EXTENSION COURSE of the ARMY SECURITY AGENCY

SUBCOURSE 20-6

MILITARY CRYPTANALYSIS, PART 1

MONOALPHABETIC SUBSTITUTION SYSTEMS

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HEADQUARTERS, ARMY SECURITY AGENCY JUNE 1947

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EXTENSION COURSE OF THE ARMY SECURITY AGENCY

SUBCOURSE 20-6, MILITARY CRYPTANALYSIS, PART I
MONOALPHABETIC SUBSTITUTION SYSTEMS

Security Considerations.

This course and the accompanying text have been ~~classified RESTRICTED~~ to facilitate their dissemination to extension students of the Army Security Reserve. Nevertheless, this material is to be safeguarded in the same manner as ~~CONFIDENTIAL~~ matter, and every precaution will be taken to prevent disclosure to unauthorized personnel.

Introduction.

This is the first of a series of subcourses on the science of military cryptanalytics. The purpose of this subcourse is to teach the student the methods of analysis of systems which form a basis for the more simple military cipher systems. An understanding of these principles is necessary to grasp the advanced cryptanalytic techniques employed in the attack on the complex systems which comprise present-day military cryptography.

The scope of this subcourse is: fundamental principles; uniliteral substitution; polyliteral substitution; polygraphic substitution; and miscellaneous monoalphabetic substitution systems. It consists of nine lessons and an examination as follows:

Lesson 1, Fundamental principles; frequency distributions.

Lesson 2, Uniliteral substitution with standard cipher alphabets.

Lesson 3, Uniliteral substitution with mixed cipher alphabets.

Lesson 4, Polyliteral substitution with mono-equivalent cipher alphabets.

Lesson 5, Polyliteral substitution with poly-equivalent cipher alphabets.

Lesson 6, Polygraphic substitution: 4-square and 2-square matrices.

Lesson 7, Polygraphic substitution: Playfair systems.

Lesson 8, Polygraphic substitution: quadricular tables.

Lesson 9, Miscellaneous monoalphabetic substitution systems.

Examination.

30 credits are allowed for the subcourse. You will not be limited as to the number of hours you may spend in the solution of the subcourse, any lesson, or the examination. For statistical purposes you are required to enter the number of hours spent on solution in the answer sheet.

Texts and materials furnished:

Military Cryptanalysis, Part I (1942).
*Appendix 2 (November 1946).
*TM 11-484, Elementary Military Cryptography, March 1945.
*TM 11-485, Advanced Military Cryptography, 8 June 1944.
*Strip device (ASA Training Aid No. 1).

*Printed and blank alphabet strips (Training Aid No. 2).

Cross-section paper.

*This material may be retained upon completion of the subcourse. No other materials are required.

This course was prepared under the direction of the Chief, Army Security Agency.

Special Instructions.

So far as practicable, detailed work sheets which usually form a part of the solution should be submitted with the solutions. In all the lessons of this subcourse, it is required that the student recover all the cipher and plain text alphabets used. He will also be required to state the method of operation of each system and give the keys upon which each component is based. The specific keys and any cipher table employed must be recovered.

EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20–6	Military Cryptanalysis, Part I
LESSON 1	Fundamental principles; frequency distributions
CREDIT	3
TEXT ASSIGNMENT	Text, Sections I to IV, inclusive; attached memoranda
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	None

EXERCISES

Weight

4 1. What four fundamental operations are involved in the solution of practically every cryptogram?

2 2. In the solution of cryptograms involving a form of substitution to what simple terms is it necessary to reduce them in order to reach a solution?

2 3. Is it always necessary to determine the specific key in order to reconstruct the plain text?

10 4. Using cross-section paper prepare a uniliteral frequency bar distribution of the letters of the following paragraph:

> "The shortest and surest way to live with honor in the world
> is to be in reality what we would appear to be; all human
> virtues increase and strengthen themselves by the practice
> and experience of them."

2 5. *a.* What percent (in round numbers) of the letters in English telegraphic text are *E*'s?

2 *b.* What are the four most frequent consonants in English telegraphic text?

2 *c.* What are the four most frequent digraphs in English telegraphic text?

2 *d.* Account for the discrepancies between frequencies of letters in English literary text and English telegraphic text.

4 6. What four facts can be determined from a study of the uniliteral frequency distribution of a cryptogram?

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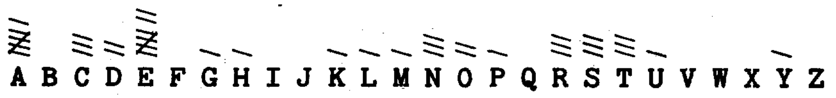
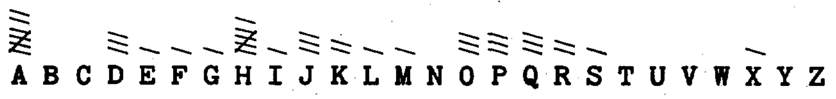
5 7. Determine the class to which the cipher systems, which were used in enciphering the following messages, belong:

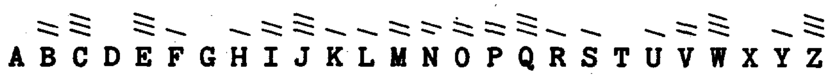
a. ORANA THPNO SKTCD MEEES CERAE
RNUSA ETLGD AYECA



5 *b.* DHJJK QOAHR XKSOF HPQGA PPHLA
DIADE HJROA MAHQA

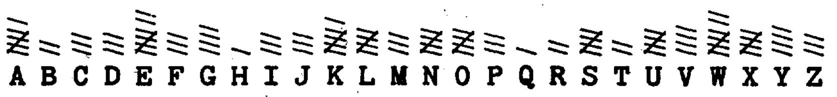


5 *c.* ROLEH KBWFZ CQCPZ NVJWZ MIVEQ
EPCIN OJSJU YMWQB

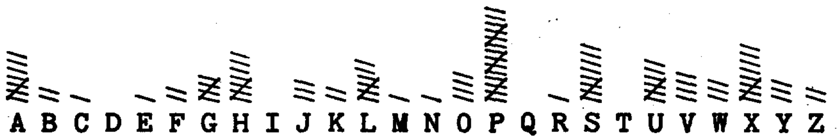


8. Which of the following substitution ciphers are monoalphabetic?

5 *a.* UJKLW EUVKL FSPAQ PHTKR DZNGL
SELYN XYXBX JDATU WEUZG WFVXM
MNZAY AOSGU DCLGI OEWJE IFOKM
KNWAP KOIEV AROEV WSCWN SBCYX



5 *b.* HUPYP XXAEP AFGZP VGLHA SLXHU
SXXAY PWKAS LHPRH ALOBA XPLVS
WUPJP OBSHU HUPGF XGKPH PVSWU
PJOPZ SVPYS MPOAX ULSLP CGNJX



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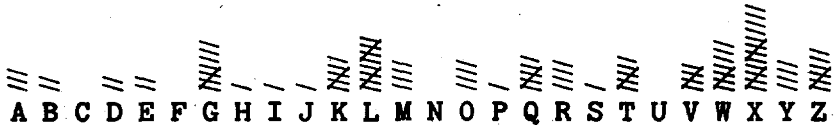
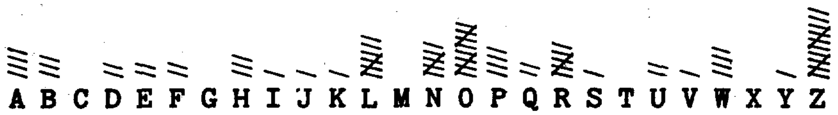
5      c. G X Y V L  Z X M X S  L O Z G R  W E J L X  P W T K Z
          G M X L W  Q I V Z W  Q B R X K  K T D V L  M X A E X
          V H M X A  L O T L Y  T K D W X  G B Q K Q  L W Z X G
          R T Y Y Z  K T O X G  A W X L Q  L O Z G R  X V W G Q
```

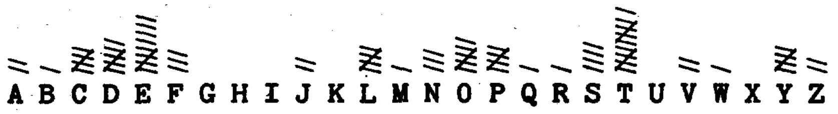


9. The following messages were enciphered monoalphabetically. Determine in each case whether the cipher alphabet used was a standard or mixed alphabet and if standard, whether direct or reversed.

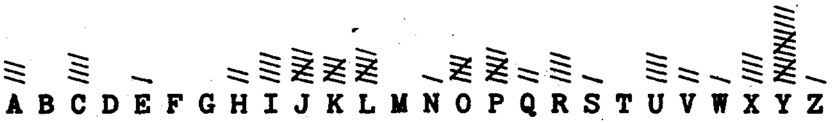
```
5      a. A N V O R  L O U N Q  R L E Z W  Z H N E Z  W Z B O R
          Z K Y L F  A O Z S O  O N O R F  P J Z P P  L D Z D N
          L R Z L B  L A B W Z  H N A P O  W Q H O O  R Z I Z U
```



```
5      b. E S P A P  L V D L Y  O E C Z F  R S D T Y  E S T D O
          T D E C T  M F E T Z  Y B F T N  V W J T O  P Y E T Q
          J T E L D  O T C P N  E D E L Y  O L C O N  T A S P C
```



```
5      c. P Y H Y L  X O L W Y  J J V Y X  O I L Y R  Y Q Y P J
          K N Y L K  Y H Y L C  P A Y A C  L Y X I R  Q Y J V O
          Z K O X C  P C R E K  U K U P J  I U J U O  P R I A S
```



25 10. From the intercepted traffic of three intercept stations operating in the same sector of the front, the following messages were selected for study by a member of the cryptanalytic section at GHQ. They are undoubtedly three versions of one enemy message, but there appears to be a number of differences, due no doubt to operating difficulties at the several stations. Study the messages and reconstruct from them the actual message sent by the enemy station.

I. Time intercepted 1612 by HS WFF V LDC

```
GR   35   BT
 NR17 DYBIE DUFTO AMEJA KIBON
SGCOY FOBAK DODLA LUFYD KAWAL
APAYN CODAP KEDUR JOPID JENOX
MEHAZ LOGIS KUTEG EVAUK IPBEM
KEHZA HOBWE AVDUZ FOFA_ EMCOZ
EGBLO DOFYO ENC__ MAWEN _____
_____ _____ _____ _____ _____
```

II. Time intercepted 1610 by MR MFF V LDC

```
GR   35   BT
 NRI_ DYBIE BUFTO AMEJA KIBON
IPKO_ F_BAK DODLA LUFYL KAWAL
APAYN _____ __DUA __PID JENOX
NEHAZ LOGIS KUTEG EVAUC IRBW
KEHZA SOBWE VADUZ FOFET EMCOZ
EGBLO DOFYO AECDA MAWEN ___OM
EMCOZ ACFAH LOFIR 0935
```

III. Time intercepted 1612 by YG WFF V LDK

```
GR   __   BT
 NR17 DYBIE DUFTO AMEJA KSBON
IPCOY ___A_ DO___ LUFYL KAWAL
APETYN CODAP KEDUR WOPID JENOX
MEHAZ LOGHKUTEG EVAUK IPBEM
KEHZA HOBWE AVDUZ FOFET EMCOZ
EGBLO DOFYO ENCOA MAWEN MAWEN
EXFOM EMCOZ ACFAH LOFIR 0935
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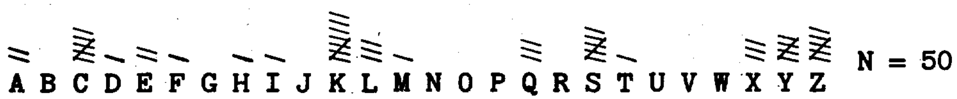
MEMORANDUM ON THE ϕ (PHI) TEST

1. The student has seen how it is possible by ocular examination to determine whether or not a substitution cipher is monoalphabetic. This tentative determination is based on the presence of a marked crest and trough appearance in the uniliteral frequency distribution, and also on the number of blanks in the distribution. Hence, the absence of marked crests and troughs in the uniliteral frequency distribution indicates that two or more cipher alphabets are involved: the flattened-out appearance of the distribution constitutes one of the tests for a polyalphabetic substitution cipher. However, when the distribution contains a small number of elements, ocular examination and evaluation becomes increasingly difficult and hazy. Now, the student may ask, does a mathematical test exist that could determine the monoalphabeticity or non-monoalphabeticity of a distribution?

2. Without going into the theory of probabilities at this time, or into the derivation of the formulas involved, let it suffice for the present to state that there is such a test, known as the "ϕ (phi) test." With this test, the "observed value of ϕ" is compared with the "expected value of ϕ random" and the "expected value of ϕ plain." The formulas are $E(\phi_r) = .0385N(N-1)$ and $E(\phi_p) = .0667N(N-1)$, where N is the total number of elements in the distribution. The use of these formulas is best illustrated by an example.

3. The following short cryptogram with its accompanying uniliteral frequency distribution is at hand:

```
QCYCH  ADSKS  YZZQE  CYKYK  QZYSK
LSZAC  TKFCX  LKLKC  ESZMX  KISZX
```



The observed value of ϕ is calculated by applying the formula f(f–1) to the frequency (f) of each letter and totaling the result. Thus,

	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	
N =	2		6	1	2	1		1	1		8	3	1				3		6	1				3	5	6	= 50
f(f–1) =	2		30	0	2	0		0	0		56	6	0				6		30	0				6	20	30	=188

The expected value of ϕ random is

$$E(\phi_r) = .0385N(N-1) = .0385 \times 50 \times 49 = 94.3$$

The expected value of ϕ plain is

$$E(\phi_p) = .0667N(N-1) = .0667 \times 50 \times 49 = 163.4$$

Now since the observed value of ϕ, 188, is equal to and in fact greater than $E(\phi_p)$, then we have a mathematical corroboration of the hypothesis that the cryptogram is monoalphabetic. If the observed value of ϕ were nearer to $E(\phi_r)$, then the assumption would be that the cryptogram is non-monoalphabetic. If the observed value were just half-way between $E(\phi_r)$ and $E(\phi_p)$, then decision would have to be suspended as there is no further statistical proof in the matter.

4. Two further examples may be illustrated:

	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	
	\			\	\\	\\\	\\\\	\\			\				\\\\	\\		\						\		\\\	N=25
a.	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	
	0			0	2	6	12	2			0				12	2		0						0		6	f(f–1)=42

	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	
			\				\	\	\\	\	\	\	\\\	\	\		\	\\		\	\		\	\	\\	\\\	N=25
b.	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	
			0				0	0	2	0	0	0	6	0	0		0	2		0	0		0	0	2	6	f(f–1)=18

Since both distributions have 25 elements, then for both

$$E(\phi_r) = .0385 \times 25 \times 24 = 21$$

$$E(\phi_p) = .0667 \times 25 \times 24 = 40$$

Hence distribution *a* is monoalphabetic, while *b* is not.

5. The student must not assume that statistical tests in cryptanalysis are infallible or absolute in themselves: statistical approaches serve only as a means to the end, in guiding the analyst to the most probable fruitful sources of attack. To illustrate this point, if the ϕ test is taken on the *plaintext* letters of the phrase

A QUICK BROWN FOX JUMPS OVER THE LAZY DOG

		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	
N	=	\\	\	\	\	\\	\	\	\	\	\	\	\	\	\	\\\\	\	\	\\	\	\	\\	\	\	\	\	\	=33
		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	
f(f–1)	=	2	0	0	0	2	0	0	0	0	0	0	0	0	0	12	0	0	2	0	0	2	0	0	0	0	0	=20

$E(\phi_r) = 40.7$ $E(\phi_p) = 70$

it will be noticed that the observed value of ϕ is exactly half of $E(\phi_r)$, therefore "conclusively" proving that the above phrase could not possibly be plaintext in any language! The student should be able to understand the cause of this cryptographic 'phenomenon.'

MEMORANDUM ON TRAFFIC INTERCEPTS

1. Before a military cryptanalyst can begin the analysis of an enemy cryptographic system, it is necessary for him to study the intercept material that is available to him, isolate the messages that have been enciphered by means of the cryptographic system to be studied, and to arrange the latter in a systematic order for analysis. This work, although apparently very simple, may require a great deal of time and effort.

2. Since, whenever practicable, two or more intercept stations are provided to copy traffic emanating from the stations of one enemy radio net, it is natural that there should be a certain amount of duplication in the work of the several stations. This is desirable since it provides the cryptanalysts with two or more sets of the same messages so that when one intercept station fails to receive all the messages completely and correctly, because of set difficulties, local static, or poor operation, it is possible by studying the other sets to reconstruct accurately the entire traffic of the enemy net.

3. In all intercept activities where operators are used for copying the traffic, one of the most likely errors to be found is caused by the human error in reception. For this reason cryptanalysts and their assistants should be familiar with the Morse telegraph alphabets and the most common errors of wire and radio transmission methods so as to be able to correct garbled groups when they occur. In this work reference is made to the table given on page 82 of TM 11–484 (Elementary Military Cryptography).

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EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

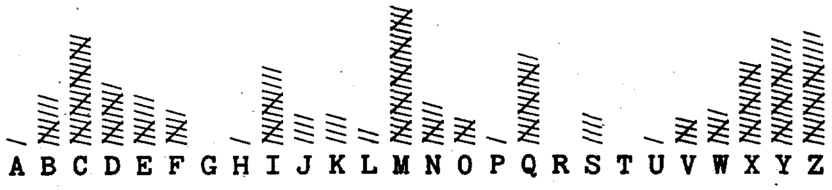
SUBCOURSE 20–6	Military Cryptanalysis, Part I
LESSON 2	Uniliteral substitution with standard cipher alphabets
CREDIT	3
TEXT ASSIGNMENT	Text, Section V; attached memorandum
MATERIALS REQUIRED	None
SUGGESTIONS	None

EXERCISES

Weight

40 1. *a.* Solve the following cryptogram:

	5	10	15	20	25
A	J M Q V S	Q Z X I F	F M Z S L	I Z M L Z	C E M E B
B	F Q O M E	M D X Y Q	O Z C Y Y	X J M Z I	V M Z I Y
C	O Q W Y I	D K Y M V	M Z M N Q	E Q K M X	C C W Z B
D	C Y I X I	C D Y Y X	C B Z Q I	F Z C Q N	H W D O X
E	I C D J Q	Y P M M D	Y M V M Z	M F S N Q	E Q K M N
F	Q D N E W	O J M A W	I B E M D	X N M Y X	Z C S M N
G	Y X C B U	M Q Z M E	C V I D K	C W Z X Z	C C B Y X
H	C Z M Q Z	B C Y I X	I C D Y Y	X C B Z Q	F Y X C D



$\phi = 2636$ $E(\phi_p) = 2654$ $E(\phi_r) = 1531$

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5 *b.* What is the specific key?

5 *c.* Name two methods of solving ciphers of this type.

2. Solve the following cryptograms:

10 *a.* Q H H Y L Y D W Q J J M E F C

10 *b.* Y X S E D Y F S X U H W X U S

5 *c.* What are the specific keys?

10 3. *a.* In the solution of a substitution cipher by completing the plain component sequence involving reversed standard alphabets, what are the successive steps?

5 *b.* What is the first step one should take in attempting to solve an unknown cryptogram that is obviously a substitution cipher?

5 *c.* If this step is unsuccessful and the cryptogram is obviously monoalphabetic in character, what type of cipher alphabet may be assumed to have been used?

5 *d.* Why do monoalphabetic cryptograms involving standard cipher alphabets yield such a low degree of cryptographic security?

MEMORANDUM ON CRYPTANALYTIC PROCEDURE

The following suggestions will promote systematization of procedure and logic in analysis. Experience has shown that time and labor can be saved by careful attention to these instructions.

1. Most of the problems in this course are already laid out in worksheet form, to spare the student the clerical labor of copying out the text. However in those cases where worksheets must be prepared, the cipher text should be copied in ink on cross-section paper, one letter per cell. There should be a single space between letters or digraphs in monoalphabetic systems, and a single space between period lengths in polyalphabetic systems. In aperiodic systems groupings may be in five letters, unless the system lends a better alternative. At least three spaces between successive lines of cipher text is recommended in order to leave room for multiple assumptions. Line and column indicators are to be made for each cryptogram, to facilitate reference in the step-by-step commentary. Margins should be left on all sides for notes, etc. *All* worksheets and notes should be submitted together upon the completion of a lesson.

2. Enciphering alphabets, enciphering diagrams, etc., as well as all keywords and specific keys should be included in a solution. Keyword derivation from transposed sequences will also be shown. Whereas there should be a letter-for-letter decryptment *under* the cipher text, the final plaintext version in word-lengths should correct any errors or garbles in the text. Nulls or indicators showing sentence separation, change of key, etc., may be enclosed in parentheses.

3. If completing the plain component sequence yields no solution, then uniliteral frequency distributions (or digraphic distributions, if a digraphic system) should be made. Triliteral frequency distributions will enable the separation of vowels and consonants and furnish much additional valuable data. In a difficult case triliterals may give the only clues to solution: this is especially true in foreign language cryptograms. If the problem entails the selection of proper generatrices in polyalphabetic ciphers, the use of alphabet strips will save much time. In polypartite systems, reduce the cryptogram to monoliteral terms wherever possible.

4. Repetitions should be underscored in a manner facilitating their location and interpretation: colored pencils will be found useful. It is recommended that the frequencies of letters comprising the repetitions be inscribed over their respective letters. Likewise, the frequencies of the first 10 and last 10 letters should also be inscribed, as in many cases these positions lend themselves readily to attack. If the problem proves difficult, then it is best to inscribe the frequencies over all the cipher letters of the text, in order better to visualize *frequency-patterns* of words.

5. Step-by-step analyses should accompany all problems: they should be brief and concise, yet at the same time specific. The steps should be jotted down *as they are made*, and at the end they should be combined into a complete resume of the analysis. It is not necessary to be verbose, but *all* the steps which were taken to achieve solution should be specified, so that at any future date the solution may be reconstructed following the exact manner in which it was first accomplished. Assumptions of words, etc., should be referred

to with line and column indicators and couched in the proper cryptologic language or symbols. All keywords and specific keys, as well as the mechanics of the general system, should be stated at the end of the commentary.

6. Violations of cryptographic security observed in the problem studied may be included at the close of the commentary. These violations may be stereotypic phraseology (especially in beginnings or endings of messages), related keywords, keywords of military nature, unnecessary punctuation, general wordiness, or any other practices dangerous to cryptographic security which may be seized upon by the cryptanalyst as entering wedges in solution.

EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20-6	Military Cryptanalysis, Part I
LESSON 3	Uniliteral substitution with mixed cipher alphabets
CREDIT	3
TEXT ASSIGNMENT	Text, Section VI; attached memorandum
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	None

EXERCISES

Weight

20 1. *a.* Construct a triliteral frequency distribution showing one prefix and one suffix of the cryptogram below. On the worksheet below indicate by underscoring in black all repetitions of three or more letters. Other significant details may be marked in different colors.

6 *b.* Prepare a condensed table of repetitions of digraphs and trigraphs appearing more than twice, and include all repetitions of longer polygraphs.

20 2. *a.* Using the data obtained in *a* and *b* above, complete the solution of the cryptogram.

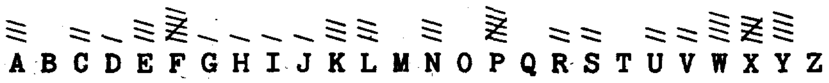
```
            5         10         15         20         25

A    S R I K N  A Q J I R  N Q A I P  F T E A I  O J I R I
B    J I P J G  G A Q Q A  J I R E J  B B A P R  N V R N R
C    P H K S T  N R E F H  Q S I A O  L S A I H  N H A E Y
D    X J I R J  B J T N K  H S N J F  Q Q S J K  J I R K N
E    A Q J I R  N Q S H S  R Q S L H  S B J T N  S L E A U
F    A Q A J I  A Q A I U  A P A I A  S X J B Y  F T R G J
G    T I S H A  I G J U A  I O V R Q  S S J H S  S H P D J
H    T N K J Q  A S A J I  Q V R Q S  J B B H N  N R F F Q
J    N A E O R  Q S J K P  J I B A N  G H S A J  I J B S L
K    A Q N R K  J N S A Q  N R M T R  Q S R E X
```

2 *b.* Determine the cipher alphabet and the keyword used. What is the specific key ($A_p = \theta_c$)?

3. Using the same components as determined in 2*b*, solve the following cryptograms and indicate the specific keys:

10 *a.*

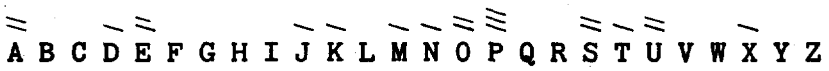
```
F P F E N   I Y R U E   P W S F X   F W V X K   D F G Y P
A L C A S   K N V A L   W E Y X P   L P C J N   Y U X H R
K P F W X
```



$\phi = 144$ $E(\phi_p) = 198$ $E(\phi_r) = 114$

10 *b.*

```
E P S S P   A O E O A   D K T P U   U X M N J
```



$\phi = 16$ $E(\phi_p) = 25$ $E(\phi_r) = 15$

2 4. *a.* What two places in every message lend themselves more readily to successful attack by the assumption of words than do any other places? Why?

2 *b.* What is meant by the "probable word method" of solution?

2 5. *a.* What is meant by the word pattern "A B C B A D B"?

b. For each pattern given below, indicate one good English word that contains the pattern:

2 (1) A B C B A D B
2 (2) A A B A
2 (3) A B C D A

6. The following cryptograms, enciphered with random cipher alphabets, are in bona fide word-lengths. Solve them.

5 *a.*

```
H Y  A R V J Z G H A R O T  V K  C G K M M G K H Z M  L K U G
L K U G  O R O E  H O Z  E M V H F S R M J R O T
J E H Z P U H G V E G M  R O  M C J K K S J K U M E
```

5 *b.*

RGRQRU TDSPYURDP ZFTAVDRC AYCFO

JO DRZYUUFSPPFUZR TFADYGP

7. In solving several unrelated monoalphabetic cryptograms the following cipher alphabets were reconstructed. Recover all keywords in each case. To expedite solution, significant segments have been underlined.

2 *a.*

P: 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
C: N L W P F R T H S Y D Q A K V E B M X G C O Z I J U

2 *b.*

P: 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
C: Z Q X P E O N M W L K J H G F D B V Y U T R I C S A

2 *c.*

P: 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
C: P Q E R V M O Z W U T H A X B C D F S Y G I J K L N

2 *d.*

P: 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
C: A U Z J T X H S W G R M B N O C I Q F E K Y P D V L

2 *e.*

P: 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
C: C K V E B O Y F D P Z G Q H S I T L W N J U R A M X

MEMORANDUM ON ALPHABET RECONSTRUCTION AND KEYWORD DERIVATION

1. Concurrent with the solution of a cryptogram, there should be a simultaneous effort in the reconstruction of the general system and recovery of the specific keys. Much labor can thus be saved as recovery of the keys early in the stages of solution transforms the process of decrypting into one of decryptographing.

2. A cipher alphabet consists of two sequences, e.g.,

a. the plain component is a standard alphabet, cipher component mixed;
b. the cipher component is a standard alphabet, plain component mixed;
c. both components are the same mixed sequence;
d. both components are the same mixed sequence, running in reverse; or
e. the components are differently mixed sequences.

3. Let us examine several types of mixed sequences, using the keyword HYDRAULIC as an example:

```
4 9 3 7 1 8 6 5 2
H Y D R A U L I C
B E F G J K M N O
P Q S T V W X Z
```

The ordinary keyword-mixed sequence derived from the above will be:

a. H Y D R A U L I C B E F G J K M N O P Q S T V W X Z

The two principal transposition-mixed types will read:

b. H B P Y E Q D F S R G T A J V U K W L M X I N Z C O and

c. A J V C O D F S H B P I N Z L M X R G T U K W Y E Q

Other types may arise from route transpositions as follows:

d. H B P Q E Y D F S T G R A J V W K U L M X Z N I C O

e. H Y B P E D R F Q S G A U J T V K L I M W X N C O Z

f. P B Q H E S Y F T D G V R J W A K X U M Z L N I O C

g. H Y D R A U L I C O N M K J G F E B P Q S T V W X Z

h. O C I L U A R D Y H B P Q S T V W X Z N M K J G F E

i. H Y E B P Q S T G F D R A U K J V W X Z N M L I C O

j. C P I O Q B L N S E H U M Z T F Y A K X V G D R J W etc.

Any transposition system may be employed to produce a systematically-mixed sequence: practicability of method is the only determining factor. It must be remembered that the greatest amount of systematic mixing will produce a sequence inherently no more secure than a random alphabet.

4. The student would do well to construct both enciphering and deciphering versions of cipher alphabets recovered. For example, in the following case

Plain:	J	Q	N	M	F	H	L	E	B	R	S	K	G	Y	Z	O	T	I	C	D	U	V	A	W	P	X
Cipher:	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

no semblance of a key is apparent; but in the inverse form

Plain:	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
Cipher:	W	I	S	T	H	E	M	F	R	A	L	G	D	C	P	Y	B	J	K	Q	U	V	X	Z	N	O

the key-phrase "NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THEIR PARTY" is quite clear. In other types of mixed sequences, first the one form is attacked, and then if negative results are obtained the inverse form is treated.

5. Let us consider the following cipher alphabet:

P:	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
C:	D	W	Z	M	S	O	C	R	Y	A	T	X	B	E	F	U	G	Q	H	I	V	J	K	L	N	P

The section $\begin{matrix}V&W&X\\J&K&L\end{matrix}$ seems to be superimposed parts of the non-keyword portions of mixed sequences. Adding Y Z to the plain component, we get $\begin{matrix}V&W&X&Y&Z\\J&K&L&N&P\end{matrix}$ which is certainly consistent as far as alphabetical progression goes, and indicates that the letters M and O are present in the keyword of the cipher component. Continuing in this vein, the section $\begin{matrix}M&N&O&Q&S&T&V&W&X&Y&Z\\B&E&F&G&H&I&J&K&L&N&P\end{matrix}$ is rapidly established by correlating both sequences. It is obvious that the plain component keyword begins right after the Z, and that the cipher component keyword probably just precedes the B. Going to the right, $\begin{matrix}Z&R&H\\P&Q&R\end{matrix}$ suggests keywords like RHOMBOID, RHEUMATISM, etc. These trials are quickly repudiated; therefore we go on to $\begin{matrix}Z&R&E\\P&Q&S\end{matrix}$ which is acceptable. $\begin{matrix}Z&R&E&K\\P&Q&S&T\end{matrix}$ is found wanting, but $\begin{matrix}Z&R&E&P\\P&Q&S&U\end{matrix}$ is very satisfactory, and this is soon expanded to $\begin{matrix}Z&R&E&P&U&B&L&I&C\\P&Q&S&U&V&W&X&Y&Z\end{matrix}$, and in a moment or two we recover the complete cipher alphabet:

P:	R	E	P	U	B	L	I	C	A	N	D	F	G	H	J	K	M	N	O	Q	S	T	V	W	X	Y	Z
C:	Q	S	U	V	W	X	Y	Z	D	E	M	O	C	R	A	T	B	E	F	G	H	I	J	K	L	N	P

6. In the example below the student will observe that the alphabets are reciprocal: this is an indication of identical sequences at a shift of 13, or that a mixed sequence running against itself in reverse has been employed. In this case the $\begin{matrix}W&X&Y&Z\\Z&Y&X&W\end{matrix}$ points to the latter hypothesis.

P:	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
C:	H	O	J	F	T	D	N	A	K	C	I	M	L	G	B	S	U	V	P	E	Q	R	Z	Y	X	W

Starting with the $\begin{matrix}V&W&X&Y&Z&R\\R&Z&Y&X&W&V\end{matrix}$ cluster, we see that the keyword begins with the letter R; therefore the next letter should be a vowel. $\begin{matrix}Z&R&A\\W&V&H\end{matrix}$ is not acceptable, but $\begin{matrix}Z&R&E\\W&V&T\end{matrix}$ is fine, showing that the letter U appears in the keyword. Continuing the same line of reasoning as in the preceding example, and with a little further experimentation, the final alphabet is discovered to be

```
P: R E P U B L I C A N D F G H J K M O Q S T V W X Y Z
C: V T S Q O M K J H G F D N A C I L B U P E R Z Y X W
```

7. In the next example, all efforts to derive keywords on the basis of keyword-mixed sequences are fruitless: the conclusion is therefore drawn that this is a case of a transposition.

```
P: 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
C: A C S E J Y I G W L F V M H X N K Z P B Q R D U T O
```

Considering the mechanics of the cryptography involved, and assuming for the time being that Z is at the bottom of the matrix and not in the keyword, we start with the letters to the left, or if this fails, to the right of Z in the cipher component, obtaining the column

```
N
K
Z
```

which is not incompatible if N is in the keyword on the top row. If we place Y to the left of Z and build up *its* column, we get

```
E N
J K
Y Z
```

which is certainly excellent. This is expanded into

```
I M E N
G H J K
W X Y Z
```

which quickly becomes

```
7 1 8 4 3 5 2 6 9
-----------------
P A R L I M E N T
B C D F G H J K O
Q S U V W X Y Z
```

This last example was very easy because none of the letters V W X Y Z appeared in the keyword; but other cases should hardly prove more difficult.

8. Two additional methods that have been encountered for deriving mixed sequences may be mentioned. One is a slight modification of the preceding paragraph, when the keyword contains repeated letters, viz:

```
1 8 7 3 4 9 5 2 6
-----------------
C O M . I T . E .
A B D F G H J K L     which produces the mixed sequence
N P Q R S U V W X
Y Z

  C A N Y E K W F R I G S J V L X M D Q O B P Z T H U
```

The other method is the interrupted-key columnar transposition system, viz:

```
2 1 3 5 4 6
-----------
J A N U R Y
B C)
D)
E F G)            which produces the mixed sequence
H I K L M)
O P Q S)
T V W X Z -)

  A C F I P V J B D E H O T N G K Q W R M Z U L S X Y
```

The first example will succumb to the treatment outlined in paragraph 7, whereas the second method is vulnerable owing to the presence of the fragments E H O T, F I P V and G K Q W in the sequence which may be anagrammed. Note the fragment B D E H O T, composed of an ascending sequence of letters: this is an outward indication of the interrupted-key columnar method.

9. There are still other methods used for the production of mixed sequences, but space does not permit giving further examples. However the student should by this time be able to devise methods of attack for any special cases that may present themselves, based upon the weaknesses or peculiarities inherent in the system of cryptography involved.

EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20-6	Military Cryptanalysis, Part I
LESSON 4	Polyliteral substitution with mono-equivalent cipher alphabets
CREDIT	3
TEXT ASSIGNMENT	Text, Section VII; attached memorandum
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	None

EXERCISES

Weight

20 1. Solve and recover all keys:

					5					10					15
A	DT	LR	WE	OE	OE	WH	RR	WR	LA	WH	WA	DE	DA	WR	LE
B	LE	OR	RE	WT	OR	WA	OH	WH	OR	LE	LR	WA	RR	RR	WH
C	WA	WH	OE	OR	LE	LE	WR	WA	WH	OH	LR	LE	LR	WA	OH
D	OE	LR	OA	OA	OE	LR	OR	RE	OA	OA	WH	WT	WH	WA	WA
E	WR	WA	WH	DE	RT	OE	WH	WH	RE	OR	OA	RT	OE	LR	OR
F	RE	WR	WE	WA	OH	DE	WR	LR	WA	WA	WR	WA	WH	DE	DA
G	LR	LR	WA	WH	OA	DE	LR	LT	LT	LR	OA	WR	DE	WR	LR
H	WA	OA	LR	RA	RA	LR	WE	OE	DE	RT	OE	WH	RR	WR	LA
J	WH	WA	DE	DA	WR	LE	LE	OT	WH	OE	WH	WH	WA	RA	LR
K	OE	OH	WH	RE	OT	DT	OR	RE	RE	WR	DE	WR	LR	WA	OR
L	LE	OR	OE	DE	WR	LE	LE	WH	OE	DT	OA	WE	LT	LT	LR
M	OE	DE	OA	DE	LR	LT	OH	LR	LE	LR	WA	WH	LE	OT	WH
N	WA	WA	WR	WA	RR										

	A	E	H	R	T
D	3	12	–	–	3
L	2	13	–	21	5
O	10	14	6	10	3
R	3	7	–	5	3
W	22	4	22	13	2

$\phi=2288$ $E(\phi_r)=1362$ $E(\phi_p)=2270$

(25-element alphabet)

20 2. This message was sent by the Fifteenth Infantry. Solve it and recover all keys:

					5					10					15
A	CY	AO	NX	CN	NO	CN	AO	AO	OG	ON	NG	BY	OX	OX	RO
B	CG	NY	RO	AN	RE	AG	RO	OX	AO	AN	AX	AX	AG	AN	AG
C	CN	RO	OX	OX	BY	AN	AG	CN	BE	CX	BN	BX	CG	RO	ON
D	CO	RE	CN	AY	BG	CE	ON	NO	AO	OG	RO	NO	NO	RO	RE
E	OO	NG	BY	OX	OX	RY	AG	AX	BY	AN	OG	CN	AO	OY	OG
F	NO	OX	CY	NX	OG	AO	AN	CN	AG	RE	AG	BY	OG	NO	AO
G	BO	AO	CN	CG	AG	CN	ON	BO	CN	AO	OY	CO	OE	ON	NO
H	AO	OG	RO	NO	NG	RO	NO	AG	CN	RE	AO	OX	RX	AE	BY
J	AN	BO													

	E	G	N	O	X	Y
A	1	9	7	12	3	1
B	1	1	1	3	1	6
C	1	3	11	2	1	2
N	–	3	–	9	2	1
O	1	7	5	1	9	2
R	5	–	–	9	1	1

$\phi=716$ $E(\phi_r)=410$ $E(\phi_p)=960$ (approx.)

(36-element alphabet)

20 3. Solve and recover all keys:

					5					10					15
A	RG	GP	EE	GR	RG	GP	ES	GR	RG	PP	GE	PR	GE	RG	GS
B	AS	GR	RR	GS	AE	PP	GP	GA	PP	RA	EA	ES	GR	RG	PP
C	GE	RA	PR	GS	RE	GP	AR	GP	GS	PP	GP	RG	RA	EA	PP
D	PS	PG	AR	PE	GA	RR	RG	GP	RR	RE	PG	PP	RA	EA	RS
E	PG	PE	RG	AR	PE	GA	RR	RG	GP	RR	RP	AE	GS	GA	AP
F	GP	PP	RA	EP	ES	GP	RA	GP	RA	PE	PR	PR	AE	GR	GP
G	RA	GA	GP	GP	RR	GP	RR	GR	AS	AS	GP	RR	GR	GS	PP
H	GP	AE	GE	RS	PG	RG	GS	RE	PP	GR	GG	GS	PP	GR	PG
J	GA	PG	RS	RE	PG	AS	PR	GS	GA	GE	RR	EA	ES	GR	RG
K	RR	RP	GS	PP	PP	GS	AE	GR	PG	GA	EP	RG	GP	EE	GR
L	RA	GR	PP	GR	PG	GA	AR	GS	RA	RP	GP	GP	GA	GS	PE
M	ES	PG	RG	GR	ER	GP	RR	RP	GE	RG	GP	AG	GR	AS	GP
N	GA	PP	GS	AE	AR	PA	EP	RG	GP	PR	AE	GE	RG	GP	EE
P	GP	RA	PP	GP	RR										

	A	E	G	P	R	S
A	–	7	1	1	5	5
E	4	3	–	3	1	5
G	11	7	1	27	16	14
P	1	5	10	16	6	1
R	11	4	16	4	12	3

$\phi = 2294$ $E(\phi_r) = 1164$ $E(\phi_p) = 2260$ (approx.)

(30-element alphabet)

~~RESTRICTED~~

20 4. Solve and recover all keys:

					5					10
A	AAC	ACA	AAA	ACA	AAC	ACA	ACC	BAC	ACA	CCA
B	CAA	ACB	AAC	BCC	ACA	ABA	ABA	BAA	BBB	ACA
C	ACC	ACB	BCC	BAB	ACA	AAC	AAA	AAB	CBA	ACA
D	AAA	CAA	ACB	AAC	ABB	BBC	AAC	ACA	BBB	AAB
E	BCC	ACA	ACC	ABB	CBB	AAB	ABC	ABC	BAA	BBA
F	CBA	BAA	ACC	BAC	ACA	ABB	CAA	ACC	ACA	CBB
G	CAB	CAA	ABA	AAB	ABB	AAB	CAA	ACC	ABA	ACC
H	CAA	AAC	ABB	BBC	CAA	AAA	AAC	BCA	ABA	AAB
J	CBC	CAA	ACC	ACA	AAA	AAB	CBA	ACA		

	A	A	A	B	B	B	C	C	C
	A	B	C	A	B	C	A	B	C
A	5	7	8	5	5	2	14	3	8
B	3	1	2	1	2	2	1	–	3
C	8	1	–	3	2	1	1	–	–

$\phi=486$ $E(\phi_r)=284$ $E(\phi_p)=505$ (approx.)
(27-element alphabet)

~~RESTRICTED~~

5. The following is a text in the Baudot teletype code enciphered by a simple machine employing five two-position switches which operate polarized relays. Each switch has the function of changing the polarity of its respective baud (a single "mark" or "space" impulse), if the switch is in the 'active' position. If the switch is in the 'inactive' position, the polarity of the baud is unaffected. The switch settings remain constant for each message. As an example, if switches 1 and 4 are active (*), and 2, 3 and 5 are inactive (–), then the word ENEMY is enciphered thus:

Key:	*—*–	*—*–	*—*–	*—*–	*—*–
Plain:	MSSSS	SSMMS	MSSSS	SSMMM	MSMSM
Cipher:	SSSMS	MSMSS	SSSMS	MSMSM	SSMMM

It is suspected that the same signature is in the text as was present in Problem 2. Solve the message and recover the switch settings.

	1	2	3	4	5	6	7	8	9	10
A	MSMSS	MSMMS	MSSSM	MMSMM	MMMMS	MSSSM	SMMMS	SMSSS	SSSSS	SMSMS
B	MSMSS	MSSSS	MSSSM	SSMMM	MMSSM	MMSMS	MSMMM	MMMSM	MMMSM	SSMMM
C	MMSSM	MMMMM	SSMSM	MMSMM	MSMSS	MSSSM	SMMSM	MMMMM	MSMSS	MMSSM
D	MMMSS	MMMSS	SSMSM	MMMMM	SSSSS	MSSSM	SSSMM	MMSSM	MMMMM	SSMSM
E	MSSSM	MSMMS	MSSMM	MSSSM	MSSMM	SSMSM	SMMSS	MSMSS	MSMMS	MSSMM
F	MSSSM	SMMMS	SMSMM	MMSSM	SMMSS	MMSSS	SMMSM	SMSSM	MSMMS	SSSSS
G	MMMSS	MSSMS	SMSMS	MMMSM	MMMSM	MSSSM	MSSSM	SMMSM	MSMSS	SMMSS
H	SMMSM	MSMSS	SSMSM	MMMMM	MSSSM	MMSMM	MSMMS	MMMSS	MSSSM	SMMMS
J	SMSSS	MSMSS	SMSMS	MSSSM	MMSSM	MSSMM	SSSMM			

	M	M	M	M	S	S	S	S
	M	M	S	S	M	M	S	S
	M	S	M	S	M	S	M	S
MM	5	1	4	4	3	1	6	1
MS	1	5	–	8	4	1	13	1
SM	–	3	4	3	1	3	1	2
SS	2	–	5	–	2	–	–	3

$\phi = 386$ $E(\phi_r) = 234$ $E(\phi_p) = 480$ (approx.)

(32-element alphabet)

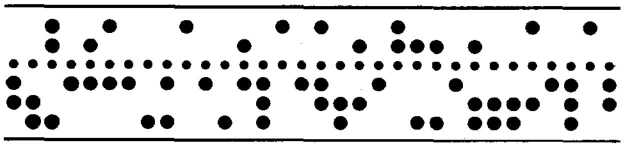
MEMORANDUM ON THE BAUDOT TELETYPE CODE

Teletypewriters employ in their operation a fixed-length five-element code similar to the Baconian quinqueliteral cipher. Each character in the code consists of five "mark" or "space" impulses in the 32 possible permutations. However, to allow for a greater number of characters than 32, a "Fig." indicator changes to an upper alphabet and the "Ltr." indicator re-establishes the lower alphabet. The other process symbols, in addition to the space between words, are the CR (carriage return) which returns the carriage to the left-hand margin on the completion of a line; the LF (line feed) which feeds the paper, rolling the carriage to the next lower line; and the "Bell" which rings a bell to signal the operator at the receiving end that there is traffic ready to be transmitted. Below is a diagram of the normal Baudot code in international use; the black dots represent the holes in the teletype tape which are the "mark" impulses, while the "space" impulses are unperforated.

UPPER CASE	WEATHER SYMBOLS	↑	⊕	○	↗	3	→	↘	↓	8	↙	←	↖	•
	COMMUNICATIONS	–	?	:	$	3	!	&	£	8	'	(	)	.
LOWER CASE		A	B	C	D	E	F	G	H	I	J	K	L	M
	1	●	●		●	●	●				●	●		
	2	●		●				●		●	●	●	●	
	FEED HOLES	○	○	○	○	○	○	○	○	○	○	○	○	○
	3			●			●		●	●		●		●
	4		●	●	●		●	●			●	●		●
	5		●					●	●				●	●

UPPER CASE	WEATHER SYMBOLS	⦶	9	ø	1	4	🔔	5	7	⦶	2	/	6	+	-	<	≡			
	COMMUNICATIONS	,	9	ø	1	4	🔔	5	7	;	2	/	6	"	≀	<	≡			
LOWER CASE		N	O	P	Q	R	S	T	U	V	W	X	Y	Z	BLANK	C.R.	L.F.	SPACE	LTR. SHIFT	FIG. SHIFT
	1				●		●		●		●	●	●	●					●	●
	2			●	●	●			●	●	●						●		●	●
	FEED HOLES	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	3	●		●	●		●		●	●		●	●					●	●	
	4	●	●			●				●		●				●			●	●
	5		●	●	●			●		●	●	●	●	●					●	●

The example below is a Baudot tape, containing the beginning of the phrase "NOW IS THE TIME FOR ALL GOOD MEN. . . ."



NOW IS THE TIME FOR ALL GOOD MEN

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EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20-6	Military Cryptanalysis, Part I
LESSON 5	Polyliteral substitution with poly-equivalent cipher alphabets
CREDIT	3
TEXT ASSIGNMENT	Text, Section VIII; attached memorandum
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	None

EXERCISES

Weight

5 1. *a*. What is the purpose of providing variants in a cipher system?

5 *b*. From the cryptanalytic point of view, how does simple monoalphabetic substitution differ from monoalphabetic substitution with variants?

20 2. Solve and recover all keys:

					5					10					15
A	RA	DE	KE	PE	VE	TI	BO	LA	GO	DU	JO	BE	KI	BI	JO
B	BU	JA	VA	ME	LA	BE	KI	RE	FE	DO	VI	JO	SA	DO	JE
C	KI	BA	MO	SA	CU	GE	GE	PI	BO	KI	JU	CE	CI	MI	NE
D	PO	JU	CE	RE	NA	BU	BE	KO	RA	DE	KE	TE	SE	TI	JO
E	FA	GO	DU	DO	JE	KI	DI	JO	BU	JA	CE	BO	FO	BA	BU
F	DA	LE	JO	NI	DO	NA	BO	BE	PI	GI	ME	TE	CO	JO	TI
G	SA	BO	TI	DU	MO	FA	BU	NA	DU	DE	TO	GI	BE	SE	BU
H	GE	CO	PA	TA	KE	CE	NA	VA	MO	LO	ME	NA	DU	DE	CE
J	BO	FO	DA	DU	DA	LE	BO	SI	JO	VA	DO	DE	TI	NI	DO
K	CO	FI	DE	VE	CI	BU	DA	LE	BO	VI	DO	NA	JO	BE	KI
L	VA	DU	DE	KO	GO	RE	MO	PE	SA	RA	JE	KA	DO	PI	RI

~~RESTRICTED~~

20 3. Solve and recover all keys:

					5					10					15
A	DR	DD	SY	DA	RA	RR	SB	YA	BT	TY	AR	HI	DB	TB	AD
B	YY	YB	SA	AA	HI	DA	TD	HR	YB	TD	RB	RI	AI	HH	BT
C	DD	IA	AI	BB	HA	YD	TH	YA	HI	BA	YT	YD	YY	BD	YH
D	SD	DI	SB	AA	ST	YD	RH	SD	SR	YR	DT	SR	RA	RR	YB
E	SA	BT	TY	HR	AI	DB	IB	AD	DY	YB	SA	HA	HI	DA	TD
F	TS	DB	SH	YH	DI	SD	TT	TT	YY	HH	ST	YI	SB	AA	ST
G	DD	AH	DH	YT	RH	HI	ID	AR	SB	BA	RI	HB	AI	HI	RH
H	DB	SH	HA	RI	DA	AI	IB	YB	DI	SI	DD	YA	BB	YT	HH
J	II	YH	TY	BS	DD	YR	SR	RI	HH	TD	DT	TA	AI	RY	ST
K	SH	DH	AB	AI	TI	YT	AH	HY	AR	AI	RH	DI	YD	DD	YA
L	TB	DT	HH	SB	AA	DT	DD	RH	YD	DR	YB	DH	SH	SR	DD
M	DA	SI	RI	ID	ST	BD	SI	SD	TT	BH	SH	RI	AA	HI	BB
N	IS	BI	HI	RH	AY	DB	BA	AI	DH	SH					

25 4. Solve and recover all keys:

					5					10					15
A	99	18	57	82	12	28	78	90	25	04	15	30	04	06	14
B	57	34	64	20	72	15	30	02	57	44	84	52	66	11	81
C	87	58	35	78	31	14	70	90	68	47	30	13	15	21	86
D	92	43	10	30	35	20	31	32	64	18	57	26	84	12	06
E	34	25	69	72	90	78	07	90	31	29	57	50	82	19	53
F	31	72	51	36	10	86	36	47	18	67	26	04	92	82	30
G	08	31	58	90	88	87	91	10	20	82	31	14	56	57	31
H	88	04	31	30	66	47	30	36	18	99	20	06	97	31	21
J	55	99	18	20	10	28	74	68	90	41	69	82	90	78	31
K	86	88	15	91	26	92	72	87	14	43	20	53	28	64	92
L	47	02	58	35	10	96	05	34	37	85	06	26	80	50	92
M	68	10	70	81	92	18	02	86	49	47	07	82	94	06	69
N	15	21	90	56	10	40	01	68	90	15	35	57	52	32	60
P	47	64	36	71	06	55	00	68	78	45	52	12	69	43	

~~RESTRICTED~~

25 5. This message is suspected of having an ending similar to Problem 4. Solve it and recover all keys:

					5					10					15
A	22	08	71	29	19	83	05	34	76	58	05	56	62	26	22
B	35	48	75	13	78	58	34	65	02	07	71	51	87	35	96
C	10	32	69	45	47	81	46	11	01	14	67	37	75	79	35
D	30	53	29	37	46	60	19	30	94	66	49	68	88	57	98
E	84	93	30	86	28	90	51	04	53	03	84	76	58	31	57
F	42	12	86	49	36	79	54	28	09	38	24	41	86	63	79
G	08	28	67	68	66	94	22	63	71	66	83	56	05	07	58
H	95	60	19	62	26	48	23	59	40	38	15	67	43	92	42
J	62	77	43	79	54	69	38	65	16	82	10	96	67	97	57
K	48	93	24	13	53	29	46	37	32	65	12	94	84	95	68
L	83	93	98	37	75	79	45	12	97	84	53	03	75	76	95
M	31	29	32	21	49	17	25	73	00	69	86	36	79	45	19
N	77	98	38	95	97	93	94	98	72	42	59	00	08	50	44
P	27	26	62	57	06	91	23								

~~RESTRICTED~~

FREQUENCY DISTRIBUTIONS

	A	E	I	O	U
B	2	6	1	8	7
C	–	5	2	3	1
D	4	6	1	8	7
F	2	1	1	2	–
G	–	3	2	3	–
J	2	3	–	9	2
K	1	3	6	2	–
L	2	3	–	1	–
M	–	3	1	4	–
N	6	1	2	–	–
P	1	2	3	1	–
R	3	3	1	–	–
S	4	2	1	–	–
T	1	2	5	1	–
V	4	2	2	–	–

Problem 2

	A	B	D	H	I	R	S	T	Y
A	5	1	2	2	9	3	–	–	1
B	3	3	2	1	1	–	1	3	–
D	5	5	8	4	4	2	–	4	1
H	3	1	–	5	8	2	–	–	1
I	1	3	1	–	1	–	1	–	–
R	2	1	–	6	6	2	–	–	1
S	3	5	4	6	3	4	–	5	1
T	1	2	4	1	1	–	1	3	3
Y	4	6	5	3	1	2	–	4	3

Problem 3

	0	1	2	3	4	5	6	7	8	9
0	1	1	3	–	4	1	6	2	1	–
1	7	1	3	1	4	6	–	–	6	1
2	6	3	–	–	–	2	4	–	3	1
3	7	10	2	–	3	4	4	1	–	–
4	1	1	–	3	1	1	–	6	–	1
5	2	1	3	2	–	2	2	7	3	–
6	1	–	–	–	4	–	2	1	5	4
7	2	1	4	–	1	–	–	–	5	–
8	1	2	6	–	2	1	4	3	3	–
9	9	2	6	–	1	–	1	1	–	3

Problem 4

	0	1	2	3	4	5	6	7	8	9
0	2	1	1	2	1	3	1	2	3	1
1	2	1	3	2	1	1	1	1	–	4
2	–	1	3	2	2	1	3	1	3	4
3	3	2	3	–	2	3	2	4	4	–
4	1	1	3	2	1	3	3	1	3	3
5	1	2	–	4	2	–	2	4	4	2
6	2	–	4	2	–	3	3	4	3	3
7	–	3	1	1	–	4	3	2	1	6
8	–	1	1	3	4	–	4	1	1	–
9	1	1	1	4	4	4	2	3	4	–

Problem 5

MEMORANDUM ON STEREOTYPIC BEGINNINGS AND ENDINGS

Within the confines of the comparatively limited scope of military messages, stereotypy of phraseology is inevitable. Particularly in the beginnings of messages is this limitation apparent: thus these positions lend themselves most readily to attack by the cryptanalyst. The following list of stereotypes have a high frequency of positional occurrence, and therefore are to be shunned by the cryptographer as conscientiously as they are looked for by the cryptanalyst. It is to be noted that a stereotypic initial word often may suggest a whole opening phrase. For example, if a message begins with the word HEAVY, then it is not too unlikely that the opening phrase is "HEAVY ARTILLERY (FIRE, BARRAGE) (FALLING, INTERDICTING) . . . .," which might be expanded into "HEAVY ARTILLERY FIRE FALLING ON OUR POSITIONS (NORTH, EAST, SOUTH, WEST) OF. . ."

BEGINNINGS

ACKNOWLEDGE
ADVANCE
ADVISE
ARRIVE
ATTACK
ATTENTION
CANCEL
CITE
COMMANDING (GENERAL)
COMMUNICATION (OFFICER)
CONCENTRATE
CONFIRM
CONTINUE
DEPART (-URE)
DISCONTINUE
ENEMY
EQUIPMENT
EXPEDITE
FOLLOWING
FOR
FROM
HEAVY
HOSTILE
INFORM (-ATION)
IN REPLY (TO) (YOUR)
LOCATION (OF)
NUMBERS (1, 1st, 2, 2nd, etc.)
ORDERS
OUR
PARAPHRASE
PLEASE
POSITION
PREPARE
PROCEED
RECEIPT
RECEIVE
RECOMMEND
REFER (-RING) (TO) (YOUR)
REFERENCE (YOUR) (MESSAGE, RADIOGRAM, TELEGRAM) (NUMBER)
REPEAT
REPORT
REQUEST
REQUIRE
RERAD
REURAD
SEND
SUPPLY
VERIFY
YOUR (S)

ENDINGS

ACKNOWLEDGE
ADVISE (IMMEDIATELY)
CONFIRM
END
END OF MESSAGE
IMMEDIATELY
NUMBERS (1, 1st, 2, 2nd, etc.)
PERIOD
REPLY
REFERENCE
REQUESTED
SIGNED (NAME)
STOP
TITLES (MAJ, COL, ETC.)

EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20–6	Military Cryptanalysis, Part I
LESSON 6	Polygraphic substitution systems: 4-square and 2-square matrices
CREDIT	3
TEXT ASSIGNMENT	Text, pars. 41–44, Section IX; attached memoranda
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	Review Section VIII, TM 11–485

EXERCISES

Weight

4 1. *a.* What is polyliteral substitution? What is polygraphic substitution?

4 *b.* In true digraphic substitution, if RE_p yields QN_c, is it possible for RN_p to yield AZ_c?

2 *c.* What is the fundamental purpose of polygraphic substitution?

10 2. *a.* Construct a digraphic frequency distribution of the cryptogram below.

20 *b.* The following cryptogram is suspected to contain the word INFANTRY. Solve it and recover all keys:

					5					10					15
A	AF	SM	DH	FG	SP	OS	AB	TU	ZF	OG	TR	UH	IF	PQ	SO
B	RO	MA	CS	KN	SM	KH	TT	UF	HF	UE	QM	OC	NU	DC	EA
C	AM	QM	AF	VD	LK	BT	QU	FC	NI	TT	CG	MT	SA	HH	PU
D	ZR	KU	IW	RH	DS	IM	SW	AC	MT	SP	OS	AB	GN	KP	TD
E	TT	TU	IM	II	SN	SA	HH	QM	SH	II	PQ	RH	DS	IM	SW
F	YO	CC	UF	QI	TR	MT	SP	OS	AI	KU	KU	IW	SO	RO	MA
G	CS	KN	YO	QA	FC	CS	VS	DH	LS	KS	AC	QT	OQ		

~~RESTRICTED~~

20 3. The enemy is suspected of using a 4-square matrix wherein the plain components are mixed sequences and the cipher components are standard alphabets (I=J) inscribed in straight horizontals. Solve the following cryptogram and reconstruct the original matrix:

					5					10					15
A	DO	GV	XX	HA	TP	PN	DF	OW	FS	YN	DP	YK	DP	YK	WH
B	WL	IA	NF	OB	DE	GV	HX	VC	OP	RY	OP	DQ	RY	WT	DP
C	YK	DP	YK	QZ	FS	IX	GW	DB	AF	HW	NE	VO	YA	LZ	CW
D	TY	DQ	GN	WN	NS	IH	CA	VI	HH	OF	WZ	YN	WM	WH	OG
E	EV	YN	NL	NK	XI	WH	WL	IA	NF	OB	DE	GV	FS	OF	WH
F	NF	OP	DQ	XO	FA	WN	LQ	DP	YK	BP	IE	DP	YK	SD	NQ
G	DP	YK	TP	PN	VT	TF	BL	MW	CW	IE	TE	FS	CY	OK	YD
H	OM	XE	VT	FS	IX	HB	IH	MP	YN	LZ	YN	NW	GR		

20 4. Solve the following cryptogram and reconstruct the enciphering matrix. It is suspected that this message probably has a stereotypic ending.

					5					10					15
A	NK	KZ	FQ	KG	QD	RR	RO	NK	MV	TR	KE	HQ	FZ	QR	PE
B	NK	RD	FW	IV	EF	FF	XT	NB	LZ	NV	EU	RO	PQ	DA	ML
C	EU	KV	FF	LL	FM	CF	QP	EI	RC	SO	RS	BC	SD	LN	CD
D	IE	HG	TM	VE	FP	QP	SI	KZ	FW	FP	NB	QR	IZ	IW	EF
E	FF	XT	LW	NX	PD	KK	KV	RD	FP	QR	MX	AR	PZ	FW	ML
F	EU	IN	FF	LW	NC	LN	CD	QP	SI	KE	FR	HP	ON	IM	HC
G	SM	KZ	IL	FN	FP	LV	LQ	PD	AS	FK					

~~RESTRICTED~~

20 5. The following two messages were intercepted on the same circuit half an hour apart, message "B" being in answer to a request for a repeat. Solve the texts, and determine the cause of the cryptographic error involved:

MESSAGE "A"

					5					10					15
A	DS	ZM	CM	GI	QM	AB	VG	ED	SU	XI	TO	SQ	OR	NR	SB
B	PN	QO	HN	TB	LL	QN	QS	SI	CR	YU	TQ	CC	KG	AT	FN
C	YF	VG	ED	CG	NU	MO	LL	NP	SO	SB	NP	SQ	OR	NR	SB
D	PN	CM	MB	RP	OG	LL	YX	CM	GI	QM	AB	SO	NQ	LZ	LC
E	FD	YR	VI	OR	SB										

MESSAGE "B"

					5					10					15
A	OY	RU	PU	KV	TU	WO	IW	LL	NR	EV	VD	NB	BZ	YZ	NO
B	AS	TD	HS	VO	DE	TS	TY	NV	PZ	SR	VB	PM	FW	WQ	XS
C	SK	IW	LL	PW	YR	CD	DE	YC	ND	NO	YC	NB	BZ	YZ	NO
D	AS	PU	CO	UC	BW	DE	SF	PU	KV	TU	WO	ND	YB	DI	DM
E	XL	SZ	IV	BZ	NO										

MEMORANDUM ON THE SOLUTION OF 2-SQUARE MATRICES

1. If the student reviews paragraph 34 of TM 11–485, he will refresh his memory on the enciphering and deciphering processes of the two types of 2-square matrices. In the horizontal 2-square matrix illustrated in Fig. 36, the first member of the plaintext digraph comes from the same square as the second member of the cipher-text digraph, whereas the $\theta^2{}_p$ comes from the same square as the $\theta^1{}_c$. Thus in the digram, $TH_p = SD_c$; $AN_p = UO_c$; $RE_p = ER_c$; $MO_p = OM_c$. However, the cryptography of the vertical 2-square matrix is analogous to that of the 4-square system, in that the $\theta^1{}_p$ and the $\theta^1{}_c$ come from the upper component, whereas the $\theta^2{}_p$ and $\theta^2{}_c$ are found in the lower component. Thus in Fig. 38, $CO_p = IA_c$; $RE_p = IL_c$; $CA_p = CA_c$; $WI_p = WI_c$.

2. The cryptographic idiosyncracies of 2-square matrices may be exploited by the analyst in attacking such systems. In the vertical 2-square, 20% of the possible 625 plaintext digraphs will be self-enciphered, such as $CA_p = CA_c$ in the example. In the horizontal 2-square, 20% of the 625 digraphs will be enciphered by themselves in reversed form, as in the example $RE_p = ER_c$. Therefore if an examination of the cryptogram at hand discloses a goodly proportion of cipher digraphs which could well be plaintext digraphs, then one may assume that a vertical 2-square has been used. On the other hand, if a large number of cipher digraphs could be good plaintext digraphs if the positions of the letters were reversed, then the assumption would arise that the cryptogram was produced by a horizontal 2-square matrix. Sometimes skeletons of words or even whole phrases are self-evident in the text, affording an easy entering wedge into the problem.

3. During the reconstruction of the squares of the matrix, the student should keep clear on his worksheets which letters are in the same row, and which are in the same column. It will be found expeditious to draw a dividing line (either horizontal or vertical, depending on the type of 2-square involved) on the page to keep the elements of the two squares independent, recording the values which are in the same row or column, writing down the letters as they are assumed until enough values have been established to facilitate reconstruction of the matrix. In the early stages of this process the student must exercise care in recording the letters so that no false relationships are formed; in other words, the values should be written down so that they are not in the same row or column with any other letters than those with which they are known to be related. This will entail spreading the work rather widely over the page.

DIGRAPHIC IDIOMORPHS: GENERAL

	AB AB	
–G EN ER	AL AL	AR M–
NE	ED ED	
–P RO CE	ED ED	
–S UC CE	ED ED	
–D ET RA	IN IN	G–
–L	IN IN	G–
–M	IN IN	G–
OB TA	IN IN	G–
QU	IN IN	E–
RA	IN IN	G–
RE MA	IN IN	G–
SH	IN IN	G–
–T RA	IN IN	G–
CR	IS IS	
PO SI TI	ON ON	
–A	RE RE	EN FO RC ED
–A	SU SU	AL
BO	TH TH	E–
WI	TH TH	E–
–P AR	TI TI	ON
RE PE	TI TI	ON
	VI VI	D–

	AB — AB	
–M	AI NT AI	N–
RE	AR GU AR	D–
	CH UR CH	
	DE CI DE	
	DE CO DE	
	DI VI DI	NG
SP	EA RH EA	D–
–R	ED UC ED	
–S CH	ED UL ED	
–B	EE NN EE	DE D–
	EM BL EM	
AM	EN DM EN	T–
CO NT	EN TM EN	T–
–S EV	EN TE EN	
–S EV	EN TE EN	TH
	EN TR EN	CH
	ER AS ER	

	AB — AB	
TH	ER EF ER	EN CE
TH	ER ES ER	VE
WH	ER EV ER	
–C AR EL	ES SN ES	S–
	GE OR GE	
SC	HO OL HO	US E–
–I LL UM	IN AT IN	G–
	IN CL IN	E–
–F IR	IN GL IN	E–
MA	IN TA IN	
–I NF AL	LI BI LI	TY
–A	ME ND ME	NT
SO	ME TI ME	
–O	NE NI NE	
	NO TK NO	WN
	NO WK NO	WN
–A PP OI	NT ME NT	
–C ON TE	NT ME NT	
–C	OM PR OM	IS E–
–P	ON TO ON	
–T HR	OU GH OU	T–
–N	OW KN OW	N–
	PH OS PH	OR US
	PO ST PO	NE
TR OO	PS HI PS	
PA	RA PH RA	SE
–P	RE FE RE	NC E–
	RE FE RE	NC E–
–T HE	RE FO RE	
–P	RE PA RE	
	RE TI RE	
	RE VE RE	NT
–C	RO SS RO	AD S–
CA RE LE	SS NE SS	
AT	TE MP TE	D–
	TH AT TH	E–
–F OR	TH WI TH	
–I NV ES	TI GA TI	ON
ES	TI MA TI	ON
–D ES	TI NA TI	ON
AC	TI VI TI	ES
–H	UM DR UM	

AB — — AB

–P	AN AM AC AN	AL
	AR BI TR AR	Y–
	AS SO ON AS	
AC	CE PT AN CE	
	EM PL AC EM	EN T–
–Q UA RT	ER MA ST ER	
–I NT	ER PR ET ER	
–A CC	ES SO RI ES	
	IN CL UD IN	G–
–D	IR EC TF IR	E–
TO	MO RR OW MO	RN IN G–
PA	NA MA CA NA	L–
–I	NT ER ME NT	
–I	NT ER VE NT	IO N–
CO	NT IN GE NT	
–C	ON DI TI ON	
–T OM	OR RO WM OR	NI NG
	RA DI OG RA	M–
	RE AS SU RE	
–P	RE MA TU RE	
–D EF EN	SI VE PO SI	TI ON
IN	TE RD IC TE	D–
QU AR	TE RM AS TE	R–
IN	TE RP RE TE	R–
IN	TE RR UP TE	D–
–F OR	TI FI CA TI	ON

AB — — — AB

	AR MO RE DC AR	
	EN FO RC EM EN	T–
RE	EN FO RC EM EN	TS
	IN DE TE RM IN	AT E–
	IN TE RE ST IN	G–
	IN TE RF ER IN	G–
	IN TE RV EN IN	G–
–I	NC OM PE TE NC	E–
–C	ON GR ES SI ON	AL
–D EM	ON ST RA TI ON	
–C	ON SU MP TI ON	
	PH OT OG RA PH	
	TH IR TE EN TH	

AB — — — — AB

–I	NS TA LL AT IO NS
–C	ON CE NT RA TI ON
–C	ON FL AG RA TI ON
–C	ON SI DE RA TI ON

AB — AB AB

	IN CL IN IN	G–
MA	IN TA IN IN	G–

EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20-6	Military Cryptanalysis, Part I
LESSON 7	Polygraphic substitution systems: Playfair cipher systems
CREDIT	3
TEXT ASSIGNMENT	Text, pars. 45-46, Section IX; attached memoranda
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	Review Section VIII, TM 11-485

EXERCISES

Weight

35 1. What are the characteristics of the normal Playfair cipher which make it recognizable?

20 2. Solve the following and recover the keyword:

					5					10					15
A	QO	AP	QO	CM	PQ	BQ	HO	WE	OB	DQ	WE	LC	FT	OF	TE
B	OC	AO	OC	CK	BX	CM	BV	LF	LX	EX	TW	SD	ND	VL	VR
C	FR	XV	AR	VD	LZ	SB	XV	FW	QV	DL	BK	CM	SB	XV	WS
D	QO	PA	BQ	TE	OC	FR	BV	VQ	QV	TL	VQ	CX	LY	FW	WS
E	QO	PA	BZ	RF	PV	IV	VD	SZ	TW	XE	WE	OB	IR	DC	PV
F	VZ	SD	ND	MD	FV	ZD	MH	ZD	VP	BG	MH	DC	VB	RO	CK
G	PA	AP	MS	AO	TW	XE	VD	LZ	VL	ZR	RZ	LY	OQ	RZ	QR
H	CS	AR	DC	MA	YM	MS	BX	LP	TK	TK	DW				

~~RESTRICTED~~

20 3. The following cryptogram is suspected to contain the word DIVISION. Solve it and recover the original enciphering square.

					5					10					15
A	MP	QK	KA	SZ	QK	KA	HX	EH	LK	YS	ND	TP	CQ	OL	NP
B	RC	AH	LM	SK	ND	YG	QK	DU	RF	QK	EH	LK	YS	ND	TP
C	SA	OE	SY	FR	QP	FE	YS	MO	FD	AF	RJ	RS	DU	RF	RN
D	TP	CQ	UL	LM	SK	ND	UD	FM	JE	HR	VN	QK	UD	EC	LF
E	AK	BH	IY	QV	SM	FO	SY	DY							

20 4. *a*. Solve the following cryptogram and recover the original enciphering square. It is suspected that this message is signed "WINTHROP COL INF."

					5					10					15
A	4L	65	4L	C3	1V	PV	7W	XV	ZX	B1	DS	O7	L4	CW	4K
B	OF	RT	4L	79	OL	HR	YN	MR	RM	DQ	QV	9R	6M	CX	4K
C	QF	4N	4L	79	OL	HR	OP	E4	NR	QB	4M	XS	WN	ØE	NU
D	GC	QX	4K	ØD	51	NP	Z5	4R	L4	VQ	PF	HN	4L	79	OL
E	HR	EM	8X	41	ND	AP	Z1	4N	XC	M4	RT	P6	4M	5H	FZ
F	C3	R9	Q4	CI	2H	XZ	48	1Ø	L4	YN	PQ	LM	HR	T4	PQ
G	BQ	RM	D3												

2 *b*. What is the principal disadvantage of such a system for military purposes?

~~RESTRICTED~~

20 5. The following message was intercepted and solved by the cryptanalytic section at GHQ. The plaintext was found to read: "DIVISION RESERVES HAVE REACHED CROSSROADS EIGHT NINE THREE DASH B." Reconstruct the general system and show the specific key:

```
GKATJ  AHPOG  FBRCQ  RBISX  CGFLG

KERED  EKOBQ  RHKUB  RZGKE  RIWKU

KAKUG  XKOHK  EBFEL  AKESX
```

6. From the solution of three Playfair ciphers, the following squares were derived. Reconstruct the original squares and show the keywords.

```
5     a.  Y P T G V
          C F A L Z
          Q I U D B
          K X E S N
          R M O H W

5     b.  Z P E W L
          Q U G Y S
          A R H B C
          I D V K T
          M F X N O

5     c.  W Z R T V
          O P X Y L
          M U H N E
          A B S I C
          K Q D F G
```

DIGRAPHIC FREQUENCY DISTRIBUTIONS

	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	
A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	2	-	-	-	-	-	-	-	-	6
B	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	2	-	-	-	-	2	-	2	-	1	9
C	-	-	-	-	-	-	-	-	-	-	2	-	3	-	-	-	-	-	1	-	-	-	-	1	-	-	7
D	-	-	3	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	1	-	-	-	6
E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	1	2	-	-	-	6
G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
H	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	2
J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
L	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	2	2	8
M	1	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	6
N	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
O	-	2	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	7
P	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	6
Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	-	2	-	-	-	-	7
R	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	4
S	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5
T	-	-	-	-	2	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	8
U	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
V	-	1	-	3	-	-	-	-	-	-	-	2	-	-	-	1	2	1	-	-	-	-	-	-	-	1	11
W	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	5
X	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	5
Y	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Z	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3
	4	5	7	10	7	2	2	2			5	4	4		8	4	6	9	5	1		11	6	5	2	7	

Problem 2

	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	
A	-	-	-	-	-	1	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
B	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2
D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	3
E	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
F	-	-	-	1	1	-	-	-	-	-	-	-	1	-	1	-	-	1	-	-	-	-	-	-	-	-	5
G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
H	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	2
I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
J	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
K	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
L	-	-	-	-	-	1	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	5
M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	2
N	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	5
O	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Q	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	7
R	-	-	1	-	-	2	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	6
S	1	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	2	1	7
T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3
U	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
V	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Y	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	4
Z	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	3		2	7	3	4	1	4		1	10	2	4	2	2	6	2	2	4		2	1		1	4	1	

Problem 3

~~RESTRICTED~~

MEMORANDUM ON PLAYFAIR KEYWORD DERIVATION

1. Reconstruction of the square in Playfair ciphers takes place concurrently with the evolution of the plaintext, once a few correct assumptions are made. However, the square that is derived may not necessarily be the original enciphering square: more than likely it will be one of the 24 possible cyclic permutations of the original square. If the Playfair consisted of a keyword-mixed sequence, a permutation of the square will cause no difficulty in recovering the original matrix and hence the keyword. For example, if the derived square is Q T L N O then the square P Y R A M is easily constructed because of the tell-tale letters U V W X Z occurring in a row of the derivative square. But when the Playfair square consists of a transposition-mixed sequence, then a different procedure must be adopted.

```
Q T L N O      P Y R A M
X Z U V W      I D S B C
A M P Y R      E F G H K
B C I D S      L N O Q T
H K E F G      U V W X Z
```

2. As an example, let us take the transposition matrix 5 8 6 1 4 3 2 7 from which A F T D K is the original square. Using the methods illustrated in a previous memorandum ("Alphabet reconstruction and keyword derivation"), the columns I D S will afford rapid recovery of the keyword. But if instead of the original square we had one of its permutations such as Q S Z R E , then the columns F V O are without significance; therefore the procedure above is inapplicable without a slight modification.

```
5 8 6 1 4 3 2 7      A F T D K
P Y R A M I D S      W I H V M
B C E F G H K L      G U P B N
N O Q T U V W X      Z R E Q S
Z                    L X Y C O
```

```
I D S
H K L
V W X
```

```
Q S Z R E      F V O
C O L X Y      T M L
D K A F T      V W X
V M W I H
B N G U P
```

3. Since it will be noted that a permutation of the rows will not affect the procedure of keyword recovery, then we construct a 9 x 5 rectangle Q S Z R E Q S Z R which contains the five squares of the successive permutations of the columns. A 5 x 5 cut-out square will be found convenient in testing each permutation in turn. Affirmative results will be obtained when the correct permutation is reached, which in this case is the third square in the rectangle, namely

```
Q S Z R E Q S Z R
C O L X Y C O L X
D K A F T D K A F
V M W I H V M W I
B N G U P B N G U
```

```
Z R E Q S
L X Y C O
A F T D K
W I H V M
G U P B N
```

~~RESTRICTED~~

DIGRAPHIC IDIOMORPHS: PLAYFAIR

AB BA

SC	AB BA	RD
	AF FA	BL E–
	AF FA	IR
–B	AG GA	GE
–H AW	AI IA	N–
	AL LA	RE AS
–B	AL LA	ST
–F	AL LA	CY
IN ST	AL LA	TI ON S–
–P AR	AL LA	X–
	AP PA	RA TU S–
	AP PA	RE L–
	AP PA	RE NT
	AP PA	RE NT LY
	AR RA	NG E–
	AR RA	Y–
–B	AR RA	CK S–
–B	AR RA	GE
–E MB	AR RA	SX SE D–
–N	AR RA	TI ON
	AS SA	IL AN T–
	AS SA	UL T–
–A MB	AS SA	DO R–
–I MP	AS SA	BL E–
–M	AS SA	CR E–
–P	AS SA	GE
	AT TA	CH
	AT TA	CK
	AT TA	IN
–B	AT TA	LI ON
–R	AT TA	N–
	BO OB	YT RA P–
IN	DE ED	
–W	EB BE	D–
	EF FE	CT
	EF FE	CT IV E–
CO MP	EL LE	D–
–E XC	EL LE	NC E–
–E XC	EL LE	NT
–E XP	EL LE	D–
–I MP	EL LE	D–
–P	EL LE	T–
PR OP	EL LE	D–
–R EP	EL LE	D–

SH	EL LE	D–
–H	EM ME	DI N–
ST	EM ME	D–
ST	EP PE	D–
AV	ER RE	D–
CO NF	ER RE	D–
–I NT	ER RE	D–
–R EF	ER RE	D–
	ES SE	NC E–
	ES SE	NT IA L–
AD DR	ES SE	S–
–C OM PR	ES SE	D–
CO NF	ES SE	D–
IM PR	ES SE	D–
–L	ES SE	N–
–M	ES SE	NG ER
PR	ES SE	D–
PR OF	ES SE	D–
–P RO GR	ES SE	D–
–S TR	ES SE	D–
–S TR	ES SE	S–
–V	ES SE	L–
WI TN	ES SE	S–
AB	ET TE	D–
–C IG AR	ET TE	S–
–B	ET TE	R–
–L	ET TE	R–
–E IG	HT TH	RE E–
–R	IB BI	NG
FO RB	ID DI	NG
–D	IF FI	CU LT
–B	IL LI	ON
–F	IL LI	NG
–K	IL LI	NG
–M	IL LI	ME TE R–
–M	IL LI	NG
–M	IL LI	ON
SH	IL LI	NG
SP	IL LI	NG
–T	IL LI	NG
–W	IL LI	AM
–W	IL LI	NG
	IM MI	GR AN T–
	IM MI	GR AT IO N–

	AB BA	
	IM MI	NE NT
SW	IM MI	NG
–B EG	IN NI	NG
SP	IN NI	NG
–W	IN NI	NG
CL	IP PI	NG
SH	IP PI	NG
–S TR	IP PI	NG
	IR RI	GA TI ON
–M	IS SI	NG
–M	IS SI	ON
–A DM	IS SI	ON
EM	IS SI	ON
–H	IS SI	NG
PE RM	IS SI	ON
TR AN SM	IS SI	ON
EM	IT TI	NG
–F	IT TI	NG
–S PL	IT TI	NG
PE RM	IT TI	NG
–A FT ER	NO ON	
FO RE	NO ON	
	NO ON	TI ME
–F	OL LO	W–
–H	OL LO	W–
–C	OM MO	N–
–C	OM MO	TI ON
PO SI TI	ON NO	RT HO F–
–R EC	ON NO	IT ER
	OP PO	RT UN E–
	OP PO	RT UN IT Y–
	OP PO	SE
	OP PO	SI TE
	OP PO	SI TI ON
–C	OR RO	BO RA TE
–C	OR RO	DE
–T OM	OR RO	W–
–B	OT TO	M–
–C	OT TO	N–
CA	RE ER	
–S	UC CU	MB ED

	AB — BA	
PR	AC TI CA	BL E–
PR	AC TI CA	L–
–T	AC TI CA	L–
–D IV	EB OM BE	R–
	EN GI NE	ER
–G	EN UI NE	
–I NT	ER FE RE	
–I NT	ER FE RE	NC E–
–P EN	ET RA TE	
–R	EV OL VE	R–
	IN FI NI	TE
–D	IS PO SI	TI ON
–S	IT UA TI	ON
CA	NA DI AN	
VE TE RI	NA RI AN	
NI	NE TE EN	
NI	NE TE EN	TH
	PE RC EP	TI ON
–P	RE MI ER	
–S UR	RE ND ER	
–0 UR	SE LV ES	
TH EM	SE LV ES	
DE	SE RV ES	
RE	SE RV ES	
	SE RV ES	

	AB	—	—	BA		
	DE	BA	RK	ED		
	DE	CL	AR	ED		
	DE	FE	ND	ED		
	DE	MA	ND	ED		
	DE	PA	RT	ED		
	DE	PL	OY	ED		
	DE	PO	RT	ED		
	DE	SE	RT	ED		
	DE	TA	CH	ED		
PR	EC	ED	EN	CE		
	EM	PL	OY	ME	NT	
	EN	TR	AI	NE	D–	
	ME	AS	UR	EM	EN	T–
	NE	GL	IG	EN	CE	
	NO	TA	TI	ON		
	PA	RA	GR	AP	H–	
	RE	CE	IV	ER		
	RE	CO	RD	ER		
	RE	GI	ST	ER		
	RE	PE	AT	ER		
	RE	PO	RT	ER		
	RE	VO	LV	ER		
–P	RO	JE	CT	OR		
AS	SE	MB	LI	ES		

	AB	—	—	—	BA	
	DE	SE	CR	AT	ED	
	DE	SI	GN	AT	ED	
	DE	SP	AT	CH	ED	
	EN	EM	YP	LA	NE	S–
–D	ET	ER	IO	RA	TE	
–S	EV	EN	TY	FI	VE	
	IR	RE	GU	LA	RI	TY
	NO	MI	NA	TI	ON	
	SU	SP	IC	IO	US	

AB	—	—	—	—	BA
DE	MO	NS	TR	AT	ED
NO	TI	FI	CA	TI	ON

EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20-6	Military Cryptanalysis, Part I
LESSON 8	Polygraphic substitution: quadricular tables
CREDIT	3
TEXT ASSIGNMENT	Text, Section IX
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	Review Section VII, TM 11-485

EXERCISES

Weight

30 1. The following cryptogram is suspected to contain the word RECONNAISSANCE. Solve the text, and reconstruct the enciphering diagram:

					5					10					15
A	SA	CJ	JY	RO	HT	KP	LP	DO	CV	PS	LN	PE	GN	RP	SP
B	FP	LU	QT	LW	PR	CJ	KL	RN	QE	RO	CV	MF	SE	LZ	QZ
C	RR	AO	TH	SQ	PG	TL	GL	NR	QS	UZ	KK	KK	JE	MV	NL
D	LU	AR	QE	SA	MW	KK	LP	SL	AP	PZ	QV	KK	PB	CJ	JY
E	RL	CJ	HA	CO	AR	BH	LL	JH	QT	RP	AS	SL	RP	SL	NL
F	QJ	QT	AJ	NL	IG	NR	WX	AI	HI	YD	KK	JE	CP	YO	SP
G	KO	FB	QT	QP	YP	NZ	SO	AM	DZ	KR	FP	SX	PK	FJ	PR
H	OE	AK	CE	AS	LP	DO	PB	SI	AX	SX	PB	LP	HT	WX	RF
J	GZ	QT	LW	PR	CJ	JY	AK	HT	JY	AA	NN	SX	CB	RO	WE
K	SA	RD	LL	ML	AX	AF	YU	NC	PK	MS	NE	QJ	QT	AJ	

35 2. This cryptogram is suspected of having a beginning similar to that of Problem 1. Solve the text, and reconstruct the enciphering diagram:

	1	2	3	4	5	6	7	8	9	10
A	003	315	097	114	347	261	067	217	314	241
B	195	062	350	115	006	451	062	141	072	472
C	189	192	018	400	189	067	315	097	530	403
D	115	393	262	609	192	356	115	186	122	467
E	212	071	074	237	235	114	416	115	393	271
F	055	293	186	552	009	062	471	141	150	193
G	186	516	184	266	274	470	002	238	053	186
H	141	072	236	516	189	004	195	191	479	067
J	008	397	080	137	105	189	391	262	343	408
K	133	273	071	084	274	400	367	223	403	186
L	211	524	008	292	011	122	393	284		

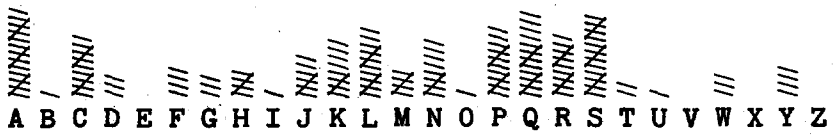
35 3. This cryptogram is suspected to begin with the stereotype "REFERRING TO YOUR MESSAGE" or "REFERENCE YOUR MESSAGE." Solve the text, and reconstruct the enciphering diagram:

	1	2	3	4	5	6	7	8	9	10
A	MRA	DMT	GCI	YIY	MFG	NNL	SRK	QFB	DMD	WII
B	DSZ	GNM	IJA	GOO	LGI	DEV	LTD	GCI	IYD	LCI
C	MMT	JIU	PNM	VZP	LGI	DMY	ITI	POV	GIP	TGO
D	PLM	MCH	JPB	MRC	DGK	FWJ	IHC	EEF	MDO	DSZ
E	TEN	DGK	FWI	NNM	LEV	EZF	TAS	DIP	HMT	TDL
F	GTR	QMD	MZU	ROD	NPC	JNJ	GCI	IQM	UZK	LIY
G	NJN	CWQ	MZF	VOD	NWG	PRG	NLC	URP	MIA	DGI
H	VRG	NRF	URV	PIF	DUJ	TDL	POJ	VRT	DAZ	MRI
J	IFX	DGG	DHV	VZP	IQM	EMF	JPC	SMK	JLM	MND
K	PQW	YZB	OZN	IJY	IPJ	DMD	YJP	NIP	EMF	JPC
L	SMK	JLF	ENG	NPW	FNV	FJJ	IWI	GTT	MOT	EOW
M	CRV	WLF	ELE	TSZ	TNM	VRS	MTR	TEQ	VRV	QJQ
N	MRV	NOV	GIP	RMT	KQX	GCJ	ELC	MZH	PRT	LNM
P	LCR	IYR	CZY	GPW	XPA					

FREQUENCY DISTRIBUTIONS

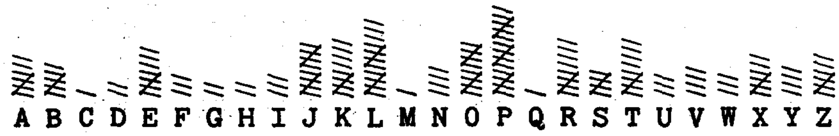
Problem 1

Θ^1_c:



$\phi=1368$

Θ^2_c:

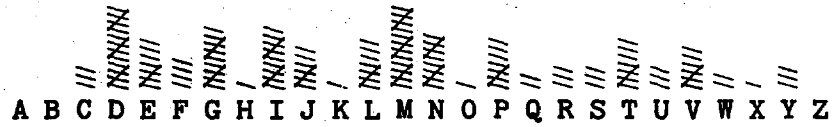


$\phi=1090$

$E(\phi_p)=1471$ $E(\phi_r)=849$

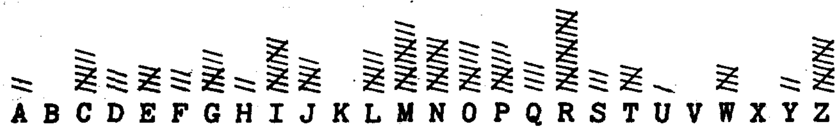
Problem 3

Θ^1_c:



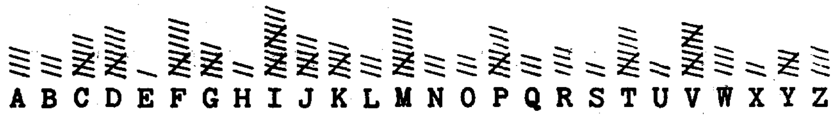
$\phi=1094$

Θ^2_c:



$\phi=981$

Θ^3_c:



$\phi=794$

$E(\phi_p)=1207$ $E(\phi_r)=696$

EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20–6	Military Cryptanalysis, Part I
LESSON 9	Miscellaneous monoalphabetic substitution systems
CREDIT	3
TEXT ASSIGNMENT	Text, Section X
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	Read appended Partial Analysis Sheets

EXERCISES

Weight

2 1. *a.* What characters are most used in practical cryptography today?

2 *b.* What is the usual preliminary procedure in solving cryptograms involving symbols?

4 *c.* In monoalphabetic substitution with variants, what characters are most commonly used? Why?

2 2. What is the primary purpose of an analytical key?

25 3. Solve the following cryptogram, and recover all keys:

```
             5          10         15         20         25
   ---------------------------------------------------------
A | B U F W W  H E A G H  M I T A J  J S K L S  M N H I U
B | Y U Q A I  A U M Q M  U W I Z U  V O J F H  G U F M D
C | G Q Y K Q  L L S U I  Y K C G S  W U F Q U  U Q K C F
D | I W H Q K  O G S W I  Y J Y O Y  S K X F Q  I A D Q B
E | Y K J Y S  V C L L C  S S H J W  Y M J Y S  X W Y K B
F | J U K K U  P T P W I  I U Q H K  X H Y K B  J Y C O F
G | Y Q E N V  Q I C U Y  B I R R W  P I Y Y N  P S W J E
H | P M I O P  U Q A R H  K Y Y Q C  G W P G E  P G A E L
J | S V T F E  L T K B T  D X V S X  S R M Y F  Q X T S H
K | D T T D Y  C F X F Q  H U S G T  G U D X C  H S B S O
L | W L H Q Q  N Z H K F  J H K I U  S W W A L  H S I N W
M | U Q Q W U  S K Q S I  U M H I T  U I Z W H  H P H W U
```

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20 4. Below is an intercepted message which is suspected to begin with the words "FIFTH DIVISION." Solve it and recover all keys:

```
67267 86555 72872 85237 72857

63872 77684 78277 86378 38528

62377 85863 78058 86259 59158

56660 58580 68167 05959 27768

59388
```

20 5. This message below is suspected to contain the same plain text as Problem 4. Reconstruct the general system and recover all keys:

```
35591 59228 86600 24635 78881

77777 84330 10435 55399 66611

29872 58700 29388 75008 07106

97640 02300 31858 06958 97442

02232 76849 91300 14090 68678

74923 00102 44092 91100 55720

49766 83330 77512 24780 11110

30663 30444 60122 11898
```

25 6. The enemy is using a system incorporating a 10 x 10 bipartite square consisting of letters, digits and syllables. The row and column coordinates are invariable, but a different internal chart is used each day. The chart for 16 December was reconstructed and found to be based on the keyword PYRAMIDS as follows:

	0	1	2	3	4	5	6	7	8	9
0	P	Y	R	RA	RE	RED	RES	RI	RO	A
1	1	AL	AN	AND	AR	ARE	AS	AT	ATE	ATI
2	M	ME	I	9	IN	ING	ION	IS	IT	IVE
3	D	4	DA	DE	S	SE	SH	ST	STO	B
4	2	BE	C	3	CA	CE	CO	COM	E	5
5	EA	ED	EN	ENT	ER	ERE	ERS	ES	EST	F
6	6	G	7	H	8	HAS	HE	J	Ø	K
7	L	LA	LE	N	ND	NE	NT	O	OF	ON
8	OR	OU	Q	T	TE	TED	TER	TH	THE	THI
9	THR	TI	TO	U	V	VE	W	WE	X	Z

The next day the following cryptogram, suspected to contain the word CROSSROADS, was intercepted. Solve the text, reconstruct the chart for the day, and determine the specific key:

					5					10					15
A	20	88	50	58	95	63	62	30	69	69	94	15	58	92	07
B	84	73	60	35	77	95	61	38	78	30	50	66	94	15	44
C	84	62	12	12	20	38	31	42	67	67	93	52	01	83	10
D	32	02	79	10	36	84	72	94	44	68	79	54	78	69	50
E	58	95	58	79	62	14	30	50	71	94	35	87	79	97	58
F	02	02	10	78	47	22	97	58	88	09	84	53	03	01	93
G	44	78	79	79	78	30	50	79	57	55	59	54	08	54	94
H	72	89	72	60	82	72	94	44	92	07	79	82	05	10	79
J	94	10	10	02	58	28	97	58	02	02	43	69	05	96	50
K	93	50	58	95	63	58	07	11	21	50	71	94	35	84	27
L	30	54	87	50	35	68									

PARTIAL ANALYSIS SHEETS
LESSON 9, MILITARY CRYPTANALYSIS, PART I

Problem 3

In taking a uniliteral frequency distribution of this cryptogram, it was observed that the positions of the peaks and troughs of the distribution seemed to change during the compilation. The over-all distribution is

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	
8	7	9	6	6	12	10	20	19	11	18	9	9	5	6	9	21	4	22	10	24	5	19	8	21	3	N=300

$\phi = 4136$ $E(\phi_p) = 5983$ $E(\phi_r) = 3363$

If the cryptogram is divided into two 150-letter sections, then the distributions are as follows:

	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	
1.	5	4	5	2	1	7	5	8	10	9	12	5	6	1	4	2	10	–	10	2	14	2	9	3	13	1	ϕ=1144
2.	3	3	4	4	5	5	5	12	9	2	5	4	3	4	2	7	11	4	12	8	10	3	10	5	8	2	ϕ= 970

$E(\phi_p) = 1520$ $E(\phi_r) = 868$

When the message is divided into three 100-letter sections, then

	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	
1.	5	2	2	2	1	6	5	5	8	4	6	3	5	1	3	–	9	–	6	1	11	1	6	1	6	1	ϕ= 498
2.	2	3	5	–	4	1	3	4	6	6	7	3	2	2	2	8	5	3	5	1	5	2	6	2	13	–	ϕ= 484
3.	1	2	2	4	1	5	2	11	5	1	4	3	2	2	1	1	7	1	11	8	8	2	7	5	2	2	ϕ= 522

$E(\phi_p) = 660$ $E(\phi_r) = 381$

When divided into four 75-letter sections, the distributions are

	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	
1.	4	1	2	1	1	5	4	4	5	3	4	3	5	1	1	–	6	–	4	1	11	1	4	–	3	1	ϕ= 293
2.	1	3	3	1	–	2	1	4	5	6	8	2	1	–	3	2	4	–	6	1	3	1	5	3	10	–	ϕ= 306
3.	2	2	2	1	5	2	3	2	4	1	2	2	2	2	1	6	5	4	5	4	2	3	3	3	7	–	ϕ= 212
4.	1	1	2	3	–	3	2	10	5	1	3	2	1	2	1	1	6	–	7	4	8	–	7	2	1	2	ϕ= 322

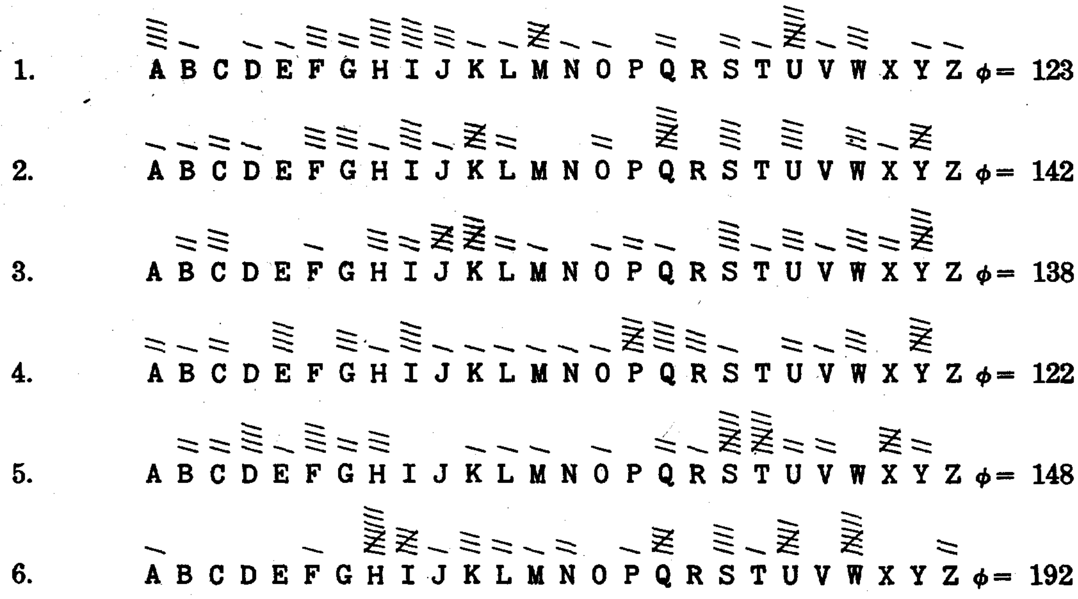
$E(\phi_p) = 370$ $E(\phi_r) = 212$

Upon dividing the text into five 60-letter sections, the distributions are

	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	φ=
1.	4	1	–	1	1	3	3	4	5	3	2	3	5	1	1	–	4	–	3	1	8	1	3	–	2	1	180
2.	1	1	4	1	–	3	2	2	3	4	5	2	1	–	2	–	5	–	7	–	3	1	4	1	8	–	200
3.	–	3	2	–	2	1	–	2	6	3	5	–	1	2	2	6	3	2	1	1	4	1	4	2	7	–	178
4.	2	1	2	3	3	4	4	3	–	–	2	2	1	–	–	2	4	2	5	7	2	2	1	4	4	–	156
5.	1	1	1	1	–	1	1	9	5	1	3	2	1	2	1	1	5	–	6	1	7	–	7	1	–	2	238

$E(\phi_p) = 236$ $E(\phi_r) = 136$

Finally, upon dividing the cryptogram into six 50-letter sections, the distributions are



$E(\phi_p) = 163$ $E(\phi_r) = 94$

This last set of distributions gives the most satisfactory results, both as regards the φ-test *and also the expected number of blanks* (cf. chart on page 25 of Text). From these several sets of distributions we were trying to determine the first two or three sections of the text that were monoalphabetically enciphered. The division not only seems to be approximately 50 letters, but it also appears that practically all the sections are of equal length.

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EXTENSION COURSE OF THE ARMY SECURITY AGENCY
LESSON ASSIGNMENT SHEET

SUBCOURSE 20–6	Military Cryptanalysis, Part I
EXAMINATION	
CREDIT	3
TEXT ASSIGNMENT	None
MATERIALS REQUIRED	Cross-section paper of ¼ inch squares
SUGGESTIONS	None
EXERCISES	

Weight

Until now the problems of each lesson have followed very closely the order of subject matter in the text, so that the student knew fairly well what types of systems were involved. This examination is designed to test the student's power of observation and logic in determining the general cryptographic system. All that is required in the five problems below is the determination of the general system, together with the reasons for the particular classification. Solution of the message texts is not mandatory, but strongly recommended: recovery of the plaintexts and specific keys certainly would furnish the student with irrefutable proof of the validity of his hypotheses.

```
20      1. L W H P C  X B V L W  H V K Z J  P B P G R  B X H S L
           Q K R H V  F R L X B  T C S B P  K S B Z K  R C N B P
           F W H P D  W H V G T  B P D S B  N D Q K W  F T B V F
           Q F R H R  D Z D S H  P D Q K Z  B X G V H  N L R F X
           H Q C Z K  S B V J Q  M R H X B  S L Q B R  F W J S B
           T K Z H W  M S B N L  S B Q B X  K S D T H  T M N H P
           C T B P H  V D S J V  D W H V H  N L Q H P  C Q C R B
           R L W K R  H V F X F  R B N C S  B P J P H  V D Z F Z
           B V L W C  W B Z F S  B W B P L  X X X X X
```

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```
20    2. EMURB WPZLS ERMWU ROBOP UWBWB
         QTION IYBHY VMIWB EGOPS CDVCC
         ODCXS OUDIY MCYXD YHSOU SMONB
         QTION OBOPZ DNOIL LBERO RTREM
         DTENR TBNTA KBCOO BOBEZ SKZZS
         MEGEB DFGNS HRLIX SESVR LESUU
         SKSPE WLDEG BWDMT ZTION SIVME
         RETAK PHTIM BHHOH IZUDM OEKHP

20    3. GHUIP GJHNI MBSPR IUSNS SHPGB
         RQSAJ OOQRS SIPQS MHVJI PQIVV
         JFKIH GSANY PTKKD YJKQX ZVNPR
         OQNJS NUYEF ENPZV NPROQ QTKLN
         FFHON QUPOQ HUQTV OTNDO JTKLP
         OWOJT EJWNQ EKJAE IOUTI QQGTB
         ANNKZ XVUKR EMMQR RTEII KVPXV
         UKRRE MWKIK VPXVU DAEIP RSQII
         GWQLQ UXVVX VUATG WQQVP
```

20 4. These two messages were intercepted on the same circuit during a morning offensive.

Message "A"

```
ILPUR PSBOK YBDGY YNCNP VXHCJ
ROKFI NPXVP EWHLX KWYXQ BVYDB
YYZCX
```

Message "B"

```
RBVYW BYYZC THEEB MMEZI ABXHW
SYXCK NNBYM SXQDY AEPCX
```

20 5.

```
SWWSN SDWPN XDFQF DSCDF AWKDM
VDZFD QYINB PGPPG LATNN TQRTS
IHYXM OUPWN YTVAP UGOBZ RZFQI
HNDKD XDAUB ODFFD INWTW UPGBO
ALDWK XUBIZ ZPPGI NAEAR ZAUMM
UXIYV IOEXF QWPWI QDARO ZFYHI
PMBOO BADNW TBBTA GBZPH WSQRO
BWINW AVZOX FFYNG DQOZH YXZZX
NGDNI FTRWI AUPRR PVSON MBGSP
ZGQDF
```

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