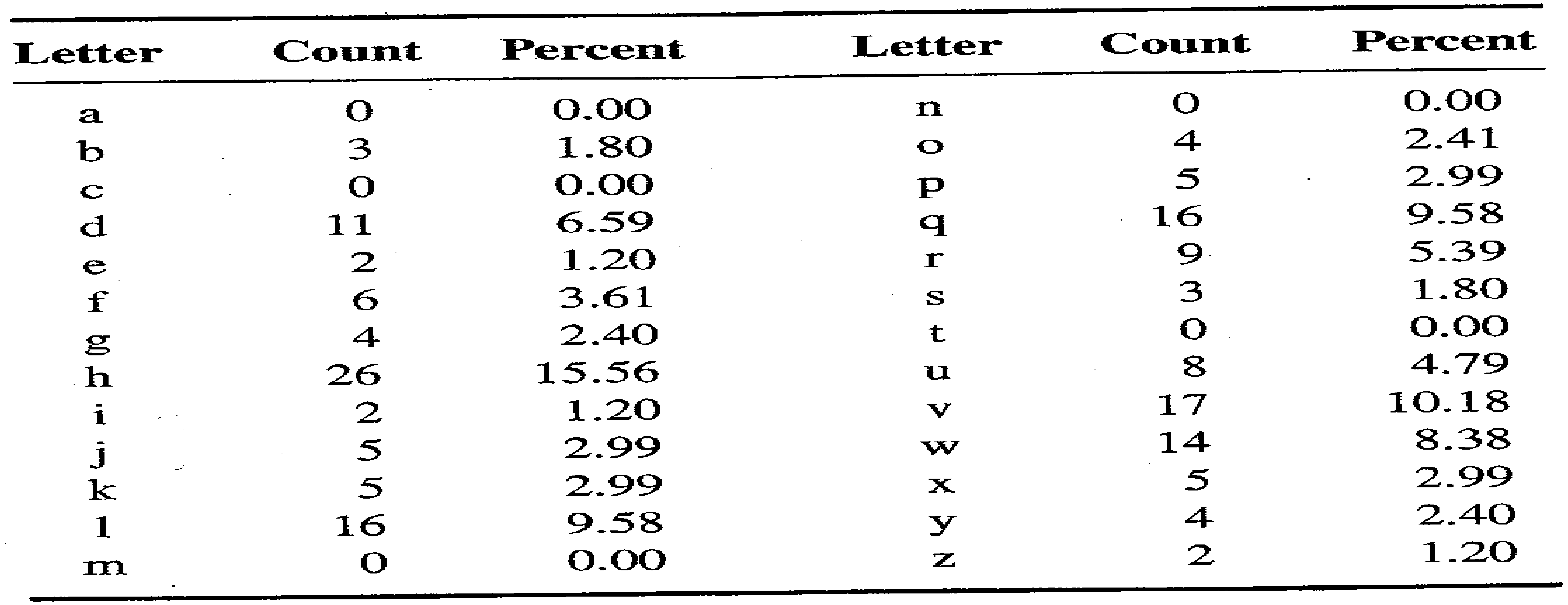
- Example : - Eve has intercepted the following ciphertext. Using a statistical attack, find the plaintext.

Ciphertext= hqfubswlrq lv d phdqv ri dwwdlqlqj vhfxuh frppxulfdwlrq

- When Eve tabulates the frequency of letters in this ciphertext, she gets:

h=26, v=17 and so on.

Frequencies of characters



Letter	Count	Percent	Letter	Count	Percent
a	0	0.00	n	0	0.00
b	3	1.80	o	4	2.41
c	0	0.00	p	5	2.99
d	11	6.59	q	16	9.58
e	2	1.20	r	9	5.39
f	6	3.61	s	3	1.80
g	4	2.40	t	0	0.00
h	26	15.56	u	8	4.79
i	2	1.20	v	17	10.18
j	5	2.99	w	14	8.38
k	5	2.99	x	5	2.99
l	16	9.58	y	4	2.40
m	0	0.00	z	2	1.20

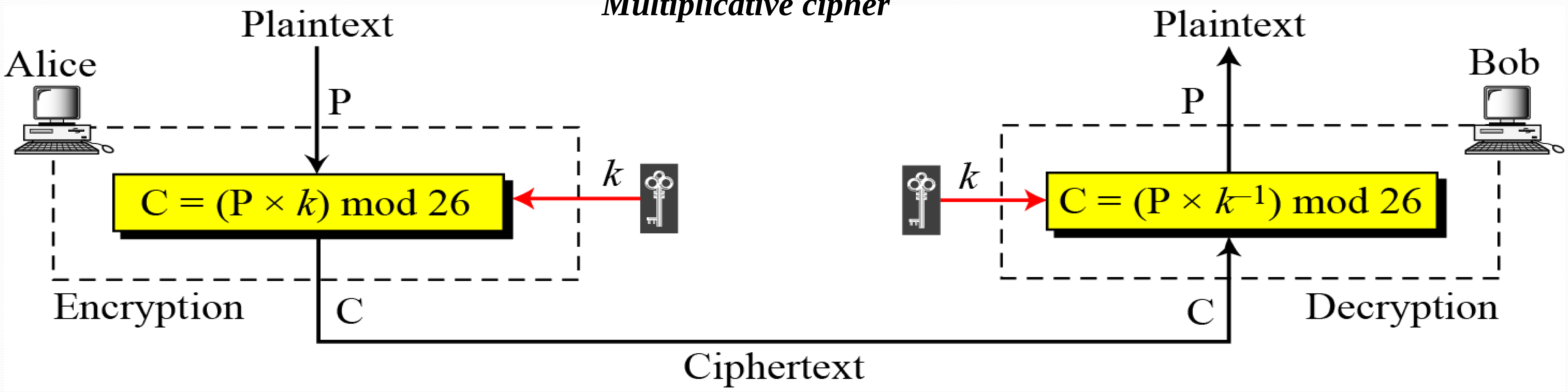
- So we will replace each character with the corresponding high frequency in plaintext as shown: -

Plaintext = ENCRYPTION IS A MEANS OF ATTAINING SECURE COMMUNICATION

Which means that the key is =3 ? How?

- **Multiplicative Ciphers:** - In a multiplicative cipher, the plaintext and ciphertext are integers in Z_{26}; the key is an integer in $Z_{26}*$.

Multiplicative cipher



- The key domain for any multiplicative cipher which must be in Z26*, is the set that has only 12 members: 1, 3, 5, 7, 9, 11, 15, 17, 19, 21, 23, 25.(**why**)
- Example: - We use a multiplicative cipher to encrypt the message “hello” with a key of 7. The ciphertext is “XCZZU”.

Plaintext: h → 07	Encryption: (07 × 07) mod 26	ciphertext: 23 → X
Plaintext: e → 04	Encryption: (04 × 07) mod 26	ciphertext: 02 → C
Plaintext: l → 11	Encryption: (11 × 07) mod 26	ciphertext: 25 → Z
Plaintext: l → 11	Encryption: (11 × 07) mod 26	ciphertext: 25 → Z
Plaintext: o → 14	Encryption: (14 × 07) mod 26	ciphertext: 20 → U

- Cryptanalyses of the multiplicative cipher based on finding the multiplication inverse of the key (where the multiplication inverse of **7 is 15**) as shown

Ciphertext X → 23	Decryption: (23 * 15) mod 26	plaintext= 7→h
Ciphertext C → 2	Decryption: (2 * 15) mod 26	plaintext= 4→e
Ciphertext Z → 25	Decryption: (25 * 15) mod 26	plaintext=11→l
Ciphertext Z → 25	Decryption: (25 * 15) mod 26	plaintext=11→l
Ciphertext U → 20	Decryption: (20 * 15) mod 26	plaintext=14→o